PICCOLO Cruise Report

RRS *Sir David Attenborough*

Cruise SD035

January – March 2024

PICCOLO

UEA University of East Anglia

PML Plymouth Marine Laboratory

University of Plymouth

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Sea Mammal Research Unit

University of Leeds

Relevant grant numbers:

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Cruise report compilation: Romy Hall and Alex Tate (British Antarctic Survey)

Cover photo: Steaming towards the Larsen C Ice Shelf, 30/01/2024, Karen Heywood (UEA)

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1. Introduction

1.1 Overview

Processes Influencing Carbon Cycling: Observations of the Lower limb of the Antarctic Overturning (PICCOLO)

PICCOLO was funded in 2017 as part of the Role of the Southern Ocean in the Earth System (RoSES) NERC-supported research programme (https://roses.ac.uk). We intended to build on the large-scale, physics-focussed NERC National Capability programme ORCHESTRA, by focussing on the biological and biogeochemical components of the Southern Ocean system.

PICCOLO addresses RoSES Challenge 2. Our goal is to quantify the crucial processes that determine carbon cycling in the lower limb of the Southern Ocean overturning circulation, with two deliverables:(i) Definition and quantification of the key processes controlling the rate of carbon uptake in the lower limb of the Southern Ocean overturning circulation;(ii) Mechanistic understanding of those key processes, and a roadmap for their parameterisation in climate-scale models.

The specific objectives of PICCOLO are to:
(i) Obtain first-of-a-kind, systematic, year-round measurements of the processes controlling the rate of carbon uptake in the lower limb of the Southern Ocean overturning circulation;
(ii) Use these observations to define the key processes that must be correctly characterised in models of the SO carbon system, quantify their contribution to the system's efficiency, and assess how models must represent their mechanistic operation.

PICCOLO focuses on gaining mechanistic understanding of CO_2 uptake and sequestration in the lower limb of the Southern Ocean overturning circulation. This lower limb presents enormous practical challenges to achieve the required year-round sampling. PICCOLO involves a large consortium of scientists in different UK institutions, together with international project partners.

The cruise was highly successful (despite being the first major science cruise on the new ship, with every berth taken and every laboratory used). Highlights included more than 130 multidisciplinary CTD profiles encompassing a wide range of physical, biological and chemical properties, and extensive surveys using nets and an optical profiler. We successfully recovered the PICCOLO mooring deployed a year ago on the SDA Polar Science Trials, and also achieved a short, high-temporal-resolution redeployment at the same location. A variety of autonomous platforms were deployed including ocean gliders, profiling floats, a freely-drifting sediment trap and drones. Seals were tagged with sensors, and an intensive observational campaign was conducted on the sea ice.

1.2 Acknowledgements

We thank Captain Will Whately and all the officers and crew for their professionalism and skill, and for excellent communications throughout the voyage. They made us welcome, were always

friendly and helpful, and were patient with us as we got to grips with what was a new ship for almost everyone. We were especially thankful for the swift, sensitive and efficient way in which they dealt with the medical evacuation, that enabled a positive outcome.

We thank all the BAS technical support teams, both those onboard and those back in the UK who contributed to making the voyage such a success. Particularly fervent thanks to Alex Tate who kept our data on track, working so hard behind the scenes to organise us patiently and with good humour. We thank Alex and Romy Hall for pummelling this cruise report into shape. We recognise that getting information out of scientists is like herding cats. We thank the BAS team for dealing with shipping, flights and all the other logistics.

Thank you to the PICCOLO team! You stuck with us for so many years waiting for the field campaign, with your enthusiasm and sense of humour undented. We thank those who supported the field campaign from the UK (for example the glider pilots and those who helped with equipment shipping and set up). Special thanks to all those onboard – you each contributed to the wonderful atmosphere and it is an honour to have been to sea with you all. You worked so hard, and were always positive even when things didn't go according to plan. We cannot possibly mention everyone here, but we particularly thank Sophie Fielding, whose expertise during mobilisation, demobilisation and throughout the cruise was invaluable.

We thank NERC for funding the PICCOLO project and the voyage, and the RoSES programme for encouraging us though the 8 years while we waited for the ship time to be available. It was well worth the wait!

Karen Heywood and Tom Bell, Co-chief scientists

1.3 Personnel

SDA crew

Name	Rank
William Whatley	Captain
Fergus Walker	Chief Officer
Matthew Chapman	2nd Officer
Luke Kelly-Granger	2nd Officer Nav
Josh Mcleod	3rd Officer
Andris Kubulins	Chief Engineer
Geraldine Wythe	2nd Engineer
Christopher Henry	3rd Engineer A
Lewis Bumstead	3rd Engineer B
Greg Dalgarno	3rd Engineer EXT
Thomas King	4th Engineer
Robert Sutton	Deck Engineer
Bryn Ferguson	Deck Engineer
Michael Gloistein	Electronics Officer

Name	Rank
David Peck	CPO Science
John Melville	CPO Deck
Craig Lennon	PO Deck
Joseph Laurance	Launchman
Gethyn Roberts	SG1
Daelyn Peck	SG1
Aiden Keenan	SG1
Neil Macdonald	SG1
Bryn Foulkes	SG1
Patrick McKerchar	SG1
Christopher Walton	Purser
Aaron Harper	Chief Cook
Micah Hendrickx	Second Cook
Nicholas Greenwood	Senior Steward

Harrison Dorgan	ETO
Steven Amner	ETO
Arnis Macans	Motorman CPO
Carlos Vargas	Motorman PO

Graham Raworth	Cook Steward
Desislava Fileva	Steward
Anita Buttle	Steward
Liam O'Brien	Doctor

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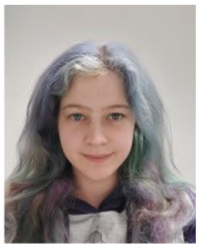
Shaun Miller	Lab Manager	shalle@bas.ac.uk

As well as those listed above there were two parties of palaeoclimatologists onboard at the start and the end of the cruise period. A US team of eight were deployed on James Ross Island and a British team of four were deployed on Seymour Island. Note that Aisling Smith (BAS Lab Manager) assisted in SD035 mobilisation in Punta Arenas but did not sail.

Figure 1.3-1: SDA crew and SD035 cruise participants on sea ice in the Weddell Sea


Alastair Lough


Angela Milne


Bethany Wilkinson


Robert Brewin


Carol Robinson


Chiara Krewer


Elise Droste


Emily Rowlands

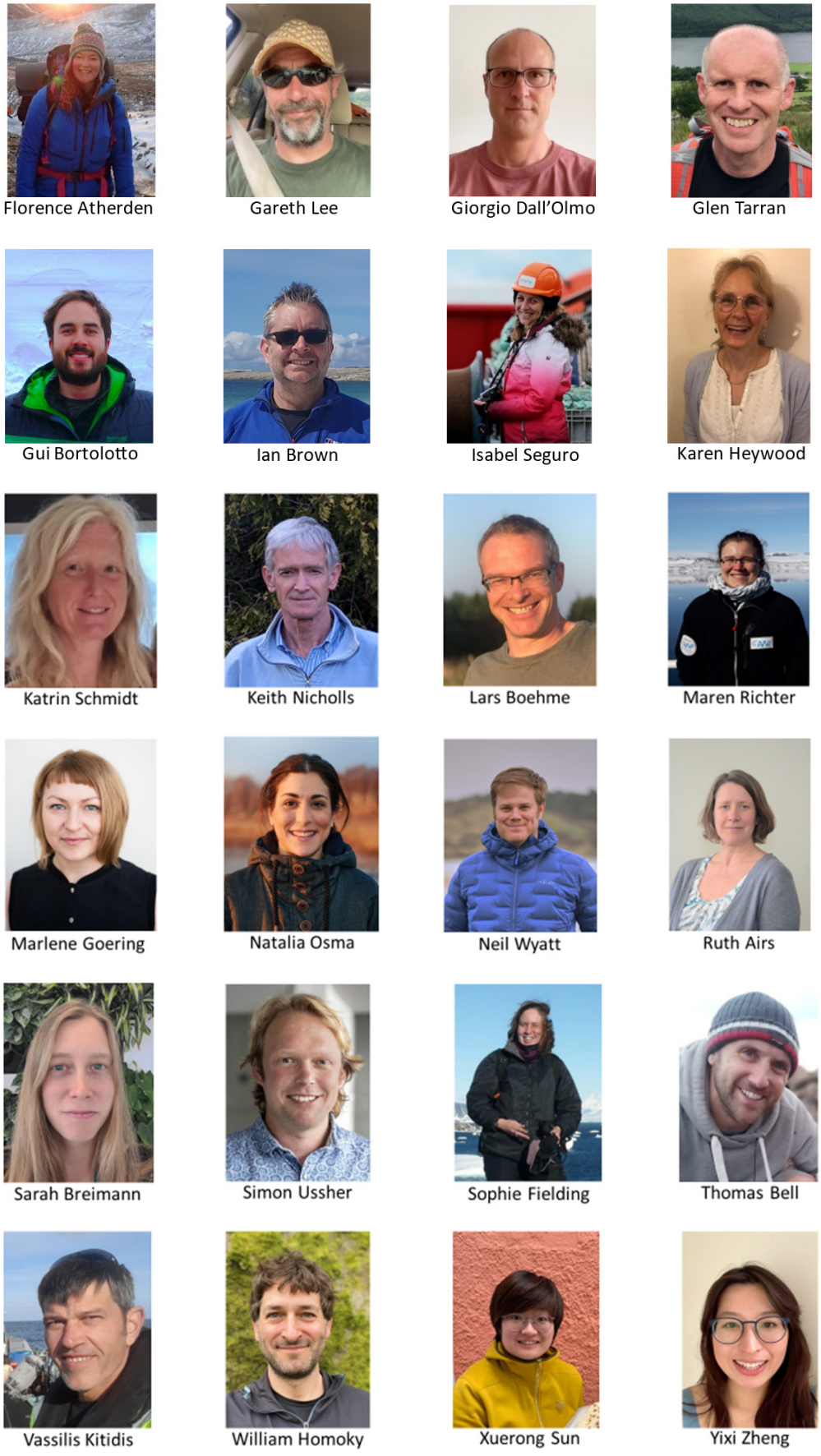


Figure 1.3-2: SD035 science party photos

1.4 Cruise diary

Authors: Karen Heywood[1], Tom Bell[2]

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[1]School of Environmental Sciences, University of East Anglia, Norwich, UK

Wednesday 17th January
Depart Punta Arenas at 13:00 local time. Ship's local time is GMT – 3 for the entire cruise.

Thursday 18th January
Steaming towards the Falklands.

Friday 19th January
Refuelling all day in the Falklands.

Saturday 20th January
As we were waiting for additional crew members to arrive in the Falklands, we decide to use the time to undertake test CTDs. We steamed to the nearest 500 m isobath for test CTDs with stainless and metal-free (TM) CTDs for the ship to establish procedures. These tests were for the ship rather than for PICCOLO. We returned to the Falklands in the afternoon and picked up the crew members.

Sunday 21st January
Steaming across Drake Passage

Monday 22nd January
We undertook PICCOLO science test CTDs, both stainless and metal-free, followed by Mammoth and RMT net deployments for the ship to practice.

Tuesday 23rd January
We deployed the trace metal fish for the first time in the morning. We arrived at James Ross Island at 10 am local time. Logistics commenced taking equipment to James Ross Island.

Wednesday 24th January
Entirely devoted to logistics deploying islanders to James Ross Island. Passage to Seymour Island overnight, leaving at 10pm.

Thursday 25th January
Entirely devoted to logistics deploying equipment to Seymour Island.

Friday 26th January
The islanders were taken to Seymour Island in the morning. Once we'd heard that they were safely ashore, we steamed to just beyond the 200 m isobath to undertake a test primary productivity (PP) CTD station to 200 m depth. This was followed by deployments of the optics rig, one with tape over the sensors and one normal profile. Then a CTD profile for radium, followed by deployment of the trace metal fish.

Saturday 27th January

We departed Seymour Island in the early morning and made our way towards the mooring location, having received positive communications with the palaeontologists onboard Seymour. Sea ice coverage meant that the trace metal fish had only brief deployments when safe, and the uncontaminated sea water (UCSW) was turned off on every now and then. We arrived at the mooring site about midday, and were very pleased to find that the acoustic release communicated straight away. Swath bathymetry over the mooring showed that all the sensors were present and the mooring was vertical. There was a large sea ice floe close by. After a biogeochemistry (BGC) CTD (007) close to the mooring site, we had hoped to recover the mooring but there was too much sea ice. We stayed close by, and did a mammoth net and optics rig deployment.

Sunday 28th January
The overnight mammoth net was aborted because of strong winds. The sequence of PP, BGC, TM CTDs began at 2am. At 8 am we broke off the CTDs to recover the mooring, which was released and spotted at 09:15. All mooring instrumentation onboard by 11:30. Afternoon activities began with two radium (stainless frame) CTDs, followed by an optics cast (toward the end of this, the ship was rotated so that the sun was in the right sector for good irradiance observations) and a mammoth net. Finally, an optics cast took place. All activities took place within 2 miles of the mooring site. Some surveys were taken steaming around an ice-free triangle to undertake testing of the shipboard ADCPs.

Monday 29th January
2am PP cast was aborted as a fault was found that could not be fixed in time. The BGC was then cancelled for the same reason and to allow enough time to perform the fix. The problem was found to be in the CTD cable, which needed cutting and re-terminating. The CTD sequence began again with the TM CTD going into the water at 4am. The mooring was redeployed in the same location with virtually the same set of sensors.

Tuesday 30th January
Sequence of CTDs starting at 2am to calibration of the mooring. We then steamed for the Larsen ice shelf as an opening in the sea ice had appeared to enable us to reach it.

Wednesday 31st January
We arrived at the Larsen ice shelf. We undertook a series of CTD casts (mostly repeating stations occupied by Keith Nicholls during his survey of the region in 2002). Two ocean gliders, SG565 and SG673, were deployed in the morning, using the Fast Rescue Craft (FRC) launched from the ship. After more CTDs, an RMT net was undertaken in the evening, together with a physics-only CTD (no samples).

Thursday 1st February
An RMT net was followed by the sequence of CTDs. More CTDs repeating previous 2002 stations were completed, close to the ice shelf. We recovered the two gliders in the evening, with a calibration CTD cast in between the two recoveries. Recoveries were undertaken using the FRC.

Friday 2nd February
We did our sequence of CTDs starting pre-dawn, together with mammoth nets and optics rigs. We conducted our final CTD stations in the afternoon, and left the Larsen ice shelf area at 4pm. This was followed by a BGC CTD (SS1), the first of a widely-spaced series across the continental shelf towards James Ross Island. The sea ice was closing in due to winds from the east, so we were keen to get past Seal Nunataks before the gap in the sea ice became impassable.

Saturday 3rd February
From 2 am we did the full sequence of CTDs and a mammoth net, in water about 500 m depth. We passed Seal Nunataks in the afternoon, followed by a BGC CTD (SS3). We then did RMT net trawls for krill.

Sunday 4th February
As strong winds were forecast, we spent the day in the lee of James Ross Island where conditions were much calmer. After the full sequence of CTDs from 2 am, we deployed the floating trap for the first time. This deployment was done tethered to the ship. A sequence of tests of the TM CTD was undertaken to solve bottle closing issues. The trap was recovered in the evening.

Monday 5th February
We steamed north and then east through strong winds. A towfish deployment was completed.

Tuesday 6th February
We deployed three Seagliders (SG565, SG673 and SG558 respectively during the morning. Conditions were challenging, with winds increasing from 30 to 50 knots, so the final deployment was done in large seas. It was too rough for small boat deployments, so they were done over the stern. Despite conditions, all three gliders were fine and are now in the hands of the glider pilots at UEA. Test deployments were undertaken to resolve problems with bottles not firing on the TM CTD, and also to soak some new bottles before the Geotraces station. A calibration BGC CTD was also undertaken at the glider deployment location.

Wednesday 7th February
We arrived at the GEOTRACES intercalibration station (a previous Polarstern GEOTRACES station) in the early morning. After a mammoth net, we deployed the TM CTD (69). There were spooling issues with the TM winch which delayed the upcast by about an hour. Then we steamed south to the start of our section across the continental slope (station T1). At T1 we deployed the floating trap (untethered) while we did CTD casts and nets.

Thursday 8th February
The westward section back to the continental shelf began. The sequence began with a night-time ("midnight") mammoth net. CTDs began at 03:00 at station T1 (4000 m isobath): PP, BGC, TM. Optics rigs were deployed simultaneously with deep stations. After a day-time mammoth net, the floating trap was recovered. Two physics-only CTDs were done to give better spatial coverage of the section as we steamed westward.

Friday 9th February
The usual sequence of CTDs began at 03:00 at station T2 (3500 m isobath), with mammoth nets before and after. The towfish was deployed for a while, and two physics-only CTD undertaken.

Saturday 10th February
The midnight mammoth net was cancelled due to strong winds. The usual sequence of CTDs began at 03:00 at station T3 (3000 m isobath). There were problems with the stainless steel CTD, eventually traced to the swivel; the repair was tested with physics-only CTDs.

Sunday 11th February
The midnight mammoth net had to be cancelled as there wasn't sufficient time after the repairs to the CTD. The usual sequence of CTDs began at 03:00 at station T4 (2500 m isobath). This was

followed by an RMT net, in which Euphausia Superba were caught, and three physics-only CTDs.

Monday 12th February
The full sequence of CTDs was undertaken at the 2000 m isobath (T5), including two radium casts, optics rig and mammoth nets before and after. Two physics-only CTDs were done.

Tuesday 13th February
The full sequence of CTDs was undertaken at the 1500 m isobath (T6), including two radium casts and mammoth nets before and after. One physics-only CTD was added midway to T7.

Wednesday 14th February
The full sequence of CTDs was undertaken at the 1000 m isobath (T7), including two radium casts, optics rig and mammoth net. A physics-only CTD and an RMT net were done en route to T8. A 'midnight mammoth' net was undertaken just before midnight.

Thursday 15th February
The full sequence of CTDs was undertaken at the 500 m isobath (T8), including two radium casts. It was challenging as the ship drifted into shallower water during casts, so we kept having to reposition. In the afternoon we did a swath survey from the shelf break towards the mooring, whilst also looking for seals to tag. We tagged two seals, a young male elephant seal, and a Weddell seal, both on ice floes, using small boat deployments. This took most of the swath survey time, and we had time for only one physics-only CTD. We arrived at the PICCOLO mooring location in the evening, and deployed the mammoth net at about 11pm.

Friday 16th February
After a sequence of PP+BGC+TM+Radiumx2 CTDs at the mooring site, we deployed the floating trap, freely drifting, at about 9am. We had hoped to recover the mooring, but it was under a sea ice flow, so we did an acoustic calibration as the conditions were very good – glassy calm. We then recovered the mooring for the final time, and recovered the floating trap. Then we headed towards the sea ice to look for seals.

Saturday 17th February
We spent the day looking for Weddell seals (or elephant seals) to tag, but did not find any. We did an RMT8 net in the evening.

Sunday 18th February
We spent the day looking for Weddell seals (or elephant seals) to tag. We found one Weddell seal in the late afternoon, but it was too fat – meaning that it is unlikely to have moulted yet so would be unsuitable to tag. In any case it went into the water before we could investigate. We found a patch of open water to undertake observations in, to compare with our upcoming under-ice observations. A mammoth net was deployed once it was dark.

Monday 19th February
We did our usual sequence of PP+BGC+TM+2xradium CTD casts, as well as a daytime mammoth net and optics rig deployments. Then we headed south to find a region with a suitable sea ice floe for drilling, surrounded by high ice concentration. We found a suitable floe after lunch, and landed three people (Lars, Keith, and Fergus) onto the floe for an initial inspection for safety purposes. They drilled some small holes and pronounced the floe suitable for us to use, with ice thickness about 1 m. We deployed the floating trap into the polynya, but then came the bad news that we had a sick person onboard and had to undertake a medical

evacuation to Seymour Island. We recovered the trap and steamed north as quickly as possible. Science activities were suspended.

Tuesday 20th February
We steamed north to medevac the sick person. Neither Marambio nor King Gorge Island proved suitable for the BAS Dash 7 to fly into because of weather conditions, so we steamed south to Rothera.

Wednesday 21st February
We continued to Rothera, where the sick person was transferred to the waiting Dash7 aircraft and taken to Punta Arenas. We left immediately afterwards.

Thursday 22nd February
We steamed north.

Friday 23rd February
We recovered two gliders SG558 and SG673, and undertook a BGC calibration cast. Unfortunately SG565 had lost communication and was not recovered (it was tracked for about a week on Argos tag fixes, so was clearly still diving, but subsequently lost even that). We then steamed to the centre of the Powell Basin to recover a glider for the BIOPOLE project.

Saturday 24th February
We arrived at the BIOPOLE Slocum glider location in the early hours and located it using its strobe light. As it had not been flying well, we wanted to recover it in daylight to identify whether it had broken a wing or triggered its recovery rope. We undertook two CTDs for calibration whilst waiting for dawn. At dawn we returned to the glider and found it in a patch of brash glacial ice. The ice was giving the glider a battering as it moved with the swell. Unfortunately as we watched, the glider sank between the chunks and did not reappear. We searched for it for several hours, but in the end had to conclude that it had be irreparably damaged by the ice. We steamed south, deploying the trace metal fish for a transect from the open Powell Basin to the continental shelf.

Sunday 25th February
We steamed south overnight, and the morning found us undertaking a biogeochemical CTD for calibration of the BGC Argo float deployment that took place immediately afterwards. Subsequently we did an RMT8 net, tagged two Weddell seals, and collected a large chunk of brown ice to analyse the biogeochemistry of the algae.

Monday 26th February
A BGC CTD (133) was undertaken in fairly open water for comparison with the on-sea-ice work. An ice floe was investigated for ice work but was deemed too thick. A second floe was deemed suitable, and a large team was deployed onto the ice for a series of hole and core drilling and on-ice experiments all day. A successful day on the ice culminated in a group photo. An optics rig was undertaken after everyone was recovered from the ice. The floating trap was deployed.

Tuesday 27th February
On-ice work began at a different sea ice floe in the morning. A crabeater seal was tagged on the same ice floe. After on-ice activities were completed, the floating trap was recovered.

Wednesday 28th February

Our plans to spend the day seal tagging were interrupted as we had to steam north rapidly to pick up the BAS team on Seymour Island whose tents had ripped in the wind. We picked up the personnel in the late afternoon in strong winds. An RMT8 net was then done.

Thursday 29th February
We spent the night hunting for a reasonably ice-free region to deploy the floating trap, Caravela and a glider. This was to be a 24 hour intensive set of observations in one area (our "supersite"). In the morning, we deployed glider SG676, then Caravela and then the floating trap. A CTD (134), optics rig and daytime mammoth net were undertaken.

Friday 1st March
Overnight we undertook our final sequence of night-time mammoth + PP+BGC+TM+Radium x 2 CTDs. We then recovered the floating trap, Caravela and the glider. For the rest of the day, we undertook a test CTD (140) and tagged 3 crabeater seals.

Saturday 2nd March
We recovered the equipment from the Seymour Island team, and then moved to James Ross Island. Two Weddell seals were tagged.

Sunday 3rd March
Equipment and people were uplifted from James Ross Island.

Monday 4th March
The palaeontologist teams did a day trip to Vega Island. PICCOLO science teams were able to have a recreational visit in the afternoon. Five Weddell seals were tagged on nearby beaches meaning that all 19 seal tags were deployed.

Tuesday 5th March
The BIOPOLE mooring was deployed in the central Powell Basin, and then we steamed north.

Wednesday 6th March
We steamed north across Drake Passage.

Thursday 7th March
We steamed north across Drake Passage.

Friday 8th March
We steamed north across Drake Passage. We arrived in Punta Arenas in the evening.

Saturday 9th March
We cleared customs.

1.5 Cruise track

Figure 1.5-1 shows the SD035 cruise track with the following chronological order; Punta Arenas (Chile) -> Falkland Islands -> NW Weddell Sea -> Rothera Station (medevac) -> NW Weddell Sea -> Punta Arenas (Chile).

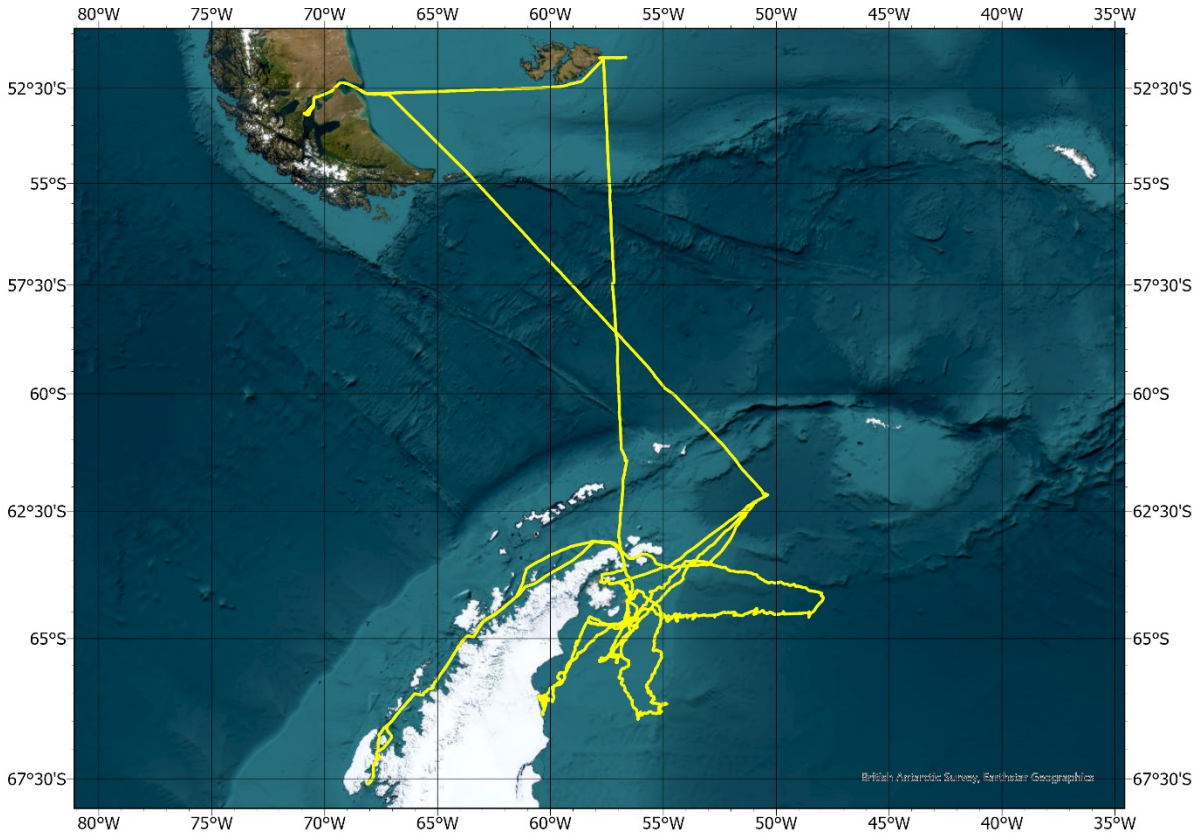

Figure 1.5-1: SD035 cruise track (Mercator projection)

2. Data Management

Author: Alex Tate[1]

[1]*UK Polar Data Centre, British Antarctic Survey, Cambridge, UK*

2.1 Summary

Overall, the data management systems proved to be robust and reliable and there were very few cases of underway data loss during SD035. Underway data logging systems continuously recorded the outputs from 61 data streams, data were synchronised to central disk storage from a further 17 systems, and a wide range of datasets acquired by cruise participants were collated, described, and stored on the cruise leg directory. The event logging system was well used by cruise participants as were the Grafana data visualisation dashboards.

This was one of the first science cruises where participants had full access to the Starlink connections. Currently the welfare ("Snowlink") connection has no access to internal systems so the majority of cruise participants could no longer access Grafana data visualisations on their personal devices. It is recommended that this situation is reviewed as easy access to the Grafana dashboards is very useful for situational awareness. On a wider level, the presence of a fast and reliable ship-to-shore connection does pose a systemic issue for the centralised management of cruise datasets. Backing up data to the central storage areas onboard has always been a key recommendation to avoid data loss and this risk prompted most to backup data to the cruise leg directory. However, there is anecdotal evidence that individuals are now using the increased bandwidth to back up scientific data to personal or institutional repositories onshore. This reduces the risk of data loss but means that the bifurcation of cruise datasets, that almost always occurs after a cruise finishes, now happens at an earlier stage.

2.2 Datasets collected

The tables (Table 2.2-1 and Table 2.2-3) below provide a summary of all the datasets collected on SD035 and they are intended as an initial place for future users (and data managers) to discover the breadth of data acquired on the cruise. Each table has the following information, where relevant:

- Dataset – Brief title of the dataset.
- Instruments – List of the platform/instruments/sensors used in the collection/analysis of the dataset and (optionally) a link to a matching BODC vocabulary term or a manufacturer website.
- Description – Brief description of the dataset although in many cases this is a pointer to the relevant cruise report section.
- Metadata – Links to any metadata recorded on the cruise. Usually split between scanned paper logs and digital-first information.
- Digital Data – Links to any digital outputs, usually split between raw and processed products. A value of, 'See contacts' means that digital data are assumed to exist but they were not located on the SD035 cruise archive.
- Physical Samples – A description of any physical samples that form part of the dataset, especially if they will return from the vessel for onward analysis.

- Contacts – Names of individuals who were involved in the creation of the dataset (key contact is in bold). Where relevant, also includes the names of individuals not on the cruise, but who are known to be heavily involved with the dataset.

Any pathnames given are relative to the cruise 'leg' folder (/data/cruise/sda/20240113)

Table 2.2-1: Datasets collected during SD035, organised by platform.

Platforms

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Dataset	**Ship's permanently fitted underway sensors**	
Instruments	Multiple (see RVDAS sub-section in Section 2.5 below)	
Description	Timestamped outputs from 61 separate data streams as recorded by the RVDAS data logging system. Includes permanently fitted sensors associated with position and attitude, sea surface oceanography, atmosphere and meteorology, bathymetry, and platform monitoring. Available as daily ascii files and replicated within a PostgreSQL database.	
Metadata	Digital logs	work/data_management/event_logs/digital_logs
	Individual message metadata	work/data_management/data_products/ Underway_data_description_message.pdf
Digital data	Raw daily files	system/datalogger_basnoc_rvdas/acquisition/
Contacts	**Alex Tate (BAS)**	

Dataset	**Uncontaminated sea water sampling**	
Instruments	Non-toxic sea water supply (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0413/)	
Description	Sea water sampled from the ship's uncontaminated sea water supply. Water is sourced from an inlet that can be deployed 30 cm below the hull, the depth of which is ~7.1 m. Due to a mixture of environmental conditions and hoist issues, sampling also occurred with the inlet in either the flush or retracted position – see underway water sampling Section 4.1 for more details. Water was sampled from a number of labs around the vessel. See Table 2.2-3 for the onward processing of underway water samples.	
Metadata	Paper Logs	work/scientific_work_areas/Underway_discrete_samples/UW_sampling_sheet_copies/
	Digital Logs	work/data_management/event_logs/Eventlog_exports/ UW_Uncontaminated_seawater_lab.csv work/data_management/event_logs/Eventlog_exports/ UW_Deck_Lab.csv
Digital data	Raw	See related water analysis datasets (Table 2.2-3) for data links
Contacts	See related water analysis datasets (Table 2.2-3) for contacts	

Dataset	**Underway uncontaminated sea water optics system**	
Instruments	Sea-Bird DH4 Data Handler WET Labs ac-s in-situ spectrophotometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0834/) TriOS OPUS spectrophotometer (https://www.trios.de/en/opus.html) Chelsea Technologies LabSTAF Single Turnover Active Fluorometer (https://chelsea.co.uk/products/labstaf/)	
Description	A series of sensors dedicated to optical properties of seawater were attached to the ship's uncontaminated seawater flow. See optics Section 4.1.2 for further details.	
Metadata	Paper logs	work/scientific_work_areas/Optics/LogBook
	Digital logs	
Digital data	Raw	work/scientific_work_areas/Optics/Data
	Processed	work/scientific_work_areas/Optics/Processed
Contacts	**Xuerong Sun (U. of Exeter),** Giorgio Dall'Olmo (OGS), Bob Brewin (U. of Exeter)	

Dataset	**Above-water radiometry measurements**	
Instruments	Sea-Bird (Satlantic) Hyperspectral Surface Acquisition System (HyperSAS) (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1334/)	
Description	The irradiance sensor was installed on the centre main mast while the two hyperspectral radiance sensors were installed on the foremast along with a tilt and heading sensor. See radiometry Section 4.3.2 for more details.	
Metadata	Paper logs	
	Digital logs	
Digital data	Raw	work/scientific_work_areas/Optics/Data/HSAS/raw
	Processed	work/scientific_work_areas/Optics/Data/HSAS/Level_2
Contacts	**Bob Brewin (U. of Exeter),** Giorgio Dall'Olmo (OGS), Xuerong Sun (U. of Exeter)	

Dataset	**Eddy covariance CO_2 flux system**	
Instruments	Picarro G2311-f flux gas concentration analyser (https://www.picarro.com/environmental/products/g2311f_ec_flux_gas_concentration_analyzer) Metek uSonic3 ultrasonic anemometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1402/) LPMS motion reference unit	
Description	The CO_2 flux system comprises a Picarro gas analyser sampling air from the foremast with a foremast-mounted Metek anemometer and co-located motion reference unit.	
Metadata	Paper logs	
	Digital logs	

Digital data	Raw	system/gas_pml_co2flux
Contacts	**Thomas Bell (PML)**	

Dataset	**Ship-fitted underway pCO_2 system**	
Instruments	Dartcom Live pCO_2 system	
Description	A permanently-fitted pCO_2 system comprising foremast-sourced air intake, uncontaminated seawater intake and calibration gas standards.	
Metadata	Digital logs	
Digital data	Raw	On the local pCO2 machine and within emailed data outputs
Contacts	**Ian Brown (PML**), Thomas Bell (PML), Vassilis Kitidis (PML)	

Dataset	**Stand-alone pCO_2 sensor**	
Instruments	Pro-Oceanus CO2-Pro CV Submersible pCO_2 Sensor (https://pro-oceanus.com/products/pro-series/co2-pro-cv)	
Description	A stand-alone pCO_2 sensor was used to continuously measure pCO_2 from the uncontaminated seawater flow as well as being deployed through the sea ice and on the Caravela autonomous surface vehicle.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	work/scientific_work_areas/Seawater pCO2
Contacts	**Thomas Bell (PML),** Vassilis Kitidis (PML), Ian Brown (PML)	

Dataset	**Stand-alone pH sensor**	
Instruments	ANB Sensors S series Oceanographic pH Sensor (probably S1000) (https://www.anbsensors.com/wp-content/uploads/2020/09/SSeries_pHSensor_Datasheet.pdf)	
Description	A stand-alone pH sensor was used to continuously measure pH from the uncontaminated seawater flow in the same location as the stand-alone pCO_2 sensor. It was also deployed on CTD casts 129 and 134 (Ship events 245 and 288) for calibration purposes.	
Metadata	Digital logs	
Digital data	Raw	See contact.
Contacts	**Gareth Lee (UEA)**	

Dataset	**Sea ice camera imagery (hull/ice interactions)**	
Instruments	GoPro11 (forward looking) GoPro7 (aft looking)	
Description	Occasional use of two GoPro cameras mounted on the railing of deck 6 to record interactions between sea ice and the ship's hull.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports

Digital data	Raw	Work/scientific_work_areas/Sea_ice_GoPro_images
Contacts	**Alex Tate (BAS),** Jeremy Wilkinson (BAS)	

Dataset	**Sea ice camera imagery (forward looking)**	
Instruments	2 x Campbell Scientific outdoor observation and surveillance field cameras	
Description	Continuous recording of images from two cameras mounted to railings on the foremast. Associated with the eddy covariance CO_2 flux system.	
Metadata	Digital logs	
Digital data	Raw	system/gas_pml_co2flux/acquisition/Cameras
Contacts	**Thomas Bell (PML)**	

Dataset	**Wave radar**	
Instruments	Rutter Sigma s6 WaMoS II wave radar (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0999/)	
Description	The wave radar gives information about the wave height, length, and other parameters of the waves.	
Digital data	Digital logs	
Digital data	Raw	system/wave_rutter_sigma_s6_wamos_ii/acquisition
Contacts	**Alex Tate (BAS)**	

Dataset	**EA640 singlebeam bathymetry**	
Instruments	Kongsberg EA640 singlebeam bathymetric echosounder (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0965/)	
Description	Singlebeam echosounder operating throughout the cruise, providing depth below transducer. For more details see the bathymetry Section 4.3.3.	
Metadata	Digital logs	work/data_management/event_logs/digital_logs
Digital data	Raw	system/singlebeam_kongsberg_ea640/acquisition/data
Contacts	**Alex Tate (BAS)**	

Dataset	**EK80 bio-acoustic data**	
Instruments	Simrad EK80 bio-acoustic echosounder (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1205/)	
Description	A high precision scientific echo sounder, designed to simultaneously operate frequencies ranging from 10 to 500 kHz.	
Metadata	Digital logs	
Digital data	Raw	system/bioacoustic_simrad_ek80/acquisition/EK80_Data
Calibration	work/scientific_work_areas/Acoustic_calibration	
Contacts	**Sophie Fielding (BAS)**	

Dataset	**EM122 multibeam bathymetry**	
Instruments	Kongsberg EM122 multibeam bathymetric echosounder (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0492/)	
Description	Full ocean depth multibeam echosounder used during most of the cruise to map water depths. For more details see the bathymetry Section 4.3.3.	
Metadata	Digital logs	work/data_management/event_logs/digital_logs
Digital data	Raw	system/multibeam_kongsberg_em122/acquisition/raw
	Processed	work/scientific_work_areas/ Multibeam_Bathymetry /em122
Contacts	**Alex Tate (BAS)**	

Dataset	**EM712 multibeam bathymetry**	
Instruments	Kongsberg EM122 multibeam bathymetric echosounder (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0492/)	
Description	Continental shelf depth multibeam echosounder used in the Larsen C area to map water depths. For more details see the bathymetry Section 4.3.3.	
Metadata	Digital logs	work/data_management/event_logs/digital_logs
Digital data	Raw	system/multibeam_kongsberg_em712/acquisition/raw
	Processed	work/scientific_work_areas/ Multibeam_Bathymetry /em712
Contacts	**Alex Tate (BAS)**	

Dataset	**Vessel-mounted acoustic doppler current profiler (VMADCP) data**	
Instruments	Teledyne RDI Ocean Surveyor 75kHz vessel-mounted ADCP (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0351/) Teledyne RDI Ocean Surveyor 150kHz vessel-mounted ADCP (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0062/)	
Description	VMADCP data were collected throughout the cruise predominately using the 150kHz instrument. For more details see the VMADCP Section 4.3.4.	
Metadata	Digital logs	work/data_management/event_logs/digital_logs
Digital data	Raw	system/adcp_teledyne_ocean_surveyor/acquisition
	Processed	work/scientific_work_areas/hydrography/underway See files: os75nb.nc and os150nb.nc
Contacts	**Karen Heywood (UEA)**, Yixi Zheng (UEA)	

Dataset	**Sea ice sampling**	
Instruments	A large metal cage	
Description	A single piece (~1.5m^3) of sea ice was collected using a metal cage from the side of the vessel. See analytical dataset details below for the onward processing this sea ice.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports

Contacts	See related water analysis datasets (Table 2.2-3) for contacts

Dataset	**Marine Mammal Observations (MMO)**	
Instruments	Binoculars	
Description	MMO watches were undertaken ahead of turning on the multibeam bathymetric echosounders.	
Metadata	Digital logs	work/data_management/event_logs/digital_logs
Digital data	Raw	None
Contacts	**Alex Tate (BAS)**	

Stainless Steel CTD Frame

Dataset	**Stainless Steel CTD frame vertical profiling sensor and sampling data**
Instruments	Sea-Bird SBE 911plus CTD systems (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0058/) Paroscientific Digiquartz pressure sensor (part of http://vocab.nerc.ac.uk/collection/L22/current/TOOL1508/) 2 x Sea-Bird SBE3plus temperature sensors (part of http://vocab.nerc.ac.uk/collection/L22/current/TOOL1508/) 2 x Sea-Bird SBE4C conductivity sensors (part of http://vocab.nerc.ac.uk/collection/L22/current/TOOL1508/) 2 x Sea-Bird SBE5T submersible pumps (part of http://vocab.nerc.ac.uk/collection/L22/current/TOOL1508/) 2 Sea-Bird SBE43 oxygen sensors (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0036/) WETLabs C-Star transmissometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0160/) Chelsea Aquatracka III fluorometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0424/) Tritech PA-200 altimeter (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0059/) WETLabs CDOM fluorometer (up until cast 128) SBE18 pH sensor (replaced CDOM fluorometer from cast 129) (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0069/) WETLabs ECO BB(RT)D backscatter sensor (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0060/) Biospherical Instruments Inc. QCP-2350 PAR sensor (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1186/) Seabird SBE35 standard thermometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0318/) Sea-Bird SBE32 carousel water sampler (24 position) Up to 24 x Ocean Test Equipment Model 110 water samplers (20 litres) (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0412/)

Description	The sensors listed above formed the standard setup for most of the cruise. See BAS engineering Section 3 for more detailed configuration notes and the CTD Section 5 for sensor processing. See Table 2.2-3 for the onward processing of bottle samples. The following sensors were occasionally attached to the stainless steel frame for calibration purposes: Valeport RapidPro CTD (cast 068)– See 'sea ice floe' datasets. Valeport RapidPro SV (cast 011) – See 'mammoth net' datasets. AML Minos CTD (cast 007) – Possibly not used elsewhere. Seal Tags – See 'seal' datasets. ANB Sensors S series Oceanographic pH Sensor (casts 129, 134)– See 'SDA' datasets. Sami PH Sensor (cast 129) – See 'Piccolo mooring' datasets (long-term deployment) Sami PH Sensor SN=p0312 (cast 129) - See 'Piccolo mooring' datasets (short-term deployment) Sea-Bird SBE37 CTD (cast 129) – See 'Piccolo mooring' datasets. Aanderaa Seaguard II (cast 129) – See 'Piccolo mooring' datasets.	
Metadata	Paper Logs	work/scientific_work_areas/CTD_LADCP/Logsheets
	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	system/ctd_seabird_sbe911plus/acquisition/data/SD035/CTD/Data
	Processed	work/scientific_work_areas/CTD_LADCP/CTD
Contacts	**Karen Heywood (UEA)**, Maren Richter (UEA), Yixi Zheng (UEA), Keith Nicholls (BAS), Carson McAfee (BAS)	

Titanium CTD Frame

Dataset	**Titanium CTD frame vertical profiling sensor and sampling data**
Instruments	Sea-Bird SBE 911plus CTD (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0058/) Paroscientific Digiquartz pressure sensor (part of http://vocab.nerc.ac.uk/collection/L22/current/TOOL1508/) 2 x Sea-Bird SBE3plus temperature sensors (part of http://vocab.nerc.ac.uk/collection/L22/current/TOOL1508/) 2 x Sea-Bird SBE4C conductivity sensors (part of http://vocab.nerc.ac.uk/collection/L22/current/TOOL1508/) 2 x Sea-Bird SBE5T submersible pumps (part of http://vocab.nerc.ac.uk/collection/L22/current/TOOL1508/) 2 Sea-Bird SBE43 oxygen sensors (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0036/) WETLabs C-Star transmissometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0160/)

	Chelsea Aquatracka III fluorometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0424/) Valeport VA500 altimeter (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1738/) Satlantic PAR sensor (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0973/) Sea-Bird SBE32 carousel water sampler (24 position) Up to 24 x Ocean Test Equipment Teflon-coated C-Free Model 130 water samplers (12 litres) (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0418/)	
Description	The sensors listed above formed the standard setup for most of the cruise. See BAS engineering Section 3 for more detailed configuration notes and the CTD Section 5 for sensor processing. See Table 2.2-3 for the onward processing of bottle samples.	
Metadata	Paper Logs	work/scientific_work_areas/CTD_LADCP/Logsheets
	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	system/ctd_seabird_sbe911plus/acquisition/data/SD035/CTD/Data
	Processed	work/scientific_work_areas/CTD_LADCP/CTD
Contacts	**Karen Heywood (UEA)**, Maren Richter (UEA), Yixi Zheng (UEA), Keith Nicholls (BAS), Carson McAfee (BAS)	

Both CTD Frames

Dataset	**Lowered Acoustic Doppler Current Profiler (LADCP) data**	
Instruments	Teledyne RDI 300kHz Workhorse Monitor direct-reading ADCP (2 per CTD frame) (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0061/)	
Description	Downward and upward looking LADCP instruments were attached on both the Stainless Steel and Titanium CTD frames and data were collected on every CTD deployment. Further details can be found in the LADCP Section 6.	
Metadata	Paper Logs	work/scientific_work_areas/CTD_LADCP/Logsheets
	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	system/ctd_seabird_sbe911plus/acquisition/data/SD025/LADCP/Data
	Processed	work/scientific_work_areas/CTD_LADCP/LADCP
Contacts	**Karen Heywood (UEA),** Maren Richter (UEA)	

Optical Rig

Dataset	**Optical Rig profiling sensor data**
Instruments	Sea-Bird DH8 Data Handler Sea-Bird SBE 19plus V2 SEACAT CTD (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0871/)

	WET Labs {Sea-Bird WETLabs} ac-s in-situ spectrophotometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0834/) WET Labs {Sea-Bird WETLabs} ECO BB3 backscattering sensor RBR Tridente chlorophyll fluorescence and optical backscattering sensor (https://rbr-global.com/products/sensors/rbrtridente/) Marine Optics SC6 six-channel backscattering sensor (https://insitumarineoptics.com/sc6/) Secchi Disk (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0430/) RBR Concerto CTD + Tridente (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0856/) Sequoia Scientific FlowControl-Sub 3-way valve and filter (https://www.sequoiasci.com/product/flowcontrol-sub/) Sensing Secchi Disk (bespoke Arduino based sensing package, see Brewin et al. Under Review) Forel-Ule colour chart based on the LaMotte scale Forel-Ule colour chart based on Novoa et al (2014)	
Description	A series of instruments and optical disks/charts attached to a small deployment frame, focussing on optical properties within the top ~300 m of the water column. The optical rig was deployed throughout the cruise and each deployment consisted of a number of up/down casts.	
Metadata	Paper logs	work/scientific_work_areas/Optics/LogBook/ log_book_optics_rig.pdf
	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	work/scientific_work_areas/Optics/Data/Optics_rig/Raw
	Processed	work/scientific_work_areas/Optics/Data/Optics_rig
Contacts	**Giorgio Dall'Olmo (OSG), Bob Brewin (U. of Exeter)**	

Trace metal towfish

Dataset	**Towfish sea water samples**	
Instruments	National Oceanography Centre torpedo towfish water sampler (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0555/)	
Description	The trace metal towfish was deployed whenever possible throughout the cruise at a depth of around 1-2m depending on vessel speed and conditions. See Table 2.2-3 for the onward processing of towfish-derived water samples.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	See relevant datasets within Table 2.2-3.
Contacts	See related water analysis datasets (Table 2.2-3) for contacts.	

Rectangular Midwater Trawl 8 (RMT8)

Dataset	**Krill length frequency analysis**
Instruments	British Antarctic Survey Rectangular Midwater Trawl 8 (http://vocab.nerc.ac.uk/collection/L22/current/NETT0180/)

Description	See RMT8 Section 12.1.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	work/scientific_work_areas/Nets/RMT8
Contacts	**Sophie Fielding (BAS), Katrin Schmidt (U. of Plymouth)**	

Dataset	**Krill sampling**	
Instruments	British Antarctic Survey Rectangular Midwater Trawl 8 (http://vocab.nerc.ac.uk/collection/L22/current/NETT0180/)	
Description	See RMT8 Section 12.1.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports work/scientific_work_areas/Nets/RMT8
Digital data	Raw	work/scientific_work_areas/Nets/RMT8
Physical samples	Selected samples were frozen at -80°C for subsequent trace metal analysis at the University of Plymouth. Other samples were preserved in formalin for future taxonomic analysis.	
Contacts	**Sophie Fielding (BAS), Katrin Schmidt (U. of Plymouth)**	

Dataset	**Krill fecal pellet incubation experiments**	
Instruments	British Antarctic Survey Rectangular Midwater Trawl 8 (http://vocab.nerc.ac.uk/collection/L22/current/NETT0180/)	
Description	A series of seven incubation experiments taking krill fecal pellets and incubating them in trace-metal clean water. Filtered samples were then prepared for onward analysis of macronutrients, flow cytometry, and dissolved iron (see nutrients/flow cytometry datasets in Table 2.2-3).	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports work/scientific_work_areas/Nets/RMT8
Digital data	Raw	See contact.
Physical samples	Filters have been placed in Nalgene vials and stored at -20°C for return to the University of Plymouth for dissolved iron analysis.	
Contacts	**Katrin Schmidt (U. of Plymouth)**	

Dataset	**RMT8 environmental monitoring data**	
Instruments	A BAS Down-wide Net Monitor (DWNM) comprising; a CTD, camera, lights, altimeter, light sensor, current meter.	
Description	An environmental monitoring and control system fixed to the RMT8 net.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports work/scientific_work_areas/Nets/RMT8
Digital data	Raw	work/scientific_work_areas/Nets/RMT8/Raw_DWNM
Contacts	**Sophie Fielding (BAS),** Gareth Flint (BAS), Katy Cartlidge (BAS)	

Mammoth Net

Dataset	**Zooplankton sampling**	
Instruments	Hydro-Bios MultiNet Mammoth (http://vocab.nerc.ac.uk/collection/L22/current/NETT0187/)	
Description	See Mammoth Section 12.2.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	N/A
Physical samples	Selected samples were frozen at -80°C for subsequent trace metal analysis at the University of Plymouth Other samples were preserved in formaldehyde for future taxonomic analysis.	
Contacts	**Sophie Fielding (BAS), Katrin Schmidt (U. of Plymouth)**	

Dataset	**Mammoth environmental monitoring data**	
Instruments	CTD and flow meters attached to the Hydro-Bios MultiNet Mammoth frame	
Description	Pressure, temperature, conductivity and flow rates are constantly (1Hz) recorded to an internal disk and downloaded after each deployment.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	work/scientific_work_areas/Nets/Mammoth/RAW Files
Contacts	**Sophie Fielding (BAS),** Gareth Flint (BAS), Katy Cartlidge (BAS)	

Dataset	**Zooplankton preservation experiment**	
Instruments	Hydro-Bios MultiNet Mammoth (http://vocab.nerc.ac.uk/collection/L22/current/NETT0187/)	
Description	See zooplankton preservation Section 10.5.2.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	See contact.
Physical samples	Zooplankton samples were preserved using a variety of techniques to evaluate the effect of formalin preservation.	
Contacts	**Flo Atherden (BAS)**	

Moorings

Dataset	**PICCOLO mooring sensors and sampling**
Instruments	Original long-term deployment: Sea-Bird ECO FLbb Fluorometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1361/) SAMI-pH Ocean pH Sensor (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1613/) Simrad Wideband Autonomous Transceiver (120kHz) (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1208/) Sea-Bird SBE37-SMP-ODO MicroCAT CTD (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1459/) Green Eyes LLC Aqua Monitor water sampler

	(Prob. http://vocab.nerc.ac.uk/collection/L22/current/TOOL0381/) McLane PARFLUX Mark78H-21 Sediment Trap (21 x 500ml bottles) (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0785/) Aanderaa Seaguard II Recording Current Meter inc. • Aanderaa 4330 oxygen optode (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1247/) • Aanderaa 4520 current sensor SD035 short-term deployment: As above but without the Simrad Wideband Autonomous Transceiver (120kHz)	
Description	The PICCOLO mooring was initially deployed on SD025 (2023-02-17) and was recovered at the start of SD035 (2024-01-29). The mooring was turned around (data and samples offloaded) and redeployed for a short period of time during SD035, being recovered on 2024-02-16. See PICCOLO mooring Section 8.1 for further details.	
Metadata	Configuration	work/scientific_work_areas/Mooring/SD035_Mooring_Setup
	Digital logs	See PICCOLO mooring Section 8.1
Digital data	Raw	work/scientific_work_areas/Mooring/SD025_mooring_data work/scientific_work_areas/Mooring/SD025_mooring_data
Physical samples	Sample bottles from the McLane sediment trap were packed in vermiculite and will be returned to the British Antarctic Survey for analysis. Samples from the Aqua Monitor were analysed for various parameters onboard – See Table 2.2-3 for more details.	
Contacts	**Sophie Fielding (BAS),** Flo Atherden (BAS), Emily Rowlands (BAS), Giorgio Dall'Olmo (OSG)	

Dataset	**BIOPOLE mooring sensors and sampling**	
Instruments	Sea-Bird SBE37-SMP-ODO MicroCAT CTD (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1459/) Teledyne RDI Workhorse Sentinel-300 Acoustic Doppler Current Profiler (ADCP) (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0295/) 2 x McLane PARFLUX Mark78H-21 Sediment Trap (21 x 500ml bottles) (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0785/) Aanderaa Seaguard II Recording Current Meter inc. • Aanderaa 4330 oxygen optode (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1247/) • Aanderaa 4117F pressure sensor (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1207/) • Aanderaa 4296 turbidity sensor • Aanderaa 4520 current sensor	
Description	The BIOPOLE mooring had been deployed on SD025 (2023-03-02) and recovered on SD033 (2023-12-04) to avoid iceberg damage. Sensor data was downloaded on SD035 and the mooring was opportunistically redeployed at the end of SD035 (2024-03-05)	
Metadata	Configuration	work/scientific_work_areas/Mooring/SD035_Mooring_Setup
	Digital logs	See Biopole mooring Section 8.2

Digital data	Raw	work/scientific_work_areas/Mooring/SD025_mooring_data
Physical samples	Sample bottles from the McLane sediment trap had been processed and stored on SD033.	
Contacts	**Sophie Fielding (BAS),** Flo Atherden (BAS), Emily Rowlands	

Uncrewed Surface Vehicles

Dataset	**AutoNaut 5.0 sensor data (Caravela)**	
Instruments	1 x Autonaut 5.0 uncrewed surface vessel https://autonautusv.com/autonaut-5 Fitted with: Airmar 120WX Ultrasonic WeatherStation https://www.airmar.com/Product/120WX Apogee CS301 pyranometer https://www.campbellsci.com/cs301 Apogee SL-510 pyrgeometer https://www.apogeeinstruments.com/sl-510-ss-pyrgeometer-upward-looking/ Rotronic HC2A temperature and humidity sensor https://vocab.nerc.ac.uk/collection/L22/current/TOOL1641/ Nortek Signature1000 Acoustic Doppler Current Profiler https://vocab.nerc.ac.uk/collection/L22/current/TOOL1009/ Sea-Bird SBE 49 FastCAT CTD https://vocab.nerc.ac.uk/collection/L22/current/TOOL0827/ SD035 additions: Pro-Oceanus CO2-Pro CV Submersible pCO_2 Sensor (https://pro-oceanus.com/products/pro-series/co2-pro-cv) Sea-Bird ECO FLbb Fluorometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1361/) pH sensor (type unknown)	
Description	Caravela was deployed on a single occasion between 2024-02-29 12:49 and 2024-03-01 13:11. See USV Section 17 for further details.	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	work/scientific_work_areas/Caravela/FLBB See contacts for other sensor data collected.
Contacts	**Karen Heywood (UEA), Gareth Lee (UEA)**	

Gliders

Dataset	**Glider sensor data**
Instruments	4 x Kongsberg Maritime Seaglider M1 gliders (SG565, SG673, SG558, SG676) (http://vocab.nerc.ac.uk/collection/B76/current/B7600002/) Glider SG565 Sea-Bird CT Sail CTD (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1188/)

	Kongsberg Maritime CONTROS HydroFlash O2 oxygen optode (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1540/) WET Labs ECO Puck Triplet BBFL2-IRB scattering fluorescence sensor (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1311/) Imagenex 853 Echo Sounder (https://vocab.nerc.ac.uk/collection/L22/current/TOOL0950/) Glider SG673 Sea-Bird CT Sail CTD (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1188/) Aanderaa 4831 oxygen optode (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1239/) WET Labs ECO Puck Triplet BBFL2-IRB scattering fluorescence sensor (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1311/) ClearWater pH Lab-On-Chip (LOC) sensor (https://www.clearwatersensors.com/ph-sensor/) Glider SG558 Sea-Bird CT Sail CTD (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1188/) Aanderaa 4831 oxygen optode (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1239/) ClearWater Nitrate + Nitrate Lab-On-Chip (LOC) sensor (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1896/) Glider SG676 Sea-Bird CT Sail CTD (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1188/) Aanderaa 4831F oxygen optode (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1240/) WET Labs ECO Puck Triplet BB2FL-IRB scattering fluorescence sensor (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1881/) Biospherical Instruments QSP-2150 underwater PAR sensor (https://vocab.nerc.ac.uk/collection/L22/current/TOOL1305/) Imagenex 853 Echo Sounder (https://vocab.nerc.ac.uk/collection/L22/current/TOOL0950/)	
Description	Four gliders were deployed during SD035 and comprised UEA Mission 67 (see https://www.ueaglider.uea.ac.uk/mission67). Brief deployment information below, see glider Section 13 for more details. SG565 (BAS owned) – 2 deployments (Larsen ice shelf area: dives 1 – 21, NW Weddell Sea shelf slope: dives 22 – 40) SG673 (UEA owned) – 2 deployments (Larsen ice shelf: dives 1 – 22, NW Weddell Sea shelf slope: dives 23 – 180) SG558 (UEA owned) – 1 deployment (NW Weddell Sea shelf slope: dives 1 -196) SG676 (UEA owned) – 1 deployment (NW Weddell Sea shelf: dives 1 – 18)	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	work/scientific_work_areas/Gliders

Contacts	**Gareth Lee (UEA),** Karen Heywood (UEA), Yixi Zheng (UEA),

BGC-Argo float

Dataset	**BGC-Argo float profiling sensor data**	
Instruments	NKE Provor CTS5 float (https://nke-instrumentation.com/produit/provor-cts5/) See https://fleetmonitoring.euro-argo.eu/float/3902492 for sensor details.	
Description	A single BGC-specific Argo float (WMO ID = 3902492) was deployed during the cruise. See optics Section 4.1.2 for further details.	
Metadata	Website	https://fleetmonitoring.euro-argo.eu/float/3902492
Digital data	Raw	https://fleetmonitoring.euro-argo.eu/float/3902492
Contacts	**Giorgio Dall'Olmo (OSG), Bob Brewin (U. of Exeter)**	

Drones

Dataset	**BAS drone imagery**	
Instruments	DJI Mavic2 Pro	
Description	The BAS-owned and operated Mavic2 drone was operated throughout the cruise for a variety of purposes including: a) site mapping during on-ice work, b) seal spotting, and c) over-the-side deployment observations. See RPAS Section 18 for further details.	
Metadata	Digital Logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	work/scientific_work_areas/Drone
Contacts	**Carson McAfee (BAS)**	

Dataset	**UEA drone imagery**	
Instruments	DJI Mavic3 Pro	
Description	The UEA-owned and operated Mavic3 was operated occasionally during the cruise, mainly to observe on-ice activities and to follow the progress of the uncrewed surface vehicle, Caravela.	
Metadata	Digital Logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	See contact.
Contacts	**Gareth Lee (UEA)**	

Floating Sediment Trap

Dataset	**Floating sediment trap sampling**
Instruments	BAS floating sediment trap comprising: • 3 x stainless-steel carousels spaced out on a deployment wire to capture different depths. Each carousel contains 4 sampling bottles. One bottle was polycarbonate lined to allow trace-metal sampling. • Marking buoy with Iridium beacon
Description	The floating sediment trap was deployed either tethered to the ship or free-roaming depending on conditions. Each carousel bottle was sampled for a different analytical purpose. These included:

	1) Particulate Organic Chemistry (POC), Particulate Inorganic Chemistry (PIC) and Silica analysis 2) Micro- and Nano-plastic analysis 3) Trace metal particulate analysis 4) Phytoplankton and faecal pellet analysis See Table 2.2-3 for the onward processing of sediment trap samples	
Metadata	Digital logs	work/data_management/event_logs/Eventlog_exports
Digital data	Raw	See relevant datasets within Table 2.2-3.
Physical samples	See Table 2.2-3 for the onward processing of sediment trap samples	
Contacts	**Emily Rowlands (BAS), Flo Atherden (BAS**)	

Seals (as a platform)

Dataset	**Seal tag data**	
Instruments	4 x SMRU CTD-Satellite Relay Data Loggers (CTD-SRDL) 7 x SMRU CTD-Satellite Relay Data Loggers with additional fluorometry and light levels (F-CTD-SRDL) 8 x CTD-Satellite Relay Data Loggers with additional Oxygen sensors (O-CTD-SRDL)	
Description	Oceanographic data loggers were attached to a variety of seal species (Elephant, Weddell, Crabeater) encountered on sea ice and land. Locational information and data relay is achieved through the Argos satellite system. See seal tagging Section 11 for more details. Seal tags were also deployed on a number of stainless steel CTD frame deployments for calibration purposes.	
Metadata	Digital logs	work/scientific_work_areas/Seal_tagging
Digital data	Website	https://www.smru.st-andrews.ac.uk/protected/ct179/ct179.html (password protected)
Contacts	**Lars Boehme (U. of St Andrews), Gui Bortolotto (Aberystwyth U.)**	

Dataset	**Seal faecal sampling**	
Instruments	A plastic spoon	
Description		
Metadata	Digital logs	work/scientific_work_areas/Seal_tagging
Digital data	Website	https://www.smru.st-andrews.ac.uk/protected/ct179/ct179.html (password protected)
Contacts	**Lars Boehme (U. of St Andrews), Gui Bortolotto (Aberystwyth U.), Emily Rowlands (BAS)**	

Sea ice floes (as a platform)

Dataset	**Surface snow sampling**
Instruments	A snow scoop

Description	Surface snow samples were collected during on-ice work. These were subsequently melted onboard for onward sub-sampling and analysis.	
Metadata	Paper logs	work/scientific_work_areas/On-ice sampling/SD035_through_ice_logsheets/scanned_logsheets
Digital data	Raw	See relevant datasets within Table 2.2-3.
Physical samples	Snow samples were analysed for various parameters onboard – see Section 7.1.2 and microplastic and trace metal analytical datasets (Table 2.2-3) for more details.	
Contacts	**Angela Milne**, Neil Wyatt, Simon Ussher (all University of Plymouth) **Flo Atherden (BAS),** Emily Rowlands (BAS)	

Dataset	**Ice core profiling and sampling**	
Instruments	KOVACS MARK II ice coring system (9cm x 1m) (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1249/)	
Description	Ice cores were collected during on-ice work. These cores were described, temperature profiled, and sectioned in the field and then returned to the ship for onward analysis – see Section 7.1.3 and Table 2.2-3 for more details.	
Metadata	Paper logs	work/scientific_work_areas/On-ice sampling/SD035_seaice_coring_logsheets/SD035_seaicecoring_logsheets_completed_scans
Digital data	Raw	work/scientific_work_areas/On-ice sampling/ SD035_icecore_temperature_20240308.csv Also, relevant datasets within Table 2.2-3.
Physical samples	Ice core samples were analysed for various parameters onboard – see Table 2.2-3 for more details.	
Contacts	**Elise Droste (UEA)** – BGC cores**, Angela Milne (U. of Plymouth)** – TM cores	

Dataset	**Sub-ice CTD profiling and water sampling**
Instruments	Stihl BT131 Earth Auger with 300mm bit (https://www.stihl.co.uk/en/p/earth-augers-bt-131-petrol-earth-auger-75112) KC Denmark Model 30.000 winch (https://www.kc-denmark.dk/products/winches/small-winches-operated-by-hand/small-winch-operated-by-hand.aspx) Valeport RapidPro CTD (https://www.valeport.co.uk/products/rapidpro-ctd/) Ocean Test Equipment Teflon coated C-Free chamber water sampler (Niskin), model 114 (5 litre) (https://www.oceantestequip.com/water-samplers.php)
Description	Access holes were created at both sea ice floe locations using the auger and then a hand operated winch was used for CTD and Niskin bottle deployments. While the RapidPro CTD was primarily deployed through holes in the sea-ice during on-ice work, it was tested using the KC Denmark winch from the vessel

	(ship event 237) and was deployed on the ship's stainless steel CTD frame for calibration purposes (ship event 126).	
Metadata	Paper logs	work/scientific_work_areas/On-ice sampling/SD035_through_ice_logsheets/scanned_logsheets
Digital data	Raw	work/scientific_work_areas/RapidCast/CTD work/scientific_work_areas/On-ice sampling/EVENT268_IceFloe8/RapidCast/CTD/raw_data work/scientific_work_areas/On-ice sampling/EVENT27_IceFloe9/RapidCast/CTD/raw_data Also, relevant datasets within Table 2.2-3.
Physical samples	On-ice CTD samples were analysed for various parameters onboard – see Table 2.2-3 for more details.	
Contacts	**Yixi Zheng (UEA),** Keith Nicholls (BAS), Carson McAfee (BAS)	

Dataset	**Sub-ice pumped water sampling**	
Instruments	Makita 18V vacuum pump (Radium sampling) Peristaltic pump (unknown type) (BGC sampling)	
Description	Pumped water samples from the interfacial layer were collected through holes in the sea ice at both floe sites. Some holes were created specifically using a 50 mm auger drill bit while others were reused ice core holes. See on-ice interfacial Section 7.1.4 and on-ice radium Section 7.1.6 for more details.	
Metadata	Digital logs	work/scientific_work_areas/On-ice sampling/SD035_through_ice_logsheets/scanned_logsheets
Digital data	Raw	See relevant datasets within Table 2.2-3.
Physical samples	Water samples were analysed for various parameters onboard – see Table 2.2-3 for more details.	
Contacts	**Elise Droste (UEA)** – BGC sampling, **Alistair Lough (U. of Leeds)** – Radium sampling	

Dataset	**On-ice flux chamber**	
Instruments	Gasmet DX4015 FTIR gas analyser (https://www.gasmet.com/products/category/portable-gas-analyzers/dx4015/) Eosense eosAC gas flux chamber (https://eosense.com/products/eosac-multi-species-soil-flux-chamber-2/)	
Description	A flux chamber and gas analyser were deployed at a single location per ice floe with the system running for approximately two hours. See on-ice Section 7.1.8 for more details.	
Metadata	Paper logs	work/scientific_work_areas/On-ice sampling/SD035_seaice_coring_logsheets/SD035_seaicecoring_logsheets_completed_scans
Digital data	Raw	See contact.
Contacts	**Ian Brown (PML)**	

Dataset	**Sub-ice optical system**	
Instruments	2 x Li-Cor PAR sensors (unknown model) Li-Cor LI-1400 data logging system Sensing Secchi Disk (bespoke Arduino based sensing package, see Brewin et al. Under Review) Low-light Sensing Secchi Disk (bespoke sensing package made by Bob Brewin and Carson McAfee during SD035) Sea-Bird ECO FLbb Fluorometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1361/)	
Description	A series of optical measurements taken above and below the ice during on-ice work on both floes visited. Augmented with continuous radiometry measurements taken from the ship (see 'Above-water radiometry measurements' dataset above) and GoPro camera footage (see Sub-ice imagery dataset below).	
Metadata	Paper logs	work/scientific_work_areas/Optics/Data/Ice_work/240226/On_Ice work/scientific_work_areas/Optics/Data/Ice_work/240227/On_Ice
Digital data	Raw	work/scientific_work_areas/Optics/Data/Ice_work/240226/On_Ice work/scientific_work_areas/Optics/Data/Ice_work/240227/On_Ice
Contacts	**Bob Brewin (U. of Exeter),** Giorgio Dall'Olmo (OGS), Xuerong Sun (U. of Exeter)	

Dataset	**Sub-ice imagery**	
Instruments	Insta360 X3 camera (https://www.insta360.com/product/insta360-x3) MarCum (unknown model) GoPro (unknown model)	
Description	A variety of waterproof cameras were deployed through holes in the sea ice to a) observe ice and sub-ice conditions, b) observe coeval sub-ice deployments through nearby holes, and c) for outreach purposes. The cameras were also used to capture video and stills from activity above the ice surface. See on-ice photography Section 7.1.9 for more details.	
Metadata	Paper logs	
Digital data	Raw	work/scientific_work_areas/On-ice sampling/EVENT268_IceFloe8/ work/scientific_work_areas/On-ice sampling/EVENT273_IceFloe9/
Contacts	**Carson McAfee (BAS)**	

Water analysis datasets

Water was collected using a variety of devices and methods on SD035 for onward preparation, filtering, and analysis. Each analytical dataset table indicates the sampling sources they were taken from, as well as the **approximate** number of environmental samples processed. This number was taken from sampling source log sheets and does not consider onward sample splitting/merging, calibration/blank measurements, ignored samples, or transfers of samples from one analytical process to another. In some cases, a sampling source was known to be used but the number of samples processed is unknown, so it is green but has been left blank.

Sampling sources have been described in the platform-related datasets above (Table 2.2-1) but they are listed below for clarity, along with an abbreviated term that is then used in the analytical dataset tables.

Table 2.2-2: Description of sampling source abbreviations used in Table 2.2-3

Sampling source	**Abbreviation**
Niskin bottles on the Stainless Steel CTD frame	CTD
Niskin bottles on the Titanium CTD frame	TiCTD
Ship's uncontaminated seawater supply	UCSW
Trace metal towfish water sampler	Tow fish
Sea ice sampled from the ship	Sea Ice
Sea ice snow sampling (on-ice work)	Snow
Sea ice cores (on-ice work)	Ice Core
Niskin bottles attached to the on-ice winch wire (on-ice work)	Ice CTD
Through-ice pumped seawater supply (on-ice work)	Ice Pump
Floating sediment trap bottles	Float Sed
Piccolo Mooring sediment trap bottles	Moor Sed
Piccolo Mooring Aqua Monitor bags	Aqua Mon

Table 2.2-3: Water analysis datasets collected during SD035.

