ANTARCTIC CIRCUMNAVIGATION EXPEDITION

CRUISE REPORT

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Abstract

The international Antarctic Circumnavigation Expedition (ACE), organised by the Swiss Polar Institute (SPI), took place in the austral summer of 2016 / 17. Departing from Cape Town in December 2016, the *R/V Akademik Tryoshnikov* sailed around the Southern Ocean, navigating the following route:

Cape Town (20 December 2016) - Hobart (18 January 2017) via:
Marion Island, Iles de Crozet et Kerguelen and Heard Island

Hobart (22 January 2017) - Punta Arenas (22 February 2017) via:
Mertz glacier, Balleny Islands, Mount Siple, Scott Island, Peter I Island and Diego Ramírez (Chile)

Punta Arenas (26 February 2017) - Cape Town (19 March 2017) via:
South Georgia, South Sandwich Islands and Bouvetøya

Scientists from 22 distinct projects studied a wide range of disciplines, collecting data and samples from the Southern Ocean and a number of terrestrial sites on islands around Antarctica, as well as the continent itself.

In this cruise report, the full details of the purpose of the cruise, on-board data and sample collection, and project methods and preliminary results are described.

Additional information

This document is compiled and edited from reports provided by many scientists from 22 distinct on-board projects who studied a wide range of disciplines, collecting data and samples from the atmosphere, the Southern Ocean and a number of terrestrial sites on islands around Antarctica, as well as the continent itself.

The expedition was made possible by funding from the Swiss Polar Institute and Ferring Pharmaceuticals.

Keywords

Antarctic, Antarctic Circumnavigation Expedition, ACE, Southern Ocean, Iles Crozet, Iles Kerguelen, Marion Island, Heard Island, Mount Siple, Mertz glacier, Peter I Island, Scott Island, Balleny Islands, Diego Ramírez, South Georgia, South Sandwich Islands, Bouvetøya, Atlantic Ocean, oceanography, atmosphere, terrestrial, marine, biology, meteorology, chemistry, glaciology

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The report is compiled from the inputs of many participants over all five Legs so this is truly a community document. All project reports have been checked by the respective Principle Investigator. Photographs in this document are all by participants of the expedition unless stated otherwise. Our thanks to Laurence Mottaz at SPI who spent many long hours trying to standardise the many different inputs across all the projects!

David W H Walton

ACE Chief Scientist

2 Summary

The Antarctic Circumnavigation Expedition (ACE) was conceived as a bold international initiative, organised through the Swiss Polar Institute using a chartered Russian vessel and primarily supported through a Swiss foundation. Its objective was to sample the Southern Ocean all around the continent in a single season but also to integrate research on and around the sub-Antarctic islands into this voyage. An international call for Projects resulted in over 100 being assessed by an international panel. Each Project was selected on its own science quality without any attempt to develop a linked programme. A combination of an enthusiastic review panel and a lack of familiarity with this ship allowed the panel to select 22 Projects, which proved to be a challenge given the space and time available. The expedition provided two BO 105 helicopters and three zodiacs for landing parties on the islands. The foredeck of the ship was modified to allow the installation of the Remotely Operated Platform for Ocean Sciences (ROPOS) for Leg 2.

The initial Leg from Bremerhaven to Cape Town was devoted to a Maritime University for 49 young marine scientists. Some Projects also collected data on this Leg and tested scientific equipment but a contaminated sea water supply and a lack of time for stations meant that this was less valuable than it could have been. The expedition installed its own server for data storage and on-board network, and built an expedition communications system based around two Iridium stations as the ship's satellite equipment did not provide the expedition with an adequate facility, especially south of the equator.

The first science Leg from Cape Town to Hobart had to contend with some difficult weather. Landings were made on Marion Island, Iles Crozet and Kerguelen but the lack of a permit from the Australian authorities at short notice denied the planned landing on Heard Island. Dredging was successful around Marion, Crozet, Kerguelen and Heard Islands in sampling the benthos. Despite difficult flying and boating conditions Projects managed to sample freshwater bodies, soils, flora and fauna on Marion, Ile de la Possession and Kerguelen and aerial surveys to census bird colonies were undertaken at Ile aux Cochons. A new sea water line allowed continuous measurements of phytoplankton to begin immediately after leaving Cape Town. However, problems with the position of the seawater inlet in rough seas caused limitations for all continuous flow monitoring. The ship's radar was used to continuously measure wave height and integrate this with surface current and wind data, whilst specialised sampling systems continuously measured aerosols and sampled the air stream for biogenic particles. Measurements of the Acoustic Deep Scattering Layer using the ship's echo sounders began in the North Atlantic and continued until the end of the voyage in Bremerhaven. A study on precipitation used a micro-rain radar and regular launches of radiosondes, whilst a second Project sampled stable water isotopes as tracers to quantify aspects of the regional water cycle.

The second Leg from Hobart to Punta Arenas avoided Macquarie Island because of a major storm and spent several days at the Mertz Glacier investigating the area previously covered by the Mertz Glacier Tongue. The expedition then visited the Balleny Islands which were unusually free of pack ice, moved on to Scott Island and then, as satellite photographs showed an unusual lack of pack ice, visited Siple Island and the Marie Byrd Land coast before progressing to Peter I Island. Sailing up the west coast of the Antarctic Peninsula and across the Drake Passage the expedition briefly visited the Diego Ramírez Islands before reaching Punta Arenas. The continuous sampling continued throughout this period and a new Project began acoustically mapping the presence of whales. The glaciologists took ice cores from the Mertz Glacier, the Balleny Islands and Peter I Island for palaeoclimate reconstruction whilst peat samples were taken from Diego Ramírez for a study on changes in the Southern Ocean carbon dioxide sink capacity. ROPOS was deployed at a number of sites to study undisturbed benthic communities but was unable to reach its potential due to a combination of equipment problems, ice, sea state and limited deployment periods.

Heading east the expedition visited South Georgia for several days but bad weather severely constrained activities on all but one day after which the ship headed for the South Sandwich Islands. The weather there was good but the Government refused to issue a permit for helicopters so no landings could be attempted. Finally the ship sailed to Bouvetøya where it proved possible to land on the ice cap but not on any of the

beaches. Dredging proved fruitful at the South Sandwich Islands and around Bouvetøya and whilst the first ice core was obtained from Bouvetøya the refusal of helicopter permits meant that valuable opportunities for coring on the most promising high altitude ice sheets at South Georgia and on the South Sandwich Islands were missed.

CTD stations were taken all along the track but not as frequently as requested due to limitations on the CTD crane in all except calm seas, a lack of available time, and winch failures. Trace element sampling was conducted in parallel, with a specialised trace rosette and winch system. Optical measurements were made with a suite of instruments both continuously and from a frame deployed at CTD stations. Continuous measurements were made on the sea water line by several Projects. Work on the role of bacteria and viruses was only partly successful due to equipment failures. Samples were taken for microplastics at most stations, from the underway water and on island beaches.

Dredging was mostly conducted at night and required a multibeam sea bed survey before dredge deployment making this a lengthy activity. In addition the ship had difficulty in remaining at a speed of less than 2 knots which made it difficult to keep the dredge on the bottom.

Several Projects opted for continual measurements northbound from Cape Town to Bremerhaven to compare with their Antarctic data.

Although the Projects on board were selected separately a great deal of common ground was discovered during the expedition allowing Projects to share sampling and data. Most Projects were unable to achieve all their original objectives but every Project was successful in acquiring enough new samples and data to make the cruise valuable.

The expedition logged 3,106 events at 96 locations as well as en-route, collecting 27,801 samples. Activities included the release of 90 radiosondes, 63 CTD casts (typically to 1000 m) and 63 Agassiz trawls. 127 scientists, supported by a team of 28 which included 12 journalists, formed the on-board expedition party, representing 23 countries and 73 scientific institutions.

ACE intends to make all of its data freely available after two years and encourage interdisciplinary outputs between projects. To support this a number of meetings between projects have been organised or are still planned, a grant has been obtained for a data research project funded by the Swiss Data Science Centre and projects will be making multiple presentations at both Scientific Committee for Antarctic Research meetings and disciplinary meetings like the European Geophysical Union.

3 Establishment of the Antarctic Circumnavigation Expedition (ACE)

ACE was based on an idea conceived by Dr Frederik Paulsen in 2015. There had been very few circumnavigations of the Antarctic continent for scientific purposes, and of those that had been undertaken, none had incorporated the islands within the Southern Ocean as part of the research. Dr Paulsen saw an opportunity here to provide new circum-Antarctic baselines for monitoring measurements, research that linked the islands to their surrounding sea and a major Project to start Swiss polar activities through the soon to be formed Swiss Polar Institute. The principal difficulty was finding a suitable research vessel that could undertake the lengthy voyage whilst also navigating safely in ice.

Figure 1: Dr Frederik Paulsen in Cape Town at the commencement of the three science Legs of ACE.

The Russian Arctic and Antarctic Research Institute (AARI) in St Petersburg had its newest research/logistics vessel the *Akademik Tryoshnikov* available for deployment. The ACE Foundation, established in Switzerland by Dr Paulsen as a charitable organisation devoted to furthering science and exploration, agreed to lease the vessel for the austral summer 2016-2017 to undertake an international cruise.

In order to maximise the value of the science undertaken and organise the expedition ACE established a Technical Committee composed of senior representatives of Antarctic organisations in Australia, France, Norway, South Africa, UK and Switzerland. The Technical Committee, chaired by Professor Philippe Gillet of EPFL, Lausanne launched an open call for applications in December 2015, closing on 31 January 2016. Over 100 applications were received and an independent international assessment panel was established which met in Paris in February 2016 to short-list the best Projects. Previously the Technical Committee had undertaken a logistics assessment of each application to assess the practicability of what was proposed.

After two days of discussions, the panel finally chose 22 Projects, which were then subjected to a further assessment in terms of funding and manpower to fit the proposed personnel into the available ship space

and the costs within the total budget. This proved difficult as no member of the ship's crew was able to attend the Paris selection meeting. The technical description provided of the laboratories and the science equipment on the ship was limited and only a few of the panel had been able to visit the ship for a day in St Petersburg.

The expedition was divided into five Legs – Leg 0 Bremerhaven to Cape Town, Leg 1 Cape Town to Hobart, Leg 2 Hobart to Punta Arenas, Leg 3 Punta Arenas to Cape Town, Leg 4 Cape Town to Bremerhaven. Using a conservative estimate of mean speed the total charter period was determined as departing 20 November 2016 from Bremerhaven to arrive back in Bremerhaven 11 April 2017. The Antarctic sector was determined as 90 days leaving Cape Town 20 December 2016 and arriving back to Cape Town 19 March 2017, with stops to re-victual and change science staff in Hobart, Australia and Punta Arenas, Chile.

The ship did not come equipped with suitable helicopters and boats. Accordingly, ACE decided to use two helicopters (Messerschmitt-Bölkow-Blohm BO 105) previously used for rat eradication on South Georgia. A third helicopter was taken along as a source of spare parts. In addition, four zodiacs were purchased to provide both safety cover for the helicopters and landing facilities for scientific parties.

Most Projects decided to change their staff at least once, and sometimes twice, during the cruise. A small number of Project staff were on for all three Antarctic Legs and just three people for all five Legs.

The Technical Committee decided to copy an initiative of the Alfred Wegener Institute and use the south-bound period – Leg 0 – as an opportunity to provide training and education for marine science students. Forty-nine students (Masters, Doctoral and Post-Doctoral) eventually took part in this Leg with lectures and practicals organised by staff from University of Cape Town and EPFL, under the auspices of the Russian Geographical Society (RGO) based in St Petersburg.

The Technical Committee also agreed that some Projects could use Leg 0 as an opportunity to test out equipment and to collect comparative temperate and tropical data on this Leg. In due course the opportunity to continue data collection was also offered on Leg 4 back northwards to Bremerhaven.

With route and the ports already decided ACE made an early decision on which port agents to use in each of the four ports the ship would use. The agents chosen were those already familiar with handling the complex requests from research vessels.

4 Details of *Akademik Tryoshnikov*

Figure 2: The Akademik Tryoshnikov. Image: Arctic and Antarctic Research Insitute.

The *Akademik Tryoshnikov* is the newest ship in the fleet operated by AARI. Design work was undertaken in the 1980s but the building of the ship was delayed by some years due to the political changes from the USSR to Russia. The ship was finally completed and launched in 2012.

It was designed as a mixed cargo and research vessel, with a 1A Finnish ice classification, meaning it can operate without icebreaker assistance in pack ice up to 1 m thick. Its principal role is to carry staff and cargo to Arctic and Antarctic stations on an annual basis. Equipped with two helicopterdecks and a large helicopter hangar, it has a number of dedicated laboratories built into the superstructure as well as a forward deck for four container laboratories. These container laboratories cannot be easily accessed in poor weather and have no telephone connections although they do have normal 3-phase electricity and can have freshwater supplied.

Two very large cranes are provided for the forward holds but these can only be used when the ship is anchored or tied up. Two smaller cranes are installed on the laboratory container deck, there is a CTD winch and crane on the port side, a further crane on the helicopter deck allowing access to the lower rear decks through a limited hatch (mainly used for food storage in the cold and freezer rooms) and there are two further winches and an A-frame on the rear deck for science use.

The ship has a small cold room in one of the forward container labs whilst the principal walk-in -20 ^{o}C room is installed in the rear laboratory used for benthic studies. There is no +5 ^{o}C nor any -80 ^{o}C science facilities. A small domestic fridge in the CTD analysis room was available (although it proved barely adequate to store low-temperature reagents let alone specimens). A large -80 ^{o}C chest freezer was therefore purchased and loaded in the UK into the hangar and further two upright -80 ^{o}C freezers were added in Hobart. A liquid

nitrogen plant and storage Dewar flasks were installed in the helicopter hangar to provide instant freezing capability for specimens.

The linked CTD laboratories contained a number of analytical instruments that were not required on this cruise and were removed to make room for other incoming instrumentation. By current standards these laboratories are small, inflexible and inadequately equipped with sinks and certified gas pipework for analytical use. The small fume cupboard had deficient ventilation which could not be used on some occasions as the extracted air leaked back into adjoining rooms providing a toxic hazard. A cupboard beneath the fume cupboard was used for storing acids separately as there was no dedicated storage facility for these. A small cupboard in the main CTD room comprised all the chemical storage facilities but was too small for an expedition of this size and could not meet current standards for separation of chemical classes, drip/drainage trays and ventilation, or labelling. A new steel cabinet was therefore purchased to contain some of the toxic chemicals. A chemical risk assessment register was developed and the required hazard notices were posted. Spill kits were purchased. The expedition devised its own system for collection and storage of chemical waste – containers were purchased for separate classes and waste was finally stored in drums on the rear deck to be discharged to specialist waste handlers in port.

A number of containerised laboratories were loaded on board for specific Projects. The ship did not have the matching electrical connections and a series of small transformers were thus commissioned to allow the equipment in them to run. The ship can provide high voltage (360 – 420 V) connections with four lines: Neutral, phase 1, 2, and 3. In addition, standard 230 V power is available, but limited connections exist. Using an uninterruptable power supply to protect instrumentation is advisable. The container loaned by the Alfred Wegener Institute (AWI) for controlled temperature incubations could not be made to work for a number of reasons and that part of the Project was cancelled. The extra container laboratories on the foredeck had no water or telephone connections and very limited electricity supplies. They were not accessible at all in poor weather.

Although there is a VSAT system on board it will only function for satellites in the Northern Hemisphere. Communication systems on the ship were poor beyond the equator. The expedition was therefore fortunate to be loaned two Iridium systems which were modified to provide email, voice and data communications for the entire expedition.

There was no adequate server and data store system available for the science data already in place. A fully-fledged data storage system was constructed to archive all the data including the ship's navigation and meteorological data. A local area network was already installed in the ship and ACE was able to connect to this, facilitating data backup and connectivity across the ship.

Ship data including position and meteorological information was displayed only on the bridge, in the dining room and in the CTD control room but not in every laboratory or in the scientists' cabins, which made recording position and other details for many Projects more difficult than it should have been. This was overcome by constructing an on-board intranet which was accessible through the local area network.

There is a single sea water intake installed 4.5 m down in the hull with an unlagged pipe leading up through the engine room to the CTD laboratory. This was heavily corroded, as was the sea water pump, making the sea water supply totally unusable. This had to be replaced in Cape Town with a new pump and temporary plastic hosing which was then sufficient to supply both the equipment in the CTD room and the oceanography laboratory above the fore deck. There was, however, still some uncertainty about the potential rise in sea water temperature between the intake and the laboratories.

A Chelsea Instruments FerryBox was installed in the CTD laboratory. It had been unused for some years and was effectively uncalibrated. It was therefore sent to the manufacturers for cleaning and recalibration before the ship left Bremerhaven and re-installed with the assistance of Chelsea Instruments technical staff in Southampton. It was not set up to archive the data except for when reaching ports, meaning that scientists could not view the data in real time, check the quality of the data or ensure it was backed-up. To

overcome this, scripts were written to download the data on a regular basis and by the third Leg, an application on the intranet allowed scientists to view the data in near real-time.

The existing distilled water system produced an inadequate quality of water for the analyses required. A MilliQ system was installed in the CTD room but serious corrosion in all the freshwater pipework overwhelmed the system until the installation of three in-line filters in advance of the MilliQ.

The Akademik Tryoshnikov does not have any large common room or bar facilities. The dining rooms were therefore used in part as office space and for meetings and lectures, which proved both inhibiting and complicated as the kitchen staff closed the rooms for cleaning several times every day which severely limited its availability. The only meeting room on the ship was reserved for the captain's use.

5 Cruise overview and maps

5.1 Pre-cruise Organisation

The multinational Technical Committee, chaired by Professor Philippe Gillet, managed surprisingly well to develop the original concept of Dr Paulsen's into a feasible expedition despite the very short timescale. An open international call for Project proposals was made in December 2015 and the choice of the participating ones was made by an expert panel that met in Paris in February 2016. Over 100 Projects were proposed and the panel selected 22 on the basis of science quality. It was not possible to link the Projects at that stage nor to determine the necessary staffing to be successful in their principal objectives. It was, however, clear at that stage that the cruise participants proposed by the 22 Projects totalled far more than the ship capacity and the funding requested was almost three times that which was available. Discussions with each Project finally produced reductions that could be accommodated in the three Legs around the continent. Very limited information was available on the *Akademik Tryoshnikov* facilities and, with considerable difficulty, visits for a small number of PIs were arranged to the ship in St Petersburg during the summer.

The route had been planned before the Projects were chosen, as had the length of the cruise which was required for the charter agreement, and included a period each day for science work like CTD stations, but this proved to be insufficient time to cope with multiple deployments of sampling systems at stations, equipment failures and bad weather at reduced speeds.

A meeting of all the PIs in Lausanne provided the opportunity to develop some of the principal objectives of the cruise and linkages between Projects. The oceanographic Projects worked together on detailed planning of proposed stations and this document became the initial station plan for the expedition. It did, however, prove to be optimistic in what could be achieved and many fewer stations were achieved than were originally proposed.

The ship did not provide helicopters and these were in due course collected from the UK on Leg 0. Two helicopter pilots and two experienced mechanics supported all the flying operations. It was also lacking in small boat support and zodiacs were purchased and experienced zodiac drivers employed.

The Chief Scientist was not appointed until April 2016, providing an unusual scenario where many of the key decisions had already been taken. The ship provided a doctor and a very well-equipped surgery. Medical fitness had to be established for all participants and this was done using a modified checklist based on French experience at the Institut Polar Français Paul-Emile Victor (IPEV). As this was not a formal government expedition extra insurance for ship and all passengers was necessary.

The ship was fuelled in Bremerhaven for the entire voyage as its extra tank capacity for carrying fuel for the research stations gave it an unusually large capacity. In the light of the rust contaminated freshwater supply a large supply of bottled drinking water was loaded and distributed daily.

5.2 Permits

Since the expedition intended to work on and around the sub-Antarctic islands as well as the Southern Ocean and the continent, permitting was a major issue from the beginning. As all the islands are national territory each one had to be applied to and negotiated with separately for the necessary permits. In addition clearance for working offshore in the Exclusive Economic Zone (EEZ) of the islands was also required, as everywhere in the world, and this is subject to separate permit applications through diplomatic channels. Normally it is the owner of the vessel who applies through their government for marine research permission but AARI declined to undertake this and it fell to the Swiss Government, through its Foreign Affairs Department, to undertake this for the expedition with the Governments of South Africa, Australia, France, Chile, Norway and the UK.

Applications to island authorities to land and conduct research went to the Government of South Georgia and the South Sandwich Islands, Terres Australes et Antarctiques Françaises (TAAF) for Crozet and Kerguelen, the Australian Government for Heard Island, Tasmanian Parks and Wildlife for Macquarie Island, Norwegian Polar Institute for Bouvetøya, the South African Government for Marion Island, and the Chilean Government for Diego Ramírez Islands. The expedition applied successfully to the Russian Government for a permit for all activities within the Antarctic Treaty area. Every authority had a different form, a different assessment procedure, different information on what is allowed and which areas are closed, and may require applications in languages other than English (French for TAAF, Spanish for Chile). The permit application process to so many authorities proved a major task for many months before the expedition and some permits did not arrive until after the expedition had begun.

5.3 Route overview

As previously described, ACE comprised Legs 1 to 3 of the complete journey, with Leg 0 being a Maritime University and providing opportunity to test and set-up equipment as well as collect data whilst passing down the Atlantic Ocean. Likewise, Leg 4 also provided an extra opportunity of data collection between South Africa and Europe. Start and end dates and locations are shown in Table 1.

Table 1: Start and end, dates and locations of the Legs of ACE.

Leg	Start location	Start date	End location	End date
0	Bremerhaven, Germany	2016-11-19	Cape Town, South Africa	2016-12-15
1	Cape Town, South Africa	2016-12-20	Hobart, Australia	2017-01-19
2	Hobart, Australia	2017-01-22	Punta Arenas, Chile	2017-02-22
3	Punta Arenas, Chile	2017-02-26	Cape Town, South Africa	2017-03-19
4	Cape Town, South Africa	2017-03-22	Bremerhaven, Germany	2017-04-11

Note that some Russian scientists from Project 22 were on board from St Petersburg to Bremerhaven and Bremerhaven to St Petersburg and also collected data on these parts of the voyage, although they were not technically part of the expedition.

Figure 3: Map of Legs 1 to 3 with main ports (large red font) and island stops (small red font). Note that the track is only an approximation.

5.4 Leg 1 (20 December 2016 - 19 January 2017)

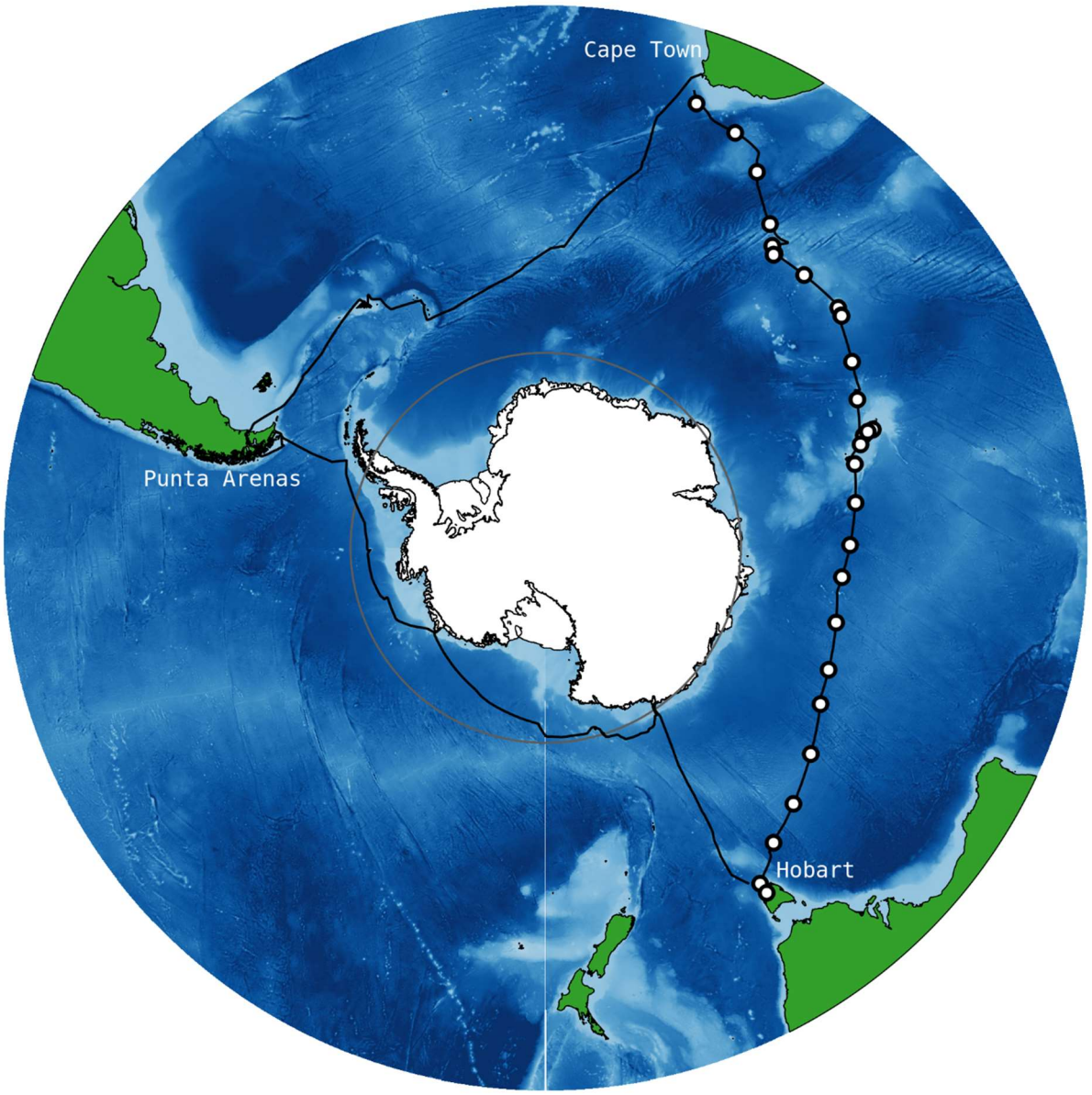

Figure 4: Noon positions on Leg 1 from Cape Town to Hobart shown by white dots. Antarctic Circle shown by the solid grey line.

Below is a summary of photographs from Leg 1, showing some of the sub-Antarctic islands visited en-route.

Figure 5: Research station on Marion Island

Figure 6: CTD deployment during Leg 1

Figure 7: King penguins in a small cove on Marion Island.

Figure 8: Terrestrial sampling on Ile de la Possession, Iles Crozet.

Figure 9: Port aux Français research station, Iles Kerguelen.

Figure 10: Heard Island.

5.5 Leg 2 (22 January 2017 - 22 February 2017)

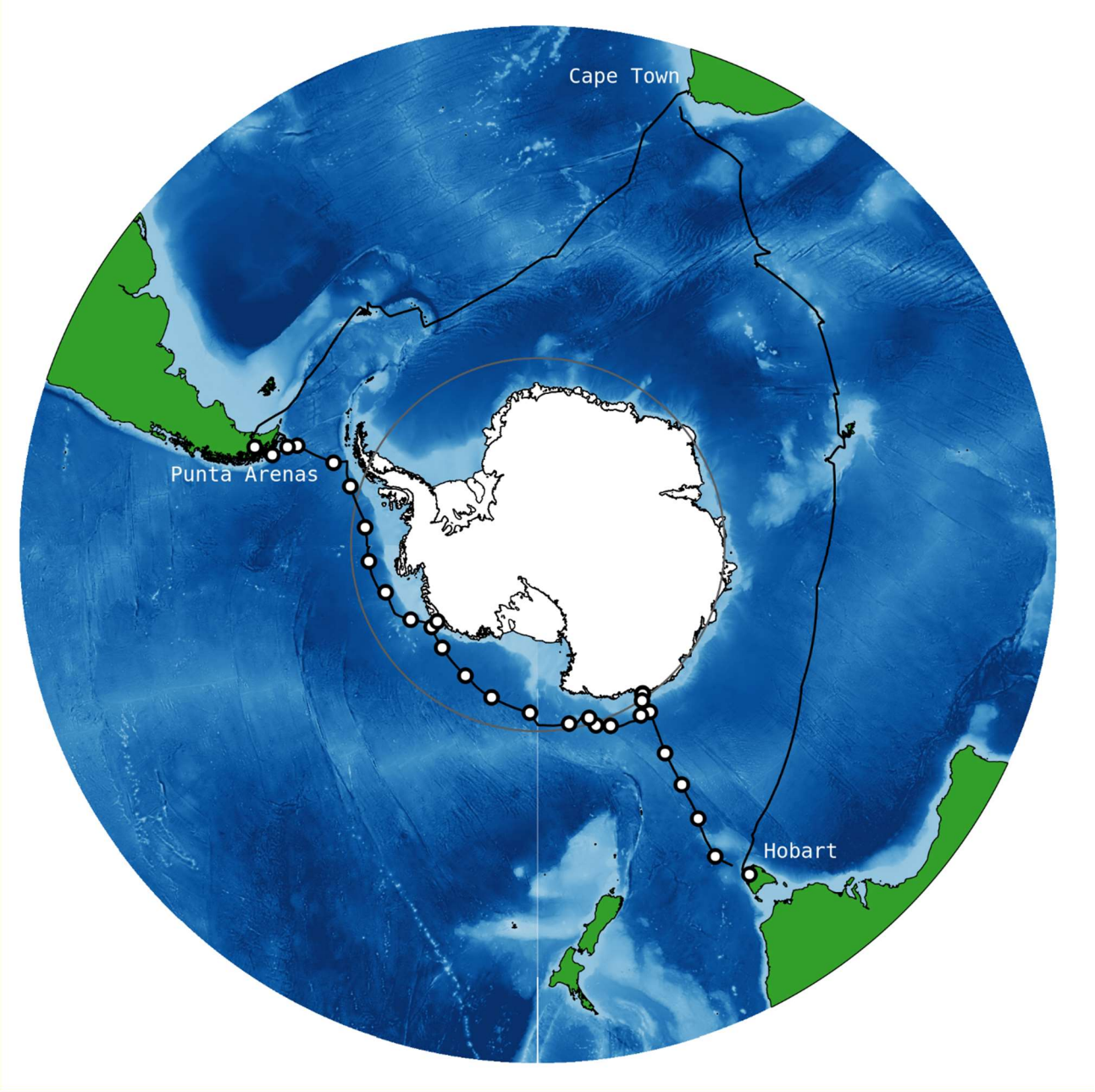

Figure 11: Noon positions on Leg 2 from Hobart to Punta Arenas shown by white dots. Antarctic Circle shown by the solid grey line.

Below are a few photographs from the locations visited on Leg 2.

Figure 12: Akademik Tryoshnikov nose-in to ice shelf in Mertz Polynya.

Figure 13: Balleny Islands.

Figure 14: Scott Island.

Figure 15: Mt Siple, Marie Byrd Land coast.

Figure 16: Peter I Island.

Figure 17: Meteorology station on Isla Gonzalo, Diego Ramírez.

5.6 Leg 3 (26 February 2017 - 19 March 2017)

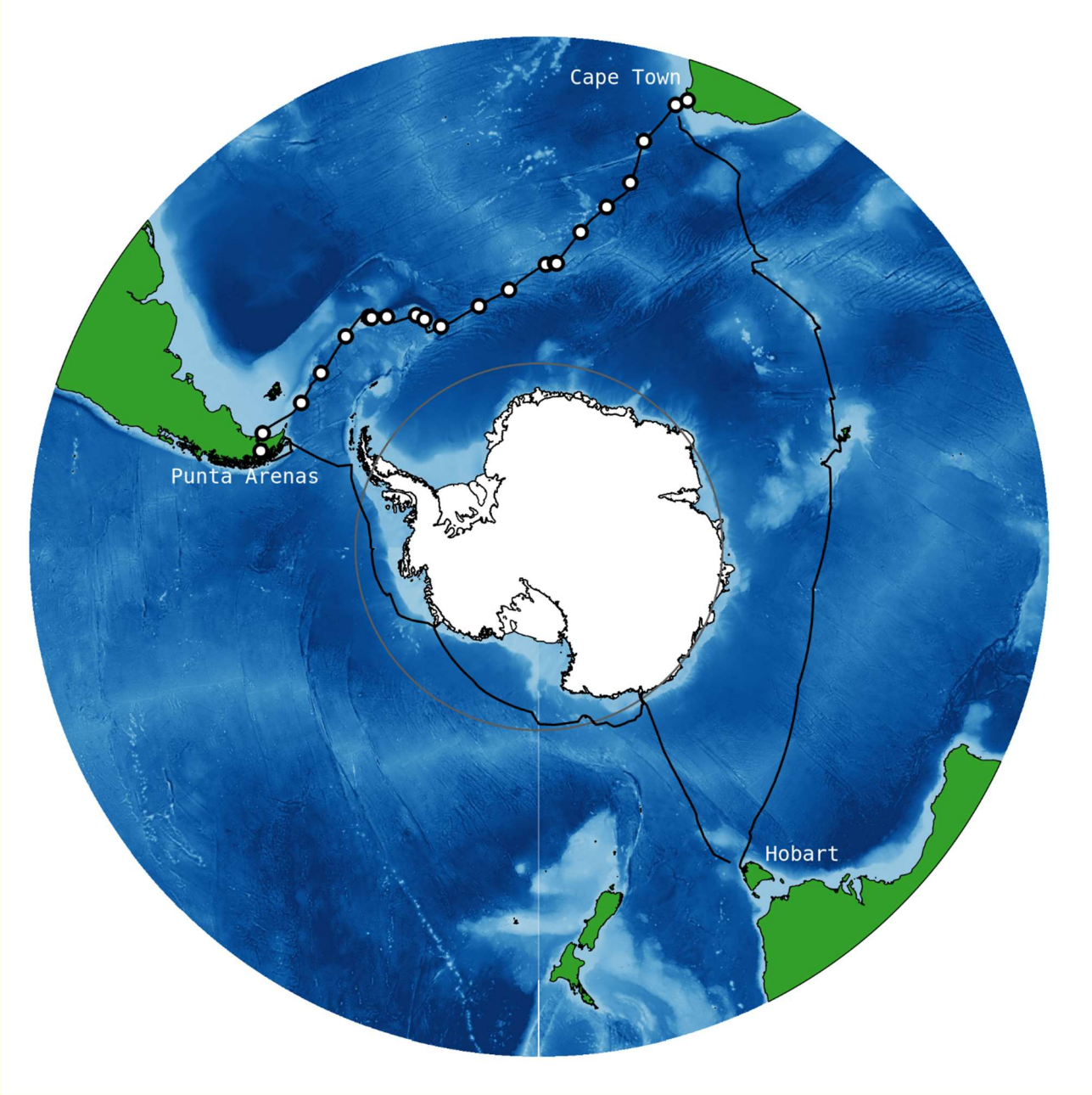

Figure 18: Noon positions on Leg 3 from Punta Arenas to Cape Town shown by white dots. Antarctic Circle shown by the solid grey line.

Below are a number of photographs of locations visited during Leg 3.

Figure 19: West Cumberland Bay, South Georgia.

Figure 20: King penguins at St Andrews Bay, South Georgia.

Figure 21: South Sandwich Islands.

Figure 22: Bouvetøya.

Figure 23: Leg 3 participants.

5.7 Time on board

All times within this document, data files, metadata and the database are recorded in UTC unless noted otherwise. Dates (also in UTC) are in the format DD MONTH YYYY in the text, or YYYY-MM-DD in tables of this document, where YYYY is the year, MM is the two-digit month and DD is the two-digit day.

All science on the ship was done in UTC. The time on board, known as "ship time", changed every few days during the expedition because of the circumpolar nature of the track. Note that the time was always changed between midnight and 08:00 ship time, but the exact time of the change was never known because it varied. This does not affect any of the times in this document or in the sampling done because everything was done in UTC.

Time changes were confusing for many on board, and could have been helped by having more prominent clocks around the ship in UTC time. The problem was partly mitigated by providing the UTC time, date and Julian day on the front page of the intranet so it was easily found. On the 05 February 2017 (UTC) the ship crossed the international dateline causing even more confusion!

Table 2: Time changes took place on a regular basis. These are listed here with the on-board time and the time in UTC in which all of the science was recorded.+ hours are ahead of UTC and - hours are behind. Leg 4 operated entirely on a ship time of UTC +2 hours.

Date the time changed (UTC)	Date the time changed (ship time)	Time on board ship ahead or behind of UTC	Date the time changed (UTC)	Date the time changed (ship time)	Time on board ship ahead or behind of UTC
2016-11-19	2016-11-19	+1	2017-02-07	2017-02-07	-11
2016-11-23	2016-11-23	0	2017-02-08	2017-02-08	-10
2016-12-06	2016-12-06	+1	2017-02-10	2017-02-10	-9
2016-12-09	2016-12-09	+2	2017-02-13	2017-02-13	-8
2016-12-22	2016-12-22	+3	2017-02-14	2017-02-14	-7
2017-01-02	2017-01-02	+4	2017-02-16	2017-02-16	-6
2017-01-04	2017-01-04	+5	2017-02-18	2017-02-18	-5
2017-01-10	2017-01-10	+6	2017-02-19	2017-02-19	-4
2017-01-12	2017-01-12	+7	2017-02-21	2017-02-21	-3

2017-01-12	2017-01-13	+8	2017-02-28	2017-02-28	-2
2017-01-14	2017-01-15	+9	2017-03-05	2017-03-05	-1
2017-01-16	2017-01-17	+10	2017-03-07	2017-03-07	0
2017-01-17	2017-01-18	+11	2017-03-11	2017-03-11	1
2017-02-05	2017-02-05	-12	2017-03-14	2017-03-14	2

5.8 Noon positions

Table 3: noon positions of Akademik Tryoshnikov on Legs 1-4, with data obtained from Trimble GPS, GLONASS and hand-held GPS operated by Project 22.

Date and time (UTC)	Latitude (decimal degs N)	Longitude (decimal degs E)	Leg
2016-12-21 12:00:00	-36.9046	18.7559	1
2016-12-22 12:00:00	-38.1771	24.5505	1
2016-12-23 12:00:00	-40.6843	29.3601	1
2016-12-24 12:00:00	-44.5042	34.7221	1
2016-12-25 12:00:00	-46.2086	36.8942	1
2016-12-26 12:00:00	-46.8752	37.8662	1
2016-12-27 12:00:00	-46.8745	37.8662	1
2016-12-28 12:00:00	-46.7194	37.8963	1
2016-12-29 12:00:00	-46.3988	43.4567	1
2016-12-30 12:00:00	-46.1239	50.6211	1
2016-12-31 12:00:00	-46.3783	51.8122	1
2017-01-01 12:00:00	-46.3739	51.9034	1
2017-01-02 12:00:00	-48.2319	58.7185	1
2017-01-03 12:00:00	-49.6544	64.5407	1
2017-01-04 12:00:00	-50.5044	70.5105	1
2017-01-05 12:00:00	-49.3620	70.1008	1
2017-01-06 12:00:00	-49.9548	70.1413	1
2017-01-07 12:00:00	-51.1415	71.7914	1
2017-01-08 12:00:00	-52.3555	74.8019	1
2017-01-09 12:00:00	-53.1392	81.7053	1
2017-01-10 12:00:00	-54.1077	89.4084	1
2017-01-11 12:00:00	-54.8440	95.7629	1
2017-01-12 12:00:00	-54.6004	104.5245	1
2017-01-13 12:00:00	-53.6918	113.3845	1
2017-01-14 12:00:00	-52.8078	119.6579	1
2017-01-15 12:00:00	-50.6638	127.8920	1
2017-01-16 12:00:00	-48.4701	135.9344	1
2017-01-17 12:00:00	-46.7277	142.3072	1
2017-01-18 12:00:00	-44.0445	147.4213	1
2017-01-19 12:00:00	-42.8801	147.3412	1
2017-01-20 12:00:00	-42.8801	147.3413	In port
2017-01-21 12:00:00	-42.8801	147.3412	In port
2017-01-22 12:00:00	-42.8801	147.3413	2
2017-01-23 12:00:00	-46.4901	150.3847	2
2017-01-24 12:00:00	-51.1141	149.6874	2
2017-01-25 12:00:00	-55.4278	149.0745	2
2017-01-26 12:00:00	-59.6173	148.6515	2
2017-01-27 12:00:00	-64.7815	146.2352	2
2017-01-28 12:00:00	-67.1210	144.8697	2
2017-01-29 12:00:00	-67.1287	145.0485	2
2017-01-30 12:00:00	-67.0638	145.0021	2
2017-01-31 12:00:00	-66.4484	146.3010	2

2017-02-01 12:00:00	-65.0030	148.9443	2
2017-02-02 12:00:00	-65.5108	158.1467	2
2017-02-03 12:00:00	-66.1647	162.1968	2
2017-02-04 12:00:00	-67.2907	163.5405	2
2017-02-05 12:00:00	-67.1592	170.0959	2
2017-02-06 12:00:00	-67.3837	-179.7889	2
2017-02-07 12:00:00	-68.8032	-177.2945	2
2017-02-08 12:00:00	-69.8797	-163.1447	2
2017-02-09 12:00:00	-71.1023	-151.1061	2
2017-02-10 12:00:00	-72.2279	-137.1829	2
2017-02-11 12:00:00	-73.0065	-127.8503	2
2017-02-12 12:00:00	-74.0053	-127.4260	2
2017-02-13 12:00:00	-71.3676	-120.6228	2
2017-02-14 12:00:00	-69.9028	-107.4440	2
2017-02-15 12:00:00	-68.6431	-95.6928	2
2017-02-16 12:00:00	-68.1758	-84.1018	2
2017-02-17 12:00:00	-65.3785	-72.5779	2
2017-02-18 12:00:00	-62.5098	-68.0351	2
2017-02-19 12:00:00	-57.7367	-67.5408	2
2017-02-20 12:00:00	-56.7331	-68.6125	2
2017-02-21 12:00:00	-55.3860	-71.2653	2
2017-02-22 12:00:00	-53.1702	-70.9067	2
2017-02-23 12:00:00	-53.1702	-70.9067	In port
2017-02-24 12:00:00	-53.1702	-70.9067	In port
2017-02-25 12:00:00	-53.1702	-70.9067	3
2017-02-26 12:00:00	-52.6660	-67.5811	3
2017-02-27 12:00:00	-55.1032	-58.7549	3
2017-02-28 12:00:00	-55.0023	-51.4007	3
2017-03-01 12:00:00	-54.1771	-42.5241	3
2017-03-02 12:00:00	-54.2875	-36.4781	3
2017-03-03 12:00:00	-54.1506	-36.4808	3
2017-03-04 12:00:00	-54.4303	-36.1485	3
2017-03-05 12:00:00	-55.3640	-33.4530	3
2017-03-06 12:00:00	-56.9815	-27.9177	3
2017-03-07 12:00:00	-57.8736	-26.7036	3
2017-03-08 12:00:00	-59.5002	-23.9842	3
2017-03-09 12:00:00	-58.6642	-14.0070	3
2017-03-10 12:00:00	-57.3848	-6.6706	3
2017-03-11 12:00:00	-54.5897	1.4050	3
2017-03-12 12:00:00	-54.3599	3.2403	3
2017-03-13 12:00:00	-54.4032	3.5826	3
2017-03-14 12:00:00	-50.5104	7.5442	3
2017-03-15 12:00:00	-47.2089	11.2879	3
2017-03-16 12:00:00	-43.9834	14.0853	3
2017-03-17 12:00:00	-39.2697	14.5073	3
2017-03-18 12:00:00	-34.7343	17.2027	3
2017-03-19 12:00:00	-33.9116	18.4283	3
2017-03-20 12:00:00	-33.9039	18.4237	In port
2017-03-21 12:00:00	-33.9039	18.4237	In port
2017-03-22 12:00:00	-33.9039	18.4237	4
2017-03-23 12:00:00	-30.9076	15.4620	4
2017-03-24 12:00:00	-26.1913	11.2753	4
2017-03-25 12:00:00	-21.5204	7.2964	4

2017-03-26 12:00:00	-16.9193	3.5010	4
2017-03-27 12:00:00	-12.3371	-0.1878	4
2017-03-28 12:00:00	-7.7423	-3.8174	4
2017-03-29 12:00:00	-3.0682	-7.4740	4
2017-03-30 12:00:00	1.4490	-11.0040	4
2017-03-31 12:00:00	5.0438	-13.7918	4
2017-04-01 12:00:00	9.1080	-16.9746	4
2017-04-02 12:00:00	14.2609	-18.0030	4
2017-04-03 12:00:00	20.0003	-18.3455	4
2017-04-04 12:00:00	25.5942	-18.9324	4
2017-04-05 12:00:00	31.1363	-18.4427	4
2017-04-06 12:00:00	36.0945	-15.4947	4
2017-04-07 12:00:00	41.0606	-12.2019	4
2017-04-08 12:00:00	45.7917	-8.0828	4
2017-04-09 12:00:00	49.7589	-3.1013	4
2017-04-10 12:00:00	52.0702	2.7040	4
2017-04-11 12:00:00	53.7172	8.2800	4

5.9 Stations

A station was defined as a specific location where different sampling methods (sampling events: see section 9) were used to collect different data sets or samples with the aim of grouping together these activities for future reference.

A full list of all stations is provided in the appendix in tables 48 (terrestrial) and 49 (oceanographic). They have been denoted as "successful" where they were carried out, even if all deployments did not take place successfully and "cancelled" where they were planned at some point but in fact did not take place due to operational problems. Each station was numbered so it can be identified and referred to in the literature, particularly in this document.

Station numbers were assigned by the data manager and were unique but stations did not necessarily happen in sequential order. A station was labelled as having a type “marine” if sampling events took place from the ship, and “terrestrial” if the sampling events were done at the terrestrial sites. On the smaller islands a station could cover a whole island (eg. Scott Island). However, at places such as South Georgia, there were a number of terrestrial stations because sampling took place over a much larger area of the island. Terrestrial stations included a variety of activities undertaken by Projects doing experiments at locations on islands. These were recorded as taking place at a central location where the sampling was done (this was usually taken from the location of the sampling event).

Oceanographic (marine) stations comprised a set of equipment deployments and measurements that were taken when the ship was stationary. It should be noted that although sampling events may have occurred at the same station, there will be some spread in location for instance as the ship drifted with currents, or in certain areas on islands. Oceanographic station positions were recorded from the location of the first sampling event that occurred at that station.

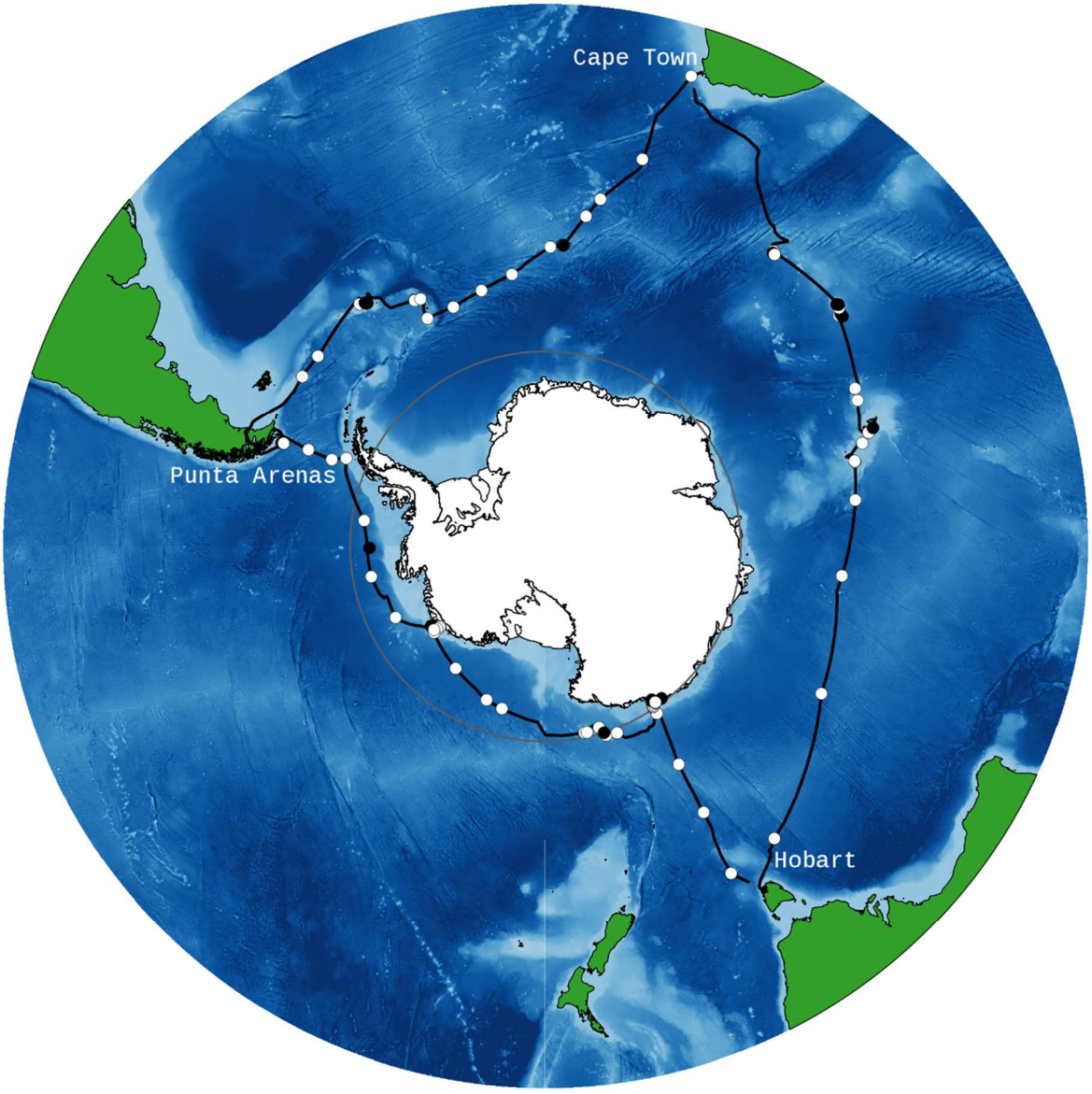

Figure 24: The ACE cruise track (one-hour resolution; solid black line) is shown with the stations (oceanographic – white dots; terrestrial – black dots). The main ports are labelled. The Antarctic Circle is also shown (solid grey line).

5.10 Island visits

In Table 4 are the dates on which islands were visited. The dates of arrival and departure do not necessarily coincide with the first or last date of fieldwork on the island because they are taken from when the ship anchored or left the vicinity of the islands.

Table 4: Dates on which the ship arrived at and departed from each of the islands.

Island name	Island group or port name	Arrival date (UTC)	Leaving date (UTC)
	Cape Town , South Africa	2016-12-15	2016-12-20
Marion Island	Marion and Prince Edward Islands	2016-12-26	2016-12-28
Ile de la Possession	Crozet Islands	2016-12-30	2017-01-01
Kerguelen	Kerguelen Islands	2017-01-05	2017-01-06
Heard Island	Heard Island	2017-01-08	2017-01-08

	Hobart, Australia	2017-01-18	2017-01-22
Mertz Polynya		2017-01-28	2017-01-28
Mertz Glacier	Antarctic Continent	2017-01-29	2017-01-31
Cape Denison	Antarctic Continent	2017-01-30	2017-01-30
Young Island	Balleny Islands	2017-02-03	2017-02-03
Scott Island	Scott Island	2017-02-06	2017-02-06
Lauff Island	Near Siple Island	2017-02-11	2017-02-11
Maher Island	Near Siple Island	2017-02-11	2017-02-11
Siple Island	Siple Island	2017-02-11	2017-02-12
Peter I Island	Peter I Island	2017-02-15	2017-02-15
Bartolomé	Diego Ramirez	2017-02-20	2017-02-20
Gonzalo	Diego Ramirez	2017-02-20	2017-02-20
	Punta Arenas, Chile	2017-01-22	2017-01-26
Grytviken	South Georgia	2017-03-02	2017-03-02
Nordenskjold Glacier	South Georgia	2017-03-02	2017-03-02
Penguin River	South Georgia	2017-03-02	2017-03-02
St Andrews Bay	South Georgia	2017-03-04	2017-03-04
South Sandwich Islands	South Sandwich Islands	2017-03-06	2017-03-07
Bouvetøya	Bouvetøya	2017-03-11	2017-03-13
	Cape Town, South Africa	2017-03-19	

6 Expedition Diary

(all times are ship time, NOT in UTC)

6.1 Leg 0

November 2016 (date specified with each activity below)

14 *Akademik Tryoshnikov* in Bremerhaven.

15 Began loading cargo.

16 Students arrived for Maritime University.

19 Sailed from Bremerhaven 22:00 for Southampton.

20 Stormy weather in English Channel.

21 Arrived Southampton.

22 Loaded cargo and helicopters. Departed 24:00.

23 Onwards Maritime University.

December 2016 (date specified with each activity below)

14 Attempted calibration of echo sounder system in St Helena Bay, Western Cape.

15 Ship arrived Cape Town at Immigration wharf. Moved later to central berth.

16 Discharged students.

17 Cleaned ship.

18 Scientists embarked for Leg 1. Revictual. Took on cargo. Installed new sea water pump and pipe.

19 Took on cargo; installed science equipment. Placed container labs on front holds.

6.2 Leg 1

20 Sailed to immigration. Fumigated two holds and hangar. Departed 23:20 with none of the outstanding jobs completed – no sea water supply to labs, two transformers still not coupled up to laboratory containers, Dyeema cable not respooled on port winch and trace metal rosette system untested, laboratory containers on forward hatch not electrically connected. Containers on racking still lacking water connection.

21 First short cast 200 m to test CTD, marginal sea state, damage to CTD bottle when hit the ship on recovery. Length of jib on crane limits deployment in any significant sea state. Sea water supply established giving up to 50 L/min clean sea water. Waste acid bath drum broke free in laboratory and flooded floor. Sea water pump failed in the late evening unexpectedly. Two scientists locked in Hold 2 by crew when working late – now have to collect VHF before going into hold. Start regular PI meetings at 18:00.

22 Additional hour added to local time. Sea state precludes CTD. Repeat Fire and Safety talk. Marion Island field party planning meeting. Ellwood container finally connected to transformer. Sea water supply re-established (failure due to running dry when roll exposed inlet). First successful radiosonde launch.

23 Helicopter briefings. Sea water supply failed again – watch system discussed. Fixed lamp in freezer room. Sea water connected to container laboratory 1. All underway systems except FerryBox now operational.

24 Heavy weather all day. Started on new rolling 5-day activity format. Agreed format for dredging at Marion with multibeam first to assess ground. Biosecurity talk and checks. FerryBox put back on line.

25 Arrived Prince Edward Island at 22:30. Multibeam not satisfactory and unable to select sites from pictures as too poor quality. Followed by shallow CTD and nets. Dredging not possible.

26 Raining and blowing but all field parties deployed finally by helicopter. Failure of Bolshiyanov party to call in and failure of communications to contact them after return time. Search parties from base failed to find them and recalled at 21:00. Part of Chown party returned to base too late for pick up with rising winds and spent the night there.

27 Early helicopter mobilisation to collect Bolshiyanov field party after VHF call heard. Party wet but otherwise unaffected. Search teams from base called back at around 05:00. Medivac of base person requested. Reduced number of field parties with all distance deployment cancelled. Rising winds precluded helicopter collection and 19 people stayed on island. Some further sample collection in afternoon. Confirmation from AARI that we should undertake medivac.

28 05:00 helicopters loading medivac then field parties completed by 07:30. Sailed for shallow leeward cast to 400 m. Station 2. CTD failed at 600 m. Successful first trial deployment of trace metal rosette but some bottles failed to fire. Successful trial of dredge – four runs completed on arbitrary sites with no multibeam support.

29 Passage to Crozet Islands. Calm seas all day. No stations. Repaired CTD sea cable termination.

30 Arrive Crozets – Île aux Cochons at 12:00. Standing 2 miles off with safety boats. Helicopter bird survey work, sea calm but with rain clouds gathering. Îlots des Apôtres not possible in time available and too cloudy. CTD 400 m at Station 8 followed by trace metal rosette.

31 Île de la Possession. Anchored close in to Baie Americaine. Very windy. Visit to station to collect three local guides. Flying very turbulent so helicopter flights suspended. Eventual agreement on landing by zodiacs. All field parties recovered from beach in late afternoon.

January 2017 (date specified with each activity below)

1 Île de la Possession. Bird survey flight to Île de l'Est not possible. Helicopters again deployed field parties in the morning but rising windspeed caused curtailment of operations and recall of field parties by lunch time. Sailed at 14:30 to dredge site. Initial dredge very productive but dredging curtailed by lack of ship control at low speeds.

2 Passage to Kerguelen. PI discussion in afternoon of options given existing weather and flying conditions. Safety discussion with zodiac drivers.

3 Passage to Kerguelen. CTDs not possible as heavy seas. Dredging in evening very successful. Night time working for first time. Launch of first pair of SOCCOM floats in 3000 m.

4 Passage to Kerguelen. Attempted late night dredging on track but most hauls poor.

5 On Kerguelen with day of zodiac operations and helicopter operations started late due to mooring delays. Day foreclosed by rapidly rising katabatic winds making recovery of field parties by both helicopters and zodiacs difficult.

6 Day started with winds of 40 knots so no flying. Rising winds caused cancellation of programme at 09:30 and departed lunchtime for Heard Island.

7 Ship took a zig-zag path south to minimise rolling arriving at the Heard EEZ around 07:00. Sea almost flat calm with winds less than 10 knots and limited visibility. Deployed trace metal rosette first then nets followed by 500-metre CTD then towed bongos and a further 150-metre CTD at Station 16. Moved to dredge site at Pikes Bank around 14:00. Very rich site.

8 Heard Island at just before 08:00 with the Macdonald Islands in the distance. Sunny and calm cruising along the north coast with occasional glimpses of the slopes of Big Ben and the Laurens Peninsula. Clouds cleared as we left to give superb view of the whole island with summit plume. The dredging site at Gunnari Ridge proved poor – possibly too deep in sediment. Changing position to another part of the plateau did not improve the catch.

9 CTD station delayed until after lunch as we were over a sea mount at 08:00. Chart soundings seem especially poor here. Station 19. Deep CTD winch failed at 400 m on recovery – finally fixed. Front winch failed with Trace Metal Rosette at 1000 m due to spooling problems but was also fixed. Pump for filling 1000-litre tank was not especially effective and only managed around 700 L in six hours. Exceptional weather with sun, no wind and calm sea!

10 On passage. Continuing good weather progressing at 15.5 knots. No stations.

11 Full station (Station 20) rescheduled for 10:00 with freshening winds and sea state. Problems with CTD winch resulting in very slow wire speeds. Vertical bongos failed twice with net wrapping around the cod end. Total time on station, nine hours due both to very slow winch speeds, deep casts, and long lunch break. Ship rolling a little but not too badly. SOCCOM float launched.

12 On passage – no stations. Continuing calm weather with good speed of over 14 knots.

13 Still calm but speed dropped with headwind and swell to 12 knots. Decided not to include an extra station as all winches affected by computer problem and now running slow.

14 CTD station 21 near 120 °E at 10:00 took only five and a half hours. Grey and overcast with low swell. Fire in container 3 caused by the oven overloading the circuit and burning out the transformer so no power there until Hobart. All frozen samples moved to main -20 ^{o}C freezer.

15 On passage – no stations. Very misty, calm sea. Making over 13 knots.

16 Still calm and making up to 15 knots. 13:00 neuston net deployed and radiometer deployed off bow. Winches can still be used if they are stopped repeatedly to manually reset spooler.

17 CTD station 22 at lunch time.

18 On passage.

19 Arrive Hobart 09:00.

20 In port. Loading of cargo etc. Press conference in afternoon followed by reception at Governor's house. Began installation of Remotely Operated Platform for Ocean Sciences (ROPOS) on hatch covers. Discussions with Tasmanian Parks and Wildlife failed to restore full science permit for Macquarie Island, making value of visit questionable.

21 In port. Farewell reception in evening at Casino. Continued installation of ROPOS. Sailing will need to be delayed to allow this to be completed.

6.3 Leg 2

22 Sailed 24:00 finally with ROPOS all aboard.

23 Beautiful weather. Boat drill and expedition talk. CTD station 23 at 17:00 very successful but CTD wire showing very poor spooling. First sonobuoy launched. Weather report troubling so cancelled visit to Macquarie Island because of major storm around island.

24 Acid spill in CTD wet laboratory requiring spill kit and respirators to clear up. Skirting edge of storm with winds up to 60 knots and waves up to 9 m. Lack of communication with container labs on fore deck a continuing problem. Foredeck and all container labs closed due to weather.

25 CTD station 24 for Polar Front water completed in less than 5 hours. Winches still not working properly. New rules agreed for container labs and Hold 2 with handsets on channel 16 and at least a one-hour warning of closing access.

26 Almost flat calm all day. Repaired software on CTD winch. Late afternoon CTD at station 25. TMR bottles all failed to fire so cast repeated. CTD wire to 1500 m to respool cable. Tried out mini Remotely-Operated Vehicle (ROV) for filming.

27 Flat calm still. Meetings with glaciologists on safety procedures. Biosecurity checks. Planning for visit to Cape Denison.

28 Arrive Mertz polynya. Entered pack around 02:00. Arrived Mertz Glacier around 15:00. Weather awful with winds of 40 knots. Searched for low shelf with little success. CTD station 26.

29 Perfect day with calm and blue sky, sunny all day. Drilling on snow dome successful. ROPOS first deployment terminated by alarm on a motor. CTD station in 700 m followed by usual nets. Tried out midwater trawl successfully followed by Agassiz trawl. Ship berthed with bows into ice barrier!

30 Another excellent day to start with. Cape Denison party despatched and landed but re-embarked within 30 minutes due to winds of 40 knots and rising. Cold overnight at -10 ^{o}C. ROPOS redeployed offshore in 900 m very successfully – ship holding station very well. ROV recovered late afternoon. Drilling party to fast ice completed in record time. Sonobuoy deployed into polynya by helicopter. CTD stations 32-36.

31 Overcast start soon starting to snow. Helicopters cancelled. Rapid move away from Mertz as pack ice started closing around ship so ROPOS cancelled. Established short CTD profile transect out into polynya stations 38-42. Determined possible new site for ROPOS on shelf break and new programme developed for following day. Meetings to establish what to do and where at Balleny Islands.

February 2017 (date specified with each activity below)

1 Early start at 05:30 to try for CTD failed due to pack ice. Sailed for new site on shelf break but CTD, dredge and trawl not possible. Sailed for second possible ROPOS site and began multibeam scan in heavy pack but this did not clear so ROPOS cancelled.

2 Pack ice in all directions until around 05:00 then some more open water. Several more areas of pack including one very dense area on track.

3 Station at 04:00, completed in four and a half hours. Pretty smooth sea with only 2 m swell to Balleny Islands which we reached around 16:00. Dredging at Cape Ellsworth at Young Island very successful.

4 After helicopter reconnaissance of Borradaile Island and north end of Young Island, deployed drilling party to low-level ridge on Young Island where the ice core team collected a 17 m core. Attempt to land on Borradaile spit by zodiac failed. Coastal photographic survey of Young and Buckle Islands successful. Dredging near Buckle Island successful with lots of mud. Sailed down to near Sturge Island for CTD followed by launch of ROPOS by Sturge seamount.

5 On passage for Scott Island. CTD deployed to study phytoplankton bloom.

5 Arrived Scott Island late afternoon and crossed International Date Line! Weather poor so undertook swath mapping of the area around the island until late evening and then launched ROPOS. ROPOS failed due to technical problem. No possibility of zodiac landings due to huge breaking swell.

6 Poor visibility and snow showers delayed helicopter operations until after 11:00. Managed all the field party landings despite recurrent snow showers and collected some excellent samples. Further swathing around Scott Island did not show up suitable trawl site as seabed too rough. Departed around 15:00 for mouth of Ross Sea looking for blue whale aggregation. CTD station 88.

7 Beautiful sunny day! Now making over 14 knots. Revised schedule with short CTD this evening. Group photo on front helicopter deck.

8 Additional CTD today (station 91) with cast to 3500 m to obtain deep Antarctic Bottom Water. This did not however solve the spooling problem on the CTD winch. Ice photos show considerable ice around Peter I Island with no obvious way in yet.

9 Overcast with reduced visibility but very calm. Full CTD station 92 after lunch.

10 Very calm with many tabular bergs. PI discussion on activities around Mt Siple rather than Peter I Island because of pack ice. Decided to divert for exploration of the Siple area.

11 Evening visits to islands in front of Mt Siple after helicopter reconnaissance. Zodiacs taking tourist trips, including crew.

12 Very successful drilling on Mt Siple producing 24 m core from 750 m altitude with Project 6 and snow sampling. Two sites dredged around Mt Siple base. Parties deployed to large penguin rookery. Late evening visit to beach by rookery. Successful ROPOS deployment in calm bay at ice edge.

13 Departed from ROPOS site at around 08:00 for trawling on shelf break. Winch 1 failed so used winch 2 which has unsafe couplings on wire. One trawl only then abandoned site. Shallow CTD station 67 took over two hours.

14 Very calm again, making 14.5 knots. Stations 100 and 101, morning full station and late evening shallow CTD with TMR.

15 Arrived one and a half hours early at Peter I Island so decided to try and obtain ice core. Island almost out of ice but with plenty of loose pack with huge numbers of seals. Drilling camp successful in sunshine but out of communication range. 13-metre core obtained. Fly-by photos of bird cliffs, sampled sea ice algae, few snatched samples on beach reached with difficulty in zodiac through loose pack.

16 Further discussions about number and position of CTD stations as time is now short. Weather continuing good.

17 Very calm seas still so over 14 knots. Corrosion overload on MilliQ filters in freshwater system so will require extensive spares in Punta Arenas. CTD on shelf early evening before crossing Drake Passage.

18 Full CTD station 72 in mid-Drake in late evening with worsening weather. Preparing landing party details for Diego.

19 Sea state worsening with wind from east. Originally picking pilots up at Cape Horn but they were not there but behind Richmond Island adding 120 miles to our passage. CTD cancelled due to lack of time. Took inside passage so did not arrive at Diego Ramírez until around 06:00 in the morning.

20 Confusion over permits and landing requirements but finally cleared with Santiago Foreign Affairs to go ashore in afternoon. Filled morning with trawling. Landing mainly by helicopter with zodiacs to the beach on Gonzalo starting after 14:00 in sunshine with occasional showers. Most parties deployed to Gonzalo as easier to land by helicopter. Updraft on Bartholomé and uneven landing made helicopter operations very difficult there. Islands completely covered by birds with large black-browed and grey-headed albatross colonies as well as rockhopper penguins.Very few skuas but many caracaras. Finished by 19:00 and began trawling again on route out at 24:00.

21 Misty morning turning to rain as we tracked along to Cockburn Channel. MilliQ parts obtained in Santiago and sent to Punta Arenas.

22 Arrive Punta Arenas. Alongside around 09:00. Began immediate discharge of ROPOS.

23 In port at Punta Arenas. Swiss Embassy reception in evening. Continued with discharge of ROPOS.

24 In port. All ROPOS finally discharged. Cargo.

6.4 Leg 3

25 Container labs replaced on hold. Finally sailed 22:00.

26 Shelf CTD first station but winch problems resulted in six and a half hours for station.

27 On passage. Full CTD station 77.

28 On passage. Swell increasing and ship starting rolling. Short CTD only at station 78.

March 2017 (date specified with each activity below)

1 On passage. CTD cancelled early as rising wind and swell; ship rolling heavily. Forecast is following storm will overtake us with swell up to 8-10 m and wind speed up to 40-50 knots. Biosecurity lecture in the morning and biosecurity check after lunch.

2 Arrived at Grytviken, South Georgia early. Cleared ship. Lovely sunny day with everyone ashore. Lots of sampling and excursions. Calibration of echo sounders at anchor near Hope Point for Project 5 took 12 hours. Moved overnight to Stromness Bay.

3 High winds blowing offshore caused ship to drag its anchor so moved from Stromness Bay to cruise in Cumberland West Bay in snow showers. Eventually decided to go in afternoon to Prion Island as possible diversion. Weather still poor with heavy swell in Bay of Isles and no landing possible – retreated to Rosita Harbour for protection. No night dredging possible.

4 Moved from Rosita Harbour in early morning heading south along the coast. Snowing with limited visibility at St. Andrews Bay so no helicopters. Completed all landings despite snow showers using zodiacs. Around two metres of ice core obtained. Departed on transect requested by Project 5 through king penguin feeding area.

5 Dredging in early morning cancelled as swell at 8 m and wind continuing. Moved to near Drygalski Fjord to assess possibility of landing on south coast to collect peat cores. Limited bathymetry meant ship had to stand off at least two miles, winds too high for helicopters and passage in poor seas too long for zodiacs. Headed off to South Sandwich Islands in heavy sea state with very large swell pushing speed down to 8 knots – continuing all day.

6 CTD station with McLane pumps – used three. Failure of TMR required recasting. CTD winch run to 1500 m to test which was fine. Lost cod end on neuston net due to excessive phytoplankton at surface overwhelming collector. Cold with snow showers. Arrived Candelmas Island early evening and after multibeam began trawling at 23:15. Six successful trawls with great variety.

7 Departed early morning for Saunders Island and waited there to sample ammonia plume from rookery but snow showers diminished strength of signal. Continued to Southern Thule.

8 Excellent weather but strong swell. Anchored close and launched zodiacs although no landings allowed. Good dredging site.

9 On passage.

10 On passage. CTD station 93.

11 Arrived at Bouvetøya late. Unable to make it in time for reconnaissance. CTD station 94.

12 Bouvetøya. Reconnaissance done and sites selected but initial focus on terrestrial sites which were completed by helicopter. Dredging OK but rather uniform.

13 Bouvetøya. Landed drilling party early but problems reduced core to 14 m. Pulled party off just after lunch as cloud developed. Tried to find beach for sampling but swell too high to land anywhere. Dredging in 500 m in morning. Departed around 15:00.

14 Short station (100) followed by full station (101) whilst on passage.

15 On passage.

16 Final station. Station 103 including McLane pumps. CTD and TMR 1000 m bottles failed to fire so repeated, making station over eight hours in length. Weather good to start but deteriorating to very heavy sea with fore deck closed.

17 On passage. Rough sea in the morning but calming later.

18 On passage. Sunny and warm. Station 104. Last bongo and neuston net. Clearing up and packing.

19 Cape Town, docking at immigration before moving to central berth.

20 In port.

21 In port.

22 In port.

6.5 Leg 4

23 Sailed for Bremerhaven 22:00.

24 March to 9 April on passage.

April 2017 (date specified with each activity below)

11 Arrived in Bremerhaven.

12 Began cargo discharge.

13 Continued cargo discharge.

14 Continued cargo discharge.

19 Continued cargo discharge.

20 Complete cargo discharge.

7 Data collection

7.1 Science equipment on board

The majority of the equipment listed below in Table 5 was brought on board by the Projects participating in the expedition. Where the item is marked as "ship-based" in the comments column, this was an item that was owned by the ship and already installed on board.

Table 5: Summary of equipment used by projects during ACE.

Instrument name	Short name	Serial number	Make	Model	Comments
7x50 Binoculars	Binoculars				
10x32 Binoculars	Binoculars		Zeiss		
a-Sphere In-Situ Spectrophotometer	a-Sphere	SP110411	Hydro-Optics, Biology & Instrumentation Laboratories		
Aanderaa Oxygen Optode 4175			Aanderaa	4175	FerryBox sensor; ship-based
Acoustic Doppler Current Profiler	ADCP		Teledyne	RDI broadband	Ship-based
Aerodynamic Particle Sizer	APS	70512029	TSI	3320	
Aerosol Chemical Speciation Monitor	ACSM	3	Aerodyne	ToF	
Aetholometer		32	Magee Scientific	AE 33	
Aetholometer			V.E.Zuev Institute of Atmospheric Optics Siberian Branch, Russian Academy of Sciences		
Agassiz trawl net			British Antarctic Survey, UK		
Aspirator					Used by Project 22
Atmospheric pressure interface time-of-flight mass spectrometer	Api-TOF		Tofwerk		Operated alternating as nitrate CIMS
Berlese-Tullgren extractor			Monash University		For heat extraction of arthropods
Bio optical profiling system	ECO Triplet	1198	Wetlabs	BBFL2	
Bio optical profiling system	ECO Triplet	1507	Wetlabs	BBFL2	
BioSampler	SKC		SKC Inc. USA		
Biospherical Surface Ocean Reflectance System	BioSORS	28000504101	Biospherical Instruments		
Bongo net 100 micron					Phytoplankton sampling
Bongo net 200 micron					Zooplankton sampling

Bongo net 300 micron					Microplastic sampling
Ceilometer CL31			Vaisala	CL31	Ship-based
Chlorophyll-a fluourescence induction and relaxation instrument	FiRe		Satlantic		
Cimel Sun Photometer	Cimel		CIMEL Electronique		
Cloud Condensation Nuclei Counter	CCNC		DMT	100	
Cloud water sampler			TROPOS		
Condensation Particle Counter	CPC3022	561	TSI	3022	
Condensation Particle Counter	CPC3772	70933282	TSI	3772	
Condensation Particle Counter	CPC3010		TSI	3010	
Condensation Particle Counter 3772	CPC3772		TSI	3772	Operated with SPIN
Coriolis Air Sampler	Coriolis	1	Bertin Technologies, France		
Coriolis Air Sampler	Coriolis	2	Bertin Technologies, France		
Coulter Counter		unknown	Beckman		
CTG MiniPack CTD-F			Chelsea Technologies Group	MiniPack CTD-F	FerryBox sensor; ship-based
CTG UniLux 2125-016-PL-A			Chelsea Technologies Group	2125-016-PL-A	FerryBox sensor; ship-based
Digital SLR Canon EOS camera	Canon DSLR EOS camera		Canon	5D Mark IV	
Digital SLR Canon EOS camera	Canon DSLR EOS camera		Canon	7D Mark II	
Digital SLR Canon EOS camera	Canon DSLR EOS camera		Canon	5Ds	
17 - 40 mm Canonlens			Canon		
70-200 Canon mm lens	Canon lens		Canon		
24-105 Canon mm lens	Canon lens		Canon		
Digital SLR Nikon camera D810	Nikon DSLR camera		Nikon	D810	
Directional Frequency Analysis and Recording Sonobuoy	DIFAR Sonobuoy		Ultra Electronics Sonar Systems	AN/ SSQ-955-HIDAR	All sonobuoys have different serial numbers which are recorded in the data

Dynamic Above Water Radiance (Lu) and Irradiance (Ed) Collector	DALEC		In-Situ Marine Optics		
EK60 echo sounder	EK60		Simrad AS	EK60	
EK80 echo sounder	EK80		Simrad AS	EK80	
Equilibrator Inlet Mass Spectrometer	EIMS	PTM28631-44520048			
Expendable Bathythermograph	XBT		Sippical and Tsurumi-Seiki (TSK)	T-7	Each XBT had a unique serial number, noted in data files. Available from the ship.
Fast Repetition Rate Fluorometer	FRRF				Used by project 1
FerryBox			Chelsea Technologies Group	AquaLine	Ship-based
Flow cytometer cube			Partec	Cube 8	
Flow meter					Used on various nets
Gamma-4 transmissometer		G4110401	Hydro-Optics, Biology & Instrumentation Laboratories		
Gas chromatograph		US00037478	Agilent Technologies	6890a series G1530A	
Gas chromatography-mass spectrometer	GCMS	U51223A402	Agilent Technologies	5975-T LTM-GC/MSL	
Global Navigation Satellite System	GLONASS				Ship-based
Global Positioning System	GPS				Used by Project 22
Global Positioning System	GPS		Garmin	eTrex 30X	Handheld; used by Project 4
Go Pro Hero 3 +	Go-Pro		Go-Pro	Hero 3+	Installed on Agassiz trawls
Go-Pro Camera	Go-Pro		Go-Pro		Installed on bridge
Ground Penetrating Radar		3307	GSSI Inc.	SIR 3000	
Ground Penetrating Radar Antenna		885	GSSI Inc.	504005	
Guildline Autosal 8400B Salinometer	Autosal	70231	Guildline	8400B	Ship-based
HD Mini-Zeus Camera	HD Mini-Zeus		Instant Pacific	Zeus 1080i/59.94	
HD Zeus Camera	HD Zeus		Insight Pacific	1080i/59.94	

High volume digitel air filter sampler		1	Digitel		PM10
Hydrins			IXBLUE		Ship-based
HydroDAS data logger	HydroDAS	HD110410	HydroDAS		Attached to IOP frame to control instruments
Hydrogen generator			Cylinder Free	CFH600	Used to provide hydrogen to instrument used by project 8
HydroScat-6 Spectral Backscattering Sensor & Fluorometer	HydroScat-6	HS110455	Hydro-Optics, Biology & Instrumentation Laboratories	6	
Hygrometer		1			Used to monitor operation of equipment for project 7
Hygrometer		2			
Hygrometer		3			
Ice nuclei spectrometer	SPIN		DMT		
iDirac	iDIRAC	DMS	Universities of Cambridge and Cranfield		
iDirac	iDIRAC	isoprene	Universities of Cambridge and Cranfield		
Imaging Flow Cytobot	IFCB				
Inclinometer		162200139	Measurement Specialities		Operated by Project 11/ situated in acoustics lab
Inclinometer					Ship-based
Inherent Optical Properties frame	IOP frame		Hydro-Optics, Biology & Instrumentation Laboratories		
Isaac-Kidds Mid-water Trawl	IKMT				
ISUS V3 continuous nitrate sensor	ISUS		SeaBird Electronics		Used as part of Project 13
Kinematic Global Positioning System	GPS		Topcon	Hiper Ga	Used with ground penetrating radar system
Kovacs ice core drill			Kovacs		
Logitech HD webcam			Logitech	C270 HD	
Low volume digitel air filter sampler		2	Digitel		
Lowered Acoustic Doppler Current Profiler	LADCP				Deployed on some CTD casts
McILane Pump					In situ

Metal frame					CTD frame; ship-based
Micro Rain Radar	MRR		METEK	MRR-2	
Microtops Sun Photometer	Microtops	16823	Microtops		
MilliQ system					Provided by G. Massé for use by all projects
Multibeam echo sounder	Multibeam		ELAC Nautik	SeaBeam 3020	Ship-based and operated
Nano Scanning Mobility Particle Sizer	Nano SMPS	PSI002	Paul Scherrer Institute	PSI	
Neuston net 200 micron					Microplastic and zooplankton
Neutral Air Ion Spectrometer	NAIS		AIREL		
Niskin bottles					Ship-based
Nitrogen plant					Provided by G. Massé for use by all projects
Omnidirectional very-high frequency antenna	Omnidirectional VHF antenna		PCTel	MFB1443	
Online Hyperspectral Integrating Cavity Absorption Meter	OSCAR		TriOS		
Oxygen sensor		431619	SeaBird Electronics	SBE 43	Installed on ROPOS ROV
Ozone Monitor	O3	753DB	2B Technology		
pH sensor			SeaBird Electronics	SBE 18	FerryBox sensor; ship-based
Photoelectrical aerosol particle counter	AS particle counter			AZ10	
Photosynthetically Active Radiation Sensor	PAR sensor	10252			FerryBox sensor
Picarro G2400 gas analyser	Picarro G2400	1004CFKADS2024	PICARRO	G2400	
Picarro Gas Scouter			Picarro	GasScout	
Picarro L1115-i-i Laser Spectrometer	Picarro L1115-i-i		Picarro	L1115-i-i	
Picarro L2120-i laser spectrometer	Picarro 2120	HBDS2190	Picarro	L2120-i	
Picarro L2130-i laser spectrometer	Picarro 2130	HIDS2018	Picarro	L2130-i	
Picarro L2130-i laser spectrometer	Picarro L2130-i		Picarro	L2130-i	

Portable Sun Photometer	SPM		V.E.Zuev, Laboratory of aerosol optics, Institute of Atmospheric Optics, Siberian Branch of Russian Academy of Sciences, St Petersburg, Russia		
Purge and trap system			Tekmar Teledink	Stratum	
QCP-2300 Logarithmic Quantum Cosine Irradiance Sensor	QCP-2300 Cosine PAR sensor	4664	Biospherical Instruments Inc.	QCP2300	
Radiosonde			Internet Systems	iMet ABX(n)	Each radiosonde has a unique serial number that is recorded in the data files
ROPOS remotely operated vehicle	ROPOS ROV		Canadian Scientific Submersible Facility	prototype	
Russian peat sampler			Eijkelkamp		
SBE 11plus V2 deck unit	SBE 11plus V2	11P56769-0839	Sea-Bird Electronics	SBE 11plus V2	Installed on CTD
SBE 3plus Premium CTD Temperature Sensor	SBE 3+	5307	Sea-Bird Electronics	SBE 3+	Installed on CTD
SBE 3plus Premium CTD Temperature Sensor	SBE 3+	6146	Sea-Bird Electronics	SBE 3+	Installed on CTD
SBE 4 Conductivity Sensor	SBE 4C	3793	Sea-Bird Electronics	SBE 4C	Installed on CTD
SBE 4 Conductivity Sensor	SBE 4C	4624	Sea-Bird Electronics	SBE 4C	Installed on CTD
SBE 43 Dissolved Oxygen Sensor	SBE 43	3430	Sea-Bird Electronics	SBE 43	Installed on CTD
SBE 43 Dissolved Oxygen Sensor	SBE 43	4319	Sea-Bird Electronics	SBE 43	Installed on CTD
SBE 5T submersible pump	SBE 5T	53667	Sea-Bird Electronics	SBE 5T	Installed on CTD
SBE 5T submersible pump	SBE 5T	55625	Sea-Bird Electronics	SBE 5T	
SBE 911plus Conductivity Temperature Depth recorder	SBE 911+ CTD		Sea-Bird Electronics	SBE 911+	Installed on CTD
SBE 9plus Conductivity Temperature Depth recorder	SBE 9plus CTD	09P31934-0730	Sea-Bird Electronics	SBE 9plus	Installed on CTD
SBE19PLUS V2 Conductivity	SBE 19plus CTD	19P49661-6316	Sea Bird Electronics	SBE19PLUS V2	Installed on ROPOS ROV

Temperature Depth Recorder					
SBE37-SM MicroCAT C-T (P) Recorder	MicroCAT	4990	Sea-Bird Electronics	37-SM	
SBE49 Fastcast Conductivity Temperature Depth Recorder	SBE49 Fastcast CTD	4963830-0236	SeaBird Electronics	SBE49 Fastcast	Installed on IOP frame
Scanning Mobility Particle Sizer	SMPS	PSI001	Paul Scherrer Institute custom-made		
Sea-Bird Scientific Carousel Water Sampler	SBE 32		Sea-Bird Electronics	SBE 32	Ship-based
Seabird SBE18	SBE18		Sea-Bird Electronics	SBE18	FerryBox sensor; ship-based
Seapoint Chlorophyll Fluorometer		3120	Seapoint	Standard version	
Sediment corer					Installed on ROPOS
Single-beam transducer		LSE179	ELAC Nautik		Ship-based
Single-beam transducer		LSE313	ELAC Nautik		Ship-based
Snow particle counter	SPC				
SOCCOM float	SOCCOM	F6091	Seabird Electronics	NAVIS	
SOCCOM float	SOCCOM	F6092	SeaBird Electronics	NAVIS	
SOCCOM float	SOCCOM		APEX		
Spectral Absorption and Attenuation Meter	AC-S		WETLabs		
Spidertracks		G-BATC	Spidertracks		Installed on helicopters
Spidertracks		G-TVAM	Spidertracks		Installed on helicopters
Stainless-steel bucket					Microplastic sampling
Suction sampler					Installed on ROPOS
Supercooled Liquid Water Content sampler	SLWC		Anasphere		
Teledyne PSA 916 Sonar Altimeter	PSA 916	50414	Teledyne Benthos	PSA 916	Installed on CTD
Temperature probe	4Temp				Installed on ROPOS
Temperature-depth recorder	TDR				Installed on CTD, but normally deployed on marine predators
Thermistor string					Used in ice cores
Totalisator			Palmex		

Trace metal rosette	TMR		General Oceanic		Using Niskin X bottles
Trimble Global Positioning System	GPS		Trimble		Ship-based
Ultra-short baseline	USBL				Deployed with ROPOS
Unidirectional antenna			PROCOM	CXL 70-3LW/s	Used with radiosondes
UV-1800 UV-VIS spectrophotometer	UV-1800	A11454835195	Shimadzu	UV-1800	Ship-based (quartz couvettes belonged to project 8)
UWITEC corer			UWITEC		Used by Project 22
UWITEC short gravity corer			UWITEC		Used by Project 9
Vaisala Weather Station			Vaisala		Ship-based
Valve monitor					Used to monitor underway water flow to Project 1 equipment
Voltmeter					Used to make measurements of temperature on thermistor string
VWR Microbiological air sampler	SAS		VWR, Italy		
Wardenaar peat corer			Eijkelkamp		
Wave and current monitoring system	WaMoS		OceanWaveS	WaMoS II	Uses ship-based radar
Welch vacuum pump	Welch	1	Welch		
Welch vacuum pump	Welch	2	Welch		
Welch vacuum pump	Welch	3	Welch		
Wenglor snow particle counter	Wenglor		Wenglor		
WETlabs ECO-FLCDRTD CDOM Sensor	ECO CDOM Fluorometer	2344	WETlabs	ECO-FLCDRTD	
WETLabs Scattering Meter	BB9		WETLabs		
Wideband Integrated Bioparticle Spectrometer	WIBS			4	

Table 6 lists generic faults on board that caused issues with equipment and therefore potential data loss or possibly adversely affected the data or instrumentation. Note that instrument-specific faults can be found in the relevant section for that instrument, or the associated Project reports.

Table 6: List of generic faults on board.

Date (UTC)	Time (where known; UTC)	Fault	Instruments or data affected
2018-12-06	Unknown; two periods of 10 minutes	Electricity was turned off in wet labs	Nitrate sensor EIMS Triplets
2018-12-09	Unknown	Reduced flow rate in underway water supply	All instrumentation connected to underway water line, but in particular: EIMS nitrate sensor Imaging Flow Cytobot

7.2 ACE-collected data streams

All data collected by ACE scientists were stored on the expedition Network Attached Storage (NAS; see IT and data management sections for more information) in a folder in ace_data, named after the instrument. As this is usually an acronym, a full list of this mapping between folder name and instrument can be found in the database (see main_sampling method and main_specific_device tables).

7.3 Ship-collected data streams

Several data streams (see Table 7) were collected by instruments belonging to the ship or being operated by ship personnel. Detailed information about each of the data streams can be found within the relevant folder within the ship_data area on the NAS or in the rest of section 7 of this document. Information about the variables in each data file, problems with data streams and more information about the instrumentation can be found within each of the relevant folders as well, but a brief overview is provided here.

A full diagram of the ship's network including these data streams can be found in Figure 31.

Table 7: Summary of ship data streams.

Data stream	Data folder	Description
FerryBox	ship_data/FerryBox	Instrument comprising a number of sensors recording data about the water passing through it from the continuous underway sea water supply (ASCII format)
GPS (Trimble)	ship_data/gps_trimble	GPS from Trimble in multibeam room (raw NMEA strings in text files)
GLONASS	ship_data/gps_bridge1	GLONASS from bridge (raw NMEA strings in text files)
ADCP	ship_data/adcp	ADCP (raw data in N1R N2R format)
Multibeam	ship_data/multibeam	Multibeam echosounder (raw and some processed data)
Motion (inclinometer data)	ship_data/motion	Raw motion data in txt files
Meteorology	ship_data/met_data	Daily txt files

7.4 Navigation data

There were two sources of navigation data on the ship that were used: the first was a feed from a Trimble Global Positioning System (GPS) and the second from the bridge-based Global Navigation Satellite System (GLONASS). These data sources will be described below, then more information about the data will follow.

7.4.1 Trimble GPS

Two Trimble antennae were mounted athwartship on top of the helicopter control tower on the same level as the bridge. It is unknown how their position affected the data quality. The data were then received by two control units in the acoustics laboratory on deck 4.

The Trimble GPS passed through a serial port connection to a Windows computer which operated the multibeam echo sounder. Several instruments or data sets received a direct feed of data from this GPS: multibeam echosounder, singlebeam echosounder (during Legs 0 - 3 only), motion data and the sonobuoy computer (Legs 2 – 3).

On the computer operating the EK80 it was saved into daily files in a shared folder (using National Marine Electronics Assication (NMEA) Router software), then backed up every hour onto the NAS (ship_data/gps_trimble folder) and imported into the database in real-time (in the table ship_data_gpggagpsfix). The daily files contained the full set of NMEA strings as recorded without any alteration. When the data were imported into the database, only a subset of NMEA strings and data fields were stored (see Table 8).

The first Trimble GPS data were recorded at 2016-12-21 06:59:14 UTC and can be found in the gpsdata.log file in ship_data/gps_csv_track. Due to an error not selecting an option in the software, daily files were not created until the 23 December 2016. The data from the Trimble GPS was saved into daily files from the 23 December 2016 until reaching Bremerhaven on the return journey (12 April 2017).

Events occurred before the 21 December 2016 on Leg 1 (but also on Leg 0) for which GPS data will be required. Data from the Trimble GPS go into the motion data files, so the GPS track could also be extracted from here for the dates prior to the 21 December 2016.

This GPS was turned off when stationary, so there are gaps in this data stream when the ship stopped in port or at islands. The first time this happened on Leg 1 (at Marion Island) is when the copying of the GLONASS was setup, in addition to the requirement of having a "back-up" data source.

This data set is fully documented (with details about gaps in data, quality checking and full information about the instrumentation) in the ship_data/gps_csv_track/documentation folder. This is essential reading for anyone considering using this data set as when quality checking was done (during Leg 4 for the whole cruise) there were a number of occasions when the Trimble and GLONASS feeds differed substantially.

7.4.2 Global Navigation Satellite System (GLONASS)

The Bridge operated a GLONASS rather than GPS. The GLONASS antennae lie approximately 20 metres further forward on the ship than those for the Trimble GPS. They are both mounted on the crow’s nest. The signal was received and transferred to a panel on the bridge, then via a serial port to another computer on the bridge. The Franson GPS Gate software (version 2.6) operating on a computer on the bridge sent the NMEA strings over the User Datagram Protocol (UDP) to the ACE network.

Data were saved into daily files by the kplex software running on Lubuntu and imported into the database live using the Python script nmea_file2db.py. The full set of NMEA strings was saved in these files (see Table 8 for the full list of these). At the same time the kplex software served the NMEA strings on a Transmission Control Protocol (TCP) port so anyone on the ACE network could have easy access to the GPS and GLONASS data in real-time.

Several instruments or data sets received a direct feed from this navigation system: the ship-based Acoustic Doppler Current Profiler (ADCP), FerryBox, meteorology data and the Max-Seaview software on a computer in the CTD dry laboratory.

Further information about the set-up and data collection from these instruments can be found in the full set of documentation with the data.

7.4.3 Summary of navigation data

The GPS feeds (and daily log files) include the following National Marine Electronics Association (NMEA) strings (see Table 8).

Table 8: - List of NMEA strings that are available from each of the navigation data streams and also output into the database (ship_data).

NMEA string	GLONASS	Trimble GPS	Database
GPZDA	Y	Y	Y
PORZX	Y		
GPRMC	Y		
GPGGA	Y	Y	Y
GPVTG	Y	Y	Y
GPHDT	Y		
GPROT	Y		
PRDCU	Y		
GPGSA	Y		
GPDTM	Y		
PORZD	Y		

The database tables (ship_data_gpggagpsfix, ship_data_gpvtgvelocity, ship_data_gpzdadate time) contain the navigation data of the NMEA string from which they take their name. Each table contains data from both data streams which can be distinguished by the device_id field (63 for GPS Trimble or 64 for GPS Bridge1 (GLONASS), these are foreign keys to the main_sampling_method table). As can be seen by the name of the database tables, only three of the NMEA strings were parsed into the database and only latitude, longitude, date and time were then output into CSV files using a script, but this could easily be done for any of the other required NMEA strings if necessary. These CSV files are generated by the script exportgpstracks.py and are done for four different time resolutions: 1 hour, 5 minute, 1 minute and 1 second (time resolution of data collection).

Having both data streams was advantageous in case one stopped working or the network connection was broken for some reason (as happened a couple of times). An additional problem of the software on the bridge computer crashing also meant that at times there were no navigation data being logged. Gaps in these data can be found in the ship_data/gps_bridge1 and ship_data/gps_trimble folders in files called data-coverage_startdate_enddate.json. They were produced in JSON format in order to make it easier to parse the files at a later stage.

Events were recorded for the navigation data in the database, by using the times when there were no data recorded. With the start and end times of when there were data logged in JSON format, it made it much easier to parse and put into the database.

Some quality checking was done on the navigation data sets by comparing both of the fields. The following steps were taken and can be read about in full in ship_data/gps folder/gps_documentation. Results of this can be seen in the same folder. The initial quality checking entailed:

- compared distance between points for each navigation data stream at a one-minute resolution and flagged if the distance is greater than 15 metres from what it should be (the antennae for the different systems are mounted about 20 metres apart);

- compared calculated speed of ship between one-minute points and flagged if greater than 20 knots (to identify spikes; it seems that there is one plausible case when the ship is doing this speed);

- checked flagged areas for confirmation on map.

7.5 Conductivity-temperature-depth (CTD) recorder

7.5.1 Introduction

A CTD unit was used to vertically profile the water column at the stations around the track. 64 casts at 44 stations were completed successfully during the expedition. The CTD was operated by Tahlia Henry (Legs 0 and 3), Jennifer Hutchings (Leg 1) and Marie-Noëlle Hussais (Leg 2), assisted by Nina Schuback and Stéphane Aebischer. The ship's crew, Mikhail, Iiuri and Artem, operated the winch and were present for all deployments.

At each station the SBE 3plus and SBE 4c sensors that were part of the SBE 9plus CTD unit, respectively measured temperature and conductivity. Data was recorded by the SBE 11plus (V5.2) deck unit in the CTD dry laboratory for the downcast and upcast.

7.5.2 CTD instrumentation

An SBE 32 carousel with 23 10-litre niskin bottles and one 5-litre niskin bottle, with an SBE 5T pump and SBE 11plus deck unit were used. These all belonged to the ship and were already on board. In addition, a set of instruments owned by one of the expedition Projects was used throughout the expedition (see section 0).

In addition to the instrumentation in section 0 a Lowered Acoustic Doppler Current Profiler (LADCP; for Project 21) was added to certain casts on Leg 2 to measure the current flow in the water column and a Temperature-Depth Recorder (TDR; for Project 5) was also attached to various casts throughout the expedition in order to calibrate the instrument in similar waters to which similar instruments were being deployed on marine predators from South Georgia as part of the same Project.

7.5.3 Calibration

Calibration certificates can be found in section 15.6 of this document.

7.5.4 CTD deployment procedure

Jennifer Hutchings, Tahlia Henry, Alexander Haumann, Maria Tsukernik, Carles Pina Estany

The CTD was deployed from the winch in the centre of the port side of the ship. During Leg 0, there were problems deploying it partly because the end of the crane was very close to the ship but also because the CTD frame itself was very light. Weights were installed from the beginning of Leg 1 which improved the deployments.

The following steps were taken to complete a CTD deployment (Jennifer Hutchings, Leg 1):

Preparation > 1 hour ahead

- Arm bottles
- Make sure bottles closed (top screw tight, bottom spigot out and turned to side of pin)

Preparation 10 minutes ahead

- Clean optical sensors with kim wipes and distilled water
- Remove syringes from salinity cells
- Check clouds and sea state

To start deployment

- Ask Winchman to inform on radio when CTD over side, and to descend immediately to 10 m
- Crew science team moves CTD on deck and over side
- Power on (SBE 11)
    - In Seasave: Real Time Data -> Start; choose begin archiving immediately
- Pumps on (Check SBE 11 is showing 0111)
- 2-minute wait at 10 m

- Note time, latitude and longitude
- Ask Winchman to go up to surface
- At surface in Seasave:
- !!!!!! Real time data -> Begin Archiving Data !!!!!
    - or when using begin archiving immediately, note scan number at surface

During deployment

- Instruct Winchman “Go Down to x depth at 0.5 m/s” (x is normally 150 m)
- Note location of DCM, changes in water properties
- Note sample priorities from bottles.
- Instruct Winchman “Go Down to y depth at 1m/s” (if winchman suggests a different speed, he is interested in safety of ship and equipment)
- Note physical structure of profiles and assign locations for salinity and oxygen standards
- Complete Rossette Sheet

At *bottom* depth

- Note Location and Time at Bottom
- Fire bottles if required

During upcast

- Instruct Winchman “up to depth z at 1 m/s”
- Count down distance to firing depth “5,4,3,2,1, Stop”
- Wait 1 minute
- Fire bottle; repeat for all firing depths
- Instruct Winchman to come to surface and tell you when at surface

At surface

- At surface stop
- Real Time Data -> Stop
- Pumps off.
- Turn off power SBE 11.
- Crew bring rosette in and secure to deck or floor in wet laboratory.
- Rinse triggers and optical sensors with filtered water.
- Ask about bottle integrity. Note any failures and plan to fix these after sampling.
- Flush and seal salinity cells (syringes).
- When all done sampling dump water slowly (avoid flood). Best to empty through tube into bucket, then release small amount water to floor. The floor drain is inadequate.
- Rinse instruments and rosette with hose. Finish sensor and trigger rinse with filtered water.

7.5.5 Summary of CTD casts

Originally, we planned 95 CTD stations throughout legs 1 to 3. This original station plan was designed (by Alexander Haumann, Jennifer Hutchings, and Michael Ellwood) for the scientific purpose of sampling waters across frontal systems (north, in-between, south), upstream and downstream of islands, and with approximate equal spacing between these stations. A number of stations consisted of a deep and an additional shallow cast, where the latter was carried out to fulfil the high water demands for the surface layer (top 150 m). The deep cast was typically 400 m, 1000 m, or 1500 m deep, depending on its location. The deepest casts (1500 m) were carried out north of the Subantarctic Front to sample surface, mode, intermediate and upper deep waters, whereas 1000-metre casts were carried out south of the Subantarctic Front were the deep waters are shallower. A number of 400-metre casts were carried out in between the

deeper casts to sample the upper ocean. Due to a combination of severe weather conditions, technical issues, and temporal constraints, only 44 of the original planned 95 stations were carried out, with fewest stations during leg 1 and most stations during leg 2.

A full list of CTD casts can be found in the appendix in Table 49 but here is a summary of notes of problems with the casts:

7.5.5.1 Leg 1 CTD cast problems

Operator: Jennifer Hutchings

CTD cast 000, event number 4

Ship first positioned such that wind would blow it over CTD line. Had to ask to reposition. Bottle number 21 broke and number 9 was leaking (bracket joint cracked). Elastic fixed for number 9. Number 21 has been epoxy and zip-tied back together.

Rosette flung against ship as cannot bring it up fast enough in 8-metre sea. Wind was rising.

We had deployed in 4-metre sea, but with rising sea state the situation had deteriorated by the time we were needing to recover. The CTD went straight down (thank you for the weights), and there was less yo-yoing than leg 0 experienced.

22 December 2016 – no cast. Maintenance work.

The CDOM sensor was swapped for an ECO FLBBRTD. This sensor belongs to Emanual Boss. Serial number 4391. Physically installed by Nina Schuback.

CTD cast 001, event number 75

Forgot to “Start Archiving”, so no data saved. Stephane Aebischer saved screen shots of every window. Bottle 24 failed to fire.

CTD cast 002, event number 80

Blew fuse at 650 m. Returned to deck. Trouble shooting. There is resistance in the slip ring transferring power from winch to ship. Short here or on the sea cable at some depth perhaps.

CTD cast 003, event number 123

Started archiving at 30 m.

CTD cast 004, event number 264

Had wrong PSA file on start because system had crashed and I used the wrong file. Caught this and used ACE psa file in seasave after 10 m. Forgot to return to surface, but restarted cast from 10 m with correct psa file. Used archive immediately option to avoid data loss. Will need to cut off header lines.

CTD cast 005, event number 285

Changed config file to try to record back scatter data from ECO FLBB. Set to collect voltage with polynominal and setting coefficient to 1. This did not work. Channel 3 does not have any voltage coming to it.

CTD cast 006, event number 317

Station 19, note was mislabled as station 16 in seasave files. Edited header file by hand. Removed PAR sensor and altimeter. SUCCESS on downcast. No failure at 650 m. Sea cable good! Taking O_2 and salinity samples from bottle 21 to check integrity of bottle. Fired 700-metre bottle too soon (trigger happy!). Winch failed at 405 m. Fixed by crew. No information on what was wrong, but said okay to fire bottles on way up and take another shallow cast on this station. Bottle 12, trigger failed (this was known to be intermittent on

leg 0). Bottle 19 leaked. Stéphane Aebischer tightened elastic. Bottle 24 had top cock open. Reinstalled PAR and Altimeter sensors. Inspection of altimeter sensor shows one bent pin and a badly aged o-ring by the sensor head.

CTD cast 007, event number 318

Bottle 2 leaking.

22 January 2017 - no cast. Maintenance.

Removed triggers and soaked over night in soapy water.

CTD cast 008, event number 369

SOCCOM calibration cast. Ship turned 180 degrees while CTD in water at surface. Sea state and wind rising, so that might be the reason. Winch incredibly slow. Running on manual, not sure but there may be an electrical issue. Need to figure out from crew what is the problem and identify if maintaince needed in Hobart. No bottle compromised. SOCCOM float deployment after cast.

CTD cast 010, event number 401

Removed PAR and altimeter sensors, just in case the rosette yo-yoed at deepest depth. 1000-metre cast, supporting SOCCOM deployment. SOCCOM deployment was cancelled just as rosette came on deck, so we did not sample for dissolved inorganic carbon and pH. Altimeter sensor bracket needs attention: screw hole is stripped out.

CTD cast 011, event number 402

Send altimeter fixation for repair. Tightened bottle elastic on numbers 1, 2, 3, 4, 6, 7.

CTD cast 012, event number 607

1000-metre cast, kept PAR and altimeter sensors on for this cast. Bottle 6 leaked, was completely empty on deck. Inspected it, not sure what the problem was.

CTD cast 013, event number 608

No events to report. The sea state had risen by the end of cast, crew successfully retrieved CTD. Bottle 24: white ring on outflow sprigot lost in the ocean.

7.5.5.2 Leg 2 CTD cast problems

Operator: Marie-Noëlle Houssais

No details of problems are available.

7.5.5.3 Leg 3 CTD cast problems

Operators: Tahlia Henry and Stéphane Aebischer

CTD cast 001, event number 2201

The depth of the cast was 1500 m, therefore the PAR and altimeter sensors were removed (due to lack of dummy plugs) and replaced for the next cast. Once both instruments were plug back in however each had to be reconfigured and added to the CTD operating config file.

For the casts that followed, the PAR sensor was used but the data obtained does not seem accurate even though the same parameters were given to the PAR sensor set-up (as seen in the previous Leg setup and calibration spreadsheet).

The CTD winch cut out at 1500 m which resulted in a delay cast duration of 3 hours. The crew serviced the winch as best as possible. However for cast 003 (event number 2568) which was meant to be a 1000-metre

(PAR sensor attached) cast turned into a deeper cast to 1500 m as the crew wanted to test the winch. We were only informed of this once the CTD was already underway, hence resulting in the PAR sensor going beyond the instruments operational capacity.

CTD cast 013, event number 3114

The cast went down to 1500 m. On the up cast three bottles were fired at the intended depth (two at 1500 m; one at 1000 m) and the computer screen froze. Note that the computer referred to a loss of connection for the data acquisition pipe (therefore no data recorded from that point). The SeaSave program was restarted and the data archived which continued at bottle position 4 and ended at bottle position 20. The water budget and sample depths were adjusted accordingly to match the new profile and position at which the bottles were fired.

CTD file names for cast 013 (first data acquisition = ACE201603_013.hex; second data acquisition = ACE201603_013a.hex)

Rosette and Niskin Integrity:

The bottles and sensors were flushed and washed with MilliQ water/Fresh water after every cast. The o-rings lining the tops and bottoms of the Niskin bottles are somewhat worn, which lead to leaking bottles, however these were thoroughly cleaned and o-rings replaced for Niskins that were causing problems. Spignot and tap o-rings were changed on some of the Niskin bottles (numbers 4 and 24) in order to stop leaking. All leashes remained intact.

7.5.6 Data acquisition, storage and management

The CTD was connected to a Windows computer in the CTD wet laboratory and was operated from here by expedition personnel as previously mentioned. Data were collected via the deck unit on the PC which ran Seasave version 7.0.2.

Files were saved in a folder for each leg (eg. ACE_LEG_01) and had the following naming convention:

ACEYYYYMM_XXX*

Where YYYY is the year, MM is a two-digit month, XXX is a three-digit cast number which began from 001 on each leg (note that on some legs there was a test cast which was numbered 000). Raw file types produced were .bl, .hd, .hex and .XMLCON.

Data were backed-up to the expedition NAS via a shared folder on the PC. Backups were done on an hourly basis.

7.5.7 Data processing

Data was post-processed with the SBE Seasave (V7.23.2) software. Although some data processing took place on board, full data processing will take place following the cruise and the data will be made available to cruise partipants and after a two-year embargo, to the general public with full details of the post-processing.

7.6 Underway water supply

Jennifer Hutchings, Anastasia Tarasenko, Franziska Gerber, Maria Tsukernik, Carles Pina Estany, Alexander Haumann

7.6.1 Introduction

The underway water system was an integral source of data and samples for ACE marine-based Projects, but was also a huge source of secondary data for other Projects as well.

7.6.2 Physical set-up

The underway water supply pumped water from 4.5 m below the freehold of the ship, up into the wet laboratory. The sea water supply was installed after the initial construction of the ship.

Unlagged pipes from the inlet ran through the engine room and up through two decks before reaching the wet laboratory.

The water supply was split into two: one pipe ran into the wet laboratory as normal, and the other supply was directed to Project 1's container on the foredeck (see the Project 1 report for more details about this). This section of the report will focus on the supply which ran to the wet laboratory, however generic information about the supply itself, does apply to the supply also going to the container.

As the underway water supply had not been used for a long time, it was rusty, thereby causing problems with both particulate rust clogging the supply, pump and instrumentation and also rust itself causing issues with the instrumentation sensors.

Given these issues that were noticed during Leg 0, a plastic pipe was installed in Cape Town to avoid contamination. This new system piping was translucent, thereby letting in light and potentially biasing measurements of biological properties of the water. This was resolved by covering the pipe in black duct tape. The pipe was also insulated where possible to reduce any temperature changes in the incoming flow.

In the wet laboratory, the water ran out into a sink, where water samples were collected for a large number of Projects. In addition to this, there were a number of instruments connected to off-shoots of the supply in this laboratory. These include EIMS (see Project 13), ECO Triplets (see Project 8), the Imaging Flow Cytobot (see Project 1 and Project 13) and a FerryBox (see section 7.7 and Project 18).

7.6.3 Water sampling

597 sampling events from the underway water supply took place over Legs 1 – 4, resulting in 9169 samples. Each event resulted in one or more water samples. Where samples were taken at the same time, this was classed as one sampling event, in order to be able to group the samples together (see the Events section in the Data Management chapter of this document for more information).

Samples were normally taken every three hours, but depending on the Project this could be less often. These times were normally 00:00, 03:00, 06:00 etc., where all times were in UTC. We are especially grateful to Nina Schuback (Legs 1 – 3) and Clarisse Lemonnier (Leg 4) for preparing this schedule and entering events into the database for the underway water sampling.

See Table 51 for details of the frequency of particular parameters from the underway water supply.

7.6.4 Water supply pump log

A non-self priming pump was used to pump the water into the ship. In rough seas, the pump sometimes switched off as the intake came out of the water and was exposed to the air. It then needed to be reprimed and turned on again. A log of when the pump was on and off will be available with the final FerryBox data set, illustrating periods when resulting data may not be as reliable or other potential issues. In particular this was the case on 24 December 2016, when a lot of troubleshooting of the FerryBox took place, requiring turning the supply of water on and off on a regular basis.

7.6.5 Issues with the water supply

Below is a list of problems that may have caused lack of data or problems with data connected to the underway water supply. Individual problems are also noted within individual instrumentation and Project reports.

- The temperature of the water probably increased between the inlet and the wet laboratory because of the length of piping it had to travel through as well as passing unlagged through the

engine room. It is estimated that this temperature difference was +1°C but varied during the cruise (see Project 18).

- Initial rust in the pipes caused damage to instrumentation connected to the water supply. Instrumentation was repaired and cleaned before Leg 1 (see details in individual instrumentation and Project reports).
- Rolling of ship caused the water inlet to be exposed to the air, thereby causing the pump to shut off and require a manual restart. Dry-running of instrumentation linked to the water supply causes potential damage to them in addition to lack of data and inaccurate measurements. This was mainly a problem on Leg 1 and did not occur so much on the following Legs. It was overcome by having a "pump-watch" where a monitor restarted the pump when it stopped running. Additionally, the pump was turned off during port calls and at several occasions in close proximity of islands or in sea ice.
- Even if the pump was not switched off, a large amount of bubbles and air in the underway line during heavy rolling might have caused measurement inaccuracies. Table 9 summarises periods of heavy rolling during leg 1 when the pump was adversely affected. Note the pump watch was particularly busy on the cross-swell cruise track south from Cape Town to Marion Island on leg 1.

Table 9: Periods (UTC) of heavy rolling that affected the sea water pump.

Start date (UTC)	Start time (UTC)	End date (UTC)	End time (UTC)	Approximate cutout frequency
2016-12-24	02:25:00	2016-12-25	05:05:00	10 minutes
2016-12-25	07:00:00	2016-12-25	14:49:00	hourly
2016-12-25	23:45:00	2016-12-26	06:15:00	once
2016-12-26	10:30:00	2017-01-03	01:56:00	Infrequent (6 times)
2017-01-03	06:22:00	2017-01-03	08:18:00	20 minutes
2017-01-03	13:04:00	2017-01-07	17:48:00	Infrequent (8 times)

7.7 Aqualine FerryBox (Thermosalinograph)

An Aqualine FerryBox, manufactured by Chelsea Technologies Group Ltd. was attached to the underway water system in the wet laboratory to provide constant data about the water coming from a depth of 4.5 m below the water's surface. The above section about the underway water supply (section 7.6) should be read carefully to understand the FerryBox operation and data.

7.7.1 Setup

Figure 25: Aqualine FerryBox connected to the underway water supply on the Akademik Tryoshnikov. *Controls of the instrument are in the top right-hand corner of the image. The water inlet is in the pipe on the lower part of the image and the outlet from the pipe that runs horizontally across the centre of the image.*

7.7.2 Calibration

The FerryBox was sent to the manufacturer Chelsea Technologies Group Ltd for overhaul and calibration in the summer of 2016 prior to the cruise as it had not been used for some time. The FerryBox arrived at the ship the day before leaving Bremerhaven and was re-installed at sea but was not working properly by the time the ship reached the UK. Chelsea sent technical support to the ship in Southampton to complete the installation. When the underway water was finally turned on it was discovered that the sea water pump was rusty and the sensors were quickly coated in rust and failed to perform to specification.

Table 10: Calibration Dates on FerryBox sensors.

Instrument	Serial Number	Date Calibrated	Calibrated By
Minipack CTD Fluorometer	10-7676-001	2016-09-16	Chelsea
Oxygen Optode	6792/06	2016-09-23	AANDERRA
SBE 18pH	180789	2016-09-09	SeaBird
Pump	96484041		Lenntech
Unilux	2015-016-PL-D	2016-08-24	Chelsea

Copies of the calibration certificates of these sensors can be found in section 0 of this document.

7.7.3 Operations of the FerryBox

7.7.3.1 Leg 0

Anastasiia Tarasenko and Franziska Gerber cleaned all FerryBox sensors during Leg 0. They ensured the FerryBox was running as expected and worked out how to dump data from the FerryBox to the PC for inspection. Their data dump method made use of the intrinsic way the FerryBox is designed to operate, only dumping ascii data when the ship goes into port, so artificial ports were made in order to so this. A python script was written by Anastasiia Tarasenko to plot the FerryBox csv data.

7.7.3.2 Legs 1 - 4

The FerryBox was added to the ship's local area network (LAN) and was been assigned an IP address 192.168.20.6.

Note, if a factory reset is done on the FerryBox its IP address will return to the default address of 192.168.0.100. Also, care should be taken when resetting the FerryBox from a backup, as this could also change the IP address back to the default. It is very useful to be able to ssh to the FerryBox from anywhere on the ship. It is possible to check what the current and backup settings are in the following files:

```
/var/FerryBox/conf/FerryBox.ini          (current settings)
/var/FerryBox/conf/FerryBox.bak        (backed up settings)
```

Initially, in order to fix a station to download the data using Ferrycon, the FerryBox program, the bridge was called for an expected location of ship one half hour ahead in time. If this wasn't feasible, the position of the ship was estimated using the MaxSea navigation tools on the computer nearest the FerryBox in the dry laboratory. To add this position for the download:

```
ssh fbuser@192.168.20.6
 password is f3rryb0x
/FerryBox/bin/ferrycon
settings add PORTLAT_n DDMM.ddddS
settings add PORTLONG_n DDDMM.ddddS
settings add PORTDISTANCE_n 10
settings save
quit
```

Walk to FerryBox and turn instruments off, turn power off, wait, turn power on, turn instruments on.

FerryBox setting can be checked using

```
/FerryBox/bin/ferrycon settings list
```

This should now cause a csv file to be dumped when the circle surrounding (PORTLAT_n, PORTLONG_n) of radius 10 km is entered by ship.

The output file is found in /var/FerryBox/www/data

It has a name with the date of when the last data dump occurred. i.e. the date is the start of the data stream in that file.

Two data dumps were made on Leg 1 before the more efficient autonomous system described below, was used. The dumped file names were:

1_210-6761_301116_0139.csv

1_210-6761_291216_0139.csv

How to change the IP to the 192.168.20.6 (ACE "ip") if a factory reset is done

The FerryBox manual says that FerryBox will try to use a DHCP server, but this doesn't work. It also explains how to change the default IP using FerryBox/bin/ferrycon - but this doesn't work either.