Dataset	**Dissolved Oxygen (O_2) analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float Sed	Moor Sed	Aqua Mon
	203	73										
Instruments	Automated Winkler titration system (probably http://vocab.nerc.ac.uk/collection/L22/current/TOOL1145/)											
Description	O_2 analysis to assist in the calibration of the oxygen sensors on the Titanium and Stainless Steel CTD frames. See dissolved oxygen Section 9.2 for more detail.											
Metadata	Paper Logs											
	Digital logs	See dissolved oxygen Section 9.2.										
Digital data	Raw	work/scientific_work_areas/Oxygen CTD (only partial results up to CTD cast 113)										
Physical samples	None											
Contacts	**Carol Robinson (UEA)**											

Dataset	**Community respiration derived from the decrease in dissolved oxygen concentration (CR_{02})**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float Sed	Moor Sed	Aqua Mon
	103								2			
Instruments	Automated Winkler titration system (probably http://vocab.nerc.ac.uk/collection/L22/current/TOOL1145/)											

Description	See respiration Section 10.1. Also included time-series experiments.	
Metadata	Paper Logs	
	Digital logs	See respiration Section 10.1.
Digital data	Raw	See contact.
Physical samples	None	
Contacts	**Carol Robinson (UEA)**	

Dataset	**Community and size fractionated respiration derived from the reduction of INT**											
Sample Type	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	19				1				2			
Instruments	N/A (samples filtered for future analysis)											
Description	See respiration Section 10.1. Also included time-series experiments.											
Metadata	Paper Logs											
	Digital logs	See respiration Section 10.1.										
Digital data	Raw	N/A										
Physical samples	Sample filters will be returned to the University of East Anglia for INT analysis											
Contacts	**Isabel Seguro (UEA)**											

Dataset	**Community and size fractionated respiration measured with the classical Electron Transport System (ETS) method**											
Sample Type	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	228								2			
Instruments	N/A (samples filtered for future analysis)											
Description	See respiration Section 10.1.											
Metadata	Paper Logs											
	Digital logs	See respiration Section 10.1.										
Digital data	Raw	N/A										
Physical samples	Sample filters will be returned to the University of East Anglia for ETS analysis											
Contacts	**Natalia Osma (University of Antofagasta, Chile)**											

Dataset	**Community and size fractionated respiration derived from pyridine nucleotide concentrations and an enzyme kinetic model (EKM).**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	208											
Instruments	N/A (samples filtered for future analysis)											

Description	See respiration Section 10.1.	
Metadata	Paper Logs	
	Digital logs	See respiration Section 10.1.
Digital data	Raw	N/A
Physical samples	Sample filters will be returned to the University of East Anglia for EKM analysis	
Contacts	**Natalia Osma (University of Antofagasta, Chile)**	

Dataset	**Primary Productivity (PP) analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	108				1				2			
Instruments	Hidex 300SL liquid scintillation counter											
Description	See primary productivity Section 10.4.											
Metadata	Paper Logs	Logs exist but were packed before they could be scanned. See contacts for details.										
	Digital logs	See primary productivity Section 10.4.										
Digital data	Raw	work/scientific_work_areas/Radiochemistry/CTD Data										
Physical samples	Water samples have been returned to the UK as waste but there is the potential for further analysis work.											
Contacts	**Ruth Airs (PML), Ian Brown (PML)**											

Dataset	**Bacterial Productivity (BP) analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	108				1				2			
Instruments	Hidex 300SL liquid scintillation counter											
Description	See primary productivity Section 10.4.											
Metadata	Paper Logs	Logs exist but were packed before they could be scanned. See contacts for details.										
	Digital logs	See primary productivity Section 10.4.										
Digital data	Raw	work/scientific_work_areas/Radiochemistry/CTD Data										
Physical samples	Water samples have been returned to the UK as waste but there is the potential for further analysis work.											
Contacts	**Ruth Airs (PML), Ian Brown (PML)**											

Dataset	**Photosynthetic Irradiance (PI) Curve analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
Instruments	Hidex 300SL liquid scintillation counter											

Description	See primary productivity Section 10.4.	
Metadata	Paper Logs	Logs exist but were packed before they could be scanned. See contacts for details.
	Digital logs	See primary productivity Section 10.4.
Digital data	Raw	work/scientific_work_areas/Radiochemistry/CTD Data
Physical samples	Water samples have been returned to the UK as waste but there is the potential for further analysis work.	
Contacts	**Ruth Airs (PML), Ian Brown (PML)**	

Dataset	**Phytoplankton-released Dissolved Organic Carbon (DOC) analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
Instruments	Hidex 300SL liquid scintillation counter											
Description	See primary productivity Section 10.4.											
Metadata	Paper Logs	Logs exist but were packed before they could be scanned. See contacts for details.										
	Digital logs	See primary productivity Section 10.4.										
Digital data	Raw	work/scientific_work_areas/Radiochemistry/CTD Data										
Physical samples	Water samples have been returned to the UK as waste but there is the potential for further analysis work.											
Contacts	**Ruth Airs (PML), Ian Brown (PML)**											

Dataset	**Dissolved Organic Matter (DOM) including Dissolved Organic Carbon (DOC), Total Organic Carbon (TOC), Total Dissolved Nitrogen (TDN) and Dissolved Organic Phosphorus (DOP) analysis**											
Sample source	CTD	TiCTD	UCSW	Tow Fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	180				1			8				
Instruments	N/A (samples prepared for future analysis)											
Description	See respiration Section 10.1.											
Metadata	Paper Logs											
	Digital logs	See respiration Section 10.1.										
Digital data	Raw	N/A										
Physical samples	Filtered samples were frozen at -20 °C and will be returned to the UK and then onto the Alfred Wegner Institute for further analysis.											
Contacts	**Isabel Seguro (UEA),** Guilherme Bortolotto (Aberystwyth U.), Boris Koch (AWI)											

Dataset	**Abundance and composition of microbial plankton communities by flow cytometry**

Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	340	305			1		19	15				
Instruments	Becton Dickinson FACSort Flow Cytometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0521/)											
Description	For details see flow cytometry Section 9.10. Additional flow cytometry work was conducted on samples collected for other purposes (e.g., to test for bottle effects in incubations or test the efficacy of filtration processes)											
Metadata	Paper Logs											
	Digital logs	See flow cytometry Section 9.10.										
Digital data	Raw	See contact.										
Physical samples	None remained after analysis.											
Contacts	**Glen Tarran (PML)**											

Dataset	**Abundance and composition of microbial plankton communities by microscopy**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	144				1			8	2			
Instruments	N/A (samples prepared for future analysis)											
Description	For details see flow cytometry Section 9.10.											
Metadata	Paper Logs											
	Digital logs	See flow cytometry Section 9.10.										
Digital data	Raw	N/A										
Physical samples	Samples were preserved with Lugol's solution and will be returned to the UK for microscopy analysis											
Contacts	**Glen Tarran (PML)**											

Dataset	**Abundance and composition of microbial plankton communities by FlowCam**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	109											
Instruments	N/A (samples prepared for future analysis)											
Description	For details see flow cytometry Section 9.10.											
Metadata	Paper Logs											
	Digital logs	See flow cytometry Section 9.10.										
Digital data	Raw	N/A										
Physical samples	Samples underwent reverse filtration and were preserved with Lugol's solution and will be returned to the UK for FlowCam analysis											

Contacts	**Glen Tarran (PML)**

Dataset	**Salinity analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	66	93					24		2			
Instruments	Guildline Autosal 8400B Salinometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0454/)											
Description	Sample analysis to calibrate concurrent salinity sensors. For details, see salinometry Section 9.1.											
Metadata	Paper Logs	work/scientific_work_areas/Salinometer/logsheets										
	Digital logs	work/scientific_work_areas/Salinometer/										
Digital data	Raw	work/scientific_work_areas/Salinometer/data/raw										
Physical samples	None remained after analysis.											
Contacts	**Lars Boehme (U. of St Andrews),** Maren Richter (UEA), Yixi Zheng (UEA), Shaun Miller (BAS)											

Dataset	**Nutrients analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	1042	362	89	29	1		48	8	2			
Instruments	Seal Analytical AutoAnalyser 3HR (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1113/)											
Description	A fully automated Segmented Flow Analysis (SFA) system was used for analysis of Nitrate, Nitrite, Silicate, Phosphate and Ammonium from a wide range of water sampling methods. For further details, see the nutrients Section 10.3.											
Metadata	Paper Logs											
	Digital logs											
Digital data	Raw	work/scientific_work_areas/Nutrients/PICCOLO Cruise SD035 2024_final.zip										
Physical samples	None remained after analysis.											
Contacts	**Sarah Breimann (PML),** Bethany Wilkinson (PML), **Malcolm Woodward (PML)**											

Dataset	**Chlorophyll-a analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	117				1			8				
Instruments	Turner Designs Trilogy fluorometer (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0459/)											
Description	See Chlorophyll-a Section 10.11.											

Metadata	Paper Logs	
	Digital logs	work/scientific_work_areas/Chlorophyll
Digital data	Raw	work/scientific_work_areas/Chlorophyll
Physical samples	None remained after analysis.	
Contacts	**Bethany Wilkinson (PML),** Sarah Breimann (PML), Malcolm Woodward (PML)	

Dataset	**Carbonate chemistry analysis including Dissolved Inorganic Carbon (DIC) and Total Alkalinity (TA).**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	472	14	90				25	8	2			16
Instruments	Marianda VINDTA 3C total inorganic carbon and titration alkalinity analyser (http://vocab.nerc.ac.uk/collection/L22/current/TOOL0481/)											
Description	See carbonate chemistry Section 10.7.											
Metadata	Paper Logs	work/scientific_work_areas/Carbonate_Chemistry/DICTA_sampling_sheets										
	Digital logs											
Digital data	Raw	work/scientific_work_areas/Carbonate_Chemistry/DICTA_preliminary_data										
Physical samples	Due to time constraints, not all samples were analysed onboard. Those remaining were fixed (with mercuric chloride solution) and will be returned to the University of East Anglia for analysis.											
Contacts	**Elise Droste (UEA),** Gareth Lee (UEA), **Dorothee Bakker (UEA)**											

Dataset	**Particulate Organic Chemistry (POC), Particulate Inorganic Chemistry (PIC) and Silica analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	168	6						8	2	5		
Instruments	N/A (samples filtered for future analysis)											
Description	For details see particulate matter Section 10.12.											
Metadata	Paper Logs											
	Digital logs	See particulate matter Section 10.12										
Digital data	Raw	N/A										
Physical samples	Water samples underwent filtration under pressure through 25 mm micro-glass fibre (for POC/PIC) and polycarbonate (for Silica) filters and these air-dried filters will be returned to the British Antarctic Survey for further analysis.											
Contacts	**Flo Atherden (BAS),** Emily Rowlands (BAS)											

Dataset	**Micro and nano-plastic analysis**

Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
										5		
Instruments	N/A (samples prepared/filtered for future analysis)											
Description	For details see floating sediment trap Section 14 and on-ice activity Section 7.1.2. Note that seal poo collected by the seal tagging team was also sampled for microplastic content.											
Metadata	Paper Logs											
	Digital logs	See floating sediment trap Section 14.										
Digital data	Raw	N/A										
Physical samples	Nanoplastics: 50ml samples were frozen at -20°C for return to the UK for gas chromatography-mass spectrometry (GCMS) analysis. Microplastics: Samples were filtered, and the filters were frozen at -20°C for return to the British Antarctic Survey for Focal Plane Array Fourier Transform Infrared (FPA FTIR) analysis.											
Contacts	**Flo Atherden (BAS),** Emily Rowlands (BAS)											

Dataset	**Chromophoric Dissolved Organic Matter (CDOM) analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	300							8				
Instruments	VWR UV-3100PC UV/Visible Spectrophotometer (https://uk.vwr.com/store/product/22037841/null)											
Description	For details see CDOM Section 9.9.											
Metadata	Paper Logs											
	Digital logs	See CDOM Section 9.9.										
Digital data	Raw	See contact.										
Physical samples												
Contacts	**Vassilis Kitidis (PML)**											

Dataset	**Dissolved Organic Matter (DOM) Photochemistry analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	12				1							
Instruments	Custom-built solar simulator used to incubate samples for onward analysis. Setup details are described in Kitidis et al. (2011) https://doi.org/10.1016/j.marchem.2011.08.004											
Description	For details see photochemistry Section 10.3 but note that incubated samples were analysed for DIC/TA/pH and CDOM and results will be included in those analytical datasets.											
Metadata	Paper Logs											

	Digital logs	See photochemistry Section 10.3
Digital data	Raw	N/A
Physical samples		
Contacts	**Vassilis Kitidis (PML)**	

Dataset	**High-Performance Liquid Chromatography (HPLC) analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	8	21	81		1		3		2			
Instruments	N/A (samples filtered for future analysis)											
Description	See HPLC sub-section within Section 4.1.2.											
Metadata	Paper Logs	work/scientific_work_areas/Optics/LogBook										
	Digital logs											
Digital data	Raw	N/A										
Physical samples	Filters from the HPLC sampling were flash-frozen in liquid nitrogen and will be returned to the UK for analysis.											
Contacts	**Xuerong Sun (U. of Exeter),** Giorgio Dall'Olmo (OGS), Bob Brewin (U. of Exeter)											

Dataset	**Trace metal analysis including Total Dissolvable Iron (TdFe), Dissolvable Iron (dFe), Soluble Iron (sFe), Iron Isotopes (Fe-iso), Barium Isotopes (Ba-iso), Nitrate Isotopes (NO3-iso) and trace metal particulates (amount and fractionation)**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
		332		30		16		6		5		
Instruments	N/A											
Description	The clean chemistry team sampled from a variety of sources that were specially designed to be free of metal contamination. The majority of samples were filtered and stored for UK-based analysis but Dissolved Iron (dFe) samples were analysed onboard using flow injection methods. See trace metal Section 9.5 for more details.											
Metadata	Paper Logs											
	Digital logs	work/scientific_work_areas/Trace Metal Team/TM Station Logs										
Digital data	Raw	See contacts.										
Physical samples	Filters from the water samples (TiCTD, towfish, On-ice CTD, floating sediment trap) were stored frozen and will be returned to: • University of Plymouth for onward ICP-MS analysis and flow injection methods • University of St. Andrews (Luke Bridgestock) for Barium isotope analysis • University of Leeds (Alistair Lough) for Iron isotope analysis • University of Edinburgh (Raja Ganeshram) for Nitrate isotope analysis											

	Snow and ice cores were stored frozen and will return to the University of Plymouth.
Contacts	**Angela Milne**, Neil Wyatt, Simon Ussher (all University of Plymouth)

Dataset	**Iron-cycling of krill – size fractionation of potential food**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
		27		5				2				
Instruments	N/A (samples filtered for future analysis)											
Description	Water samples were taken from a variety of trace-metal clean sources throughout the cruise and size-fractionated through filtration for onward analysis in the UK. See Iron cycling in Krill Section 10.5.1 for more details.											
Metadata	Paper Logs											
	Digital logs	See Iron cycling in Krill Section 10.5.1										
Digital data	Raw	N/A										
Physical samples	Filters were stored in Nalgene vials and for each sample source there are a number of size fractionations (plus replicas) for onward analysis in the UK of particulate iron (at -80C), total nitrogen (at -20C), and lipid biomarkers (at -80C).											
Contacts	**Katrin Schmidt (University of Plymouth)**											

Dataset	**Nutrient addition bioassay experiment**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
		6						1				
Instruments	Custom-built temperature-controlled incubator Chelsea Technologies LabSTAF Single Turnover Active Fluorometer (https://chelsea.co.uk/products/labstaf/)											
Description	Samples were amended with Iron and Manganese and incubated in a variety of light conditions. Periodically these samples were analysed for chlorophyll fluorescence (LabSTAF work by Neil Wyatt). Chlorophyll-a, nutrients, and flow cytometry were also measured – see relevant analysis dataset tables. See nutrient addition bioassay Section 10.2 for more details.											
Metadata	Paper Logs											
	Digital logs	See nutrient addition bioassay Section 10.2										
Digital data	Raw	See contact.										
Physical samples	Some samples were preserved and will return to the UK for identification of phytoplankton community structure by microscopy.											
Contacts	**Neil Wyatt**, Angela Milne, Simon Ussher (all University of Plymouth)											

Dataset	**Oxygen Isotope (^{18}O) analysis**											
	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon

Sample source	49	291	65	22				6	2			
Instruments	N/A (samples taken for future analysis)											
Description	Seawater samples were taken from a variety of sources for onward analysis in the UK. See oxygen isotope Section 10.8 for more details.											
Metadata	Paper Logs											
	Digital logs											
Digital data	Raw	N/A										
Physical samples	Samples were stored at 4°C and will be returned to the British Antarctic Survey for isotopic analysis											
Contacts	**Chiara Krewer (U. of Leeds),** Will Homoky (U. of Leeds)											

Dataset	**Radium analysis**											
Sample source	CTD	TiCTD	UCSW	Tow fish	Sea Ice	Snow	Ice Core	Ice CTD	Ice Pump	Float. Sed	Moor. Sed	Aqua Mon
	126								2			
Instruments	Scientific Computer Instruments RaDeCC delayed coincidence counting system (http://vocab.nerc.ac.uk/collection/L22/current/TOOL1243/)											
Description	Analysis of Radium isotope concentrations. See radium cruise Section 10.6 for further details.											
Metadata	Paper Logs											
	Digital logs	work/scientific_work_areas/Trace Metal Team/Radium by SS-rossette/Logs										
Digital data	Raw	work/scientific_work_areas/Trace Metal Team/Radium by SS-rossette/RaDeCC raw data										
Physical samples	MnO_2 coated acrylic fiber samples will be returned to the University of Leeds for further analysis. Selected Radium CTD casts were subsampled (into 1L bottles) and these samples will return to the UK for possible mass spectrometry work.											
Contacts	**Will Homoky (U. of Leeds)**, Alastair Lough (U. of Leeds), Chiara Krewer (U. of Leeds)											

2.3 Cruise directory structure

A new folder was setup when the cruise participants joined the vessel (2024-01-13) to hold all data generated during SD035. The full SAN pathname was /data/cruise/sda/current/ ('current' being a symbolic link to /20240113) although most cruise participants accessed this path through a Samba connection called, 'leg'. Within the cruise folder were the following sub-directories

/system – contains read-only instrument sub-directories containing data synchronised from local acquisition machines (e.g., /system/ctd_seabird_sbe911plus for all raw CTD data).

/work - is a writable area for cruise participants and contains the following sub-directories

/cruise_information – Folder to store official cruise documentation such as standard operating procedures etc.
/cruise_report – Folder to store the final cruise report.
/cruise_summary_form – Folder to store the CSR to be sent to BODC. The CSR forms the basis of the cruise entry in their online cruise inventory.
/data_management – An area for the onboard data managers to store summary data (e.g., scanned paper event logs) and provide access to useful data and information products such as sensor metadata and cruise tracks.
/scientific_work_areas – A folder for cruise participants to store their onboard work related to the cruise. Sub-folders should normally be named with the type of equipment or science discipline rather than an individual's name and filenames should be relevant and meaningful.
/X_other_work_areas – A folder to store work files that need to be backed up but are not directly related to the cruise science objectives. Folders should be named using an individual's name in this area.

The directory template generally worked well throughout the cruise and only limited tidying up was required at the end of the cruise prior to the backup being created. At present all users access the 'leg' directory using a generic account and while this prevents issues around permissions, it causes problems when multiple users try and edit the same document. This isn't actually possible as the filesystem doesn't natively support multi-user document editing, but the use of a generic user account means it is impossible to know who has locked out a particular document for editing. This results in lots of saved copies of slightly different versions of the original document.

2.4 Data synchronisation and data volumes

The total data volume under the SD035 cruise leg folder was 8.8 TB, with the /work sub-directory containing 1.8 TB.

Automated scripts (rsync append) periodically synchronise data from local acquisition machines to the central onboard Storage Area Network (SAN) and these data are visible under the cruise leg /system sub-directory. A full list of the synchronised systems that acquired data on SD035 can be found below (Table 2.4-1), with their size on disk:

Table 2.4-1: Synchronised data systems and their data volume over the cruise period

System Name	Description	Size in GB
adcp_teledyne_ocean_surveyor	Ocean Current Profilers (75 + 150kHz)	6.6
aerosol_handix_pops	Optical Particle Spectrometer	1.5
bioacoustic_simrad_ek80	Multi-frequency bio-acoustic echosounder	1300
bioacoustic_simrad_me70	Multibeam bio-acoustic echosounder	45
bioacoustic_simrad_ms70	Multibeam bio-acoustic echosounder	90
camera_axis_m1045	Front-facing webcam	14
ctd_seabird_sbe911plus	CTD data from Titanium and Steel frames	2.9
datalogger_bas_eventlog	Eventlog database backup	0.1
datalogger_basnoc_rvdas	RVDAS primary underway data logger	204

datalogger_noaa_scs	SCS secondary underway data logger	106
gas_pml_co2flux*	PML CO_2 flux system	303
multibeam_kongsberg_em122	Bathymetric multibeam echosounder	19
multibeam_kongsberg_em712	Bathymetric multibeam echosounder	8.4
platform_bas_dwnm*	Down Wire Net Monitor system	0
platform_light_structures_ilms	Ice Load Monitoring System	293
singlebeam_kongsberg_ea640	Bathymetric singlebeam echosounder	195
wave_rutter_sigma_s6_wamos_ii	Wave radar	4600

* New synchronisations added during the cruise

The synchronisation scripts ran smoothly during SD035 but there are a number of wider issues that need addressing for future cruises:

- The rsync commands use the - -append-verify flag which is very efficient but makes the assumption that acquisition machines will collect data in an additive fashion and won't have many (or any) modifications to existing files once they are written. This is true for some systems (e.g., multibeam echosounders) but with other systems (e.g. CTD, ADCP) there were file modifications made by users to files on the source computer that did not get captured on the SAN. This is not what most users expect (they expect the SAN to exactly mirror the acquisition machine) so there is a need to revisit the rsync commands used on some of the machines. This issue was previously noted on SD025.

- A monitoring framework is required to verify file synchronisation and flag files on the source machine that could be deleted (and then actually delete them) to ensure there is sufficient disk space for future operations. During SD035, the Simrad EK80 biological echosounder stopped recording on at least one occasion because of disk space issues and files had to be manually checked and then removed before data collection could recommence. This issue was previously noted on SD025.

- There is a need to review some the existing synchronisations to ensure they are working as expected. For example, the Simard ME70 and MS70 instruments were not turned on during SD035 and yet the cruise leg contains over 130Gb of data from these instruments – this is caused by archival data saved to an inappropriate directory on the source PC and requires action to sort out for future cruises. Also, the recording of full resolution wave radar data was appropriate for early trials cruises but was not appropriate for SD035 given the data storage it takes up (> 50% of the entire cruise archive).

ctd2met transfer script

The automated script that transforms CTD output data into a summary format that is sent to the UK Met Office worked well throughout the cruise. Successful integration into the forecasting models relies on the CTD operator running through their series of post-cast scripts relatively soon (within a few hours) after the CTD is recovered to deck. Initial CTD operator training and familiarisation meant that the first few test CTD casts did not make it in, but all the later casts were assimilated successfully. Attempts to manually mirror the CTD acquisition PC with the SDA SAN (addressing the rsync --append issue in the previous section) re-triggered the ctd2met script for previously deployed casts. Fortunately, the Met Office systems ignored these duplicates as they had occurred too far in the past.

2.5 Underway data logging systems

Overview

Underway data usually refers to the outputs of systems that make continuous measurements of the environment when they are operational. Underway data loggers usually receive (or request) these outputs, timestamp them, and store them securely for onward reuse.

Some data systems can provide their entire digital data output to underway data loggers in real-time (e.g., air temperature sensors) while other systems produce data that are too complex to be recorded by underway loggers (e.g., underwater video) – these systems typically record to local acquisition machines and these data are synchronised to central storage onboard (see synchronisation section above). In the middle are systems that create complex datagrams but also output simplified summary information that can be integrated into underway loggers (e.g., wave radar summary statistics).

The SDA operates a primary underway data logging system (RVDAS) and a secondary system (SCS) to provide an element of redundancy. The pathway from underway sensor output to data access and visualisation is given in Figure 2.5-1 below:

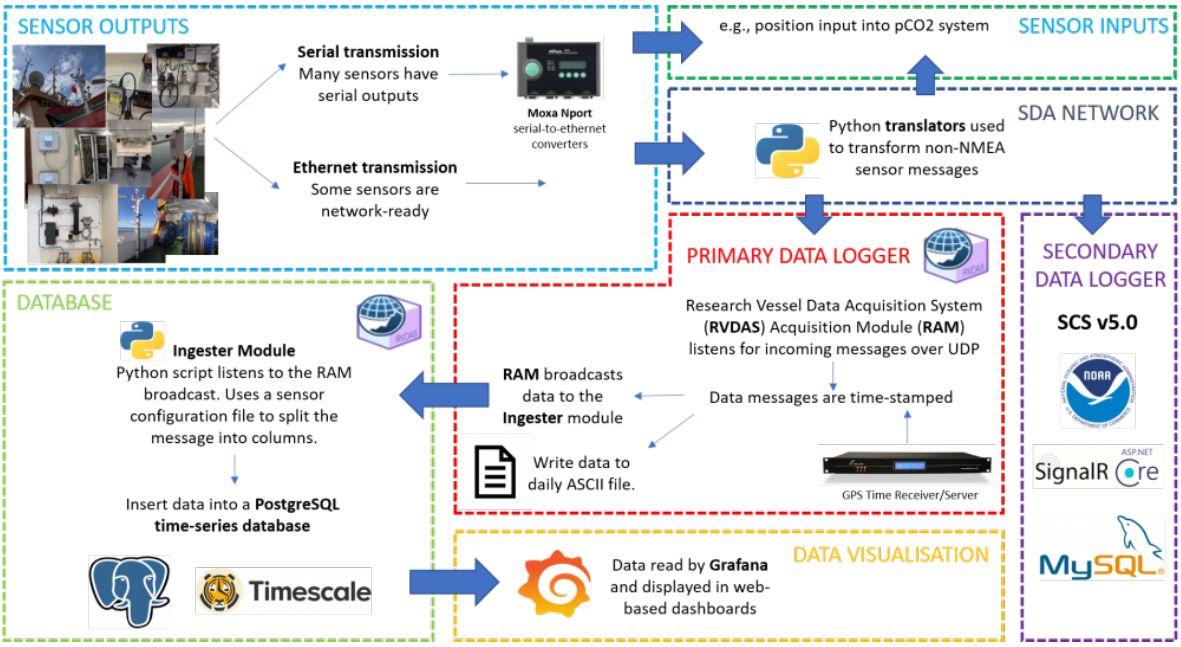

Figure 2.5-1 Data workflow of the SDA underway logging system

Research Vessel Data Acquisition system (RVDAS)

RVDAS is a co-development between the National Marine Facilities team at the National Oceanography Centre, and members of various marine science support teams at BAS. It is the primary logging system used on the SDA and has been operational since March 2021 when the first GPS sensors were integrated. During SD035, RVDAS logged 61 separate data streams – details of which can be seen in the tables below:

Table 2.5-1: Colour index of system groups used in Table 2.5-2

	Position and Attitude		Bathymetry
	Sea Surface Oceanography		Potential Field
	Atmosphere and Meteorology		Monitoring systems

Table 2.5-2: A list of all the underway data streams logged by RVDAS during SD035.

	System Name	RVDAS filename
	Fugro Oceanstar v3 GNSS	sd_gnss_fugro_oceanstar_centremast1
	SAAB R5 Supreme GNSS	sd_gnss_saab_r5_supreme_centremast1
	Seatex GNSS (Part of Kongsberg Seapath 330)	sd_gnss_kongsberg_seapath_320_port1
	Seatex GNSS (Part of Kongsberg Seapath 330)	sd_gnss_kongsberg_seapath_320_stbd1
	Seatex MRU5+ (part of Kongsberg Seapath 330)	sd_attitude_kongsberg_seapath_320_motion_port1
	Seatex MRU5+ (part of Kongsberg Seapath 330)	sd_attitude_kongsberg_seapath_320_motion_stbd1
	Kongsberg Seapath 330 Heading	sd_attitude_kongsberg_seapath_320_heading_port1
	Kongsberg Seapath 330 Heading	sd_attitude_kongsberg_seapath_320_heading_stbd1
	iXblue Phins Surface PAA00011-C inertial navigation system (Heading)	sd_attitude_ixblue_phins_surface_heading_crp1
	iXblue Phins Surface PAA00011-C inertial navigation system (Attitude)	sd_attitude_ixblue_phins_surface_motion_crp1
	SMC (Ship Motion Company) IMU-108 motion reference units	sd_attitude_smc_imu108_heli1
	Raytheon Standard 30 MF Gyro	sd_attitude_raytheon_standard_30mf_port1
	Raytheon Standard 30 MF Gyro	sd_attitude_raytheon_standard_30mf_stbd1
	Safran (Sagen) BlueNaute Gyro	sd_attitude_safran_bluenaute_centreline1
	Northern Solutions EMES60 Electromagnetic Speed Logger	sd_speedlog_northern_solutions_emes60_hull1
	Skipper DL850 Doppler Speed Logger	sd_speedlog_skipper_dl850_hull1
	Sonardyne Ranger2 USBL	sd_usbl_sonardyne_ranger2_hull1
	Sea-Bird Electronics SBE45 MicroTSG Thermosalinograph	sd_thermosalinograph_seabird_sbe45_ucsw1
	Sea-Bird WET Labs C-Star Transmissometer (CST)	sd_transmissometer_wetlabs_cstar_ucsw1
	Sea-Bird WETStar Flow-through Fluorometer (WSCHL)	sd_fluorometer_wetlabs_wschl_ucsw1
	Heitronics CT15.85 Infrared Radiation Thermometer	sd_radiometer_heitronics_ct15_85_port1
	Heitronics CT15.85 Infrared Radiation Thermometer	sd_radiometer_heitronics_ct15_85_stbd1
	Rutter sigma S6 WaMoS II wave radar	sd_wave_rutter_sigma_s6_wamos_ii_bridge1
	Valeport miniSVS Sound Velocity Probe	sd_soundvelocity_valeport_minisvs_ucsw1
	Sea-Bird Electronics SBE38 Thermometer	sd_thermometer_seabird_sbe38_ucsw1
	Sea-Bird Electronics SBE38 Thermometer	sd_thermometer_seabird_sbe38_ucsw2
	Observator OMC-116M Windsensor	sd_anemometer_observator_omc116_portmast1
	Observator OMC-116M Windsensor	sd_anemometer_observator_omc116_stbdmast1
	FT Technologies FT702LT V22 Windsensor	sd_anemometer_ft_tech_ft702lt_centremast1
	Biral SWS-200 Visibility & Present Weather Sensor	sd_met_biral_sws200_stbd1
	Eliasson CBME80 Ceilometer	sd_cloud_eliasson_cbme80_stbd1

	Sea-Bird Satlantic Photosynthetically Active Radiation (PAR) Sensor	sd_radiometer_satlantic_par_foremast1
	Sea-Bird Satlantic Photosynthetically Active Radiation (PAR) Sensor	sd_radiometer_satlantic_par_scimast1
	Vaisala HMP155E Air Temperature & Humidity	sd_met_vaisala_hmp155e_scimast1
	Vaisala HMP155E Air Temperature & Humidity	sd_met_vaisala_hmp155e_scimast2
	Vaisala HMP155E Air Temperature & Humidity	sd_met_vaisala_hmp155e_foremast1
	Kipp & Zonen SGR4-A Pyrgeometer (IR radiation)	sd_radiometer_kipp_zonen_sgr4_foremast1
	Kipp & Zonen SGR4-A Pyrgeometer (IR radiation)	sd_radiometer_kipp_zonen_sgr4_scimast1
	Kipp & Zonen SMP22-A Pyranometer (Solar irradiance)	sd_radiometer_kipp_zonen_smp22_foremast1
	Kipp & Zonen SMP22-A Pyranometer (Solar irradiance)	sd_radiometer_kipp_zonen_smp22_scimast1
	METEK Usonic-3 Class-A H Anemometer	sd_anemometer_metek_usonic3_portmast1
	METEK Usonic-3 Class-A H Anemometer	sd_anemometer_metek_usonic3_stbdmast1
	METEK Usonic-3 Class-A H Anemometer	sd_anemometer_metek_usonic3_portmast1
	Vaisala PTB330 Barometer	sd_met_vaisala_ptb330_v1_aerosol1
	Vaisala PTB330 Barometer	sd_met_vaisala_ptb330_v1_aerosol2
	Vaisala CL31 Lidar Ceilometer	sd_cloud_vaisala_cl31_stbd1
	Thies Clima Laser Precipitation Monitor (Disdrometer)	sd_met_thiesclima_5_4110_scimast1
	Campbell Scientific (Goodrich) 0871LH1 Freezing-Rain sensor	sd_met_campbell_0871lh1_scimast1
	Michell Instruments Optidew2 Chilled Mirror Hygrometer	sd_met_mitchell_optidew2_aerosol1
	Kongsberg EM122 multibeam echosounder	sd_multibeam_kongsberg_em122_hull1
	Kongsberg EM712 multibeam echosounder	sd_multibeam_kongsberg_em712_hull1
	Kongsberg EA640 singlebeam echosounder	sd_singlebeam_kongsberg_ea640_hull1
	Skipper GDS102 singlebeam echosounder	sd_singlebeam_skipper_gds102_hull1
	Dynamic Gravity Systems (DgS) AT1M Gravity Sensor	sd_gravimeter_dgs_at1m_grav1
	ODIM Winch logging and monitoring system[1]	sd_winch_odim_v3_wcr1
	Litremeter LMX.24 PeltonWheel Flowmeter with a Fluidwell F112-P control/display unit	sd_flowmeter_litremeter_lmx24_ucsw1
	Kongsberg Vessel Insight data logging system[1]	sd_datalogger_kongsberg_vessel_insight_omni0
	Schneider APC Temperature Data Logger[1]	sd_platform_schneider_ap8953_omni0
	Comet T3510 Air Temperature and Humidity[1]	sd_platform_comet_t3510_omni0
	Yotta A1819 Air Temperature[1]	sd_platform_yotta_a1819_omni0
	C4R hoist monitoring[1]	sd_platform_c4r_hoist_hull1

[1] These systems comprise multiple sensors logging together to a single data stream. A metadata element such as serial id is recorded to differentiate individual sensors.

The RVDAS acquisition module (RAM) worked reliably throughout SD035 and there were only limited time periods when incoming data streams did not get written to daily ascii files. These short periods were known about prior to SD035 and are related to when VMWare starts and ends the daily back up of the RVDAS production server. The exact amount of data lost isn't always the same but taking a 1Hz GPS stream as an example (Fugro Oceanstar), around 9 messages are dropped per day, spread over two short periods usually in the evening. This

represents a 0.01% loss and while this isn't noticed by most users, a solution is needed to enable a 100% logging rate.

The RVDAS ingester module (Postgres database writer) worked extremely well and there were no known dropped messages due to system overload.

Scientific Computing system (SCS v5.1.2)

The SCS is developed by the National Oceanic and Atmospheric Administration (NOAA) and is freely available at https://scsshore.noaa.gov/ . The SCS is used as a secondary data logger on the SDA and while the software provides a wide range of functions, the only module in use is the ACQ logging service. This works in a very similar way to RVDAS by listening to incoming data streams, timestamping them, and then writing the output to daily ascii files and a MySQL database table. Most (but not all) of the data streams in Table 2.5-2 are replicated in the SCS and these data could be used to backfill RVDAS should it suffer an outage. It should be noted that an upstream failure (e.g., in a Moxa unit or in one of the Python translators) would affect SCS just the same as RVDAS.

Before the start of SD035, a routine update to the SCS software (from v5.0.68 to v5.1.2) appeared to work correctly but showed errors on restart. Following assistance from NOAA staff, this was traced to an apostrophe within an SQL statement that formed part of the update. The missing update steps were manually completed and after dealing with a host of validation issues (expected as part of the update) the software ran normally. Initially all SCS services were started, and this worked fine for a while but a few days later the SCS virtual machine crashed with memory issues. The virtual machine was restarted and all SCS services were disabled except for the ACQ (the pre-SD035 norm) – this configuration performed reliably for the rest of the cruise.

Underway sensors – data management notes

Detailed information about the performance of underway sensors, and sensor history such as replacements and calibration can be found in the AME cruise report sections and equipment event logs. However, there were a number of sensor issues during the cruise that highlighted deficiencies in data management procedures that could be improved in future:

- Metek uSonic anemometer failure – See BAS engineering report (Section 2) for full details of the failure. Sensors can fail for many reasons but in this case the failure wasn't picked up for several days after the fault occurred, despite the sensor outputting nothing but null values. The Grafana monitoring dashboard showing data presence/absence was of no use in this case. An instrument-specific data quality dashboard would have picked up the failure and these should be developed for all the underway sensors. Initially they can focus on very simple QA/QC checks on output values (alarm if null or physically impossible values etc.).

- Instrument swaps – the foremast PAR sensor, the foremast temp/humidity sensors, and one of the UCSW temperature sensors were replaced during SD035 with newly calibrated versions. This standard activity requires that the replacement sensors be configured in the same way as the sensors they are replacing. This configuration information should be in sensor data knowledge documents but was spread across a variety of informal documents and was not easy to locate.

- UCSW system – Due to technical deficiencies with the uncontaminated seawater system (described elsewhere in this report) during SD035, there was a lot of focus on knowing when the system was operational. While we monitor the position of the seawater inlet hoist and the flow rate to the UCSW sensors, we do not currently monitor the seawater pumps. Acquiring a data feed from the pumps should be investigated in consultation with the pump manufacturers and the SDA Deck Officers.

2.6 Event logging

Keeping a record of when events occur during a cruise is vital in providing context to scientific data collected. A web-based event logging system is available on the vessel for users to record events. At the most basic this must include a timestamp and a comment, but more structured user-defined columns can be added, and each event can be annotated with relevant underway data (e.g. position, water depth, wind speed, air temperature etc.) based on matching timestamps.

An overarching bridge event log exists for officers of the watch to record all science events that they are aware of – these are typically over-the-side deployments such as CTD casts. In addition, cruise participants also created event logs – these were typically associated with a particular instrument or sampling method. Event logs can be downloaded as csv files for reporting purposes. Table 2.6-1 describes the event logs created on SD035.

Table 2.6-1: Event logs created during SD035

Event log name	**Event log description**
SDA Underway Systems (non-UCSW)	Events relating to the permanently fitted underway sensors on the SDA (excluding the uncontaminated seawater system)
Floating Sediment Trap	Events relating to the deployment and recovery of the floating sediment trap
Sea Ice GoPro Cameras	Events relating to the operation of GoPro cameras observing ice/hull interactions
Glider	Events relating to the deployment and recovery of gliders
Marine Mammal Observations	Events relating to the Marine Mammal Observation watches
Multibeam EM122/EM712	Events relating to the operation of the Kongsberg EM122/EM712 bathymetric echosounders
UW_Towfish	Water sampling events from the seawater supply provided by the deployable trace metal towfish
EK80	Events relating to the operation of the Simrad EK80 bio-acoustic echosounder
UW_Deck_Lab	Water sampling events from the uncontaminated seawater supply in the Deck Lab
Mammoth	Events relating to the deployment of the Mammoth net.
RMT8	Events relating to the deployment of the RMT8 net
VMADCP	Events relating to the operation of the vessel-mounted Teledyne Ocean Surveyor acoustic doppler current profilers
CTD	Events related to the deployment of the Titanium and Stainless Steel CTD frames and associated sensors.
UW_Uncontaminated _seawater_lab	Water sampling events from the uncontaminated seawater supply in the UCSW Lab

Uncontaminated Seawater System - SDA sensors	Events relating to the permanently fitted sensors within the uncontaminated seawater system

The event logging system was well used by bridge officers and the science party but there were several issues arising that need addressing in the future. In most cruises, it is assumed that deployment events (i.e. ones that have event numbers) happen sequentially one-at-a-time. During SD035, there were many occasions when this assumption didn't hold – for example there were optics rig deployments routinely occurring at the same time as CTD deployments. This made it difficult for bridge officers to keep track of event numbering and there were numerous mistakes made throughout the cruise that required laborious retrospective corrections. A re-designed event system would show individual deployments as separate entities rather than all together in one big table – it would then be clear which deployments are still active and make it much easier to keep track of event numbering.

2.7 Data visualisation

Grafana (v10.4.1) data visualisation dashboards were used extensively onboard by cruise participants and ship's crew. During SD035 there were a small number of new Grafana additions and a lot of minor modifications to existing dashboards. These modifications mostly involved dashboards showing winch information given the large number of over-the-side deployments during the cruise.

2.8 Longer-term data management developments

The SDA data systems continue to evolve and the SD035 period was used as an opportunity to continue long-term development activities. These included:

Integrating new data steams into RVDAS

USBL tracking data (three different messages) from the science USBL system were integrated on 2024-01-25. This means that the location of subsea equipment (with attached USBL beacons) can be added to event logs.

3. BAS Engineering Support Overview

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Instrumentation used on the cruise

It is worth noting that the previous cruise experienced issues with the UCSW inlet deployment pipe and sealing valve. It cracked and caused a leak. This was repaired during that cruise, and when we joined the ship in January a section of the inlet pipe had been removed for repair in Punta Arenas. As a result, the section of pipe holding the SBE38's was also removed.

Later in the cruise (approximately the 9th Feb.) it was pointed out that there was a substantial difference between the two sensors (~0.1°C). We had a number of theories why, but were not able to find the exact reason. We topped up the glycol levels in the probe caps on 11/02/2024 at ~20:30, but this did not resolve the issue. We also tested an alternative SBE38 sensor fitted in the pipe mount, but this didn't affect the values significantly. So we decided to leave the system alone, and deal with a mostly constant offset.

Note that all the optical sensors on the foremast and science mast were cleaned on the 16/01/2024.

Table 3-1: List of instruments and sensors used on the cruise

Instrument	#SN if Used	Make and Model	Comments
Acoustic			
Bio Multi-beam(ME70)	No		
Bio Multi-beam(MS70)	No		
Bio Multi-freq (EK80)	Yes		
Omnidirectional SU94	No		
Omnidirectional SC94	No		
Scanmar net system	No		
Echo sounder (EA640)	Yes		For ocean depth
Bottom profile (Topas)	No		
Swath (EM122)	Yes		
Swath (EM712)	Yes		
ADCP 75kHz	Yes		
ADCP 120kHz	Yes		
USBL	Yes		
Underway Mini SVS	Yes		
K-Sync	Yes		
Meteorological			
Air Temperature and Humidity 1 foremast	U0221024	Vaisala HMP-155	Incorrect humidity values. Swapped on 15/01/2024 at ~17:15. SN is most recent.
Air Temperature and Humidity 2 science mast 1 inboard	S0850275 2020	Vaisala HMP-155	

Air Temperature and Humidity 3 science mast 1 outboard	S0850273 2020	Vaisala HMP-155	
3D Winds foremast	0115018894	Metek uSonic-3 Cl.AH	Had failed. Swapped on 19/01/2024 (between ~12:37 and ~14:00). SN is most recent.
3D Winds science mast 2 port	0111016979	Metek uSonic-3 Cl.AH	
3D Winds science mast 2 stbd	0111016978	Metek uSonic-3 Cl.AH	
Dew Point PT100	174768	Mitchell Inst. Opti-Dew 2	
Dew Point Chilled Mirror	174220	Mitchell Inst. Opti-Dew 2	
Ceilometer	U0250643	Vaisala CL31	
PAR Sensor foremast	PARSERICSA-2212	Seabird PAR-SER ICSA	Showed signs of weathering. Swapped on 16/01/2024.
PAR Sensor science mast	PARSERICSA-2040	Seabird PAR-SER ICSA	
Precipitation	07200150	TheisClima Drisdrometer	
Freezing Rain	0490	Rosemount 0871LH1	
Radiometric SST 1 port	13316	Heitronics CT15.85	
Radiometric SST 2 stbd	13317	Heitronics CT15.85	
Solar Radiation SW foremast	190029	Kipp & Zonen SMP22-A	
Solar Radiation LW foremast	190056	Kipp & Zonen SGR4-A	
Solar Radiation SW science mast	190028	Kipp & Zonen SMP22-A	
Solar Radiation LW science mast	190057	Kipp & Zonen SGR4-A	
Visibility Sensor	Not Fitted		
Barometer 1 upper	N2410065	Vaisala PTB 330	
Barometer 2 lower	N2410066	Vaisala PTB 330	
Ceilometer	#SN/No	Viselea ???	
Underway Sea Water			
Fluorometer	WSCHL-1664	Wetlabs	Most-recent calibration on 2nd Feb. 2023
Transmissometer	CST 1505DR	C-Star	Most-recent calibration on 16th Aug. 2023
Thermosalinograph	SBE45 0724	SBE45	Most-recent calibration on 12th Sep. 2023

Temperature 1	SBE38 0765	SBE38	Most-recent calibration on 12th Sep. 2023
Temperature 2	SBE38 1143	SBE38	Most-recent calibration on 12th Sep. 2023
Flow Meter	24/414055	Litre-miter	
Towed Systems			
Magnetometer	No		
XBT	No		
Rapid cast (CTD)	Yes	Rapid Pro CTD	
Rapid cast (SVP)	Yes	Rapid Pro SVP	
Other Ship Science Systems			
Gravity Meter	AT1M-100	Dynamic Gravity Systems AT1M	
Piccaro	No		
Black Carbon	Yes		
TE49i	No		
Goniomiter	SN/0029-3460313	XERIUS RXG134	7 digit hex tag would be useful (from item to be recovered)
Ship wave radar	No		
Workboat Systems			
EM2040	No		
EK80	No		
Seapath	No		
SVS	No		

Swath (EM122)

This system was operated by Alex Tate (Data Manager) during the cruise, so see his report for more details. However, on the 8th March, Alex approached us saying that he had an issue with the EM122. At the time he power cycled the system and it returned to normal. However on the 8th the system failed again, and after running a BIST test the problem indicated the TX board in slot 17. This indicated that we had an intermittent issue with the system. After some tests, we concluded that, unfortunately, we did not have sufficient knowledge or time to resolve this issue before the end of the cruise. We reinstalled the original TX board and left the system and spares in the state we found them. A further BIST showed that the system was fully operational again.

USBL

The USBL system was used extensively during the cruise. By default a beacon was attached to the Ti CTD Frame (2012), SS CTD Frame (2010) and the Mammoth net (2013). The depth values provided by these beacons became a useful meta data tool to confirm the correct operation of the Mammoth net, and to understand the effects on currents on the frame location. Additionally these beacons add a level of safety in the case of a frame falling off the cable (which will hopefully never be needed).

CTDs

See extensive notes on CTD termination and Niskins within *SD035 Report E&T_V3.pdf*.

Table 3-2: CTD summary statistics

No# Of Casts SS	106	No# of Successful Casts (SS)	104
Max Depth of SS	3932 m (071)	Min Depth of SS	Na
Cable Removed Standard (m)	0 m	No# of Re-terminations (elect.)	5
No# Of Casts Titanium	35	No# of Successful Casts (Titanium)	35
Max Depth of Titanium	4047 m (069)	Min Depth of Titanium	Na
Cable Removed Titanium (m)	2m	No# of Re-terminations (elect.)	1

CTD Termination

The night before the first cast CS performed a mega test on the sub sea pigtail attached to the SS bullet. Unfortunately this had been damaged in its transport from the boom to the midships location. CS had to perform a new electrical termination.

This initial termination worked well until the 29/01/2024 (before cast 013). The termination failed before the cast, and CM was called to evaluate early in the morning. Having a failure so early in the cruise, after so few casts, was odd. A new electrical termination was done, and tested on cast 013. This worked fine until the 30/01/2024, where it failed during cast 017.

For context the SS CTD was being deployed from the midships gantry. This is also the location where the Mammoth net is deployed from. The original plan had been to run the deep tow cable over the midships gantry to be used for the Mammoth net. This would require switching CTD and Deep Tow bullets over the midships gantry sheeve for every CTD/Mammoth change over and would most likely lead to damage to both terminations.

After discussion with Gareth Flint and the Science Bosun, we decided to use the CTD cable for both systems. This would only require moving the CTD SS bullet off the CTD frame, and on to the Mammoth shackle. Gareth changes the securing bolt on the bullet pin for an R-Clip, which made the mechanical release easier. For the subsea pigtail we fitted a blanking plug.

However, we believe that the cause of the electrical termination failures was coming from the net swap over, where the pigtail would be exposed to additional strain on its termination, which would not be the norm.

After the failure on cast 017, CM tested the termination, and splinted the electrical element to prevent bending. We were able to reestablish communications, and complete the cast sequence, without breaking for a long re-termination. During cast 018 the instrument data came through fine, but the water sampler failed to return confirmation of a fire. After this there was a natural halt to CTD operations for a day while transiting to a new location.

During the 31/01/2024 Cm and Deck Engineer (Rob Sutton) worked together to solve the problem. One solution would be to perform the same electrical termination again, but mechanically brace and strengthen the area around the solder. This did not feel like a good long term solution. Another option is to switch between the CTD and Deep Tow Cables, but this would most likely lead to damage on both bullets, and take longer each time. The last solution (proposed by a scientist onboard) was to use an Oil Filled junction (OFJ).

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The prepared end of the winch cable comes out of the bullet enters the RHS of the brass body, and the pigtail enters on the left. Screw terminate the ends together. Cover and seal with the plastic hose, and then fill up with oil. The cable gland is the final seal.

There are numerous benefits of using this new termination style:

- It's simple.
- Quick to re-terminate a pigtail (as little as 10 min).
- Does not require soldering.
- Does not require nasty Scotchkote.
- No measurable degradation in termination resistance. At all.

- Very sturdy and mechanically sound.

This termination was fitted for cast 019, and worked flawlessly for the remainder of the cruise, with absolutely no change in its termination resistance. The bullet and OFJ were swapped between the SS CTD and the Mammoth net numerous times, with no particular care taken, and it continued to work well.

Table 3-3: CTD configuration(s)

	SS CTD			**Ti CTD**	
Instrument Type	**SN**	**Height off Base**		**SN**	**Height off Base**
Swivel	1961018	2575		19615990	2588
SBE32	0922	1625		32-1201	1625
SBE35	0047	1397		NA	NA
9Plus	0541	390		0771	350
Temp 1	2705	425		03-6830	375
Cond 1	4471	505		04-6184	445
DO 1	43-0245	495		43-4251	465
Pump 1	1813	550		05-9187	525
Temp 2	5766	425		03-6158	375
Cond 2	2289	505		04-4721	445
DO 2	43-2290	495		43-3634	465
Pump 2	4488	550		05-11702	525
SBE18	1178	550		NA	
Transmissometer	1831DR	290		1836TR	265
Fluorometer	12-8513-002	310		170664001	280
FLCDRTD	4837			NA	NA
BBRTD	1635			NA	NA
PAR	70636	1510		1117	1517
Altimeter	10127.244738	95		61151	55
Master LADCP	14897	355		1000	135
Slave LADCP	15060	1680		1001	1515

Cells highlighted red had the sensor/instrument replaced – see detail below. A more extensive version is available in *SD035 Report E&T_V3.pdf*.

SS Instrument and Configuration file changes

- The transmissometer was manually calibrated at 14:03 on 27/01/2024
    - Seasave file name: SD035_SS_TransmissometerCal_01
    - The following values were recorded, and then inserted into the master xmlcon file.

TW	W0	Y0	A0	A1	Y1		M	B
100	4.7	0.003	4.803	4.782661	0.002442		21.37829	-0.05221

- Par Sensor changed 70442 to 70636 on 27/01/2024
    - No known issue with sensor. It was changed but later found to be a software issue. The PSA file for seasave display windows were configured to show the PAR value from a "Satlantic Par" (ne used on Ti Frame) instead of a "Biospherical Instruments Par. As such the sensor values were not displaying. We therefore created a different Ti and SS seasave display file to accommodate the difference I the installed instruments.
    - Manual Cal performed at 13:33

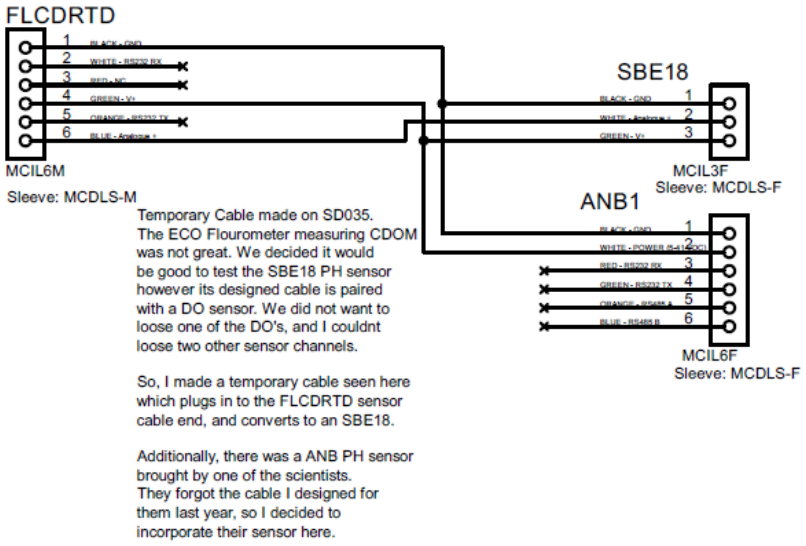
CW	Cal Const	Vd	Offset
0.00000498	20080321285.14	0.003663	-0.05022180793

- Primary Conductivity Cell xmlcon values changed from SN 2255 to SN 4471 on 27/01/2024.
    - The fitted instrument is SN 4471, but the cal values in the xmlcon reflected the sensor SN2255 that had been installed on the previous cruse. The instruments and frame had been left assembled from the previous Biopole cruise, and we used the same xmlcon file. This needs to be communicated to the team on the previous cruise. The master xmlcon file has been corrected, and the specific cast files to date have been corrected.
- Additional CTD (from Bob Brewin) added to SS frame during cast 007/event 013.
- The "Rapid SVP" was fitted to the SS frame for a test deployment. Cast 011/ Event 022.
- SBE35: 0056 replaced with 0047 at ~12:50 on 31/01/2024
    - During cast 021 we were running a second test on the oil filled electrical termination. The data from the cast seemed to be coming through fine, but the water sampler did not reply during the fire commands. We manually incremented through the fire commands and recovered the system. After the cast we note that all bottles had fired, and checked the SBE35 data file to correlate the received fire commands and the times at which they were

received. Good confidence that the 35 got the commands and that the bottles fired at correct depths. Initially assumed that the termination had failed again. However after recovery the termination looked good. So… the issue must either be with the SBE35, SBE32 or the 9 plus. We have decided to swap out the SBE35 on next cast to check.

    - Update 11/02/2024. The problem has not come back. So there must be an issue with the SBE35.

- Niskin in position 9 (double spigot) was replaced with a different single spigot niskin.
    - Niskin changed on 02/02/2024 at ~12:00 before cast 044/event 86.
- Rapid CTD added to SS frame for cast 068 on the 06/02/2024.
    - External CTD deployed to test profile of the stand-alone instrument for the ”on ice” work later in the cruise.
- Swivel: 196111 replaced with 1961018 at ~22:00 UTC on 10/02/2024 (problem identified during cast 083)
- The TnC Duct plastic for the secondary line was repaired at ~23:11 on 16/02/2024.
    - After cast 119, MR noted that the TnC duct that the syringe attaches to on the secondary instrument line was loose. CM removed the T sensor, and repaired the fitting. This affected casts 119, 120, 122, 123.
- Eco Fluorometer 4837 replaced with SBE18 PH Sensor 1178. ~ 21:48 on 23/02/2024
    - Before cast 129 we removed the Eco Fluorometer C-Dom as it was not registering any good data. Instead, we thought it best to use the channel to measure pH values using our SBE18. A custom cable was made to connect the SBE18 on to the FLCDRTD sensor cable, as well as an additional ANB pH Sensor (from Gareth Lee) with serial number: 300290. The ANB sensor was used on cast 129, and then removed.



- Primary C cell rinsed with triton on 23/02/2024 at ~22:30

- Shortly before the cast CM was notified that the C-Cell values had drifted, and they suspect there has been oil fouling. With limited time before the cast CM made a 2% triton mix, and flushed the primary cell for 10 minutes before cast 019/event 254.

- Primary and Secondary C-Cell rinsed with triton at ~22:40 on 23/02/2024
    - After cast 019, CM flushed and soaked the primary and secondary C-Cells with a 2% triton mix. This was contained to the C cells, and not in the DO membranes. The C Cells were left to soak for two hours in preparation for cast 130.
- Primary and Secondary C-Cells soaked in triton from ~12:00 to 24:00 on the 24/02/2024.
    - After cast 131, both primary and secondary C cells were removed from the SS frame and left to soak in a 2% triton mix in a warm office for 12 hours. Occasionally the water was agitated in the soaking tub. This will hopefully encourage any oil fouling to come loose from the c cell walls.
- Mooring instrument Calibration Cast 134/Event 288
    - On 29/02/24 the SS CTD was fitted with a number of different mooring related instruments to calibrate against the CTD sensors.
        - Sami PH Sensor 1, SN: P0280
        - Sami PH Sensor 2, SN: P0312
        - SBE37, SN: 24673
        - Aanderaa Seaguard SN: 2476
        - ANB PH Sensor SN: 300290
- The transmissometer was manually calibrated at 18:28 on 05/03/2024
    - Seasave file name: SD035_SS_TransmissometerCal_02
    - The following values were recorded, and then inserted in to the master xmlcon file.

TW	W0	Y0	A0	A1	Y1		M	B
100	4.7	0.003	4.803	4.782661	0.002442		21.29462	-0.09412

Ti Instrument and Configuration file changes

- Before the first cast, during the frame assembly, we noted that the Ti SBE32 was showing signs of rust. The fitted unit (SN:1200) was replaced with a new unit (SN:1201).
- The transmissometer was manually calibrated at 01:28 on 20/01/2024
    - Seasave file name: SD035_Ti_TransmissometerCal_01
    - The following values were recorded, and then inserted into the master xmlcon file.

TW	W0	Y0	A0	A1	Y1		M	B
100	4.703	0.003	4.45	4.37117	0.002442		21.6578	-0.05289

- SBE43 Primary. SN 3595 was swapped for 4251 on 27/01/2024 at 23:18.
    - After Ti Cast 004, it was noted that the data from the Primary DO sensor was completely wrong. Oscillating in a decaying sine wave pattern. Not even close to a realistic oxygen trend. It was removed from the CTD. New sensor was updated in the config file.
- SBE4 Primary. SN 4721 was swapped for 4671 on 29/01/2024 at 20:40.
    - After Ti Cast 013, we noted that C2 was showing 99.99. After the cast we tested the sensor again, and it appeared to be fine. And a later test showed that the C2 cell was showing 99.9 again. Cal File Not Yet Updated.
- After Ti Cast 013 We also note that the transmissometer values looked very bad. Decided to do another Transmissometer Calibration on 29/01/2024 at ~20:52. After the cal we entered the new cal values in to the Ti XMLCON master file, and noted that I had not actually entered the last cal values. This explains why the values looked so bad. These have now been updated, and values look good again. We have modified all the past Ti Cast xmlcon files.
    - The following values were recorded from the manual calibration, and then inserted into the master xmlcon file.

TW	W0	Y0	A0	A1	Y1		M	B
100	4.703	0.003	4.45	4.37298	0.00242		21.64872	-0.05239

    - On 03/03/2024 CM Modified the following Ti xmlcon files to reflect the correct Transmissometer cal values. 001, 004, 010, 013.
- Also modified the Ti conf file to show the newly added C2 cell. The new conf file is valid for all Ti casts following cast 013. All previous Ti Casts need to reflect the changes.
- 04/02/2024 CM conducted 8 test casts with the C-Free niskins after “tweaking” the tension settings.
    - The results varied, with inconsistent success at the last cast.
    - Decide to fit the spare C-Free niskins from the hold to replace the very bad fitted niskins. This will require a long soak for the niskins.
- On 06/02/2024 CM and CS conducted two additional test casts (066 and 067).
    - On cast 066 there were 18 “new” niskins (from the 2023 order) fitted and 6 “old” niskins (from the 2022 order) fitted to the frame. All niskins were fired and brought back onboard to conduct a pressure test on the “tweaked” niskin seals.
    - On cast 067, 12 niskins were fitted to the frame and sent to 27m to collect water for an overnight soak.
- CTD landed on the sea floor during cast 094, at approximately 11:30 on 12/02/2024.

- Exact cause is unknown. Essentially the winch operator heaved rather than hauled after reaching the bottom. A full incident report has been written to analyse the event. In summary no instrumentation was damaged. The frame had no damage. The winch had no damage. No-one was hurt.

- The transmissometer was manually calibrated at 16:37 on 03/03/2024
  - Seasave file name: SD035_Ti_TransmissometerCal_03
  - The following values were recorded, and then inserted into the master xmlcon file.

TW	W0	Y0	A0	A1	Y1		M	B
100	4.703	0.003	4.45	4.23443	0.002445		22.3576	-0.05466

- On 03/03/2024 CM and AT worked through the LADCP files for the Ti Casts. We found that the files for cast 034 and 102 were incorrectly downloaded. CM downloaded the raw files from the LADCP units (noting that the incorrect file had been downloaded for the slave LADCP) and renamed appropriately. CM then cleared the entire memory of the LADCP units (master and slave) by using the "RE ErAsE" command. This cleared out the entire memory. Fresh slate.

- CM completed another transmissometer cal. Values saved in the excel spreadsheet, and updated in the master xmlcon file.

- During the frame disassembly at the end of the cruise, we noted that the new SBE32 that was fitted at the start also shows signs of rust. This is obviously no good. The issue appears to be from the screws that hold the flat plate to the release mechanism.

TMF Niskins

At the start of the cruise a number of new fittings were used on the pressurised airlines in the lab, in addition to new pipework. Initially these were thought to stick out too far and might bump and break during the pre and post cast transit. However these appear to have worked well, and had positive feedback from the scientists.

WRT the niskins, we had mixed success. At the start of the cruise we used a mix of 12 old C-Free niskins (bought in 2022 for the first science trials) and 12 new C-Free niskins (bought in 2023 for this cruise, with double handles). However after the first couple of casts the "old" niskins began to fail and not close properly.

The initial assumption was that the rubber band on the side (natural rubber) had weakened with age, and was not pulling tight enough. The initial solution to this was to pull the band tighter and tie a knot. This did not solve the problem and we continued to have niskins fail.

The next step was to adjust the tension on the tip and bottom o-rings/ball valve. This was done in the clean lab, supervised by Angie Milne and Simon. Wearing hair net, gloves and clean crocks. Also had to leave dirty clothes outside. Essentially limiting the possibility of contaminating via touch transfer, or dust.

Under the ball valve there is a compression plate with springs underneath, and two plastic bolts to adjust the height of the compression plate. On the face plate there is another downward facing compression plate that is adjusted by 4 plastic hex grubs. When the grubs were completely loosened, we found that there was still al lot of force on the ball valve from the bottom compression plate. So we tightened/lowered the bottom compression plate until there was no upward force on the top compression plate. Under this situation we had removed the majority of force acting on the ball valve, and adding friction. The consequence is that under this state there is not enough force on the ball valve seal to create a airtight seal on the water in the niskin, and it leaks out. At this point we then adjusted the top plates grubs to add the minimum amount of force to the ball valve so that it would seal.

This appeared to work quite well on some of the niskins with a definite improvement in the success rate. However it was an intermittent success in that there was no predictability in which niskins would fail, or when. Every cast was a case of “wait and see”. This is not how we should conduct our science.

The next thing we tried as to lubricate the o-rings that made contact with the ball valves, so as to reduce friction. Initially I proposed Molykote 44, which has no metal components, and is not tacky. This is the lubricant we use on our subsea connectors. We applied a very thin coat to the outer layer of the o-rings, which worked well for the first two casts, and then began to grip on the ball valve. This was unexpected. So we removed the ball valves and wiped the ball and o-rings clean of the grease. Another alternative is to use Molykote 55 (white o-ring grease), but we opted to avoid using another unknown lubricant. After the clean the ball vales worked reasonably well, but still not consistently.

The next option was to increase the tension of the external rubber band, and possibly use our spare banding. The problem however is the spare rubber banding onboard is black, rather than white, which has components that may contaminate the sample water. We soaked the spare banding in sea water overnight, and dipped it on a 1000m deep CTD. This should have made them clean enough for use, but we never ended up trying it.

By the end of the cruise, most of the bottles had been tweaked to work semi-reliably, with some that never managed to be configured correctly. After further inspection of the niskins it became

clear that every one is slightly unique. A tweak and fix for one, will not work for another. Some tolerances of the assembly are so different that they could not be tweaked in to a working state.

I believe that if we were to add additional banding, or tighter banding, that we would be able to achieve a higher rate of successful fires (where the ball valves close fully), however we did not have the correct materials to try this.

Another comment to be made is that the springs under the compression plate appear to be exposed stainless steel, rather than Teflon coated. See the pictures below.

A lot of effort has been made to remove any iron based contamination on the frame, instruments and niskins, and the manufacturer has opted for rusty springs near the water intakes. Overall I am not impressed with the quality of the niskins we have ordered. This will be fed back to the supplier, and the relevant science parties. My recommendation would be to try and purchase alternative “Go-Flo” style niskins over the coming years and trial them independently.

On Ice Work

During a practice sampling session, we simulated the process of sampling from the niskins on the ice. Science teams were able to practice the process, timing and sequence for their various sampling requirements, and were also able to identify any parts that they had not yet thought of. This saved time during the actual ice floe days, and improved the quality of the collected samples.

We spent two full days on two separate ice floes: Event 268 and Event 273. There is a dedicated report to detail the work covered during these days. Overall, everything worked well. Niskin “2023V301” was found to leak when the air vent was opened for sampling on Event 268. This would indicate that there was not enough of a seal on the ball valve. Rather than tighten the compression plate, we decided to risk the possible aerosol contamination over a niskin that

would not fire. So no adjustments were made, and the niskin was used again for the second floe.

Goniometer

An RXG134 Goniometer was set up to assist in the recovery of the UEA gliders. Charles used an AXG134-A antenna mounted on the bridge. It was difficult to identify which tags belonged to the gliders because no one in the glider teams had made a record of the 7 digit hexadecimal ID tag for their gliders beacon. Additionally we found that the ship generally has a large number of active beacons at any one time…(at least 7 active beacons, seal tags etc.)

However, making an educated guess as to which beacons were located where, the goniometer appeared to work very well and corroborate the GPS data. Charles is currently looking at a more permanent install at the crow's nest.

4. Underway Measurements

4.1 Uncontaminated seawater supply (UCSW)

Authors: Tom Bell[1], Alex Tate[2]

[1]Plymouth Marine Laboratory, Plymouth, UK
[2]UK Polar Data Centre, British Antarctic Survey, Cambridge, UK

Throughout the PICCOLO research cruise, there were multiple issues with the UCSW. The inability to run the UCSW continuously when in/near to sea ice is a major problem for a polar research ship. Other polar research ships have UCSW systems that are run successfully and on a continuous basis in ice. A redesign of the SDA UCSW system is needed.

Issues with the UCSW included:

(i) bubbles in the supply leading to erroneous data on all optical sensors and dissolved gas measurements;

(ii) bubbles leading to air in the system and the UCSW pumps tripping out;

(iii) ice caused the UCSW filter/screen to block, leading to frequent and sustained periods with the UCSW switched off whenever we encountered sea ice;

(iv) krill also caused blockages, and small krill often made it past the screen into other instruments, etc. causing additional contamination and blockages;

(v) the UCSW was extremely time consuming to unblock once ice had been sucked into the ship, with the options restricted to either: a) waiting for ice to melt (hours); or b) a manual effort to unblock (repeatedly turning on the pump and clogging filter, then unblocking the filter until all slush ice had been removed between the intake and the filter);

(iv) breakages of the plastic valves leading to leaks and compromising the integrity of the system and ultimately the ship.

(v) the bridge were able to retract the UCSW pole, but unable to redeploy, creating extra work for the engineers (and particularly problematic at night when everyone was on day shifts).

(vi) the mechanism for raising and lowering the UCSW pole failed, with no backup motor on board. Once this failed, the pole had to be kept retracted and bubbles were unavoidable while the ship was moving.

The deck engineers worked very hard to minimize bubbles in the UCSW supply (reducing the frequency of the main pump to 35 Hz to reduce cavitation, and restricted the outflow valve to ensure sufficient flow to the required labs). The deck engineers also spent an inordinate amount of time switching pumps on and off, clearing filters, etc. as we went in and out of ice-covered regions, came on/off station, etc. These actions were recorded in a spreadsheet by the deck engineers and transferred to a relevant digital event log, an export of which is available within the cruise archive. There were ~150 occasions where the on/off status of the pumps changed during the cruise.

Due to the large number of issues encountered, it was not a trivial task to identify periods of time where the underway data from the UCSW sensors could be trusted. A monitored sensor on the UCSW hoist provided continuous recording of the hoist position (deployed, flush, up) and a monitored flow meter on the UCSW wall showed whether water was getting to the thermosalinograph, fluorometer, and transmissometer sensors. Unfortunately, there is currently no automated monitoring of the pumps within the underway logging system so there is always the possibility that the tap to the UCSW wall sensors is turned off (flow meter pump will show zero flow) but the system is otherwise working with valid data coming from the upstream Sea-Bird SBE38 temperatures sensors and Valeport miniSVS sound velocity probe. However, in practice, the UCSW wall tap was always left open and the change in flow rate was due to upstream changes (hoist movement, pumps on/off etc.).

Early in the cruise, it was agreed that a hoist position status of 'deployed' or 'flush' and a UCSW sensor wall flow rate > 0.7 litre/minute constituted a 'working' system. This was based on the assumption that when the hoist was 'up', the gate valve to the sea would be shut, and it accounted for the fact that there could be some residual flow through the flow meter even when the pumps had stopped working. This ceased to be a robust method when the hoist motor failed and from 2024-02-12 the system was operated with the hoist in the 'up' position but with the gate valve left open. UCSW sensor wall flow rate > 0.7 L/min remained as the single best criterion to broadly determine when the system was and was not working throughout the cruise.

Figures 4.1-1 and 4.1-2 below provide a visual representation of the changes through the cruise and the periods of time that had the most issues, generally corresponding with presence of sea ice. Note that the UCSW wall wasn't turned on properly until leaving the Falklands (2024-01-20) and was switched off on the transit back to Punta (2024-03-07).

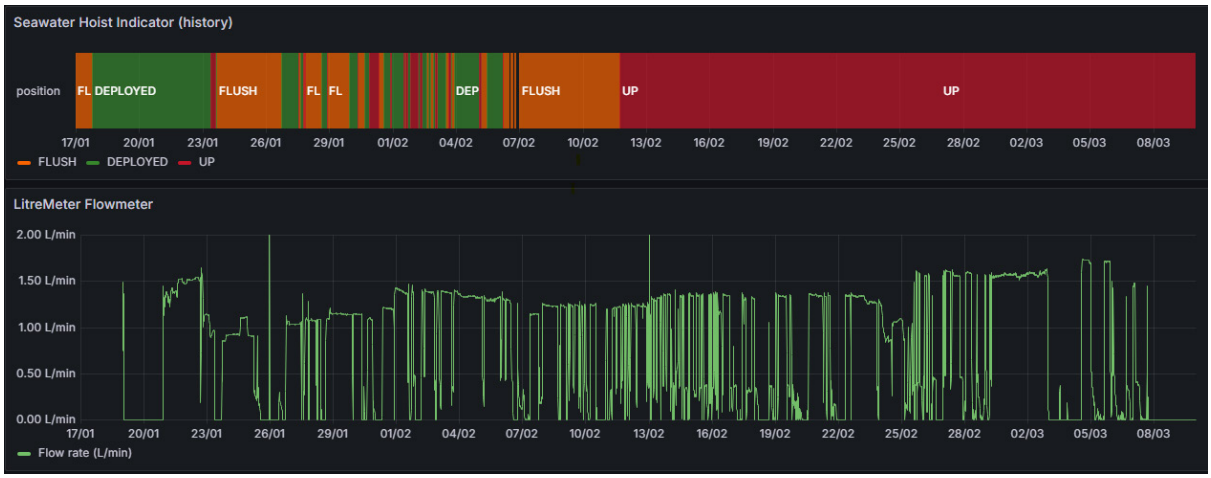


Figure 4.1-1: UCSW hoist position status (top), and UCSW sensor wall flow rate (bottom) throughout the duration of SD035 (2024-01-17 to 2024-03-09).