The only way the IP was changed during ACE was to:

ssh into the FerryBox (if a factory reset has been done it will be in the IP 192.168.0.100. Set the IP of the computer to 192.168.0.1; connect directly with a cable to the FerryBox). For su, the admin password is the same as the user password.

```
su
vi /var/FerryBox/conf/FerryBox.ini
```

Change the IPDEFAULT to 192.168.20.6

Restart the FerryBox

After doing this the FerryBox will be available on the IP 192.168.20.6 again, accessible from the network.

Cleaning and re-installing FerryBox

Holly Pearson (Project 8) helped install the cleaned sensors.

An o-ring for the minipack was lost. This was being replaced by a niskin bottle o-ring. An appropriately sized o-ring should be installed as soon as possible. The niskin o-ring works, but will fail eventually as it is under tension.

7.7.4 Data acquisition

The standard FerryBox system consists of a Debian system setup by Chelsea Technologies. The FerryBox came with an ssh server (so scp, rsync can be used) and a Web server (Apache). Using a Web browser and going to the IP (e.g. http://192.168.20.6) it is possible to see the FerryBox's Chelsea Technologies interface to download files generated at ports or fixed stations.

As previously described, in order to extract data using this method, predetermined stations need to be preconfigured into the system, meaning that near real-time data from the FerryBox to know when the ship was crossing oceanic fronts for example, was not possible. Despite the best efforts of those on board on Leg 0, this was not properly solved until Leg 1. If this method was not used, then data were only available in binary format.

7.7.5 Daily data

Obtaining access to the data was a priority on Leg 1 which resulted in the following set-up: the previous day's data were dumped every day at 02:00 UTC in ASCII format, using the script dump_data_to_ascii.py (this used the ferrycon program) and a cronjob. Data were saved in daily files into the folder /var/www/FerryBox-ascii on the FerryBox and the fbuser on the FerryBox had a cronjob that executed the script. In order for the data to be backed-up on to the ACE data storage, the FerryBox was connected to the ACE network.

Note that the FerryBox had to be switched on at 02:00 UTC for the cronjob to trigger the script to run: if for some reason it was not, the data were not dumped in ASCII format, however the data were still saved in the FerryBox.

An alternative option to output all of the FerryBox data was to use the command:

```
ferrycon audit -R
```

This can be redirected into a file in order to post-process the data. The file in the FerryBox utils/splitter.py can be used, after adjusting the dates (see the lines 42 and 43 in the script), to split the FerryBox data into different files. The files were accessed by using rsync to transfer them to the ACE data storage, however rsync was not installed on the FerryBox system (it was left in a non-standard directory). Below is an example command of how the data were transferred:

```
rsync --progress -rvt –rsync-path=/home/fbuser/bin/rsync
fbuser@192.168.20.6:/var/FerryBox-ascii/*.csv
/mnt/ship_data/FerryBox/original_data_from_FerryBox
```

As the rsync command asked for the password, it is important to set up ssh public key authentication. This should be copied to /home/fbuser/.ssh/authorized_keys

Please note that when the FerryBox was using these scripts around 29 December 2016, the serial ports were being read by two applications: serial_port_reader and the native FerryBox software, ferrycon. This resulted in some data corruption.

7.7.6 Near real-time data

Despite this being very valuable, we did not have time to implement this during the first few Legs of the expedition. On Leg 3, the data dump was done every five minutes and a python script parsed it into the ACE database. Unfortunately, this method was not done on the FerryBox itself but as part of a website set up on the intranet, Django application and database. These are described further in the IT and Data Management sections of this report and the code can be found here: https://github.com/cpina/science-cruise-data-management

The date, time, salinity, conductivity, oxygen, temperature and fluorimeter were loaded into the database and displayed graphically on the intranet using an HTML template and Javascript. This was updated every five minutes.

This could be done using the command

```
show_last_data.sh
```

in /home.fbuser/bin which dumps the data to the screen all the data since the last time it was executed. If this is done every few minutes, plotting software could be used to display the data in near real-time.

More information about the set-up can be found in a guide left on board the ship and in documentation held by the Swiss Polar Institute.

7.7.7 Data retention on the FerryBox

No process was set-up to delete the ASCII-dumped files from the FerryBox so they were retained until the backups had been backed-up or at the end of each Leg. Binary logs of data are deleted automatically by the FerryBox when they are older than 60 days so care should be taken to make sure backups of the data in ASCII format are taken on a long cruise.

7.7.8 Data channels

Below the channels show the different variables recorded by the sensors attached to the FerryBox. As can be seen in the table, some of the channels were not used and we were unsure about the use of some of them.

Table 11: Details of channels recorded by the FerryBox.

Column	Value	Comment
1	D	Indicates this is a data record
2	Date	Date the measurement was taken
3	Time	Time the measurement was taken
4	Longitude	Longitude the measurement was taken (dec degs N)
5	Latitude	Latitude the measurement was taken (dec degs E)
6	Current Ship State	The state of the ship when the measurement was taken either for extract records this will always be set to AT SEA
7	Speed	Speed of the ship
8	Lux Channel 1	(µg/L); Calculation done in UniLux
9	Lux Channel 2	Empty
10	Lux Channel 3	Empty
11	Lux Voltage 1	
12	Lux Voltage 2	Internal reference voltage
13	Lux Temperature	(°C)
14	Optode Oxygen	O_2 concentration (µM)
15	Optode Saturation	O_2 saturation (%)
16	Optode Temperature	(°C)
17	Optode D Phase	(°)
18	Optode B Phase	(°)
19	Optode R Phase	(°)
20	Optode B Amp	
21	Optode B Pot	
22	Optode R Amp	
23*	Salinity	
24*	Conductivity	
25*	Temperature	(°C)
26*	Pressure	(dbar); Pressure at input (dbar = deci-bar i.e. 14 dbar ⍰ 1.4 bar)
27*	Fluorimeter	(ftu); Calculation done in MiniPack
28	Spare Channel 1	MiniPack supply voltage (V)
29	Spare Channel 2	MiniPack supply current (A)
30	Spare Channel 3	Either Spare Channel 3 or Spare Channel 4 are giving ΔT (°C)
31	Spare Channel 4	
32	Spare Channel 5	Voltage output pH-server = Vout Needs to be converted: pH = 7.0 +(Vout - pHoffset)/(pHslope*°K*1.98416E-4) where: pHoffset = 2.5600 pHslope = 4.5897 °K = output Column 25 + 273.15 K
33	Spare Channel 6	

34	Spare Channel 7	
35	Spare Channel 8	
36	Spare Channel 9	
37	Spare Channel 10	
38	Spare Channel 11	
39	Spare Channel 12	
40	Spare Channel 13	
41	Spare Channel 14	
42	Spare Channel 15	
43	Spare Channel 16	
44	Spare Channel 17	
45	Spare Channel 18	
46	Spare Channel 19	
47	Spare Channel 20	
48	Error indications	

7.7.9 Water supply issues and the data quality

When the pump to the underway water supply suffered issues, particularly on Leg 1 due to the water inlet being exposed and therefore causing the pump to switch off automatically, the FerryBox was not always turned off, so the log of times when the pump was not on should be used to identify periods when the FerryBox data may be suspect. Possible ways of identifying when the pump was off, but the FerryBox was on, could be by looking for unexpected rises in temperature data.

Figure 26, Figure 27 and Figure 28 show periods of time when the pump was on and off (green lines) are demonstrated by the gaps in temperature data (red lines). Where the FerryBox was on when the pump was off, the temperature rises quite quickly: a sudden increase in temperature can be seen as the temperature of the FerryBox temperature sensor increases. This can be seen very easily on Leg 1.

There are periods where data cannot be seen: during these periods the FerryBox itself (as well as the pump) was off (usually due to bad weather).

Leg1

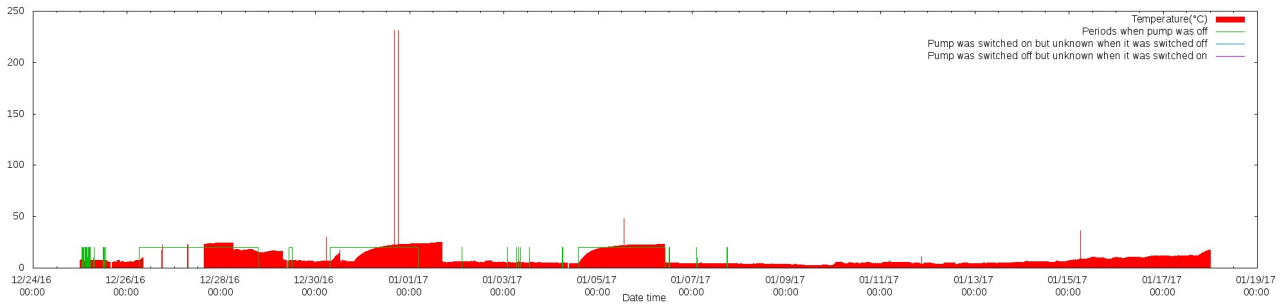

Figure 26: Underway water supply during Leg 1 with periods when the pump was off.

Bad weather was quite common on this Leg and the pump was off for some periods of time as can be seen. It was also restarted quite often.

Leg2

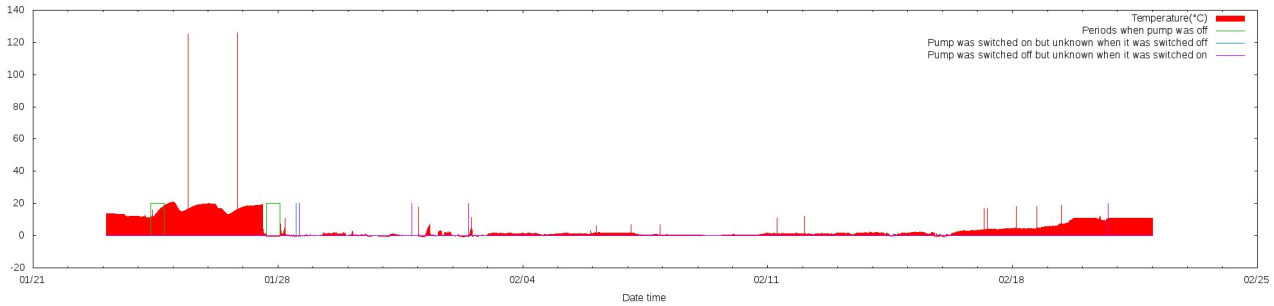

Figure 27: Underway water supply during Leg 2 with periods when the pump was off.

Besides the initial bad weather the pump and FerryBox was on for longer than on Leg 1 with fewer problems. Often, full periods of time when it was off and on were unknown: the pump log contains times where it was switched on or off but often not both. This can be seen quite often in this plot.

Leg3

Note the period between 02 March 2017 and 06 March 2017 when both the pump and the FerryBox were off (when the ship was at South Georgia).

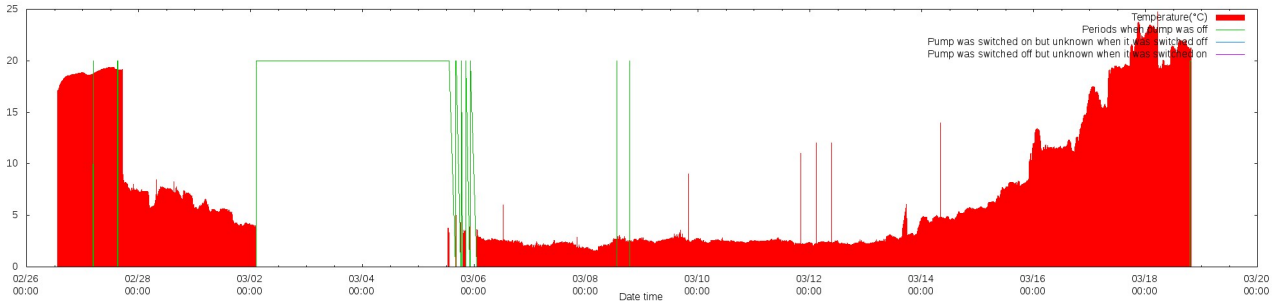

Figure 28: Underway water supply during Leg 3 with periods when the pump was off.

The FerryBox data was running continuously from Punta Arenas (switched on 26 February 2017 at 13:00 UTC) to Cape Town (switched off 18 March 2017 at 19:00 UTC) except for the times when the underway line was switched off. However, leg 3 data should not be used prior to 27 February 2017 at 18:00 UTC. Before this time the FerryBox was running but the outlet valve was closed for unknown reasons, leading to no flow through the instruments. After that the valve was opened and pressure remained between 1.5 and 2 bar throughout the remainder of leg 3.

7.7.10 Data processing

No data were post-processed during the cruise. Minimal amounts of quality checking were done due to lack of time.

The FerryBox was not always turned off when the pump was not running. These stagnant samples should be cut out of the data time series. To do this use the pump log and island visit times to note when the FerryBox was not receiving a continuous water flow.

There is a motion sensor on board that provides pitch and roll information. When the ship rolls sufficiently, the underway water inlet is above water, and sucks in air. This causes an increase in air bubbles or complete stoppage of flow and the pump to need repriming. It may be the case that large downward (to lower salinity) spikes in the FerryBox time series are related to this.

The noise in the salinity time series could be handled by low-pass filtering, or averaging the data. This will require interpolation to a uniform time series (say a 20-second interval), and applying a filter. As the noise is likely related to contamination in the water stream the time series may also be biased low. The best

tactic to address this is to employ the salinities from water samples (autosal determined salinities). These are collected every four hours, and could be used for a bias correction.

The temperature of the underway water is biased by perhaps +1 °C but varies throughout the cruise (see Project 18). We did not do a bias correction against CTD surface data during the cruise. This will be done during the post-processing.

The salinity and temperature will be calibrated against the CTD casts wherever possible.

More quality checking needs to be done with the FerryBox data. The fluorescence data is quite unstable. During the cruise no-one had time to investigate the fluorimeter data properly and all data should be checked and correlated to make sure that it can be properly used.

7.8 Acoustic Doppler Current Profiler (ADCP)

An RDI Teledyne Ocean Surveyor Broadband/Narrowband ADCP ran during various phases of the voyage. This instrument was ship-based and was operated by the crew using Teledyne VmDAS (version 1.46.5) software to collect data. It operated at a centre frequency of 76.8 kHz and navigational data from the GLONASS (see section above) were fed into the dataset to give a positional reference and source of motion (tilt). No settings were changed when the instrument was turned on each time. More information about the set-up can be found in the VMO output files.

It should be noted that this instrument was not calibrated during ACE and therefore data quality is unknown.

7.8.1 ADCP data management

Towards the end of Leg 1, this computer was connected to the ACE network and the folder in which the files were being saved, was shared (to back up the data as described in the section, Backing-up data, above).

Data were saved in its raw format with output files in the following formats:

ENR - binary

N1R- data from NMEA input 1

N2R- data from NMEA input 2

LOG – text log file about data inputs (NMEA etc.)

ENS – binary file

ENX – binary file

STA – binary file

NMS – binary file

VMO – contains details of setup

LTA - binary file

7.9 Multibeam echo sounder

7.9.1 Surveys

Multibeam data were collected to look for potential trawling sites (seabed type and depth), with particular interest for Projects 3 and 10. Additionally on Leg 2, Project 21 utilised these data to look at potential deployment sites for the ROPOS ROV.

Very few data were collected on Leg 1 to avoid unnecessary interference with the echo sounder data. However in shallower water around Marion Island, some multibeam transects were run to provide more information for the trawling.

Gridded surveys were not completed unless a site looked to be of interest, then parallel lines of swathing were run over this potential site to look at the seabed.

7.9.2 Setup

The ELAC Nautik 3020 multibeam echo sounder was operated from the acoustic laboratory on level 4 by the on-board acoustician from the ship's crew. The Windows computer from which it operates received a feed from the Trimble GPS and motion sensor (see Figure 188, and sections 7.4 and 7.10 for more information).

The instrument operates at 20 kHz and is setup and operated using Hydrostar Online software. The transducer location can be seen in Figure 56.

The transducer has 256 beams and are normally operated with a maximum swath angle of 140 degrees. During this cruise, 90 degrees was used when there was seen to be a rocky seabed and 120 degrees when the seabed was sandy. Many of the other settings were changed automatically in the software according to the conditions at the time (i.e. pulse repetition rate was lower in deeper water and higher in shallower water). The relevant settings were captured in the raw data files.

Before each multibeam survey was done, the sound speed profile was obtained from the Sound Speed Sensor, the ELAV SSV-3000. Additionally, the multibeam operator performed a CTD cast using a Titanium Sea and Sun Technology hand-held CTD. Data for this are available within the folder ship_data/ctd_titanium, although do not appear to be useable.

7.9.3 Multibeam data management

A new network was created and connected to the ACE network, then the folder on the multibeam computer where the data were saved was shared in order to back up the data (see section 9.9). When new raw data were collected, these new folders had to be added to the back-up script manually because of the directory set up. All raw and processed data were saved. Full details on the directory format can be found in the ship_data/multibeam folder with the data.

Raw data comprised ELAC Nautik .xse and .ssv files. These can be opened in Hydrostar Online software which was used on board by the ship's personnel, but also in MB-System, open-source software with very good documentation. Metadata (start / end times of each file, bounding box and other information) were extracted from the raw data files using mbdatalist and mbinfo commands in MB-System (this is fully documented in the documentation with the data files).

In order to provide the scientists with a view of the data, QINSy (version 8.0) software was used to provide gridded (grd) files. These are available in ship_data/multibeam/gridded but were not viewed in any detail during the cruise.

7.10 Motion data

Data about the 3D motion of the ship were collected from the 27 November 2017 until the ship reached Bremerhaven at the end of Leg 4.

Roll and pitch data were collected from the same computer as the multibeam data, so were transferred to the NAS in the same way from a shared folder. The Trimble GPS feeds into this dataset and so is also recorded here for future reference.

Hydrins software is used to collect the data from the inclinometer which is installed in the centre of the ship. The software is run from the same Windows computer that operates the multibeam echo sounder.

See Figure 188 which displays the set-up in the acoustic laboratory for the information on how the data feeds are linked together.

7.11 Meteorology data

Irina Gorodetskaya, Jenny Thomas

7.11.1 Instrumentation

The *Akademik Tryoshnikov* is well-staffed with two meteorologists. Data were collected from a Vaisala weather station with numerous duplicate instruments, mostly on top of the monkey island of the ship. The MAWS 420 system onboard includes pressure sensors, ultrasonic wind sensors, humidity and temperature sensors, present weather detector, and ceilometer. The pressure, wind, humidity and temperature sensors are installed on two beams extended over the ocean from the starboard and port sides of the ship (see Figure 29). The sea-surface temperature (SST) instrument was not functioning (SST skin temperature was measured manually daily using infrared thermometer on both sides of the ship). The present weather detector ("Rain Cap") was providing only optical visibility information - precipitation sensor was not working. Radiation sensors include only solar and UV radiation. There are no longwave radiation measurements.

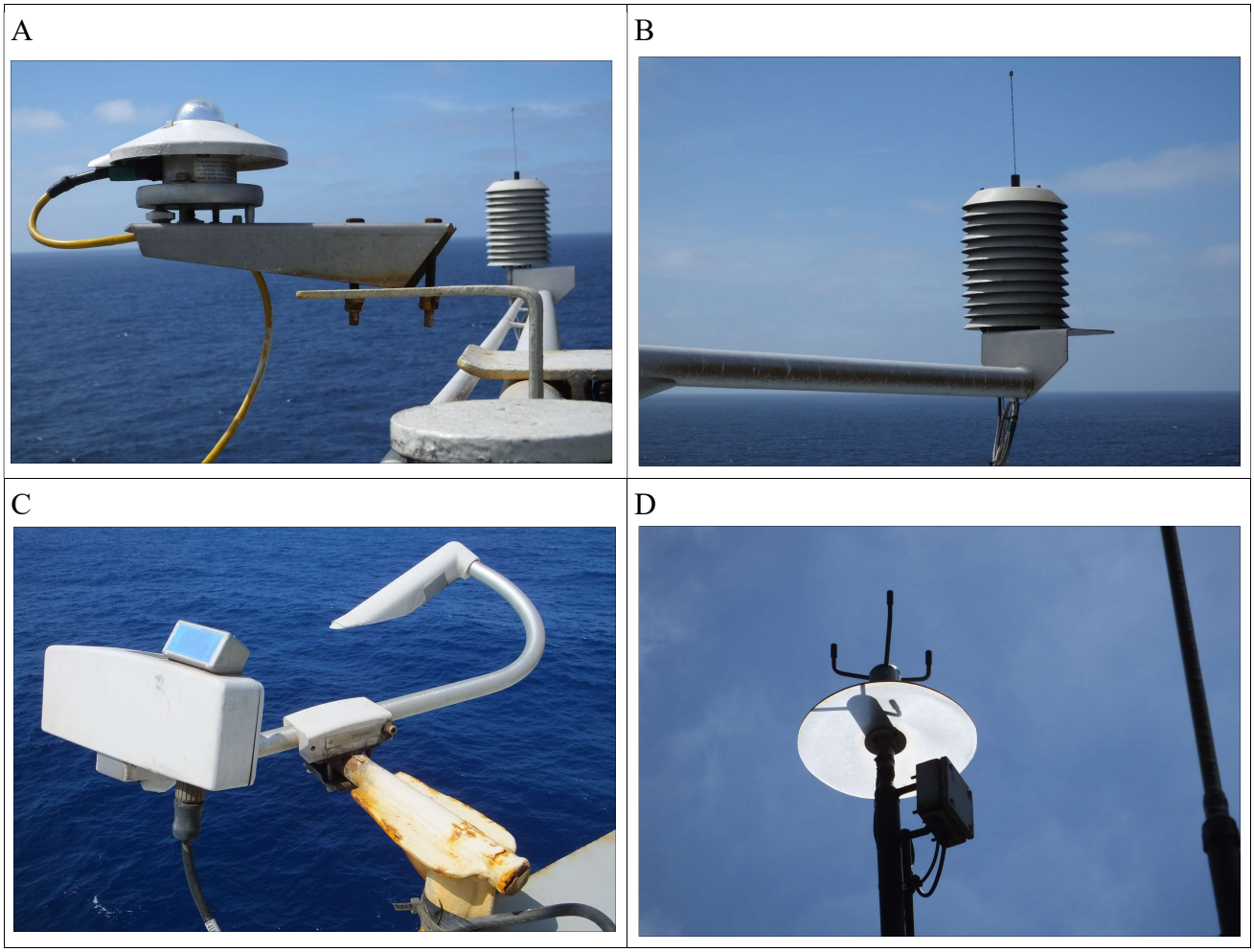

Figure 29: A – instrument that measures solar radiation on the left, and the temperture and humidity sensor on the right. B – temperature and humidity sensor. C – the sensor on the right measures the horizontal visibility and the small device on top of the box on the left gives the weather code. D – this device measures the wind. Images Carles Pina Estany.

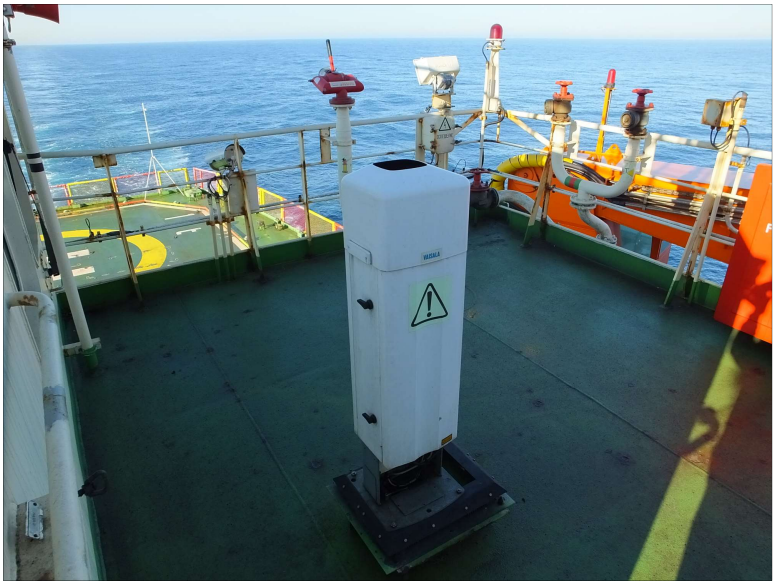

Figure 30: Ceilometer based on the rear deck of the ship next to the helicopter pad control room.

7.11.2 Data collection

Data were collected on a computer in the meteorology room and copied in daily files onto another Windows computer in that room by the ship's meteorologist. This second computer was connected to the same network as the GLONASS, and in order to backup the data, a new shared folder was created. From here the data were transferred to the expedition NAS (ship_data/met_data folder) and a script written to parse the text files to insert it into the database tables, ship_data_metdataall and ship_data_metdatawind.

Each of the data files that comes from the meteorologist's computer contains some data that are collected at 30-second intervals, and other data that are collected at 3-second intervals. Each of these sets of data contain different information and therefore it made more sense to split them into separate database tables to make them more usable. These files are fully documented in ship_data/met_data/documentation.

It seems that the data undergo some processing by the Vaisala computer before reaching the main software but Vaisala need to be contacted to find out more about these algorithms. Raw data from the ceilometer were required by Project 18 (in order to apply their own algorithms) so raw data have been recorded and can be found in the ship_data/met_data/ceilometer folder. These raw files are binary and as of the end of Leg 3, Project 18 were still waiting for information from Vaisala on how to decode these datagrams.

For more information about each individual instrument or data set, see the following documentation published by Vaisala:

MAWS420_D210397EN-B.pdf - MAWS420 information

CL31_UserGuide.pdf - Ceilometer

ptb220_userguide.pdf - pressure sensor information

PWD22_UserGuide_EN.pdf - present weather detector information.

HMP155_UserGuide_EN.pdf - humidity and temperature sensors information

7.11.3 Live weather display

The meteorology data is displayed on screens in the main deck mess and acoustics laboratory on the fourth floor, which was useful for those needing to have a quick look when sampling, but it would have been nice to also display this on the intranet (no investigation was made as to whether this would have been possible

with the display, but it was not possible with the data from the instruments because this was only received on a daily basis). Other data sets

7.12 Depth data

Some teams, primarily those doing the benthic trawling, had asked to be able to see the water depth in a more convenient manner; their only way to see it when trawling was to go upstairs to the CTD laboratory and look at the screen. However this was inconvenient and relied on the person operating the echo sounder having their screen on the echo sounder software (this screen was repeated down in the CTD laboratory).

After considering a number of different solutions and working with with Paul Fernandes (operating the echo sounders for Project 5 on Leg 3) the depth information from the echo sounder was displayed on the Intranet page in real-time. Depth data were read from the echo sounder (Simrad) software which operated the EK60 and EK80. The NMEA strings were sent over the network and received by the ACE server using kplex, then saved into a file. An NMEA parser was built to insert this data in the database. The data were displayed on the front page of the Intranet. Depth data were also retained in the database.

Two important things regarding this data should be noted:

- the data that were displayed were raw. Spikes in the data can occur and if transiting over uneven ground this problem is amplified. The depth data has undergone no quality checking or processing.
- the teams that wanted this data for their use, would still find it very beneficial to have the seafloor depth from the echo sounder data when it has been processed by Project 5, if they are able to export the resulting values (this is easily done from the software that will be used when they process the data and to ensure the bottom depth is quality-checked is also necessary).

8 IT

Carles Pina Estany (software engineer) and Jen Thomas (data manager)

Although the ship's crew did not have an IT expert, there was a network engineer (Artem) and operator of ship-based equipment (Iiuri) who both were very helpful. Working closely with them ensured we were able to connect to the network successfully, obtain data from crucial instruments on board and maintain communications. Data management and IT support were provided by ACE to the scientists by the expedition for Legs 1 – 4 inclusive. All software described in this section can be found here: https://github.com/cpina/science-cruise-data-management

8.1 Data storage and network equipment

A system with large data volume capacity and some redundancy was essential to deal with the situation i.e. no access to internet bandwidth to transfer data to a more secure location during the expedition and very limited access to acquire more hardware only at the ports. The table below shows the list of equipment that was required in order to set-up the on-board network and data storage system.

Table 12: List of equipment bought to set up the on-board network and data storage system.

Item	Quantity	Notes
SYNOLOGY DISKSTATION DS1815+ 8-Bay Network Attached Storage (NAS)	2	
WD RED 8.0TB 3.5" WD80EFZX HDD	15	Installed in NAS and for back-up
SEAGATE 8TB 3.5" IRONWOLF NAS HDD	15	Installed in NAS and for back-up
APC Smart-UPS 1000VA UPS	2	One for each NAS
Vantec nst-DP100S3 nexstar HDD duplicator	2	To make back-up of hard drives in NAS
Netgear GSS116E-100EUS 16-port Switch	2	
CAT5e UTP Flylead 2m	8	
POWER EXT 1.8M - M-F	4	
TP-LINK Router model TD-W8970	2	Main one plus a backup and to provide wifi access to ship's network in coffee room next to the mess
8-port TP-LINK network switch model TL-SF1008D	~10	Used for connecting equipment in laboratories to network
USB fast ethernet adapters (DLINK DUB-E100)	~8	Useful to allow Mac users and to connect laboratory equipment to ship's network
Extension cables and plug adapters (various sockets to South African; various to European)	Many	Plug sockets on board were 2 round pins (as in most of Europe)
Ethernet cables	30 (2m), 10+ (others)	Mostly 2 m length but other lengths were useful for connecting laboratories and equipment (not available from ship. Some very short ones (used for patch panels) would have been useful as the ship were close to running out when connecting all of the laboratories and cabins to the network on the patch panel.

8.2 Setting up equipment

Throughout Leg 1 an old HP laptop (HP G62, 2 GB of RAM, Intel Core i3 CPU) was used as a server. This was an old one belonging to the data team and so very convenient because it could be setup before joining the ship (essential as the connectivity was not good enough for download of packages on board initially). The following packages were installed:

- Virtual Box with Linux Poseidon installed to be able to use MB System (processing software for multibeam data);
- Django (for the data-entry system and intranet page);
- a number of packages that turned out to be useful during Leg 1 for testing possible email setups;
- Git server (version control for code).

The Network Attached Storage (NAS) was also set-up prior to departure. Some large files needed downloading and installing before it was properly set-up.

8.3 Network

Whilst the ship had an existing network (known as the ship network), an additional network was created specifically for the expedition (known as the ACE network). It should be noted that there are other networks on the ship which will not be discussed further except in specific cases.

Initial plans were to have only the ACE network in the expedition office (room 336 on deck 1). This consisted of a one 1-Gigabit switch for the two NAS boxes, laptops of the data and IT team, the server and one laptop available for other users (so they could access the internet, intranet and enter metadata). However, it was possible to connect the majority of the cabins and laboratories to the ship's network. The cabin ports were connected to the ship's switch (in room 340) by Artem, and the switch was connected to the ACE network (see Figure 31 for the ACE network diagram). This was working from the beginning of the first Leg, vastly improving the data management and security of the data, as well as making general work on the ship much more efficient

In addition to laboratories and cabins, one of the containers (for Project 7 but also containing Project 8 and Project 11 equipment) was also connected to the ACE network via the communications room and then to the ACE switch. During Leg 2, two additional containers were connected to the ACE network (for Projects 2 and 21) and finally the Project 1 container was connected for Leg 3 using very long (20 m plus) ethernet cables.

The network that was used for the labs and cabins was 192.168.20.0/24 and the DHCP server and DNS server were configured by the data management team. This IP address was chosen in order to connect additional laboratory computers that were possibly already connected to additional networks (eg. to laboratory devices). Choosing an unlikely network address made it possible to add USB ethernet devices to some computers and connect them to the ACE network and the original network minimising the amount of changes required.

During the voyage additional networks were added: an Iridium network to connect the ACE servers to Iridium communications (initially we did this using WiFi) giving a choice between which Iridium satellite should be used at a given time and to have redundancy in case of problems with one of the Iridiums. Others were also added to get the GPS and meteorology data: another network was created for this purpose with the ship's crew. The final, simplified diagram of the network setup can be seen in Figure 31.

These extra networks (for the GLONASS / GPS and meteorology data) allowed the ship equipment to be kept on separate networks as requested by the crew.

In order to get the data from the Multibeam computer, the crew wanted to create a secondary IP on that computer, on a different network connected to the unmanaged switch (despite this being bad practice) rather than connect to the ACE network: 192.168.20.0/24 was used.

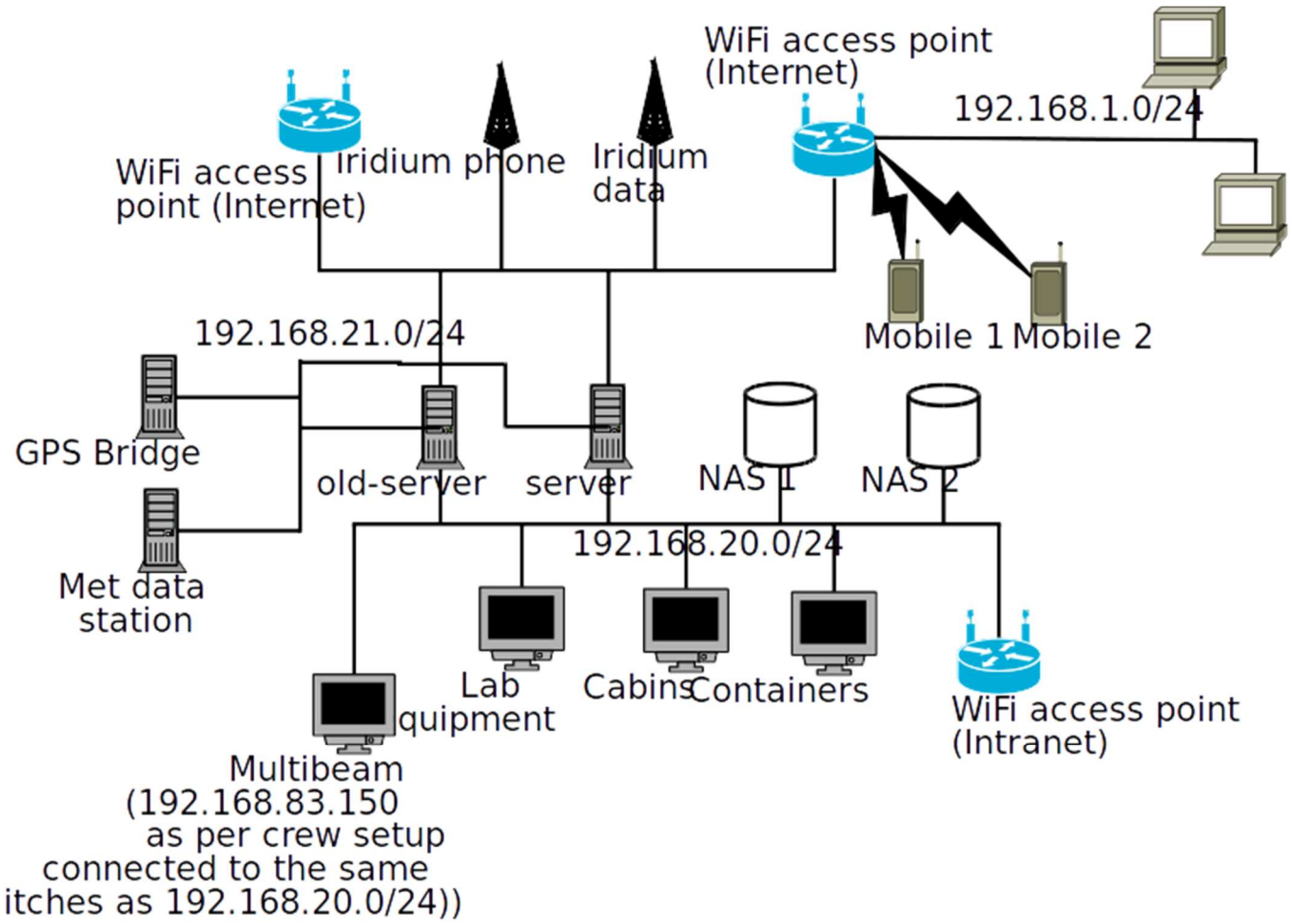

Figure 31: ACE network on board the Akademik Tryoshnikov *during ACE.*

8.3.1 What worked well

The network worked correctly. Note that the old-server and server are just laptops and network interfaces were added using USB. Having both Iridiums on the same network was very useful to have extra redundancy and capacity. The ship network makes sense to be separate.

Artem from the ship's science support team was very helpful in setting up the network and solving problems with it throughout the cruise.

8.3.2 What did not work well

The Multibeam set-up was not the best option as it mixed two logical networks in the same physical network but it was the only option given by the crew.

8.3.3 Future recommendations

The laboratories (CTD, benthic, acoustic laboratories) have one or two network ports each. It is important to bring switches and cables of all sizes to connect all the equipment that might be needed.

As mentioned: it is possible to connect the laboratories and cabins to the network by asking the crew. If a lot of cabins and other ports need to be used, it is worth bringing some very short ethernet cables (< 0.5 m) for the crew to use on their switch as they did not always have enough.

A large number of USB to ethernet adapters were used. Some laboratory computers were connected to instruments using a network port, therefore in order to connect them to the ACE network, a USB to ethernet adapter was used. USB to ethernet devices were also used for the ACE servers to expand their

networking ports and connect them easily to more networks, as well as used by expedition members that had computers without network ports (many Macs for example).

WiFi access points were useful and perhaps an access point for the Intranet in the office could have been useful as well. One team brought an access point for the benthic laboratory.

Improving the speed of the network would increase the capacity of copying data around the ship in order to back it up.

8.4 Servers

An old HP laptop (2 GB of RAM, Intel Core i3 CPU) was used as a server, using a LUbuntu 16.10 operating system. Originally this server was going to be a server for the Intranet event-logging system and to collate GPS track data, but after some weeks on Leg 1 the it had some overheating problems causing it to shut down. Copying data from many sources caused some of these problems with the server and in addition to this it was doing a variety of tasks, adding to the increased load (copying data from expedition and ship-based equipment to NAS; parsing GPS data and inserting it into the database, generating the ship's track for the intranet map, database backups, etc.).

A spare Lenovo (T460S, 8 GB of RAM, 320 GB SSD storage, Core i7 processor) laptop was borrowed from Leg 2 onwards as a second server, initially to aid with the new email system. After some time the database was also moved from the old server to the new server. The next natural step was to move all the services that users use, (such as the event system, DHCP, DNS and email) to the new server and use the old one for batched things like generating cruise track data sets, copying of data (so it could be restarted without any consequences) and generate the aggregation of data sets (it can be slow without consequences for the users).

8.4.1 Future recommendations

Having two servers was very useful:

- as a backup in case that one failed;
- to have one for the more critical things and the other one to do batch processes.

8.5 Communications with Iridium

8.5.1 General overview

Having two Iridium communication systems on board allowed the expedition to:

- Have phone calls (with a booking system);
- Use the expedition email system;
- Download/upload "big files" (about 100-200 MB per night, depending on circumstances);
- Use of ssh (particularly used by the data team to manage the mail system, download big files and reduce the size of files on the server, etc.);
- Use of WhatsApp (sometimes better, sometimes worse) for the expedition members;
- Very, very limited internet browsing or other internet usages: this required lots of patience, caused frustration and was only useful for a very few people at the same time.

8.5.2 Setup

A VSAT system on board the ship works in the northern hemisphere but not in the southern hemisphere. Given this, and the limitations of VSAT at very low and very high latitudes, the Iridium system used on board ACE was very useful when managed properly.

Prior to departure from Cape Town, ACE mounted two Iridium systems for the use of the expedition. The bandwidth of each one was 128 kilobits/second in ideal conditions. The Iridium systems worked independently of each other which was very useful in case one failed. One antenna was mounted on the

monkey island and the other one on the same deck level as the bridge to the aft. This was on the other side to the Captain's Iridium to which the expedition did not have access.

One Iridium system was available for phone calls on the fourth floor; hereafter it is known as the phone Iridium. One phone line was available for the expedition and another line was connected to the office used by the guests of the expedition. When the phones were not in use, Internet (using WiFi) was available from a RedBox router but when they were in use there was no data connectivity available.

The other Iridium system, hereafter known as the data Iridium, was connected to the ACE office via the ship's network, and from there, there was a TP-Link router providing WiFi (limited to 40 kilobits/second, lower priority) and two cable connections (the rest of the bandwidth, higher priority).

During Leg 1, the full Iridium setup was only configured the day before leaving Cape Town, so there was very little time to explain to the expedition the best way to prepare for this in terms of internet and email use and limitations. Using a web browser was virtually impossible and desktop applications such as Outlook and Thunderbird did not cope well either. For Leg 2 an email system was prepared (see section 8.6 for more information).

Near the end of Leg 2, the phone Iridium was connected to one of the ACE servers to use the available bandwidth (this Iridium generally got less use when the telephone was not in operation).

On Leg 3 the network evolved again by connecting both Iridiums to the ACE network allowing use of both the data Iridium and the phone Iridium if needed. Comparing both Iridiums when phone calls were not in progress, showed that the phone Iridium usually had a better connection than the data Iridium, so when emails were not downloaded fast enough the more reliable phone Iridium was used. When the downloads failed overnight for some reason in the early hours of the morning there was the option of using both Iridiums.

8.5.3 Technical issues

We learnt a lot about using Iridium during the expedition and were constantly improving the way the email system and data downloads / uploads were managed. Part of the reason was that the Iridium connection was unstable due to it changing satellites every few minutes. Once this problem was realised, changes to the system were made to accommodate it, but this is one of the main reasons that emails did not work well on Leg 1 with the standard software.

Part way through Leg 2, the data Iridium started hanging and needed to be powered off using the power cord cable (later on we discovered that under the admin login if we pretended to change the configuration it would restart), before connecting it again. After emailing Iridium support they decided that the Iridium was faulty and arranged a delivery to Punta Arenas for the beginning of Leg 3 (although in the end it was not used).

There did not appear to be any worsening problems with it during Legs 3 and 4 so it was not changed.

8.5.4 General use of Iridium systems

The internet and email system were widely used. Communications would not have been possible without this system and it was essential to ensure that scientists and other members of the expedition were able to receive help, advice or data from their PI or supervising organisation. Unfortunately this was not as successful during Leg 1, but this problem was mitigated by the implementation of the email system from Leg 2 onwards.

Usage of the system on board seemed to be fair and could be used by all members of the expedition if they were trying to use it within its capabilities; again the on-board email system made this much easier (see more details in section 8.6).

Throughout Legs 2, 3 and 4 after connecting an Ethernet cable from the office to the phone Iridium to take advantage of the extra bandwidth, there were problems with cable disconnections, but scripts monitoring this allowed the problem to be recognised and it to be reconnected before causing too many issues on most occasions.

Disruption was caused by several attempts to download large entertainment files through a WiFi connection which slowed the Iridium system enormously. This was controlled by instituting a password system.

8.5.5 Future recommendations

The Iridiums gave connectivity everywhere *en route* (even at very southerly latitudes) and we were very grateful to have it on board. In some areas there might be other Internet providers that might be able to offer faster connectivity. It would be worth complementing the Iridium connectivity (everywhere) with other providers that might be faster until certain latitudes.

8.6 Email system

8.6.1 Email set-up on Leg 1

(This system is not recommended: check the email set-up on Legs 2, 3 and 4 in section 8.6.2).

For users, Mozilla Thunderbird was recommended for checking emails, after changing the settings to optimise performance, because the Iridium connection was very unstable. Some used Microsoft Outlook and others used Macmail with varying degrees of success. The data team helped them to set-up Thunderbird on the ship but this became quite difficult for the variety of setups of different email providers and Thunderbird timing out frequently during the “settings verification”. It was very time consuming both to help users and for them to receive and send emails.

8.6.2 Email set-up on Legs 2, 3 and 4

After the telecommunications problems of Leg 1, in Hobart a new email system was prepared.

A Virtual Private Server (VPS; from Gandi.net) and a new domain (ace-expedition.net) were bought and an external (on the Internet) mail server set up. Then an internal email server (on board) was set up to fetch the emails from the external server.

Users were created on a leg-by-leg basis.

To receive the emails the internal server queried the internet server and asked which users have emails and then fetched them.

IMAP and SMTP servers were setup (so an email client could be used) but a Webmail was also setup using Roundcube, to make it easier for the users to access the email on board. Email was then accessible from any connection to the ACE network on board the ship making it very accessible for users. The email system was a very effective means of communication within the ship as well (emails to other expedition members did not leave the ship so arrived instantaneously). Users were unable to access their emails from outside of the ship.

Being a new domain and new IP, some mail servers (gmail.com, office365, btinternet, icloud, etc.) marked the email as spam or rejected the emails during the first ten days or so. Each of these mail servers was notified, one by one, that the domain was not spam and after a few days the situation was much better.

The email size limit was initially 100 KB, then increased to 200 KB, then for Legs 3 and 4, 300 KB. Very rarely more than 15 emails were in the queue and the majority of emails were less than 10 KB (only text). Some days, more than 1,000 emails were sent out from the ship (this figure does not include internal emails within the ship), indicating that the system was well-used.

If an oversized email was received, a system was developed so that users were sent a notification, therefore if needed, the email could be downloaded using a script. If the contents were a PDF file a script could be used to resize it before downloading it from the server; it was very useful for scientific papers for example.

All scripts to create users, notify them about oversized emails and so forth, are part of the git repository on Github with the rest of the intranet code (http://github.com/cpina/science-cruise-data-management.git).

8.6.3 Dealing with large files

The Iridium internet connection was quite unstable (it was completely disconnected every 10 minutes on average) to be used by systems that depend on a stable connection. The disconnections did not appear to have any correlation with latitude or position.

In addition to reading and sending emails, the main use of the internet was to download files required by scientists to complete their work effectively, and upload the work of the media team. The best way for downloading files was to fetch data in an automatic way overnight, using the commands, rsync or wget. For example, to download 15 MB of weather forecasts (which was required for the planning of Project 11 and set up on Leg 1) it took around 40 minutes, using rsync.

The bandwidth usage was maximised overnight from Leg 2 onwards, when there were not as many other users. To give an idea of how it was used on an average night, the following uploads and downloads took place:

a) Journalists had a 30 MB upload that they managed (in a shared folder on the network). This was uploaded to the ace-expedition.net server.

b) Weather data downloads (15 MB) for Project 11.

c) Other weather data downloads (about 15-50 MB, depending on the day) for Project 18.

d) Modis ice information downloads (about 4 MB; only the weeks that it was needed on Leg 2)

e) General one-off downloads that would be needed by someone (eg. papers, email attachments).

f) A queue of “overflow” uploads, first come first served, following the completion of other jobs, until 08:00 ship time. It could do another 30 to 60 MB depending on the size of the previous jobs, the speed, and connectivity.

The system to upload files involved copying the files to a directory and a script running to upload these to the external server using a limited portion of the bandwidth. Files were then available from a URL which was emailed to the data team to forward on to the person requiring the file.

An overflow space allowed anyone to upload anything extra that they needed to send (used to send blog entries, additional media files, data files from equipment that was not working and other things). For those who used the system, it was very useful and avoided them having to use their normal email to upload files even of a few megabytes which would have been unlikely to work with the unstable connection. The queue overflow system software is available on Github at http://github.com/cpina/rsync-queue.git.

Media usage of the internet connection varied largely between Legs depending on the assignments of the teams on board. In particular on Leg 2, a lot of large videos and images were sent out to be broadcast on news programmes. The journalists on this Leg utilised the file upload and queuing system to the full and were able to upload news pieces successfully. It helped that they reduced the file size of their pieces using video editing and compression, so that a 3-minute video of broadcast quality could be reduced to around 90 MB which could generally be uploaded over a few nights or less, depending on connectivity.

8.7 Intranet

An intranet was constructed to allow users to view a number of useful utilities, data entry forms, documents and share information. Initially it began with the data entry system for cruise metadata (see the data management section), visualising the metadata on a map with the current location, provide some useful information such as UTC time, julian day, and ship speed, as well as open and share documents.

Throughout the cruise, additional facilities were added as requested or as the team had time to add more features that would be useful. In no particular order these were:

- time conversion between ship time and UTC – added during Leg 2;
- converter between position coordinates in different formats (decimal degrees, degrees and decimal minutes, and degrees, minutes and decimal seconds) – added during Leg 2;
- time to position converter;
- visualisation of FerryBox data in near-real time – added during Leg 2;
- display of weather forecast files;
- access to on-board email system – added during Leg 2.
- display of date/time in UTC, Julian day, latest position – added during Leg 1.
- current water depth – added during Leg 3.
- announcements – added during Leg 1 (used from end of Leg 1 for PI meeting notes).

This intranet was available throughout the ship when connected to a network port and for Legs 2 and 3, through WiFi in the coffee room on the main deck.

The Intranet was built using Django running on a Lubuntu server. The code is available at http://github.com/cpina/science-cruise-data-management.git

Figures below show some screenshots of the intranet:

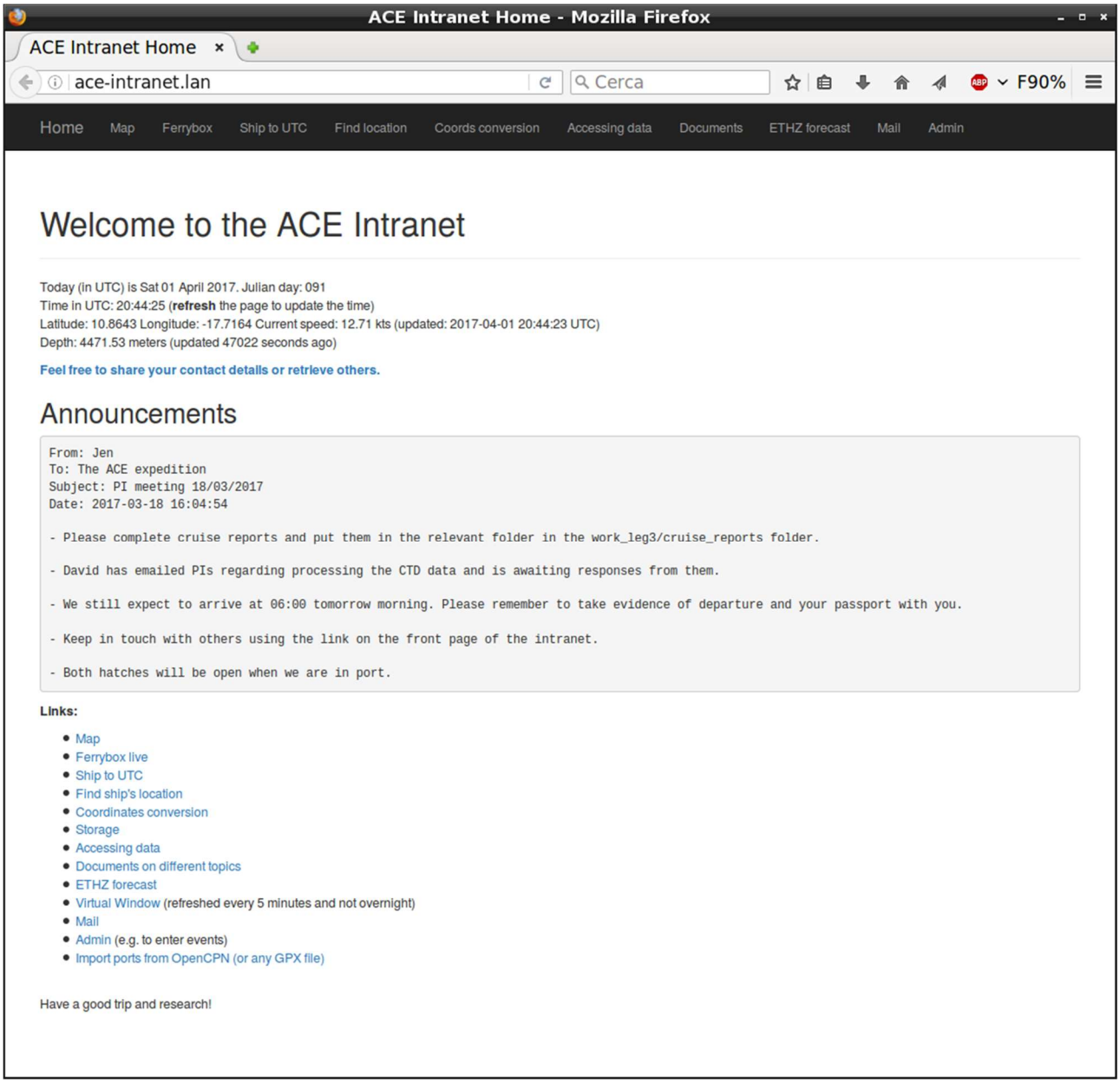

Figure 32: The homepage with GPS feeds, depth feed and announcements, all fed from the database.

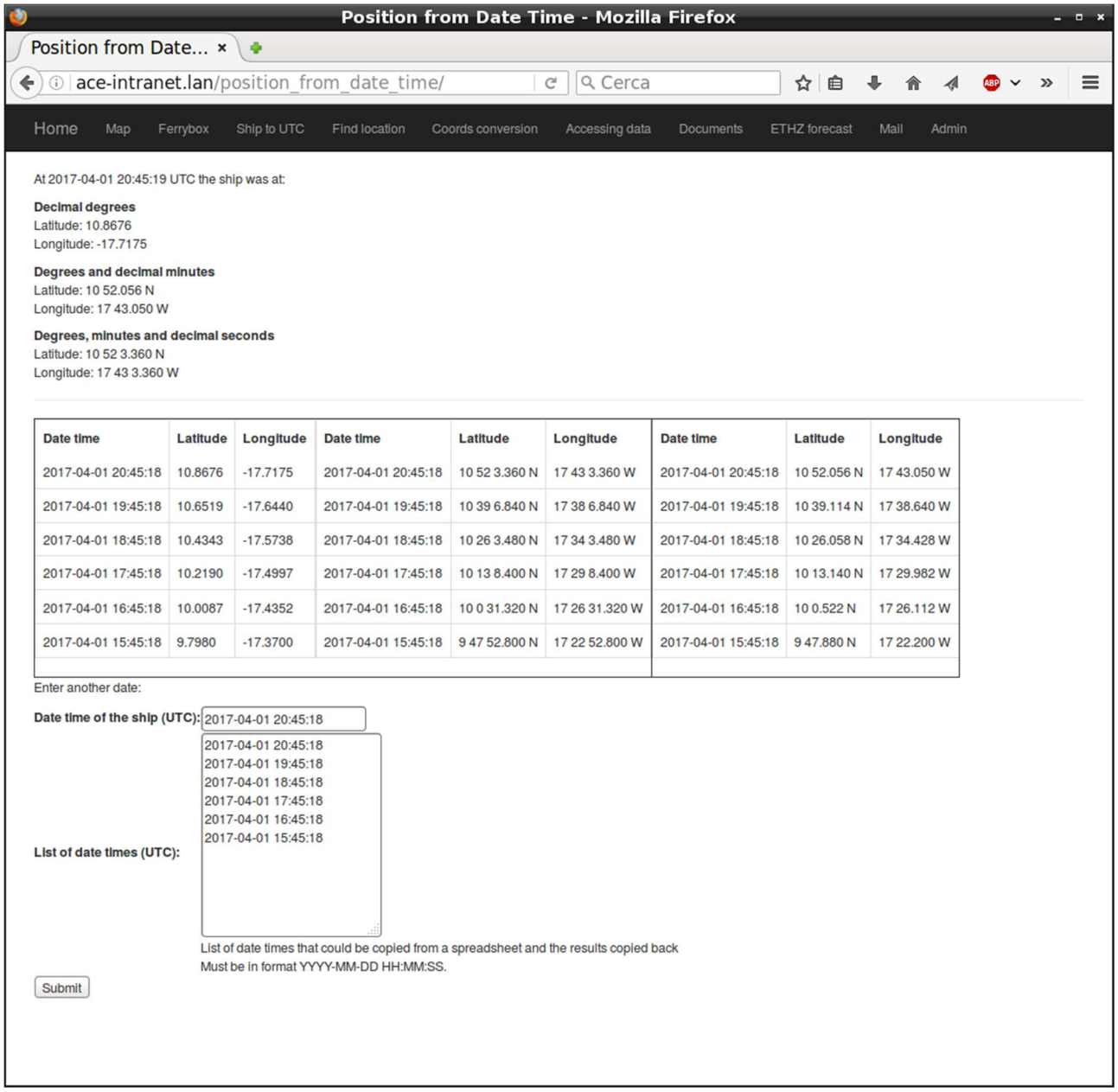

Figure 33: One of the utilities that was written: given the UTC date and time, find the ship's position. In particular this was used by marine predator observers and had the added functionality that a list of times could be copied and pasted from a spreadsheet, then the resulting positions, copied and pasted back to the spreadsheet.

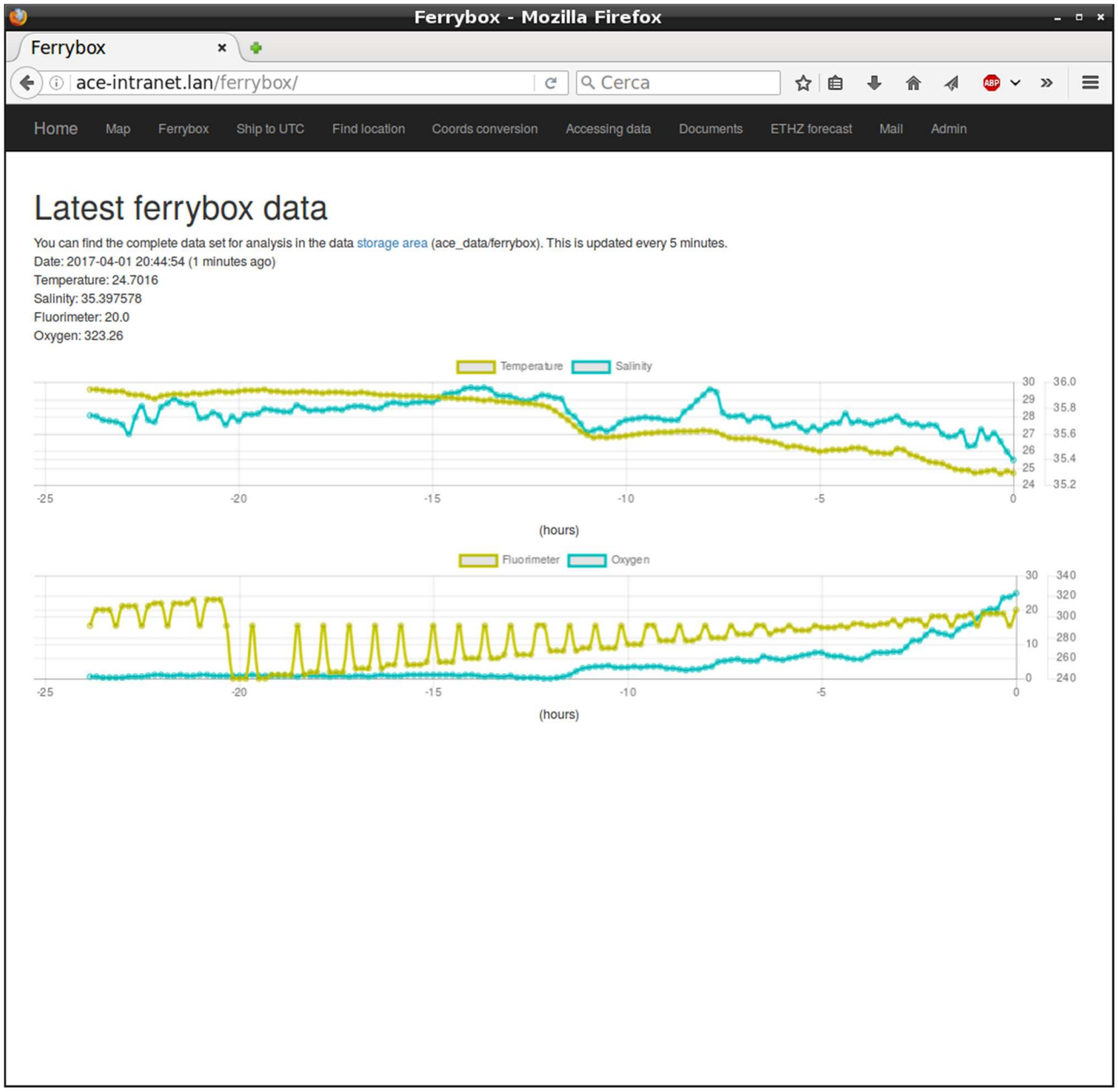

Figure 34: A view of the FerryBox near real-time data feed which is taken from the database and updated every 5 minutes (note that this is two days after crossing the Equator, hence the high water temperature!).

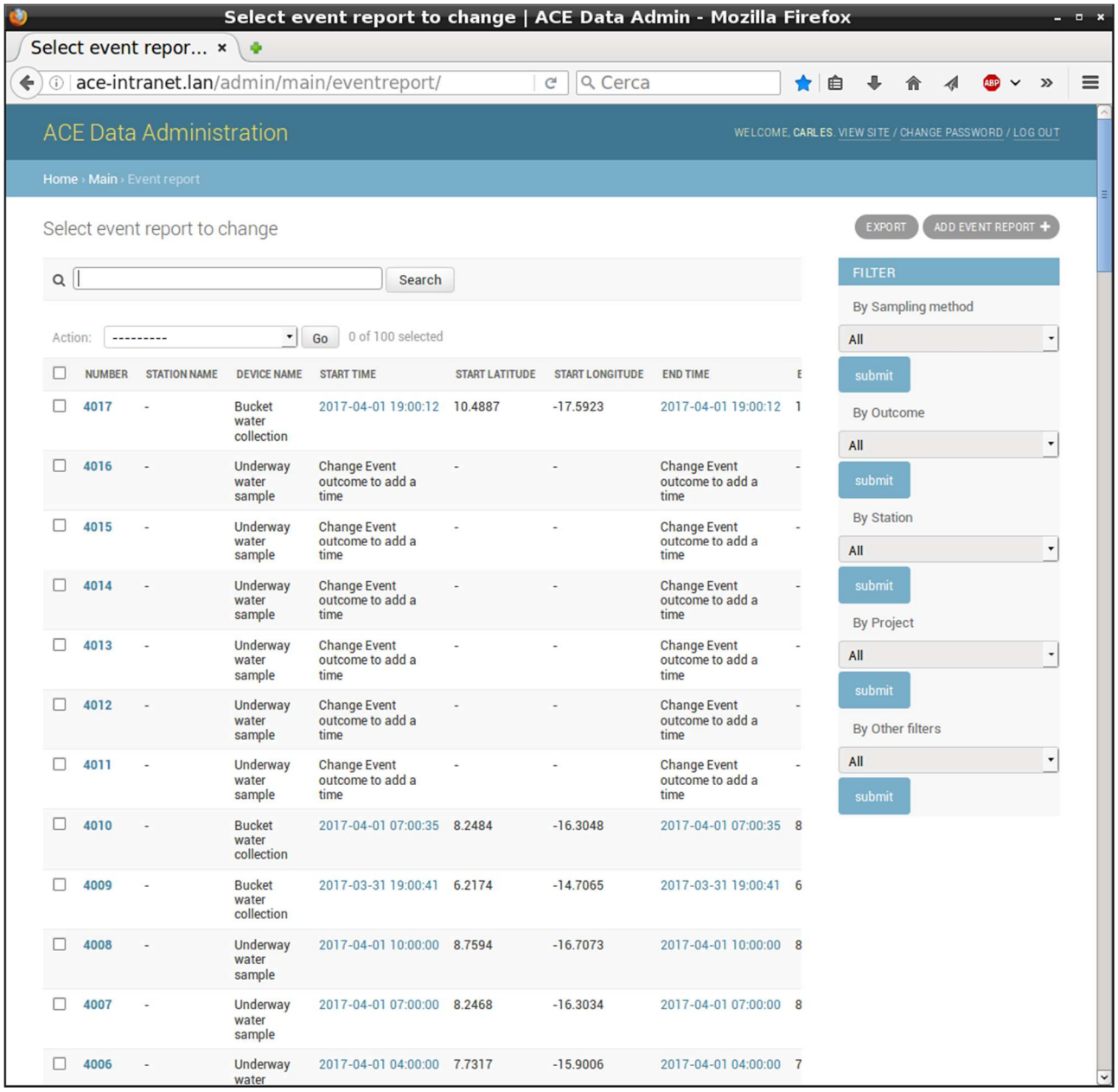

Figure 35: The event report: a view of the main place to see events and event actions which were entered into the database. The search bar at the top and filters were very helpful to query the database.

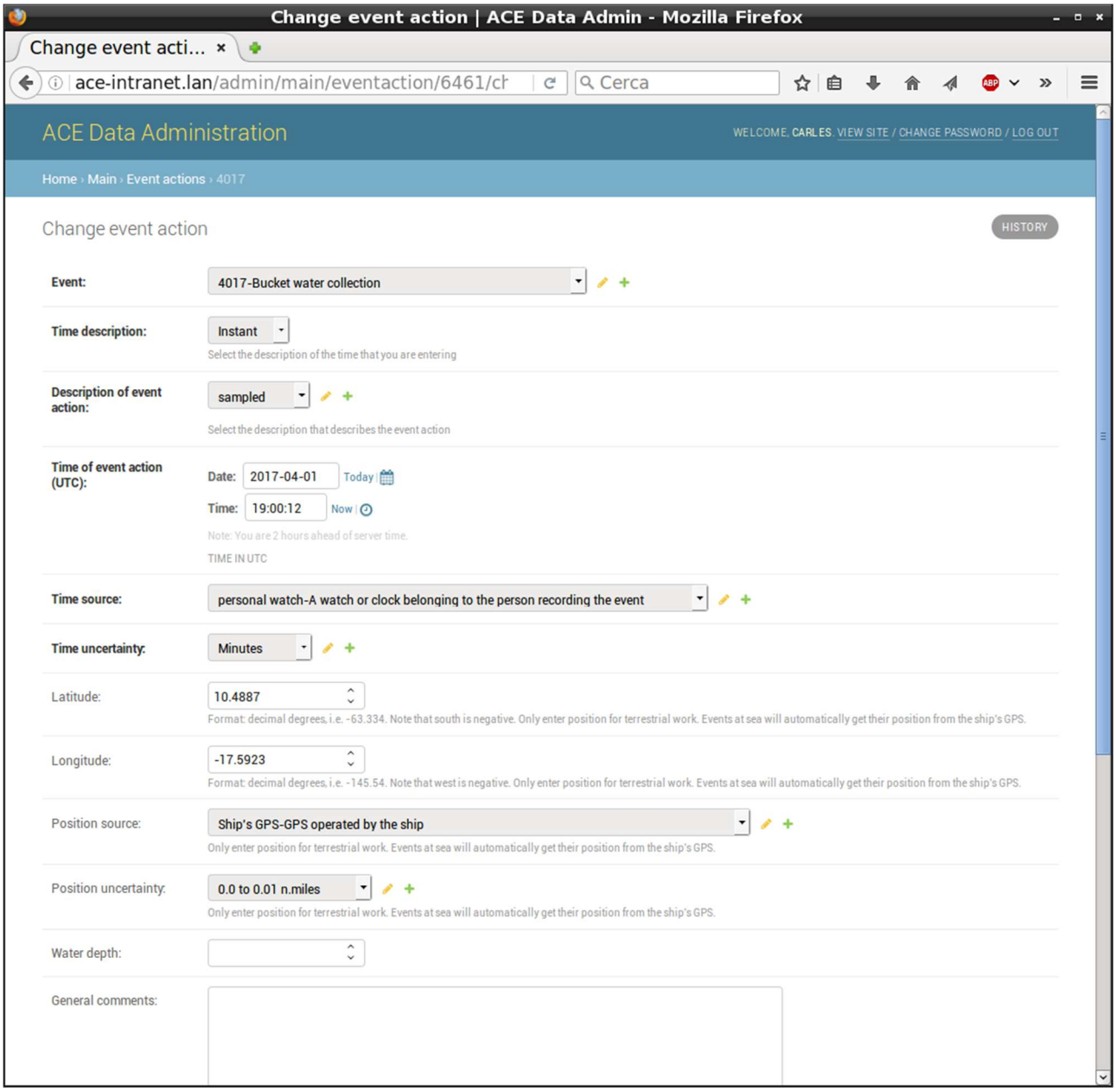

Figure 36: One of the multiple data-entry forms where users could insert information into the database; in this case an event action. Drop-down boxes were useful to ensure use of controlled vocabulary and compulsory fields are shown in bold.

8.8 Setting up science equipment

During various pieces of science equipment were set up with the help of the data team, from connecting them to the ACE network, to dealing with intricate software problems to be able to read data. Below are some of these details which might help to give understanding into how things worked on board and what was possible.

8.8.1 Leg 1

FerryBox (many Projects): connected it to the network so all the data was backed up daily, helped with some problems to extract the data from the sensors instead of having it create manual ports and other things (see the FerryBox cruise report for more information).

Connected the “Swiss container” to the ACE network so scientists from several Projects (7, 8, 11) could connect to the container instruments and computers from the cabins or the labs, or indeed connect to the ACE network from the container. This was very valuable during poor weather so the scientists could still monitor their equipment when they were not able to get out to the container.

We helped to setup the snowflake counters (Project18), the XBT (in test mode; many Projects), bio-optical instruments (Project 1), and also to fix some of the equipment laptops.

8.8.2 Leg 2

The ROPOS (Project 21) and Project 2 containers on the foredeck were connected to the ACE network.

The ROPOS ROV displayed a continuous live stream of video whilst it was deployed. A WiFi access point to the ACE network was set up in the coffee room in order to be able to display this video in the mess room where the laptop was connected to the television via a VGA or HDMI cable and to the ACE network via WiFi. The video was played using vlc.

To help ROPOS connect the software that they needed on the bridge and also to allow them to have the real-time video on the bridge routing was done between the bridge network and the ACE network for the specific IPs when ROPOS required it.

FerryBox (many Projects) live feed was setup to ingest temperature, salinity, oxygen and fluorescence (these were identified as being the most useful variables) into the ACE database and display these live on the intranet.

CIMEL (bio-optical instrument; Project 1) – helped with accessing the software and operating the instrument.

Ceilometer – worked with crew and Project 18 members to access the raw data produced by the ceilometer (see section 7.11).

Winches (many Projects) - most of the winches (particularly the CTD winch) had software issues. After many contacts, tests and details sent to the winches company (Adrian Winch), the winch software was updated, solving some of the problems. The main problem on the CTD winch was that the numeric keyboard was not appearing and the crew could not change some of the settings that they wanted to change. Note that apparently the winches lacked regular maintenance.

8.8.3 Leg 3

DALEC device (Project 1) - usually the device is used with a router but in this case the router was not provided. The DALEC tries to connect to the router and the computer should connect to the router to access the DALEC. The final solution, after some debugging was to use an Android phone as a portable router on the bow in Hotspot mode.

Portable Picarro - a portable Picarro was not creating the WiFi network as it previously did which was required to download the data. The solution was to connect the Picarro to a screen (the television in the mess was used) and used this video output to see that the operating system of Picarro (Microsoft Windows) needed to be repaired in order to be able to boot normally.

Purge trap gas chromatography mass spectrometer (Project 8) - this software already had some problems on Leg 2 when connected to two networks (one to connect the laptop to the instrument and the other to the ship's network for data backups). After some debugging the only way to fix it seemed to be to remove the secondary USB to ethernet adaptor when loading the mass spectrometer software and connect it again when loaded.

Temperature Depth Recorder (TDR; Project 5). In this case we had to setup the Bluetooth connection again which is the method used to download the data. Previous TDR records were also deleted from the device to make it easier to transfer data to the computer.

One of the teams (Project 3) bought a WiFi access point to have access to the intranet from their laboratory. The access point was setup so the team could access to the required information in an easier manner when needed.

Echo sounder Simrad software (Project 5) - two problems arose: one with the network settings communicating with the transducer: the manual had a mistake with the IP settings creating an IP conflict, and some missing information how to find the transducer IP. This happened setting up the equipment for Leg 4. The other problem was with the GPS and the mouse: when connecting the GPS the mouse was moving randomly on the screen. The GPS was disconnected from the serial port adapter and the enumerator disabled, settling on the device manager for this given port.

8.8.4 Leg 4

MAXDOAS (Project 8) - it seemed that MAXDOAS was not working at times. Project 8 was in constant communication with the MAXDOAS experts. After looking in detail at the software and problems we realised that the software does not record data after sunset and before sunrise and that it was being checked for data before sunrise.

Echosounder EK 80 (Project 5) - the echosounder suddenly stopped working during a routine change of configuration. After checking the symptoms (which was that one of the Transceivers was busy) it was discovered that the license expired on the 1 April 2017.

On the first day of Leg 4 the communication between all the cabins, laboratories and the ACE servers stopped working: one ship network port in the office seemed to be faulty. The connection was changed to another port in the office, fixing the problem. Repercussions of this problem would have been that the network would have only been accessible within the office.

One night a cable from the WiFi router appeared, connected to the expedition network causing two DHCP servers on the same network and the problems that this causes: computers were given the wrong IP for the ACE network and were therefore not able to access it.

The communication with the GLONASS stopped working as happens every couple of weeks. The software had crashed (which is the usual problem) and had to be restarted.

8.9 Software engineering

The intranet webpage, data-entry system, sample-entry system, communications, FerryBox real-time statistics, gathering information from a vast range of sources into the database (FerryBox, meteorological data, depth, GPS, etc.) was built during the two weeks leading up to the cruise and developed further during the cruise. The very particular email system (built to be useful in these specific conditions: 80 people and 2 Iridiums in the Antarctic) was built over a couple of days between Legs 1 and 2.

As a result of this, usual best practices in software engineering could not be applied: things would take too long to be done for this short (three-month) expedition. Usually we would have done unit tests, more refactoring, pair programming, code reviews, etc. multiplying the time of development but at the same time making a system that is more robust, easier to use for the users, more reliable (with better error checking adding quality and robustness to the data) and more useful for future expeditions.

9 Data Management

Jenny Thomas and Carles Pina Estany

9.1 Introduction

This section of the cruise report will describe the data management activities, how they were implemented during the cruise, how well they did or did not work and some recommendations for how things could be improved in the future from things we learnt during the cruise.

Any documents or templates that were used and described below can be found in the data_admin folder and all software described in this section can be found at https://github.com/cpina/science-cruise-data-management

9.2 Data-entry system and database

In order to capture all data and sample collection during the expedition, an event recording system (in a database) based on that used by the British Oceanographic Data Centre (BODC) and British Antarctic Survey (BAS), was set up. This section will describe how this system was set up specifically for ACE, how it worked and future recommendations and changes.

No on-board system was already setup for the recording of everything that happened on the ship and no standard software was available for this, so this system was conceived by the data management team prior to the expedition (beginning two weeks before leaving Cape Town). The type of system and detail of metadata required had already been specified by the Swiss Polar Institute so the backbone of this was put in place. The following sections include more information about how this was constructed and the principles upon which it was based.

9.3 Database

A MySQL database (version 5.7) with associated data-entry system was developed in Python using the Django framework (all are free and open source tools). All the source code is available in Github: http://github.com/cpina/science-cruise-data-management.git so it can be reviewed or reused on similar expeditions.

The database was designed to hold metadata about the cruise. For example, information about the ship, expedition personnel, project information, instruments, all the way down to the events (see section 9.6) and information about the data and samples. In general the database did not hold data sets that were collected during the cruise from instruments or by scientists, but some of the data that were collected from ship-based equipment (see section 7.3) were held here in order to make it possible to query them.

When possible the schema and controlled vocabularies were re-used from external parties such as BODC and BAS to make it easier in the future to store the metadata records in other locations and make them more widely available.

Generally, the data-entry system was designed to allow scientists to add data manually within the forms which could be easily customised to make it user-friendly. Improvements were made throughout the cruise to make it easier and less confusing. In addition to this, a number of sets of controlled vocabulary were used. A number of different tools were created to import from spreadsheets and other data files for this reason, as well as to import other data.

Full documentation of the database including the schema is available if required.

The database was backed up on an hourly basis with the backups being stored on the NAS in the data_admin area. None of the backups was deleted.

9.4 Database performance

At the beginning of the Leg 1 a new events system (database) did not contain any events (records). When the database began to be populated some of the operations became too slow, taking at least 5 seconds (e.g. to add an event action) and this was not even after half of the cruise. Some time during Leg 2 was taken to fix performance issues in different pages of the data-entry system to make it easier for users.

9.5 Introducing the system to expedition participants

At the beginning of Leg 1, the data management team was introduced but did not give a formal presentation because the system was still in full development. Each team was spoken to individually to show those who would be responsible for entering and logging each team's data, how to use the system, backup their data and record samples. At the start of Legs 2 and 3, a full presentation was given, with more information directed at those who would be entering the data. Additionally at the beginning of Leg 3, meetings were requested with each team to ensure that there were no changes in sampling between Legs, metadata records could be completed and to ensure nothing was being missed, as the introductory presentation was only given to the new members of the expedition. Finally at the beginning of Leg 4, all expedition participants attended a full briefing about the data management and communication systems on board.

Deadlines to submit metadata, sample records (discussed later) and data were not given at the beginning, but it was emphasised that this should be done at least on a weekly basis for oceanography work (or work that was carried out on the ship) and after each island visit for terrestrial work. Regular requests and deadlines were made and announced at PI meetings during each Leg. During Leg 4, Tuesdays and Saturdays were "data days" when sample records and data were submitted.

9.5.1 What worked well

Comparing all of these methods of introducing users to the system (which included communications, IT and data management and was therefore lengthy!) the preferred route was to give an overall talk to everyone, then have an individual meeting with each Project to ensure nothing was missed.

An overall presentation was essential to give an overview of the system to newcomers – this introduced them to the concepts as soon as possible and was necessary before they began sampling which was often soon after departure.

Group meetings allowed:

- the data team to get a better understanding of what each team was doing.
- details on how to use the system, how the team could make the most of the data-entry system and other facilities to be given, and how to avoid making mistakes / checking for errors, could be tailored to each team, making it much more effective.
- the data team to address issues that we had during previous Legs to ensure that they did not reoccur during that leg.

9.5.2 What didn't work well

- Not all teams attended the group meetings.
- Group meetings were very time-consuming (generally an hour was required for each group) and with 22 Projects this was impossible to achieve before each group began sampling. This would be better done before the cruise whenever possible to cut down on the time required.
- Participants who had been on previous Legs missed out on hearing about new developments in the systems, which could have improved their experience, because they did not attend the introductory meetings at the beginning of Legs 2 and 3.

- Some data or sample collection was seen as not worth backing up or recording by some Projects, meaning it was not known about by the data team and therefore not included in the metadata database.

9.5.3 Future recommendations

9.5.3.1 Pre-cruise preparation:

- work with the cruise planning team from the beginning to ensure data management systems are integrated into everything as the planning evolves (Project planning details should also be incorporated from the start so that instruments are already in the system for example – this would allow the data manager to be more prepared and know what data sets to expect).
- work with the scientists as they are planning the Projects and particularly at cruise planning meetings to introduce data management, what will be expected of each team, what to expect from the data management (and IT) team, what facilities will be available on board, what data and metadata will be expected from each Project.
- request a full work plan from each team so that all data collection that is expected can be checked upon.

9.5.3.2 During the cruise:

- set proper regular deadlines for completing tasks: i.e. event metadata each day, sample sheets two specific days per week, data backups two specific days per week, etc.
- ask for a revised work plan at the start of each Leg and follow it up during the Leg to make sure that there haven't been any changes.
- have team meetings;
- spend time with each group following their sampling or data collection method to understand what they are doing, how they are numbering samples and how logs are being recorded.
- make the metadata available in full reports throughout the cruise so errors can be rectified and metadata checked.

9.5.3.3 After the cruise:

- -ensure teams know that any further errors will be followed up after the cruise;
- make scientists aware of how the data and database will be available after the cruise and what they can use it for.

9.6 Event recording

Anything that was deployed or done in order to collect data or take samples was recorded as an event. Some examples are the deployment of a net, release of a radiosonde or a period of time spent collecting invertebrates from an island.

Each event has a beginning and end, or instantaneous time associated with it (known as an event action) and is undertaken by a specific sampling method (instrument or method of collecting a sample). For this expedition, sampling methods rather than instruments were used to describe events because in many cases, especially for the terrestrial work, a specific instrument was not used, but it should be noted that a sampling method could also be an instrument. Where they were used, instruments were fully described and were linked to sampling methods. Positions of the start and end, or instantaneous times of the events were inserted into the database every hour from the ship's GPS data streams (see the section on ship data later in this report) where sampling occurred at sea and from hand-held GPS devices or map coordinates for terrestrial work. Each event action had details about the time and position source and precision.

Each event had "data" and / or "samples" ticked against it, so the data team knew whether to expect data and / or samples associated with the event. Unfortunately, we did not have time to be able to implement any checks in this regard (this would be fairly straightforward to do for samples, but in the case of data, the data files would need to be linked to the event).

In addition, events were marked as having the following outcomes as a way of being able to check whether event actions, data and samples should be recorded against it:

- not yet happened – this was assigned when an event had been created but it had not yet taken place;
- invalid – the event was entered but for some reason it did not take place (note that events were never deleted from the system to avoid problems of using event numbers for multiple events);
- failure – the event took place but for some reason was unsuccessful (i.e. something major broke). Event actions were still expected for these events because they still took place.
- success – the event was completed (event actions were expected).

9.6.1 Particular differences

Sonobuoys

The end position for sonobuoys was not entered into the database, nor taken from the ship's GPS track because the buoy was free-floating and therefore this could not be determined from the ship's GPS. If these positions are needed they should be taken from the data files.

9.7 Sample recording

Every sample that was collected, was associated to an event so that its origin can be traced in the future. In addition, it was important to capture sample details to ensure there is a permanent record of the samples that exist, where they will end up after the cruise and have a complete log of what was on board for when arriving at customs.

9.7.1 Sample numbers

Each sample was given a unique identifier: ship (AT), cruise (ACE), Leg 0-4, Project (1-22), Julian day (3-digits), event number, owner (PI initials), number of sample, eg.

AT/ACE/1/12/001/5/SF/1

Some Projects already had pre-labelled sample containers or institution-specific labels, so these sample numbers were recorded as a Project sample number. This was in addition to the ACE (expedition) sample number displayed here above. Such information as the contents, preservation and storage type as well as where the samples are to be offloaded, were recorded.

9.7.2 Data entry

Teams were asked to add these columns to their pre-prepared spreadsheets so as not to create extra work for them and also to ensure that this other information was stored for future reference (although this was not databased).

In order to aid entry of the samples into the database, a spreadsheet template was created which included the required fields. Before import into the database, the file was checked visually by the data management team (checking controlled vocabulary, headers which were required for the script, looking for any obvious mistakes), then a script uploaded the file into the database, again checking the controlled vocabulary and performing other automated checks. Duplicate ACE sample numbers were queried, as were empty compulsory fields but a lot more error checking would have been useful at this stage (see future recommendations section). Only one team chose to enter the samples directly into the database using the web interface instead of the spreadsheets: although this was an option open to everyone, it was not really practical in most cases because of the number of samples collected.

9.7.3 Data checking

In addition to the visual checks before importing the samples, further quality checking that was done included:

- checking the sampling method associated with the sample event was recorded as being used by the Project;
- ensuring the number of samples uploaded into the database matched the number in the submitted spreadsheets.
- checking the events that were associated with the samples were "successful" – this was done in the script during Leg 4, but by going back and checking reports for previous Legs.
- checking the events had a Julian day that corresponded to the Leg in which the sample was recorded (added to the script in Leg 4, but done manually using reports from the database for other Legs).
- after all samples were imported (during Leg 4), the sample_validation_report.py script was run for extra checking.

During Leg 4 a lot more quality checking was done using a script (sample_valdiation_report.py) which picked up on the points listed above to ensure everything already in the database met these requirements. The details of what errors occurred and changes made are logged in data_admin/data_quality_checking/sample_checking_log).

9.7.3.1 Inaccuracies in sample spreadsheets

Having a consistent columns and vocabulary on the sample spreadsheets is one of the keys to be able to incorporate them in the database and run the checks automatically without lots of manual intervention. Entering each sample into the database manually was not a viable option given the number of samples collected, so spreadsheets were a more practical option for most teams. Despite having controlled vocabularies in these spreadsheets and full instructions there were many mistakes which were very time consuming to rectify, leaving little time for checking the integrity of the data until Leg 4.

9.7.4 Completing sample spreadsheets

Entering the data about samples was normally not a priority for teams, making it much more difficult to have time to get the data into the database and therefore check the data thoroughly.

Having reports for teams to check on a regular basis is a useful way for Projects to see what they have logged, pick up on mistakes and help them ensure that their record keeping is correct. A few teams took advantage of this, and many errors were corrected during Leg 3 for the few that did, which would have been extremely difficult if it had to be done post-cruise. However this was not done by the majority of the teams. Producing the final lists for customs from this database, as well as doing regular audits of the samples, would perhaps be a better way to encourage completing this necessary information. Additionally, making teams more aware of these requirements before the cruise would be helpful.

9.7.5 What worked well

- The sample database table held in the region of 27,000 samples.
- Quality checking that was done with Project 8 helped a great deal to ensure that the data were correct.
- The spreadsheet was very simple to complete and if all samples were being recorded in a spreadsheet by each team, it should not have required too much extra effort (a lot of fields were drag and drop, so in general it was only the sample number that needed to be changed by row).
- It was essential to have the original file name in the database next to the sample – this helped a great deal with solving problems.

9.7.6 What did not work well

- Julian day caused a lot of confusion and was probably unnecessary in the ACE samples number as this information also came from the event number, although if there were errors it helped in checks.

- Leg number is not really needed: the events could be linked to a Leg as well. This would reduce the number of errors entering the samples.
- Sample integrity checking should have been done by the script much sooner (earlier than Leg 4).
- Spreadsheets should have been given out with the controlled vocabulary from the beginning, rather than simply stating what the controlled vocabulary should be in a set of instructions.
- All teams should have been asked for their full spreadsheet including all of the information that they needed, rather than them just giving the information that was required for the database.
- The database was partially aimed at being used as a record for customs, but Projects had to complete their own separate reports for customs, not utilising the database. If more emphasis had been placed on using the database, this may have given entering the data more importance.

9.8 Other database tables and recorded information

The database is very extensive and contains a large number of tables so not all of that information can be reproduced here, however this section will give a brief overview of some of the tables that may be of more interest, that are not already mentioned. Full documentation on the database can be found in data_admin/documentation/ace_expedition_database.

Table 13:

Section	Table	Description
Main	Island landings	Information about who visited each island and when
Main	Islands	Information about each island
Main	CTD casts	Mapping between CTD cast number (used in data files) and event number (used in event log and sample records)
Main	Legs	Start and end date, time and location of each Leg of the cruise.
Main	People	List of all who took part in the ACE expedition, on which leg(s) they participated, their institution and for which Projects they contributed.
Main	Time changes	Time on board the ship relative to UTC.
Main	TMR casts	Mapping between TMR cast number (used in data files) and event number (used in event log and sample records).
Underway sampling	Underway sampling	List of parameters that were sampled from the underway system and when (during Legs 1, 2, 3).
CTD	CTD bottle triggers, variables, sample volumes	Tables describing when each bottle was fired and what was sampled from each bottle on each cast.

9.9 Backing-up data

Data from ship-based computers, laptops connected to Project instruments, instruments that worked remotely and not connected to a computer, and hand-crafted spreadsheets were the different sources of data that needed to be backed up. With a huge variety of instruments and sampling methods, each backup was generally setup individually.

Three methods were used to back-up data from scientists:

a) Portable storage (hard disks, SD cards etc.)

A program that used the rsync command copied the data from the portable hard drive to a read-only (to all except for data management admin users) area, called “ace_data”, on the NAS. A log was kept of when the directory was last imported. After the first setup for each hard disk this was very easy to do.

b) Users saved data in shared folders on their computers and it was fetched automatically

Users save data in shared folders on a computer that was connected to the ACE network (so all the data is local for them and not dependent on network status). Every hour a cron job collects all the data from the different areas and stores them in the relevant folders in the read-only ace_data area on the NAS. The origin IPs, shared folders and destination folders are easily entered into the database, making this a very time-efficient method of backing-up the database.

c) Users saved data into a staging area on the NAS

A password-protected data staging area on the NAS was written to by users and then data were moved to the ace_data area.

All of these methods had one thing in common which was to not delete anything. There was a downside to this when users moved raw data files in their storage area (hard drive, shared folder, etc.) there would then be duplicates. However, not deleting anything was seen to be more important than deleting something which if required by the user, would possibly not be recoverable. Folders where duplicates existed, were tidied at the end of Leg 3 using a script to identify duplicates in the folders and also to detect possible missing files from the computers compared with the backups – this was done with the assistance of the scientist.

Generally the preferred method by the data management team was b) (automatic syncing from computers), because this ensured data were backed up on a regular basis, very few problems were encountered and there was minimal time required to administer it. Only the initial setting up of a fixed IP, sharing the folder and testing was required.

Method a) worked well for those who chose to use it but in fact in two of these cases it would have been preferable to use method b). The problems that we found were that teams missed some files when copying from the laboratory computers to the hard disk, delays getting the hard disks, and more administrative work to get the hard disk, copy, return it back and so forth. We also found that some teams re-organised the hard disk or changed directory names slightly by mistake or on purpose: this caused problems because the script used to back it up would not find the new directory names and manual changes were needed. As a result of this, when possible, we suggest to use the networked approach and automatic backups instead. It is worth mentioning that using portable hard disks or other ways of storage is convenient for some systems that might not be able to be connected so the data can be backed up.

9.9.1 What worked well

- As already mentioned, using a shared folder was the preferable method for being the most reliable, secure and time-efficient.

9.9.2 What didn't work well

- Reorganisation of files on hard disks before back-up is considered bad practise as files can be corrupted or deleted inadvertently.

9.9.3 Future recommendations

- Ensure that scientists are aware that files should not be renamed or moved in what is considered the primary copy of the data. Secondary copies can be copied into separate folders if required at a later date but must not be moved.
- Teams may need some help to use commands such as rsync to ensure that all files are copied onto portable data storage and avoid missing data files.

9.10 Data areas

A number of data storage areas were set up on the NAS with varying permissions and purposes. These are described below:

ace_data - read only - all data collected on board the cruise were stored and backed up here. Organised by instrument.

external_data - read only - data from external sources that was of interest to parties on board. Included terrain maps, satellite images and bathymetry of the islands visited.

intranet_documents - read only - a collection of useful and interesting documents such as the weekly menu, blogs, island information and emails sent to PIs.

ship_data - read only - data streams that came from ship-based instruments.

work_leg# - read and write for each Leg in turn - an area for each Leg which was writable during the Leg but read-only afterwards. Contained an area that could save work which was backed-up, as well as photographs and cruise report drafts.

data_admin – read and write for data team only – contained backed up administrative documents as well as documentation about quality checking and more.

9.11 Access to data

All data collected on board were accessible by all participants with read-only permissions.

9.11.1 Data reports and quality checking

Due to the number of Projects on board, quantity of data coming in and lack of set up time, there was very little time for quality checking of the metadata in the ACE database. However, the following things were done to produce reports to make data useful and available to the scientists, as well as conduct some error checking.

9.11.1.1 Ship data streams

At the end of Leg 1 some navigation and meteorology data were exported for some teams into CSV format. This was done in one-off setups which were hard to maintain (e.g. creating new files every day instead of deleting old files).

During Leg 2 this software was consolidated to have more reliable exports that were easier to use. The result was that a cruise track and weather data was generated from the beginning of the Leg to the current day, during the night every night. The cruise track from each Leg was saved separately and entitled cruise_track_startdate_enddate.csv and was created in four different resolutions: 1 second, 1 minute, 5 minute and 1 hour. More can be read about how this was done in the documentation stored with the GPS data (ship_data/gps_bridge1 and ship_data/gps_trimble) and in the ship data section of this report.

Full details of quality checking of other data streams can be found in the document data_admin/ace_expedition_database.

9.11.1.2 Event recording and sample metadata

Throughout the cruise, users were able to access the reports of events and samples so they were able to check their own data entry. There was an export facility from the database reports that allowed users to output the data into files and open them in spreadsheets for example. Users were encouraged to do this for their own records, to avoid making typing errors when recording position information for example.

The data team did the majority of the checking on the database, but during Leg 3, reports were produced in CSV format so that each team could check these thoroughly. New reports were generated for all the Projects: behind the scenes the events, samples, sampling methods, latitudes, longitudes, Projects, etc. are all linked in the database. Users did not have a global view of the links butreports were generated (available on work_leg3/reports area) for each Project or sampling method, tying more data together.

The reports are important to help users put data together, and also to show that the data put into the system is used to generate information that might be used by them. This might underline how important it is to have complete and correct data because mistakes in the data entry have consequences later on.

The expertise of the data team were such that combining metadata of their samples (for example where they were collected) with the meteorology data or other data sets, was a fairly straightforward task. This offer was only taken up by two Projects and there was no evidence to suggest that more than two Projects checked their reports of samples that were held in the database.

9.11.1.3 Specific data reports requested

The following requests for reports were received:

- Average of the meteorology data (wind speed, temperature, humidity) over periods of 10-minutes so Projects can correlate their data with this. Done for Project 20.
- List of all samples collected by all Projects at each CTD and underway event. Requested by Project 1 and done for all Projects.
- Lists of all samples collected by each Project, with their locations, times and sampling methods. Done for all Projects.
- Report of all sampling methods used for each Project (used for quality checking). Done for all Projects.

Other reports were created for the data team for quality checking purposes.

9.12 Metadata records

9.12.1 Background

After discussions with other data centres involved in polar science, it was decided to create metadata records for each data set that was collected during ACE. One reason for this is that the data collected by ACE are environmental data and considered to be of public interest by the Swiss Polar Institute (SPI). In addition to this, one way to increase their re-use is to make them more easily discoverable. These metadata records are to be created in the Global Change Master Directory (GCMD) which is a large metadata repository hosted by NASA, covering a wide range of scientific disciplines and hosting specifically Antarctic metadata. One advantage of this repository is that it has sub-repositories which are targeted towards certain users and therefore this is another way to increase discoverability of the data. It is hoped that ACE data will be made available through two of these: the Antarctic Master Directory (AMD) and the Southern Ocean Observing System (SOOS) as well as the general main repository and subject-specific data repositories.

In addition to the GCMD, it was foreseen that Digital Object Identifiers (DOIs) will be created for each dataset when they are published. Therefore the DataCite Metadata Schema (version 4.0; DataCite Metadata Working Group (2016)) was also incorporated into the metadata records to ensure this information was also captured.

9.12.2 Metadata dataset

A dataset was considered as the grouping of related data files from the expedition. In some cases it made sense to split these into legs because the data were sufficiently different to warrant this, but in other cases it is for the entire cruise. Data sets were not compiled from data files across projects or instruments.

Metadata records have the advantage in the GCMD system that they can be linked together. Therefore Projects that were recording fairly distinct data sets can then have their records linked.

It should be noted that metadata records produced during the ACE expedition are only of the raw data and samples collected. Additional metadata records should be created for the processed data and the data that results from sample processing; these datasets may not, and indeed are unlikely, to correspond on a one-

to-one basis with the raw dataset and sample dataset records. It is essential that related data sets are linked.

9.12.3 Creating the metadata records

Data were input into the system during a series of interviews with the on-board team members. This work began on Leg 2. Where no PI was on board, the records were completed with the team members on board and emailed to the PIs for checking. Each PI was sent a short description of what the metadata records were for, and were explained that they would get to see each record again before publication. It is essential that this happens.

9.12.4 Technical setup

The GCMD metadata record system is based on an XML schema which was downloaded before the cruise. This schema is in Directory Interchange Format (DIF). Database tables were built to fulfil the schema and also linked where necessary with the existing ones. In general, new tables were constructed unless an existing one could serve the same purpose. Tables of controlled vocabularies were also imported using those on the GCMD website, although we discovered that the schema is not consistent in some places. Documentation on the website is ok but is only available as webpages so was not particularly helpful with the poor internet bandwidth.

Controlled vocabularies were also imported from the DataCite Metadata Schema (DataCite Metadata Working Group (2016)).

New features were added to the Django / Python data-entry system in order to improve data entry in both speed and quality. The ability to be able to copy an entry was very useful but it seemed easy to not save the previous entry with a result of missing the entry.

The full database schema is described in the documentation.

9.12.5 Reviewing the metadata records

The system automatically outputs the metadata records as Microsoft Word documents to provide a user-friendly way for PIs to provide feedback on the record. In addition, they are also output in DIF XML. This format encapsulates all the information in a validated standardised format: it also serves to double check that all the required fields are filled in and the structure of the XML format is as it should be.

9.13 References

DataCite Metadata Working Group. (2016). DataCite Metadata Schema Documentation for the Publication and Citation of Research Data. Version 4.0. DataCite e.V. http://doi.org/10.5438/0012

Directory Interchange Format (DIF) Writer's Guide, 2016. Global Change Master Directory. National Aeronautics and Space Administration. [https://gcmd.nasa.gov/add/difguide/].

10 Project details

10.1 Project 1

Long term changes in phytoplankton abundance and composition in the Southern Ocean and their impact on biological productivity

PI David Antoine (Australia)

Aims & Objectives

The capacity of the Southern Ocean to act as a long-term carbon dioxide sink will only be revealed upon a better understanding of the impacts of various forcing mechanisms on phytoplankton physiology and community structure. By examining a large variety of in situ bio-optical and physiological parameters this Project aimed to develop and validate appropriate regional ocean colour algorithms. The bio-optics suite included instruments to measure the inherent optical properties (IOPs – scattering, attenuation and absorption), apparent optical properties (AOPs – down-welling irradiance, upwelling radiance, reflectance), as well as the fluorescence signal to determine the photosynthetic efficiency of the phytoplankton community. These data were complemented with a range of biogeochemical measurements, linking the optical properties to carbon content, size distribution and taxonomic composition of phytoplankton communities.

All data measured and sampled will be used to parameterize the particle field through empirical relationships between IOPs, size, pigment and carbon content. This information in conjunction with AOPs, radiative transfer models and reflectance inversion algorithms will allow us to use satellite ocean colour radiometry to investigate biological responses (through changes in biomass, community structure and physiology) to seasonal, inter-annual and decadal variability in ecosystem physical drivers at the required spatial and temporal scales.

The Project aims to:

- Develop and build a consistent data set of radiometric, optical and biogeochemical variables for the Southern Ocean
- Validate and develop regionally-specific ocean colour algorithms through inverse modelling and empirical relationships
- Apply this new understanding to current measurements of ocean colour radiometry as well as previous measurements dating back over 10 years

Achieving these aims will allow us to address key questions of bio-optical relationships to biogeochemical properties, as well as changes to the phytoplankton communities in the Southern Ocean.

Underway sampling

A new pump and temporary rust-free sea water underway supply system was installed during the first week of Leg 1. The pipe was transparent plastic and unlagged. This was addressed by wrapping the pipe in dark plastic and lagging it as far as possible to minimise temperature change. Unfortunately, the pump did not prime itself and switched off regularly during bad weather as the ship rolled taking the intake above water. It therefore needed to be watched 24 hours a day and restarted as necessary. The flow rate was highly variable and could not be regulated, and so was often too high, having downstream impacts on continuous bio-optical measurements from the underway water supply via an optical board. The temperature offset between intake and outlet in the laboratory is unknown and being a centrifugal pump, damage to phytoplankton cells is likely.

With the sea state much calmer during Legs 2 and 3 than during Leg 1, problems with the pump not self-priming after shutting off in rough seas were minimal. The pump was shut off during the South Georgia,

South Sandwich and Bouvetøya island visits and during a severe storm encountered on the 04 and 05 March 2017. Figure 37 shows the extent of our realised oceanographic sampling.

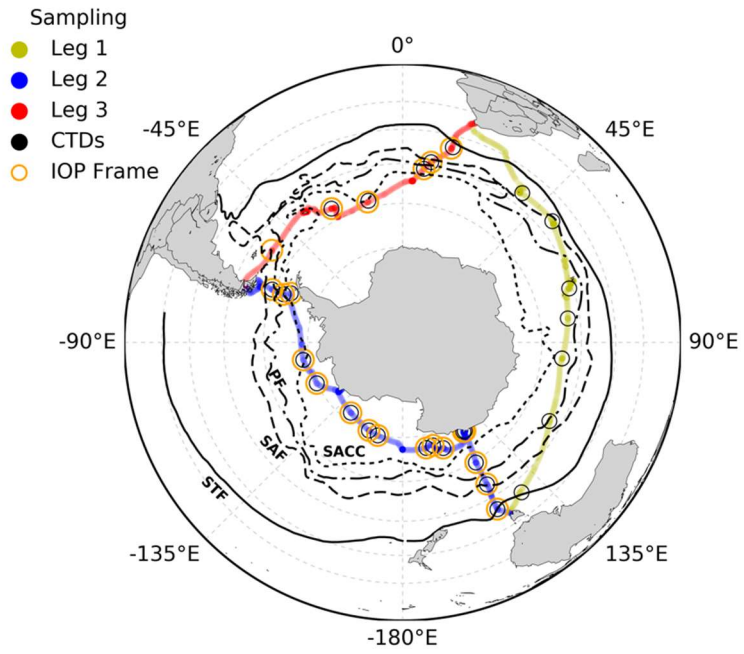

Figure 37: Realised oceanographic sampling. Underway sampling points were taken at 3 hourly intervals from the underway water supply along tracks marked Leg 1 (yellow), Leg 2 (blue) and Leg 3 (red). Samples were analysed for a variety of parameters outlined below. In addition optical properties were continuously measured along each track. Samples were collected at depth at CTD stations (black circles) and the Inherent Optical Property (IOP) frame was deployed at stations marked (orange circles).

Discrete sampling from underway water supply

At three hourly intervals (see Figure 37) the underway water supply was sampled for the following set of measurements: phytoplankton pigment analysis by HPLC & phytoplankton absorption spectra (these samples were flash frozen and stored at -80°C until analysis at Villefranche sur Mer, France), [chla] (chlorophyll a concentration from 250 ml samples were planned to be analyzed fluorometrically on board the ship, but due to a missing cuvette, samples from Leg 1 had to be frozen for later analysis. On board analysis of [chla] samples was completed during Legs 2 and 3), POC (samples for particulate organic carbon were pre-processed on board the ship and stored until the end of Leg 3 for final analysis at the University of Cape Town in 2017), particle size distribution (particle size distribution in water samples from 2 – 60 µM were analyzed using a Coulter Counter (Beckman) on board the ship), photo-physiology by FRRF (a Chelsea FastTracka III with a FastAct laboratory system was used to acquire chla fluorescence vs light curves), nutrients (samples for macronutrient analysis were stored at -20°C for analysis at the University of Cape Town), DIC (samples for dissolved inorganic carbon were collected every 9 hours and stored until analysis at LOCEAN in Paris, France).

Close to 150 underway sampling points were collected in this way during Leg 1. Over 100 sampling points were collected during Leg 2 and a further 73 sampling points were collected during Leg 3 giving a total of 331 sampling points for all three Legs combined. Several other groups joined in the underway sampling during Leg 1 and time-points were matched up for data sharing.

Continuous sampling from the underway water supply

Several instruments were running continuously using water from the underway water supply (See Figure 38); these instruments were run in-line utilizing a custom-made bio-optics flow board (Figure 38). The flow

board consists of large particle traps, debubblers, valves and filters (2.0 µm and 0.2 µm) to distribute the water across all the bio-optical instruments.

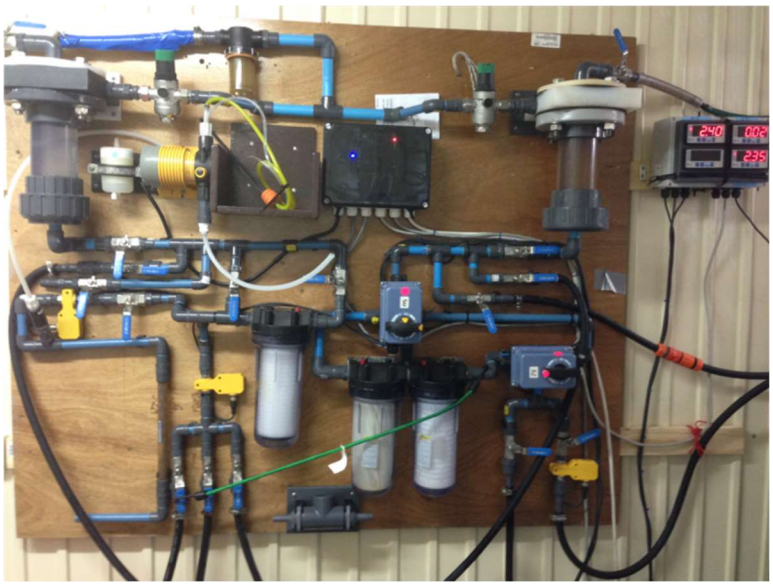

Figure 38: Optical board diverting the flow of underway seawater through particle traps, debubblers, valved and filters being distributed to various bio-optical instruments.

Optical instruments installed in the biology container included two hyperspectral absorption meters (AC-S, WetLabs and OSCAR, Trios) and a 9 wavelength backscatter sensor (BB9, Wetlabs). Filtrate and Milli-Q blanks were run at regular intervals and the instrument were cleaned while the underway water supply was switched off near islands. A multi-excitation fluorometer (MFL, JFE Advantech) was planned to be run continuously, but was not functional in our current optics set up. Collectively, the continuous IOP instrumentation collected over 1,200 hours of data over Legs 1-3 and each instrument has collected > 33,000 data points.

AC-S

The WETLabs Spectral Absorption and Attenuation Meter (ac-s) performs concurrent measurements of the water's absorption (a) and attenuation (c) characteristics through incorporation of a dual path optical configuration in a single instrument. The spectral range is between 400-730 nm. The ac-s was set up to measure continuously flow-through chamber, receiving seawater from the ship's underway supply. The set-up ensured a continuous stream of seawater flowed into the bottom of the 'a' tube and out the top, leading into the bottom of the 'c' tube, before flowing out of the top of the 'c' tube and into the custom Perspex container that housed the ac-s. The ac-s was constantly kept at seawater temperature due to the continuous overflow. The ac-s measured unfiltered seawater to determine the total absorbance and attenuation, and filtered seawater to measure the absorbance and attenuation of Gelbstoff and other small debris/detritus. The difference between the two measurements provides the absorption and attenuation spectra of the particle field which is dominated by phytoplankton in the Southern Ocean. Initial problems were encountered with running of the instrument due to two channels of the 'a' tube not measuring any data. Alterations were made to the automated scripts to account for this. This instrument worked continuously during Legs 1, 2 and 3.

BB9

The WETLabs Scattering Meter (ECO BB9) contains three BB3 instruments, each providing a backscatter measurement for three different wavelengths (collectively 412nm, 440nm, 510nm, 532nm, 595nm, 650nm, 676nm and 715nm). A data multiplexer was attached to power the BB3 instruments, to read the data and to re-format and output the data from all BB3s in a synchronized manner. The back-scattering coefficient is

useful inherent optical properties because; the spectral reflectance of the ocean is, to first order, proportional to it. Moreover, several pieces of information about the abundance or composition of marine particles can be derive from it. The ECO-BB9 worked continuously during all three Legs. Cleaning of the instrument at Bouvetøya revealed some particles of paint and the inner coating of the BB9 tubes in the cleaning solution. It is unknown whether these particles may also be present during measurements. The impact of backpressure on the BB9 outflow is also currently unknown.

OSCAR

The TriOS OSCAR has been designed to measure the particulate light absorption in natural waters in the range of 360-750 nm. The OSCAR overcomes sampling limitations of low concentration of particles by measuring the seawater inside an integrating sphere, minimizing scattering problems and sample handling whilst improving sensitivity. The OSCAR measures both unfiltered and filtered seawater at time intervals of 15 seconds. Problems were encountered initially with the database used to store data, but these issues were overcome by utilizing an empty database. The instrument has an optimal temperature range of 5-40^{o}C, and as temperatures will have gone below the lower limit this will need to be considered when interpreting the data. Due to several plumbing problems during Leg 2, data for the later part of the Leg is not continuous. The plumbing problems were resolved at the beginning of Leg 3 by incorporating a plastic overflow chamber to the instrument set-up. This allowed continuous data to be collected during Leg 3.

FIRe

Phytoplankton photophysiology was measured continuously using a chla fluorescence induction and relaxation instrument (FiRe, Satlantic). The FIRe had the following parameters:

STF: 100

STRP: 60

STRI: 60

MTF: 600

MTRP: 60

MTRI: 100

Sample Delay: 300 ms

Number of Samples: 12

Blank samples were collected from the GF/F filtrate of the midnight underway sample.

IFCB

An imaging flow cytobot (IFCB) was installed in the CTD lab, automatically drawing samples from the underway water supply at 20 minute intervals and analyzing these qualitatively for phytoplankton taxonomic composition. Problems with camera alignment and focus, probably due to damage during shipping to Bremerhaven, resulted in no satisfactory data being acquired during the second half of Leg 1 and all of Legs 2 and 3.

Sampling from CTD casts

During Leg 1, samples were taken at seven stations, at 16 stations in Leg 2 and 27 stations in Leg 3. At each station samples were taken at 6-8 depths resolving the upper 100 metres of the water column for essentially the same parameters as analyzed at each underway sampling point (see above).

During the SOCCOM deployment calibration cast additional samples for DIC were taken at 22 depths.

Only a fraction of the initially planned CTD rosette casts were realized during Leg 1 due to bad weather and technical problems, resulting in a dataset smaller than anticipated.

FRRf samples from CTD casts were measured with the following parameters:

Sat flashlets: 100

Pitch: 2 µs

Rel flashlets: 25

Pitch: 84 µs

Sequence interval: 100 ms

Sequence reps: 32

The PMT and LED settings were adjusted accordingly to account for *in situ* biomass, optimizing signal to noise ratio.

IOP frame

An 'optical frame' composed of two external batteries and five instruments (a Gamma-4 transmissiometer, an a-Sphere spectrophotometer, a HydroScat-6 backscattering sensor, a CTD, and a HydroDAS data logger) (Figure 39) was on board but not used during Leg 1. The IOP frame was deployed 21 times during Legs 2 and 3 (Figure 39) and an additional deployment was done for a dark measurement. Bad weather prevented charging of the internal batteries on two occasions, and so two IOP frame casts may have been affected by poor data quality or missing data.

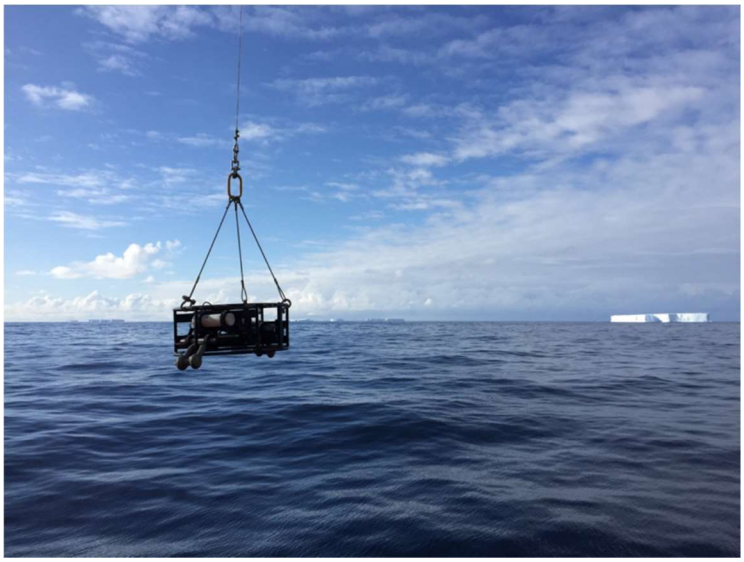

Figure 39: Inherent Optical Property (IOP) frame deployed via the winch.

Above water radiometry

Above water radiometry was assessed using two instruments installed on the bow of the ship (see Figure 40). A customised platform was constructed and installed in Cape Town to enable deployment of the instruments out of the ship's shadow and allowing access for instrument maintenance. Both of these instruments (BioSORS, Biospherical Instruments and DALEC, In-Situ Marine Optics) operate using the same principles and measure the spectra of upwelling radiance (Lu), sky radiance (Lsky) and downwelling Irradiance (Ed) in order to determine the Remote Sensing Reflectance (RSR).

Figure 40: BioSORS and DALEC radiometers in place at the bow of the ship. The DALEC instrument and Lsky and Lu sensors of the BioSORs instrument package were accessible via a custom built platform.

After initial software problems with the BioSORS instrument, approximately 20 measurements were completed during the second half of Leg 1. Fifty-two measurements were completed during Leg 2 and 56 on Leg 3. Good data acquisition with the BioSORS instrument required the ship to be stationary or steaming at < 8 knots, while the sun was positioned on either side of the ship, which were conditions not often experienced.

The DALEC instrument was not functional during Leg 1, and was sent for repairs. The DALEC instrument was repaired in Australia during Leg 2 and returned for operation in Leg 3. Initial communication issues with the DALEC prevented immediate use of the instrument but were quickly resolved with the use of a mobile phone to act as a Wi-Fi data transmitting and communication hotspot. Unfortunately after 1-2 days of data collection, the instrument was damaged during a severe storm on the 04 March 2017. The damage was assessed to be irreparable on board and the instrument was retired for the remainder of the voyage.

Additionally, surface photosynthetically active radiation (PAR; irradiance 400-700 nm) was continuously logged during all of Legs 1-3. This data requires no further processing and is available to all expedition participants.

10.2 Project 2

A dynamic, functional biogeography of the sub-Antarctic

PI Steven Chown (Australia)

Aims and Objectives

The Functional Biogeography of Antarctica Project (AFBA) of the Antarctic Circumnavigation Expedition (ACE) aims to provide a comprehensive biogeographic analysis of the sub-Antarctic, including relationships with Antarctica and other continents, and to use this information as a basis for improving conservation responses to climate change and to biological invasions, the region's most significant environmental change drivers. The Project is entirely terrestrial and field based, involving the collection of insects, springtails, plants and soils from as many islands and sites as possible around the Antarctic.