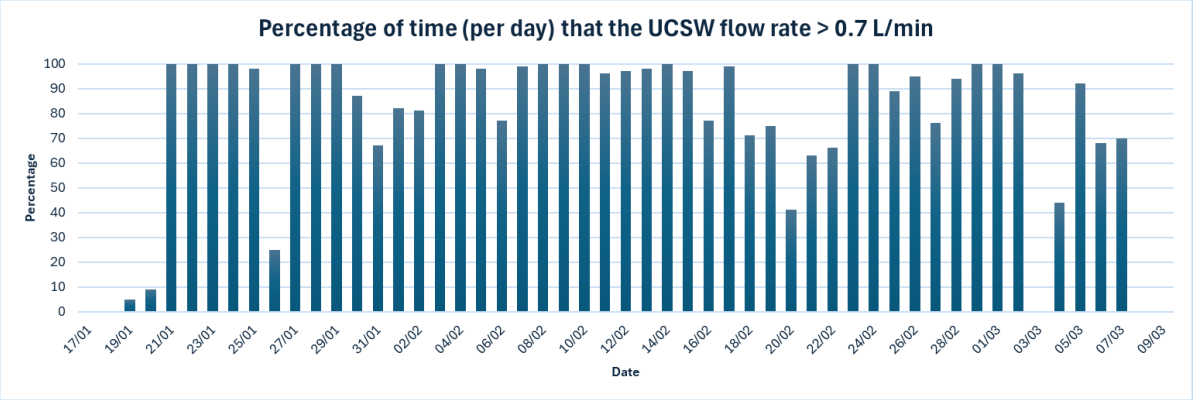


Figure 4.1-2: Percentage of time (per day) that the flow to UCSW sensor wall > 0.7 L/min throughout the duration of SD035 (2024-01-17 to 2024-03-09).

A complete list of the measured UCSW parameters that were observed (using both sensors and from collected water samples) are described in Section 2.2, with a comprehensive description of the general underway data logging systems in Section 2.5. Most recent date of underway sensor calibration is included in Table 3-1. The calibration sheets are available upon request from Carson McAfee (BAS).

4.1.1 Underway Thermosalinograph

Authors: Lars Boehme[1]

[1]School of Biology, University of St Andrews, St Andrews, UK

Two Sea-Bird SBE 38 sensors measured the external sea surface temperature and one Thermo-Salinograph (Sea-Bird SBE 45) is connected to the underway water sampling system to provide salinity.

Sea surface temperature (SST)

Two SBE38 sensors measure temperature outside the hull at about 7 metres depths. One sensor is about 10cm in front of the other sensor. There was an offset between the two sensors with the forward sensor measuring lower with a median value of 0.0692°C compared to the further aft sensor between 19th January and 6th March 2024. An example is shown in Figure 4.1.1-1.

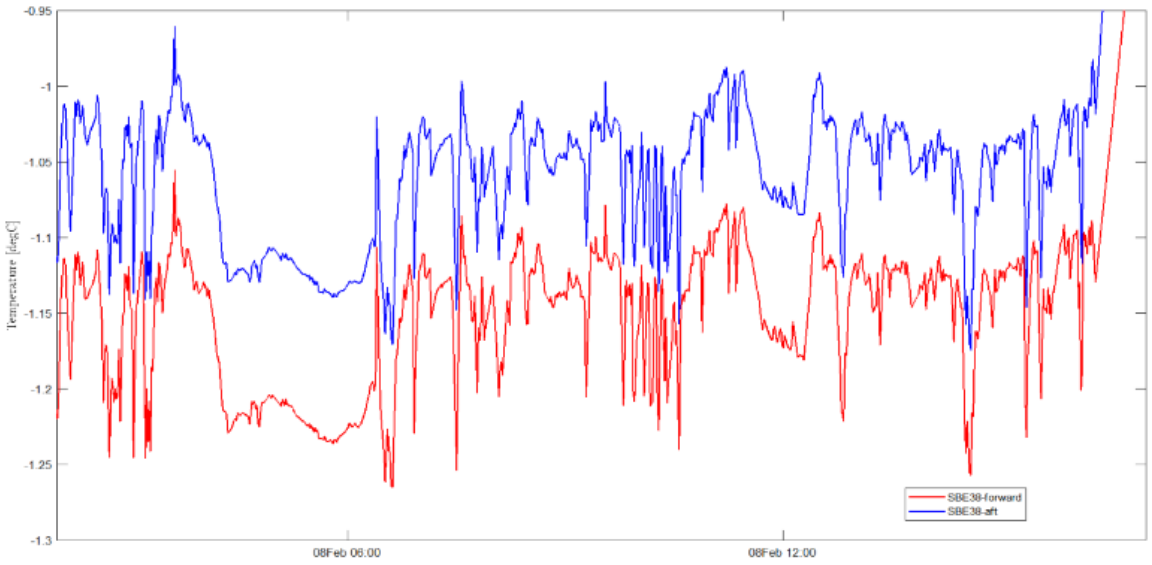


Figure 4.1.1-1: Example of temperature measurements by the two SBE38 sensors at 7 metres depth.

The sea surface temperatures recorded by the SBE38s during the cruise were compared to the surface measurements of the primary stainless-steel CTD based on profiles between 22nd January and 1st March 2024. For each CTD station the mean CTD temperature at 7dbar was compared to the closest SST measurement if the flowrate of the underway system was higher than 1l/min. The forward external temperature sensor showed a median offset of ΔT_{forw} = -0.3087°C and therefore reading slightly to high temperatures. The aft external temperature sensor showed a median offset of ΔT_{aft} = -0.3712°C and therefore reading slightly to high temperatures (Figure 4.1.1-2). This difference between the two sensors of 0.0624°C reflects the value previously estimated (Figure 4.1.1-1).

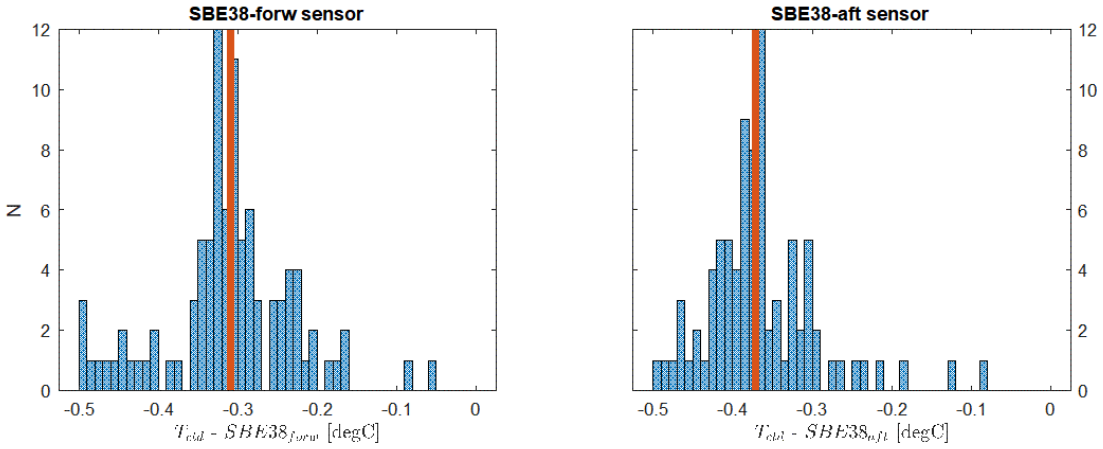


Figure 4.1.1-2: Differences between CTD temperatures at 7 dbar and water temperatures measured on the forward (left) and more aft (right) SBE38 temperature probes. The median values are shown by red vertical lines.

TSG Salinity

Water samples were taken from the underway system and salinity determined by salinometry using an Autosal 8400B (see Section 9.1). The TSG SBE 45 salinities and their variability were extracted based on the time when samples were taken from the underway system over a 3-minute period. Obvious outliers, often associated with samples taken to close to the activation of the UCSW system and the associated temperature drift, were removed. The final median offset between the salinometer results and the SBE45 salinities is +0.010 PSU (Figure 4.1.1-3) meaning the measured values of the SBE 45 were too low.

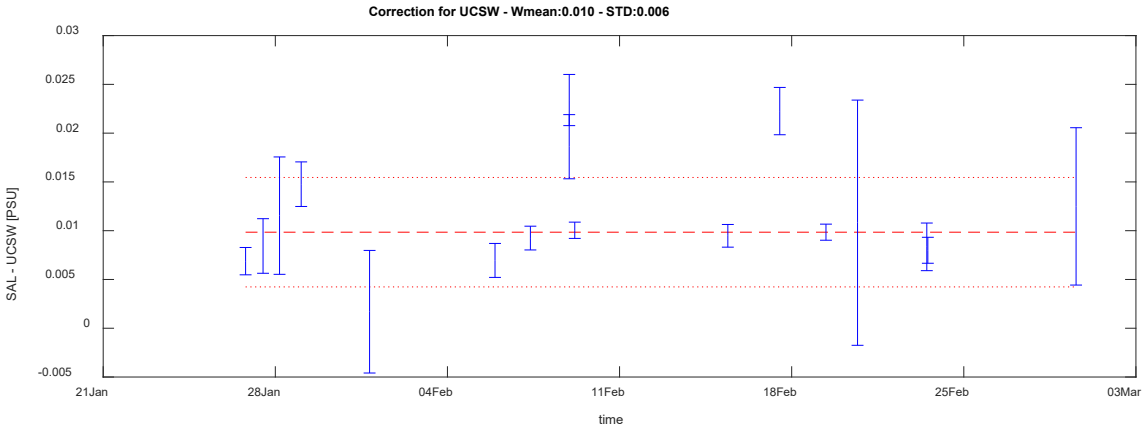


Figure 4.1.1-3: Salinity differences between the water samples taken from the UCSW system and analysed using the Salinometer and the derived salinities from the SBE 45 (blue). Proposed correction of +0.010 PSU shown as dashed red line and the estimated error of ±0.006 PSU shown as red dotted lines.

4.1.2 Optical seawater measurements

Authors: Giorgio Dall'Olmo[1], Xuerong Sun[2], Bob Brewin[2]

[1]National Institute of Oceanography and Applied Geophysics (OGS), Trieste, Italy
[2]University of Exeter, Exeter, UK

Objectives

Surface optical properties were measured using the ship's uncontaminated sea water supply in order to:

- investigating the feasibility of determining proxies of iron limitation;
- determining the optical properties of different phytoplankton size fractions;
- improving ocean-colour algorithms in the Weddell Sea.

Methods

Particulate beam-attenuation and absorption coefficients (400–750 nm) were determined quasi-continuously from the ship's underway water following methods detailed in Dall'Olmo et al. (2009). See Figure 4.1.2-1 for a schematic of the underway optics system.

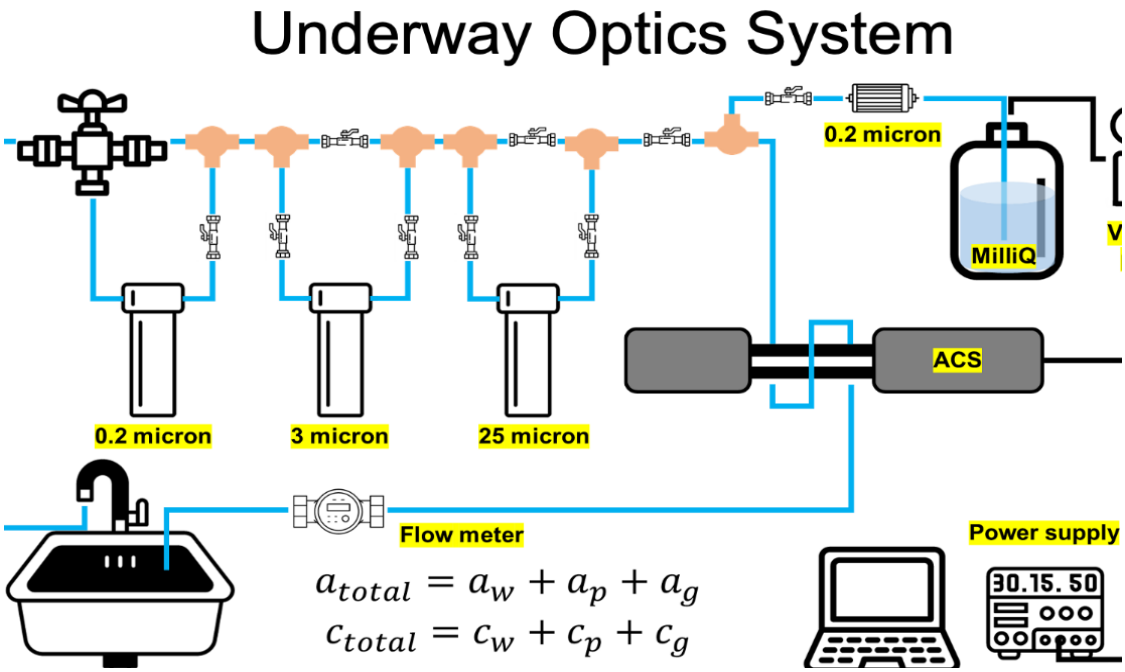


Figure 4.1.2-1: Schematic of the underway optics system on SD035

Briefly, we used the ACS instrument (WET Labs, serial number 297) to measure the optical properties of seawater from the ship's underway system, which operates at a depth of approximately 7 meters. The optical properties include the total absorption coefficients and total attenuation coefficients, *a* and *c*. At regular intervals of every hour, the underway optics system automatically passes seawater through a 0.2-micron filter (SUEZ Memtrex NY MNY921EGS) for ten minutes. This process facilitates the acquisition of absorption and attenuation coefficients of particulate matter in seawater, referred to as a_p and c_p.

Throughout the PICCOLO cruise, we have collected a_p and c_p observations at various stations (red circles), as shown in Figure 4.1.2-2. Additionally, we obtained a few underway a_p and c_p data during transits (blue squares). The presence of bubbles in the underway system significantly affected the data quality of the ACS instrument (as mentioned below). Moreover, due to the abundant sea ice and krill in the study area, the ship's underway system was occasionally blocked, together resulting in a lack of continuous underway observations.

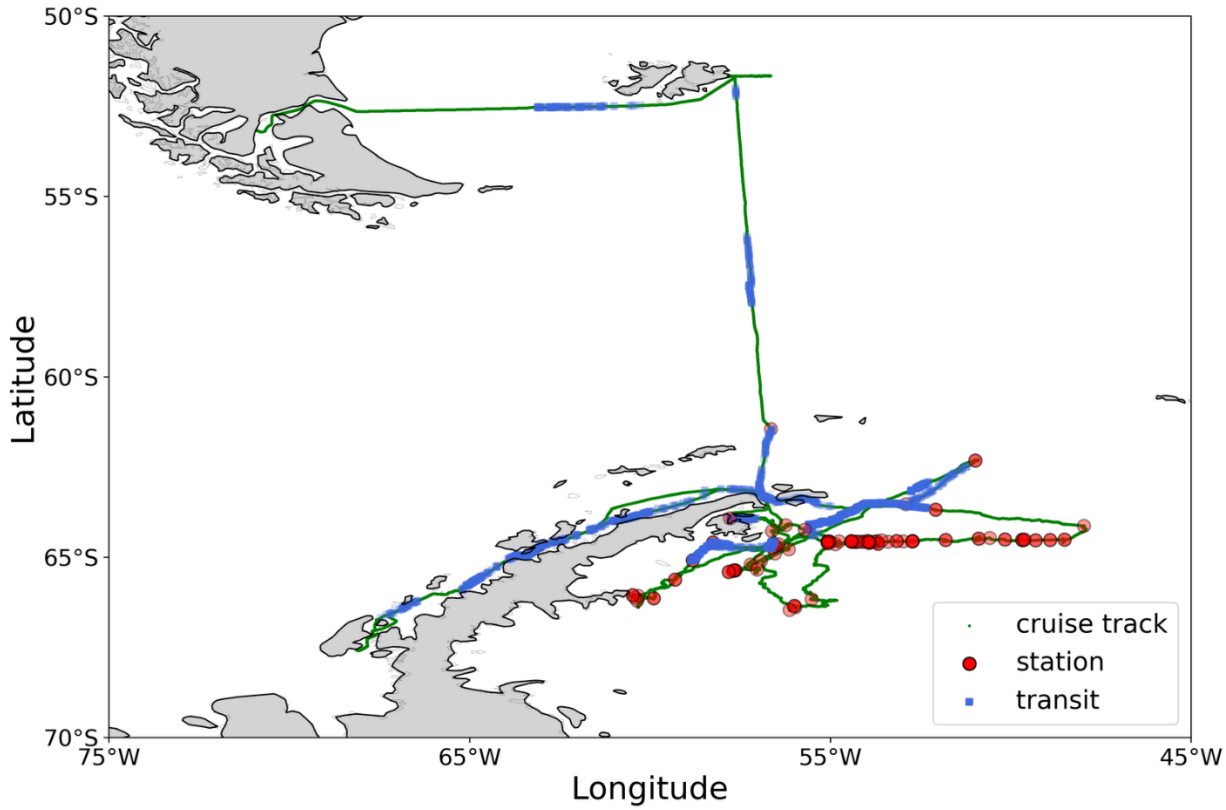


Figure 4.1.2-2: Map of underway sampling locations

During the PICCOLO cruise, we introduced a novel approach by measuring the optical properties of particles within distinct size ranges using specific cartridge filters (i.e., <25µm; <3µm, Polygard® CR Cartridge Filter) directly and simultaneously via the underway optics system, which has never been conducted before in the study area. These measurements can be used to assess the contributions from particles of different sizes to the total chlorophyll-a concentration, often referred to as the "colour of the ocean", which will help understand the causes of the “bio-optical anomaly” of the Southern Ocean. These size experiments were done only at stations where the duration of stay was longer.

At the beginning of the cruise, we used the DH4 and its associated software to collect data from the ACS in the underway optics system. However, we were experiencing unexpected interruptions in data collection from the ACS. Through troubleshooting and experimentation, we found that rebooting the power supply after interruptions effectively resolved this problem. We then used the open source INLININO (https://github.com/OceanOptics/Inlinino), combined with programming to detect data collection interruptions and manage the power supply. This approach successfully solved the interruption problem with ACS data collection. The software and codes mentioned above can be found in the "work\scientific_work_areas\Optics\Data\Underway\IOPs\Software" directory.

Post-processing of the underway measurements involved several steps, including 1-minute bin median calculation, quality control, temperature and scattering correction, and estimation of chlorophyll-a concentration. The Python code, along with preliminary measurements of a_p and c_p, can be found in the "\work\scientific_work_areas\Optics\Processed\Underway\ACS" directory.

The ship's LabSTAF fast-repetition rate fluorometer was used to determine photophysiological parameters continuously. The settings used for this sensor were saved in files continuous_dynamic_FLC.flc, continuous_dynamic_FLC.rsf, and continuous_dynamic_FLC.rst. Briefly, in order to investigate the light-acclimation status of phytoplankton, we collected single-turnover curves at different white light background levels. The LabSTAF flow-through cell was directly plumbed into the underway system after the 0.2-um filter and before the ACS instrument. This means that the LabSTAF measured every hour 0.2-um filtered seawater, which can be used as a blank in the post-processing phase. A blank was also measured at the end of the cruise by adding MilliQ water in the cleaned flow-through chamber of the instrument (data were save in file 240303-1859_blank.rsf). The flow rate through the LabSTAF was determined (0.14 L/min) on 24 Jan 2024 at 23:45 with respect to the measured flow rate of the underway system (19 L/min, note the flow rate for the underway system is expressed in nominal units from the software, i.e., not real units). The last 42 cm of tubing (ID: 0.55 cm) before the flow-through cell inflow were covered with black tape to dark acclimate cells before they entered the instrument's flow-through chamber.

A UV spectrophotometer (Opus, Trios, Germany) was also connected at the end of the underway optical system to estimate NO_3 concentrations. A flow-through cell was built to ensure water was flowing through the interrogation region of the sensor. A UV spectrum approximately every 15 seconds. A set of NO_3 standards (5, 10, 20, 30 and 40 uM; dissolved in MilliQ water), low-nutrient seawater sample (salinity of 35.9233 PSU, NO3 < 1 uM) and MilliQ water (both freshly sampled from the MilliQ machine as well as that used to prepare the standards) were measured at the end of the cruise by first cleaning the flow-through cell with MilliQ water, then rinsing the cell with part of the standard, and finally filling the chamber and the inflow and outflow tubing (ID = 0.5 inches) with the standards. Data for each standard were collected for 5 minutes.

HPLC discrete samples in support of optical data

To validate and calibrate the optical data, for example, the chlorophyll-a concentration derived from the a_p and fluorescence data, we collected the HPLC pigment samples from both the underway system and the CTD Niskin bottles. This was done to correlate with the optical data obtained from the underway system and the optical rig, respectively. Briefly, a certain amount of water, depending on its turbidity, was filtered through Whatman GF/F glass microfibre filters (pore size 0.7 µm, diameter 25 mm) under low vacuum pressure. These filters were then placed in the cryovials, flash-frozen in liquid nitrogen, and stored in the -80 freezer. For the underway optics system, we also collected the size-fractionated HPLC pigments samples for various stations. Water samples were also collected from the ice cage and ice floes (on-ice work sites) for both HPLC pigment and particulate/phytoplankton absorption measurements.

Bubble problems, (partial) solutions, and recommendations for the future

Bubbles were a major problem for the underway optical measurements which in most cases were only reliable at stations. Bubbles had two main sources:

- The pumping system was found to generate significant amounts of bubbles when the pump was operated at >35 Hz. Thus bubbles were created by the pump itself, probably by cavitation. The solution to this was to keep only 1 pump running at 35 Hz, which removed most of the bubbles from the system. However, by reducing the frequency at which the ship's pump was operated, the flow rate in the system was also significantly reduced. This reduction resulted in insufficient flow rates for the pCO_2 system. To solve

this additional problem, the pressure in the uncontaminated-seawater (UCSW) system was increasing by partially closing the outflow valve of the system, which increased back pressure and the flow rate to the pCO_2 system.

Recommendation: To ensure reproducibility of the conditions required to have UCSW free from bubbles generated by the ship's pump, it seems fundamental to have a continuous digital log of the pump settings as well as a measurement of the back pressure in the system.

- After the ship's pump had been properly tuned to minimize generation of bubbles, another source of bubbles became apparent when the ship was moving at speeds >~5 knots. When ice was present, the UCSW pole (i.e. aka "hoist") needed to be retracted inside the ship. As a consequence, bubbles entered the UCSW system. We believe these bubbles are generated by the ship and outside the ship when the ship is moving and form a sheath just below the hull. The hoist penetrates through this sheath and allows the UCSW system to access bubble-free water. When the hoist was retracted ("UP"), at higher ship's speeds bubbles were almost always present and precluded us from collecting usable underway optical data. Interestingly in some rare occasions, bubble-free water was measured at speeds of ~14 knots: it remains unclear what caused this bubble-free water at high speeds.

Recommendation: The German Polarstern and the Swedish Odum have USWV systems that can be run in ice. If a redesign of the SDA UCSW system is needed, we would recommend contacting the engineers of these ships and ask for the designs of their system.

4.1.3 Seawater partial pressure of carbon dioxide (pCO_2)

Authors: Tom Bell[1], Vassilis Kitidis[1], Ian Brown[1]

[1]Plymouth Marine Laboratory, Plymouth, UK

Measurements of the partial pressure of CO_2 in seawater were made during the PICCOLO fieldwork using two different approaches:

a) the ship's seawater pCO_2 system (PML-Dartcom Live pCO_2 instrument)

b) a stand-alone sensor (ProOceanus CO_2 PRO-CV)

The PML-Dartcom Live pCO_2 instrument in the salinometer/UCSW rooms was the primary vehicle for underway pCO_2. Preliminary data suggest that the two systems were generally in good agreement. A series of ice and krill blockages to the UCSW supply significantly impeded continuous operation.

4.1.3.1 Dartcom Live pCO2 system

The ship's pCO_2 system (PML-Dartcom Live pCO_2 instrument) comprises a showerhead equilibrator vented through a second equilibrator, in-line oxygen optode and platinum resistance thermometer, nafion dryer, non-dispersive infrared detector (LiCOR, LI-840) and associated hardware and electronics (Kitidis et al. 2017). Gas standards (BOC Ltd.; nominal mixing ratios 250, 380, 450 ppmv in synthetic air; calibrated against NOAA primaries) were

located in the gas bottle rack forward of the hangar and an air sampling line was taken from the foremast.

It was found that the atmospheric measurements were largely below their expected values (ca. 360 ppmv) when sampling from the foremast airline. The corresponding values for a Tedlar gas bag filled on the foredeck were approximately 420 ppmv as expected. A blockage in the airline could conceivably lead to a vacuum and explain the abnormal concentrations. However, neither pressure, nor temperature decreased as would have been expected by such a blockage. We also examined the possibility of dilution of the 'air' stream by a source of low CO_2. A leak of low-CO_2 standards was ruled out by isolating the standards - low air values persisted. A leak of low-CO_2 from equilibrated seawater would have drawn air from the secondary equilibrator and ultimately lab-air via the secondary equilibrator vent. This would have registered on the vent flow meter as a continuous influx of air which was not observed. Whilst the cause of the abnormally low-CO_2 readings in air is not clear at present, we concluded that there was no fundamental flaw with the instrument and that the corresponding seawater measurements were reliable. For reliable atmospheric CO_2 concentrations, data from the calibrated CO_2 flux system located in the atmospheric laboratory should be used.

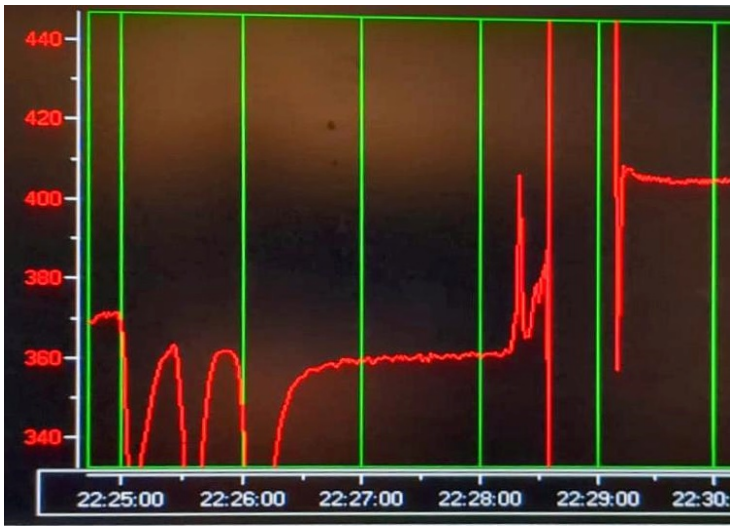


Figure 4.1.3.1-1: CO_2 (ppm) observations using the Dartcom system. First flat line just after 22:26 hrs is atmospheric CO_2 sampled through the ship's air inlet line. Second flat line after 22:29hrs is atmospheric CO_2 collected in a Tedlar bag from the forward Heli deck.

One issue occurred a few times during the cruise - the Dartcom system's embedded PC crashed. Sometimes the PC rebooted, sometimes it did not. When the PC did reboot, this highlighted that the Dartcom software was not set to autostart as part of the boot procedure. This problem was rectified at the end of the PICCOLO cruise. The cause of the PC crashing was looked into by BAS IT. Although the exact cause was not clear, the PC runs very slowly, and only has a single processor. Running Windows 10 on such an under-resourced PC may be the cause of the crashes. This should be investigated further by BAS.

Reference

Kitidis, V. et al., Surface ocean carbon dioxide during the Atlantic Meridional Transect (1995-2013); evidence of ocean acidification. Progress in Oceanography, 2017. 158: p. 65-75.

4.1.3.2CO2-Pro CV sensor

The CO_2-Pro CV sensor (https://pro-oceanus.com/products/pro-series/co2-pro-cv) is designed for in situ use in fresh or saline environments, can be externally powered or powered by an internal battery, and is submersible to a depth of 600 m. The principle of operation is that gaseous CO_2 in seawater is allowed to diffuse through a semi-permeable membrane into a measurement cell. CO_2 in equilibrium with seawater is then measured with ±0.5% accuracy (or ≈ 2ppm) using non-dispersive infrared (NDIR) detection. A common issue with NDIR detectors is that the signal drifts considerably. The CO_2-Pro CV automatically compensates for baseline drift by periodically measuring CO_2-scrubbed air. The response time of the sensor is a function of the flow rate. It is on the order of minutes, and will be exactly determined by data processing after the cruise. Seawater CO_2 concentrations are expressed and recorded as the partial pressure of CO_2 (in parts per million, ppm) that is in equilibrium with the CO_2 in seawater.

Serial communication is used to connect and download data from the CO_2-Pro CV, as well as to program the data acquisition (duration, frequency, etc.) during future deployments. The sensor was always setup to collect data in continuous mode, sampling every second. When connected to the uncontaminated seawater (UCSW) in the Deck Lab, data were logged on a laptop via a serial port (19200 Baud) with a Python script. When used for on ice deployments and on the autonomous surface vehicle (Caravela), data were logged internally and downloaded upon recovery. For the UCSW data collection, the sensor was set to auto-zero every 6 hours. During on ice and Caravela deployments, the sensor was set to auto-zero every 12 hours.

The CO_2-Pro CV is factory calibrated using WMO traceable standards (https://gml.noaa.gov/ccl/). No additional calibration was performed during the PICCOLO fieldwork, but two approaches will be used to retrospectively cross-check and calibrate the data:

1) Pro CV CO_2 uncontaminated seawater (UCSW) measurements will be compared with results from the Dartcom Live pCO2 instrument
2) Carbonate chemistry (Total Alkalinity and Dissolved Inorganic Carbon) samples were routinely collected concurrent with the Pro CV sampling, and these will be used to calculate the expected seawater pCO_2.

Figure 4.1.3.2-1*: CO_2-pro CV sensor.*

Physical setup in deck lab

The sensor was setup and directly connected to the UCSW in the Deck Lab from 29th January until 26th February. Raw data will require extensive post-processing to address the frequent interruptions caused by the UCSW being turned off and on. Seawater was pushed through the measurement cell of the sensor at ~1.4 LPM. TA/DIC samples were collected and pH observations (UEA sensor installed on 7th Feb) made on seawater exiting the sensor. The sensor was set to perform an autozero every 6 hrs. Krill blocking the UCSW filter were problematic as the filter did not catch everything, meaning that they could clog other elements of the system, including inside the pCO2 sensor head. This became an issue just before the sensor was removed from the UCSW to prepare for the through ice work.

Figure 4.1.3.2-2: Krill 'detritus' caught in the sensor head prior to the initial through ice work (which became the medical evacuation)

4.1.4 Underway ANB pH sensor

Author: Gareth Lee[1]

[1]*School of Environmental Sciences, University of East Anglia, Norwich, UK*

Underway pH measurements were taken from the Deck lab underway tap with an ANB pH sensor. https://www.anbsensors.com/

The S series pH sensor is based on patented electrochemical technology to provide a calibration free sensor. The biggest reason why electrochemical based pH sensors require frequent recalibration is reference electrode drift, where the reference to which the pH is measured against is not stable and moves with time, making the measurements inaccurate until the sensor is recalibrated. ANB's technology contain an innovative reference tracker, which follows any drift in the reference and accounts for it in-situ, removing the need to manually

recalibrate. The S series is made from robust materials and is all solid state, making it ideally suited for the extreme environments found in the world oceans. The key element of the S series is its sensing transducer, which is where ANB's innovative sensing chemistry is found. It contains a series of solid-state carbon impregnated electrodes from which the electrochemical measurements are conducted. The onboard computer on the sensor analyses the electrochemical measurement and the temperature of the solution and combines these factors to produce a pH, with no compensation for depth required. The outputs of the sensor are time, pH temperature and health. The output of the health is key to end user experience as it provides a qualifier on the accuracy of the pH response and gives an indication of maintenance required in real time. Maintenance is a simple abrasion over the surface of the transducer, with the supplied abrasion block. The process replenishes the transducer interface, and after the abrasion has completed, the sensor is ready for deployment, with no recalibration necessary. The lifetime of the sensor is dependent on the number of measurements it records, and therefore depends on the measurement profile set by the end user. The transducer provides about 15,000 measurements before maintenance is required. A continuous measurement cycle will give about 5 days before re-abrasion is required.

Figure 4.1.4-1: ANB electrode transducer configuration

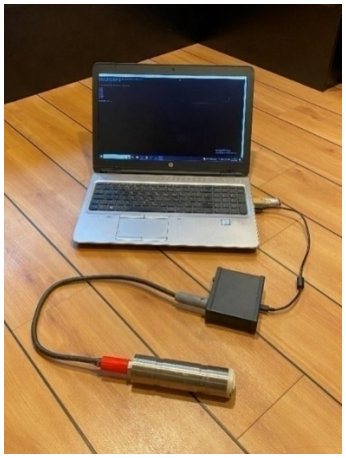


Figure 4.1.4-2: ANB S series pH sensor

ANB pH sensor (serial number 300290) was set up in the SDA deck lab from 5th February to 28th February 2024. Previously it had been in the UCSW laboratory. The pH sensor was set up in conjunction with a pCO_2 sensor (Pro Oceanus CO2 PRO CV) and the ship's UCSW sensor outputs were also available. The sensor was also attached to the SS CTD rosette for CYD casts 129 and 134 (Event 245 and 288), which were pH sensor calibration casts.

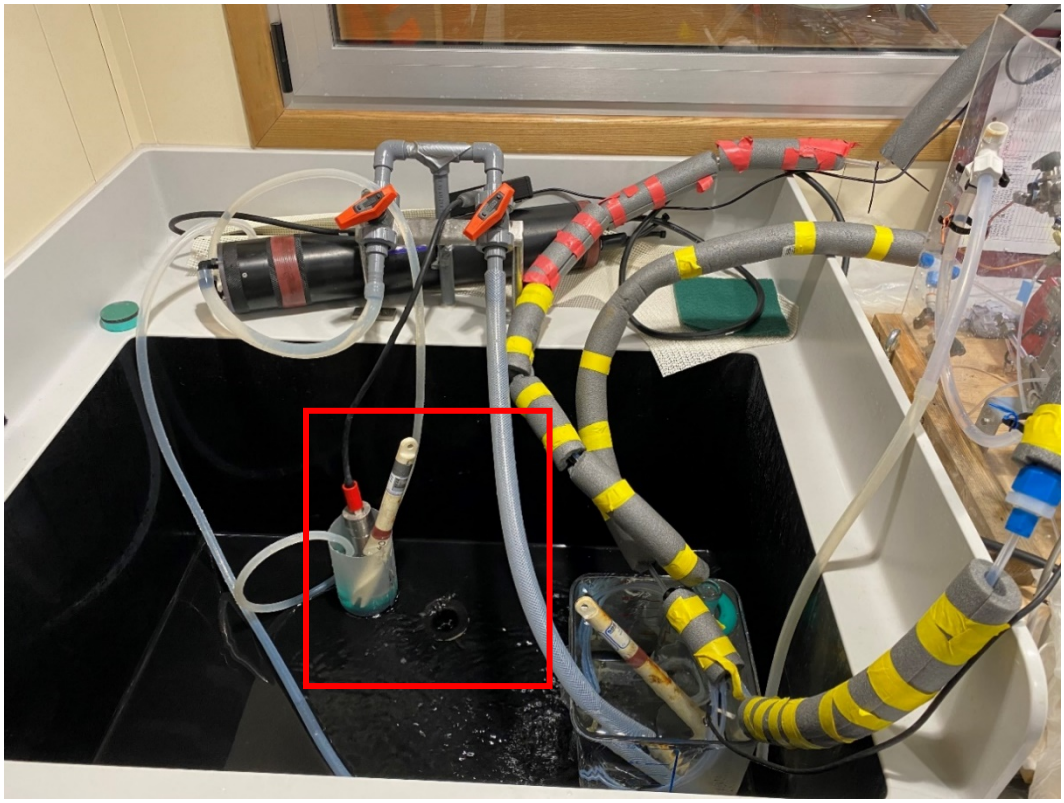


Figure 4.1.4-3: The setup in the deck lab

The setup consisted of submerging the ANB pH sensor in the outflow of the pCO2 sensor. The pH sensor was set to measure continuously, meaning a pH measurement every ~23 seconds. Regular abrasion of the sensor was completed every 3-4 days and logged. At no point did the health indicator show an unhealthy transducer.

A subsample for Total Alkalinity (TA), Dissolved inorganic carbon (DIC) and nutrients were taken twice daily to cross reference the pH measurements. TA and DIC samples were also taken for the CTD casts.

The data will be processed, and quality controlled back at UEA and the final data-set will be available.

4.2 Atmospheric observations

Author: Tom Bell[1]

[1]*Plymouth Marine Laboratory, Plymouth, UK*

Figure 4.2-1 plots a subset of the underway observations that were collected during the PICCOLO/SD035 cruise. A description of all of the different operational sensors logged by the SDA underway system can be found in Section 2.2. A description of how the sensors were logged and the location of the data can be found in Section 2.5.

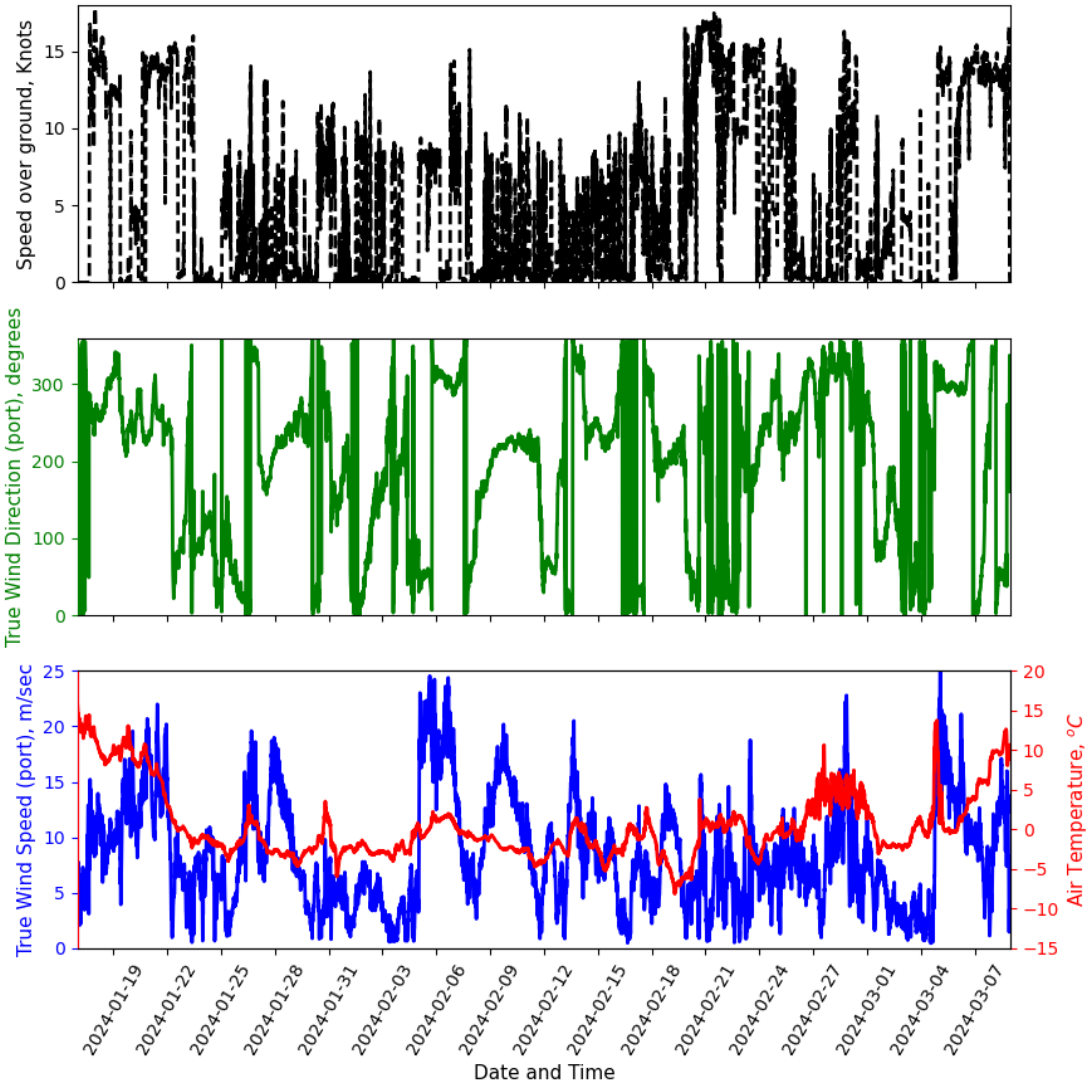


Figure 4.2-1: Timeseries of ship speed, wind direction, wind speed and air temperature during the PICCOLO cruise.

4.2.1 Air-sea CO_2 fluxes

Author: Tom Bell[1]

[1]Plymouth Marine Laboratory, Plymouth, UK

Flux system description

Air-sea fluxes of CO_2, sensible heat, and momentum were continuously measured on the SDA using the eddy covariance method. This method requires rapid (10 Hz) sampling of the following:

- 3-dimensional wind velocities and air temperature using a Metek sonic anemometer (uSonic-3)
- 3-dimensional acceleration and rotation using a LPMS motion sensor
- CO_2 mixing ratio in the atmosphere (Picarro G2311-f instrument)

The PML Metek sonic anemometer, LPMS motion sensor, and a 1/2 in. Teflon gas inlet (along with a 1/8 in. Teflon tube for nitrogen puff) are mounted near the top of the ship's foremast. The Picarro is rack mounted in the atmospheric lab. A Gast vacuum pump (referred here as the inlet pump, housed just behind the instrument rack in the blue cooler box under the bench) is used to rapidly draw air from the foremast into the atmospheric lab. The Picarro sub-samples from that ½ in. Teflon inlet tube via a ¼ in. Teflon tube, through a particle filter, and a Nafion drier (to remove water vapor). A Waterwatcher device (located within the enclosed shaft up to the foremast) is used to sense if water has entered the inlet tube. Two 3-way solenoid valves are activated when the Waterwatcher is activated, causing air to be pushed back out the inlet in the reverse direction by the Gast pump.

Figure 4.2.1-1: Foremast setup (left photo): The 1/2 in. Teflon gas inlet tube (with 1/8 in. Nitrogen puff tube) is mounted below the ship Metek (top of picture). The LPMS and PML Metek sonic are mounted on a separate horizontal mount at the bottom. Power/data cables (~45 m) and Teflon tubes (~40 m) run from the foremast to the atmospheric lab.

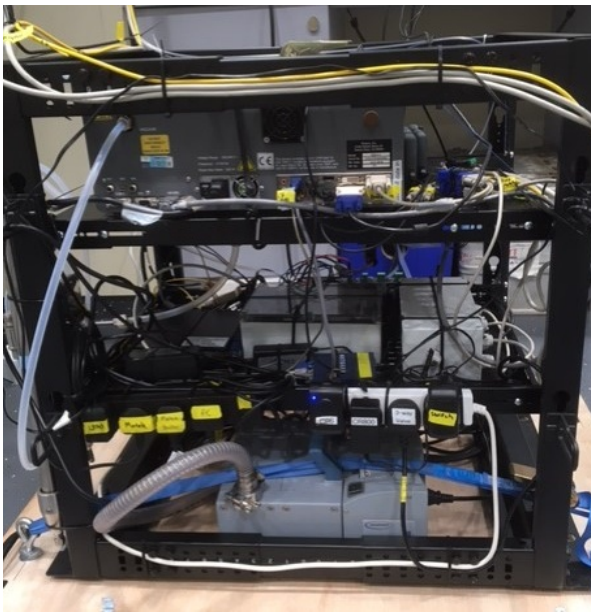


Figure 4.2.1-2: Atmospheric lab setup (right photo): Picarro (with internal PC) on the top shelf with 2 external hard drives, CR6 and CR800 Campbell loggers, 3-way solenoid valves (x2), 2-way solenoid valve, external PC on the middle shelf; Picarro instrument pump (Vaccubrand) on the bottom.

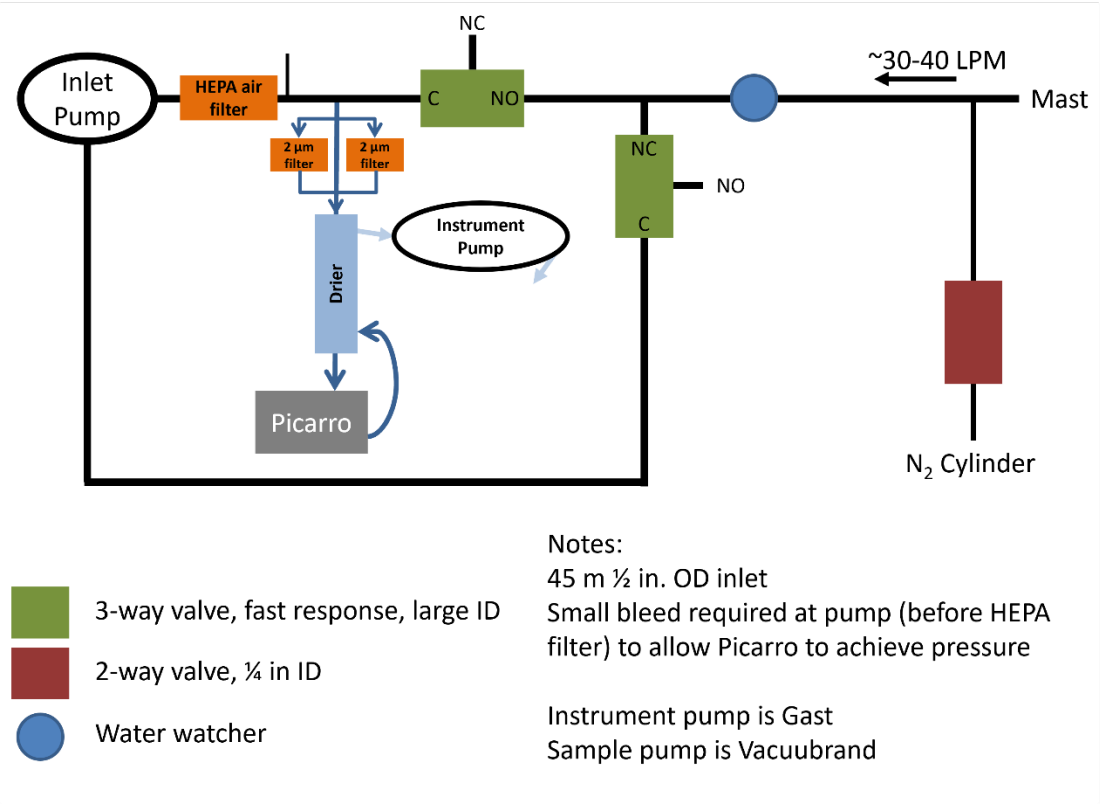


Figure 4.2.1-3: CO_2 flux system setup

Cruise notes

The Picarro was manually calibrated three times throughout the cruise (26th Jan, 18th Feb, 4th March). Each calibration used cylinders provided by Royal Holloway University of London:

- Cylinder #136 (CO_2: 744 ppm; CH_4: 2.538 ppm)
- Cylinder #137 (CO_2: 481 ppm; CH_4: 2.065 ppm)
- Cylinder #138 (CO_2: 373 ppm; CH_4: 1.789 ppm)

The flux system ran continuously throughout the cruise. Near the beginning of the cruise, the LPMS signal was lost intermittently, often associated with the ship shaking due to breaking ice. Investigation on 31st January identified that the issue was a loose connection within the CR6 data logger. This was sorted and the strain relief improved to avoid recurrence, solving the problem for the rest of the cruise.

The medical evacuation during the cruise led to a potential scenario where a helicopter would land on the SDA. This required that the foremast was lowered and, as a result, was a test of the routing of our cables and tubing. This test identified two problems (both fixed during the cruise):

- One data cable had been mistakenly looped over itself during installation, which meant that a lot of slack had to be created (removing cable ties, etc.) for the mast to be lowered without damaging the cable.
- The tubing quick connects were easily disconnected, but the ends of the tubing were pulled out of the ship as the mast lowered and were left dangling in mid-air. This was an

issue when the mast was raised back up, as the fittings would have got caught in the hinge.

After the medical evacuation was complete, the snagged cable was rerouted and secured/tidied with cable ties. A length of string was secured inside the mooring deck and then connected to the tubing – during subsequent lowering/raising of the mast, the string can be used to easily recover the tubing and avoid it getting caught in the hinge.

One additional issue plagued the flux system throughout – the embedded PC controlling the Picarro (and associated logging of CR6 and CR800 data) crashed every few days and required a manual intervention in order to restart and recommence data logging. BAS IT helped look at the issue, but it was difficult to diagnose. The problem seems to be associated with the virtual memory allocation and the ability of the PC to manage this resource. Toward the end of the cruise, we increased (and set) the allocated virtual memory (min. 4050 MB, up to max. of 8100 MB). Another crash occurred after this and the remaining change was to reduce the frequency that the system was scanned for antimalware. Not enough time remained to test whether this change was effective.

4.3 Other underway observations

4.3.1 Sea ice observation cameras

4.3.1.1 Foremast sea ice cameras

Author: Tom Bell[1]

[1]Plymouth Marine Laboratory, Plymouth, UK

Two *Campbell Scientific Outdoor Observation and Surveillance Field Cameras*[1], otherwise known as *CCFC*, were mounted on the met platform. Images will ultimately be used to determine the extent of sea ice coverage. The CCFC are rugged environmental cameras with an operating temperature range of -40°C to +60°C and include an internal heater to keep the lens clear of ice and snow. Two 45 m cables (communication and power) were run from the met lab to each camera. At the met platform, the cables were connected to short (5 m) tails via waterproof connectors, which ultimately connect to the cameras.

Figure 4.3.1.1-1: Port side CCFC camera setup. The setup was equivalent for the starboard side camera, with camera angle setup to overlap slightly directly forward of the bow.

The cameras are continuously powered, and controlled by a Dell micro-PC in the PML air-sea flux equipment rack in the atmospheric lab. The system operates autonomously. The micro-PC communicates with and controls the cameras over an isolated ethernet network (herein referred to as the *camera network*) via a USB ethernet interface connected to a small 5-port switch, to which both cameras are also connected. After booting, the micro-PC automatically started a Python script that set camera parameters and scheduled periodic image capture using HTTP requests. The script contained logic to ensure images are only captured between sunrise and sunset. This relies on the feed from the ship's underway systems being available in order to calculate sunrise and sunset times at the current position.

The cameras had been removed before the PICCOLO cruise in order to upgrade their firmware. The cameras were reinstalled at the beginning of the cruise, and still images of the sea surface were successfully captured every 30 seconds for the duration of the cruise. Images were collected looking forwards and slightly to the port and starboard sides of the ship.

Image capture settings were identical on both cameras: Maximum image resolution (2592 x 1944) with lossless quality and autofocus disabled. Cameras were setup on 16th January 2024 - an autofocus was performed, with the value (186) applied manually to both cameras. The autofocus was redone on the 18th January 2024, with the portside camera manually set to 191, and the starboard side camera set to 183.

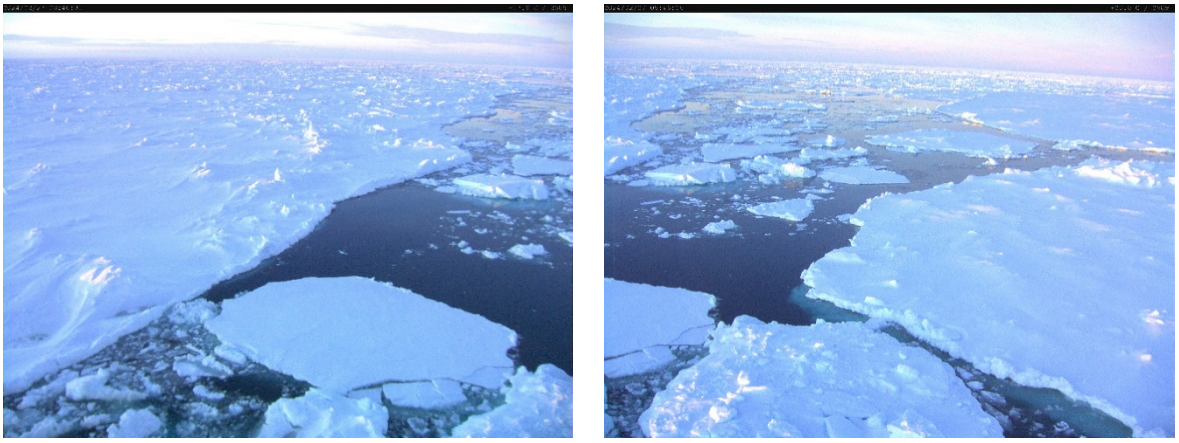


Figure 4.3.1.1-2: Example of images collected simultaneously by port (left) and starboard (right) side cameras.

Cruise-specific notes

From early February, it was identified that the cameras were icing over because of a combination of cold air temperatures and exposure to wind chill on the camera lenses. The lens defroster threshold (measured by an internal sensor) was changed from 3°C to 10°C, which temporarily solved the problem. However, the issue re-occurred on 11th February so the threshold was increased to 25°C for the rest of the cruise (effectively meaning that the camera heaters were left permanently on).

One other issue led to error flags (but did not cause images to stop being acquired). The Suntime Python library that was initially used in the cruise could not handle >2 sunrise/sunset events in one day (a problem that occurred when the ship moved, thus creating a day with three (artificial) events. This error was solved on 11th February by switching to an alternative Suntime library.

4.3.1.2 Sea ice GoPro camera

Author: Alex Tate[1]

[1]UK Polar Data Centre, British Antarctic Survey, Cambridge, UK

Background

An equipment installation request (SDA_SEIR_06) was made by Jeremy Wilkinson and Michael Thorne (both BAS) to opportunistically collect imagery and video of the SDA's hull interacting with sea ice during SD035. These images will be used to validate data collected by the vessel's permanently fitted ice load monitoring system (ILMS). Camera equipment (1 x GoPro 11, 1 x GoPro 7, 1 x Insta360, various accessories) was provided by Jeremy ahead of the cruise and transported to the vessel by science support personnel. A comprehensive user guide was also supplied with recommendations for camera installation and configuration.

Summary

The installation of forward and aft looking GoPro cameras assisted by AME staff (see BAS engineering report, Section 2). The cameras were attached to a metal bar connected to the railings on Deck 6 at a longitudinal location equivalent to SDA frame 99 (see Figures 4.3.1.2-1 and Figure 4.3.1.2-2A).

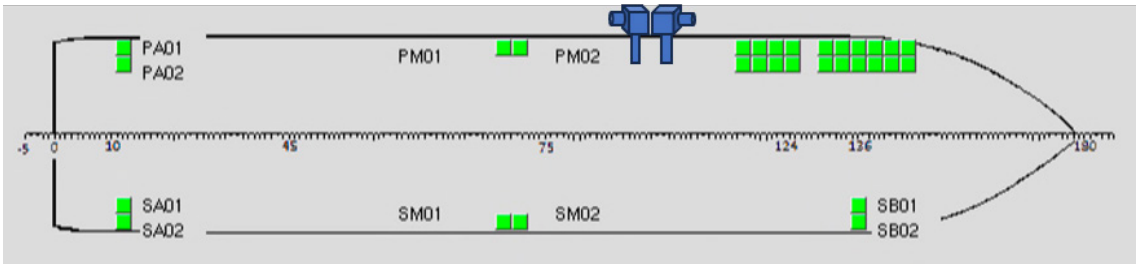


Figure 4.3.1.2-1: Approximate location of the two GoPro cameras (blue) in relation to the ILMS accelerometers (green squares).

Figure 4.3.1.2-2A (left) shows the mounted cameras on Deck 6 port-side, just forward of the entrance to the helicopter workshop. This setup provided images forward (GoPro 11, Figure 4.3.1.2-2B, middle) and aft (GoPro7, Figure 4.3.1.2-2C, right)

Both cameras were configured to collect timelapse photos every 0.5 seconds with a linear aspect (as opposed to wide-angle). Both units had GPS turned on and time set to UTC. Time was corrected at the start of each deployment using the appropriate function within the GoPro Quik app used to configure and control both cameras.

GoPro camera deployments occurred opportunistically (as time permitted) throughout the cruise when the ship was transiting through sea ice, as summarised in Table 4.3.1.2.

Table 4.3.1.2: GoPro camera deployment periods

Date	Deployment period	Comment
2024-01-26	10 minutes	Installation testing
2024-01-27	15 minutes	Limited sea ice, stopped recording
2024-01-30	3.5 hours	
2024-02-02	4 hours	

2024-02-03	3.5 hours	
2024-02-07	4 hours	Forward camera memory card filled after 1.5 hours
2024-02-10	4.5 hours	
2024-02-13	1 hour	
2024-02-17	4 hours	

Cameras were brought inside after each deployment to download imagery from their local memory cards (which were then cleared) and to allow the external battery pack to be recharged. The dual camera setup, which utilized a shared USB battery pack stored in a dry sack, generally worked well but due to an abundance of caution, the equipment was never left out overnight or when not recording.

A total of 320,000 (812 GB) GoPro images were recorded during the cruise.

The Insta360 camera was provided with the intension of being deployed at the end of a 3 m extension pole from the forward opening in the Deck 5 (anchor/mooring) winch space. Unfortunately, there was no time found to deploy this camera due to other priorities.

Issues and recommendations

Many of the SD035 cruise priorities required the ship to be in ice-free water for optimal results (seawater sampling, current profiling, bio-acoustics, over-the-side deployments). This meant that even in areas of high sea-ice concentration, the ship actively avoided interactions with sea-ice wherever possible. This is the opposite of what is required of a hull/ice interaction study and there were fewer opportunities than expected to record these interactions given the study location.

Even given the above, a camera operator dedicated to the task would undoubtedly have deployed the cameras more often and recorded more images throughout the cruise. However, if there is a long-term aspiration to collect these kinds of data without human intervention, then the following aspects need to be addressed.

- Power – the cameras need a permanent power supply rather than relying on a consumer-grade battery pack. There were several occasions when the battery pack had to be warmed up to room temperature before it would function properly again.
- Image storage – the cameras need to be able to automatically backup data to the ship's Storage Area Network through a network connection. Local file storage should only be used as a fallback if this synchronisation fails.
- File size and image selection – If the GoPro cameras had been used constantly throughout the whole cruise at the same settings, they would have collected around 60 TB of data. This is currently an unsustainable volume and thought must be given to image resolution and frequency. Filtering routines should also be investigated so images are only stored permanently to disk when sea-ice is present.

- Ruggedisation - While the GoPro cameras proved robust, they were not used in particularly bad weather, and it is unclear that they would function for months at a time in polar conditions. This is especially true of the setup used on SD035 where the power port had to be partially exposed to allow continuous battery charging.

Most of these aspects have been addressed in the camera component of the PML sea ice camera system, so a more robust system could easily be setup. However, it is not possible to use the data from the PML cameras because, although these cameras do show general sea ice conditions ahead of the vessel, they do not show ice/hull interactions, nor is their set logging frequency particularly suitable for ILMS validation.

4.3.2 Radiometry

Authors: Bob Brewin[1], Giorgio Dall'Olmo[2], Xuerong Sun[1]

[1]University of Exeter, Exeter, UK
[2]National Institute of Oceanography and Applied Geophysics (OGS), Trieste, Italy

Objectives

To measure hyperspectral remote sensing reflectance continuously during PICCOLO to:

- investigating the relationship between ocean colour and biogeochemical variables collected in the Weddell Sea (e.g., chlorophyll-a concentration and particulate organic carbon).
- validate and potentially improve satellite algorithms of chlorophyll-a concertation and particulate organic carbon for use in the PICCOLO project.

Methods

Above-water radiometric measurements were taken quasi-continuously using a SeaBird/Satlantic HyperSAS system. The HyperSAS optical remote sensing system provided hyperspectral measurements of spectral water-leaving radiance, sky radiance and downwelling spectral irradiance, from which the above-water remote-sensing reflectance (Rrs) was computed in a similar manner to past Atlantic Meridional Transect cruises (Brewin et al. 2016; Lin et al. 2022; Pardo et al. 2023). The 136- channel HyperOCR radiance and irradiance sensors (calibrated in June 2023) were mounted onboard the ship for simultaneous viewing of the sea surface and sky.

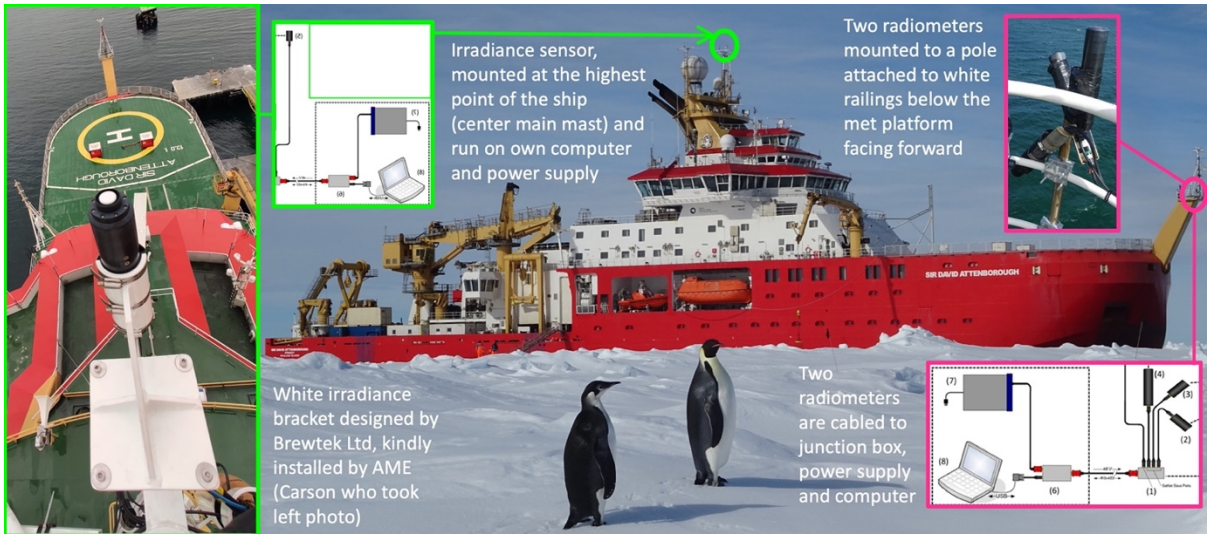


Figure 4.3.2-1: Set-up of the HyperSAS system during the PICCOLO Cruise.

The irradiance sensor was mounted to the centre main mast of the ship (Figure *4.3.2-1*), at the highest point on the vessel. A bracket was made by Brewtek Ltd for mounting the sensor. It was connected (separately to the radiometers on the foremast) to a laptop (synced with the real time clock of the ship) and power supply in the Aerosol laboratory on deck 10. The two radiometers, and a tilt and heading sensor (the latter not used as we utilised the ships positioning and gyro), were mounted to the foremast facing forward (centre line of the ship) and cabled down the foremast and into the Atmospheric laboratory on deck 5 (Figure *4.3.2-1*). The radiometers were connected to a power supply and laptop (synced with the real time clock of the ship). Both irradiance sensors and the radiometers were run using SatView software. Raw data files were processed using SatCon software to produce ".dat" files, which were then read into code developed using IDL software, for processing the data using calibration files, and integrating it with the ships met data required for quality control. The radiance sensors were cleaned four times during the cruise (when we were permitted access to the foremast), and generally found to be clean, albeit impacted by ice on one occasion (see below). The irradiance sensor was not cleaned during the trip, as we were not permitted access to the main mast (too dangerous when at sea).

The system was run continuously from the 20th of January (leaving the Falklands) through the to the 5th of March when it was taken down during calm weather when at Vega Island. Figure 4.3.2-2 shows a timeseries of data collected on the 6th February, and Figure 4.3.2-3 shows an example of remote sensing reflectance data collected in the Gerlache straight on the 22nd of February.

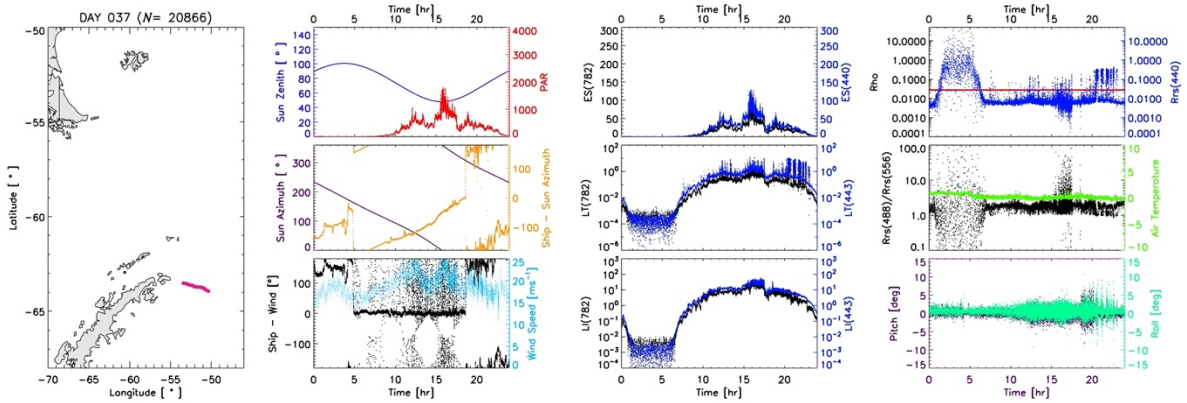


Figure 4.3.2-2: Example of a times-series of HyperSAS data, and data from the ship's underway system used in the processing, on the 6th of February 2024.

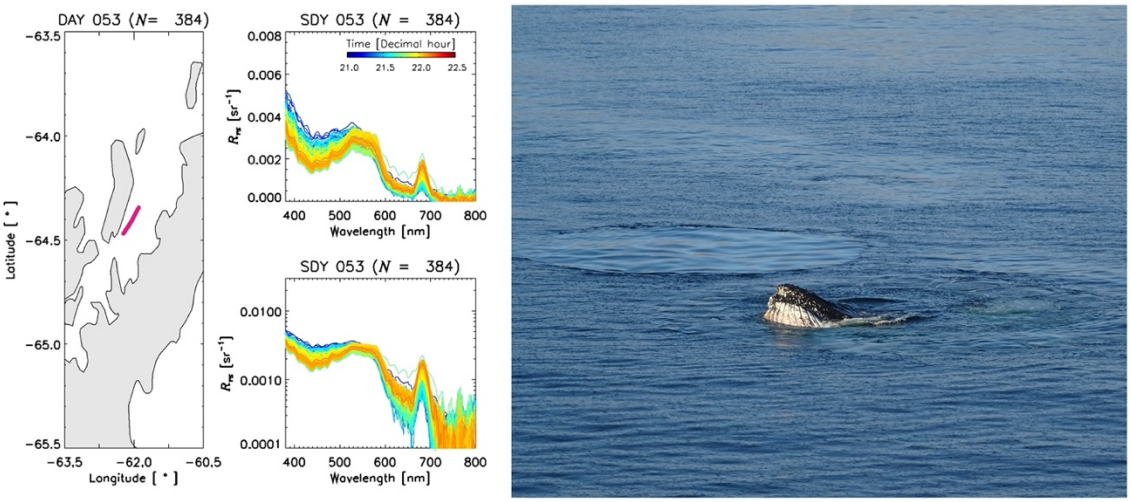


Figure 4.3.2-3: Left, examples of remote-sensing reflectance spectra collected in the Gerlache straight on the 22nd of February 2024 as we passed through a large bloom of phytoplankton. Right humpback whales feeding on plankton and krill around the same time the spectra were collected.

Issues

Three main issues were found when running the HyperSAS setup on PICCOLO.

1. For a few days 10-11th February 2024, the water-leaving radiance sensor was covered in ice (see Figure 4.3.2-4A). The sky-radiance sensor was also impacted by ice on these days, though not over the sensor head, and so not thought to be impacting data. The ice was removed using warm water and cleaned with acholic wipes on the 11th of February. A heating system to keep the sensors warm may be worth considering in the future, when operating these systems in very low air temperatures.

2. The shutters failed on the sky-radiance sensor for three days of the cruise (7th, 12th and 15th February). Not sure exactly why. Air temperatures were low (around -5 degrees C),

but the sensor had been working at similar air temperatures, so may have been caused by another unknown factor. They came back to life the following days.

3. The largest problem was with the irradiance sensor. Although we mounted it on the main mast of the ship, at the highest point on the ship, it was close to the ship's exhaust, and was impacted by exhaust fumes from ship (see Figure 4.3.2-4B-D). The irradiance sensor was not cleaned during the trip, as we were not permitted access to the main mast (too dangerous when at sea). As a result, the sensor got dirty during the cruise, significantly impacting the downwelling irradiance data. Future operations should consider mounting the sensor on the foremast (though that is not ideal either, as it is not at the highest point of the vessel and will see the ship) or developing some sort of self-cleaning technique to keep the sensor head clean.

Figure 4.3.2-4: (A) Photo on the 11th of February of ice that grew on the water-leaving radiance sensor. (B) Photo of irradiance sensor when mounted at the start of the cruise and (C) at the end of the cruise, prior to cleaning. Note the change in colour of the cosine collector caused by the sensor being close to the ships exhaust (see D for example of exhaust fumes from ship, taken on the 3rd of March from Seymour Island).

Correction of Es data

When taking the irradiance sensor down, we performed a test of the impact of dirt accumulating on the sensor head during the cruise from exhaust fumes. Carson kindly cleaned the sensor head, and we collected data for 5 minutes before and after the cleaning took place. We saw a large change in downwelling irradiance (see Figure 4.3.2-5A). Though the change in magnitude was considerable, the shape of irradiance was relatively flat in the blue-green region of the spectrum, decreasing a little in the red and near infra-red regions (see Figure 4.3.2-5B).

To perform a correction, we compared the irradiance sensor with the PAR sensor on the foremast, under the assumption the foremast is not severely impacted by exhaust fumes like the main mast was (Figure 4.3.2-5C). We computed PAR using our spectral irradiance sensor on the main mast (integrating downwelling light over the visible spectrum and converting to the same units as the PAR sensor on the foremast), then looked at the ratio of PAR on the foremast to that on the main mast, over the duration of the cruise (Figure 4.3.2-5D). As expected, we observed an increase in this ratio, consistent with the spectral irradiance sensor on the main mast being impacted by the exhaust fumes. We modelled this change at a function of time using an 8-order polynomial relationship (Figure 4.3.2-5D, red line). We then scaled the change observed from the cleaning exercise (assuming once cleaned, the sensor readings were consistent with those at the start of the cruise) using the polynomial model (Figure 4.3.2-5D red line), to correct the spectral data on the main mast (Figure 4.3.2-5E).

We acknowledge this correction assumes PAR on the foremast is not impacted by the ship, which is not the case, as it is not in the highest position. It also assumes the calibration of the sensor did not change over the duration of the cruise. Results showed that the magnitude of remote-sensing reflectance decreased with the correction, but the ratio of blue to green remote-sensing reflectance was not significantly impacted (see Figure 4.3.2-6), owing to there being little change in the shape of irradiance before and after the clean (i.e. spectrally flat) in the blue-green region of the spectrum (see Figure 4.3.2-5B).

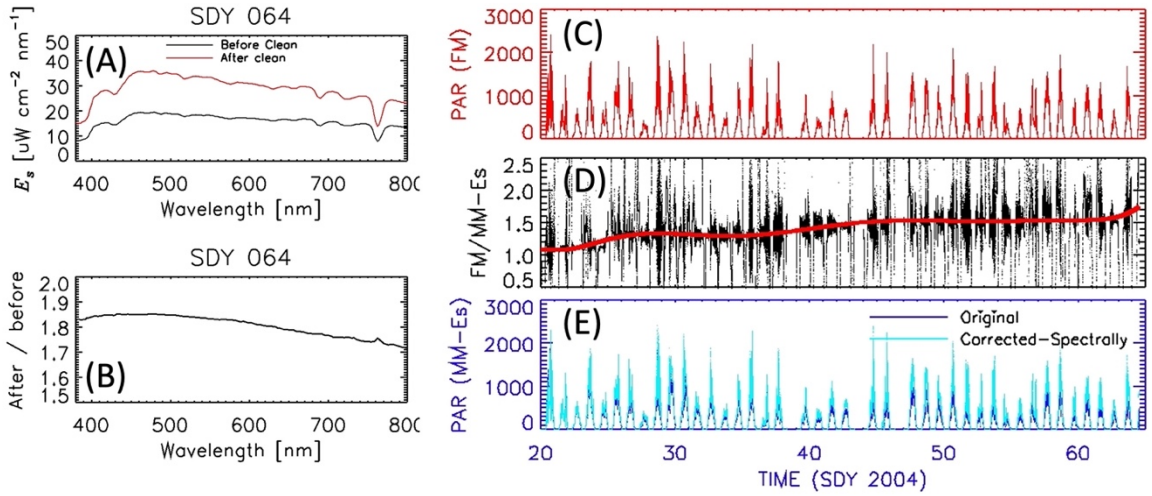


Figure 4.3.2-5: (A) Downwelling irradiance before after cleaning the sensor at the end of the cruise. (B) Ratio of downwelling irradiance before and after the cleaning. (C) PAR on the foremast (FM) at the times when data were collected by the spectral irradiance sensor (note the missing days reflect the time the sky-radiance sensor was not operating, due to issue with the shutters). (D) Ratio of PAR on the foremast (FM) to PAR computed on the main mast (MM) from the spectral irradiance (Es) sensor. Red line is an 8-order polynomial. (E) Original PAR (dark blue) and corrected PAR (light blue) from the spectral irradiance (Es) sensor on the main mast.

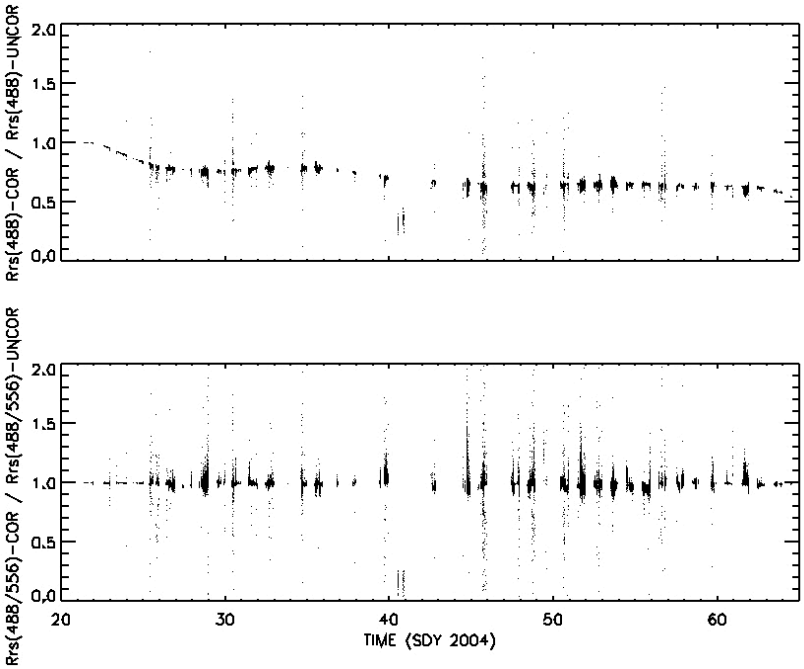


Figure 4.3.2-6: Top image show the ratio of Rrs(488) between corrected and uncorrected data over the cruise. Bottom image shows the ratio of Rrs(488)/ Rrs(556) between corrected and uncorrected data over the cruise, illustrating a very minor influence on the shape of the Rrs spectra, when correcting the Es data.

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Lin, J., Dall'Olmo, G., Tilstone, G., Brewin, R.J.W., Vabson, V., Ankso, I., Evers-King, H., Casal, T. & Donlon, C. J. (2022) Derivation of uncertainty budgets for continuous above-water radiometric measurements along an Atlantic Meridional Transect. Optics Express, 30 (25), 45648-45675. https://doi.org/10.1364/OE.470994

Pardo, S., Tilstone, G., Brewin, R.J.W., Dall'Olmo, G., Lin, J., Nencioli, F., Evers-King, H., Casal, T. G. D. & Donlon, C. J. (2023) Radiometric assessment of OLCI, VIIRS, and MODIS using Fiducial Reference Measurements along the Atlantic Meridional Transect. Remote Sensing of Environment, 299, 113844, https://doi.org/10.1016/j.rse.2023.113844

4.3.3 Bathymetry

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Summary

Multibeam and singlebeam bathymetry data were collected throughout the cruise and have added useful coverage along the poorly surveyed eastern side of the Antarctic Peninsula. The multibeam systems were almost always used in a secondary (low ping frequency) capacity as Piccolo science objectives focused on other acoustic instruments (Simard EK80 for biomass, Teledyne RDI Ocean Surveyor 75/150kHz ADCP for water currents).

The deep-water Kongsberg EM122 multibeam echosounder generally performed well throughout SD035 and in most conditions. Exceptions were during periods in heavy sea ice and occasional interference from other acoustic sources, primarily the low frequency EK80 transducer. A couple of hardware issues occurred towards the end of the cruise as described in the BIST section below.

The mid-water Kongsberg EM712 multibeam echosounder was only used during the Larsen C period. As seen on previous cruises (e.g. SD025, Polar Science Trials) the EM712 acquisition software (Seafloor Information System, SIS) cannot be run for more than a few hours at a time without it becoming unresponsive and needing to be restarted.

The Kongsberg EA640 singlebeam echosounder was used throughout the cruise and provided water depths for most science deployments. A software update during the 2023 refit period has thankfully fixed the daily EA640 acquisition machine crashes and the system proved robust and reliable throughout the cruise. It was generally operated through the Kongsberg K-Sync unit and, like the multibeam systems, played a secondary role to the EK80 and ADCP.

The following sections briefly describe the multibeam operational settings, processing routines and surveys. As multibeam data collection was only a secondary activity, details have been reduced to a minimum and only focus on changes since SD025 (Polar Science Trials, Jan-March 2023). For full details regarding default settings and processing routines, see the multibeam equipment section within the SD025 cruise report.

Equipment Information

RRS Sir David Attenborough is set up with two multibeam bathymetry systems: the Kongsberg EM122 and EM712. The two echosounders are used at specific depth ranges as shown in Table 4.3.3-1.

Table 4.3.3-1: Echosounder characteristics on RRS Sir David Attenborough

Model	Angle	Depth Range	Acquisition Software
EM122	1°x 1°	50 – 7000 m	Seafloor Information System (SIS) – version 4.3.2
EM712	1°x 1°	3 – 3000 m	Seafloor Information System (SIS) – version 4.3.3

Installation Parameters

Installation parameters for both systems are unchanged from SD025. No calibration was undertaken on either system during the cruise and the last time a patch test was undertaken was August 2022.

Operational Settings

The equipment was operated using Kongsberg Information System (SIS) software. Runtime parameters were the same as used in SD025, apart from the dual swath mode. During the EM712 surveys, the dual swath mode was left on DYNAMIC and was only turned to OFF towards the end of the survey. During the EM122 surveys, the dual swath mode was generally OFF except for a few days (15th -17th February) when it was DYNAMIC. Previous recommendations were to turn off the dual swath mode in all but EM122 deep water surveys. Another reason for keeping it off is that it has a deleterious effect on the EK80 when operating simultaneously through the K-Sync unit.

The EM122 and EM712 were mostly operated in external trigger mode via K-sync allowing multiple acoustic instruments to be operated at the same time. K-Sync settings were altered throughout the cruise to suit acoustic objectives but as stated in the summary the multibeam was of secondary importance and was usually in a K-Sync group that only pinged once every 4-8 cycles (cycles being 3 second intervals).

BIST reports (hardware tests)

The Built In Self Tests (BIST) were carried out at the commencement of surveying for each instrument and all tests passed - unfortunately the results were not saved.

An issue with acquiring EM122 data when swapping to a new survey after leaving Vega Island (2024-03-04 22:33Z) prompted a BIST run. This failed with TX36 Board 17 reported as missing. A brief power cycle of the transceiver did not fix the issue (in fact there were more errors) so the transceiver was powered down overnight just in case it was an overheating problem. Looking back at previous data showed that the problem had actually occurred at 2024-03-03 10:41:45, whilst stationary just off James Ross Island and a number of subsequent files (survey SD035_b lines 372-376) have no useable depth data.

The following day (2024-03-05) the BIST ran successfully after waiting for sufficient time for the transceiver to power on. The transit survey across the Drake Passage then ran smoothly. However, after the survey concluded (2024-03-08), the BIST failed again with a TX36 board 17 problem. AME located a spare TX36 board and attempted a like-for-like replacement. This gave new and additional errors, and the original board was returned to the transceiver. It was noted that a number of the ethernet interconnectors in the transceiver required very little movement to stop communicating and care was taken to ensure all relevant lights were flashing before trying a final BIST. The final BIST passed all tests but it is probable that there is an intermittent fault and this problem will re-occur.

A BIST was run on the EM712 at the end of the cruise and all tests passed. This and all other BIST reports (except the initial two) were saved locally to D:/sisdata/common/bist/.

Surface Sound Velocity and Sound Velocity Profiles

Sound velocity profiles were acquired from the numerous CTDs deployed throughout SD035 and these provided adequate corrections within the main science areas. However, the transit to and from Rothera during the medevac was undertaken on a profile collected in the Weddell Sea so this period (EM122 survey SD035_b) may well have sound velocity issues. Similar issues might also be evident in the transit from the Biopole mooring site across Drake Passage towards Punta Arenas.

The surface sound velocity was taken from the surface value within the vertical profiles rather than the underway sound velocity probe. As in previous cruises, interruptions to the uncontaminated seawater flow meant that the SV probe was frequently sampling static water and could not be reliably used as an SV data source within the multibeam systems.

Data processing

Raw data were automatically written to the local data drive (D:/sisdata/raw/'survey name') on the EM122 and EM712 acquisition machines. These data were synchronised every 10 minutes to the SDA Storage Area Network and were symbolically hard-linked to the following paths:

/data/cruise/sda/current/system/multibeam_kongsberg_em122/acquisition/raw/'survey name'
/data/cruise/sda/current/system/multibeam_kongsberg_em712/acquisition/raw/'survey name'

All data were pre-processed with MB System v5.7.8 and limited amounts of data were cleaned using the mbedit graphical interface.

File Structure

A common file structure was created to hold all the MB-System data located under

/data/cruise/sda/current/work/scientific_work_areas/Multibeam_Bathymetry/

Within this folder are sub-folders for each instrument which include survey level data plus initial grids.

Survey Information

EM122/EM712 survey periods and geographical coverage are summarised in Table 4.3.3-2 and Figure 4.3.3-1 below. There were breaks in the logging of multibeam data between the timeframes listed due to the vessel being stationary (scientific deployment, hove to etc), crossing over previously swathed areas or for periods where data quality was particularly bad. These extra details can be found in the dedicated multibeam event log. Files consist of a maximum of one hour of data.

Table 4.3.3-2: Multibeam survey periods, files acquired, and files processed/cleaned.

Sensor	Survey name	Start time (UTC)	End time (UTC)	No. of files	No. files processed	Description

EM122	**SD035_a**	2024-02-12 18:17:47 2024-02-23 11:16:17	2024-02-20 17:45:59 2024-03-03 10:41:45	377	31	Main Piccolo science area in the north-western Weddell Sea prior to medevac Main Piccolo science area in the north-western Weddell Sea after medevac
EM122	**SD035_b**	2024-02-20 17:48:29	2024-02-23 11:13:59	66	0	Medevac transit from the northern end of the Antarctic peninsula to Rothera and back again.
EM122	**SD035_c**	2024-03-05 10:06:40	2024-03-07 17:47:05	57	0	Transit north from the Antarctic peninsula towards Punta Arenas via the Biopole mooring site.
EM712	**SD035_a**	2024-01-30 18:12:23	2023-02-04 16:09:11	95	26	Northern end of the Larsen C ice shelf

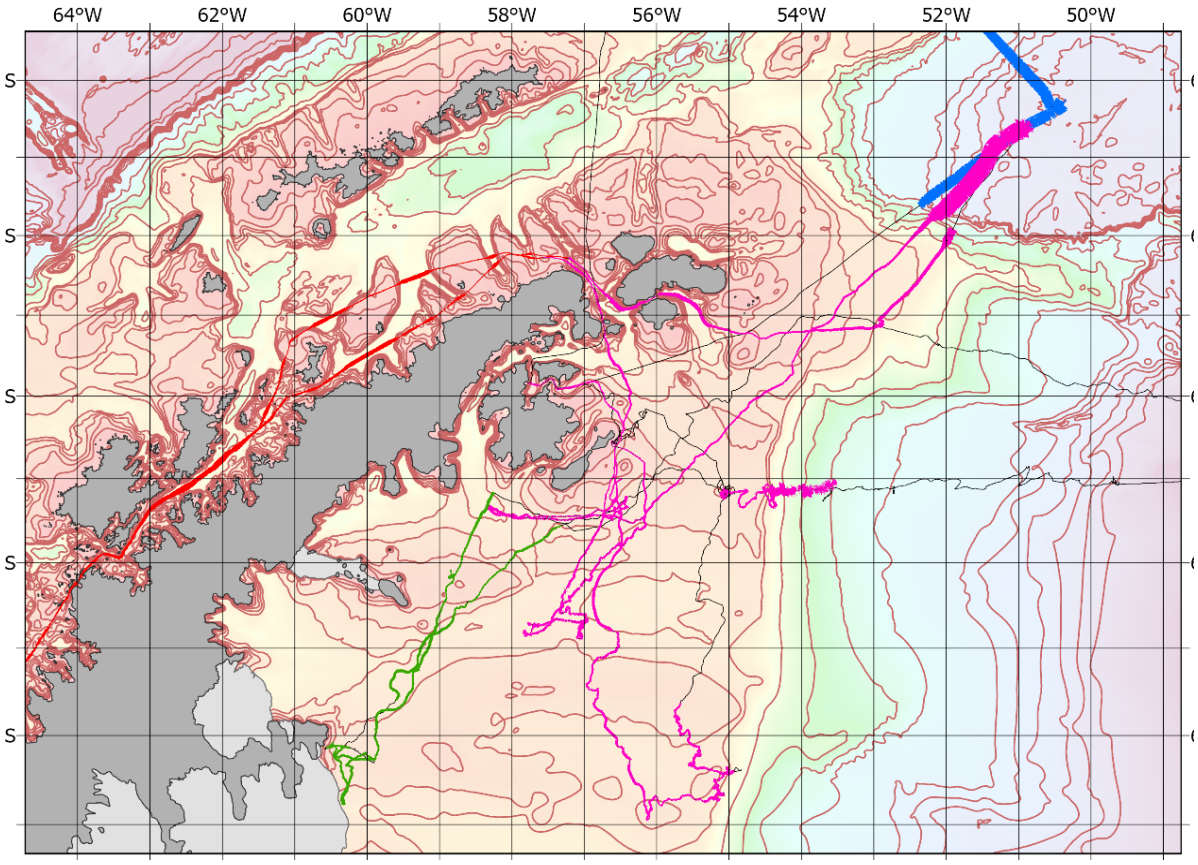

Figure 4.3.3-1: An overview of the EM122 and EM712 bathymetry surveys. EM122: SD035_a = pink, SD035_b = red, SD035_c = blue, EM712: SD025_a = green.

Initial survey results

While no dedicated bathymetric survey was undertaken during SD035, ~600 hours of multibeam data were acquired in areas with relatively poor bathymetric coverage. When cleaned, the EM712 data near Larsen C will combine well with previous James Clark Ross and Polarstern survey work in the area. EM122 data collected in the wider Weddell Sea area will make an important contribution to regional mapping efforts and will appear in the next version of the International Bathymetric Chart of the Southern Ocean.

Observations, issues, and recommendations

Recommendations made during last year's SD025 cruise are still outstanding and will likely stay this way until the EM712 acquisition software is upgraded and a source of non-aerated seawater can be reliably provided to the sound velocity probe. These issues were known about at the start of SD035 and meant that the EM712 was only used for one time-limited survey near the Larsen C ice shelf and all sound velocity information came from the deployed CTDs rather than the SV probe.

- It is strongly recommended that Kongsberg are contacted to see whether a new acquisition PC and software upgrade can be provided/installed for the EM712 in the first summer refit period ahead of further science usage.

Following the EM122 transceiver problems noted in the BIST section:

- Report the EM122 TX36 test failures to Kongsberg for advice and possible rectification.

Most of the bathymetric data collection during SD035 was controlled through the Kongsberg K-Sync synchronisation unit and there were numerous changes made to the K-Sync configuration settings throughout the cruise that affected the multibeam ping frequency.

- It is recommended that we investigate whether the K-Sync settings can be recorded automatically to keep track of these changes.

There was discussion throughout the cruise about the water depth values provided by the EA640 singlebeam echosounder. This provides depth value below the hull transducer, corrected using a constant 1500 ms^{-1} sound velocity throughout the water column. It is left to end-users to add the current draft of the ship (~7.1m) to the below transducer value and use Carter tables (or similar) to determine more accurate water depths based on sound velocity profiles appropriate to the current location. Discussions centred on whether a sound velocity corrected water surface-to-seabed value could be provided from the EA640 for operational purposes (e.g. CTD operation). The draft offset is easy to solve in Grafana but inputting an up-to-date sound velocity profile into the EA640 may result in just as many problems as it solves.

- Create a discussion paper to describe the steps needed to sound velocity correct (in real-time) the EA640 depth data and the pros/cons of such an approach.

4.3.4 Vessel-Mounted Acoustic Doppler Current Profiler

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Operation of VMADCP

An Acoustic Doppler Current Profiler (ADCP) measures the ocean currents' speed and direction using the Doppler effect. It pings in specific frequencies and receives return pings from the partials/bubbles in the water. The frequency shift occurs during the travel of the signal due to Doppler effect will then be converted to ocean current velocities.

Onboard RRS Sir David Attenborough (SDA), we have a Vessel-Mounted Acoustic Doppler Current Profiler (VMADCP), which is an ADCP that is mounted near the hull of our ship. Our VMADCP is manufactured by Teledyne in the model of Ocean Surveyor. It has two sonars with frequencies of 150 kHz (OS150) and 75 kHz (OS75). A higher frequency generally allows us to detect the water velocity reaching a deeper water, with a lower vertical resolution.

In this cruise, we use the command files created in SD033 to configure VMADCP and the associated Vessel-Mounted data acquisition system (VmDAS). We tried different files for both OS75 and OS150. For the most of time, a configuration from the file called "os150nb_450m_wt_8mbins_thru_ksync.txt" is used. This configuration enables us to use K-Sync, a software that send commands to acoustic sensors to guide them to ping in a specific sequence and intervals, preventing different acoustic signals from intervening each other.

Problems with data acquisition, recording, and hardware

Several problems mentioned in the previous cruise report still remain to be solved (a-e) while more problems have been noticed in this campaign (f-i).

a. Only one sonar can be used in one time. Traditionally, one can open two interfaces of VMADCP and operate the 150-kHz and 75-kHz sonars at the same time. However, currently we can only choose to use one of the two frequencies at a time, details regarding this issue can be found in SD025 Polar Trials cruise and 'E&T Elec Report'.

b. Either the 150-kHz or 75-kHz sonars can reach the designed water depth, which are 400 m and 700 m, respectively. This problem was initially considered to be caused by the low number of particles in the water column, but later we noticed that, even when we were in productive waters, the OS75 can still only detect water depth to about 400 m. As mentioned in the previous cruise reports (the BIOPOLE cruise and the trail cruise), OS150 onboard does not detect much deeper, compared to OS75, while it has less issues in cold water regions and shelf seas, we decided to use OS150 for most time of this cruise.

c. The connections between the VMADCP and the ship GPS and heading were lost twice. The first time when it was lost, it was caught within a few hours, but the second time lasted for longer than a day. We therefore started to check at least three times a day whether the VMADCP is producing reasonable measurements.

d. The VMADCP generates files with the max size cap as 10 Mb for all files, including single-ping, GPS and heading files. New files are generated following the name format as "sdXXX_os150nb_YYYYMMDDTHHMMSS_NNN_nnnnnn.XXX" (e.g., "sd035_os150nb_20240305T205418_063_000000.VMO"), where the NNN is the file number which increments every time when the VMADCP stops and restarts, nnnnnn is

the number which increments every time when the max size cap is reached. Ideally, all files generated from the same time will be stored under the same time with different extensions. However, single-ping files were written in a faster rate compared to the rate in which GPS and heading data were written. This results in the inconsistency among the file names of single-ping, GPS and heading files, generated from the same period of time. Our solution in this cruise is to stop and restart the data collection at least three times a day, so that most files generated from the same period can be stored under same file names. We are not certain of the consequences of this issue.

e. VMADCP computer froze for two times. We had to do a hard restart of the computer and restart the VMADCP again. This happens twice in two days. The reason is still unknown.

f. VMADCP rebooted itself for several times when we were in deep waters. A restart of the computer did not help but configuring the VMADCP to work without K-Sync solved the issue. We suspect that this issue is caused by following reasons: K-Sync was programmed to trigger VMADCP pings about every 1 or 2 seconds. However, when the water is clear and deep, VMADCP cannot receive the reflected ping within 2 seconds. While VMADCP was waiting for the reflectance, K-Sync will make another attempt to trigger VMADCP's ping. This somehow confused and upset the VMADCP so that it triggered a reboot of itself, which takes a few seconds too. Hence, after the reboot, VMADCP became completely out of the sync, leading to another reboot in a few seconds. This issue was partially solved by increasing the K-Sync interval from 1 or 2 seconds to 6 or 7 seconds.

g. Once we removed VMADCP from K-Sync, the reconnection, for some unknown reasons, will not be built automatically. So that we had to restart the VMADCP and restart the data collection.

h. VMADCP gave very noisy data when we operated VMADCP in the marginal ice zone. Breaking sea ice normally creates loud noise which affects the acoustic sensors onboard. However, in this cruise, even when we were not breaking the sea ice, passing marginal sea ice zone has led to very noisy data, i.e., a large number of pings show unrealistically high water speeds. And for an unknown reason, VMDAS does not recognise them as "bad-quality data" by giving it a low "percentage good". We suspect that the location where the VMADCP is mounted is not well sheltered from the ice.

i. VMADCP stores the data in where the user asks it to store under the name which the user asks it to have, which means that the users can overwrite files and can name files collected by OS75 with OS150's name. During our some of our sonar tests, due to an oversight, some data from OS75 were wrongly named as they were from OS150. Those files have been picked up in data processing (file batches #8 and #9).

Data processing

We used CODAS python library (pycodas) to process and visualise the VMADCP data onboard. Note, one does not need to have python skills for running the processing scripts, but a basic bash skill is required. CODAS provides a very detailed documentation for the users https://currents.soest.hawaii.edu/uhdas_fromships/EXAMPLE_atseaweb/programs/adcp_doc/index.html. Reading through the whole documentation is strongly recommended, especially for non-python users.

The processing of VMADCP in this cruise follows the sequence below:

a. Download data daily from the server (>cruises/SD035/system/adcp_teledyne_ocean_surveyor/acquisition/150kHz/), store them in a raw-data folder locally. VMADCP will keep writing the files, even when one is downloading. Note, due to the problem-d mentioned above, one needs to download all files from the same time stamp, not just the from same file name to make sure that they download the whole file.

b. Open terminal, locate to the right data-process folder, activate the pycodas library and run "adcp_database_maker.py". This python script will convert VmDAS style data into the University of Hawaii Data Acquisition System (UHDAS) data. In this cruise, short-term averaged (STA) and single-ping (ENR) data were converted daily.

c. Close the GUI in step-b and run python script "data_viewer.py".

Previous cruise reports have mentioned that CODAS is flagging a large number of single-ping data when converting them to UHDAS-style data. Due to the mentioned problem-h, our operation in the marginal ice zone made this data quality issue worse. Further investigation is required to process the single-ping data using CODAS.

Based on the transducer alignment test Teledyne conducted on 6 Sep 2022, the alignment angle is 45.5º for the OS150 and 46.1 for the OS75. Alex Tate and Yixi Zheng also made an estimation of the transducer depth to be 8 m, based on the ship height and the water depth of hull. Further investigation is required to obtain accurate transducer angle, depth and the distances between the transducer and the gyro etc.

For simplicity, when configuring the VMADCP, a transducer angle of 45º and a transducer depth of 6 m are used in the command files. Hence, if the alignment angle has not changed since the alignment angle test in 2022, a misalignment angle is expected. As for the most of the cruise we used watertrack and OS150, at the end of the cruise, the following calibrations (Table 4.3.4-1), based on watertrack calculations on the non-edited data for OS150 from the whole cruise are shown below.

Table 4.3.4-1: OS150 calibration values

	OS150, based on STA
xducer_dx	-3.092946
xducer_dy	9.488174
Angle (median)	1.0350
Amplitude (median)	-0.8040

A potentially serious consequence of the mentioned problem-d in the previous session is, when CODAS is processing those data, we suspect that CODAS might not recognise the which gyro file is matching which single ping file. This somehow is not a problem for VMDAD so that VmDAS can still produce reasonable STA time series. Further investigation is required to find a

conclusion of whether the CODAS is reading the right combination of single-ping, ship speed and heading files.

As CODAS cannot process our single-ping data properly, we turned to use MATLAB script adapted from Deb Shoosmith (Nov 2005), with corrections made by multiple institutes and observationalists. This script identified a misalignment angle of -0.5501 and a scaling factor for the amplitude of 1.001330, both via water tracking. The report from this script is in below.

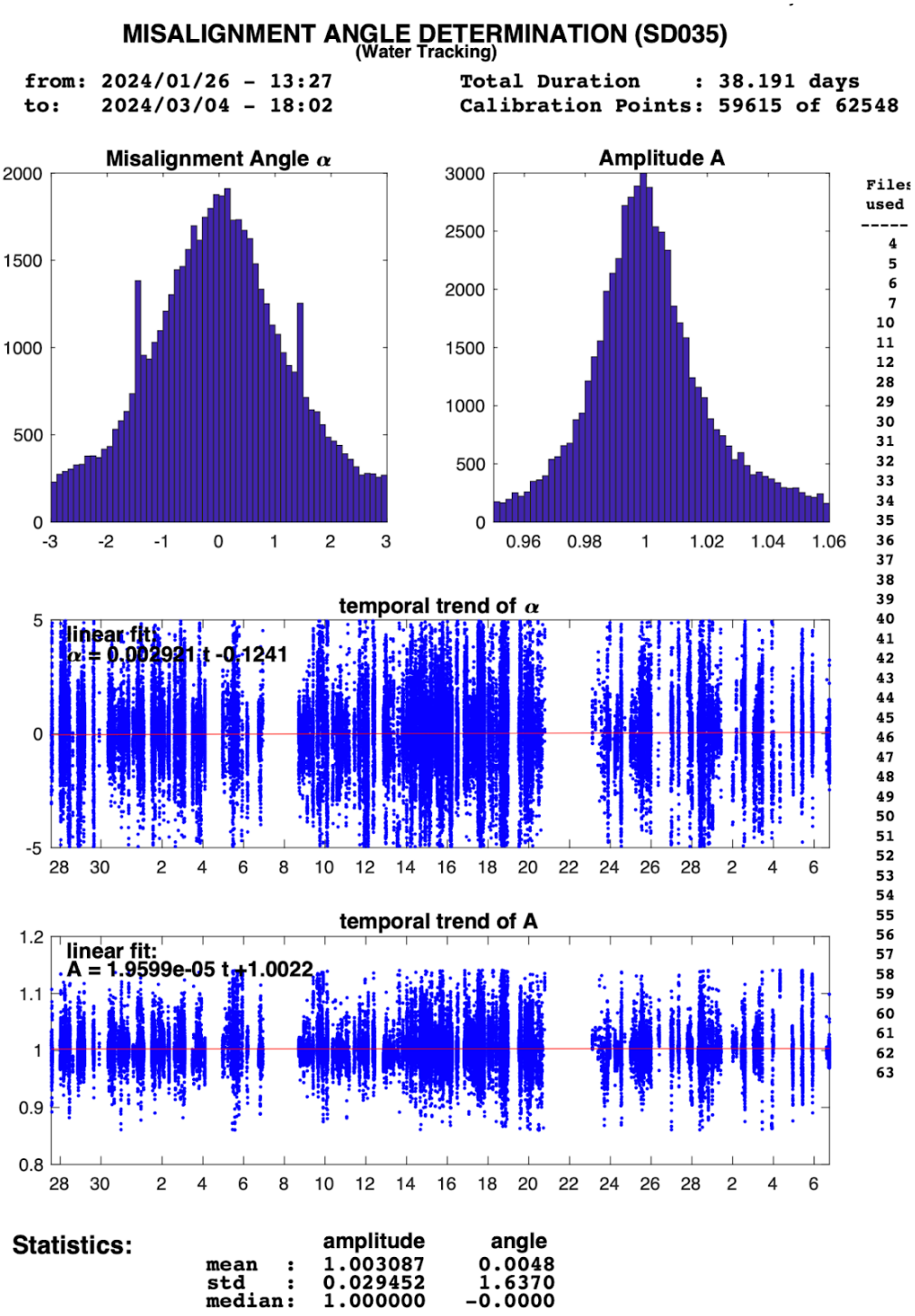

Figure 4.3.4-1: Report from the MATLAB script, with water-tracking.

During the cruise, there were several times when we went to the northern Weddell Sea and made a few sharp turns. We plotted maps with the ocean currents as the arrows near those sharp turns to validate misalignment angle.

Preliminary results

We started the VMADCP on 26/Jan/2024, after we dropped the palaeontologists on the island and stopped the VMADCP on the 7/Mar/2024. During this time, due to the problems mentioned above, including losing connection to the gyro and computer being frozen, software stopping recording etc, there are some data gaps in the VMADCP time series.

There are two main gaps in the following plots. The first gap was from the disconnection between GPS and the VMADCP, as mentioned above. This happened in VMADCP batch #28-29 files. Povl Abrahamsen kindly corrected part of the MATLAB code for us to partially resolve this issue. His correction has rescued a couple of days of data and now the data gap caused by this disconnection between VMADCP and GPS is less than two days. This disconnection started on 6/Feb, 23:15, and was recovered on 8/Feb, 16:22. In between, we had a GEOTRACES station, and the first CTD station at the transect T (T1). It reconnected on our way to the first physics-only station after T1 (T1-1). The ship GPS and gyro data were stored in the drive, so can be converted to the required VMADCP format. More work needs to be done to retrieve the GPS data from the ship, manipulate the data format to match what the VMADCP needs, and embroider the GPS data into the VMADCP files.

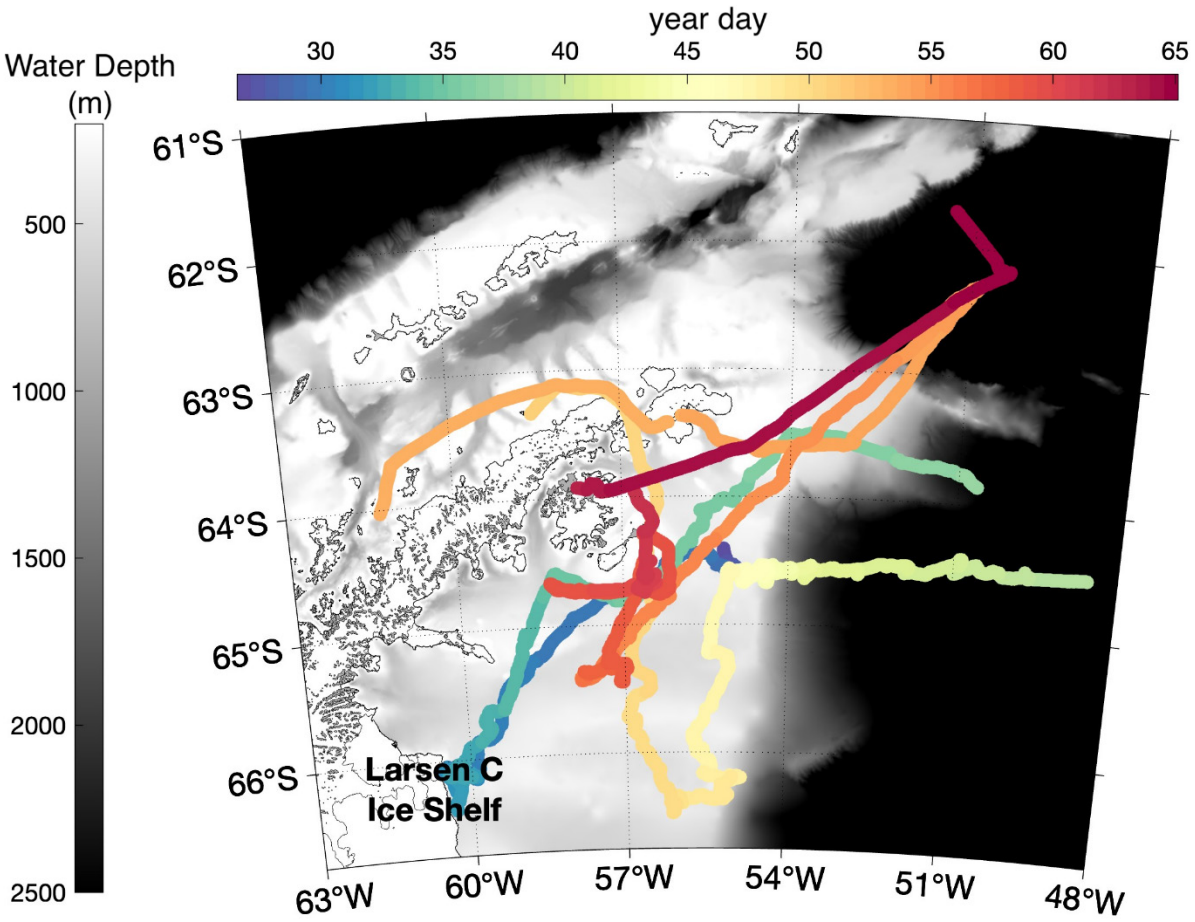

Figure 4.3.4-2: The map of our study region. Dots show the locations of our data points, with their colours indicating the year day when the data were collected.

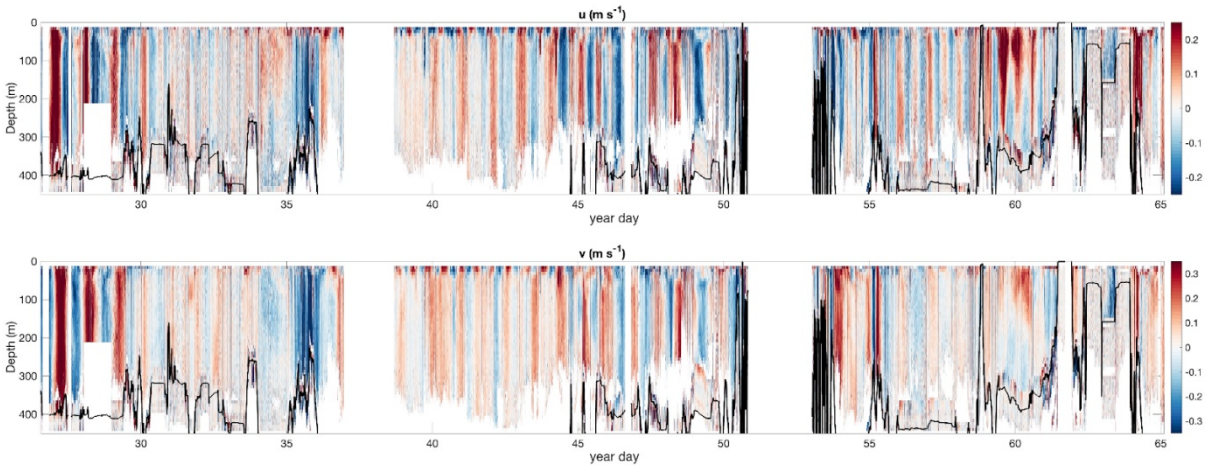

Figure 4.3.4-3: The time series of the ocean zonal and meridional velocities. Black lines indicate the bathymetry from BedMachine v3.

All results seem good so I obtained the following corrections from the MATLAB codes,

```
misalignment_nb = -0.5501;   % for SD035, there's only
narrowband, Yixi, 21/May/2024
amplitude_nb    = 1.001330;
```

The report from the MATLAB code is shown above. I tuned the misalignment angle and amplitude to make the medium correction 0. There is some uncertainty whether this is positive or negative.

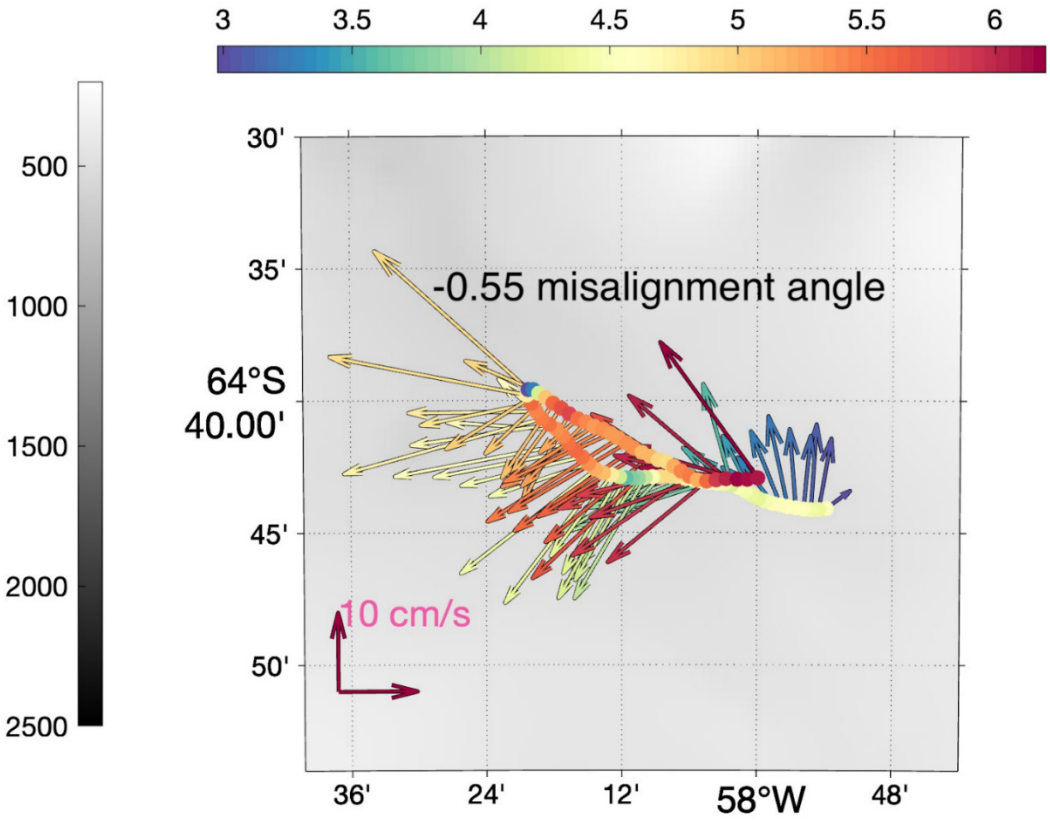

Figure 4.3.4-4: ADCP velocities with a misalignment of -0.55 degrees. Dots are coloured by the ship's speed and the colour of the arrows is time.

I tried to compare the VMADCP with CATS2008, but not so useful:

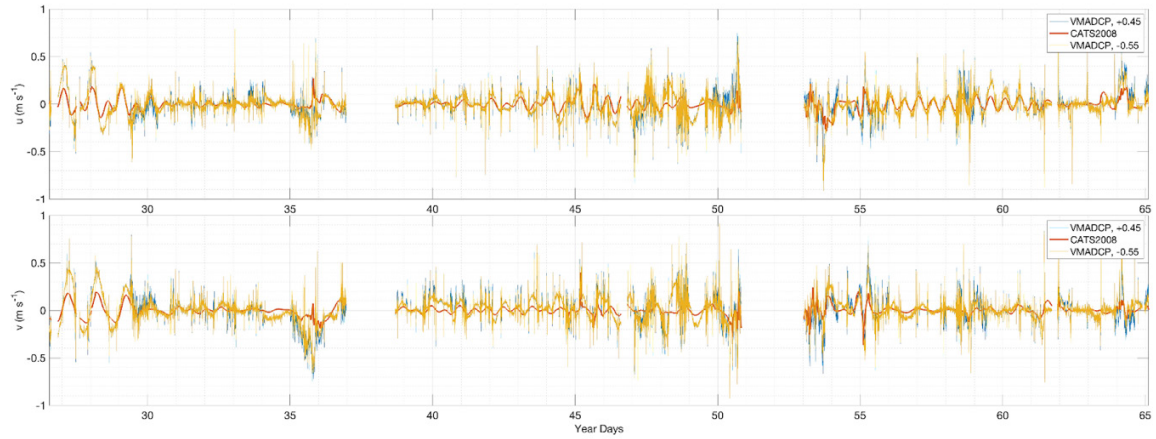

Figure 4.3.4-5: Comparison of the VMADCP current velocities with the CATS tidal model predictions for the same time and location, using two different misalignment angles.

I also checked the transect T, with the LADCP on the top of it, not working much.

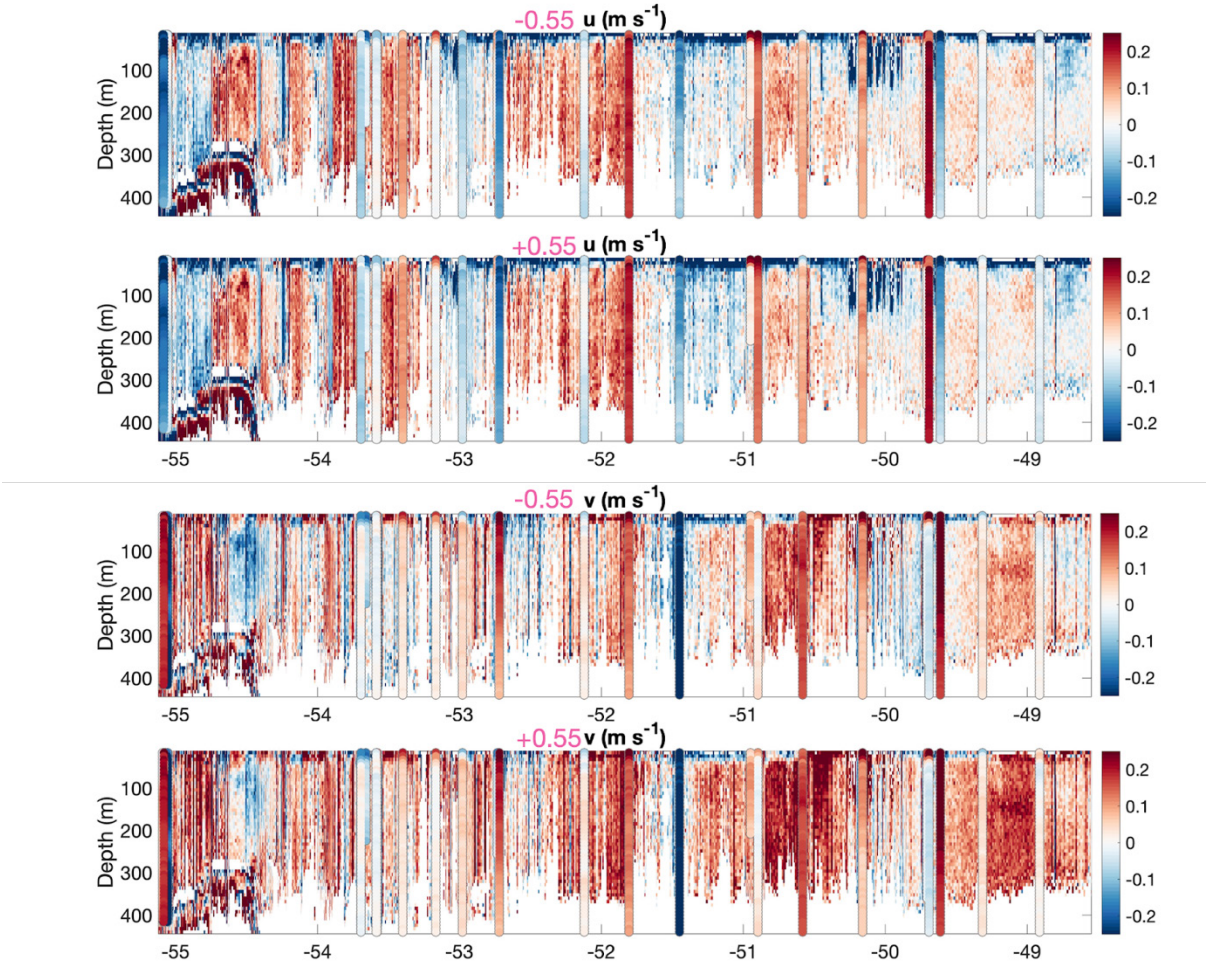

Figure 4.3.4-6: VMADCP currents (upper two panels show eastward component and lower two panels show northward component), showing comparison of a positive and negative misalignment angle, for the slope CTD section. LADCP velocities at the CTD stations are superimposed using the same colour scale.

I think, from the northern tip part, without that much tides, it's clear that the negative misalignment angle is better.

4.3.5 EK80 Multifrequency Echosounder

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Introduction

The SDA is equipped with a six frequency Simrad EK80 scientific echosounder operating at 18, 38, 70, 120, 200 and 333 kHz. All transducers are mounted on the hull behind ice windows.

During cruise SD035, the EK80 echosounders were operated continuously to collect information on the horizontal and vertical distribution of krill and micronekton (i.e. small pelagic fish). At most times, transmission rates and intervals of all actively transmitting acoustic instruments were synchronised using the K-Sync to reduce interference. EK80 transceivers were used during transits from the Falkland Islands to the Peninsula. The EK80 was calibrated drifting in the Weddell Sea amongst sea ice on 16/02/2024.

EK80 data

The EK80 was operated using Simrad EK80v. 21.15.1 software. The EK80 was switched on and temperature and salinity updated to values anticipated at the Peninsula (T = 0°C, S = 33.2). The raw data files (SD-Dyyyymmdd-Thhmmss.raw) were logged to the local PC, which was backed up at regular intervals to the samba drive (data\\cruise\sda\current\system\bioacoustic_simrad_ek80\acquisition\EK80_data). Raw data were collected to a range of 1100 m except during the calibration where data was collected to 500m.

The ping rate was generally maintained at 3 seconds whether the EK80 was controlled by the k-sync or internally, except during calibration where it was increased to 1 second. When data collection ranges were reduced pulse transmission rates (i.e. ping rates) of the echosounders could be increased to maximize horizontal resolution of the data.

EK80 parameter settings

Data were collected using the following settings prior to calibration (Table 4.3.5-1). Transducer parameters and environmental settings were updated after the calibration (see SourceCal T1-T6 results below).

Table 4.3.5-1: EK80 default settings

Variable	18 kHz	38 kHz	70 kHz	120 kHz	200 kHz	333 kHz
Temperature	0	0	0	0	0	0
Salinity	33.2	33.2	33.2	33.2	33.2	33.2
Mode	Active	Active	Active	Active	Active	Active
Pulse type	CW	CW	CW	CW	CW	CW

Transducer type	ES18	ES38-7	ES70-7C	ES120-7C	ES200-7C	ES333-7C
Transducer Serial No.	2172	190-narrow	437	1588	666	210
WBT Serial no.	720835	721576	721579	721585	721591	721746
Transducer depth (m)	0	0	0	0	0	0
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024	1.024
Max Power (W)	1600	2000	750	225	150	50

Pulse transmission (i.e. ping) rates of the EK80 were controlled through the k-sync using variable settings depending on whether the swath multibeam sonar (EM122) and ADCP were being operated at the same time. The EK80 was set to maximum ping rate, and a ping rate of 3000ms was set within the k-sync. In addition, the setting of maximise ping rate was enabled (ticked) in the EK80 runtime ping settings.

EK80 echosounder calibration

An acoustic calibration of the 18, 38, 70, 120 and 200 kHz transducers was carried out adrift in the Weddell Sea on the 16/02/2024. Conditions were favourable with minimal wind and DP usage. Transmission of the EK80 was internal at a ping rate of 1000ms, all other acoustic instruments were switched off. Each transducer was calibrated in turn, with all transducers transmitting through the entire calibration. Standard EK80 calibration procedures were used as documented for previous cruises. The SDA's 38.1 mm tungsten carbide sphere was used for all transducers. TS gains were similar (within 0.3 dB) to values obtained in February 2023.

A CTD (Event 220) was undertaken prior to the calibration for radium, and this was used to average temperature and salinity from the surface to 30 m (depth of the calibration sphere) and were -1.5°C and 33.5 PSU. Notably it is not possible to put a temperature below 0 degrees into the EK80 software.

Each transducer was calibrated at the environmental settings measured with the CTD cast and used throughout the cruise. Parameters from the EK80 lobes calibration were updated onto the EK80 software. In the recent software version 21.15.1, the calibration software has been upgraded. One challenge, frequently occurring after calibration is it suggests values exceed limits. This still occurred on the 120 and 38 kHz calibration. Editing of the data did not resolve the issue, but since the calibrations were within 0.3 dB of previous calibrations, the calibration value was accepted.

The calibration sphere was initially hard to control, and unable to enter the northwest area of the transducers. Initially the ship was made to spin to try and see if water current was influencing where the sphere could be seen. However, it was eventually noted that the slimpet on the port side had moved out of position. Once back in position the calibration went smoothly.

SourceCal T1
  # AbsorptionDepth = 5.000 # (meters) [0.000..10000.000]
  # Acidity = 8.000 # (pH) [0.000..14.000]
  # EffectivePulseDuration = 0.831 # (milliseconds) [0.001..50.000]
  # Frequency = 38.00 # (kilohertz) [0.01..10000.00]
  # MajorAxis3dbBeamAngle = 6.30 # (degrees) [0.00..360.00]
  # MajorAxisAngleOffset = -0.01 # (degrees) [-9.99..9.99]

```
  # MajorAxisAngleSensitivity = 18.000000 # [0.100000..100.000000]
  # MinorAxis3dbBeamAngle = 6.25 # (degrees) [0.00..360.00]
  # MinorAxisAngleOffset = -0.14 # (degrees) [-9.99..9.99]
  # MinorAxisAngleSensitivity = 18.000000 # [0.100000..100.000000]
  # PulseDuration = 1.024 # (milliseconds) [0.001..200.000]
  # SaCorrectionFactor = -0.1100 # (decibels) [-99.9900..99.9900]
  # Salinity = 33.500 # (parts per thousand) [0.000..50.000]
  # SamplingFrequency = 20.8333333 # (kilohertz) [0.0100000..1000.0000000]
  # SoundSpeed = 1447.21 # (meters per second) [1400.00..1700.00]
  # Temperature = 0.000 # (degrees celsius) [-3.000..100.000]
  # TransceiverImpedance = 5400.0 # (ohms) [0.0..1000000.0]
  # TransceiverSamplingFrequency = 1500.00 # (kilohertz) [1.00..5000.00]
  # TransducerGain = 26.7700 # (decibels) [1.0000..99.0000]
  # TransducerModeActive = true # [false..true]
  # TransmittedPower = 1000.00000 # (watts) [1.00000..30000.00000]
  # TvgRangeCorrection = SimradEK80 # [None, BySamples, SimradEx500, SimradEx60,
BioSonics, Kaijo, PulseLength, Ex500Forced, SimradEK80, Standard]
  # TwoWayBeamAngle = -20.700000 # (decibels re 1 steradian) [-99.000000..11.000000]

SourceCal T2
  # AbsorptionDepth = 5.000 # (meters) [0.000..10000.000]
  # Acidity = 8.000 # (pH) [0.000..14.000]
  # EffectivePulseDuration = 0.930 # (milliseconds) [0.001..50.000]
  # Frequency = 200.00 # (kilohertz) [0.01..10000.00]
  # MajorAxis3dbBeamAngle = 5.72 # (degrees) [0.00..360.00]
  # MajorAxisAngleOffset = 0.29 # (degrees) [-9.99..9.99]
  # MajorAxisAngleSensitivity = 23.000000 # [0.100000..100.000000]
  # MinorAxis3dbBeamAngle = 5.64 # (degrees) [0.00..360.00]
  # MinorAxisAngleOffset = -0.13 # (degrees) [-9.99..9.99]
  # MinorAxisAngleSensitivity = 23.000000 # [0.100000..100.000000]
  # PulseDuration = 1.024 # (milliseconds) [0.001..200.000]
  # SaCorrectionFactor = -0.0100 # (decibels) [-99.9900..99.9900]
  # Salinity = 33.500 # (parts per thousand) [0.000..50.000]
  # SamplingFrequency = 31.2500000 # (kilohertz) [0.0100000..1000.0000000]
  # SoundSpeed = 1447.21 # (meters per second) [1400.00..1700.00]
  # Temperature = 0.000 # (degrees celsius) [-3.000..100.000]
  # TransceiverImpedance = 5400.0 # (ohms) [0.0..1000000.0]
  # TransceiverSamplingFrequency = 1500.00 # (kilohertz) [1.00..5000.00]
  # TransducerGain = 25.8500 # (decibels) [1.0000..99.0000]
  # TransducerModeActive = true # [false..true]
  # TransmittedPower = 150.00000 # (watts) [1.00000..30000.00000]
  # TvgRangeCorrection = SimradEK80 # [None, BySamples, SimradEx500, SimradEx60,
BioSonics, Kaijo, PulseLength, Ex500Forced, SimradEK80, Standard]
  # TwoWayBeamAngle = -20.700000 # (decibels re 1 steradian) [-99.000000..11.000000]

SourceCal T3
  # AbsorptionDepth = 5.000 # (meters) [0.000..10000.000]
  # Acidity = 8.000 # (pH) [0.000..14.000]
  # EffectivePulseDuration = 0.911 # (milliseconds) [0.001..50.000]
  # Frequency = 70.00 # (kilohertz) [0.01..10000.00]
  # MajorAxis3dbBeamAngle = 7.34 # (degrees) [0.00..360.00]
```

```
  # MajorAxisAngleOffset = 0.03 # (degrees) [-9.99..9.99]
  # MajorAxisAngleSensitivity = 23.000000 # [0.100000..100.000000]
  # MinorAxis3dbBeamAngle = 7.35 # (degrees) [0.00..360.00]
  # MinorAxisAngleOffset = -0.05 # (degrees) [-9.99..9.99]
  # MinorAxisAngleSensitivity = 23.000000 # [0.100000..100.000000]
  # PulseDuration = 1.024 # (milliseconds) [0.001..200.000]
  # SaCorrectionFactor = -0.0200 # (decibels) [-99.9900..99.9900]
  # Salinity = 33.500 # (parts per thousand) [0.000..50.000]
  # SamplingFrequency = 20.8333333 # (kilohertz) [0.0100000..1000.0000000]
  # SoundSpeed = 1447.21 # (meters per second) [1400.00..1700.00]
  # Temperature = 0.000 # (degrees celsius) [-3.000..100.000]
  # TransceiverImpedance = 5400.0 # (ohms) [0.0..1000000.0]
  # TransceiverSamplingFrequency = 1500.00 # (kilohertz) [1.00..5000.00]
  # TransducerGain = 26.2800 # (decibels) [1.0000..99.0000]
  # TransducerModeActive = true # [false..true]
  # TransmittedPower = 750.00000 # (watts) [1.00000..30000.00000]
  # TvgRangeCorrection = SimradEK80 # [None, BySamples, SimradEx500, SimradEx60,
BioSonics, Kaijo, PulseLength, Ex500Forced, SimradEK80, Standard]
  # TwoWayBeamAngle = -20.700000 # (decibels re 1 steradian) [-99.000000..11.000000]

SourceCal T4
  # AbsorptionDepth = 5.000 # (meters) [0.000..10000.000]
  # Acidity = 8.000 # (pH) [0.000..14.000]
  # EffectivePulseDuration = 0.937 # (milliseconds) [0.001..50.000]
  # Frequency = 333.00 # (kilohertz) [0.01..10000.00]
  # MajorAxis3dbBeamAngle = 7.00 # (degrees) [0.00..360.00]
  # MajorAxisAngleOffset = 0.00 # (degrees) [-9.99..9.99]
  # MajorAxisAngleSensitivity = 23.000000 # [0.100000..100.000000]
  # MinorAxis3dbBeamAngle = 7.00 # (degrees) [0.00..360.00]
  # MinorAxisAngleOffset = 0.00 # (degrees) [-9.99..9.99]
  # MinorAxisAngleSensitivity = 23.000000 # [0.100000..100.000000]
  # PulseDuration = 1.024 # (milliseconds) [0.001..200.000]
  # SaCorrectionFactor = 0.0000 # (decibels) [-99.9900..99.9900]
  # Salinity = 33.500 # (parts per thousand) [0.000..50.000]
  # SamplingFrequency = 41.6666667 # (kilohertz) [0.0100000..1000.0000000]
  # SoundSpeed = 1447.21 # (meters per second) [1400.00..1700.00]
  # Temperature = 0.000 # (degrees celsius) [-3.000..100.000]
  # TransceiverImpedance = 5400.0 # (ohms) [0.0..1000000.0]
  # TransceiverSamplingFrequency = 1500.00 # (kilohertz) [1.00..5000.00]
  # TransducerGain = 25.0000 # (decibels) [1.0000..99.0000]
  # TransducerModeActive = true # [false..true]
  # TransmittedPower = 50.00000 # (watts) [1.00000..30000.00000]
  # TvgRangeCorrection = SimradEK80 # [None, BySamples, SimradEx500, SimradEx60,
BioSonics, Kaijo, PulseLength, Ex500Forced, SimradEK80, Standard]
  # TwoWayBeamAngle = -20.700000 # (decibels re 1 steradian) [-99.000000..11.000000]

SourceCal T5
  # AbsorptionDepth = 5.000 # (meters) [0.000..10000.000]
  # Acidity = 8.000 # (pH) [0.000..14.000]
  # EffectivePulseDuration = 0.397 # (milliseconds) [0.001..50.000]
  # Frequency = 18.00 # (kilohertz) [0.01..10000.00]
```

```
   # MajorAxis3dbBeamAngle = 9.77 # (degrees) [0.00..360.00]
   # MajorAxisAngleOffset = -0.15 # (degrees) [-9.99..9.99]
   # MajorAxisAngleSensitivity = 15.500000 # [0.100000..100.000000]
   # MinorAxis3dbBeamAngle = 9.87 # (degrees) [0.00..360.00]
   # MinorAxisAngleOffset = 0.00 # (degrees) [-9.99..9.99]
   # MinorAxisAngleSensitivity = 15.500000 # [0.100000..100.000000]
   # PulseDuration = 1.024 # (milliseconds) [0.001..200.000]
   # SaCorrectionFactor = 0.0600 # (decibels) [-99.9900..99.9900]
   # Salinity = 33.500 # (parts per thousand) [0.000..50.000]
   # SamplingFrequency = 35.7142857 # (kilohertz) [0.0100000..1000.0000000]
   # SoundSpeed = 1447.21 # (meters per second) [1400.00..1700.00]
   # Temperature = 0.000 # (degrees celsius) [-3.000..100.000]
   # TransceiverImpedance = 5400.0 # (ohms) [0.0..1000000.0]
   # TransceiverSamplingFrequency = 1500.00 # (kilohertz) [1.00..5000.00]
   # TransducerGain = 23.5000 # (decibels) [1.0000..99.0000]
   # TransducerModeActive = true # [false..true]
   # TransmittedPower = 1600.00000 # (watts) [1.00000..30000.00000]
   # TvgRangeCorrection = SimradEK80 # [None, BySamples, SimradEx500, SimradEx60,
BioSonics, Kaijo, PulseLength, Ex500Forced, SimradEK80, Standard]
   # TwoWayBeamAngle = -17.000000 # (decibels re 1 steradian) [-99.000000..11.000000]

SourceCal T6
   # AbsorptionDepth = 5.000 # (meters) [0.000..10000.000]
   # Acidity = 8.000 # (pH) [0.000..14.000]
   # EffectivePulseDuration = 0.924 # (milliseconds) [0.001..50.000]
   # Frequency = 120.00 # (kilohertz) [0.01..10000.00]
   # MajorAxis3dbBeamAngle = 7.04 # (degrees) [0.00..360.00]
   # MajorAxisAngleOffset = 0.07 # (degrees) [-9.99..9.99]
   # MajorAxisAngleSensitivity = 23.000000 # [0.100000..100.000000]
   # MinorAxis3dbBeamAngle = 7.05 # (degrees) [0.00..360.00]
   # MinorAxisAngleOffset = -0.10 # (degrees) [-9.99..9.99]
   # MinorAxisAngleSensitivity = 23.000000 # [0.100000..100.000000]
   # PulseDuration = 1.024 # (milliseconds) [0.001..200.000]
   # SaCorrectionFactor = -0.0300 # (decibels) [-99.9900..99.9900]
   # Salinity = 33.500 # (parts per thousand) [0.000..50.000]
   # SamplingFrequency = 25.0000000 # (kilohertz) [0.0100000..1000.0000000]
   # SoundSpeed = 1447.21 # (meters per second) [1400.00..1700.00]
   # Temperature = 0.000 # (degrees celsius) [-3.000..100.000]
   # TransceiverImpedance = 5400.0 # (ohms) [0.0..1000000.0]
   # TransceiverSamplingFrequency = 1500.00 # (kilohertz) [1.00..5000.00]
   # TransducerGain = 25.8500 # (decibels) [1.0000..99.0000]
   # TransducerModeActive = true # [false..true]
   # TransmittedPower = 225.00000 # (watts) [1.00000..30000.00000]
   # TvgRangeCorrection = SimradEK80 # [None, BySamples, SimradEx500, SimradEx60,
BioSonics, Kaijo, PulseLength, Ex500Forced, SimradEK80g, Standard]
   # TwoWayBeamAngle = -20.700000 # (decibels re 1 steradian) [-99.000000..11.000000]
```

Challenges and Errors

Whilst the backup of the .raw files occurs using an automated script, it does not clear the .raw data files from the local drive. As a result the EK80 stops pinging and recording when its disks

are full. With the setup on the SDA, the EK80 was frequently removed from screens as other people wanted to use the space. This results in this error not being seen. Until automated scripts are available checks need to be made of the instruments to ensure the hard-drives are not filling up. It isn't clear where this responsibility lies and it needs to be made clear.

The calibration winch on the port side rode into the wrong place, which made locating and controlling the sphere challenging. Remember to check its position, rather than blaming ship movement first!

During calibration, the new software identified some of the calibrations as exceeding allowable limits – specifically Beamwidth alongship and Beamwidth athwartship outside of the target range. The below methods was used to resolve this error – but the method is unsatisfactory as it isn't obvious why this is currently in place.

Table 4.3.5-3: EK80 activities

Time	Latitude	Longitude	Depth (m)	Wind speed (m/s)	Comment
21/01/2024 17:34	-56.643	-57.256	3963.45	16.6	EK80 switched on. Set to 3 second ping rate through k-sync. Synchronised with ADCP, EA640 and occasionally the EM122 and 712
16/02/2024 15:28	-64.61594	-55.0625	382.77	2	Changed water temperature to 0 (wont go below), and salinity to 33.5. Updated from CTD 123 (sv profile). Temp should be -1.4, Sal should be 33.5
16/02/2024 15:42	-64.61583	-55.0618	382.77	2.3	Start of 38 kHz. Ship moving around quite a lot making sphere challenging to control
16/02/2024 17:03	-64.62004	-55.0662	382.77	1.2	Bad alongship values - removed lots, still no improvement
16/02/2024 17:04	-64.62001	-55.0664	382.77	1.2	Calibration for 38 kHz uploaded
16/02/2024 17:09	-64.61993	-55.0671	382.77	0.7	Start 120 kHz calibration
16/02/2024 17:33	-64.61961	-55.0717	382.77	3.4	120 kHz cal okay. 0.2 dB difference from last
16/02/2024 17:35	-64.61971	-55.0718	382.77	3.7	Calibrating 200kHz
16/02/2024 18:50	-64.62263	-55.0677	382.77	2.4	Finished 200 kHz - along and athwart errors. Updated calibration
16/02/2024 18:59	-64.62321	-55.0664	382.77	2.7	calibrating 70 kHz
16/02/2024 19:07	-64.62386	-55.0658	382.77	1.6	70 kHz calibrated - no erroneous points

5. Ship-based CTD Measurements

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CTD operations

SD035 operated two different CTD systems: A stainless steel frame (SS) and a tracemetal free frame (Ti). A list of sensors on the frames can be found in Table 3-3 within Section 3 of this report.

In total we ran 141 CTD casts on SD035. Normal operations saw a suite of five consecutive casts

1) the primary productivity (PP) cast with the SS frame to 200 m at 2 am (later moved to 3 am) ship time.
2) a full depth biogeochemistry (BGC) cast with the SS frame
3) a full depth tracemetal cast with the Ti frame (with bottles fired on the fly on the upcast)
4) a full depth radium cast on the SS frame with six Niskin bottles fired at each requested depth
5) a second full depth radium cast on the SS frame with six Niskin bottles fired at each requested depth

Additionally, we ran several physics only casts in which no water was sampled from the Niskin bottles and several test and troubleshooting casts. All casts that were not for CTD test purposes had the LADCP on the SS or the Ti frame recording water velocity profiles. The deck unit advanced conductivity relative to temperature by 0.073 seconds.