Field sampling

No work was conducted en route to the first Leg 1 stop, Marion Island. Between islands and en route to Hobart, extractions of invertebrates using Berlese-Tullgren extraction were undertaken. No sampling at sea was undertaken.

Based on the initial call for proposals, an adjudication of day length, and experience of operational conditions, the AFBA Project proposal assumed 20 hours field work at each of the Prince Edward (Marion – 2 days) and Crozet (Possession – 2 days) Islands, and 30 hours at Kerguelen (3 days). The assumption was also made that the voyage planning and schedule included appropriate poor weather contingency time. Unfortunately only 17 hours were available at Marion Island (26 and 27 December 2016), 10 hours at Possession Island (31 December 2016 and 01 January 2017) and just four hours at Kerguelen Island (06 January 2017). No access to high elevation sites was possible on either Possession or Kerguelen Islands owing to time restrictions and high winds, precluding any sampling for species best found at altitude. Key basal genera in the Ectemnorhinus group were to have been collected at higher elevations on Possession and Kerguelen – an essential requirement for Project success. Overall, 31 hours of the planned 70 were available for field work – less than half that anticipated.

On each island, insects and springtails were collected by hand, beating and aspiration from various localities. Samples of vegetation and soil were also collected in keeping with permit restrictions – typically far fewer samples were collected than AFBA had permits for, because of time restrictions. Many of these samples were then placed in Berlese-Tullgren extractors in the container laboratory placed on the exposed foredeck of the Akademik Tryoshnikov. Several soil samples from each island were treated with RNA later and refrigerated, and several were also stored as is at -20 °C. The Berlese-Tullgren extractions continued until invertebrates were no longer appearing in the collection vials of the extractors.

Identifications were not made in the container laboratory, as this proved too difficult to work in. Therefore, no counts of specific species sampled were available en route. Taxa collected include Coleoptera, Hemiptera, Lepidoptera, Collembola, Acari, and plants in the genera *Acaena, Bryum*, and *Poa*. Other species constituted the vegetation samples taken, including various bryophytes, lichens and vascular plants. Sampling was limited to the east coast of Marion Island between Ships Cove, First Red Hill and Archway Bay. Sampling was limited to the Morne Rouge, Port Alfred and Mont Branca areas of Possession Island. On Kerguelen, sampling took place between Molloy and Plateau du Tussok. Sampling was time-limited and very spatially restricted on Possession and Kerguelen Islands. Extracted material was preserved in ethanol and transferred in foil-covered vials to the -20 °C freezer for later genomic analysis at AFBA partner laboratories. The material was disembarked in Hobart.

Leg 2 operations: (1) Macquarie Island was not attempted at all (due to a major storm); (2) whilst an initial flight did reach Cape Denison high winds caused the landing to be immediately aborted and no further attempts were made to reach the site; (3) at the Balleny Islands it transpired that ACE had failed to request

an entry permit for the ASPA on Sabrina Island and a single opportunity to land on Buckle Island by zodiac failed; (4) Scott Island was successful landed on by helicopter where we had about one hour to sample; (5) the unscheduled visit to the Siple coast allowed us one hour of sampling on Maher Island, one hour of sampling on Lauff Island and three hours on Siple Island; (6) in difficult ice conditions and with deteriorating weather we just managed to reach one coastal site on Peter I Island for 15 minutes sampling time; (6) the visit to Diego Ramírez allowed us to sample on Isla Bartolomé and subsampling of material collected by two Projects on Isla Gonzalo added some limited material. These samples remained on Berlese funnels in the AFBA laboratory (on foredeck) extracting invertebrates due to the short time between this final collection and disembarking at Punta Arenas.

Initial sorting of lichen and funnel samples revealed mites (the genus *Nanorchestes* from Siple region, and a large oribatid and a prostigmatid mite from Peter I Island) and surprisingly a polychaete from Peter I that is likely to be the first record on any Antarctic island.

On Leg 3 samples were only collected from South Georgia and Bouvetøya as a ban on the use of helicopters meant it was not possible to land on the South Sandwich Islands. In South Georgia we aimed to get to two sites in particular: (i) King Edward Point/Grytviken/Maiviken and (ii) Stromness Bay. These sites had been sampled before, and therefore would provide valuable information on new invasive species (particularly expected in the invertebrates). An optimal sampling system was, however, not possible due to the insistence of the Government that we visit Grytviken before we were able to land anywhere. To shelter from a developing storm we went straight to Grytviken where the weather was good and sampled there and Maiviken (Figure 41). The following day we moved to Stromness Bay but were blown out by the katabatic winds without landing and took refuge in the Bay of Isles to attempt a landing on Prion Island. This was also foiled by bad weather and we returned south to finally land in St Andrews Bay in a snowstorm. Here we successfully collected most of our sampling targets, although sampling was complicated by the snow covering the ground, the snowy blizzard conditions, and aggressive fur seals on the beach. No attempt was made to visit Rogged Bay on 05 March 2017 due to bad weather, and we left the island on the evening of 04 March 2017.

King Edward Point/Grytviken/Maiviken

We arrived at King Edward Point on 02 March 2017, landing around noon for around five hours of sampling. The group spread out to get as much sampling done as possible: KM (see Table 15 for initials) stayed in the area of King Edward Point and Grytviken to sample soils and plants, and got additional help from volunteer Amy King (AK; BAS), while EMB and FLS went to Maiviken, collecting beetles, plants, and soils along the way (see Figure 41a-f). Both groups were successful, resulting in many samples from both regions. KM and AK managed to obtain plentiful samples of the KEP/Grytviken area, with 15 sites being well sampled. EMB and FLS particularly focused on the collection of beetles, and were successful in finding beetles in and around Lancetes Lake. Unfortunately no *Colobanthus quitensis* was found for EMB's Project.

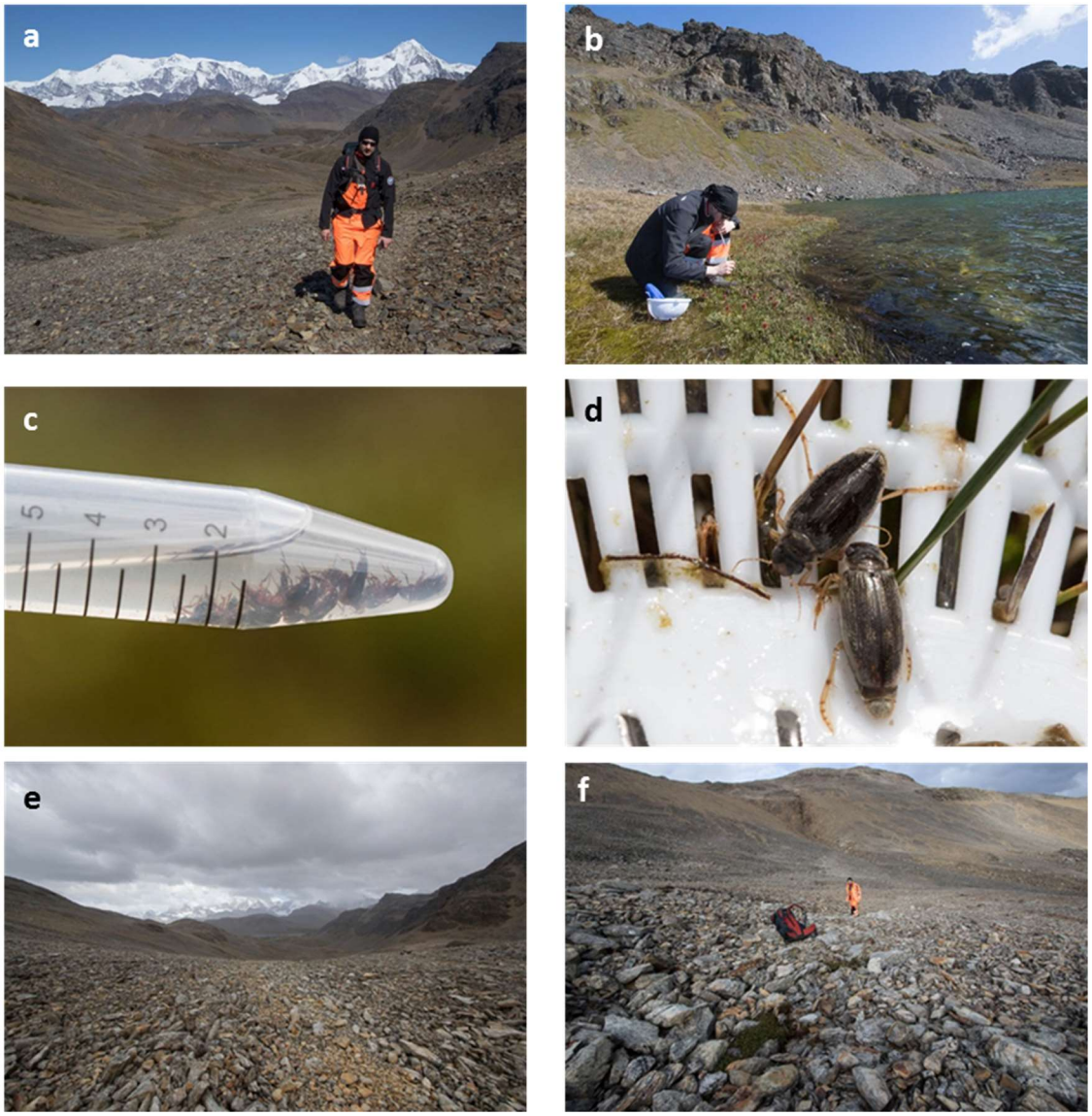

Figure 41: a) walk to Maiviken, b) sampling at Lancetes Lake c) Hydromedion sparsutum *samples, d)* Lancetes angusticollis *samples, e-f) the high altitude area where* Perimylops antarcticus *could be found.*

Figure 42: Stormy conditions on March 3rd did not allow us to visit Stromness Bay.

St. Andrews Bay

St. Andrews Bay was visited on 04 March 2017. The weather was snowy/blizzard and the ground was covered with snow. We sampled in several locations on the beach, in particular near a sheltered ledge (Figure 43), for protection of the weather and where the ground was not covered with snow.

Figure 43: (a-e) The sheltered ledge where most sampling was done, d) dry mosses in cracks below the ledge were a great sampling spot for Hydromedion sparsutum *e) inquisitive locals were curious to see what we were up to, f) snow covered ground complicated sampling amongst the penguin colony.*

Bouvetøya

On 11 March 2017 we managed to sample on Bouvetøya. It was a sunny but cloudy day on the island with changing cloud cover. Due to the exposure of the sites we sampled at two different sites with 10-15 minutes at each site while the helicopter waited, and guide Guillaume Maurel was the communication person between the helicopter and ourselves. The first site was on the southeast of the island (-54.445, 3.404; 83 m altitude); the second site was Rustadkollen (-54.450, 3.332; 216 m altitude or higher, as the

GPS did not obtain a clear altitude measure of this site). The two other locations we had permits for (Agaardbreen and Moseryggen), were far too dangerous to land. Rustadkollen was particularly good for sampling and was full of mosses (with carpets of ~10 cm) and lichens. The flight was difficult due to the strong winds. The descent to Rustadkollen was further complicated by flying birds around the cliffs, although none came close to the helicopter. In total ~16 samples were taken at both sites.

Table 14: Station/activities overview.

Date	Location	Event number	Comments
2017-03-02	KEP/Grytviken (South Georgia)	2381	KM and Amy King sampling plants, soils and invertebrates
2017-03-02	KEP/Grytviken/Maiviken (South Georgia)	2380	EMB and FLS sampling plants, soils, invertebrates, with a particular focus on beetles
2017-03-04	St. Andrews Bay (South Georgia)	2458	KM, EMB and FLS sampling plants, soils and invertebrates
2017-03-11	Bouvetøya Island	2752	KM, EMB and FLS sampling plants, soils and invertebrates

Our team was under the impression that the Berlese-Tullgren extractors in place were not as efficient as the commercial Berlese-Tullgren extractor owned by Pete Convey, due to the former lacking a temperature gradient from above. This possibly caused a lot of invertebrates to crawl to the inside of the core instead of to the bottom (and ethanol tube). For the Bouvetøya samples we set up additional Berlese-Tullgren extractors of Pete Convey.

Some confusion was caused by the transferral of samples between Project 9 and our own on previous Legs. Despite the best efforts of both teams to keep samples in order on the previous Leg, changing of team members meant some information was lost. Being the last Leg, it was up to our team to sort these issues and submit corrected sample sheets.

Table 15: Team participants.

Leg number	Participants
1	Steven Chown (PI), Charlene Janion-Scheepers, Helen Baird, Rachel Hallas, Rachel Leihy
2	Mark Stevens, Ian Hogg
3	Felipe Lorenz Simoes (FLS), Elisabeth Biersma (EMB), Katherine Moon (KM)

10.3 Project 3

Antarctic seabed carbon capture change (ASCCC)

PI David Barnes (UK)

Aims and objectives

The ASCCC Project attempted to quantify carbon storage by life on the seabed (so-called "blue carbon"), and how this varies in time and space around the sub-Antarctic continental shelves. This is a big area - there are several million square kilometres of continental shelf around the Southernmost Indian, Pacific and Atlantic Oceans and north Southern Ocean region. There is good reason to suggest that benthos there are a major source of blue carbon storage and sequestration through burial. Climate change has been boosting regional phytoplankton blooms and warming the shelf waters, and the expected response of the study benthos is increased growth, and thereby more carbon storage. As such, they could represent one of Earth's largest negative feedback on climate change, and are therefore important in constraining errors in climate models.

Methodology

Trawls and boxcore were lifted from the forward holds onto the stern trawl deck at Cape Town. The nets were shackled to both trawls, the tow wires checked over and camera fit to placement slots trialled. Only one of the two winch cable termination assemblies arrived (the one posted did not arrive in time). The ship's science group leader Mikhail Romanov fitted the socket hook and applied the Wirelock two part compound to it, and allowed 24 hours for setting. One of the trawls was then shackled up to this and stowed, beside the other trawl on the starboard side, forward of the winch base. These were made sea-worthy by tying down with strops.

In view of the size of the A-frame and the load tolerances of winch and wire, we brought a bespoke mini-Agassiz trawl frame (60 kg, 1.25 x 0.4 m gate opening) and three sets of nets (mesh size: 1 cm inner, 10 cm outer, respectively). The short bridles and nets provided just enough clearance to leave the working deck gates closed, thus creating a safer working environment whilst deploying and recovering the trawl. Two of us wearing safety boots, harnesses and inflatable life-vests steadied the trawl with 8-metre long ropes through the frame. Prior to deployment a GoPro 3+ digital camera with a strong LED light in water-tight housings pointing ahead at roughly 45° were installed taking videos or series of still images of the trawl gate and the space ahead and to one side of the trawled path. Initially, 1.5 times the depth was paid out in cable (this was later changed to 2 to 2.5 times the depth) and after five minutes of trawling time, the trawl was winched up again.

Normally before launching the trawl the multibeam was used to scan the sea floor to determine its roughness and what track should be taken to maximize the success of the trawl and minimize damage from hitting rocks.

After recovering the trawl, the cod end was opened and the catch transferred to one or two large buckets; for large catches this was made possible by hoisting the frame and lifting the open cod end into the buckets. The ASCCC team took turns with Project 10 in leading the sorting of the catch in the relatively small wet laboratory.

Variation in space was addressed by trawling specimens from key locations (southern Indian Ocean and Southern Ocean on Leg 1) as well as imagery from on-board cameras. Specimens were identified taxonomically and assigned to different ecological functional groups, to simplify examination of relative contributions to carbon storage. The time element of carbon capture and storage was investigated by examining the growth patterns of longer-lived organisms, revealed within skeletal banding.

Outdoor clothing, vials, stationary and battery chargers were set up in the wet laboratory. Empty boxes, spare vials, trawl nets and trawl matting was stored behind the -20 °C freezer. 75 L of ethanol in 5-litre tubs

was carried through into the -20 °C freezer and arranged with the empty storage boxes for vials. Christoph Held set up the photographic station in the starboard, forward-most corner of the laboratory. A mortuary table was provided and tied to the sink uprights to provide sorting space. Vials were stowed in the upright cupboards and underneath the sorting table. We borrowed a pump for seawater from Project 16 of Christel Hassler and set this up in the adjoining corridor space, using a pipe temporarily run through the water tight door (which was opened by crew when on station).

For Leg 1 our requested protocol was to deploy 3 x Agassiz trawl and 1 x box core at one site at each of Marion and Possession Islands, three sites around Kerguelen Island, one site on route to Heard Island and one site at Heard Island. We planned to undertake mainly night sampling, at maximum 0.5 knots at 30 metres per minute veer and haul speeds, with stern doors open for tethered team members to steady deployed and recovered trawls. Go Pro cameras would be set running and exchanged on low battery (shown by light fade).

Outstanding issues

There was a known lack of experience for the ship in undertaking any trawling operations and for the early part of this Leg a refusal of the crew to work at night made scheduling difficult. A lack of a seawater supply on the rear deck meant washing the catch proved difficult, there was no independent communication with the bridge other than through the winch man Romanov and the complete absence of any station information display either on the deck or in the laboratory made recording locations difficult. Given these problems the procedure outlined above worked reasonably well.

Restricting work to daylight hours for the first half of the sampling period lead to a significant delay for the trawl teams (as for everyone else), which was alleviated to some degree by conducting limited trawling activity at night at Kerguelen and Heard.

A problem that persisted throughout the expedition was that the ship was trawling at speeds around 2 knots rather than the requested 0.5 knots as the Captain said it was not possible to use the slower speed, and the winch speed was consistently too high. The underwater footage showed that after hitting the seafloor the trawl typically spent some time on the bottom with slack on the wire because the wire was paid out too fast, and thereafter spent significant amounts of time “flying” above the bottom due to a combination of the low weight of the frame and the high drag due to the trawling speed being too high. Increasing the amount of cable paid out lessened the problem somewhat but did not fully solve it.

Sampling

Sampling success varied by location, driven by weather conditions, time constraints and ship/crew issues. Of the 21 trawls planned 13 were successfully undertaken, with a further three failures. Five of these 13 trawls were at the original locations planned (S. Kerguelen and Pike Bank). None of six box cores planned took place. Go Pro recording took place on 14 of the 20 attempted, with three camera failures (one due to flood caused by impact on the light, two setting mode issues).

Results

In our trawls we recorded 14 phyla of invertebrate metazoans (Annelida, Brachiopoda, Bryozoa, Crustacea, Chelicerata, Chordata, Cnidaria, Echinodermata, Entoprocta, Hemichordata, Mollusca, Nematoda, Nemertea, Porifera). Noteworthy are three decapod crustaceans (hermit crab, brachyuran crab) from Marion Island and lithodid crabs from Kerguelen site 1. These are among the southernmost records for benthic decapod crustaceans and neither was abundant in our trawls. More regularly found were peracarids (mostly isopods, amphipods and tanaids), with Antarcturidae and Serolidae standing out as important in groups that are characterised by cryptic species complexes but again local abundances were low. Typically, sites were dominated by a few very abundant taxa, which varied strongly between regions and as expected correlated with bottom type (rubble vs sediment). A detailed analysis requires a more complete identification of the preserved material as well as underwater footage.

The functional group composition of benthos varied considerable between, but little within, the study locations. Eight of 13 functional groups were recorded at Kerguelen site 2, 10/13 at Heard Island, 11/13 at each of Marion and Possession islands, 12/13 at Pike Bank and all 13 at Kerguelen site 1.

Figure 44: A collection of invertebrates from the trawls of the ASCCC team from Marion, Crozet and Kerguelen (ACE Leg 1). Photos: C. Held, AWI.

On Leg 2 it became obvious that some of our equipment and Zarges boxes were missing – with some indication they were taken on to the quayside at Cape Town but without from our team members and apparently no record. A search was instituted at Cape Town but the boxes were never found. A bespoke powerboard (for UK appliances but with a EU plug) was removed from the laboratory on the third day (several appliances were unplugged, including battery charger and a laptop) and was also never found.

The inability to trawl in anything but calm conditions continued to inhibit trawling success. In relatively good conditions around Scott Island, we were forced to abort a trawl due to the mild wind conditions being perpendicular to the only possible trawl path and the ship unable to hold course at 2.5 knots.

The main aft winch was temperamental. The second winch was not adequately terminated. The crew were happy to switch to the second winch when issues occurred with the main winch even though we explained our safety concerns to them.

The Agassiz Trawl tow line was shortened by more than 50% (against our wishes and expert advice) by the crew. Despite explaining that this increased the risk of damage, loss of trawl and the possibility of severe injury to those on deck as the eye bolts were not designed to take this new lateral force, the crew determined that this was not a problem.

Sample success

Sampling success was been disappointingly low (eight of expected 15 trawls), driven by constraints of weather, technical failures, the ship's capabilities and a certain extent by management prioritization. We were unable to operate at Macquarie Island due to a storm that forced the area to be abandoned. We succeeded in obtaining three trawls from the Balleny Islands. We aborted a deployment at Scott Island due to the ship's inability to maintain a course at less than 2.5 knots at the only site amenable to trawling. Peter I Island sampling was abandoned due to heavy sea ice and the alternative site chosen was Mt Siple on the Antarctic continental coast. We succeeded in two trawls close to the shelf ice edge but a third trawl on the shelf break was abandoned due to the failure of the rear winch. The winch was repaired and we were able to conduct three trawls to the north of Diego Ramírez.

During Leg 3 our research was supported across most levels to effectively meet our sampling requirements at the South Sandwich Islands and Bouvetøya. However, there was no marine sampling for our Project at South Georgia as very bad weather for all of the night periods and high winds and heavy swell during the day made deployment impossible. The ship continued to trawl at too high a speed and on the final trawl at Bouvetøya the trawl was severely damaged when the trawl hit a large dropstone. The ship speed was recorded as 3 knots at the time. Due to prioritisation by the Chief Scientist almost all trawling was allocated to the night shift. The consequences of which were 1) no marine sampling at South Georgia, 2) Storm petrels were attracted to the light and risked injury flying into the aft area of the ship (eight were recorded in one night at Candlemas Island), and 3) limited communication capacity between ship personnel, the ASCCC Project and management outside of working hours. However, we succeeded in obtaining six trawls at the South Sandwich Islands, three at Candlemas Island and three at Southern Thule. We succeeded in three shallow trawls (<300 m), and one deeper trawl (500-700 m) at Bouvetøya.

Results

In our trawls we recorded 13 phyla of invertebrate metazoans (Annelida, Brachiopoda, Bryozoa, Crustacea, Chelicerata, Chordata, Cnidaria, Echinodermata, Hemichordata, Mollusca, Nemertea, Porifera and Urochordata). Typically, sites were dominated by a few very abundant taxa, which varied strongly between sites and, as expected, correlated with bottom type (rubble vs sediment). As expected the continental shelf sites were vastly richer than those of Balleny Islands sites. This is in part due to the Balleny Islands sites being shallower and heavily ice scoured, and partially explained by island biogeography theory which predicts that smaller islands further away from continents hold lower diversity.

10.4 Project 4

Sub-Antarctic Ice Coring Expedition (Sub-ICE)

PI Liz Thomas (UK)

Aims and objectives:

Project Sub-ICE aimed to obtain the first ice core climate records and radar stratigraphy data from glaciated Antarctic and sub-Antarctic islands. Specific objectives were to:

- Capture records of southern hemisphere westerly winds and climate variability over recent decades;
- Determine ice volume, internal layering and basal structure, annual mean temperature, and presence of liquid water at the drill sites;
- Evaluate the human impacts on the islands by measuring local and long-range atmospheric pollutants;
- Improve glacial mass-balance estimates by measuring surface albedo, crystal grain size and borehole annual average site temperatures;
- Measure ice core aerosols and aerobiology –complementing ship-board measurements and develop novel climate and circulation proxies over past decades;
- Determine optimal locations for future deep ice core drilling Projects.

There were no useful sites in Leg 1. Our ice core and radar target sites for Leg 2 were the Mertz region, the Balleny Islands and Peter I Island. Ice cores were retrieved from each of these locations and an opportunistic core was taken on Mt Siple in the Getz Ice Shelf region. A total of 83 m of ice core was recovered, filling 17 ice core boxes. Surface snow samples were also collected from all sites. Thirteen boxes were stored in the -20 °C 'glaciology freezer' on the 2nd deck and four were stored in the main -20 °C science freezer on the trawl deck. The boxes are to be offloaded in Punta Arenas and held at the Instituto Antártico Chileno (INACH) before transfer to Rothera Station (UK), from there they were transported by the research ship *Shackleton* back to the UK.

Methodology

All ice coring was done with a Kovacs ice core drill powered by an electric motor. This drill system uses a 1kVA 4-stroke Honda generator to drive a heavy-duty power drill that turns the drill barrel and rods. The same drill was also used to drive a winch to aid pulling up the core from the borehole. Surface snow samples were collected in clean zip lock bags from the top ~2–3 cm of the snowpack.

Ten-metre borehole temperature measurements were made with a thermistor string lowered down the borehole.

The airborne radar did not arrive in time to Hobart for the departure of Leg 2 due to shipping delays and a Chilean customs strike. Project objectives specific to the airborne radar: ice volume, internal layering and basal structure could not be completed as planned and Gino Cassasa who was leading this element elected to withdraw from the cruise when the radar did not arrive.

We took a small terrestrial ground-penetrating radar (GPR) and a Differential Global Positioning System (DGPS) which allowed observations of the near surface snow stratigraphy, accumulation distribution internal layering over the top ~50 to 100 m depending on the site. The terrestrial GPR consists of a control unit and an antenna of 400 MHz manufactured by Geophysical Survey Systems Inc. (GSSI). The instruments were installed on a sledge together with the DGPS. This system was pulled following a grid around the ice core site to obtain parallel profiles of the subsurface in the surrounding area. Waypoints of initial and final position of each profile were recorded as well as the navigation track with a GARMIN (GPS) device.

Sampling locations and log

Mertz Core 1 – Cape Hurley ice core site

Cape Hurley is a low elevation ice dome on the eastern side of the Mertz Glacier above Fisher Bay. It has not previously been cored. Based on satellite images the site appears well suited to obtain climate and atmospheric chemistry records from the Mertz region and has simple ice flow. We did a helicopter scout of the site and the fast ice site (described further below) on the morning of the 29 January 2017 and could not see any crevasses. François Bernard (Ben), our mountain guide, probed the ground at both sites during the scout and established them to be safe. After returning from the scouting flight the field party was flow out with the drilling and snow accumulation radar gear to the Cape Hurley site. The helicopters then departed.

Deployment Date: 29 January 2017 (ship time, AEST)

Latitude: 67.5596 deg S Longitude: 145.3125 deg E

Elevation: 320 m (on handheld GPS)

Time deployed to ice: 16:20 (ship time, AEST)

Drilling time: 4.5 hours

Weather: -2°C, sun, high cloud, good surface definition.

Field party: Brad Markle, Joel Pedro, Guisella Gacitua, François Bernard (guide), Baptiste Bernard (guide), Julia Schmale (ACE-SPACE Project).

Drill depth and cores: 20.25m, the core sections are labelled M1_01 to M1_29.

Comments on drilling: The Kovacs drill performed very well in these warm conditions. The only issue we had was with core dogs sticking occasionally in the warm conditions. It was very useful to have practiced with the same drill in Greenland 6 months ago – we were up and drilling within 30 mins of landing on site. The core contained some melt layers. Julia Schmale from the ACE-SPACE Project and both mountain guides helped us with the drilling when they were not busy with their own work. The temperature thermistor was deployed for 20 mins in the borehole, the 10 m temperature estimate is subject to calibration.

The helicopter VHFs were out of range at this site, which was ~ 40 km from the ship. We kept scheduled contact with the ship by Iridium phone. Shuttle flights brought some guests to the site and picked up full ice core boxes part way through the drilling. Once returned the ice was stored in the -20°C 'glaciology freezer' on the 2nd deck.

Comments on GPR: 3.6 km of measurements in parallel lines of 265 m per 110 m. Files were recorded using a setup that allowed a maximum of ~80 m penetration depth and fast data collection, compromising the resolution of the upper layer. After data analysis it was determined that the range of depth should be set to a maximum depth of 50 m since features are not evident below this depth, and this gave better resolution of the upper layers. Slow collection (higher density of data) means that the system does not respond well in the field and often gets stuck during the data collection.

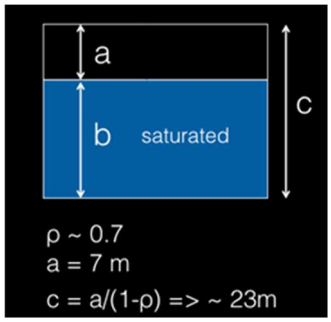

Figure 45: Sketch of fast ice composition at Mertz site 2, based on a rough density estimate (to be refined by laboratory measurements of core density).

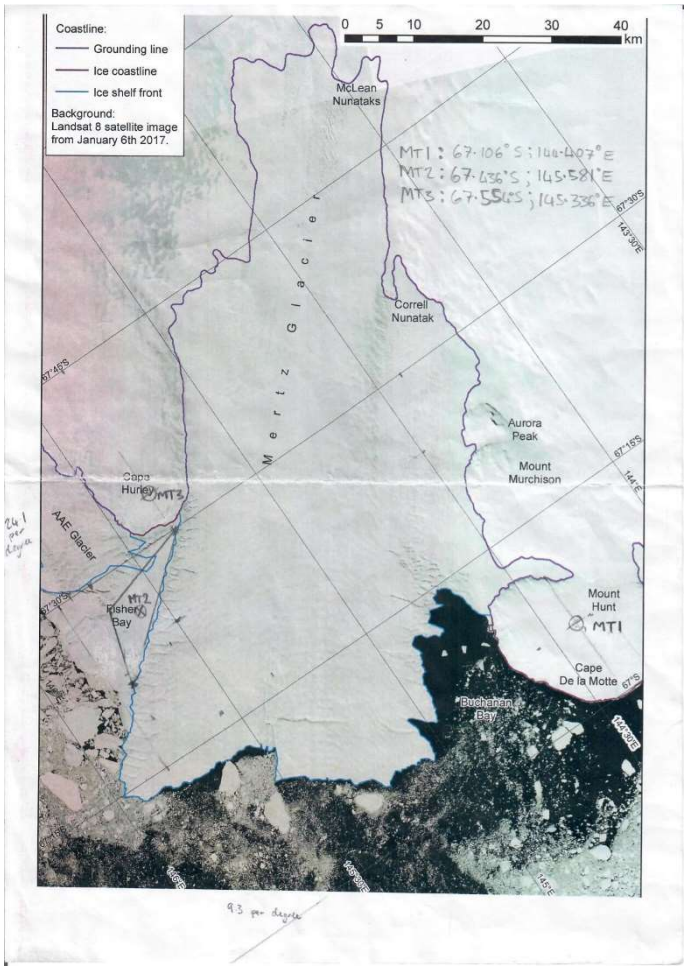

Figure 46 : Mertz region. Our Cape Hurley site (Mertz Core 1) is labeled MT3 on the map and out Fisher Bay site (Mertz Core 2) is labeled MT2 on the map.

Mertz Core 2 – Fisher Bay fast ice site

Fisher Bay is bounded on the east by the Mertz Glacier and on the west by the AAE glacier. Within the bay is a triangular wedge of fast ice, thought (though unconfirmed) to be amongst the thickest in East Antarctica. The precise thickness, age and proportion of marine versus meteoric ice that makes up the fast ice is unknown and of great interest to researchers working on ice—ocean interaction around the Mertz. We selected a site in the centre of the wedge of fast ice to drill and measure snow accumulation. Helicopter operations on the morning of 30 January 2017 were prioritised to Cape Denison; however strong wind in that area prevented operations. Winds were low enough over the Mertz itself that we could be safely deployed to Fisher Bay site.

Deployment Date: 30 January 2017(ship time, AEST)

Latitude: 67.44109 deg S Longitude: 145.57445 deg E

Elevation: 6 m (on handheld GPS)

Time deployed to ice: 15:09 (ship time, AEST)

Drilling time: 3 hours

Weather: -2°C, warm and sunny with increasing high cloud, good surface definition.

Field party: Guisella Gacitua, Brad Markle, Joel Pedro, François Bernard (guide), Baptiste Bernard (guide), Julia Schmale (ACE-SPACE Project).

Drill depth and cores: 9.31 m, the cores are labelled M2_01 to M2_14.

Comments on drilling: The first six metres were regular firn containing melt layers. At a drill depth of 6.23 m we brought up a core with seawater gushing out of the drill barrel – this was unnerving. Experts on the Mertz had advised us that the fast ice was likely 20 to 50 m thick. The ice itself was dense and contained bubbles, presumably of seawater or brine. We had some concern about getting our drill contaminated with this sea water but chose to try and drill a bit more in the name of discovery and ice–ocean interaction. We retrieved another three metres of solid ice containing bubbles and peering down the borehole could see the water level sitting around 6 m. On the last run we had trouble getting the drill back up and for fear of getting it permanently stuck, we decided to finish our sea ice drilling at depth of 9.3 m. We did not measure the borehole temperature due to the water. Surface snow samples were also collected. We drilled a dozen short cores to clean the drill in the field and rubbed all equipment in snow. We later triple rinsed all equipment in deionised water to remove salt.

We again kept scheduled contact with the ship on Iridium phone. Shuttle flights brought guests to the site and picked up full ice core boxes part way through the drilling.

Comments on GPR: 894 m of measurements. Two parallel lines of 270 m. A preliminary assessment of the measurements showed the GPR performed poorly given the highly saturated ice and the salt content in the ice column. Further processing of the data is expected to improve the data interpretation.

Balleny Islands, Young Island

The Balleny Islands sit in the Antarctic seasonal sea ice zone at the boundary of the polar westerlies and Antarctic coastal easterlies. Prior to the cruise, we examined satellite images of the three major islands (Young, Buckle and Sturge) for good ice core sites with low crevasse danger. We were hopeful to drill more than one of the islands, however given the short time available (one and half days) and the need for good weather for helicopter operations it was a good result to get the one core from Young Island — the first ever ice core from the Balleny islands. The ship arrived at Young Island on the night of 03 February 2017. The island was mostly obscured by cloud. On the morning of the 04 February 2017, cloud over the top of the island still put our preferred drilling site out of reach. A scouting helicopter flight located a crevasse-free area on the south end of the island which we agreed to take in case the weather worsened. The Young Island core holds great promise for investigating past meridional shifts in the westerlies and in regional sea ice extent.

Deployment Date: 04 February 2017 (ship time)

Latitude: 66.52896 deg S Longitude: 162.5598 deg E

Elevation: 238 m (on handheld GPS)

Time deployed to ice: 09:00 04 February 2017 (ship time)

Drilling time: 3.5 hours

Weather: -5 °C, High cloud and clearing to sun. Consistent high winds, 30 knots consistent. Increasing to perhaps 40 knots. Blowing snow to head height.

Field party: Guisella Gacitua, Brad Markle, Joel Pedro, François Bernard (guide), Julia Schmale (ACE-SPACE).

Drill depth and cores: 16.88 m, the cores are labelled Y1_01 to Y1_28.

Comments on drilling: We made a wall from ice core boxes and bags to provide some shelter from the wind and blowing snow and got drilling. We had excellent assistance again from Ben and Julia and credit to pilots for deploying us to the site. Helicopters visited with guests during drilling and took out filled ice core boxes. After around three hours the drilling became difficult and cores hard to retrieve probably due to chip build up in the borehole and refreezing on the drill. At risk of losing the drill and with deteriorating conditions we stopped drilling at 16.88 m. Melt layers were observed in the ice cores. Surface snow samples were also collected.

The temperature thermistor was deployed for 14 minutes, the 10 m temperature estimate is subject to calibration.

Comments on GPR: 2.9 km of measurements in parallel lines of 140 m and 230 m. The preliminary profiles showed several crevasses near the ice core position covered by about 4–5 m of well-stratified snow. Data wasrecorded to satisfy good resolution of the near surface layering.

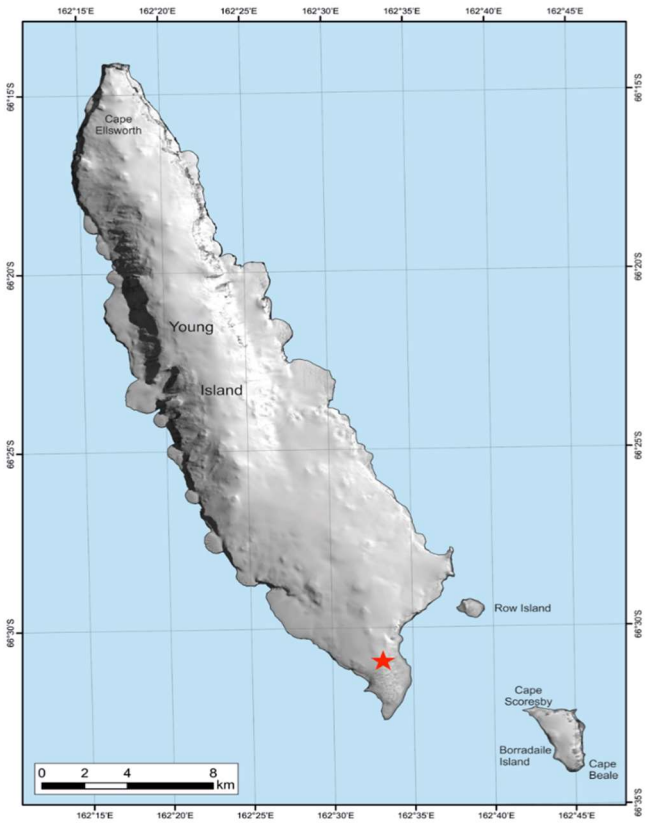

Figure 47: Young Island. The red star marks our core site.

Figure 48: 4 GPR set up: Guisella pulling the GPR on Young Island.

Siple Island, Mt Siple

Mt Siple is a shield volcano of 3110 m elevation, which rises from Siple Island on the coast of Marie Byrd Land. Getz ice shelf surrounds the island. Recent data shows that the Getz and nearby ice shelves on the Amundsen Sea Coast are in negative mass balance due to high rates of marine basal melt. The cause of this basal melt is debated, but has been linked to tropical forcing of the Amundsen Sea Low (ASL) influencing upwelling of warm Circumpolar Deep Water under the ice shelves. The ACE cruise diverted to Siple Island since ice conditions were predicted to be difficult at Peter I Island. Our interest in a core from here was motivated by the potential of this region to record changes in the ASL, temperatures and sea ice conditions in this fast-changing region of Antarctica. A scouting flight on the morning of 11 February 2017 located a crevasse free, slightly sloping shoulder between two glacier valleys on the northeast side of the mountain (higher elevations were under cloud). We deployed to this site and drilled a 24-metre core. To our knowledge, this is the first ice core from the region.

Figure 49: Mt Siple ice coring. Brad drilling with the Kovaks system.

Deployment Date: 11 February 2017 (ship time)

Latitude: 73.3206 deg S Longitude: 126.66315 deg W

Elevation: 685 m (on handheld GPS)

Time deployed to ice: 11:15 11 February 2017 (ship time)

Drilling time: 5 hours

Weather: High clouds on arrival. Low clouds over sea below site. Warm (+8°C). No wind. Increasingly sunny. Increasingly warm. By afternoon, snow was melting on gear.

Field party: Guisella Gacitua, Brad Markle, Joel Pedro, François Bernard (guide), Julia Schmale (ACE-SPACE Project).

Drill depth and cores: 24.14 m, the cores are labelled Sip_01 to Sip_36.

Comments on drilling: The core was recovered in excellent condition and contained some melt layers. Drilling went well despite the warm conditions and some refreezing on the drill. Helicopters visited with guests during drilling and took out filled ice core boxes. After around four hours the drill was getting rather difficult to retrieve and we stopped drilling at 24 m rather than risk losing the drill. Weather conditions improved as we drilled and the summit of the mountain came clear and fully into view.

The temperature thermistor was deployed for 43 minutes (temperature estimate subject to calibration). Surface snow samples were also collected.

Comments on accumulation radar: 2.7 km of measurements covering an area of 250 m by 250 m. Since the glaciated area seemed to be highly crevassed from the air before landing, once a clear coring spot was decided Guisella, Ben and Baptiste performed a survey with the GPR while roped up for safety. This survey showed that the area was clear of crevasses. The GPR was then continued to cover the area around the ice core. Preliminary observations of the data show clear/strong reflections at multiple layers indicating seasonal melting at the snow depth variations due to wind drift.

Peter I Island

Peter I Island is almost completely covered by an ice cap and is heavily crevassed. No ice core has previously been retrieved from the island and we are not aware of any published work on the ice thickness and mass balance of its glaciers. An ice core from the island is of extreme interest due to the location of the site in the seasonal sea ice zone of the Amundsen and/ Bellinghausen Seas. Due to time pressures in getting to Cape Horn only two hours were available for drilling on the island. We were very fortunate to get a weather window and deployed to a site on the ridge named Midtryggen in a small saddle on the eastern side of the island, which was the only non-heavily crevassed site we could find. The site overlooked main glacier Storfallet. We managed two hours drilling before conditions became difficult with descending cloud and poor surface definition.

Deployment Date: 15 February 2017 (ship time, AEST)

Latitude: 68.865 deg S Longitude: -90.515 deg W

Elevation: 730 m (on handheld GPS)

Time deployed to ice: 14:07 15 February 2017 (ship time)

Drilling time: 2 hours

Weather: Estimated +2°C. Clouds not far above site, patch of sun. Warm (worked in shirt sleeves). Soft fresh snow on ground. Some patches of hard wind blown surface.

Field party: Guisella Gacitua, Brad Markle, Joel Pedro, François Bernard (guide), Julia Schmale (ACE-SPACE), Baptiste Bernard (guide).

Drill depth and cores: 12.29 m, the cores are labelled Pet_01 to Pet_18.

Comments on drilling: The core was recovered in good condition and contained some melt layers and full cores appearing like solid ice with bubbles. Helicopters visited with guests during drilling and took out a filled ice core box. Surface snow samples were also taken. The temperature thermistor was not deployed.

Comments on snow accumulation radar: 2.6 km of measurements in lines of 100 per 100 m. In this case the area was restricted by the possibility of being crevassed. Radar profiles showed several well-covered crevasses at different depth.

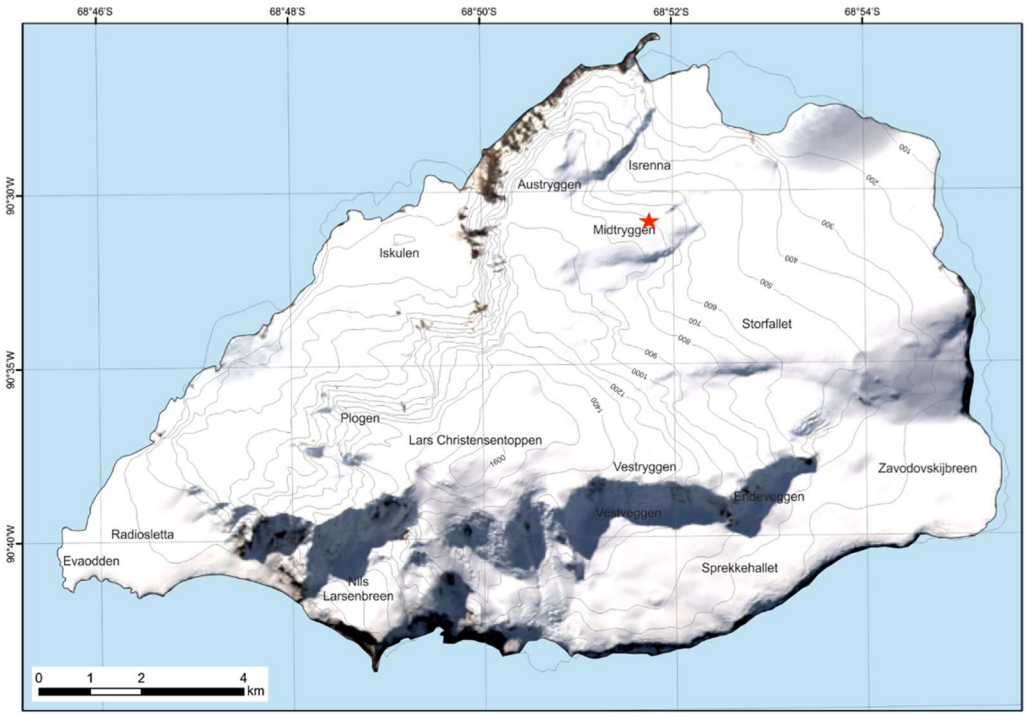

Figure 50: Peter I Island. Ice core site marked by a red star. The plateau close to the summit labelled Lars Christenstoppen would be an excellent site for a future deeper drilling campaign.

South Georgia – Nordenskjold Glacier, Cumberland Bay

Nordenskjold Glacier is a fast moving marine terminating glacier in Cumberland bay. It has been visited previously by an ice core group from the Climate Change Institute, University of Maine in 2012. The team retrieved an ice core from the eastern edge of the glacier. The Sub-ICE team were supported by staff from the Government of South Georgia and South Sandwich Islands (GSGSSI) to transport the team from the *Akademik Tryoshnikov*, anchored in western Cumberland bay, to the western edge of the Nordenskjold Glacier as the expedition AT zodiacs were committed to landings at Grytviken. The GSGSSI jet boat landed the team on a small beach ~50 m from the glacier terminus. We then trekked ~30 minutes over the moraine to reach the glacier. The glacier was covered in several centimetres of rubble and rock. After clearing way the surface using ice axes we started drilling using the power head and the 1-metre drill barrel.

Deployment Date: 02 March 2017 (ship time)

Latitude: 54.376 deg S Longitude: 36.4 deg W

Elevation: 50 m (on handheld GPS)

Time deployed to ice: 12:00 (ship time)

Drilling time: 1 hour

Weather: sun, blue skies and warm.

Field party: Liz Thomas, Mariusz Potocki, Roger Stilwell

Drill depth and cores: 2.2 m, the core sections are labelled NS_01 to NS_3.

Comments on drilling: The Kovacs drill worked well for the first core but by the second core the drill got stuck and required a lot of extra force to pull it out. The third drill got stuck and investigation down the borehole revealed that the core was completely submerged in water. The power head was used to pull the core barrel out of the hole by keeping the drill rotating whilst pulling the barrel out. We decided not to drill any further in case the drill became stuck again. The ice cores were placed in layflat tubing and insulating aluminium bags before putting them in backpacks to carry them back to the shore. From there the ice cores were placed in an insulated ice core and loaded onto the GSGSSI jet boat. The ice cores were taken directly to the -20^{o}C freezer at King Edward Point and will be returned to the UK via the British Antarctic Survey (BAS) research ship.

Comments on GPR: No GPR was taken at Nordenskjold.

Figure 51: South Georgia ice core sites. Locations of ice cores drilled on the Nordenskjold and Heany Glaciers on the northern coast of South Georgia.

Figure 52: Water filled borehole on the Nordenskjold Glacier.

South Georgia – Heaney Glacier, St Andrews Bay

Heaney Glacier is a land terminating glacier in St Andrews Bay on the northern coast of South Georgia. As far as we know, it has never been sampled for ice cores. Landing on the beach in St Andrews Bay it was ~3 km inland to the terminus of the Heaney glacier. A large glacial lake prevented access on the eastern side of the glacier so we took a route over moraine on the western side. Recent snowfall covered the area however underneath the snow the glacier was covered in several centimetres of rubble and rock. After clearing way the surface using ice axes we started drilling using the power head and the 1 m drill barrel.

Deployment Date: 03 March 2017 (ship time)

Latitude: 54.42 deg S Longitude: 36.22 deg W

Elevation: 100 m (on handheld GPS)

Time deployed to ice: 09:00 (ship time)

Drilling time: 1 hour

Weather: light to heavy snowfall, low cloud

Field party: Liz Thomas, Mariusz Potocki, Roger Stilwell, Amy King

Drill depth and cores: 1.72 m, the core sections are labelled HG_01 to HG_3.

Comments on drilling: As with the Nordenskjold Glacier, the drilling at Heaney Glacier was slow and resulted in the drill getting stuck after just 50 cm. The ice retrieved was badly water damaged, creating fine horizontal fractures in the ice core resulting in several breaks per drill. We did retrieve a few ~50 cm sections which appear to be of good enough quality for high resolution chemistry analysis. We attempted to drill for a few more metres but the core quality never improved and the drill kept getting stuck. The kovacs drill does not work well in wet ice conditions where the chippings stick to the side of the barrel and prevent the barrel being lifted out. The ice cores were placed in layflat tubing and insulating aluminium bags before putting them in backpacks to carry them back to the shore. From there the ice cores were placed in an insulated ice core box and loaded onto the zodiacs. The ice cores were taken to the -20^{o}C “glaciology freezer”.

Comments on GPR: No GPR was taken at Heaney.

Figure 53: Ice core team at St Andrews Bay

Bouvetøya

Bouvetøya is a small glaciated island in the South Atlantic, regarded as the most remote island in the world. The island is formed from an extinct volcano with steep cliffs and a caldera rising ~800 m above sea level. The island is Norwegian and specific permits were granted for the Sub-ICE Project to use helicopters to reach a suitable ice core drilling location. The day of deployment was extremely calm, with very little wind, but a thick blanket of cloud at ~1000 m. After searching for a suitable site, we selected one on the eastern flank of the island at ~350 m well below the cloud.

Deployment Date: 13 March 2017 (ship time)

Latitude: 54.422 deg S Longitude: 3.391 deg E

Elevation: 350 m (on handheld GPS)

Time deployed to ice: 07:00 (ship time)

Drilling time: 5 hours

Weather: Light winds, high cloud cover, intermittent periods of sunshine. Cloud descended from the summit by early afternoon.

Field party: Liz Thomas, Mariusz Potocki, Roger Stilwell, Amy King, Julia Schmale (ACE-SPACE),

Drill depth and cores: 13.75 m, the core sections are labelled B_01 to B_24.

Comments on drilling: We started drilling using the same drill setup as Leg 2, with the electric power drill and the Honda generator. However, after the fourth drill the screw in the power drill severed, making the drill unusable. The 4-stroke powerhead used in South Georgia was sent out and used to drill the remainder of the ice core. The power head was not suitable to use in the horizontal position so we were unable to use the sidewinder winch and therefore all cores from Bouvetøya were pulled up by hand.

The site was covered by a small layer (~3-5 cm) of surface snow (presumed to be recent) and below this the ice was granular in consistency. Beyond a depth of ~1.5 m we found evidence of large melt layers but no debris. The granular snow became “sticky” and made it hard to pull the cores out. Instead of pulling out straight, the barrel would only rise in a turning motion. Below ~8 m the borehole had widened and we

started to retrieve good quality ice cores which we could pull out easier. We had to make several adjustments to the core dogs to ensure they were tight enough and changed from the 1.5 m barrel to the 1 m barrel when the spring became too loose. The last 5 m of drilling was the smoothest but by this time the cloud had descended and we stopped drilling. A total of 13.75 m of ice was transported in 3 insulated boxes to the -20^{o}C “glaciology freezer” on the ship.

Comments on GPR: 1.8 km of measurements in 9 lines from 120 to 210 m in length, covering ~ 0.016 km2 of glacier. Files were recorded using a setup that allowed a ~50 m penetration depth and slow data collection, with better resolution of the upper layers. The preliminary profiles do not show crevasses near the ice core position.

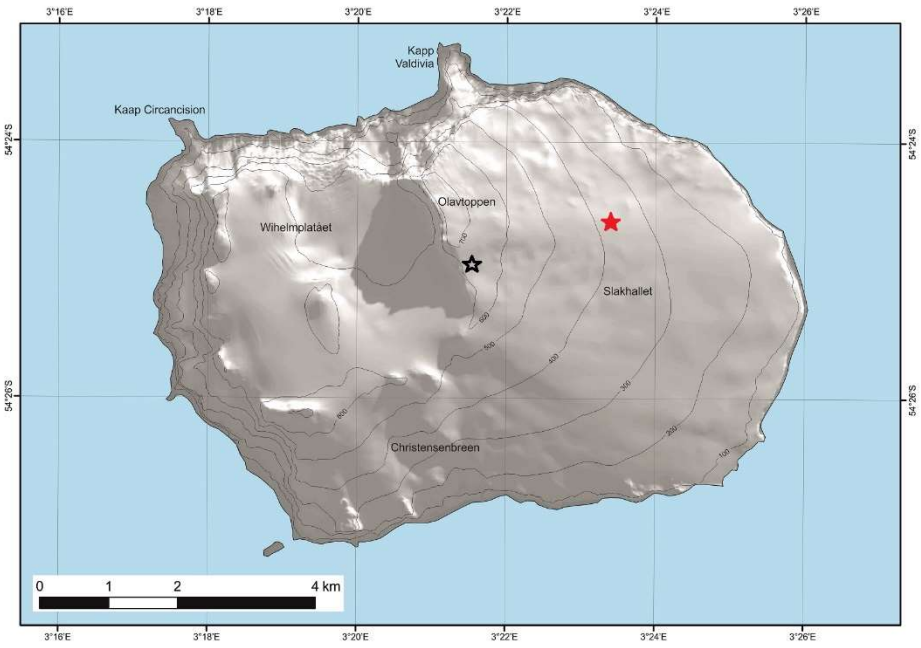

Figure 54: Bouvetøya . Ice core drilling location (red star) and original landing site (black star), which would make an excellent location for ice core drilling if the weather conditions were favourable.

10.5 Project 5

Circum-Antarctic distribution of acoustic deep scattering layers, and associated foraging behaviour of deep-diving predators

PI Andrew Brierley (UK)

Aims and Objectives

Deep Scattering Layers (DSLs), also sometimes called the "phantom bottom", are ubiquitous features of the world ocean, but data on DSLs in the Southern Ocean are sparse. They comprise communities of fish (lantern fish, myctophids) and zooplankton. Our previous work has revealed pronounced differences in DSL depth and biomass across frontal zones (Boersch-Supan et al., 2012) and suggests the possibility of a global DSL biogeography (Proud et al., 2016).

The daily vertical migrations of animals in DSLs, from deep water (200 – 1000 m) in daylight to shallower water (< 200 m) to feed at night, make an important contribution to the 'biological pump' that moves carbon from the surface to the ocean interior (Brierley, 2014). Fish in DSLs are hunted by diving predators such as elephant seals and king penguins (Boersch-Supan et al., 2012) and are also potentially of commercial interest (St. John et al., 2016). Data on Southern Ocean DSLs are needed to improve ecosystem-based management and to improve our understanding of biogeochemical cycling and drivers of predator foraging behaviour.

This Project aimed to:

- Map the depth and biomass of acoustic Deep Scattering Layers (DSLs).
- Add a Southern Ocean component to a global mesopelagic biogeography.
- Examine associations between the DSL prey-field and predators foraging behaviour by analysing their dive depths and duration.

Methodology

The *Akademik Tryoshnikov* has two hull mounted single-beam transducers (see Figure 55), built and installed by ELAC Nautik (Kiel, Germany).

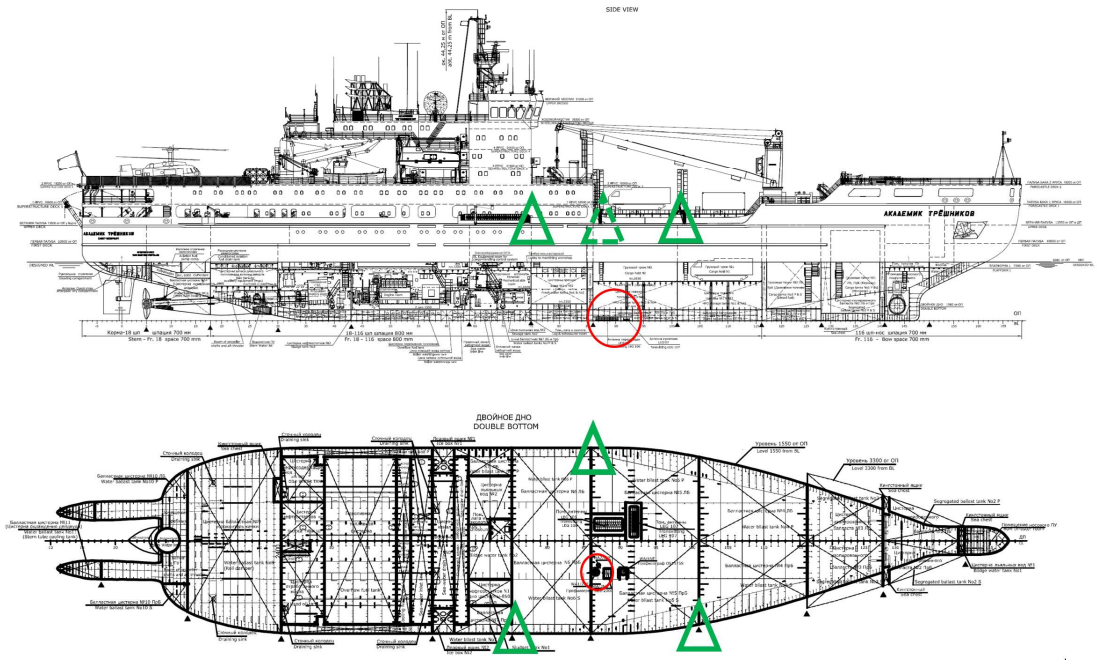

Figure 55: Transducer positions, marked by red circles, and calibration line positions marked by green triangles. Dashed triangle represents position of portside calibration line.

Installation of acoustic equipment

Here the step by step sonar coupling process is briefly described necessary to collect acoustic data aboard the *Akademik Tryoshnikov* during ACE. The nature of the data collection platform, namely an ice breaker type vessel (class 7), did not allow for the installation of a typical sonar system as per regular fisheries surveys due to the design of the ship's hull. For this reason, two scientific transceivers or General Purpose Transceivers (GPTs; electronic units which process the acoustic signal) manufactured by the Norwegian company Simrad AS had to be coupled with the transducers of the bottom profiler sonar of the ship produced by the German company ELAC-Nautik. The equipment was installed in the hydroacoustics laboratory on deck 4 (Room 625), where we had access to the transducer cable via a ceiling panel.

The *Akademik Tryoshnikov* bottom profiler uses two "single beam" transducers, which operate at the discrete frequencies of 12 (LSE 179) and 200 kHz (LSE 140), with the possibility of operating the low frequency unit with a wider band which goes from 12 to 20 kHz. To obtain analyzable information from these transducers, two different transceivers capable of providing a standard and reliable data output were required. The Simrad EK60 and the new broadband unit, the Simrad EK80 are the standard sonar transceiver units available on the market for scientific purposes. The latter has broadband capabilities which allowed it to operate the LSE 179 transducer between 12.5 and 14.5 kHz during dedicated sample stations.

The following paragraphs give practical information on how the two systems were coupled together with a schematic to show the proper connectors.

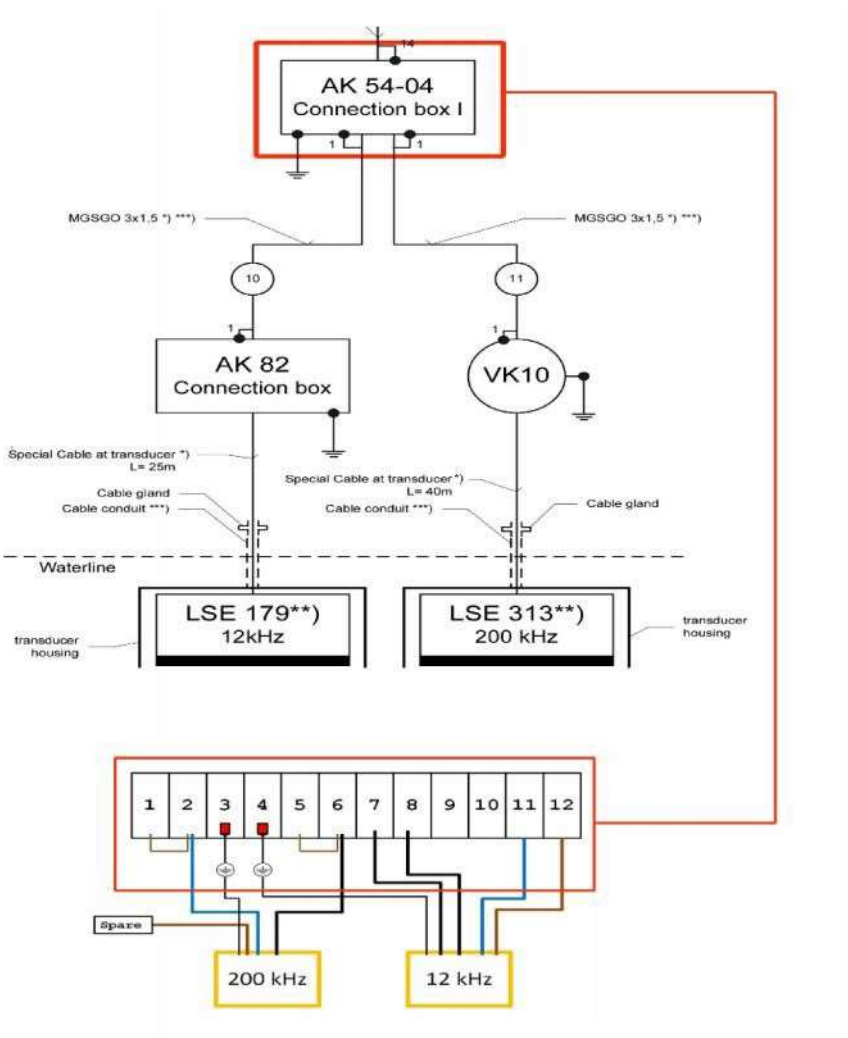

Figure 56: Interconnection Box AK 54-04 wiring diagram. The low frequency need a twin cable line to avoid power loss of the signal from the transducer to the transceiver. The transducers were disconnected from the AK 54-04 junction Box to be wired into to the Simrad GPTs.

Simrad EK80 – ELAC Nautik LSE 179

The ELAC-Nautik low frequency transducer - LSE 179 - was installed approximately 40 m in line from its processor unit. The low frequency and the distance between the two system components of this sonar generated the necessity to amplify the signal by splitting it into two cables and avoid its weakening along the line. For this reason, as shown in Figure 56, it connects into the junction box AK 54-04 with two wires (2 IN and 2 OUT). The EK80 Transceiver electronic circuits allow to connect different transducer types - single beams, dual beam, split beams - but every transducer calls for its own plug and its precise wiring. For single beam transducers, the EK80 requires a connector that wires in parallel the cable IN and OUT of the transducer. That scheme is slightly different from the one suggested from Simrad for their own transducers. The wiring drawing details are presented in Figure 57. It is also suggested by the manufacturer to install the transducer cable in a steel unit conduit to avoid any interference. The solution aboard the *Akademik Tryoshnikov* was a special conduit tube is described later.

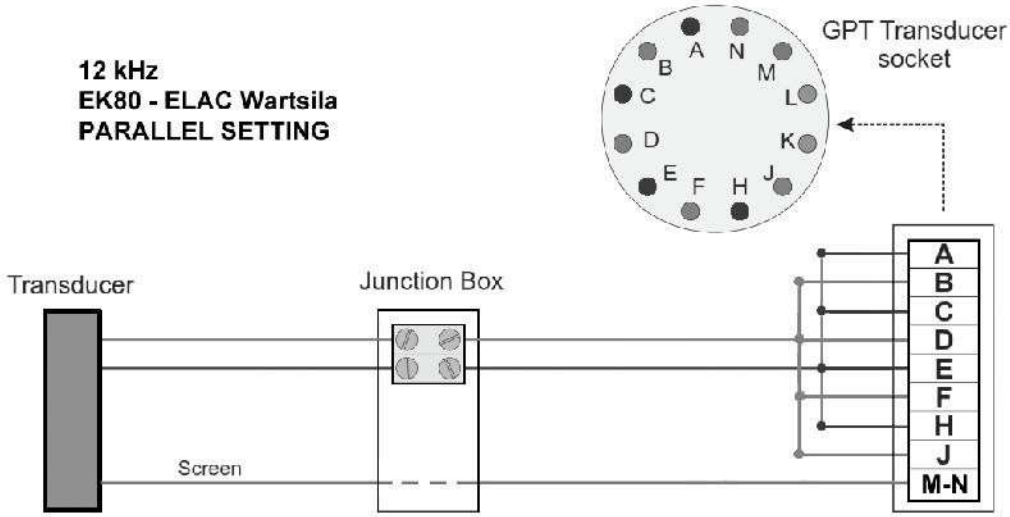

Figure 57: Schematic drawing of the parallel wiring required to interconnect the EK80 transceiver with the Elac-Nautik LSE 179 transducer.

Simrad EK60 - ELAC Nautik LSE 140

The connection of the 200 kHz transducer was not straightforward. Initially the system seemed not to be working but the reasons were more related to the need for a good calibration, which was performed during Leg 3. Such high frequencies are usually suitable for fine scale measurements of small fish close to the surface (Figure 58).

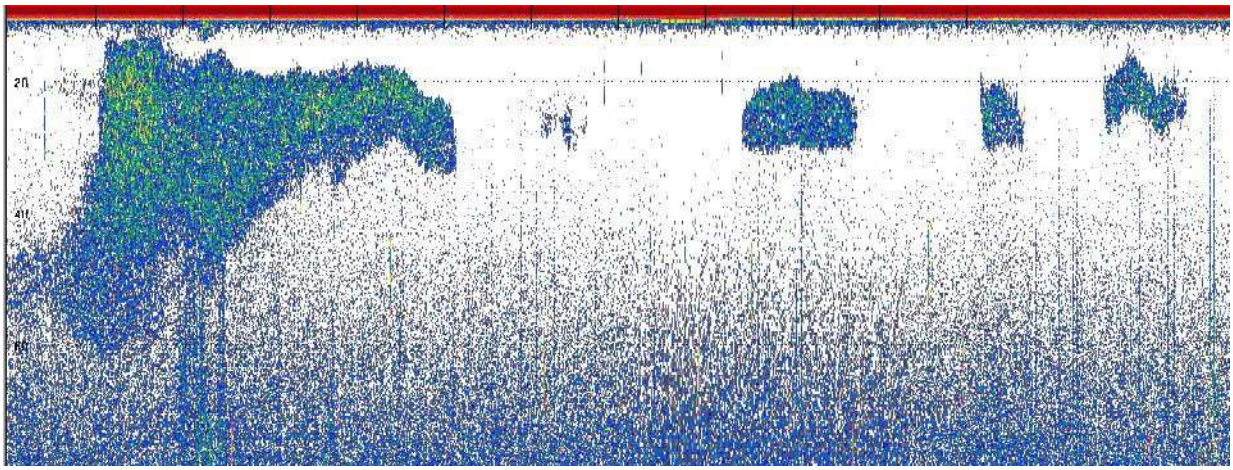

Figure 58: Once the continental shelf was reached, DSLs seemed to fade to be substituted by dense aggregation of fish (may be mostly in larvas and juvenile stage) and Krill. It was in those shallow areas (maximum depth between 800 and 200 m) where the high resolution of the 200 kHz come to be handy.

To couple the EK60 split beam transceiver unit (Simrad EK60) with a single beam transducer, the connector must be wired as described in the drawing of Figure 59 (Anon 2006), with a serial configuration. It is important that the signal cable is well screened in a metal tube or for the case described here in a special insulated tube composed of three layers: rubber, aluminum foil and cardboard (this was also used for the EK80 connection). The follow on was then merely simply tuning up the different software settings to obtain a good reading. The data will be post-processed after a careful calibration experiment which will follow standard procedure for acoustic instrumentation (Demer et al., 2016; Foote et al., 1983).

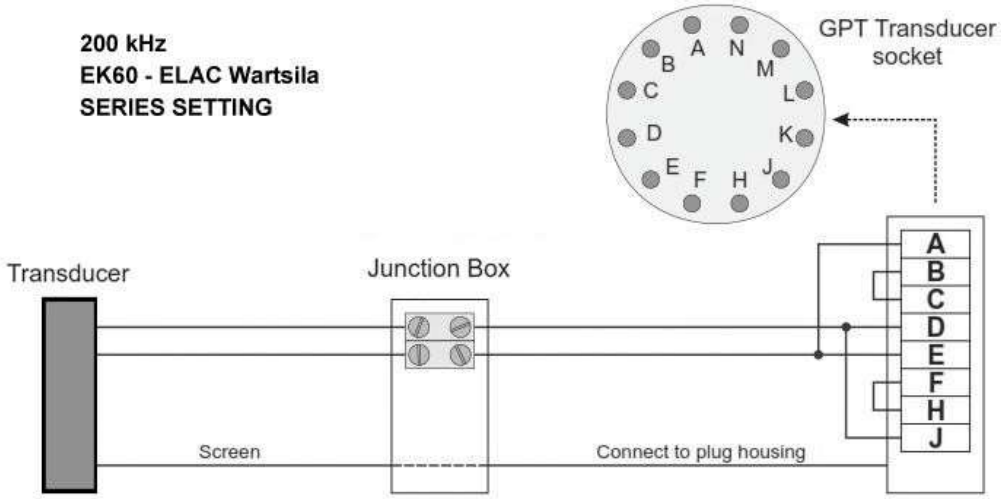

Figure 59: Schematic drawing of the serial wiring required to interconnect the EK60 transceiver with the Elac-Nautik LSE 140 transducer.

Teledyne ADCP

Acoustic Doppler Current Profilers (ADCP) use Doppler effect (change in the observed sound pitch that results from relative motion) by transmitting sound at a fixed frequency and listening to echoes returning from sound scatterers in the water. These sound scatterers are small particles or plankton that reflect the sound back to the ADCP. During oceanographic campaigns ADCP are usually used to study the magnitude and direction of underwater currents, but the ADCP acoustic return could also be used as a proxy to measure the volume backscattered from plankton in the water column (Kaltenberg 2004). It was our intention to attempt a calibration of the acoustic transducer and use the data that were continuously stored by the *Akademik Tryoshnikov's* ADCP unit at a center frequency of 76.8 kHz (Figure 60).

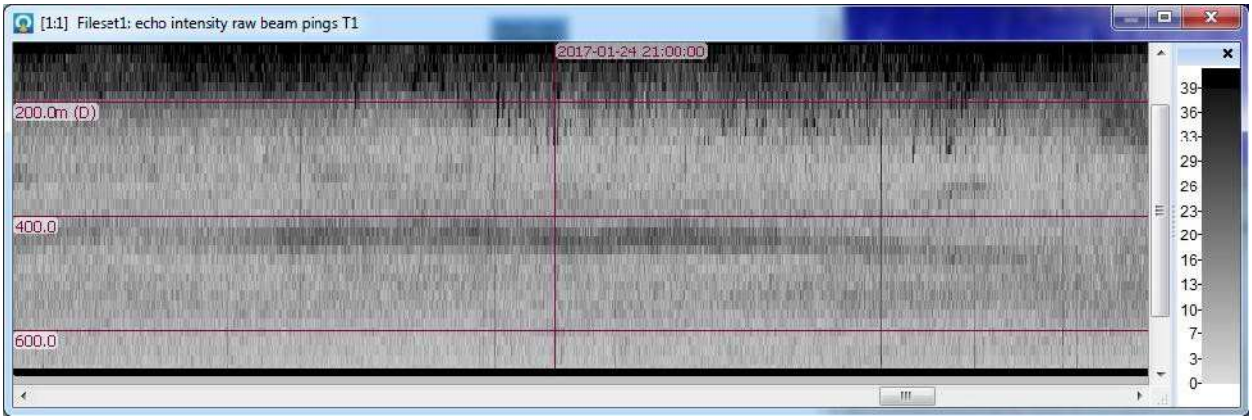

Figure 60: Echo intensity data of the front ADCP beam pre-processed using the software Echoview (Echoview Software Pty Ltd). The DSL is clearly visible and the depth must be correct considering the geometry of the instrument.

The ADCP data may also be used to understand the relation between DSLs and underwater current directions and its magnitude. To do so it would be necessary to calibrate the instruments with an easy ship maneouvre which consists of a mini survey. By sailing along a square track that covers 1 nm square, it is assumed that currents in this small area are constant. By running along this small track, it is possible to check the beam placement related to the vessel bow and correct the raw data for precise estimations.

Acoustic data collection and DSL

Two downward looking sonars (commonly known as echo-sounders) were used to collect data during ACE. An ELAC-Nautik LSE 179 transducer was interfaced with a Simrad EK80 wide-band transceiver, and operated in a frequency bandwidth of 12 to 14.5 kHz. Long continuous wave (CW) and frequency modulated (FM) pulses were used to achieve long range detection (otherwise impossible to achieve with higher frequencies transducers) and insonify DSL and to get information about bathymetry. At the same time an ELAC-Nautik LSE 140 transducer, drove by a Simrad EK60 transceiver, was collecting high resolution data in the first 200 m of the water column at a center frequency of 200 kHz (Bandwidth 3088 Hz). The two sonar units were installed in the hydro acoustics laboratory on deck 4, where the transducer junction box AK 54-04 (Figure 56) was easily accessible via a ceiling panel.

During Leg 0 various WBT settings were tested to determine the optimum setup for the main expedition.

During Leg 1, we operated the sounder continuously whilst underway and stopped recording whilst at anchor. Normal operation consisted of using a 12.5 kHz CW pulse (frequency selected to avoid interference), a transmit power of 100 W and pulse duration of 16.384 ms (filename prefix: 'ACE').

Once the LSE 140 and the EK60 were properly coupled and tested during Leg 2, data were continuously stored using a CW pulse of 1024 µs at intervals of 256 µs and a power of transmission of 150 W. The high frequency unit covered, with a good SNR and a high resolution, the upper 200 m of the water column, while the long pulse (16.384 ms) of the low frequency was chosen to optimize the SNR, and allow the detection of weak scatterers (< -80 dB re $1m^{-1}$) occurring at depth over 500 m.

The selected transmit power value of 100 W for the low frequency transducer (LSE 179) is relatively small compared to standard operating protocols for such units (c. 2000 W). The transmitting power limitation is mainly due to an impedance mismatch between transducer/transceiver. Higher power setting may indeed damage the transceiver seriously. Background noises were also monitored by storing data in "PASSIVE" mode both for CW and FM pulses 10 minutes per day. We selected the longest available pulse duration (16.384 ms) to optimize the signal-to-noise ratio, allowing us to detect weakly scattering DSLs (< -80 dB re 1m-1) occurring deep (> 500 m) in the water-column.

Once a day, during daylight we collected data for one hour using a FM pulse (filename prefix: 'ACE_FM'), operating between 12.5 and 14.5 kHz, 100 W transmit power and 8.192 ms pulse duration, to obtain frequency spectra observations of the mesopelagic community. The sounder was also run in passive mode for both the CW pulse (filename prefix: 'PASSIVE') and FM pulse (filename prefix: 'PASSIVE_FM') for 10 minutes each day to assess the level of background noise received by the transducer. Raw data recorded amounted to around 27 GB of storage space in total.

The Acoustic Doppler Current Profiler (ADCP) was run continuously, with the exclusion of shallow waters in which the unit was turned off to avoid interference with the multibeam echosounder used for bottom mapping to find locations for trawling. The broadband RDI ADCP operates at a center frequency of 76.8 kHz with a beam angle opening of 30°. Data samples were checked and pre-processed using Echoview 7.1. The preliminary check allowed us to be confident of the data quality (Figure 60). The next step should be a proper acoustic calibration, which is something rarely attempted with this instrument which are merely used to measure underwater currents.

The use of CTD data is also a fundamental routine during acoustic surveys. The data profile collected allows the operator to update the sonar equation (Urick 1983) and have precise reading (range) from the instrument. After each CTD cast the data were post processed using the software Seasave 7.0.2. The data were hence used to update the environmental parameters of the echosounder software.

Preliminary results

The raw echosounder data were processed into gridded power values (depth by time) using echoview version 7.1.29.302212 (Myriax, Hobart, Australia). After the expedition, data will be transformed to volume backscattering strength (Sv) values (Maclennan et al., 2002) and biological layers (DSLs) will be extracted using the Sound Scattering Layer Extraction Method (SSLEM: Proud et al., 2015); screenshots taken whilst running the EK80 software are shown below in Figure 61 for both modes of operation (CW and FM pulse).

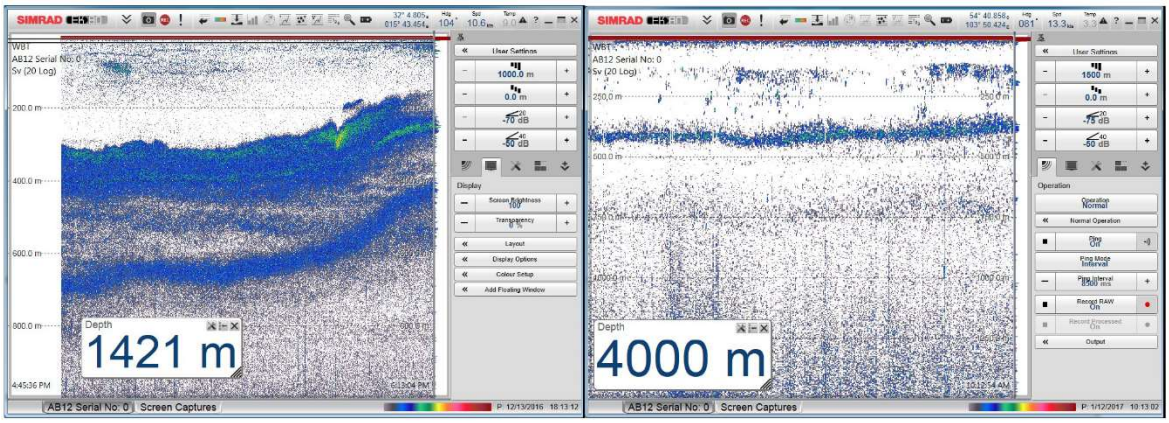

Figure 61: : An example of data recorded using the EK80 WBT (Simrad, Bergen, Norway). Sv (Volume backscattering strength) values shown (0 – 1,000 m) whilst operating with a FM pulse (left image) between 12.5 and 14.5 kHz and CW pulse (right image) at 12.5 kHz.

Observations during Leg 2. Hobart to Punta Arenas.

During Leg 2 we kept the regular data collection routine as set in Leg 0 and 1 when the water depth was over 500 m.

Observations during Leg 3. Punta Arenas to Cape Town

Both echosounders were run more or less continuously throughout Leg 3, as outlined in the reports of the earlier Legs. A total of approximately 300 hours sampling was made on each echosounder. The noise levels on both frequencies (12 and 200 kHz) were much higher than would normally be acceptable on a research vessel. The attempts to minimize noise levels undertaken on the earlier Legs of the cruise were noted and no reasonable alternative was found. Operating settings from the previous Legs were therefore maintained throughout.

Whilst adequate amounts of data were collected the quality is well below what is expected from a research vessel. In our view RV *Akademik Tryoshnikov* in the present configuration is not well suited for future acoustic research. Echosounder data were logged onto an external hard drive and saved into the same directory format as used on the previous Legs. Copies of the raw data have been passed to the Data Management team.

A CTD logger for use on seals was attached to the ship's CTD rosette on stations sampling to 1000 m or less on seven occasions. Data were downloaded and copies have been sent to the Data Manager. Although all data were successfully downloaded there were difficulties in establishing and maintaining Bluetooth communication with the device.

Deep scattering layers were noted almost continuously whilst the vessel was moving in water deeper than 500m. DSLs did not appear to be present on the shelf areas of any of the islands. Detailed analyses of the data will be undertaken using the proprietary software Echoview.

Echosounder Calibration Report

Leg 0

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On the 14th December we performed a warm-water calibration of the LSE179 transducer, close to Cape Town (Lon: 18° 11.17' E; Lat: 32° 33.757' S), using the standard target method (Foote et al., 1983). We measured on-axis Target Strength values of a tungsten carbide sphere (38.1 mm) and used the EK80 software to estimate values of transducer gain (G0) over the intended operating frequency range for Leg 1 (12.5 – 14.5 kHz). Calibration data (filename prefix: 'CAL') will be processed after the expedition. A further cold-water calibration was undertaken at South Georgia on Leg 3.

It was originally intended that calibrations of EK60 and EK80 echosounders should be undertaken during a visit to Stromness Harbour, South Georgia. The site was chosen because local knowledge from BAS scientists had indicated that the water quality was good and representative of oceanic conditions. The site was investigated twice but on both occasions the wind speed was too great to even consider a calibration. Calibration was undertaken in Cumberland East Bay at the anchorage used for access to King Edward Point, South Georgia. This is not an ideal site due to the amount of freshwater present from glacial runoff. The anchorage itself was not sufficiently deep to allow a full calibration at the long pulse length used on the 12 kHz echosounder, however, calibrations were undertaken for all the other pulse lengths and for the 200 kHz system.

Calibration of the single beam transducers used on the ship takes longer than is normal for the current generation of split beam echosounder because precise information on where the calibration sphere is located within the beam angle or even whether it is anywhere near the beam, is unavailable. In a trouble free situation it was known that such calibrations took about six hours per echosounder. Although a request had been made to keep the foredeck clear and to avoid small boat operations around the forward end of the ship, calibration was interrupted for about three hours during setup. Apart from that a reasonably good calibration was successfully completed in a total time of 14 hours.

Leg 3

Calibration of the scientific echosounders took place on 02 March 2017 by Paul Fernandes and Inigo Everson, assisted by Russell Leaper.

Background

It is normal practice with fisheries acoustic surveys to calibrate echosounders at least twice according to the current international protocol (Demer at al., 2015) during a survey. The process involves suspending a standard sphere of known target strength (TS) in the transducer beam and measuring the echo levels using the echosounder settings agreed for the survey.

In planning for ACE, a period of time was requested for echosounder calibration near to Cape Town, prior to the start of Leg 1, and at South Georgia during Leg 3. The Leg 1 calibration had been attempted but unfortunately, due to a number of difficulties, the results were inconclusive and consequently gain settings, consistent with obtaining results were set. All other settings were specified before the start of ACE. Failure to achieve a good calibration in Cape Town put added pressure on the second calibration exercise, scheduled for South Georgia.

Preparation

Experience from the first calibration indicated that a number of key modifications would be necessary to successfully undertake the exercise at South Georgia.

Table 16: Equipment available on the ship for calibration

Item	Specification	Source
Calibration sphere	Tungsten carbide 38.1mm diameter	University of Aberdeen
Tools	Various	University of St Andrews
Fishing rod and reel	2 small ones	University of St Andrews

Fishing rod and reel	1 sea angling setup	University of Aberdeen

The following items were purchased for the purpose in Punta Arenas:

Table 17: Items purchased in Punta Arenas for calibration

Item	Specification and purpose	Quantity
Aluminium pole	6 metres, 5cm dia, wall thickness 4mm	3
D shackle	Small to fit into end of Al pole	3
SS ring	Large carabiner to act as fairlead	3
Fishing line	Support bridles for calibration sphere	100 m
G clamp	To clamp Al pole to bulwark	3
Trawl twine	Securing items to ship	2 spools

Figure 62: Starboard side foredeck showing the forward support pole ready for use.

A shackle was attached to the outboard end of each pole from which hung a large carabiner. Two supporting guy lines were attached to the outboard end of each pole and tied to convenient locations on the superstructure (Figure 63). Fishing reels loaded with Dacron Matrix Pro, 36 kg, 0.35 mm line were attached to the inboard end of each pole. The poles were lashed to G clamps fixed to the bulwarks with a 4.5 metre outreach. The inboard end of each pole was lashed to the superstructure. The original intention was to arrange the poles such that they held the bridles at positions giving a 120° horizontal angle from the sphere to the tip of the pole. Such an ideal arrangement proved impossible due to the design of the ship. A

compromise was reached that gave as wide an angle between any pair of bridles. The locations of the poles are shown in Figure 63 and are the same as chosen for the first calibration.

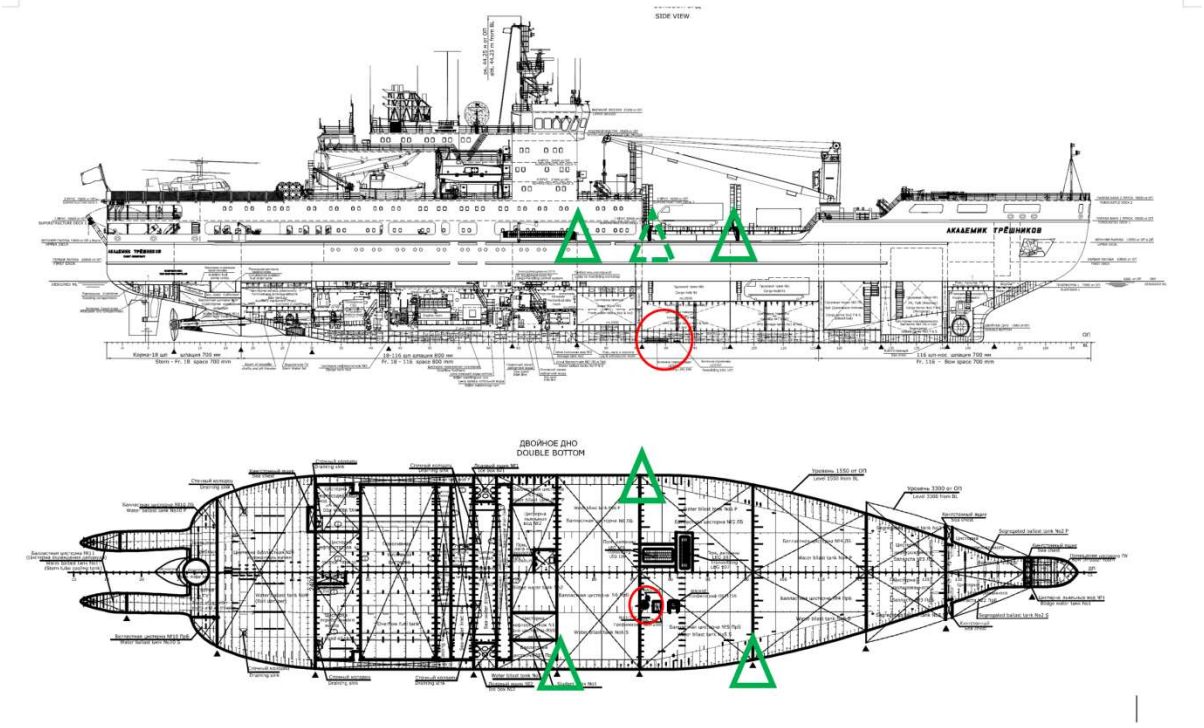

Figure 63: General arrangement plan to show locations of the three poles to support the calibration bridles, green triangles and the two transducers, red circle.

Horizontal positions for the three poles are shown in Table 18.

Table 18: Horizontal positions of poles required for acoustic calibration.

Direction	Port	Stbd Fore	Stbd Aft
12 kHz			
Alongships distance from side of ship (m)	15.4	7.9	7.9
Athwartships distance inboard from bulwark (m)	0	13.0	11.0
200kHz			
Alongships distance from side of ship (m)	13.6	9.5	9.5
Athwartships distance inboard from bulwark (m)	0	13.0	11.0

The length of each bridle needed to set the sphere at 15 metres vertically below each transducer was calculated and the results presented in Table 19.

Table 19: Bridle length, sphere to reel to set the target sphere at 15m below the transducer.

Transducer	Port bridle	Stbd Fwd bridle	Stbd Aft bridle
12 kHz	39.41	37.08	37.27
200 kHz	38.44	37.70	37.89

Calibration results

The echosounder data collected during calibration were analysed using custom software written in R. The analysis procedure consisted of importing the entire volume backscattering strength ("20 log R", Figure 64) and target strength ("40 log R", Figure 65) echograms from Echoview corresponding to the calibration. These echograms were processed in Echoview to exclude the seabed and the transmit pulse (removal of

the upper 17 m). The files were then further trimmed to isolate the volume backscattering strengths and target strengths from the sphere echo.

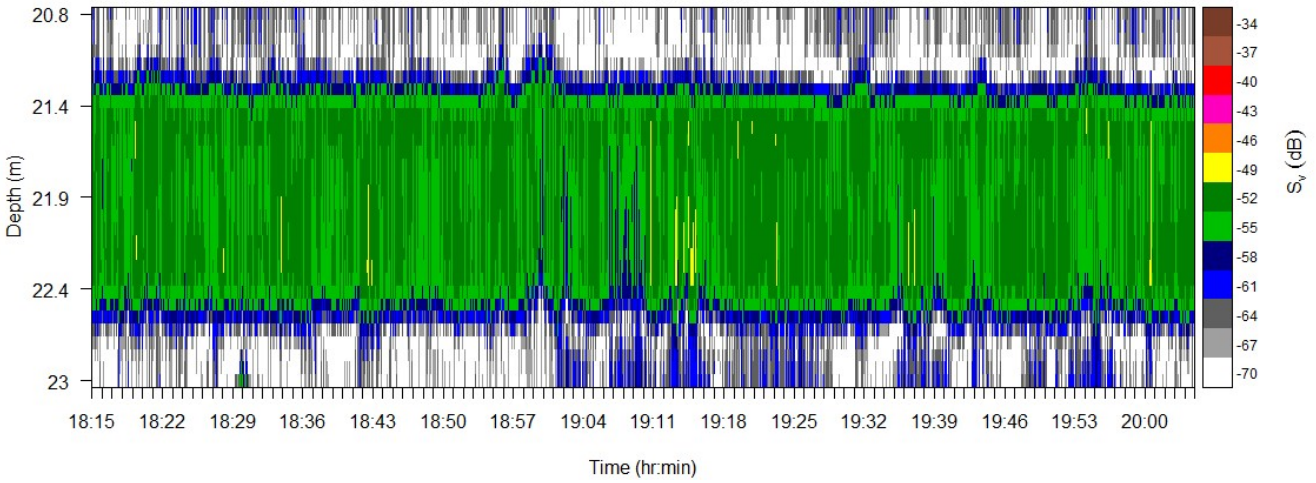

Figure 64: Trimmed volume backscatterring strength echogram showing echoes from the sphere collected between 18:15 and 20:06 on the 2 March 2017 with a 2 ms pulse length.

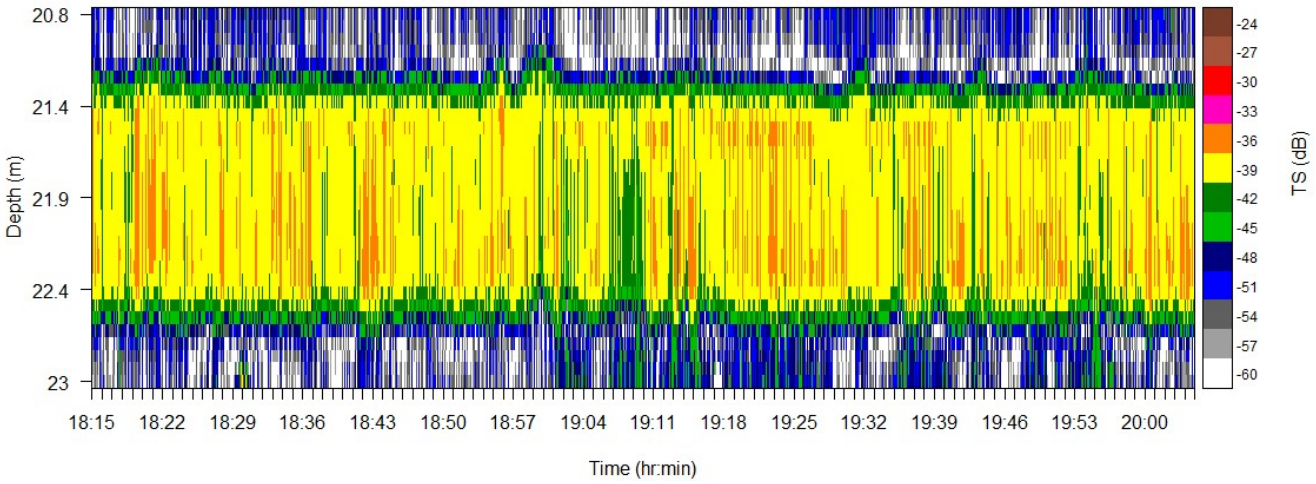

Figure 65: Trimmed target strength echogram showing echoes from the sphere collected between 18:15 and 20:06 on the 2 March 2017 with a 2 ms pulse length.

The target strengths were then filtered to extract the upper 2.5% of the data, assuming that these were representative of the sphere being in the centre of the beam. The mean on-axis sphere TS was then calculated by averaging the upper 2.5% of the sphere data in the linear domain. The ping numbers corresponding to these upper 2.5% TS were then used to isolate the corresponding volume backscattering strengths (VBS). The Nautical Area Scattering Coefficients (NASC) were then calculated from these VBS. The new Gain setting and Sa correction were then calculated according to Demer et al. (2015). The results of the various calibrations at pulse lengths of 2, 4, 8 and 16 ms on the 12.5 kHz EK80 echosounder are given in Table 1. As the pulse length increases the new gain gets higher and the new sa correction gets larger: this is unusual and will require further analysis. It is likely that the theoretical TS, which in this instance was

a single value across all pulse lengths, will need adjusting according to the appropriate bandwidth (which was not available at the time of writing).

Table 20: Simrad EK80 12.5 kHz calibration results from the exercise carried out at South Georgia on 2 March 2017 at various pulse lengths as indicated. Common parameters include the theoretical TS = -41.61 dB, the range to the sphere = 21 m, the equivalent beam angle=-14.7 dB, the old Gain = -18.1 dB, old sa correction = 0. The number of pings is the number which the means are calculated on and represent the upper 2.5% of the data.

Pulse length (ms)	Number of pings	<TS> measured (dB)	NASC measured (m2.nmi-2)	New Gain (dB)	New sa correction (dB)
2	281	-36.20	433	20.81	-1.02
4	13	-34.06	528	21.87	-1.65
8	15	-31.5	452	23.15	-3.27
16	20	-30.13	255	23.84	-5.20

Field party liaison

During the visit to South Georgia, it was hoped that there would be an opportunity to liaise with the field party at Hound Bay who are studying at-sea behaviour of birds and seals. Unfortunately, inclement weather prevented much activity with zodiacs and the walk from Hound Bay to St Andrews Bay in white-out conditions would have been too treacherous to undertake. No contact was therefore possible with the field party.

On departure from Bouvetøya on 13 February 2017, there was severe unaccountable signal attenuation, resulting in significant dropout and loss of bottom detection. We were told that all the ship's acoustic instruments were switched OFF at the time. The fault, if that is what it was, suddenly resolved itself and the echosounders operated normally. We do not know the cause but suspect it was one of the bridge sounders that had been accidentally left running. The same problem occurred on 18 March 2017 as we approached Cape Town.

DSL: Preliminary qualitative observations

We continued testing regularly the Telemetry electronics to be used around South Georgia in Leg 3. We installed a second sonar frequency which was not operative in Leg 0 and 2, and it is now available to provide a fine scale from the upper layer of the water column between 10 and 200 m.

DSL were observed most of the time once clear of the islands shelves (Figure 66A). Typical depth of the layers was between 200 and 600 m (Figure 66B). The diel vertical variation was clear and observable qualitatively during data collection (Figure 66C). It is expected to find a strong correlation of the latter with the data collected by the ship light sensor. The presence of fresh water masses seemed to affect the layers in proximity of the ice pack, but such observation need to be confirmed by a more careful analysis of the data. Indeed, the various community of organism could be just scattered and not visible in a first look of the echograms. Some echogram examples are shown below as representative of the observations collected. Occasionally the double bottom effect could be tricky to determine during the data collection. The approach to that issue in data post processing should be more careful scrutiny of the echograms (Figure 68).

Related Activities

Paul Fernandes gave research seminar entitled "Seeing underwater with sound: fisheries acoustics and the deep scattering layer" to explain the work undertaken on Project 5 and show how the results will help in understanding the Southern Ocean ecosystem. He also noted that the extensive nature of the DSL might at some time in the future encourage fishers to engage in exploiting the various resources. During the preparation for this seminar data were collected using a GoPro camera lowered to the seabed close to

Bouvetøya to demonstrate the sounds produced by the echosounder. The resultant video contained unique footage of the demersal species *Notothenia coriiceps* living openly on a coarse sand seabed. Although previously known to be common at Signy Island, South Orkneys, this species is thought to be unreported from Bouvetøya.

Inigo Everson presented two short videos one of a fish survey and the other about longlining for toothfish and the evidence that was needed in order for the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) to establish strict seabird bycatch elimination measures.

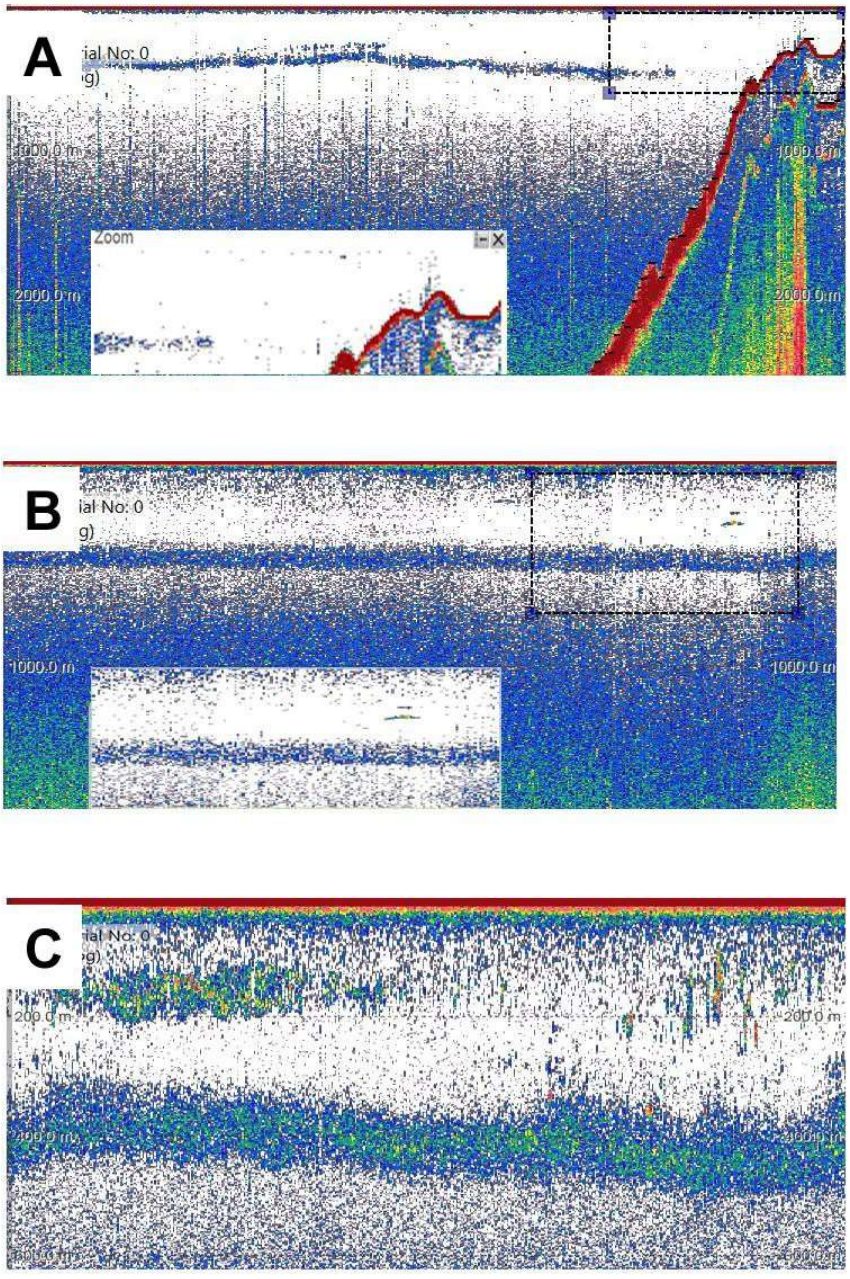

Figure 66: A) DSLs usually disappear while the ship was approaching the continental shelves and in proximity of the islands. B) Typical diurnal position of the DSL in the water column C) Vertical night migration of the DSL typically encountered during the ACE Leg 2

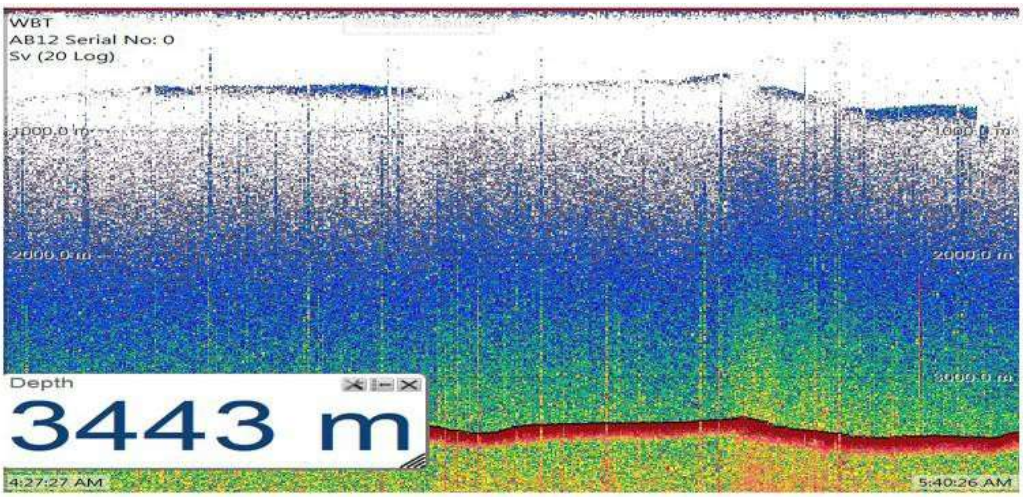

Figure 67: Typical example of misleading double bottom case. Such can be eliminated with a careful data preprocessing.

Visual detection of marine mammals and penguins

Visual observations for cetaceans were carried out during Leg 2 (similar observations were carried out on Legs 1, 2 and 3 for Project 20, and Legs 2 and 3 for Project 14) using standard line transect protocols; a single observer monitored a 90° sector, from ahead to abeam of the ship, looking for cetaceans with the naked eye and using 7x50 binoculars to confirm potential sightings. High-resolution digital photographs were taken where possible to confirm species' identification (Figure 68). Environmental conditions were recorded at the start of each 'on effort' period, and thereafter whenever conditions changed. For each sighting, the species, UTC time, direction of the group relative to the vessel's track line, approximated distance of the group (either estimated in metres, or as a reticle measurement from the binoculars' internal reticle), and group size (as a minimum estimate where exact numbers were not possible) were recorded, as well as any conspicuous behaviors observed.

*Figure 68: Minke whale (*Balaenoptera acutorostrata*) were encountered often close to the ice pack. Killer whale (*Orcinus orca*) was seen rarely but in large groups.*

Approximately 100 hours' visual survey effort was completed, covering ~2300km transect. A total of 513 individuals were seen across 167 sightings. Blue whales (*Balaenoptera musculus*), fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), Antarctic minke whales (*Balaenoptera acutorostrata*), southern bottlenose whales (*Hyperoodon planifrons*), hourglass dolphins (*Lagenorhynchus cruciger*), long finned pilot whales (*Globicephala melas*) and killer whales (*Orcinus orca*) were all positively

identified, as well as several sightings where no specie identification was possible, either due to sighting conditions, distance, or quality of the sighting event). Two other ACE projects carried out a dedicated efforts to monitor marine mammal (both with passive acoustic and opportunistic visual census) and sea birds along the expedition track. The information exchange and the cooperation with those has clearly helped to increase the success of all parties involved.

These data will be analyzed using distance sampling techniques to identify areas high and low density of cetaceans, and these densities will be compared to the relative acoustic backscatter recorded by the EK80 echosounder during the survey.

Weather and ice: how they affected data collection in ACE Leg 2

Considering the sample capability of our instruments, namely scientific echosounders and Acoustic Doppler Current Profiler (ADCP), we had relatively constant good weather condition for Leg 2. Our goal to study the DSL indeed was simplified by the characteristic depth ranges which these communities of fish and zooplankton inhabit, between 200 and 500 m (Brierley 2014; Proud et al. 2016). During fisheries acoustic surveys the most challenging information to collect are from species which can be found close to the surface or in the immediate vicinity of the bottom. The difficulty to collect data at those depths is caused by two physical phenomena known as: acoustic blind zone and acoustic dead zone (Simmonds and MacLennan 2005). Notwithstanding that the echogram of Figure 66 could seem noisy at first glance, it is clear the DSLs are in a range which gives a good Signal to Noise ratio (SNR) and a clear record of what we were aiming to study in our Project.

Another common issue, when sounding deep waters is a signal processing artifact known as the double bottom (DB). Often the double bottom is mistakenly interpreted as a DSL (Figure 67). . Many times during Leg 2 we could see on screen a DB which an inexperienced operator might confuse with an actual DSL (Figure 66). Furthermore, keeping the actual seabed always on screen is an easy way to discriminate DBs from actual DSLs. The depth of the DB was most of the time under 1000 m and thus it was not a problem given that DSL were typically between 200 and 500 m (Figure 66).

More problematic is the collection of data in icy waters. The influence of fresh water masses could be corrected by the constant update of the sonar equation (Urick 1983) through the practical application of the CTD casts data collected and used daily to update the environmental settings of the sonar. The real problem arose when the ice pack was crossed. The position of the transducers under the ship hull and the impossibility of avoiding the ice creates noise marks in the echograms (Figure 69). Therefore, part of the data must be excluded notwithstanding it may be useful to define the bathymetry of the explored areas.

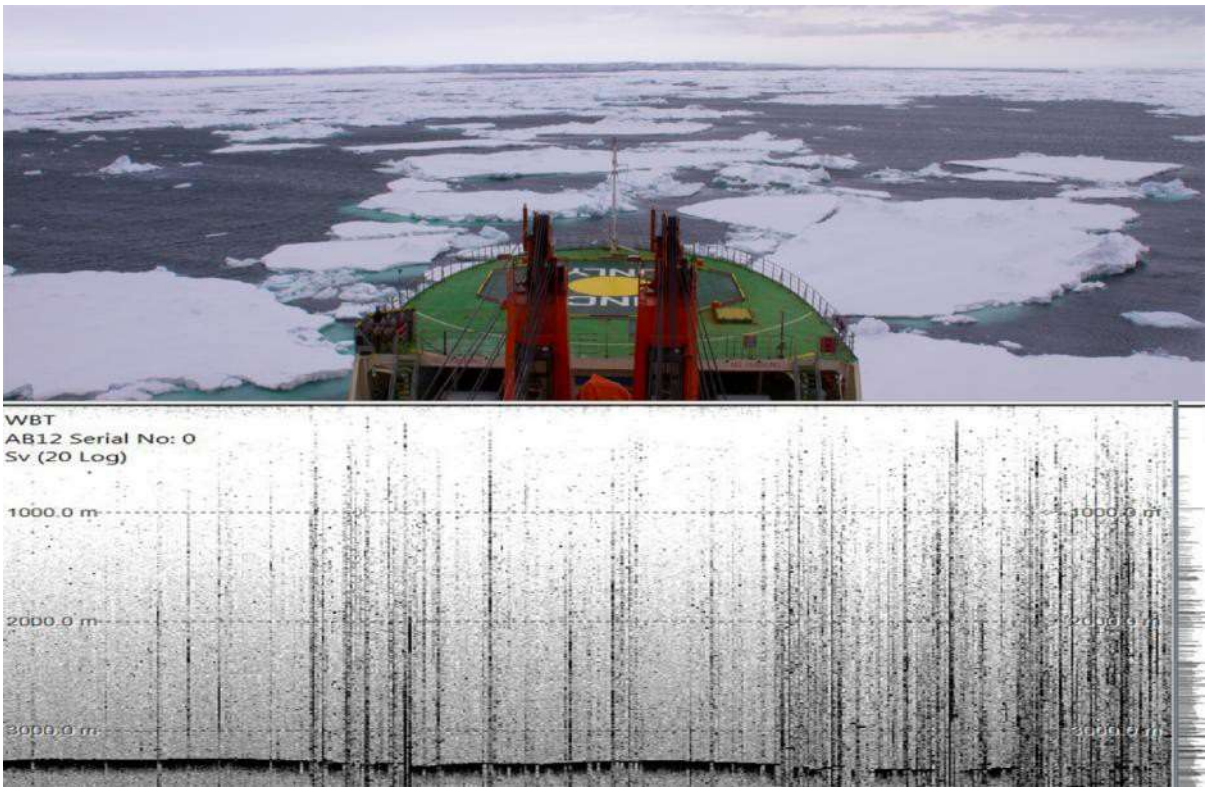

Figure 69: Effect on the echosounder reading of the ice breaking while the Akademik Tryoshnikov *passed through the Antarctic Ice pack*

The instruments worked well during Leg 2 with the occasional failures due to power problems or system reset. What is clear at this point is the need of an accurate calibration procedure to fine tune the system. After a careful inventory of the material stocked in the cargo hold it is clear that upcoming experiments need particular attention during planning. The ship's dimensions are impressive and longer and stronger fishing lines are needed for a successful calibration.

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10.6 Project 6

BIOAIR: Aerobiology over Antarctica

PI David Pearce (UK)

Aerial transport has been identified as an important source of biological input to remote locations. However, the contribution of aerial dispersal in shaping patterns of biodiversity and ecosystem function remains poorly understood, mainly due to the lack of coordinated efforts in gathering data at appropriate temporal and spatial scales. With the considerable effort devoted in recent decades to understanding atmospheric circulation in the South Polar Region, here we sought to investigate the atmospheric ecology of Antarctica, from local to continental scales.

Aims and Objectives

1. Continuous aerobiological sampling throughout the cruise path.

2. Comprehensive back track trajectory analysis linking the data collected to develop new predictive models of biological propagule transfer.

3. Simultaneous land-based sampling at a) South African, b) South American and c) Australasian locations, to determine their contribution as sources of propagules.

4. Simultaneous land-based sampling on each of the islands, to identify the level of aerial biological in/output at specific isolated locations, create a terrestrial aerobiological map of Antarctica and model aerobiological interactions at a range of spatial scales.

5. Simultaneous land-based sampling at Antarctic stations to identify propagules reaching the continent.

6. To establish baseline observations including the potential influence of changing sea ice patterns, human impact and environmental change for future work.

7. To establish an analysis pipeline as a legacy for aerobiological monitoring and analysis, to be validated by the Sanger Institute and available for future analyses.

8. To link to marine spray to identify the proportion of aerobiota of marine origin.

9. Isolate and archive viable microbes caught for subsequent physiological analysis.

10. Establish a cost-effective, innovative workflow for single-cell genome sequencing of aerobiology samples and develop enabling technologies for future environmental genomic studies.

Methodology

1. Membrane filtration. Welch vacuum pumps were used to draw air through 47 mm 0.2 µm cellulose nitrate filter membranes 24 hours a day (12h x 2) (marine) or as long as possible (terrestrial), where 12 hours would be ideal, 6-8 hours optimal and 3 hours likely limited but potentially successful.

2. Impaction onto a surface. A VWR Microbiological air sampler (surface air sampler) (VWR, Italy) was used to direct high velocity jets of air onto a mm 0.2 µm cellulose nitrate filter membrane. This was done over 8 hours (both terrestrial and marine).

3. Impaction into a liquid (medium volume). A BioSampler (SKC Inc. USA) was used to collect air samples in 30 ml of sterile Milli-Q water. Due to the fragile nature of the apparatus, this was mainly used as a backup and for comparative purposes.

4. Impaction into a liquid (high volume). A Coriolis air sampler (Bertin Technologies, France) was used to collect high volumes of air into 15 ml sterile Milli-Q water.

5. A Sartorius MD8 was acquired, but could not be used as the consumables were unavailable in time.

6. Passive accumulation. Nutrient agar and R2A agar plates were used to collect viable cells (high and low nutrient requiring respectively) from the air in 10 minute periods.

7. Membrane filtration was used to collect samples over 12 hours for incubation at 4°C for 12 hours in RNALater and subsequent freezing at -80°C for proteomic analysis.

8. Control samples were obtained from the sterile equipment used, the ship's fuel, swabbing the laboratory spaces and specifically deploying samplers around different parts of the vessel.

9. Precipitation was collected as often as possible and filtered through 47 mm 0.2 µm cellulose nitrate filter membranes. These were stored at -80 °C.

10. A portable weather station was used to monitor how closely the local environment at the point of sampling was reflected by the ship's underway data stream.

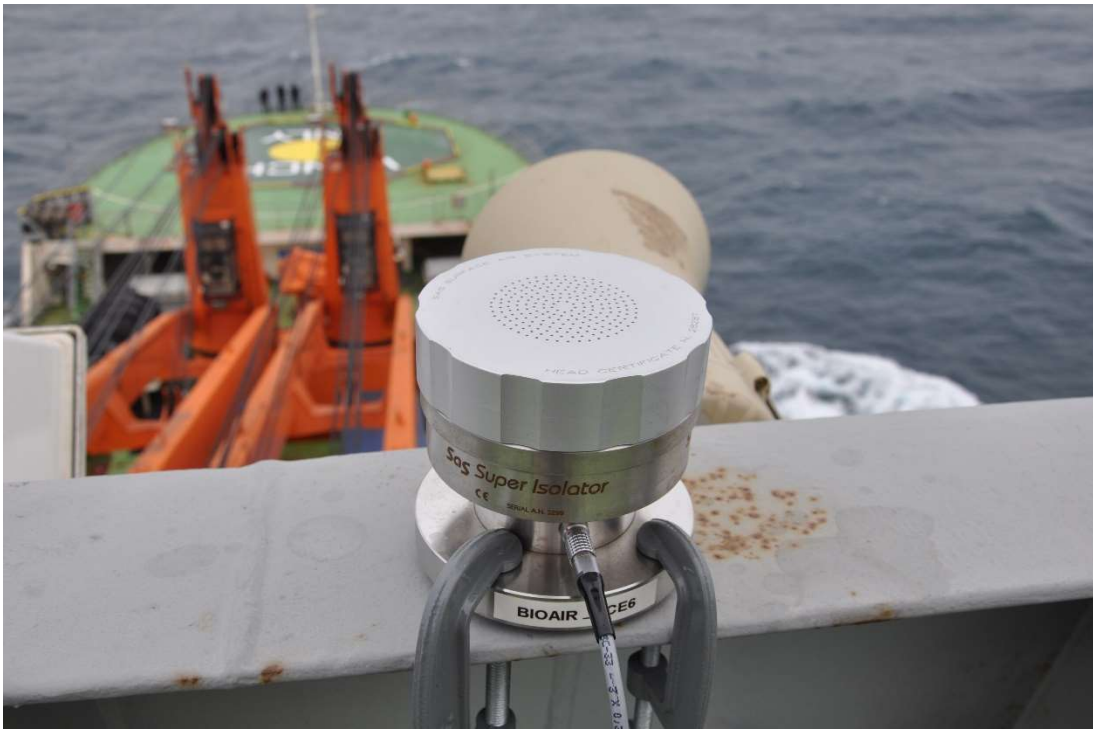


Figure 70: Sampling from the ship

Marine samples were collected throughout the voyage (also in Port) over 24-hour cycles.