The CTD data was transferred from the CTD operator PC in the winch control room to the SDA data storage (leg/system). From there it was downloaded and processed with the SBE Data processing Software Version 7.26.7

Cast metadata is provided below:

Table 5-1: CTD cast metadata

Time UTC	Latitude	Longitude	Water depth	CTD depth	Station ID	Event number	CTD number	CTD type
20/01/2024 11:52	-51.6511	-56.6743	508.81	462	Test0	1	1	Test
20/01/2024 13:44	-51.6511	-56.6743	508.43	498	Test0	2	2	Test
22/01/2024 14:42	-61.4547	-56.6768	477.24	457	Test1	3	3	BGC-Max
22/01/2024 16:21	-61.4528	-56.6615	469.81	454	Test1	4	4	TM
26/01/2024 16:49	-64.0968	-56.1307	382.75	203	Test2	8	5	PP
26/01/2024 19:23	-64.1071	-56.1963	365.21	353	Test2	10	6	Rad
27/01/2024 17:37	-64.5757	-55.0534	430.94	413	Mooring	13	7	BGC-Max
28/01/2024 04:56	-64.5608	-55.0609	431.93	202	Mooring	18	8	PP
28/01/2024 06:50	-64.5703	-55.0671	432.36	415	Mooring	19	9	BGC

28/01/2024 08:27	-64.5353	-55.0796	396.67	371	Mooring	20	10	TM
28/01/2024 15:39	-64.5759	-55.0588	437.86	420	Mooring	22	11	Rad
28/01/2024 17:29	-64.5742	-55.0594	438.54	420	Mooring	23	12	Rad
29/01/2024 08:21	-64.585	-55.0774	419.81	413	Mooring	30	13	TM
29/01/2024 09:34	-64.5766	-55.0829	432.72	422	Mooring	31	14	Rad
29/01/2024 11:47	-64.5733	-55.0891	433.72	415	Mooring	32	15	Rad
30/01/2024 04:54	-64.5876	-55.0859	430.08	200	Mooring	41	16	PP
30/01/2024 06:27	-64.5814	-55.0791	429.32	418	Mooring	42	17	BGC
30/01/2024 07:58	-64.5754	-55.0834	433.73	420	Mooring	43	18	BGC
31/01/2024 08:59	-66.1358	-59.8817	322.39	313	N104	44	19	BGC-Max
31/01/2024 10:16	-66.1359	-59.8893	322.95	313	N104	45	20	TM
31/01/2024 11:33	-66.1341	-59.9041	322.96	315	N104	46	21	Rad
31/01/2024 13:27	-66.1328	-59.9144	323.1	309	N104	49	22	Rad
31/01/2024 20:11	-66.0723	-60.1691	351.21	340	N102	54	23	BGC-Max
31/01/2024 22:31	-66.0774	-60.5858	190.49	186	N96_shelf	55	24	Physics
01/02/2024 01:48	-66.0563	-60.4852	342.85	330	N96	57	25	Physics
01/02/2024 04:47	-66.0564	-60.4871	338.3	203	N96	59	26	PP
01/02/2024 06:19	-66.0564	-60.4864	339.08	23	N96	60	27	BGC
01/02/2024 07:07	-66.0563	-60.4827	342.4	333	N96	61	28	BGC
01/02/2024 08:21	-66.0563	-60.4798	345.04	333	N96	62	29	TM
01/02/2024 09:31	-66.0562	-60.4776	342.81	332	N96	63	30	Rad
01/02/2024 11:22	-66.0559	-60.4805	344.19	328	N96	65	31	Rad
01/02/2024 13:45	-66.2056	-60.3539	357.29	347	N97	66	32	Physics
01/02/2024 16:15	-66.3823	-60.3405	480	466	N98_5	67	33	BGC-Max
01/02/2024 17:49	-66.3866	-60.3325	482.25	467	N98_5	72	34	TM
01/02/2024 18:51	-66.3865	-60.3249	481.57	467	N98_5	74	35	Rad
01/02/2024 22:38	-66.1742	-60.2236	361.43	351	Calibration1	75	36	Physics
02/02/2024 01:28	-66.0992	-60.0266	327.35	317	N103	76	37	Physics
02/02/2024 04:54	-66.1338	-59.8923	321.87	200	N104	78	38	PP
02/02/2024 06:20	-66.1339	-59.8947	319.53	313	N104	79	39	BGC
02/02/2024 08:48	-66.1255	-60.3888	361.06	349	N96_5	80	40	TM
02/02/2024 09:47	-66.1247	-60.3981	364.06	353	N96_5	81	41	Rad
02/02/2024 11:31	-66.1248	-60.4135	354.26	340	N96_5	83	42	Rad
02/02/2024 12:51	-66.1187	-60.4264	338.52	330	N96_5	84	43	BGC-Max
02/02/2024 16:02	-66.0675	-60.3331	399.99	382	N101	86	44	BGC-Max
02/02/2024 17:10	-66.0673	-60.3326	400.33	386	N101	87	45	TM

02/02/2024 22:14	-65.8113	-59.6134	430.56	417	SS1	89	46	BGC-Max
03/02/2024 04:54	-65.6271	-59.2911	430.27	200	SS2	91	47	PP
03/02/2024 06:31	-65.6265	-59.2957	431.41	417	SS2	92	48	BGC
03/02/2024 07:31	-65.6265	-59.297	431.11	417	SS2	93	49	TM
03/02/2024 08:30	-65.625	-59.3029	431.28	419	SS2	94	50	Rad
03/02/2024 10:13	-65.6241	-59.3018	431.34	414	SS2	97	51	Rad
03/02/2024 17:08	-65.0831	-58.8189	258.28	252	SS3	99	52	BGC-Max
04/02/2024 04:58	-64.5864	-58.2635	499.23	200	SS4	103	53	PP
04/02/2024 06:23	-64.5884	-58.2597	498.82	483	SS4	104	54	BGC
04/02/2024 07:29	-64.589	-58.2575	498.12	482	SS4	105	55	TM
04/02/2024 08:32	-64.5891	-58.2571	497.93	483	SS4	106	56	Rad
04/02/2024 10:09	-64.5891	-58.2571	498.86	479	SS4	108	57	Rad
04/02/2024 18:50	-64.5891	-58.2411	493.74	21	SS4	112	58	TM
04/02/2024 20:03	-64.5888	-58.2345	489.76	19	SS4	113	59	TM
04/02/2024 20:18	-64.5884	-58.235	488.48	19	SS4	114	60	TM
04/02/2024 21:26	-64.5857	-58.2351	485	19	SS4	115	61	TM
04/02/2024 21:41	-64.5857	-58.2351	484.95	19	SS4	116	62	TM
04/02/2024 21:59	-64.5855	-58.2349	484.76	20	SS4	117	63	TM
04/02/2024 22:09	-64.5854	-58.2348	484.65	19	SS4	118	64	TM
04/02/2024 22:23	-64.5854	-58.2349	484.65	19	SS4	119	65	TM
06/02/2024 11:56	-63.6795	-52.084		99	Calibration2	121	66	TM
06/02/2024 15:32	-63.6798	-52.1178	996.24	497	Calibration2	124	67	TM
06/02/2024 17:32	-63.6792	-52.1205	993.68	963	Calibration2	126	68	BGC-Max
07/02/2024 11:47	-64.1338	-47.9718		4047	Geotraces	128	69	TM
08/02/2024 05:46	-64.5327	-48.4958	3987.47	200	T1	133	70	PP
08/02/2024 07:13	-64.5293	-48.4955	3986.73	3932	T1	134	71	BGC
08/02/2024 10:29	-64.5037	-48.5335	3976.35	3920	T1	135	72	TM
08/02/2024 19:09	-64.524	-48.9118	3895.49	3844	T1_1	138	73	Physics
08/02/2024 23:07	-64.5292	-49.3146	3718.5	3668	T1_2	140	74	Physics
09/02/2024 05:48	-64.5289	-49.7051	3541.22	200	T2	142	75	PP
09/02/2024 07:12	-64.5228	-49.694	3531.52	3471	T2	143	76	BGC

09/02/2024 10:37	-64.5314	-49.6072	3588.69	3534	T2	144	77	TM
09/02/2024 18:22	-64.5211	-50.157	3319.75	3258	T2_1	148	78	Physics
09/02/2024 22:16	-64.4756	-50.5813	3185.6	3133	T2_2	150	79	Physics
10/02/2024 05:47	-64.5202	-50.9521	3043.36	200	T3	151	80	PP
10/02/2024 07:09	-64.5042	-50.9116	3057.85	3010	T3	152	81	BGC
10/02/2024 09:48	-64.4519	-50.857	3128.07	3111	T3	153	82	TM
10/02/2024 16:59	-64.5497	-51.4487	2905.82	2769	T3_1	156	83	Physics
10/02/2024 20:27	-64.5613	-51.879	2788.13	1542	T3_2	158	84	Physics
10/02/2024 23:14	-64.5274	-51.8116	2792.54	2736	T3_2	159	85	Physics
11/02/2024 05:52	-64.5508	-52.7338	2543.22	201	T4	160	86	PP
11/02/2024 07:14	-64.5541	-52.728	2545.75	2493	T4	161	87	BGC
11/02/2024 11:35	-64.5858	-52.7164	2557.75	2505	T4	162	88	TM
11/02/2024 18:14	-64.559	-52.9791	2447.84	2393	T4_1	166	89	Physics
11/02/2024 21:17	-64.554	-53.1718	2346.29	2293	T4_2	168	90	Physics
12/02/2024 00:16	-64.5716	-53.4013	2197.88	2147	T4_3	169	91	Physics
12/02/2024 06:08	-64.6092	-53.6553	1983.07	201	T5	171	92	PP
12/02/2024 07:24	-64.6243	-53.685	1947.26	1885	T5	172	93	BGC
12/02/2024 10:46	-64.5417	-53.5862	2024.28	1977	T5	173	94	TM
12/02/2024 12:47	-64.5478	-53.5823	2022.6	1979	T5	175	95	Rad
12/02/2024 15:12	-64.5343	-53.5788	2027.41	1975	T5	176	96	Rad
12/02/2024 17:18	-64.5357	-53.5845	2021.18	1970	T5	177	97	Rad
12/02/2024 22:19	-64.566	-53.7232	1869.24	1826	T5_1	179	98	Physics
13/02/2024 00:22	-64.5683	-53.8157	1755.56	1721	T5_2	180	99	Physics
13/02/2024 05:49	-64.5558	-53.9906	1484.93	201	T6	182	100	PP
13/02/2024 07:09	-64.5553	-53.9878	1488.78	1445	T6	183	101	BGC
13/02/2024 09:58	-64.5767	-53.9041	1621.81	1567	T6	185	102	TM
13/02/2024 11:44	-64.5935	-53.9229	1591.51	1551	T6	186	103	Rad
13/02/2024 13:58	-64.5937	-53.9512	1546.47	1504	T6	187	104	Rad

13/02/2024 16:08	-64.5735	-53.9684		1476	T6	188	105	Rad
13/02/2024 22:51	-64.5679	-54.1149	1282.08	1246	T6_1	192	106	Physics
14/02/2024 05:47	-64.5553	-54.2571	996.92	200	T7	194	107	PP
14/02/2024 07:23	-64.5736	-54.2775	947.47	932	T7	195	108	BGC
14/02/2024 09:10	-64.5509	-54.2681	971.39	934	T7	196	109	TM
14/02/2024 11:12	-64.5776	-54.2443	1024	976	T7	197	110	Rad
14/02/2024 12:51	-64.5637	-54.2909	921.1	869	T7	199	111	Rad
14/02/2024 21:03	-64.5679	-54.3361	800.77	783	T7_1	201	112	Physics
15/02/2024 06:05	-64.5789	-54.4082	524.77	200	T8	205	113	PP
15/02/2024 07:26	-64.5745	-54.4048	553.72	543	T8	206	114	BGC
15/02/2024 08:43	-64.5711	-54.4117	530.39	534	T8	207	115	TM
15/02/2024 10:15	-64.5753	-54.4089	532.72	523	T8	208	116	Rad
15/02/2024 11:36	-64.5688	-54.4142	527.46	519	T8	210	117	Rad
15/02/2024 22:37	-64.5697	-54.7548	399.83	372	T8_1	214	118	Physics
16/02/2024 06:10	-64.5777	-55.0401	425.18	201	Mooring	216	119	PP
16/02/2024 07:34	-64.586	-55.0612	418.62	403	Mooring	217	120	BGC
16/02/2024 08:34	-64.594	-55.0774	409.92	401	Mooring	218	121	TM
16/02/2024 09:23	-64.5999	-55.0839	412.6	398	Mooring	219	122	Rad
16/02/2024 10:38	-64.6008	-55.0858	405.73	391	Mooring	220	123	Rad
19/02/2024 05:50	-66.3603	-55.9877	325.87	200	IceStation1	240	124	PP
19/02/2024 07:26	-66.3516	-55.9914	335.19	321	IceStation1	241	125	BGC
19/02/2024 08:40	-66.3458	-55.999	355.52	351	IceStation1	242	126	TM
19/02/2024 09:35	-66.3418	-56.0054	367.55	356	IceStation1	243	127	Rad
19/02/2024 11:07	-66.3408	-56.0122	369.84	352	IceStation1	244	128	Rad
23/02/2024 22:37	-63.5392	-52.8961	543.84	518	Calibration3	254	129	BGC-Max
24/02/2024 06:09	-62.3308	-50.9882	3368.69	1009	Biopole Glider	255	130	Physics
24/02/2024 07:23	-62.3308	-50.9882	3369.01	999	Biopole Glider	256	131	TM

25/02/2024 10:58	-64.7839	-56.154	419.7	403	Float1	258	132	BGC-Max
26/02/2024 05:50	-65.4087	-57.8138	425.67	411	IceStation2	266	133	BGC-Max
29/02/2024 17:59	-64.6984	-56.5475	341.36	339	Supersite	288	134	Calibration
01/03/2024 06:00	-64.6629	-56.424	395.76	201	Supersite	293	135	PP
01/03/2024 07:30	-64.6618	-56.4275	396.43	382	Supersite	294	136	BGC
01/03/2024 08:26	-64.6592	-56.4295	397.42	384	Supersite	295	137	TM
01/03/2024 09:27	-64.6575	-56.4328	392.55	379	Supersite	297	138	Rad
01/03/2024 10:38	-64.6565	-56.4349	389.19	375	Supersite	298	139	Rad
01/03/2024 16:39	-64.7335	-56.6086	351.16	99		300	140	Test
05/03/2024 15:43	-62.1613	-50.3792	3436.19	3379	Biopole Mooring	311	141	Physics

Locations of casts split by cast type (see Table 5-1) can be seen below:

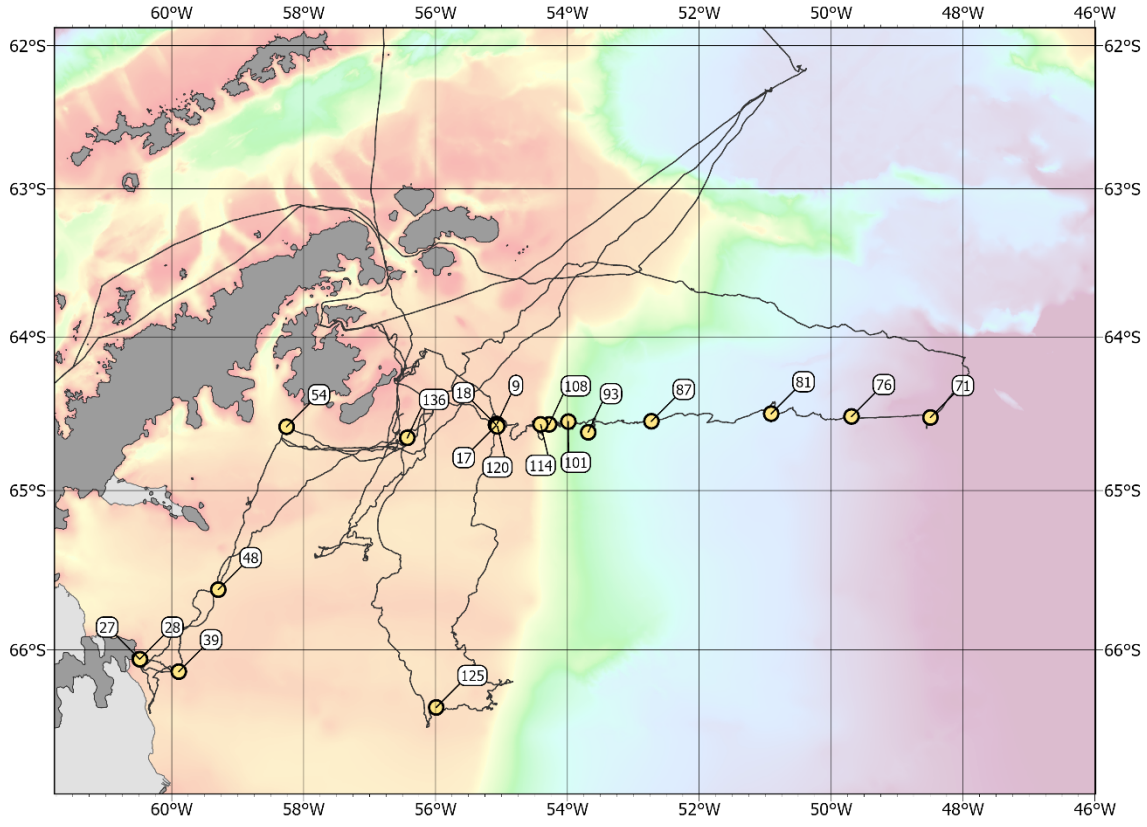


Figure 5-1: Locations of all BGC cast stations

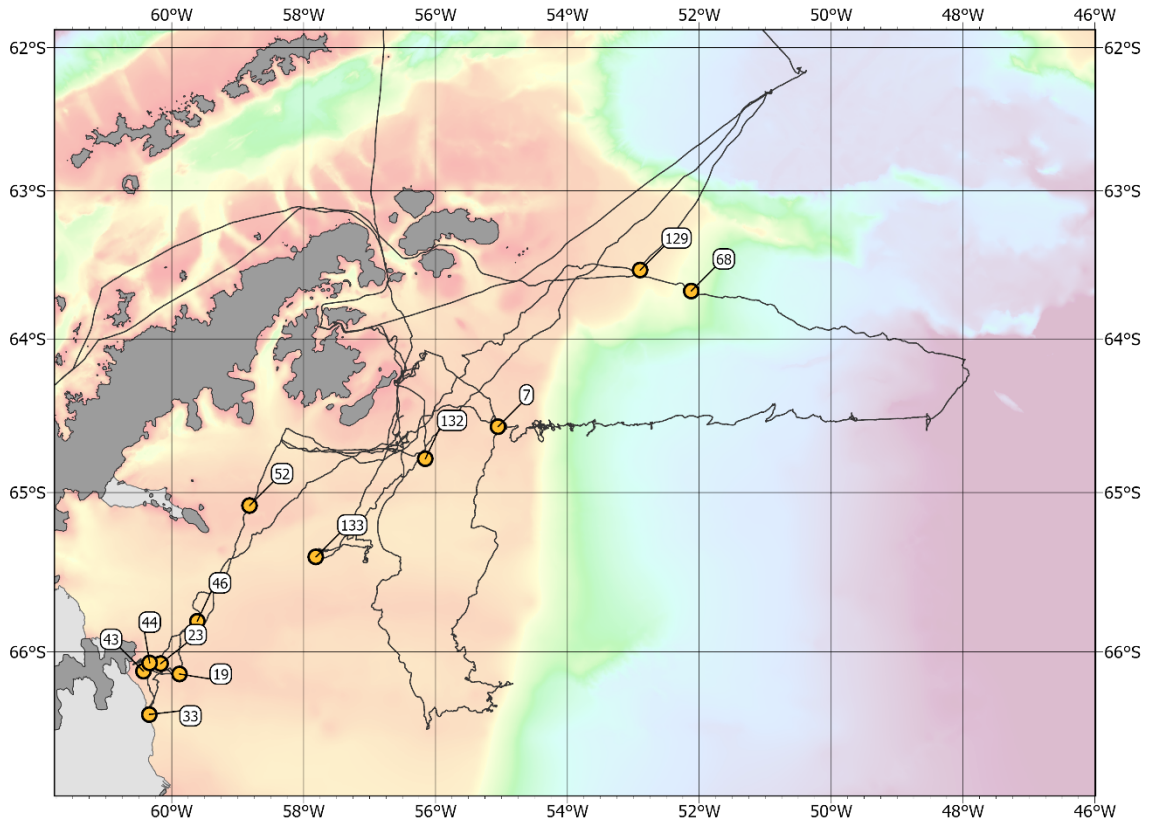


Figure 5-2: Location of all BGC-Max stations

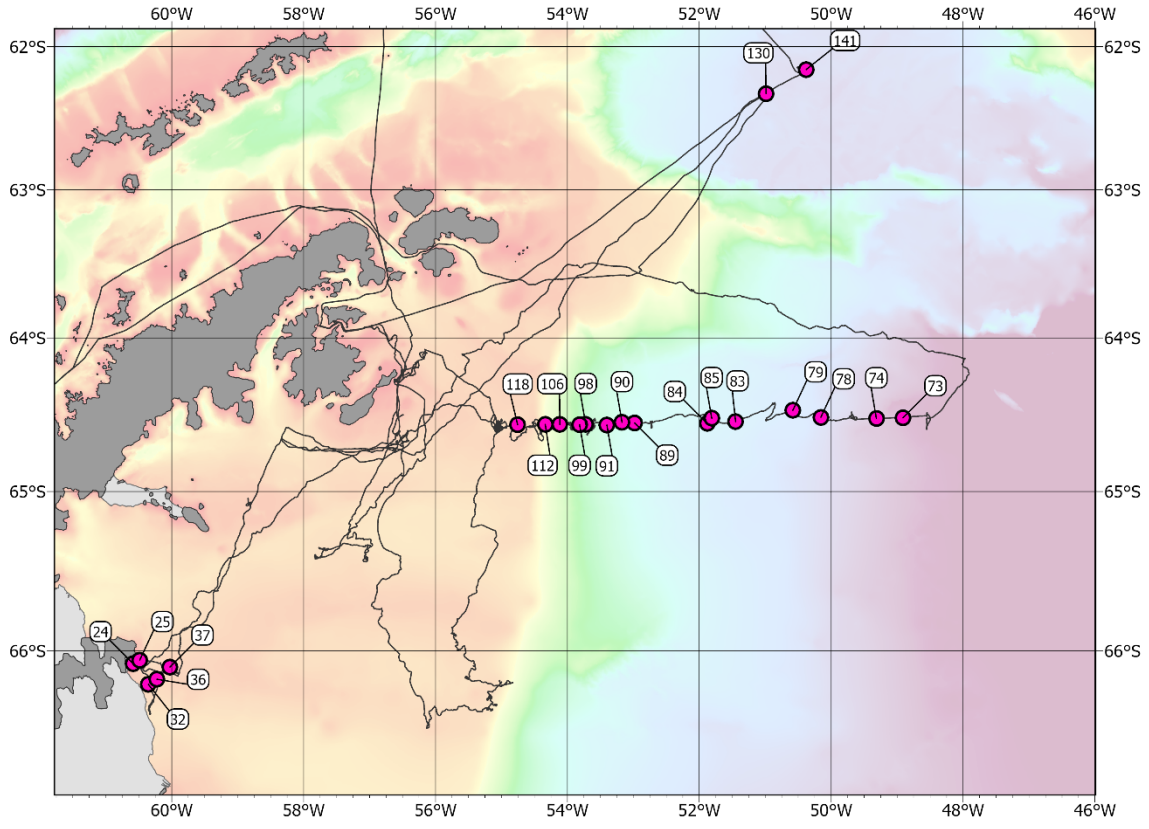


Figure 5-3: Location of all physics only stations

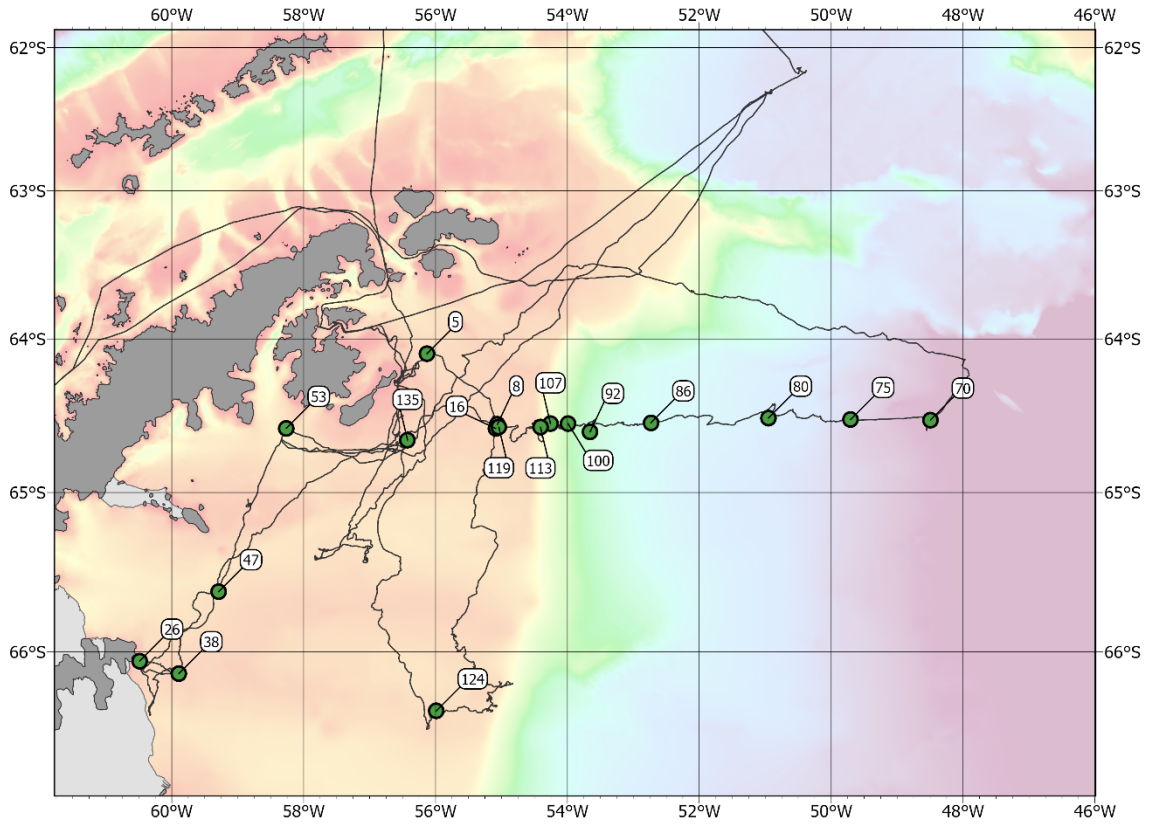


Figure 5-4: Location of all PP stations

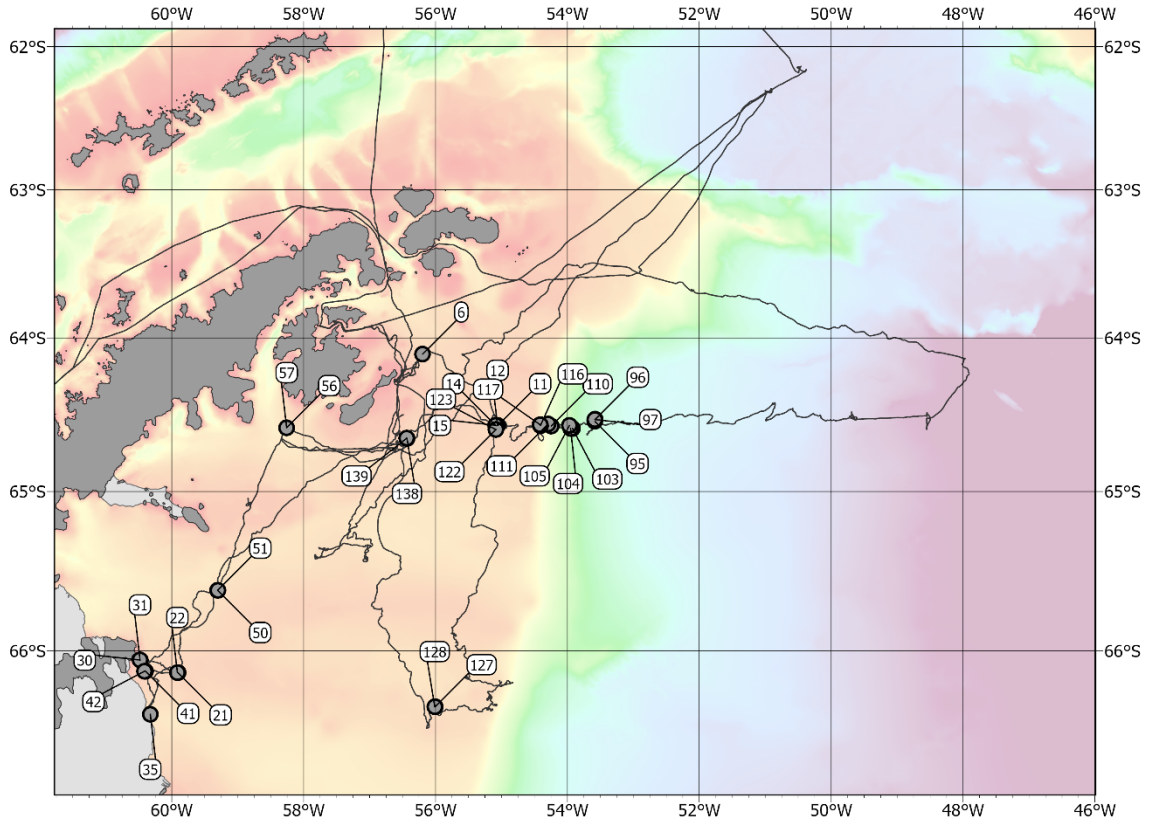


Figure 5-5: Locations of all Radium casts

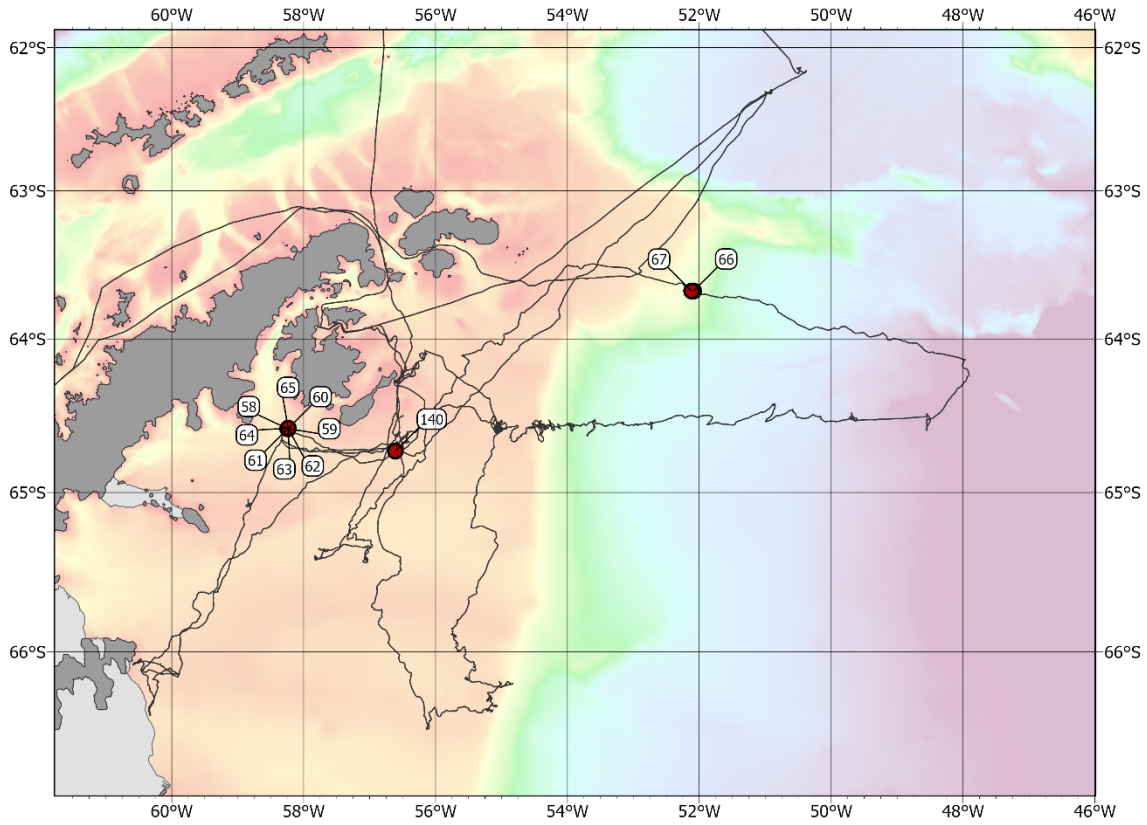


Figure 5-6: Locations of CTD tests

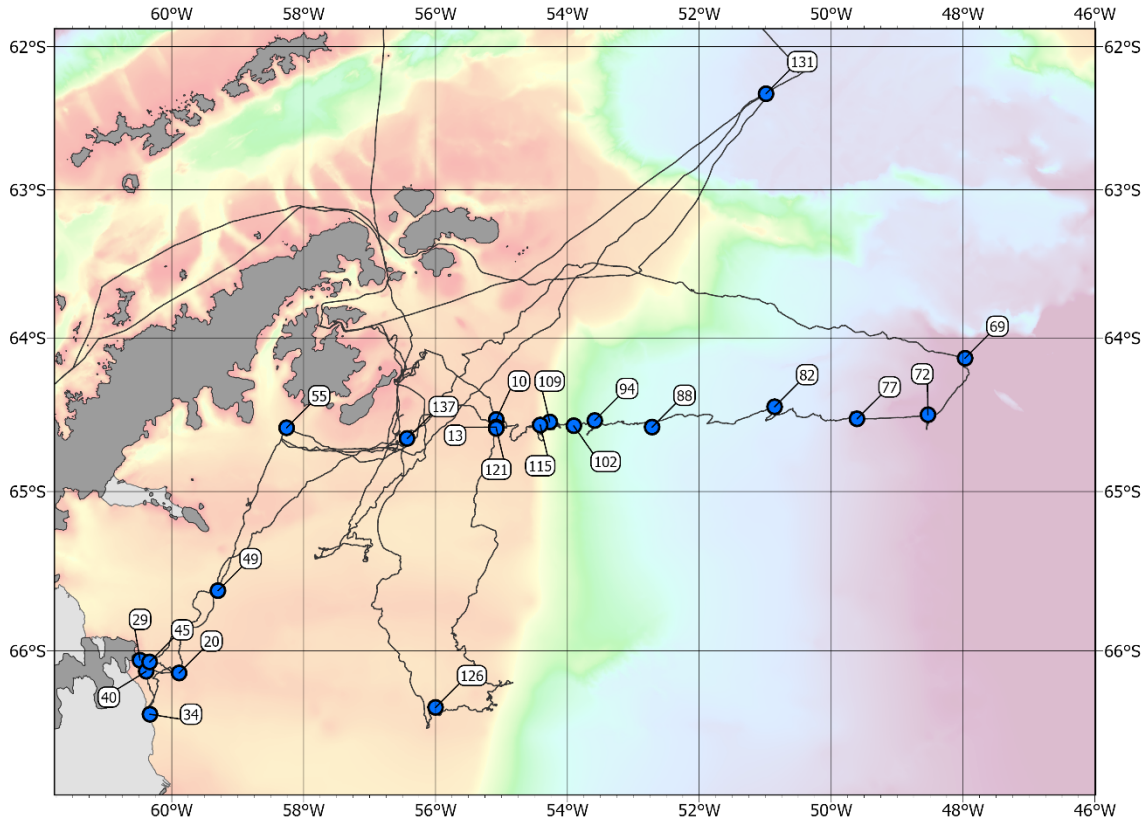


Figure 5-7: Locations of TM casts

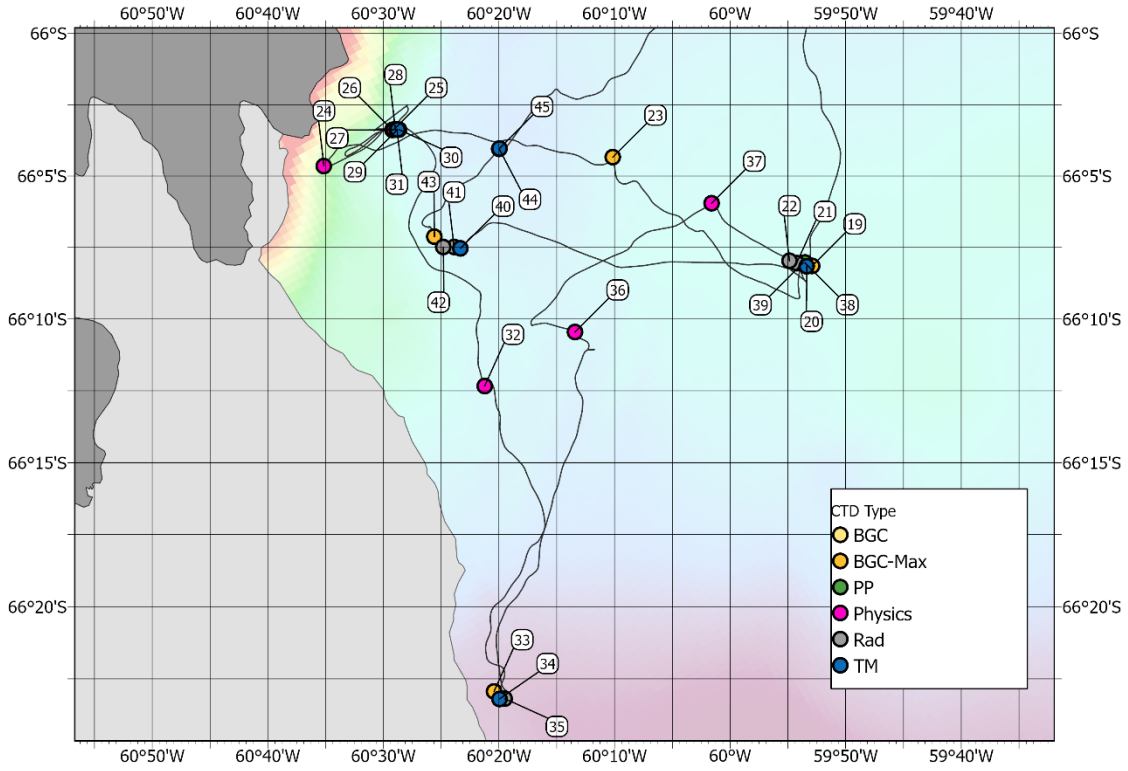


Figure 5-8: All stations close to the Larsen C ice shelf

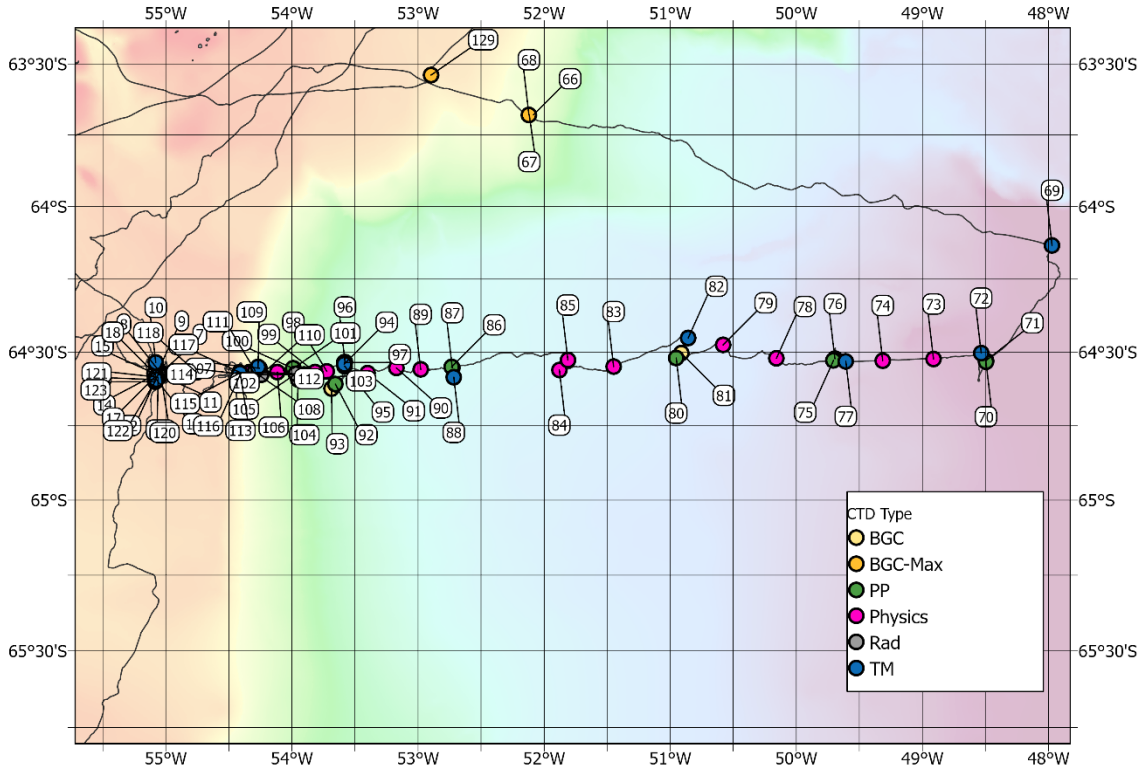


Figure 5-9: The shelf transect with all CTD casts, note that symbols overlap, to see locations of specific cast types see the individual cast type maps

Processing steps

The postprocessing was automated with two batch scripts: SD035_Process_All_SS.CMD and SD035_Process_All_Ti.CMD which called the sbe batch file SBE_STEPS_SD035.txt. This in turn called the PSA files found in the PSA_files folder on leg/work/scientific_work_areas/CTD_LADCP/scripts

For individual casts the command file SD035_CTD_processing.CMD was run which also called the sbe batch file SBE_STEPS_SD035.txt

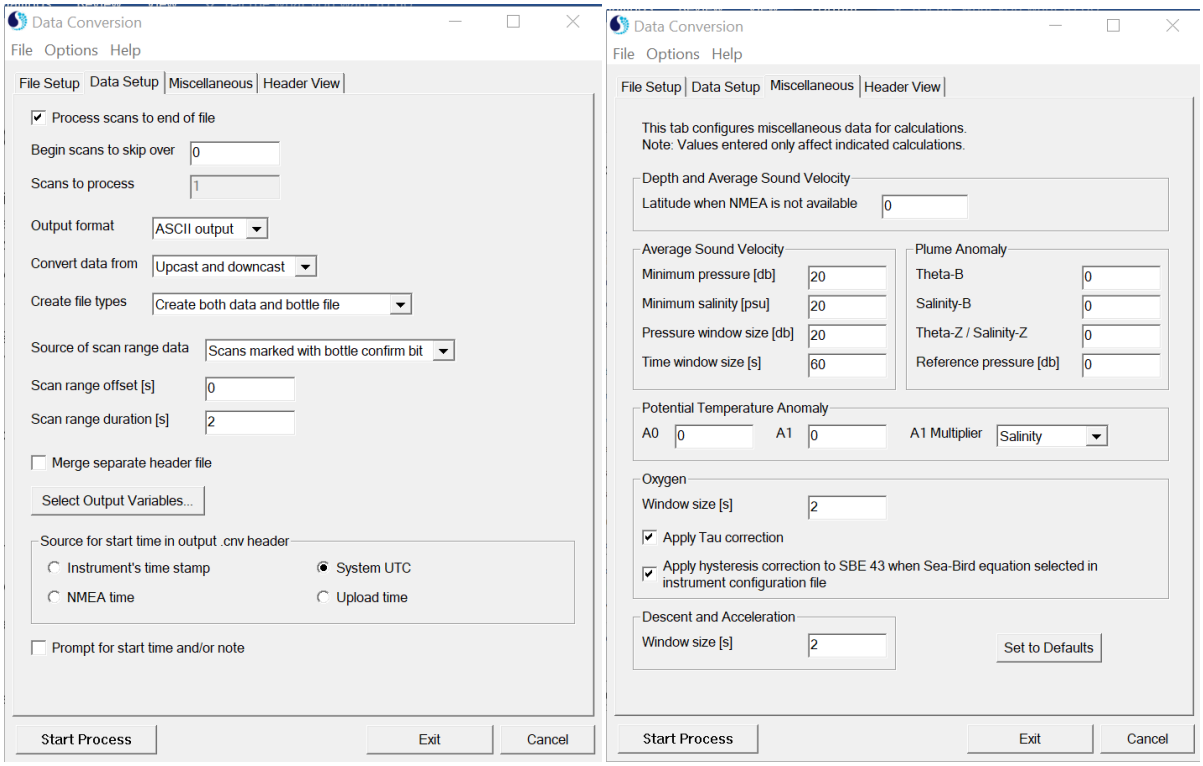
After the Ph sensor was added to the SS frame, SS data was processed with SBE_STEPS_SD035_Ph.txt and the associated .psa files.

Casts 003, 083 and 084 had bad data at the start or end of the casts that needed to be disregarded for processing. For these casts individual Derive psa files exist and a shared psa file for all further processing steps.

All processing scripts plus a README file are on leg/work/scientific_work_areas/CTD_LADCP/scripts

Data conversion

Settings were the same for SS and Ti frames.



Filter

Pressure: low pass filter with time constant of 0.15 seconds

Align
The settings differed for SS and Ti frames. For the SS sensors advance values were:

Conductivity (primary and secondary): -0.025 seconds

Oxygen, raw (primary and secondary): 3 seconds

For the Ti frame the settings were

Oxygen, raw (primary and secondary): 4 seconds

Cell thermal mass
Both SS and Ti frames were processed the same. Both primary and secondary conductivity values were corrected. The value for alpha (thermal anomaly amplitude) was set to 0.03 and the value for 1/beta (thermal anomaly time constant) was set to 7.

Loop edit
Both SS and Ti frames were processed the same. Settings were: fixed minimum velocity = 0.1m/s, remove surface soak, soak depth 20 m (minimum 10 m, maximum 40 m), use deck pressure as pressure offset, exclude scans marked bad.

Derive
Derive was run with the standard settings and tau correction for oxygen values enabled.

Bin
Data was binned into 1 db and 1 second bins for the entire dataset, and to 1 db for the downcast only. Exclude bad scans was enabled and include surface bin was disabled.

Bottle summary
Tau correction for oxygen was enabled.

Additional processing

After processing with SBE data processing the data was further processed using the Matlab routine sd035_ctd_processing.m. This extracted processed CTD data and averaged it over bottle scan ranges as well as over the depth range at which the bottles were located relative to the CTD sensors to produce mean and std of post-processed bottle values. It then bin-averaged the CTD data to a 1 m bin and split the data into down and upcasts.

The binned and split CTD data was then loaded into CTD_quicklook.m, plot_TS_all.m or plot_sections.m to produce down and upcast profiles, TS diagrams and transects for the collected data.

Quality control

We investigated differences of the primary and secondary channel sensors with each other using sensor_diff.m, differences between the temperatures sensors on the SS frame and the SBE35 were investigated using tp3_vs_sbe35.m

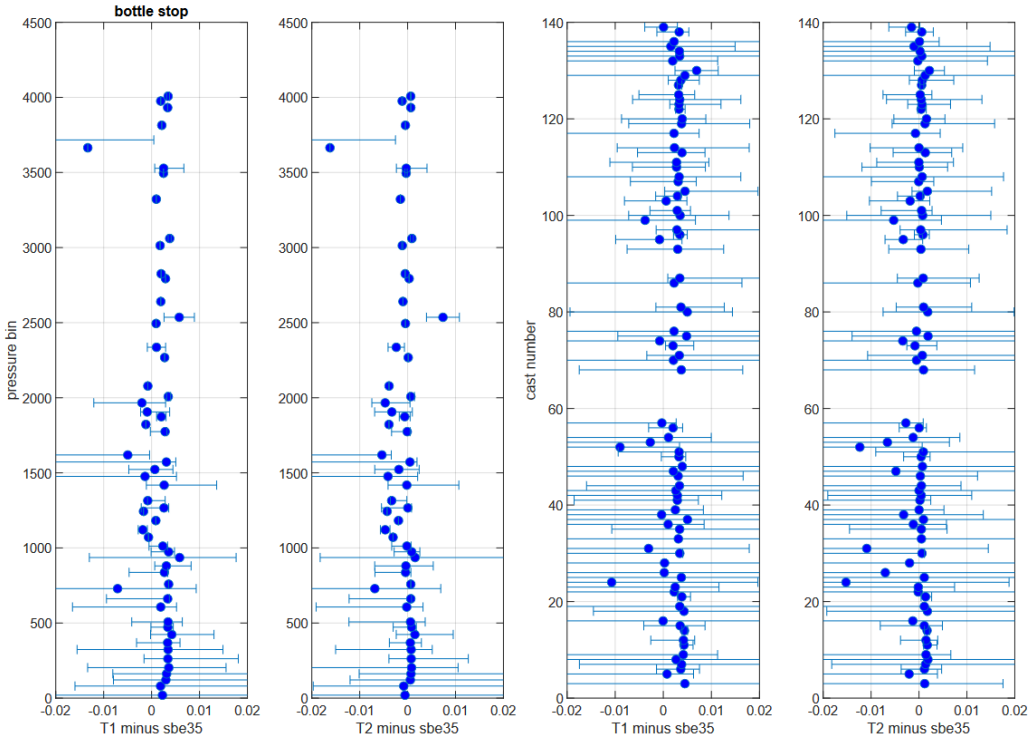


Figure 5-10: Difference between the sbe35 and the primary and secondary sbe3p sensors on the SS frame over the time of the bottle stops, as given by the .bl file. Dots are median differences, errorbars are 95th percentiles.

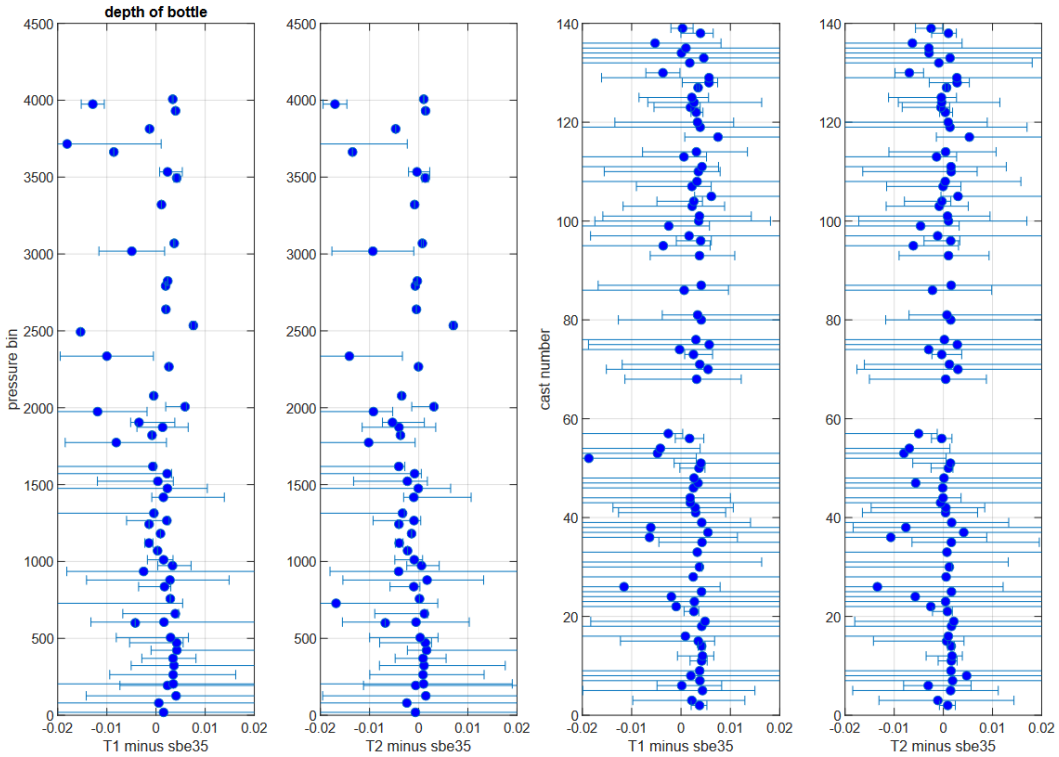


Figure 5-11: Difference between the sbe35 and the primary and secondary sbe3p sensors on the SS frame over the depth of the bottles. Dots are median differences, errorbars are 95th percentiles.

Comparison with the sbe35 showed that averaging temperature (and other variables) over the time of the bottle stop (rather than the depth at which the bottle is located) produced lower mean absolute differences and a lower spread in differences. There was no obvious relationship between t3p to sbe35 difference and depth or cast number. Variability in differences was lowest for depths that were below the thermocline and the temperature maximum but shallow enough to have been sampled by more than a hand full of casts. We corrected for differences between the 3p sensors and the sbe35 by calculating the median difference for each sensor and then applying this as an offset to the xmlcom files. The change in the xmlcon file was done with the python script changexmlcon_SS.py after which the SD035_Process_All_SS.CMD and sd035_ctd_processing.m scripts were run.

These scripts handled seabird postprocessing and Matlab binning plus bottle file generation for all SS frame casts with the adjusted xmlcon files. Note that SBE data processing rounds the offset value in the xmlcon files to 4 significant figures, thus an offset of 0.000458 K in the xmlcon file appears as an 0.0005 K offset in the cnv file header. Thus, the median difference between the corrected t3p sensor values and the sbe35 does not reach zero, instead median differences after correction are 1e-6 and -1.5e-5 for the primary and secondary t3p sensors, respectively.

Conductivity offsets relative to the salinometer are discussed in the salinometer section of the cruise report. The adjustments to the slope factor of the xmlcon file were also achieved with changexmlcon_SS.py and changexmlcon_Ti.py, respectively. Following the adjustments SBE_Process_All_SS.CMD, SBE_Process_All_Ti.CMD, sd035_ctd_processing.m and manual processing for casts 003, 083 and 084 was rerun.

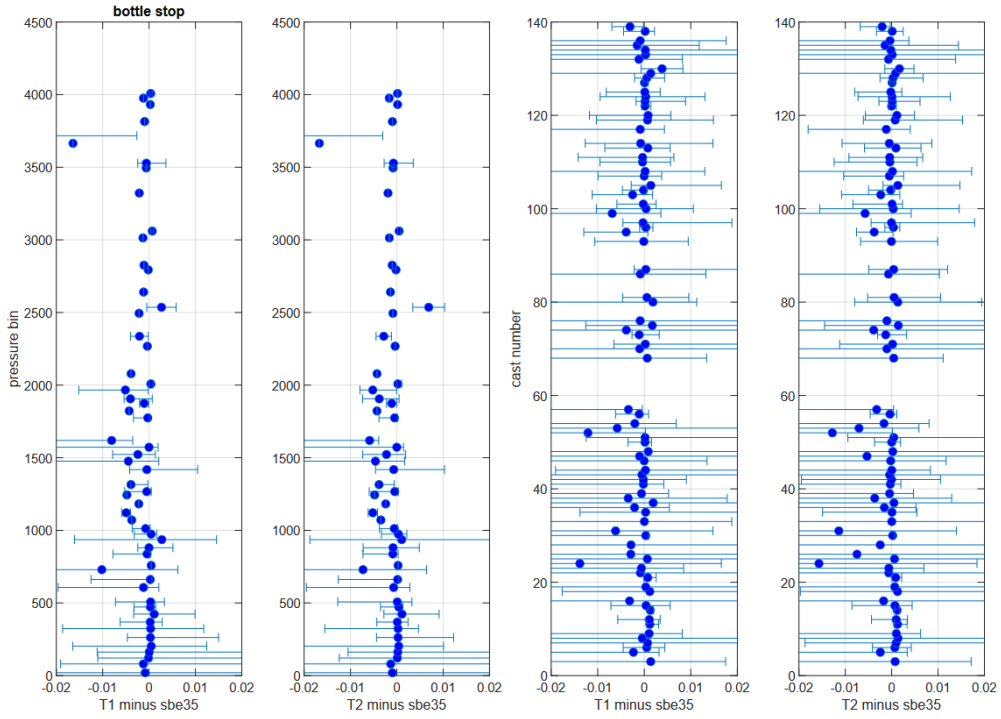


Figure 5-12: Difference between the sbe35 and the primary and secondary sbe3p sensors on the SS frame over the time of the bottle stops, as given by the .bl file. The sbe3p values have been adjusted to match the sbe35. Dots are median differences, errorbars are 95th percentiles.

The difference between the primary and secondary sensors on the SS frame showed some depth and time dependence.

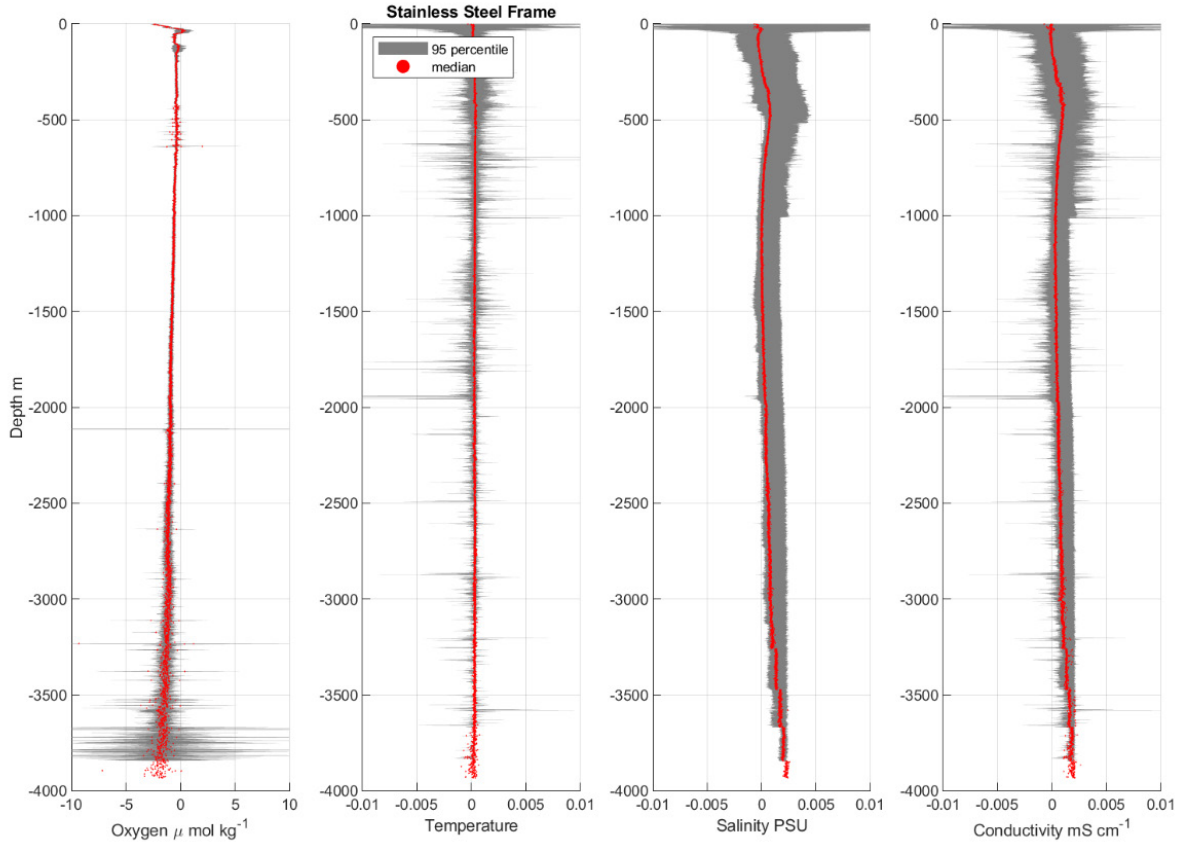


Figure 5-13: Differences between primary and secondary channel instruments on the SS frame against depth. Differences calculated after temperature and conductivity correction.

Frame	Oxygen (micro mol per kg)	Temperature C	Salinity g per kg	Conductivity mS per cm
SS	-0.59	0.0003	0.0003	0.0005
Ti	-12.99	0.0007	0.0004	0.0009

Oxygen differences became lower with depth (the absolute difference increased) with sensor 2 reading higher oxygen values relative to sensor 1 at depth. Temperature differences showed no depth dependence, though variability was higher for measurements shallower than 500 m. Depth dependence of conductivity is complex with a non-linear difference between the sensors with depth. Variability in difference is again higher for water shallower than 500 m.

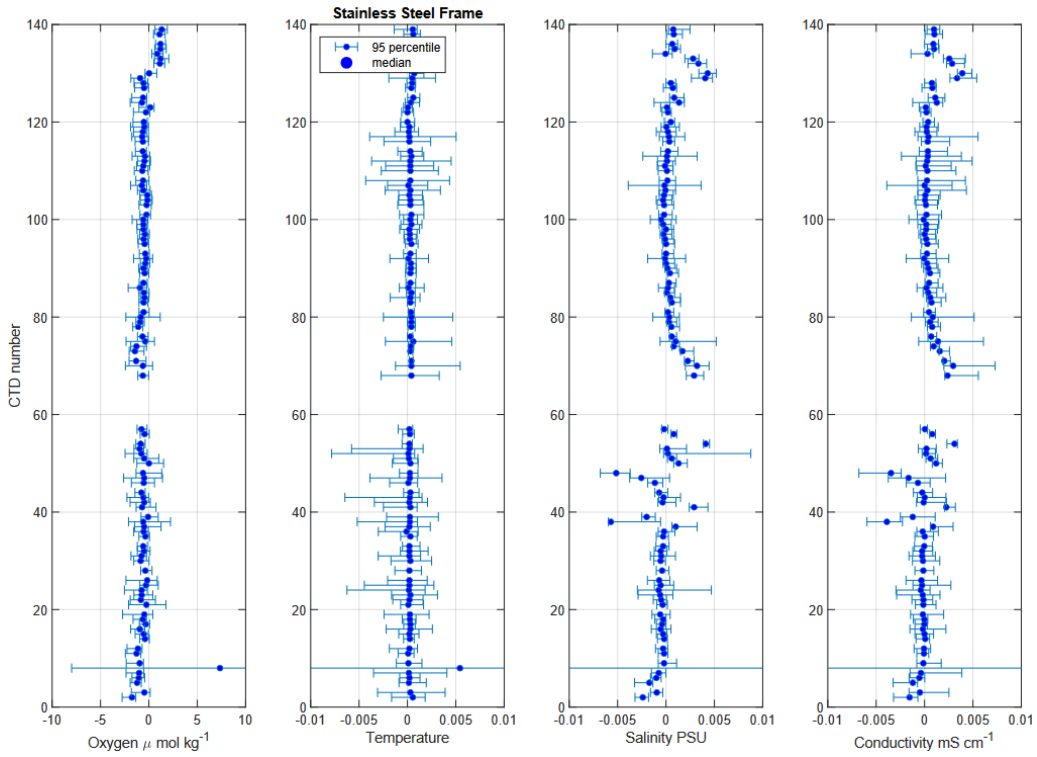


Figure 5-14: Differences between primary and secondary channel instruments on the SS frame against station number. Differences calculated after temperature and conductivity correction.

Oxygen and temperature differences did not show a time dependence. Conductivity difference was low and negative (secondary sensor reading higher values relative to sensor 1) at the start of the cruise. After about 3rd February the difference became highly variable and changed sign several times. After about 6th February the difference settled to positive values and exponentially decreased before stabilizing to a positive difference (sensor 1 reading higher conductivity than sensor 2). The absolute difference remained similar to the absolute difference at the start of the cruise. To test if (oil) contamination caused the change in sensor behaviour channel 1 was soaked in triton on 23 February. The sensor difference increased as expected but remained positive (sensor 1 reading higher conductivity than sensor 2). On 24 February both channels were soaked in triton. Salinity samples were taken from all test casts over this period to monitor effects on salinometry. Conductivity difference between sensors also showed a depth dependence. The difference between the sensors increased rapidly with depth to a local maximum at 400 m before gradually decreasing to a local minimum at approximately 100 m depth. It then proceeded to increase with depth to a maximum difference at the deepest measurements (almost 4000 m). Variability on difference was high in the top 1000 m and the distribution changed shape several times and rather abruptly.

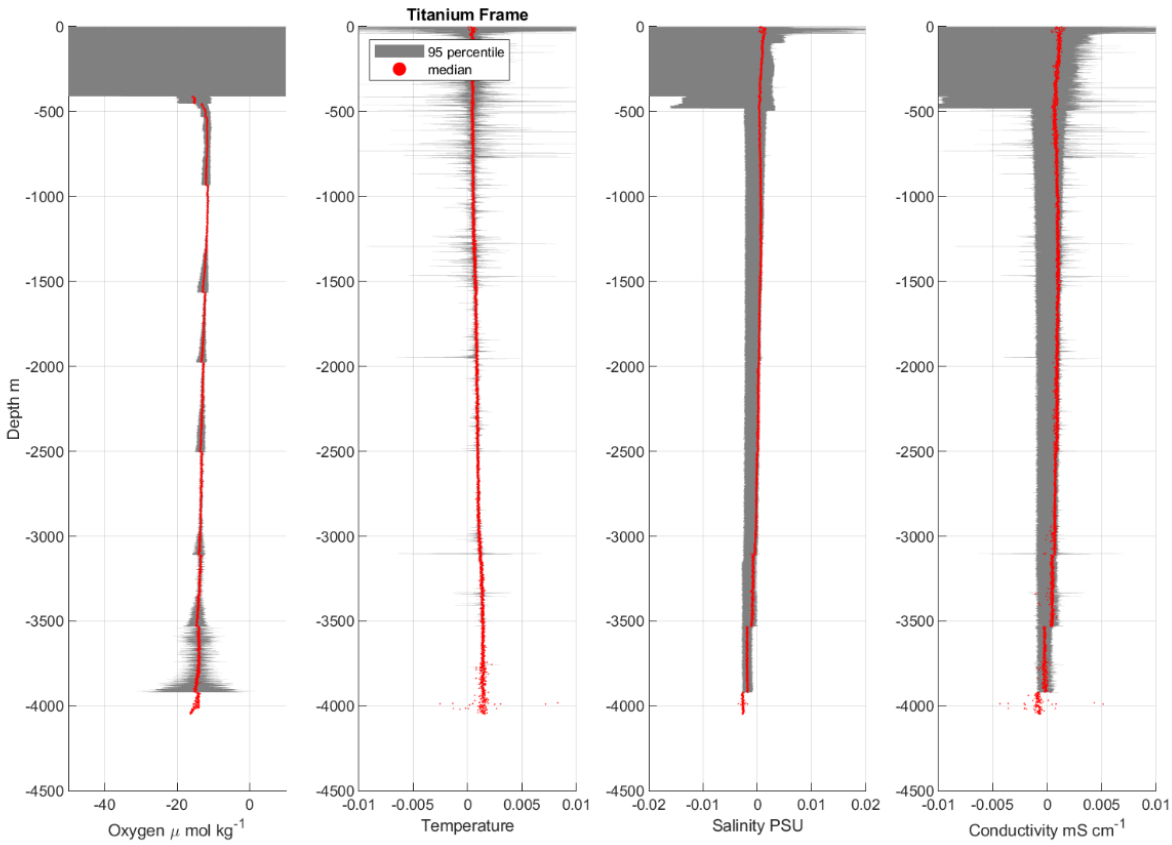


Figure 5-15: Differences between primary and secondary channel instruments on the Ti frame against depth. Differences calculated after conductivity correction.

On the Ti frame all pumped sensors showed some depth dependence. Absolute oxygen difference was high throughout, increased with depth and showed especially high values in the top 400 m and close to the sea floor. Temperature difference increased slightly with depth and variability was higher in the thermocline than in the deep ocean. Conductivity difference became more negative with depth with most of the change happening in the upper 500 m and another increase in difference for the deepest casts. This increase in difference at very large depths is possibly an artefact of the low number of casts that reached depths greater than 3000 m.

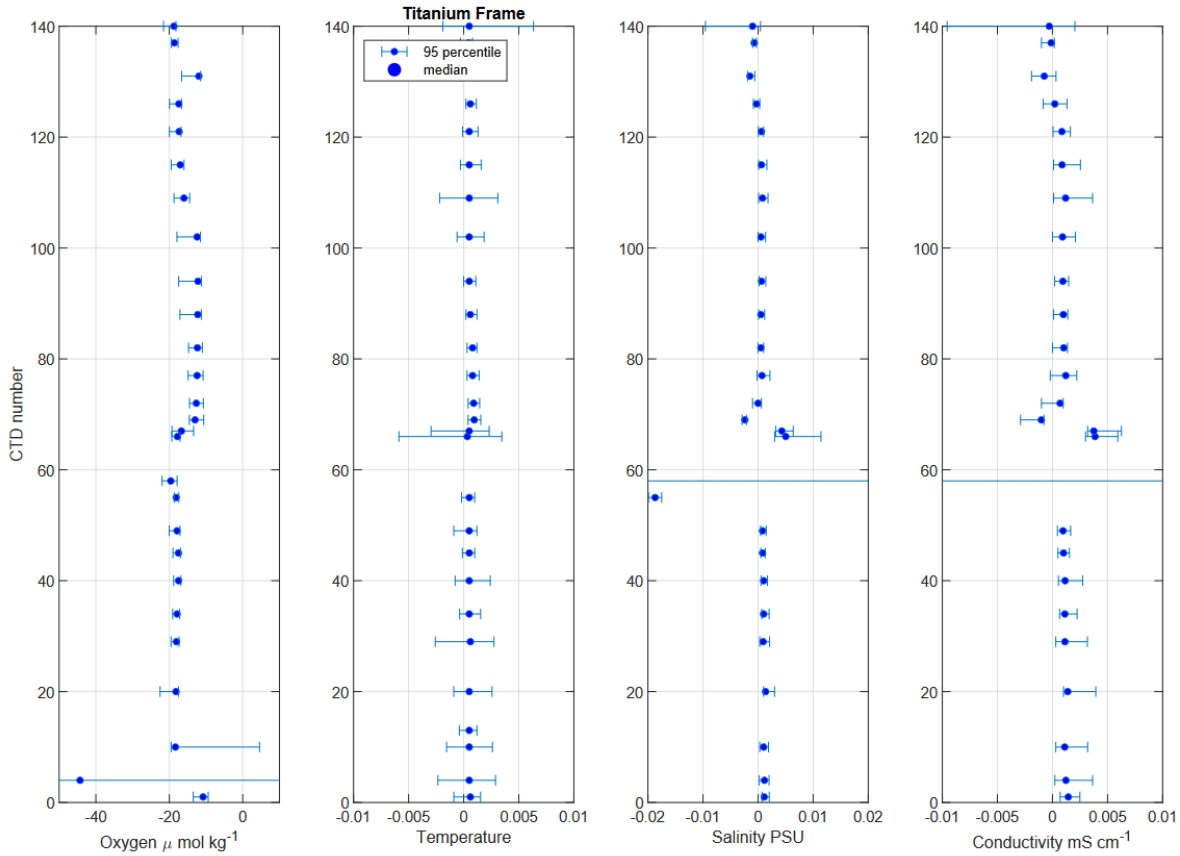


Figure 5-16: Differences between primary and secondary channel instruments on the Ti frame against station number. Differences calculated after conductivity correction.

Preliminary CTD results

We found signatures of several distinct water masses. Surface water was generally fresh and cold. Close to Larsen Ice shelf we found HSSW and ISW. A deep temperature maximum on the shelf slope and in the deep ocean was composed of mCDW. Shelf slope casts and deep ocean casts additionally sampled Weddell Sea Deep Water. Age of the water mass could be seen from oxygen concentration which was high in the surface and deep water, and low in the mCDW.

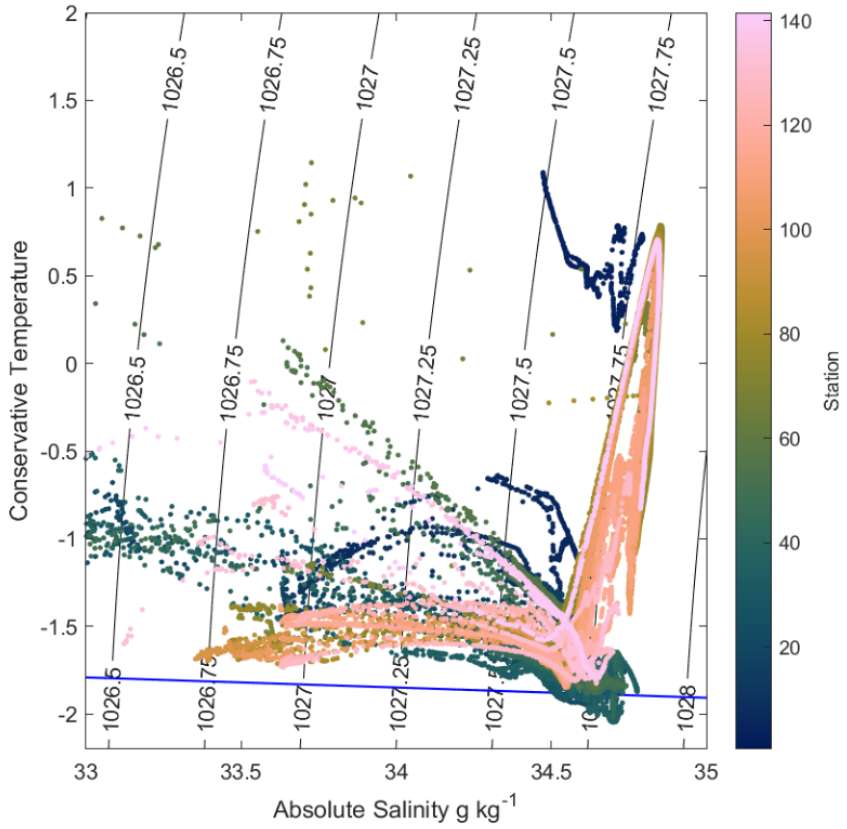


Figure 5-17: TS diagram of all casts color-coded by cast number.

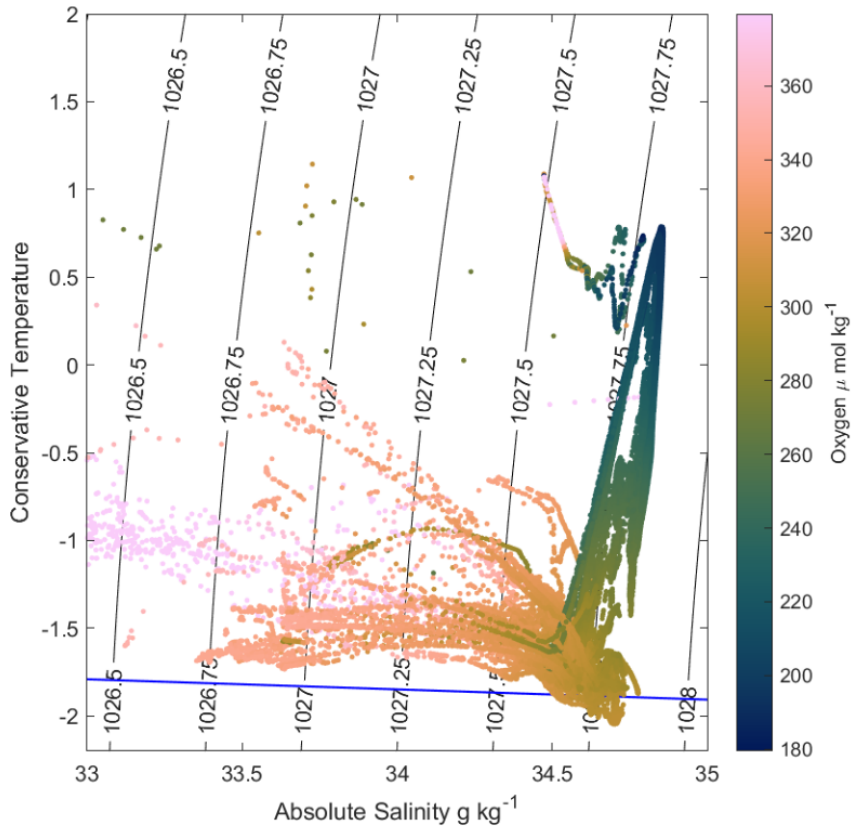


Figure 5-18: TS diagram of all casts color-coded by oxygen concentration.