Terrestrial samples were collected as opportunity permitted. High altitude locations, remote from the marine environment would have been optimal. However, weather conditions and time available made this challenging. Fortunately, on each of the three islands visited in Leg 1, strong easterly off-shore winds ensured that low altitude close to the coast samples could be representative of the island terrestrial aerobiota.

Figure 71: Terrestrial sampling at Île de la Possession by Julia Schmale and David Pearce.

Results

Leg 1 (for illustration purposes only)

Total samples collected:

>200 marine samples

> 5 terrestrial sample locations

6 Precipitation samples 200 ml, 520 ml, 100 ml, 750 ml, 1 l and 230 ml

Sampling periods completed:

i) Marion Island day 1, 5 hours: near-optimal sample

ii) Marion Island day 2, 12 hours: ideal sample

iii) Possession Island day 1, 50 minutes (only the Coriolis was used due to logistic constraints, as this can cope with sample times < 1 hour)

iv) Possession Island day 2, 1 hour 10 minutes (time cut short due to weather conditions)

v) Kerguelen day 1, 3 hour (time cut short due to weather conditions)

DNA has been extracted,and in the first instance it is being amplified, and the 16S hypervariable region will be sequenced, quality-filtered and assigned to taxonomic categories. Alpha and beta diversity analyses will be produced and compiled. When key zones are identified, a subset of samples (one from each zone) will be subjected to shotgun metagenomic sequencing. Viable bacteria and fungi will be recovered using traditional microbiological methods. Culturable species will be sequenced and cryogenically archived for the scientific community to use via the standard culture collections.

Key challenges

1. Avoiding exhaust, sewerage and kitchen output from the ship

2. Relatively limited time in the field yielding potentially low biomass samples

3. The Coriolis functions by battery only, which sometimes is not recognised by the equipment

4. Waterproofing the generator and pumps in the field (and during deployment via Zodiacs)

5. Maintaining sterility in multi-use laboratories

6. Leg 1 most likely represents a single biogeographic province, so samples from Legs 2 and 3 are extremely important to meet the original objectives of the study

No Project personnel were able to be on Legs 2 and 3. However Julia Schmale managed to run sampling equipment at several sites.

10.7 Project 7

Study of Preindustrial-like Aerosol - Climate Effects (ACE -SPACE)

PI Julia Schmale (Switzerland)

Aims and objectives

Aerosol-cloud interactions are the least understood anthropogenic influence on climate change (IPCC, 2013.) A major cause of this limited understanding is the poorly quantified state of aerosols in the pristine preindustrial atmosphere, which defines the baseline against which anthropogenic effects are calculated. The Southern Ocean is one of the last regions on Earth with a pristine, and hence preindustrial-like, atmosphere. The uncertainty in aerosol induced radiative forcing (± 0.7 from a mean of -0.55 W/m^2) is twice the uncertainty for CO_2 (± 0.35, mean +1.68 W/m^2). Models also grossly underestimate cloud solar reflectance in this region, by as much as 30 W/m^2 in summer, probably due to the poor representation of aerosol-cloud interactions.

During ACE-SPACE the main objective is to characterise aerosol properties and their interactions with clouds. The main aims were to:

- Create enhanced understanding of aerosol properties, how trace gases modulate aerosol properties, and processes that are key to aerosol-cloud radiative forcing, including formation and growth of new particles and relevant chemical species, e.g., from marine emissions;
- Improve satellite retrieval over the Southern Ocean by linking in-situ cloud condensation and ice nuclei measurements through on-board remote sensing with cloud droplet number concentrations from satellite observations;
- Evaluate and constrain global climate model simulations using aerosol and cloud observations, and understand the implications for radiative forcing and related uncertainty.

The specific objectives on *Akademik Tryoshnikov* were:

- Determination of aerosol number concentrations, size distributions, and chemical composition (including bioaerosol) around Antarctica, north and south of the polar front, on the open ocean, and near islands;
- Investigation of aerosol-cloud interactions by means of online cloud condensation and ice nucleation measurements, collection of cloud water and offline filter analyses;
- Investigation of aerosol provenance, source apportionment, and new particle formation.

ACE-SPACE generated and retrieved data through three main activities:

- *In-situ* measurements on board the *Akademik Tryoshnikov*
- Use of remote sensing data from satellites
- Aerosol modelling

Methodology

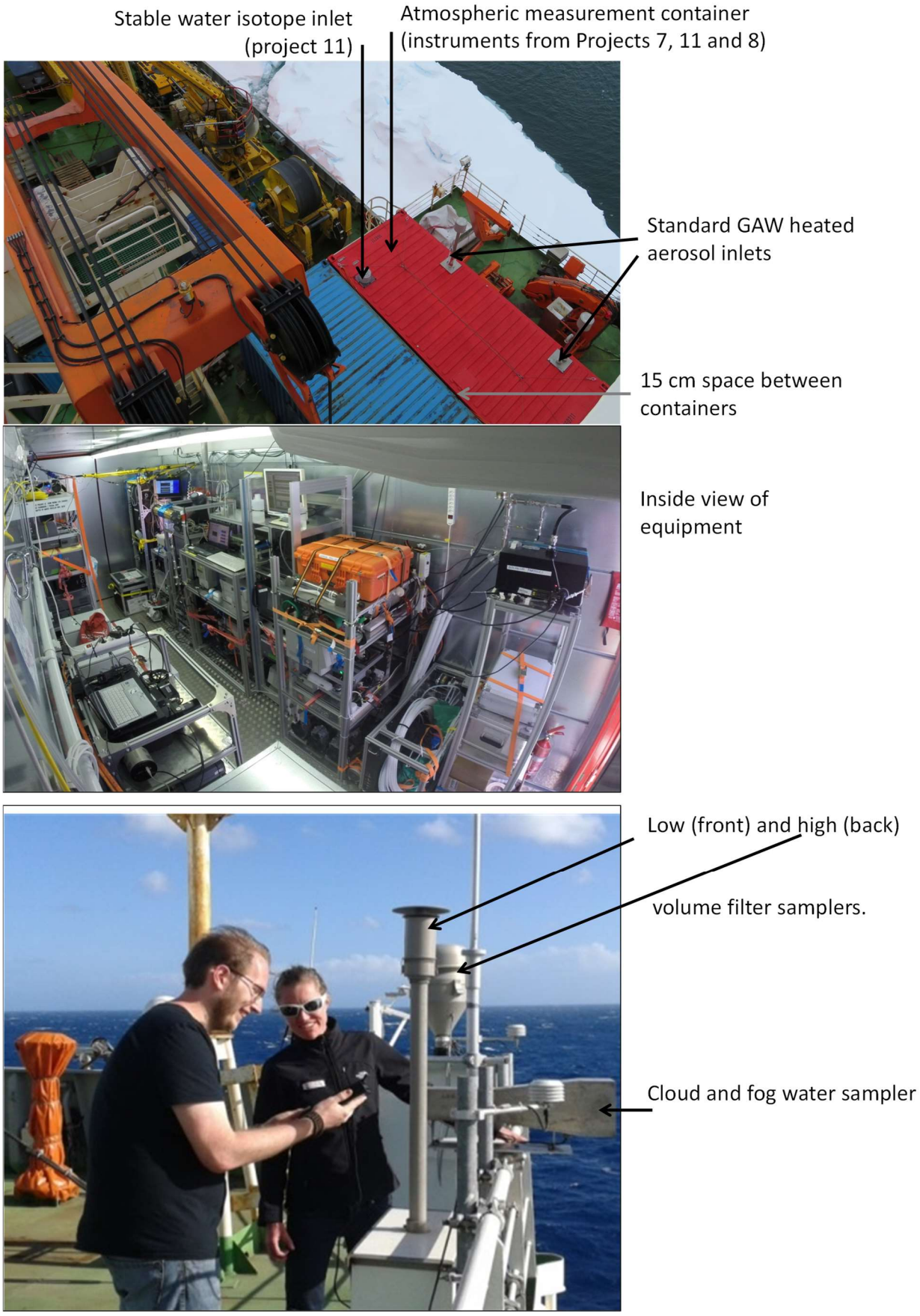


Figure 72: ACE-SPACE container location, interior and sampling methods.

Figure 73: Standard 20 foot container housing the laboratory with various air inlets.

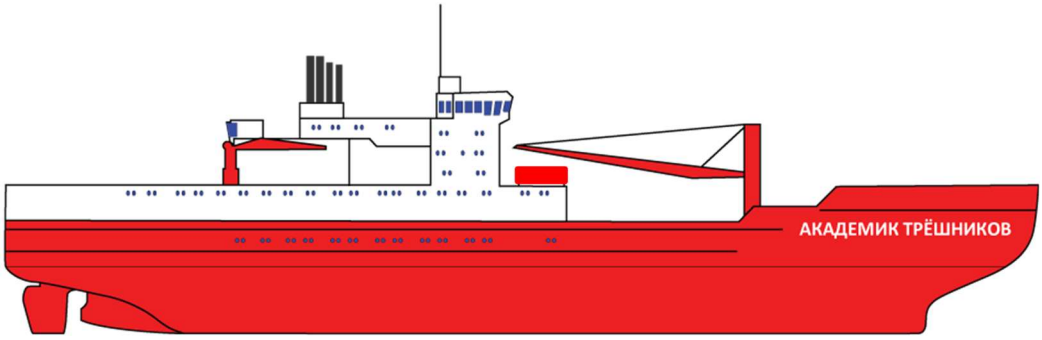


Figure 74: Position of the container on the ship, 2nd deck, starboard side, and the filter samplers on the upper deck. Drawing by D. Farinotti

Table 21 provides a list of all instruments, the variables they measure, and the measurement mode (continuous or discrete sampling). All continuously measuring instrumencts were placed in a laboratory container shown in Figure 76. The container (Figure 72; Figure 73) was designed especially for ship expeditions to accommodate specific needs, which include:

- an air-conditioned environment to keep ambient temperature at about 20 °C to avoid instrument overheating, condensation of water, or freezing of operating liquids (e.g. butanol)
- single phase 230 V power supply with secured circuits,
- an infrastructure that allows for fixing heavy instrument racks (up to 300 kg) to keep operating during storms and to keep instruments on shock mounts within the racks to keep turbo pumps and delicate circuit boards functioning despite the constant motion of the ship,
- an infrastructure that allows the mounting of sophisticated air inlets to continuously sample ambient air.

Three air inlets were used. Two of those are identical and follow the Global Atmosphere Watch (GAW) recommendation for aerosol inlets (GAW Report No. 227, 2nd Edition, 2016). The vertical extent of the inlets was 2 m, with 1.5 m reaching above the container roof. The third inlet consisted of a simple stainless-steel tube of 10 cm diameter with a 90-degree bend at the top end to prevent rain and waves from entering. The vertical extent above the container was about 1 m.

Figure 75: Position of container on the ship, close to a frame from which nets were deployed and a cargo crane.:

Table 21: List of instruments deployed, variables measured, measurement mode, calibration and Legs covered.

Nr.	Instrument name	Quantity	Measured Variable	Measurement mode / time resolution	Calibration information	Legs covered
1	Scanning mobility particle sizer (Paul Scherrer Institute, custom made)	2	Size distribution of particles in the range from 5-200 nm and 10-400 nm	Continuous / 5 minutes	Monthly calibration of size determination	1,2,3,4
2	Condensation Particle Counter (TSI models, 3772, 3010 and 3022)	2	Particle number concentration above 10 nm (3772), 20 nm (3010), 7 nm (3022)	Continuous / 10 seconds	Comparison among instruments every two weeks	1,2,3,4
3	Ozone monitor (2B)	1	Ozone mixing ratio	Continuous / 10 seconds	Calibration before and after expedition	1,2,3,4

4	PICARRO gas analyser (G2400)	1	Mixing ratios of CO_2, CO, CH_4, and water vapour	Continuous / 5 seconds	Calibration before and after expedition	1,2,3,4
5	Time-of-flight Aerosol chemical speciation monitor (Aerodyne)	1	Mass concentration of aerosol chemical constituents of submicron non-refractory particles including: chloride, organics, nitrate, ammonium, and sulphate	Continuous / 30 minutes	Calibration every two weeks	1,2,3,4
6	Wideband Integrated Bioparticle Spectrometer (WIBS-4, DMT)	1	Size distribution, shape and fluorescence of particles between 0.5-20 micrometer	Continuous / 1 second	Online calibration	1,2,3,4
7	Aethalometer (AE-33, Aerosol)	1	Black carbon concentration	Continuous / 1 second	Online calibration	1,2,3,4
8	Aerodynamic particle sizer (TSI, model 3321)	1	Size distribution of particles in the range of 0.5-20 micrometer	Continuous / 5 minutes	Calibration before and after the expedition	1,2,3,4
9	Online gas chromatograph (iDIRAC, custom built by Universities of Cambridge and Cranfield)	2	Measurement of isoprene and dimethylsulfide (DMS)	Continuous / 10 minutes	Online calibration with isoprene standard	Isoprene: 1,2, 3,4
10	Atmospheric pressure interface time-of-flight mass spectrometer (Api-TOF, Tofwerk)	1	Measurement of the chemical composition of ions and molecules in the air, operated as Api-TOF for ion observations, operated as chemical ionisation mass spectrometer with HNO_3 or with electrospray using $NaNO_3$ for non-charged compounds	Continuous / 10 minutes	Calibration before and after expedition	2,3,4

11	Neutral air ion spectrometer (NAIS)	1	Size distribution of ions, clusters and small particles	Continuous / 1 second	Calibration during data processing	2,3,4
12	Cloud condensation nuclei counter (CCNC-100, DMT)	1	Activation of aerosol particles at various supersaturations (polydisperse)	Continuous / 1 second	Calibration during data processing	1,2,3,4
13	Ice nuclei spectrometer (SPIN; DMT)	1	Size distribution and number concentration of ice nuclei	Semi-continuous / 1 second	Calibration during data processing	2,3,4
14	high volume filter sampler (Digitel)	2	Collection of total suspended particulate matter	24, 12, 8-hour filters depending on environmental conditions	Sampling stops when wind comes from ship exhaust direction	0,1,2,3,4
15	Cloud water sampler (TROPOS, custom built)	1	Collection of cloud and fog water	Every time the ship is in a cloud or in fog	Does not apply	0,1,2,3,4
16	Sun photometer (MICROTOPS) for the marine aerosol network	1	Aerosol optical depth	As often as possible when there are no clouds in front of the sun	Calibrated before the expedition	1,2,3

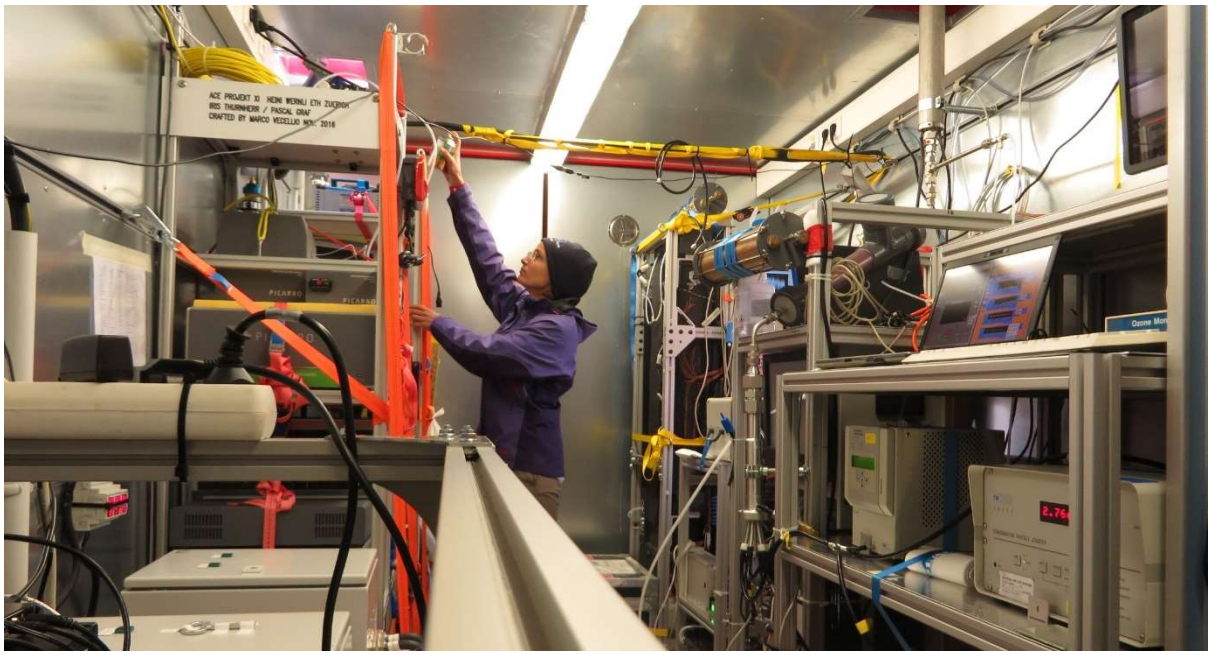


Figure 76: Set up of instruments inside the container.

The data will be processed according to community standards and best practice. All mass spectrometric data will be processed in Igor Pro (Wave Metrics), based on community data routines, and Tofwerk's Tofware. All other data will be processed in a range of programmes including e.g., Matlab and Python. For details, please contact the PI of the Project.

All digital data is saved in raw format on the expedition's servers. Once quality-assured and assessed data sets have been created they will be downloadable from the Swiss Polar Institute as well as other data bases (e.g., EBAS and GASSP) in easily readable data formats such as text files. Data will be provided as time series.

The data will be screened for contamination of the ship exhaust. For that purpose, the wind direction, particle number concentration fluctuations, the particle chemical composition (mainly black carbon) and trace gas concentrations of CO_2 and CO will be used.

Filter and water samples will be analysed after the expedition has finished. Analyses will be for ice nuclei number concentration and chemical compounds (organic carbon, elemental carbon, major ions, metals).

Those data will be made available in the same format and in the same locations as the real-time data. Sample events were recorded during the expedition and are available in the expedition event list.

Meta data of all time series will be provided with the final data products.

Problems encountered

The ship provides simple laboratory-like containers, which were not suitable for this Project's purposes as they had a limited power supply (16 A, 220 V), could not be modified to fix equipment to the ground or walls, and did not contain openings for air inlets.

The ship's power supply system offers either one phase 220 V or three phase 400 V. The three phase current does not have a neutral line because the ship's generator operates in delta formation. Accordingly, the plugs only have four pins. To operate suites of equipment that have high power consumption and consist of single phase consumers (this Project has e.g., 2 x 32 A at 400 V with about 20 consumers), we had purpose built transformers that provided three phase current, the ground and neutral line.

In terms of exhaust gas exposure, no area on the ship is continuously clean. The very front of the ship (helicopterdeck) might be used for small, rugged rather autonomous equipment but that cannot be accessed in bad weather. The container deck is a decent compromise. When the wind comes from the front the stack is downwind, but if it comes from the back or the back-port site (with the container being on the starboard site) it is likely that exhaust gas will be sampled if the wind speed is higher than the movement of the ship.

There is a crane directly next to the container position that occasionally operates above the containers. All instruments on container roofs including inlets might be in danger in those instances depending on the awareness of the crane operators.

Depending on wind speed and direction, a wind tunnel-like situation occurs on the container deck. Winds are channelled in between the containers and the ship superstructure. Doors in this corridor can easily be damaged and in high winds safe access is virtually impossible.

The position of our container was directly next to the ship's container with the smaller -20°C freezer. Every time the compressor for the cooling unit turned on, it generated a burst of particles which we see with the CPCs, NAIS, SMPS and Api-ToF.

Containers with double doors that need to be operated need to be placed with the double doors towards the ship, because there is not enough space for opening them on the other side.

There is inadequate chemical storage on the ship, adequate gas storage exists, but only in the fore peak locker which is inaccessible in bad weather. There is only one small oven for drying items (e.g., silica gel). The ship also did not provide any MilliQ quality water.

Preliminary results

We recorded full time series data sets for each instrument for the duration of their deployment (see Table 21). This means that for most variables a record around Antarctica and back to Northern Europe is available.

Roughly 50 % of the data are influenced by the ship's exhaust gas. This number will change depending on the region in which measurements were performed. During Leg 1 and 3 mostly westerly winds occurred between 40 and 60 °S, coming from behind, locating the measurements downwind of the stack. During Leg 2, easterly winds were more dominant near the Antarctic coast, placing the container upwind of the ship stack.

10.8 Project 8

Surveying Organic Reactive Gases and Particles Across the Surface Southern Ocean (SORPASSO)

PI Rafel Simo (Spain)

The oceans, that cover 70% of the Earth, influence climate in the long term by shaping biogeochemical cycles and in the short term by exchanging reactive gases and aerosol precursors. Current climate models are limited by existing knowledge of these ocean-atmosphere exchanges onto which anthropogenic forcing occurs. The Southern Ocean is itself an important player in the Earth climate system, and it is also an ideal region where to study ocean-atmosphere connections because distance from continent emissions and circumpolar atmospheric circulation make its air the most pristine.

Aims and Objectives

SORPASSO aims to carry out circumpolar measurements of surface ocean gases and particles important for atmospheric chemistry and climate, and their biological, chemical, hydrological and optical drivers. Satellite data and numerical modelling will be used a posteriori to extrapolate observations into regional understanding.

Methodology

1. Discrete samples from underway and CTD casts

Unless indicated otherwise, surface seawater samples were collected at a total of 76 stations: 14 CTD casts (Niskin bottles) and 40 underway samples (typically every 6 hours: 00:00, 06:00, 12:00, 18:00 (ship time)). In four of the CTD casts sampled, six different depths from the photic zone were analysed.

1.1. VOC (volatile organic compounds) concentrations in seawater:

The concentrations of several VOCs (dimethylsulphide, CSO, CS_2, CH_3I, CH_2I_2, CH_2ClI, Isoprene, $CHBr_3$ and CH_2Br_2) in seawater were measured with a purge and trap (Stratum, Tekmar Teledink) gas chromatography-mass spectrometry (5975-T LTM-GC/MSL, Agilent Technologies) system.

The sample water was taken from the Niskin bottles or the underway tap with glass bottles with glass caps, leaving no head space. Subsamples of 25 ml were taken and filtered through GF/F filters while introduced to the system. Duplicates were run. Standard solutions in methanol were used for calibration.

1.2. Particulate and dissolved methylamine (MA) concentrations in seawater:

For MAs, samples were collected only daily.

For the particulate MA, volumes (1.1 L x 3) were gravity filtered through 0.7 µm GF/F filters. Filter papers were stored at -80°C. Blank filter papers were also frozen periodically each time a fresh batch of filters was opened.

For the dissolved MA, the filtrate was acidified (pH 1) using concentrated HCl and prepared for preconcentration of MAs onto a PDMS fibre (Supelco) at 60°C for 2.5 hours before determination using a gas chromatograph (GC) (Agilent 6890 Series) fitted with a volamine column and NPD detector (Agilent, UK). Prior calibration of the GC was performed during Leg 0 using mixed MA standards made from commercially available hydrochlorides (Sigma Aldrich).

On one occasion, samples were taken in tandem from the underway and CTD cast at the same location for a cross comparison.

1.3. Dimethylsulphoniopropionate (DMSP) and acrylate concentrations in seawater:

Aliquots (15 ml) of seawater samples were heated to initial boiling in the microwave, 150 µl of 36% HCl was added and they were stored at room temperature. The samples will be analysed in Dr David Kieber's laboratory at the State University of New York, Syracuse. A total of 106 samples have been collected.

1.4. Nitrogen-containing osmolyte concentrations in seawater:

For N-osmolytes, 3 replicates of 50 ml and 3 replicates of 2 ml seawater volumes were syringe filtered through pre-washed 0.2 µm polycarbonate filters which were blotted dry and stored frozen at -80°C. The filters will be analysed post-cruise by High Performance Liquid Chromatography at Plymouth University / Plymouth Marine Laboratory (UK).

1.5. Light absorption of organic matter (CDOM) in seawater:

Coloured dissolved organic matter (CDOM) light absorption spectra of unfiltered seawater samples were obtained with the ship's UV- spectrophotometer (UV-1800, Shimadzu). Analyses were run in duplicates, along with blanks of MilliQ water.

1.6. Iodide and Iodate concentrations in seawater:

Aliquots (15 ml) of seawater samples were collected in plastic tubes and stored frozen at -20°C. Analysis of iodide and iodate will be conducted at the IQFR-CSIC, Madrid.

1.7. Transparent Exopolymeric Particles (TEPs) and Coomasie Stainable Particles (CSPs) in seawater:

Seawater samples (2 l) were filtered in 250-ml aliquots through a 0.4 µm polycarbonate filter. Then, 0.5 ml of Alcian Blue Working Solution were added to two of the filters and two blanks, and they were stored in 2 ml cryovials at -20°C. The other two aliquot filters and two blanks were treated with 0.5 ml of Coomasie Working Solution and equally stored.

We additionally filtered, stained and froze smaller aliquots (50 ml) every third day (approximately) for TEP and CSP characterisation by microscopy.

1.8. Numbers of bacteria and pico-, nano- and microalgae in seawater by Flow Cytometry:

Seawater samples were also aliquoted in cryovials to count the microorganisms. Duplicates of 4.5 ml plus another replicate of 1.8 ml were killed by addition of 1% paraformaldehyde plus 0.05% glutaraldehyde (final concentrations), and stored at -80°C.

In the lab on land, samples were thawed and analysed with a PARTEC Cube 8 flow cytometer equipped with a laser emitting at 488 nm.

For pico- and nanoplankton abundance, thawed samples were added 10 µl per 2000 µl sample of a 105 ml-1 solution of yellowgreen 0.92 µm Polysciences latex beads as an internal standard. Samples were then run at high speed (approximately 75 µl min^{-1}) for 4-10 minutes with Milli-Q water as a sheath fluid. Five-six groups of phytoplankton (*Prochlorococcus* spp., *Synechococcus* spp., picoeukaryotic, nanoeukaryotic amd microeukaryotic algae, and cryptophytes) were distinguished and enumerated on the basis of the differences in autofluorescence and light scattering characteristics.

For Bacterial abundance, thawed samples were stained with SYBRGreen I (Molecular Probes) at a final concentration of 10 µM and left in the dark for about 15 minutes. Samples were run at a low flow rate (approximately 15 µl min^{-1}) for 2-4 minutes with Milli-Q water as a sheath fluid. We added 10 µL per sample of a solution of yellow-green 0.92 µm Polysciences latex beads (105 beads ml^{-1}) as an internal standard. Bacteria were detected by their signature in a plot of side scatter versus green fluorescence. Bacteria were enumerated separately as high-nucleic-acid-containing (HNA) and low-nucleic-acid-containing cells (LNA), and the bacteria counts presented are the sum of these two types.

1.9. Samples for bacterial cultures and single amplified genomes (SAGs):

From a few of the casts, 50 ml samples were taken at four depths, typically 5 m, Deep Fluorescence Maximum, mesopelagic and deep (1000 m). Samples were prefiltered through a 200 um mesh. For bacterial cultures, triplicate aliquots of 1ml were fixed by adding 75 µl of DMSO Working Solution, and stored in cryovials at -80°C. For SAGs, triplicate aliquots of 1 ml were fixed by adding 143 µl of Betaine Working Solution, and stored in cryovials at -80°C. Analyses will be conducted at the ICM-CSIC.

2. Continuous underway measurements: Instruments and parameters.

2.1. ECO Triplet Sensors

The ECO Triplet sensors provide a continuous record of the following parameters: chlorophyll fluorescence (phytoplankton), phycoerythrin fluorescence (cryptophytes), backscattering of particles at 470 nm, 535 nm and 650 nm (amount of particles and clues to size distribution), and organic matter fluorescence. Time resolution is one second.

During the first ten days of Leg 1 some problems were detected when restarting the pump, since a flush of black rusty particles arrived in the instruments. Therefore, they had to be properly cleaned repeatedly. However, from 1-17 January 2017 the pump did not stop, thus there was no need to restart it and we have not found a significant concentration of particles that could have threatened the quality of our measurements. We also had to set up a debubbler in order to avoid the bubble flushes produced by the pump when big waves hit the vessel.

During the call in Hobart, we slightly modified the setup of the two bio-optical ECO Triplet sensors that were placed in one of the sinks of the CTD wet lab (Figure 77). We replaced the hand-made debubbler with a commercial one, and changed part of the tubing positions. Flow rates were adjusted to around 3 l/min for the sensors flow, and 10 l/min for the sampling flow.

No major problems with the sensors were encountered during Leg 3. The continuous chlorophyll fluorescence data, displayed on the screen at the CTD wet lab, has proved very helpful to make decisions on CTD cast positions. The backscatter sensors served as a warning system for the presence of krill swarms near the surface.

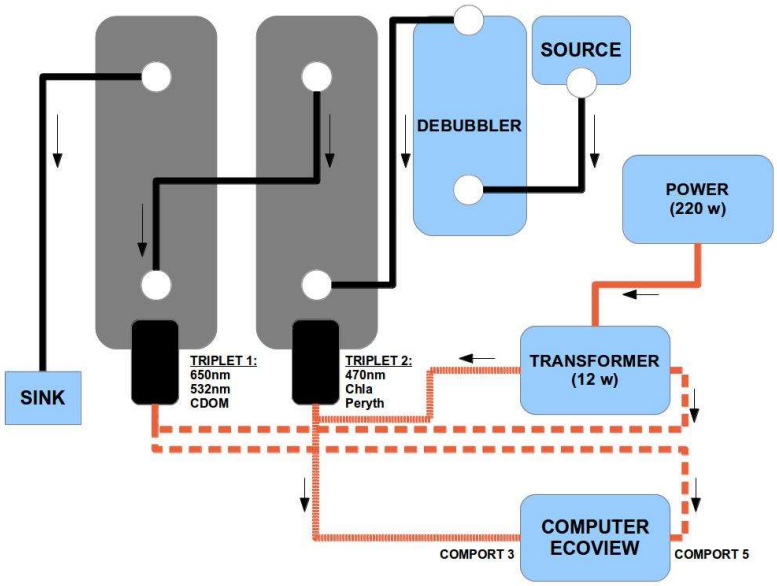


Figure 77: Set up of the ECO Triplet Bio-optical sensors in the CTD room.

3. Atmospheric samples and measurements

3.1. VOCs in the atmosphere

Air samples were collected daily (or less) for airborne VOC concentrations. 3 L of air were withdrawn by a small portable pump, and VOCs were trapped in Carbotrap adsorption cartridges, which were then sealed and stored in the fridge (4°C). A total of 12 samples were taken. Analysis will be conducted by thermal desorption gas chromatography-mass spectrometry at IDAEA-CSIC, Barcelona.

3.2. Reactive halogens in the atmosphere

A MAXDOAS spectrograph, installed in the atmospheric container, continuously recorded halogen profiles in the troposphere. Time resolution is five minutes. The data analysis will be conducted at the IQFR-CSIC, Madrid. After the problems during Leg 2, a new GPS was sent by our colleagues from the IQFR-CSIC and the problem was fixed at Punta Arenas. During Leg 3 the system reported problems with several COM ports that stopped the measurements during some periods.

4. Preliminary results

Trace gases: We made some of the first measurements of methylamines, isoprene, OCS and CS_2 concentrations in the Southern Ocean, and added to the existing datasets of DMS and halomethanes. Trimethylamine (TMA) was the main amine detected in the dissolved phase; dimethylamine and monomethylamine were detected only rarely. The predominance of TMA in Southern Ocean samples during ACE is consistent with a previous cruise (PEGASO) in the Antarctic region, where all amines were detected but TMA was most frequently measured and the most abundant of the methyamines. Note that methylamines are, together with DMS and isoprene, important contributors to aerosol formation and growth.

Overall across the Southern Ocean, trace gases occurred typically at rather low concentrations: DMS 0.5-2 nM, isoprene and $CHBr_3$ 2-10 pM, iodomethanes <5 pM. Within this seascape of generally low trace gas concentrations, some hotspots stood out as high emission loci, generally associated with island-influenced waters and coastal polynyas of high biological productivity. In the case of volatiles that act as scents for animal foraging, like DMS, it makes sense that strong emission gradients occur to help orient foraging behaviour.

Organic particles: We sampled for Transparent Exopolymeric Particles (TEP, mostly polysaccharides) and Coomasie Stained Particles (CSP, proteinaceous) as potential contributors to organic aerosols. In the case of the proteinaceous particles, these are the first-ever measurements in the Southern Ocean. We also sampled what will be the first measurements of algal N-osmolytes (glycine betaine, choline and TMAO) in the region.

TEP distribution roughly parallels that of chlorophyll *a*, which is consistent with the role of phytoplankton as the main TEP source, yet the two variables did not co-vary with strong proportionality. CSP show some correlation with pigment markers of phytoplankton mortality.

Figure 78: The air-sea interface across which ocean and atmosphere exchange reactive substances.

Figure 79: Rafel Simó sampling airborne volatiles on the bow.

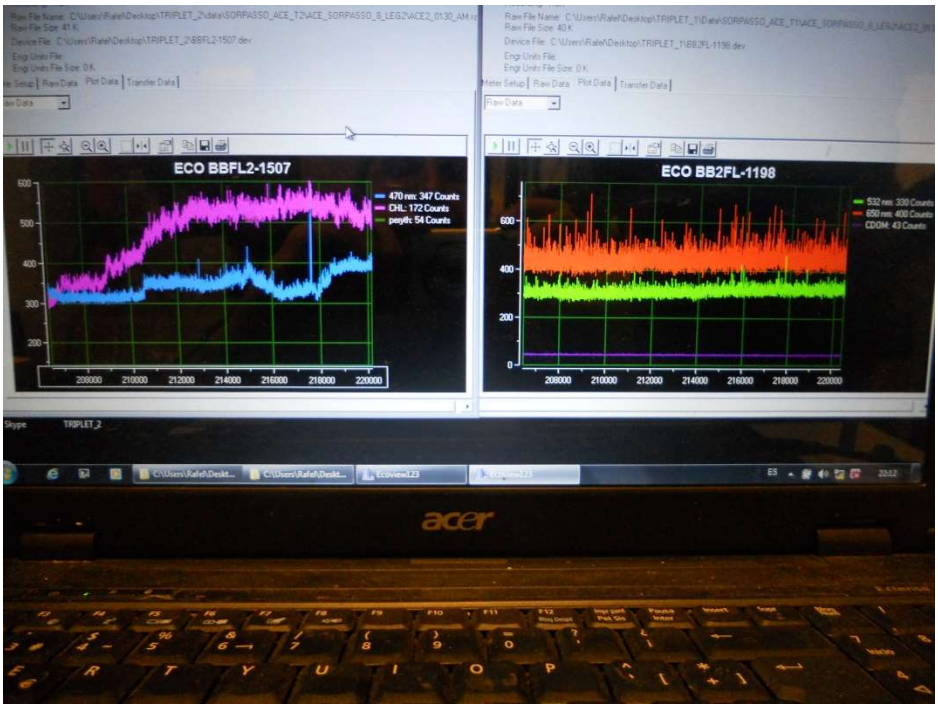


Figure 80: Continuous record of phytoplankton fluorescence and particle concentrations.

Figure 81: Holly Pearson and Marina Zamanillo in the air-sea exchange lab.

10.9 Project 9

Southern Ocean westerly winds and the global CO_2 sink

PI Dominic Hodgson (UK)

Climate changes have been attributed to the increasing concentrations of greenhouse gases (e.g. CO_2) in our atmosphere. These measured increases in atmospheric CO_2 are partly controlled by changes in the ability of the world's oceans to absorb CO_2 at the surface (e.g. via diffusion and the biological pump) versus release of old carbon to the atmosphere from deep ocean reservoirs (e.g. via upwelling and out gassing).

More than one quarter of the CO_2 emitted to the atmosphere from human activities is absorbed by the world's oceans, substantially slowing the rate of climate change. Of the oceans, the Southern Ocean plays a major role accounting for 43% of the global oceanic uptake of anthropogenic CO_2.

Changes in the strength of the Southern Hemisphere Westerly Winds (SHW) influence Southern Ocean circulation and control how much carbon rich deep water reaches the ocean surface. This determines whether the Southern Ocean acts as a net source or sink of atmospheric CO_2. We can reconstruct past (decadal to millennial) changes in the SHW by generating records of wind-driven aerosols and other proxies in sediment records from lakes and bogs on the west coasts of sub-Antarctic islands in the core belt of the SHW.

Aims and Objectives

To determine whether the Southern Ocean acts as a net source or sink of atmospheric CO_2 by developing robust palaeoclimate records of Holocene westerly wind behaviour from the subantarctic islands.

ACE provided a unique opportunity to extend our research; increasing the spatial and temporal coverage to key sites not typically visited by national programmes. The application of common methodologies by our international team will help build a more complete understanding of the SHW in different ocean sectors and determine how they modulate the oceanic uptake of CO_2 over millennial timescales.

Leg 1

Field sampling aims: Collection of lake and peat sediment cores and ecological and geochemical reference samples from selected sites on the west coasts of Marion, Crozet, Kerguelen, and Heard Island.

a) Marion Island

The field team was deployed to the Puisie area, a small peninsula situated between Crawford Bay and the Blackrocks Plateau. It rises to a height of 73 m and is very exposed to the westerly winds, which could be seen generating abundant plumes of sea spray at nearby Cape Hooker. It has the advantage of being outside of the main volcanic plume which periodically deposits tephra across the eastern part of Marion Island such as the Albatross Lakes area and near the base. A brief survey of peat depths on the saltspray influenced coastal herbfield showed the thicker deposits (1.5 m) were towards the coast where burrowing petrels were nesting at the cliff tops. Peats in depressions and channels / drainage line mires were often underlain by water and so coring sites were selected on the small-scale ridges and rises to avoid these saturated deposits. Three core sites were selected for triplicate sampling.

b) Île de la Possession, Crozet Archipelago

Objectives on Île de la Possession were to sample sea spay impacted lakes that have been previously identified in three areas from their elevated conductivity. These are Pointe Basse (46°21'26.09"S, 51°42'15.29"E), Le Jardin Japonais and (46°21'58.23"S, 51°41'51.64"E) and Lac Coeur. We also planned to

sample adjacent peatlands including the deep peat deposits revealed by the river channel in the vicinity of Pointe Basse and a raised bog at 46°22'31.30"S, 51°41'06.42"E, 2 km away.

The intention was to use the helicopter landing pad and shelter at Les Cabanes de Pointe Basse and sample from there. Although the permit application for this was submitted in June 2016, the permits were only issued a few hours before arriving at Île de la Possession. These apparently stated that access to the sites was permitted only if field parties were landed near the centre of the island and walked the rest of the way to Pointe Basse. No reason for not using the helipad was provided to the field team. As the alternative landing site would have required 2 x 4 hours of shuttling our equipment it was immediately apparent that the sampling was not possible within the allocated time.

We therefore proposed an alternative site at Lac Coeur which is also impacted by sea spray, and has both shelter and a helicopter landing site at the La Perouse Hut which is within around 0.5 km. Access to this site was also denied because it was not included in our original permit application (our original alternate was Lac Perdu 46°26'31.51"S, 51°45'15.46"E which we subsequently rejected due to its low conductivity). Thus by making access to the first site impractical and not permitting an alternative we were prevented from achieving our objectives on Île de la Possession. The weather also played a part with poor flying and boating conditions occurring during parts of both days of our visit.

Two days were allocated for terrestrial sampling. On the first day the weather was too poor for flying operations. Some boats were deployed to the beach at Baie Américaine, but by mid-day high winds made it unsafe for boating operations and our team was not landed. On day two, half a day was allocated for field sampling before moving the ship offshore for dredging operations. Wind and visibility initially prevented flying so the field team deployed by Zodiac to Baie Americaine and the Vallée de Branloires to collect samples for the reference data sets. Due to a combination of the weather and permit restrictions imposed by the French authorities none of the sea spray impacted lakes were sampled.

c) Îles Kerguelen

Two days were allocated for terrestrial sampling at Iles Kerguelen. Poor weather (high winds) impacted on both the boating and flying schedules. Our first objective was to visit Presqu'Île Jeanne D'Arc and sample the lake at Mt Tizard 49°42'4.51"S, 70° 2'2.60"E but deteriorating weather prevented access to this site. The second site was the Peninsule Courbet, specifically the Côte des Gorfous Dorés, 49° 9'3.74"S, 70°13'36.19"E which has a west facing coastline and an emergency shelter at Cataractes caboose. This site was accessible by helicopter because the approach from the Port aux Français avoided the turbulence associated with mountainous terrain elsewhere. Two domed ombotrophic peat bogs were selected for triplicate sampling with some very promising 2-3 m peat sequences being retrieved from sea-spray impacted sites. Two domed ombotrophic peat bogs were found between the cabin and the beach and were sampled with triplicate Russian cores over a period of five hours in the field.

Figure 82: Map showing sampling area of Courbet Peninsula on Iles Kerguelen

Figure 83: 2.5 m of peat core, recovering approximately 11'000 years of material was extracted from the Côte des Gorfous Dorés, on the Courbet Peninsula, Ile Kerguelen

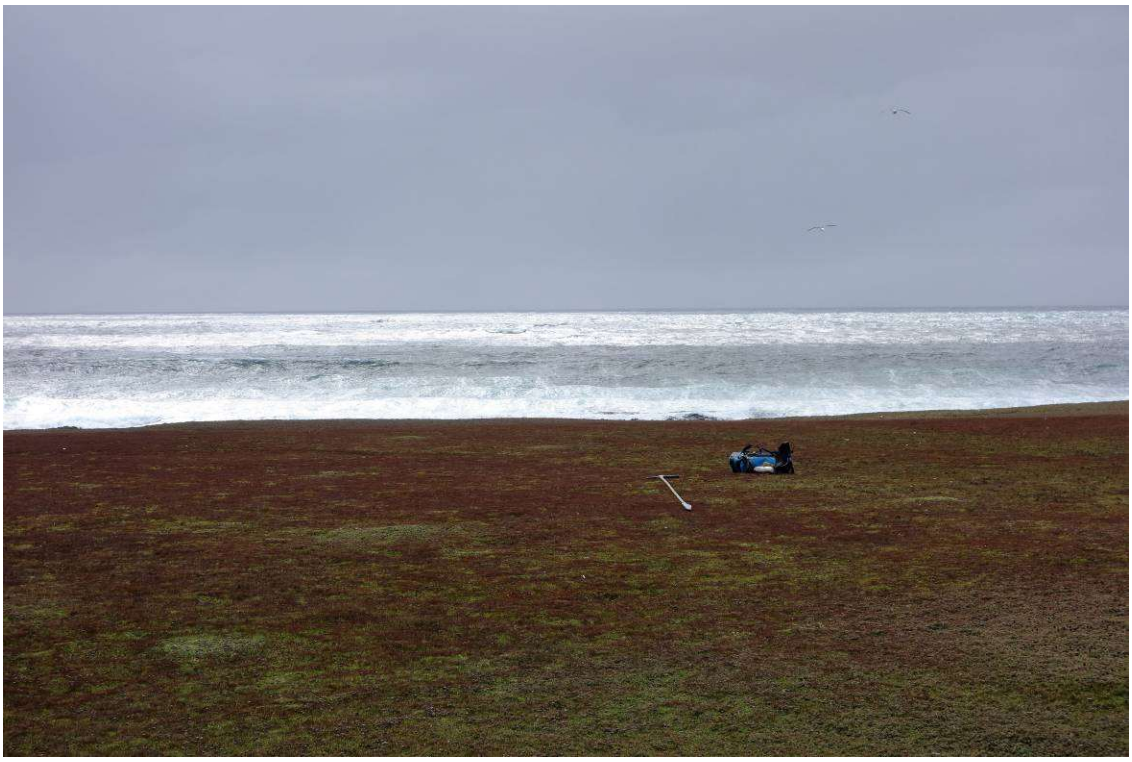


Figure 84: The second "Cataractes" coring site on the Courbet Peninsula, Ile Kerguelen

d) Heard Island

The expedition vessel was denied a permit to visit the territory of Heard and McDonald Islands, which is Australian territory. The ship passed the island in excellent weather and was afforded views of most of the island including the summit of Big Ben, which was emitting steam from its crater. For future reference the sites identified for studying the westerly winds are listed below:

Southwest Bay

- Cape Gazert (deep Azorella bank) – helicopter access only
- Pageos Moraine 53.02°S, 73.22°E (coastal Azorella and moss peats, similar habitat to the 2 m deep peats descried from Dovers Moraine in the east) – Access on foot via boat (Atlas Cove) or by Helicopter - Emergency shelter at Atlas Cove Hut (3 km from sampling site)
- Dover's Moraine / Spit Bay was chosen as a back up site for poor weather, but is not exposed to the westerly winds.

The aims at these sites were to sample monoliths from closed cushion carpet – see Bergstrom classification of Heard Island vegetation, and to collect surface sample transects for diatoms and testate amoebae.

Other comments: First, as with all work in the sub Antarctic the weather played a major role in determining access to our target sites. Future expeditions could reduce this risk by allocating more time for island visits, increasing the opportunity for favourable weather windows. Second, in some cases the late approval of permits created uncertainty within the teams and gave them little time or opportunity to open a dialogue to overcome practical considerations relating to site access.

Leg2

a) Macquarie Island:

Due to bad weather (storm), Australia Day the day after our estimated day of arrival, and tourist boats the day before and after (making impossible for the station people to help us), the stop to Macquarie Island was simply cancelled. It is unfortunate that certain factors such as Australian Day or tourist ships were not pointed out at the time of application by the authorities so that changes might have been considered in the schedule. It is certainly a substantial loss for our Project since Macquarie Island was the only island relatively close to Australia and within the westerly wind belt.

We collected cores of 2.55 m (HP1, upper terrace) and 1.37 m depth (HP2, lower terrace) in 2013.

HP1 -54.49769584 158.9002432

HP2 -54.49703082 158.8995446

Figure 85: North Head / Wireless Hill on Macquarie Island showing the relatively flat top which should be surveyed for peat deposits

b) Balleny Islands:

This small group of islands is very sparsely vegetated. Access is difficult and therefore we have asked PI Steven Chown's group to sample any moss banks into monoliths to meet the requirements of our Project. Unfortunately, while an attempt was made to put people ashore on the only safe beach (the others are under massive glacier tongues that break permanently), the zodiacs could not land safely due to rough weather condition. The beach parties therefore came back to boat without landing.

Figure 86: Balleny Islands

c) Scott Island

F. De Vleeschouwer and M. Stevens were able to land on Scott Island by helicopter. The bad weather conditions and late arrival allowed only 45 minutes of fieldwork that gave them 6 proto-soil samples with small mosses growing on them (AT/ACE/2/9/37/1581/DH/SC-17-xx). Those soils where developed in basaltic rock cracks sheltered from the wind. A subsample from these will be stored for our Project (for E. Pinseel's analyses). Details on the samples can be found on M. Stevens' separate Excel sheet.

Figure 87: Scott Island viewed upon our arrival.

Figure 88: An example of the proto-soils and mosses from Scott Island.

d) Mount Siple area

The cruise was diverted towards Mount Siple area because we were told that the pack ice was too thick around Peter I Island. We were offered the choice between gambling for Peter I Island or going straight to Mount Siple area which was, exceptionally, ice-free this year. This second choice was adopted unanimously during the PI meeting.

F. De Vleeschouwer and L. Gandois had the opportunity to visit Maher and Lauff (sometimes misspelled "Loft" on sample labels and files) Islands, two rather small rocks partly covered with snow at the Northern edge of Mount Siple. On Maher Island, a short West (inland) – East (sea) transect of 500 m was performed collecting soils, sometimes with algae and penguin inputs for Eveline Pinseel (AT/ACE/2/9/41/1560/DH/MAHER xx). As Lauff Island was pretty much covered by snow with no real soil development, only 3 proto-soil samples were randomly taken where they could be found in basaltic rock cracks (AT/ACE/2/9/41/1564/DH/LOFT xx). The next day, F. De Vleeschouwer joined M. Stevens and I. Hogg to visit an ice-free area on the SW of Mount Siple. This area, which was much larger than the two previous island, and home of a rather important Adélie penguin colony, making it difficult to access any undisturbed material. Nevertheless, one soil sample with penguin inputs was collected at the Eastern ridge of the ice-free area. Three moss samples were also collected (one at the same location as the soil, and two at the Western ridge of the area). All these samples have been subsampled into three (A, B, C) parts, two of which have been frozen (A, B) and one kept in the cold room. In addition, M. Stevens and I. Hogg will also provide us with the remainder of the 13 samples which their group collected at the three islands.

Figure 89: Moss outcropping at the Western ridge of the ice-free area on the SW of Mount Siple.

Coordinates for the 4 samples on Mount Siple (AT/ACE/2/9/42/1581/DH/SIPLE xx)

Siple 1: S73.54043°, W127.44500°, 161m a.s.l.

Siple 2: same as Siple 1

Siple 3: S73.54088°, W127.4221°, 165m s.s.l.

Siple 4: same as Siple 3

e) Peter I Island

Two soil and moss samples were collected by M. Stevens and I. Hogg during a 10-minute beach landing over the four-hour stop-over at Peter I Island in very heavy ice.

f) Diego Ramírez Islands

After a short reconnaissance flight, it appeared evident that there was only one patch of peatland, a cushion grass peatland on the top of the plateau behind the weather station on Gonzalo Island. The rest of the islands are covered by tussock grasses (Poaceae family) that grows as singular plants in hummocks, or bunches, as well as millions of birds and their nests. This is not suitable for the formation of stratigraphic peat deposits.

The peatland was not deep and had a small South (top) to North (bottom) slope. It was around 100 m by 50 m. The maximum depth at the lower side was just one metre. The middle and top parts were a bit less than 50 cm deep. Together with D. Berliner and W. Moutier, F. De Vleeschouwer and L. Gandois we took several cores with full overlaps as well as a wardenaar core at the bottom of the peatland. Furthermore, we cored a single 50 cm core in the middle of the peatland and three 50 cm cores at the top. Most of the cores have quite a lot of mineral material, up to spall gravels. Likely, these were blown in by wind, brought by birds, or carried from the rocks above during heavy rain.

Five surface samples on a West-East transect were taken on the peatland for Eveline Pinseel. These were subsampled into 3 (A, B for freezer and C for fridge). We did not go on the slope because it was very steep, slippery and covered by tussocks and birds nests everywhere. Additional samples will come from the other island (Bartolomé) collected by Project 2. Nathalie van der Putten will subsample them once ready on Leg 3.

Figure 90: Isla Gonzalo showing the Chilean Meteorological Station and the access path to the top of the ridge.

Leg 3

a) South Georgia

The main west facing site that we applied to visit is Rogged Bay, 54°52'14.53"S, 36° 7'30.36"W. The weather on the third day at the island was very poor. The ship was able to get to the area off Drygalski Fjord but the wind conditions were too difficult as well as a high swell stopping flying operations. Landing by zodiac was considered but the Captain would not go in close on the south side of the island due to a lack of bathymetric information and the Chief Scientist ruled out a two hour zodiac trip in deteriorating weather.

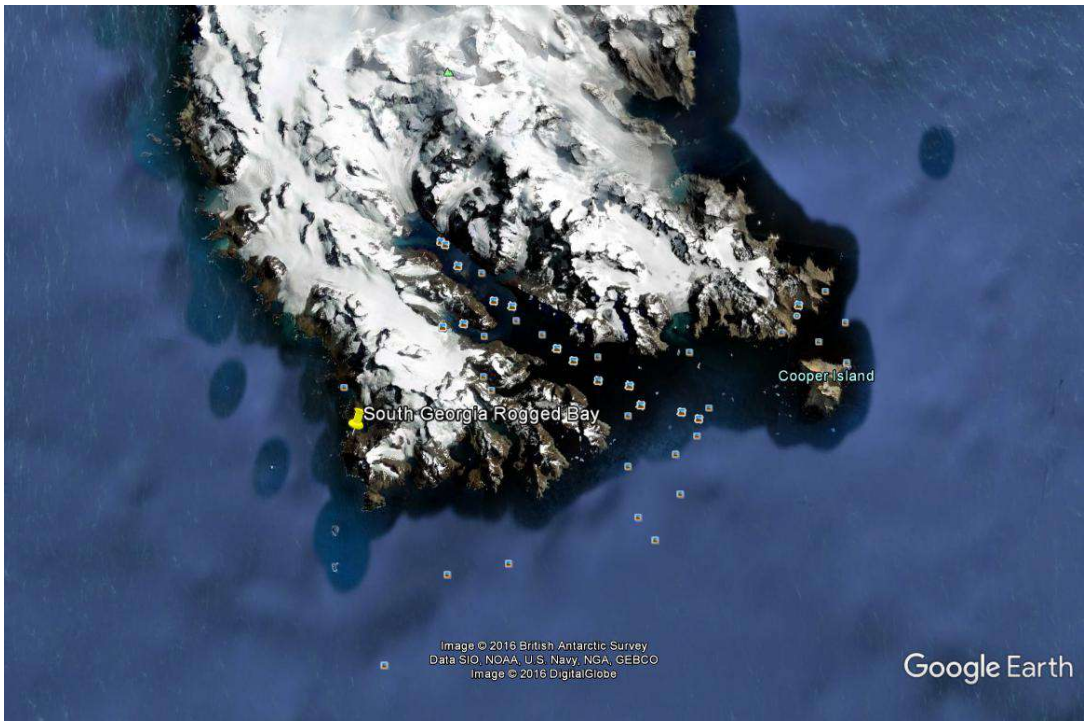


Figure 91: Satellite image of Rugged Bay sampling site on South Georgia (Image: Google Earth).

Figure 92: Satellite image of Rugged Bay sampling site on South Georgia (Image: Google Earth).

Arrival at South Georgia (SG), Grytviken Thursday 02 March 2017 in the morning. After the formalities necessary to get the permission to work on the island, all expedition members went on land. No sampling was done by Project 9. The weather was very good during the complete day but going to Rogged Bay (or Stromness) before Grytviken was not an option because of the necessary formalities. The weather deteriorated in the evening. Rogged Bay was cancelled definitively as weather predictions for the coming two days would not allow landing with Zodiacs. As a backup I suggested resampling the moss peat bank at

Kanin Point in Husvik Harbour (Van der Putten et al., 2009). The ship headed to Stromness Bay during the night and anchored in Stromness Harbour around 08:00 on the 03 March 2017. The wind was so strong that the ship dragged its anchor and left Stromness Harbour. No attempt to land on the island was made during that day. On the 04 March 2017 St. Andrews Bay was planned. A potential site was found in the paper of Lewis-Smith (1981), in Hound Bay, north of St. Andrews Bay (Figure 93). An attempt to land on the southern side of the peninsula between the two bays in order to be close to the sampling site was planned. However, in the morning of the 4th visibility was too bad because of falling snow to risk landing elsewhere than the beach of St. Andrews Bay. We went on land for 1.5 hours. We did not expect to find peat deposits in St. Andrews Bay (out-wash plain). Moreover, because of the snow cover, it was difficult to see the landscape/vegetation. No sampling was done.

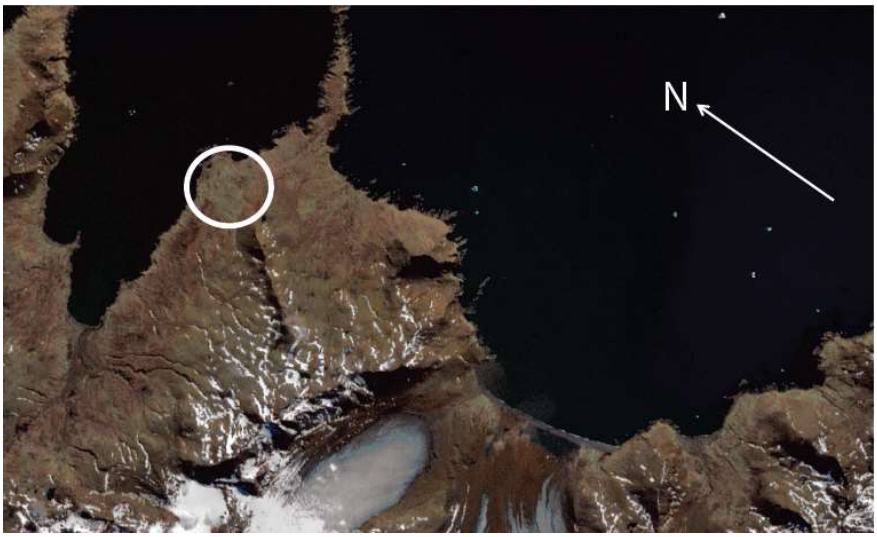


Figure 93: Landsat of St.Andrews and Hound Bay (South Georgia) with the potential sampling site marked.

b) Bouvetøya

This island is mainly covered by snow and ice and very sparsely vegetated in just a few small areas. All vegetation occurs on steep and unstable cliffs and access is extremely difficult. We arrived at the island on Saturday the 11 March 2017, late afternoon. Sampling was on the 12 March 2017 at Rustadkollen on the south-west coast of the island (54° 27’ S, 3° 19’ E, 216 m asl, Figure 94) in collaboration with Catherine Moon, Elisabeth Biersma and Felipe Lorenz Simoens (Project 2). Moseryggen, known to have a 15 cm thick peat deposit (Engelskjøn, 1987), was too difficult/dangerous for landing with the helicopter. The time for sampling was around 25 minutes (the helicopter stayed on the site) so there was unfortunately no time for prospecting the area. A moss carpet was sampled: three approximately 10x10 cm samples were cut out reaching the gravel (Site A 1-3; Figure 95). The thickness is about 5-8 cm. A second moss carpet was sampled by cutting out one 10x10 cm sample as there was no time to take more samples (Site B). On both sites a smaller surface sample was taken for diatoms for Eveline Pinseel (Ghent University, Belgium).

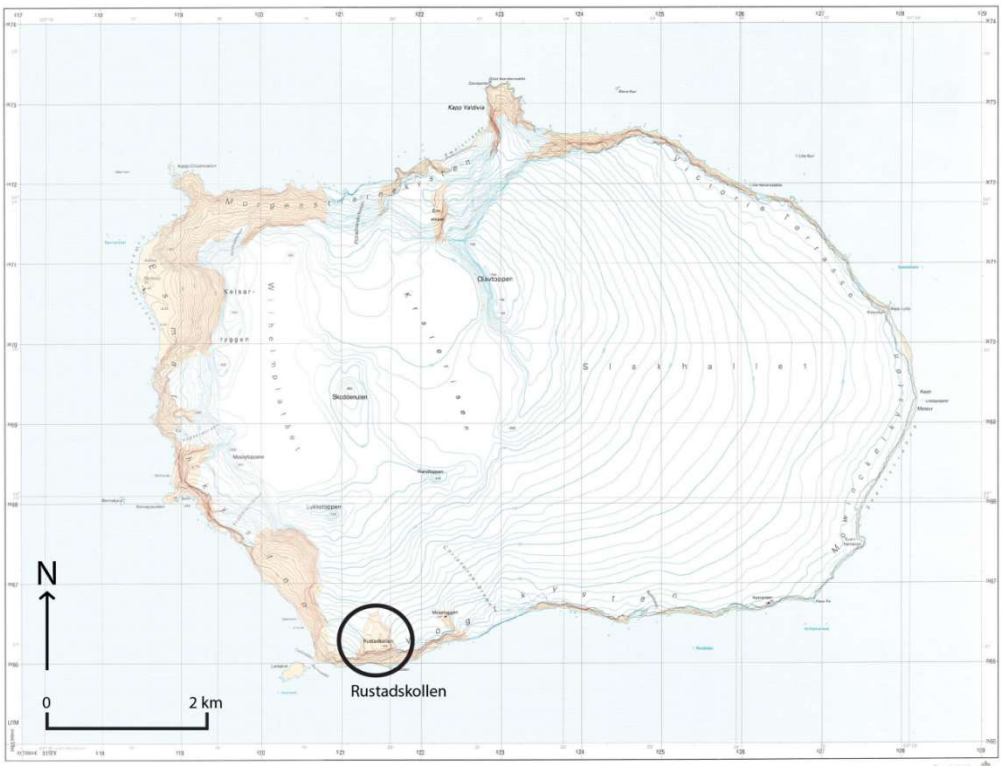


Figure 94: Map of Bouvetøya (Norsk Polar Institute, 1986) with the sampling site marked with the circle.

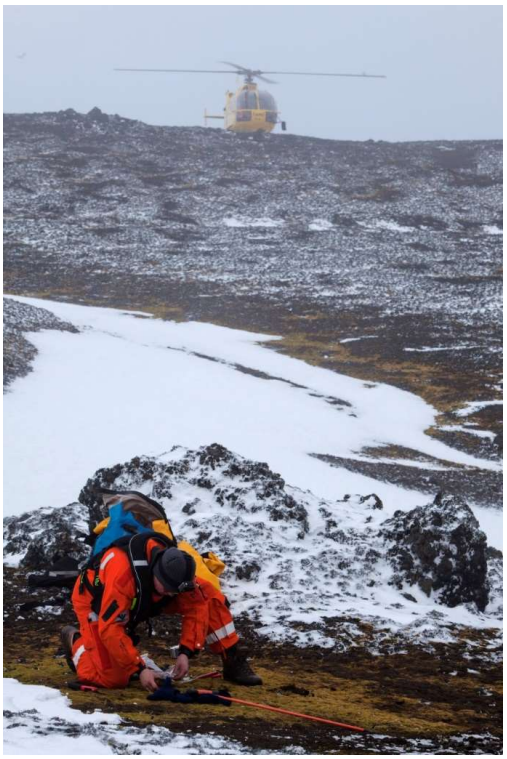


Figure 95: Sampling of the Site A moss carpet, Rustadkollen, Bouvetøya.

CASS-126. South Georgia / Bird Island sampling

Angela GaLego-Sala and Alex Whittle will visit Bird Island under separate funding arrangements.

Aim to fully survey the ‘meadow’ peatlands and extract triplicate peat cores from most promising sites down to bedrock. Multiple cores from each key site – plus a master core for ^{14}C.

Repeat lake conductivity – after rainfall does lake salinity increase or decrease (latter indicating dilution)?

Surface sample top 2 mm for wider regional transfer function.

10.10 Project 10

Testing the diversity of marine refugia at sub-Antarctic Islands

PI Nerida Wilson (Australia)

The sub-Antarctic environment is commonly thought to host a recently colonized postglacial community. During the Last Glacial Maximum (LGM), glaciation, sea ice extent and persistent ice scour are thought to have heavily impacted the sub-Antarctic marine fauna. The idea has been corroborated for marine taxa by genetic studies that indicate post LGM re-colonisation of eradicated marine kelp (Fraser et al., 2009). However, in other marine invertebrate groups like crinoids, genetic studies have also revealed that some sub-Antarctic areas (eg. Kerguelen) acted as long-term refugia (Hemery et al., 2012).

Aims and objectives

Our Project used a diversity of techniques to investigate whether sub-Antarctic areas have acted as glacial refugia for marine taxa. These approaches include genetics, metabolomics and comparative biology to compare both sub- and continental Antarctic areas. We are looking to understand whether the sub-Antarctic hosts diverse or distinct populations in relation to genetic profiles, natural products chemistry, or evolutionary changes in host-parasite interactions. This Project will build on data already collected from Antarctica, and international collaborations across four countries (Australia, Chile, Italy, USA). We tried to collect benthic organisms from as many sites as possible to provide spatial context to evolutionary scenarios. This will ensure that this work builds a baseline for future change. All accessioned samples will be securely maintained and available in museum collections.

Sampling methodology

See Project 3 for technical details of trawl equipment and deployment protocols, as Projects 3 and 10 shared trawl deployments. Planned sharing involved alternate trawls to each team, but since many of these deployments were cancelled, shared trawl catches also occurred.

Total trawl events

Note that several trawls that were failures are noted here as 'success' since they may have contained a few individual samples that were retained.

Table 22 list of all trawling events carried out by project 10 during ACE. If the trawl was deployed, it was considered to have an outcome of "success", however if it was planned and then cancelled, or an event number was assigned by mistake, it was deemed "invalid".

Leg	Station number	Event number	Date & time (UTC)	Start latitude (dec degs N)	Start longitude (dec degs E)	End latitude (dec degs N)	End longitude (dec degs E)	Outcome
1	5	59	None	None	None	None	None	Invalid
1	5	58	None	None	None	None	None	Invalid
1	5	57	2016-12-28 13:23:01	-46.7168	37.8948	-46.7181	37.7723	Success
1	5	56	2016-12-28 12:30:40	-46.719	37.8944	-46.7171	37.895	Success
1	5	55	2016-12-28 11:49:00	-46.7176	37.9004	-46.7189	37.8946	Success
1	5	54	2016-12-28 09:50:34	-46.7257	37.894	-46.7214	37.8932	Success
1	11	161	None	None	None	None	None	Invalid
1	11	160	None	None	None	None	None	Invalid

1	11	159	None	None	None	None	None	Invalid
1	11	158	None	None	None	None	None	Invalid
1	11	157	None	None	None	None	None	Invalid
1	11	156	2017-01-01 13:36:08	-46.6696	51.7992	-46.7122	51.8234	Success
1	13	216	None	None	None	None	None	Invalid
1	13	215	2017-01-03 18:00:09	-49.7677	64.8728	-49.7837	64.8678	Success
1	13	214	2017-01-03 16:47:15	-49.7266	64.8893	-49.7612	64.8748	Success
1	13	213	2017-01-03 15:30:42	-49.7278	64.896	-49.7462	64.8664	Success
1	13	212	2017-01-03 14:22:12	-49.7262	64.8916	-49.7335	64.8939	Success
1	13	211	2017-01-03 13:27:37	-49.7331	64.8713	-49.7439	64.8402	Success
1	15	237	None	None	None	None	None	Invalid
1	15	236	None	None	None	None	None	Invalid
1	15	235	2017-01-04 20:21:12	-49.9879	70.6234	-49.9559	70.6164	Success
1	15	234	2017-01-04 17:50:41	-50.0021	70.6722	-50.0013	70.6559	Success
1	15	233	2017-01-04 18:27:31	-50.002	70.6595	-49.9955	70.6344	Success
1	15	232	None	None	None	None	None	Failure
1	16	274	2017-01-07 16:49:39	-51.1434	71.8443	-51.1601	71.8158	Success
1	16	273	2017-01-07 16:15:06	-51.1404	71.8693	-51.1426	71.851	Success
1	16	272	2017-01-07 12:45:48	-51.1471	71.758	-51.1515	71.7304	Success
1	16	271	2017-01-07 11:15:21	-51.137	71.8269	-51.1415	71.7914	Success
1	16	270	2017-01-07 10:45:00	-51.1347	71.8448	-51.1365	71.8304	Success
1	16	269	2017-01-07 10:03:56	-51.1285	71.8555	-51.1347	71.8453	Success
1	17	278	2017-01-08 09:28:59	-52.3439	74.6238	-52.3399	74.7123	Success
1	17	277	2017-01-08 08:53:52	-52.3352	74.6503	-52.3502	74.6067	Success
1	18	316	2017-01-08 12:42:55	-52.3515	74.7873	-52.3349	74.7727	Success
1	18	282	None	None	None	None	None	Invalid
1	18	281	2017-01-08 12:09:03	-52.3551	74.7982	-52.3463	74.7806	Success
1	18	280	None	None	None	None	None	Failure
1	18	279	2017-01-08 11:01:51	-52.3528	74.8278	-52.3554	74.801	Success
2	26	1030	2017-01-29 03:20:00	-67.146	144.8422	-67.1299	144.8317	Invalid
2	43	1147	None	None	None	None	None	Failure

2	46	1209	2017-02-03 09:15:00	-66.1627	162.1874	-66.1742	162.2029	Success
2	46	1210	2017-02-03 10:15:00	-66.1606	162.1788	-66.1634	162.2079	Success
2	46	1211	2017-02-03 11:15:00	-66.1608	162.171	-66.1648	162.1977	Success
2	46	1212	2017-02-03 12:20:00	-66.1481	162.2009	-66.1501	162.2338	Success
2	46	1213	None	None	None	None	None	Invalid
2	46	1214	None	None	None	None	None	Invalid
2	48	1241	2017-02-04 04:02:50	-66.7105	162.8409	-66.7211	162.8895	Success
2	48	1243	None	None	None	None	None	Invalid
2	48	1244	None	None	None	None	None	Invalid
2	48	1245	None	None	None	None	None	Invalid
2	48	1246	None	None	None	None	None	Invalid
2	50	1294	None	None	None	None	None	Failure
2	50	1295	None	None	None	None	None	Invalid
2	50	1296	None	None	None	None	None	Invalid
2	50	1297	None	None	None	None	None	Invalid
2	50	1298	None	None	None	None	None	Invalid
2	50	1298	None	None	None	None	None	Invalid
2	58	1529	2017-02-11 21:02:08	-73.1621	-126.9499	-67.2986	-79.3798	Success
2	59	1530	2017-02-11 22:00:00	-73.162	-126.9777	-73.1614	-126.9537	Success
2	60	1531	2017-02-11 15:36:00	-73.525	-127.4741	-73.5646	-127.6298	Success
2	60	1532	2017-02-12 01:29:00	-73.2015	-127.2637	-73.1901	-127.3161	Success
2	61	1533	2017-02-12 17:29:00	-73.8861	-127.5207	-73.757	-127.724	Success
2		1586	None	None	None	None	None	Invalid
2		1587	None	None	None	None	None	Invalid
2		1588	None	None	None	None	None	Invalid
2		1589	None	None	None	None	None	Invalid
2		1590	None	None	None	None	None	Invalid
2		1591	None	None	None	None	None	Invalid
2	74	2033	2017-02-20 11:57:00	-56.7336	-68.6117	-56.7242	-68.6458	Success
2	74	2034	2017-02-20 12:56:46	-56.7246	-68.6459	-56.7154	-68.665	Success
2	74	2035	2017-02-20 14:20:00	-56.7356	-68.6078	-56.7313	-68.6225	Success
2	74	2036	2017-02-21 03:20:56	-56.2491	-69.6554	-56.259	-69.6664	Success
2	74	2037	2017-02-20 04:04:00	-56.2591	-69.6584	-56.2598	-69.6704	Success
2	74	2038	2017-02-21 04:40:19	-56.26	-69.6766	-56.2605	-69.687	Success
2	74	2039	None	None	None	None	None	Invalid

2	74	2040	None	None	None	None	None	Invalid
2	84	2374	2017-03-07 01:13:50	-57.1578	-26.7738	-57.1489	-26.7546	Success
3	84	2376	2017-03-07 03:07:16	-57.1547	-26.7666	-57.1501	-26.749	Success
3	84	2378	2017-03-07 05:50:27	-57.1529	-26.7608	-57.1966	-26.7953	Success
3	90	2588	2017-03-08 00:20:23	-59.4699	-27.3017	-59.4709	-27.2825	Success
3	90	2590	2017-03-08 02:40:47	-59.4698	-27.2791	-59.4718	-27.264	Success
3	90	2592	2017-03-08 04:15:06	-59.4679	-27.2823	-59.4873	-27.2139	Success
3	98	2765	2017-03-11 21:16:27	-54.4249	3.5148	-54.419	3.4935	Success
3	98	2767	2017-03-11 22:00:49	-54.4249	3.5244	-54.4222	3.5014	Success
3	98	2769	2017-03-11 22:52:19	-54.4241	3.52	-54.4244	3.5257	Success
3	99	2942						Success

Sampling

Leg 1

We retained samples from a total of 24 events, many of which were carried out by our Project, and some that were donated from other events. At Marion Island, we collected intertidally (n = 4 events) and subtidally via Agassiz trawls (n = 2 events). At Possession Island in the Crozet group we collected intertidally (n = 1) and subtidally via Agassiz trawls (n = 1). Coming onto the Kerguelen Plateau we sampled at Leclaire Rise, with samples from 4 trawls. At Kerguelen Island itself, we collected intertidally (n = 1) and carried out trawls nearby (n = 2). Heading south to Pike Bank, we carried out more Agassiz trawls (n = 6). The final site was west of Heard Island, at Gunnari Ridge, where we had a low yield deployment and then moved to a nearby area and carried out the final trawls (n = 2).

Leg 2

We retained samples from a total of 16 events, most of which were carried out by our Project, and some that were collected from ROPOS deployments. The ship did not visit Macquarie Island due to inclement weather and therefore no sampling occurred in that region. At Balleny Island we collected subtidally via Agassiz trawls (n = 3 events). Intertidal sampling did not occur as there were no accessible beaches. The intertidal area was not accessible at Scott Island and trawling was not possible due to very rough ocean floor around the island. At Mt Siple we collected subtidally via Agassiz trawl (n= 2) and then again at the shelf break in the Amundsen Sea (n = 1). Dense pack ice surrounding Peter I Island (at all depths less than 3 km) prevented trawling. Intertidal collecting occurred at this location (n = 1). Intertidal collection occurred at Diego Ramírez (n = 1) and collected subtidally via Agassiz trawl at two locations (n = 3).

Leg 3

We retained samples from a total of 14 events, most of which were carried out by our Project, and some that were donated from events from the other trawl team, Project 3. We conducted intertidal sampling at two locations in South Georgia (Grytviken and St Andrews Bay) and deployed a fish trap (Bay of Isles). At

the South Sandwich Islands we collected subtidally via Agassiz trawl (n = 6 events) at Candlemas (n = 3) and South Thule (n = 3) Islands. Intertidal sampling did not occur as landing via helicopter or zodiac was not possible. At Bouvetøya we collected subtidally at East Bouvetøya (n = 4) via Agassiz trawl. We were unable to trawl at South Georgia after submitting 3 priority sites due to bad weather and issues with Project prioritisation.

All voucher organisms will be accessioned into the collections of the Western Australian (WA) Museum, where full collection details are available. Samples for chemical analysis will be maintained at University of South Florida.

Processing methodology

Samples were retrieved from the trawl net (or hand collected from shore) and sorted into major taxon groups in the laboratory. Species were identified as finely as possible, photographed and given a WA Museum registration number. The identified lot was photographed and preserved. Most samples were placed into chilled 96% ethanol (ETOH), and some were fixed in 10% formalin, with subsamples of tissue taken into ETOH. A few samples were fixed in RNAlater for transcriptomic studies. Preserved samples were placed into -20 °C storage. ETOH preserved samples had a complete change of ethanol 24-48 hours after collection, and some were further monitored and changed until the ETOH remained clear. Samples collected for chemical analysis were placed in plastic bags and frozen at -20 °C. Data were recorded into a field notebook, and later transferred into a FileMaker Pro database, where photographs were linked with records. This will be used to export details to the WA Museum database (Collective Access).

Problems encountered

The winches on the Akademic Tryoshnikov are quite weak in comparison to other research vessels and incapable of handling a full size Agassiz trawl. This necessitated the design and purchase of new small and lightweight trawls by BAS (see Barnes, Project 3 report for equipment details). This reduced the payload of each trawl, and with additional issues limiting trawl opportunities, reduced the overall collection of samples to a low level. This could have been mitigated by increasing the number of trawls but the overall work schedule for the ship was very tight, and this was ultimately not possible.

Multibeam data were initially collected to assist with trawl site selection but the quality of data collected was poor, and not considered to be worth continuing as an activity. Trawls were thus deployed ‘blind’ which incurs a higher risk of equipment loss which is usually not acceptable. That we did not lose any trawls was probably due to the very lightweight construction of the equipment. This was evident when multibeam data was not used at the last site of Bouvetøya (event 2941) where a rocky benthic substrate was encountered and the trawl was damaged. Please see the report from Project 3 for a detailed report of this incident.

Initial plans to undertake trawling at night were delayed by crewing problems for operating the winches, resulting in the loss of much work time.

Deployment techniques (i.e. letting wire out too quickly) reduced the efficacy of many trawls.

The lowest working speed of the ship appeared to be limited to around 3 knots, which is far too fast for efficient trawling. Pointing directly into the wind was vital for reducing ship speed and keeping the trawl on the bottom.

Specimen data

Specimens will be accessioned into the WA Museum database by mid-2017, and should be available online (via OZCAM; www.ozcam.org.au) by end 2017. Any samples used in genetic analyses will have that data accessioned into GenBank, with links to the voucher number.

References

Fraser, C, Nikula, R, Spencer, HG, Waters JM (2009) Kelp genes reveal the effects of subantarctic sea ice during Last Glacial Maximum. PNAS 106: 3429-3253.

Hemery LG, Eléaume M, Roussel V, Améziane N, Gallut C, Cruaud C, Couloux A, Wilson NG. (2012) Comprehensive sampling reveals circumpolarity and sympatry in seven mitochondrial lineages of the Southern Ocean crinoid species *Promachocrinus kerguelensis* (Echinodermata). Molecular Ecology 21: 2502-2518.

Key personnel

PI Dr Nerida Wilson will manage the overall Project, produce reports and ensure that collection data and DNA sequences are made available after publication. Western Australian Museum; nerida.wilson@museum.wa.gov.au

Alex Hickling will provide technical assistance during Leg 1 and Leg 3. Western Australian Museum; alex.hickling@musueum.wa.gov.au

Prof. Bill Baker will examine chemical variation in natural products and participate on Leg 1. University of South Florida; bjbkaer@usf.edu

Assoc. Prof. Jan Strugnell will assist with the genetic refugia component and participate on Leg 2. James Cook University; jan.strugnell@jcu.edu.au

Kara Layton, PhD student, will assist with the genetic refugia component and participate on Leg 2. University of Western Australia/WA Museum; kara.layton@museum.wa.gov.au

Danielle Demers, PhD student, will assist with the chemistry component and participate on Leg 2. University of South Florida; dhdemers@mail.usf.edu

Dr Rebecca Cumming will provide assistance with specimen processing during Leg 3. University of Otago.

Javier Naretto, PhD student, will assist with the genetic refugia component and participate on Leg 3. Universidad de Chile, Santiago; j.naretto.a@gmail.com

10.11 Project 11

Investigation of air-sea interaction in the Southern Ocean from stable water isotope measurements

PI Heini Wernli (Switzerland)

Aims and Objectives

The Southern Ocean is characterised by diverse weather systems, which lead to severe weather conditions - heavy precipitation, wind storms, fog - and impact ocean evaporation, the water budget of the remote islands, and Antarctic precipitation. Quantifying these processes and their interplay is essential for understanding Earth's climate. Stable water isotopes (SWI), which occur naturally in the ocean, land surface waters and the atmosphere, can be used as tracers of the complex processes that govern the global and regional water cycle. Therefore, we measure SWI in atmospheric vapour during the ship voyage and observe the variability of precipitation events with a micro rain radar. Liquid samples are collected from precipitation events, from the ocean and from accessible surface waters on the islands. Together with trajectory-based analysis methods, these observations provide a unique opportunity to investigate the variability of ocean evaporation conditions as recorded in SWI signals in vapour, the variability of

precipitation processes revealed by the radar and combined SWI measurements in vapour and precipitation, and oceanic source conditions of water that is later deposited in Antarctic ice cores.

Measurements on board

Picarro laser spectrometers L2130-i and L1115-i: Isotopic composition of atmospheric water vapour

Two Picarro cavity ring-down laser spectrometers (L2130-i-i, L1115-i-i) are situated in the Atmospheric Measurement Container (see Figure 96(b)) on deck 2 to continuously measure $\delta^{18}O$ and $\delta^{2}H$ in atmospheric water vapour with a resolution of 0.8 s and 5 s for L2130-i and L1115-i, respectively. Figure 96(a) shows the flow diagram of the setup in the Container. The inlet pump directs the flow from the inlet to the instruments. There is an external/internal pump for L2130-i/L1115-i, respectively. An outflow line collects all the air from the instrument's outlets and directs it to the outside of the container.

The inlet (see Figure 96(c)) is mounted on top of the container and connected to the instruments by a 1.5 m long heated tube (PFA tubing inside). In the container, all tubings are PFA and are thermally isolated to prevent condensation in the tubings. A Steriwex millipore filter is mounted on the inlet line (see Figure 96(d)). The inlet consists of three concentric cylinders with perforated walls. This multi-layer system is chosen to prevent precipitation and sea spray from entering the inlet line. A heating cable heats the inlet to prevent condensation within.

Two calibration runs per day with two standards (depleted [GRIP:-34.59‰/ -267.33‰], enriched [MP16: -11.42‰/ -82.05‰]) at two different water vapour concentration (ambient water vapour concentration and 12000 ppm) are done with L2130-i using the standard delivery module [SDM] by Picarro. The SDM delivers the calibration standards to the vapourizer where the samples are vapourized and delivered to L2130-i. The standards are renewed at the beginning of every leg and sampled on regular basis.

L2130-i data is calibrated using the calibration runs. L1115-i, which serves as a backup instrument is calibrated with the L2130-i data. Finalized data are expected approximately one year after the end of the expedition.

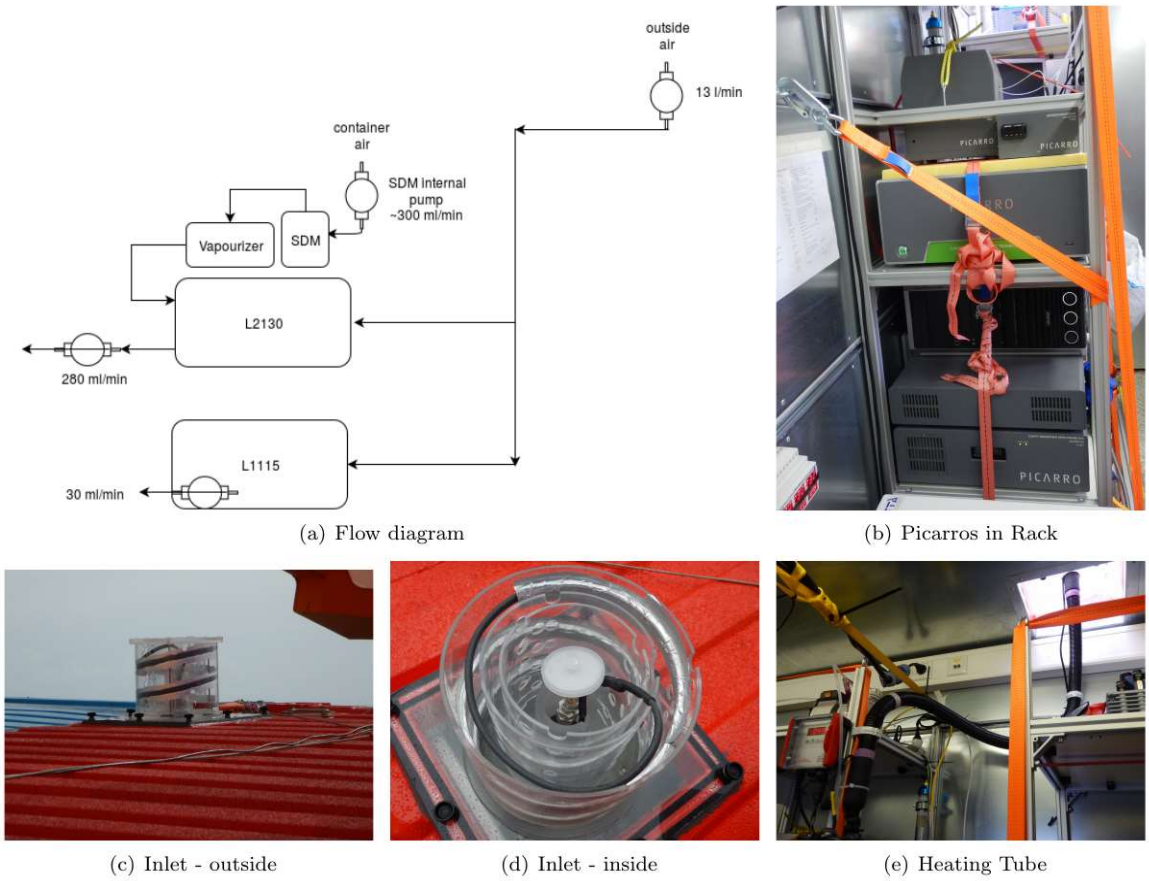


Figure 96: Setup of laser spectrometers L2130-i and L1115-i in the atmospheric measurement container. (a) Flow diagram (b) Picarros in Rack (c) Inlet - outside (d) Inlet - inside (e) Heating Tube

Both laser spectrometers functioned continuously during Leg 1. During head-wind events with high wind speed, sea spray was reaching deck 2. Salt from sea spray was found in the outer ring of the inlet. An influence on the isotopic signal measured during these periods might be possible.

During the cold weather conditions (air temperature below 0 °C) on Leg 2, no ice formation on the inlet was observed. After large snowfall events, liquid water was found on the top of the inlet and around the inlet from molten snow. The laser spectrometers were run continuously during Leg 2 leading to a total of 66 days of measurements since Cape Town (on 21 February 2017).

Spectrometers were run continuously during Leg 3 leading to a total of 90 days of measurement between leaving and arriving in Cape Town.

Precipitation sampling

Precipitation Totalisator

A precipitation totalisator from Palmex using the large funnel (diameter: 25 cm) collects precipitation on long time scales (Figure 97(a)). The totalisator was emptied approximately once a day, depending on the amount of rainfall. The location of the totalisator changed on the 03 January 2017 at 12:00 UTC from the monkey bridge (position Totalisator A in Figure 97(d)) onto the helicopter control room on deck 4 (position Totalisator B in Figure 97(d)). We expected this position to be less influenced by the engine exhaust as the wind was mainly coming from behind during Leg 1. Seventeen totalisator samples were collected during Leg 1. Due to high wind speeds during some precipitation events we sampled less rain than expected as

parts of the slantwise falling precipitation might be missed. Thus the totalisator samples might be biased towards precipitation which fell during low wind speed conditions.

The location of the totalisator changed on the 26 January 2017 at 12:00 UTC from the helicopter control room on deck 4 (position Totalisator B in Figure 97(d)) onto the monkey bridge (position Totalisator A in Figure 97(d)). The position on deck 4 was too close to the exhaust.

On 28 January 2017 at 11:00 UTC the snow funnel was installed on the totalisator (see Figure 97(b)). Only two snowfall samples were collected with the totalisator. The snowfall was disturbed by the ship's movement and too small amounts of snow where sampled with the snow funnel. Eleven long-term precipitation samples (7 rainfall, 4 snowfall) were collected during Leg 2, where two of the snow samples were collected over several hours with the small shielded funnel shown in Figure 97(b). Five totalisator samples (3 rainfall, 2 snow and graupel) were collected during Leg 3.

(a) Precipitation Totalisator (b) Precipitation Totalisator with snow funnel (c) Precipitation Sampler with shielded funnel

(d) Locations on RV

Figure 97: Location of precipitation totalisator (Totalisator Aand Totalisator B), the high resolution sampling devices (Sampler 1-4) and the Atmospheric Measurement Container (Atm. Meas. Container). (a,b) Precipitation Totalisator (c) Precipitation Sampler with shielded Funnel (d) overview sampling locations on research vessel.

High Resolution sampling

During precipitation events a high resolution sampling method was applied. Three sampling devices (shown in Figure 97(c)) were stationed on deck 2 and deck 4 (Sampler 1-4 in Figure 97(d)). The sampling location of an event was chosen according to the wind direction. Precipitation samples were collected in 20 ml bottles and were manually changed every 5-30 minutes, depending on rain intensity.

Due to the high wind velocity during many precipitation events we sampled less rain than expected. Thus we constructed a one-sided shielded funnel during Leg 0 which was positioned such that the shield was leeward of the wind. This way we caught horizontally falling precipitation, too.

During Leg 2 high resolution snowfall was sampled in a similar way as the high resolution rainfall. On the 04 February 2017 the sampling device at position Sampler 1 was changed to position Sampler 4 because the snowfall along the ship's side was often moving upwards due to the ship's movement and could not be sampled at position 1. The sampling device was moved back to position Sampler 1 on the 19 February 2017 at 14:00. The sampling location of an event was chosen according to the wind direction. If possible snowfall was collected on deck 2 to minimalize any influence from the stack. Snow samples were collected in 20 ml bottles and were manually changed every 10-60 minutes, depending on snowfall intensity.

The setup for high resolution rainfall sampling stayed the same during Leg 3 as during the previous legs. Snowfall was sampled with the large funnel. Most of the snow was sticking to the inside wall of the funnel and was filled into the bottle when the sample was changed. Only one snow event was sampled with high resolution.

The main problem encountered was that samples collected on deck 2 were contaminated with a significant amount of sea spray when the wave height was high and the wind was strong and coming from the sector 270 to 360 degrees relative to the heading of the ship. Therefore, the second part of event P33 (ACE event number 2295) was missed completely. Samples on the port side of deck 4 were polluted by parts of the stack and therefore rejected. The same conditions were encountered during event P35 (ACE event number 3398). Some samples were therefore collected on deck 4 despite of a head wind. Samples collected at the two original locations on deck 4 were both polluted by particles from the stack. Two new positions were therefore tried (see positions Sampler 1b and Sampler 2b in Figure 97). Samples collected at the new location on the starboard side were also polluted and partly shielded by the ship structure. Samples from the new location on the port side were not polluted, but the wind was channelled between superstructure and stack and therefore very strong. Part of the precipitation might therefore have been missed.

A total of 463 precipitation samples were collected using the high resolution sampling (Leg 1: 17 rainfall events/ 135 samples; Leg 2: 9 snowfall, 4 rainfall events/ 256 samples; Leg 3: 1 snowfall, 3 rainfall events/ 72 samples).

All precipitation samples were dry stored for the analysis of stable water isotopes after the expedition with a Picarro laser spectrometer. Finalized data are expected 1.5 years after the end of the expedition.

Ocean surface waterTwenty ml ocean surface water samples were collected from the underway line once a day. The sampling time was at 12:00 or 18:00 ship time (occasionally at 00:00 or 06:00 ship time). Additionally surface water from CTD casts was collected. A total of 59 bottles were collected (22/20/17 samples during leg 1/2/3, respectively). The ocean water samples were dry stored for the analysis of stable water isotopes after the expedition with a Picarro laser spectrometer. Finalized data are expected 1.5 years after the end of the cruise.

Island sampling

During Leg 1, we sampled freshwater from lakes, ponds and rivers on three sub-antarctic islands. The samples were taken with 20 ml glass bottle. The island samples are documented by photographs, GPS coordinates and the description of the sampling area and the samples.

Twentyfive freshwater samples from Marion Island were taken along Skua Ridge towards Juniors Kopp, from Gentoo Lake and around Macaroni Bay. On Île de la Possession 22 of the 24 samples were taken in the Vallée des Branloires (river and ponds/lakes) near Baie Americaine. Two samples were collected from the Rivière du Camp near the base. Fourteen samples were collected on Kerguelen between Pointe Molloy and Rivière du Sud (to the east of the base Port-aux-Français).

The freshwater samples from the islands were dry stored for analysis of stable water isotopes after the cruise with a Picarro laser spectrometer. Finalized data are expected 1.5 years after the end of the expedition.

Due to time limitations during the island visits on Île de la Possession and Kerguelen, we were not able to sample in our preferred areas (i.e. several lakes at different altitudes with primarily atmospheric water input and loss) or were only able to take few samples. Only on Marion Island were we able to sample a lake above 200 m a.s.l. Thus most samples originate from lakes situated below 50 m altitude within wetlands.

During Leg 2, terrestrial snow samples were collected from the Mertz glacier (5 samples), the Balleny Islands (Young Island, 3 samples), Scott Island (12 samples), at the Siple coast (3 samples from Lauff Island, 8 samples from the outcrop and 3 samples from Mt. Siple) and on Peter I Island (3 samples). Liquid water samples from ponds and a stream were collected at Diego Ramírez (2 samples from Isla Bartolomé and 4 samples from Isla Gonzalo).

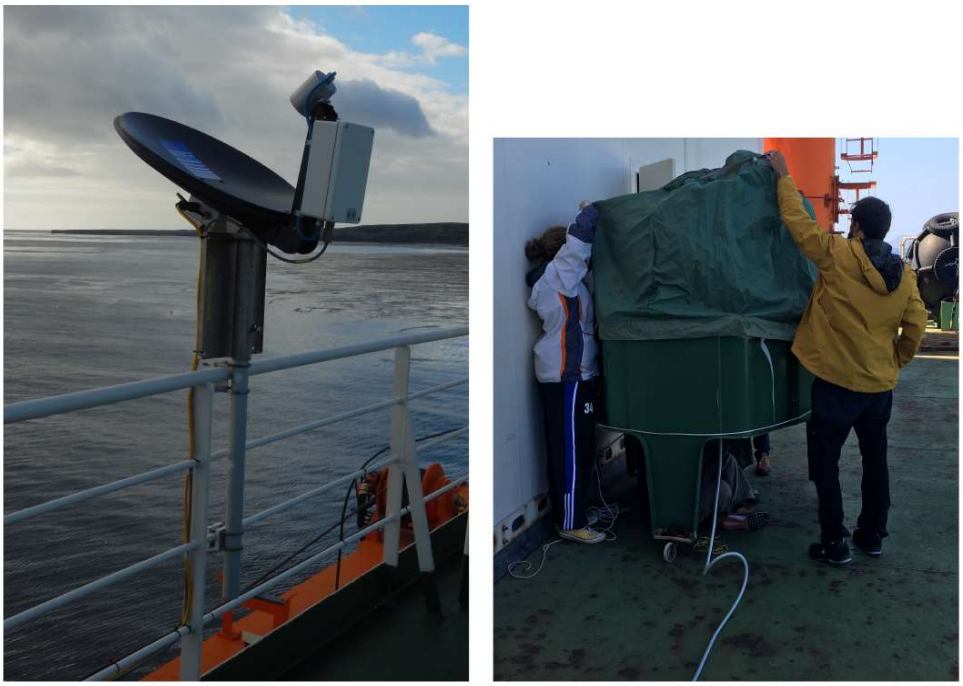
The samples were collected by Julia Schmale (Mertz, Balleny, Mt. Siple), Lois Maignien (Lauff Islands), François de Vleeschouwer (Isla Gonzalo), Peter Ryan and Jasmine Lee (Isla Bartolomé) and Iris Thurnherr (Scott Island, outcrop at Siple coast).

During Leg 3, terrestrial water samples were collected from 2 sites on South Georgia (12 and 5 samples) and from one site on Bouvetøya (3 samples). Snow samples were collected from a large tabular ice berg close to the South Sandwich Islands (1 sample) and from 2 sites on Bouvetøya (4 and 2 samples). The sample from the ice berg was collected by Baptiste Bernard, the samples from Bouvetøya were collected by Julia Schmale and Katherine Moon.

Micro rain radar (MRR): Monitoring Precipitation

A micro rain radar of the type METEK MRR-2 was installed on the ship's superstructure (deck 5) on the starboard side, opposite of the exhaust stack (Figure 98). The MRR was running continuously, with a 10-second temporal resolution. Reflectivity and Doppler velocity were measured in 31 range gates in a vertical column above the radar. From this data, the approximate rain rate and the height of the melting layer were obtained to decide on precipitation sampling and its time resolution.

The vertical resolution was 150 m at the beginning of Leg 1 and was set to 100 m at 12:45 UTC on the 27 December 2016 for the rest of the leg. The data is directly processed by the manufacturer's software and was visualized on a shuttle PC in the hydro acoustics laboratory in real-time.



(a) Micro rain radar (b) Structure to inflate balloon

Figure 98 Micro-rain radar and balloon inflation

Data was recorded with the factory default software of METEK and raw (extension .raw), processed (extension .pro) as well as averaged (extension .ave) data were archived on the shuttle PC and on the intranet. The instrument was calibrated by the manufacturer before the expedition and a calibration constant of 1818832 was used. After the cruise, the data will be checked and corrected for the ship's motion if necessary. However, the data looks reasonable and no clear influence of pitching and rolling on the data can be seen. A time series of precipitation intensity and drop size distribution will be generated from the dataset. We are surprised, how well the radar performs even under conditions where the ship rolled by up to 20 degrees. The computer on which the software was running had a time shift compared to the ships internal clock. This time shift was monitored and protocoled once a day until the clock was synchronized with the intranet time on the 25 December 2016. We expect a complete, continuous dataset for the whole of Leg 1 with a total size of about 25 GB.

During Leg 2 the MRR was running continuously, with the exception of eight hours on the 26 January 2017, four hours on 02 January 2017 and four hours on 04 February 2017, with a 10 seconds temporal resolution. We expect a nearly continuous dataset for the whole Leg 2 with a total size of about 30 GB. About 130 hours of precipitation were measured on 31 days during Leg 2.

About 84.5 hours of precipitation were measured on 16 days during Leg 3.

The dataset will be finalised within a year after the end of the cruise. About 100 hours of rain were measured on 24 days during Leg 1.

Daily and Event-based Radio soundings: Vertical structure of the atmosphere

Radiosondes of the type iMet ABX(n) from Intermet Systems were launched on several occasions. We used KAYMONT 200 g balloons and a de-reeler was attached between the radiosonde and the balloon to simplify the launch, especially in windy conditions. The signal was received by a unidirectional antenna (PROCOM CXL 70-3LW/s), connected to an AR-8600DX receiver by a 20 m UHF cable. The signal was transferred to the shuttle computer in the hydro acoustics laboratory with an audio cable. SkySonde Server software version

1.0.2.1 from NOAA/GMD was used to convert the signal and SkySonde Client version 1.1.8.6 was used to display and process the data. The antenna was located on superstructure deck 5 until the 03 January 2017, when it was relocated to the roof of the helicopter control room due to frequent shielding of the connection by the top deck. The new location provided a better angle for visual contact between radiosonde and antenna, especially during situations with strong tail winds. The radiosonde often disappeared behind the top deck and the signal was lost between 6 and 10 km height. In case of visible contact, the signal can be received until the radiosonde is back close to the surface and up to more than 100 km away.

The radiosondes were switched on in the hydro acoustics laboratory about 15 minutes prior to the launch to test the proper functioning and reception of the signal. The balloon was filled with about 1 m^3 helium with a plastic nozzle, which was connected to a pressure regulator sitting on a 50 L helium bottle. The balloon was inflated under a plastic rack covered by a hood, which was situated on the helicopter deck (see Figure 98). It was attached to the hangar door prior to inflation and within reach of the hose. The plastic construction simplified the filling procedure, especially in windy conditions. At first, the amount of helium in the balloon was estimated by measuring the lift force of the balloon. It turned out to be difficult to measure this weight accurately because the wind was irregularly pressing on the hood and thus alternating the lift force. Therefore, the size of the balloon was taken as a reference. We achieved ascent rates closest to 5 m/s when the balloon was slightly touching the plastic frame on every side. Once the target size was reached, the balloon was closed with a cord and the hood of the plastic structure was removed.

The radiosonde and a de-reeler were attached to the balloon only shortly before the launch to simplify the handling and to avoid damaging of the sensors on the radiosonde. The radiosonde and the balloon were launched from the helicopter deck. The exact location depended on wind direction and strength.

Several problems were encountered before, during or after the launches. Inflating the balloon using the plastic construction is not favorable for the fragile skin of the balloon and leads to explosion heights, which are 5 to 10 km lower than launches without the construction, which were performed during Leg 0. However, the radiosondes reached the tropopause in all but one occasion, where there was not enough helium in the balloon. A more frequent problem was the loss of the signal, which is already described earlier in this section. The signal was lost on 13 occasions, of which six were lost below the tropopause. Launching the balloon in windy conditions was very challenging. With winds from 270 to 90 degrees relative to the ship allowed easy inflation and an easy release from the plastic construction, because the superstructure provided an area behind the hangar which was shielded from the wind. However, the lee-rotors were required to launch the radiosonde at the side of the helicopter deck (instead of its centre) over the railings because the balloon often did not ascend for a few seconds after release.

Inflating balloons and releasing them from the plastic construction was also challenging with winds from the back, which were often encountered.

Table 23: Number of samples and variables for measurements during ACE. P_{air} is the air pressure and T is the air temperature.

Instrument	Number of samples			Analysed variables
	Leg 1	Leg 2	Leg 3	
Laser spectrometer L2130-i & L1115-i	continuous data			$\delta^{18}O$, $\delta^{2}H$, H_2O-conc.
Totalisator	17	11	5	$\delta^{18}O$, $\delta^{2}H$
Rain sampler	135	265	72	$\delta^{18}O$, $\delta^{2}H$, salinity
Underway & CTD	22	20	17	$\delta^{18}O$, $\delta^{2}H$
Island sampling	63	53	27	$\delta^{18}O$, $\delta^{2}H$, salinity
MRR	continuous data			Reflectivity, Doppler velocity
Radiosondes	29	43	18	P_{air} , T, humidity, wind speed and direction
Inclinometer	continuous data			ship motion, room temperature

Misjudgement of or slight changes in the wind direction led to one collision and destruction of the radiosonde with one of the cranes on the side of the helicopter deck and several near-misses. Strong winds from about 90 to 135 and 215 to 270 degrees provided the most challenging conditions: the hangar provided no shelter and several balloons were ripped apart after releasing them from the plastic construction.

A total 29 of 34 launches were successful on Leg 1. A problem with missing GPS information in the first parts of the ascent was encountered when the radiosonde was inside the hangar until a few seconds before the launch.

A total 36 of 36 ABX launches and 7 of 8 RSB launches with Anasphere SLWC were successful on Leg 2.

A total 15 of 17 ABX launches and 3 of 3 RSB launches with Anasphere SLWC were at least partly successful. One ABX sonde had problems with the temperature sensor above about 3250 metres and one RBS with Anasphere SLWC had a broken humidity sensor.

The data was received in real-time and was processed directly by the software. No post processing is intended and the finalised dataset is therefore already available. These measurements were organized and conducted together with Project 18.

Inclinometer: Ship movement in high resolution

An inclinometer (Serial No. 162200139) from Measurement Specialties was installed under a desk in the hydro acoustics laboratory. The inclinometer logged the room temperature and the ship motion along its x- and y axes with 10 Hz resolution. The x-axis points along the ship, i.e. rolling causes rotations around the x-axis. The data is stored on the computer in .csv files with the date as names. A new file was opened once a day. The inclination sensor lost connection to the computer approximately every second day. This caused data gaps from a few seconds up to several hours, depending on how rapidly the problem was recognised. Nevertheless, the data is available for more than 90% of the time.

ACE Forecast: Daily forecast from ECMWF data

Daily weather pictures from ECWF six-hourly forecast were provided by the ETH-Team of Project 11. The forecast was downloaded during the night and available on the intranet and on our web page: data.iac.ethz.ch/ace/.

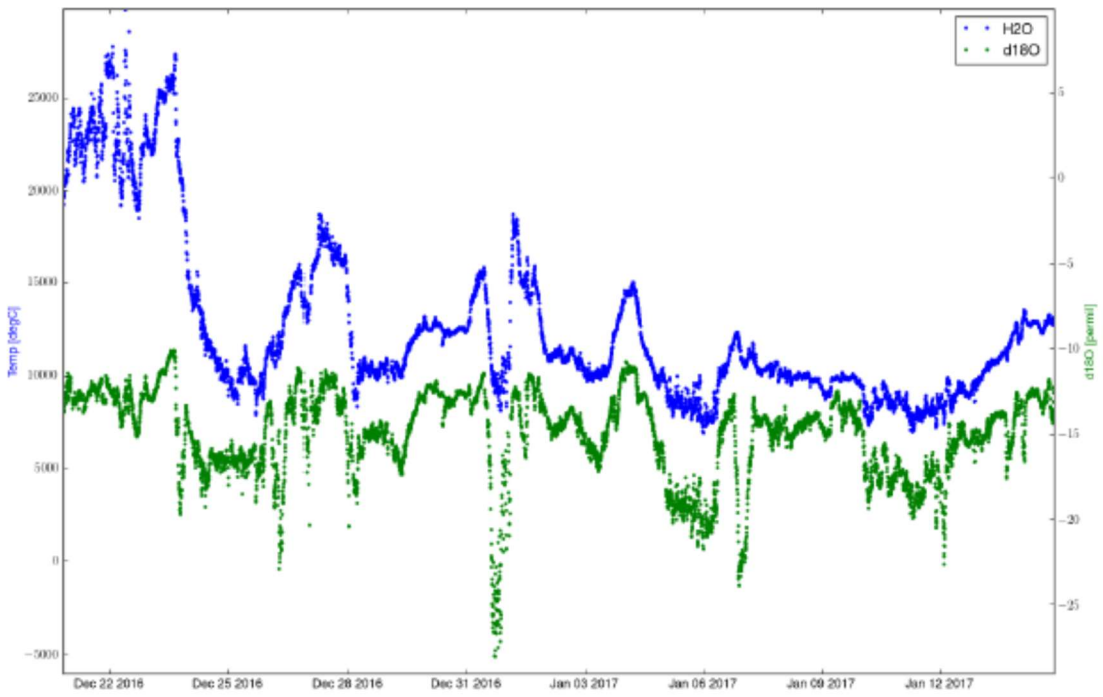


Figure 99: Pre-calibrated 5-minute average of atmospheric water vapour concentration [ppm, blue] and $\delta^{18}O$ [permil, green] during Leg 1 (17 December 2016 - 14 January 2017) from laser spectrometer L2130-i.

Preliminary Results

Figure 99 shows the pre-calibrated stable water isotope measurements during Leg 1 from 17 December 2016 - 14 January 2017 in water vapour with the laser spectrometer L2130-i. The atmospheric water vapour concentration decreases strongly during the transect from Cape Town to Marion Island. Accordingly the water vapour depletes in ^{18}O. $\delta^{18}O$ shows high variability in the Southern Ocean due to diverse weather events as, for example, the passage of cyclones and air mass changes. Especially remarkable are the very low $\delta^{18}O$ during New Year's Eve.

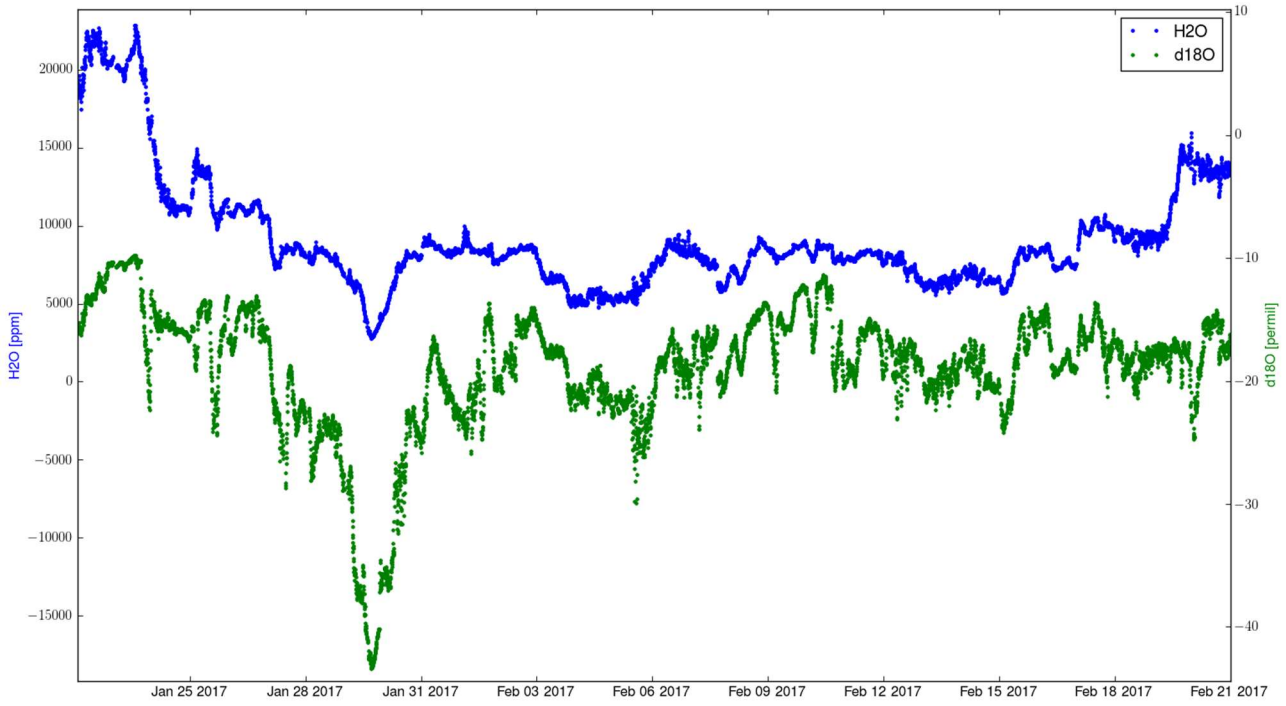


Figure 100: Pre-calibrated 5-minute average of atmospheric water vapour concentration [ppm, blue] and $\delta^{18}O$ [permil, green] during leg 2 (22 January 2017 – 20 February 2017) from laser spectrometer L2130-i.

Figure 100 shows the stable water isotope measurements during Leg 2 from 22 January 2017 - 20 February 2017 in water vapour with the laser spectrometer L2130-i. The atmospheric water vapour concentration decreases strongly during the transect from Hobart to Mertz glacier and stays low during most of leg 2. Very low values in $\delta^{18}O$ are measured at Mertz glacier, most likely due to the advection of Antarctic air masses.

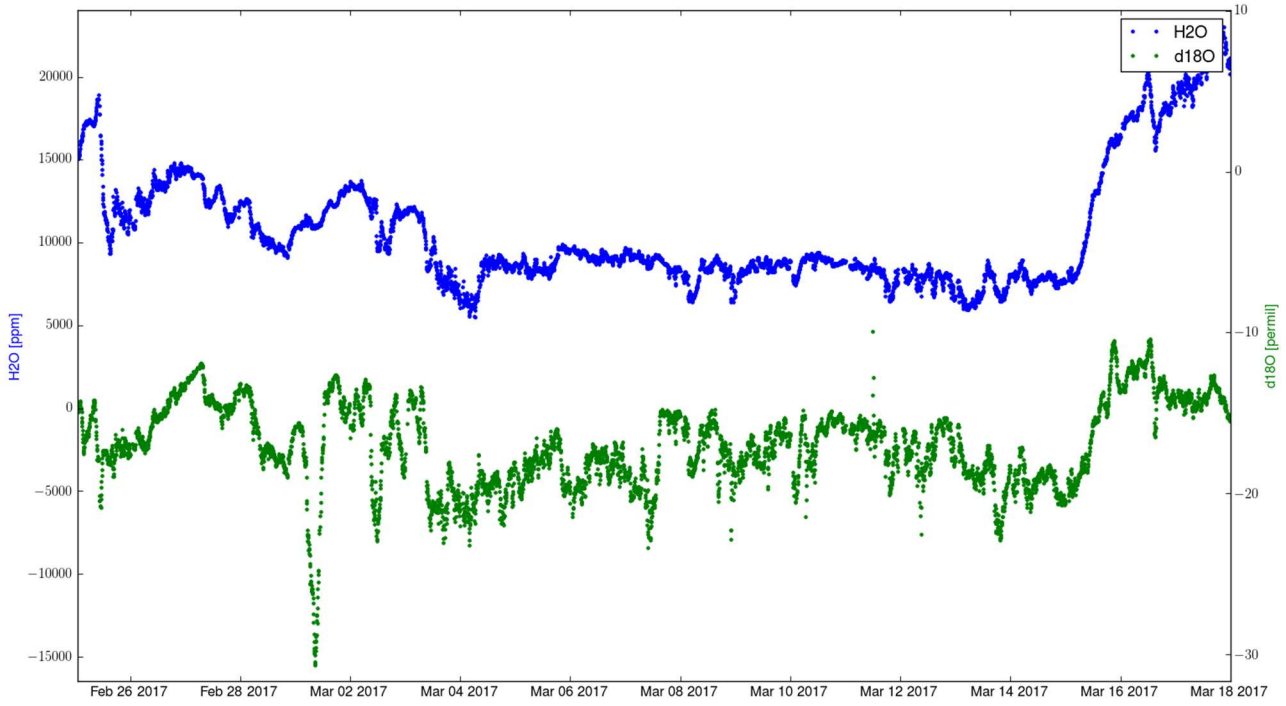


Figure 101: Pre-calibrated 5-minute average of atmospheric water vapour concentration [ppm, blue] and $\delta^{18}O$ [in ‰, green] during leg3 (25 February 2017 – 18 March 2017) from laser spectrometer L2130-i.

Figure 101 shows the stable water isotope measurements during Leg 3 from the 25 February 2017 to the 18 March 2017 in water vapour with the laser spectrometer L2130-i. The atmospheric water vapour concentration decreased during the first week, which was in accordance with the dropping air and sea surface temperature. The water vapour concentration was very stable between 04 - 15 March 2017, before it started to increase strongly towards the end of the cruise. Except for the beginning and the end of Leg 3, the isotope ratio roughly follows the evolution of the water concentration. The low values at the beginning are likely caused by air coming from the west which was previously depleted in heavy isotopes when flowing over the Andes and experiencing rainout.

There is a particularly strong decline in heavy isotopes with $\delta^{18}O$ values of less than -30 ‰ on 01 March 2017, which marks the arrival of the first phase of the storm under whose influence we stood the following days.

Acknowledgments

We would like to thank the Swiss Polar Institute, Ferring Pharmaceutical and BNP Paribas for supporting our project. Furthermore, we thank Julia Schmale and her team for the organisation and allocation of the Atmospheric Measurement Container. For helping hands during the radio soundings, collection of precipitation and samples on land**,** we thank all involved scientists and crew members.