At the intersection between cold, fresh shelf waters and warmer, saltier off shelf waters we saw interleaving both in the TS diagrams and the downcast traces.

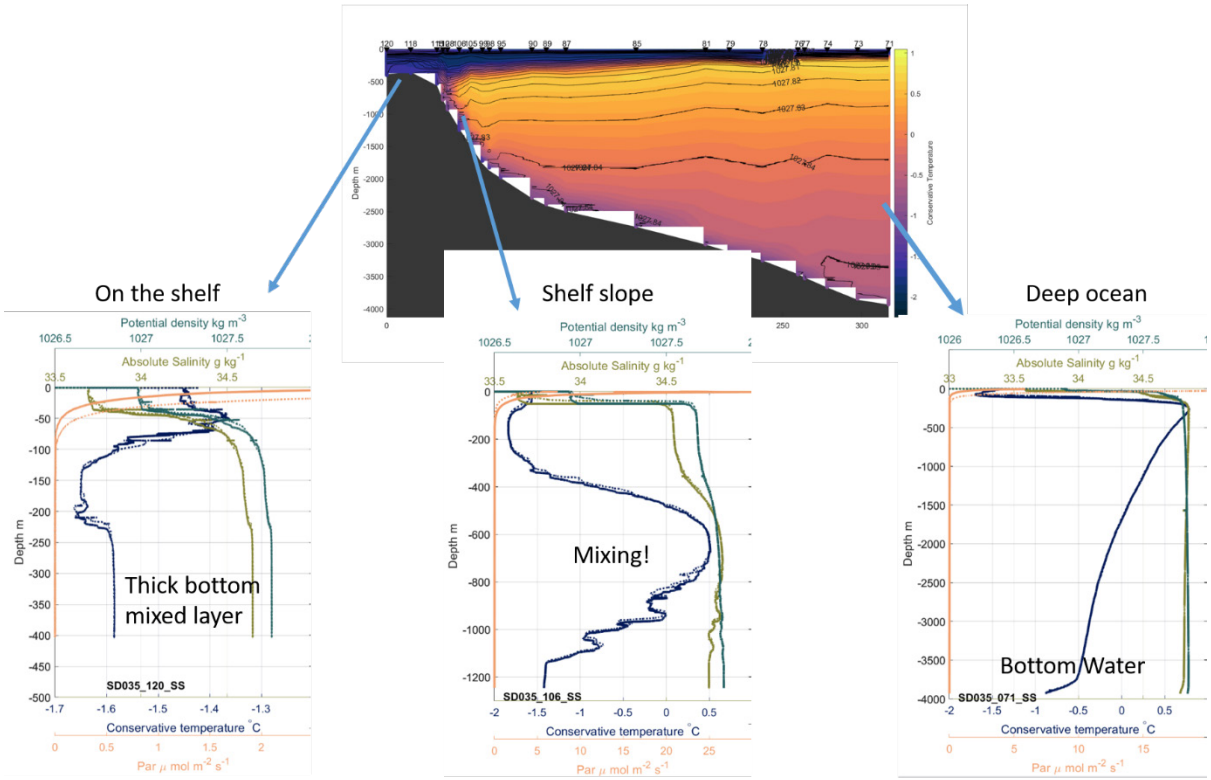


Figure 5-19: Shelf transect showing temperature as colour with representative downcast traces shown below.

6. Lowered Acoustic Doppler Current Profiler (LADCP)

Author: Maren Richter[1]

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LADCP data was collected for all CTD casts apart from those performed for CTD or bottle testing purposes. The LADCP settings are found in SD035_ladcp_BAS_MASTER.CMD and SD035_ladcp_BAS_SLAVE.CMD

The LADCP data was saved on the CTD operator PC and then transferred to the SDA data system before being downloaded to a laptop for further processing. Raw LADCP data was combined with 1 s binned CTD profiles in the LDEO IX software package for Matlab. The scripts set_cast_params.m and batch_ladcp_processing.m were modified to suit our data structure and naming conventions.

Processed LADCP profiles were detided with detide_ladcp.m which uses the CATS08_v2023 tide model called by Chad Greene's Tide Model Driver for Matlab.

Some LADCP profiles did not compile or threw up errors as can be seen in the Table 6-1 below. Increased error estimated due to high shear generally occur during deep (long) casts. Casts 3, 83 and 84 had issues compiling due to issues with the CTD data (soak or upcast corrupted). We noted that the Master and Slave setup has the ADCPs pinging at slightly different rates. As this was the default BAS setup and the data/processing quality did not seem affected we decided to leave the scripts as is. It would, however, be worth exploring the reasons for this choice in ping rate for future cruises.

Table 6-1: LADCP data summary

cast	LADCP used	LADCP processed	Quality
1	x	x	found 173 (5.5% of total) velocity measurements > 2.5 m/s; weak down looking beam 3
2	x	x	OK
3	x		does not run, stops at loadctd: No valid vertical velocities --- aborting
4	x	x	OK
5	x	x	found 139 (4.1% of total) velocity measurements > 2.5 m/s; removed 14 pressure spikes during: 2 scans
6	x	x	OK
7	x	x	OK
8	x	x	OK
9	x	x	OK
10	x	x	OK
11	x	x	OK
12	x	x	OK
13	x	x	OK
14	x	x	OK
15	x	x	OK
16	x	x	OK

17	x	x	Large compass deviation: 18.7311; last LADCP depth is -409
18	x	x	OK
19	x	x	OK
20	x	x	OK
21	x	x	OK
22	x	x	OK
23	x	x	large up/down bias (u=1.94m/s; v=-1.58m/s) --- GPS problems?
24	x	x	OK
25	x	x	OK
26	x	x	OK
27			no ADCP file
28	x	x	OK
29	x	x	OK
30	x	x	OK
31	x	x	OK
32	x	x	OK
33	x	x	OK
34	x	x	mean ping rates differ in downlooker/uplooker data; cast duration differs in downlooker/uplooker data; Large compass deviation: 171.3049
35	x	x	OK
36	x	x	OK
37	x	x	OK
38	x	x	OK
39	x	x	OK
40	x	x	OK
41	x	x	OK
42	x	x	OK
43	x	x	OK
44	x	x	OK
45	x	x	OK
46	x	x	OK
47	x	x	OK
48	x	x	OK
49	x	x	OK
50	x	x	OK
51	x	x	OK
52	x	x	OK
53	x	x	OK
54	x	x	OK
55	x	x	OK
56	x	x	OK
57	x	x	OK
58			TM Niskin bottle firing test cast, LADCP not logging
59			TM Niskin bottle firing test cast, LADCP not logging
60			TM Niskin bottle firing test cast, LADCP not logging
61			TM Niskin bottle firing test cast, LADCP not logging

62			TM Niskin bottle firing test cast, LADCP not logging
63			TM Niskin bottle firing test cast, LADCP not logging
64			TM Niskin bottle firing test cast, LADCP not logging
65			TM Niskin bottle firing test cast, LADCP not logging
66			TM Niskin bottle firing test cast, LADCP not logging
67			TM Niskin bottle firing test cast, LADCP not logging
68	x	x	found 227 (6.8% of total) velocity measurements > 2.5 m/s
69	x	x	Increasing error estimate because of elevated shear - inverse difference
70	x	x	OK
71	x	x	Increasing error estimate because of elevated shear - inverse difference
72	x	x	Increasing error estimate because of elevated shear - inverse difference
73	x	x	Increasing error estimate because of elevated shear - inverse difference
74	x	x	Increasing error estimate because of elevated shear - inverse difference
75	x	x	removed 26 pressure spikes during: 2 scans
76	x	x	Increasing error estimate because of elevated shear - inverse difference
77	x	x	Increasing error estimate because of elevated shear - inverse difference
78	x	x	Increasing error estimate because of elevated shear - inverse difference
79	x	x	Increasing error estimate because of elevated shear - inverse difference
80	x	x	OK
81	x	x	Increasing error estimate because of elevated shear - inverse difference
82	x	x	Increasing error estimate because of elevated shear - inverse difference
83	x	x	last LADCP depth is -2113; Increasing error estimate because of elevated shear - inverse difference
84	x		Cannot determine time offset between CTD and LADCP time series --- aborting
85	x	x	Increasing error estimate because of elevated shear - inverse difference
86	x	x	OK
87	x	x	Increasing error estimate because of elevated shear - inverse difference
88	x	x	found 189 (3.1% of total) velocity measurements > 2.5 m/s Increasing error estimate because of elevated shear - inverse difference
89	x	x	OK
90	x	x	Increasing error estimate because of elevated shear - inverse difference
91	x	x	OK
92	x	x	OK
93	x	x	OK
94	x	x	Increasing error estimate because of elevated shear - inverse difference
95	x	x	OK
96	x	x	OK
97	x	x	OK
98	x	x	OK
99	x	x	OK
100	x	x	Increasing error estimate because of elevated shear - inverse difference
101	x	x	OK
102	x	x	Increasing error estimate because of elevated shear - inverse difference
103	x	x	OK
104	x	x	OK
105	x	x	OK

106	x	x	OK
107	x	x	OK
108	x	x	OK
109	x	x	OK
110	x	x	Increasing error estimate because of elevated shear - inverse difference
111	x	x	OK
112	x	x	OK
113	x	x	OK
114	x	x	OK
115	x	x	OK
116	x	x	OK
117	x	x	Large compass deviation: 20.144
118	x	x	OK
119	x	x	OK
120	x	x	OK
121	x		loadctd: No valid vertical velocities --- aborting
122	x	x	OK
123	x	x	OK
124	x	x	OK
125	x	x	OK
126	x	x	OK
127	x	x	OK
128	x	x	OK
129	x	x	OK
130	x	x	OK
131	x	x	OK
132	x	x	OK
133	x	x	OK
134	x	x	OK
135	x	x	OK
136	x	x	OK
137	x	x	OK
138	x	x	OK
139	x	x	OK
140	x	x	OK
141	x	x	Increasing error estimate because of elevated shear - inverse difference

7. Sea-Ice-Based Measurements

7.1 On-ice work

7.1.1 Introduction

Author: Keith Nicholls[1]

[1]Polar Oceans Team, British Antarctic Survey, Cambridge, UK

Aims

The original PICCOLO project included the use of AUTOSUB to provide profiles of ocean characteristics up to the base of sea ice, undisturbed by the presence of a ship. With AUTOSUB's absence from the project, on-ice work was planned as a partial replacement for the lost observational capability. Broadly, the aim was to disembark a team onto a floe, drill an access hole using an auger, and deploy a CTD and sample bottles into the upper 100 m.

As a result of the opportunity to work on the sea ice, the aims were further broadened to include sea ice coring for BGC and trace metal observations, sampling for radium, and optical measurements, amongst other activities.

Floe selection, safety check and overview of each day

Floe selection

The approach to a candidate floe was made from downwind to prevent airborne impurities from the ship contaminating the surface snow. In addition, thrusters were not used to thrust away from the floe to avoid disrupting the under-ice conditions. The floe was assessed for overall breadth, to ensure the under-ice sampling site could be 100 m or more from open water; flatness, to make it easier to compare near ice base observations between access holes and to avoid ridges on ice floes, potentially leading to holes later covered by snow; and ice depth, as more than around 1.5 m would make the larger access holes more difficult to create, and there were limits on the consumables and processing capacity for the ice cores. Additionally, the aim was to find a floe that was largely surrounded by other floes, to provide an environment as representative as possible of ice-covered waters.

Safety check

Once a suitable floe had been located, the ship drew alongside, starboard side to, and deployed typically three people onto the ice using a Wor Geordie personnel basket. The BIOPOLE team (SDA033) had found that driving at speed into the floe gave a secure and stable basis for the ship. We didn't need to adopt that method during SDA035, which meant that there was no danger of the ship disrupting the platform from which we wished to work. Scramble nets were slung over the side, and a second Wor Geordie deployed from starboard side aft for use in an emergency.

The team of three (two from the science team and one from the Bridge) took a 50 mm auger, powered by cordless drill, an ice-thickness gauge, bog-chisels, a spade, and flagged bamboos. The team was equipped with throw lines and life jackets, and a radio. The ice was tested with a bog chisel, and the ice thickness measured near the disembarkation point. The floe was then assessed by walking to likely-looking areas, probing en route, and measuring the ice thickness. Flagged bamboos were used to mark safe areas that could potentially be the sampling sites. If

the floe was deemed suitable, the equipment was off-loaded, and the gangway deployed for personnel and lightweight equipment. Radios and throwlines were distributed evenly, i.e. one radio and a minimum of two throwlines in each group. A lifejacket was included in all personal protective equipment.

None of the larger floes of a suitable thickness were un-deformed: most displayed several systems of small pressure ridges. The snow covering was thin on all the floes visited, only being thicker around the ridges. The snow itself was heavily transformed by melt and refreezing, and early in the day easily supported a person's weight. Later, the crust softened and gave way underfoot. The ice beneath was always intact. All the floes offered a safe platform from which to work.

Overview of each day

Floe 4 was investigated mid-afternoon, 19/2/24 (Events 247 & 252, 1630 – 1850). The plan was to decide that day if it was suitable, with a view to starting on-ice work on the 20th. The floe was thought suitable, but a medevac meant that science activities had to be paused for several days.

Floe 7 was found and investigated early on 26/2/24 (1045-1110, Event 267). This floe was too thick. Floe 8 was then investigated (Event 268, 1214) and found to be suitable. Equipment was off-loaded, the gangway deployed, and the day spent working on the ice. The ice was finally vacated at 2211.

On the next day, 27/2/24, Floe 9 was identified and assessed. It was found suitable, and activities were largely repeated (Event 273), with all personnel off the ice by 1852.

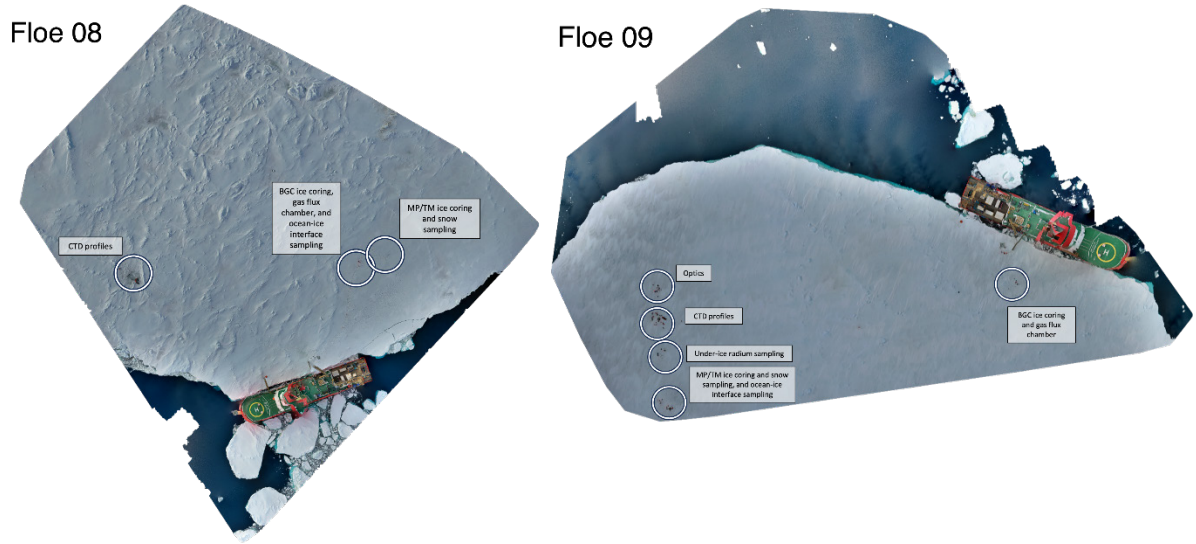

Figure 7.1.1-1: On-ice sampling sites indicated on stitched drone images for Floe 08 and Floe 09.

On-ice activities - overview

Snow sampling

Surface snow sampling for micro-plastics and trace metals was done before the remaining groups deployed to their various sites. A pair from each of the micro-plastics and TM teams

sampled from four sites approximately 15 m upwind of the original safety survey. The two pairs were separated, across-wind, by approximately 15 m.

Ice coring for trace metals and micro-plastics

The sites for coring for TM-free and micro-plastics needed to be sufficiently upwind of other sites and the ship to avoid contamination while the cores were being transferred to plastic bags.

BGC ice coring

Up to six ice cores were required for BGC sampling. The site location was not critical, except that any interfacial sampling that was going to be related to the ice-ocean portion of the core needed to be sufficiently far from the ship and ice edge to be representative of sub-ice conditions.

Sampling interfacial water

A hole created using the ice corer was suitable for interfacial water sampling. Water was recovered using a peristaltic pump via a hose positioned at the ice ocean interface. A temperature and a PH sensor were also located at the interface. The same hole was used to supply interfacial water to a pCO_2 sensor.

Sub-ice CTD profiling and water sampling

A 300-mm hole was made to allow water samples to be recovered using water-sampling bottles and profiling of the sub-ice shelf conditions to a depth of about 95 m. This hole was made at least a ship length from the ship, and ideally a similar minimum distance from the nearest open water. The access hole was created using a Stihl BT131 Earth Auger with a 300 mm bit, and extension rods. As the extensions were not flighted, to avoid sideways drift of the hole, a 50-mm pilot hole was used to guide the auger.

A variety of observations were made through the access hole: a pCO_2 profile; profiles with a RapidCast CTD; profiles with a fluorometer seal tag and a DO sea tag; optics profiles; and video photography using several different cameras. Seal tag casts were also made through the access hole that had been drilled for the optics experiments. (3.7). Water samples were obtained using four, 5-litre OTE C-Free (Model 114) sampling bottles with TM free messengers. Two bottles were dedicated to three TM-free casts, and another two were used for two, BGC casts. The RapidCast CTD, which had a titanium housing, was used on all bottle casts.

A stainless steel, KC Denmark Model 30.000 portable hand winch was used to deploy instruments through the 300 mm hole. This winch included a 3:1 gear box, an electronic line-out counter, and a frame on which to mount the winch.

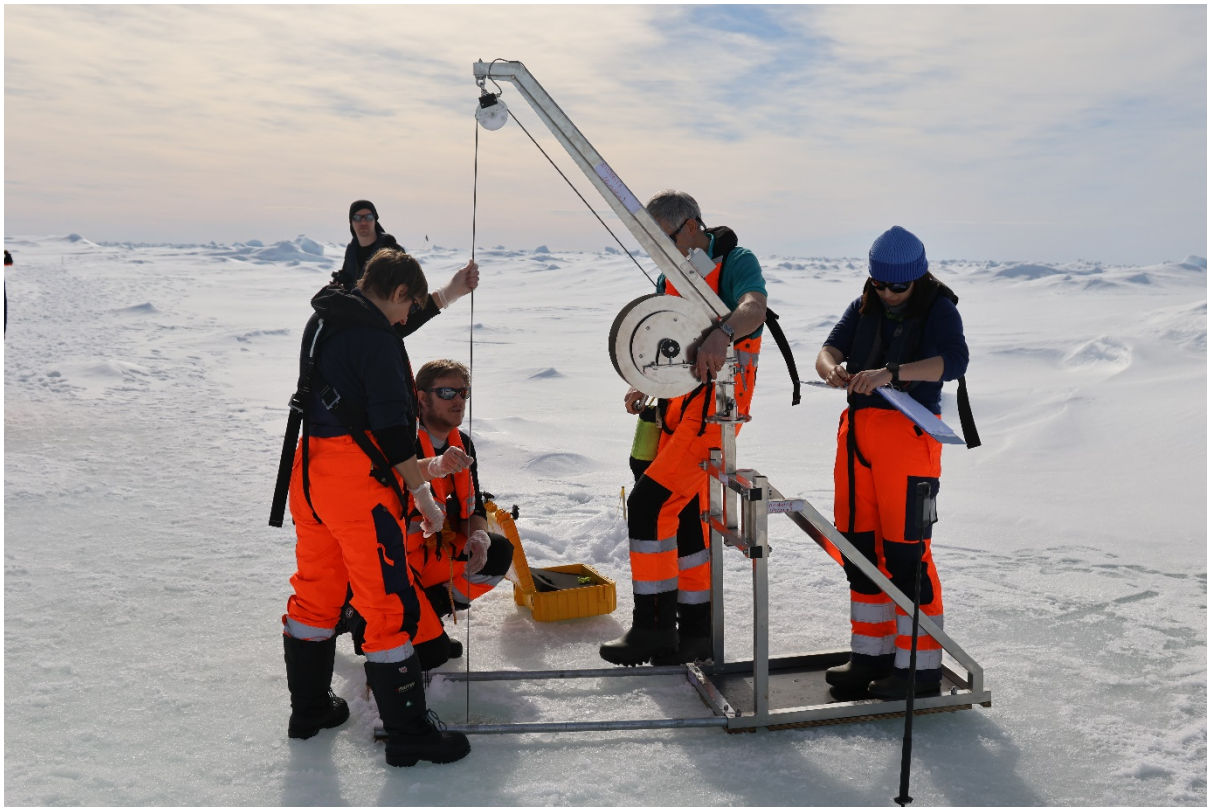

Figure 7.1.1-2: The KC-Denmark winch used during sea ice activities.

Radium sampling

The 50-mm access hole required for the radium sampling needed to be close enough to the sub-ice shelf sampling site (3.5) to be able to relate the results to the TM-free water samples. A vacuum pump arrangement was used to fill six 20-litre carboys with water from near the ice-ocean interface.

Optics

The 300-mm auger was used to create an access hole for the optical experiments. This site was selected to be away from routes of heavy traffic to attempt to reduce shading etc of the ice during the experiments. Optics casts were also made through the BGC access hole.

Flux chamber

An instrument to measure any gas fluxes from the ice was installed quite close to the ship. The flux chamber ran for about 2 hours on each of the two deployments.

Photography

A drone surveyed the two ice floes to help document the activities and provide a simple way of measuring relative distances between the various stations. A variety of cameras were used both for under-ice imagery and to aid in documentation. Under-ice imagery was provided using a MarCum camera, which gave imagery in real time; a GoPro camera; and an Insta360, 360-degree camera.

7.1.2 Snow sampling

Authors: Angela Milne[1], Simon Ussher[1], Flo Atherden[2], Emily Rowlands[2]

[1]School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth, UK
[2]Ecosytems Team, British Antarctic Survey, Cambridge, UK

Microplastics in snow

Since its first introduction in the 1950s, there is now enough plastic pollution to form a permanent and distinct layer in the earth's fossil record. But with comparably low visible plastic pollution in Antarctica, little is known about this plastic legacy on the frozen continent. We collected snow samples from two ice floes with the aim of providing new insights into the presence of plastic pollution in some of the most remote sections of Antarctica and shed light on potential long-range atmospheric transport of microplastics.

At each of the four sites sampled on each floe, two technical replicates were taken. To collect samples, the first 2 cm of snow was removed from the surface before 500 ml polypropylene bottles were filled with snow with a plastic scoop (floe 8) or metal spoon (flow 9). All bottles were rinsed three times with milli-q before sample collection. At two of the sites on each floe, a blank was collected. This involved opening one of the pre-cleaned polypropylene bottles approximately 50 cm away from where the 'true' sample was being collected and closing the bottle once the 'true' sample bottle was closed. The blank will provide insight into microplastic contamination that may have come from the sampler and sampling equipment. All snow samples collected were stored at -20°C. In Cambridge, the samples will be melted and filtered in a plastics-clean laboratory before undergoing Focal Plane Array Fourier Transform Infrared analyses which allow the detection of microplastics down to 11 µm.

Trace metal snow sampling

Upon initial occupation of 2 large ice floe sampling sites, the ship approached from a downwind direction and moored next to the ice floe (Ice floe stations 8 and 9). Snow sampling was conducted first, a joint party of trace metals (Milne and Ussher) with microplastics researchers. Four stations were occupied each sampled in duplicate at the most upwind side of the icefloe. This took place in a line upwind of any track made by initial workers checking the floe and perpendicular to the wind direction which was light northerly/north westerly (see Table 7.1.2-1)

Snow samples were collected in 1L acid washed low density polyethylene bottles (Nalgene) and polypropylene scoops. Researchers lay facing the wind wearing latex clean room gloves and Tyvek sleeves. Pristine snow was collected by scooping snow from the top 10cm of the ground. Typical snow depths were 20-30 cm on the floes and all snow looked to be refrozen as large crystals rather than new 'powder'.

At Ice Floe 8 it was a S to N transect adjacent to the ship, faint westerly wind (sampling into the wind). Paired sampling (2 bottles) at each location. Sampling with Emily & Flo (plastics). At Ice Floe 9 there was some evidence of animal activity (prints from seals and penguins) and a resident seal interrupted sampling but stayed ca. 10 m away.

Samples were returned to the SDA clean lab and acidified (2 mL per litre) with Romil Ultrapure hydrochloric acid. Blanks included an acid blank and 2 bottle process blanks which were taken to the site (Ice Floe 9) opened and left for the same time as the sampling (5 minutes) closed and returned empty for analysis. Laboratory analysis will be conducted by ICP-MS in the shore laboratory at the University of Plymouth.

Table 7.1.2-1: Snow sample log

Date	Time (24 h GMT)	Label ID	Comments (e.g. location / Station information)
26/2/24 Ice Flow 8 On Flow prior to coring etc	12:41	01	Location 1. Depth in area ~ 18cm. Top layer sampled (10cm).
	12:44	02	Location 1. Finished 12:46.
	12:58	03	Location 2. Depth of snow ~ 36cm. Top layer sampled (10cm).
	13:00	04	Location 2. Finished 13:02.
	13:10	05	Location 3. Depth of snow ~7cm.
	13:13	06	Location 3. Finished 13:15.
	13:20	07	Location 4. Deep areas of snow, up to 4ft (122 cm). Top layer sampled (10cm).
	13:23	08	Location 4. Finished 13:25
27/2/24 Ice Flow 9 On Flow Prior to coring etc.	Start: 11:09	09 & 10	**Location 1**:
	Stop: 11:18		Depth ~4cm.
	Start: 11:20	11 & 12	**Location 2**: Towards edge of ice flow
	Stop: 11:32		Depth ~53cm
	Start: 11:41	13 & 14	**Location 3**: Blank sample collected (B1), empty bottle left open during collection.
	Stop: 11:52		Obvious wind felt. Depth ~10cm.
	Start: 12:00	15 & 16	**Location 4**: Blank sample collected (B2), empty bottle left open during collection.
	Stop: 12:12		Depth ~6cm.

7.1.3 Ice cores – BGC

Authors: Elise Droste[1,2], Ian Brown[3]

[1]Alfred Wegener Institute, Bremerhaven, Germany
[2]School of Environmental Sciences, University of East Anglia, Norwich, UK
[3]Plymouth Marine Laboratory, Plymouth, UK

Objective

The objective to collect ice cores was to understand its vertical gradients in various sea ice properties and components. Properties at the top and at the bottom of the ice core help determine the fluxes at the ice-air and at the ice-seawater interface. The vertical profile throughout the sea ice core reflects some of its history and evolution of the sea ice in previous seasons. From this, we can derive a better understanding of the role of sea ice in surface biogeochemical processes, such as gas exchange and carbon sources/sinks.

We collected sea ice cores from both PICCOLO sea ice floes (Floe 08 and Floe 09). We collected a set of sea ice cores for a number of biogeochemical variables, which we refer to as the "BGC cores". These included samples and measurements for temperature, salinity, nutrients, seawater oxygen isotopes, cDOM, flow cytometry, DIC/TA, CH_4/N_2O, primary production, and pigments (Tables 7.1.3-1 and 7.1.3-2). The other set of sea ice cores we collected included cores for the analysis of trace metals and microplastics (Tables 7.1.3-1 and 7.1.3-2). This set of cores is referred to as "TM cores". Sea ice cores within each set were co-located on the floe. To avoid contamination, the TM cores were collected upwind of the ship and all other activities on the ice.

Equipment

To drill the cores, we used two Kovacs® Mark II ice corers with a 9 cm diameter and 1 m length core barrel. One corer was dedicated to the BGC cores, while the other was cleaned and used for the TM cores. However, during the drilling on Floe 08, the barrel of the TM corer got irreparably damaged and coring for the TM cores proceeded with the BGC corer. And extension piece was used when the sea ice thickness was more than 1 m. Drilled sea ice cores were carefully placed on a re-purposed PVC half pipe/drain lined with a tape measure. A separate PVC half pipe/drain was used for the TM cores, which was cleaned on board to minimize

contamination of the trace metal cores. Sea ice temperature was measured with a VWR digital temperature probe. Cores that required sectioning in the field were sectioned with a saw. Sections were collected in appropriate storage bags or containers and placed in plastic or foam boxes for continued storage or processing once on board the ship. Coring and handling of the ice cores was done wearing vinyl gloves.

General conditions on the sea ice

Days spent on Floe 08 and 09 were sunny and relatively warm with very little – if any – wind. Sea ice thickness on Floe 08 was about 200 cm, while on Floe 09 it was around 150 cm. Sea ice in the region had gone through deformation, as ice floe was characterized by many hummocks. The snow was described as "sugary". The transition between the snow layer and the sea ice was difficult to identify due to the presence of snow ice, formed by seawater flooding the ice-snow interface and refreezing of the saturated snow. Many areas around Floe 08 and patches within the sea ice were "slushy". The first cores drilled on Floe 08 had to be discarded, because the sea ice was so porous and "rotten" that hardly any of the ice remained intact enough to be recovered from the coring barrel.

Sea ice core sectioning and sampling

Per sea ice floe, we collected six types of sea ice cores. Each core was destined for a separate array of variables to be measured and analyzed, some of which overlapped between cores (Tables 7.1.3-1 and 7.1.3-2). While the intention is to relate the profiles of each of these variables to each other to constrain sea ice biogeochemical processes, it can be challenging to match up profiles between different cores which inevitably have slightly different lengths. Different methods exist to map sea ice profiles of different variables onto each other, but issues with some of these methods have been identified in that they distort gradients measured at the bottom and top of the sea ice where important exchange processes take place. This is a challenge emerging within the sea ice community, which is becoming increasingly more interdisciplinary in its science. It is being addressed with a new approach to sea ice coring and sectioning based on extensive field work, mainly in the Arctic, and has been applied during the PICCOLO ice coring activities.

The sea ice thickness encountered at the ice coring sites during PICCOLO ranged between about 150 and 200 cm, meaning that each "total" core consisted of a top and bottom core. Sectioning e.g. 15 cm length sections for the top core started at the top, while sectioning of the bottom core started at the bottom (see Figure 7.1.3-1 for an example). The idea behind this approach is that the middle part of the total core will consist of a section that likely has a length less than 15 cm (or slightly more than 15 cm if more volume for samples is required). Once samples have been analyzed, the values for the top and the bottom of the total core can easily be mapped onto each other, regardless of differences in the total length of each total core. The part of the profile in the middle of each total core can be averaged or interpolated. This method assumes that the largest gradients are usually found at the top and bottom of the sea ice.

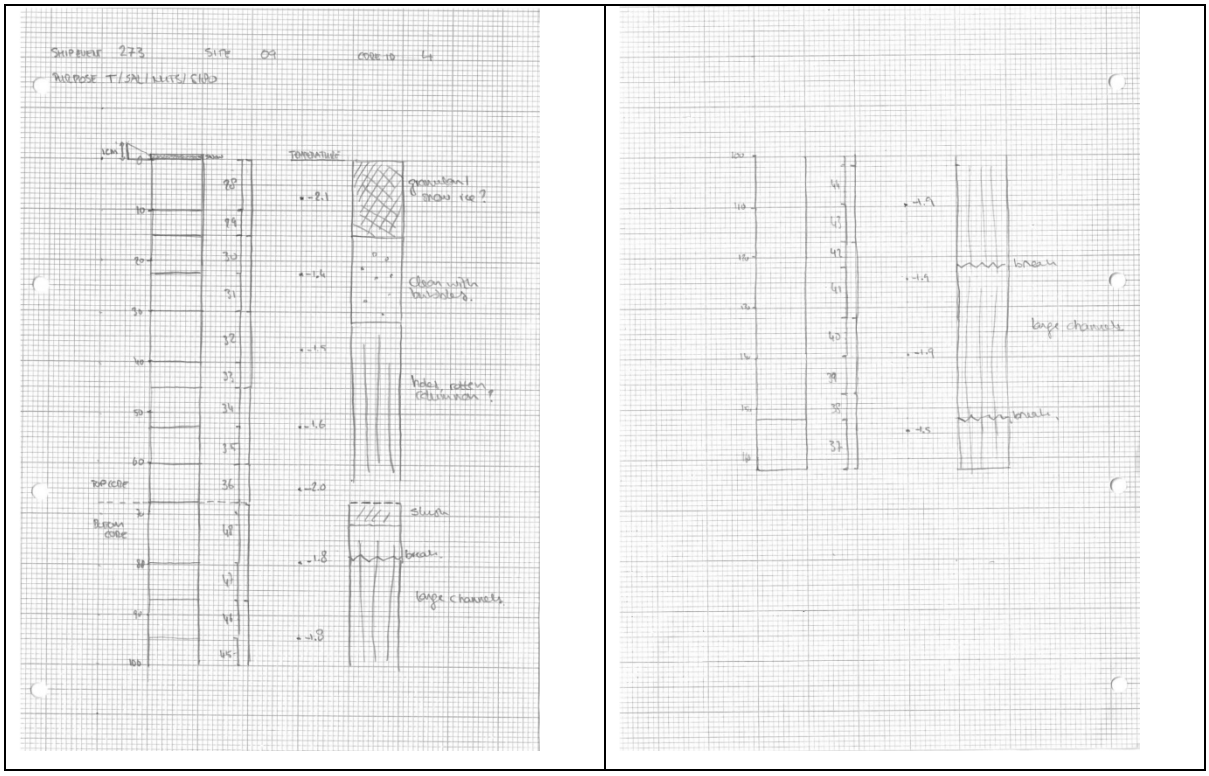

Figure 7.1.3-1: Example of sea ice sectioning in the field (Floe 09, Core ID 4).

Table 7.1.3-1: Overview of sea ice cores collected on Floe 08 on 26 February 2024

Core ID	Purpose/variable to be measured	Part of core used	Number of cores	Contact person
5	Nutrients/seawater oxygen isotopes/salinity/cDOM/flow cytometry (/temperature)	Full core	1	Sarah Breimann (nutrients), Will Homoky (seawater oxygen isotopes), Vassilis Kitidis (cDOM), Glen Tarran (flow cytometry), Elise Droste (temperature)
7	DIC/TA/cDOM/Temperature	Full core	1	Elise Droste
8	CH_4/N_2O	Full core	1	Ian Brown
6	Primary production (PP), pigments	Only bottom 20 cm	1	Ian Brown (PP), Bob Brewin (pigments)
4	Microplastics/POM/temperature	Full core	1	Emily Rowlands
	Trace metals	Full core	2 full cores, 1 half core	Simon Ussher

Table 7.1.3-2: Overview of sea ice cores collected on Floe 09 on 27 February 2024

Core ID	Purpose/variable to be measured	Part of core used	Number of cores	Contact person

4	Nutrients/seawater oxygen isotopes/salinity/cDOM/flow cytometry/temperature	Full core	1	Sarah Breimann (nutrients), Will Homoky ($\delta^{18}O$), Vassilis Kitidis (cDOM), Glen Tarran (flow cytometry), Elise Droste (temperature)
6	DIC/TA/cDOM	Full core	1	Elise Droste
7	CH_4/N_2O	Full core	1	Ian Brown
5	Primary production (PP), pigments	Only bottom 20 cm	1	Ian Brown (PP), Bob Brewin (pigments)
	Microplastics/POM	Full core	1	Emily Rowlands
16, unknown	Trace metals	Full core	2	Simon Ussher

Salinity/nutrients/ seawater oxygen isotopes/cDOM/cytometry/temperature

The first sea ice core was dedicated to the measurement of temperature and sampling of salinity, nutrients, $\delta^{18}O$, cDOM, and flow cytometry. To obtain highest accuracy, temperature measurements were made as quickly as possible after the core had been removed from the ice. Incremental holes were drilled along the length of the core, in which the temperature was measured. For the samples. the intention was to collect 15 cm length sections, but the sampling cups (which were washed with 10% HCl and Milli-Q prior to getting onto the ice) used to store them in were too small. This is why the ice core was sectioned and collected into 7.5 cm sections (or as reasonably close to that as possible) instead, which would be combined to complete the intended 15 cm length sections once melted later in the process. Once on board, these samples were temporarily stored in the -20°C freezer until we had capacity to continue processing. On 3 March 2024, these sections (for both Floe 08 and Floe 09) were melted in 40°C water baths and subsequently cooled back to room temperature. For most of these small sections, there was enough volume to collect a nutrient sample prior to merging the adjacent samples. Another nutrient subsample was then collected from the merged sample, as well as subsamples for salinity, $\delta^{18}O$, cDOM, and flow cytometry. The nutrient samples were filtered through 0.45 µm multi-cellulose ester membrane filters, using a sterile syringe.

While we collected temperature measurements for the top core of the nutrient/salinity/ $\delta^{18}O$/etc. core on Floe 08, we accidentally discontinued the measurements on the bottom core. We therefore decided to re-do the temperature measurements for the full core of the DIC/TA/cDOM core, which was collected directly after the first one.

DIC/TA/cDOM and CH_4/N_2O

The DIC/TA/cDOM and CH_4/N_2O ice core sections (15 cm length) were collected in Tedlar® bags. Once brought back on board, mercuric chloride solution was added to the bags containing CH_4/N_2O ice core sections. The bags were then sealed with Clip'n Seal ® and evacuated through a valve on the bag with a vacuum pump. The CH_4/N_2O ice core sections were subsequently melted at lab temperature (~15°C). We ensured they were fully melted for 3 days, after which the contents of the Tedlar® bags were transferred to 500 mL borosilicate bottles. After melting a volume of compressed air was added removing 145 ml of water creating a headspace. The sample was then shaken on an IKA® shaker for 15 minutes to allow for full equilibration to occur. 60 mLs of the equilibrated headspace was then transferred to a glass vial and sealed with a crimped cap for transportation back ashore and analysis via gas chromatography.

Once evacuated, the DIC/TA sea ice sections were melted in a 4°C storage fridge for 3-4 days to ensure that the samples melted slowly to avoid fast dissolution of any ikaite ($CaCO_3 . 6H_2O$) minerals that may have been present in the ice. One unit of ikaite dissolution increases the DIC content by one unit and increases the TA content by two units. Ikaite formation within brine channels and dissolution in sea ice meltwater potentially plays an important role in the seasonal cycle of the marine carbonate chemistry and atmospheric CO_2 uptake by the ocean in polar oceans. The melting of the DIC/TA sea ice samples was monitored throughout the day. As soon as a section had melted completely, the sample was parsed in a cold room between 4 and 6°C. Most samples completed the melting process overnight from 1 to 2 March. A DIC/TA sample was collected by carefully pouring the melted sea ice into a in a borosilicate bottle, minimising turbulence as best as possible. Due to a lack of volume, we were unable to overflow the bottle like we normally do. The remainder of sample in the Tedlar® bag was used to collected a filtered TA sample and a cDOM sample. For the filtered TA sample, between 55 and 100 mL of sample was filtered through 0.22 µm multi-cellulose ester membrane filters, using a syringe. Any ikaite larger than 0.22 µm would have been filtered out of the sample, implying that any differences seen in the TA measurements of the filtered TA sample and the unfiltered TA sample indicates the contribution of ikaite to sea ice DIC and TA content.

Primary production

Only the bottom 20 cm of the sea ice core was collected for primary production. This section was collected in a ziplock bag, weighed 1 kg, was melted in the dark in 4 L of filtered seawater at approximately 2°C. The incubation for primary production measurements started within 24 hours of ice coming on board.

Microplastics/POM

The core for microplastics/POM analysis was collected in plastic bags as part of the TM ice core set. The total core was sectioned in the field to fit into the foam box for storage.

Microplastic has permeated the Antarctic marine ecosystem from the surface waters to the seabed and has been detected in keystone species such as Antarctic krill (Euphausia superba). From Arctic studies, sea ice has been identified as a significant microplastic sink due to its ability to scavenge particles from the water column during formation. A preliminary study on sea ice from the east Antarctic has shown that Antarctic sea ice can also accumulate microplastics at higher levels than surrounding waters. However, quantification of microplastic abundance in Antarctic sea ice has been hindered by technical difficulties, arising in part, from the high concentrations of biological matter.

We collected three ice cores in total – one from floe 8 and two from floe 9, upwind of other samplers and the ship to minimise contamination. Avoiding the use of plastic in the field is particularly difficult and samples were collected using nitrile gloves and placed into polypropylene bags, however, to further rule out contamination, only the inner part of each core will be analysed.

Microplastic assessment will be achieved using a recently developed analytical method. In short, samples will be melted in a plastics clean laboratory in Cambridge before undergoing enzymatic digestion and oxidation, followed by density separation. This minimalistic approach was developed to limit contamination and prevent sample loss, which is particularly important in potentially low contamination areas such as Antarctica and the Southern Ocean. Microplastic polymers will then be identified via Focal Plane Array micro–Fourier Transform Infrared (FPA µFTIR) microscopy.

Trace metals

The cores for trace metal analysis were cut into <60 cm sections and collected in polyethylene bags and placed in an insulated core box in a -20°C freezer on the ship. These will be processed at BAS in Cambridge and analysed for trace metals at University of Plymouth using ICP-MS techniques.

Challenges

Most challenges occurred on our first day on the ice, which was on Floe 08.

- The sea ice was very porous. The first coring attempts came up with hardly any ice, as it completely collapsed within the barrel and fell through the hole. This also made it more difficult to do accurate sectioning of the core. The high porosity of the ice also mean that the sea ice melt volume was less than expected, but the volumes were still large enough for the planned measurements.
- The drill used for coring overheated on Floe 08, but this was solved by switching to a lower speed/higher torque.
- The barrel of the corer used for the TM coring on Floe 08 got irreparably damaged during the first attempt at coring. The corer used for the BGC cores was therefore used instead for all other TM cores.

Ice coring activities went more smoothly on the second day on the ice (on Floe 09), which was mostly a result of having had the experience and lessons learnt on Floe 08. We took things a bit slower and took our time to first describe the core stratigraphy and sea ice conditions in our field notes, instead of rushing through the coring activities. The sea ice was also less challenging to core on Floe 09.

Preliminary results

Weather and sea ice conditions were comparable between the two PICCOLO ice floes, but preliminary results show a few points of contrast, too. The temperature of the ice was higher by ~1.5°C on Floe 08 (Figure 7.1.3-2). It is possible that this difference is due to the time of day of the measurement and proximity of the sampling site to the ship. The temperature profile on Floe 08 was measured later in the day and in the sun, while the profile on Floe 09 was measured earlier in the day and in the shade of the ship. Another contrast was the snow depth, which was thicker on Floe 08 (~20 cm) than on Floe 09 (< 5 cm).

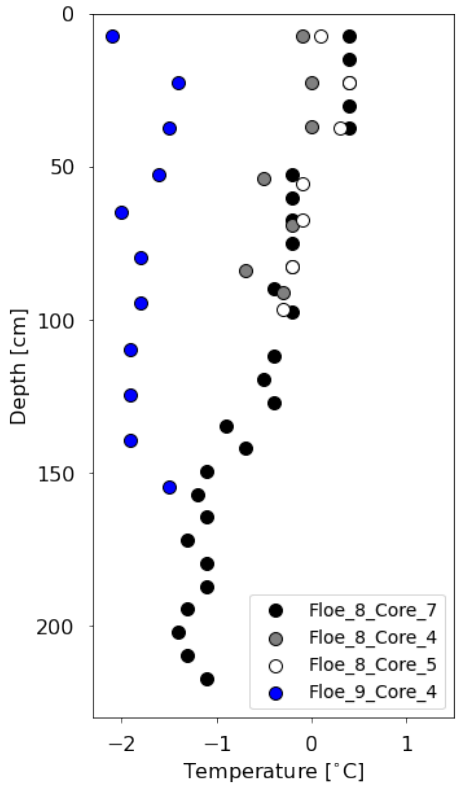

Figure 7.1.3-2: Sea ice core temperature profiles for Floe 08 and Floe 09.

7.1.4 Interfacial water sampling

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[1]*Alfred Wegener Institute, Bremerhaven, Germany*
[2]*School of Environmental Sciences, University of East Anglia, Norwich, UK*

To sample the water directly underneath the sea ice, we used one of the ice core holes in the sea ice. On Floe 08, we used the hole of core ID 7 (of which the core was used for DIC/TA/temperature). On Floe 09, we used the hole of core ID 16 (of which the core was used for trace metals). We attached Tygon® tubing to a long bamboo stick marked with centimetres (Figure 7.1.4-1). The tubing was fed through a peristaltic pump, which has a maximum flow rate of about 0.8 L min^{-1}. At the lower end of the bamboo stick, we attached a temperature probe and a pH sensor. The stick was then secured through the hole and positioned so that the end of the tubing was between 5 and 15 cm below the sea ice. Ice thicknesses at the interfacial water sampling site on Floe 08 and 09 were 200 cm and 155 cm, respectively.

Samples were collected for the following variables: CH_4/N_2O, DIC/TA (duplicate), nutrients, salinity, cDOM, pigments, chlorophyll, AFC/Lugols, primary productivity/bacterial productivity/DOC, DOM, POC, respiration, and seawater oxygen isotopes (triplicate). On the outlet-side of the peristaltic pump, the tubing was connected to a Pro Oceanus CO_2 analyser. The outlet of the Pro Oceanus CO_2 was problematic in terms of bubble formation. This is why we decided to collect the CH_4/N_2O and DIC/TA samples first, and only connect the Pro Oceanus CO_2 analyser immediately afterwards.

Figure 7.1.4-1: Set up of the peristaltic pump to sample seawater at the ocean-ice interface on Floe 08 (left) and on Floe 09 (right).

7.1.5 CTD casts and water sampling

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We used multiple CTD instruments to obtain salinity and temperature profiles. In our first pilot cast, to obtain an estimate of the mixed-layer depth, we used a CastAway, a CTD instrument that has an integrated screen that displays the profiles immediately after the cast. Unfortunately, the CastAway failed to record any data. We therefore conducted all our CTD profiles using a RapidCast. The RapidCast uses titanium for all the external metal parts and hence is trace-metal (TM) free.

The length of the winch rope we used was approximately 97 m. The winch had an electronic line-out meter. Before deployment, we measured an approximately 23.5-m length of the rope and calibrated the line out reading (22.9 m) against that length. We tied a 17-kg, epoxy-covered weight to the end of the rope to minimise the effect of ocean currents tilting the rope (Figure 7.1.5-1). We used another string to tie the RapidCast to the weight and measured the distance between the weight and the conductivity sensor of the RapidCast. During our on-ice work, a winch operator controlled the rope line out. We winched the rope at about 30 cm per second for both upcast and downcast.

For taking the water samples, we used two bottles and two messengers designated to fire the bottles (Figure 7.1.5-1). For each CTD cast, we winched down the rope and zeroed the rope reading when the top of the weight is entering the water. We then lowered another 2-10 metre of rope and attached bottle #1 to the rope before continuing winching down. We recorded the rope reading when the top of bottle #1 entered the water, and continued winching down the rope a distance that depended on the desired depth interval between the two bottles #1 and #2. We then attached bottle #2 and messenger #1 to the rope and winched down while noting the line out reading when the top of bottle #2 reached the water. Subsequently, the winch operator winched downwards again, until we reached the desired bottle sampling depth. Messenger #2 was then clipped around the wire and dropped, which fired the upper bottle and triggered the release of the next messenger, firing the lower bottle.

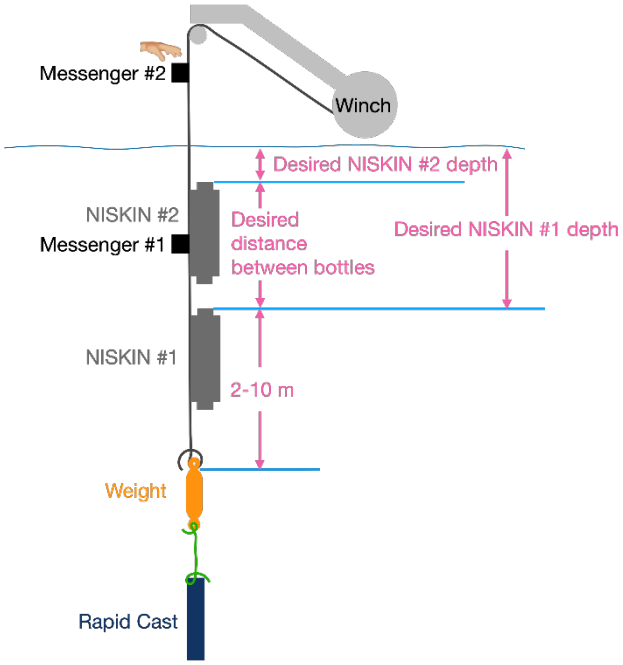

Figure 7.1.5-1: Schematic of the arrangement used for water bottle sampling.

We conducted eight CTD casts on Floe #8 and six CTD casts on Floe #9. Every time the magnetic tag was removed from the RapidCast, it generated one file, yielding six files on the first day and four on the second (new files were not necessarily started between bottle casts). On both days, we repeated CTDs through the same hole. Two CTD casts from the first day and one CTD cast from the second day reached the maximum line out (CTD depth was ~ 98 m), the remainder being shallow casts with their maximum depths dependent on the purpose of the cast.

RapidCast recorded the temperature, conductivity and pressure at a 32 Hz sampling rate. We show here the conservative temperature and absolute salinity measured for the different floes. The upper few metres of CTD data from each cast showed serious spiking when the profiler had not had enough time to soak. In those cases the data from the up-cast was preferred. Thus, we flag for removal the first ~4,000 scan counts (equivalent to about 2 mins) in each data file (Table 7.1.5-1). For several files, as a result of longer time on the surface for preparations, the RapidCast was switched on for a couple of minutes before entering the water, so a more scan counts need to be flagged. To minimise the flagged scan counts, we conducted a visual inspection of the time series of the temperature and conductivity, and marked the scan counts when the measurements stabilised (Table 7.1.5-1). The scans when the RapidCast was within the borehole (above the ice base) were also flagged. This was essentially for all measurements when the pressure registered less than 0.8 dbar.

Table 7.1.5-1. The cut-off scan count for each file.

	File #1	File #2	File #3	File #4	File #5	File #6
Floe #8	10,000	8770	13,800	2070	4000	11,270
Floe #9	16,500	4,000	4,000	11,000		

The relatively limited resolution of the RapidCast data was noticeable: the data were stored to three-decimal places, which results in steppiness in the unfiltered profiles. For the data shown in Figure CTD #2, a Chebyshev low-pass filter was used with a cut-off frequency of 0.16 Hz (equivalent to roughly 1.8-m bin, depending on the speed of the profiler). We follow the Thermodynamic Equations of 130 Seawater-10 (TEOS-10; McDougall and Barker, 2011). More detailed quality control for the data will be required.

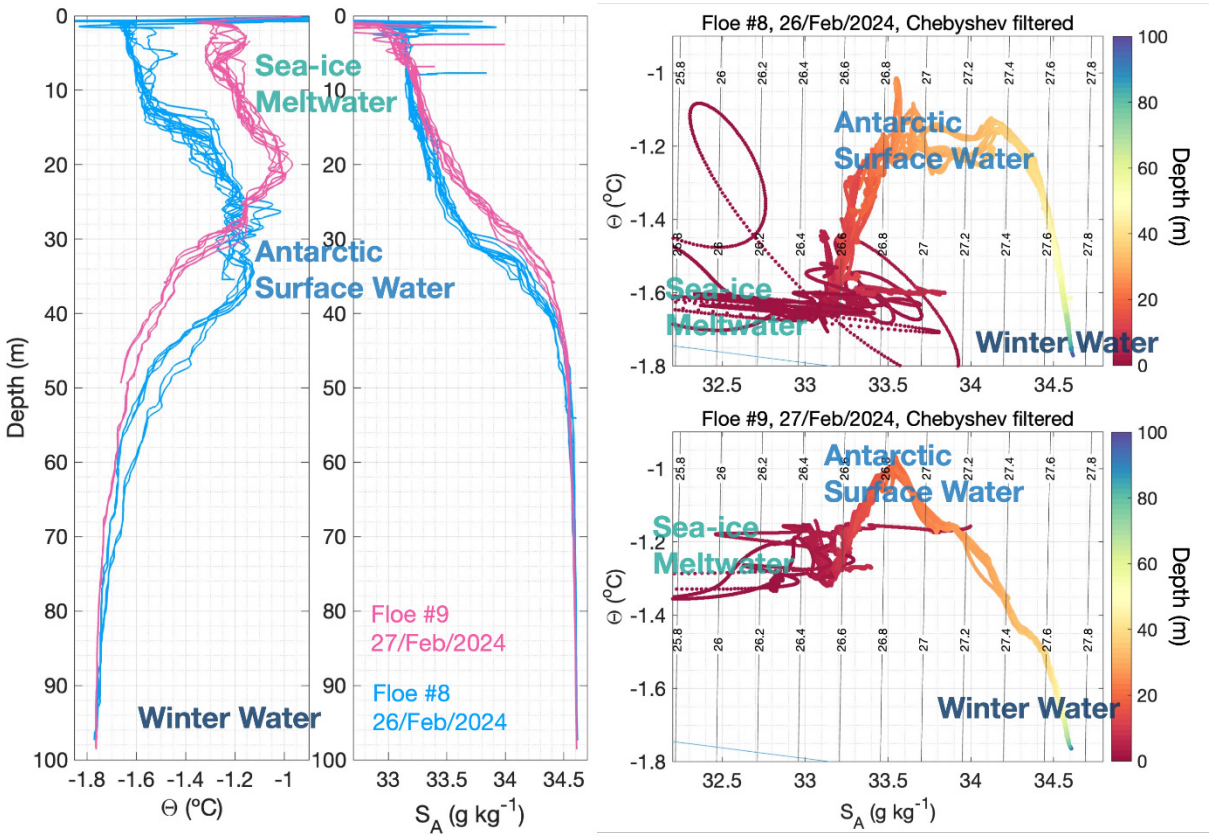

Figure 7.1.5-2. The profiles and T-S diagram of the conservative temperature and absolute salinity (S_A) from our two ice floes. The approximate locations of the different water masses are marked in bold font.

Trace metal water column sampling

Under ice water column samples were collected using Ocean Test Equipment - GoFlo type bottles (Water Sampler, C-Free, Teflon coated, 5 L) with external elastic cords for trace metal work. These bottles had been pre-soaked with filtered seawater collected from the trace clean tow-fish to clean and precondition for under ice sampling. Two bottles were dedicated to the trace metal sampling which was undertaken before the biogeochemical casts. These two bottles were used to sample three depths. For the shallowest depth, water was collected from 5 m & 8 m using both bottles; the separation was needed to ensure that the messenger would close the lower bottle. On recovery of these shallow samples, the water was dispensed into an acid-clean 20L LDPE carboy. This was done away from any other on-ice activities and 'upwind' to prevent possible contamination of the collected water. Sampling for deeper depths (20m & 40 m for both ice floes) was undertaken once sufficient water had been collected to cover all

parameters needs. On recovery, each GoFlo bottle was placed into a cooler. Once collection of water column water was completed, the two GoFlo bottles and the 20L carboy were returned to the clean sampling laboratory on the ship for sampling. This followed a similar manner to that undertaken by the sampling of the 12L GoFlo bottles (i.e. unfiltered samples were collected first, followed by filtered (0.2 µm) samples by pressurising the GoFlo bottles). The record of samples collected from under ice are recorded in Table 9.5-1 of the trace metal station log.

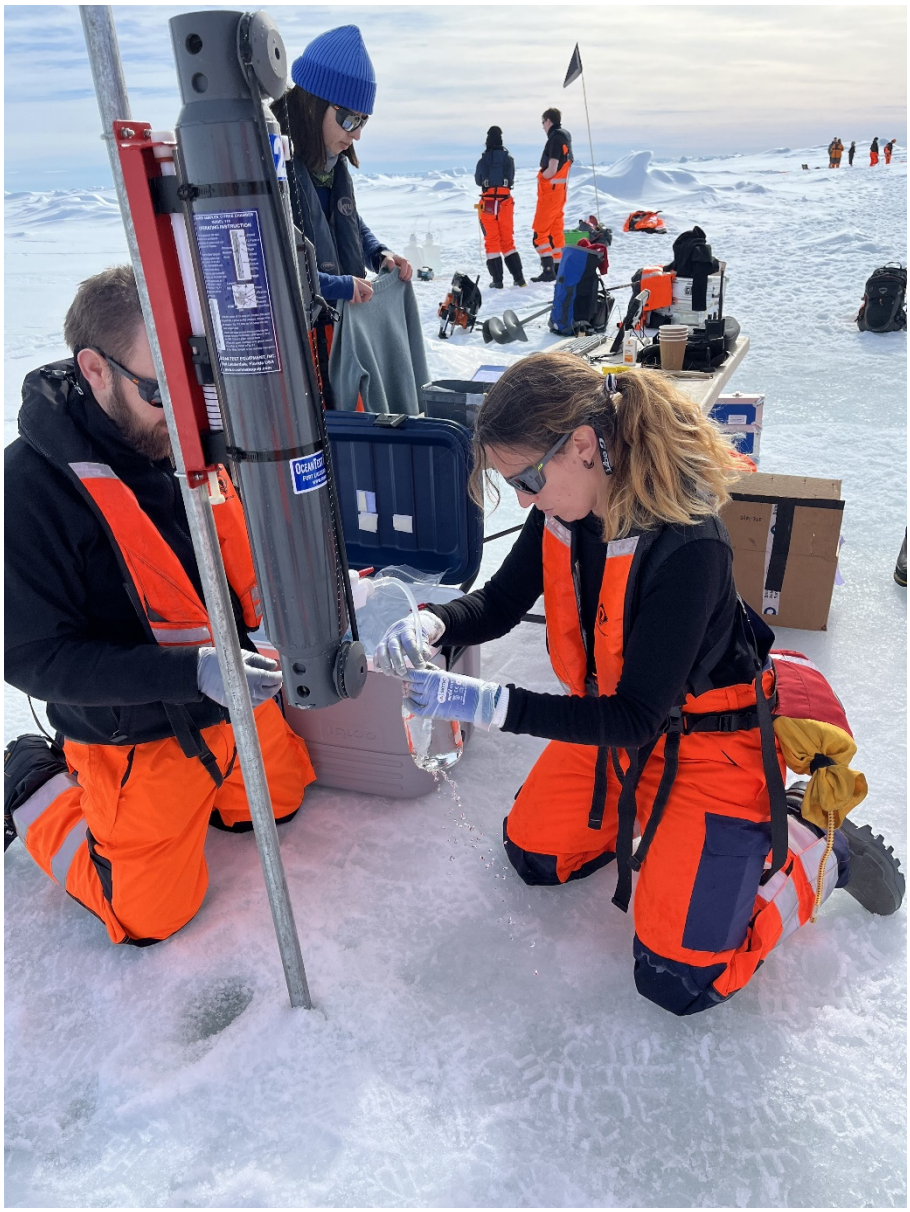

Figure 7.1.5-3: Drawing samples from one of the OTE C-Free sample bottles

pCO_2 instrument profiles

One cast on each ice floe was for a pCO_2 profile. The instrument was clamped to a length of rope suspended beneath the weight, and just above the RapidCast CTD. The pump for the instrument was mounted on the RapidCast, along with a self-recording pH sensor. To ensure that all instruments were sampling the same water, the pH sensor and the inlet to the pump were mounted as close as possible to the CTD measurement volume.

The package was lowered to discrete depths and left at each depth for four minutes (Floe 8) or six minutes (Floe 9).

7.1.6 Radium sampling

Authors: Alastair Lough[1], Will Homoky[1], Chiara Krewer[1]

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Holes were drilled through the ice flow with a 50 mm auger drill. Radium samples were collected from the interface of the ice hole, ~5 cm from the underside of the ice. An LDPE tube was zip tied to an extendable nylon pole with stainless steel connectors. Stainless steel connectors were taped so as not to pose a contamination risk for trace metals. Greater than 140 L of seawater was collected into carboys through the tubing using a battery powered portable vacuum pump (Makita). Sampling 100 L used 1x battery pack and a spare was required to complete the sampling. Ten-minute breaks were taken between removing 20 L volumes to minimize any potential disturbance of the fresher melt water-seawater interface. A video was taken directly from the sampling hole using an insta360 camera. On ice floe 8 (hole 16) a video was taken directly from the sampling hole after sampling was complete and on ice floe 9 from a second hole (hole 13) next to the sampling hole 15 taken during pumping. The video from ice floe 8 shows a shear boundary between layers of water of differing density, indicating minimal disturbance of the meltwater-seawater interface. The video from ice floe 9 is limited due to ice obstructing the camera. After sampling filled 20 L carboys were then taken back to the ship to pass the water over the MnO2 fibre in the same way the CTD samples were processed. A single (>140 L) sample was taken from each of the ice floes sampled during SD035.

7.1.7 Optics

Authors: Bob Brewin[1], Giorgio Dall'Olmo[2], Xuerong Sun[1]

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Objectives

Our objectives were to measure the attenuation of spectral irradiance and photosynthetically available radiation (PAR) through the ice and the water column below it, to:

- investigate absolute light levels directly below the ice relative to light at the surface, for use in primary production incubations.
- investigate changes in spectral light through the ice caused by snow, ice, and ice algae.
- measure and investigate the attenuation of light in the water beneath the ice.
- measure and investigate backscatter and chlorophyll-a fluorescence in the water beneath the ice.

Measurements were collected on two floes (8 and 9) on the 26th (Hole 10 and 11) and 27th February (Hole 12 and 14).

Equipment

- 2x Li-Cor PAR sensors.
- 1x Sensing Secchi Disk measuring multi-spectral visible light (built by Bob and Tom Brewin before the cruise).
- 1x Low light Sensing Secchi Disk (built by Bob and Carson during the cruise) measuring very low multi-spectral visible light levels (adjusted gains and integration time, following light level estimate of Mobley et al. (1998) below ice) and pressure (see Figure 7.1.7-1A-B)
- Above-surface pole for collecting surface light measurements above the height of people and kit used on the ice (built by Bob, see Figure 7.1.7-1C).
- Swing arm (built by Bob and Rob, Deck Engineer) designed to collect light measurements away from the 300-mm auger hole (see Figure 7.1.7-1D, E and G).
- ECO-FLBB Backscatter and chlorophyll-a fluorescence sensor (same instrument used on the PICCOLO mooring, see Figure 7.1.7-1F).
- PAR sensor and spectral irradiance sensor (HyperOCR) measuring surface light continuously on the ship for the duration of the events (see Figure 7.1.7-1C).

Method

On the 26th of February, at hole 11 (ice thickness 1.535 m), light was measured above surface (to calibrate sensors with ship PAR and irradiance sensors), and below hole 11 (while one PAR sensor measured above it) using the swing arm, directly below the ice at 1.535 m, and at 2.325 m below ice surface, at a single fixed angle. A light, backscattering and fluorescence profile was then performed down to 46 m depth, deployed through the auger hole. A second profile was also performed in hole 10 (ice thickness around 0.8 m) where water samples were collected. Go-Pro footage was collected below both holes for analysis after the sampling. Viewing the hole beneath the ice demonstrated how variable the ice algae and thickness was and highlighted potential issues of light coming through the auger hole and influencing light measurements (even with the swing arm). This informed the sampling on the following day.

On the 27th of February, at hole 12 (ice thickness 1.16 m) light was measured above surface (to calibrate sensors with ship PAR and irradiance sensors). Unfortunately, the Li-Cor PAR logger ran out of memory so the calibration with PAR on the ship could not be performed (though we had data from the previous day for calibration), but the spectral irradiance measurements (from the sensing Secchi disk) were successfully collected. Spectral light below hole 12 was then measured using the swing arm at 1.16 m below the ice surface, i.e. directly below the ice base, at four different angles (to check for variations in light levels), and also at 2.01 m below surface ice surface. Data were collected with and without covering the hole with a black bag and towel, to check if the light coming through the auger hole was influencing light measurements. Go-Pro footage was collected below hole 12 with and without covering the hole (Figure 7.1.7-1H and I) and suggested that covering the hole reduced the light considerably. A light, backscattering and fluorescence profile was then performed down to 46 m depth in hole 11, deployed though the auger hole. A second profile was also performed in hole 14 (where water samples were collected).

Figure 7.1.7-1. (A and B) Low-light black Sensing Secchi Disk designed to measure very low multi-spectral visible light levels. (C) Above-surface pole for collecting surface light measurements above the height of people and kit used on the ice. (D, E and G) swing arm designed to collect light measurements away from the 300 mm auger hole. (F) Profiling using the low light Sensing Secchi Disk and ECO-FLBB Backscatter and chlorophyll-a fluorescence sensor. (H and I) differences in the light environment between not covering (H) and covering (I) the auger hole, as seen from a Go-Pro.

Initial Results

Initial data processing (subject to cross-check and post processing) suggests light levels directly below the ice (PAR) were at around 0.2-0.4% of light above the surface at hole 11 (Ice thickness 1.535 m) and around 1 % of light above the surface at hole 12 (Ice thickness 1.16 m). We found a significant reduction in light levels recorded below the ice (of around 25% in absolute values) by covering the auger hole when sampling. However, this had only a small influence on the percent change in light levels relative to the surface (where light was so much higher). The low light level Sensing Secchi Disk seems to successfully capture attenuation in light levels in the water below the ice, and we successfully measured profiles of backscattering

by particles and chlorophyll-a concentration at the four holes on both floes (see example in Figure *7.1.7-2*).

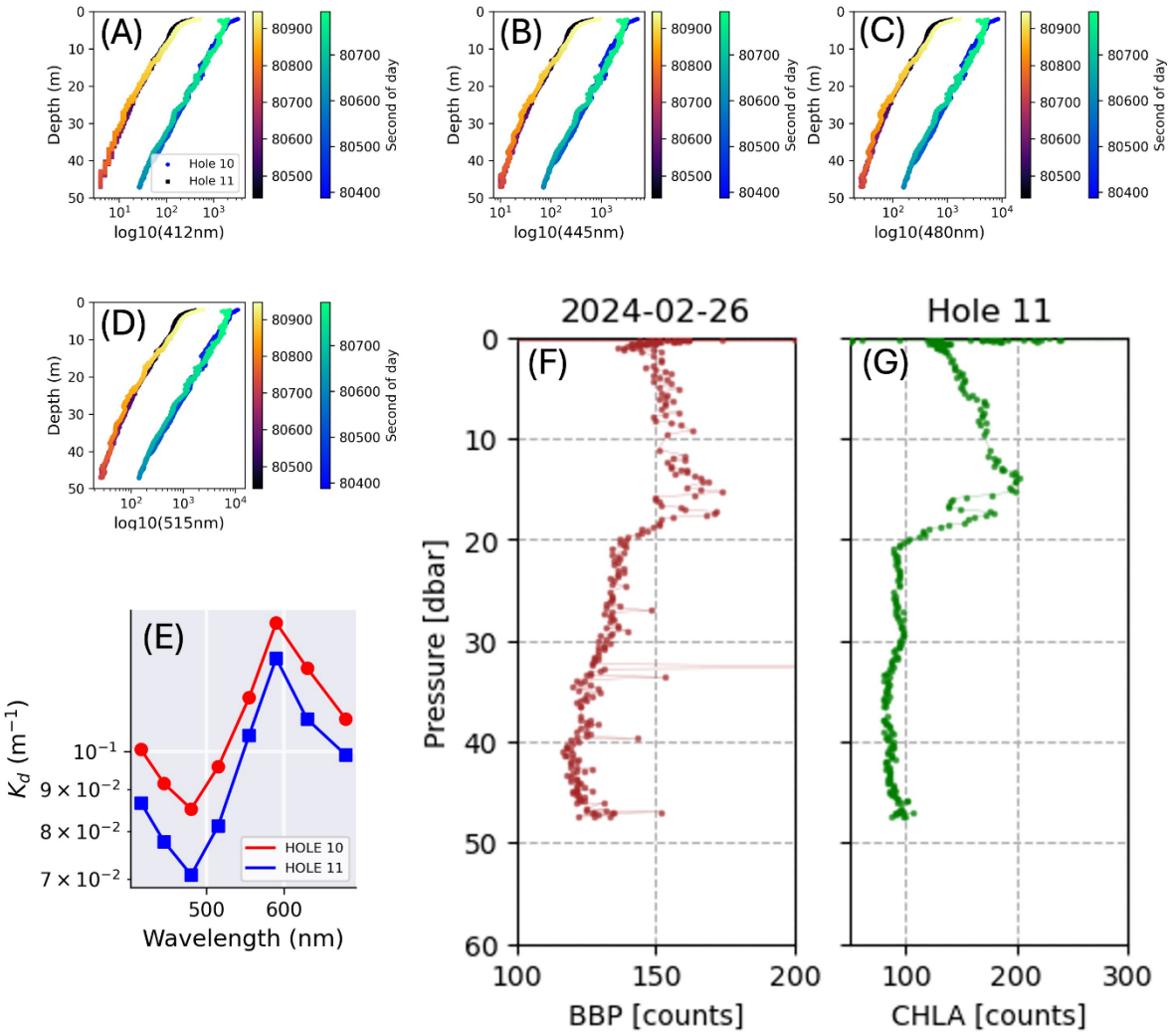

Figure 7.1.7-2 (A-D) Show vertical profiles of spectral light data at 412, 445, 480 and 515 nm, below the ice at holes 10 and 11 on floe 8, measured using the low-light level Sensing Secchi disk. The red and orange colored data are from hole 11 (where ice thickness was much greater, at 1.5 m) and blue green data from hole 10 (ice thickness 0.8 m) and illustrate large difference in the magnitude of light levels below the ice, as a function of thickness. (E) are initial spectral attenuation coefficients fitted to the whole profile. (F and G) are vertical profiles of particle backscattering and Chl-a derived from the ECO-FLBB backscatter and Chl-a fluorescence sensor.

Acknowledgements

- The AME Carson, Rob and Byrne, the deck engineers, were fundamental in allowing us to develop the kit to do these measurements. They were all amazingly helpful. We also thank Sophie Fielding for suggesting using (and lending us) the ECO-FLBB Backscatter and chlorophyll-a fluorescence sensor.
- We thank Tom Brewin at Brewtek Ltd for remote assistance in building the low light level Sensing Secchi Disk.
- We thank the captain and the officers for coordinating all operations and the crew for their help.

References

Mobley, C.D., Cota, G.F., Grenfell, T.C., Maffione, R.A., Pegau, W.S. and Perovich, D.K., 1998. Modelling light propagation in sea ice. *IEEE Transactions on Geoscience and Remote Sensing*, *36*(5), pp. 1743-1749.

7.1.8 Greenhouse Gas Flux Chamber Flux chamber

Author: Ian Brown[1]

[1]*Plymouth Marine Laboratory, Plymouth, UK*

At the BGC ice core location an Eosense® eosAC gas flux chamber connected to a Gasmet® DX4015 FTIR gas analyser was set up to measure any fluxes of CO_2, CH_4 or N_2O coming from the ice. The analyser and chamber were each connected to a 12 volt leisure battery with the flux chamber set to lift and flush the headspace at 10 minute intervals. The flux rate is then calculated based on the rate of increase in the chamber headspace concentration over the intervening 10 minute period. The system was run for approximately 2 hours on each ice floe.

7.1.9 Photography

Author: Carson McAfee[1]

[1]*Antarctic Marine Engineering, British Antarctic Survey, Cambridge, UK*

Four different camera types were used to document the ice floe work. One was a 360-degree (Insta360) camera that could be deployed via a 50 mm hole to just beneath the ice base and was mounted on a pole; another was a MarCum camera, which had the advantage of giving a real time display, and again could be deployed to a few metres depth. Various GoPro cameras with waterproof housings were also used. A Mavic quadcopter flew survey grids over the floes. The photographs obtained were later stitched together to provide detailed photographic geo-referenced maps. Figure 7.1.9-1 and Figure 7.1.9-2 show low-resolution stitches with the positions of the various activities indicated.

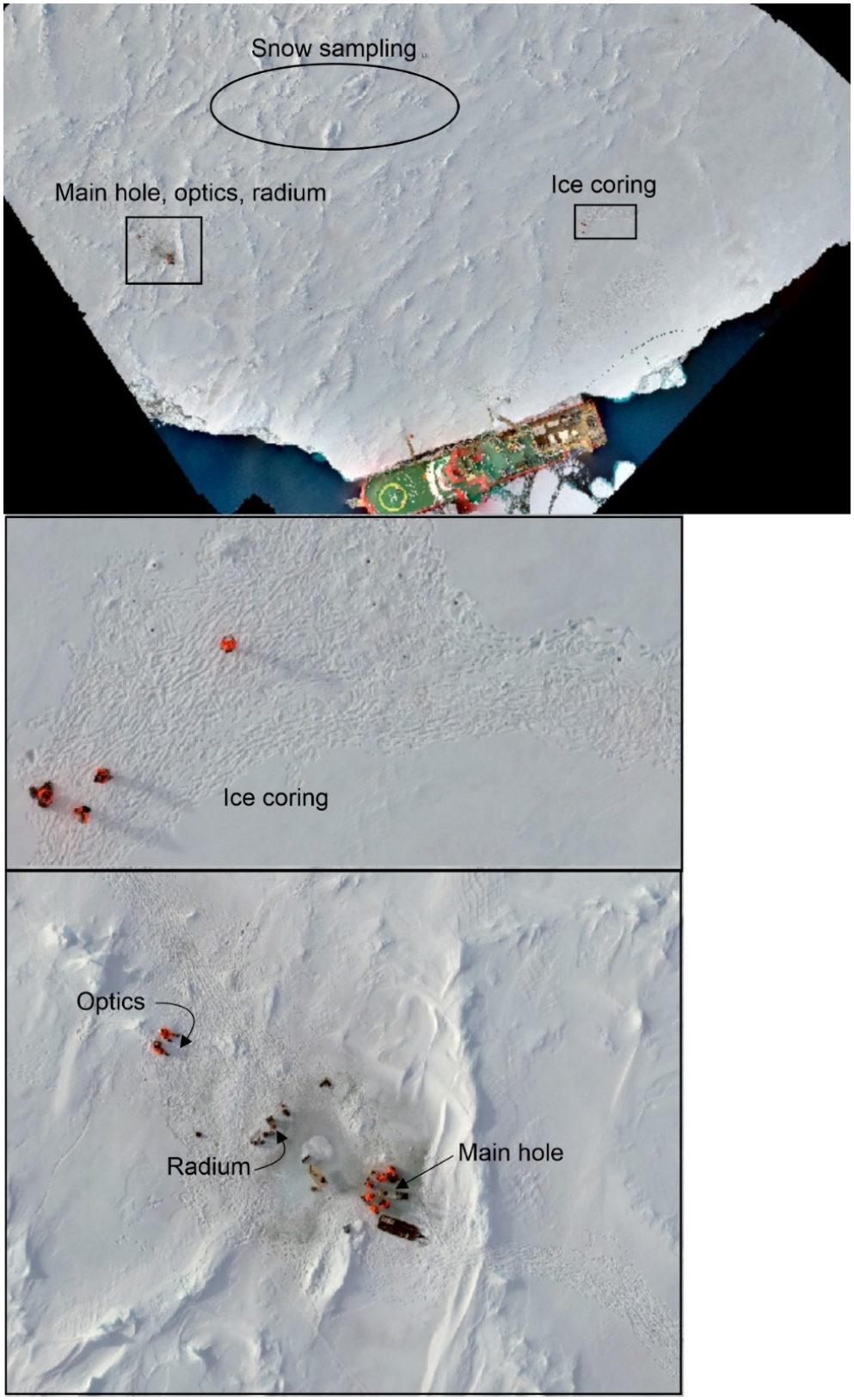

Figure 7.1.9-1: Distribution of activities on Floe 8.

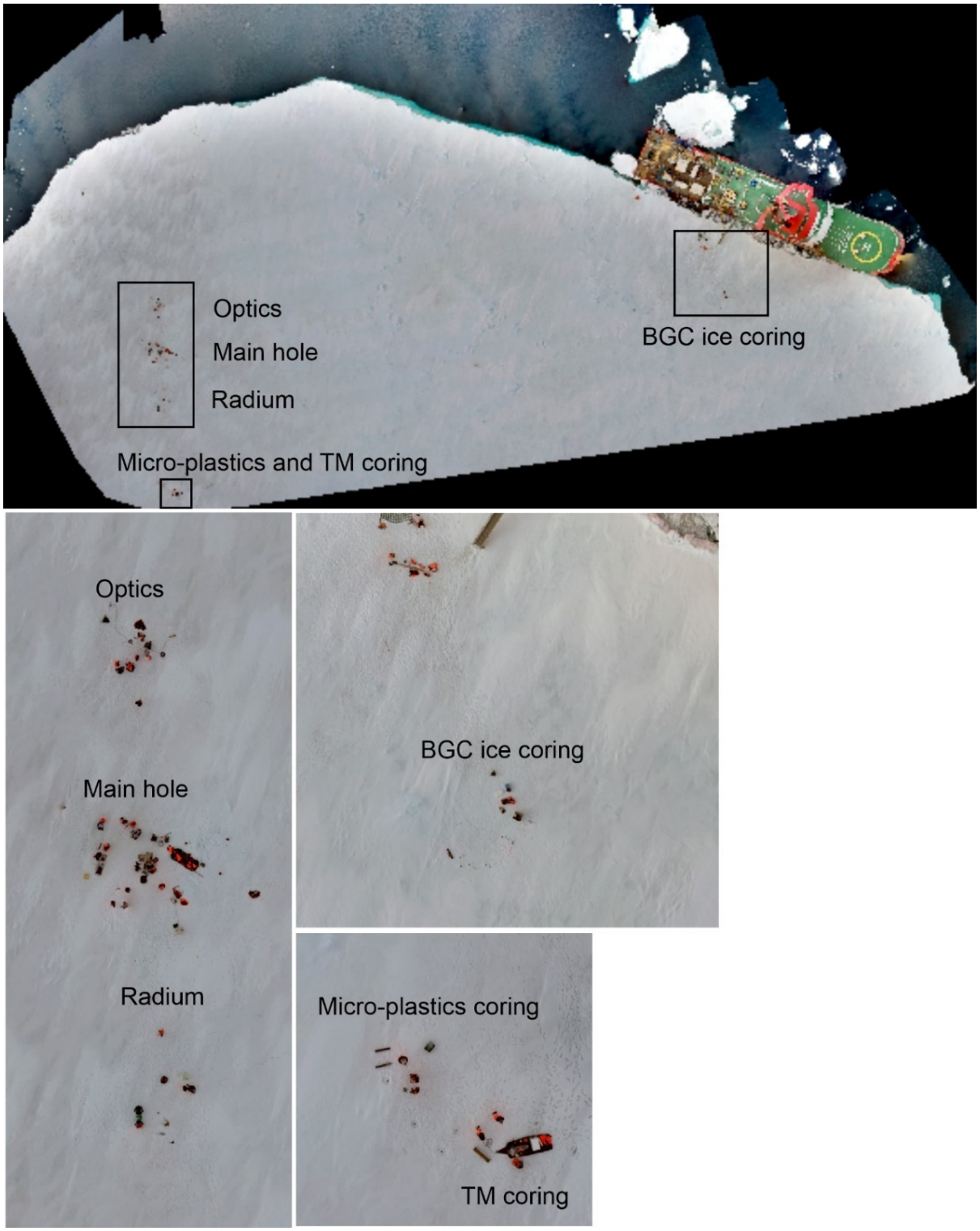

Figure 7.1.9-2: Distribution of activities on Floe 9

7.1.10 Documentation

Author: Alex Tate[1]

[1]UK Polar Data Centre, British Antarctic Survey, Cambridge, UK

Summary

Documenting on-ice work was challenging for several reasons. There were a lot of very different activities happening at the same time and these were spread over relatively large areas which made centralised coordination difficult. There was a difference in reporting requirements which meant that some potentially useful information was not recorded during certain activities. For example, variables like snow depth might not have been recorded at a site that was drilled to deploy an underwater camera. While many individuals assisted in the on-ice activities, there were relatively few who had experience of on-ice work and the associated metadata that is routinely collected. This was compounded by the fact that only two floes were visited, which gave little time to learn lessons and revise/improve logging workflows.

Despite the challenges, the majority of on-ice sampling and deployments were well described in the field and the planning ahead of deployment (log sheets, workflows etc.) captured most of the complexity encountered. Log sheets were tidied up in the days after on-ice work and were all scanned and saved to the cruise work folder (see relevant datasets in the data management section).

Log Sheets

Prior to deployment on the sea ice, there were onboard discussions about how site and sampling metadata should be recorded. A set of logging sheet templates for ice coring activities were provided by Elise Droste – these were based on forms used extensively during the MOSAIC expedition in the Arctic. They consisted of:

- SD035_icecoring_metadata_sheet – An overview sheet that described an entire site (each floe visited) and summarised every core taken and what had occurred to them (sampled, photographed, sectioned etc.).
- SD035_icecoring_sampling_sheet – A logging sheet used to describe each individual ice core as well as any sections/samples taken for onward analysis.
- SD035_icecoring_temperature_sheet – Very similar to the ice core sampling sheet but designed to record temperature values from each core.

The coring forms described above were modified to fit other on-ice requirements including through-ice sampling and profiling. The following forms were created:

- SD035_through_ice_metadata_sheet – Included most of the metadata elements (ice thickness, snow depth etc.) of the ice core sampling sheet and incorporated a primary purpose tick box (CTD, Optics, Radium etc.).
- SD035_through_ice_cast_samples – This sheet was used to record metadata about any instrument that could be 'cast' through a hole including the deployment of CTDs, optical instruments, underwater cameras and pCO_2 sensors. It also had sections to record water bottle sampling.
- SD035_through_ice_pump_samples – Very similar to the ice cast sampling sheet but tailored towards sampling a particular water depth using a continuously running pump.

Identifying labels

Ahead of deployment on the ice, agreement was reached on identifying labels to be used during data collection. These included:

- Ship event number – To maintain consistency with other SD035 deployments, a single event number was used to cover all the on-ice activities on a particular ice floe. The

event started with the first safety party reaching the ice floe and ended when the last person was back onboard. Events that occurred on the ice (coring, casts, drone flights etc.) belonged to the floe (as a platform) and not the ship so were not provided with additional ship event numbers.
- Site id – The two ice floes visited were given the site IDs 'Floe8' and 'Floe9' with the numbering sequence following on from previous floes visited for seal tagging purposes.
- Core/Hole ID – Cores were given numeric identifiers, and to avoid duplication on the ice, the coring teams were provided with physical markers with number on them. The hole created after coring was given the same number. Hence the coring of 'Core 2' created 'Hole 2' that could have been used for onward instrument deployments.

Issues/Recommendations

- The numbered core/hole markers were made in haste and could have been better designed. A marker that could be clearly visible to an overpassing drone would have been ideal.
- Documenting the various depth measurements of CTD casts was a non-trivial activity. An upgraded form could contain a schematic of the winch system for the recorder to annotate to make things a little easier to conceptualise.
- Although on-ice work has occurred during previous polar cruises, the work has rarely been as varied and intensive as on SD035. It is recommended that we provide data management guidance for future cruises to assist with on-ice activities. This guidance would be a sub-set of the broader range of activities that are related to a particular science cruise but don't occur on, or attached to, the primary vessel. These kind of 'off-ship' activities should also be considered during the upcoming redevelopment of the SDA event logging system.
- On-ice work was undertaken in almost perfect weather conditions (calm, mostly sunny, not too cold) which was good as we only had standard office clipboards and paper forms. It is recommended that weatherised recording equipment is used for future on-ice work.

7.2 Brown Ice Collection

Authors: Isabel Seguro[1], Ruth Airs[2]

[1]University of East Anglia, [2] PML

To collect sea ice from the SDA, the ship steered into sea ice in order to break it into smaller manageable sections, and to enable observation of the underside of the ice. A deck party identified suitable chunks of ice to bring onto deck. Requirements were: observable colouration of the sea ice by phytoplankton; sea ice chunk of a suitable size and shape to be brought onboard. A metal cargo cage was deployed attached to a deck crane (Fig. 7.2-1 A). A large piece of brown-coloured ice (0.5-0.7m^3) was collected (25th February, event number 264), by lowering the cage under the desired chunk of sea ice slowly raising it again. The sea ice was then brought on deck, where it was photographed and subsampled (Fig. 7.2-1 B). The ice was broken into smaller pieces by Ruth Airs and Isabel Seguro. Subsamples of ice were taken by using a clean hammer and chisel (Fig. 7.2-1 C), and an ice saw. 1.458 kg of sea ice was added to 12 L of filtered seawater in a carboy. The carboy was left in the dark at 4°C for 12 h for the ice to melt,

starting at 16:00. Subsamples of the diluted melted brown ice were collected for different analysis and experiments as explained in the different sections of this report.

Figure 7.2-1 (A-C): A) Metal cargo cage deployed attached to a deck crane, B) sea ice brought on deck and photographed, C) Subsamples of ice taken using a clean hammer and chisel.

8. Moorings

8.1 PICCOLO mooring recovery and redeployment

Sophie Fielding[1], Flo Atherden[1], Emily Rowlands[1], Giorgio Dall'Olmo[2]

[1]Ecosytems Team, British Antarctic Survey, Cambridge, UK
[2]National Institute of Oceanography and Applied Geophysics (OGS), Trieste, Italy

The PICCOLO mooring was deployed on 17th February 2023 at the PICCOLO site (-64.57367 N, -55.05936 E) during SD025, in 420 m water depth. It was recovered on 28th January 2024 (-64.5743 N, -55.0679 E), and is referred to throughout as the long-term mooring (SD025 mooring).

The PICCOLO mooring was later re-deployed on SD035 on 29th January 2024 (-64.578, N, -55.0651, E) in 420m water depth, and recovered on 16th February 2024 (-64.5702 N, -55.0663 E). It is referred to throughout as the short-term mooring (SD035 mooring).

The PICCOLO mooring recovery attempts occurred amongst ice (Figure 8.1-1). Since the PICCOLO mooring was a shallow mooring, it was located prior to release on the ships echosounders (e.g. Figure 8.1-2). Recovery of the long-term mooring was delayed ~16 hours whilst ice moved through the location, waiting for a hole to recover in. Recovery of the short-term mooring was in less ice, and the ship was used to move some ice out of the way prior to release. Both times locating the mooring in the echosounder and the short nature of the mooring meant recovery could be timed for holes in sea ice.

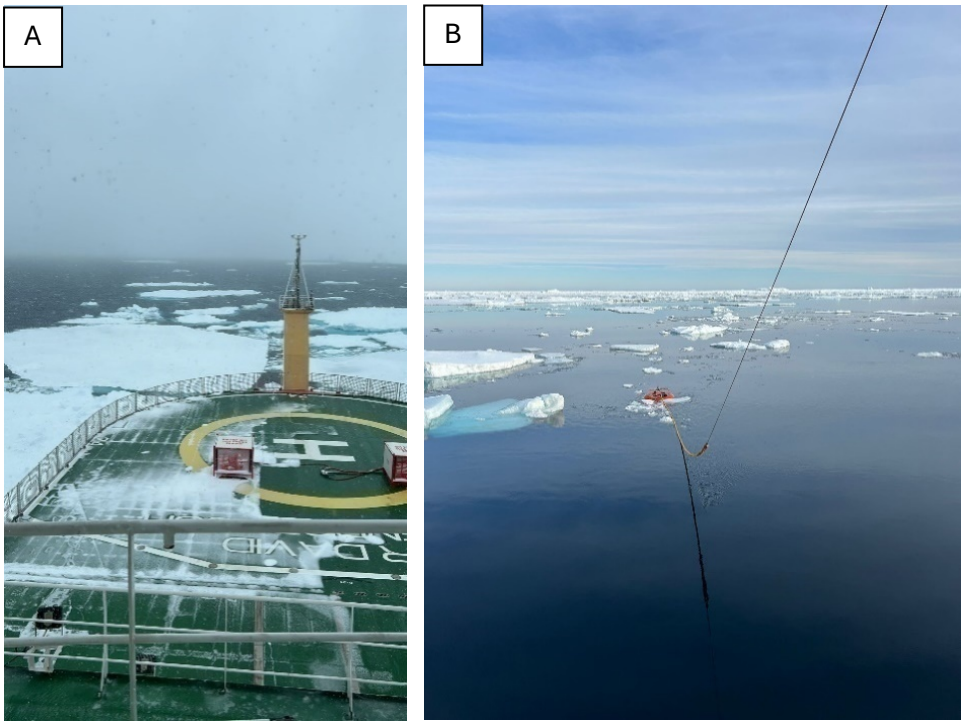

Figure 8.1-1: A) view of mooring location from bridge, B) recovery in sea ice, C) redeployment in ice.

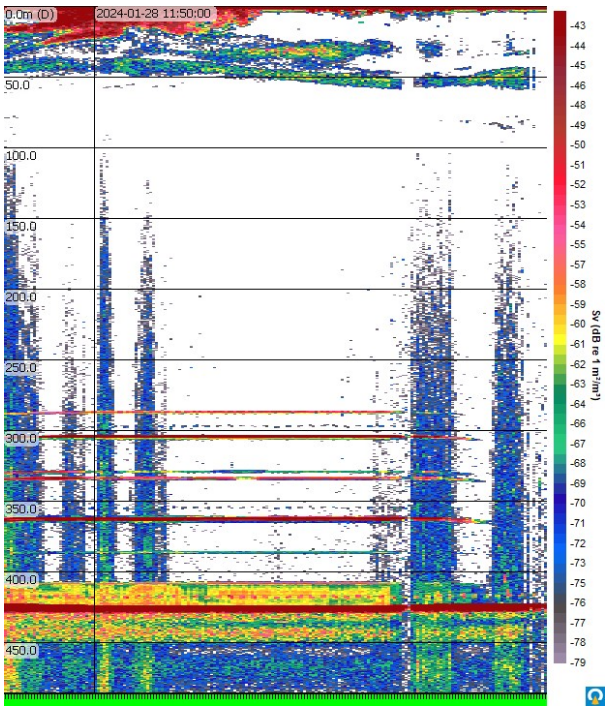

Figure 8.1-2: 38 kHz MVBS (Sv, dB) collected over PICCOLO mooring. Targets at 290, 300, 320, 350 and 370m are the surface recovery buoy, top buoy, aquamonitor, sediment trap and seaguard respectively.

The PICCOLO long-term mooring was equipped with the following instruments. Wetlabs Eco FLBBb, SBE SMP37 CTD+DO, Simrad WBAT 120 kHz echosounder, Sami pH sensor,

aquamonitor water sampler, Maclane sediment trap, Seaguard current meter and DO sensor. The sensors were arranged as follows:

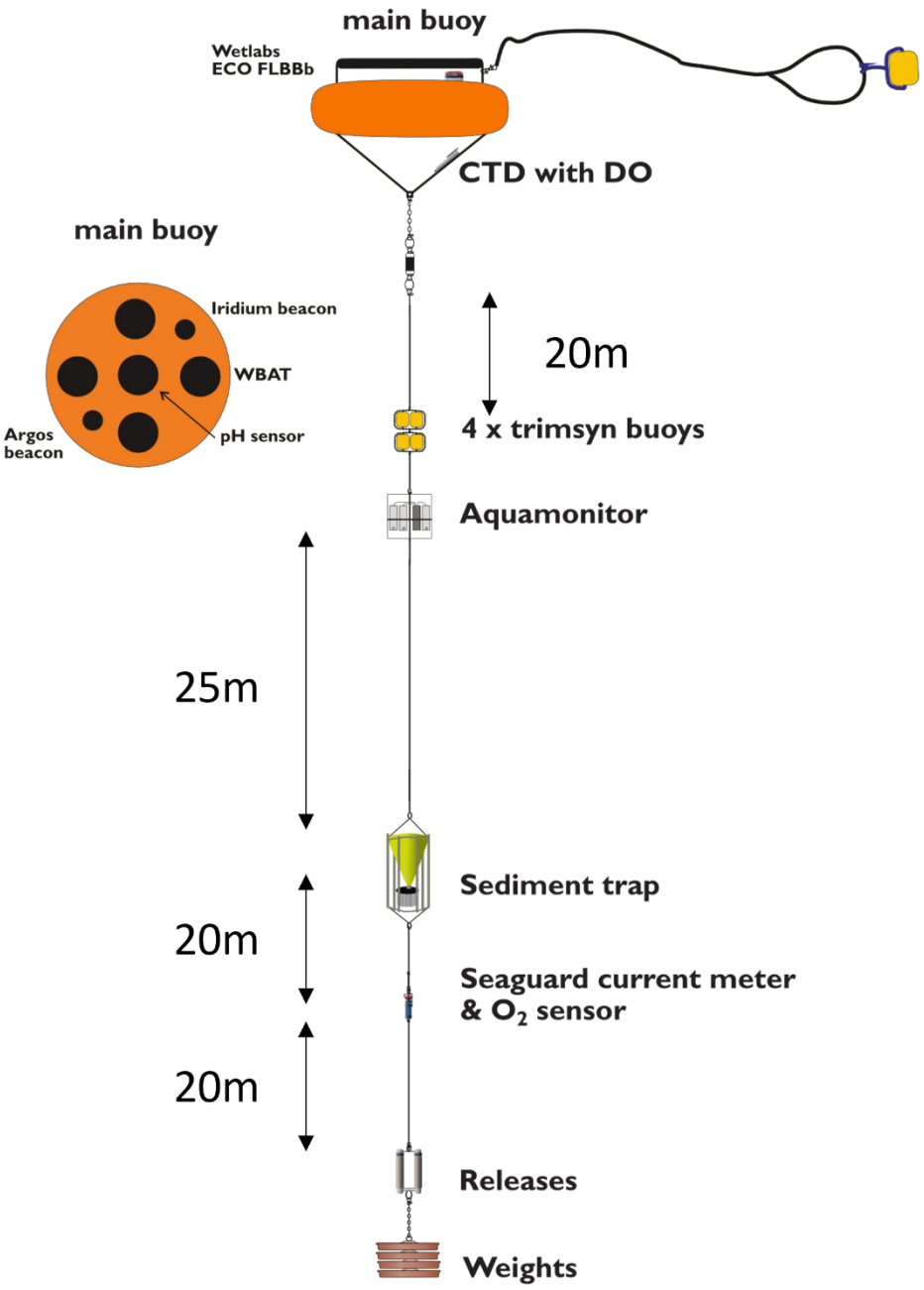

Figure 8.1-3: Long-term mooring diagram. The short-term mooring was the same, except the surface buoy did not house a WBAT echosounder.

Aquamonitor

Recovery of Aquamonitor 2023-2024: Upon recovery, it was clear there had been a failure with the tubing on the aquamonitor. The majority of the tubing had been removed and was no longer attached to the ports (Figure 8.1-4). On inspection with the aquamontior, some bags had been filled and others had not (summarised in Table 8.1-1) this implied that some samples were filled as programmed and the tubing remained intact, some samples have been filled and the tubing was then removed, and some samples were prevented from being captured as the tubing had

failed prior to the programmed fill date. Strong tides and currents present at the mooring site may have removed the tubes, however we suggest for future deployments different tubing should be used, and conversations with the manufacturer are taking place.

Figure 8.1-4: The AQUAMONTITOR on recovery from the long-term mooring.

Table 8.1-1: Bag and tubing status of the aquamonitor after the long-term mooring deployment (2023-2024).

Port No.	Bag No.	Tubing status	Bag filled	Sampling Date & Time
2	1	Yes	Yes	18/02/2023 00:07
3	2	Yes	Yes	18/02/2023 00:17
4	3	Yes	Yes	08/03/2023 16:07
5	4	Yes	Yes	08/03/2023 16:17
6	5	Yes	Yes	27/03/2023 08:07
7	6	Yes	Yes	27/03/2023 08:17
8	7	Yes	Yes	15/04/2023 00:07
9	8	Yes	Yes	15/04/2023 00:17
10	9	Yes	Yes	03/05/2023 16:07
11	10	No	No	03/05/2023 16:17
12	11	Yes	Yes	22/05/2023 08:07

13	12	No	No	22/05/2023 08:17
14	13	No	No	10/06/2023 00:07
15	14	No	No	10/06/2023 00:17
16	15	No	No	28/06/2023 16:07
17	16	No	No	28/06/2023 16:17
18	17	No	No	17/07/2023 08:07
19	18	No	No	17/07/2023 08:17
20	19	No	No	05/08/2023 00:07
21	20	No	No	05/08/2023 00:17
22	21	No	No	23/08/2023 16:07
23	22	No	No	23/08/2023 16:17
24	23	No	No	11/09/2023 08:07
25	24	No	No	11/09/2023 08:17
26	25	No	No	30/09/2023 00:07
27	26	No	No	30/09/2023 00:17
28	27	Yes	Yes	18/10/2023 16:07
29	28	No	Yes	18/10/2023 16:17
30	29	No	No	06/11/2023 08:07
31	30	No	No	06/11/2023 08:17
32	31	Yes	Yes	25/11/2023 00:07
33	32	Yes	Yes	25/11/2023 00:17
34	33	No	No	13/12/2023 16:07
35	34	No	No	13/12/2023 16:17
36	35	Yes	Yes	01/01/2024 08:07
37	36	No	No	01/01/2024 08:17
38	37	Yes	Yes	20/01/2024 00:07
39	38	No	No	20/01/2024 00:17
40	39	No	No	Recovered before sample
41	40	No	No	Recovered before sample
42	41	No	No	Recovered before sample

43	42	No	No	Recovered before sample
44	43	No	No	Recovered before sample
45	44	No	No	Recovered before sample
46	45	No	No	Recovered before sample

Redeployment and recovery of Aquamonitor Jan – Feb 2024: 250 ml sample bags were filled with 50 ml of Certified Reference Material (CRM, Batch 67 matching the previous deployment). The CRM was spiked with an additional 40 µl of saturated mercuric chloride solution to create a concentration of 0.02 % in the final sample volume of 250 ml. To minimise air contamination, air within each bag was syringed out and CRM was added with a 50 ml syringe. Bags were weighed before and after the addition of CRM. Different tubing was used for redeployment and tubing was secured to the aquamontior using pliers to ensure they are on as tight as possible. Movement of the Aquamonitor plunger was tested before redeployment as well as alignment of the ports. The Aquamonitor was deployed with a new battery.

Aquamonitor sampled every 2.5 days, with XXX bags filled upon recovery in February (Table 8.1-2). Some bags which should have sampled were not filled (CRM entirely removed) or underfilled (not 250 ml final volume). All tubing was attached to the ports. Check valves were tested, and work as required (only allowing one way flow). We suggest that when filling the bags with CRM the syringe weakened the opening of some tubes, compromising the seal where tubing meets the check valve. This may have caused the sample to leak out once the aquamonitor is at depth and under pressure. For future deployments special care needs to be taken when filling bags and a review of what tubing and syringe to use is required. In addition, some of the screws holding the aquamonitor in place need replacing due to corrosion.

Table 8.1-2: Status of Aquamonitor sample bags recovered from the short-term mooring (Jan-Feb 2024). Only bags scheduled to sample are included in this table, the remaining bags did not sample and were not expected to and as such were not included in this table.

Port no.	**Bag No.**	**Sample Bag Filled?**	**Sampling Date & Time**
2	1	Full	01/02/2024 19:07
3	2	Full	01/02/2024 19:17
4	3	Full	04/02/2024 07:07
5	4	Full	04/02/2024 07:17
6	5	Full	06/02/2024 19:07
7	6	Completely empty (No CRM)	06/02/2024 19:17
8	7	Full	09/02/2024 07:07
9	8	Partially filled	09/02/2024 07:17
10	9	Full	11/02/2024 19:07
11	10	Completely empty (No CRM)	11/02/2024 19:17
12	11	Full	14/02/2024 07:07
13	12	Full	14/02/2024 07:17
14	13	Full	16/02/2024 19:07
15	14	Full	16/02/2024 19:17

pH Sami

Recovery of pH Sami 2023-2024: Upon recovery the pH Sami (Serial Number p0280) programme was stopped, the PH constant salinity data and raw pH data was downloaded and the Sami was flushed with Milli-Q. The Sami was then soaked in freshwater for over a day and then stored. The Sami appears to have sampled as programmed.

Redeployment and recovery of pH Sami Jan – Feb 2024: A different pH Sami (Serial Number p0312) was used for the short-term mooring, though the deployment programme were set to match the long-term mooring, sampling every 2 hours. The Sami was flushed with Milli Q prior to deployment. The Sami was placed within the buoy and secured with a cone as with the long term (2023-2024) mooring.

FLbb

A SeaBird ECO-FLBB (s/n 7717) with channels for chlorophyll fluorescence and optical backscattering (at 700 nm) was installed on the upper side of the main buoy, facing outwards and paying particular attention to avoid reflections from the buoy. The sensor was programmed to sample every 5.5 hours for 1 minute at 1 Hz during the year-long deployment and every 30 minutes for 1 minute at 1 Hz during the month-long deployment. Batteries were replaced (by Gareth Flint) between the year-long and month-long deployments. After each deployment, raw data were downloaded using ECO-View and saved in ascii format in the following files:

scientific_work_areas/Mooring/EcoFlbb_7717/backedup_by_grg/flbb.raw

scientific_work_areas/Mooring/EcoFlbb_7717/2nd_deployment/flbb_2nd_deployment.raw

Simrad WideBand Acoustic Transceiver

The Simrad WBAT (Serial number 240809) and associated 120 kHz transducer (Serial number 127) was deployed on the long-term mooring only. The WBAT worked well throughout the whole deployment and data exist (15 pings CW, 15 pings FM, 5 pings FM passive at a 4 second ping rate) throughout the deployment. Raw data were saved to scientific_work_areas/Mooring/SD025 mooring data/WBAT. Figure 8.1-5 shows the mission plan.

The WBAT was not redeployed on the short-term mooring.

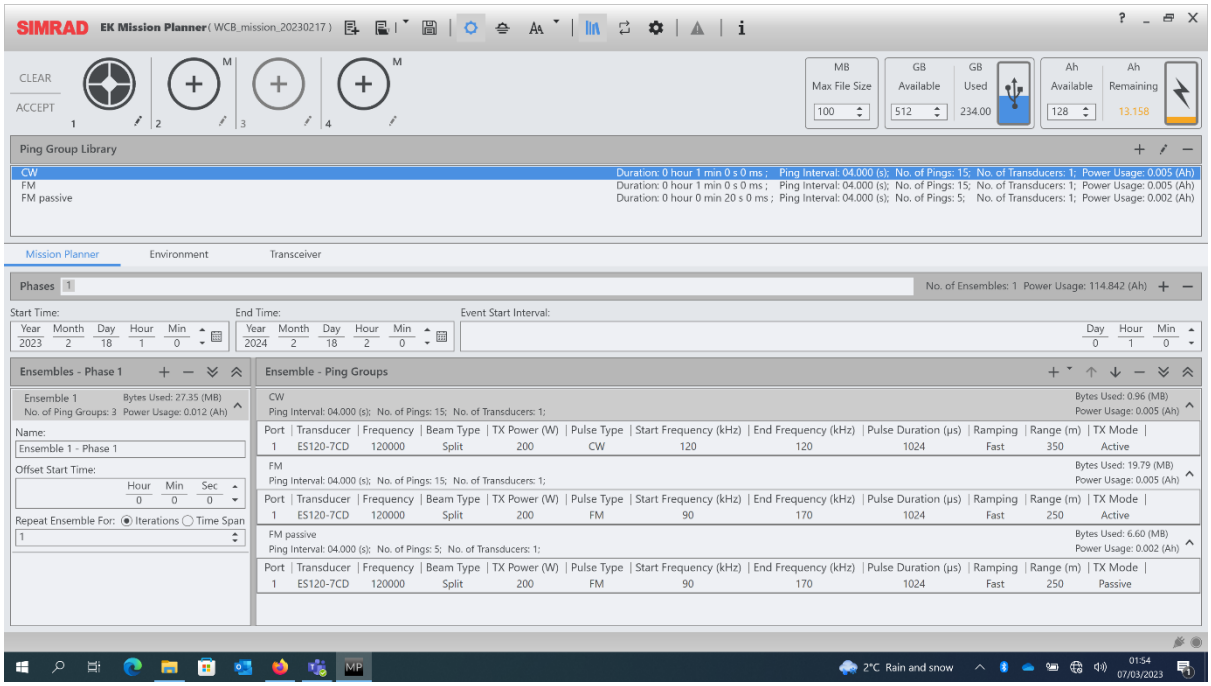

Figure 8.1-5: Simrad WBAT mission plan

CTD with DO SMP37_24673

The SBE SMP37 CTD with DO sensor (SN 24673) was recovered, data downloaded. The CTD worked for the whole long-term and short-term deployment. During the long-term deployment the CTD recorded depth and DO measurements once every hour (SAMPLEINTERVAL=3600). During the short-term deployment the CTD recorded depth and DO measurements every 10 minutes (SAMPLEINTERVAL=600).

Current meter with o2 – Seaguard 2476

The Seaguard current meter with DO sensor (SN 2476) was recovered, data downloaded. The Seaguard worked for the whole long-term and short-term deployment. During the long-term deployment the Seaguard recorded data once every hour (SAMPLEINTERVAL=3600). During the short-term deployment the CTD recorded depth and DO measurements every 10 minutes (SAMPLEINTERVAL=600).

Sediment trap

Recovery of trap serial number ML 15559-02

Recovery of the sediment trap (deployed on 17th February 2023 -SD025), equipped with 21 x 500ml bottles, each containing buffered formaldehyde (4%).

Table 8.1-3: Deployment schedule set for the long-term mooring (SD025)

Event number	Time/Date GMT	Days open
1	18/02/2023 00:00:01	3
2	21/02/2023 00:00:01	8
3	01/03/2023 00:00:01	10
4	11/03/2023 00:00:01	10
5	21/03/2023 00:00:01	11
6	01/04/2023 00:00:01	30

7	01/05/2023 00:00:01	31
8	01/06/2023 00:00:01	61
9	01/08/2023 00:00:01	31
10	01/09/2023 00:00:01	30
11	01/10/2023 00:00:01	31
12	01/11/2023 00:00:01	10
13	11/11/2023 00:00:01	10
14	21/11/2023 00:00:01	10
15	01/12/2023 00:00:01	10
16	11/12/2023 00:00:01	10
17	21/12/2023 00:00:01	11
18	01/01/2024 00:00:01	10
19	11/01/2024 00:00:01	10
20	21/01/2024 00:00:01	11
21	01/02/2024 00:00:01	10
22	11/02/2024 00:00:01	

Upon recovery it was clear that the sediment trap had not fully rotated as expected. Bottle number 6 was aligned under the collection cone (highlighted in the schedule above), whilst based on the recovery date of 28th Jan 2024, bottle number 20 should have been sampling. From the trap bottles (Figure 8.1-6) as well as from other equipment on the mooring (e.g. the aquamonitor boxes which were heavily packed with sediment), large volumes of sediment had saturated the mooring. Tests post recovery showed that the sediment trap battery life was still sufficient however, we were not able to manually rotate the carousel. We suspect that sediment has blocked the carousel disks from rotating – this will be explored further when the sediment trap is dismantled back in Cambridge. Bottles were packed in vermiculite boxes and stored at room temperature for analyses back in Cambridge.

Figure 8.1-6: The six bottles that collected material from the sediment trap ML 15559-02

Deployment of trap serial number ML 15789-01

For the short-term PICCOLO mooring (deployment on 29th January 2024, recovery on 16th February 2024), the following schedule was set since it was unclear when the opportunity would arise to recover the mooring within the cruise:

Table 8.1-4: Deployment schedule set for the short-term mooring (SD035)

Event number	Time/Date GMT	days open
1	30/01/2024 18:00:00	1
2	01/02/2024 18:00:00	2
3	03/02/2024 18:00:00	2
4	05/02/2024 18:00:00	2
5	07/02/2024 18:00:00	2
6	09/02/2024 18:00:00	2
7	11/02/2024 18:00:00	2
8	13/02/2024 18:00:00	2
9	15/02/2024 18:00:00	2
10	17/02/2024 18:00:00	2
11	19/02/2024 18:00:00	2
12	21/02/2024 18:00:00	2
13	23/02/2024 18:00:00	2
14	25/02/2024 18:00:00	2
15	27/02/2024 18:00:00	2
16	29/02/2024 18:00:00	2
17	02/03/2024 18:00:00	2
18	04/03/2024 18:00:00	2
19	06/03/2024 18:00:00	2
20	08/03/2024 18:00:00	2
21	10/03/2024 18:00:00	2
22	12/03/2024 18:00:00	

Recovery of trap serial number ML 15789-01

Upon recovery of the short-term sediment trap, it was clear from the bottles that the trap had sampled as expected with bottle number 9 (highlighted on the schedule above) located under the collection cone as per the set schedule, and all previous bottles having collected material (Figure 8.1-7). Bottles were packed in vermiculite boxes and stored at room temperature for analyses back in Cambridge.

Figure 8.1-7: The 9 bottles that collected material from sediment trap ML 15789-01

Mooring instrument calibration

Both the Seabird CTD (with oxygen sensor) and the Seaguard were strapped to the stainless steel CTD (Event 288) and set to record data at the highest sample rate to compare with the calibrated oxygen sensor on the stainless steel frame. Data were downloaded and stored on the workdrive in the mooring folders.

pH Sami: To determine whether there were any *in situ* pH measurement effects, both pH Samis were placed on a shallow CTD cast (320 m) and set to sample every 5 mins for 1 hour. DIC and TA water samples were collected from 6 depths (320m, 60m, 20m, 10m, 6m, 2.2m) with the CTD waiting for 6 minutes at each depth to ensure a pH Sami samples was taken. In addition, two other pH sensors were mounted onto the CTD Frame (SBE 18 and ANB S Series). Upon recovery the Sami used for the short-term mooring (Jan – Feb 2024) had samples with no issues. This Sami was then flushed with Mili-Q and soaked in freshwater. However, the Sami used for the long-term mooring (2023-2024) had failed. It may have begun sampling before entering the water column, thereby taking in air and causing a blockage that prevents sampling. We suspect this may be the case as the Milli Q flush on recovery failed however further investigation is required.

Table 8.1-5: Summary of long-term mooring equipment and data collection (SD025 deployment, SD035 recovery)

Height above bottom (m)	Nominal Depth (m)	Instrument/SN	Parameters measured	Sample Interval (mins)	Start/stop time UTC (dd/mm/yyyy hh:mm:ss)	Comments
100	310	Novatech flasher/VHF (SN D07-017)				
100	310	Xeos Argos Beacon (SN 152637)				
100	310	Simrad WBAT echosounder + 120 kHz transducer (SN 240809 + SN127)	Acoustic backscatter (Sv)	60	18022023 12:00:00 28012024 19:00:00	Whole dataset recovered
100	310	SBE SMP37 CTD + DO (SN 24673)	T,C,P, DO	60	17022023 21:00:00 28012024 18:01:00	Whole dataset recovered
100	310	Ecoflbb (SN 7717)	Turbidity, Backscatter	330	16022023 19:30:00 28012024 21:56:00	Whole dataset recovered
100	310	pH sami (SN p0280)	pH	120		
80	330	Trimsyn buoys (4)				
75	335	Aquamonitor	Water	2-4 weeks		
50	360	Sediment Trap (SN 15559-02)	Sediment	2-4 weeks	18022023 00:00:01 01042023 00:00:01	Sediment trap stopped rotating at bottle 6
30	380	Seaguard Current Meter and DO (SN 2476)	U,V,W,T, DO	10	17022023 21:20:00 28012024 23:00:00	Whole dataset recovered
15	415	Acoustic Release SN 573				
15	415	Acoustic Release SN 2061				

Table 8.1-6: Summary of short-term mooring equipment and data collection (SD035 deployment and recovery)

Height above bottom (m)	Nominal Depth (m)	Instrument/SN	Parameters measured	Sample Interval (mins)	Start/stop time UTC (dd/mm/yyyy hh:mm:ss)	Comments
100	310	Novatech flasher/VHF (SN D07-017)				
100	310	Xeos Argos Beacon (SN 152637)				
100	310	SBE SMP37 CTD + DO (SN 24673)	T,C,P, DO	10	30012024 07:00:00 17022024 16:00:00	Whole dataset recovered
100	310	Ecoflbb (SN 7717)	Turbidity, Backscatter	330	29012024 16:58:00 16022024 22:38:00	Whole dataset recovered
100	310	pH sami (SN p0312)	pH	120		
80	330	Trimsyn buoys (4)				
75	335	Aquamonitor	Water	2.5 days		
50	360	Sediment Trap (SN 15789-01)	Sediment	2 days	30012024 18:00:00 15022024 18:00:00	Sediment trap stopped rotating at bottle 9 (at scheduled point)
30	380	Seaguard Current Meter and DO (SN 2476)	U,V,W,T, DO	5	30012024 00:10:00 17022024 20:00:00	Whole dataset recovered
15	415	Acoustic Release SN 573				
15	415	Acoustic Release SN 2061				

8.2 Biopole mooring

Sophie Fielding[1], Flo Atherden[1], Emily Rowlands[1]

[1]Ecosytems Team, British Antarctic Survey, Cambridge, UK

The Biopole mooring deployed on SD025 was recovered on SD034, the cruise prior to the PICCOLO cruise (SD035), to prevent the potential for the Iceberg A23a. All data from the instruments were downloaded into a folder into the current cruise directory to ensure a backup of the data existed (\work\scientific_work_areas\Mooring\Biopole mooring). A description of the datasets can be found in Table 8.2-2.

The Biopole mooring was redeployed on the 05/03/2024 in 3438m water depth. The triangulated position was 62° 09.058' S, 50° 28.857' W (See Table 8.2-1 and Figure 8.2-1 for details).

Table 8.2-1: Biopole mooring deployment triangulation values.

Position	Latitude (°)	Longitude (°)	Range (m)	Water depth (m)	Distance (m)
Pos1	62° 08.8698' S	50° 30.936' W	4050	3438	2140
Pos2	62° 08.2134' S	50° 27.528' W	4034	3437	2111
Pos3	62° 11.0136' S	50° 29.834' W	4817	3438	3373
PosMooring	62° 09.058' S	50° 28.857' W			

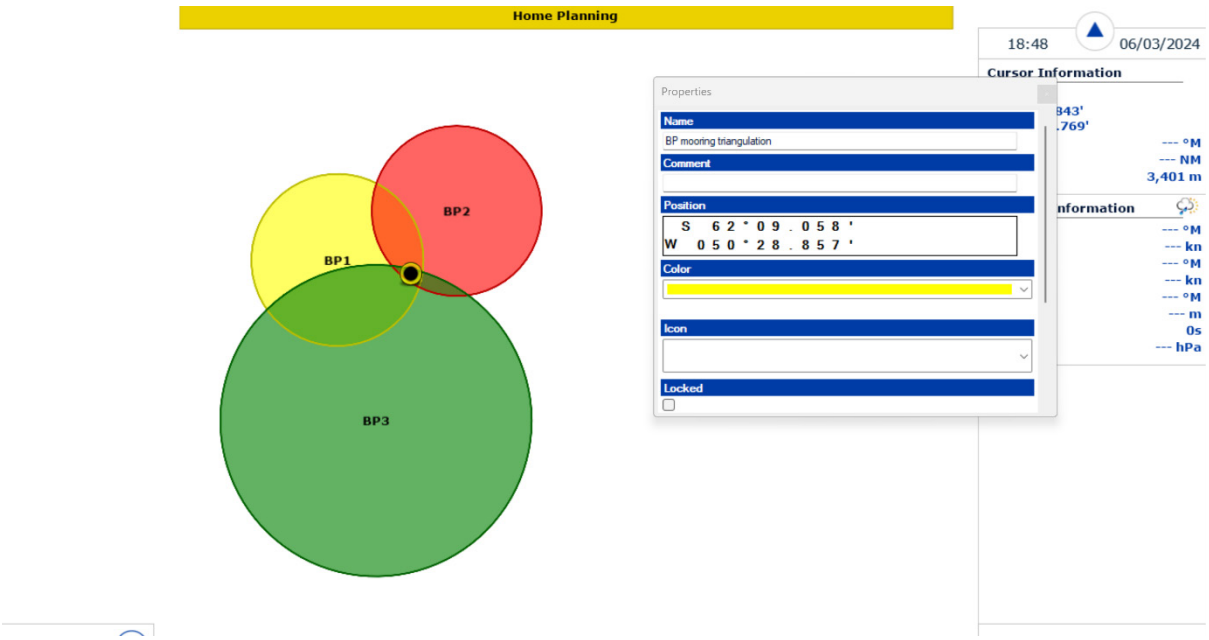

Figure 8.2-1: Biopole mooring deployment triangulation screenshot.

To prevent having to remove all of the rope from the mooring winch, an additional 200 m of mooring rope was located (175m and 25m (from PICCOLO mooring)) and added to that already on the mooring winch for deployment. The setup was then reversed (after agreement with the PI that the 1400m original length would be changed to a 1350m length in the top section and vice versa in the bottom section). The mooring deployment went smoothly. The only noticeable challenge was that the 20m rope that was to separate the Trimsyn cluster and the deep sediment trap from the original mooring was found between the 200m and 1400m sections of rope on the mooring winch, instead of in its expected location (based on the SD025 mooring report) between the 1000m and 200m ropes. It isn't clear whether this was an error or planned. Notably the Seaguard is fitted with a pressure sensor so the deep sediment trap depth can be identified with some confidence. The Biopole mooring was re-deployed with line lengths given in Figure 8.2-2 and Table 8.2-3.

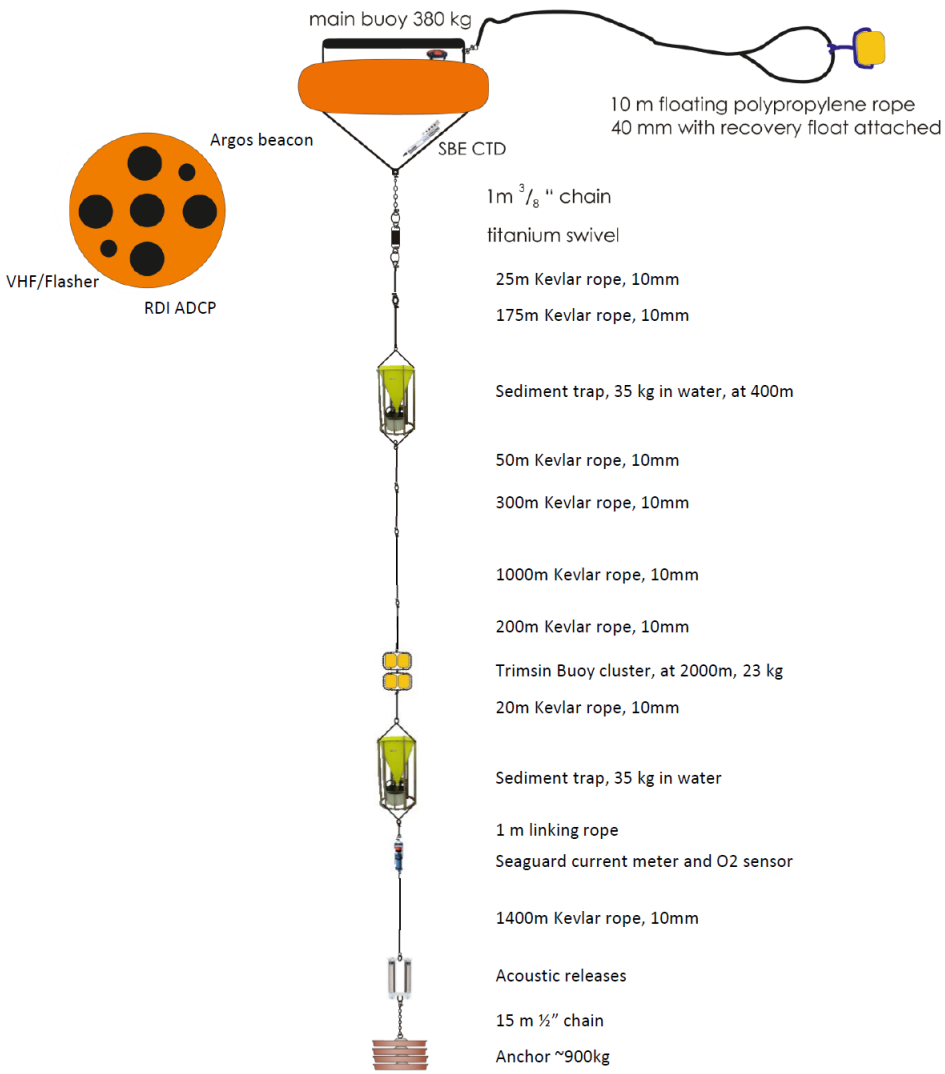

Figure 8.2-2: Mooring deployment schematic (05/03/2024)

Table 8.2-2: Recovered data from the Biopole mooring.

Height above bottom (m)	Nominal Depth (m)	Instrument/SN	Parameters measured	Sample Interval (mins)	Start/stop time UTC (dd/mm/yyyy hh:mm:ss)	Comments
3200	195	Iridium Beacon				
3200	195	Argos Beacon?				
3200	195	SBE SMP37 CTD (SN 13719)	T,C,P	60	22022023 00:00:00 04122023 16:00:00	Whole dataset recovered
3200	195	ADCP (SN 24636)	U,V,W	60		Whole dataset recovered
		200 m rope				
3000	395	Sediment Trap (SN ML13176-01)	Sediment	2-4 weeks	04032023 00:00:01 16122023 00:00:01	
		1400 m rope				
		200 m rope				Not 20 m rope found between 200m and 1400m rope here
1405	1995	Trimsyn buoys (4)				
		20 m rope				
1385	2015	Sediment Trap (SN ML15559-01)	Sediment	2-4 weeks	04032023 00:00:01 16122023 00:00:01	
1385	2015	Seaguard Current Meter, pressure, turbidity, DO (SN 1184)	U,V,W,Press,T,DO,	10	03032023 00:20:00 04122023 15:00:00	Whole dataset recovered
		1000 m rope				
		300 m rope				
		50 m rope				
15	3385	Acoustic Release SN 1219				
15	3385	Acoustic Release SN 2007				

Table 8.2-3: Instrument details for the Biopole mooring deployment 05/03/2024.

Nominal Depth (m)	Instrument/SN	Parameters measured	Sample Interval (mins)	Start time	Comments
215	Novatech flasher/VHF				
215	Argos Beacon				
215	SBE SMP37 CTD (SN 13719)	T,C,P	60	08032024 00:01:00	
215	ADCP (SN 24636)	U,V,W	60	In water	
	200 m rope				
415	Sediment Trap (SN ML13176-01)	Sediment	2-4 weeks		
	1000 m rope				
	300 m rope				
	50 m rope				
	200 m rope				
1965	Trimsyn buoys (4)				
	20 m rope				
1985	Sediment Trap (SN ML15559-01)	Sediment	2-4 weeks		
1985	Seaguard Current Meter, pressure, turbidity, DO (SN 1184)	U,V,W,Press,T,DO,	10	08032024 00:00:00	
	1400 m rope				
3385	Acoustic Release SN 2061				
3385	Acoustic Release SN 513				

As summarised in Table 8.2-3, the mooring was redeployed with the following sensors and settings. All config files have been retained in \work\scientific_work_areas\Mooring\Biopole mooring.

Seabird CTDO: Serial Number 037-13719

The Seabird CTD was set to sample every 3600 seconds (1 hour), starting 04 Mar 2023 00:00:00. The CTD was put on the ship's CTD to 1000m (event 172) to allow calibration of data, before deploying on the main buoy of the mooring

ADCP 300 kHz: Serial Number 24636

The ADCP was setup with 8 m bins, 15 minute ensembles and 11 pings per ensemble. The system was set to turn on deployment. A new battery was fitted and the o-ring greased prior to deployment. Annoyingly it was then found that the end cap needs to be removed before the mooring bracket can be attached.

Biopole mooring deployment ADCP setup file

```
;SD035 05/03/2024
CR1
CF11101
EA0
EB0
ED2000
ES35
EX11111
EZ1111101
WA50
WB1
WD111100000
WF176
WN25
WP11
WS800
WV175
TE00:15:00.00
TP01:21.81
CK
CS
;
;Instrument       = Workhorse Sentinel
;Frequency        = 307200
;Water Profile    = YES
;Bottom Track     = NO
;High Res. Modes  = NO
;High Rate Pinging  = NO
;Shallow Bottom Mode= NO
;Wave Gauge       = NO
;Lowered ADCP     = NO
```

;Ice Track = NO
;Surface Track = NO
;Beam angle = 20
;Temperature = 5.00
;Deployment hours = 13200.00
;Battery packs = 1
;Automatic TP = YES
;Memory size [MB] = 256
;Saved Screen = 2
;
;Consequences generated by PlanADCP version 2.06:
;First cell range = 10.02 m
;Last cell range = 202.02 m
;Max range = 156.42 m
;Standard deviation = 1.11 cm/s
;Ensemble size = 654 bytes
;Storage required = 32.93 MB (34531200 bytes)
;Power usage = 424.06 Wh
;Battery usage = 0.9
;
; WARNINGS AND CAUTIONS:
; Advanced settings have been changed.

Seaguard Serial number 1184

Fitted with Pressure sensor 4117F S/N 2049, Oxygen sensor S/N 3924, Turbidity sensor S/N 69 and acoustic doppler sensor S/N 1477

Set to start on 3rd March 2023 at 00:00:10, logging every 10 minutes.

Sediment traps

Trap bottle solution: 1 L of 37% formalin was buffered with 5 g of sodium tetraborate (BORAX) and left to dissolve for 24 hours. 100 g of sodium chloride was added to 19 L of filtered seawater and left to dissolve for 24 hours. The buffered formalin and sea water were then mixed to create 20 L of 4% formalin solution. The remaining 1L 4 % formalin trap solution required to fill all 42 500 ml bottles was sourced from solutions made up during the previous BIOPOLE cruise (SD033). This solution was made up using the same method.

Sampling intervals for both sediment traps are available in (Table 8.2-4) and were programmed to match previous BIOPOLE deployments.

Table 8.2-4: Event timings for the Biopole sediment traps. Each event number represents 1 increment of rotation, therefore sampling began after event 01 when the first bottle is moved underneath the sampling funnel.

EVENT NUMBER	DATE TIME (GMT)
01	Mar/06/24 00:00:01
02	Mar/11/24 00:00:01
03	Mar/21/24 00:00:01
04	Apr/01/24 00:00:01

05	May/01/24 00:00:01
06	Jun/01/24 00:00:01
07	Jul/01/24 00:00:01
08	Aug/01/24 00:00:01
09	Sep/01/24 00:00:01
10	Oct/01/24 00:00:01
11	Nov/01/24 00:00:01
12	Nov/16/24 00:00:01
13	Dec/01/24 00:00:01
14	Dec/16/24 00:00:01
15	Jan/01/25 00:00:01
16	Jan/16/25 00:00:01
17	Feb/01/25 00:00:01
18	Feb/15/25 00:00:01
19	Mar/01/25 00:00:01
20	Mar/11/25 00:00:01
21	Mar/21/25 00:00:01
22	Apr/01/25 00:00:01

9. Water Sample Analyses (State Observations)

9.1 Salinometer

Author: Lars Boehme[1]

[1]School of Biology, University of St Andrews, St Andrews, UK

Salinometry measurements were made from water samples from the primary stainless-steel (SS) and the trace-metal-free (TM) ship-based CTD rosettes in order to calibrate the primary and secondary conductivity sensors on the two SBE911plus CTDs. Samples were chosen from water depth with stable water masses (e.g. bottom or surface) and were measured on an Autosal 8400B (Certificate #73103-45079; SN 73103), in a temperature-controlled room. The temperature of the salinometry room varied between 22.0 and 23.1° C during all measurement periods with a mean around 22.6°C. The salinometer was last serviced and aligned by OSIL in May 2023. The last calibration certificate was from September 2019. The stated resolution of the salinometer is ±0.0002 PSU for salinity with an accuracy of about ±0.002 PSU for salinity within a 24-hour period. The bath temperature of the salinometer was set to 21°C during the cruise.

Standardization and stability

The Autosal was setup before leaving Punta Arenas following chapter 5 in the GUILDLINE Instruments technical manual (TM8400B-L-00). It was then standardized using the procedure as described in chapter 6.2.2. using IAPSO standard seawater (SSW, batch P167, K_{15} = 0.99988, S = 34.995 PSU). The STANDARDIZE control setting was 4 on the outer ring and 09 on the inner ring. The salinometer was not standardised again as each session was started and concluded with measurements of individual SSW. The Standby and Zero readings were recorded at different points throughout the cruise. Both readings conformed to the stability requirements and did change less than ±1 digit (Figure 9.1-1). A recalibration was therefore not required.

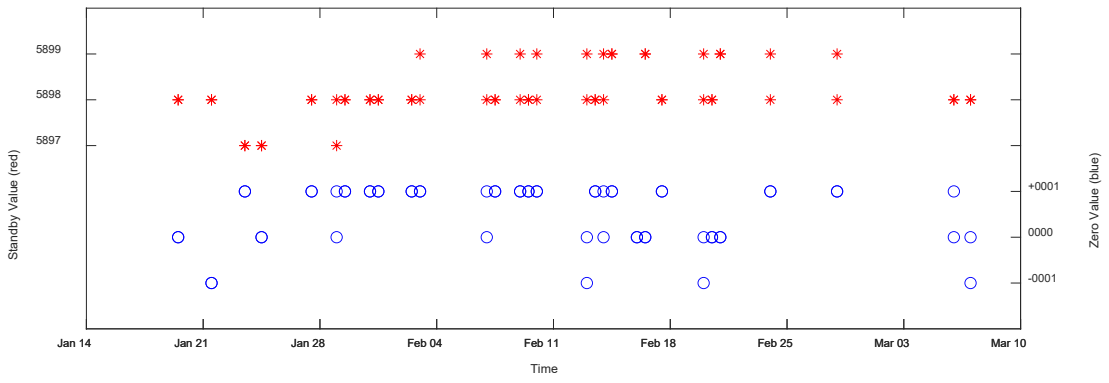

Figure 9.1-1: Standby (red stars) and Zero (blue circles) values of the Autosal (SN:73103) over time.

Over time, no drift of the Autosal was recorded with uncorrected values showing slight variability within the stated accuracy (Figure 9.1-2) staying with ±0.001 PSU from the mean

value. The mean correction was 34.9950 PSU (real SSW Batch P167 salinity) minus mean uncorrected measured SSW value of 34.9935 ±0.0004 PSU meaning that all measured salinities had to be corrected by about +0.0015 PSU. Any potential short-term drift was corrected by using SSW at the beginning and end of each session.

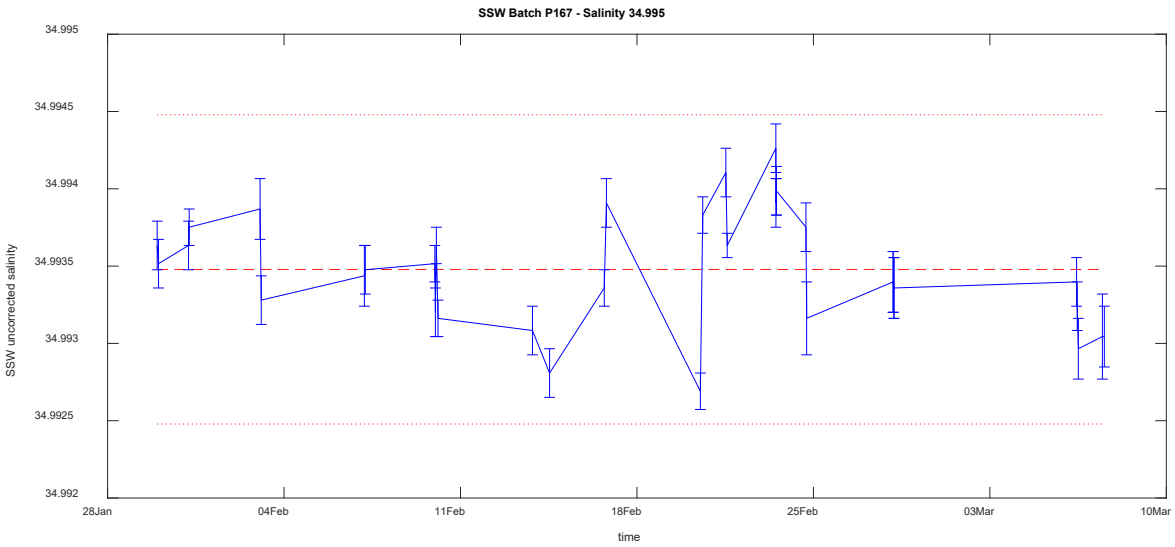

Figure 9.1-2: Uncorrected salinity readings of Standard Seawater of 34.995 PSU over the cruise duration and their standard deviation in blue. The mean value of 34.9935 PSU is shown as a red dashed line and the red dotted lines show the mean ±0.001 PSU.

Measurement procedure

Readings were logged using the Ocean Scientific International: Ocean Data Logger version 1.2 computer program, which was running on a laptop connected to the salinometer. The measurement procedure as outlined in chapter 5 in the GUILDLINE Instruments technical manual was used for all sessions with a slight variation. The conductivity cell of the salinometer was flushed with sea water and then switched to "read" to soak the cell and warm up the electronics before any samples were measured.

At the start of each session, a conductivity ratio was obtained using IAPSO standard seawater (Batch P167). The salinometer was flushed at least three times with IAPSO standard seawater prior to obtaining a conductivity ratio. The difference between this conductivity ratio thus obtained and the true conductivity ratio of IAPSO standard seawater (K_{15} = 0.99988) was assumed to be due to a drift in the salinometer. The same procedure was done at the end of each session and a linear drift between the two values was calculated and applied for each reading taken during that session.

The salinometer was flushed three times with each sample prior to taking readings. Three ensembles of readings were taken from each sample. For each ensemble, Ocean Data Logger waited 10 seconds after the salinometer was switched to "Read" and took 10 readings and calculated the mean. Additional ensembles were taken when the conductivity ratios varied considerably; anomalous ensembles were removed from the record. An anomalous ensemble for a given sample was taken to be one for which the calculated practical salinity differed from

that of the other two (or more) ensembles by more than ±0.003 PSU, the stated accuracy of the salinometer. Mean practical salinity for each sample was calculated from all remaining ensembles and the drift correction (see above) applied.

Results

Primary ship-based CTD

The salinities measured using the salinometer were assumed to be correct within the stated accuracies. Figure 9.1-3 shows the differences between the measured salinities from the salinometer and the derived salinities based on the two CTD channels based on the rosette files. The difference is minimal at the beginning but a clear change in the difference is visible between CTDs #28 and #43 (February 1st to February 2nd).

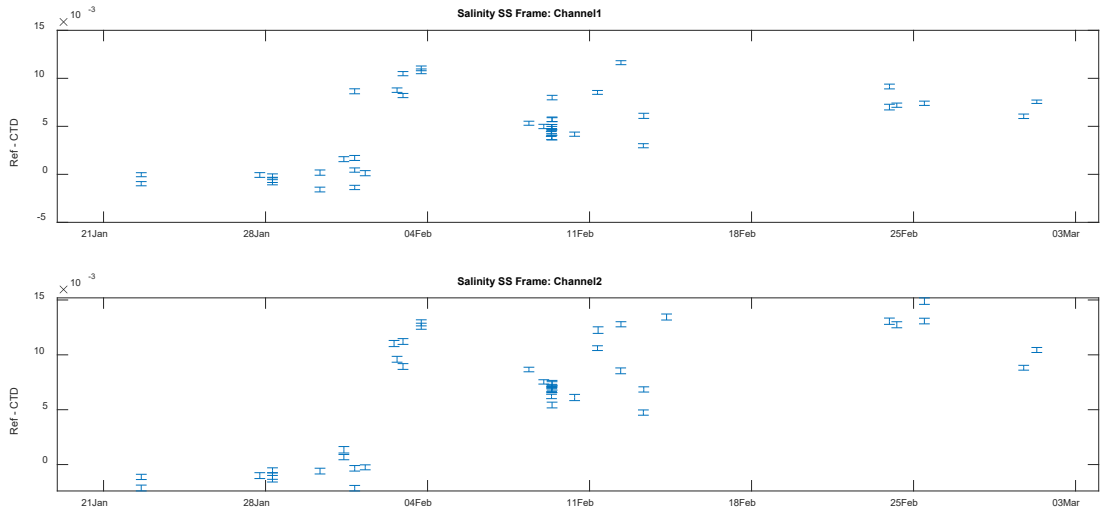

Figure 9.1-3: Salinity differences between the Salinometer and the derived salinities from the two CTD channels based on the rosette files from V8 of the processed CTD data

The correction to the CTD needs to be done on the conductivity sensors. Using the temperature measured by the main CTD at the depth each bottle sample was obtained, the true conductivity at that depth was calculated from the salinometer salinity reading. This reading was then compared to both the primary and secondary conductivity sensors on the CTD. The ratio of the salinometer-calculated conductivity and the CTD-measured conductivities are presented in Figure 9.1-4 as a function of the date the CTD cast was performed. Ratios greater than 1 indicate that the CTD reading is too fresh; values less than one indicate that the CTD reading is too salty. Only water samples that were associated with a low variability in the CTD reading were used.

Further investigations are needed for the final corrections, but based on the current data the following corrections to the conductivity readings of the primary CTD are suggested. The first and second conductivity channels of the processed CTD data (V8) before and including February 1st need a median conductivity correction factor for the primary conductivity cell of 0.99999581 (n = 7) and the secondary conductivity cell of 0.99997349 (n=7). From February 2nd the median conductivity correction factors are 1.00015919 (n=25) for the primary conductivity cell and 1.00019363 (n=25) for the secondary conductivity cell.

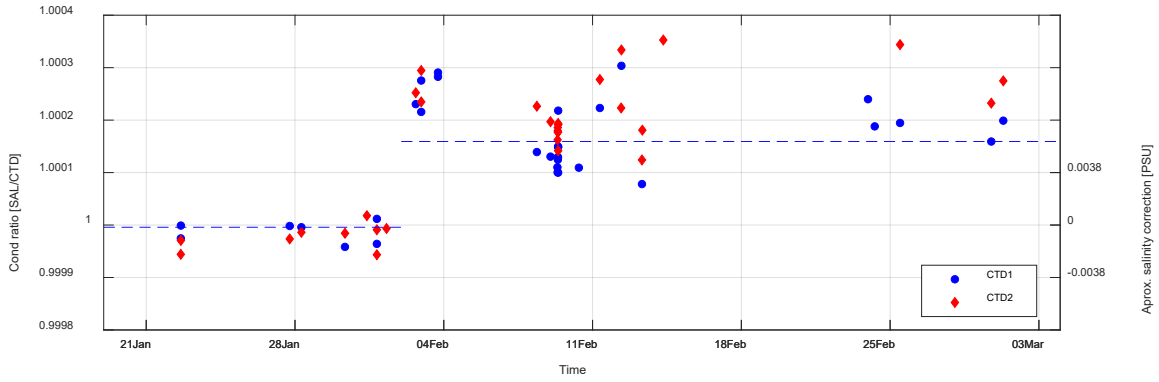

Figure 9.1-4: Conductivity ratios between the salinometry based conductivities and the primary (blue circle) and secondary (red diamond) conductivity cells of the primary ship-based stainless-steel CTD. The blue dashed lines give the proposed corrections before and after February 2nd.

Trace-Metal free CTD

The Trace-Metal free Titanium CTD (Ti) was checked in the same way using the measured salinities from water samples collected from Niskin bottles and the associated rosette files from the processed CTD data V8. The ratio of the salinometer-calculated conductivity and the CTD-measured conductivities are presented in Figure 9.1-5 as a function of the yearday the CTD cast was performed.

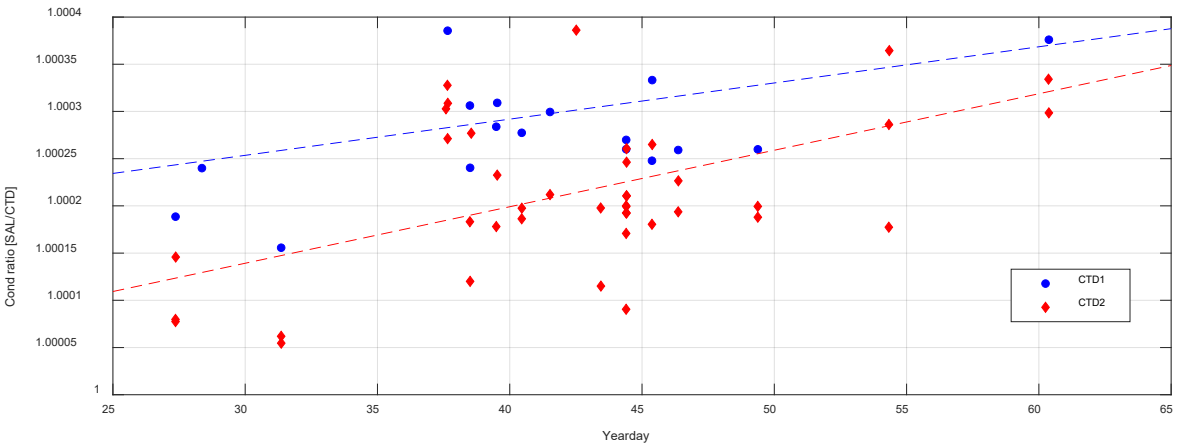

Figure 9.1-5: Conductivity ratios between the salinometry based conductivities and the primary (blue circle) and secondary (red diamond) conductivity cells of the ship-based Ti CTD. The blue dashed line give the proposed linear correction for the primary channel and the red dashed line is the proposed linear correction for the secondary channel.

Primary channel conductivity correction factor:

Crf1 = 0.00000383 * *yearday* + 1.00013852

Primary channel conductivity correction factor:

Crf2 = 0.00000599 * *yearday* + 0.99995965

with *yearday* being day of the year (1 Jan 12:00 = 0.5).