10.12 Project 12

A multi-disciplinary, multi-resolution approach to understanding nutrient cycling and microbial diversity in changing Subantarctic ecosystems

PI Sarah Fawcett (South Africa)

Aims and objectives

The broad goal of ACE Project 12 is to use microbial diversity (where 'microbial' refers to phytoplankton, bacteria, and zooplankton) and metabolic activity in conjunction with measured chemical and physical parameters to develop an integrated model of the Subantarctic island systems in order to better understand their role in Southern Ocean productivity. More specifically, the objective was to characterise microbial community composition and diversity in the waters surrounding three Subantarctic island systems (Prince Edward and Marion Islands, Crozet/Kerguelen/Heard Island, South Georgia/South Sandwich Islands), in mesoscale eddies, and in the open Antarctic Circumpolar Current (ACC). The investigations of microbe-nutrient interactions would focus on nitrogen (N) because it exists in marine systems in numerous forms, is stoichiometrically linked to carbon (C), and is primarily transformed by biology. To quantify new production (and thus C export), the sources (e.g., upwelling, eddies, island runoff) and forms (new vs. regenerated) of N supplied to the upper ocean and island systems would be identified, as would the role of different plankton in driving export. The extent to which island-derived N persists spatially with distance from land would also be investigated, along with biologically-mediated transformations of this N (e.g., nitrification, N assimilation), and microbial metabolic potential and activity.

Sampling methodology

The primary sampling technique proposed for Project 12 included CTD casts and bongo nets. Unfortunately, due to the limitations of the vessel and time constraints, too few CTD casts and plankton trawls were conducted to meet all the objectives of the Project. It was therefore decided to also sample from the underway system. Underway sampling took place at 06:00, 12:00 and 18:00 (ship time) each day.

Nitrogen dynamics

Ammoniums:

For the underway samples, duplicate 45 ml samples were collected and one sample was immediately frozen (-20 °C) while the other was analyzed on the ship using the fluorometric method of Holmes et al. (1999). The frozen sample will be analyzed in the lab at the University of Cape Town (UCT), South Africa. When sampling from the CTD, ammonium samples were collected from every depth and treated in the same way as the underway samples.

Nitrate isotopes:

From the underway, a 50 ml sample was collected in a square High Density Polyethylene (HDPE) bottle and frozen (-20 °C) for isotopic analysis; a duplicate sample was collected in a 50 ml centrifuge tube and treated the same as the HDPE sample. Duplicate nitrate isotope samples were taken from every depth from the CTD and immediately frozen. The isotopic analysis will be conducted at Florida State University, USA using the denitrifier method (Sigman et al. 2001); this is currently underway.

Particulate organic carbon (POC) / particulate organic nitrogen (PON):

From the underway, duplicate 2000 ml samples were collected and filtered through 25 mm combusted 0.3 μm Glass Fibre filters (GF-75; Sterlitech). From the CTD, 2000 ml from the 10 shallowest depths were sampled and filtered. The filter paper was transferred to combusted tinfoil and stored in the freezer (-80 °C)

to be further analyzed at UCT using an elemental analyser-isotope ratio mass spectrometer; this is now complete.

Community composition and diversity

Flow cytometry:

Along with every POC/PON sample collected, underway and CTD, 1.5 ml of seawater was transferred into a 2 ml Eppendorf tube and fixed using 100 µL gluteraldehyde. The samples were incubated in the fridge for 1-4 hours then stored in the freezer (-80 °C). All analysis will be completed at UCT.

Fluorescence-activated cell sorting (FACS):

From the underway, duplicate 4 l spigot bottles were filled with seawater that was immediately filtered through a 0.4 µm polycarbonate filter (Whatman). When sampling from the CTD, duplicate 4 l aliquots were collected from the surface, fluorescence maximum, 30 m and just below the fluorescence maximum (total of four depths). The filters were stored in 5 ml cryovials with ~4 ml of pre-filtered (low nitrate) seawater and fixed with 200 µL gluteraldehyde. After 1-4 hour incubation in the fridge, the cryovials were transferred to the freezer (-80 °C). Samples will be sorted at the Flow Cytometry Core Facility at the University of Cape Town, after which sorted populations will be analysed for nitrate isotopes.

Phytoplankton molecular samples:

From the underway, duplicate 2000 ml seawater samples were collected and filtered through a Sterivex capsule (0.2 µm) using a peristaltic pump. From the CTD, duplicate 2000 ml samples from the shallowest three depths were collected and filtered. Once filtration was complete, the Sterivex was sealed, flash-frozen in liquid nitrogen, and stored in the freezer (-80 °C).

Size fractionated chlorophyll-a

Underway sampling: Three 500 ml seawater replicates were filtered through a 47 mm filter tower stack loaded with the following filter papers: 20 µm nylon net, 2 µm polycarbonate filter, and 0.7 µm glass fibre filter. The goal was to analysed the chlorophyll samples onboard, but the Turner 10AU fluorometer had an upper limit calibration issue and the filters were therefore preserved in tinfoil envelopes and frozen (-80 °C) for later analyses at the South African Environmental Observation Network (SAEON). Samples were also collected from the CTD using the same approach as described above, with replicates taken from the surface and the depth of the fluorescence maximum.

Phytoplankton diversity

Samples to determine phytoplankton diversity were collected from the underway system, CTD (surface and fluorescence maximum) and using 100 µm-mesh Bongo nets. The underway and CTD sampling involved collecting 1000 ml seawater samples that were preserved with 7% glutaraldehyde. In addition, water was filtered from the underway system through 20 µm filters until clogged (20-120 l) to further concentrate the microphytoplankton (diatoms). Oblique phytoplankton bongo trawls down and up from the fluorescence maximum were conducted after most of the CTD stations (seven trawls in total) and the samples were preserved in 7% glutaraldehyde.

Zooplankton diversity

Samples for zooplankton diversity were obtained from oblique double bongo (200 µm mesh) trawls - 15 minutes at the depth of the fluorescence maximum. The material collected in the first net was split, with one half preserved in ethanol and the other frozen at -20 ^{o}C for taxonomic analysis in South Africa. The contents of the second net were washed through a filtration stack consisting of 5000, 2000, 1000, 500, 250 and 150 µm mesh. The samples from each size class were dried onto a glass fibre filter, placed in petri-

dishes and frozen at -20 ^{o}C for molecular and isotopic analyses. The filtration of underway water through a 20 µm filter also yielded good samples of microzooplankton.

Microbial diversity and metabolic potential

Underway sampling: Three 2 l aliquots of seawater were collected in 5 l plastic bottles from the underway system and filtered through 0.2 µm polycarbonate filters in Pall filter cups. All three filters were rolled up and stored together in a single labelled 5 ml screw-capped tube with RNALater. The samples were stored sequentially at 4 °C and -20 °C for 24 hours before being transferred to the -80 °C freezer for long-term storage. In Cape Town, DNA will be extracted from these filters using the MoBio Power Water DNA Extraction kit. An amplicon library of the V4-V5 region of the 16S ribosmal RNA (rRNA) gene will be generated and sequenced for assessment of the bacterial community profile. CTD sampling: Sampling occurred sporadically. Water from the surface and fluorescence maximum were collected from the shallow casts. Three aliquots of 2 l of seawater were collected from three different Niskins bottles and were processed as described for underway sampling.

Constraints and limitations

Project 12 proposed to sample CTD casts both upstream and downstream of each Subantarctic island, as well as CTD stations in-between the islands. Unfortunately, this sampling requirement could not be met due to vessel limitations (unable to deploy the CTD in seas > 4 m or in strong wind) and time constraints. The limited number of CTD stations compromised several objectives of the original proposal. However, several components of the Project could be salvaged through regular sampling from the underway system, using the few CTDs and bongo trawls for calibration. In addition, ACE allowed Project 12 to sample the inshore environment around Île de la Possession and Kerguelen using zodiacs, hand-held CTDs and surface sampling. ACE also allowed Project 12 to sample the inshore environment around Bouvetøya using zodiacs in order to attain inshore and midshore surface samples. Unfortunately, no phytoplankton or zooplankton bongo nets were conducted during Leg 3 and therefore it will be difficult to determine the composition and dynamics of the zooplankton communities in the South Atlantic and surrounding the islands.

There were some technical problems with equipment in the laboratory. Filter towers were constructed by gluing three Pall filter cups together. Continued use resulted in leaks from the cups themselves and breaks in the sealed areas, which lowered the effectiveness of the vacuum filtration. New towers were built twice during Leg 3 to overcome these issues. During Leg 3, it was further observed that the water would often pool above the final 0.7 µm filter. Removal of the perforated plastic disk below the filter significantly improved water flow through the filter. No damage to the filter was observed so the discs were removed for subsequent filtrations.

Bacterial sterility on the ship was somewhat limited without Bunsen burners. Forceps used to replace and remove filters from the filter cups were washed in ethanol and briefly air-dried. Cardboard bases were washed three times with MilliQ water between filtrations to minimize cross contamination of the filtered samples.

Preliminary results

During Leg 1, a total of seven CTD stations, seven phytoplankton bongo trawls, five zooplankton bongo trawls, 52 underway sampling events and five inshore island stations were successfully sampled. The study site map below shows the geographic spread of the sampling events.

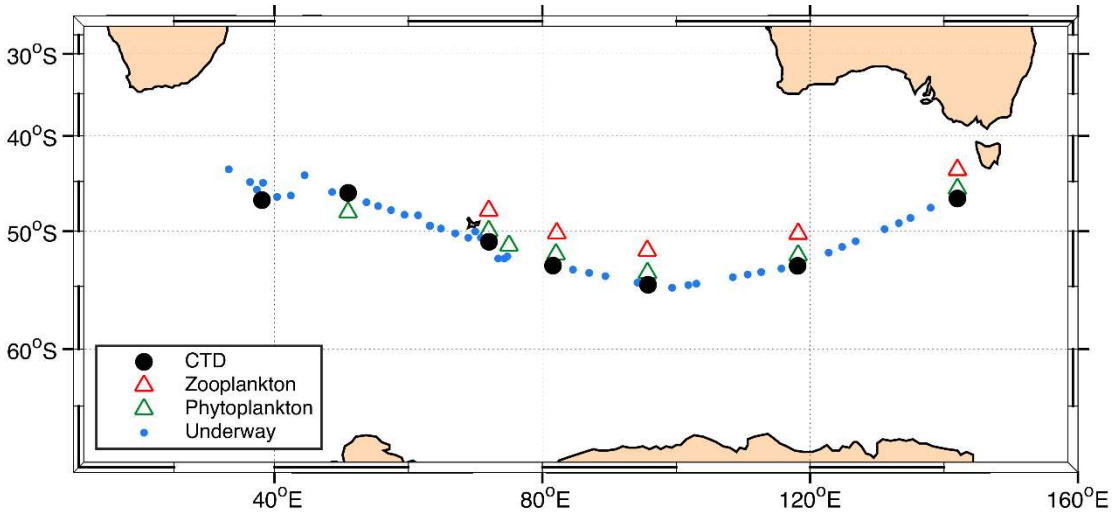


Figure 102: Study site map showing leg1 sampling locations for Project 12.

All 2000+ samples collected during Leg 1 will be analysed ashore in South Africa and the USA.

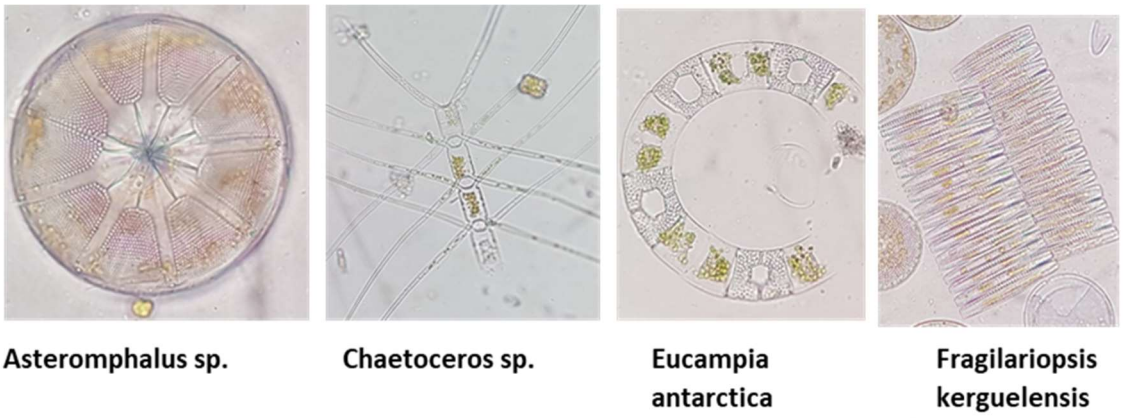


Figure 103: Diatoms from the underway system (400 x using a Zeiss Primostar light microscope)

Figure 104: Selected zooplankton from the bongo trawls

Data returns

More than 2000 samples were collected for Project 12 during Leg 1. All the samples will be analysed by mid 2018 and finalised datasets will be provided to ACE as near as possible to the end of the Project. In an attempt to meet some of the Project's initial objectives and to collect sufficient data for the student Projects, a grant application was submitted to the South African National Antarctic Programme (SANAP) (and was successful) to study selected island ecosystems in more detail (specifically, the Prince Edward Islands).

Key personnel on Leg 1

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Leg 3

A total of nine CTD stations, thirty-one underway sampling events, four island nutrient and isotope samples and one inshore island station were successfully sampled on Leg 3. The map shows the geographic spread of the samplings. Around 1500 samples were collected for Project 12. These will be processed following the Leg 1 samples, with the exception of the POC/PON and ammonium samples. Analyses of these is complete and following quality control, these data will be submitted to ACE.

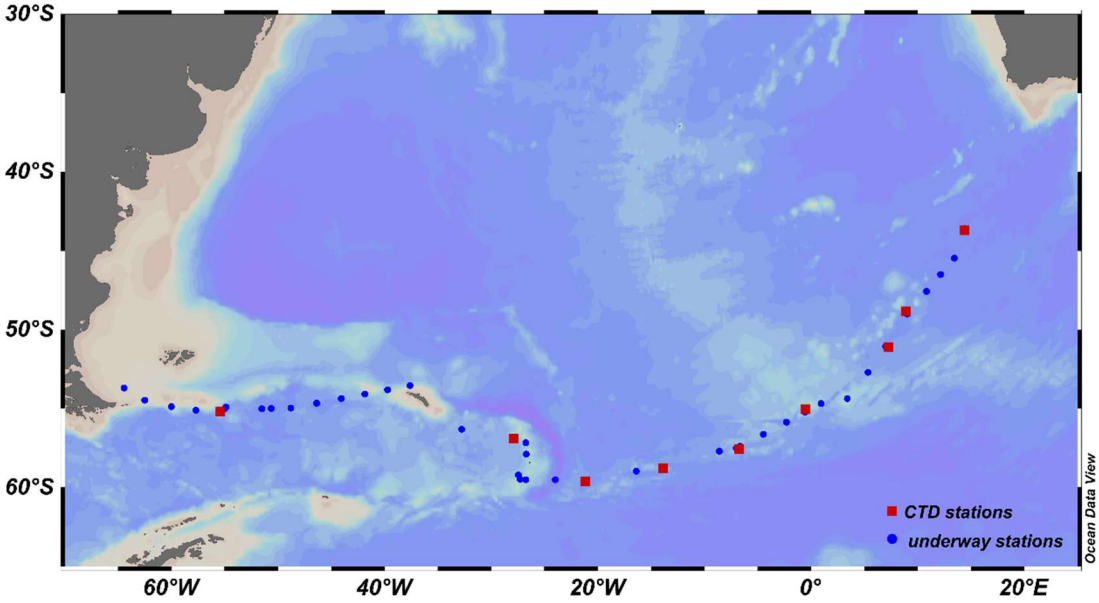

Figure 105: Study site map showing sampling locations for the duration of Leg 3 for Project XII; the red squares show the CTD stations and the blue circles the stations where underway samples were taken.

Key Personnel on Leg3:

Raquel Flynn	**Heather Forrer**	**Samantha Waterworth**
Nitrogen dynamics and isotopes	Nitrogen dynamics and isotopes	Microbial diversity & genetics
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References

Holmes RM, Aminot A, Kérouel R, Hooker BA and BJ Peterson (1999) A simple and precise method for measuring ammonium in marine and freshwater ecosystems. Canadian Journal of Fisheries and Aquatic Sciences 56:1801-1808. https://doi.org/10.1139/f99-128

Sigman DM, Casciotti KL, Andreani M, Barford C, Galanter M and JK Böhlke (2001) A bacterial method for the nitrogen isotopic analysis of nitrate in seawater and freshwater. Analytical Chemistry 73:4145–4153.

10.13 Project 13

Antarctic Circumpolar Study of the relation of Carbon Export Production to Plankton Community Characteristics

PI Nicolas Cassar (USA)

Aims and Objectives

Our goal was to investigate some of the physiological and ecosystem mechanisms governing net community production in the Southern Ocean. More specifically, we aimed to test the relationship between plankton community diversity and net community production.

Sampling

We sampled to determine the following:

Figure 106: A second generation Equilibrator Inlet Mass Spectrometry (nXT-EIMS) sampling seawater underway.

1) High-resolution O2/Ar-derived net community production (NCP), estimated by a second generation (nXT) Equilibrator Inlet Mass Spectrometry (EIMS) sampling from the ship's seawater underway system. The mass spectrometry data was recorded continuously onto a desktop and was backed up on a USB drive every 24 hours, and finally the data was backed up to the ship's data server. In the later data processing we will take 2-minute averages.

This was the first cruise for this new instrument. Both the hardware and software functioned well. The specially designed waterproof frame, and the thermal control of mass spectrometer and gas lines provided us data with higher accuracy than the previous version of EIMS. That was because there was less water vapor interference and greater stability in temperature and pressure. The newly developed all-in-one software Triton also functioned well. There was a loss of communication between the PC and the mass spectrometer, which happened several times during the cruise and had been recorded in the data log file with timestamps.

The inert gas Ar has physical properties similar to O_2. Using measured O_2 and Ar underway we can calculate the O_2 supersaturation caused by biology. The biological O_2 supersaturation at the ocean surface can be calculated as below,

$$\Delta(O_2/Ar) = \left[\frac{(O_2/Ar)}{(O_2/Ar)_{sat}} - 1\right]$$

Assuming steady state and neglecting vertical mixing across the mixed layer boundary, NCP could be calculated as:

$$NCP = k\rho[O_2]\Delta(O_2/Ar)$$

Where ρ is mixed layer density, and k is the gas transfer velocity for O_2 estimated from reanalysis winds, a wind speed parameterization, and a gas exchange weighting.

2) Plankton diversity. Plankton community biomass, composition and taxonomy will be accessed from the DNA samples collected, using high-throughput sequencing of Eukaryotic, Archaeal and Bacterial ribosomal RNA gene markers. Discrete DNA samples were taken every six hours from the ship's seawater underway system for spatial variability, and at CTD stations for vertical profiles of plankton community characterizations.

Our biological observations were also complemented with the underway Imaging Flow Cytobot (IFCB) observations conducted by Project 1. Unfortunately the IFCB did not work during Leg 2 and Leg 3. The internal camera appeared broken and could not capture phytoplankton cell images properly.

3) Island microbial communities. We sampled on several islands for DNA analyses to explore island-to-island variability in fresh water and soil microbial communities. During Leg 3 we took samples for microbial biodiversity from South Georgia (rivers and soil near penguin colonies), as well as some surface snow samples from Bouvetøya.

The DNA samples taken from all three Legs, including 3 µm and 0.2 µm filter membranes, and 0.2 µm Sterivex filter cartridges, are summarized below:

Table 24: Number of DNA samples and water filter samples collected by project 13 during ACE..

Leg	Route	Number of DNA samples	Number of filters
Leg 0	Bremerhaven to Cape Town	100	200
Leg 1	Cape Town to Hobart	79	158
Leg 2	Hobart to Punta Arenas	176	391
Leg 3	Punta Arenas to Cape Town	88	203
Leg 4	Cape Town to Bremerhaven	66	132
Total		509	1084

Equipment issues

We found that the ship's original underway line was unsuitable for biological and chemical sampling because of a large amount of rust in the pump and pipes. A new pump and plastic tubing were installed in Cape Town on the ship from the intake to the wetlab (CTD) laboratory. The plastic tubing was covered with duct-tape and black plastic bags to exclude light but unfortunately no insulation was initially provided for the lines. The temperature increase from the intake through the engine room to the CTD laboratory (through the ship's hallway) was significant, especially when the water became colder. Foam insulation for the tubing was finally added in Hobart.

Because the ship's CTD was not engineered for deployment in rough seas, we only had a limited number of CTD deployments during Leg 1. The use of Expendable Bathythermographs (XBTs) on other Legs helped to characterise the physical properties of the water column. In our case, we were particularly interested in the depth of the mixed layer.

10.14 Project 14

Circumpolar acoustic mapping of endangered Southern Ocean marine mammals

PI Brian Miller (Australia)

Aims and Objectives

The overall aim of this Project was to conduct a passive acoustic survey of the distribution of vocalising marine mammals during the Antarctic Circumnavigation Expedition. While most marine mammal species are known to produce underwater vocalisations, some species are more amenable to detection via passive acoustic survey than others. The species of interest during Leg 2 were blue whales and fin whales because these species are known to make repeated loud low frequency calls that can frequently be detected from many tens to several hundreds of kilometres away. Thus, blue and fin whales are particularly amenable to passive acoustic survey via low-frequency radio-linked hydrophones (e.g. directional sonobuoys).

Specific aims of the project during Leg 2 were to:

- Map the location and boundaries of meso-scale aggregations of calling Antarctic blue whales
- Investigate whether Antarctic blue whales were present at a potential hot-spot in the mouth of the Ross Sea where they have been found on two previous voyages.
- Investigate the distribution of calls from pygmy blue whale in the Tasman Sea, subantarctic, and Chilean waters.

Methods

Underwater listening stations were conducted from the Akademik Tryoshnikov during Leg 2 (Hobart to Punta Arenas) of ACE. At each listening station an SSQ955-HIDAR sonobuoy (Ultra Electronics Sonar Systems, UK) was deployed to a depth of 140 m in DIFAR (standard analog) mode. Listening stations were conducted every 30-60 nmi along the voyage track during transit and at each island stop and marine science station. This sampling regime was a tradeoff that attempted to balance high spatial resolution with the finite number of sonobuoys available for this Project. Two acousticians worked opposing 12 hour shifts for 24-hour coverage to ensure that sonobuoys were deployed at regular spatial intervals. On a few occasions sonobuoys were deployed at intervals less than 30 nmi in order to try to obtain better recordings or localisations of specific groups of animals.

While the focus of this Project was passive acoustic mapping, visual survey for marine mammals was also conducted when possible. Visual observations were conducted from the monkey island, and sighting effort, species, and group size of sightings were recorded. Photographs of sightings were taken whenever possible to provide confirmation of species identification.

Instrumentation, software, and data collection

Each sonobuoy transmitted underwater acoustic signals from the hydrophone and directional senors back to the ship via a VHF radio transmitter. Radio signals from the sonobuoy were received using an omnidirectional VHF antenna (PCTel Inc. MFB1443; 3 dB gain tuned to 144 MHz centre frequency) and a Yagi antenna (Broadband Propagation Pty Ltd, Sydney Australia) mounted on the top of the helicopter control room at a height of approximately 21 m. The antennas were each directly connected to a WiNRADiO G39WSBe sonobuoy receiver via low-loss LMR400 coaxial cable. The radio reception range on the Yagi antenna was similar to previous Antarctic voyages, and was adequate for monitoring and localisation out to a typical range of 12-14 nmi provided that the sonobuoy was within the main axis of the antenna. The radio reception on the omnidirectional antenna typically provided 5-8 nmi of omnidirectional reception from sonobuoys. During transit the Yagi antenna provided about 55 minutes of acoustic

recording time per sonobuoy given the typical 14-15 knot transit speed, and both antennas together were able to provide radio reception for up to 6 hours (i.e. the maximum life of a 955 sonobuoy) when sonobuoys were deployed within 5 nmi of a Station. Received signals were digitised via the instrument inputs of a Fireface UFX sound board (RME Fireface; RME Inc.). Digitised signals were recorded on a personal computer as 48 kHz 24-bit WAV audio files using the software program PAMGuard (Gillespie et al. 2008). Data from both the Yagi and Omnidirectional antenna were recorded simultaneously as wav audio channels 0 (left) and 1 (right), thus each recorded WAV file contains a substantial amount of duplication since both antennas and receivers were typically receiving the same signals from the same sonobuoy.

In addition to regular listening stations, a prototype reusable sonobuoy was deployed 800 m away from the ship via zodiac for listening station #98 in shallow water off the coast of Mt Siple. This reusable sonobuoy consisted of a VHF radio and lead-acid battery housed in a PVC spar buoy, and a DIFAR sensor connected to the spar buoy via approximately 20 m of coiled sonobuoy cable with an elastic core that served to minimise movement in the water column. The GPS position of deployment was measured via a handheld GPS and relayed back to the ship by the deployment team in the zodiac. The reusable sonobuoy functioned well, was calibrated with ship noise, and data quality appeared to be sufficient to localise the zodiacs, as well as a few faint calls from Antarctic blue whales and a minke whale.

Calibration

Directional calibration

The magnetic compass in each sonobuoy was calibrated/validated upon deployment as described by Miller et al. (2015). Calibration procedure involved measuring the mean bearing error and standard deviation of errors between the GPS derived bearing from the sonobuoy to the ship and the magnetic bearing to the ship-noise reported by the sonobuoy. Typically 15-20 bearings were used for each calibration as the ship steamed directly away from the deployment location.

Intensity calibration

A hydrophone sensitivity of 122 dB re 1 µPa was applied to recordings via the Hydrophone Array Manager in PAMGuard. This value is the reference intensity at 100 Hz for a DIFAR sonobuoy, and should generate a frequency deviation of 25 kHz (Maranda 2001). According to manufacturer's specifications, the WiNRADiO G39 WSB has a voltage response of 1 V-peak -peak at 25 kHz frequency deviation. The gain of the instrument input on the Fireface UFX was set to 20 dB, yielding a maximum voltage input voltage range of 8.36 V peak-peak. These calibration factors, along with the shaped filter response provided by Greene et al. (2004) can be used to obtain calibrated pressure amplitude from the recorded WAV audio files.

Monitoring and analysis

Aural and visual monitoring of audio and spectrograms from each sonobuoy was conducted for at least an hour at each listening station. Two different spectrograms were typically viewed, one for low-frequency sounds with the following parameters: 250 Hz sample rate; 256 sample Fast Fourier Transform (FFT); 32 sample advance between time slices. The other spectrogram was used to view mid-frequency sounds with the following parameters: 8000 Hz sample rate; 1024 sample FFT; 128 sample advance between time slices. Monitoring was typically conducted in real-time as data were being acquired, and the intensity scale of the spectrogram was adjusted by the operator to suit the ambient noise conditions.

Signals from marine mammals, ice, and other sources were detected and classified manually, and their time and frequency bounds were marked on the spectrogram. The PAMGuard DIFAR module (Miller et al. 2016) was then used to measure the direction of arrival and intensity of suitable calls from a variety of species such as tonal, frequency-modulated, and pulsed calls of baleen whales; whistles and trills from pinnipeds;

and also some whistles from toothed whales. Echolocation clicks from sperm whales were noted in the PAMGuard UserInput (free form notes stored in the PAMGuard Sqlite database), but were not able to be localised with the DIFAR module due to limitations inherent in directional sensors in the sonobuoy. Each detection, bearing, and intensity measurement were saved as PAMGuard binary files in addition to the DIFAR_Localisation table of the PAMGuard database. In addition to PAMGuard binary files and audio files, the PAMGuard settings and metadata were saved inside the PAMGuard Sqlite database.

Preliminary results

A total of 159 directional sonobuoys were deployed during Leg 2, yielding 259 hours of underwater passive acoustic data.

Objective 1: Map distribution of Blue Whales

The calls of Antarctic blue whales (Rankin et al. 2005) were detected on 140 of the 159 listening stations. At many of these listening stations, the detection consisted of only a fragment of a 26 Hz tone, the first unit of the three-part call (AKA Z-call or song) of Antarctic blue whales (Figure 107).

The first detection of Antarctic blue whales occurred during the transit from Hobart to Mertz at a latitude of 56^{o} 30’ S, (presumably near the Antarctic polar front), and they were then detected at all but one listening station south of 56^{o} 30’ S. On 77 listening stations frequency modulated (FM) calls (Figure 108) believed to be from blue whales were detected.

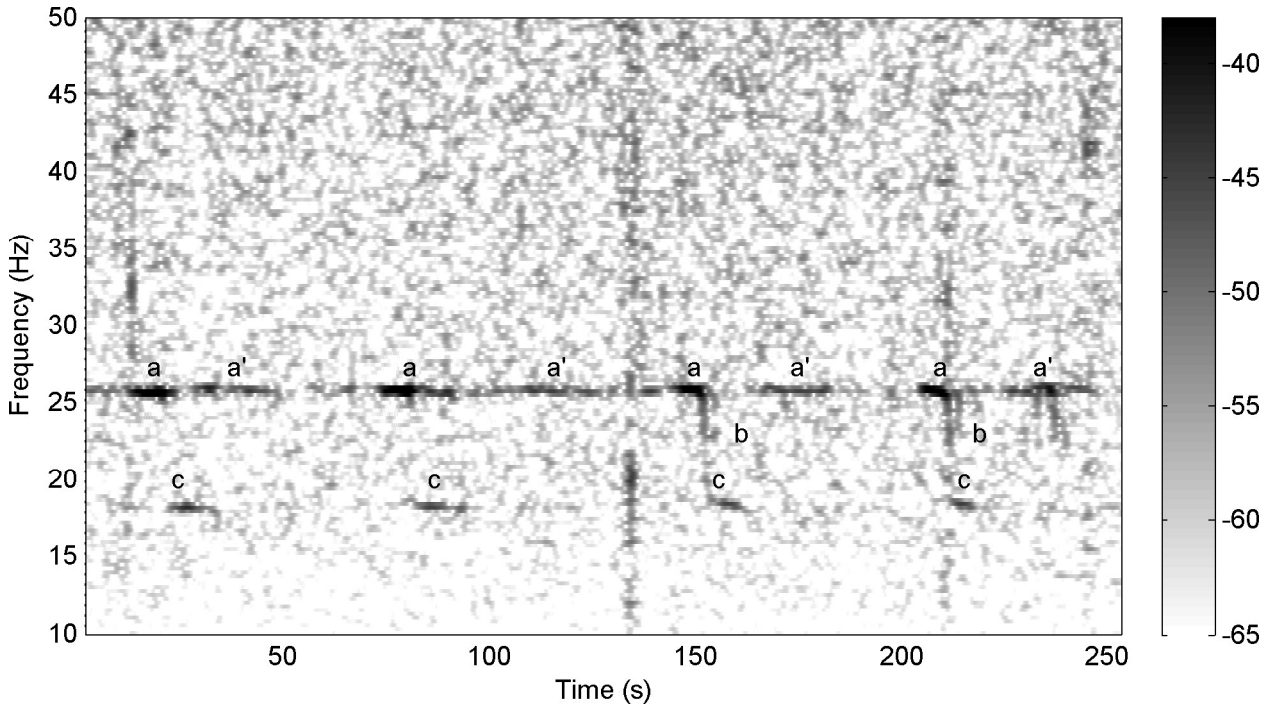

Figure 107: Spectrogram of stereotyped Antarctic blue whale tonal calls (AKA song, or Z-calls). The start of the spectrogram is 10 February 2017 at 16:30:48. The three stereotyped units that comprise Antarctic blue whale song are labelled as a, b, and c. All three units are not always detected, with unit a being the most frequently detected. In this recording at least two whales are calling, with the second caller indicated as a’. Spectrogram parameters: sample rate 125 Hz; 512 sample FFT, 95% overlap between time slices. Arbitrary intensity scale.

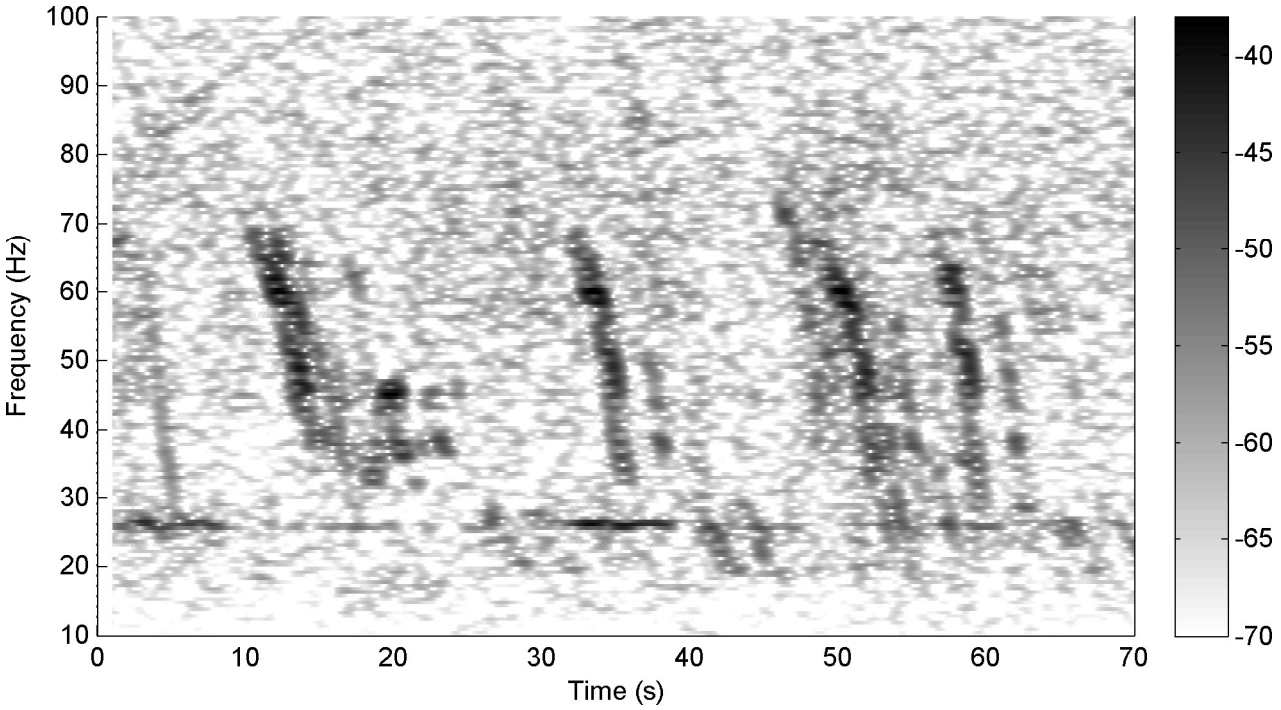

Figure 108: Spectrogram of blue whale FM calls (AKA D-calls). Blue whale FM calls are typically downswept, more than 2 seconds in duration, and have energy between 80 and 30 Hz. Recorded on 01 Jan 2017 11:10. Spectrogram parameters: sample rate 250 Hz; 512 sample FFT, 95% overlap between time slices. Abitrary intensity scale.

Bearings to more than 15,000 calls from blue whales were obtained in real-time during Leg 2, and preliminary maps of their distribution were created using PAMGuard Viewer. Separate maps were created for tonal (Figure 109) and FM calls (Figure 110). These preliminary results show every localised call, and appear to reveal information about the distribution and spatial boundaries of groups of calling Antarctic blue whales. However, these maps should not be used for making inferences about the density of calls or abundance of animals. Inferences about density will first require standardisation of the recording time and also the probability of detecting blue whales at each station. Estimating the probability of detection involves measuring noise levels and modelling acoustic propagation and detection range for each station, and such analysis will need to be conducted after the voyage.

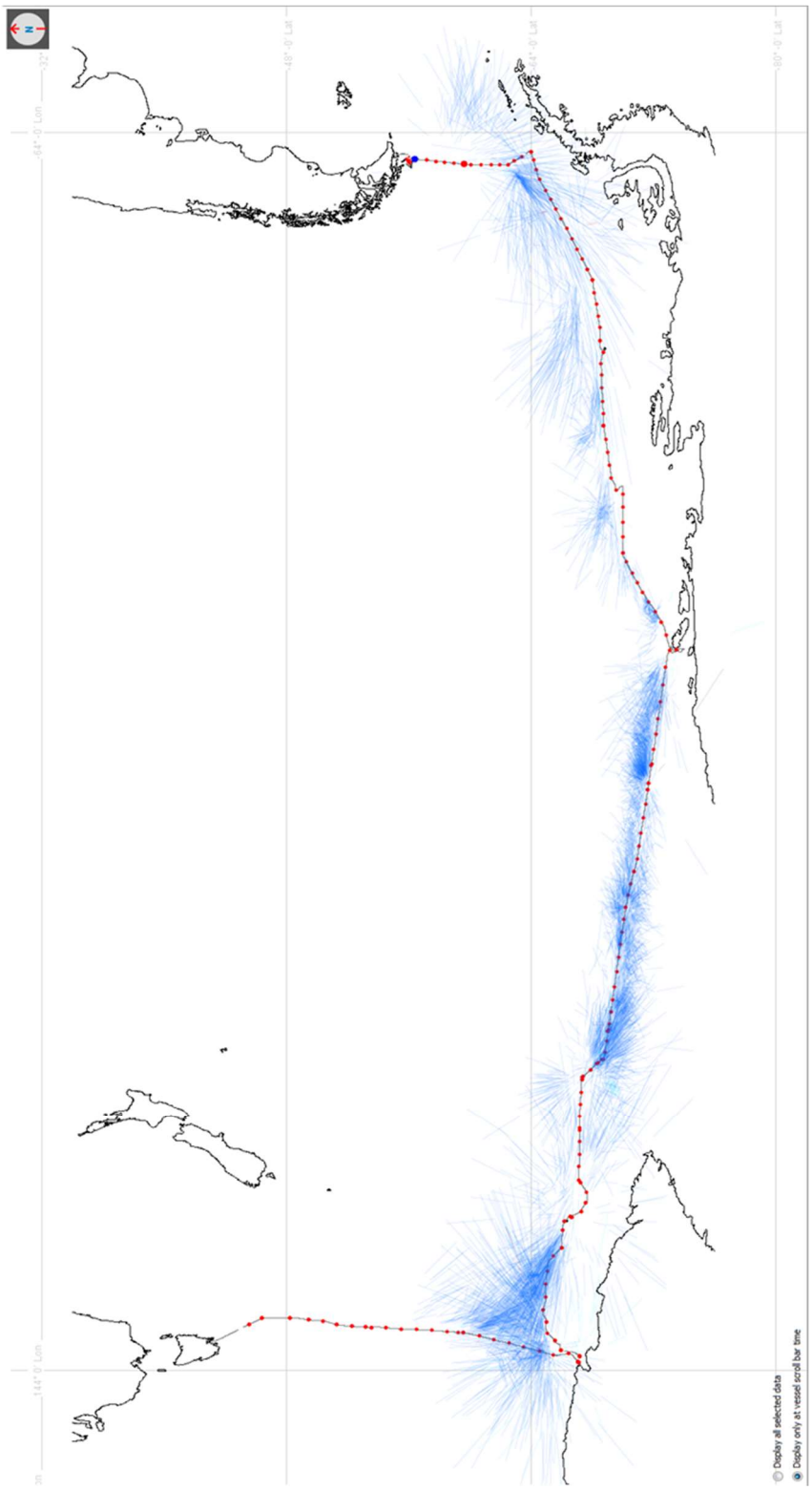

Figure 109: - Map of bearings for acoustic detections of unit A of Antarctic blue whale song. Map generated in PAMGuard viewer. Red circles show the location of listening stations. Blue lines show bearings to Unit A of Antarctic blue song. Lines are 70% transparent so that multiple overlapping bearings produce a darker colour.

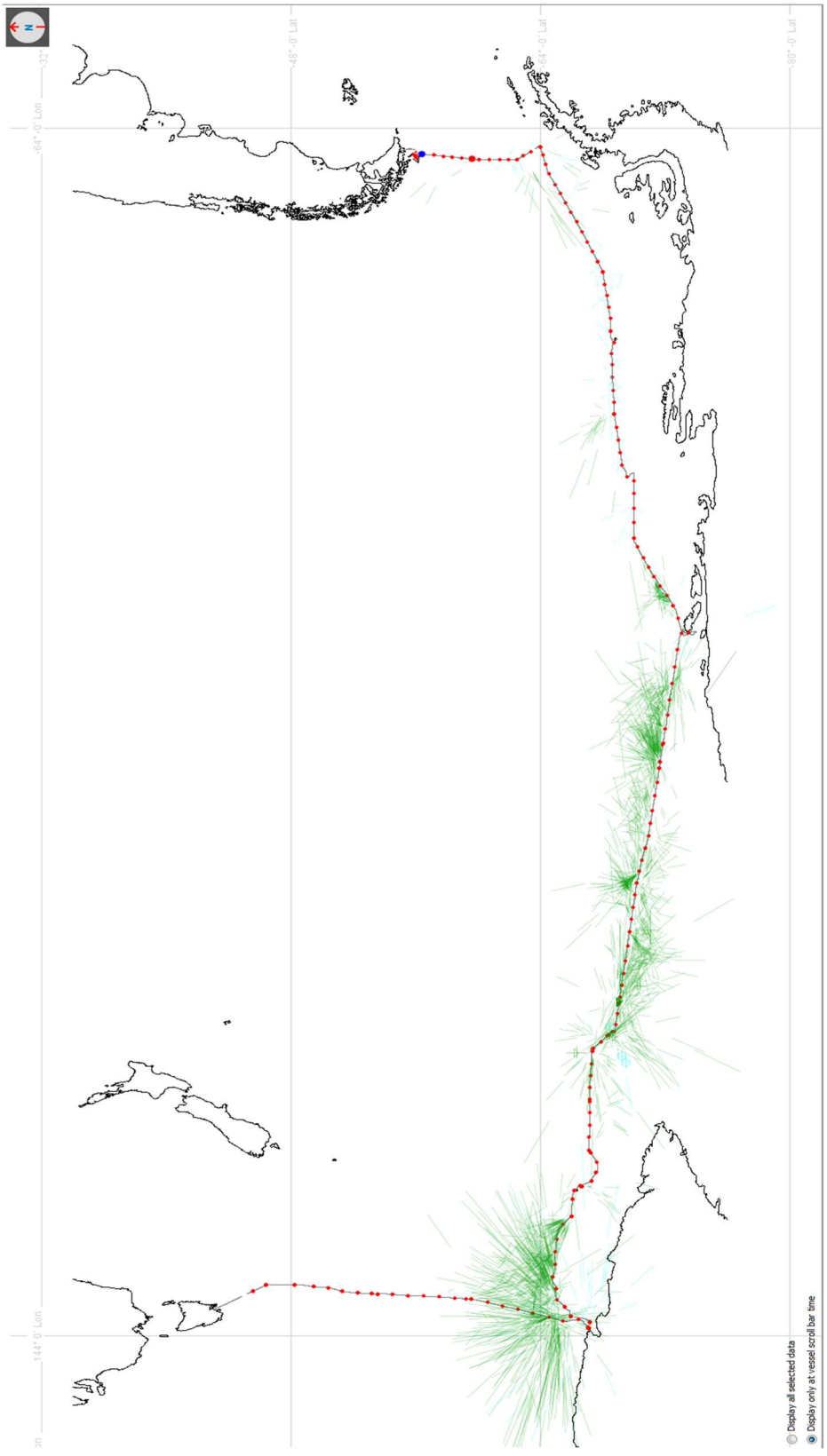

Figure 110: Map of bearings for acoustic detections of blue whale FM calls. Map generated in PAMGuard viewer. Red circles show the location of listening stations. Green lines show bearings to FM calls of Antarctic blue whales, and are plotted as 70% transparent so that overlapping bearings produce a darker colour.

Objective 2: Investigate presence of Antarctic blue whales in the mouth of the Ross sea (potential hotspot)

When departing from Scott Island on 07 February 2017, Antarctic blue whale tonal and FM calls were detected and located coming from an area where they had been seen before on two prior voyages. The voyage track was altered slightly more to the south to move closer to this location to more precisely map the distribution of whale calls in this area. The *Akademik Tryoshnikov* passed through the previous Antarctic blue whale hotspot at night, and intense calls of Antarctic blue whale tonal calls and blue whale FM calls were detected. The following morning three Antarctic blue whales were seen along the trackline over two sightings. Photographs were taken to confirm species identification (Figure 111), but the groups were too distant to obtain photographs for individual identification. Two Antarctic blue whales were seen and photographed again on 10 February 2017 in a single sighting, but again the whales did not present at an angle or distance suitable for photographic identification.

Figure 111: Photograph of Antarctic blue whale seen on 7 Feb 2017 at 20:14 UTC (top), and of Antarctic blue whale seen on 10 Feb 2017 at 17:36 UTC (bottom).

Objective 3: Investigate the distribution of calls from pygmy blue whales in the Tasman Sea, subantarcic and Chilean waters

No calls from pygmy blue whales were detected in the Tasman Sea, subantarctic or Chilean waters during ACE Leg 2.

Objective 4: Collect data on the distribution of calls from other marine mammals

During the 159 listening stations calls from eight different species of marine mammal were identified. Species that were acoustically identified were: Antarctic blue whale (*Balaenoptera musculus intermedia*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliea*), minke whale (*Balaenoptera bonaerensis*), sperm whale (*Physeter macrocephalus*), killer whale (*Orcinus orca*), crabeater seal (*Lobodon carcinophaga*), and leopard seal (*Hyrurga leptonyx*). In addition to the detections of marine mammal sounds, impulsive broadband noise from ice was also noted for each sonobuoy when detected. However, only a small subset of detections of ice-noise were localised. Table 25 shows the number of listening stations that had detections of each call type, and the number of localisations obtained during monitoring.

Table 25: List of call types that were detected, the number of listening stations on which they were detected, and the total number of bearings obtained in real-time during monitoring.

Call Type	Number of listening stations with detections	Number of real-time localisations
Antarctic blue unit 'a'	140	11270
Antarctic blue unit 'b'	31	-
Antarctic blue Z-call	15	49
Blue whale FM (D-call)	77	4281
Tasman Pacific (New Zealand) blue	0	0
Indo-Australian pygmy blue	0	0
Southeast pacific (Chilean) blue	0	0
Unidentified low frequency sound	89	687
Unidentified baleen whale downsweep	52	-
Fin whale FM (downsweep)	21	444
Fin whale 20 Hz note	12	377
Minke whale downsweep	5	62
Minke whale bioduck	2	13
Sei whale	0	0
Sperm whale	16	-
Killer whale	17	406
Humpback whale	20	1630
Crabeater seal	2	0
Ross seal	0	0
Weddell seal	0	0
Leopard seal	14	45
Seismic airguns	0	0
Ice	112	520
Total	159	19784

Visual observations

A total of 104 sightings of cetaceans were made by our Project personnel on Leg 2 (Table 26). Photographs were taken for 82 of these sightings for the purposes of species identification. Overall, 88 of these sightings were made across 26.5 hours of sighting effort, and the remaining 16 occurred while off-effort. One sighting was a mixed-species group of both blue and fin whales.

Table 26: List of species visually sighted with total number of sightings and number of individual animals per species.

Species	Number of sightings	Number of individuals
Antarctic blue whale (Certain)	2	4
Antarctic blue whale (Likely)	3	5
Antarctic minke whale	44	127
Fin whale (Certain)	4	7
Fin whale (Likely)	3	13
Hourglass dolphin	1	10
Humpback whale	33	72
Killer whale	1	8
Long-finned pilot whale	1	50
Peale's dolphin	2	17
Sei whale	1	1
Unidentified whale	10	17
Total	105	331

While at Mertz Glacier on 29 January 2017, single-species recordings were made of Antarctic minke whales on two occasions. Photographs were obtained to confirm species identification (Figure 112). While the total number of calls recorded was low, they are still notable since there are only a handful of reported recordings of these sounds made in the confirmed presence of this species.

Figure 112: - Photographs of Antarctic minke whale recorded near the Mertz Glacier on 29 January 2017.

In addition to the visual observations and photographs collected by E. Miller, there were two other Projects that independently recorded sightings of marine mammals during Leg 2. Project 20: Monitoring of threatened albatrosses and penguins: population censuses and distribution at sea (PI: Ryan) and Project 5: Active acoustic detection of deep scattering layers (DSL) and marine mammal visual observations (PI: Brierley). Each had dedicated personnel conducting visual sightings surveys from either the monkey island or bridge. More information on the aims, methodology, and results of these Projects can be found in their voyage reports for Leg 2.

Problems encountered

Only minor problems were encountered during data collection for this Project. The main problems encountered included sonobuoy failures and software crashes. Crashes in the analysis software PAMGuard typically occurred once every two to three days, but these generally occurred outside of listening stations and thus had a minimal impact on data collection. Failures of up to 10% of sonobuoys were anticipated based on failure rates measured during previous voyages. During Leg 2, only four of 159 sonobuoys failed to yield any data, and three of the 159 sonobuoys were considered partial failures. Partial failures functioned reliably for less than an hour before failing to transmit or before the directional sensors were deemed to be unreliable for localisation. Including partial failures, the failure rate of sonobuoys during Leg 2 was 4.4%, much lower than previous voyages.

While marine science stations and island stopovers provided opportunities to obtain longer duration listening stations than those during transit, ship and radio noise during some stations and stopovers affected the quality of data. Noise from thrusters (Figure 113) was a notable source of loud and frequent intermittent noise at many stations. In addition to potentially masking marine mammal sounds from being detected, thruster noise regularly saturated the recording chain, even when sonobuoys were deployed more than two nautical miles from the station.

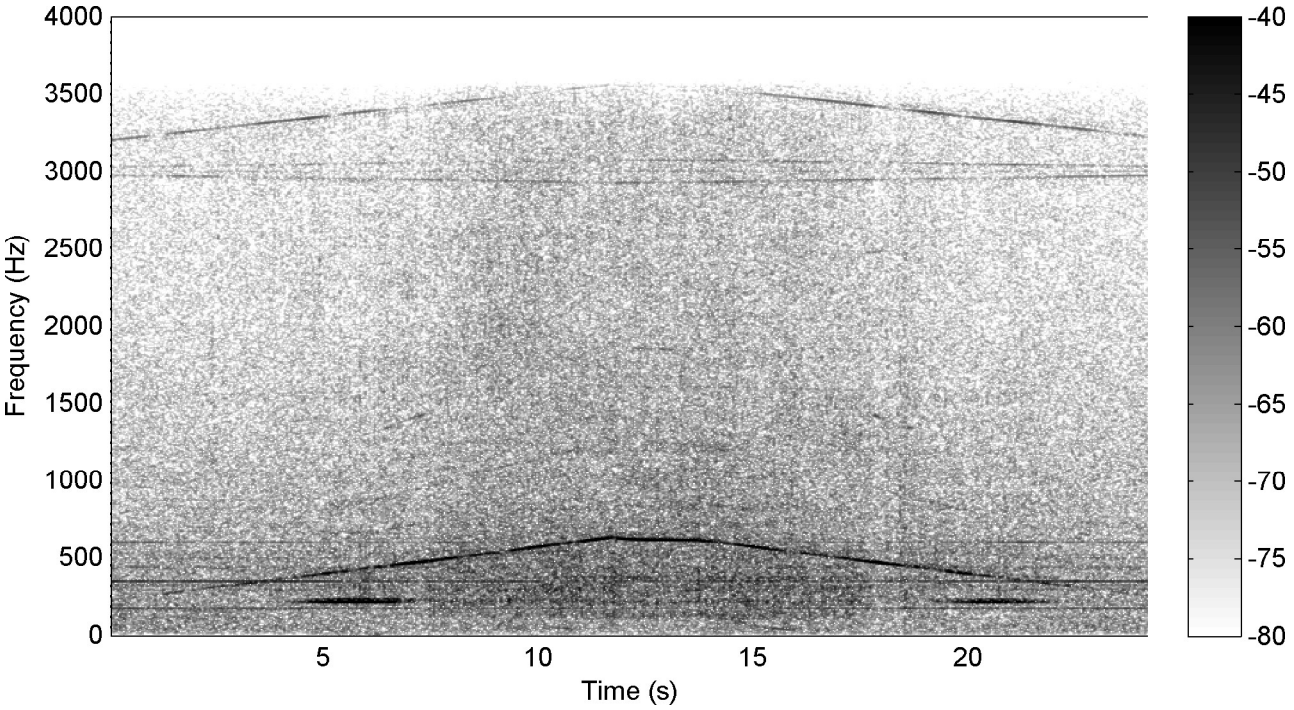

Figure 113: Spectrogram of thruster noise from the Akademik Tryoshnikov

Leg 3

Data collection on Leg 3 followed the same protocols as Leg 2 with sonobuoy deployments every 30 nm with additional opportunistic deployments. A total of 141 sonobuoys was deployed between Punta Arenas and Cape Town. The equipment all continued to work well during Leg 3 with no major problems with hardware or software. Deployments at CTD stations when the vessel was stationary for several hours were attempted where possible. However, ensuring that a sonobuoy was deployed close enough to the vessel to obtain good radio reception without the directional aerial (which only pointed aft), but not too close to the vessel because of thruster and propeller noise, was not always straightforward.

Results are given here for the first 122 buoys deployed up until the 15 March 2017. This generated 141 hours of acoustic recordings. Of these there were four total failures where no radio signal was received from the buoy and four partial failures where transmission stopped within 20 minutes of deployment. Three of those partial failures were on the first day of deployments on Leg 3 and were attributed to dropping the buoys into an area of turbulence on the port side generated by the propeller. It is possible that this level of turbulence caused some damage to the buoys. All subsequent buoys were deployed from the starboard side where the 'paddlewheel' effect from the left-handed propeller would be more likely to push them away from the vessel. The overall failure rate was still lower than previous cruises and within the manufacturer's guidance for expected failures.

Table 27: lists the species heard on Leg 3 alongside the equivalent numbers for Leg 2.

	Leg 2		**Leg 3**	
Call Type	No. of listening stations with detections	No. of real-time localisations	No. of listening stations with detections	No. of real-time localisations
Antarctic blue unit 'a'	140	11270	116	5090
Antarctic blue unit 'b'	31	-	14	-
Antarctic blue Z-call	15	49	4	13
Blue whale FM (D-call)	77	4281	27	749

Tasman Pacific (New Zealand) blue	0	0	0	0
Indo-Australian pygmy blue	0	0	0	0
Southeast pacific (Chilean) blue	0	0	0	0
Unidentified low frequency sound	89	687	27	141
Unidentified baleen whale downsweep	52	-	-	-
Fin whale FM (downsweep)	21	444	6	24
Fin whale 20 Hz note	12	377	5	67
Minke whale downsweep	5	62	0	0
Minke whale bioduck	2	13	0	0
Sei whale	0	0	0	0
Sperm whale	16	-	13	-
Killer whale	17	406	0	0
Humpback whale	20	1630	39	414
Crabeater seal	2	0	0	0
Ross seal	0	0	0	0
Weddell seal	0	0	0	0
Leopard seal	14	45	0	0
Seismic airguns	0	0	0	0
Ice	112	520	66	211
Buoy failures			4	
Total	159	19784	122	6709

The cruise track and sonobuoy deployments (red dots) are shown in Figure 114. This also shows the bearings to Antarctic blue whale FM calls. These indicate relatively close proximity to vocalising blue whales and can be seen to be clustered in three areas, west of South Georgia, northwest of South Georgia and between the South Sandwich Islands and Bouvetøya. The group of whales encountered to the northwest of South Georgia were close to two long-term bottom mounted acoustic recorders. This should allow a comparison of the localisations from the sonobuoys with longer-term data on whale presence in the area.

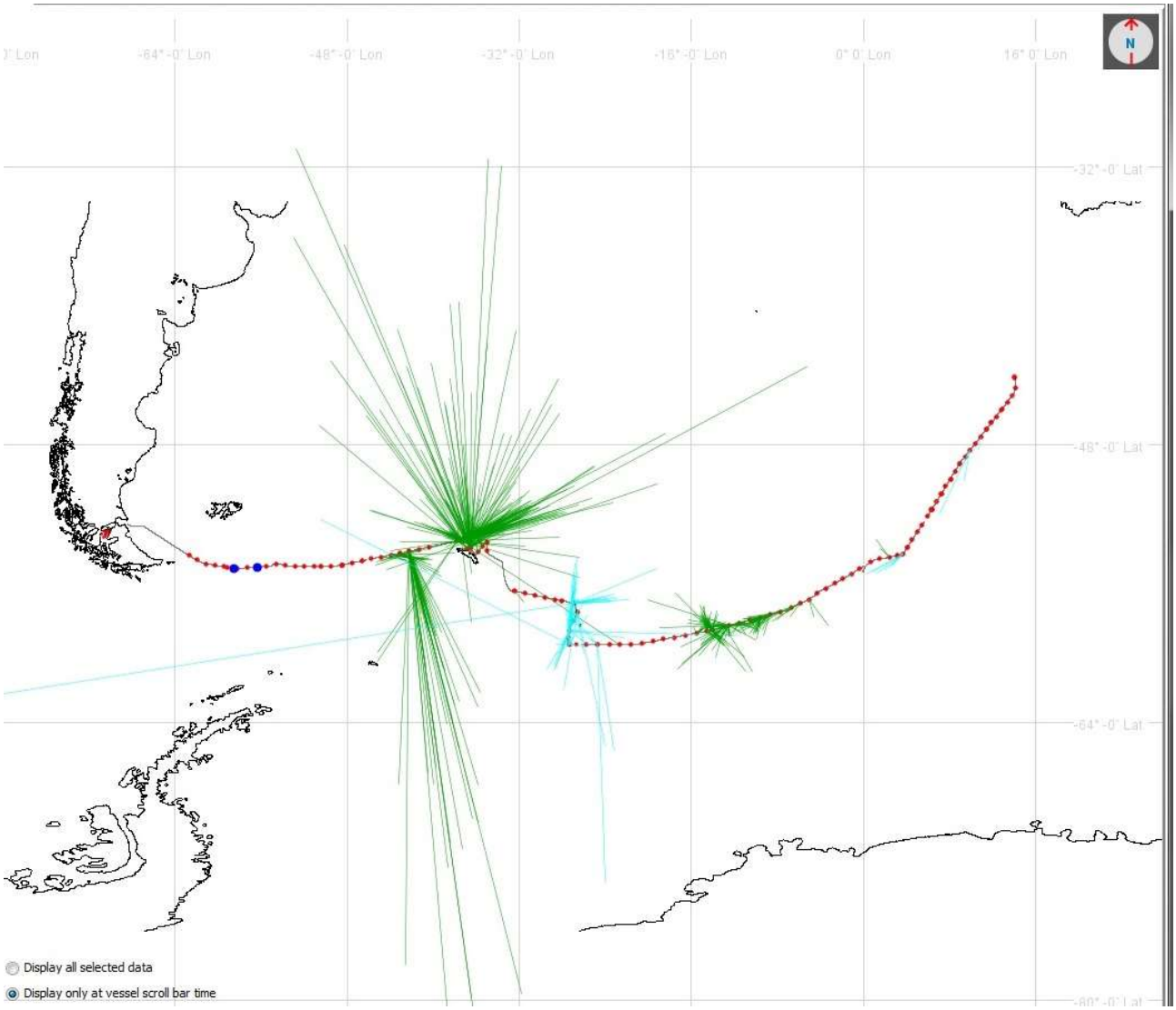

Figure 114: Leg 3 sonobuoy deployments up until the 15 March 2017 (red dots). Green lines indicate bearings to Antarctic blue whale FM calls. Pale blue lines indicate bearings to ice noise which was particularly prevalent around the South Sandwich Islands. Map created in PAMguard.

Bearings to the unit A, Antarctic blue whale calls which were by far the most frequent call type recorded for any species are shown in Figure 115.

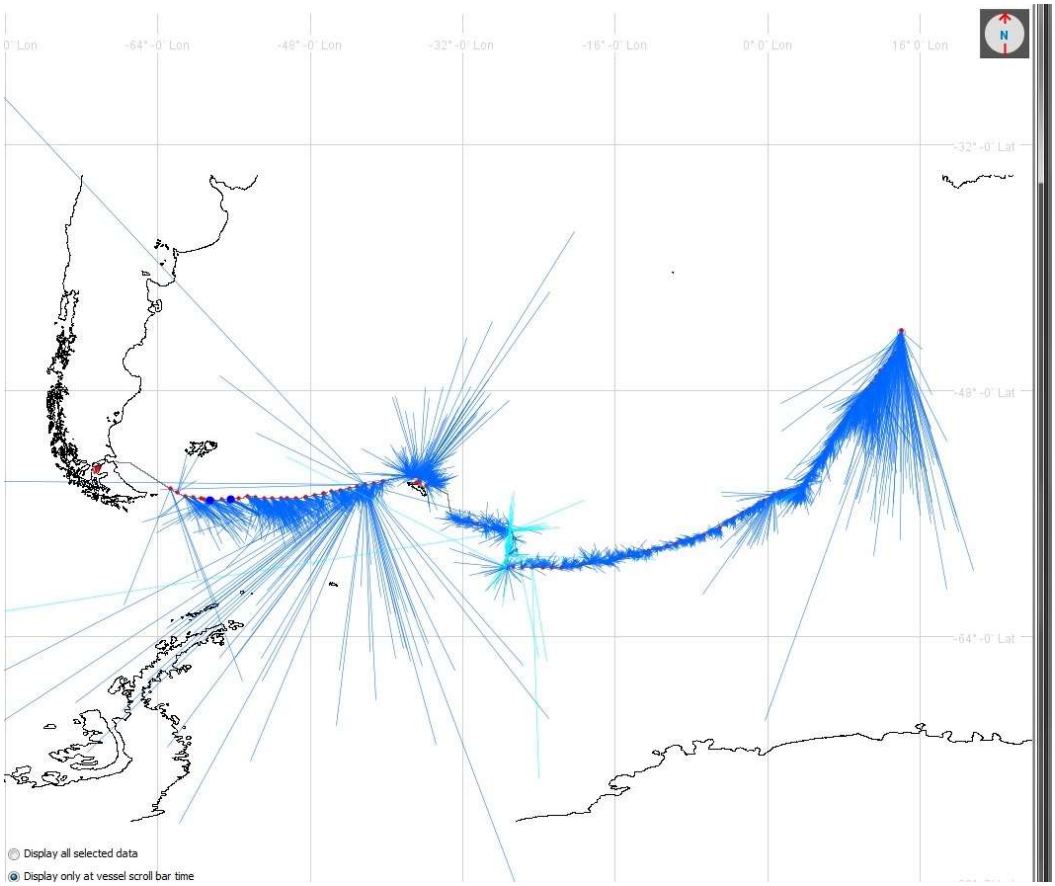

Figure 115: Blue lines indicate bearings to Antarctic blue whale unit A calls. Shorter lines indicate the highest received levels. Pale blue lines indicate bearings to ice noise which was particularly prevalent around the South Sandwich Islands. Map created in PAMguard.

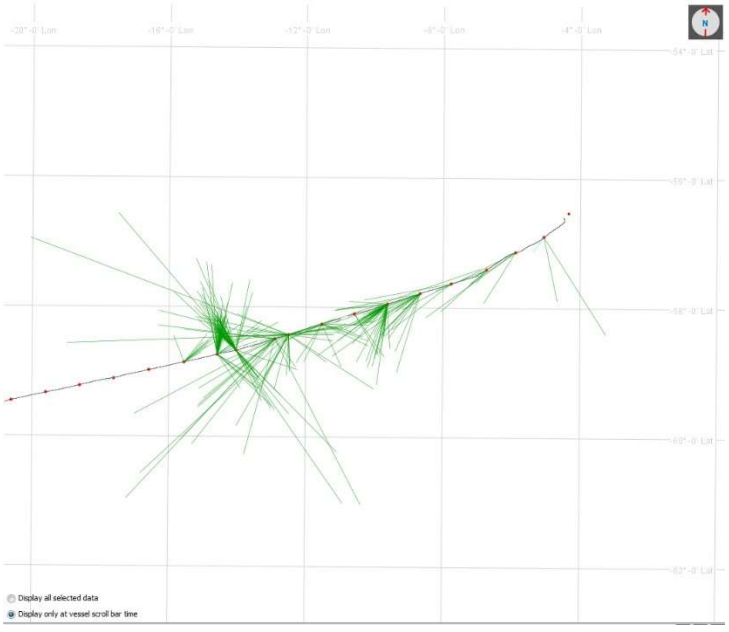

Figure 116: Large scale plot of Antarctic blue whale FM calls (green lines) received between South Sandwich Islands and Bouvetøya. Shorter lines indicate higher received levels. Red dots indicate sonobuoy deployments.

The track from South Sandwich Islands to Bouvetøya passed through an aggregation of vocalising Antarctic blue whales. It can be seen from Figure 116 that whales were both sides of the vessels track. Three blue whales were seen during a CTD station but none was sighted when the vessel was making way and could have altered course for a closer approach. Figure 116 also shows how bearings from successive sonobuoys can be triangulated to give approximate locations.

Up until the 15 March 2017 on the passage between Bouvetøya and Cape Town, all the calls received from Antarctic blue whales were from astern of the vessel suggesting no vocalising whales north of Bouvetøya. The received levels of the calls also decreased as the vessel headed north. Some experimental trials were conducted with sonobuoys deployed in pairs with one hydrophone set to a depth of 140 m and the other set to 300 m. The aim of these experiments was to investigate any differences with received level and the depth of the receiver. Recordings collected over a range of received levels as the vessel headed away from vocalising whales can also allow estimates of bearing accuracy for weak calls (by comparing bearings to the same call from different buoys) and the relative detection probability for calls under different noise conditions (by using the signals from each buoy in a similar way to independent observer experiments).

During the 17 and 18 March 2017 some Antarctic blue whale unit A calls were detected to the northwest.

Estimate of total data returns

For this Project data are digitised in real time for each sonobuoy and data collection continued until the end of Leg 3. Total data returns are expected to be approximately 400-500 hours of recorded acoustic data.

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Personnel Leg 2

Brian Miller – PI, Lead acoustician

Elanor Miller – Acoustician & Lead visual observer

Australian Antarctic Division	Australian Antarctic Division

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Susannah Calderan	Russel Leaper

10.15 Project 15

Tracing the iron cycle in Southern Ocean waters

PI Michael Ellwood (Australia)

Incubation and mesoscale enrichment experiments demonstrate that iron is a key micronutrient limiting the growth of phytoplankton in Southern Ocean waters and, through this the Southern Ocean's role in mediating atmospheric carbon dioxide. It is the bioavailable iron pool that shapes phytoplankton communities and growth in iron-limited regions.

Aims and Objectives

The original objectives of this Project were to understand the interactions between plankton biology, macro- and micro-nutrients (iron), and POC export from Southern Ocean surface waters through:

- the measurement of in-situ abundances of macronutrients and trace metal micronutrients (particulate and dissolved) and their isotope composition;
- investigation of plankton biology (e.g. phytoplankton stock, productivity, physiology, community structure)
- targeted incubation experiments involving the natural plankton community using trace metal amendments and a multi-metal approach to understand bioavailability [this proved impossible to achieve].

Sampling

Water column sampling was done for Projects 15 and 16. The water column was sampled with the regular CTD rosette, the trace metal rosette (TMR), and the underway sampling system. Particles were collected at three depths with three McLane large volume in-situ pumps.

Samples were collected from the regular rosette for nutrients (Alfred Wegener Institute (AWI)) and biogenic silica (ETH Zürich (ETHZ)). One shallow cast was also sampled for Cr isotopes (University of Saskatchewan).

Samples were collected from the TMR for chromium isotopes (U. Saskatchewan), chromium speciation (University of Bern), Zn, Cd, Si and Fe isotopes (ETHZ), Fe speciation (University of Geneva) and bioavailability (U. Geneva), humics (U. Geneva), and saccharides (U. Geneva).

Samples were collected from the underway sampling system for chromium isotopes and speciation (U. Bern), and for biogenic silica (ETHZ).

Particle samples were collected from trace metal concentration and isotopes (U. Bern, ETHZ, U. Saskatchewan).

Trace Metal Rosette deployments

Seven TMR stations (Figure 117) were sampled on Leg 1 using a trace metal clean rosette equipped with 12 L X-Niskin bottles deployed on a Dynema line. A purpose-built series of blocks was constructed to direct the cable from the winch on the second superstructure deck to a position on the main deck, allowing the rosette to be deployed from and landed on the main deck directly outside the trace metal storage container. The crane used for deployment allowed considerable clearance from the side of the ship, facilitating safe deployment and recovery in more adverse conditions. Trace metal rosette deployments were coupled with deployments of a conventional CTD rosette deployments.

Dissolved samples were collected by gravity filtration through acid cleaned 0.2 µm AcroPak filters (Pall). Samples will be analyzed for dissolved metal concentrations (e.g. Fe, Zn, Cd, Cr), stable isotope composition (δ^{114}Cd, δ^{56}Fe, δ^{66}Zn, δ^{53}Cr), Cr redox speciation, and dissolved Fe speciation. Unfiltered nutrient samples were also collected from all bottles.

Eleven stations were planned during Leg 1 – a test station, three paired stations upstream and downstream of Marion, Crozet and Kerguelen islands, and four stations crossing the polar front during the transit from Heard Island to Hobart. Due to time and weather restrictions, only seven of these stations were sampled, with some stations around the islands omitted.

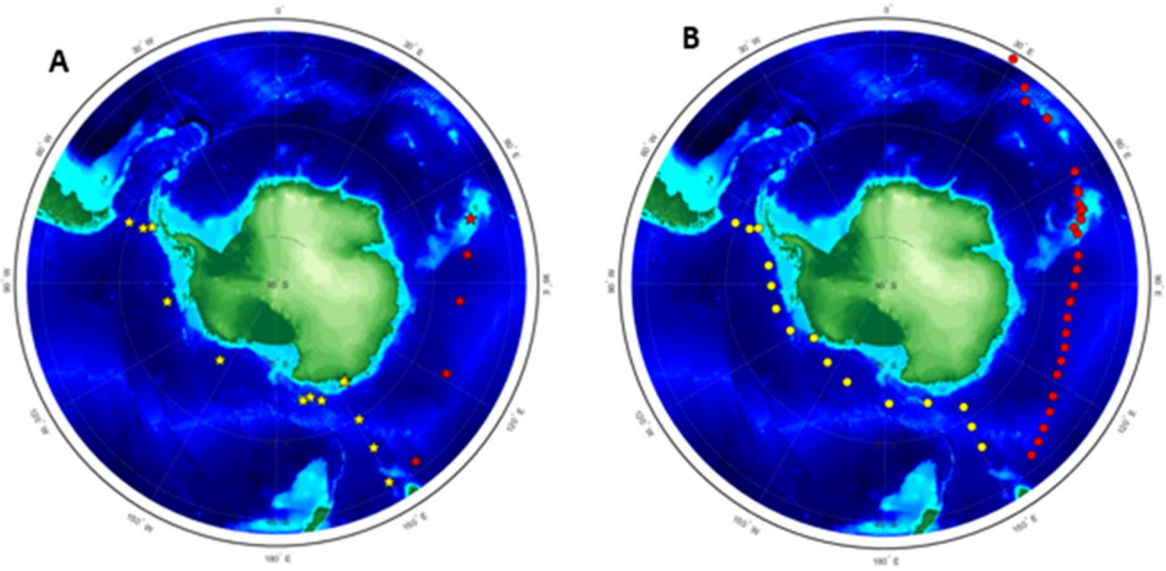


Figure 117: Map of stations occupied on Leg 1 (red) and Leg 2 (yellow) of the ACE voyage. Trace metal rosette (A) and underway (B) sampling are shown.

On Leg 2, 13 stations were sampled. Three stations complemented the transect followed at the end of station 1 from the Sub-Antarctic Zone (SAZ) to south of the Polar Front at 60°S. Two stations were done in the Mertz polynya to explore iron bioavailability and Cr isotopic signature in highly productive waters. These stations will provide a useful contrast to the iron-limited, low productive waters in the open Southern Ocean. Three stations were done upstream, in between and downstream of the Balleny Islands and complemented with two stations in the Ross and Amundsen Sea prior to Peter I Island. We finished with a transect of four stations from the West Antarctic Peninsula to Chile across the Drake Passage.

For Leg 3 samples were collected at two stations south of the Polar Front; one between South Georgia and the South Sandwich Islands, and one between the South Sandwich Islands and Bouvetøya. The other two stations were located between Bouvetøya and Cape Town; one at the Polar Frontal Zone (PFZ) and one north of the PFZ.

Cr isotope sampling from regular rosette

The first deployment of the TMR on Leg 3 Leg 3 failed because of a bad connection. Because Cr is less susceptible to contamination than other metals, seawater was collected from the shallow regular rosette cast at this station for Cr isotope measurements to be conducted at U. Saskatchewan (Table 30).

In Situ Pumps

The initial sampling plan involved collection of suspended particulate samples with large volume in-situ McLane pumps at six stations on Leg 1 in addition to the 11 stations of dissolved samples. Due to time restrictions the particulate sampling was cancelled for Legs 1 and 2.

Four pump deployments were done on Leg 3 at the same stations as for the Trace Metal Rosette (Table 31). One of the four pumps was damaged during transport and could not be used. Particles thus collected at three depths each cast using 1 µm pore size Nucleopore filters. Particle samples were stored -20°C. They will be digested at ETHZ and the resulting solutions will be distributed between investigators at ETHZ, U. Bern and U. Saskatchewan for trace metal concentration and isotopic analysis.

Incubations

Due to technical problems with the AWI temperature controlled container it was not possible to undertake any incubations.

Sampling from the regular rosette for Nutrients and Biogenic silica (BSi)

Nutrients and BSi samples were collected directly from the CTD rosette using latex or vinyl gloves at seven stations on Leg 1, 16 stations on Leg 2 and eight stations on Leg 3 (Table 28). For each depth, nutrients were sampled in duplicate in 15 ml falcon tubes. Prior to filling, each tube was pre-rinsed three times with the sampling seawater and directly placed into a -20°C freezer upright and double bagged. Regarding BSi sampling, between 1.5 l and 2 l of seawater were collected in pre-rinsed (three times) polycarbonate (PC) bottles for each depth and subsequently stored in a cooler. Around 1.5 l seawater of each depth was filtered on 0.8 µm cellulose acetate filter (25 mm) using a vacuum filtration system. At the end of the filtration, 0.2 µm filtered seawater from the sampling site was used to rinse down the funnel cup. Finally, the filters were stored in petri dishes, bagged and put into a -20°C freezer.

Underway sampling

Samples for BSi, Si stable isotopes and Cr stable isotopes were taken at regular intervals (usually once daily; Table 32) from the ship's underway seawater sampling system. BSi samples were filtered as above; samples for Si and Cr isotopes were filtered under clean conditions using a 0.2 µm Acropak cartridge filter into acid-cleaned Low Density Polyethylene (LDPE) bottles, which were double-bagged and stored at room temperature in the dark.

Analyses

Shore-based analysis: We will use a double spike method to measure the stable isotope ratios of Fe, Zn and Cd simultaneously in small volumes (1-4 l) of seawater. The metals are extracted from seawater using Nobias PA-1 chelating resin, purified from salts and interferences by anion exchange chromatography in small columns, and analyzed by double spike multi-collector inductively coupled plasma mass spectroscopy (MC-ICPMS). The procedure has very low blanks and yields data with high precision allowing us to distinguish natural variability in the oceans. Separate analysis of seawater samples for stable Fe isotopes at ETHZ and the Australian National University (ANU) will provide valuable data for intercomparison between different laboratories. Silicon stable isotopes will be analyzed using a standard-sample bracketing following extraction of Si from seawater using co-precipitation with brucite, and purification using cation-exchange chromatography. Cr stable isotope will be determined using a double spike procedure and Thermal Ionization Mass Spectrometry (TIMS) at the University of Saskatchewan. Cr is extracted from seawater by co-precipitation and purification using anion exchange resin. Samples for Cr speciation have been prepared on board (brucite co-precipitation) and will be measured using ICPMS. Iron chemical speciation along with usual suspects for iron binding (saccharides and humics) will be analysed by spectroscopy and

electrochemistry at the University of Geneva, active catalytic polymers will be determined by electrochemistry at Zagreb University (Croatia).

Participants

Leg 1: Michael Ellwood (Australian National University), David Janssen (University of Victoria, Canada), Matthias Sieber (ETH Zurich, Switzerland), Damien Cabanes (University of Geneva, Switzerland), Philippe Arpagaus (University of Geneva, Switzerland).

Leg 2: Christel Hassler (University of Geneva, Switzerland), Samuel Jaccard (University of Bern, Switzerland), Greg De Souza (ETH Zurich, Switzerland), Damien Cabanes (University of Geneva, Switzerland).

Leg 3: Nolwenn Lemaitre (ETH Zurich, Switzerland), Julie Janssen (University of Tasmania), Maureen Soon (University of British Columbia), Roger François (University of British Columbia).

Table 28: Leg 3 Samples collected from the regular rosette

Lat	-54.9994	
Long	-55.0103	
Station #	77	
Event #	2201	
Julian day	58	
Depth (m)	Nutrients (ml)	Biogenic silica (l)
15	15	2
30	15	2
45	15	2
65	15	2
85	15	2
100	15	2
125	15	2
150	15	2
250	15	2
350	15	2
600	15	2
1000	15	2

Lat	-57.0016	
Long	-27.9849	
Station #	88	
Event #	2568	
Julian day	65	
Depth (m)	Nutrients (ml)	Biogenic silica (l)
underway	15	2
5	15	2
30	15	2
60	15	2
85	15	2
100	15	2
150	15	2
200	15	2
300	15	2
500	15	2
800	15	2
1000	15	2

Lat	-59.5047	
Long	-21.0112	
Station #	91	
Event #	2625	
Julian day	67	
Depth (m)	Nutrients (ml)	Biogenic silica (l)
underway	15	2
15	15	2
150	15	2

Lat	-58.6653	
Long	-14.0121	
Station #	92	
Event #	2652	
Julian day	68	
Depth (m)	Nutrients (ml)	Biogenic silica (l)
5	15	2
15	15	2
30	15	2
50	15	2
60	15	2
100	15	2
125	15	2
150	15	2
250	15	2
500	15	2
750	15	2
1000	15	2

Lat	-57.5052	
Long	-7.012	
Station #	93	
Event #	2691	
Julian day	69	
Depth (m)	Nutrients (ml)	Biogenic silica (l)
mq blank	15	2
underway	15	2
15	15	2
150	15	2

Lat	-54.6662	
Long	0.9506	
Station #	94	
Event #	2725	
Julian day	70	
Depth (m)	Nutrients (ml)	Biogenic silica (l)
underway	15	2
15	15	2
150	15	2

Lat	-49.0003	
Long	9.0031	
Station #	101	
Event #	2968	
Julian day	73	
Depth (m)	Nutrients (ml)	Biogenic silica (l)
5	15	2
15	15	2
30	15	2
70	15	2
100	15	2
125	15	2
150	15	2
200	15	2
300	15	2
500	15	2
800	15	2
1000	15	2

Lat	-43.9953	
Long	14.0749	
Station #	103	
Event #	3114	
Julian day	75	
Depth (m)	Nutrients (ml)	Biogenic silica (l)
5	15	2
15	15	2
30	15	2
45	15	2
75	15	2
100	15	2
150	15	2
200	15	2
400	15	2
500	15	2
750	15	2
1000	15	2

Table 29: Leg 3 Samples collected from the TMR.

Latitude (dec degs N)	-56.9794						
Longitude (dec degs E)	-27.9163						
Station number	88						
Event number	2583						
Julian day	65						
	Nutrients (ml)	**Cr isotopes (l)**	**Cr(III) (ml)**	**Metal isotopes (l)**	**Fe speciation (ml)**	**Humics (ml)**	**TPZT (ml)**
5	15	2x1*	15	4	400	80	2x10
10	15	2x1*	15	4	400	80	2x10
30	15	2x1*	15	4	400	80	2x10
60	15	2x1*	15	4	400	80	2x10
85	15	2x1*	15	4	400	80	2x10
100	15	2x1*	15	4	400	80	2x10
150	15	2x1*	15	4	400	80	2x10
200	15	2x1*	15	1	400	80	2x10
300	15	2x1*	15	1	400	80	2x10
500	15	2x1*	15	1	400	80	2x10
800	15	2x1*	15	1	400	80	2x10
1000	15	2x1*	15	1	400	80	2x10
Cr isotope samples taken in duplicate to intercalibration between U. Bern and Sasktachewan							
Latitude (dec degs N)	-58.6655						
Longitude (dec degs E)	-14.0005						
Station number	92						
Event number	2653						
Julian day	68						
	Nutrients (ml)	**Cr isotopes (l)**	**Cr(III) (ml)**	**Metal isotopes (l)**	**Fe speciation (ml)**	**Humics (ml)**	**TPZT (ml)**
5	15	1	15	4	400	80	2x10
15	15	1	15	4	400	80	2x10
30	15	1	15	4	400	80	2x10
50	15	1	15	4	400	80	2x10
60	15	1	15	4	400	80	2x10
100	15	1	15	4	400	80	2x10
125	15	1	15	4	400	80	2x10
150	15	1	15	1	400	80	2x10
250	15	1	15	1	400	80	2x10
500	15	1	15	1	400	80	2x10
750	15	1	15	1	400	80	2x10
1000	15	1	15	1	400	80	2x10
Latitude (dec degs N)	-48.9997						
Longitude (dec degs E)	9.0032						
Station number	101						
Event number	2969						

Julian day		73					
	Nutrients (ml)	**Cr isotopes (l)**	**Cr(III) (ml)**	**Metal isotopes (l)**	**Fe speciation (ml)**	**Humics (ml)**	**TPZT (ml)**
5	15	2	15	4	400	80	2x10
15	15	2	15	4	400	80	2x10
30	15	2	15	4	400	80	2x10
70	15	2	15	4	400	80	2x10
100	15	2	15	4	400	80	2x10
125	15	2	15	4	400	80	2x10
150	15	2	15	4	400	80	2x10
200	15	2	15	1	400	80	2x10
300	15	2	15	1	400	80	2x10
500	15	2	15	1	400	80	2x10
800	15	2	15	1	400	80	2x10
1000	15	2	15	1	400	80	2x10
Latitude (dec degs N)		-43.9816					
Longitude (dec degs E)		14.0749					
Station number		103					
Event number		3115					
Julian day		75					
	Nutrients (ml)	**Cr isotopes (l)**	**Cr(III) (ml)**	**Metal isotopes (l)**	**Fe speciation (ml)**	**Humics (ml)**	**TPZT (ml)**
5	15	2	15	4	400	80	2x10
15	15	2	15	4	400	80	2x10
30	15	2	15	4	400	80	2x10
45	15	2	15	4	400	80	2x10
75	15	2	15	4	400	80	2x10
100	15	2	15	4	400	80	2x10
150	15	2	15	4	400	80	2x10
200	15	2	15	1	400	80	2x10
400	15	2	15	1	400	80	2x10
500	15	2	15	1	400	80	2x10
750	15	2	15	1	400	80	2x10
1000	15	2	15	1	400	80	2x10

Table 30: Leg 3 Sampling from the regular rosette for Cr isotopes

Latitude (dec degs N)		-55.0023
Longitude (dec degs E)		-50.0427
Station number		78
Event number		2263
Julian day		59
Depth (m)	**Nutrients (ml)**	**Cr isotopes (l)**
5	15	1
20	15	1

40	15	1
60	15	1
100	15	1
300	15	1
400	15	1

Table 31: Leg 3 Sampling with Large Volume in situ pumps.

Latitude (dec degs N)		-56.9794	
Longitude (dec degs E)		-27.9163	
Station number		88	
Event number		2573	
Julian day		65	
pump #	**Depth (m)**	**duration of filtration (mins)**	**Volume filtered (l)**
1	30	60	68.5
3	200	60	165.6
6	1000	60	225.1
Latitude (dec degs N)		-58.6655	
Longitude (dec degs E)		-14.0005	
Station number		92	
Event number		2655	
Julian day		68	
pump #	**Depth (m)**	**duration of filtration (mins)**	**Volume filtered (l)**
1	50	60	137
3	250	60	196.3
6	1000	60	216
Latitude (dec degs N)		-48.9997	
Longitude (dec degs E)		9.0032	
Station number		101	
Event number		2971	
Julian day		73	
pump #	**Depth (m)**	**duration of filtration (mins)**	**Volume filtered (l)**
1	70	60	101.4
3	200	60	169.6
6	1000	60	353.8
Latitude (dec degs N)		-43.9816	
Longitude (dec degs E)		14.0749	
Station number		103	
Event number		3119	
Julian day		75	
pump #	**Depth (m)**	**duration of filtration (mins)**	**Volume filtered (l)**
1	30	60	43.6
3	200	60	193

6	1000	60	382.1

Table 32: Leg 3 Underway samples.

Latitude (dec degs N)	Longitude (dec degs E)	Event number	Julian day	Cr isotopes (l)	Cr(III) (ml)	Biogenic Silica (l)	Si isotopes (ml)
-52.8774	-66.4789	2189	57	1	15	2	250
-55.1163	-58.0984	2231	58	1	15	2	250
-54.9953	-50.6231	2243	59	1	15	2	250
-57.8736	-26.7037	2330	66	1	15	2	250
-57.3848	-6.6705	2665	69	1	15	2	250
-54.6644	0.9545	2731	70	1	15	2	250
-50.9179	7.1345	2789	73	1	15	2	250

Acknowledgments

The Project 15 team would like to thank the Chief Scientist, David Walton, the Captain, Officers and Crew of the RV *Akademik Tryoshnikov*. This Project acknowledges funding from EPFL, the Swiss Polar Institute and the Swiss National Science Foundation.

10.16 Project 16

Biodiversity and isolation of bacteria and viruses in contrasted regions from the Southern Ocean

PI Christel Hassler (Switzerland)

Aims and objectives

The Southern Ocean ecosystem exerts a disproportionate control on the global carbon cycle, playing therefore a pivotal role in the global climate system. The recognition of bacterial and viral impact on elemental transformation, recycling and export (including carbon and iron) is rapidly growing. Recently, it was demonstrated that marine viruses possess Carbohydrate Active enZymes (CAZymes) that could depolymerize complex bacterially produced carbohydrates within 96 hours in solution. Considering that carbohydrates could represent up to 50% of marine dissolved organic matter (DOM) and that viruses are typically found at up to 108 per ml in the ocean, the role of viruses and microbes in elemental cycling is certainly underestimated. This thus represents a promising emerging field. Whereas reports of bacterial biodiversity in the Southern Ocean do exist, viral biodiversity has not yet been documented holistically.

Here, we will (i) describe viral and bacterial biodiversity through seawater filtration and subsequent shotgun metagenomic (viruses) and 16S rRNA gene (bacterial) sequencing, (ii) measure and contrast microbial mortality due to zooplankton grazing and viral lysis via Landry-style incubation experiments, (iii) isolate microbial and viral specimens for further laboratory work. Emphasis will be made on four Southern Ocean contrasted regions (Sub-Antarctic, Polar front, in the open ocean and in the vicinity of islands) to represent the variability likely encountered across this vast oceanic region.

Initial issues impacting the Project

Several major issues were encountered during Leg 1 that led to the postponement and adjustment of our proposed experiments. It became clear early on that CTD deployment would be limited to conditions (<4 m wave height, low winds parallel to the direction of the ship) not found often in the Southern Ocean. In order to preserve sampling for bacteria (in conjunction with N. Cassar, Project 13) and viruses, our Project began sampling from the underway seawater system at regular intervals. Any CTDs deployed were also sampled at 15 m, 150 m, and 1000 m for bacteria and viruses, with two additional surface samples for future comparison to the underway system.

Although it may have rescued some of the oceanographic requirements, the underway system was not without faults; when the pump inlet rose above the water level as the ship rolled, the pump ran dry and could not automatically re-prime, so required 24-hour monitoring to prevent irreversible damage. All Projects using the underway system came together to create a watch system, but a different solution needed to be found for the remaining Legs, for the health and well-being of those sampling.

An additional complication during Leg 1 was the set-up of the incubation container necessary for incubation experiments being performed by our group and Project 15. The container had to be put into Hold 2 for its protection and although it had electricity it lacked a water supply necessary to run the refrigeration. The ship lacked all standard plug in facilities for complex container labs and although ACE had a transformer manufactured that would supply the container with power the control system refused to function and thus nothing could be done on Leg 1. The backup refrigerator in Hold 1 ran at 2°C for sample storage and plate incubation.

Sampling

Underway

Water from the underway was sampled daily for viral metagenomics when no CTD deployment was scheduled. In Leg 1, we conducted a comparison of counts of colony forming units (CFUs; proxy for number of culturable bacteria) from seawater collected at 5 m with the CTD and seawater collected at 5 m using the underway system. There were notably more CFUs in the underway system, which we interpreted as contamination probably due to biofilm growth on the tubing of the underway system; we therefore stopped all isolation of bacteria from the underway system.

Tank experiment

Tank operation involved a polyethylene pipeline deployed at 25 m depth from the rear of the ship and a Teflon pump. The aim was to filter 1000 l of surface seawater and concentrate viral suspension and marine natural organic matter by a factor of 1000-times using the process of ultrafiltration. This operation thus benefitted both Projects 15 and 16.

On Leg 1 a seawater sample was collected at Station 19 (Event 324) during a 6 hour stop. Seawater (~ 600 l) was pumped from 35 m below the surface using a trace metal clean Teflon pump connected to an acid-washed PE tube. Seawater was pre-filtered at 0.2 µm using two 1500 Acropak cartridges before collection and storage in a 1000 l acid-washed tank located outside until the start of ultrafiltration at 100k Daltons. Prior to ultrafiltration, 20 l and 500 ml were sampled for metagenomics on viruses and bacteria/viruses isolation, respectively. Following the ultrafiltration step, we collected 1 l of concentrate solution which has been split for further analysis back in home laboratory as follows:

Table 33: Volume of water and conditioning used for collecting samples from different experiments.

Experiment	Samples	Volume (mL)	Conditionning	Acid washed
EPS in situ	dFe	0.5	cryovial	Y
	EPS for incubation	150	500 mL LDPE bottle	Y
EPS for "biogeochemistry"	DOC	1	pyrolysed glass tube	N
	Fe chemistry, HA-like, ICP	60	250 mL LDPE bottle	Y
	Uotago	10	20 ml Fluorinated bottle	Y
	FFF-ICP-MS	10	20 ml Fluorinated bottle	Y
	FT-ICR-MS (for AWI)	10	60 ml Fluorinated bottle	Y
	Fe biodisponibility	100	250 mL LDPE bottle	Y
	Backup	15	20 ml Fluorinated bottle	Y
EPS for glycochemistry	EPS for lyophilization	240	500 mL LDPE bottle	N

Samples were kept in -20°C in the benthic laboratory.

During Leg 2, our Teflon pump broke while filling the tank in the Mertz Polynya as the ship was operating its engines at time of pumping. No further tank operation was thus possible during the expedition. This therefore compromised the characterisation of natural organic matter and live viruses culture collection as planned for ACE. We decided not to use the underway system to fill our tank as bacteria contamination comes hand in hand with potential contamination of organic matter and viruses. Moreover, the underway line was contaminated with iron and thus was judged not suitable for our scientific purposes.

Isolation of bacteria and viruses

Isolation of bacteria and viruses was performed on CTD casts at 15, 150, and 1000 metres depths (Figure 118 and Figure 119). For each depth, 500 ml of seawater were filtered on 0.2 µm pore-size at low pressure (< 200 mm Hg) and under flow laminar hood. Bacteria were isolated by spreading the few drops of seawater left on the filter on agar plates. We used two different types of media: Marine Agar (or “rich medium”) and R2A (or “poor medium”) and three technical replicates were performed for each of them. The remaining filtrate was kept for isolation of viruses in the home laboratory. Both bacteria and viruses are kept alive at 2°C in the fridge located in Hold 1.

Precipitation of viruses

Viruses were sampled from the underway seawater system (Figure 118) at approximately equally spaced stations along the path of transit of the vessel, which resulted in a sample every 18-24 hours, depending on travel time and deployment of CTDs. Underway samples were always taken in coordination with CTD deployments to create a consistent and comparable dataset.

Virus Precipitation Protocol:

Assemble one 142 mm filtering manifold and attach the filter apparatus to a vacuum bottle and vacuum pump with a pressure gauge (max. pressure = -0.25 bar).

Rinse all bottles and the filtering rig with at least 500 ml MilliQ water

Sample >20 l of 20 µm-filtered seawater by first rinsing the sample bottle with seawater once and then filling the bottle as much as possible (this may be restricted during CTD sampling, but additional water is needed for rinsing).

Wear gloves and use ethanol-sterilized forceps for handling all filters.

Remove bacteria and larger particles by filtering seawater using a 0.22 µm 142 mm Millipore Express Plus filter, making sure that the vacuum pressure does not exceed -0.25 bar. When using the vacuum pump and 10 l vacuum bottle, first rinse the vacuum bottle with filtrate, then rinse a second 20 l carboy with filtrate. Transfer filtrate when the 10-litre bottle is full.

Subsample three flow cytometry aliquots of filtrate by transferring 2 ml into 2 ml-cryovials pre-aliquoted with 5 µL 50% glutaraldehyde.

Treat the virus fraction (0.22 µm filtrate) with $FeCl_3$ to precipitate the viruses by:

Add 20 ml of 0.02 µm-filtered acidified MilliQ water to the pre-weighed 0.59 g of anhydrous $FeCl_3$ to create a 10 g/l $FeCl_3$ stock. Keep this stock covered from the light and only use for ~5 days.

Add 2 ml of 10 g/l Fe Stock Solution to each 20 l of filtrate (if the filtrate volume exceeds 20 l, adjust $FeCl_3$ volume accordingly). Shake vigorously for one minute.

Let the $FeCl_3$ treated filtrate sit for 1 hour at room temperature or overnight at 4 °C.

Rinse the filtration rig with 70% ethanol and 500 ml MilliQ

Filter the $FeCl_3$ treated filtrate using a 0.45 µm, 142 mm, Express Plus membrane.

Note: This process takes significantly longer when using a vacuum pump vs. a peristaltic pump, typically ~3hrs for the final filtration stage.

Fold the 0.45 µm filter precipitate-side-out and place into a 50 ml centrifuge tube being careful not to scrape off any of the $FeCl_3$ on the edge of the tube (having precipitate facing out aids in dissolving the precipitate). Seal the cap of the tube with Parafilm.

The filters are stored in the 50 ml tubes at 4 °C until ready to resuspend the precipitated viruses post-expedition. Be sure the caps are on securely so that the filters do not dry out.

CTD sampling

Water was sampled from 15, 150 and 1000 m (Figure 118) for metagenomic sequencing and culturing of both viruses and bacteria. These samples will be used to describe microbial biodiversity at different depth to contrast the different dominant processes.

Figure 118: Marion Fourquez (foreground) sampling for bacterial and viral isolates. Rachel Cable (background) filtering 20 L seawater for Southern Ocean viral metagenomics.

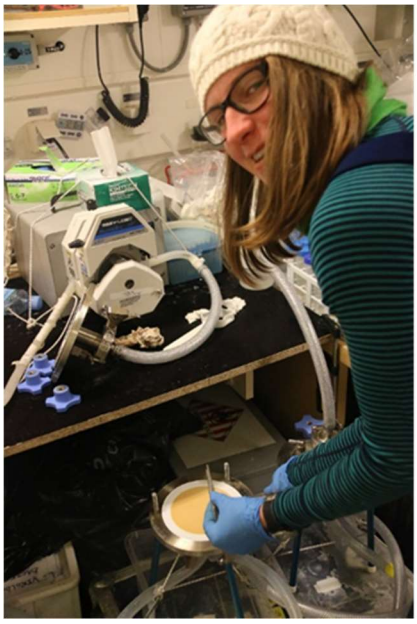


Figure 119: Rachel Cable filtering for Southern Ocean viruses. Seawater is 2 µm-filtered to remove bacteria, archaea, and picoeukaryotes, thus enriching for viruses. Next, $FeCl_3$ is added to the seawater to bind to and flocculate free virus particles. Virus flocs are then filtered (orange filter above) and the filter shipped to the laboratory for subsequent virus DNA extraction and shotgun metagenomic sequencing.

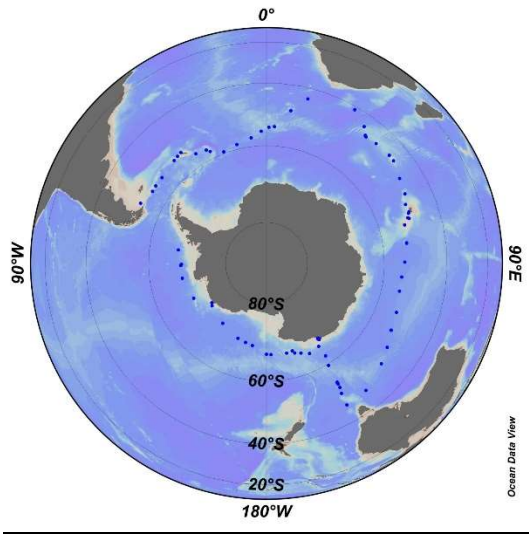


Figure 120: *Map of sampling for virus precipitation. A total of 170 sample from 99 stations including 37 CTD casts were collected.*

Snow and Ice samples

On Leg 2 samples of snow collected on Mertz Glacier, Mertz region pack ice, Balleny Islands, Peter I Island and sea ice collected at Peter I Island were filtered to simultaneously collect bacteria and viruses for metagenomics analysis in collaboration with Project 13. On Leg 3 a sample of snow was collected from Bouvetøya. The snow was slowly melted under sterile conditions in the laboratory. The resulting 10.7 l of snowmelt was filtered to collect bacteria and viruses for metagenomic analysis, in collaboration with Project 13.

Experimental work

Bacterial Isolations

Samples for bacterial isolation were collected from three CTD stations. For each station, three depths were sampled (15 m, 150 m, 1000 m). At each depth, six plates on were inoculated. Colonies have grown on all all plates inoculated (Figure 119). Bacteria growing on solid media were transferred to new agar plates to continue the isolation process. In addition to targeted bacterial growth, for each depth at each station, viruses were collected (<0.2 µm seawater) for isolation back in the laboratory. The growing bacterial strains will be used as hosts, unfortunately plaque assays were unsuccessful to isolate a specific phage.

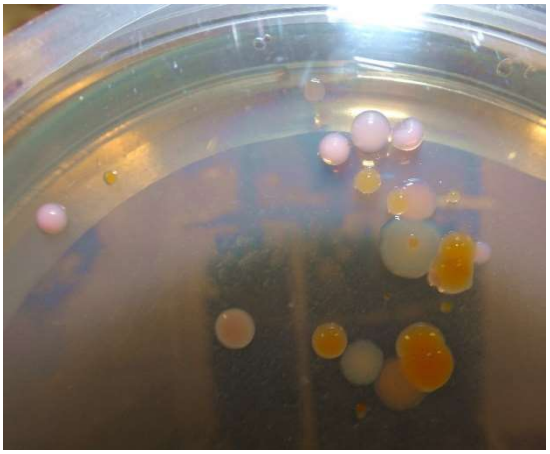
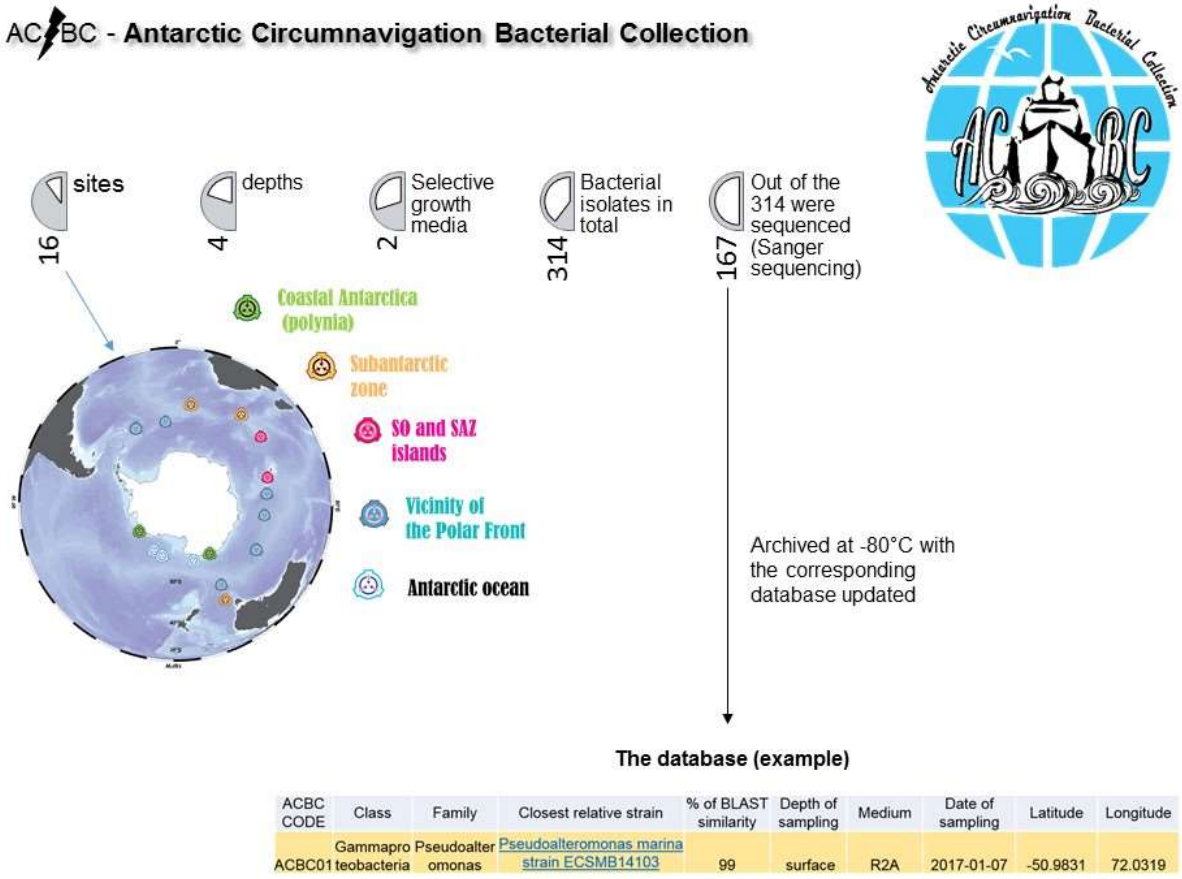


Figure 121: Colonies growing on plates inoculated with Southern Ocean seawater.

The 167 bacteria isolated were identified by Sanger sequencing and constitute the Antarctic Circumnavigation Bacterial Collection (ACBC) currently stored at -80 °C at U. Geneva and U. Michigan (Figure 122).We found that 127 out of them were type strains, nine non-type strains and 32 others could be considered as new strains.



ACBC CODE	Class	Family	Closest relative strain	% of BLAST similarity	Depth of sampling	Medium	Date of sampling	Latitude	Longitude
ACBC01	Gammaproteobacteria	Pseudoalteromonas	Pseudoalteromonas marina strain ECSMB14103	99	surface	R2A	2017-01-07	-50.9831	72.0319

Figure 122: Overview of the ACBC culture collection

Participants on Board

Leg 1: Rachel Cable (University of Michigan, USA), Marion Fourquez (University of Tasmania, Australia; University of Geneva, Switzerland)

Leg 2: Christel Hassler (University of Geneva, Switzerland), Rachel Cable (University of Michigan, USA), Marion Fourquez (University of Tasmania, Australia; University of Geneva, Switzerland)

Leg 3: Rachel Cable (University of Michigan, USA), Marion Fourquez (University of Tasmania, Australia; University of Geneva, Switzerland), Melissa Duhaime (University of Michigan, USA)

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The Project 16 team would like to thank the Chief Scientist, David Walton, the Captain, Officers and Crew of the RV *Akademik Tryoshnikov*. This Project acknowledges funding from EPFL, the Swiss Polar Institute and the Swiss National Science Foundation.

10.17 Project 17

Metocean properties of the sub-Antarctic and Antarctic waters: winds, waves, currents, ice, and their interactions

PI Alessandro Toffoli (Australia)

Aims and Objectivesω

By installing a Wave and Surface Current Monitoring System (WaMoS II, a marine X-Band radar) on the research vessel *Akademic Tryoshnikov* and using the Meteostation and GPS on-board, this Project can produce a large database of winds, waves and surface currents. The instrumentation will operate in any weather and visibility conditions, and at night, monitoring the ocean continuously over the entire Circumnavigation. Concurrent satellite observations of wind, waves and sea ice will be acquired from TerraSarX satellites over the duration of the expedition to complement the database.

Records are vital for:

- assessing the wave environment in the Southern Oceans (wave physics); and
- calibrating/validating wave models (in particular, WAVEWATCH III, the world leading wave model).
- It is intended that the Project will result in the most advanced metocean database for sub-Antarctic and Antarctic waters and the most up-to-date physics for wave-current and wave-ice interaction in WAVEWATCH III.

Cruise Activities

Sea state conditions were continuously monitored using a Wave and Surface Current Monitoring System (WaMoS II), a wave device based on the marine X-Band radar (see details of data acquisition in the next section). Sea state consists of the directional wave energy spectrum $E(\omega, \theta)$, where ω is the angular frequency and θ is the direction of propagation. Basic parameters such as the significant wave height (a representative measure of the average wave height), the dominant period, wavelength, mean wave direction, etc. were inferred from the wave spectrum. Surface current speed and the concurrent direction were also recorded by WaMoS II.

The instrument was installed in and operated from Bremerhaven so data is available for all five Legs (Leg 0, Leg 1, Leg 2, Leg 3 and Leg 4). Raw images were stored any time that the X-Band radar was operated in a range of 1.5 NM (i.e. anytime it was not used for navigational purposes). Images were then processed by the instrument itself and outputs, namely the directional wave spectrum and supporting ship and weather information, were archived in an external hard-drive.

The instrument operated autonomously during Leg 0, Leg 1 as no PIs were on board the vessel. PIs Toffoli and Reichert participated on Leg 2 and controlled the performance of the instrument. During Leg 2, problems were detected in the way WaMoS II communicated with other instruments on the ship and hence the way input data were supplied. Specifically, WaMoS did not receive information of ship position, ship speed, ship course and meteorological data (wind speed and direction). The issue was resolved and a new configuration file was uploaded in WaMoS II (just after leaving the Mertz Glacier). Outputs from Leg 0, Leg 1 and part of Leg 2 will need to be reprocessed. The updated data set will be provided to the Swiss Polar Institute soon after the cruise ends.

In addition, during Leg 2, a careful assessment of the instrument performance was carried out daily. This consisted of comparing visual observations of the sea state with real time data outputs. After uploading the correct configuration file, measurements looked correct. However, wave height still seems to be slightly

overestimated. A more careful assessment of the wave height will be processed soon after the cruise finishes.

Weather and Sea Conditions

During Leg 0, the ship navigated along West Africa and a Westerly swell was constantly monitored. During Leg 1, the vessel navigated along the path of strong winds, namely the Roaring Forties and Furious Fifties. High sea conditions were dominated by locally generated swell. In between storms, mild sea states were detected with a strong swell component.

In Leg 2, the vessel headed to the Antarctic continent. A severe storm was crossed at its edge (west of Macquarie Island) on the way to the Mertz Glacier. The rest of the crossing of the Southern Ocean was with quite calm seas. Approaching Mertz, the vessel crossed the Marginal Ice Zone (MIZ). In the presence of broken sea ice, the WaMoS was generally not operated as the X-Band radar was used for navigation. In any case, the radar backscatter from the ice would have been too strong, adding too much noise to the image – especially for large concentrations of sea ice (> 30%). Nonetheless, a few hours of images were recorded, while navigating the MIZ. These acquisitions are limited to sea ice concentrations of about 30% or less. Based on visual observation, results obtained in the MIZ seem reliable.

A more complete data set of wave records in the MIZ can be inferred from the GPS altitude (note, however, that data recording has some gaps). These data are only reliable for very long swells (longer than 200 m – twice the ship length). Under these circumstances, the ship can be assumed to behave as a buoy and observations are trustworthy. A comparison with WaMoS II data in an ice-free zone indicates that wave height from the GPS altitude slightly underestimates the significant wave height. In any case, relative information (such as the energy losses compared to a benchmark measurement) still remain reliable.

Sea ice was also encountered on the route to Balleny Islands. An interesting swell penetrating the sea ice was tracked there on 02 February 2017 (UTC). Some ice was also encountered near Peter I Island.

The rest of the cruise nearby the Antarctic continent was characterised by very low wind, and hence low wind-generated waves. Swells were very gentle too. Overall, wave height was hardly above 2 m.

The sea state in the Drake Passage was particularly mild (despite its notorious reputation), with wave height of 6-7 m. WaMoS II operated intermittently as radar was often kept at a range of 6 NM. Nonetheless, there was a good coverage of the Drake Passage. At the time of the crossing, the sea state was characterised by an opposing sea state, with a westerly swell propagating against an easterly wind sea.

Back-ups

A full back-up of the output after Leg 0 and Leg 1 was carried out in Hobart; a second back-up was carried out in Punta Arenas after completion of Leg 2; a third back-up was carried out after Leg 3 in Cape Town; a final back-up was carried out after Leg 4 in Bremerhaven. At the end of Legs 2, 3 and 4, backups were also done to the expedition NAS.

Sampling Methodology

The instrumentation

The sea state (namely surface waves and currents) is measured continuously by a wave and current monitoring system WaMoS II. This is a remote sensing system based on a nautical X-Band radar generally used for navigation and ship traffic control. Nautical radars are designed to monitor hard targets like ships at ranges of up to around 100 NM. For this application the radar is used to scan the sea surface nearby at a range up to 1.5 NM (i.e. ~2.5 km). This allows continuous monitoring of a relative large area (~ 20 km²) around the ship with high spatial (~4.5 m) and temporal resolution (~2 s) compared to standard in situ or

satellite remote sensing sensors. Under favourable conditions (i.e. sufficient wind and waves), signatures of the sea surface itself become visible in the near range of X-band radar images (see an example in Figure 123). These signatures include spatial and temporal information of the sea surface waves (locally generated wind sea and swell) and surface currents.

WaMoS II is a high-speed video digitizing and storage device that can be interfaced to any conventional navigational X-band radar and includes a software package running on a standard PC. The software acquires input images from the radar (but it does not control the radar!), processes the raw data and stores it in an external Hard-Drive. Outputs and concurrent radar images are displayed in real time on the display (see Figure 123).

Wave measurements

A WaMoS II wave measurement consists of the acquisition of a sequence of radar images (32 images a minute) and the subsequent wave analysis. For the wave analysis the spatial and temporal sea clutter information is transformed into the spectral domain by means of a three dimensional Fast Fourier Transform at three independent locations in the image (normally one in front of the ship and two at the sides). Besides the directional unambiguous sea state information, surface currents (speed and direction of propagation) are also extracted. The standard WaMoS II software delivers in real time unambiguous directional wave spectra (Figure 123) and time series of the integrated standard wave parameters: significant wave height (Hs), peak wave period (Tp), peak wave direction (θp) and peak wavelength (λp) among many others. These data can be made available to the user on the WaMoS II PC (see an example of the display in Figure 123) and can also be transferred to other stations via ethernet, NMEA etc.

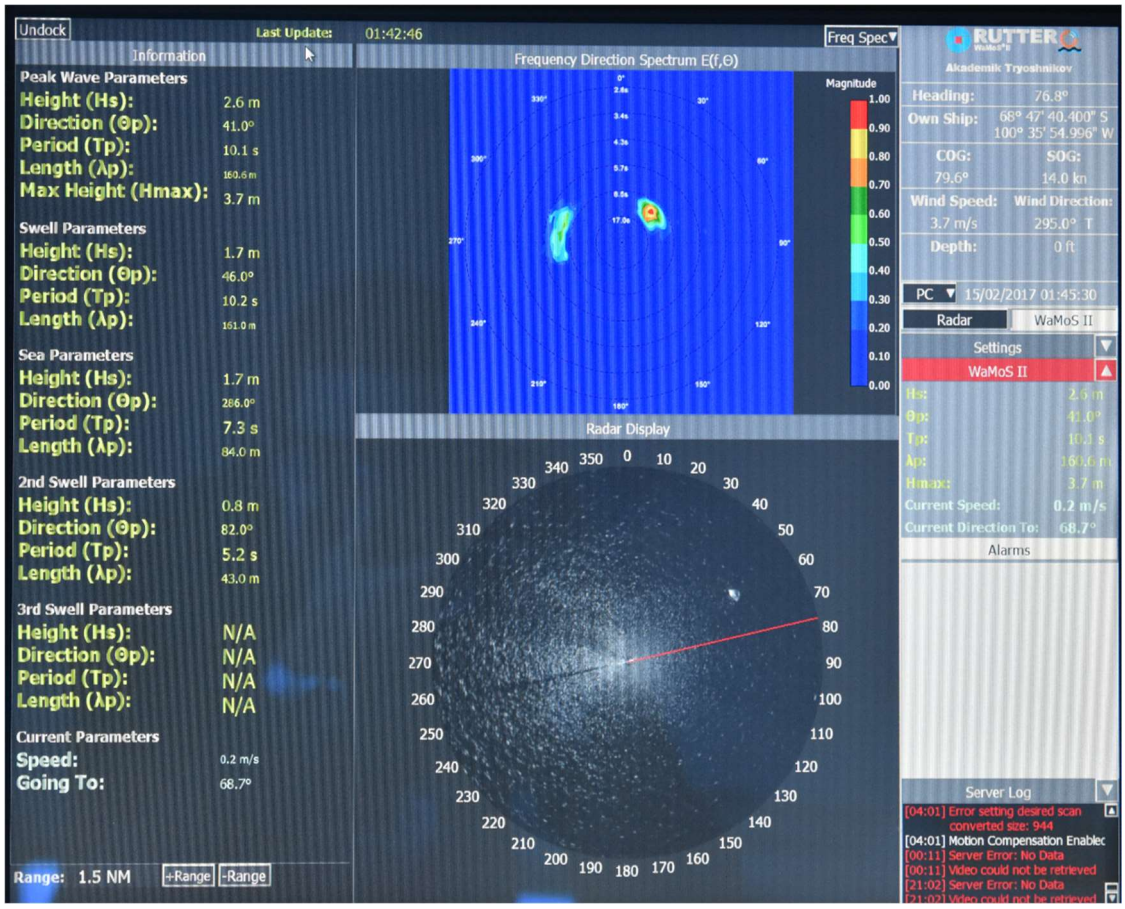


Figure 123: Screen shot of WaMoS II: Sea state parameters (left column); wave spectrum and radar image (upper panel and lower panel, respectively, in the middle column); ship data (right column).

File types

Output files are stored according to two main categories: single and mean. The former contains output data for every sequence of 32 images (approximately 1 minute). The latter contains an average of the output over 20 minutes. The average is based on a moving average process.

Output data consists of the frequency spectrum E(ω) (file extension D1S), the wavenumber spectrum E(kx,ky) (file extension D2S) and the frequency-directional E(ω, θ) (file extension FTH).

Each of these files is complemented by supporting information about the atmospheric conditions, the ship (ship speed, course, position, etc.) as well as post processing information. In addition, the file contains integrated parameters (data obtained by post-processing the wave spectrum) such as significant wave height, peak period, mean periods, mean wave direction, etc.

WaMoS II also stores a time series of wave parameters (significant wave height, peak period, etc.) for each recording time. Time series also includes information on location (latitude and longitude).

Satellite data

Wave data were complemented with satellite images acquired from the TerraSarX satellites. Data acquisitions were at selected locations, primarily over the Antarctic Circle (Mertz, Balleny Islands, Peter I Island). An example image is shown in Figure 124. From the image, information of average wave height (significant wave height), wave period and wind speed can be retrieved. In addition, images provide

information of ice type. Additional satellite images will be retrieved from the European Space Agency archive after the cruise.

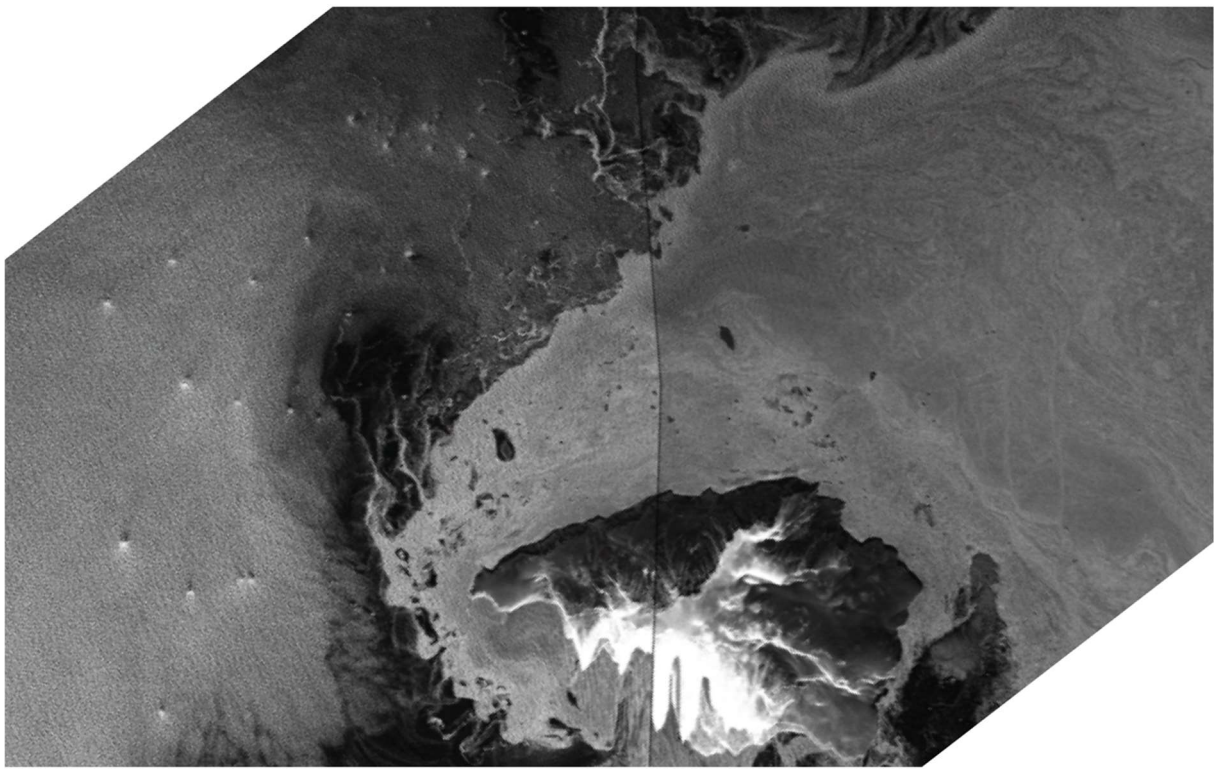


Figure 124: Example of TerraSarX image.

Cruise Track

Measurements were continuously taken along the route.

It is important to note that WaMoS only operated when the X-Band radar was set at a range of 1.5 NM. Therefore, data are limited to the time and location when the radar operated in the correct range. Any other time, radar images were not recorded and, concurrently, output data were not stored.

Personnel on Board

Leg 2 only: Alessandro Toffoli (The University of Melbourne), Konny Reichert.

10.18 Project 18

Quantifying precipitation and its contribution to surface freshening in the Southern Ocean

PI Katherine Leonard (Switzerland)

Report by Alexander Haumann, Irina Gorodetskaya, Jennifer Hutchings, Maria Tsukernik

The Southern Ocean has become less salty in recent decades and several suggestions have been made as to why this is happening. It could be due to an increase in sea-ice melting further north than before, due to increased precipitation or decreased evaporation, or possibly due to increased melting of major ice shelves around the edge of the continent. Most likely a combination of all these factors contributed to the long-term freshening together with potential changes in ocean circulation and mixing processes. However, a direct attribution of the surface salinity changes to the corresponding surface fluxes is challenging since existing surface flux estimates are highly uncertain, especially the atmospheric freshwater flux (precipitation and evaporation). An alternative to measuring the surface fluxes directly is provided by analysing the sea water oxygen isotopic composition and salinity to estimate the strength of different freshwater flux sources. At present, there is no circum-Antarctic estimate of these freshwater sources and their distribution. Understanding these freshwater fluxes and their long-term changes is critical because they control the vertical density stratification in the Southern Ocean and the associated exchange of carbon and heat of the deep ocean with the atmosphere.

Aims and objectives

This project aims to obtain a circumpolar data set of the sea water oxygen isotopic composition ($\delta^{18}O$) and salinity in order to derive a surface ocean freshwater flux balance. Therefore, we collect sea water samples from the ship's underway water supply and the CTD casts. These samples are analysed in different laboratories on shore. From these data, we will estimate the fraction of the surface salinity difference with respect to the subsurface that is associated with sea-ice melting and freezing fluxes and the fraction that is associated with meteoric sources, i.e. precipitation, evaporation, and glacial meltwater.

In order to study the horizontal and vertical extent of the water masses that are affected by a certain freshwater source, we monitor the oceanographic conditions throughout the expedition by measuring temperature and salinity using a thermosalinograph (TSG) that is connected to the underway line and vertical temperature and salinity profiles from the CTD sensor. The latter are supplemented with XBT temperature profiles in places where no CTD station are realised. The discrete salinity samples are used to calibrate both the CTD and TSG sensors. These data will then be used to determine the extent and properties of the water masses sampled throughout the cruise, which will be valuable information for other projects as well.

As our project aims to specifically constrain the very uncertain freshwater fluxes from the atmosphere, we were monitoring the precipitation and its properties throughout the cruise, in collaboration with Project 11. Several optical sensors were used to measure the precipitation intensity and snow particle size distribution. We also applied a technique of snow crystal casting using formvar solution that allows to preserve the shape of the snow flakes and sleet for further analysing the size and crystal habit distribution of the snowfall. Further, we have obtained external funding in order to realise the radiosonde program with daily and event-driven radiosonde launches to study the vertical profiles of the lower atmosphere. Information about the tropospheric vertical profiles will be used to calculate moisture fluxes and also to better understand processes responsible for precipitation intensity and its microphysical properties. These measurements provide an important new constraint on how much freshwater falls onto the Southern Ocean that can be used to evaluate and improve model simulations.

In addition, our Project took the lead in launching SOCCOM floats during Leg 1 and coordinating the associated CTD calibration casts. These autonomous float measurements provide an important backbone for the long-term observational network in the Southern Ocean and its temporal changes.

Oceanographic sampling, data collection, and methodology

The oceanographic sampling and data collection was carried out by Jennifer Hutchings during Leg 1, by Maria Tsukernik during Leg 2, and Alexander Haumann during Leg 3 of the ACE expedition. The oceanographic samples and data that we collected consists of

1) sea water samples for $\delta^{18}O$ and salinity analysis from the underway line

2) continuous surface salinity and temperature measurements by the Aqualine Ferrybox TSG

3) sea water samples for $\delta^{18}O$ and salinity analysis from the Niskin bottles on the CTD rosette

4) depth profiles of salinity and temperature by the CTD sensors

5) XBT temperature profiles

6) iceberg meltwater samples for $\delta^{18}O$ analysis

The above sampling and data collection is described in detail in the corresponding sections below.

1) $\delta^{18}O$ and salinity sampling from the underway sampling

The sea water supply on *Akademik Tryoshnikov* has its intake located at 4.5 m below the surface at the front of the ship. As the ship rolls during stormy seas it is frequently exposed leading to an accumulation of air and bubbles in the line. The underway line pumps sea water into the ship and runs through the ship into the CTD wet laboratory at the back of the ship. The original sea water system was apparently rarely used during previous cruises and the pump as well as the feeder pipe were heavily rusted, delivering brown water with a high suspension of rust particles. Therefore, the system was completely replaced in Cape Town. A new pump and a temporary PVC pipe were installed to provide continuous flow to the CTD laboratory and to the containers on upper foredeck (star-deck) during the expedition. Whilst this solved the rust problem it had its own problems as the water line was transparent and not initially lagged. During the port call in Hobart it was insulated with a ca. 1 cm thick layer of foam.

One challenge faced by all the members of the oceanography team was ensuring that the sea water supply provided uninterrupted flow. As the pump is not self-priming it went off several times in rough weather once the input port was above water. During these times it was manually re-primed. During the stormy seas in Leg 1 we were obliged to establish a 24-hour “pump watch”, which we kept going until the end of Leg 1. During Leg 3 we went through two storm systems. One of them influenced most of the transect from Punta Arenas to South Georgia and the other one the second part of the transect from Bouvetøya to Cape Town. Among the issues, resulting from the higher swell associated with these storm systems were failures of the underway-line pump. The pump was also switched of in close proximity to South Georgia due to too much organic material in the water. Additional information on the times when the pump was switched on and off will be available with the FerryBox data set (see section 7.6.4).

The original sampling strategy for the surface water sampling from the underway line was to sample every 0.5° longitude or latitude, which translates to every 25-50 km or every 1-2 hours, depending on latitude and ship speed. However, it was impossible to perform this task on the ship as the workload was too high. Therefore, we collected samples every six hours during Leg 1 and the first part of Leg 2 (until 30 January 2017) and every three hours during the remainder of Leg 2 and Leg 3 between islands and stops, and at a higher frequency when crossing fronts or together with other events (XBT, CTD, iceberg). The three-hourly

sampling captures the surface waters of the Southern Ocean at a resolution of about 66 to 83 km (about every 1° of longitude or latitude), depending on the ship speed that varied between 12 and 15 knots. During Leg 3 sampling was interrupted during stops at the islands, when leaving Punta Arenas, and when before arriving in Cape Town. During this leg the sampling started on 26 February 2017, 15:15 UTC and ended on 18 March 2017, 09:54 UTC.

For the sampling, the salinity bottles (minimum 200 ml) and isotope bottles (10 ml) were filled by 1/10 with sea water, shaken vigorously for 10 seconds and flushed over the seal cap. This procedure was performed three times and subsequently the bottles were filled with the sea water. Salinity samples were filled to just below the shoulder of the bottle and the isotope bottles about 0.5 to 1 cm below the top. Isotope bottles are capped with a rubber seal and with metal caps that were crimped on. Due to the issues encountered with the salinometer (see below) we used three different types of salinity bottles. Leg 1 salinity samples were all collected in original OSIL 250 ml glass salinity bottles. These were re-used during Leg 2. They are closed using a plastic seal and screw cap. Due to a shortage of salinity bottles parts of the Leg 2 samples had to be collected in (300 ml) "drinking" glass bottles, which are sealed with a normal screw cap only that is air tight. For Leg 3 we borrowed additional 200 ml glass salinity bottles from the Scripps Institute of Oceanography that were used throughout Leg 3 (except for a few samples in the beginning of the leg that were collected in the "drinking" bottles). These were also closed with a plastic seal and a screw cap. The use of different bottles triggered a post-cruise discussion of the ideal bottle to be used for salinity sampling. More details on this discussion with examples of samples collected during this cruise and the associated challenges are illustrated in the following video: https://www.youtube.com/watch?v=ixfXIuuTuzY (Gereon Budéus, AWI, 2017). A collection of duplicate samples with each bottle type revealed no substantial influence of the bottle type on the results (see below).

Sea water samples for $\delta^{18}O$ and salinity analysis were collected from the underway line in the CTD wet laboratory. We also sampled a number of duplicates from the underway line for inter-laboratory calibrations and additional feature analysis. We also took samples during CTD stations from the underway line, and often these were taken in conjunction with surface samples from the CTD Rosette. These duplicates are used to test the water quality from the underway line. We do not anticipate any problems for our samples, except if there is rust contamination that affects the salt samples. These duplicates revealed in a post-cruise analysis that salinity samples are not affected by any potential contamination in the underway line.

From the underway line, we collected a total of 68 salinity and $\delta^{18}O$ samples each during Leg 1, 140 salinity and $\delta^{18}O$ samples each during leg 2, and 120 salinity and $\delta^{18}O$ samples each during Leg 3. In total, this amounts to 328 salinity and $\delta^{18}O$ samples each from the underway line. In addition, a total of 12 duplicate salinity samples and 216 duplicate $\delta^{18}O$ samples were collected from the underway line during Legs 2 and 3 for inter-laboratory calibration, comparison of different sampling bottles, and more detailed analysis of specific events.

2) Surface salinity and temperature measurements by the Aqualine Ferrybox TSG

The underway near-surface salinity and temperature were recorded throughout most of the cruise by the Aqualine FerryBox thermosalinograph (TSG) that was connected to the underway line. A detailed description of this system, the methodology, and issues is described in section 7.7. Our team was largely responsible for setting up, servicing, and monitoring the system throughout the cruise and parts of the post-processing of the data. Any data that might be recorded by the system while the pump of the underway line was switched off (see section 7.6.4) should not be used. Overall, the Ferrybox recorded the passing of the major fronts in the Southern Ocean while going south and while going north again by showing pronounced gradients in surface temperature and salinity and also recorded several passing

eddies and upwelling events. A more careful analysis of these features is necessary after filtering and correcting the data.

An initial comparison between the salinity measured by the TSG sensor and the salinity measured in the samples from the underway line (Figure 125) shows large biases of the salinity that largely follow the latitude and surface ocean temperature of the cruise. Comparing the temperature recorded by the TSG sensor with the CTD sensor from the near-surface waters also shows a clear warm bias of the TSG that is most likely induced by the heating of the water in the underway line while being transported through the ship's interior. These issues will be addressed in a careful post-processing of the dataset.

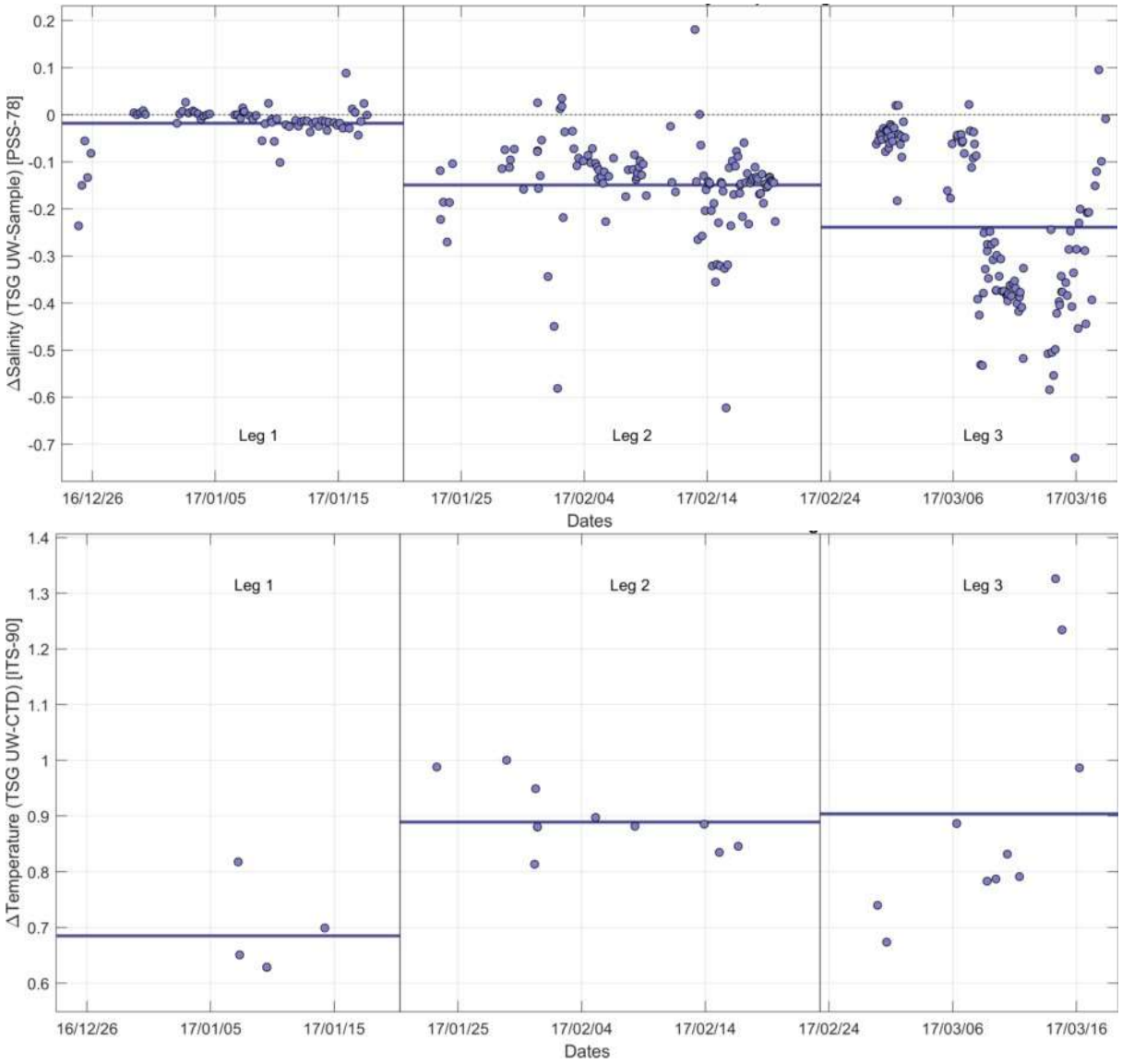


Figure 125: Upper panel shows the difference between the underway TSG sensor and the salinity measured in the underway samples. Lower panel shows the difference between the underway TSG sensor and the CTD sensor near the ocean surface. Horizontal lines show the corresponding mean difference for each leg. Figure by A. Haumann.

3) CTD water collection

Salinity and $\delta^{18}O$ samples were taken from the Niskin bottles on the CTD rosette for most CTD stations (see section 7.5 for details of the CTD setup) and about seven to 12 different depth levels. We chose depths to characterise the upper ocean profile, each subsurface water mass, and the lowest possible water mass, as

well as to calibrate the salinity profile. Depth levels were chosen from the downcast to represent each water mass and vary throughout the cruise. The depth levels to which the casts were performed were determined to reduce the time spent at each station and to represent the upper ocean water masses. Therefore, casts typically range from shallow/fast casts of a depth of 400 m to deeper casts of about 1000 m south of the Polar Front (where the deep waters are shallower) and 1500 m north of the Polar Front (to capture most of the mode and intermediate water layers). The spatial distribution of the stations were previously selected for a good representation of all water masses on either side of the frontal systems and in between the fronts, as well as to represent an approximate equal spacing. Due to technical issues and weather conditions only 44 of the originally planned 95 CTD stations were carried out of which our project sampled 39. On several occasions one station consisted of multiple casts.

During Leg 1, our project was responsible for the CTD operation and we sampled 11 casts at seven stations for salinity and $\delta^{18}O$. Salinity samples were taken for broken bottles on CTD casts 6 and 7, to check for bottle integrity. During Leg 2, we sampled 22 casts at 22 stations. During Leg 3, we sampled 10 casts at all stations 10 that were carried out, out of 16 planned CTD stations. Four of the six cancellations of CTD stations during Leg 3 were due to weather conditions. The five deep stations that sampled Circumpolar Deep Water (CDW) in the lower most bottles were complemented by five shallow stations that went down to 400 m to capture all surface water characteristics, i.e. summer and winter water layers and sometimes upper CDW. A summary of the CTD stations that were sampled by our project is provided in Table 34.

Table 34: Summary of CTD casts sampled for salinity and $\delta^{18}O$ by project 18 during Legs 1 to 3.

Event	Station	Cast	Leg	Date Time (UTC)	Lat (dec degs N)	Lon (dec degs E)	Cast depth [m]	Comment
75	2		1	2016-12-28 06:55:00	-46.9196	38.1172		CTD data not archived
123	8	3	1	2016-12-30 13:10:00	-46.1788	50.9974	398	
264	16	4	1	2017-01-07 05:15:00	-50.987	72.0292	496	
285	16	5	1	2017-01-07 08:23:00	-50.9813	71.9939	147	Only for duplicates
317	19	6	1	2017-01-09 08:14:00	-53.1688	81.5736	1005	
318	19	7	1	2017-01-09 13:04:00	-53.131	81.7266	150	Only for duplicates
369	20	8	1	2017-01-11 04:14:00	-54.8512	95.7441	1514	Float deployment
370	20	9	1	2017-01-11 11:05:00	-54.8519	95.7697	148	Only for duplicates
401	21	10	1	2017-01-14 02:05:00	-53.1975	118.1205	988	
402	21	11	1	2017-01-14 05:30:00	-53.236	118.1942	151	Only for duplicates
607	22	12	1	2017-01-17 06:44:00	-46.9097	141.9254	1002	
910	23	1	2	2017-01-23 06:14:00	-46.3989	150.4066	988	
932	24	3	2	2017-01-25 00:05:00	-53.5626	149.2557	1002	

961	25	5	2	2017-01-26 06:08:00	-59.6004	148.5715	1003	
1026	26	7	2	2017-01-28 22:00:00	-67.1029	144.9368	716	
1093	33	10	2	2017-01-30 08:32:00	-67.0656	144.946	619	
1099	36	13	2	2017-01-30 23:52:00	-67.1758	145.7311	772	
1103	38	15	2	2017-01-31 04:27:00	-66.996	146.0349	482	
1108	42	18	2	2017-01-31 10:02:00	-66.6297	146.2465	165	
1128	41	19	2	2017-01-31 19:45:00	-65.894	146.3318	709	
1144	43	20	2	2017-02-02 18:09:00	-66.001	159.003	1002	
1240	47	22	2	2017-02-04 10:53:00	-67.2913	163.545	1002	
1282	49	23	2	2017-02-05 02:32:00	-67.1004	167.3921	1001	
1460	54	25	2	2017-02-08 07:07:00	-69.743	-165.0198	403	
1465	55	26	2	2017-02-08 18:30:00	-70.179	-159.0796	3800	
1487	56	27	2	2017-02-09 22:29:00	-71.6929	-143.7245	1002	
1557	59	29	2	2017-02-11 09:52:00	-72.9913	-127.8352	814	
1626	67	30	2	2017-02-13 21:38:00	-70.0017	-115.5093	400	
1633	68	31	2	2017-02-15 02:58:00	-68.7398	-99.9977	401	
1753	70	32	2	2017-02-16 15:34:00	-68.0103	-82.0331	400	
1878	71	33	2	2017-02-18 01:07:00	-63.9696	-66.2697	393	
1891	72	34	2	2017-02-18 10:09:00	-62.5028	-67.9987	1001	
1901	73	35	2	2017-02-19 01:02:00	-59.5945	-67.9198	1001	
2201	77	1	3	2017-02-27 21:24:00	-54.982	-54.982	1498	North of SAF
2263	78	2	3	2017-02-28 15:37:00	-54.997	-50.038	400	ACC frontal zone
2568	88	3	3	2017-03-06 07:01:00	-56.997	-27.975	1505	Polar waters
2625	91	5	3	2017-03-08 18:26:00	-59.503	-21.009	401	Polar waters
2652	92	6	3	2017-03-09 11:21:00	-58.664	-14.008	1003	Polar waters
2691	93	8	3	2017-03-10	-57.505	-7.01	400	Polar waters

				09:48:00				
2725	94	9	3	2017-03-11 09:19:00	-54.664	0.955	401	Polar waters
2965	100	10	3	2017-03-14 07:18:00	-51.044	7.002	398	Polar waters
2968	101	11	3	2017-03-14 19:40:00	-49.001	9.001	1001	ACC frontal zone
3114	103	13	3	2017-03-16 05:08:00	-43.99	14.077	1500	North of SAF

As for the underway line, for the sampling from the Niskin bottles each, the salinity bottles (200 ml, from Scripps Institute of Oceanography) and isotope bottles (10 ml) were filled by 1/10 with sea water, shaken vigorously for 10 seconds and flushed over the seal cap. This procedure was performed three times and subsequently the bottles were filled with the sea water. Salinity samples were filled to just below the shoulder of the bottle and the isotope bottles about 0.5 to 1 cm below the top. Both bottles are capped with a seal. Salinity bottles were closed with a screw cap and isotope bottles with metal caps that were crimped on.

From the CTD bottles, we collected a total of 58 salinity and 53 $\delta^{18}O$ samples during Leg 1, 135 salinity and 141 $\delta^{18}O$ samples during Leg 2, and 80 salinity and $\delta^{18}O$ samples each during Leg 3. In total, this amounts to 273 salinity and 274 $\delta^{18}O$ samples from the CTD bottles. In addition, a total of 38 duplicate salinity samples and 67 duplicate $\delta^{18}O$ samples were collected from the CTD bottles during Legs 1 to 3 for inter-laboratory calibration, comparison of different sampling bottles, and more detailed analysis of specific events. Six (one Scripps salinity bottle and two “drinking” bottles at each station) of the duplicate salinity samples from two CTD stations during Leg 3 were taken to assess the difference between using normal salinity sampling bottles and the “drinking” bottles that were mostly used on Leg 2 and to assess the effect of storing the bottles. The first station at which we collect these duplicate salinity samples was at station 100 (cast 010, event 2965) at 400 m and second one was at station 101 (cast 11, event 2968) at 1000 m. We collected an additional five salinity and $\delta^{18}O$ samples each from different depth levels of the trace metal rosette (TMR; event 2653) that was performed right after the CTD cast 6 (event 2652) at station number 92 during Leg 3 for later bottle intercomparison between the two sampling methods.

4) CTD salinity and temperature profiles

Our project was responsible for the CTD casts during Leg 1 and parts of Leg 2. In addition, our project took lead in planning the CTD locations and depth levels, as well as overseeing the physical oceanography program throughout most of the cruise (except for the Mertz area). A detailed CTD report is provided in section 7.5 of this cruise report. The CTD rosette was equipped with two temperature and salinity sensors throughout the cruise. The second sensor failed during Leg 3. We here briefly compare the salinity from both sensors with the measured values from the bottles (Figure 126). Both sensors show a clear drift towards lower salinities throughout the cruise, which needs correction in a post-cruise calibration. The scatter (largest during Leg 2) is most likely associated with the sampling, rather than the instrument or the sample storage.

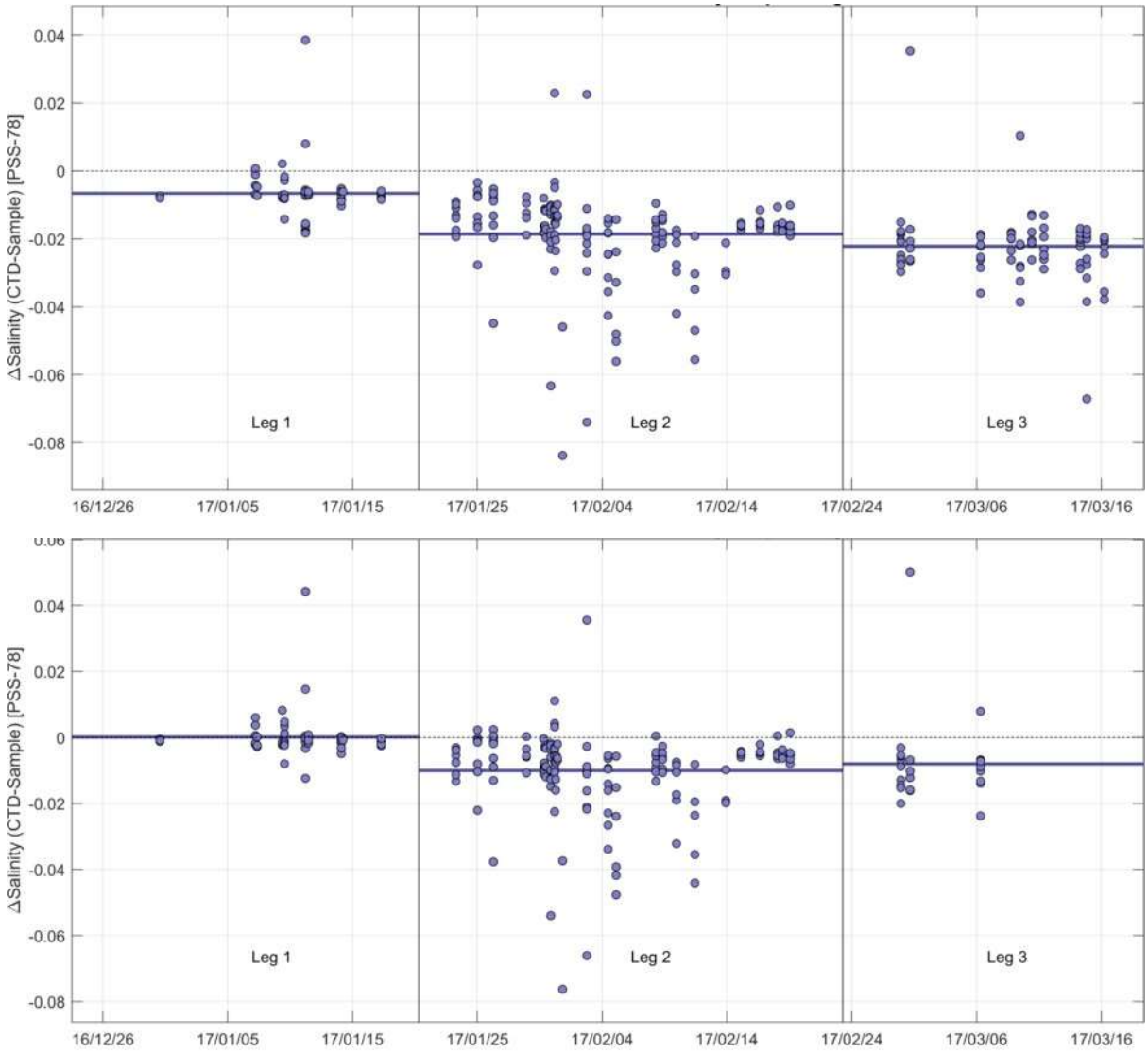


Figure 126: Upper panel shows the difference between the first CTD sensor (00) and the salinity measured in the bottle samples. Lower panel shows the difference between the second CTD sensor (11) and the salinity measured in the bottle samples. Horizontal lines show the corresponding mean difference for each leg. Figure by A. Haumann.

5) Expendable Bathythermograph (XBT) temperature profiles

Throughout Legs 2 and 3, we complemented the CTD stations with 40 (26 during Leg 2 (1 failed) and 14 during Leg 3) Expendable Bathythermograph (XBT) probes. XBT probes were launched when crossing fronts, CTD stations were cancelled, or when spacing between stations was large (see Table 35 for a list of XBT locations). The recorded temperature profile can be used to determine the depth of the mixed layer, and the layer thickness of water masses if they are identifiable from the temperature profile, e.g. the extend of the winter water layer. Seven of the 14 profiles during Leg 3 were recorded in polar waters. One profile was recorded when entering the polar waters in the west at the PF (event 2280) and one when leaving the polar waters in the east at the PF (event 3013). This change in water masses can be depicted from the vertical temperature profile. One probe (event 2684) during Leg 3 was launched at CTD station 92 (cast 006, event 2652) for temperature sensor intercomparison and calibration. A similar intercomparison is possible for two XBT probes during Leg 2 (events 1110 and 1111 during CTD event 1096).

Table 35: XBT deployment details.

Event	XBT cast	Leg	Date (UTC)	Release time (UTC)	Lat (dec degs N)	Lon (dec degs E)	Comment
956	1	2	2017-01-25	09:20:54	-54.7758	149.1706	
957	2	2	2017-01-25	19:24:45	-57.1669	148.9209	
991	3	2	2017-01-27	01:27:51	-62.4301	147.3803	
1027	4	2	2017-01-27	13:05:00	-65.0245	146.0937	
1036	5	2	2017-01-28	04:41:10	-67.1269	145.0406	Failed
1038	6	2	2017-01-28	07:58:53	-67.0788	144.9855	
1110	7	2	2017-01-30	20:57:16	-67.2068	145.7193	At CTD 1096
1111	8	2	2017-01-30	21:06:33	-67.2056	145.7187	At CTD 1096
1175	9	2	2017-02-02	04:10:03	-65.0372	155.8928	
1293	10	2	2017-02-05	15:04:30	-67.1673	171.9316	
1361	11	2	2017-02-07	16:01:38	-69.002	-174.7345	
1458	12	2	2017-02-07	23:16:39	-69.3626	-170.0352	
1492	13	2	2017-02-09	06:53:34	-70.745	-154.6251	
1493	14	2	2017-02-09	13:23:09	-71.1837	-150.1208	
1507	15	2	2017-02-10	10:04:06	-72.1214	-138.6127	
1528	16	2	2017-02-10	18:03:05	-72.5783	-132.6564	
1609	17	2	2017-02-13	09:11:52	-71.8564	-122.0311	
1632	18	2	2017-02-14	07:56:43	-69.9994	-109.9534	
1673	19	2	2017-02-15	15:49:38	-68.5998	-93.1943	
1712	20	2	2017-02-16	09:20:43	-68.3104	-85.7629	
1802	21	2	2017-02-17	03:47:58	-66.4858	-76.4338	
1875	22	2	2017-02-17	21:16:52	-64.2699	-68.186	
1889	23	2	2017-02-18	08:18:30	-62.8286	-67.6204	Drake Passage
1914	24	2	2017-02-19	00:05:35	-59.768	-67.9523	Drake Passage
1917	25	2	2017-02-19	07:01:35	-58.9477	-67.7844	Drake Passage
1939	26	2	2017-02-19	16:23:23	-56.6964	-67.3532	Drake Passage / South American shelf
2230	27	3	2017-02-27	13:58:21	-55.118	-58.1449	Before SAF
2264	28	3	2017-02-28	12:13:54	-55.0007	-51.3113	Between fronts
2280	29	3	2017-02-28	19:53:03	-54.9644	-48.8374	At PF
2334	30	3	2017-03-01	13:09:35	-54.1127	-42.1332	Instead of CTD, after PF, polar waters
2340	31	3	2017-03-01	18:40:46	-53.8667	-40.1921	On Scotia Ridge, polar waters
2566	32	3	2017-03-05	18:05:33	-56.2828	-33.0062	Between South Georgia and South Sandwich, polar waters
2621	33	3	2017-03-07	16:15:02	-58.7792	-27.3169	Polar waters
2637	34	3	2017-03-08	11:09:50	-59.5011	-24.3685	Southern most point in Atlantic, polar waters
2684	35	3	2017-03-09	12:39:42	-58.6652	-14.0022	At CTD event 2652, polar waters

2976	36	3	2017-03-13	22:56:03	-52.7065	5.3401	South of PF, polar waters
3013	37	3	2017-03-14	14:51:46	-49.9352	8.1011	At PF
3103	38	3	2017-03-15	10:17:35	-47.5168	10.9041	AT SAF
3123	39	3	2017-03-15	18:52:15	-46.0193	12.7657	North of SAF
3444	40	3	2017-03-17	13:17:51	-39.0047	14.7335	Northern most XBT in Atlantic

The *Akademik Tryoshnikov* donated XBT probes to our project. We are truly grateful to them for providing us the probes. The XBT probes are manufactured and distributed by T.S.K./Sippican Tsurumi-Seiki Co. Ltd., Yokohama, Japan (http://www.tsk-jp.com) and are of the type T-7, which is rated to 760 m at a ship speed of up to 15 knots and has a measuring time of 120 seconds. All of the probes launched during Leg 3 recorded the temperature profile down to about 789 m. Profiles were recorded by the TS-MK 150N unit and archived and post-processed by the MK-150 software.

Prior to each launch the USB connection between the computer and the TS-MK 150N unit as well as the functioning of the archiving software was checked. XBT probes were left outside on the main deck at the stern for at least one day before launch to reduce an existing surface temperature bias. Nevertheless, some surface biases remain and will be accounted for by post-processing the data. Possible reasons are an interference from the ship, waves and bubbles, or the unknown age of the probe. Probes were launched from the stern of the ship either on the port or starboard side depending on wave and wind direction. They were launched using the T.S.K. hand-held XBT/XCTD launcher system. The probes were loaded to the launcher and dropped at an arm-length distance from the railing. During the unspooling of the copper wire, which transmits the data from the probe to the launcher and then to the recording unit, the launcher was held at an approximate 45° angle with respect the horizontal, facing to the water surface. After the wire had fully unspooled the wire was ripped apart. Subsequently, the raw data file stored by the MK-150 software was post-processed to an .XBT-file and to a 1 m binned file.

6) Iceberg samples

Onm06 March 2017, we approached a tabular iceberg. A field party went on to the iceberg and collected some surface samples for us. The samples were collected with a shovel in a zipper bag. Three samples are from the surface of the iceberg (57 m above sea level) and two from 0.5 m below its surface. We melted the samples in a closed plastic bottled and filled them into the $\delta^{18}O$ bottles after rinsing and shaking the bottles three times (about 1/10 of bottle filled with sample meltwater). The five samples are associated with the event 2595. They can be compared to the sampling events 2323 and 2594 from the underway line that were taken when the ship was in close proximity to the iceberg to assess the meltwater signal in the sea water. Similar comparisons should be performed to the $\delta^{18}O$ signal from the ice cores collected on the islands (Project 4).

$\delta^{18}O$ sample storage, processing, and analysis

$\delta^{18}O$ sample bottles from all three legs were repacked during Leg 3, separating all duplicate samples in different boxes. All samples are packed in small cardboard boxes and separated by foam or cardboard. All samples were stored on the ship until Bremerhaven and were not supposed to freeze. All normal/unique samples will be send first to British Antarctic Survey (BAS), Cambridge, UK and all duplicates to ETH Zürich, Zürich, Switzerland. The samples that are send to BAS are analysed for their oxygen isotopic composition in a mass spectrometer at the NERC Isotope Geosciences Laboratories (NIGL) at the British Geological Survey (BGS) in the period September to November 2017.

Salinity sample storage, processing, and analysis

Salinity samples were originally supposed to be processed on board the *Akademik Tryoshnikov* using the ship's Guildline Autosal 8400B Salinometer. However, on Leg 1 we found that the salinometer had probably not been serviced and aligned since 2010 and was not in any condition that would allow us to achieve the desired data quality. It was partially serviced in Hobart, but major issues were still reported on Leg 2 (see below for details). Therefore, all salinity samples were only collected but not processed on the ship, increasing our requirement for salinity bottles.

All samples from Leg 1 (six crates of bottles) were processed at the Institute for Marine and Antarctic Studies (IMAS) at CSIRO in Hobart, Australia, by Kendall Sherrin on a Guildline Autosal Laboratory Salinometer 8400(B) during the port call (19 – 20 January 2017). Samples from Legs 2 and 3 (in total 504 samples, 208 from Leg 3) stayed on the ship and were stored in the Autosal room until they were offloaded in Bremerhaven in April 2017. All samples were shaken up once in the middle of Leg 3 and again during Leg 4 to prevent the salt from precipitating out of the sample. They were processed at Alfred Wegener Institute (AWI) in Bremerhaven, Germany by Gereon Budéus on an Optimare Precision Salinometer (OPS; https://www.youtube.com/watch?v=tgHlLfbkHdw) in the period April to August, 2017.

There were concerns that the "drinking" bottles might not seal well as no seal cap is used in between the screw cap and the bottle. Additionally, the quality of all the salinity samples might degrade before they were processed. A number of duplicate samples were therefore processed on the ship's Autosal. After some additional testing and troubleshooting and closely monitoring the room temperature, it proved possible to achieve reasonably good measurements with the Autosal on the ship (see section below). Salinities from duplicate bottles could be reproduced at an accuracy of at least 0.003 PSU or better. The small differences might either result from the Autosal (note that measurements from one sample bottle were stable at a much higher accuracy), or from variations of the sampled water. Additionally, we had anticipated using an RBR Salinometer for comparison but the RBR Salinometer pump was blocked and could not be used without substantial cleaning. By the end of Leg 3 and after considerable troubleshooting it seemed reasonable to process salinity samples on the ship's Autosal. However, the amount of work on the ship for project 18 to be carried out was simply too much to allow for processing all the samples. Two duplicate samples from the underway line (at event 1796) and two from the CTD Niskin bottle (15 m, event 1901) were collected in "drinking" bottles during Leg 2. During Leg 3, we collected two duplicates (one "drinking" bottle and one normal bottle) from CTD Niskin bottles at 400 m (event 2965) and another two duplicates (one "drinking" bottle and one normal bottle) from another cast at 1000 m (event 2968). These four duplicates were also processed on the ship. There is an additional set of each of these salinity duplicates (one "drinking" bottle and one normal bottle each) from Leg 3 that was processed on the OPS at AWI in Bremerhaven, Germany for comparison. The results of this comparison are shown in Figure 127 and suggest that there was no bias induced by using different sampling bottle types or by storing the bottles on the ship.

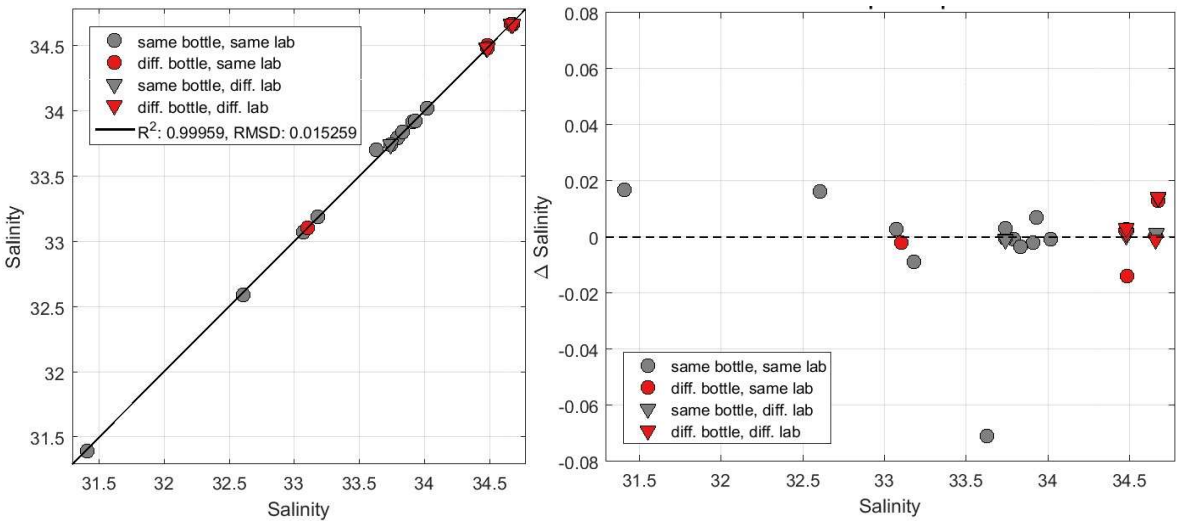


Figure 127: Left panel compares the duplicate salinity (PSS-78) measurements performed on same or different bottle type (grey or red) or the same or different instrument (circles and triangles, either the ship's Autosal or the OPS). Right panel shows the same measurements but the difference between the values on the y-axis. See text for details. Figure by A. Haumann.

On-board salinometer

A Guildline Autosal 8400B Salinometer (ship-based; make/model: Guildline 8400B; serial number: 70231; distributed and serviced by OSIL, UK) was provided on the ship. This instrument belonged to AARI. During the ACE expedition on board the ship it was noticed that the instrument was last serviced and aligned in June 2010 (maybe again after that point by an AARI technician) and the next service and alignment would have been due in June 2011 and June 2012, respectively. In addition, the instrument had not been maintained in a clean state and the bath water was filled with algae. Tahlia Henry drained the bath during Leg 0 and refilled it with DI water.

During Leg 1 Jennifer Hutchings performed maintenance of the instrument and tested it. She noticed floaters in the bath when inspecting the Autosal in Cape Town. She removed the floaters and refilled water bath with DI water and one cap of bleach. Running an old standard through, it is apparent that electrode 2 has some persistent bubble collection, however it is easy to deal with this by flushing the water should a bubble persist. The aquarium bulb fittings were filthy and needed cleaning. The Autosal never got up to temperature because bulbs needed to be replaced. The salinity cell was cleaned by flushing it with rust deoxidizer (CLR is called for in North America, which was the closest available in Cape Town). Then, it was flushed ten times with ethanol and flushed with DI water for 15 minutes. The pump was working. The only problem up until we started using the machine for training appeared to be the heat lamps that needed to be replaced.

While running samples through the machine for training during Leg 1 the following faults developed in order: 1) Flush is leaking water. 2) Air was introduced into the sample line due to poor line management between changing samples. It took 15 minutes of continuous purging and refilling to get rid of air in line, though still a problem. 3) Bottle stopper is old and not sealing any longer. There is a crack near the air intake and pieces of stopper have fallen into the DI water bottle. 4) On further attempts to clean the cell by flushing with DI water the purge stopped working completely. We opened the Autosal chassis and front and inspected all lines. There were no obvious loose tubes, compromised tubes or blockages in the tubes. In order to investigate further we would need to take apart the machine internal case. It was suspected that either algea or rubber particles are the cause of the poor performance of the machine. Due to these issues with the instrument we were unable to run salt samples during Leg 1 of ACE. Cleaning fluids for use with

the Autosal have been left in the Autosal room for Leg 2. There are also additional cleaning fluids in the CTD dry laboratory.

Further it was noticed that the room does not maintain a constant temperature, fluctuating between 22°C and 30°C over a five day period (paper log on wall next to the Autosal). The Autosal seems to be stable on standard readings to within acceptable tolerance (+/- 10).

Stefan Vogel replaced all tubing and light bulbs during Hobart port call and did the overall cleaning as well. Initial testing was performed by Irina Gorodetskaya in Hobart and in the beginning of Leg 2 with an attempt to obtain stable readings. The problem of varying room temperature remained. Remaining reported issues from the tests during Leg 2 were: 1) Values out of range and standard value not reachable with suppression switch or standardization knob. 2) Strong drift in readings. Due to the time constraints and intensive sample collection necessary for the project, during Leg 2 no samples were processed on the Autosal either.

During Leg 3 additional testing and troubleshooting was performed by Alexander Haumann: 1) The instrument was turned off and should be left running. Switched instrument on 24 February 2017 and kept running ever since. 2) 26 February to 03 March 2017: Monitored stability of standby value. Standby value is stable over time as long as the room temperature is stable. However, it changes with a changing room temperature. Lower temperatures lead to a lower standby value. 3) Both the red light of the heater lamp and both lamps work fine (flashing) at all times. Also flashing if switching between sensor 1, 2 and both. 4) Moved instrument to the front of the table in order to allow for some more space for ventilation in the back. Now there are about 20-30 cm between the wall and the instrument. This allows for a better cooling and heating by the two ventilators. 5) Took of the back cover and de-dusted all filters and ventilators. Also the data and power cable were squeezed by the back cover and are now freed up. 6) Overflow and tank drain are connected with a tube (not sure if this correct). Anyway, the tube had a bend and was replaced it. 7) Replaced the tank that was used to collect the water with a bucket and put a weight on the tube from the cell drain. Now it hangs freely and does not touch anything. 8) During most of the testing phase room temperature was stable within 0.2°C. 9) Opened front to connect two temperature sensors through the top hole. Note that these are not really accurate thermometers and only show a one decimal. Bath temperature is set to 27°C and stable at 0.1°C (a better stability test is not possible with instruments available on board). Thermometer 1: 26.5°C. Thermometer 2: 26.4°C. The discrepancy between the set and measured temperature might also result from an offset by the thermometers. 10) Flushing two bottles of MilliQ water. Adjusting flow rate to a slow enough value to let sample heat to measured value. Note that flow rate was previously set to maximum. 11) Standardization knob was previously set to 0. Seems unrealistic. 12) Flushed cell three times with cleaner and left cleaner in cell over night. Then flushed a whole bottle of MilliQ water. Cleaner: 5 ml TitronX, 25 ml MilliQ, 170 ml Methanol. Flushing worked better after this procedure.

Then, during Leg 3, an attempted standardisation was performed: 1) Note all values are reported in double conductivity ratio read from the instrument display. 2) Standardisation to 1.99966: three flushes, suppression to 1.9, five readings (value rising and not stable, values far too low). Last fill used for a first rough standardisation before bottle is almost at minimum level. Standardisation knob at 491. 3) Standardisation to 1.99966. Three flushes. Three readings (stable within 0.00005). Three fills with adjusting standardization knob (stable within 0.00002). 4) Flushing a bottle of MilliQ water. Three flushes, suppression at 0.0, nine readings (all at 0.00017) 5) Waiting for 30 minutes. 6) Standardisation to 1.99966: three flushes, suppression at 1.9, eight readings (not stable, values rising by 0.00025 throughout eight readings. 7) Flushing a bottle of MilliQ water. Three flushes, suppression at 0.0, seven readings at 0.00018. Left in MilliQ water. 8) Testing 24 hour later. Values changed from previous day. Re-standardise. 9) Readings are very unstable when ship is moving a lot in the waves (jumping up and down between values).

Salts could only be processed in calm waters. 10) Stable measurements during sample processing on 16 March 2017 (see above).

Remaining open issues after Leg 3 are: 1) Dripping cell drain when pump is on. Is that correct? 2) Tube inside touches heater spiral. Is that ok? 3) How accurate values would we like to achieve? 4) Is it at all possible to get something useful if the instrument was last serviced and aligned in 2010?

Recommendations for future use of the instrument: 1) Stabilise room temperature (air conditioning). 2) Service and align instrument.

In addition to the Autosal, we were successful in calibrating the RBR micro-salinometer, belonging to G. Massé, with batch P160 of standard sea water during Leg 1 on 16 January 2017. In order to do this we needed to find a time when the room temperature was reasonably stable. The standard used is batch number P160, K value 099983 and Salinity 34.993 PSU. It is our understanding that this standard can be left in the standard cell and used without further calibration for much of the cruise, while we have batch P160 standards available for daily standardisations of the sample cell. Testing stability of salinity measurement, we recorded salinity of standard sea water in the sample cell every 10 minutes. Mean salinity for a 3-hour stability test, 30 second averaged data recorded every 10 seconds, was 34.9933 PSU, with a standard error on the mean of 0.0007 PSU. Mean ratio was 0.9998. This is within the documented precision of the instrument (0.002 PSU).

Salt crate 7 contained samples extracted from a single rosette bottle for testing. These were used to test the repeatability of salinity measurement throughout a day. Three samples measured just before lunch 16 January 2017. Came back before dinner to measure two more samples. There were bubbles in the standard cell. Measurement 4 and 5 reflect erroneous values due to bubbles. It was decided to refill the standard cell on another day, and we aborted the repeatability test. From this initial test we can see that the measurements made by the RBR are within 0.001 PSU of each other when the standard cell is bubble free. While the RBR salinometer takes longer to use than the Autosal, and requires great care in calibrating and filling the standard cell, it does appear it will provide data of accuracy required for freshwater mass budget work. There were more samples in Salt crate 7, from a single Niskin bottle, that can be used for further assessing the stability of the instrument once the standard cell is stable. However, due to temporal constraints and issues with particles in the system during Leg 3, the RBR was not further used.

SOCCOM float deployments

In coordination with Prof. Lynne Talley from Scripps Institute of Oceanography, the ACE cruise agreed to deploy six SOCCOM floats during Leg 1 of the cruise. However, due to logistical and organisational issues, we realised in Cape Town that launching six floats would not be feasible and providing 1.5 km calibration CTD casts would be quite a challenge. As a compromise, we decided to launch SOCCOM floats in pairs, requiring only three stations in total. In addition, pair deployment provides calibration for the instruments against each other, insuring meaningful data collection even in absence of a calibration CTD cast.

At deployment site 1, buoys 1 (id: F6091; event number: 95) and 2 (id: F6092; event number: 196) were deployed on 03 January 2017 around 07:00 UTC. Start of deployment: 06:46 UTC at 49 25.483S 62 56.822E with a water depth of 2964 m. End of deployment: 07:15 UTC at 49 25.896S 62 55.537E with a water depth of 3044 m. Buoys had all sensors cleaned except optode. Entered water without interference (did not hit ship). Both buoys communicated successfully after the initial deep profile. However, the pH sensors on both buoys were not working correctly. In response to this issue, it was decided not to deploy the second pair of Navis Seabird floats, but to deploy the APEX floats instead as a pair between latitudes of 100 E and 120 E.

Given the weather forecast for deployment site 2, with a storm chasing the ship and bad weather expected for four days from the 12 January 2017, we decided to do a station on 11 January with 1500 m calibration cast and deployment of the two buoys. Given the heavy water demand from Projects on this cruise it is only possible to get all water needs met with two casts – a deep cast followed by a shallow cast. The deep CTD station 20 cast 8 (event number 369) 1500 m started at 04:14 UTC. The coordinates for the CTD were 54 31.081S and 95 44.690E. Two APEX buoys (ids unknown; event numbers 376 and 377) deployed 11 January 2017 around 09:30 UTC. Coordinates at the end of deployment: 54 48.96S 95 40.18E at 09:40 UTC with a water depth of approximately 4000 m. After the deep CTD was completed, but before the shallow cast was performed, the ship had to steam for half an hour to a new site. We took this opportunity to launch the APEX SOCCOM floats as the ship was starting to move. The floats were already prepped open, we cleaned the sensors and successfully completed the launch in less than half an hour. The shallow 150 m CTD cast started at 11:05 UTC at the location 54 51.156S and 95 46.035E. Data for this cast corresponds to event number 370. Together with other teams we collected samples from the full 1.5 km and 150 m shallow cast profiles for Ph/TAlk, DIC/TAlk, nutrients, salt, nitrate isotopes, Ammonia, biogenic silica, $\delta^{18}O$. Chlorophyll-a at 200 and 150 m. Oxygen at 1500, 500, 150, 80 and 15 m was analysed on board by Project 21. Water sample log for the SOCCOM deployment is saved as a separate document entitled ACE_leg1_SOCCOM_ALL_CTD_SAMPLES_LOG.xls. Both APEX SOCCOM floats successfully communicated after the initial deep profile.

Big thanks to Ian Tindall, the helicopter engineer with his assistance in launching the floats. Tremendous thanks for all the marine groups helping us collect and process the water samples for the SOCCOM float calibration. pH samples collected during the SOCCOM float cast will be shipped from Hobart to the Dickson Laboratory at the Scripps Institute of Oceanography for analysis.

Deployment 3 of the floats was cancelled due to a problem with the SBE pH sensors on Navis floats. Navis SOCCOM floats will be off-loaded in Hobart and shipped back to the University of Washington.

Atmospheric sampling, data collection, and methodology

The atmospheric part of the project included precipitation measurements using various techniques, launching radiosondes for vertical profiling of the atmospheric variables, and collecting meteorological and cloud data. Atmospheric measurements were performed by Maria Tsukernik during Legs 1 and 3, and by Irina Gorodetskaya during Leg 2. During all legs, postdoctoral researcher Annick Terpstra hired by Irina Gorodetskaya at the University of Aveiro was doing weather and atmospheric river monitoring and forecasts used for planning event-based frequent radiosonde measurements. During Leg 2 the forecast maps were transferred daily to the ship server. The amount of precipitation (rain and snow) particles was measured using photo-electric particle counters ("Wenglors") and a Snow Particle Counter (SPC). SPC records the number of particles per each particle size bin (at one-second resolution) thus providing particle size distribution, while Wenglors record the total number of particles (at 10 second resolution).

During each snowfall, we were collecting snowflake imprints by means of the formvar-coated slides. During Leg 2, almost 300 slides were collected during the snowfall events occurring between 27 January and 17 February 2017. The slides with snowflakes imprints have been scanned using a high-resolution slide scanner (University of Zürich, Switzerland) and are being analysed using a Matlab program allowing to recognise particle size and geometry. These data will be used together with snow particle counters and effective reflectivity from Micro Rain Radar (MRR; installed by project 11) to estimate snowfall rates with the highest possible precision. We also had equipment for doing snowflake macro-photography, however warm near surface temperatures (around 0°C) prevented us from applying this approach.

Radiosondes were launched on a daily basis and more frequently during interesting events (precipitation and in vicinity of atmospheric rivers). Unfortunately, we missed the atmospheric river events during Leg 2

because the ship followed the good weather window almost the entire leg. Weather and atmospheric river monitoring and forecast were done using the European Centre for Medium-range Weather Forecasts (ECMWF) operational forecasts, the Antarctic Mesoscale Prediction System and satellite images. A lot of effort was put into obtaining the information and software required for updating the ship's MAWS system in order to record raw ceilometer backscatter profiles in addition to the processed cloud base heights. Near-surface meteorological information was acquired using ship's equipment and metadata were provided by the ship's meteorologist.

1) Precipitation particle counters

Three snow particles sensors were installed in Cape Town (before Leg 1) on the upper bridge of *Akademik Tryoshnikov*. One Snow Particle Counter (SPC) and two Wenglor photo-electric sensors both connect to data loggers located indoors. The data loggers for both sensors were installed in the "Intership communication system" room of superstructure deck 4 (where public Iridium phone was also installed). All three sensors were successfully connected in the beginning of Leg 1 (on 09 January 2017) and started to produce continuous data flow. Two Wenglor sensors were writing data on a Campbell scientific CR1000 data logger internal memory card. Testing time was limited by the heavy use of the data logger room by expedition members using the phone and WiFi.

Figure 128: Position of precipitation particle counters on the monkey island above the bridge (left), snow particle counter (top right) and Wenglors (bottom right). Note how the two Wenglors are installed perpendicular to each other..

Snow particle counter (SPC) data:

SPC records snow particle size distribution for particle size range from 36 to 490 µm at 7 µm bin resolution at 1-second time resolution. The data from SPC logger (CF memory card) were downloaded to the project's PC (Toughbook) using the CF-card reader with USB connection. The data log files (eg, 000B.LOG) were converted to ascii text format using SnowPCbin2ascii.exe program (eg, data file for 30 January 2017 is U170130_080800Snow-04-1sec-org-000B.csv). Due to frequent usage of the room where SPC logger and PC were installed, we were downloading the data in chunks after several days of measurements. The data

were converted to daily ascii files. An example of particle size distribution obtained for one of the days with snowfall during Leg 2 is shown in figure below.

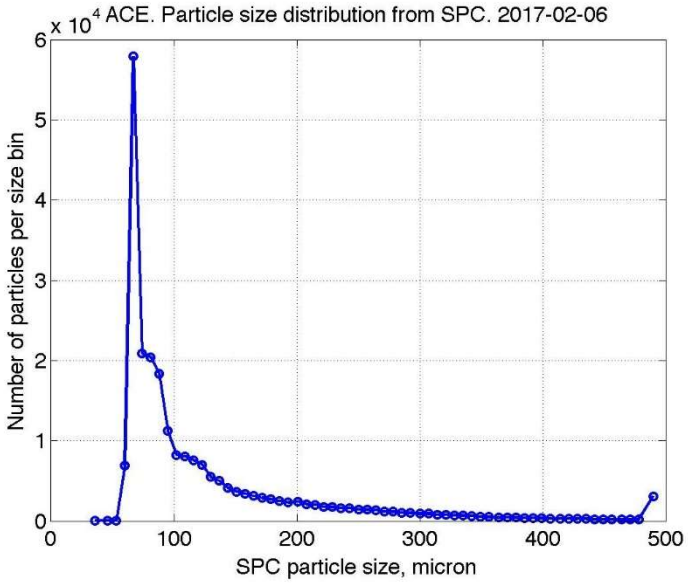


Figure 129: Snowfall particle size distribution obtained from SPC measurements on 6 February 2017 (based on 1-second measurements during the entire day). Figure by I. Gorodetskaya.

Wenglor data:

Wenglor sensor records every 10 seconds the total number of particles detected. The CR1000 record line for Wenglors is as following (Snow_1 = Wenglor #1, Snow_2 = Wenglor #2): "TIMESTAMP","RECORD","batt_volt_Min","PTemp","Snow_1_Tot","Snow_1_Max","Snow_2_Tot","Snow_2_Max". During leg 2, we were downloading the data every 3-5 days when it was not snowing. Sometimes downloading was delayed by several hours because of the heavy use of the data logger room by expedition members using the Iridium phone and WIFI. The procedure of downloading the data from Wenglors to the project's PC (Toughbook): 1) Open the datalogger box with CR1000 and connect RS232 cable to the serial port. 2) Open Loggernet -> Connect -> Custom -> Highlight each of the three files (recorded last time) -> Change File Name to the current date. Do the same for each of the three files ("status", "public" and "Wenglors"). Only one file records the data. Eg, on 04 February 2017 data file is: 04_02_2017_CR1000_wenglors_TRYOSHNIKOV_2017_02_04_39_08.dat. The other two files contain only headers.

Data backup:

File were recorded to the folder: C:/Documents and Settings/leonhard/Desktop/ACE snow particles. Recording time, eg - on 04_02_2017 total number of records collected was 67130 (3,266 KB DAT file), which took 33 minutes to write. This folder was shared and backed up on an hourly basis onto the expedition data storage. BACKUP Wenglor and SPC data to the external hard drive "Leonard CTD Lab Backup" (Lacie): D:/Snow_rain_particles/SPC; D:/Snow_rain_particles/Wenglors

2) Formvar snowflake casting

During Leg 2, the ship was further south closer to the Antarctic ice sheet compared to Leg 1, which was our major snowfall sampling period. Snowfall occurred from 27 January – 17 February 2017. In total 287 formvar slides with snowflake imprints were collected, grouped into 36 snowfall events. The formvar slides collected during Leg 2 are stored in three blue boxes (capacity 100 slides each).

The formvar solution was prepared in Cape Town before Leg 1. The formvar solution preparation consists of mixing the formvar resin with formvar solvent 1,2-Dichlorethan (Ethylendichlorid) using a mixing plate to ensure homogeneous solution. The solutions of different formvar concentration were stored in separate small bottles. We had solutions: 1% (one bottle), 2% (one bottle), 2.5% (two bottles), and 3% (one bottle). As near surface temperature was rather warm - around -1 to +1°C, we found that the 1% and 2% formvar solution was working best. Later we also used 2.5% formvar solution. After Leg 2 we have left 2.5% (one bottle), 3% (one bottle), and a mix of 1% and 2% solution (half bottle).

The technique of snowflake casting was as following: 1) all the necessary material was stored in a small frigo-box (glass slides, cotton-buds, bottles with formvar solution, permanent markers, paper wipes). 2) take empty slide, wipe it from condensation, put UTC date and time on the top, turn around, apply formvar solution on the other side using a cotton bud, so that it covers the entire slide, dispose the cotton bud in a small plastic bag, close the formvar bottle, expose the slide to the snowfall (with no more than 2 seconds after applying formvar as it dries quickly), catch snowflakes during about 10 seconds, store the slide with snowflakes in a special holder, prepare a new slide. We tried to have at least 100 snowflakes (4-5 slides) per snow event. Snow event is defined as a period of snowfall with similar snowflake properties, thus continuous snowfall can have several snow events.

Our snowflake collection sites changed depending on the wind conditions and the ship's speed. Our sites were: 1) upper deck above the stern helicopter deck (outside of the multibeam and meteorology labs) on the starboard side (opposite site to the stack). This site was only used if the stack was not upwind. 2) on the stern helicopter deck. 3) next to the lifeboat on the starboard side, helicopter deck level. 4) main deck level on the back (next to the CTD lab corridor exit) - but this location is not safe when there are waves. 5) portside of the deck with Swiss containers (used for short time while collecting snow for Iris, Project 11). In between the snowflake collection we stored the frigo-box with all required material in the -20°C fridge of the benthic lab (next to the autosal room). The problem with the formvar slides is that they cannot preserve clusters of a large volume, such as dendritic clusters. These clusters were preserved as surface projection of some irregular form.

A 	B 
C	D

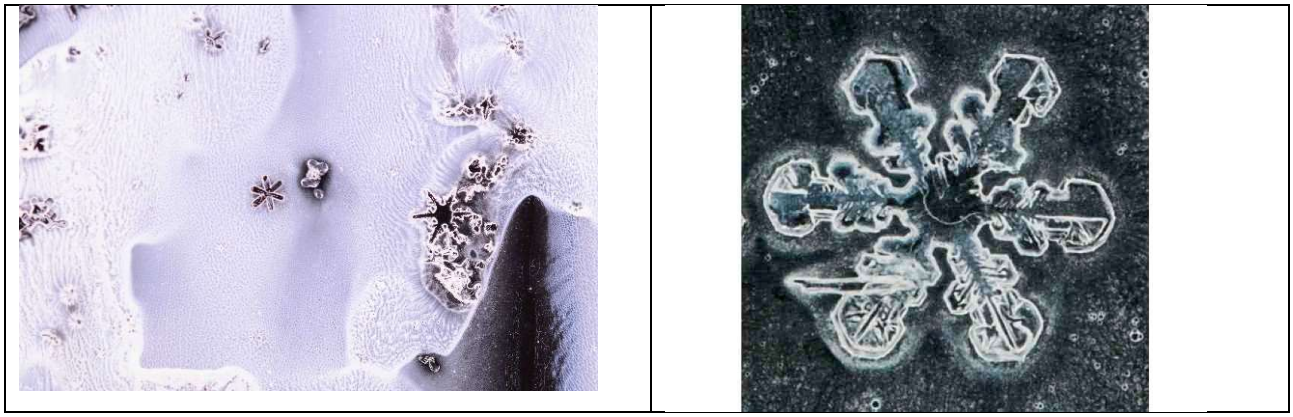


Figure 130: Formvar snowflake casting work: A) preparing a slide applying a formvar solution; B) snowflakes caught in the formvar solution before drying; C) photo of the formvar slide with snowflakes imprints; D) zoom into a dendrite snowflake imprint. Photos courtesy Irina Gorodetskaya. The macro photo of the dendrite is by Noé Sardet.

The slides with snowflakes imprints will be scanned using a high-resolution slide scanner (University of Zürich, Switzerland) and analysed using a Matlab program allowing to recognise particle size and geometry. These data will be used together with snow particle counters (measurements and data processing in this project) and effective reflectivity from MRR (installation and post-processing by project 11) to estimate snowfall rates with reduced uncertainty.

We have also collected snowflakes on big glass slides (30 x 30 cm) for the artistic project of Yvonne Weber. In total we collected snow imprints on six big slides, from which one was broken (when boxes fell in the -20°C fridge of the benthic laboratory during a storm), and one has very small amount of snowflakes. Collecting snowflakes on big slides was fun job but related with certain difficulties and needed at least two people. We have used plexi-glass slides as support for drying with pieces of styrofoam in between the glass slide with formvar snowflakes and the plexi-glass. It needed minimum two persons to prepare the slide. We put formvar using long brushes on the slide. The brushes were too wide to pass into the brown bottles with formvar solution. So we poured first some solution on the brown bottle cap, and used the long brush to apply the solution on the glass slide. The plexi-glass slide was prepared with pieces of styrofoam attached to it using a sticky white tape. After catching the snow on the big glass slide and waiting couple minutes so it dries - it was put downside on the plexiglass with styrofoam pieces and both slides attached together with a tape. Then both slides were carried down to the -20°C fridge in the benthic laboratory (all the way down to -1 level near Autosal room). The big glass slides were stored in the big white plastic box.

3) Snowflake photography

We have assembled the camera stand and did a lot of trials using different combinations of light and filters (heat diffusing, several blue filters). The inside photography with the formvar-collected snowflake imprints on glass slides gave some interesting results. Selected formvar slides with some characteristic snowflakes imprints were photographed. The best results were achieved with help of Noé Sardet (reporter and photographer during Leg 2) using his Sony macro lens. The Nikon lens that we had proved difficult to use for macro photographs.

However, our attempts to photograph "live" snowflakes turned out to be a failure because of the flakes melting on the glass slides as soon as they were put on the light source. Given a lot of time to set up the photographic equipment vs the doubtful success, we have opted for collecting as many as possible formvar slides.

4) Radiosondes

Radiosonde measurements were conducted in collaboration with Project 11. We used sondes manufactured by Intermet (USA), particularly i-Met-1-ABX and i-MET-1-RSB. The RSB sondes include XDATA cable to connect additional sensors (such as the supercooled liquid water content sensor). The data were recorded using Sky Sonde software.

Irina Gorodetskaya used external funds to purchase 85 i-MET-1 sondes (70 i-Met-1-ABX and 15 i-MET-1-RSB), and 12 cloud supercooled liquid water content (SLWC) sensors from Anasphere. This purchase was made with financial support of F. Martin Ralph (Scripps Institute of Oceanography, UC San Diego, USA) as part of collaboration on measuring atmospheric rivers around Antarctica.

The radiosonde ground station (PC with SkySonde software, radio receiver AOR AR8600, and antenna PROCOM CXL 450-3LW-SS, 3 dBd Base Station and Marine Antenna for the 450 MHz Band) were provided by Project 11 (ETHZ).

ETHZ colleagues provided 40 standard radiosondes and also rented helium bottles from Air Liquid (Germany). Each party bought corresponding amount of balloons and de-reelers from Intermet.

In total during the entire ACE expedition a total of 102 sondes were launched. Particularly during Leg 2, we have launched in total 43 i-MET-1 radiosondes (id from ace039 to ace081), including eight cloud supercooled liquid water content (CSLWC) sensors. Radiosondes give vertical profiles of temperature, humidity, wind speed and direction up to the lower stratosphere (20-25 km height). The SLWC sensors give vertical profiles of the wire vibration frequency changes (due to the ice deposition when passing through supercooled liquid water droplets), from which supercooled LWC will be estimated using Anasphere software. Radiosonde data are recorded using SkySonde software and saved in the raw and processed files. See "Radiosondes_logs_leg2.xlsx" file for information about radiosonde launches. Radiosonde data were recorded into a shared folder and copied on an hourly basis onto the expedition data storage.

Anasphere cloud supercooled LWC sensor had to be attached to the i-MET-1-RSB sensor using XDATA cable. The procedure of preparing the SLWC sensor was as following: 1) Connect the XDATA cable to 'main', use mode '1' (the sensors are typically shipped in mode '3'); 2) Insert four lithium AAA batteries (purchased separately in Hobart); 3) Turn on the sensor and make sure the servo motor starts pushing the wire down making it to vibrate when released; 4) Make sure the wire vibrates freely: the problem with almost all sensors was that the wire was touching the side of the cardboard box opening - thus before the launch sensor had to be prepared by cutting out a piece in the cardboard to make the wire vibrate freely without touching anything; 5) Attach the battery case inside carefully so that it doesn't interfere with the servo motor (eg. using duct tape), put the foam square on top with the glue side to the top and close the box; 6) Attach the cloud sensor box to the i-Met radiosonde box using duct tape - on the other side from the i-Met sensors.

The following software checks had to be performed before the launch with SLWC sensor. SkySonde server: make sure XDATA signal is received. SkySonde client: after entering all basic info - go to "Other" and choose "Anasphere LWC sensor", mark "1/ 2 frequency multiply by 2" and choose daisy chain index '1'. Also, the balloon had to be inflated slightly more compared to the standard radiosonde launch (so that it almost touches the shelter). The cloud sensor measurements are not processed by the SkySonde software. Only the change in the wire frequency with time is recorded. We will be using a new software provided by Anasphere to convert the wire frequency to cloud SLWC content.

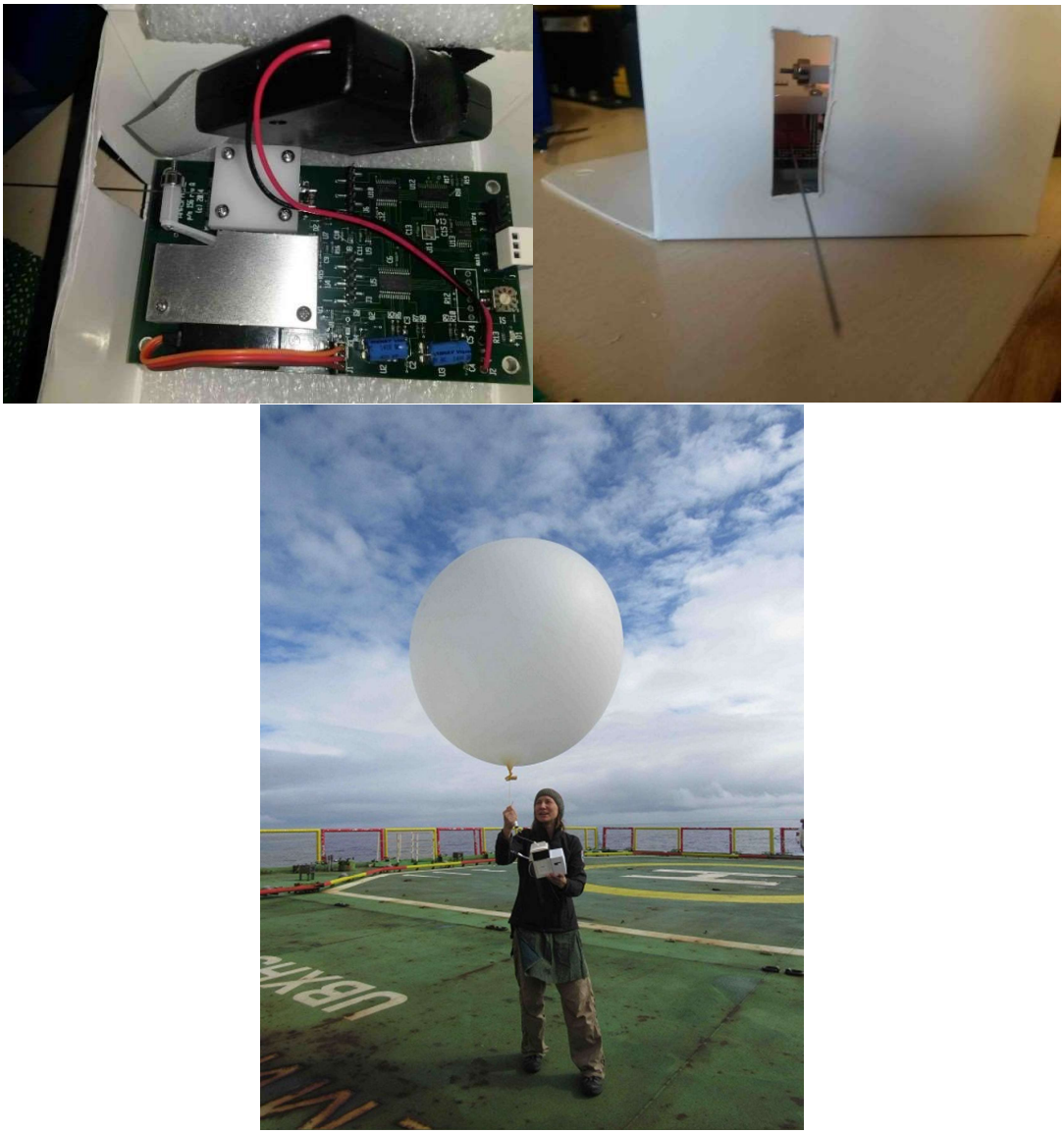


Figure 131: SLWC sensor from Anasphere (top): measuring unit (left) and wire on which ice is accreting when the sensor is passing though supercooled liquid droplets (right). Launching a radiosonde with SLWC sensor (bottom).

Atmospheric river measurements:

Atmospheric river (AR) events provide rapid transport of large amounts of moisture poleward and typically associated with intense precipitation. Thus measurements during ARs provide important information about mechanisms of intense precipitation formation over the Southern Ocean. During Leg 1 two AR events were measured on 1-2 and 3-4 of January 2017 in the Southern Indian Ocean (near Kerguelen Islands). Detailed radiosonde measurements captured the evolution of the troposphere vertical profiles before the AR passage over the ship position, within the AR and after its passage. During Leg 2 we measured a strong moisture inversion in the vicinity of a major AR bringing large amounts of snow to Mary Byrd Land (West Antarctica). The event was measured on 14-15 February 2017 and represented a peripheral heat and moisture extrusion from the main atmospheric river path. During Leg 3, an AR event was measured on 15-16 March 2017 in the Southern Atlantic Ocean. These are unique measurements of AR events over the Southern Ocean and are being presently analysed.

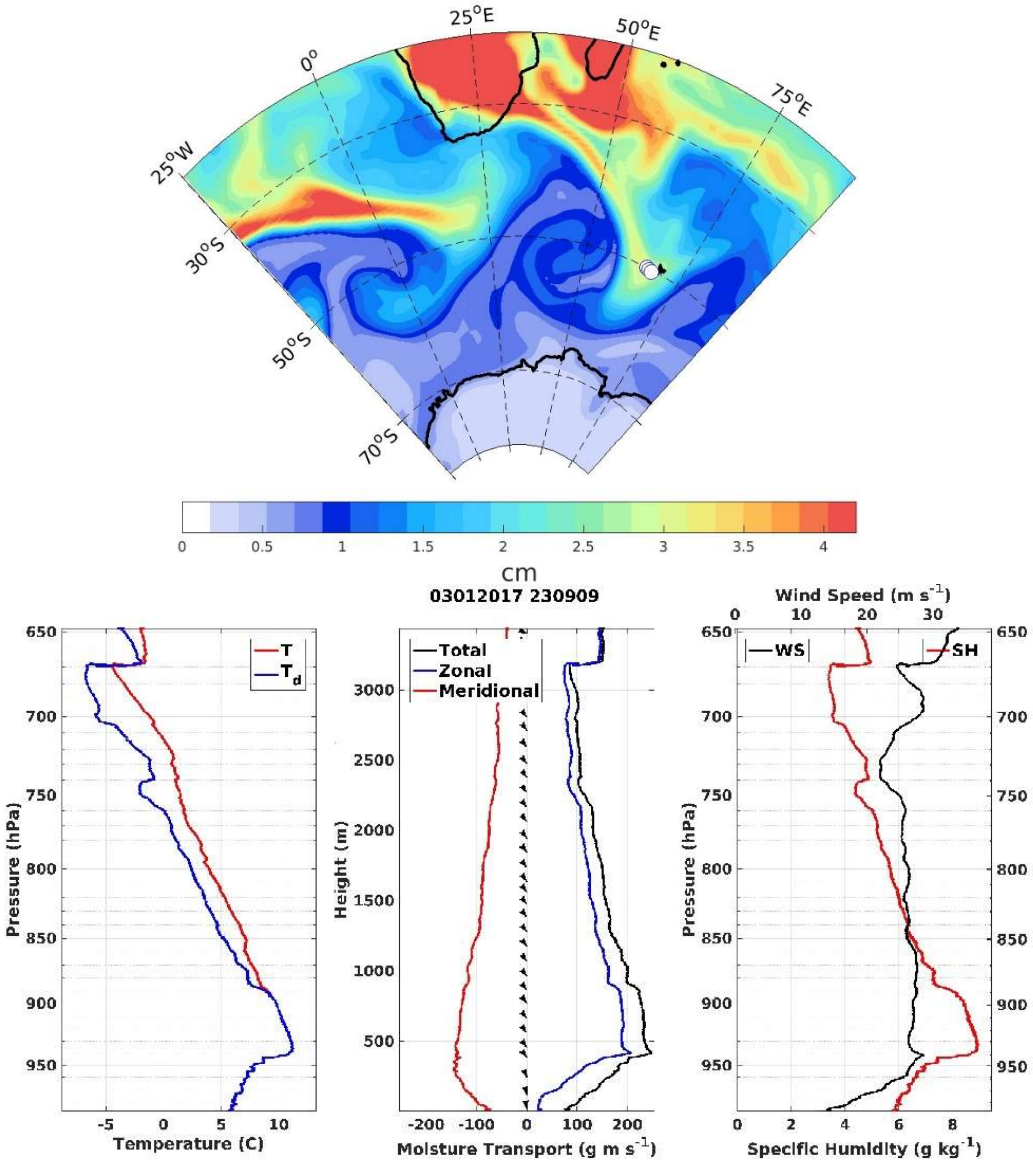


Figure 132: Measurements and analysis during an AR event on 3-4 January 2017: (top) Vertically integrated water vapour (IWV) during an AR event on 20170104-00Z (calculated using ERA-Interim reanalysis products) with white circles indicating the ship position during radiosonde launches within the AR (a tongue of high IWV values stretching from South Africa); (bottom) vertical profiles of temperature, wind speed, specific humidity and moisture transport calculated from radiosonde measurements for the same hour as the IWV map. Radiosonde measurements show strong moisture fluxes in the lowest 1-km above ground. Figures and analysis by I. Gorodetskaya.

The problem concerning AR and intense precipitation measurements particularly during Leg 2 was that the time constraints of the expedition and the fact that many other projects would succeed better in good weather did not allow to measure some very interesting and important cases of AR events. Precipitation over the Southern Ocean is typically associated with low-pressure systems and fronts (with AR events being present in particular cases) and thus accompanied by relatively high winds, meaning “bad” weather. While we were not expecting to go into the most severe weather conditions, which could pose problems to the ship's operations, following the "perfect weather window" during Leg 2 strongly hampered the representativeness of our atmospheric measurements for the region.

Collaboration with Antarctic coastal stations helped us to gather information about another important atmospheric river missed by our expedition as it hit the Mertz glacier region about five days after our ship left that area. Irina Gorodetskaya asked colleagues at the French station Dumont D'Urville located nearby

the Mertz glacier to launch additional radiosondes during this event and they agreed to launch three additional sondes (in addition to regular daily launches) that allowed to follow the evolution in the atmospheric profiles during the event and the changing position of the intense moisture fluxes. We express our big thanks to the colleagues assuring these measurements.

5) Ceilometer

The Ceilometer is a low power laser operating in near-infrared (910nm), which signal power can be converted to the atmospheric attenuated backscatter profile. It is commonly used to calculate cloud base height and vertical visibility. It can be also extended to obtain more information about precipitation and clouds (ice clouds vertical extent, virga precipitation, presence of liquid in clouds) if the entire raw attenuated backscatter profile is recorded.

Akademik Tryoshnikov has Vaisala's Marine Automatic Weather Station (MAWS) with ceilometer (CL31) data embedded into the weather marine display software. Special information was required about the MAWS system setup, which was acquired only when Irina Gorodetskaya boarded the ship in Hobart and checked the setup together with the ship's meteorologist Victor Veledin. Installation and setup of the Vaisala MAWS instruments and software is made exclusively by the Vaisala representatives in St. Petersburg and/or Helsinki. The ship's meteorologist cannot do any system modifications without official permission and technical support from Vaisala. We checked together the MAWS system setup (during the first days of Leg 2), and found that only cloud base heights processed with Vaisala software are recorded as part of the weather log data. The backscatter vertical profile is not recorded and requires a special set up. Irina contacted Vaisala on 23 January 2017 with an initial request about the possibility to change the MAWS setup in order to record backscatter profiles. After almost daily exchanges of emails and requests for engineering support, we received all the required software updates on 14 February 2017. All the information and files from Vaisala were provided and discussed with the ship's science team. On 18 February 2017 we made the necessary modifications to the MAWS system (with trembling hands as the entire ship's weather monitoring was at stake). Firstly, we downloaded the current QML logger setup file to PC before upgrading it and uploading a new setup file. Then we upgraded the MAWS QML201 firmware to version v8.05c (from version 7.00c) on logger 2 (installation was done using a CF card). QML's logger 1 was not touched. Then we uploaded the new setup file provided by Vaisala (Trans2V4.adc) to logger 2. All the file transfer was done via the terminal (the graphic interface described in Vaisala instructions didn't work for us). Success! Now the weather log data are recorded as before, while the ceilometer backscatter profiles are recorded to CF card of logger 2 (filename eg "L0170219.DAT").

The extra CF card was provided by the ship's meteorologist. We have agreed with him to download the ceilometer data at the end of Leg 3 (in Cape Town). I can recognise the ceilometer backscatter profile, however the header information is recorded as binary and Vaisala contact person doesn't provide information about the recorded profiles or conversion software. According to Vaisala, the only way is to do the conversion using MAWS Client software (to be done in Bremerhaven in April where the ship arrives after Leg 4).

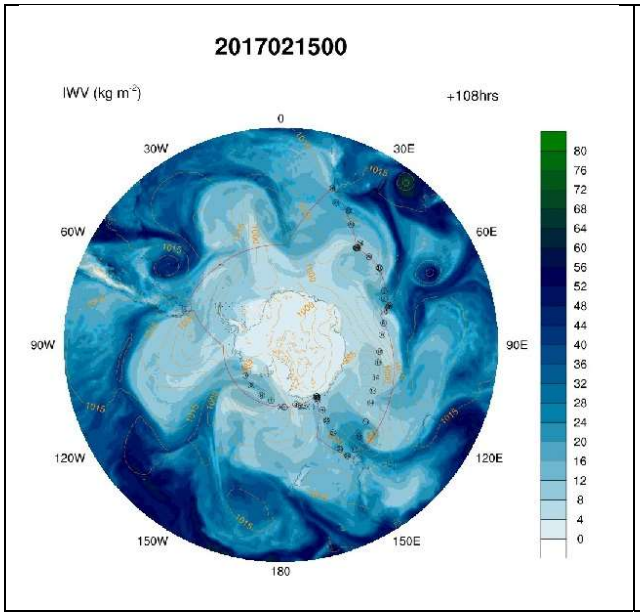
Expected ceilometer backscatter profiles information: vertical profile from 10 m above the ground level up to 7.7 km at 10-m vertical resolution, profiles averaged over 15 seconds (this information will be verified upon raw data conversion). Contact in Vaisala providing information and technical support for MAWS/ceilometer: Markku Sinkkonen, Technical Support Specialist Vaisala Oyj, Services, P.O. Box 26,FI-00421 Helsinki, Email markku.sinkkonen@vaisala.com.

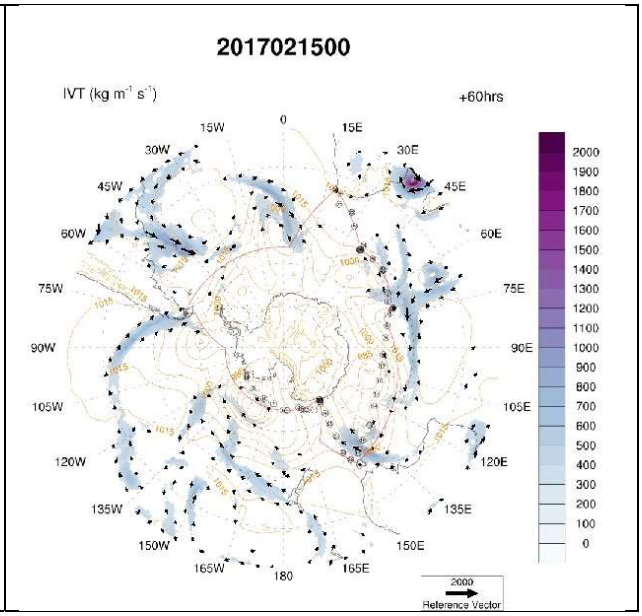
6) Weather forecasting and monitoring

The official ACE weather forecast was provided by ETHZ (project 11) using ECMWF operational data (https://data.iac.ethz.ch/ace/).

Our project used additional weather forecast information publicly available to everyone on the ship (via Intranet) and via direct AMPS link (http://www2.mmm.ucar.edu/rt/amps/wrf_plots/2017030412/ace/ - date to be modified accordingly). Firstly, the AMPS (based on the Polar WRF model) was updated upon Irina's request to include precipitable water as a new variable. Kevin Maning from UCAR also created a special window for the *Akademik Tryoshnikov* and also adapted the maps and other variables. We cordially thank all colleagues providing AMPS and ECMWF forecasts. It was very useful to compare ECMWF and AMPS during the expedition as the forecasts sometimes differed substantially. Snowfall was especially difficult to predict. Once we had two days when ECMWF predicted no precipitation, but it was snowing quite heavily and for a long duration (affecting helicopter operations near Scott Island). Checking the AMPS "10km.pcp_fqp1" (ensemble frequency 3 hour precipitation >0.1mm) showed that the ship's location was in 0.5 fraction shading (half of the model ensemble members predicted precipitation, while the other half didn't).

In addition, Irina Gorodetskaya and Annick Terpstra (postdoctoral researcher hired by I. Gorodetskaya at CESAM/U Aveiro) were doing continuous monitoring and prediction of the atmospheric rives using satellite images and 5-day forecasts based on ECMWF operational forecast. The forecast maps included circumpolar and zoomed into the *Akademik Tryoshnikov's* window images of integrated water vapour, integrated total horizontal water vapour transport, potential temperature on 2PVU maps, and precipitation. All variables were plotted together with mean sea level pressure for surface synoptic system analysis. The maps were produced daily and transferred at 02:00 (ship time) onboard *Akademik Tryoshnikov*.





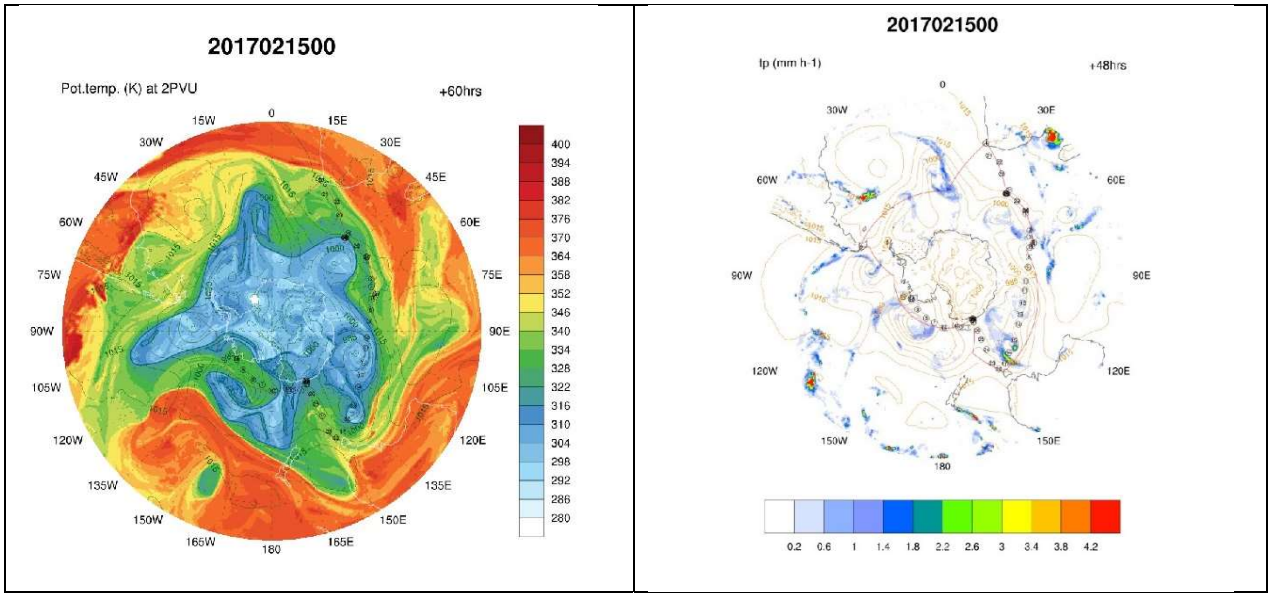


Figure 133: Circumpolar atmospheric river watch using ECMWF operational forecast for 20170215-00UTC (initialized on 2017021200): upper left) vertically integrated water vapour; upper right) vertically integrated horizontal moisture transport; bottom left) potential temperature on 2PVU surface; bottom right) precipitation (Figures by Annick Terpstra).

10.19 Project 19

The Impact of microplastic pollution on the Southern Ocean food web

PI Peter Ryan (South Africa)

Plastic pollution has been growing in all the world's oceans for many decades. Regular surveys on specific beaches around Antarctica have established the range and frequency of macroplastics and inferred sources for much of the material. It is known that plastic is impacting the marine food web, being found in the stomachs of birds and entangling seals and other creatures. The plastic is also known to breakdown in the sea into smaller particles about which little is known.

Aims and Objectives

This Project aims to establish baseline estimates for the abundance of micro-plastic particles in the Southern Ocean. Sampling was conducted at sea and on sandy beaches.

Sampling at sea

At sea sampling took place using neuston net tows to sample surface plastics (200-µm mesh) and vertical bongo net tows to sample plastics in the water column (300-µm mesh; 200 m depth). These sampling approaches were successfully tested on Leg 0, when 22 neuston and 12 bongo samples were obtained. However, rough seas and high winds, coupled with time limitations (in order for the ship to keep to the voyage schedule), reduced the number of net deployments. The first deployment, conducted east of Marion Island, was hindered by high winds, which caused the cod end of one bongo net to shatter against the side of the ship, and cracked the cod end of the neuston net. Subsequent deployments of the bongo net from the main deck (not level 2) avoided a repeat of this problem. The neuston net continued to be deployed from level 2, but without further incidents. During Leg 1, eight neuston and eight bongo samples were collected. We thank the Chief Scientist for arranging additional neuston tows *en route* between Heard Island and Hobart. A further 14 neuston and 13 bongo samples were collected on Leg 2, and 11 neuston and eight bongo samples on Leg 3, giving a grand total of 33 neuston and 29 bongo samples.

To supplement the net samples, 40-µm mesh filters were used to sample water from the ship's underway system in collaboration with Tommy Bornman (Project 12). These regularly contained brightly-coloured fibres, presumably of synthetic origin, which initially were assumed to be due to either contamination in the laboratory, or from the ship's laundry outlet. However, laboratory blanks failed to detect any fibres, and to test whether the intake was close to the laundry outlet, we sampled with a bucket from the foredeck. To our surprise, both samples collected on 16 January 2017 contained large amounts of tiny plastic particles – mostly fibres but also some fragments. It appears that there may be lots of very small plastic items in surface waters, too small for the 200-micron neuston net to detect, and only a small subset of this plastic reaches the underway intake, which is 4.5 m below the surface.

Figure 134: Neuston (left) and bongo (right) deployments from level two on the starboard side of the ship. Note how the bongo cod ends are blowing in the wind, resulting in bongo deployments being discontinued from this location

Figure 135: Peter Ryan sampling surface waters from the ship's bow with a stainless steel bucket and natural-fibre rope.

During Legs 2 and 3 we sampled surface waters and the underway system, usually with paired samples, to test whether a) microplastics occurred throughout the region, and b) surface samples consistently contained more plastics than sub-surface samples. A total of 71 surface and 85 sub-surface samples were collected throughout the cruise.

Beach samples

Sampling ashore consisted of taking a series of 10 cm deep cores (7 cm diameter) from sandy beaches on each island visited. The idea was to contrast microplastic loads in beaches close to and distant from research stations where these were present on islands, but this was not always feasible for logistical reasons. At Marion Island, only one beach (Ship's Cove) was sampled, as it is the only sandy beach of any size on the island. Duplicate samples were obtained at three levels on the beach, at each of three sites (n=18 cores), with a further three high-shore storm line samples taken. This design was replicated at Baie Américaine on Île de la Possession (n=24 cores), but access limitations due to breeding King Penguins restricted back-shore samples to along the access road at Crique du Navire, near the island's station (n=22 cores). Only a small beach adjacent to Port aux Français was sampled at Kerguelen, with two lines of cores, plus three top shore cores, giving a total of 15 samples. High winds prevented a visit to beaches on the northern coast of Peninsule Courbet (on Kerguelen), where the influence of local litter sources would be negligible. On Leg 2, sampling was only possible at two sites: eight samples were collected at Lovill Bluff, Mount Siple, and 18 samples were collected on a small beach on Isla Gonzalo in the Diego Ramírez islands. On Leg 3, beach sediments were collected at two sites on South Georgia: 12 from the point south of Grytviken and 24 from St Andrew's Bay.

Figure 136: Jasmine Lee and Giuseppe Suaria collect sediment cores for microplastics on the low shore at the sandy beach adjacent to Port aux Français, Kerguelen.

Additional sampling

Two dead birds were examined for plastics. A Salvin's Prion, killed after colliding with the ship on 24 December 2016, northwest of Marion Island, contained no mesoplastics in its stomach or gizzard, but

several fibres were found in its stomach contents when examined under a dissecting microscope. The digestive tract was removed from an Adélie Penguin chick found dead at Maher Island, Mount Siple, and stored for later examination. No fur seal scats were collected at Marion Island, where there is regular collection of scats for long-term studies on the diet of both Subantarctic and Antarctic Fur Seals (Ryan et al., 2016). No fur seal colonies were visited at either Îles Crozets or Kerguelen, and no scats were found at the small colony of South American Fur Seals on the west coast of Isla Bartolomé, Diego Ramírez. Rather disappointingly, only five Chilean Skua pellets containing the remains of Blue Petrels were collected on Isla Bartolomé; Blue Petrels are the Southern Ocean species with the highest incidence of ingested plastic (Ryan 1987).

In order to examine fish for microplastics, fishing was conducted on two days while the ship was at anchor off Marion Island, but no fish were caught. No fishing was attempted at either Îles Crozets or Kerguelen because we did not have a permit to catch fish in the reserve areas where the ship anchored. A sample of fish was obtained during trawling operations off Mertz Glacier; they were frozen for later examination of their stomach contents. No fishing took place on Leg 3.

Project 19 personnel assisted David Barnes (Project 3) to collect macro-litter from island beaches to check for invertebrate epibionts. Only four items were found at Marion Island (two on Ship's Cove and two on Trypot Beach, including a data logger), where beaches are cleaned regularly. Ten litter items were collected at the landing beach near the base on Île de la Possession (Crique du Navire) as well as the main beach at Baie Américaine, divided equally between items from oceanic and local sources; none supported any epibionts. A total of 43 mostly local-source litter items were collected adjacent to Port aux Français at Kerguelen; only seven items were thought to be of oceanic origin (one bearing traces of barnacle bases). On Leg 2, no macro litter was found at Lovill Bluff, but three items were found on the beach at Isla Gonzalo, and 26 items on approximately 200 m of gravel beach on the west coast of Isla Bartolomé in the Diego Ramírez archipelago.

Figure 137: Litter collected on the west coast of Isla Bartolomé, Diego Ramírez Islands.

Macro-litter was recorded at sea during surveys of top predators and drifting debris (see e.g. Ryan et al., 2014). During 5535 km of transects on Leg 1, 34 litter items were observed, but only eight were in the Southern Ocean distant from continental sources. During Leg 2, only four litter items were seen in 6295 km

of transects. On Leg 3, 15 litter items were seen in 3604 km of transects, but only seven of these were south of 40°S. Macro-litter was outnumbered by drifting kelps 50:1 in the Southern Ocean. More than 100 dedicated 30-minute litter surveys were conducted from the deck below the bow, approximately 8 m above the water. In most cases these surveys were conducted in tandem with top predator and drifting debris surveys (Project 20), allowing a direct comparison of data between the two methodologies.

References

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Ryan, PG, de Bruyn, PJN and MN Bester (2016). Regional differences in plastic ingestion among Southern Ocean fur seals and albatrosses. Marine Pollution Bulletin 104: 207-210.

Personnel on board

Peter Ryan (FitzPatrick Institute of Africa Ornithology, University of Cape Town, pryan31@gmail.com), Giuseppe Suaria (CNR-ISMAR (Institute of Marine Sciences – Italian Research Council, giuseppe.suaria@sp.ismar.cnr.it), Jasmine Lee (Centre for Biodiversity Conservation Science, University of Queensland, jasmine.lee1@uqconnect.edu.au), Patti Virtue (Institute of Marine and Antarctic Science, University of Tasmania, p.virtue@utas.edu.au). Assisted by Fabrice Le Bouard (Project 20).

10.20 Project 20

Monitoring of threatened albatrosses and penguins: population censuses and distribution at sea

PIs Peter Ryan/ Henri Weimerskirch (South Africa/France)

Aims and Objectives

This Project aims to assess the population sizes of surface-nesting seabird species breeding at seldom-visited localities in the Southern Ocean. Given the mid-summer timing of the ACE cruise, the main species of interest to monitor at breeding colonies were Wandering Albatrosses and King Penguins.

Cruise results

Four key breeding sites were identified for aerial surveys in Leg 1 based on the long period since they were last surveyed (>30 years): Île aux Cochons, Îles des Apôtres and Île de l'Est in the Crozets, and Peninsule Rallier du Baty in the southwest of Kerguelen. Unfortunately, high winds and poor visibility, coupled with the ship running late during Leg 1, conspired to limit aerial surveys to only one of these sites, Île aux Cochons. A flight lasting 40 minutes was conducted around this island on 30 December 2016 in reasonably good conditions. The flight was conducted with two photographers working from the port side of the aircraft with the front door removed and the back door open. The helicopter was flown anti-clockwise around the island, starting in the northeast at 200-600 m above sea level. Three high resolution (30-50 megapixel) digital SLR cameras (Nikon D810, Canon 5Ds and 5D mark IV) were used with 24-105 mm, 24-70 mm and 70-200 mm lenses to obtain images of the coastal lowlands up to the upper limit of breeding albatrosses. Special attention was paid to the large King Penguin colony on the island's east coast.

More than 1500 images were taken, and copies deposited on ACE data storage. Images of each colony were stitched together using Autopano Giga, and numbers of breeding pairs will be counted using iTAG. Very high-resolution satellite imagery is being purchased for the remaining three sites to estimate their current Wandering Albatross populations.

Figure 138: Part of the main concentration of Wandering Albatrosses on Île aux Cochons.

Figure 139: An overview of the King Penguin colony extending well inland on Île aux Cochons.

During Legs 2 and 3, aerial surveys were conducted at the Balleny Islands, Lovill Bluff (Mount Siple, augmented by ground counts), the northwestern coast of Peter I Island, and all round Bouvetøya. In addition, ground surveys were conducted at Scott Island, Maher and Lauff Islands (off Mount Siple), and Isla Bartolomé, Diego Ramírez. At the Balleny Islands, surveys covered most of the northern complex of islands (Young, Borradaile, Buckle and Sabrina, but not Row Island). Pygoscelid penguin colonies were photographed on Sabrina (plus adjacent Chinstrap Rock) and three sites on the east coast of Buckle Island.

No birds were confirmed breeding on Scott Island; the only sign of possible breeding was on the northern and western cliffs, and Haggit's Pillar, which were being inspected by a few Wilson's Storm Petrels and had several Southern Fulmars on ledges (the only vaguely accessible bird was loafing). Despite the large flock of more than 300 Cape (Pintado) Petrels sitting just offshore, there was no sign of them breeding. The only other bird seen was an immature Macaroni/Royal Penguin that was moulting on the eastern beach.

Adélie Penguins and South Polar Skuas were breeding at all three ice-free sites visited in the Mount Siple area. Most of the penguin chicks had left the colonies on Maher and Lauff Islands, so an accurate estimate of the breeding population was not possible, but based on nest scrapes and colony extent there were of the order of 250 pairs on Lauff and perhaps 2000 pairs on Maher. There were three pairs of skuas on Lauff (at least one chick), and at least four pairs on Maher (at least two with a chick). The only other bird seen was a single Snow Petrel flying around the western cliffs on Lauff Island, but the summit of Maher bore lots of footprints of Southern Giant Petrels, doubtless attracted by the many penguin chick carcasses (and lingering chicks). Breeding was somewhat later at Lovill Bluff, so a better estimate of the population here will be possible. The previous estimate from 2009 of 1500 pairs is probably an order of magnitude too low. Almost as impressive as the multitude of Adélie Penguins was the large number of South Polar Skuas, with several hundred on the main nunatak, and at least 70 on the nearby small stack. Breeding at the main colony was confined to the periphery of the penguin colonies, and there were at least two clubs of non-breeders containing around 50 birds. We counted 16 pairs with chicks, but doubtless many more pairs breed here, making it a globally significant site for both Adélies and South Polar Skuas. The only other bird seen at the site was a Snow Petrel flying along the cliff at the eastern edge of the main massif.

Figure 140: The western end of Lovill Bluff, with Adélie penguins breeding on top.

Peter I Island was briefly visited on the afternoon of 15 February 2017, allowing only a cursory inspection of the northwestern cliffs. Thousands of pairs of Southern Fulmars were breeding in this area. The images obtained will provide a baseline against which possible future population changes can be assessed, although it is hard to discriminate adults from large chicks in most of the images.

Figure 141: Two Southern Fulmar adults and 13 large downy chicks on Peter I Island.

Figure 142: A promontory on Peter I Island with large numbers of Southern Fulmar nests.

No counts were made at Isla Bartolomé, Diego Ramírez, because the albatrosses breeding at this site have been monitored quite frequently in recent years, and it was really too late in the season to add information on recent trends. Instead we attempted to sample plastic loads in Blue Petrels by searching for prey remains of Chilean Skuas, but only a few pellets were found.

The visit to Bouvetøya took place after most seabird breeding activity had ceased. However, staff from the Norwegian Polar Institute requested aerial images of the island's cliffs to assess erosion rates since they were last photographed three years ago. Favourable weather conditions on 13 March 2017 allowed good coverage of the island, and useful images were obtained of the large Southern Fulmar colonies, as well as Macaroni Penguins, which were back at their colonies preparing to moult.

Figure 143: Part of a Macaroni Penguin colony on the small islet SW of Bouvetøya.

In addition to surveys of poorly known breeding colonies, a secondary goal of Project 20 was to document the distribution of seabirds and other marine predators at sea around the Southern Ocean. Standard 300-metre wide transect counts of seabirds were made on the side of the bow with the best visibility while the ship was steaming, and recorded to the nearest 10 minute interval (modified from Tasker et al., 1984). All cetaceans and other marine mammals observed were recorded, irrespective of whether they fell within the transect area or not. Where there was uncertainty as to the identity of specific animals, photographs were taken with a Canon 7D II digital SLR and either a Canon 100-400 mm (f4.5-5.6 mark II) or Canon 500 mm (f4 mark II) lens. This proved particularly useful for assigning species identities to most prions encountered. A specific effort was made to scan the sea surface close to the ship's path for floating debris. For each debris item, we recorded its location, distance from the ship's track, item size, presence of any visible epibionts, and, for anthropogenic litter, its type of material, identity as far as possible, colour and buoyancy. Photographs of as many items as possible were taken with the same camera equipment described above to confirm item identity, and to assist with scoring the presence of epibionts.

During the three Legs of ACE, 15,430 km of transects were conducted, recording 30,035 birds from 83 seabird species, and 2,640 marine mammals (at least 26 species). By far the most surprising finding was the presence of thousands of Short-tailed Shearwaters Ardenna tenuirostris from 0-8°E around Bouvetøya. These are the first records of the species in the Atlantic sector of the Southern Ocean. It breeds in Tasmania, and typically ranges between 70-160°E. We recorded flocks east to 173°W, extending their range well into the Ross Sea, but this is trivial compared to the westward range extension from around Heard

Island to Bouvetøya! Other species recorded outside their known ranges included Fairy Prions *Pachyptila turtur* and diving petrels (probably South Georgian Diving Petrels *Pelecanoides georgicus*) between the South Sandwich Islands and Bouvetøya (~6°W to 10°E). There also were surprising numbers of Spectacled Petrels *Procellaria conspicillata* southeast of Cape Agulhas, a couple of adult Salvin's Albatrosses *Thlassarche salvini* at the western Crozets, and an aggregation of Campbell's Albatrosses *T. impavida* at Scott Island.

Figure 144: A flock of Short-tailed Shearwaters wheels past the coast of Bouvetøya.

Only 56 litter items were observed, and only 22 of these were in the Southern Ocean (south of the Subtropical Front), where the crude density of floating debris was only 0.15 items per 100 km. Our observations confirm that the Southern Ocean has the lowest densities of macro-litter globally; anthropogenic debris was outnumbered by drifting kelps 50:1.

Figure 145: A Wandering Albatross inspects a plastic spade encrusted with goose barnacles.

The Giant Kelp *Macrocystis pyrifera* was the most abundant rafting kelp close to the Prince Edwards, Crozets, Kerguelen, southern South America and South Georgia (it is absent from Heard Island and other islands farther south in the Southern Ocean). However, *Macrocystis* seldom disperses far from these islands (unlike the case in the central Atlantic, where it occurs up to 1000 km from Tristan da Cunha). The Bull Kelp *Durvillaea antarctica* was much more abundant than *Macrocystis* away from the islands, with plants seen throughout the long transit from Heard Island to Hobart, where the nearest source area is more than 3000 km away. Many of the kelps seen far from land were colonized by goose barnacles *Lepas* spp.

Figure 146: A Bull Kelp Durvillaea antarctica *drifting at sea and colonised by goose barnacles.*

On Leg 2, *Durvillaea* was seen south to 62.4°S on the Leg south to Mertz Glacier, and from 65.1°S off the Antarctic Peninsula, well south of the Antarctic Polar Front. Both *Durvillaea* and *Macrocystis* were abundant around the southern tip of South America, and around South Georgia, but they were not observed far from these islands. Sea ice prevents these kelps from growing on the South Sandwich Islands or Bouvetøya, but a few Bull Kelp plants were observed in the Atlantic Ocean sector from 54-48°S and 1-10°E, some 1900 km southeast of Gough Island, the closest source island for the species.

References

Tasker, ML, Jones, PH, Dixon, T and BF Blake (1984). Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. Auk 101: 567–577.

Personnel on board

Peter Ryan (FitzPatrick Institute of Africa Ornithology, University of Cape Town, pryan31@gmail.com), Fabrice Le Bouard (Centre d'Etude Biologiques de Chize, CNRS, fabrice.lebouard@googlemail.com), Jasmine Lee (Centre for Biodiversity Conservation Science, University of Queensland, jasmine.lee1@uqconnect.edu.au)

10.21 Project 21

Ice ocean interactions in the vicinity of the Mertz Glacier

PI Guillaume Massé (Canada)

Aims and Objectives

The main objective of this Project was to shed light on the exceptional biodiversity and the ecosystem functioning of a key Antarctic region: the Adélie land shelf. In addition to describing them in greater detail (from bacteria to higher trophic levels), we planned to determine the parameters that are either maintaining or promoting the evolution of these populations. Our strategy consisted of deploying a comprehensive set of sampling devices and probes at few sites selected according to their representativeness and their role in controlling environmental conditions of the area. In addition to these full stations, we planned to carry out a series of CTD profiling stations along a network of stations that had already been visited during the course of previous Projects in order to obtain a synoptic vision of the water masses present in the area, how they circulate and drive the large-scale trends. To do this we would:

- characterise sub-glacial processes (ice melt, formation and export of the Ice Shelf Water) and the circulation of the different water masses in the vicinity of the Mertz glacier
- characterise benthic and planktonic ecosystems and interactions between species at key stations in the vicinity of the Mertz glacier
- shipborne CTD-O_2 casts, water isotopes (^{18}O and deuterium) measurements, current profiler, along different transects (glacier front, Mertz Polynya-Adélie Depression, Mertz and Adélie Sill) located on the path of the water masses interacting with the glacier. A total of 29 stations were originally planned
- Agassiz and Beam trawls for the collection of benthic invertebrates and fishes. A total of 8 + 5 stations was originally planned.
- Box and Gravity coring for the collection of surface (up to 5 m) sediments in order to characterise sediment properties and the associated epi and endo faunal assemblages. A total of six box core stations were originally planned. Two additional deployments of a gravity corer were also planned in order to collect longer sedimentary archives for climatic reconstruction purposes.
- Water column sampling for the characterisation of zooplanktonic assemblages: a total of four stations were planned with deployment of oblique (Tucker) and mid-water (IKMT) trawls.
- Exploration of the underneath of the glacier during a remotely-operated vehicle (ROV) cruise: CTD profiling, water and ice sampling, imaging of the sub-glacial interface, current profiler and observation of both under-ice and benthic assemblages. Two stations were planned.
- Exploration of two contrasting stations at the shelf break: CTD profiling, water sampling, imaging of the water - sediment interface, current profiler and observation of benthic assemblages using ROV cruises. Two stations were planned.

To achieve all of this would have required excellent operating conditions in the polynya, low ice cover and 24-hour working by the ship dedicated only to this project.

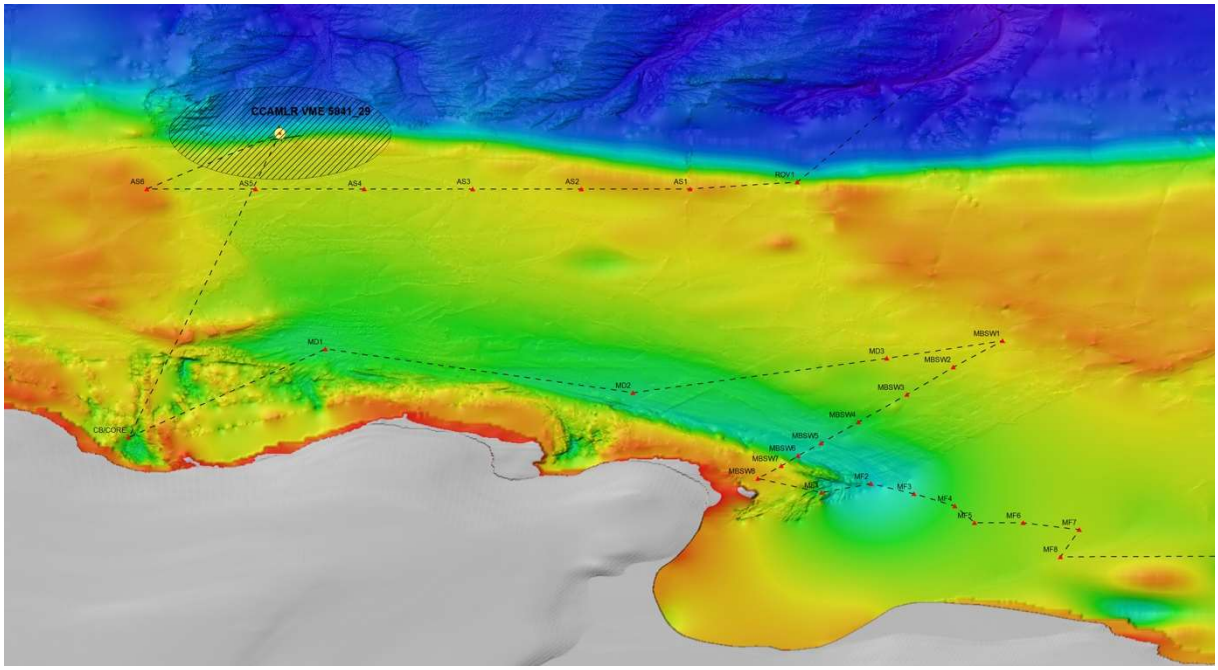

Figure 147: Initial sampling plan.

Leg 2 operations

Unfortunately, mainly due to heavy ice conditions and lack of time, only a 1/4 (24%) of the operation initially planned has been realised.

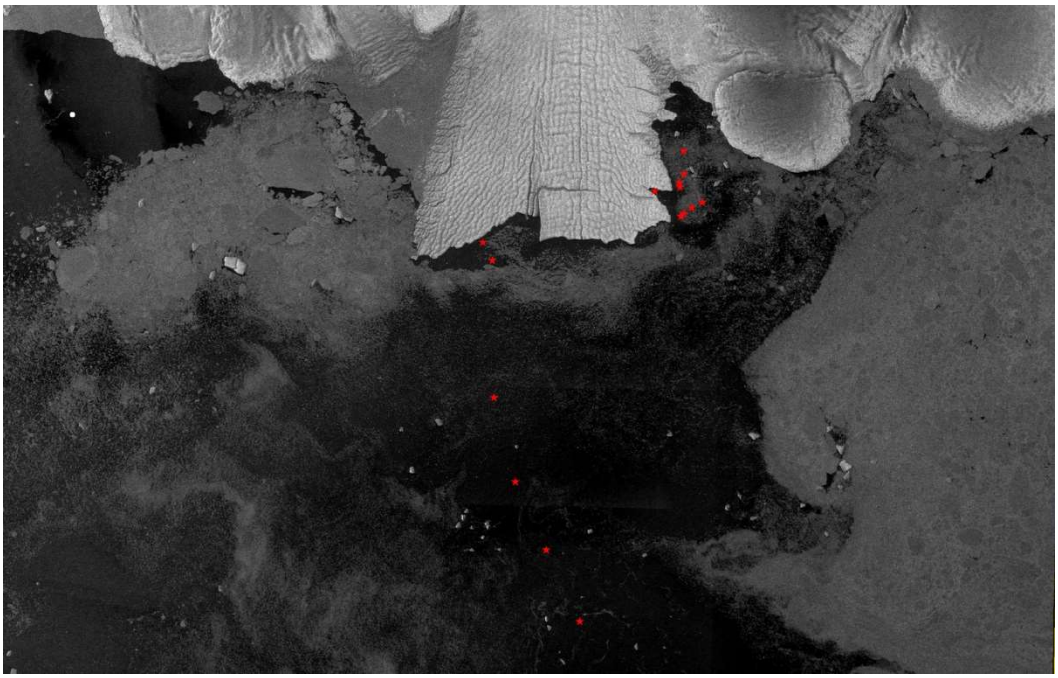

Figure 148: Locations of the stations visited during ACE cruise near to the Mertz Glacier

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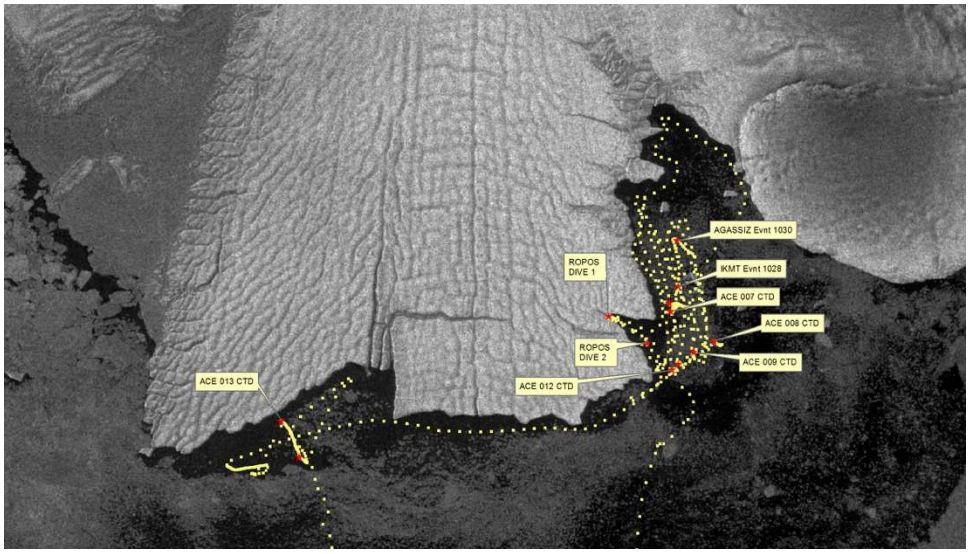

Figure 149: Overview of ACE stations in the vicinity of the Mertz glacier.

CTD related operations

We managed to carry out 10 CTD-02/LADCP (Lowered Acoustic Doppler Current Profiler) casts out of the 29 profiles which had been planned:

- one cast (CTD007) off the western edge of the glacier to characterise the vertical distribution of the different water masses close to the glacier and water samples collected were also beneficial for other Projects.
- transect of four casts (CTD009-CTD012) across the coastal slope off Buchanan Bay to identify whether a coastal current exists which transports the deep water masses out of the glacier cavity and/or the polynya.
- one cast (CTD013) at the front of the glacier and water samples collected were also beneficial for other Projects.
- one transect of four casts (CTD015-CTD018) across the trough separating the Mertz Depression from the Adélie Depression to characterise the exchanges between the two depressions.
- one cast on the Mertz Bank slope off the shelf break (CTD019) to monitor the off-shelf conditions.

On each cast, water samples were collected at different depths to measure the water isotope composition (^{18}O and Deuterium) and to calibrate the CTD sensor (dissolved oxygen and conductivity).

The rosette was also equipped with an L-ADCP (RDI Workhorse) mounted as a downlooker. To circumvent the problem of spurious current headings measured by the instrument compass due to the proximity of the magnetic pole, the profiler was coupled to an optical fibre gyrocompass which measured the orientation of the instrument. The two sets of measurements will be combined and processed back to the laboratory to provide current profiles with the correct current heading.

Water samples were also collected on the CTD casts carried out in the deep basins along the circumpolar ship track in order to compare our isotope measurements (which will be made back in the laboratory with a Picarro spectrometer) against those carried out on the same samples by other ACE teams using a different instrumental device (mass spectrometer).

ROPOS operations

It was intended to perform a ROPOS dive (ROPOS 1) underneath the Mertz Glacier to retrieve profiles of currents and water mass properties under the glacier, as well as information on the glacier base

topography, ice properties interfacial currents and benthic habitat. The dive was unfortunately aborted due to technical problems and we could only perform a short incursion into a glacier cavity without being able to sample the water column, nor to perform a complete vertical profile down to the ocean floor. The video collected during this short dive is currently under analysis.

Figure 150: - Initial ROPOS launch by Mertz Glacier.

Figure 151: ROPOS control room.

The following day, a second dive was intended at the same site in order, this time to reach the bottom of the glacier and the seafloor underneath. Unfortunately, relatively large pieces of ice calved from the glacier in the close vicinity of the ship forcing us to abandon this site.

A new site located few miles west (ROPOS 2) was found and the second dive performed. This site was too far from the edge of the glacier and it was decided to directly reach the seafloor (1100 m) and perform surveys and selected sampling. The video collected during this short dive is currently under analysis. Selected specimens we also sampled and will be analyzed once back in the laboratory. Many samples were also shared with Project 10.

It was also intended to perform additional ROPOS dives (ROPOS 1) at sites located (1) on the Eastern flank of the glacier, (2-3) at the shelf break. However, the presence of pack ice in the vicinity of the ship prevented deployments and it was decided to resume operations at Mertz and start transiting toward Balleny islands.

Siple dives. A ROV dive was performed at the shelf break and a second close to the Getz ice shelf. The dive at the shelf allows us to identify a seafloor which is dominated by basalt rock with a low species richness. The second ROV dive was very interesting. First we managed to get under the ice shelf for approximately 20 m to collect water. During the dive a surprising and unexpected behaviour was observed. The well-studied brittle star in Antarctica *Ophionotus victoriae* showed a predatory behaviour which cannot be observed without being underwater with a camera at more than 750 m. This species is known to be an opportunistic

generalist with high diet plasticity. However, nothing has ever been described or observed about a predatory behaviour. Close analysis of the video will allow us to describe in great detail this behaviour.

AGASSIZ operations

Only one trawl (Event 1030) out of the eight originally planned to have been realised in the Mertz area. A large number of benthic invertebrates have been collected and preserved for further analysis but it will be impossible to achieve the objective of biodiversity comparison as only one trawl could not allow any spatial comparison. Interestingly, the station was under the Mertz Glacier before the calving in 2010 and we observed a high number of species which were mostly filter feeders with some sponges older than 10 years (to be confirmed by laboratory analysis).

IKMT sampling

An Isaac-Kidds mid-water trawl (IKMT) was deployed once (Event 1028) and allowed us to collect krill and fishes such as *Pleuragramma antarctica*. Each fish or fish larvae will be identified, was preserved for further detailed morphological, molecular and systematic analysis in the laboratory. We will also use the otoliths to determine age and growth rates of each fish. The analyses of the otoliths from this predominant "forage" fish of the Antarctic will allow for determining if changes in the growth rates occurred before and after the Mertz calving. For krill samples, representative aliquots were sorted in order to determine the "age" of the population, identify growth stages (e.g. nauplius, metanauplius, calyptopis and furcilia) for each species commonly observed in the area (*Euphausia superba, E. crystallorophias, E. frigida*) and obtain samples for biomarker analyses.

Table 36: List of CTD-02 LADCP casts of the Mertz Project 21.Cast number is from CTD cast list during leg 2.

Cast number	Latitude (dec degs N)	Longitude (dec degs E)	Date (UTC)	Time (UTC)	LADCP file name
ACE007	-67.10280	144.93213	2017-01-28	22:25:53	ACE02000
ACE009	-67.06092	144.89736	2017-01-30	07:45:39	ACE03000
ACE010	-67.06398	144.95036	2017-01-30	08:51:12	ACE04000
ACE011	-67.06436	144.98282	2017-01-30	10:20:04	ACE05000
ACE012	-67.06395	145.00058	2017-01-30	12:06:59	ACE06000
ACE013	-67.20484	145.71826	2017-01-30	21:13:29	ACE07000
ACE015	-66.99344	146.01542	2017-01-31	04:45:07	ACE08000
ACE016	-66.86752	146.15180	2017-01-31	06:40:49	ACE09000
ACE017	-66.75192	146.20082	2017-01-31	08:23:17	ACE10000
ACE018	-66.62922	146.24446	2017-01-31	10:11:14	ACE11000
ACE019	-65.89632	146.32414	2017-01-31	20:08:32	ACE12000

Table 37: ROV Dives, trawl and IKMT position with an ACE reference to either an event or station as noted.

ACE reference	Latitude (dec degs N)	Longitude (dec degs E)	Date (UTC)	Time (UTC)	Sampling device
ACE-1030 (event)	-67.146	144.8422	2017-01-29	03:20	Agassiz Trawl
ACE-1028 (event)	-67.1158	144.894	2017-01-29	02:16	IKMT
ACE028 (station)	-67.1288	145.0484	2017-01-29	08:30	ROPOS
ACE030 (station)	-67.0926	145.0129	2017-01-30	18:00	ROPOS
ACE059 (station)	-73.0074	127.8546	2017-02-11	12:47	ROPOS
ACE062 (station)	-74.0053	127.4262	2017-02-12	02:00	ROPOS

10.22 Project 22

Evolution of the ecosystems of Sub-Antarctic Islands during Holocene and its modern conditions

PI Dimitri Bolshiyanov (Russia)

Aims and Objectives

The Project has three principal aims:

1) to reveal climate changes and sea level fluctuations during last centuries, millennia and Holocene, by studying the geomorphological construction of the islands, and sampling of the Quaternary deposits and lake sediments.

2) to develop a more precise definition of the spatio-temporal models of the atmospheric aerosol by measuring aerosol concentration, aerosol optical depth, and chemical composition of aerosols.

3) to develop a clearer understanding of the formation mechanisms of air masses in Southern Ocean for a more precise interpretation of paleoclimate from the Vostok ice cores by measuring atmospheric water vapour isotopic composition and the isotopic composition of sea, lake and river water on islands.

LEG 1

1.Paleoenvironment

Methods

Sampling of quaternary sediments in geological holes and exposes by spade. Lake sediments sampling by a UWITEC corer. All samples must be stored until the end of the Expedition and analysed in laboratories for: spore and pollen, diatoms, chemistry, determination and dating (^{14}C, Optically Stimulated Luminescence (OSL), and Electron Spin Resonance Spectrometry (ESR) methods).

Achievements:

Marion Island

26 December 2016 the group of three investigators has been delivered by helicopter to the point near the Lake Prinsloomer, which is situated 6.5 km to the north-west from the South African Station (46°50'27.8" S 37°47'04.7"E). Pilot geomorphological investigations, determination of lake level height above sea level have been done. Strong wind and rain complicated coring operations, but one core of lake sediments was taken. Sediments with a length of 60 cm consists of: 0-3 cm – organic silt with sand, gravel and small pebbles; 3-4 cm – sand with organic silt; 4-7 cm – organic silt with sand; 7-9 cm – clay with organic silt; 9-10 cm - organic silt with sand; 10-58 cm – organic silt ("gyttia"); on depth 13-20 cm is gyttia with silt, sand and gravel; 20-23 cm – gyttia with clay; 39-40 cm – gyttia with sand. 18 samples of water from the lake and the nearest ponds have been taken for isotopic composition analysis.

Four hours of work was not enough to do all the planned investigations.

Figure 152: After successful attempt of lake sediment coring in Prinsloomer Lake on Marion Island.

Possession Island

01 January 1st 2017: group of two investigators delivered by boat to the beach in the mouth of Camp River – 800 m to the north from French Alfred Faure Station on Ile de la Possession. Geomorphological investigations (measuring of marine terraces heights) focussed on a 30-metre terrace situated on the right slope of the river valley, when a 1.4 m hole was dug (46^{o}23’29” S 51^{o}48’28”E). In the hole 1. 3 m of soil bed on sand, silt and pebbles. Three samples from the soil and one sample from sand have been taken.

10-12 m abrasion terrace formed on the left side of the Camp River valley in its mouth. The terrace is overlapped by soil. Sand and gravel with silt layers have been recovered in the basis of soil. Three samples taken including one sample of sand to age determination by OSL dating method.

Only three hours of investigations was a very short time.

Figure 153: Sampling in a hole on 30 m marine terrace, covered by soil, on Ile de la Possession.

Kerguelen Island

05 January 2017. Courbet Peninsula, Cape Charlotte (49°17’51.0” S 70°31’24.4”E) of the eastern part of Kerguelen Island. It was the first place when the group landed in concordance with a plan. Two investigators and the guide worked on the marine plain for five hours. One core of lake sediments has been taken from small pond situated 9 metres above sea level. 41 samples (every 2 cm) from the core of 82 cm length, taken. Sediments consist of organic silt-gyttia with long roots of grass.

Near the ponds in the place with coordinates 49°17’59” S 70°31’23” E a hole was dug on the bottom of a drained lake, situated on 9 m higher than sea level. Sediments 1.45 m thick consists of: 0 – 1.25m – peat, penetrated by roots of grass; 1.25 – 1.45 m – gray clay with beach pebble layers. Eight samples taken for dating, spore and pollen analysis of the peat and diatom analysis of clay.

Figure 154: Search of marine sediments under a peat on Kerguelen Island.

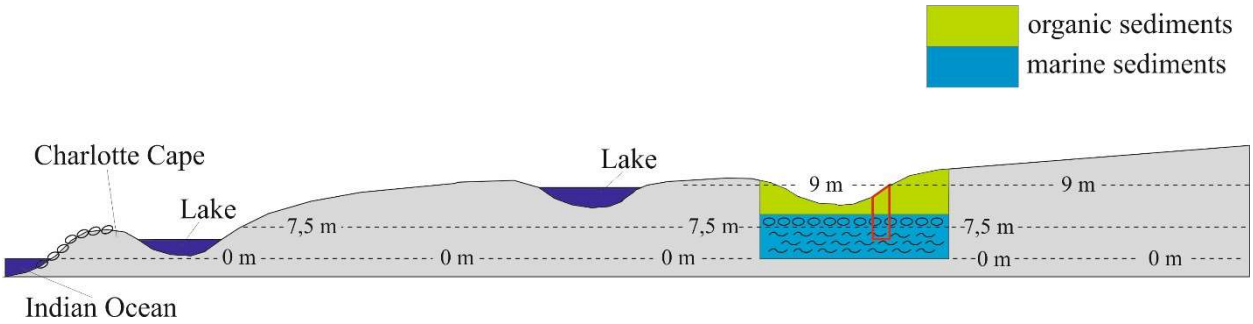

Figure 155: Scheme of recovered marine sediments bedding on the marine plain of Courbet Peninsula (Kerguelen Island).

2. Atmospheric aerosol

During Leg 1 we made the measurements of integral (atmospheric column) aerosol optical depth (AOD) and total moisture content (W), the mass (MA) and number (NA) concentration of aerosol in the boundary layer, the mass concentration of "black carbon" (MBC). The samples of atmospheric aerosol were collected for chemical analysis.

The purposes of study are:

- Receiving of experimental data to estimate radiation and climatic influence of aerosol in oceans;
- Obtaining of regional aerosol sources' influence and of zonal aerosol transport;
- Used instruments and methods.

Instrumental complex includes:

- Portable sun photometer SPM (V.E.Zuev Institute of atmospheric optics SB RAS);
- Aethalometer MDA (V.E.Zuev Institute of atmospheric optics SB RAS);
- Photoelectrical particle counter AZ-10;
- Aspirator of aerosol particles for paper filters with air pump.

The measurements of a direct sun radiation for AOD and W were taken with SPM in the whole atmospheric column in appropriate weather conditions 20-30 times per each sun day.

The MDA and AZ-10 measurements of mass and number concentrations of aerosol and "black carbon" were performed continuously with 1-hour period and 20 minutes' exposure.

The aerosol samples for ion chemical composition analysis were collected in daylight hours in dry weather conditions with an aspirator. Total air volume pumped through each filters cascade is 10 m^3 minimum (almost 10 hours with average pumping speed 18 litres per minute).

Table 38: Number of measurements that were done by aerosol complex during Leg 1 (as of 16 January 2017).

Instrument	SPM	AZ-10	MDA	Aspirator
Measurement count	639 ordinary measurements	27 diurnal cycles	27 diurnal cycles	15 filter cascades (4 filters each)

After the expedition, all data will be analysed in combination with onboard meteorological data.

3. Isotopes composition of atmospheric water vapour

We used Picarro L2120-i laser analyser of stable water isotopes combined with the home-made calibration device to measure stable water isotopic composition in the atmospheric water vapour. The instrument, calibration device and air inlet were installed and calibrated during Leg 0. So, just after leaving Cape Town we continued the measurements. We obtained information about water vapour isotopic composition with time resolution of 1.5 seconds, approximately 1.5 million data points in total. The instrument was calibrated every second day with the water standards with a known isotopic composition in order to remove instrumental error from the raw data.

We collected samples of water from the lakes and rivers on the islands for the isotopic analysis, which will be performed in the laboratory later. We got 20 samples from three islands.

Acknowledgments

We thank Fabrice Le Bouard for his great help on Kerguelen Island.

Leg 2

1.Paleoenvironment

Methods

Sampling of quaternary sediments in geological holes and exposes was performed with spade. Lake sediments sampling were obtained with UWITEC corer. All samples are stored until the end of the Expedition and will be analysed in laboratories for spore and pollen, diatoms, chemical composition, and dating (^{14}C, OSL, ESR methods).

Achievements:

Cape Denison

30 January 30 2017 two people from the Project were delivered by helicopter to Cape Denison (67° 00'31" S 142°39'48" E, Figure 156). The first few minutes of being there and observations from the helicopter before landing showed that this place was very interesting for paleoenvironment investigations. A small piece of land uncovered by ice, has an area of 1.5 x 0.8 km. This is a micro oasis really. There are small ice-free lakes, marine terraces between rocky hills of the peninsula, composed by grey mica granites and gneisses with veins of quartzite. We could see three old shorelines as minimum: 3-metre terrace (Figure 157), drift sediments on a height of 10 m and 25-30-metre terrace above modern sea level. The last one is represented by beach, appearing from under the retreating and melting passive Ice Cap (Figure 158). Drift sediments consist of algae and mosses remnants and bird feathers caught by unevenness of the ground during the time when a sea level was 10 m higher than modern. Fortunately, we had some minutes to take sample of these sediments. Testing of drift sediments composition and ^{14}C dating will enable to know the age of marine transgression.

There was no time for terrace investigations and for lake sediment coring, because it was decided to finish work due to a rapid increase of the wind speed. We only had 30 minutes for working at the Cape. It is time to refer again that small piece of land of Cape Denison is very interesting to search interaction between sea, ice cap and land for oasis formation.

Figure 156: Cape Denison, helicopter view from northwest.

Figure 157: 3-5 metre marine terrace behind the helicopter.

Figure 158: Beach of the 25-30 metre terrace, on Cape Denison.

Scott Island

A short helicopter landing on Scott Island took place on 06 February 2017. The massif of the Island, 500 m length and 54 m high, consists of black basalts as well as separate remnants. Haggits Pillar, 62 m high (Figure 159). The southern part of the island, was 20 metres high covered by passive glacier of the same thickness. The island has one small beach only and the other parts of shoreline are composed of vertical cliffs. There are no Quaternary sediments on the island. Thin layers of basalt weathering products (black gravel and sand) can be found in basalt caverns only. This is an evidence of a very young age for Scott Island (presumably first centuries of millennium).

Figure 159: Scott Island and Haggits Pillar.

Figure 160: Basalt surface of Scott Island.

Maher and Lauff Islands

Maher and Lauff Islands were visited on 10 February 2017 by helicopter. These islands lie near one of the biggest Antarctic volcanos on Siple Island. They are a part of the volcano. Maher Island (73°11’54.3” S 127°02’36.5” W, near 70 m high) composed by conglomerates (sand with basalt pebbles and boulders) inclined towards each other (to the South and to the North, Figure 159 and Figure 160). There is a thin cover of Quaternary sediments there. Sand, gravel and silt were sampled for diatom and OSL analysis. The other – Lauff Island is situated 9.5 km to the East of Maher Island, has no Quaternary sediments and is composed of horizontally laminated conglomerates.

Figure 161: Conglomerate layers inclined to the south in the foreground and to the north in the background.

Figure 162: : Conglomerates of Maher Island.

Peter I Island

Peter I Island was visited on 15 February 2017 by landing from a boat onto rock cliff. There was no beach at all on the northern side of the island. We landed at the cliff (68° 48’51” S 90°43’55.9” E) composed of horizontally layered black basalts and brown-red tuff (Figure 163). Quaternary sediments represented by detritus and sands in talus accumulations on narrow shelves of cliffs.

Figure 163: Horizontal layering black basalts and brown-red tuff of Peter I Island.

Isla Gonzalo (Diego Ramírez Archipelago)

Two researchers were put ashore by boats on 20 February 2017. A small beach (56°31'15.0" S 68°42'54.3" E) 2 metres high consists of well-rounded pebbles of quartz, shale and carbonates. The island and archipelago are remnants of old previous more vast land, composed of layers of argillaceous slates (with quartz veins), carbonates and siltstones rumpled in steep folds (Figure 164). They are low ridges (up to 150 m) with steep slopes abraded by waves. The shoreline is mostly a steep cliff. The island is surrounded by many rocks with dense algae brushwood. Thick hummocky grass is usually on slopes up to 30°. There are no sediments with the exception of slope sediments and soils. There are no clean old shorelines or terraces on slopes of the islands. A hole was dug on a 15-metre narrow shelf above the beach, revealing 1.2 metres of soil. Samples (DR-1) of soil with organic rich silt were taken from the horizon at 1.1 m near the contact with carbonate rocks. This very short visit showed that this island is not rich in sediments.

Figure 164: Layering of argillaceous slates (with quartz veins), carbonates and siltstones on Isla Gonzalo.

Figure 165: Sampling of soil in a hole under carbonate rock on Gonzalo Island.

2. Atmospheric aerosol

During Leg 2 we continued the measurements of integral (atmospheric column) aerosol optical depth (AOD) and total moisture content (W), the mass (MA) and number (NA) concentration of aerosol in the boundary layer, the mass concentration of “black carbon” (MBC).

The purposes of the study are:

- Receiving experimental data to estimate radiation and climatic influence of aerosol in oceans;
- Obtaining regional aerosol sources' influence and of zonal aerosol transport

Instrumentation:

- Portable sun photometer SPM (V.E.Zuev Institute of atmospheric optics SB RAS);

- Aethalometer MDA (V.E.Zuev Institute of atmospheric optics SB RAS);

The MDA and AZ-10 measurements of mass and number concentrations of aerosol and "black carbon" were performed continuously with 1-hour period and 20 minutes exposition.

Table 39: Number of measurements that were done by aerosol complex during Leg 2 (as of 21 February 2017).

Instrument	**SPM**	**AZ-10**	**MDA**	**Aspirator**
Measurement count	393 ordinary measurements	31 diurnal cycles	31 diurnal cycles	20 filter cascades (4 filters each)

After the expedition, all data will be analysed in combination with onboard meteorological data.

Figure 166: Measurements of a direct sun radiation for AOD and W with a Portable sun photometer.

3. Isotopes composition of atmospheric water vapour

We continued measurements of the stable water isotopes in the atmospheric water vapour. We used Picarro L2120-i laser analyser of stable water isotopes combined with the home-made calibration device to measure stable water isotopic composition in the atmospheric water vapour. Additionally we got a Picarro L2130-i analyser from the Picarro Inc. coupled with the commercial standard delivery module (Figure 167). One of the tasks for the expedition is the comparison of the two instruments and calibration devices. During Leg 2 we obtained information about water vapour isotopic composition with time resolution of 1.5 seconds, approximately 1.5 million data points in total. The instruments were calibrated every second day

with water standards of a known isotopic composition in order to remove instrumental error from the raw data.

We collected samples of water from the lakes and rivers on the islands for the isotopic analysis, which will be performed in the laboratory later. We got five samples of fresh water from the islands.

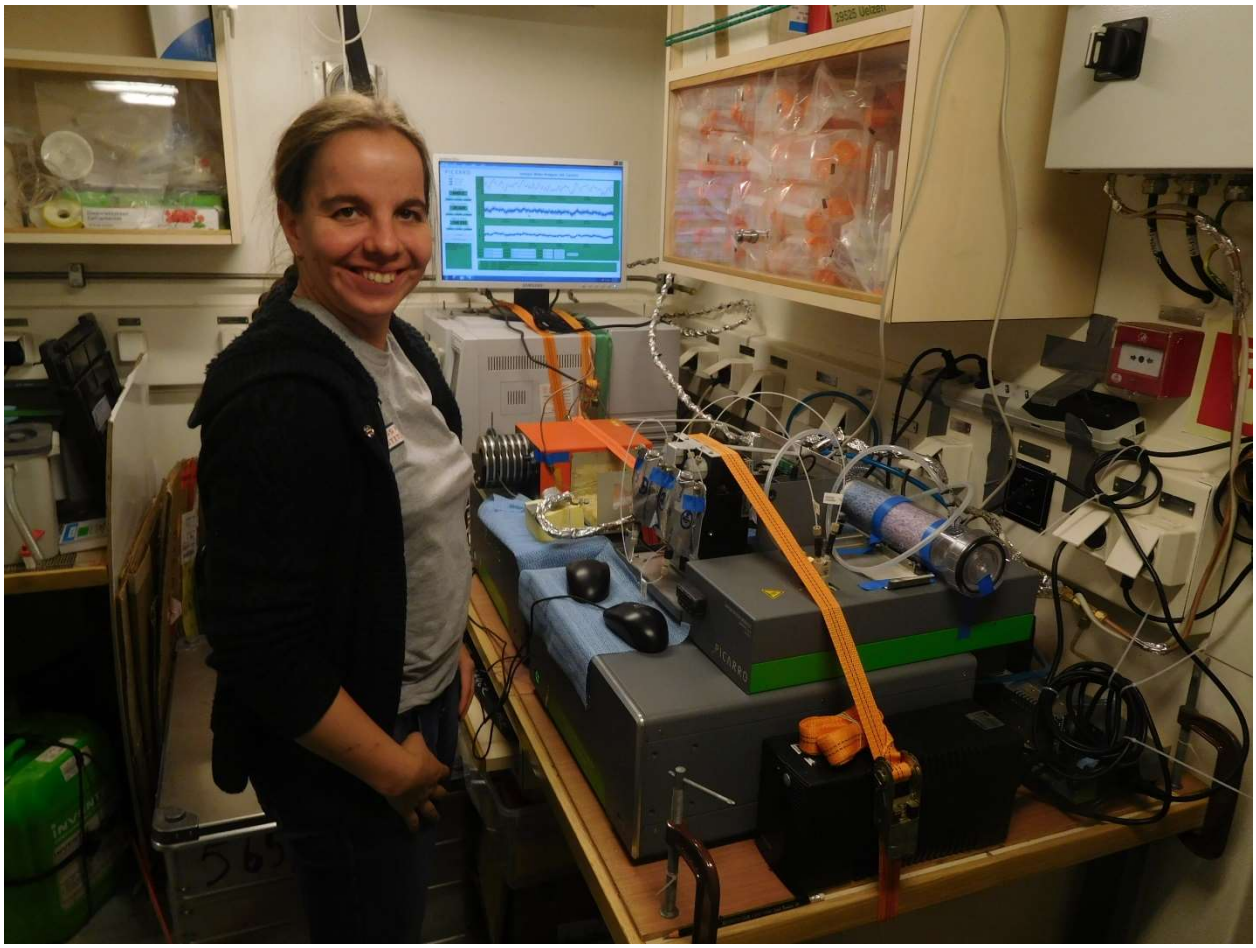

Figure 167: Picarro L2120-i laser analyser of stable water isotopes in the background, and Picarro L2130-i in the foreground.

Leg 3.

1.Paleoenvironment

Methods

Sampling of quaternary sediments in geological holes and exposes by spade. Lake sediments sampling by UWITEC corer. All samples must be stored until the end of the Expedition and analysed in laboratories for: spore and pollen, diatoms, chemistry, determination and dating (^{14}C, OSL, ESR methods).

Achievements:

South Georgia Island

Point 1. Hestesletten, Cumberland East Bay, 02 March 2017

Landing from the *Akademik Tryoshnikov* by Zodiac.

There are three lakes in the Hestesletten Valley: Upper Hamberg Lake, Middle Hamberg Lake and Lower Hamberg Lake. They lie on the flat bottom of the Valley and some time ago this part of the Valley was

under the Hamberg Glacier (Figure 168). After recession of glaciers, the Valley was occupied by sea and today the bottom of this valley is a marine terrace with 4-5 metres above modern sea level (Figure 169). The purpose of investigations were: to measure and sampling of marine terraces which are situated on altitudes from 4 to 75 metres and take a core from lake sediments to understand the time of the last marine transgression to Hestesletten Valley. Having a restricted time for investigations we worked as two pairs of investigators. One had the task of measuring and sampling terraces, the other - to take lake sediments. With a rubber boat we went upstream by Penguin River to Lower Hamberg Lake and took a sediment core using a UWITEC corer at 54°18’27” S 36°30’42” W (Figure 170). The sediments of the 2-4 m depth lake consists of 40-45 cm of grey silyy clay, underlay gravel and pebbles. The corer could penetrate through sediments to 52 cm only. Perhaps these sands, gravel and pebbles are marine sediments. Diatom analysis should help us to solve this question. Going downstream by Penguin River we sampled the 4-metre marine terrace, which was cut by the River (Figure 171). The second group measured the height of the highest marine terrace by hand. It is 75-80 metres above modern sea level. Sediments of this terrace were sampled in the hole 1.2 metres deep. Also the second pair of investigators measured terraces in Moraine Ridge situated on the eastern flank of Hestesletten Valley.

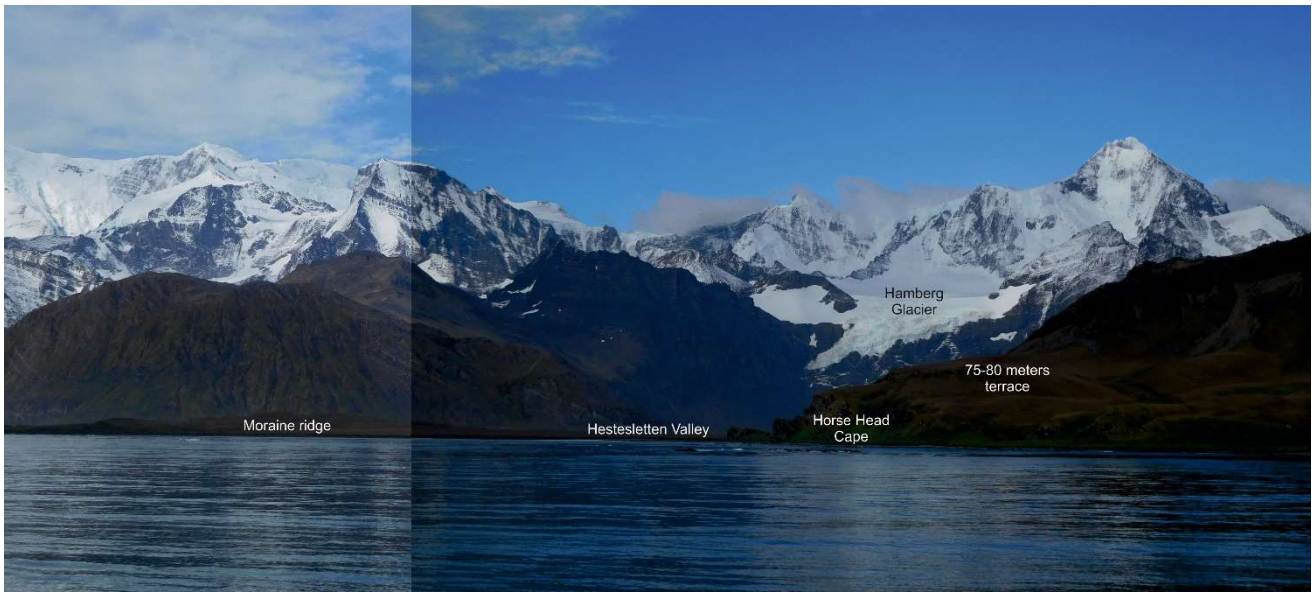

Figure 168: Landing place of paleogeography group (Project 22) in Cumberland East Bay of South Georgia.

Figure 169: Flat bottom of the Hestesletten Valley occupied by Hamberg Glacier and by sea previously.

Figure 170: Sediments sampling from Lower Hamberg Lake.

Figure 171: Marine terrace cut by Penguin River on the bottom of Hestesletten Valley.

Point 2. St.Andrew's Bay, 04 March 2017

Landing from the *Akademik Tryoshnikov* by Zodiac to the beach

The wide valley occupied by three glaciers: Heaney Glacier, Buxton Glacier and Cook Glacier with moraine ridges and hills. The glaciers are in retreat and lie 1-2 kilometres away from a beach. Geomorphological construction of this place is a long beach, marine terraces with an altitude of 2-3 metres, 8-10 metres and moraine hills behind terraces. The unnamed river from Heaney Glacier cuts through the terraces and provides a good exposure terrace sediments (Figure 172). We cleaned the face of the 8-10 terrace exposed (54°26'13" S, 36°11'34" W) with a spade, described and sampled sediments consists of layers of sand, gravel and pebbles. This is old beach sediment covered by peat and soil (**Error! Reference source not found.**). The "peat" layer has an interesting bedding (Figure 174). It lies under a poor soil and perhaps has to do with underlying marine sediments. These organic sediments have to be studied by botanical and diatom analysis.

Another interesting place was studied among the moraine hills at an altitude of 36-38 metres above modern sea level (54°26'31" S, 36°11'40" W). As usual moraine hills consisted of no sorted and no rounded boulders. But on this level there are layered sand-gravel-pebble sediments which underlie silt and clay with gravel. Pebbles are well rounded, layers are clean layered (Figure 176). This is beach sediments embedded inside the moraine landscape. Some samples have been taken from sediments to establish an age and origin of sediments.

Figure 172: Cleaning of terrace sediments in the valley of river from Heaney Glacier.

Figure 173: Beach sediments exposed in 8-10-metre marine terrace.

Figure 174: Peat layering on beach sediments in the upper part of expose.

Figure 175: Moraine hills of Heaney and Buxton glaciers.

Figure 176: Stratified beach sediments on moraine hills of Heaney and Buxton glaciers.

First 2-3-metre marine terrace has been sampled in the mouth of the Heaney Glacier river (Figure 177).

Figure 177: First marine terrace cut by river from Heaney Glacier.

South Sandwich Islands and Bouvetøya

There was no opportunity to land on these islands. Helicopter landings were excluded and the weather conditions were not suitable for boat landings. However there are some suitable objects for geomorphological and paleogeography investigation, such as a terrace around 20 m high on Thule Island (South Sandwich Islands) for instance. Really this is the top of a submerged volcano crater, but weathered by wave activity (Figure 178).

Figure 178: Terrace (top of submerged crater) between Thule and Cook islands (South Sandwich Islands).

Magellan Strait

During the stay in the port of Punta Arenas a very good set of marine terraces to the South of the port were located. A car trip was organised by a group of Project 22 on 25 February 2017 to work on those terraces. At a location situated 15 km to the south of Punta Arenas (53’16’12” S, 70°57’31” W) in the mouth of a river, terraces were measured and sampled. The highest terrace lies at 25-30 metres above modern sea level (Figure 179). Itis composed of very dense sandy silt with pebbles and with shells detritus.

At place situated near 30 km to the south of Punta Arenas had a lower 4-5 metre terrace, described and sampled at two points: 53’41’49” S 70°58’10” W and 53’39’15” S 70°57’35” W (Figure 180).

Figure 179: 25-30-metre terrace in the mouth of the river situated around 15 km to the south of Punta Arenas.

Figure 180: Lowest 3-5-metre terrace of Magellan Strait is situated 30 km to the south of PuntaArenas.

2. Atmospheric aerosol

During Leg 3 we continued the measurements of integral (atmospheric column) aerosol optical depth (AOD) and total moisture content (W), the mass (MA) and number (NA) concentration of aerosol in the boundary layer, the mass concentration of “black carbon” (MBC). The samples of atmospheric aerosol were collected for chemical analysis.

Table 40: Number of measurements that were done by aerosol complex during Leg3 (state for 13 March 2017).

Instrument	SPM	AZ-10	MDA	Aspirator
Measurement count	223 ordinary measurements	16 diurnal cycles	16 diurnal cycles	6 filter cascades (4 filters each)

After the expedition, all data will be analysed in combination with onboard meteorological data.

3. Isotopes composition of atmospheric water vapour

We continued measurements of the stable water isotopes in the atmospheric water vaporising the Picarro L2120-i laser analyser system.

We collected samples of water from the lakes and rivers on South Georgia for the isotopic analysis, which will be performed in the laboratory later.

11 Leg 0 reports

Manon Frutschi was appointed Lead Student Convenor and Dr Roland Proud was appointed Acting Chief Scientist for this Leg.

11.1 The Maritime University

There was limited advertising for the places on this Leg as there was little time available to receive the application forms and make the selections. However, the number of available places was significantly oversubscribed and selection of the participating candidates was left to the organisers in the countries of

origin. The applicants were principally Masters and Doctoral students and although they were recruited through a small number of countries their nationalities ranged much more widely.

The course was designed and overseen by Professor Isabelle Ansorge at the University of Cape Town (UCT) and was run on board by Manon Frutschi (Ecole Polytecnique de Lausanne; EPFL), Tahlia Henry (UCT) and Marcel du Plessis (South African Department of Environmental Affairs).

All of the students had obtained the necessary entry visas for Germany and South Africa in advance. However, the decision to pick up the helicopters in the UK was a later decision and the agent in the UK failed to inform the expedition that, under new regulations, although none of the students intended to go ashore, UK law now required that even transit passengers would require visas unless they had EU passports. There was therefore a problem with Borderforce on arrival in Southampton. After considerable efforts much later the Home Office agreed that this was all unwarranted and issue explanatory letters to 17 of the students with non-EU passports.

A fuller report on the Maritime University is appended in section 15.1.

Figure 181: The maritime university.

11.2 Loading in Bremerhaven

The ship's berth in Bremerhaven was close to the warehouse of the ACE port agent. With equipment for so many projects loaded over several days it proved impossible to maintain a complete list of all cargo coming on board. Several PIs decided to load equipment directly from their own vehicles without any paperwork making its re-importation at the end of the expedition a Customs problem.

At Southampton the port agent there had not correctly listed all the items for export and the lack of a Customs stamp on the paperwork made re-importation without paying duty at the end of the expedition a major problem.

At later ports material was removed from the ship without paperwork by Project scientists or notice to the Chief Scientist and new material was brought on board which was not listed. In Cape Town some boxes went missing from the quayside during a re-stowage operation suggesting that tighter security may well be needed.

To avoid this on future expeditions it is suggested that no cargo is loaded without the paperwork being checked as complete and a note is kept of all stowage locations.

Figure 182: Loading in Bremerhavn.

11.3 Science Projects

(based on a report compiled by Roland Proud)

11.3.1 General Summary

The ship restricted deployment of the CTD in weather conditions that were set to approxiately 4 metres for the maximum wave height (regardless of the mean wave height) and wind speeds of around 13-15 m/s. One reason for this caution was linked to a lack of a dynamic positioning system, the ship being difficult to keep stable whilst holding station.

The underway seawater supply was contaminated with rust so that only the mass spectrometer was able to be used during Leg 0. The internet did not work adequately on the Iridium system making even emailing a problem.

Communications between crew and the scientists were initially difficult as many of the crew members spoke little English. Ship operations, including cutting power to specific areas of the ship (i.e. CTD laboratory) and stopping the ship to carry out winch maintenance, were not communicated in advance and there were no bridge announcements in advance of bad weather conditions. During CTD and net operations, there was some surprise over the limited safety precautions required by the ship (eg. wearing of hard-hats, appropriate footwear, safety lines etc.).

11.3.2 CTD operations

Tahlia Henry

Brief description: SBE 911 CTD (Seabird), 24 bottle rosette with 10-litre niskin bottles (a 5- litre niskin bottle was used as a substitute for position 24 on the rosette). CTD sensors: temperature – TC duct (conductivity), dissolved oxygen, fluorescence, backscatter, PAR sensor and submersible pump. UPV bracket, however no instrument was attached. A sound velocity probe was added to the inner bracket of the rosette, operating independently of the system.

Maintenance on the CTD: New leashes were attached to the niskin bottles by the Russian crew. The crimps may need replacing in Cape Town or at a later stage during the voyage as they had oxidised.

During the first test cast (GPS position: 36° 20.02 N 014° 03.72 W Time: 08:45am UTC Date: 26 November 2016) communication to the CTD was lost at 1000 m. CTD was brought on board, upon observation it was visible that sea water had leaked into the cable connection. The communication wires were soldered and a new potting mould (Scotchcast 82-A1) attached to the join. Communications were tested before the potting was attached with 0110 on deck unit and a link established between sensors (deck test performed).

TC duct: Morrison seal was missing from the sensor. A septum was used as a replacement and wedged into the seal housing. The seal was replaced in Cape Town.

Altimeter bracket dislodged from the rosette frame, however it was partially attached to the frame when the CTD returned to the surface. Bracket was refitted and seated flush against the CTD frame.

General comments: Once all the repairs were done and sensors flushed, the CTD casts (CTD 01 – CTD 022) were performed with zero technical glitches experienced from the CTD rosette. The data obtained was successfully post-processed and served as a "teaching" dataset for the students on board.

However, there were a number of key issues that needed to be addressed and resolved in order to ensure successful future CTD operations.

The biggest issue experienced was the lack of communication between the operations room (CTD operator) and the bridge. One of the earlier CTD stations commenced (CTD placed on the surface) without any scientist or operator present. This was because the ship stopped prior to the station location and deployment time, without telling the scientists and the crew commenced with the cast. The CTD was brought back on board and the cast restarted.

The interface screens for the ship metadata in the CTD laboratory were off for most of the CTD operations, therefore ship station number or any further metadata could not be recorded.

The CTD was hosed down after every cast with the fresh water supply but rust was left on the instruments and frame.

The cancellation of CTDs were haphazard and communicated at the last minute to the scientists.

The CTD frame did not have any weights attached to it, thus allowing it to "fly" in the current and to bounce in the water column, resulting in uneven tension on the winch cable. New lead cylindrical weights were added to the CTD in Cape Town.

11.3.3 Other Equipment

Liquid Nitrogen plant

Operating in helicopter hangar. The heat in the helicopter hanger, a possible leak in the hose leading out of the collection dewar and flow rate of the hose undermined the output. The alarm system was not attached but stored in a box next to the liquid nitrogen plant.

Salinometer

The salinometer (Autosal) found on board was flushed and the temperature bath was refilled with distilled water. Its room was eventually temperature controlled but we were unable to successfully calibrate it despite it being listed as an operational instrument.

11.3.4 Project 5

Circum-Antarctic distribution of acoustic deep scattering layers, and associated foraging behaviour of deep-diving predators

Leg 0 participant: Roland Proud PI: Andrew Brierley

During Leg 0 various Wave Based Techniques (WBT) settings were tested to determine the optimum setup for the main expedition. The operational settings for the data collection at 12 kHz consisted of a carrier wave (CW) pulse of 100 W with a pulse duration of 16.384 µs at an interval of 8500 µs. The frequency modulated (FM) capabilities of the Simrad transceiver were also tested by collecting data one hour a day in the frequency band between 12.5 and 14.5 kHz, with a power of 100 W, a pulse length of 8.192 µs at intervals of 8500 µs. We recorded data from 27 November to the 10 December 2016, operating with a 12 kHz CW pulse, transmit power set to either 100 or 150 W and pulse duration set to either 8.192 ms or 16.384 ms. We then switched to operating with a 13.3 kHz pulse for two days (10 - 11 December 2016) and finally ended the Leg (11 - 14 December 2016) recording with a FM pulse, operating between 12.5 and 14.5 kHz, transmit power of 100 W and pulse length of 8.192 ms.

The 12 kHz echosounder was working but the 200 kHz was not. There was electrical interference coming from an unknown source, which made resolving biological signals difficult. We were also trying to synchronise the ship's multibeam (20 kHz) with the echosounders to reduce the interference between the two. We could also use the ship's Acoustic Doppler Current Profiler (ADCP; 75 kHz), by requesting this to be turned on. There was an SES sub-bottom profiler available (main frequency 35 kHz, secondary 2,3,4,5,6 and 7 kHz).

11.3.5 Project 6

BIOAIR - Aerobiology over Antarctica

Leg 0 participant: Marie Sabacka PI: David Pearce

Model kinematic back trajectories

Airborne transport of microbes may play a central role in microbial dispersal, the maintenance of diversity in aquatic systems and in meteorological processes such as cloud formation. Yet, there is almost no information about the abundance and fate of microbes over the oceans, which cover >70% of the Earth's surface and are the likely source and final destination of a large fraction of airborne microbes. Hence, our knowledge on airborne microbes over the oceans is very limited compared to that on microbes inhabiting aquatic and terrestrial environments.

The airborne prokaryotic abundance ranged from ~3000 to ~20,000 prokaryotes m^{-3} (average ~8000 cells m^{-3}) while the abundance of airborne eukaryotes ranged from ~200 to ~13,000 eukaryotes m^{-3} (average ~2000 cells m^{-3}).

Estimations of airborne microbial abundance over the open ocean are needed to resolve the biology of the atmosphere. Determining the concentration and loads of atmospheric microbes is an important step, and the estimates provided here suggest that microbes are diluted in the atmosphere more than 9 or 11 orders of magnitude relative to their concentration in seawater or soils. This could lead to the conclusion that airborne bacteria are unimportant and can be neglected. Yet, the abundance of airborne microbes may be a misleading indicator of the importance of this compartment, as the atmosphere may play a major role in

the dispersal of microbes, in the connectivity and the maintenance of diversity in the surface ocean or in regulating climatic processes through the role of airborne bacteria as nuclei of accretion for cloud and ice formation. Hence, while diluted relative to the marine or soil compartment, the estimated microbial load over the height of the boundary layer averaging ~4×10^6 prokaryotes m^{-2} and ~8×10^5 eukaryotes m^{-2} represents a formidable seed bank hovering over the North Atlantic Ocean.

We found atmospheric microbial abundances in the boundary layer over the North Atlantic Ocean ranging from 10^3 to 10^4 prokaryotes m^{-3} and from 10^2 to 10^4 eukaryotes m^{-3}, but supporting daily air-sea exchanges in the order of millions of prokaryotes and thousands of unicellular eukaryotes per square metre of oceanic surface. This limited dataset provides a first snapshot of the microbial abundances and fluxes over the North Atlantic Ocean during our cruise. Calculations based on current parameterisations are crude and should be considered as order-of-magnitude estimates. Nevertheless, our data point to a rapid exchange of microbes between the atmosphere and the surface ocean, which is not apparent from abundance data only. This rapid flux could be of major importance for the dispersal of marine microbes and for the maintenance of local diversity over the global ocean.

11.3.6 Project 7

ACE-SPACE: Study of Pre-industrial-like Aerosol Climate Effects

Leg 0 participant: Mareike Löffler PI: Julia Schmale

Collected 24 hour PM_{10} filters in the Atlantic atmospheric boundary layer between Bremerhaven and Cape Town for the analysis of ice nucleating particles and chemical components such as major ions and methanesulfonic acid. An ozone monitor recorded data on the upper deck with 1 minute time resolution. Due to the fact that power could not be provided to the Swiss atmospheric laboratory container, all other measurements did not start until Leg 1.

Meetings with the electricians on board were held to organise the power supply for the container in Cape Town but these proved difficult, not least because of language problems.

11.3.7 Project 8

Surveying Organic Reactive gases and Particles Across the Surface Southern Ocean (SORPASSO)

Leg 0 participants: Pablo Rodríguez-Ros (Barcelona), Holly Pearson (Plymouth), Nuria Benavent (Madrid) and Steph Gardner (Sydney). PI: Rafel Simó

This was a complex project with multiple measurements. The primary ones were to measure trace gases in surface seawater and their emission to the atmosphere, sample particulate organic matter in surface seawater, sample the surface water for phytoplankton and bacteria, and looking at the bio-optics of the surface water.

Operational problems for this Project:

Laboratories

- There was no warning before the crew switched off the power on the 06 December 2016 – it was off for about 10 minutes on two occasions.
- There was a lot of ship's equipment in the laboratory from previous cruises that was not used in ACE but, despite repeated requests for its relocation, this was ignored.
- One of the sinks in the wet (CTD) laboratory, next to the door, was blocked from 19 November – 1 December 2016 (not draining properly) – again repeatedly asked for it to be looked at, but no response.

- Fume hood did not work properly and so it could not be used for HCl and preservatives safely, so we had to go outdoors to pipette toxics.
- Air conditioning was not fixed in our laboratory until 3 December 2016 – very hot in the laboratory (we recorded 25°C), especially during the afternoon CTD cast when all instruments were running.
- The conditions of the sinks and the small fridge were very bad when we came on board, showing that the level of maintenance had been very poor.
- Power supply for the container labs (MAX-DOAS instrument was located here) did not work at all for Leg 0 and the communication with the crew electrician was poor.
- Rusty pipes and pump in the sea water flow-through line was not fixed until Cape Town.
- Drainage of CTD laboratory was poor with water pooling on the floor.
- CTD did not seem to have been tested prior to departure as the communication cable was repaired with tape, and failed on first deployment, and oxygen sensor did not work.

Internet

Internet was insufficient even for 14 scientists who had priority over the students. Most could not access university/institution emails even when plugged in with the cable.

11.3.8 Project 11

Investigation of air-sea interaction in the Southern Ocean from stable water isotope measurements

Leg 0 participants: Pascal Graf and Iris Thurnherr PI: Heini Wernli

We conducted the following operations on board *Akademik Tryoshnikov* during Leg 0:

- Measurement of stable water isotope in water vapour with two Laser Spectrometers in Karlsons room (on top of the bridge).
- Collection of precipitation with a rain totalisator installed on the deck on top of the bridge, starboard side (we needed access once a day), and with manual precipitation samplers, which were installed on deck 5 and deck 2 (we needed access every five minutes during precipitation events).
- Measurement of precipitation properties with a micro rain radar on deck 6, opposite to the stack (bridge level)
- Collection of CTD surface water samples (20 ml/CTD). Originally, we intended to collect samples once a day from the underway line.

Launching of radiosondes from the helicopter deck. The balloon for the launchings was inflated in the helicopter hangar.

Problems encountered during Leg 0:

For our work on board, we needed frequent weather forecasts from our team at ETH. The internet connection could not provide the emails and weather pictures required each day.

The launching of the radiosondes was not on the list of activities approved by AARI for Leg 0, although we communicated this to David Walton before the cruise. Thus we were not able to launch any sondes during almost the whole first week after Southampton. Furthermore, the communication with the bridge was difficult and the procedure to launch radiosondes changed several times during the cruise. This made it difficult for us (i) to conduct our launches and (ii) to follow the rules as we were not informed about all the changes. The last procedure we agreed upon for radiosonde launchings, fitted our need very well. Before launching a radiosonde we needed to inform the bridge by phone that we want to launch a sonde. After the ok from the bridge we needed to inform the chief meteorologist, or the meteorologist on duty, to organise the mechanic who opened the hangar door for us.

We lost the signal of the first radiosonde because the ship stopped and turned in such a direction that the sonde disappeared behind the main mast. The antenna must have visual contact to the sonde in order to receive its signal.

Due to the problems with the underway line, we needed to take ocean water samples from the CTD casts.

During precipitation events we sampled rain or snow in high temporal resolution ie. every 5-10 minutes. We could not find a satisfying solution with the bridge to do this, especially during stormy conditions and during the night. The bridge only allowed us to check our sampling device and change vials if we first went to the bridge to ask for permission and reported back to the bridge once we were done. We needed to go to the bridge in person and could not agree on an easier procedure (e.g. giving a phone call). We need to find a more convenient solution for the remaining Legs, especially if only one person from our team is on board.

Positive feedback:

Roland did his very best to help with all our problems and always tried to find a solution. Iurii, the laboratory technician in the multibeam lab, was very helpful throughout Leg 0. The collaboration with him was very good. Also other crew members, Artem (IT), Oleg (Radio), Andrej (Electrician) and Victor (meteorologist) as well as their assistants were helpful.

11.3.9 Project 13

Antarctic Circumpolar Study of the relation of Carbon Export Production to Plankton Community Characteristics

Participants on Leg 0: Yajuan Lin, Florian Trigodet PI: Nicolas Cassar

The goal of our Project was to conduct a high-resolution survey and investigate the relationship between the carbon export from the surface ocean and the plankton community characteristics along the cruise track of the ACE expedition. Leg 0 was particularly interesting because this transect from Southampton to Cape Town crossed a broad range of oceanic regions including at least seven different bio-provinces. Unfortunately, the data quality was compromised due to the rust contamination in the underway sea water line.

Sampling, issues and suggestions

1. Mass spectrometer for underway high-resolution carbon export

To measure the carbon export at high resolution underway we have developed a second-generation (nXT) Equilibrator Inlet Mass Spectrometer (EIMS). This is the first cruise for this instrument, and the hardware has been functioning well during Leg 0. The specially designed waterproof frame, and thermal control of the mass spectrometer and gas lines have worked well since the installation in Southampton. The data we have collected has higher accuracy than the previous version of EIMS because of less water vapor interference and greater stability in temperature and pressure. The newly developed all-in-one software is also functioning well despite a minor communication issue. However, unfortunately, the data is biased by the oxygen depletion in the pipeline probably caused by the reaction with metal.

The nXT EIMS used water continuously flowing from the FerryBox water line and the system was contaminated by rust particles. We conducted comparison of the flow-through water from the FerryBox line to the surface water collected by CTD casts twice a day with the oxygen measurements using an optode. There was oxygen depletion in the flow through line ranging from 1.6 to 2.2%, which is quite significant in biological O_2 measurements considering that in most of the oligotrophic ocean the biological O_2 saturation is close to zero. For example, in the first half of the cruise the preliminary biological O_2 supersaturation was around -2% which indicates a net heterotrophic system. However, with a maximum

correction of 2.2% this becomes a net autotrophic system. We are not sure how to proceed with the data analysis.

The second issue was the reduced flow rate. At the beginning of the cruise the flow rate of the FerryBox was at 15 L/min which was sufficient for our system and the other two groups sharing the CTD laboratory. However, over time the flow rate was significantly reduced. Even when all other groups closed their water systems because of the rust contamination, there was a significant decrease of flow rate on 9 December 2016 to around 2.8 L/min. The crew told us that there is only one speed of the water pump and was unable to determine the cause of the flow reduction. The problem for our oxygen system was that the reduced flow rate increased the residence time of seawater in the flow through system and this significantly increased the reaction with the metal and probably also biological respiration. This caused severe oxygen depletion - the difference of the oxygen between the CTD surface water and the flow through line increased to 4.7%. This was a huge problem for our measurements.

The third issue is lack of communication. We had a power outage and stop in the water flow in the CTD laboratory without any advance notice. Without proper shutdown of the mass spectrometer the power outage can cause significant damage to the filaments inside the analyzer, which is the most important part of the mass spectrometer. For the wet part we have a gear pump with high precision to control water sampling for the mass spectrometer. The pump head is designed for liquid and running it under dry conditions causes damage to the pump head. We did not get any notification before the water pump shutdown and the pump head was running dry for a while. All these problems could have been avoided by notification before any operation on the water line or the electricity system so we can properly turn off the running instrument.

2. DNA sampling from flow-through and CTD

DNA samples for 16S and 18S sequencing (metabarcoding) were collected from discrete seawater samples to investigate high-resolution eukaryotic and prokaryotic community profiles at regular intervals along the cruise transect.

During the first half of Leg 0, DNA sampling was conducted twice a day from the flow-through seawater and once from the CTD cast. The filters were significantly coloured by the dust particles. The iron particles should not impact DNA but there may have been biological contamination from the biofilm inside the rusty water line. We are not sure about the contamination at this stage and we expect to know more after later test sequencing of some samples. During the second half of Leg 0, we sampled twice a day from the clean CTD water. The CTD sampling depths include surface, 15 m, Deep Chlorophyll Maximum (DCM), 250 m, and 1000 m. We collected sized fractionated samples on 3 µM filter membranes and 0.2 µM Sterivex filter cartridges. The filtration volume is about 5.7 L per sample.

3. Imaging FlowCytobot (IFCB)

The IFCB is an underway imaging-in-flow cytometry system designed to characterise large nano- and microplankton during the transect. The continuous biological sampling will provide high resolution biological information matching the sampling resolution of our mass spectrometer. Unfortunately due to the rust contamination issue we turned off the continuous mode of the instrument during the early part of the cruise.

The power outage caused a loss of communication with the IFCB internal computer for two days. The communication recovered but this was not good for the instrument. We hope to get notification in advance for any power change. We plan to get an Uninterrupted Power Supply (UPS) in Cape Town to protect the system.

The instrument needs more adjustment in camera and laser alignment. The work requires taking the instrument out of its protective housing and it needs to be done in a steady environment. The adjustments were performed in Cape Town before the next leg.

4. Continuous nitrate measurements

We deployed an ISUS continuous nitrate sensor (SeaBird Electronics) at the beginning of the cruise. Because it is an optical instrument the measurement has been severely impacted by the rust in water. Before we discovered the rust contamination, we found the ISUS sensor always had a strong negative drift and we had to recalibrate it once every several hours. The data also became very noisy over time – the usual error range is between 1-2 µM and we had around 10 µM in the FerryBox flow through water. After cleaning the sensor optical window with milliQ water and ethanol, the reading returned back to normal. We stopped the sensor during the early part of the cruise to avoid further contamination.

5. Underway environmental measurements

The underway environmental parameters from the FerryBox, including salinity (conductivity) and Chl, are important for our calculation and data interpretation. However, the sensors were covered by rust particles and the readings were quite different compared with the CTD sensors.

There was another set of sensors (temperature and salinity) close to the inlet of the water line. Considering that the water line was significantly warmed through the engine room, these measurements were probably closer to the in situ condition. However, it seemed the sensors were not working properly with the temperature reading 5.7°C in tropical Atlantic Ocean and salinity at 51.

6. Internet

The Internet access was slower than other research ships and needed to be improved.

11.3.10Project 19

The Impact of Microplastic Pollution on the Southern Ocean Food Web

Leg 0 participant: Giuseppe Suaria PI: Peter Ryan

The object of the Project was to determine the extent of plastic pollution throughout the route taken by the ship through the Atlantic Ocean, sampling especially for microplastics but also recording macroplastics seen from the ship.

Net sampling

20 Neuston samples collected. Two samples were collected per day after each CTD station.

11 Bongo samples collected. One was collected every 24 hours after the afternoon CTD.

Sample processing and storage were performed after every deployment.

Visual Survey

Visual survey for floating macro debris were carried out during regular navigation of the ship between sampling stations. Observations were all performed from the bow, below the helideck. 80 transects were performed for a total of approximately 40 hours of observations.

An experiment was performed with one of the students on board to compare distance sampling methods with fixed-width strip transect method. 24 transects were run in parallel to estimate differences between the two methods.

Problems encountered during the cruise.

Access to the bow was denied until special permission was given by the bridge.

Decks were closed during rough weather in the Bay of Biscay so no observations could be made and sampling only began after one week of sailing. Most of the North Atlantic has not been sampled.

Originally container 3 was allocated to the Project, but there was no desk available and the scientist had to move to container 2.

Water was not provided in container 2 so work took place in container 1.

No air conditioning in the containers resulted in excessive air temperatured in the container (> 40 °C) in the equatorial zone.

All lights on deck superstructure 2 needed to be turned off after sunset.

The Bongo net often went under the hull during deployment.

Some neuston deployments were too close to the ship, with the net smashing onto the hull with big waves. The net still operates under the influence of the bow wave and the turbulence created by the bow-thrust can occasionally create some problems. Ideally the net should be deployed farther away from the ship.

During one neuston deployment the cod-end was lost. This could have been due either to a poor connection to the net or to strong wind conditions.

Fresh water in the container and from the hose used to rinse nets on deck was rusty.

Due to the lack of a proper way of covering the net on deck, large numbers of paint chips fell onto the nets. Contamination needed to be avoided. A tarpaulin cover with elastic rope was used after Cape Town. The ideal solution would be to store the nets in a closed metal container when not in use but this is unlikely to be possible.

11.3.11Project 22

Evolution of the ecosystems of Sub-Antarctic Islands during Holocene and its modern conditions

Leg 0 participants: Anna Kozachek and Iurii Turchinovich PI: Dmitry Bolshiyanov

Stable water isotope measurements

We installed the calibration device for the laser analyser of the isotopic composition (the analyser itself and the air inlet on the portside had been installed in Arkhangelsk, Russia) and after the first calibration on the way from Bremerhaven to Southampton we started the measurements of the atmospheric water vapour isotopic composition. For this purpose we used the Picarro L2120-i laser analyser of stable water isotopes combined with the home-made calibration device. During Leg 0 we obtained information about water vapour isotopic composition with a time resolution of 1.5 seconds: approximately 1.5 million data points in total. As the measurements are not possible at the time of calibration, we calibrated the instrument at the time of CTD operations to achieve the best possible space coverage. Also, starting from Cape Town we will get the second analyser which air inlet is planned to be on the starboard of the ship. We prepared the line for this inlet and the inlet itself.

Aerosol study

We made the measurements of integral (atmospheric column) aerosol optical depth (AOD) and total moisture content (W), the mass (MA) and number (NA) concentration of aerosols in the boundary layer, the mass concentration of “black carbon” (MBC). The samples of atmospheric aerosol were collected for chemical analysis. The measurements started on 23 November 2016.

The purposes of study are:

Receiving experimental data to estimate radiation and climatic influence of aerosols in oceans;

Obtaining of regional aerosol sources' influence and of zonal aerosol transport.

Instruments used for aerosol measurements included:

Portable sun photometer SPM (V.E.Zuev Institute of atmospheric optics SB RAS);

Aethalometer MDA (V.E.Zuev Institute of atmospheric optics SB RAS);

Photoelectrical particle counter AZ-10;

Aspirator of aerosol particles for paper filters with air pump.

The instruments were installed in the container on the second deck.

The measurements of a direct sun radiation for AOD and W were taken with SPM in the whole atmospheric column in appropriate weather conditions 20-30 times per each sun day.

The MDA and AZ-10 measurements of mass and number concentrations of aerosol and "black carbon" were performed continuously with 1-hour period and 20 minutes exposition.

The aerosol samples for ion chemical composition analysis were collected in a daylight hours in dry weather conditions with aspirator. Total air volume pumped through each filters cascade is 10 m^3 minimum (almost 9.5 hours with average pumping speed 18 litres per minute).

Table 41: Number of measurements during Leg 0 by the aerosol complex.

Instrument	SPM	AZ-10	MDA	Aspirator
Measurements count	>1000 ordinary measurements	23 diurnal cycles	23 diurnal cycles	20 filter cascades (4 filters each)

After the expedition, all data will be analysed in combination with on-board meteorological data.

Problems

We did not meet any specific problem connected with our work. The main problem was the very limited internet access.

12 Leg 4 reports

(based on a report prepared by Professor Inigo Everson)

Professor Inigo Everson was appointed Acting Chief Scientist for this Leg.

The vessel left Cape Town's Waterfront public jetty in mid afternoon 22 March 2017 and moved to a commercial jetty to complete emigration procedures, sailing at around 10.00 local time. Heading on 300 degrees at 14 knots. The following morning the team had a brief familiarisation meeting during which Inigo Everson outlined his philosophy for managing research cruises, noting he preferred the title of Scientist in Charge (SiC). Seven Projects had personnel on board during this leg in total, nine were active during the cruise:

Project 5 Inigo Everson

Project 7 Andrea Baccarini and Katrianne Lehtipalo

Project 8 Maria Castellvi Coma

Project 11 Yongbiao Weng

Project 12 Samples collected by Giuseppe Suaria and Andrea Pierucci

Project 13 Hugo Berhelot and Clarisse Lemonnier

Project 17 (automated data collection)

Project 19 Giuseppe Suaria and Andrea Pierucci

Project 22 Ana Kozachek and Iurri Turchinovich

Data Management: Jenny Thomas and Carles Pina Estany

Notes on each of these Projects are given in section 12.1 of this report.

Discussion centred around the daily sampling routines and possibilities for support and collaboration. In general discussion it was agreed that a careful eye should be kept on all freezer and coolstow spaces. These are -80°C freezers, one in the forward hold and the other in the hangar; -20 °C freezer in the benthic laboratory and refrigerators in CTD laboratory, as well as the cold room where the drinking water and some samples are stored. It was agreed that in the event of suspected failure the SiC should be notified as soon as possible and if action was thought necessary, the bridge. The deep freeze in the glaciology container was not needed and could be switched off.

Prior to departure from Cape Town the SiC was told that there had been a request for the ship's homeward bound route to be adjusted to pass near to St Helena and Ascension to allow the collection of data from the vicinity of oceanic islands that might benefit Projects 5, 7 and 19. The SiC was told that the request had been refused because permission to sample from these localities should have been sought six months in advance and no such permits had been requested, and any detour would add a time penalty to the trip. The SiC noted that the difference in distance between the actual and passing close to the islands was minimal and also that so far as he was aware no permit would be necessary providing the vessel remained outside of Territorial Waters, 12 miles. The vessel did not take a route via St Helena or Ascension Islands.

The team agreed to hold further meetings at 12:30 each day to discuss progress and raise any issues of concern.

The Chief Officer gave a Safety Briefing in the afternoon of 23 March 2017. With the relatively small change in the number of personnel under Russian regulations for safety at sea it was not necessary in addition to undertake a formal lifeboat drill. The team noted that size of the ship and the complicated nature of the companion ways meant that it was not easy to quickly find ones way around the ship. The muster station was at the helicopter hangar, access to which was limited within the accommodation spaces but simpler from outside. The scientific team agreed to check on the use of lifejackets and the routes to lifeboat stations themselves with help from those who had been onboard for earlier Legs of the cruise.

The journey northwest out of Cape Town was uneventful with fair weather all the way to the Equator. The vessel 'crossed the line' at 05:30 local time on Friday 30 March 2017.

During the afternoon of 30 March 2017 a problem had developed with one of the generators in the engine room. The vessel slowed to around 2 knots for about half an hour while the nature of the problem was investigated and then increased speed to around 10 knots for the remainder of the day. That speed was maintained for the following day whilst the generator problem was repaired. Subsequently there were no further problems.

The ship's air conditioning system is extremely effective and maintained an equable temperature through the tropics. The temperature within the Swiss red container laboratory forward of the bridge gave considerable cause for concern. The portable air conditioning unit in the container was not adequate to maintain a temperature sufficiently low to allow the instruments to function correctly. After consultation with the Ship's Chief Officer, Science, Mikhail Romanov a portable unit was sourced and proved effective through the warmest part of the trip.

During 4 April 2017 meeting the question of when sampling should cease was raised. Clarification was sought from David Walton, ACE Chief Scientist, who responded with an instruction to cease sampling on entering European waters. The Captain gave clear instructions that underway water sampling using the pumped clean seawater supply should cease when we enter Territorial Waters. The pump was turned off at 05:00 on 9 April 2017 as the vessel entered the Channel in calm weather and remained off during the day as it proceeded towards the Dover Strait.

Plans for arrival in Bremerhaven began to be put in place soon after departure from Cape Town. It was felt that the cargo lists held on the ship would be inadequate for the purpose of ensuring speedy discharge in Bremerhaven and satisfactory customs clearance. During the remainder of the cruise attempts were made to assemble a full cargo list so that from the shipside perspective it was clear the nature and extent of all cargo to be discharged. The team were particularly concerned to ensure that a comprehensive list of cool, cold (-20°C) and extreme cold (-80°C) should be prepared and that appropriate arrangements for handling and storage should be available ashore.

12.1 Science reports

12.1.1 Project 5

Uncovering the mystery of the ocean's "False Bottom".

Leg 4 participants Inigo Everson PI: Andrew Brierley

Objectives:

Whilst the main ACE Project will be providing new information on the Deep Scattering Layer (DSL) in the Southern Ocean, a previously poorly sampled area in this context, on Leg 4 we plan to monitor the changes in DSL over the latitudinal range from 30° South to around 47° North. This information will add to that already gained by similar studies in other parts of the world and highlight the importance of DSL in oceanic food webs and productivity cycles.

Sampling Methodologies:

The same acoustic equipment as had been used on Legs 0-3 was used on Leg 4. These were:

Simrad EK80 General Purpose Transceiver using the ship's installed hull mounted multifrequency transducer. This system was operated in two modes, as a single frequency tuned to 12.5 kHz, the central frequency of the transducer. This configuration was used for all of the time with the exception of one period of approximately one hour each day when the system was set to broadband mode to take account of the transducer's multifrequency capability.

Simrad EK60 General Purpose Transceiver unit operating through the ship's installed hull mounted 200 kHz transducer.

Each day each echosounder was operated in 'Passive' mode for ten minutes and data recorded of ambient noise to be subtracted from the received echolevels during post-processing. No post processing was done on Leg 4.

Calibration:

A calibration had been undertaken in Cumberland East Bay, South Georgia on Leg 3 and had been described in the report of that leg. Although satisfactory and adequate for the purposes of this study further calibrations would normally be made during a cruise of this type. It was accepted that there would be no opportunity to calibrate further either echosounder on Leg 4.

Data management and Directory structure:

Raw data files were recorded to the output data directory set up within the echosounder software. To facilitate subsequent analysis and data management filenames for some activities were renamed. This applied specifically to passive sampling and in the case of the EK80, broadband usage.

File naming system

EK60. With only one operating frequency available the file naming structure is relatively simple and is shown in Table 42.

Table 42: File naming protocol for raw data files from the EK60 echosounder system.

Mode of operation	Filename structure	Example
EK60. 200kHz in Active mode	D/yyyy/mm/dd-Thhmmss.EXT	D20170323-T124325.BOT
		D20170323-T124325.IDX
		D20170323-T124325.RAW
EK60. 200kHz in Passive mode	PASSIVE_output filename	PASSIVE_D20170402-T074641

EK80: Two systems were in operation throughout Leg 4, a single frequency for most of the day and a multiband system, operated for one hour each day. Sampling in passive mode was undertaken for all settings for ten minutes each day. The filenaming structure is set out in Table 43.

Table 43: File naming protocol for raw data files from the EK80 echosounder system.

Mode of operation	Name structure	Example
EK80. 12kHz in Active mode	D/yyyy/mm/dd-Thhmmss.raw	ACE-D20170408-T075641.raw
EK80. 12kHz in Passive mode	PASSIVE_output filename	

EK80. 12kHz in Active FM mode	ACE_FM-D/yyyy/mm/dd-Thhmmss.raw	ACE_FM-D20170408-T080925.raw
EK80. 12kHz in Passive FM mode	PASSIVE_ACE_FM-D/yyyy/mm/dd-Thhmmss.raw	PASSIVE_ACE-D20170402-T074547.raw

All raw data files were initially stored in to the main directories specified for each system. For the EK60 the data were logged onto a laptop computer belonging to Inigo Everson into the following directory structure.

C:\ProgramData\Simrad\ER60\Data\

In the case of the EK80, data were logged onto the EK60 post processor unit into the following directory structure:

Computer\E\Akademik EK80 data\

Each day, files were transferred to an archive system with the following structure. These directory structures were deliberately made echosounder specific to avoid subsequent confusion. All files, irrespective of whether they were normal operation or FM or passive were stored into the same daily directory.

The directory structures used were:

EK60 :\ProgramData\Simrad\ER60\Data\Date

The date is specified in the form: Day month (3char) year.EK60

Eg: :\ProgramData\Simrad\ER60\Data\ 27mar2017.EK60

EK80: the data are stored in daily folders set within monthly folders

Computer\E\Akademik EK80 data\Leg 4\March2017.Leg 4\DATE

or

Computer\E\Akademik EK80 data\Leg 4\April2017.Leg 4\DATE

The data storage directories were interrogated on an hourly basis and copies of all new and replacement files downloaded and stored in the ACE data management system by the Data Management team. The folders in which the data were stored were "shared" so that they were accessible over the ACE network, to allow this backup to happen automatically.

Preliminary checks to ensure all files were backed up on both the ACE data storage and the echo sounder backups, were done by the Data Management time. No post processing was undertaken on Leg 4.

Operational difficulties.

GPS System: At the start of Leg 4 navigational information came from the ship's Trimble GPS. There had been some instances of poor position fixing during earlier Legs. It was decided to rationalise the system so that both echosounders took information from the same source. Early on in Leg 4 both echosounders were linked to the ship's GLONASS system. No problems were encountered with the revised system.

Echosounder operation: The EK60 200kHz system, apart from minor interruptions, operated continuously throughout the voyage.

Interruptions to EK60:

27 March 2017. Recording was interrupted for a time due to the laptop 'hanging' during the operation of an unrelated analysis programme. On rebooting the laptop the system started again without difficulty.

31 March 2017. Recording was interrupted briefly due to laptop problem similar to that on 27 March.

3 April 2017. The display indicated that there was no transmit pulse for a period of time. This may have been because the operation setting had inadvertently been set to passive.

8 April 2017. During resetting of the GPS input it appears that the file input size limit has been relaxed resulting in extremely large files of over 500,000 Kb. Nearing the end of the cruise this error was not corrected.

The EK80 12.5 kHz and multibeam system, apart from minor interruptions, operated continuously throughout the voyage.

Interruptions to EK80:

24 March 2017. There was an increasingly noisy signal on the EK80 for which no explanation could be found. This was accompanied by some GPS errors at around the same time.

28/29 March 2017. The extended series is logged as being Multifrequency when in fact it should be single 12.5 kHz. There is clearly an error either in the echosounder setting or else the eventlog for this period.

1 April 2017. When changing settings at 08:00 the system 'froze' and could not be restarted. After a couple of hours it was concluded that the licence was no longer valid. The PI, Prof Andrew Brierley, was contacted and he arranged with Simrad for an extension of the research contract to cover the remainder of this cruise. On receipt of the licence the system was restarted and became operational again at 08:00 on 2 April. This interruption caused the loss of data for approximately 24 hours.

Eventlog: Some difficulties had been encountered in determining from the Eventlog precisely what activity was taking place at any given time. The system in operation for Leg 4 was adjusted to assign all acoustic transect sampling to one of the following categories:

EK 60 200kHz Passive

EK 60 200kHz Active

EK 80 12 kHz Active

EK 80 12 kHz Passive

EK 80 FM Active

EK 80 FM Passive

In addition new fields for start and end date and time were added. These adjustments should make it clear what activities were in progress at any one time. The new categories have been introduced retrospectively to Leg 3 and in part to Leg 2 and 1 but without fuller documentation it is not possible to be certain of the various assignments. Whilst it is hoped that the eventlog does fully reflect activities during the cruise, individual files will need to be checked in Echoview to confirm the type of activity and also the direction and speed of vessel movement. This event log will eventually be incorporated into the ACE database.

Preliminary Observations: Northbound from Cape Town good deep scattering layers (DSL) were observed more or less continuously by day at 200 to 400 metres depth up to the Equator. These layers tended to

migrate towards the surface at dusk and descend at dawn. No Echoview analyses were made of the data so it is not possible to quantify these results.

North of the Canary Islands the DSL became very much more diffuse or non-existent, a situation that continued to the end of echosounder operations at the northern end of the Bay of Biscay.

12.1.2 Project 7

Study of Pre-industrial-like Aerosol Climate Effects (ACE-SPACE)

Leg 4 participants: Andrea Baccarini and Katrianne Lehtipalo PI: Julia Schmale

ACE-SPACE will advance our understanding of a key issue in climate science: climate-relevant aerosol processes. Aerosol-cloud interactions are the least understood anthropogenic influence on climate change (IPCC, 2013.) A major cause of this limited understanding is the poorly quantified state of aerosols in the pristine preindustrial atmosphere, which defines the baseline against which anthropogenic effects are calculated. The Southern Ocean is one of the last regions on Earth with a pristine, and hence preindustrial-like, atmosphere. The uncertainty in aerosol induced radiative forcing (± 0.7 from a mean of -0.55 W/m^2) is twice the uncertainty for CO_2 (± 0.35, mean +1.68 W/m^2). Models also grossly underestimate cloud solar reflectance in this region, by as much as 30 W/m^2 in summer. It is very likely due to the poor representation of aerosol-cloud interactions.

During Leg 4 the equipment was operated as for the previous Legs 1-3 and the data collected in the same way.

Table 21 in 10.7 Project 7 provides a list of all instruments, the variables they measure, and the measurement mode (continuous or discrete sampling). All continuously measuring instruments were placed in a laboratory container.

During the time the ship was close to the equator on Leg 4 and the outside air was very hot and humid (T≥30 °C and RH≥60 %) the air conditioner inside the container could not efficiently remove the heat created by the instruments and the inside air temperature rose up to 38 °C (possibly higher close to the instruments). The air inside the container was also not mixed properly (warmer areas close to the door). We believe this was partly because the sun was heating the container surface (it was too hot to touch), and especially because the container's air conditioner exhaust could not be removed efficiently due to the limited space between containers on the deck (there are roughly 15 cm between two containers). An extra air conditioning unit was deployed to keep the temperature down.

We recorded full time series data sets for each instrument for the duration of their deployment (see Table 21). This means that for most variables a record around Antarctica and back to Northern Europe is available.

Roughly 50 % of the data were influenced by the ship's exhaust gas. This number will change depending on the region in which measurements are performed. During ACE mostly westerly winds occurred, coming from behind, locating the measurements downwind of the stack.

12.1.3 Project 8

Surveying Organic Reactive Gases and Particles Across the Surface Southern Ocean (SORPASSO)

Leg 4 participants: Maria Castellvi Coma PI: Rafel Simo

The oceans, which cover 70% of the Earth, influence climate in the long term by shaping biogeochemical cycles and in the short term by exchanging reactive gases and aerosol precursors. Current climate models

are limited by the limited existing knowledge of these ocean-atmosphere exchanges onto which anthropogenic forcing occurs. The Southern Ocean is itself an important player in the Earth climate system, and it is also an ideal region where to study ocean-atmosphere connections because distance from continent emissions and circumpolar atmospheric circulation make its air the most pristine. The team of SORPASSO aims to carry out circumpolar measurements of surface ocean gases and particles important for atmospheric chemistry and climate, and their biological, chemical, hydrological and optical drivers. Satellite data and numerical modelling will be used a posteriori to extrapolate observations into regional understanding.

1. Discrete samples from underway

Unless indicated otherwise, surface seawater samples were collected at a total 33 underway samples (every 12 hours: 06:00 and 18:00 UTC).

1.1 VOC (volatile organic compounds) concentrations in seawater

The concentrations of several VOCs (dimethylsulphide, CSO, CS_2, CH_3I, CH_2I_2, CH_2ClI, Isoprene, $CHBr_3$ and CH_2Br_2) in seawater were measured with a purge and trap (Stratum, Tekmar Teledink) gas chromatography-mass spectrometry (5975-T LTM-GC/MSL, Agilent Technologies) system.

The sample water was taken from the underway tap with glass bottles with glass caps, leaving no head space. Subsamples of 25 ml were taken and filtered through GF/F filters while introduced to the system. Duplicates were run.

Standard solutions in methanol were used for calibration.

1.2 Dimethylsulphoniopropionate (DMSP) and acrylate concentrations in seawater

Aliquots (15 ml) of seawater samples were heated to initial boiling in the microwave, 150 ul of 36% HCl was added and they were stored at room temperature. The samples will be analysed in Dr David Kieber's laboratory at the State University of New York, Syracuse. A total of 33 samples have been collected.

1.3 CDOM in seawater

Coloured dissolved organic matter (CDOM) absorption spectra of the above samples (unfiltered) were obtained with the ship's UV- spectrophotometer (UV-1800, Shimadzu). Analyses were run in duplicates, along with blanks of MilliQ water.

1.4 Iodide and Iodate concentrations in seawater

Aliquots (15 ml) of the above samples were collected in plastic tubes and stored frozen at -20°C. Analysis of iodide and iodate will be conducted at the IQFR-CSIC, Madrid.

1.5 Chlorophyll concentrations in seawater

200 ml of underway seawater were filtered through a GF/F filter. The filters were stored folded, wrapped in aluminium paper at -20 °C. Analysis of chlorophyll filters will be conducted at the ICM-CSIC, Barcelona.

1.6 Numbers of bacteria and pico-, nano- and microalgae in seawater by Flow Citometry

The aforementioned samples were also aliquoted in cryovials for enumeration of microorganisms. Three replicates of 4.5 ml were killed by addition of 1% paraformaldehyde plus 0.05% glutaraldehyde (final concentrations), and stored at -80 °C.

Whenever there was some spare time, samples from Leg 2 and Leg 3 were thawed and analysed with a PARTEC Cube 8 flow cytometer equipped with a laser emitting at 488 nm.

Pico- and nanoplankton abundance:

Before analysis, samples were unfrozen and we added 10 µl per 2000 µl sample of a 105 ml^{-1} solution of yellow-green 0.92 µm Polysciences latex beads as an internal standard. Samples were then run at high speed (approx. 75 µl min-1) for 4-10 minutes. with Milli-Q water as a sheath fluid. Four groups of phytoplankton (*Prochlorococcus* spp., *Synechococcu*s spp., picoeukaryotic and nanoeukaryotic algae) were distinguished and enumerated on the basis of the differences in their autofluorescence properties and scattering characteristics.

Bacterial abundance:

Before analyses, samples were unfrozen, stained with SYBRGreen I (Molecular Probes) at a final concentration of 10 µM and left in the dark for about 15 minutes. Samples were run at a low flow rate (approximately 15 µl min^{-1}) for 2-4 minutes with Milli-Q water as a sheath fluid. We added 10 µl per sample of a solution of yellow-green 0.92 µm Polysciences latex beads (105 beads ml^{-1}) as an internal standard. Bacteria were detected by their signature in a plot of side scatter versus green fluorescence. Bacteria were enumerated separately as high-nucleic-acid-containing (HNA) and low-nucleic-acid-containing cells (LNA), and the bacteria counts presented are the sum of these two types.

2. Continuous underway measurements: Instruments and parameters.

2.1 ECO Triplet Sensors

The ECO Triplet sensors (Figure 77) provide continuous record of the following parameters: chlorophyll fluorescence (phytoplankton), phycoerythrin fluorescence (cryptophytes), backscattering of particles at 480 nm, 535 nm and 650 nm (amount of particles and clues to size distribution), and organic matter fluorescence. Time resolution is 1 second.

3. Atmospheric samples and measurements

3.1 VOCs in the atmosphere

Air samples were collected daily (or less) for airborne VOC concentrations. 3 L of air were withdrawn by a small portable pump, and VOCs were trapped in Carbotrap adsorption cartridges, which were then sealed and stored in the fridge (4 °C). A total of 11 samples were taken. Analysis will be conducted by thermal desorption gas chromatography-mass spectrometry at IDAEA-CSIC, Barcelona.

3.2 Reactive halogens in the atmosphere

A MAXDOAS spectrograph, installed in the atmospheric container, continuously recorded halogen profiles in the troposphere. Time resolution is 5 minutes. The data analysis will be conducted at the IQFR-CSIC, Madrid. During the beginning of Leg 4 the system reported problems with several COM ports that stopped the measurements during some hours.

12.1.4 Project 11

Air-Sea Interactions in the Southern Ocean from Stable Water Isotopes Measurements

Leg 4 participant: Yongbiao Weng PI: Heini Wernli

1. Objectives

The Southern Ocean is characterised by diverse weather systems, which lead to severe weather conditions – heavy precipitation, wind storms, fog, – and impact ocean evaporation. Quantifying these processes and their interplay is essential for understanding Earth ’s climate. Stable water isotopes (SWI), which occur

naturally in the ocean, land surface waters and the atmosphere, can be used as tracers of the complex processes that govern the global and regional water cycle. Therefore, we measure SWI in atmospheric vapour during the ship voyage and observe t he variability of precipitation events with a micro rain radar. Liquid samples are collected from precipitation events and from the ocean. Together with trajectory-based analysis methods, these observations provide a unique opportunity to investigate the variability of ocean evaporation conditions as recorded in SWI signals in vapour, the variability of precipitation processes revealed by the radar and combined SWI measurements in vapour and precipitation, and oceanic source conditions of water that is later deposited on continents.

Specifically for Leg 4, the ship travelled through the Atlantic ocean from 34°S (Cape Town, South Africa) to 53°N (Bremerhaven, Germany), which provided a unique opportunity to investigate the longitudinal profile of the variability of ocean evaporation conditions as recorded in SWI signals in vapour.

2. Measurements on board

During Leg 4, the same measurements were conducted as during Legs 0-3. The measurement methods are explained in greater details in the cruise report of Legs 1-3 in section 17910.11. In this report, additional information for Leg 4 is reported.

2.1 Picarro Laser Spectrometers L2130-i and L1115-i: Isotopic composition of atmospheric water vapour

The setup of the two laser spectrometers was organized the same way as on the previous Legs. The laser spectrometers were run continuously during Leg 4 leading to a total of 113 days of measurement since leaving Cape Town. Some condensation was observed in the exhaust line of the system on 23 March 2017 (the pipe downstream of L2130) due to the relatively low temperature inside the container. The pipes with condensation are replaced with new and dry pipes with insulation. Condensation was also observed when the ship was around the equator on 31 March 2017. The line with condensation was disconnected until 02 April 2017. However, these operations should have no effect on the water vapour measurements.

2.2 Precipitation sampling: high and low resolution

There was only one precipitation sample, since almost no rain events were encountered during Leg 4.

2.2.1 Precipitation Totalisator

One totalisator sample (rainfall) was collected during Leg 4.

2.2.2 High Resolution sampling

The setup for high resolution rainfall sampling stayed the same during Leg 4 as during the previous Legs. During Leg 4, no precipitation events were sampled.

2.3 Ocean surface water

20 ml ocean water samples from the underway line were collected once a day at 18:00 ship time. A total of 17 bottles were collected during Leg 4. The ocean water samples are stored in a dry place for the analysis of stable water isotopes after the cruise with a Picarro laser spectrometer. Finalised data are expected 1.5 years after the end of the cruise.

2.4 Island sampling

No terrestrial water samples were collected during Leg 4.

2.5 Micro rain radar (MRR): Monitoring Precipitation

During Leg 4, the MRR was running continuously with a 10-second temporal resolution. We expect a continuous dataset for the whole Leg 4 with a total size of about 25 GB. The dataset will be finalized within a year after the end of the cruise. About 1 hour of precipitation was measured during the 16 days of Leg 4.

2.6 Daily and event-based radio soundings: Vertical structure of the atmosphere

Two radiosondes of the type iMet ABX were launched. Both launches were successful. The data was received in real-time and was processed directly by the software. No post-processing is intended and the finalised dataset is therefore already available.

2.7 Inclinometer: Ship movement in high resolution

The inclinometer (Serial No. 162200139) from Measurement Specialties was continuously measuring in the same location as during previous Legs. The inclination sensor lost the connection to the computer approximately every second day. This caused data gaps of a few seconds up to several hours, depending on how fast the problem was recognised. Nevertheless, the data is available for more than 95% of the time.

Table 44: Sample collection during Leg 4.

Instrument	expected samples	analysed variables
Laser spectrometer L2130-i & L1115-i	Continuous data	δ18O, δ2H, H2O-concentration.
Totalisator	1	δ18O, δ2H
Underway	17	δ18O, δ2H
MRR	Continuous data	Spectral reflectivity, Doppler velocity
Radiosondes	2	Temperature, pressure, humidity, wind speed and direction
Inclinometer	Continuous data	Ship motion, room temperature

2.8 ACE Forecast: Daily forecast from European Centre for Medium-Range Weather Forecasts (ECMWF) data

Daily weather pictures from ECMWF 6-hourly forecast were provided by the ETH-Team of Project 11 and were available on the intranet. The forecast was downloaded during the night and available on the intranet and on our web page: data.iac.ethz.ch/ace/.

3. Preliminary Results

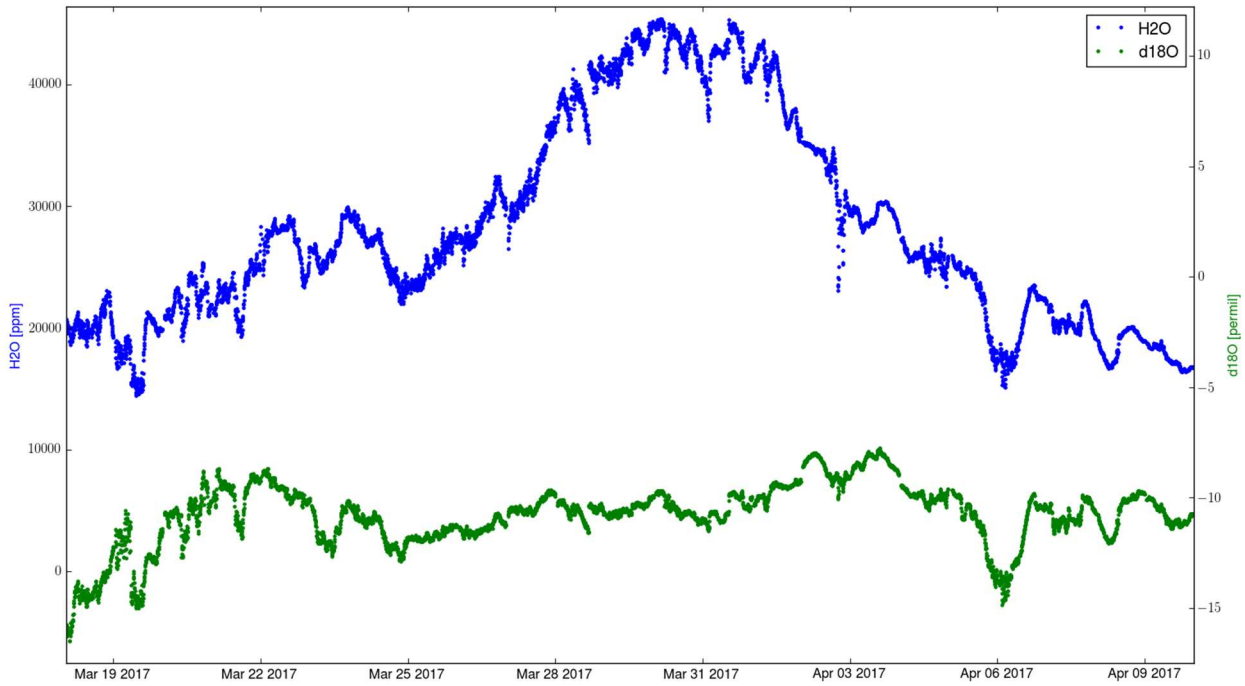

Figure 183: Pre-calibrated 5-minute average of atmospheric water vapour concentration [ppm, blue] and $\delta^{18}O$ [in ‰, green] during leg 4 (18 March 2017—09 April 2017) from laser spectrometer L2130-i.

Figure 183 shows the stable water isotope measurements during Leg 4 from 18 March 2017 — 09 April 2017 in water vapour with the laser spectrometer L2130-i.

The atmospheric water vapour concentration increases strongly around the tropics (above 40,000 ppm), and decreases gradually towards the polar. The isotope ratio roughly follows the evolution of the water concentration, especially at mid-latitudes. The isotope ratio does not vary very much around the tropics. There was a particularly strong decline in heavy isotopes with $\delta^{18}O$ values of less than -15 ‰ on 06 April 2017, which could bea signal from local ocean evaporation. From 22 – 30 March 2017, there is the possibility that the Picarro measurements have been influenced by the exhaust air from the ship (from the engine at the stern side and kitchen at the port and starboard sides) due to wind from astern (trade winds). The further interpretation of the dataset will require the weather information on board. This dataset, sampled during leg 0-4, provides a unique starting point to analyse air-sea interactions and atmospheric water vapour transport.

12.1.5 Project 13

Antarctic circumpolar study of the relation of carbon export production to the plankton community characteristics

Leg 4 participants: Hugo Berthelot and Clarisse Lemonnier PI: Nicolas Cassar

The goal of Project 13 was to investigate the net community production (NCP) and its links with the diversity of the planktonic community. For this purpose, continuous measurements of the NCP and discrete sampling for the DNA-based microbial diversity were performed on Leg 4 from the underway system.

O_2/Ar-based NCP was measured using an Equilibrium Inlet Mass Spectrometer (EIMS). This instrument has been deployed since Leg 0. The issues that have been pointed out on the previous Legs have all been addressed and the system is now fully operational. As a result of calm sea during Leg 4, the underway sampling system has known a reduced number of fail events. This will allow a high coverage of the NCP across this Atlantic Meridional transect.

Samples for composition and diversity of the Eukaryotic and Prokaryotic plankton were collected every 6 hours from the continuous underway system and will be analysed using high-throughput sequencing of the DNA. Two size fractions were collected at each time point: >3 µm on a polycarbonate membrane filter and >0.22 µm on Sterivex filter cartridges. All the samples are conserved at -80°C. During this leg, 66 samples were collected which add to the previous samples collected resulting in 509 DNA samples collected by our group during ACE.

12.1.6 Project 19

The impact of microplastic pollution on the Southern Ocean food web

Leg 4 participants: Giuseppe Suaria and Andrea Pierucci PI: Peter Ryan.

This Project aims to establish baseline estimates for the abundance of micro-plastic particles in the Southern Ocean. From this perspective, participation in Legs 0 and 4 was useful to provide calibration of sampling equipment and protocols, as well as to provide additional sampling in plastic-rich waters, so that differences between the Atlantic and the Southern Ocean could be properly assessed.

Since the ship did not stop for sampling stations during Leg 4 and because net sampling in the Atlantic Ocean was already extensively done during Leg 0, bongo and neuston nets were off-loaded in Cape Town and no net sampling was performed during Leg 4. Sampling activities were restricted to visual monitoring for floating plastic debris and to underway surface and sub-surface sampling for microplastics, as this latter sampling method was added to the Project only towards the end of Leg 1.

Sampling activities during Leg 4 were organised as follows:

Visual survey for floating macro-litter

A visual survey for floating macro-debris (> 2 cm) was carried out during daylight hours throughout the entire voyage, during regular navigation of the vessel. Observations were all performed from the bow of the ship, either from port or starboard side, depending on sun position and wind direction. Transects were run in parallel by two different observers adopting two different methodologies (distance sampling vs fixed-width transect), allowing a direct comparison between the two most common ship-based survey techniques, so that differences between these two methods could be properly assessed. Overall, 120 half-hour transects were performed during Leg 4, for a total of approximately 60 hours of observations.

Besides surveying for floating plastic debris, which was the primary goal of this activity, the abundance of flying fish (Exocoetidae), flying squid (Ommastrephidae) and floating seaweed (Sargassum sp.) was also opportunistically estimated adopting the same counting methodology used for floating debris. The presence of any other large vertebrate was also recorded during the survey – such as sunfishs, marine turtles, dolphins, sharks, whales and other large predatory fishes.

Surface and sub-surface sampling for micro plastics

Every 12 hours surface and sub-surface water samples were collected in tandem. Sub-surface water was collected from the underway water supply, whose intake is positioned at approximately 4-5 metres below the ship's hull. At the same time, surface water was sampled using a stainless steel bucket lowered from the ship's foredeck, using a natural-fibre rope to minimize contamination from sampling equipment.

All surface samples were collected from the ship's forecastle deck, in order to avoid contamination from the ship's laundry outlets. The primary goal of this activity was to provide a direct comparison between the abundance of synthetic fibres and particles in both surface and sub-surface waters, as well as to provide additional samples from plastic-rich waters, so that baseline levels of plastic pollution in the Southern Ocean could be correctly established. Once collected both samples were filtered in the CTD laboratory over

20 and 63 micrometre mesh filters and stored at -4°C for subsequent laboratory analysis. Overall, a total of 37 surface and 33 sub-surface samples were collected during Leg 4.

At every sampling event, an additional phytoplankton sample was collected from the underway water system for Tommy Bornman (Project 12). These samples were all filtered at 20 micron and fixed in 0.01% gluteraldehyde.

13 Expedition Personnel

The following list shows the participation of expedition staff, guests and logistic support personnel in the different Legs of the expedition as well as their affiliations at the time. Principal Investigators (PIs) are included even if they were not on board (identified by *).

Table 45: Expedition staff, guests and logistic support personnel.

First name	Surname	Project	Role on board	Leg(s) on board	Affiliation
Stéphane	Aebischer	21	Zodiac driver	1,2,3	Université Laval
Warren	Amerson		Guest	1	ACE Foundation
David	Antoine	1	PI	*	Curtin University
Philippe	Archambault	21	Scientist	2	Université Laval
Philippe	Arpagaus	15	Scientist	1	Univeristé de Genève
Vincent	Auger	21	Scientist	2	Canadian Scientific Submersible Facility
Andrea	Baccarini	7	Scientist	2,3,4	Paul Scherrer Institute
Helen	Baird	2	Scientist	1	Monash University
Billy	Baker	10	Scientist	1	University of South Florida
David	Barnes	3	PI	1	British Antarctic Survey
Narissa	Bax	3	Scientist	2,3	Institute for Marine and Antarctic Studies
Tarek	Bazley		Journalist	2	Al Jazeera
David	Berliner	1	Scientist	1,2,3	University of Cape Town
Baptiste	Bernard		Zodiac driver	1,2,3	ACE Foundation
Francois	Bernard		Guide	1,2	ACE Foundation
Matteo	Bernasconi	5	Scientist	2	University of St Andrews
Hugo	Berthelot	13	Scientist	4	Univeristé de Bretagne Occidentale
Elisabeth	Biersma	3	Scientist	3	British Antarctic Survey
Dmitry	Bolshiyanov	22	PI	1,2,3	Arctic and Antarctic Research Institute
Thomas	Bornman	12	Scientist	1	South African Environmental Observation Network
Alexander	Borodin		Guest	1,2,3	ACE Foundation
Stéphanie	Brabant		Journalist	1	France Télévision
Barry	Brake	21	Scientist	2	Canadian Scientific Submersible Facility
Robert	Brett		Pilot	1,2,3	ACE Foundation
Andrew	Brierley	5	PI	*	University of St Andrews
Florian	Brucker		Journalist	1	Parafilms
Aleksandr	Bukass	22	Scientist	1,2,3	Arctic and Antarctic Research Institute
Damien	Cabanes	15	Scientist	1,2	Université de Genève
Rachel	Cable	16	Scientist	1,2,3	University of Michigan
Susannah	Calderan	14	Scientist	3	Australian Antarctic Division
Samuel	Carr		Helicopter engineer	1,2,3	ACE Foundation
Nicolas	Cassar	13	PI	1	Duke University
Maria	Castellvi Coma	8	Scientist	4	Institut de Ciències del Mar

Steven	Chown	2	PI	1	Monash Univeristy
Bastien	Confino		Journalist	2	Radio Télévision Suisse
Pau	Cortés	8	Scientist	1,3	Institut de Ciències del Mar
Rebecca	Cumming	10	Scientist	3	University of Otago
Pascal	Danglas		Guest	1,2,3	ACE Foundation
Christian	de Marliave		Logistics manager	2	Éditions Paulsen
Gregory	de Souza	15	Scientist	2	ETH Zürich
Francois	De Vleeschouwer	9	Scientist	2	Centre Nationale de la Recherche Scientifique
Deidre	Galbraith		Doctor	1	ACE Foundation
Brieuc	Delbot		Zodiac driver	1,2,3	ACE Foundation
Danielle	Demers	10	Scientist	2	Univeristy of South Florida
Rachel	Downey	3	Scientist	3	Australian National University
Melissa	Dude Duhaime	16	Scientist	3	University of Michigan
Bo	Elberling		Guest	3	University of Copenhagen
Michael	Ellwood	15	PI	1	Australian National University
Inigo	Everson	5	Scientist	3,4	University of East Anglia
Sarah	Fawcett	12	PI	*	University of Cape Town
Paul	Fernandes	5	Scientist	3	University of Aberdeen
Raquel	Flynn	12	Scientist	3	University of Cape Town
Heather	Forrer	12	Scientist	1,3	University of Cape Town
Marion	Fourquez	16	Scientist	1,2,3	Université de Genève
Roger	Francois	15	Scientist	3	University of British Colombia
Manon	Frutschi		Assistant to Chief Scientist	3	École Polytechnique Fédérale de Lausanne
Guisella	Gacitúa	4	Scientist	2	Universidad de Magallanes
Laure	Gandois	9	Scientist	2	Centre Nationale de la Recherche Scientifique
Irina	Gorodetskaya	18	Scientist	2	Universidade de Aveiro
Pascal	Graf	11	Scientist	1,3	ETH Zürich
Rebecca	Hallas	2	Scientist	1	Monash University
Markus	Hartmann	7	Scientist	1	Leibniz-Institut für Troposphärenforschung
Christel	Hassler	16	PI	2	Université de Genève
Alexander	Haumann	18	Scientist	3	Princeton University
Christoph	Held	3	Scientist	1	Alfred Wegener Institute
Silvia	Henning	7	Scientist	2	Leibniz-Institut für Troposphärenforschung
Tahlia	Henry		CTD operator	3	University of Cape Town
Alexander	Hickling	10	Scientist	1,3	Western Australian Museum
Dominic	Hodgson	9	PI	1	British Antarctic Survey
Eric	Hoesli		Guest	2	École Polytechnique Fédérale de Lausanne
Ian	Hogg	2	Scientist	2	University of Waikato
Marie-Noelle	Houssais	21	Scientist	2	Centre Nationale de la Recherche Scientifique
Jennifer	Hutchings	18	Scientist	1	Oregon State University
Samuel	Jaccard	15	Scientist	2	Université de Genève
Charlene	Janion-Scheepers	2	Scientist	1	Monash University
David	Janssen	15	Scientist	1	University of Victoria

Julie	Janssens	15	Scientist	3	University of Tasmania
Amy	King	4	Scientist	3	British Antarctic Survey
Anna	Kozachek	22	Scientist	1,2,3,4	Arctic and Antarctic Research Institute
Michael	Krasnoperov		Guest	1,2,3	ACE Foundation
Jean-François	Lagrot		Journalist	3	GEO Magazine
Joshua	Lawrence	5	Scientist	2	University of Aberdeen
Kara	Layton	10	Scientist	2	Western Australian Museum
Fabrice	Le Bouard	20	Scientist	1,3	The Royal Society for the Protection of Birds
Camille	Le Guen	5	Scientist	1	University of St Andrews
Russell	Leaper	14	Scientist	3	Australian Antarctic Division
Jasmine	Lee	3, 19, 20	Scientist	1,2	University of Queensland
Katrianne	Lehtipalo	7	Scientist	4	Paul Scherrer Institute
Rachel	Leihy	2	Scientist	1	Monash University
Nolwenn	Lemaitre	15	Scientist	3	Institut Universitaire Européen de la Mer
Clarisse	Lemonnier	13	Scientist	4	Université de Bretagne Occidentale
Katherine	Leonard	18	PI	*	École Polytechnique Fédérale de Lausanne
Yajuan	Lin	13	Scientist	3	Institut Universitaire Européen de la Mer
Hazel	Little	1	Scientist	1,2,3	University of Cape Town
Peter	Lockhart	21	Scientist	2	Canadian Scientific Submersible Facility
Felipe	Lorenz Simoes	2	Scientist	3	British Antarctic Survey
Loïs	Maignien	13	Scientist	2	Université de Bretagne Occidentale
Bradley	Markle	4	Scientist	2	University of Washington
Guillaume	Massé	21	PI	2	Université de Laval
Guillaume	Maurel		Guide	3	ACE Foundation
Patrick	Méhaut		Journalist	1	France Télévision
Elanor	Miller	14	Scientist	2	Australian Antarctic Division
Brian	Miller	14	PI	2	Australian Antarctic Division
Peter	Milne	21	Scientist	2	Canadian Scientific Submersible Facility
Sharif	Mirshak		Journalist	3	Parafilms
Katherine	Moon	2	Scientist	3	Monash Univesity
Bernabé	Moreno	3	Scientist	3	Universidad Científica del Sur
William	Moutier	1	Scientist	1,2,3	Council for Scientific and Industrial Research
Javier	Naretto	10	Scientist	3	Universidad de Chile
Henrik	Normann		Guest	2	Nordic Investment Bank
Mario	Nottaris		Journalist	1	SRG SSRÑ Swiss Broadcasting Corporation
Alexandra	Olivier	1	Scientist	2	Biospherical Instruments Inc.
Jean-Frederic	Paulsen		Guest	3	ACE Foundation
Frederik	Paulsen		Sponsor	1,2,3	ACE Foundation

Maria Lund	Paulsen	3	Scientist	1	Bergen University
David	Pearce	6	PI	1	Northumbria University
Holly	Pearson	8	Scientist	1,2,3	Plymouth University
Joel	Pedro	4	Scientist	2	Niels Bohr University
Bianca	Perren	9	Scientist	1	British Antarctic Survey
Sarah	Perrin		Journalist	3	École Polytechnique Fédérale de Lausanne
Andrea	Pierucci	20	Scientist	4	Università de Cagliari
Carles	Pina Estany		Data manager and IT	1,2,3,4	ACE Foundation
Eveline	Pinseel	9	Scientist	1	Ghent University
Mariusz	Potocki	4	Scientist	3	University of Maine
Roland	Proud	5	Scientist	1	University of St Andrews
Stanley	Prusiner	101	Guest	3	University of California
Timothy	Radke		Guest	3	San Diego Medical Center
Morten	Rasch	100	Guest	3	University of Copenhagen
Eva	Reichert	17	Scientist	2	Ocean Consulting Ltd
Charlotte	Robinson	1	Scientist	3	Curtin University
Danièle	Rod		Programme manager	1	Swiss Polar Institute
Sergio	Rodrigues		Pilot	1,2,3	ACE Foundation
Pablo	Rodríguez Ros	8	Scientist	1	Institut de Ciències del Mar
Vivien	Roussel		Journalist	2	France Télévision
Peter	Ryan	19, 20	PI	1,2,3	University of Cape Town
Thomas	Ryan-Keogh	1	Scientist	1	Council for Scientific and Industrial Research
Beatriz	Salgado Murillo		Chilean observer	2	ACE Foundation
Chester	Sands	3	Scientist	2	British Antarctic Survey
Noé	Sardet		Journalist	2	Parafilms
Julia	Schmale	7	Scientist	1,2,3	Paul Scherrer Institute
Nina	Schuback	1	Scientist	1,2,3	Curtin University
Ibrahim	Sharaf		Guest	1,2,3	ACE Foundation
Matthias	Sieber	15	Scientist	1	ETH Zürich
Rafel	Simó	8	PI	2	Institut de Ciències Del Mar
Pascal	Simon		Guest	1,2,3	ACE Foundation
Maureen	Soon	15	Scientist	3	University of British Columbia
Mark	Stevens	2	Scientist	2	South Australian Government
Roger	Stilwell	4	Scientist	3	British Antarctic Survey
Jan	Strugnell	10	Scientist	2	James Cook University
Giuseppe	Suaria	19	Scientist	1,2,3,4	Institute of Marine Sciences, Italian Research Councile
Jenny	Thomas		Data manager	1,2,3,4	ACE Foundation
Elizabeth	Thomas	4	PI	3	British Antarctic Survey
Iris Livia	Thurnherr	11	Scientist	1,2	ETH Zürich
Ian	Tindall		Helicopter engineer	1,2,3	ACE Foundation
Alessandro	Toffoli	17	PI	2	University of Melbourne
Maria	Tsukernik	18	Scientist	1,2,3	Brown University
Fiona	Tummon	7	Scientist	1	ETH Zürich

Iurii	Turchinovich	22	Scientist	1,2,3,4	Arctic and Antarctic Research Institute
Nathalie	Van der Putten	9	Scientist	3	Lund University
Samuel	Verdan		Guest	2	ACE Foundation
Patti	Virtue	19	Scientist	3	University of Tasmania
David	Walton		Chief Scientist	1,2,3	British Antarctic Survey
Samantha	Waterworth	12	Scientist	1,3	Rhodes University
Henri	Weimerskirch	20	PI	*	Centre d´Études Biologiques de Chizé
André	Welti	7	Scientist	3	Leibniz-Institut für Troposphärenforschung
Yongbiao	Weng	11	Scientist	4	Bergen University
Heini	Wernli	11	PI	*	ETH Zürich
Nerida	Wilson	10	PI	1	Western Australian Museum
Marina	Zamanillo Campos	8	Scientist	2,3	Insitut de Ciències del Mar

14 Akademik Tyroshnikov principal crew list

Table 46: Crew list of the R/V Akademik Tryoshnikov *for legs 0 to 4.*

Name (SURNAME first name)	Role on board
KARPENKO Dmitry	Master
BELKOV Dmitrii	Chief mate
ZIMIN Vladimir	Chief mate
DYACHKIN Sergey	Chief mate
CHERMAN Roman	2nd mate
GORBIK Andrei	4th mate
ROMANOV Mikhail	Chief scientist support
USTIUZHANIN Oleg	Radio engineer
NIKIFOROV Konstantin	Radio technician
ANFERTEV Vladimir	Doctor
VASILYEV Alexander	Chief engineer
ILYAKOV Alexander	2nd engineer
CHIGRIN Sergey	2nd engineer
APOSTOLOV Igor	3rd engineer
LEBEDEV Sergei	3rd engineer
NEVMERZHITSKIY Evgeny	Repair engineer
ORLENKO Sergey	System engineer
SHELUKHOV Valerii	Chief electrician engineer
MOROZOV Aleksandr	Second electrician engineer
YEFIMYONOK Yury	2nd electrician engineer
AVANESOV Andrey	3rd electrician engineer
RUBLEV Sergei	3rd electrician engineer
KLYUTSYAVICHYUS Maxim	4th electrician engineer
KORNEV Gennadii	Chief electrician
LIUBIMOV Andrei	Boatswain
KARPENKO Ilia	Seaman
LISICHKIN Andrei	Seaman
MIKHNEV Vladislav	Seaman
MARTIROSIAN Georgii	Seaman
BURDUGOS Dmitrii	Seaman
PREOBRAZHENSKII Evgenii	Seaman
KORNEV Filipp	Seaman
POLEVSHCHIKOV Denis	Chief cook
VLADIMIROV Vladimir	Cook
KOROBEINIKOV Sergei	Cook
KOVALNOGOV Iurii	Cook
ZOTOV Kirill	Cook
ANDREEV Ivan	
KOCHERINA Olga	Stewardess
OSETROVA Svetlana	Stewardess

OSTROVA Liudmila	Stewardess
ANDREEVA Irina	Stewardess
MIGUNOVA Daria	Stewardess
NARYSHKINA Irina	Stewardess
VYSOTCKAIA Svetlana	Stewardess
VDOVINA Marina	Stewardess
KUPREICHENKO Kristina	Stewardess
EROKHINA Ekaterina	Stewardess
VOROPAEV Maksim	Motorman
BEZBORODKIN Aleksei	Motorman
KOVALEV Artem	Motorman
GLUSHKO Igor	Motorman
KHRUSTALEV Alexandr	Motorman
MIKHAILOV Georgii	Turner
VELEDIN Victor	Chief meteorologist
KHARSOV Ilia	2nd meteorologist
BOGACHEV Iurii	Engineer
KAVALEROV Artem	Leading electronic engineer

15 Appendix

15.1 ACE Maritime University Report

19 November 2016 – 15 December 2016

R/V *Akademik Tryoshnikov*

Conveners: Manon Frutschi, Tahlia Henry, Marcel du Plessis

*Figure 184: R/*V Akademik Tryoshnikov.

Overview

The R/V *Akademik Tryoshnikov*, was scheduled for departure from Cape Town, South Africa to undergo a circumnavigation of the Southern Ocean under the Antarctic Circumpolar Expedition (ACE). Returning from an Arctic expedition in the summer of 2016, the ship sailed to Cape Town, a 3.5-week voyage spanning the Atlantic Ocean. This leg, from Europe to South Africa, provided a unique opportunity to host an ACE Maritime University. The result was a globally diverse group of 49 students (Figure 185) carefully chosen from 152 applications.

Students

The selection criteria for the students chosen to participate in the ACE University was unique in the interdisciplinary fields of the students chosen. A total of 49 students from five continents were accepted. The target experience for the students chosen was a Masters or early PhD career researchers. The age of the students ranged from 19 to 41.

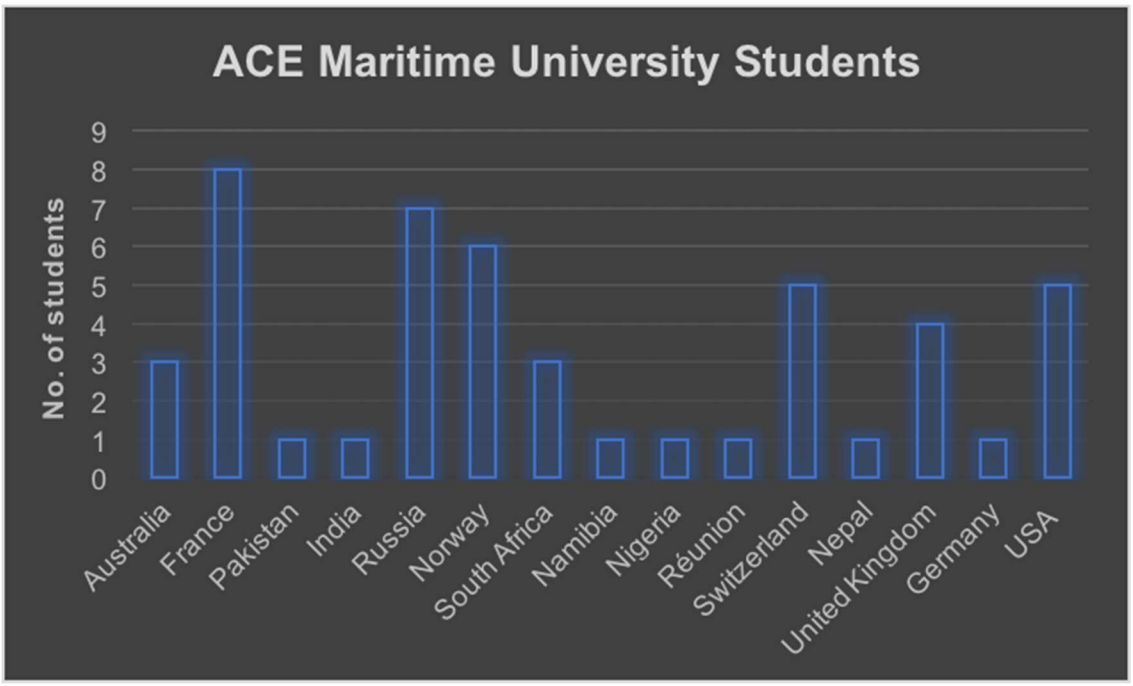

Figure 185: Number of students chosen from a diverse group of 15 countries around the world.

Scientists

There were 16 scientists participating in Leg 0 of ACE with an objective to install and test their scientific equipment to be used for Legs 1, 2 and 3. It was agreed between the ACE organisers and PIs of the various Projects that the ship-based scientists would contribute to the University. The scientists provided valuable experience for the students in a format of 'interactive deck work' with the scientists providing seminars on their research.

Format of the ACE University

Careful attention was paid in structuring the University to factor in life at sea and maximise the field component of being on a working research vessel. In addition, students gained theoretical experience of physical oceanography through a lecture-orientated environment. Thereby, a system of alternating days between lecture-orientated and assignment-driven practicals was implemented. Lecture days consisted of four, one-hour lectures including seminars delivered by the students presenting their individual research interests (see Figure 186). Two core lecture themes were provided, i) Ocean Dynamics and ii) Marine Instrumentation. These two lectures were provided by the conveners on all lectures days. In addition, deck work was scheduled daily, centred around the deployment of a 1000-metre CTD cast.

Bremerhaven to Southampton				
Timetable Plan for the first 3 days leading up to departrure of Leg Zero after Portsmouth		In Port Bremerhaven	Bremerhaven to Southampton	In Port Southampton
		Arrival on the RV Ak Treshnikov 19th November - Departure during the 19th. Immigration, cabin allocations, safety/lifeboat drill, introduction to the ship	Introduction to each student and lecturer/ship-based researcher (2 slide presentation highlighting your interests). Orientation of the ship and all the lecturering/deck facilities	Helicopters to be loaded, final equipment and personnel to arrive. Departure same day
19.00 to 20.30	Evening	Evening to settle in	Discussion of plan ahead - convenors and First Lecture "Plastisphere" (Stefano Aliani)	Students to present each night their past or current research activities.

Lectures start day after Portsmouth							
WEEK 1		22.nov.	23.nov.	24.nov.	25.nov.	26.nov.	27.nov.
Times	Module	In Port Southampton	Lecture	Assignment	Lecture	Assignment	Lecture
09.00 to 10.00	Ocean and Atmosphere Dynamics - convenor Marcel du Plessis	Helicopters to be loaded, final equipment and personnel to arrive. Departure same day	Introduction to Global Winds	Essay on *"Global observations and the need for an improved system" - case study Atlantic Ocean*	Thermohaline Circulation I	Al Gore movie "An Inconvenient Truth" and open discussion *where are we a decade later?*	Thermohaline Circulation II
10.00 to 11.00	Marine Instruments and Data Analysis - convenor Tahlia Henry		Where on the World-wide web? Global Ocean Observing Systems (GOOS)		Where on the World-wide web? - bathymetry		Where on the World-wide web? - instruments
11.00 to 12.00	Topical - Climate Change - convenor Manon Frutschi		Introduction to weather and climate in the Southern Ocean (Pascal Graf)		Stable water isotopes: How can they be measured and why are they useful (Iris Turnherr)		Retrieval of Atmospheric Trace Gases (Núria Benavent) and Aerosal Effects Marieke Loeffler
14.30 to 18.00	Deck work	Daily Deck Work in Groups of 5					
19.00 to 20.30	Evening	Students to present each night their past or current research activities.					

WEEK 2		28.nov.	29.nov.	30.nov.	01.déc.	02.déc.	03.déc.	04.déc.
Times	Module	Assignment	Assignment	Lecture	Lecture	Assignment	Lecture	Assignment
9.00 to 10.00	Ocean and Atmosphere Dynamics	Schiermeier's "Ocean under Surveillance" Nature (May 9 2013, Vol 4971) - Group work: *"The need for a global array"*	Schiermeier's "Ocean under Surveillance" Nature (May 9 2013, Vol 4971) - Group presentations: *"The need for a global array"*	Properties of Seawater: Temperature, Salinity, Denisty, Pressure	Principles of Oceanography II - Dissolved gases, pH	Practical - ODV Tutorial and CTD processing	Principles of Oceanography II - Light and Sound	Equator Crossing
10.00 to 11.00	Marine Instruments and Data Analysis			Where on the World-wide web? - robots	From the field to the lab - Manon		Data Analysis	
11.00 to 12.00	Topical - Climate Change			Phytoplankton and primary production (Steph Gardner)	Roland Proud - Python Module		Roland Proud - Python Module	
14.30 to 18.00	Deck work	Daily Deck Work in Groups of 5						
19.00 to 20.30	Evening	Students to present each night their past or current research activities.						

WEEK 3		05.déc.	06.déc.	07.déc.	08.déc.	09.déc.	10.déc.	11.déc.
Times	Module	Assignment	Lecture	Assignment	Lecture	Assignment	Lecture	Assignment
9.00 to 10.00	Ocean and Atmosphere Dynamics	Group Discussions - Communications of Climate Change	Equatorial systems and ENSO	Science Journalism and Communication Workshop	Discussion on funding from the industry (Kyle Neumann)	Glider movie - followed by a 2-3 page written proposal of a glider oriented study anywhere in the Atlantic to resolve ocean dynamics - including deployment and retrieval logistics, finances, sensors used, processes to resolve. Work in pairs.	Ocean Heat distribution, upwelling and downwelling	Impacts of Sea Level Rise (Yajuan Lin)
10.00 to 11.00	Marine Instruments and Data Analysis		Lagrangian	News article on the El Niño Southern Oscillation	Eulerian I		Eulerian II	Crossing from North to South (*How the profiles compare - Temp, Salinity, Oxygen, Fluorescence*) - incorporate the knowledge you've learned on the cruise to write scientific analysis (plots using Python or ODV) explaining the observations of the CTD data. Work in pairs.
11.00 to 12.00	Topical - Climate Change		Roland Proud - Python Module		Student presentations on scientists (Group A, B, C, D)		Metal speciation and biodiversity in estuaries (Holly Pearson)	
14.30 to 18.00	Deck work	Daily Deck Work in Groups of 5						
19.00 to 20.30	Evening	Students to present each night their past or current research activities.						

WEEK 4		12.déc.	13.déc.	14.déc.	15.déc.
Times	Module	Lecture	Lecture	MOVIE	In Cape Town
9.00 to 10.00	Ocean and Atmosphere Dynamics	Regional Ocean - Eastern Boundary Currents	Finaling movies, cleaning, group activities and showing of the official ACE movie.	Finaling movies, cleaning, group activities and showing of the official ACE movie.	Arrival
10.00 to 11.00	Marine Instruments and Data Analysis	Student presenations on scientists (Group E, F, G, H)			
11.00 to 12.00	Topical - Climate Change	Biogeochemical Modeling and Remote Sensing of Marine Trace Gasses in Polar Regions and the Global Ocean (Pablo Rodriguez-Ros)			
14.30 to 18.00	Deck work	Daily Deck Work in Groups of 5			
19.00 to 20.30	Evening	Students to present each night their past or current research activities.			

Figure 186: ACE Maritime University timetable for Leg 0.

Lectures

Ocean dynamics (Marcel du Plessis)

The students were provided with lectures on the physical oceanography of the Atlantic Ocean. The series of lectures were driven with a specific motive to understand the physical oceanographic dynamics which underlie the ocean within which the University was held. Given the diversity of backgrounds of the students, the key themes were: Global winds, Thermohaline Circulation and Atlantinc Meridional Overturning Circulation, sound and light in the ocean, gases and pH of the ocean, properties of seawater, wind-driven ocean gyres, upwelling and downwelling, western and eastern boundary currents, El Niño Southern Oscillation index and the currents around Southern Africa.

Marine Instrumentation (Tahlia Henry)

In this lecture programme students were provided with interactive means and methods to obtain oceanographic data online (worldwide web). The various ways in which scientists can gather data on physical oceanographic processes and biology was thoroughly examined from a Lagrangian and Eulerian approach to sampling. From an operational oceanographic perspective, a variety of instruments were examined, namely: CTDs, XBTs, Gliders, Drifter, ARGO Floats, Mooring Arrays and Global Arrays. Furthermore, this programme further illuminated the essential data management process and the need for sustainable global collaborations. The lectures and associated deck work were delivered through the unique viewpoint of a sea technician allowing students to obtain a real understanding for the intricacies of using instruments in an operational oceanographic environment.

Topical Climate Change (Manon Frutschi)

The students were provided seminars on the topical research activities of the ACE Leg 0 scientists. These include: Introduction to weather and climate in the Southern Ocean (Pascal Graf), Stable Water Isotopes: how can they be measured and why are they useful (Iris Thurnherr), Retrieval of atmospheric trace gases (Nuria Benavent), Aerosol Effect (Marieke Loeffler), Phytoplankton and primary production (Stephanie Gardner), Python module (Roland Proud), Metal and biodiversity in estuaries (Holly Pearson), Impact of Sea Level Rise (Yajuan Lin), Biogeochemical Modelling and Remote Sensing of Marine Trace Gases in Polar Regions and the Global Ocean (Pablo Rodríguez-Ros), Plastisphere (Stefano Aliani), Floating plastic in the

marine environment (Giuseppe Suaria) and Marine electroactive biofilms responsible for stainless steel ennoblement (Florian Trigodet).

Student presentations were performed each day with two of the students presenting their current research or experiences in science.

Assignments

The following assignments were undertaken by the students on board:

- Physical oceanography of the Atlantic Ocean
- Global observations and the need for an improved system (essay)
- Viewing of Al Gore's "Inconvenient Truth": where are we 10 years later?
- Communication of Climate Change Workshop
- Media article on El Niño Southern Oscillation combined with a workshop given by the media professional on board
- Viewing of the Robot's daring mission across the Atlantic followed by an application in using gliders to measure physical oceanographic processes across the Atlantic
- Scientific write up implementing the information learned throughout the lectures of the University with the CTD profiles collects on board.
- Scientific cruise report summarising the work done during the ACE Maritime University

Deck work

The students were divided into eight groups of 6-7 people to promote concentrated learning and practical implementation. A rotation system was derived whereby each group was assigned a particular scientist to learn deck work each day.

CTD

A CTD was deployed 15 of the 24 days at sea following a transect, between Southampton and Cape Town. The students were exposed to CTD operations and had the opportunity to be involved in the setup, deployment and post-processing of the CTD data obtained.

The SBE 911 CTD is suited with niskin bottles mounted on a rosette frame. Figure 187 shows parts of the operation of the CTD: in panel 1 you can see the spring caps shut tightly on the top of each bottle. Before deployment the thin plastic wires that are visible in panel 1 must be pulled back, opening the bottle, and hooked over some notches on the release mechanism found at the centre of the rosette. The cap situated at the top and bottom of each bottle allows water to flow through the open tube easily and prevent sampling from non-target depths as the CTD moves up and down through the water column. Within the deck groups, students were taught how to set up the niskin bottles prior to deployment and all necessary checks were conducted to ensure a successful CTD cast.

Figure 187: CTD operations.

In Figure 187, panel 2 shows the mechanism for firing the Niskin bottle caps from the control seat seen in panel 3. The operator (Panel 3) monitors the CTD status and communicates to the winch operator via a radio. Upon reaching the target depth the operator must wait two and a half minutes before firing a bottle to ensure the bottles are well flushed, as directed by Scripps Institute of Oceanography. When pressing the green fire button, or clicking on the computer screen. An electrical signal is sent down the CTD cable to release the trigger mechanism for a given bottle, thus closing the caps rapidly. Care must be taken not to double-fire bottles. Additionally it is important to make a hard copy of notes on when Niskin bottle samples are collected (deckchits). The CTD is then brought on board to allow the scientists to gain access to water samples. Students were given the opportunity to operate the CTD and fire the bottles at the target depths as well as sample the niskin bottles as per the various scientific protocol devised by the scientists (Panels 4-9).

There are in total 22 different Projects on board during ACE, eight of which were present on board during Leg 0 and started their sampling in the Atlantic:

"Circum-Antarctic distribution of acoustic deep scattering layers and associated foraging behaviour of deep diving predators"

Scientist present on Leg 0: Roland Proud – University of St. Andrews, Scotland.

This Project is using scientific echosounders to map depth and biomass of acoustic deep scattering layers (DSL) to uncover the mystery of the oceans' "false bottom". This term is used for the DSL which comprise of communities of fish (lantern fish and myctophides) and zooplankton. The Project will examine associations between DSL prey and predators to see how the daily vertical migration of DSL and predators are associated.

There were two Projects looking at aerosols; "Evolution of the ecosystems of Sub-Antarctic Islands during Holocene and its modern conditions" and "ACE-SPACE" (Study of preindustrial-like-Aerosol-Climate effects)

”Tracing back the evolution of the sub-antarctic ecosystems” and “Antarctica to reveal pre-industrial atmosphere”

Scientists present on Leg 0: Anna Kozachek, Geography Department, Climate and Environment Research Lab and Iurii Turchinovich, State Research Center "Arctic and Antarctic Research Institute", V.E. Zuev Institute of Atmospheric Optics, Russia and Mareike Löffler, Leibniz Institute for Tropospheric Research, Germany.

The Projects is sampling aerosols from the air with different methodologies to investigate the amount and composition of aerosols at sea and in the ice.

Microplastics; “The impact of microplastic pollution on the Southern Ocean food web”

Scientist present on Leg 0: Guiseppe Suaria, Institute Marine Science, Italy

The Project will survey and sample plastic through the whole ACE voyage aiming at evaluating the impact of microplastics on the Southern Ocean and the food web, including plankton, krill, fish, seals, penguin and albatrosses.

Microbes in the air; “Bioair” (Aerobiology over Antarctica)

“The role of bacteria and viruses in Carbon and iron Chemistry”.

Scientist present on Leg 0; Marie Sabacka, University of South Bohemia, Czech Republic.

Microorganisms are easily dispersed by air and therefore found everywhere. Even if Antarctica is considered the most isolated place on Earth, both cosmopolitan organisms and microbes adapted to Antarctic conditions are found in the Antarctic continent. Bioair’s aim is to find out whether these microorganisms are related to those living elsewhere and if so where they come from.

“SORPASSO” (Surveying Organic Reactive gases and Particles Across the Surface Southern Ocean).

Scientist present on Leg 0; Pablo Rodríguez Ros, Marine Science Institute / Polytechnical University of Catalonia and Nuria Benavent Oltra, Instituto de Química Física Rocasolano, CSIC, Spain, Stephanie Gardner, University of Technology Sydney, Australia and Holly Beverley Clare Pearson, Plymouth University (School of Geography Earth and Environmental Sciences), UK.

This Project will be the first one to investigate the distribution of surface ocean trace gases and particles important for atmospheric chemistry and climate and understand their biological, chemical hydrological and optical drivers in the Antarctic. Their impact is important for predicting future trends and global warming.

Phytoplankton as a climate regulator “Antarctic Circumpolar Study of the relation of Carbon Export Production to Plankton Community Characteristics”

Scientist present on Leg 0; Yajuan Lin, Institut Universitaire Européen de la Mer, and Florian Trigodet, Laboratory of Microbiology of Extreme Environment, France.

This Project is mapping the microorganisms in the sea during the whole voyage. They sample from the surface all the way down to 1000 m depth and use both imaging and DNA. They also use mass spectrometry to measure carbon uptake in the surface water.

Investigation of air-sea interaction in the Southern Ocean from stable water isotope measurements.

Scientist present on Leg 0; Pascal Graf and Iris Livia Thurnherrr, ETH Zürich, Department of Environmental Systems Science, Institute for Atmospheric and Climate Science, Switzerland.

This Project will collect and measure stable water isotopes in atmospheric vapour and precipitation and observe the precipitation events with a micro rain radar during the ship cruise. These data will be used to understand the regional water cycle.

Metocean properties of the sub-Antarctic and Antarctic waters: winds, waves, currents, ice, and their interactions

This project did not have any scientists on board during leg 0, but data were collected nevertheless.

15.2 ACE stations, Legs 1 – 3

Below are two tables containing the lists of all stations that were completed during ACE.

*Table 47: Table of terrestrial stations (see Cruise overview and maps, Stations, for more information). All station numbers marked *, were cancelled.*

Station name	Leg	Latitude (decimal degs N)	Longitude (decimal degs E)	Arrival time (UTC)	Departure time (UTC)	Comments
3	1	-46.88	37.75	2016-12-25 22:34:00	2016-12-28 18:50:00	Station at Marion Island.
6	1	-46.12	50.23	2016-12-30 09:00:00	2016-12-30 11:00:00	Aerial photography at Ile aux Cochons.
7*	1	-45.97	50.47			Aerial photography at Ile des Apotres. No events occurred at this station due to not enough time.
9	1	-46.42	51.75	2016-12-30 15:00:00	2017-01-01 12:00:00	Ile de la Possession.
10*	1	-46.43	52.22			Ile de l'Est. No work was done at this station due to bad weather.
14	1	-49.37	70.2	2017-01-05 03:00:00	2017-01-06 04:30:00	Kerguelen island. Position is the location of the base. For more accurate positions for the sampling, look at the events.
27	2	-67.5596	145.3125	2017-01-29 04:00:00	2017-01-29 10:00:00	First site on Mertz glacier. Times and positions from events. Longitude corrected to 145.3125 from 143.3125.
29	2	-67.009	142.663	2017-01-29 23:00:00	2017-01-29 23:30:00	Cape Denison. Times and positions from events.
31	2	-67.4411	145.5745	2017-01-31 03:00:00	2017-01-31 07:00:00	Second site on Mertz glacier. Positions and times from start and end of events
44	2	-66.53	162.56	2017-02-03 22:00:00	2017-02-04 02:00:00	Young Island sampling at Balleny Islands. Times and positions from event activities.
45*	2					Balleny Islands beach sampling. No visits to this location because site was not safe to access.
51	2	-67.379	-179.912	2017-02-06 23:00:00	2017-02-07 01:00:00	Terrestrial station at Scott Island. Positions from hand-held GPS from a field party. Times from helicopter-flight arrivals and departures to and from island.
63	2	-73.12	-125.225	2017-02-11 01:00:00	2017-02-11 07:00:00	Maher Island near Mt Siple.
64	2	-73.146	-124.934	2017-02-11 05:00:00	2017-02-11 07:00:00	Lauff Island near Mt Siple.
65	2	-73.321	-126.662	2017-02-11 20:00:00	2017-02-12 02:00:00	Drilling site on Mt Siple. Positions from events. Times from events.

66	2	-73.404	-125.596	2017-02-11 22:00:00	2017-02-12 06:00:00	Terrestrial rocky outcrop area near Mt Siple on Siple Island, Marie Byrd Land. Station includes both the beach area as well as the penguin colony which covered a lot of the top of the cliffs and higher part of the rocky outcrop. Times and positions estimates until confirmed by positions.
69	2	-68.84	-90.624	2017-02-15 21:00:00	2017-02-15 23:00:00	Peter I island. Position is centre point of island. Times are those of start and end times of events.
75	2	-56.5096	-68.7122	2017-02-20 18:00:00	2017-02-20 21:00:00	Bartholome island sampling, Diego Ramirez archipelago.
76	2	-56.5215	-68.7035	2017-02-20 17:30:00	2017-02-20 21:00:00	Gonzalo island in Diego Ramirez archipelago.
79	3	-54.28	-36.51	2017-03-02 12:00:00	2017-03-02 19:10:00	Work completed in the area around Grytviken on South Georgia (including areas between Grytviken and Penguin River, Brown Mountain and pass over to Maivatn).
80	3	-54.3	-36.49	2017-03-02 14:00:00	2017-03-02 20:00:00	Penguin river on South Georgia. Work done specifically at penguin river area. Dates and times taken from sampling events.
81	3	-54.25	-36.5	2017-03-02 13:30:00	2017-03-02 19:00:00	Maikviken, South Georgia.
82	3	-54.376	-36.4	2017-03-02 15:00:00	2017-03-02 17:00:00	Nordenskjoll glacier, South Georgia
85	3	-54.44	-36.19	2017-03-04 12:00:00	2017-03-04 18:30:00	Sampling area in St Andrews Bay (covers a large area within this bay).
86	3	-54.432	-36.224	2017-03-04 14:00:00	2017-03-04 16:00:00	Work on Heany Glacier near to St Andrews Bay, South Georgia
95	3	-54.422	3.391	2017-03-13 07:00:00	2017-03-13 12:30:00	Bouvetøya ice coring station
96*	3					Bouvetøya beach station.
97*	3					Bouvetøya southern side locations
102	3	-54.45	3.331	2017-03-12 14:00:00	2017-03-12 15:00:00	Terrestrial collection site on Bouvetøya. Activities were completed within a radius of 1.5 km of this point.

*Table 48: Table of oceanographic stations (see Cruise overview and maps, Stations, for more information). All station numbers marked *, were cancelled.*

Station name	Leg	Latitude (decimal degs N)	Longitude (decimal degs E)	Arrival time (UTC)	Departure time (UTC)	Comments
0	1					Test station.
1*	1					Work at this station was cancelled due to bad weather.

2	1	-46.9196	38.1172	2016-12-28 06:55:00	2016-12-28 08:29:00	Start date and time from CTD deployment event. End date and time from Neuston net event. Latitude and longitude from first event at station. Corrected from -47, 38.17 to current values from looking at GPS data.
4	1	-46.7128	37.6477	2016-12-28 16:30:00	2016-12-28 17:20:00	Start and end times from Trace metal rosette deployment event.
5	1	-46.7257	37.894	2016-12-28 09:50:34	2016-12-28 18:00:00	
8	1	-46.1623	50.8822	2016-12-30 12:48:33	2016-12-30 16:10:00	Position from the start of the first event at this location. Note that the rest of the events started approximately 10 km away from this point as the ship drifted whilst the first event was undertaken.
11	1	-46.6696	51.7992	2017-01-01 13:30:00	2017-01-01 14:40:00	Marine station south of Crozet Islands for trawling.
12	1	-49.4236	62.9484	2017-01-03 06:40:00	2017-01-03 07:00:00	Supposed to be a full station but only floats deployed due to bad weather.
13	1	-49.7331	64.8713	2017-01-03 13:20:00	2017-01-03 18:40:00	
15	1	-50.0002	70.6722	2017-01-04 18:27:31	2017-01-04 21:30:00	Trawling station enroute into Kerguelen.
16	1	-50.9929	72.0436	2017-01-07 04:14:00	2017-01-07 17:30:15	Station between Kerguelen and Heard Island. Pike Bank. Positions and times from relevant events.
17	1	-52.3552	74.6503	2017-01-08 08:53:52	2017-01-08 10:30:00	Station nearer to Heard Island.
18	1	-52.3528	74.8278	2017-01-08 11:01:51	2017-01-08 15:00:00	Station near to Heard Island. Moved to a different position nearby station 17 due to lack of samples from Agassiz trawls. Positions and times according to relevant events.
19	1	-53.1688	81.5736	2017-01-09 08:14:00	2017-01-09 19:00:00	Times and positions from those of the events at this station.
20	1	-54.8512	95.7441	2017-01-11 04:14:00	2017-01-11 12:09:00	Times and positions are from relevant events.
21	1	-53.1975	118.1205	2017-01-14 02:05:00	2017-01-14 07:27:00	Times and positions from relevant events.
22	1	-46.9097	141.9254	2017-01-17 06:44:00	2017-01-17 10:25:00	Times from events of CTDs which were the first and last events of the station.
23	2	-46.3989	150.4066	2017-01-23 06:14:00	2017-01-23 12:00:00	Position and start time from first event. Departure time from end of last event.
24	2	-53.5626	149.2557	2017-01-25 00:05:00	2017-01-25 05:27:00	Arrival time and position from first event. Departure time from event.

25	2	-59.6004	148.5715	2017-01-26 06:08:00	2017-01-26 12:31:00	Arrival time and position from first event. Departure time from last event.
26	2	-67.083	144.867	2017-01-28 22:00:00	2017-01-29 03:00:00	Times from first and last events. Position from first event.
28	2	-67.1287	145.0486	2017-01-29 07:00:00	2017-01-29 21:00:00	ROPOS station Mertz. Main station for first ROPOS deployment and other associated activities. Positions from events that occurred at this station. Time is from the time we were still in the same location.
30	2	-67.0926	145.0129	2017-01-30 00:18:00	2017-01-30 06:00:00	Second ROPOS deployment station. Times from events. Position from first event.
32	2	-67.0632	144.8988	2017-01-30 07:30:00	2017-01-30 08:00:00	CTD profile station on first CTD transect at Mertz. Times and positions from events at this station.
33	2	-67.0656	144.946	2017-01-30 08:30:00	2017-01-30 09:30:00	CTD profile station on first CTD transect at Mertz. Times and positions from events at this station.
34	2	-67.0651	144.9855	2017-01-30 09:50:00	2017-01-30 11:20:00	CTD profile station on first CTD transect at Mertz. Times and positions from events at this station.
35	2	-67.0641	145.0031	2017-01-30 11:43:00	2017-01-30 12:52:00	CTD profile station on first CTD transect at Mertz. Times and postions from events at this station.
36	2	-67.1758	145.7311	2017-01-30 20:47:00	2017-01-31 00:46:00	Full CTD station with other deployments in polynya on western side of Mertz glacier. Times and positions of this station taken from the events that occurred here.
37*	2					CTD station along second CTD transect in Mertz polynya
38	2	-66.996	146.0349	2017-01-31 04:27:00	2017-01-31 05:19:00	CTD station along second CTD transect in Mertz polynya. Times and positions from events that occurred at this station.
39	2	-66.8675	146.1516	2017-01-31 06:39:00	2017-01-31 07:03:00	CTD station along second CTD transect in Mertz polynya. Times and positions are from events that occurred at this station.
40	2	-66.752	146.1996	2017-01-31 08:08:00	2017-01-31 08:50:00	CTD station along second CTD transect in Mertz polynya. Times and positions from events that occurred at this station.

41	2	-65.894	146.3318	2017-01-31 19:45:00	2017-01-31 20:43:00	This was a planned ROPOS station but it was not done. Only a CTD happened here. Times and positions from events that occurred at this station.
42	2	-66.6297	146.2465	2017-01-31 10:02:00	2017-01-31 10:26:00	CTD station along second transect of CTDs at Mertz. Times and positions from events that occurred at this station.
43	2	-66.001	159.003	2017-02-02 18:09:00	2017-02-02 22:50:00	Full marine station before reaching Balleny Islands. Start and end times from first and last events. Position from first event.
46	2	-66.1627	162.1874	2017-02-03 09:15:00	2017-02-03 13:18:00	Marine station for trawling on northern side of Balleny Islands. Positions from first event. Times from first and last events.
47	2	-67.2913	163.545	2017-02-04 10:53:00	2017-02-04 14:05:00	Marine station in between Balleny Islands. Start and end times from first and last events. Positions from first event.
48	2	-66.7105	162.8409	2017-02-04 04:02:50	2017-02-04 06:30:00	Trawl stations to south of Balleny Islands. Start and end times from first and last events. Positions from first event.
49	2	-67.1004	167.3921	2017-02-05 02:32:00	2017-02-05 07:12:00	Full marine station between Balleny and Scott Islands. Start and end times from first and last events. Position from first event.
50	2	-67.119	168.1775	2017-02-05 08:45:00	2017-02-05 10:00:00	Agassiz trawl station near Scott Island. Marked as success because an event happened, but in fact the event was a failure.
52	2					ROPOS station near to Balleny Islands. ROV was deployed but soon cancelled due to strong currents.
53*	2					ROPOS deployment Scott Island.
54	2	-69.743	-165.0198	2017-02-08 07:00:00	2017-02-08 09:00:00	Marine station with shallow CTD enroute from Scott to Peter I Island. Position around -165.0 longitude. Times from first and last events. Position from first event.
55	2	-70.179	-159.0796	2017-02-08 18:30:00	2017-02-08 23:53:00	Estimated arrival time. Marine station with deep CTD enroute to Peter I Island. Times from first and last events. Position from first event.

56	2	-71.6929	-143.7245	2017-02-09 22:29:00	2017-02-10 02:54:00	Marine station with full cast (double) CTDs. Times from first and last events. Position from first event.
57*	2					Short marine station near Antarctic coast (approx. 115.3 W). Shallow cast.
58	2	-73.1621	-126.9499	2017-02-11 21:02:08	2017-02-11 22:30:00	Trawling station near Mt Siple. Times from first and last events. Position from first event.
59	2	-72.9913	-127.8352	2017-02-11 09:52:00	2017-02-11 16:12:00	Ropos. Times from first and last events. Position from first event.
60	2	-73.525	-127.4741	2017-02-12 00:36:00	2017-02-12 01:13:00	Second trawl site at Mt Siple. Times from first and last events. Position from first event.
61	2	-73.8861	-127.5207	2017-02-13 01:29:00	2017-02-13 02:15:00	Third trawling site in Mt Siple area. Times from first and last event. Position from first event.
62	2	-74.0053	-127.4262	2017-02-12 12:02:00	2017-02-12 16:33:00	Second ROPOS site near Mt Siple area. Times from first and last events. Positions from first event.
67	2	-70.0017	-115.5093	2017-02-13 21:38:00	2017-02-13 23:23:00	Shallow CTD station enroute from Mt Siple to Peter I. Times from first and last events. Position from first event.
68	2	-68.7398	-99.9971	2017-02-15 02:58:00	2017-02-15 05:28:00	Marine shallow CTD station with TMR before Peter I. Times from first and last event. Positions from first event.
70	2	-68.0103	-82.0331	2017-02-16 15:34:00	2017-02-16 16:08:00	CTD station between Peter I Island and Antarctic Peninsula.
71	2	-63.9696	-66.2697	2017-02-18 01:52:00	2017-02-18 03:01:00	First marine peninsula station.
72	2	-62.5028	-67.9987	2017-02-18 10:09:00	2017-02-18 13:52:47	Second marine station up peninsula.
73	2	-59.6024	-67.9249	2017-02-19 01:02:00	2017-02-19 04:11:00	Third station across the Drake Passage.
74	2	-56.7336	-68.6117	2017-02-20 11:57:00	2017-02-21 05:06:24	Trawling station off Diego Ramirez. Times from first and last events. Position from first event. Note that the later events at this station were further away from the first set that first thought, so it would be nice to have these at a different station, however all notes have been made at the first station.
77	3	-54.9994	-55.0103	2017-02-27 21:24:11	2017-02-28 03:02:00	First short marine station of Leg 3.
78	3	-55.0023	-50.0427	2017-02-28 15:37:20	2017-02-28 16:50:00	Station 400 m CTD (Project 18)

83	3	-54.2839	-36.4635	2017-03-02 09:30:00	2017-03-02 20:35:00	Cumberland Bay East - location of acoustic calibration
84	3	-57.1532	-26.764	2017-03-07 00:29:00	2017-03-07 06:20:18	Trawling station off Candlemas Island South Sandwich Islands.
87	3	-54.0172	-37.437	2017-03-03 23:59:00	2017-03-04 05:30:00	Bay of Isles
88	3	-57.0016	-27.9849	2017-03-06 07:01:42	2017-03-06 15:14:18	Full CTD station near South Sandwich Islands.
89	3	-56.9512	-27.9628	2017-03-06 15:30:00	2017-03-06 17:00:00	Iceberg near South Sandwich Islands
90	3	-59.4692	-27.3283	2017-03-07 23:28:00	2017-03-08 05:00:01	Trawling station near Bellingshausen Island.
91	3	-59.5047	-21.0112	2017-03-08 18:26:00	2017-03-08 19:31:00	First short station after South Shetland ISlands.
92	3	-58.6653	-14.0121	2017-03-09 11:21:00	2017-03-09 17:35:00	Full station between South Sandwich Islands and Bouvetøya.
93	3	-57.5052	-7.012	2017-03-10 09:48:00	2017-03-10 10:55:00	Second short station between South Sandwich Islands and Bouvetøya.
94	3	-54.6662	0.9506	2017-03-11 09:19:00	2017-03-11 10:48:00	
98	3	-54.4249	3.5148	2017-03-11 20:06:00	2017-03-12 00:14:00	Bouvetøya - trawling first day
99	3	-54.4065	3.5944	2017-03-13 09:56:00	2017-03-13 12:30:01	Second trawling site at Bouvetøya.
100	3	-51.0433	7.0055	2017-03-14 07:18:00	2017-03-14 09:08:00	First short station after Bouvetøya.
101	3	-49.0003	9.0031	2017-03-14 19:40:00	2017-03-15 02:01:00	
103	3	-43.9953	14.0749	2017-03-16 05:08:00	2017-03-16 14:05:00	Last deep CTD station enroute from Bouvetøya to Cape Town.
104	3	-34.6844	17.2347	2017-03-18 10:47:00	2017-03-18 11:23:00	Short last station with just nets for microplastics.

15.3 CTD casts

Each CTD cast was given a number beginning from 1 which was the first cast of a leg (note that leg 1 had a test cast which was given a cast number of 0). This number began from 1 again at the beginning of each leg. The event number is unique across all equipment deployments and sampling methods that took place across the cruise. CTD cast and Leg number are a unique combination. The cross-referencing between these identifications are listed in the table below for all CTD deployments on Legs 1 - 3. 63 casts took place, with one failure (event 80).

Table 49: Table of CTD casts performed during Legs 1 - 3.

Leg number	CTD cast number	Event number	Station number#	Deployment start time (UTC)	Start latitude (dec degs N)	Start longitude (dec degs E)	Deployment end time (UTC)	End latitude (dec degs N)	End longitude (dec degs E)
1	0	4	0	2016-12-21 12:29:00	-36.932	18.8092	2016-12-21 12:56:00	-36.944	.8304
1	1	75	2	2016-12-28 06:55:00	-46.9196	38.1172	2016-12-28 08:00:00	-46.918	38.112
1	2	80	4	2016-12-28 15:05:00	-46.7138	37.6298	2016-12-28 16:00:00	-46.7119	37.6488
1	3	123	8	2016-12-30 13:10:00	-46.1788	50.9974	2016-12-30 14:02:00	-46.1771	51.0035
1	4	264	16	2017-01-07 05:15:00	-50.987	72.0292	2017-01-07 06:12:00	-50.9831	72.0319
1	5	285	16	2017-01-07 08:23:00	-50.9813	71.9939	2017-01-07 08:51:00	-50.9802	71.996
1	6	317	19	2017-01-09 08:14:00	-53.1688	81.5736	2017-01-09 10:59:00	-53.1464	81.6773
1	7	318	19	2017-01-09 13:04:00	-53.131	81.7266	2017-01-09 13:31:00	-53.1272	81.7374
1	8	369	20	2017-01-11 04:14:00	-54.8512	95.7441	2017-01-11 07:24:00	-54.8237	95.6738
1	9	370	20	2017-01-11 11:05:00	-54.8519	95.7697	2017-01-11 11:37:00	-54.8459	95.7663
1	10	401	21	2017-01-14 02:05:00	-53.1975	118.1205	2017-01-14 03:00:00	-53.1976	118.1365
1	11	402	21	2017-01-14 05:30:00	-53.236	118.1942	2017-01-14 06:00:00	-53.2482	118.2076
1	12	607	22	2017-01-17 06:44:00	-46.9097	141.9254	2017-01-17 08:13:00	-46.8968	141.9389
1	13	608	22	2017-01-17 09:43:00	-46.8913	141.9619	2017-01-17 10:25:00	-46.8851	141.9765
2	1	910	23	2017-01-23 06:14:00	-46.3989	150.4066	2017-01-23 07:48:00	-46.3937	150.3951
2	2	911	23	2017-01-23 10:15:00	-46.3924	150.397	2017-01-23 10:44:00	-46.3897	150.403
2	3	932	24	2017-01-25 00:05:00	-53.5626	149.2557	2017-01-25 01:40:00	-53.5759	149.2919
2	4	934	24	2017-01-25 03:47:00	-53.6092	149.3008	2017-01-25 04:13:00	-53.6178	149.3074
2	5	961	25	2017-01-26 06:08:00	-59.6004	148.5715	2017-01-26 08:18:00	-59.5992	148.6111

2	6	963	25	2017-01-26 11:34:00	-59.6167	148.6469	2017-01-26 11:34:00	-59.6167	148.6469
2	7	1026	26	2017-01-28 22:00:00	-67.1029	144.9368	2017-01-28 22:24:00	-67.1029	144.9327
2	8	1029	26	2017-01-29 01:25:00	-67.1089	144.9291	2017-02-01 01:42:00	-65.8855	147.2954
2	9	1092	32	2017-01-30 07:34:00	-67.0632	144.8988	2017-01-30 08:04:00	-67.0584	144.8918
2	10	1093	33	2017-01-30 08:32:00	-67.0656	144.946	2017-01-30 09:22:00	-67.0625	144.9511
2	11	1094	34	2017-01-30 09:53:00	-67.0651	144.9855	2017-01-30 11:16:00	-67.0655	144.9819
2	12	1095	35	2017-01-30 11:43:00	-67.0641	145.0031	2017-01-30 12:52:00	-67.0622	144.9952
2	13	1096	36	2017-01-30 20:47:00	-67.2076	145.7204	2017-01-30 22:01:00	-67.1959	145.7171
2	14	1099	36	2017-01-30 23:52:00	-67.1758	145.7311	2017-01-31 00:19:00	-67.1699	145.7262
2	15	1103	38	2017-01-31 04:27:00	-66.996	146.0349	2017-01-31 05:19:00	-66.9871	145.9927
2	16	1104	39	2017-01-31 06:39:00	-66.8675	146.1516	2017-01-31 07:03:00	-66.8665	146.149
2	17	1105	40	2017-01-31 08:08:00	-66.752	146.1996	2017-01-31 08:50:00	-66.7504	146.2
2	18	1108	42	2017-01-31 10:02:00	-66.6297	146.2465	2017-01-31 10:26:00	-66.6287	146.2427
2	19	1128	41	2017-01-31 19:45:00	-65.894	146.3318	2017-01-31 20:43:00	-65.8996	146.311
2	20	1144	43	2017-02-02 18:09:00	-66.001	159.003	2017-02-02 19:45:00	-65.9962	159.008
2	21	1156	43	2017-02-02 21:53:00	-65.9803	159.0016	2017-02-02 22:23:00	-65.9746	158.9932
2	22	1240	47	2017-02-04 10:53:00	-67.2913	163.545	2017-02-04 12:14:00	-67.2901	163.5401
2	23	1282	49	2017-02-05 02:32:00	-67.1004	167.3921	2017-02-05 04:04:00	-67.1003	167.3706
2	24	1285	49	2017-02-05 06:12:00	-67.0977	167.3375	2017-02-05 06:45:00	-67.0968	167.3297
2	25	1460	54	2017-02-08 07:07:00	-69.743	-165.0198	2017-02-08 07:51:00	-69.7389	-165.0171
2	26	1465	55	2017-02-08 18:30:00	-70.179	-159.0796	2017-02-08 22:50:00	-70.1966	-159.0595
2	27	1487	56	2017-02-09 22:29:00	-71.6929	-143.7245	2017-02-09 23:55:00	-71.6988	-143.712
2	28	1489	56	2017-02-10 02:00:00	-71.7003	-143.6604	2017-02-10 02:26:00	-71.7013	-143.6443
2	29	1557	59	2017-02-11 09:52:00	-72.9913	-127.8352	2017-02-11 10:49:00	-73.0005	-127.8437
2	30	1626	67	2017-02-13 21:38:00	-70.0017	-115.5093	2017-02-13 22:23:00	-69.9998	-115.5029
2	31	1633	68	2017-02-15 02:58:00	-68.7398	-99.9977	2017-02-15 03:48:00	-68.7445	-99.9736

2	32	1753	70	2017-02-16 15:34:00	-68.0103	-82.0331	2017-02-16 16:08:00	-68.0091	-82.0347
2	33	1878	71	2017-02-18 01:07:00	-63.9696	-66.2697	2017-02-18 01:52:00	-63.9647	-66.2511
2	34	1891	72	2017-02-18 10:09:00	-62.5028	-67.9987	2017-02-18 11:28:00	-62.5106	-68.0244
2	35	1901	73	2017-02-19 01:02:00	-59.5945	-67.9198	2017-02-19 02:17:00	-59.598	-67.911
3	1	2201	77	2017-02-27 21:24:11	-54.9994	-55.0103	2017-02-28 01:06:51	-54.9156	-54.8986
3	2	2263	78	2017-02-28 15:37:20	-55.0023	-50.0427	2017-02-28 16:19:05	-54.9938	-50.039
3	3	2568	88	2017-03-06 07:01:42	-57.0016	-27.9849	2017-03-06 08:40:18	-56.9954	-27.9633
3	4	2576	88	2017-03-06 09:57:00	-56.9956	-27.9509	2017-03-06 10:17:00	-56.9914	-27.9447
3	5	2625	91	2017-03-08 18:26:00	-59.5047	-21.0112	2017-03-08 19:05:00	-59.5013	-21.015
3	6	2652	92	2017-03-09 11:21:00	-58.6653	-14.0121	2017-03-09 12:31:00	-58.6646	-14.0035
3	7	2654	92	2017-03-09 14:28:00	-58.6629	-13.9879	2017-03-09 14:48:00	-58.6626	-13.9852
3	8	2691	93	2017-03-10 09:48:00	-57.5052	-7.012	2017-03-10 10:26:00	-57.5039	-7.008
3	9	2725	94	2017-03-11 09:19:00	-54.6662	0.9506	2017-03-11 10:00:00	-54.6613	0.9605
3	10	2965	100	2017-03-14 07:18:00	-51.0433	7.0055	2017-03-14 08:03:00	-51.0443	6.9979
3	11	2968	101	2017-03-14 19:40:00	-49.0003	9.0031	2017-03-14 20:45:00	-49.0003	8.9989
3	12	2970	101	2017-03-14 22:21:00	-48.9979	8.9997	2017-03-14 22:38:00	-48.9964	9.0026
3	13	3114	103	2017-03-16 05:08:00	-43.9953	14.0749	2017-03-16 07:05:04	-43.9822	14.0759
3	14	3117	103	2017-03-16 09:53:00	-43.981	14.0701	2017-03-16 10:52:00	-43.9801	14.0724

15.4 CTD water sampling

Water samples were taken at various depths during CTD casts. Each project took samples to study different variables – these are listed below in Table 50, with the event number of the CTD cast (see Table 49 for more details on each cast) and each of the variables sampled. More information about the sampling methods can be found in each individual project report.

Table 50: variables sampled from each CTD cast.

Event number	Variables sampled
4	no samples taken
75	ammonium, bacteria, biogenic silica, chlorophyll-a, coulter counter + fv/fm, dic/ta, DNA, fluorescence-activated cell sorting, genetics, metaviromes, nitrate isotopes, nutrients, particulate organic carbon and particulate organic nitrogen, phytoplankton, pigments, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
80	ammonium, bacteria, biogenic silica, dic/alk, genetics, nitrate isotopes, nutrients, oxygen concentration, particulate organic phosphorus and particulate organic nitrogen
123	ammonium, bacteria, biogenic silica, chlorophyll-a, coulter counter + fv/fm, DNA, fluorescence-activated cell sorting, genetics, metaviromes, nitrate isotopes, nutrients, oxygen concentration, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, phytoplankton, pigments, salinity, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
264	amines, ammonium, bacteria, biogenic silica, genetics, metaviromes, nitrate isotopes, nutrients, oxygen concentration, particulate organic carbon and particulate organic nitrogen, phytoplankton
285	bacteria, chlorophyll-a, coulter counter + fv/fm, DNA, fluorescence-activated cell sorting, oxygen concentration, pigments, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
317	ammonium, bacteria, biogenic silica, genetics, metaviromes, nitrate isotopes, nutrients, oxygen concentration, oxygen-18 isotope, particulate and dissolved methylamines and osmolytes, particulate organic carbon and particulate organic nitrogen, salinity
318	bacteria, chlorophyll-a, coulter counter + fv/fm, DNA, fluorescence-activated cell sorting, genetics, metaviromes, pigments, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
369	ammonium, bacteria, biogenic silica, chlorophyll-a, dic/alk, genetics, metaviromes, nitrate isotopes, nutrients, oxygen concentration, oxygen-18 isotope, pH, salinity
370	ammonium, bacteria, biogenic silica, chlorophyll-a, coulter counter + fv/fm, dissolved inorganic carbon, DNA, fluorescence-activated cell sorting, isotopes, nitrogen osmolites, nutrients, particulate organic carbon and particulate organic nitrogen, pH, phytoplankton, pigments, salinity, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
401	ammonium, bacteria, biogenic silica, genetics, metaviromes, nitrate isotopes, nutrients, oxygen-18 isotope, particulate organic phosphorus and particulate organic nitrogen, phytoplankton, salinity
402	bacteria, chlorophyll-a, coulter counter + fv/fm, DNA, fluorescence-activated cell sorting, genetics, metaviromes, nitrogen osmolites, pigments, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
607	ammonium, bacteria, biogenic silica, genetics, metaviromes, nitrate isotopes, nutrients, oxygen-18 isotope, particulate organic phosphorus and particulate organic nitrogen, phytoplankton, salinity
608	bacteria, chlorophyll-a, coulter counter + fv/fm, DNA, fluorescence-activated cell sorting, genetics, metaviromes, nitrogen osmolites, oxygen concentration, pigments, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
910	ammonium, bacteria, biogenic silica, genetics, metaviromes, nitrate isotopes, nutrients, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity

911	amines, bacteria, chlorophyll-a, coulter counter and fv/fm, genetics, metaviromes, pigments, oxygen, transparent exopolymeric particles and coomasie stainable particles, volatiles
932	ammonium, bacteria, biogenic silica, genetics, metaviromes, nitrate isotopes, nutrients, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity
934	genetics
961	metaviromes
963	genetics
1026	bacteria, biogenic silica, genetics, metaviromes, n&n, oxygen concentration, oxygen-18 isotope, particulate organic carbon, phytoplankton, salinity
1029	amines, oxygen concentration, transparent exopolymeric particles and coomasie stainable particles
1092	oxygen concentration, oxygen-18 isotope, salinity
1093	oxygen concentration, oxygen-18 isotope, salinity
1094	oxygen concentration, oxygen-18 isotope, salinity
1095	oxygen concentration, oxygen-18 isotope, salinity
1096	bacteria, biogenic silica, genetics, metaviromes, nutrients, oxygen concentration, oxygen-18 isotope, salinity
1099	genetics
1103	oxygen concentration, oxygen-18 isotope, salinity
1104	oxygen concentration, oxygen-18 isotope, salinity
1105	genetics, oxygen concentration, oxygen-18 isotope, salinity
1108	oxygen-18 isotope, salinity
1128	oxygen concentration, oxygen-18 isotope, salinity
1144	ammonium, biogenic silica, genetics, metaviromes, nitrate isotopes, nutrients, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity
1156	amines, bacteria, chlorophyll-a, coulter counter + fv/fm, genetics, metaviromes, pigments, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
1240	bacteria, biogenic silica, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, genetics, metaviromes, nitrogen isotopes and equivalent nutrients, nutrients, oxygen concentration, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
1282	biogenic silica, genetics, metaviromes, nitrogen isotopes and equivalent nutrients, nutrients, oxygen concentration, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity
1285	amines, bacteria, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, genetics, metaviromes, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
1460	amines, bacteria, biogenic silica, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, genetics, metaviromes, nitrogen isotopes and equivalent nutrients, nutrients, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
1465	biogenic silica, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, genetics, metaviromes, nitrogen isotopes and equivalent nutrients, nutrients, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
1487	biogenic silica, genetics, metaviromes, nitrogen isotopes and equivalent nutrients, nutrients, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity
1489	chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, genetics, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds

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1557	oxygen concentration, oxygen-18 isotope
1626	biogenic silica, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, genetics, metaviromes, nitrogen isotopes and equivalent nutrients, nutrients, oxygen concentration, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity
1633	amines, bacteria, biogenic silica, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, genetics, metaviromes, nitrogen isotopes and equivalent nutrients, nutrients, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity, transparent exopolymeric particles and coomasie stainable particles, volatile organic compounds
1753	oxygen concentration, oxygen-18 isotope, salinity
1878	bacteria, biogenic silica, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, genetics, metaviromes, nitrogen isotopes and equivalent nutrients, nutrients, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity
1891	bacteria, biogenic silica, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, genetics, metaviromes, nitrogen isotopes and equivalent nutrients, nutrients, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity
1901	bacteria, biogenic silica, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, genetics, metaviromes, nitrogen isotopes and equivalent nutrients, nutrients, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity
2201	amines, bacteria, genetics, nitrogen isotopes and equivalent nutrients, nutrients and biogenic silica, oxygen-18 isotope, particulate organic carbon, salinity, viruses, volatile organic compounds, transparent exopolymeric particles and coomasie stainable particles
2263	oxygen-18 isotope, salinity
2568	amines, bacteria, genetics, nitrogen isotopes and equivalent nutrients, nutrients and biogenic silica, oxygen-18 isotope, particulate organic carbon, salinity, viruses, volatile organic compounds, transparent exopolymeric particles and coomasie stainable particles
2576	bacteria, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, DNA, fluorescence-activated cell sorting, genetics, metaviromes, phytoplankton, volatile organic compounds, transparent exopolymeric particles and coomasie stainable particles
2625	amines, genetics, oxygen concentration, oxygen-18 isotope, salinity, volatile organic compounds, transparent exopolymeric particles and coomasie stainable particles
2652	nitrogen isotopes and equivalent nutrients, viruses
2654	amines, bacteria, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, DNA, fluorescence-activated cell sorting, genetics, metaviromes, phytoplankton, volatile organic compounds, transparent exopolymeric particles and coomasie stainable particles
2691	amines, fluorescence-activated cell sorting, genetics, metaviromes, nutrients and biogenic silica, oxygen concentration, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, salinity, volatile organic compounds, transparent exopolymeric particles and coomasie stainable particles
2725	bacteria, fluorescence-activated cell sorting, genetics, metaviromes, nutrients and biogenic silica, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, phytoplankton, salinity
2965	bacteria, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, DNA, fluorescence-activated cell sorting, genetics, nitrogen isotopes and equivalent nutrients, oxygen concentration, oxygen-18 isotope, particulate organic carbon and particulate organic nitrogen, phytoplankton, salinity

2968	bacteria, genetics, nitrogen isotopes and equivalent nutrients, nutrients and biogenic silica, oxygen-18 isotope, particulate organic carbon, salinity, viruses, volatile organic compounds, transparent exopolymeric particles and coomasie stainable particles
2970	amines, bacteria, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, DNA, fluorescence-activated cell sorting, genetics, metaviromes, phytoplankton, volatile organic compounds, transparent exopolymeric particles and coomasie stainable particles
3114	bacteria, DNA, genetics, nitrogen isotopes and equivalent nutrients, nutrients and biogenic silica, oxygen-18 isotope, particulate organic carbon, salinity, viruses, volatile organic compounds, transparent exopolymeric particles and coomasie stainable particles
3117	amines, bacteria, chlorophyll-a, pigments, particle size distribution using the Coulter Counter and photo-physiology using the fast repetition rate fluorometer, DNA, fluorescence-activated cell sorting, genetics, metaviromes, phytoplankton, volatile organic compounds, transparent exopolymeric particles and coomasie stainable particles

15.5 CTD instrumentation

Below this table contains a list of all of the instruments deployed on the CTD rosette during Legs 1 -3.

LEG 1	Channels	1. Frequency	2. Frequency	3. Frequency	4. Frequency	5. Frequency	6. A/D Voltage 0	7. A/D Voltage 1	8. A/D Voltage 2	9. A/D Voltage 3	10. A/D Voltage 4	11. A/D Voltage 5
CTD Cast	Sensor	Temperature 1 - SP 4146	Conductivity 1 - SP 4234	Pressure, Digiquartz, 6000 psi - SP 3730	Temperature 2 - SP 5337	Conductivity 2 - SP 3793	Oxygen, SBE 43 - SP 3430	Fluorometer, WET Labs ECO AFL/FL - SP 4839	Fluorometer, Aquatracka MKIII - SP 3120	Free	Altimeter - SP 5064	Fluorometer, Aquatracka MKIII - SP 4864
Data Not Archived for Cast		y	y	y	y	y	y	y	y	y	y	y
1												
2								Fluorometer, WET Labs ECO AFL/FL - SP 4839		CTD, WET Labs, ECO AM, FLNTUD - SP 4332		
3								Fluorometer, WET Labs ECO AFL/FL - SP 4839		CTD, WET Labs, ECO AM, FLNTUD - SP 4332		
4								Fluorometer, WET Labs ECO AFL/FL - SP 4839		CTD, WET Labs, ECO AM, FLNTUD - SP 4332		
5								Fluorometer, WET Labs ECO AFL/FL - SP 4839		User Polynomial - FLNTUD - SP 4342		
6								Fluorometer, WET Labs ECO AFL/FL - SP 4839		User Polynomial - FLNTUD - SP 4342		
7								Fluorometer, WET Labs ECO AFL/FL - SP 4839		User Polynomial - FLNTUD - SP 4342		
8								Fluorometer, WET Labs ECO AFL/FL - SP 4839		User Polynomial - FLNTUD - SP 4342		
9								Fluorometer, WET Labs ECO AFL/FL - SP 4839		User Polynomial - FLNTUD - SP 4342		
10								Fluorometer, WET Labs ECO AFL/FL - SP 4839		Free		
11								Fluorometer, WET Labs ECO AFL/FL - SP 4839		Free		
12								Fluorometer, WET Labs ECO AFL/FL - SP 4839		Free		
13		y	y	Fluorometer, WET Labs ECO AFL/FL -	y	y	y	Fluorometer, WET Labs ECO AFL/FL - SP 4839	y	Free	y	y

LEG 2	Channels	1. Frequency	2. Frequency	3. Frequency	4. Frequency	5. Frequency	6. A/D Voltage 0	7. A/D Voltage 1	8. A/D Voltage 2	9. A/D Voltage 3	10. A/D Voltage 4	11. A/D Voltage 5
CTD Cast	Sensor	Temperature 1 - SP 4146	Conductivity 1 - SP 4234	Pressure, Digiquartz, 6000 psi - SP 3730	Temperature 2 - SP 5337	Conductivity 2 - SP 3793	Oxygen, SBE 43 - SP 3430	Fluorometer, WET Labs ECO AFL/FL - SP 4839	Fluorometer, Aquatracka MKIII - SP 3120	Free	Altimeter - SP 5064	Fluorometer, Aquatracka MKIII - SP 4864
1		y	y	y	y	y	y	y	y	y	y	y
2		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
3		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
4		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
5		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
6		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
7		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
8		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
9		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
10		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
11		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
12		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
13		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
14		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
15		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
16		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
17		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
18		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
19		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
20		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
20_UP		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
21		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
22		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
23		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
24		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
25		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
26_1		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
27		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
28		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
29		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
30		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
31		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
32		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
33		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
34		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y
35		y	y	y	y	y	y	y	y	User Polynomial - FLNTUD - SP 4911	y	y

LEG 3	Channels	1. Frequency	2. Frequency	3. Frequency	4. Frequency	5. Frequency	6. A/D Voltage 0	7. A/D Voltage 1	8. A/D Voltage 2	9. A/D Voltage 3	10. A/D Voltage 4	11. A/D Voltage 5
CTD Cast	Sensor	Temperature 1 - SP 4146	Conductivity 1 - SP 4234	Pressure, Digiquartz, 6000 psi - SP 3730	Temperature 2 - SP 5337	Conductivity 2 - SP 3793	Oxygen, SBE 43 - SP 3430	Fluorometer, WET Labs ECO AFL/FL - SP 4839	Fluorometer, Aquatracka MKIII - SP 3120	User Polynomial - FLNTUD - SP 4911	Altimeter - SP 5064	Fluorometer, Aquatracka MKIII - SP 4864
1		y	y	y	y	y	y	y	y	y	y	y
2		y	y	y	y	y	y	CMS, WET Labs ECO AM - SP 4331	y	y	Free	Free
3		y	y	y	y	y	y	y	y	y	Free	Free
4		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
5		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
6		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
7		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
8		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
9		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
10		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
11		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
12		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
13		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
13_A		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free
14		y	y	y	Oxygen, SBE 43 - SP 3430	CMS, WET Labs ECO AM - SP 4331	Fluorometer, Seapoint - SP 3220	User Polynomial - FLNTUD - SP 4911	Fluorometer, Aquatracka MKIII - SP 4864	Altimeter - SP 5064	Free	Free

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ECO Chlorophyll Fluorometer Characterization Sheet

Date: 6/16/2016 S/N: FLBBRTD-4391

Chlorophyll concentration expressed in µg/l can be derived using the equation:

CHL (µg/l) = Scale Factor * (Output - Dark counts)

	Analog		Digital
Dark counts	0.070	V	42 counts
Scale Factor (SF)	6	µg/l/V	0.0073 µg/l/count
Maximum Output	4.98	V	4130 counts
Resolution	0.6	mV	1.0 counts
Ambient temperature during characterization			22.0 °C

Dark Counts: Signal output of the meter in clean water with black tape over detector.

SF: Determined using the following equation: SF = x ÷ (output - dark counts), where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

Maximum Output: Maximum signal output the fluorometer is capable of.

Resolution: Standard deviation of 1 minute of collected data.

The relationship between fluorescence and chlorophyll-a concentrations in-situ is highly variable. The scale factor listed on this document was determined using a mono-culture of phytoplankton (Thalassiosira weissflogii). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer, you must perform secondary measurements on the populations of interest. This is typically done using extraction-based measurement techniques on discrete samples. For additional information on determining chlorophyll concentration see "Standard Methods for the Examination of Water and Wastewater" part 10200 H, published jointly by the American Public Health Association, American Water Works Association, and the Water Environment Federation.

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Scattering Meter Calibration Sheet

6/16/2016
Wavelength: 700 S/N FLBBRTD-4391

Use the following equation to obtain either digital or analog "scaled" output values:

$\beta(\theta_c)\ m^{-1}\ sr^{-1}$ = Scale Factor x (Output - Dark Counts)

• **Scale Factor for 700 nm**	=	1.620E-06 $(m^{-1}sr^{-1})$/counts	1.330E-03 $(m^{-1}sr^{-1})$/volts
• **Output**	=	meter output counts	meter output volts
• **Dark Counts**	=	46 counts	0.0619 volts
Instrument Resolution	=	1.0 counts	1.62E-06 $(m^{-1}sr^{-1})$
		1.3170 mV	

Definitions:

- **Scale Factor**: Calibration scale factor, $\beta(\theta_c)$/counts. Refer to User's Guide for derivation.
- **Output**: Measured signal output of the scattering meter.
- **Dark Counts**: Signal obtained by covering detector with black tape and submersing sensor in water.

Instrument Resolution: Standard deviation of 1 minute of collected data.

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ECO CDOM Fluorometer Characterization Sheet

Date: 1/14/2016 S/N: FLCDRTD-2344

CDOM (Quinine Dihydrate Equivalent) concentration expressed in ppb can be derived using the equation:

CDOM (QSDE) = Scale Factor * (Output - Dark Counts)

	Analog Range 1	Analog Range 2	Analog Range 4 (default)		Digital	
Dark Counts	0.086	0.044	0.025	V	60	counts
Scale Factor (SF)	20	40	79	ppb/V	0.0240	ppb/count
Maximum Output	4.98	4.98	4.98	V	16410	counts
Resolution	2.4	2.4	2.4	mV	2.5	counts

Ambient temperature during characterization 22.3 °C

Analog Range: 1 (most sensitive, 0–4,000 counts), 2 (midrange, 0–8,000 counts), 4 (entire range, 0–16,000 counts).

Dark Counts: Signal output of the meter in clean water with black tape over detector.

SF: Determined using the following equation: SF = $x \div$ (output - dark counts), where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

Maximum Output: Maximum signal output the fluorometer is capable of.

Resolution: Standard deviation of 1 minute of collected data.

PSA916 Altimeter
Serial number 50414

Calibration Coefficients

```
<?xml version="1.0" encoding="UTF-8"?>
<AltimeterSensor SensorID="0" SB_ConfigCTD_FileVersion="7.23.0.2" >
  <SerialNumber>50414</SerialNumber>
  <CalibrationDate>24-Jun-10</CalibrationDate>
  <ScaleFactor>15.000</ScaleFactor>
  <Offset>0.000</Offset>
</AltimeterSensor>
```

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

LOG SENSOR

Calibration Date: 12/9/15
Model Number: QCP2300
Serial Number: 4664
Operator: TPC
Standard Lamp: V-033(3/3/15)
Operating Voltage Range: 6 to 15 VDC (+)

Note: The QCP-2300 uses a log amplifier to measure the detector signal current with V = log I (Amps) / I_{Ref}

To calculate irradiance, use this formula:

Irradiance = Calibration factor * (10^Light Signal Voltage - 10^Dark Voltage)

With the appropriate (solar corrected) Irradiance Calibration Factor:

Dry Calibration Factor:	**2.38E+11**	**quanta/cm²·sec/"amps"**	**3.94E-07**	**µEinsteins/cm²·sec/"amps"**
Wet Calibration Factor:	**2.50E+11**	**quanta/cm²·sec/"amps"**	**4.15E-07**	**µEinsteins/cm²·sec/"amps"**

Sensor Test Data and Results[4)]

Sensor Supply Current (Dark):		85.3	mA							
Supply Voltage:		6	Volts							
Lamp Integrated PAR Irradiance:		9.39E+15	quanta/cm²·sec		0.01559	µEinsteins/cm²sec				
Q2-3 Immersion Coefficient:		0.95	Scalar Correction:		1	PAR Solar Correction:				1.0000
Nominal Filter OD	Calibrated Trans.	Sensor Voltage	Measured Trans.		Measured Signal (Amps)	Estimated Signal (Amps)	Calc. Output (Volts)	Error (Volts)	Error (%)	Test Irrad. (quanta/ cm²·sec)
No Filter	100.00%	4.597	100.00%		3.95E-06	3.95E-06	4.597	0.000	0.0	9.39E+15
0.3	36.10%	4.161	36.64%		1.45E-06	1.43E-06	4.155	-0.006	-1.5	3.44E+15
0.5	27.60%	4.049	28.30%		1.12E-06	1.09E-06	4.038	-0.011	-2.5	2.66E+15
1	9.27%	3.593	9.91%		3.92E-07	3.67E-07	3.564	-0.029	-6.4	9.30E+14
2	1.11%	2.700	1.26%		5.00E-08	4.39E-08	2.644	-0.056	-12.2	1.19E+14
3	0.05%	1.574	0.09%		3.61E-09	2.11E-09	1.353	-0.221	-41.5	8.57E+12
RG780	0%	1.344	0.05%		2.07E-09	0.00E+00	0.151	-1.193	-100.0	4.91E+12

Dark Before: 0.151 Volts
Light - No Filter Hldr.: 4.597 Volts
Dark After - NFH: 0.151 Volts
Average Dark 0.1512

I_{Ref} = 1.00E-10 Amps
I_{Dark} = 1.42E-10 Amps
10^{vDark} = 1.416446 Amps

Notes:
1. Annual calibration is recommended.
2. There is increasing error associated with readings below zero.
3. The collector should be cleaned frequently with alcohol.
4) This section is for internal use and for more advanced analysis.

QXX-nnnL Ver. 12/7/98 DGG

SeaBird SBE 3+ Temperature Sensor
Serial number 5307

Calibration Coefficients

```
<?xml version="1.0" encoding="UTF-8"?>
<TemperatureSensor SensorID="55" SB_ConfigCTD_FileVersion="7.23.0.2" >
  <SerialNumber>5307</SerialNumber>
  <CalibrationDate>22-Dec-15</CalibrationDate>
  <UseG_J>1</UseG_J>
  <A>0.00000000e+000</A>
  <B>0.00000000e+000</B>
  <C>0.00000000e+000</C>
  <D>0.00000000e+000</D>
  <F0_Old>0.000</F0_Old>
  <G>4.39600705e-003</G>
  <H>6.37462343e-004</H>
  <I>2.22794871e-005</I>
  <J>2.07724783e-006</J>
  <F0>1000.000</F0>
  <Slope>1.00000000</Slope>
  <Offset>0.0000</Offset>
</TemperatureSensor>
```

Sea-Bird Electronics, Inc.
13431 NE 20th St. Bellevue, Washington 98005 USA
www.seabird.com
Phone: (425) 643-9866
Fax: (425) 643-9954
Email: seabird@seabird.com

Pressure Test Certificate

Test Date: **2016-10-27** Description: **SBE-3 Temperature Sensor**

Sensor Information:

Model Number: **SBE-3**

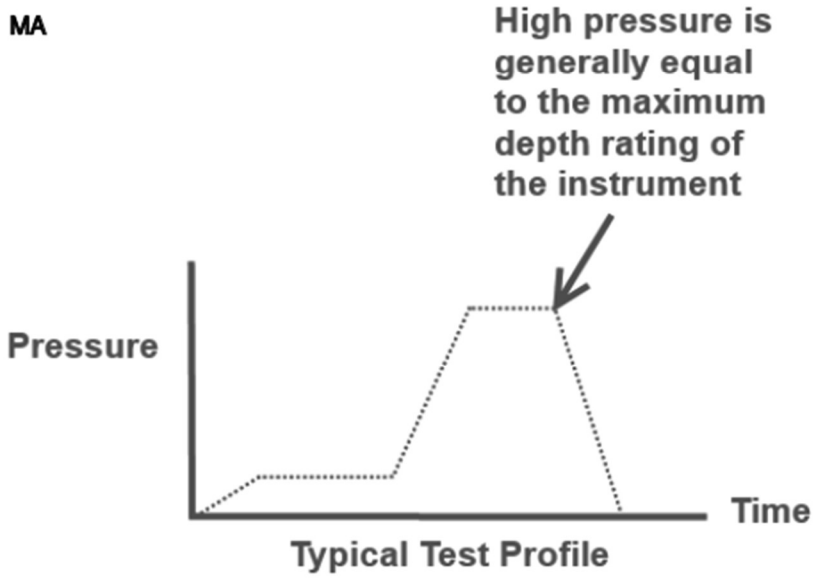
Serial Number: **6146**

Pressure Test Protocol:

Low Pressure Test: **40**	PSI	Held For: **15**	Minutes
High Pressure Test: **10000**	PSI	Held For: **15**	Minutes

Passed Test: **True**

Tested By: **MA**



Typical Test Profile

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 6146
CALIBRATION DATE: 18-Oct-16

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

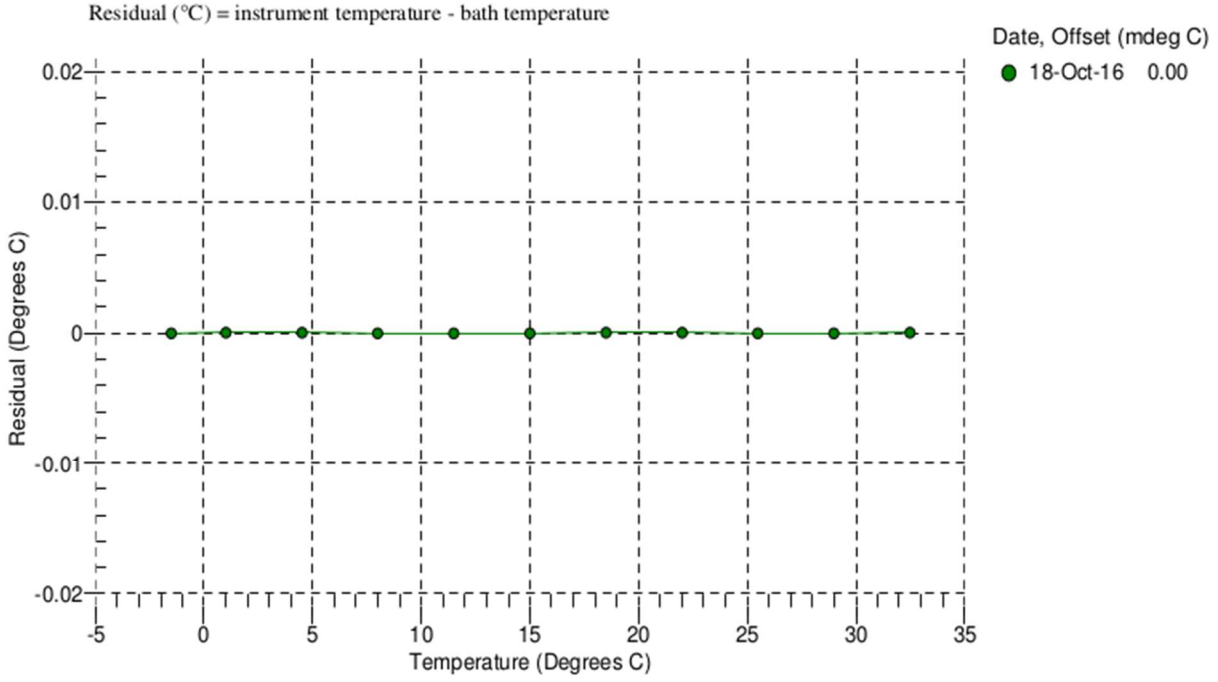
g = 4.35657614e-003
h = 6.37217402e-004
i = 2.23019622e-005
j = 2.09167184e-006
f0 = 1000.0

BATH TEMP (°C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (°C)	RESIDUAL (°C)
-1.5000	2997.270	-1.5000	-0.00001
1.0000	3171.249	1.0000	0.00000
4.5000	3426.961	4.5000	0.00003
8.0000	3697.202	8.0000	-0.00002
11.5001	3982.388	11.5001	-0.00002
15.0001	4282.890	15.0001	-0.00000
18.5000	4599.083	18.5000	0.00002
22.0000	4931.346	22.0000	0.00002
25.5000	5280.024	25.5000	-0.00000
29.0001	5645.468	29.0001	-0.00003
32.5000	6027.981	32.5000	0.00002

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 3430
CALIBRATION DATE: 18-Oct-16

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:	A = -2.7702e-003	NOMINAL DYNAMIC COEFFICIENTS	
Soc = 0.5541	B = 1.3649e-004	D1 = 1.92634e-4	H1 = -3.300000e-2
Voffset = -0.4838	C = -2.2345e-006	D2 = -4.64803e-2	H2 = 5.00000e+3
Tau20 = 1.94	E nominal = 0.036		H3 = 1.45000e+3

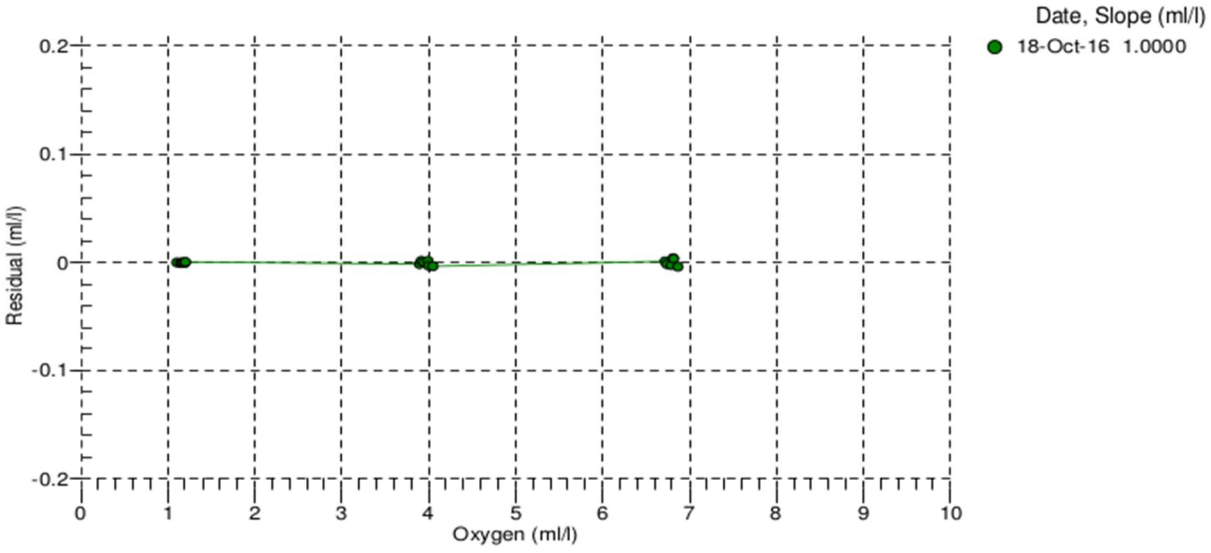
BATH OXYGEN (ml/l)	BATH TEMPERATURE (°C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.11	2.00	0.00	0.691	1.11	0.00
1.15	6.00	0.00	0.725	1.15	-0.00
1.16	12.00	0.00	0.767	1.16	0.00
1.17	20.00	0.00	0.823	1.17	-0.00
1.20	26.00	0.00	0.871	1.20	-0.00
1.20	30.00	0.00	0.903	1.20	0.00
3.90	2.00	0.00	1.214	3.90	-0.00
3.91	6.00	0.00	1.305	3.91	0.00
3.94	12.00	0.00	1.444	3.94	0.00
3.99	20.00	0.00	1.639	4.00	0.00
4.00	26.00	0.00	1.780	4.00	-0.00
4.05	30.00	0.00	1.893	4.05	-0.00
6.72	2.00	0.00	1.743	6.72	0.00
6.74	6.00	0.00	1.897	6.74	-0.00
6.79	12.00	0.00	2.137	6.79	-0.00
6.81	30.00	0.00	2.858	6.82	0.00
6.82	20.00	0.00	2.457	6.82	0.00
6.87	26.00	0.00	2.707	6.86	-0.00

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)

Oxsol(T,S) = oxygen saturation (ml/l); P = pressure (dbar)

$$\text{Oxygen (ml/l)} = \text{Soc} * (V + \text{Voffset}) * (1.0 + A * T + B * T^2 + C * T^3) * \text{Oxsol}(T,S) * \exp(E * P / K)$$

Residual (ml/l) = instrument oxygen - bath oxygen



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Pressure Test Certificate

Test Date: **07/18/16** Description: **SBE-43 DO Sensor**

Sensor Information:

Model Number: **43**

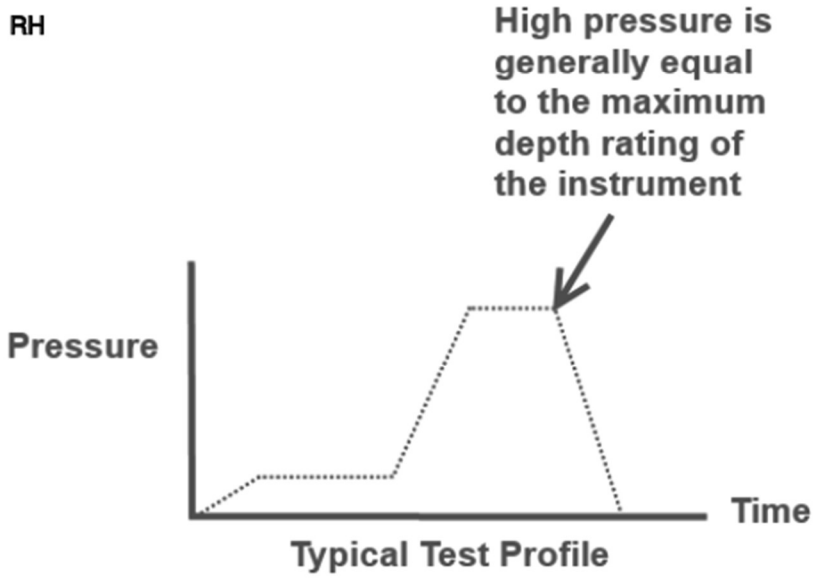
Serial Number: **3430**

Pressure Test Protocol:

Low Pressure Test:	**40**	PSI	Held For:	**15**	Minutes
High Pressure Test:	**10000**	PSI	Held For:	**15**	Minutes

Passed Test: **Yes**

Tested By: **RH**



Typical Test Profile

SeaBird SBE 4C Conductivity Sensor
Serial number 3793

Calibration Coefficients

```
<?xml version="1.0" encoding="UTF-8"?>
<ConductivitySensor SensorID="3" SB_ConfigCTD_FileVersion="7.23.0.2" >
  <SerialNumber>3793</SerialNumber>
  <CalibrationDate>10-Dec-15</CalibrationDate>
  <UseG_J>1</UseG_J>
  <!-- Cell const and series R are applicable only for wide range sensors. -->
  <SeriesR>0.0000</SeriesR>
  <CellConst>2000.0000</CellConst>
  <ConductivityType>0</ConductivityType>
  <Coefficients equation="0" >
    <A>0.00000000e+000</A>
    <B>0.00000000e+000</B>
    <C>0.00000000e+000</C>
    <D>0.00000000e+000</D>
    <M>0.0</M>
    <CPcor>-9.57000000e-008</CPcor>
  </Coefficients>
  <Coefficients equation="1" >
    <G>-1.03242424e+001</G>
    <H>1.54005141e+000</H>
    <I>-1.07101801e-003</I>
    <J>1.80478166e-004</J>
    <CPcor>-9.57000000e-008</CPcor>
    <CTcor>3.2500e-006</CTcor>
    <!-- WBOTC not applicable unless ConductivityType = 1. -->
    <WBOTC>0.00000000e+000</WBOTC>
  </Coefficients>
  <Slope>1.00000000</Slope>
  <Offset>0.00000</Offset>
</ConductivitySensor>
```

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4624
CALIBRATION DATE: 06-Oct-16

SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -9.84048254e+000
h = 1.44191703e+000
i = -4.24710763e-003
j = 3.90992198e-004

CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

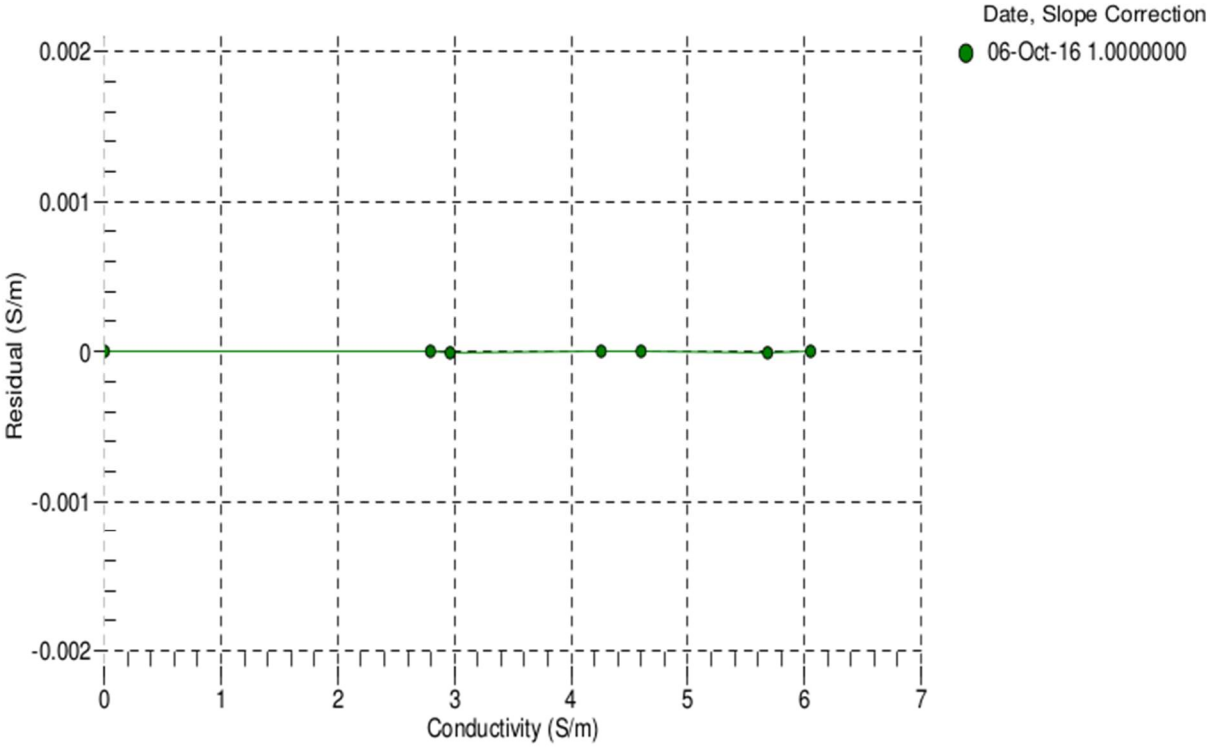
BATH TEMP (°C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.62007	0.00000	0.00000
-1.0000	34.6648	2.79351	5.13894	2.79351	0.00000
0.9999	34.6658	2.96432	5.25389	2.96431	-0.00001
15.0000	34.6673	4.25526	6.05197	4.25527	0.00000
18.5000	34.6675	4.60075	6.24811	4.60076	0.00000
29.0000	34.6672	5.68064	6.82442	5.68063	-0.00001
32.5000	34.6625	6.05220	7.01158	6.05220	0.00000

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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Fax: (425) 643-9954
Email: seabird@seabird.com

Pressure Test Certificate

Test Date: **03/17/16** Description: **SBE-4 Conductivity Sensor**

Sensor Information:

Model Number: **04**

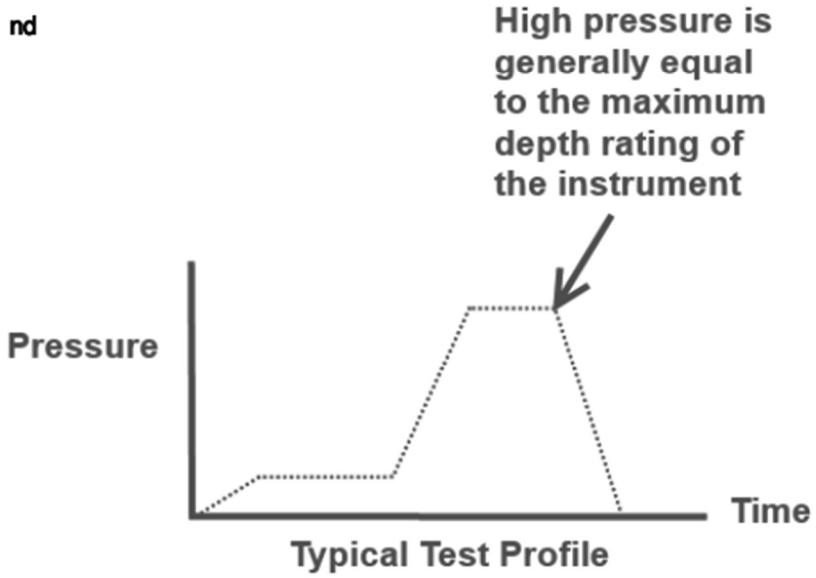
Serial Number: **4624**

Pressure Test Protocol:

Low Pressure Test: **40**	PSI	Held For: **15**	Minutes
High Pressure Test: **10000**	PSI	Held For: **15**	Minutes

Passed Test: **Yes**

Tested By: **nd**



Typical Test Profile

Calibration Record

Date: January 27, 2015
Sensor Type: Seapoint Chlorophyll Fluorometer
Serial Number(s): 3120

A comparative calibration was performed using a calibrated reference fluorometer. The reference fluorometer was calibrated with the cultured algae Isochrysis galbana.

This Seapoint Chlorophyll Fluorometer meets or exceeds the specifications stated in the supplied User Manual.

If you have any questions please contact me at 603/642-4921 or seapoint@seapoint.com

01/27/15

Signature Date

Seapoint Sensors, inc.
PO Box 368 • Exeter, NH 03833 • USA
Tel: (603) 642-4921 • Fax: (603) 642-4922
seapoint@seapoint.com • www.seapoint.com

Sea-Bird Electronics, Inc.

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SENSOR SERIAL NUMBER: 6146
CALIBRATION DATE: 19-Apr-17

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

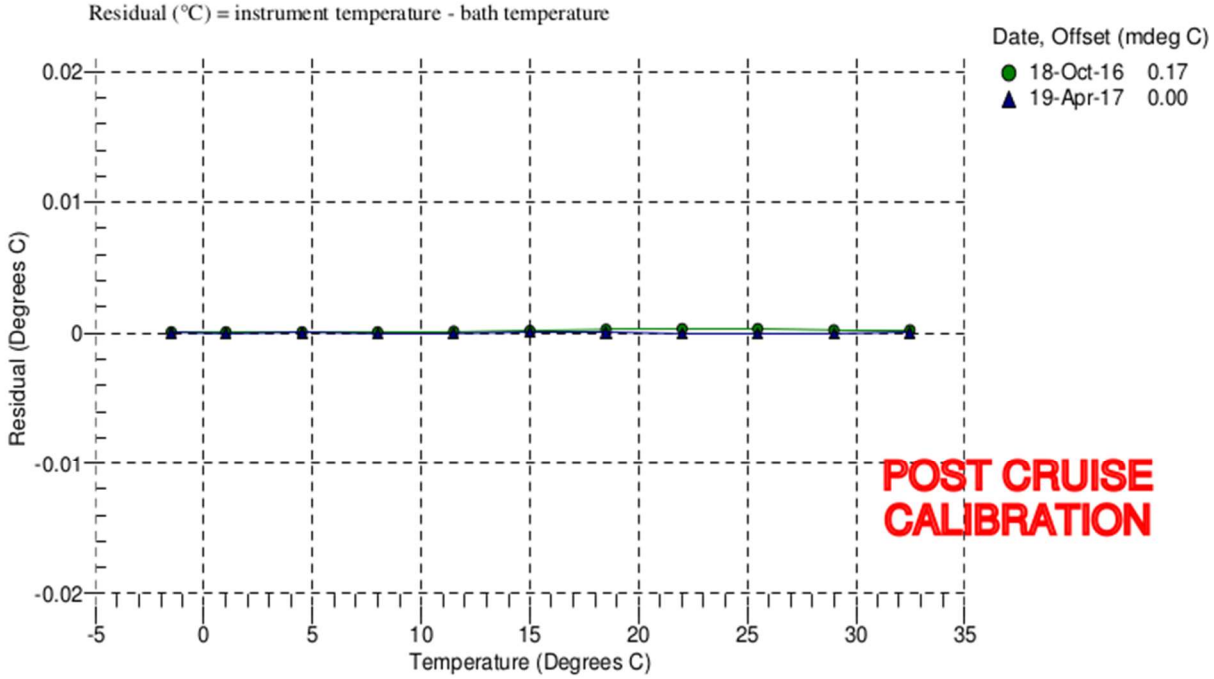
g = 4.35638771e-003
h = 6.36803077e-004
i = 2.20028262e-005
j = 2.02138975e-006
f0 = 1000.0

BATH TEMP (°C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (°C)	RESIDUAL (°C)
-1.5000	2997.266	-1.5000	0.00002
1.0000	3171.244	1.0000	-0.00002
4.5000	3426.956	4.5000	0.00001
8.0000	3697.194	8.0000	-0.00004
11.5000	3982.370	11.5000	-0.00000
15.0000	4282.870	15.0001	0.00007
18.5000	4599.058	18.5000	0.00001
22.0001	4931.323	22.0001	-0.00002
25.5000	5279.991	25.5000	-0.00002
29.0001	5645.439	29.0001	-0.00003
32.5000	6027.961	32.5000	0.00003

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4624
CALIBRATION DATE: 19-Apr-17

SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -9.85244329e+000
h =   1.44409827e+000
i =  -4.52452600e-003
j =   4.04701891e-004

CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

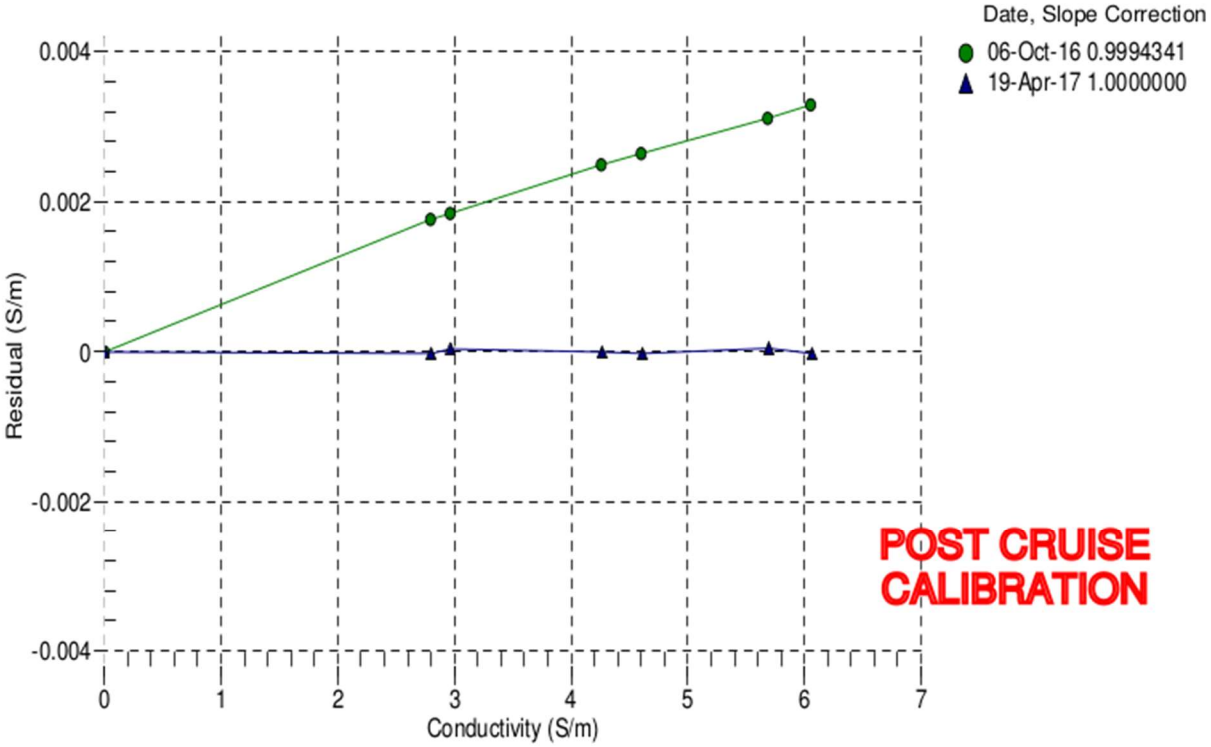
BATH TEMP (°C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.62025	0.00000	0.00000
-1.0000	34.7511	2.79981	5.14202	2.79979	-0.00002
1.0000	34.7513	2.97094	5.25709	2.97097	0.00003
15.0000	34.7517	4.26453	6.05587	4.26452	-0.00001
18.5000	34.7505	4.61058	6.25211	4.61056	-0.00002
29.0000	34.7423	5.69156	6.82843	5.69161	0.00005
32.5001	34.7269	6.06217	7.01489	6.06214	-0.00003

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



15.7 Underway water sampling

Water was sampled from the underway water supply which had an intake at 4.5 m below the surface of the sea. For more information about the operation of this water supply, see section 7.6 of this document. ACE projects sampled the water at different intervals (sampling frequency) throughout the expedition to measure the parameters listed in Table 51. Complementary samples were also taken from CTD deployments (see Table 50). More information about the methods used and processing of samples can be found within each project report.

Table 51: variables sampled at different frequencies from the underway water supply.

Variable sampled	**Sampling frequency**
chlorophyll-a	3 hours
fast repetition rate fluorometer	3 hours
high performance liquid chromatography	3 hours
nutrients	3 hours
oxygen-18 isotopes	3 hours
particle size distribution	3 hours
particulate organic carbon	3 hours
salinity	3 hours
amines	6 hours
bacteria and phytoplankton	6 hours
coloured dissolved organic matter	6 hours
coomasie stainable particles	6 hours
dimethylsulphoniopropionate concentration	6 hours
DNA	6 hours
flow cytometry	6 hours
fluorescence-activated cell sorting	6 hours
osmolytes	6 hours
particulate organic carbon and particulate organic nitrogen	6 hours
transparent exopolymeric particles	6 hours
volatiles	6 hours
dissolved inorganic carbon	6-9 hours
metaviromes	6-24 hours, depending on CTD availability
biogenic silica	12 hours
chromium isotopes	12 hours
chromium speciation	12 hours
microplastics	12 hours
chemical compounds	12 hours
ice nuclei number concentration	12 hours
silicon isotopes	12 hours
stable water isotopes	once per day from underway/CTD

15.8 FerryBox calibration certificates

Chelsea Technologies Group Ltd

Certificate Of Pressure Test

CERTIFICATE OF CALIBRATION

All test equipment and standards used are of known accuracy and traceable to national standards. Details of test equipment and standards relevant to this certificate are available upon request.

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www.chelsea.co.uk

Date of Issue:	7th September 2016
Part Number:	0210-7495N
WOT Number:	160412
Description:	Minipack CTD fluorimeter (Nephelometer)
Serial Number:	10-7676-001

REPORT

Minipack is a CTD unit combined with a fluorimeter. Data is transmitted, via an RS422 link, as a series of bit values (in the range 0 to 65535), one value per sensor (see the instrument handbook for a full description). The following equations have been determined to relate the instrument output (in bits) to the sensor stimulus. The experimental results reported are each the average of approximately 30 seconds of data. For the purposes of calibration, the instrument was set to transmit a set of bit values once per second, with burst mode 3 operational.

Pressure sensor

The pressure sensor was calibrated by connecting a precision pressure balance directly to the pressure port in the instrument sensor plate. A series of known pressures was then applied at an ambient temperature of 20°C. All pressure values are quoted relative to standard atmospheric pressure of 1013.25mbar.

A least squares best fit quadratic to the experimentally determined pressure/bit values, listed below, gives the formula:-

$$\text{Press.} = (-1.199156 \times 10^{-9} \times \text{bits}^2) + (9.523059 \times 10^{-3} \times \text{bits}) - 7.343432$$

Where:-

press. = water pressure in dbar
bits = bit output from the pressure sensor

At the time of calibration, this formula was found to be valid in the range 0 to 600 dbar, to an uncertainty of 0.05 dbar under the conditions stated above.

Temperature sensor

The temperature sensor was calibrated by immersing the entire Minipack in a temperature controlled water bath, the temperature of which was determined by a high precision Standard Platinum Resistance Thermometer. Various temperature were used, as listed below, and at each temperature, the Minipack was allowed to stabilise for a minimum of 60 minutes before readings were taken.

A least squares best fit quadratic to the experimentally determined temperature/bit values, listed below, gives the formula:-

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Registered at the above address

$$Temp. = (6.086459 \times 10^{-11} \times bits^2) + (5.99115 \times 10^{-4} \times bits) - 2.629153$$

Where:-

temp = temperature on the IPTS-68 scale
bits = bit output from the temperature sensor

At the time of calibration, this formula was found to be valid in the range -2 to 35°C, to an uncertainty of 3mK under the conditions stated above.

Conductivity sensor

The conductivity sensor was calibrated by immersing the entire Minipack in 5 brine baths of differing salinity, each one at a temperature of 20°C. The salinity of the baths was measured using a salinometer standardised against Standard Seawater supplied by Ocean Scientific. The Minipack was allowed to stabilise in each bath for a minimum of 60 minutes before any data was taken.

The measured salinities were converted to conductivity values, assuming a conductivity of 42.914 $mScm^{-1}$ for salinity 35.0 standard seawater at 15.0°C (IPTS-68).

A least squares best fit quadratic to the experimentally determined conductivity/bit values, listed below, gives the formula:-

$$Cond. = (-3.369569 \times 10^{-11} \times bits^2) + (1.106927 \times 10^{-3} \times bits) - 0.8667911$$

Where:-

cond = conductivity in $mScm^{-1}$
bits = bit output from the conductivity sensor

At the time of calibration, this formula was found to be valid in the range 0 to 70$mScm^{-1}$, to an uncertainty of 0.015$mScm^{-1}$ under the conditions stated above.

Fluorimeter

Nephelometer

Readings have been taken from the Nephelometer for a 100 FTU concentration of Formazin, prepared according to BS 6068 part 2.13 (ISO7027), suspended in pure water. A reading for pure water was also taken. The following formula is derived from these readings and relates instrument output in bits to turbidity.

$$FTU. = (0.002172189 \times Bits) - 4.069814$$

Where:-

FTU = Turbidity in FTU
Bits = Minipack output in bits when exposed to Formazin suspended in water

The above formula can be used in the range 0 - 100 FTU to an uncertainty of 0.1 FTU plus 3% of value.

Chelsea Technologies Group Ltd

Certificate Of Pressure Test

Temperature calibration readings

Bit Reading	Applied Temp °C (IPTS-68)
7674.411	1.977699
11832.857	4.465680
15990.643	6.958881
20143.215	9.465022
24293.418	11.962616
28440.510	14.461438
32577.264	16.952761
36712.555	19.451044
40849.590	21.944145
44983.680	24.447851
49114.227	26.936249
53240.242	29.442787

The uncertainty of the applied temperature is estimated not to exceed 1mK.

Conductivity calibration readings

Ambient temperature = 20°C

Bit reading	Applied conductivity $mScm^{-1}$
15109.3	15.8501
15110.9	15.8513
15110.5	15.8490
22163.4	23.6549
22164.7	23.6554
22164.6	23.6564
32542.5	35.1112
32543.6	35.1126
32544.6	35.1136
42381.0	45.9956
42381.5	45.9964
42384.2	45.9951
48265.5	52.4774
48270.7	52.4806
48270.1	52.4843

The uncertainty of the applied conductivity, assuming a conductivity of 42.914mScm-1 for salinity 35.0 standard seawater at 15°C (IPTS-68), is estimated not to exceed 0.002mScm-1.

Chelsea Technologies Group Ltd

Certificate Of Pressure Test

Pressure calibration readings

Ambient temperature = 20°C

Bit output	Applied pressure dbar
773.1	-0.003
5998.3	49.742
18317.0	166.720
30678.9	283.703
43080.3	400.685
55523.6	517.666
64242.5	599.548

The uncertainty of the applied pressure is estimated not to exceed 0.004% of value + 1mbar. The above applied pressure values are relative to a standard atmospheric pressure of 1013.25mbar

Fluorimeter calibration readings

Nephelometer

Ambient temperature 20°C

Output for detector aperture blocked	905.0 bits
Output for pure water	1873.6 bits
Output for 100 FTU suspension in water	47910.1 bits

The uncertainty of the turbidity is estimated to be less than 1%.

Equipment used during calibration :-
This instrument has had a multi-point calibration, for information on the equipment used, please consult the Calibration Manager

Name: M.J.Nicholson

Signed:

Date : 7th September 2016

Chelsea Technologies Group Ltd
Certificate Of Pressure Test

TEST REPORT

Chelsea Technologies Group Ltd

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Surrey KT8 2QZ
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Fax: +44 (0)20 8941 9319
sales@chelsea.co.uk
www.chelsea.co.uk

All test equipment and standards used are of known accuracy and traceable to national standards. Details of test equipment and standards relevant to this certificate are available upon request.

Date of Issue:	7th September 2016
Part Number:	0210-7495N
WOT Number:	WO160412
Description:	Minipack CTD (Nephelometer)
Serial Number:	10-7676-001

This is to certify that the Minipack has been pressure tested for 1 hour at 60 bar and is suitable for use to a maximum depth of 600 Metres

Equipment used during testing :-
Pressure chamber Cil 219

Signed:  **M.J.Nicholson**

Date: 7th September 2016

Registration No: 00832429
Registered at the above address

 Distribution List: Works Order Traveller **Product History Folder (Electronic Copy)**

AANDERAA a xylem brand

CALIBRATION CERTIFICATE

Sensing Foil Batch No: 5009
Certificate No:

Product: Oxygen Optode 3835
Serial No: 1367
Calibration Date: 23 Sep 2016

This is to certify that this product has been calibrated using the following instruments:

Calibration Bath model FNT 321-1-40
ASL Digital Thermometer model F250 Serial: 6792/06

Parameter: Internal Temperature:

Calibration points and readings:

Temperature (°C)	1.02	11.98	24.02	36.01
Reading (mV)	781.17	442.10	46.76	-326.25

Giving these coefficients

Index	0	1	2	3
TempCoef	2.54636E01	-3.09327E-02	2.86541E-06	-4.25774E-09

Parameter: Oxygen:

	O2 Concentration	Air Saturation
Range:	0-500 µM [1]	0 - 120%
Accuracy[1]:	< ±8µM or ±5% (whichever is greater)	±5%
Resolution:	< 1 µM	< 0.4%
Settling Time (63%):	< 25 seconds	

Calibration points and readings[2]:

	Air Saturated Water	Zero Solution (Na_2SO_3)
Phase reading (°)	3.31921E+01	6.54226E+01
Temperature reading (°C)	9.93740E+00	2.26085E+01
Air Pressure (hPa)	1.00160E+03	

Giving these coefficients

Index	0	1	2	3
PhaseCoef	-5.98884E00	1.19149E00	0.00000E00	0.00000E00

[1] *Valid for 0 to 2000m (6562ft) depth, salinity 33 - 37ppt*
[2] *The calibration is performed in fresh water and the salinity setting is set to:* 0

AANDERAA a xylem brand

CALIBRATION CERTIFICATE

Sensing Foil Batch No: 5009
Certificate No:

Product: Oxygen Optode 3835
Serial No: 1367
Calibration Date: 23 Sep 2016

SR10 Scaling Coefficients:

At the SR10 output the Oxygen Optode 3830 can give either absolute oxygen concentration in µM or air saturation in %. The setting of the internal property "Output" [3], controls the selection of the unit. The coefficients for converting SR10 raw data to engineering units are fixed.

Output = -1	Output = -2
A = 0	A = 0
B = 4.883E-01	B = 1.465E-01
C = 0	C = 0
D = 0	D = 0
Oxygen (µM) = A + BN + CN2 + DN3	Oxygen (%)= A + BN + CN2 + DN3

[3] The default output setting is set to -1

Date: 23 Sep 2016

Sign:

Tor-Ove Kvalvaag, Calibration Engineer

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SERVICE REPORT

Service Request 1005500114
Date 19-SEP-2016

CUSTOMER INFORMATION

Name: CHELSEA TECHNOLOGIES GROUP LTD.
Account : 40280417
BRUCE KIMBER
bkimber@chelsea.co.uk

PO Number:
PO160695

Bill To Address
55 CENTRAL AVENUE;WEST MOLESEY;
SURREY,KT8 2QZ,Surrey,GB

Ship To Address
55 CENTRAL AVENUE;WEST MOLESEY;
SURREY,KT8 2QZ,Surrey,GB

EVAL/CAL SBE 18 SN 180789

PRODUCT INFORMATION

Item: 18.LEGACY
Item Description: (LEGACY) SBE 18 pH Sensor
Serial: 180789

Special Notes
Services Requested:
Evaluate/Repair Instrumentation.
Perform Routine Calibration Service.
Replace the instruments "O"-rings.

Problems Found:
No Post Cal Possible.
The pH electrode was found to have reached the end of its life expectancy.

Services Performed:
Perform initial diagnostic evaluation.
Replaced the pH electrode.
Replaced the O-rings.
Performed a hydrostatic pressure test.
Performed a "Final" Calibration.

Item	Item Description	Qty
CAL_PH	SBE 18 OR SBE 27 PH ONLY CALIBRATION (4, 7, 10 PH) (FRRF)	1
CONCERT/S	CONFIRM AND RECERTIFY MODULAR SENSOR (FRRF)	1
REP/PH	REPLACE INNOVATIVE SENSORS PH ELECTRODE IN SBE 18 OR SBE 27 PH SENSOR (FRRF)	1

Unbilled Items

Item	Item Description	Qty
24023	PH SENSOR, 1/4" ISO,. P/N SBE-24023	1

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SERVICE REPORT

Service Request **1005500114**
Date 19-SEP-2016

CERTIFICATE OF CALIBRATION

All test equipment and standards used are of known accuracy and traceable to national standards. Details of test equipment and standards relevant to this certificate are available upon request.

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Fax: +44 (0)20 8941 9319
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www.chelsea.co.uk

Date of Issue:	24th August 2016
Part Number:	2125-016-PL-D
WOT Number:	160413
Description:	UniLux (Chlorophyll)
Serial Number:	024

REPORT

The Chlorophyll UniLux is provided with a calibration for the range 0-100µg/L. The dynamic range can be varied outside this factory setting by altering the LED current. The measurement range can be adjusted by changing the LED current setting from its factor set value, using the application software provided, and that the internal referencing will still provide an appropriate scaling of the final result. It is recommended, however, that to achieve the highest accuracy at other LED current setting the user should perform a specific calibration at the chosen LED current. The detection limit will be approximately 0.1% of full range.

To perform the digital calibration, readings have been recorded using de-ionised water for the baseline and a known concentration of ~100µg/L of Chlorophyll-a dissolved in acetone. The formula below is derived from these readings and relates Chlorophyll-a concentration to instrument output. The readings shown below are for the following raw data (binary counts) from the instrument:

$$Concentration = \frac{Signal}{Ref} \times Gain + Offset$$

The instrument was set for a 1Hz sampling rate and averaging 20 contiguous samples.

For the analogue calibration the output from the digital to analogue converter was scaled to give a full output range of 0-5V. Assignment of appropriate Digital Gain and Digital Offset values are described below.

Note: the zero offsets have been determined in the laboratory using purified water from a reverse osmosis/ion exchange column. It is possible that purer water may be found in clean deep ocean conditions.

Distribution List: Works Order Traveller **Product History Folder (Electronic Copy)**

Registration No: 00832429
Registered at the above address

Chelsea Technologies Group Ltd
Certificate Of Calibration

DIGITAL CALIBRATION

Ambient temperature 24°C.

0-100µg/L calibration	Data
LED current setting	62.0mA
Output for DI water	0.0230
Output for 99.1µg/L of Chlorophyll dissolved in acetone	4.5034

The following digital Gain and Offset calibration factors, derived from the measurements above, have been programmed into the instrument:

Range	Gain	Offset
0-100µg/L	**22.318945**	**-0.511434**

The uncertainty of the Chlorophyll concentration is estimated to be less than 1%. The uncertainty of digital measurement and rounding errors are estimated to be less than 1%.

ANALOGUE CALIBRATION

Ambient temperature 24°C.

Setting	Counts
0V reading	151
5V reading	3940
0-5V range	3789

The appropriate Analogue Gain is calculated by dividing the 0-5V count range by the required dynamic range and the Analogue Offset is simply the 0V reading. The following analogue Gain and Offset factors have been programmed into the instrument:

Range	Gain	Offset
0-100µg/L	**37.89**	**151**

Important note:
The chlorophyll calibration described above has been derived using chlorophyll-a dissolved in acetone. The performance of the instrument when exposed to biologically active chlorophyll in seawater, whilst still being linear, is significantly different, as biologically active chlorophyll has a much wider absorption band than extracted Chlorophyll-a in acetone and produces a larger output from the fluorimeter for an equivalent concentration. Laboratory tests using Isocryasis phytoplankton indicate that biologically active chlorophyll can give fluorescence responses up to 40 times that of Chlorophyll-a in acetone when illuminated with a blue LED source. As the actual output seen will be dependent on the particular type of plankton being studied, and the conditions under which it is measured, the user is recommended to carry out a calibration using a known concentration of the plankton species which is most likely to be encountered in situ, and to take a zero reading from pure water containing no plankton.

Name: M J Nicholson

Signed:

Date : 24th August 2016

15.9 Acoustic laboratory network set-up

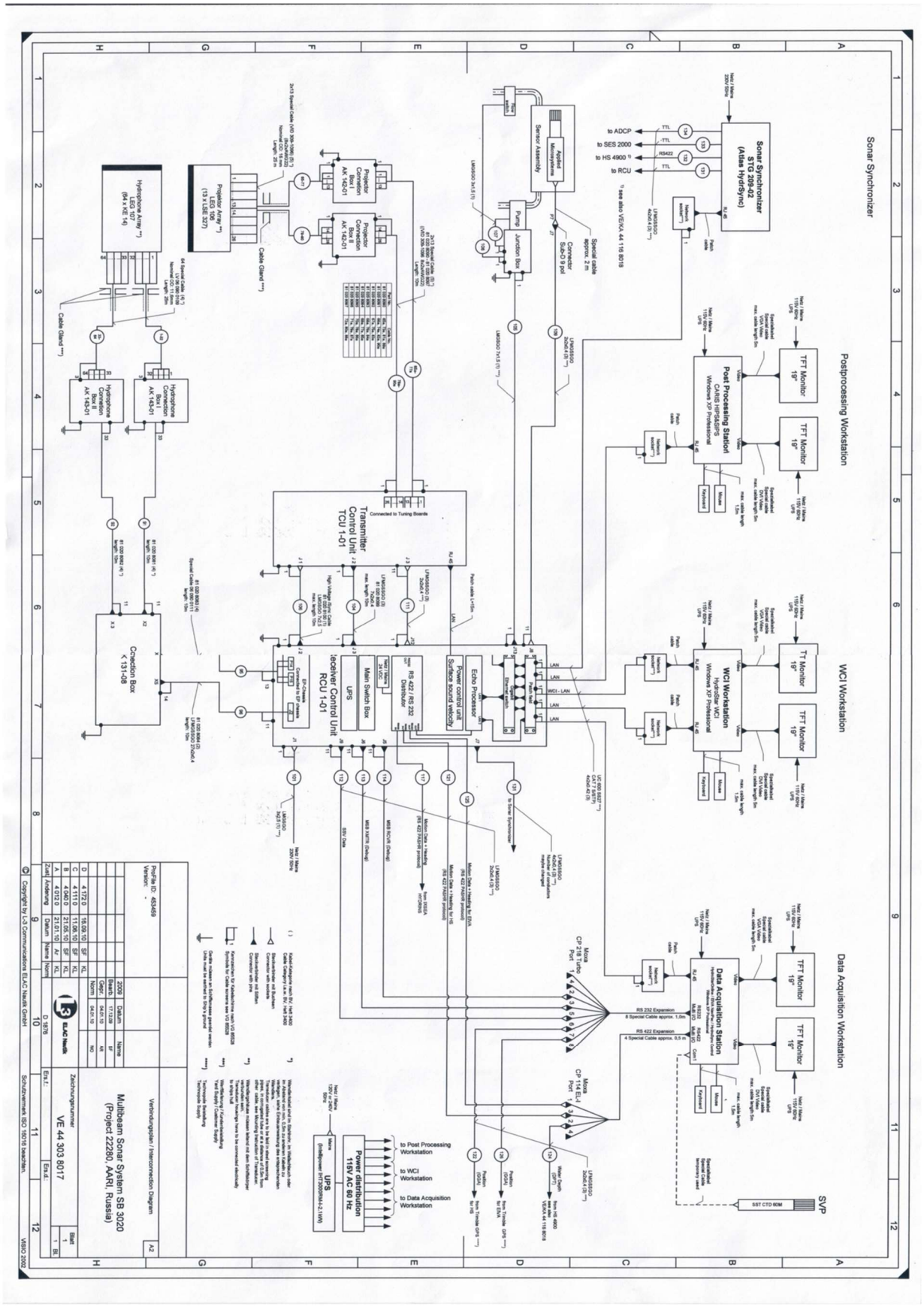

Figure 188: Network diagram of the acoustic laboratory workstations with their connected computers, instruments and data feeds.