9.2 Dissolved oxygen

Author: Carol Robinson[1]

[1]*School of Environmental Sciences, University of East Anglia, Norwich, UK*

Samples were collected from the same 6 depths as the respiration measurements on the pre-dawn CTD, and from selected depths on the subsequent biogeochemistry and trace metal clean casts. One or two 55 mL glass bottles were filled from the Niskin bottle following Langdon, 2010. Samples were fixed immediately with $MnSO_4$ and NaI/NaOH and stored underwater until analysis. Measurements of dissolved oxygen were made using an automated Winkler titration system to a photometric endpoint (Williams and Jenkinson, 1982).

Provisional results

Calibration of the CTD oxygen sensors

Winkler oxygen data will be used to calibrate the four SBE oxygen sensors on the two CTDs. Provisional data show a good relationship between the sensors and Winkler titrations. However, the offset between the secondary SBE sensor on the titanium frame (TM Oxy 1) and Winkler oxygen concentrations appears to increase with increasing oxygen concentration. All data are shown in Figures 9.2-1, 9.2-2, and 9.2-3.

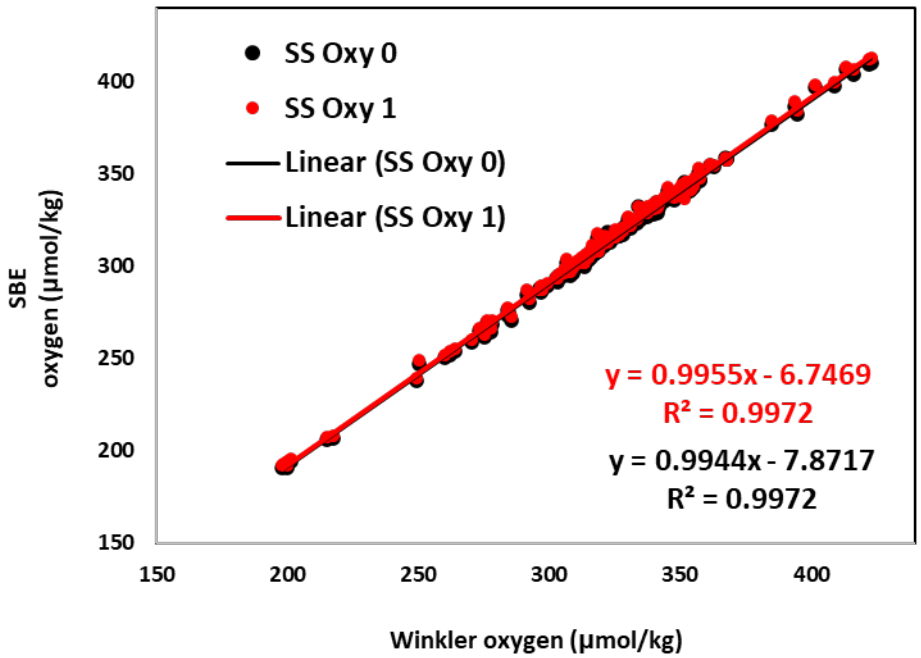

Figure 9.2-1: Regression between the two SBE oxygen sensors on the stainless steel CTD and dissolved oxygen determined by Winkler titration.

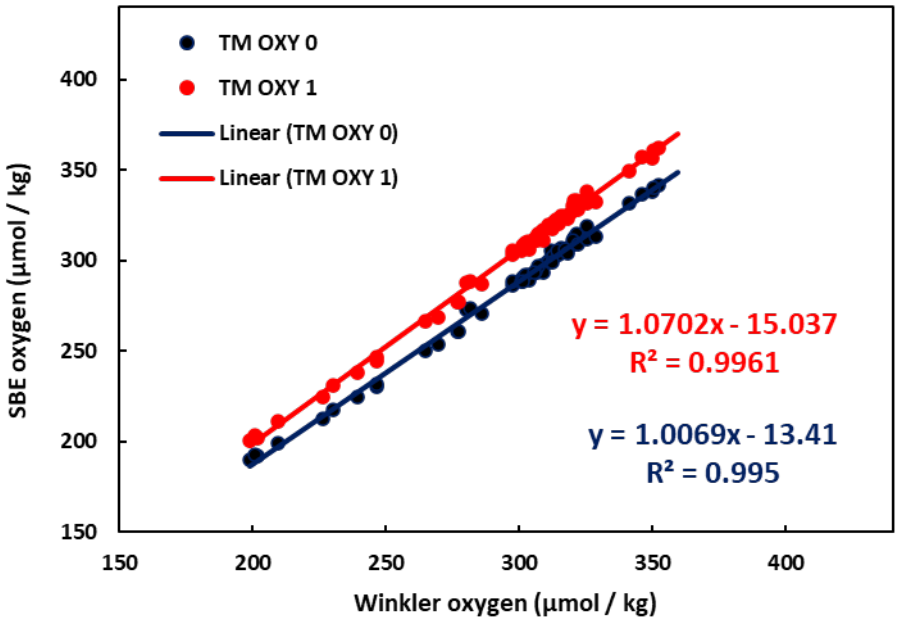

Figure 9.2-2: Regression between the two SBE oxygen sensors on the titanium CTD and dissolved oxygen determined by Winkler titration.

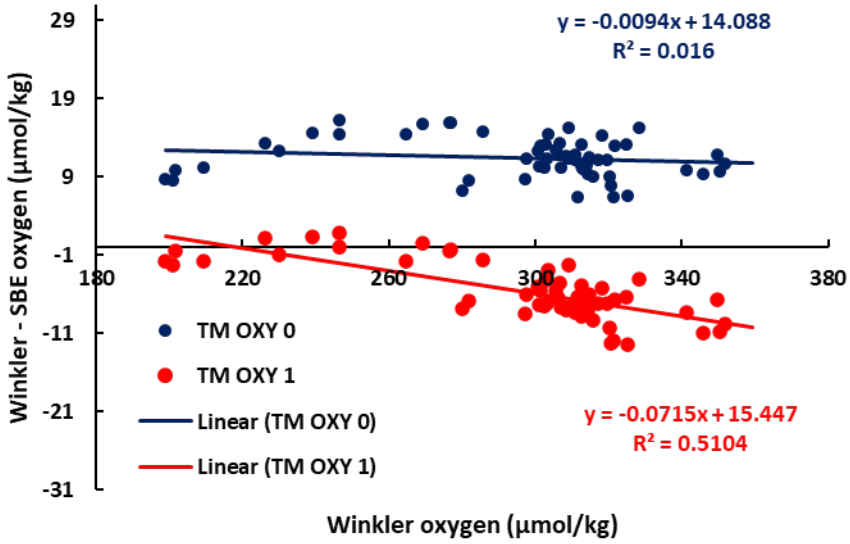

Figure 9.2-3: Offset between the SBE sensors on the titanium frame and Winkler oxygen concentrations.

9.3 Nutrients

Author: Sarah Breimann[1]

[1]Plymouth Marine Laboratory, Plymouth, UK

PICCOLO aimed to quantify carbon dynamics of the Weddell Sea through measurements including but not limited to:

- Iron limitation
- Nutrient re-introduction from krill faecal pellets
- pCO2
- Water mass dynamics
- DIC & TA
- Respiration
- Primary production

Science began for the PICCOLO expedition on the 22nd January 2024 with a test CTD and a shakedown CTD on the 26th January 2024 at Seymour island. Macronutrients – Nitrite (NO_2), Nitrate (NO_3), Ammonium (NH_4), Silicate (SiO_2) and Phosphate (PO_4) – were analysed in almost all water samples, excluding for sediment traps (floating and moored), surface snow samples and Radium CTDs. Analyses for PP (Primary Production), BC (Biogeochemistry) and TM (Trace Metal) casts were reduced where intensity of sampling increased. Profiles for the stations Larsen 1 (Figure 9.3-1), Mooring 1, (Figure 9.3-2), Seymour (Figure 9.3-3), GEOTRACES (Figure 9.3-4) and SS1 (Figure 9.3-5).

The PICCOLO sampling track spanned the Weddell sea, and followed transects from the coastal (near Seymour Island) and ice shelf (Larsen Ice Shelf) environments to off shelf sites, including a GEOTRACES intercalibration station at 4000m. The PICCOLO mooring was recovered, sampled and redeployed providing a long-term (12 month) and shorter term (1 month) dataset. Nitrate samples were analysed to provide calibration data for both the mooring and glider recovery and deployments.

Nutrient samples were analysed for UV incubation experiments (see Section 10.3 by Vassilis Kitidis), Iron limitation experiments (see Section 10.2 by Neil Wyatt) and nutrient dissolution from faecal pellets (see Section 10.5.1 by Katrin Schmidt).

Sampling and analytical methodology

Water column Sampling procedure

Acid clean 60m ml HDPE Nalgene bottles were used for all the underway and CTD nutrient sampling, these were aged, acid washed and cleaned initially, and stored with a 10% acid solution between sampling. Water column depth profile samples were taken from the 2 distinct CTD systems that were deployed. The one from the standard steel cable used 20 litre OTE CTD bottles on a Stainless Steel CTD/Rosette system and sub-samples were taken from the bottles into the Nalgene nutrient bottles once the CTD was back on deck. The sample bottle was washed 3 times before taking the final sample, and capping tightly. These were then taken immediately to the nutrient analyser in the laboratory and analysis conducted as soon as possible after sampling. With the trace metal free CTD system with clean winch and cable system and Titanium CTD frame and sensors, the bottles were either 12 litre cleaned GO-FLO's

or OTE bottles. The bottles were taken into the clean chem laboratory for processing and sampling for the nutrients. Nutrient free (Semperguard) gloves were used and other clean handling protocols were adopted. On occasion, nutrient samples needed to be frozen, in which case samples were defrosted and run according to the GO-SHIP nutrient manual protocols (Becker et al, 2020).

Underway samples were taken every two hours as standard where possible and were frozen and stored in the freezer, to be added to the next nutrient analysis.

Ice cores were defrosted in a water bath for 45 minutes at 50° and allowed to come to room temperature for 45 minutes before analysis. Cores had been sectioned to 7.5cm length, and then combined to correlate with DIC, CH4, N2O cores of 15cm length (see Table 9.3-1). Surface ice was also analysed opportunistically for nutrients (see Table 9.3-1), as were samples from on-board incubations.

Analytical methods

The micro-molar segmented flow colorimetric auto-analyser used was the PML 5- channel (nitrate, nitrite, phosphate, ammonium and silicate) SEAL analytical AAIII system with high-resolution colorimeters and using classical proven analytical techniques. The analytical chemical methodologies used were according to Brewer and Riley (1965) for nitrate, Grasshoff (1976) for nitrite, Mantoura and Woodward (1983) for ammonium, and Kirkwood (1989) for silicate and phosphate.

The instrument was calibrated with calibrated home produced nutrient stock standards and then daily quality control samples were analysed using Nutrient Reference Materials from SCOR/Jamstec and KANSO Technos, Japan. Specifically batch BW, CM, CP were used during the cruise.

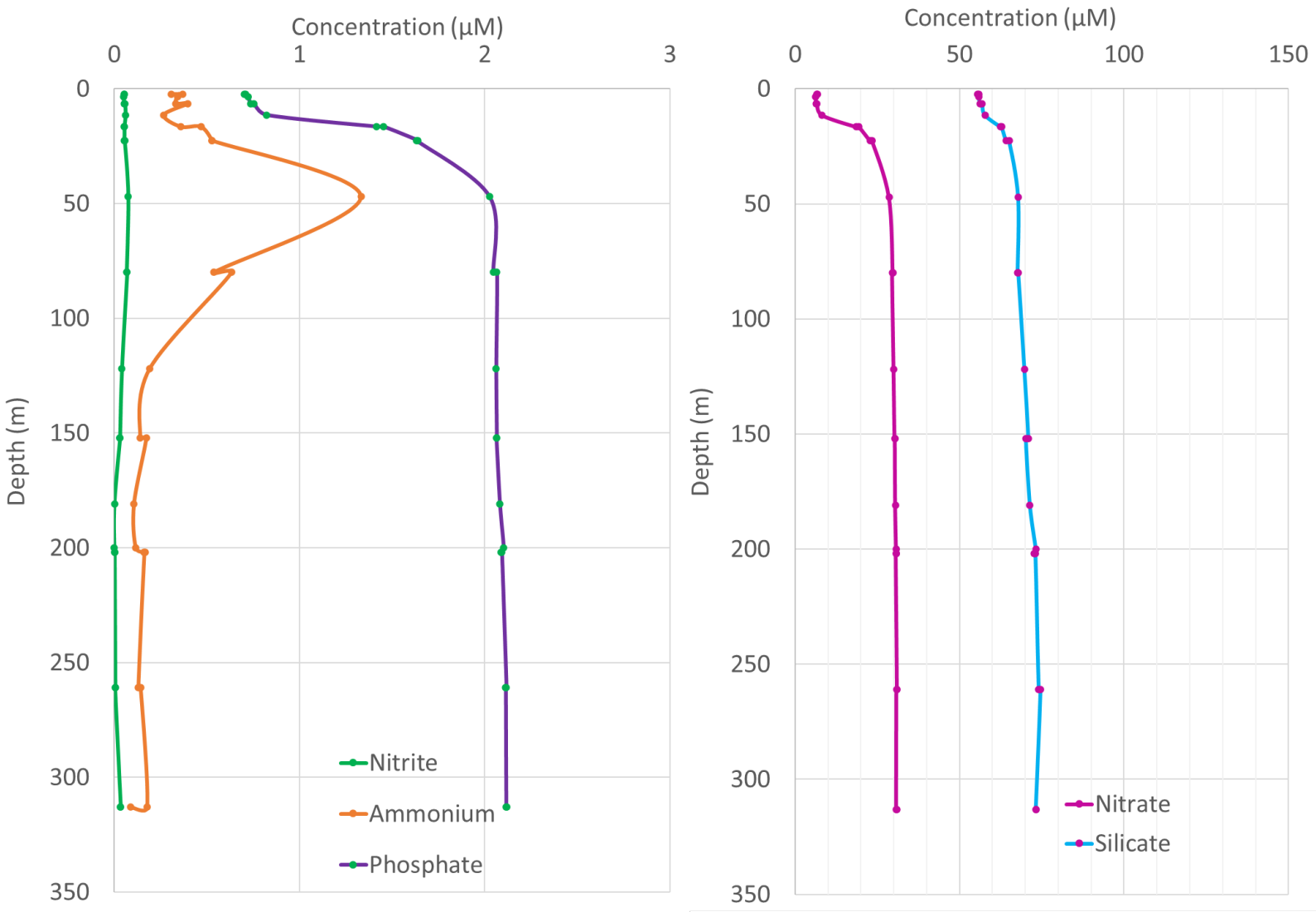

Figure 9.3-1: Nutrient profiles (NO_2, NO_3, NH_4, SiO_2, PO_4) for Larsen 1.

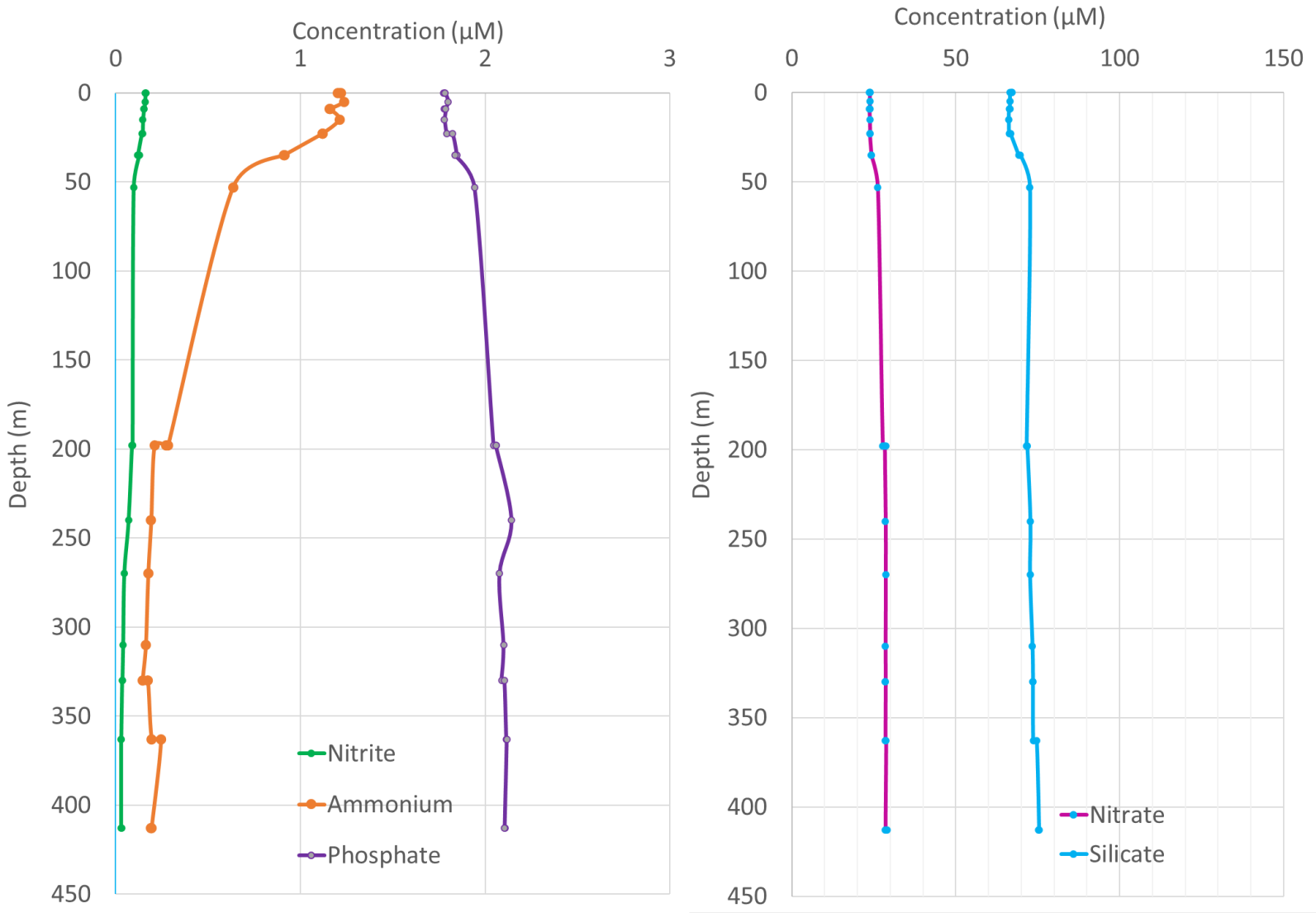

Figure 9.3-2: Nutrient profiles (NO_2, NO_3, NH_4, SiO_2, PO_4) for Mooring 1.

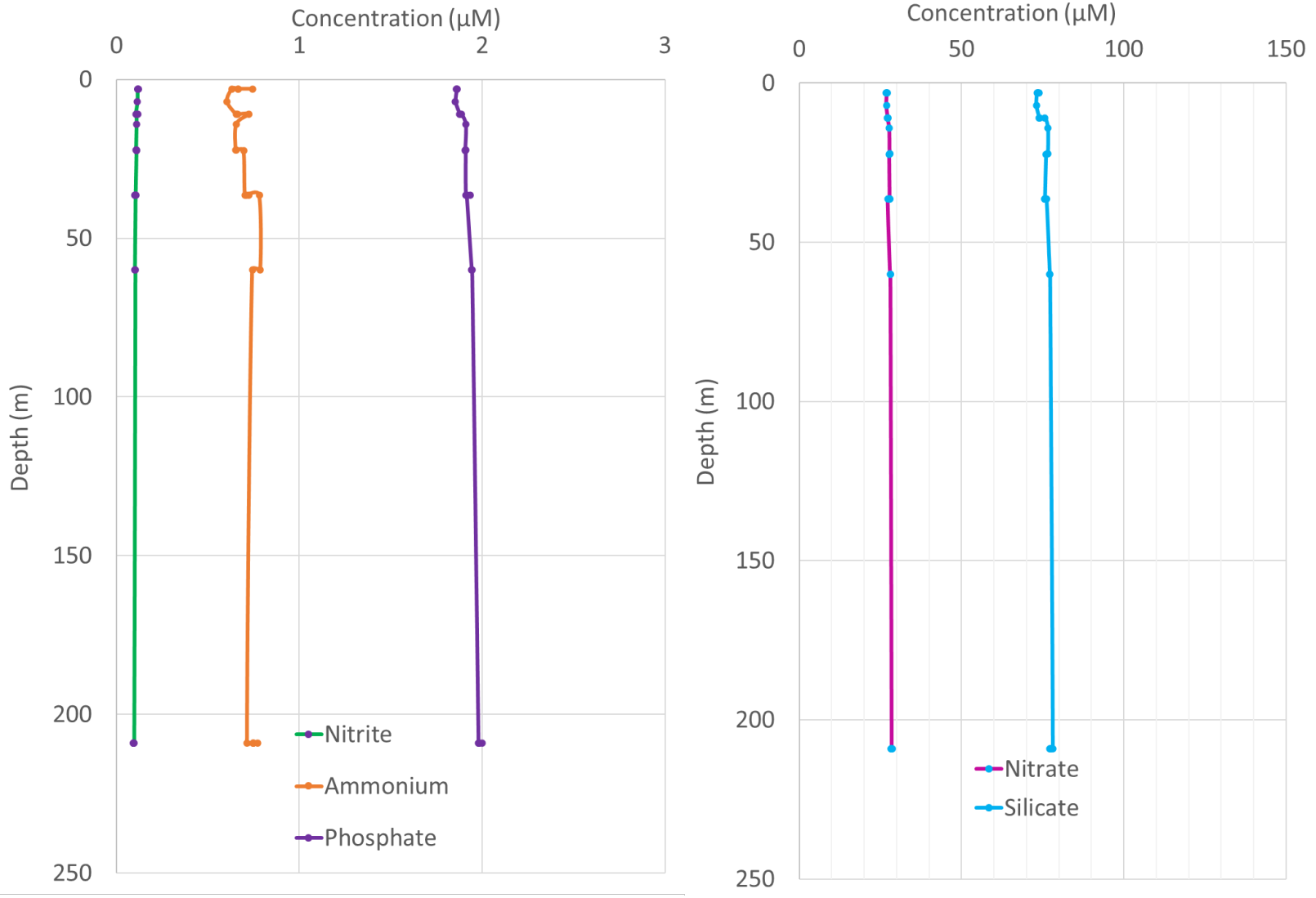

Figure 9.3-3: Nutrient profiles (NO_2, NO_3, NH_4, SiO_2, PO_4) for Seymour Island station.

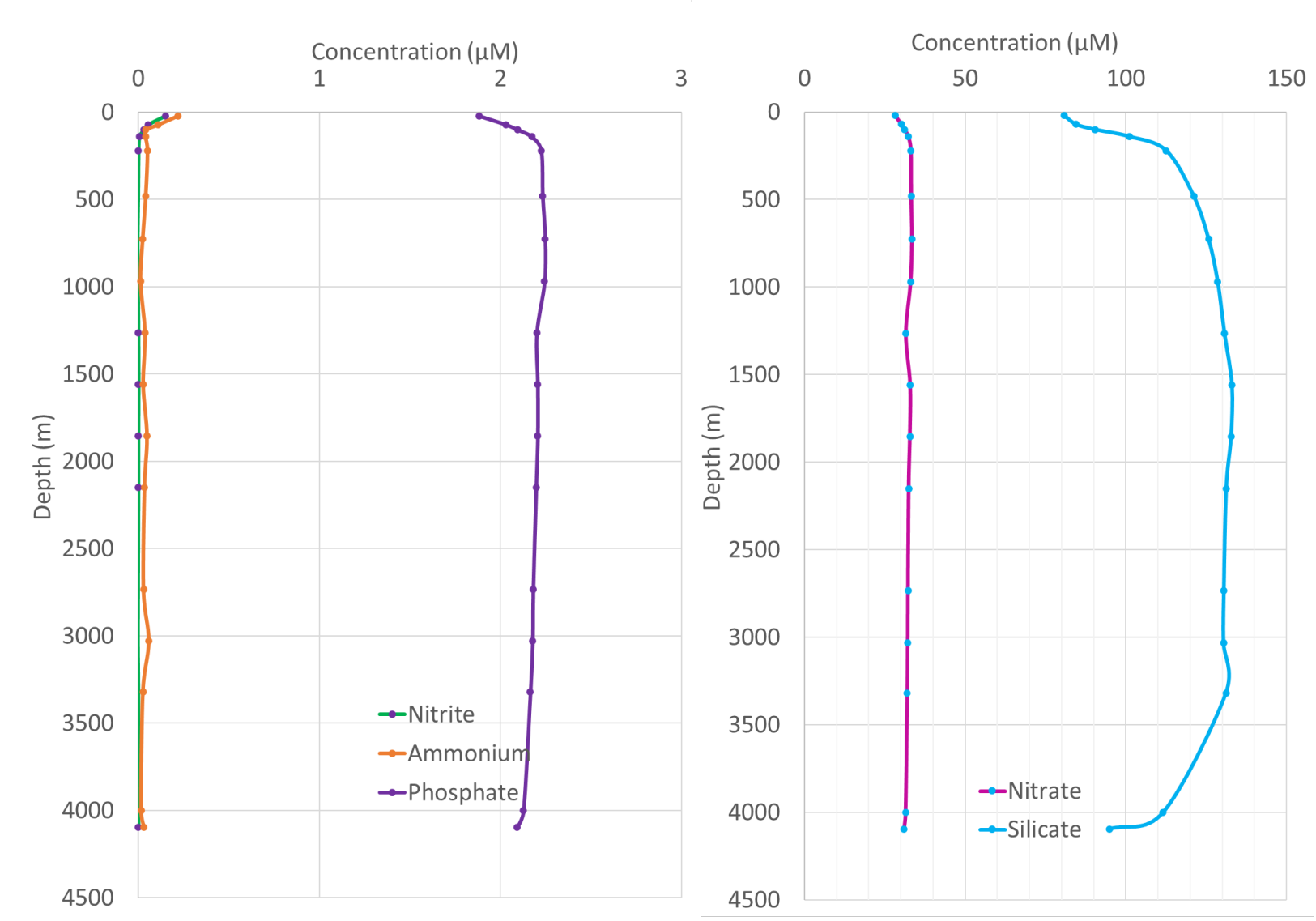

Figure 9.3-4: Nutrient profiles (NO_2, NO_3, NH_4, SiO_2, PO_4) for the GEOTRACES intercalibration station.

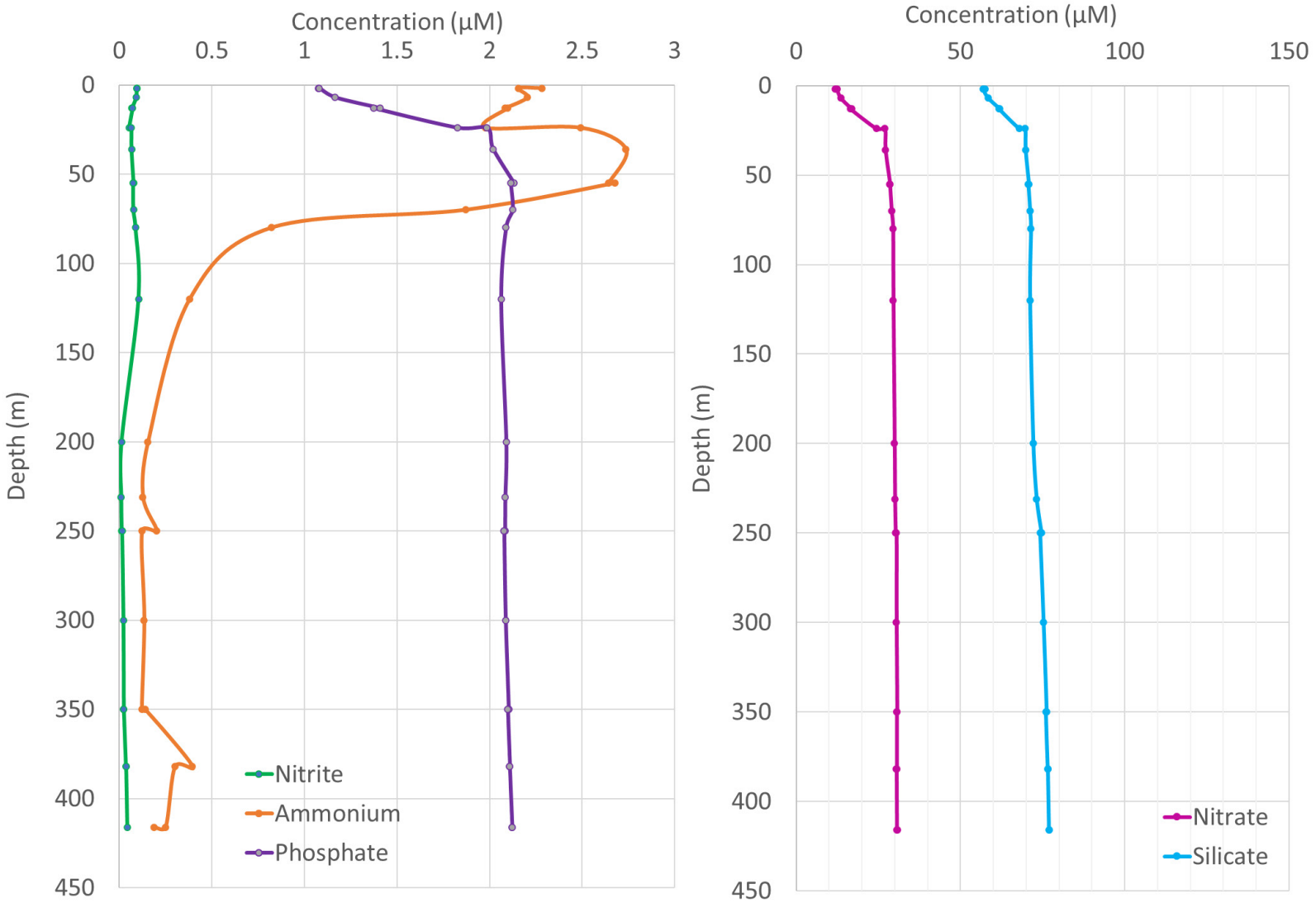

Figure 9.3-5: Nutrient profiles (NO_2, NO_3, NH_4, SiO_2, PO_4) for station SS2.

Table 9.3-1: CTD sampling

Event	CTD#	Station	Type	Date/time	Lat	Lon	Bottles sampled
3	3	Test1	BG	22/01/2024 14:42:00	-61.45473	-56.67682	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
4	4	Test1	TM	22/01/2024 16:21:00	-61.45278	-56.66144	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
8	5	Test2	BG	26/01/2024 16:49:00	-64.0968	-56.13074	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
13	7	Mooring	BG	27/01/2024 17:37:07	-64.57567	-55.05344	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
18	8	Mooring	PP	28/01/2024 04:56:00	-64.56036	-55.06062	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
19	9	Mooring	BG	28/01/2024 06:50:00	-64.56992	-55.06725	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
20	10	Mooring	TM	28/01/2024 08:27:00	-64.53534	-55.07961	1 2 3 4 5 6 7 9 11 12 13 15 16 17 18 19 21
30	13	Mooring	TM	29/01/2024 08:21:12	-64.58495	-55.07743	1 2 3 4 5 6 7 9 11 12 13 14 15 16 17 18 19 20 21 22 23 24
41	16	Mooring	PP	30/01/2024 04:54:49	-64.58763	-55.08591	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
43	18	Mooring	BG	30/01/2024 07:58:20	-64.57537	-55.08344	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
44	19	N104	BG	31/01/2024 08:59:01	-66.13578	-59.88173	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
45	20	N104	TM	31/01/2024 10:11:00	-66.13611	-59.88765	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 17 18 19 20 21 23 24
54	23	N102	BG	31/01/2024 20:11:19	-66.07234	-60.16907	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
59	26	N96	PP	01/02/2024 04:47:49	-66.05637	-60.48707	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
61	28	N96	BG	01/02/2024 07:07:09	-66.05631	-60.48266	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
62	29	N96	TM	01/02/2024 08:21:30	-66.05626	-60.47978	1 2 3 4 5 6 7 8 9 11 13 15 16 17 18 19 21 22 23
67	33	N98_5	BG	01/02/2024 16:15:38	-66.38228	-60.34047	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
72	34	N98_5	TM	01/02/2024 17:49:00	-66.38661	-60.33252	1 2 3 4 5 6 7 9 11 12 13 15 16 17 18 19 21 22 23

75	36	Cal.1	BG	01/02/2024 22:38:30	-66.17419	-60.2236	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
78	38	N104	PP	02/02/2024 04:54:01	-66.13378	-59.89225	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
79	39	N104	BG	02/02/2024 06:20:10	-66.13386	-59.89469	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
80	40	N96_5	TM	02/02/2024 08:48:10	-66.12547	-60.38877	1	2	3	4	5	7	8	9	11	12	13	15	16	17	18	19	21	22	19					
84	43	N96_5	BG	02/02/2024 12:51:27	-66.11871	-60.42639	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
86	44	N101	BG	02/02/2024 16:02:30	-66.06745	-60.33313	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
87	45	N101	TM	02/02/2024 17:10:40	-66.06733	-60.33257	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	20	21	19	23	24			
89	46	SS1	BG	02/02/2024 22:14:10	-65.81125	-59.61344	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
91	47	SS2	PP	03/02/2024 04:54:10	-65.62708	-59.29106	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
92	48	SS2	BG	03/02/2024 06:31:40	-65.62652	-59.29569	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
93	49	SS2	TM	03/02/2024 07:31:59	-65.62646	-59.29699	1	3	5	7	9	11	13	14	16	17	21	23												
99	52	SS3	BG	03/02/2023 17:08:12	-65.08307	-58.81893	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	19	21	22	23	24			
103	53	SS4	PP	04/02/2024 04:58:20	-64.58644	-58.26346	1	2	3	4	5	6	8	9	10	11	14	15	18	19	20	21	22	24						
104	54	SS4	BG	04/02/2024 06:23:50	-64.58837	-58.25968	1	2	3	4	5	7	8	10	11	12	13	14	15	17	18	19	20	22	23	24				
105	55	SS4	TM	04/02/2024 07:29:40	-64.58895	-58.25751	1	3	5	7	9	11	13	17	21															
126	68	Cal. 2	BG	06/02/2024 17:32:52	-63.67915	-52.12045	5	6	8	9	16	17	21	22																
128	69	Geotraces	TM	07/02/2024 11:47:12	-64.13382	-47.97171	1	3	5	6	7	9	10	11	12	13	15	16	17	18	19	23								
133	70	T1	PP	08/02/2024 05:46:20	-64.53265	-48.49578	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	24		
134	71	T1	BG	08/02/2024 07:13:50	-64.52934	-48.49552	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
135	72	T1	TM	08/02/2024 10:29:30	-64.50368	-48.53346	1	3	5	7	8	9	10	11	13	15	16	17	18	19	22	23								

142	75	T2	PP	09/02/2024 05:48:40	-64.52885	-49.70508	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	19	20	21	22	24			
143	76	T2	BG	09/02/2024 07:12:18	-64.52275	-49.69395	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
144	77	T2	TM	09/02/2024 10:37:10	-64.5314	-49.60718	2	3	5	7	9	10	11	13	15	16	17	18	21	23											
151	80	T3	PP	10/02/2024 05:47:20	-64.52022	-50.95213	1	2	3	4	5	6	7	9	10	11	12	13	14	15	17	18	19	20	21	23	24				
152	81	T3	BG	10/02/2024 07:09:24	-64.50417	-50.91158	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
153	82	T3	TM	10/02/2024 09:48:35	-64.45194	-50.85704	1	3	4	5	7	8	9	10	11	12	13	15	16	17	18	19	21	23							
160	86	T4	PP	11/02/2024 05:52:35	-64.55078	-52.73381	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	19	20	21	22	23	24		
161	87	T4	BG	11/02/2024 07:14:40	-64.55413	-52.72796	1	3	4	5	6	7	8	10	12	13	15	17	19	20	22	23	24								
162	88	T4	TM	11/02/2024 11:35:24	-64.58581	-52.71635	1	3	5	8	9	10	11	12	13	15	16	17	18	19	21	23									
171	92	T5	PP	12/02/2024 06:08:01	-64.60919	-53.65531	1	2	3	4	5	6	7	9	11	12	13	14	15	17	18	19	20	21	24						
172	93	T5	BG	12/02/2024 07:24:50	-64.6243	-53.68499	1	3	5	6	7	8	10	11	12	14	15	17	19	20	21	22	24								
173	94	T5	TM	12/02/2024 10:46:00	-64.5417	-53.58619	1	3	5	8	9	10	11	12	13	15	16	17	18	19	21	23									
182	100	T6	PP	13/02/2024 05:49:36	-64.55577	-53.99056	1	2	3	4	5	6	7	9	11	12	13	14	15	17	18	19	20	21	24						
183	101	T6	BG	13/02/2024 07:09:53	-64.55531	-53.98781	1	3	5	6	7	8	10	11	12	14	15	17	19	20	21	22	24								
185	102	T6	TM	13/02/2024 09:58:03	-64.57674	-53.90407	1	3	5	7	8	9	10	11	12	13	15	16	18	19	21	22									
194	107	T7	PP	14/02/2024 05:47:36	-64.5553	-54.25709	1	2	3	4	5	6	7	9	10	11	12	13	14	15	17	18	19	20	21	24					
195	108	T7	BG	14/02/2024 07:23:20	-64.57358	-54.27753	1	3	4	5	7	8	9	10	11	13	14	15	16	18	19	21	22	24							
196	109	T7	TM	14/02/2024 09:10:02	-64.55088	-54.26812	1	3	5	7	8	9	10	11	12	13	15	16	18	19	20	21	23								
205	113	T8	PP	15/02/2024 06:05:30	-64.57891	-54.40824	1	2	3	4	5	6	7	9	10	11	12	13	14	15	17	18	19	20	21	24					
206	114	T8	BG	15/02/2024 07:26:10	-64.57454	-54.40475	1	3	5	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23					

207	115	T8	TM	15/02/2024 08:43:40	-64.57112	-54.41171	1	3	5	7	9	10	11	13	15	16	17	18	23																			
216	119	Mooring	PP	16/02/2024 06:10:09	-64.57774	-55.04009	1	2	3	4	5	6	7	9	10	11	12	13	14	15	17	18	19	20	21	24												
217	120	Mooring	BG	16/02/2024 07:34:05	-64.58598	-55.06117	1	3	4	6	8	9	11	12	13	14	15	18	19	21	22	23	24															
218	121	Mooring	TM	16/02/2024 08:34:12	-64.59402	-55.0774	1	3	5	7	9	10	13	15	16	17	19	23																				
240	124	IceStation 1	PP	19/02/2024 05:50:41	-66.36028	-55.9877	1	2	3	4	5	6	7	9	10	11	12	13	14	15	17	18	19	20	21	24												
241	125	IceStation 1	BG	19/02/2024 07:26:40	-66.35158	-55.99138	1	3	5	7	8	9	10	12	13	14	16	18	19	21	22	24																
242	126	IceStation 1	TM	19/02/2024 08:40:50	-66.34583	-55.99897	2	4	5	7	9	12	14	16	19	21	23																				
254	129	Cal.3	BG	23/02/2024 22:37:09	-63.53921	-52.8961	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21											
256	131	Biopole Mooring	TM	24/02/2024 07:23:06	-62.33075	-50.98817	2	3	5	7	8	9	12	13	15	16	18	21																				
258	132	Float1	BG	25/02/2024 10:58:28	-64.78393	-56.15397	1	3	5	7	10	12	13	15	17	18	19	20	22	23																		
266	133	IceStation 2	BG	26/02/2024 05:50:45	-65.40871	-57.81378	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24								
288	134	Supersite	BG	29/02/2024 17:59:03	-64.69835	-56.54751	1	4	7	10	13	16																										
293	135	Supersite	PP	01/03/2024 06:00:30	-64.66287	-56.42403	1	2	3	4	5	6	7	9	10	11	12	13	14	15	17	18	19	20	21	24												
294	136	Supersite	BG	01/03/2024 07:30:41	-64.6618	-56.4275	1	3	5	6	8	10	11	13	14	15	18	19	21	22	24																	

Table 9.3-2: Underway sampling

Start Date & time	Latitude	Longitude	ID
24/01/2024 20:18	-63.9199	-57.7878	UW002Vas
24/01/2024 23:18	-63.9197	-57.7828	UW003Vas
30/01/2024 19:00	-64.8296	-57.4863	5
31/01/2024 09:02	-66.1358	-59.8817	6
31/01/2024 10:20	-66.1361	-59.8901	8
31/01/2024 11:00	-66.1356	-59.8968	9
31/01/2024 19:08	-66.1394	-59.9888	23
31/01/2024 19:46	-66.0866	-60.1342	10
01/02/2024 06:02	-66.0564	-60.4871	7
01/02/2024 19:21	-66.3863	-60.325	15
01/02/2024 19:31	-66.3859	-60.3246	14
02/02/2024 16:59	-66.0673	-60.3326	16
03/02/2024 05:41	-65.6267	-59.293	18
03/02/2024 22:31	-65.0537	-58.7622	19
04/02/2024 04:22	-64.5866	-58.2626	21
04/02/2024 18:46	-64.5892	-58.2414	11
05/02/2024 11:02	-64.2777	-55.7014	17
05/02/2024 13:02	-64.1544	-55.4971	12
05/02/2024 15:02	-64.0423	-55.2709	13
05/02/2024 16:59	-63.965	-54.9125	22
05/02/2024 19:00	-63.7933	-54.5655	20
05/02/2024 22:08	-63.5121	-53.9369	24
05/02/2024 23:26	-63.4976	-53.6177	31
06/02/2024 01:01	-63.5233	-53.1405	35
06/02/2024 03:10	-63.6147	-52.5436	28
06/02/2024 08:04	-63.6858	-52.0977	27
06/02/2024 08:16	-63.6844	-52.0944	25
07/02/2024 11:17	-64.1338	-47.9717	37
07/02/2024 17:14	-64.1921	-47.9793	29
07/02/2024 23:03	-64.5363	-48.4993	30
08/02/2024 01:06	-64.5307	-48.4993	44
08/02/2024 07:16	-64.5291	-48.4958	32
08/02/2024 07:26	-64.5279	-48.4972	400
08/02/2024 20:47	-64.5246	-48.9139	51
08/02/2024 23:10	-64.5292	-49.3146	41
09/02/2024 02:43	-64.5366	-49.6192	26
09/02/2024 03:40	-64.531	-49.6822	45
09/02/2024 07:16	-64.5227	-49.6939	49
09/02/2024 19:00	-64.5159	-50.157	43
10/02/2024 00:13	-64.4632	-50.5817	42
10/02/2024 07:00	-64.5058	-50.9153	34
10/02/2024 17:31	-64.552	-51.4517	77
10/02/2024 21:51	-64.5543	-51.863	46
11/02/2024 12:36	-64.5758	-52.7176	36
11/02/2024 12:49	-64.5737	-52.718	48

Start Date & time	Latitude	Longitude	ID
11/02/2024 17:35	-64.5649	-52.9223	50
11/02/2024 21:37	-64.5546	-53.1718	33
12/02/2024 01:09	-64.5707	-53.3993	52
12/02/2024 01:17	-64.5703	-53.3983	55
12/02/2024 03:40	-64.5846	-53.5953	53
12/02/2024 13:09	-64.5469	-53.5801	63
12/02/2024 13:20	-64.5462	-53.5795	65
12/02/2024 22:44	-64.5663	-53.7199	58
13/02/2024 08:16	-64.5539	-53.9969	70
13/02/2024 21:37	-64.5696	-54.1136	74
14/02/2024 07:26	-64.5732	-54.2766	76
14/02/2024 21:31	-64.5687	-54.3276	66
15/02/2024 02:48	-64.5564	-54.411	61
15/02/2024 06:53	-64.5766	-54.4079	68
15/02/2024 14:17	-64.5469	-54.4228	79
15/02/2024 20:29	-64.6431	-54.8637	59
15/02/2024 22:47	-64.5687	-54.7547	57
16/02/2024 02:50	-64.5635	-55.0639	78
16/02/2024 03:05	-64.5622	-55.0689	54
16/02/2024 13:29	-64.6093	-55.068	64
17/02/2024 11:11	-64.5622	-55.0689	73
17/02/2024 12:47	-65.8962	-55.7147	71
17/02/2024 14:37	-65.9275	-55.7086	56
17/02/2024 21:23	-66.1713	-55.5156	80
19/02/2024 04:36	-66.3664	-55.988	77
20/02/2024 14:46	-63.678	-56.6762	75
22/02/2024 13:09	-65.3003	-64.295	62
23/02/2024 10:52	-63.1315	-57.4292	60
24/02/2024 14:07	-62.3812	-51.1956	T1
24/02/2024 15:03	-62.5293	-51.4362	T2
24/02/2024 16:03	-62.6892	-51.7083	T3
24/02/2024 17:01	-62.8348	-52.0142	T4
24/02/2024 17:34	-62.8786	-52.1338	T5
24/02/2024 18:04	-62.8786	-52.1338	T6
24/02/2024 18:30	-62.9228	-52.2752	T7
24/02/2024 19:02	-62.9541	-52.3378	T8
24/02/2024 19:30	-62.9802	-52.3946	T9
24/02/2024 20:02	-63.0105	-52.4584	T10
24/02/2024 20:36	-63.0431	-52.5232	T11
24/02/2024 21:08	-63.0723	-52.5815	T12
24/02/2024 21:32	-63.0953	-52.6237	T13
24/02/2024 22:05	-63.1289	-52.6849	T14
24/02/2024 22:35	-63.1561	-52.7408	T15
24/02/2024 23:04	-63.1561	-52.7408	T16
24/02/2024 23:30	-63.1993	-52.8685	T17
25/02/2024 00:06	-63.2211	-52.9511	T18

Table 9.3-3: Trace metal TowFish samples analysed.

Start Date & time	Latitude	Longitude	ID
27/01/2024 13:00	-64.3901	-55.1948	FISH001
05/02/2024 13:01	-64.1561	-55.498	FISH002
07/02/2024 17:44	-64.2233	-47.9205	FISH003
09/02/2024 17:15	-64.5404	-49.9724	FISH004
09/02/2024 18:06	-64.5271	-50.1459	FISH005
17/02/2024 13:08	-65.8947	-55.7113	FISH006
17/02/2024 14:14	-65.9001	-55.7216	FISH007
24/02/2024 13:37	-62.3273	-51.0066	FISH008
24/02/2024 14:01	-62.3729	-51.1562	FISH009
24/02/2024 14:37	-62.4472	-51.3589	FISH010
24/02/2024 15:00	-62.5203	-51.4261	FISH011
24/02/2024 15:30	-62.6016	-51.554	FISH012
24/02/2024 16:00	-62.697	-51.7235	FISH013
24/02/2024 16:30	-62.7563	-51.8518	FISH014
24/02/2024 17:00	-62.7563	-51.8518	FISH015
24/02/2024 17:30	-62.8754	-52.1217	FISH016
24/02/2024 17:51	-62.8919	-52.186	FISH017
24/02/2024 18:30	-62.9222	-52.2739	FISH018
24/02/2024 19:00	-62.9516	-52.3326	FISH019
24/02/2024 19:30	-62.9802	-52.3946	FISH020
24/02/2024 20:00	-63.008	-52.4537	FISH021
24/02/2024 20:30	-63.037	-52.5104	FISH022
24/02/2024 21:00	-63.0645	-52.5673	FISH023
24/02/2024 21:30	-63.0933	-52.6199	FISH024
24/02/2024 22:00	-63.1234	-52.6742	FISH025
24/02/2024 22:30	-63.1514	-52.731	FISH026
24/02/2024 23:00	-63.1776	-52.7945	FISH027
24/02/2024 23:30	-63.199	-52.866	FISH028
24/02/2024 23:55	-63.2141	-52.9288	FISH029

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9.4 Dissolved organic carbon, total organic carbon, total dissolved nitrogen and dissolved organic phosphorus

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Water for total organic carbon, total dissolved nitrogen and dissolved organic carbon and phosphorous was collected from the pre-dawn cast at the same six depths as for the respiration samples. Three additional samples were collected from the biogeochemistry cast immediately after the pre-dawn cast at 200 m, at the depth of the maximum temperature and from the deepest depth sampled (see Table 10. 1-1). Sample bottles were rinsed with sample water prior to collection of 1 litre of water from each depth and the sample was immediately filtered through pre-combusted GF/F according to the protocol described in Margolin et al. (2015). Samples for total organic carbon were collected in the same manner but were not filtered. Blank samples (filtered and non-filtered MilliQ water) were collected twice during the cruise. All bottles used to store the samples and filtration equipment were acid washed in a ~5 % HCl bath for at least 6 hours, rinsed thoroughly (at least 3 times) in MilliQ and left to air dry. Filtered samples were then frozen at -20 °C and will be transported to the UK on the SDA before transport to AWI for analysis by project partner Boris Koch.

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9.5 Trace metal sampling and analysis

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Introduction

Marine primary production drives carbon fixation in the ocean and is the base of the marine food web, it is therefore an important component of the Earth system (Falkowski and Raven, 2007). Iron (Fe) based proteins are required for numerous vital cellular processes (e.g. photosynthesis, respiration, nitrogen fixation), and Fe is therefore an essential nutrient for the growth of marine microbes (Twining and Baines, 2013, Tortell et al., 1996). The low availability of trace metals such as Fe, and others such as manganese, can limit the growth of marine

microbes (Moore et al., 2013). Therefore, understanding the distribution of trace metals in the ocean is vital in understanding carbon cycling and how this may change under future climate change scenarios. In order to determine the transport mechanisms and distribution of Fe in oceanic provinces and determine any kind of meaningful mass balance requires the consideration of all forms of Fe from truly soluble molecular species to colloidal and particulate species.

In relation to the PICCOLO cruise, the aim was to determine the key rate-controlling processes of the carbon fixation and subsequent processing in the lower limb circulation. Iron is a key chemical requirement for biological production and has been shown to be limiting in most Southern Ocean waters (Tagliabue et al., 2014). The main sources of dissolved Fe (dFe) include sediments, glacial/sea-ice melt on shelf (Lin et al. 2011) and winter entrainment and upwelling in central gyre waters. Surface dFe levels vary from 0.01-0.1 nM in the surface waters of the open Weddell Gyre and up to ~1 nM over the continental shelf (Klunder et al., 2014). Subsequent surface water entrainment of dFe from these sources may control the rate of primary production and thus DIC uptake. The focus of the trace metal work related to Work Package 2: Biological carbon transformations in the upper ocean (Led by Carol Robinson), specifically *Hypothesis 2.1 Iron supply to surface waters controls the uptake of DIC by phytoplankton in the photic zone.* As part of testing for this hypothesis, we aimed to quantify the respective inputs of dFe to surface waters to evaluate their relative importance. Light is also an important factor as both dFe and light are inextricably linked via photophysiology. In parts of the low latitude Southern Ocean where the Fe limitation has been alleviated, the spring bloom will not proceed until irradiance in the mixed layer is sufficient (Venables *et al.,* 2010). We aimed to collect surface and deep water samples along a transect from the open Weddell Gyre onto the shelf (**TTP1,2**), measuring Fe (dissolved, soluble and particulate), macronutrients, tracers of continental Fe (see radium isotopes Section 9.6), water mass (temperature, salinity), photophysiology (Fv/Fm) and light (UV, PAR).

Water and suspended particulate sampling

Methodology

To study the cycling of Fe in the PICCOLO study area (SD035 Antarctic Peninsula shelf waters and Western Weddell Sea), seawater and suspended particulate samples were collected for trace metal analyses to quantify the Fe distribution of the region.

Water column samples were collected using Ocean Test Equipment - GoFlo type bottles (Water Sampler, C-Free, Teflon coated, Model 130, 12 L) with external elastic cords for trace metal work, mounted onto a titanium frame with Kevlar conducting wire. All sample processing (including water column samples collected from under ice floes) was conducted in a trace metal clean laboratory on board the SDA using clean handling techniques. GEOTRACES protocols were followed based on the GEOTRACES cookbook https://www.geotraces.org/methods-cookbook.

On a typical cast, unfiltered water samples were collected for macronutrients, dissolved oxygen analyses, salinity calibration, total dissolvable metal analyses (acidified on-board for future analyses) ^{18}O, and particle size fractionation. Samples for the determination of dFe, ^{15}N (Raja Ganeshram, University of Edinburgh), Ba (Luke Bridgestock, University of St Andrews) and Fe isotopes (Alistair Lough, University of Leeds) were filtered through a 0.2 µm cartridge filter (Sartobran, Sartorius). Approximately half of the 0.2 µm filtered seawater samples were filtered

a second time over 0.02 µm Anotop syringe filters (Ussher et al., 2010) to determine the soluble fraction of trace metals. The remainder of the seawater in the OTE bottle (or a complete separate bottle if available) was passed over 0.45 µm polyethersulfone Supor™ membrane (PES, Pall) filters to collect suspended and sinking particles. At least 7 L of water was generally filtered for particles, with the exception of surface samples and ice floe samples, where the volume was lower. All filters were stored frozen (-20°C) for analyses by sequential leach-acid digestion and ICP-MS analysis (Ohnemus et al. 2014; Milne et al. 2017) at the University of Plymouth. Samples for TdFe, dFe, sFe were acidified and those for dFe were analysed on board using flow injection methods described in Obata et al. (1993) and Klunder et al. (2011). Samples for TdFe and sFe will be analysed at the University of Plymouth using the same methodology.

A total of 24 CTD deployments were carried out with the titanium frame. The first deployment was used to 'soak' the bottles to ensure that they were 'trace metal clean' for future deployments, and is not recorded in the trace metal station log (Table 9.5-1), the second deployment was a shakedown station that did not involve the collection of all parameters. A GEOTRACES intercalibration crossover station was occupied in the first half of the cruise (Cast 069) and GEOTRACES reference materials were analysed several times during the cruise and were accurate, within uncertainty. In addition, samples were collected from two ice floes using similar OTE-Go-Flo style bottles but with a smaller volume (5L, see Section 7.1.5 of the report on ice sampling), bringing the total to 25 stations where trace metal water column samples were collected (Table 9.5-1).

Practical report

There were many practical issues with the deployment of the OTE-Go-Flo style bottles which were almost always due to the ball valve closures of the bottles not functioning (either staying open or leaking when closed) and degradation of the elastic cords becoming too loose on the exterior of the bottles. For the bottles that were older than one year (single handles), the elastics were tightened by pulling cord through the pinned clamp. Closures were adjusted via screws on the ends of the bottles and underneath the ball valve on the sprung section. Six of the older than one year bottles were replaced with the new two-handled bottles in an attempt to maximise bottle functioning capacity. Through continuous adjustment and rinsing with UHP water after each cast, bottle functioning improved. One bottle was removed to be fixed (following breakage of the outer ball valve) and taken to the workshop, this bottle was later tested with a deployment to 100 m and sampled for dFe; the results showed that the bottle was highly contaminated (> 15 nmol L^{-1}). Note that this bottle was not used for any sample collection after being fixed.

Table 9.5-1: Log of samples collected from the trace clean rosette, Station name and CTD number are listed. The EX referred to in the note section is where unfiltered water was collected for the iron limitation experiments (see Section 10.2).

Station	CTD No	DO	O18	Nuts	Salts	Flow Cyt	TdFe	dFe	sFe	FeISO	BaISO	NO3ISO	Suspended particles	Size Fract. Particles	DIC/Alk	Pigments (Giorgio)	POC	Notes
Shakedown	004	5		24		17	24	24						3				
Mooring 01	010	13	13	18	4	13	13	13	8	8	8	10	8	1				EX01
Mooring 01	013	6	11	22	4	11	20	20	12				14	2				
N104	020	6	15	22	4	15	15	15	12	8	8	10	10	1		3		EX02
N096	029	6	13	21	4	13	13	13	11	8	5	8		2				
N098_5	034		15	19		15	15	15	11	8	5	10	9	1				
N_96.5	040		13	19	4	13	13	13	11			9	9	2		2		
N101	045	6	13	21		13	13	13	11			9	11	1		1		
SS2	049		12	12	4	12	12	12	12			10	11	1		1	2	
SS4	055		10	10	3	10	10	10	10	8		8	10	1		1		
GEOTRACES	069	12	17	17	8	17	17	17	12	10	10	11	12		14			
T 1	072		16	16	4	16	16	16	12	10		12	13	1				EX03
T2	077	6	14	14	4	14	14	17	12			10	14	2		2		
T3	082		17	17	4	17	17	18	12	10	7	11	11	1		2		
T4	088		15	15	4	15	15	17	12			11	11	1		2		EX04
T5	094	6	17	17	4	17	17	17	12	10	6	11	12	1		2		*Rosette hit the bottom*
T6	102		16	16	4	16	16	16	12			11	12	1		2	3	
T7	109	4	17	17	23	17	17	17	12	10	6	12	13	1				
T8	115		13	13	4	13	13	14	12	10	6	9	10	1				EX05
Mooring 02	121	6	12	12	4	11	12	12	12			10	11	1				
Ice Station 1	126	6	11	11	4	11	11	11	11	6		9	11	1				
Biopole	131		13	13	5		13	13	12				10	1				EX06
Ice Flow 8			3	3		3	3	3		3	3	3	3	1				EX07
Ice Flow 9			3	3		3	3	3		3	3	3	3	1				
Super Site	137	6	12	12	5	12	12	12	12			10	12	1				
Total samples*	**25 casts**	**88**	**311**	**384**	**104**	**314**	**344**	**351**	**253**	**112**	**67**	**207**	**240**	**30**	**14**	**18**	**5**	

* Number indicates the number of samples collected at each depth (& not the number of replicte samples/bottles collected at any one depth)

Trace metal tow-fish deployment

Methodology

Throughout the cruise, surface samples (ca. 3-4 m depth) were collected using the BAS towed trace-metal-free fish. Along the sampling transect unfiltered samples were taken when not on station for nutrient and total dissolvable Fe analyses, and filtered (as above) for dissolved Fe analyses. Samples for additional parameters (i.e. particle size fractionation) were also occasionally collected. A total of 30 surface tow-fish samples were taken for TdFe/dFe (see Table 9.5-2) throughout the cruise focussing on opportunistic 'ice free' stretches on the shelf near the Antarctic Peninsula and a transect NE of the study area from off-shelf to on-shelf, where 30 minute resolution was obtained.

The BAS tow-fish was plumbed from the clean laboratory with acid washed, braided PVC tubing which was insulated with pipe insulation to reduce freezing on the deck. It connected via a PTFE bellows pump (Altec) then the tubing from the pump went ca. 20-30 m and terminated though the fish body. The braided PVC tubing was reinforced with larger bore PVC tubing over the top in the 2 m immediately next to the fish body. During deployment, the braided PVC tubing was then cable tied at 1m intervals up to the body to the Rolls Royce Boom on the starboard aft quarter. When brought inboard cable ties had to be cut and the tow-fish slid under the gab in the gunwales and secured with straps. The hose end protruding from the tow-fish was covered with a clean glove or bag to protect from contamination during times when spent on deck.

Practical report

The fish tubing line at deck level needed priming with clean surface seawater initially using a piece of clean hose into a carboy on the deck. We used a y-piece and two valves prior to the inlet of the pump and left this installed, but this would not be advised as it introduced air and priming was only needed the first time anyway. The winch wire was replaced with Kevlar rope on the small starboard winch. The fish flew well in the water up to ca.10 knots, after which it became very shallow, risked breaching and the hose breaking free. It was also noted that it was not possible to be outside the hull wake of the SDA, meaning there is always concern of the possible influence of the ship on trace metal measurements using this set up.

Table 9.5-2: Trace metal towfish sample log

Start Datetime	Latitude	Longitude	Water Depth	End Datetime	Nuts	O18	TdFe	dFe	Partic. Size fraction	Fv/Fm	Comments	
27/01/2024 13:00	-64.3901	-55.1948	345.92		1			1	1	1	Fv/Fm for Neil. Flushed new Go-Flo filter for 5 mins.	
05/02/2024 13:01	-64.1561	-55.498	343.87	05/02/2024 13:12	1		1	1	1			
07/02/2024 17:44	-64.2233	-47.9205	4079.74	07/02/2024 17:48	1		1	1			FSW carbov for Katrin (10L)	
09/02/2024 17:15	-64.5404	-49.9724	4501.56	09/02/2024 17:25	1		1	1			Collected 2L for Ruth & Ian	
09/02/2024 18:06	-64.5271	-50.1459	2933.36	09/02/2024 18:11	1		1	1				
09/02/2024 20:32	-64.5134	-50.1975	3304.02				1	1			Nutrients sampled but left in fridge in clean lab and not analysed.	
17/02/2024 13:08	-65.8947	-55.7113	377.21	17/02/2024 13:14	1		1	1	1		13:06-13:08 for Part fractions. 13:08-13:14 for Nuts,	
17/02/2024 14:14	-65.9001	-55.7216	372.99	17/02/2024 14:15	1		1	1				
24/02/2024 13:37	-62.3273	-51.0066	3369.43	24/02/2024 13:39	1	1	1	1				
24/02/2024 14:01	-62.3729	-51.1562	3334.03	24/02/2024 14:07	1	1	1	1				
24/02/2024 14:37	-62.4472	-51.3589	3289.35	24/02/2024 14:39	1	1	1	1				
24/02/2024 15:00	-62.5203	-51.4261	3283.55	24/02/2024 15:03	1	1	1	1				
24/02/2024 15:30	-62.6016	-51.554	3279.4	24/02/2024 15:36	1	1	1	1				
24/02/2024 16:00	-62.697	-51.7235	3255.04	24/02/2024 16:03	1	1	1	1				
24/02/2024 16:30	-62.7563	-51.8518	3209.48	24/02/2024 16:34	1	1	1	1				
24/02/2024 17:00	-62.7563	-51.8518	3209.48	24/02/2024 17:03	1	1	1	1				
24/02/2024 17:30	-62.8754	-52.1217	2340.89	24/02/2024 17:34	1	1	1	1				
24/02/2024 17:51	-62.8919	-52.186	1476.31	24/02/2024 18:02	1	1	1	1	1		Particle fraction finished 17:56. Other parameters 17:58-18:02	
24/02/2024 18:30	-62.9222	-52.2739	1086.29	24/02/2024 18:33	1	1	1	1				
24/02/2024 19:00	-62.9516	-52.3326	1011.03	24/02/2024 19:03	1	1	1	1				
24/02/2024 19:30	-62.9802	-52.3946	772.11	24/02/2024 19:34	1	1	1	1				
24/02/2024 20:00	-63.008	-52.4537	680.33	24/02/2024 20:04	1	1	1	1				
24/02/2024 20:30	-63.037	-52.5104	510.1	24/02/2024 20:36	1	1	1	1				
24/02/2024 21:00	-63.0645	-52.5673	495.98	24/02/2024 21:05	1	1	1	1				
24/02/2024 21:30	-63.0933	-52.6199	484.22	24/02/2024 21:34	1	1	1	1				
24/02/2024 22:00	-63.1234	-52.6742	471.37	24/02/2024 22:05	1	1	1	1				
24/02/2024 22:30	-63.1514	-52.731	464.78	24/02/2024 22:37	1	1	1	1	1		Nutrients in freezer.	
24/02/2024 23:00	-63.1776	-52.7945	460.51	24/02/2024 23:08	1	1	1	1			Nutrients in freezer.	
24/02/2024 23:30	-63.199	-52.866	454.52	24/02/2024 23:37	1	1	1	1			Nutrients in freezer.	
24/02/2024 23:55	-63.2141	-52.9288	443.71	25/02/2024 00:00	1	1	1	1			Nutrients in freezer.	

Sediment traps

Sinking particle samples were collected from floating sediment trap deployments. These were filtered and stored frozen for later analysis at University of Plymouth (see Section 14 for more details).

Preliminary data

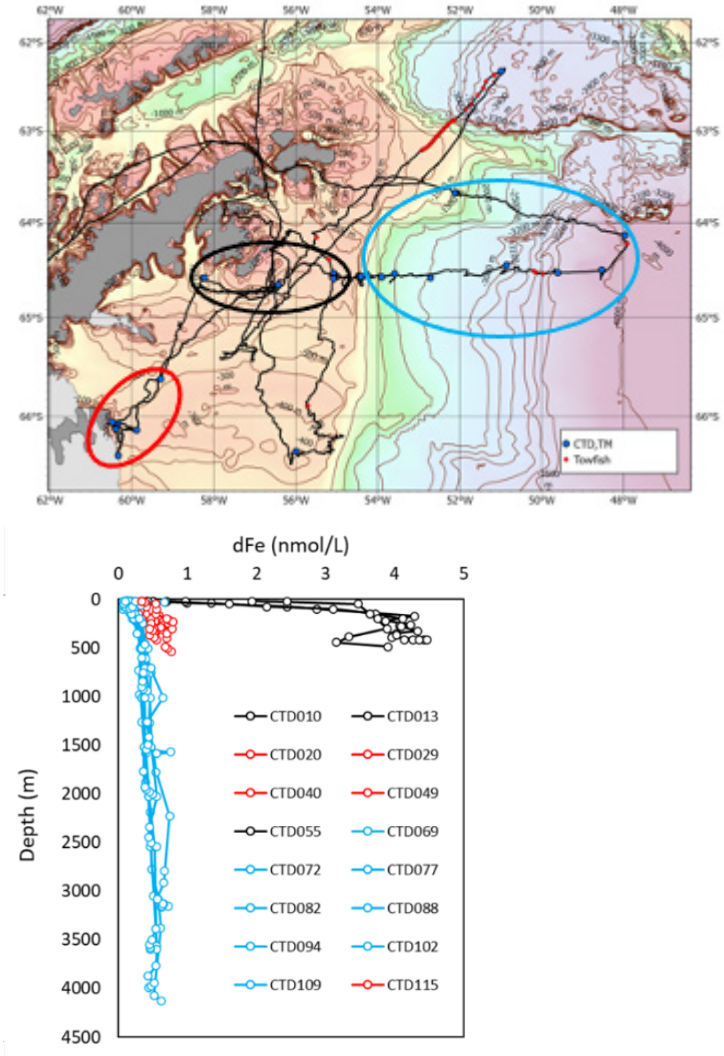

Figure 9.5-1: Dissolved iron concentrations in the water column plotted showing the 3 study locations: E-W shelf slope transect (blue), Larsen region (red) and Mooring/island locations (black).

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9.6 Radium sampling

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Objectives

Radium is produced continuously in sediments from the decay of thorium (Th) and thus displays elevated concentrations near the sediment-water interface. Radium is present in the ocean as four naturally-occurring radioactive isotopes: 223Ra, 224Ra, 226Ra and 228Ra, with half-lives (11.4 d, 3.66 d, 1600 y and 5.75 y, respectively) spanning a range of time scales relevant to both vertical fluxes of (micro)nutrients out of sediments into the overlying water column, as well as horizontal advection. As Ra is not particle reactive, the decrease in concentration of each short-lived isotope away from the source (sediments) can be used in conjunction with its half-life to constrain flux rates, and will be coupled to trace metal results to assess the magnitude of any shelf source of Fe and other metals to offshore regions.

The primary objective of the radium (Ra) work done as part of WP2 is to use flux rates from Ra analysis to quantify off-shelf iron (Fe) fluxes from the Weddell Sea shelf to the open ocean. Where practically possible rosette casts for Ra were conducted as close as possible in time and space to the trace metal titanium rosette casts.

Sampling protocol

Ra sampling requires very large volumes of water, as Ra activities are typically very low away from sediment sources. Samples of 120 L were collected from the stainless-steel Sea-Bird CTD system on-board the RRS Sir David Attenborough. Six OTE niskin bottles are fired at the same depth in order to collect the needed 120 L. Ra sampling was conducted at shelf stations and a limited number of transect stations closer to the shelf (shallower than 2000 m isobath). Two separate CTD casts were undertaken for Ra, an A cast (the first cast on station) which always sampled 5, 25, 50 and 100 m up from the sediment surface and a second B cast which characterized the upper water column profile.

Each 20 L water sample from niskin bottles was transferred to a plastic carboy. Samples collected at the same depth were then combined into 1x 120 L volume in a plastic container in the hanger. The samples were then passed through a column holding 20 g of MnO_2-coated acrylic fiber, which strongly binds Ra. Water was pumped over the fiber using aquarium pumps at a rate <1L/min. The fibers were then rinsed with Milli-Q, dried with an air gun for ~1-2 minutes. Sample MnO_2 fibers were then loaded into a Ra Delayed Coincidence Counter (RaDeCC; Scientific Computer Instruments, USA) system purged with He gas, and decay of Ra was counted for 6-10 h to quantify ^{223}Ra and ^{224}Ra content. Fibers were subsequently counted again 8-10 days after sampling to better quantify the longer lived ^{223}Ra relative to ^{224}Ra. Following decay of these short-lived isotopes, the fibers will be re-analysed using the RaDeCC to determine the activity of the parent isotopes (^{227}Ac and ^{228}Th) in the University of Leeds Cohen geochemistry labs back on-shore.

At select stations a subsample was collected into 1 L LDPE bottles directly from OTE bottles on the rosette for analysis of the long-lived Ra isotopes which may be analysed by mass spectrometry at a later time.

To address health and safety concerns raised during radium sampling on the SDA trials cruise, aquarium pumps were plugged into an extension lead protected from water ingress by an IP54 rated weatherproof box. The cable coming out of the weatherproof box's tied to the blue frame over the moon pool then overhead by securing the cable to a ratchet strap with zip ties. This ensured there were no cables trialing across the deck.

CTD samples analysed

Table 9.6-1: Overview of CTDs sampled for Radium

Event	ssCTD	Station	Depth (m)	Comment
9	6	Seymour Island	365	Shakedown
22, 23	11,12	Mooring	483	A, B
31, 32	14, 15	Mooring	433	A, B
46, 49	21, 22	Larsen N104	323	A, B
63, 65	30, 31	Larsen N96	343	A, B
74	35	Larsen N98.5	482	Single cast
81, 82	41, 42	Larsen N 96.5	354	A, B
94, 97	50, 51	SS2	431	A, B
106, 108	56, 57	SS4	498	A, B
175, 176, 177	95, 96, 97	T5	2027	A, B, C
186, 187, 188	103, 104, 105	T6	1592	A, B, C
197, 199	110, 111	T7	1024	A, B
208, 210	116, 117	T8	533	A, B
219, 220	122, 123	Mooring	413	A, B
243, 244	127, 128	Ice Station 1	368	A, B

Through-ice water sampling

Holes were drilled through the ice flow with a 50 mm auger drill. Radium samples were collected from the interface of the ice hole, ~5 cm from the underside of the ice. An LDPE tube was zip tied to an extendable nylon pole with stainless steel connectors. Stainless steel connectors were taped so as not to pose a contamination risk for trace metals. Greater than 140 L of seawater was collected into carboys through the tubing using a battery powered portable vacuum pump (*Makita*). Sampling 100 L used 1x battery pack and a spare was required to complete the sampling. Ten-minute breaks were taken between removing 20 L volumes to minimize any potential disturbance of the fresher melt water-seawater interface. A video was taken directly from the sampling hole using an insta360 camera. On ice floe 8 (hole 16) a video was taken directly from the sampling hole after sampling was complete and on ice floe 9 from a second hole (hole 13) next to the sampling hole 15 taken during pumping. The video from ice floe 8 shows a shear boundary between layers of water of differing density, indicating minimal disturbance of the meltwater-seawater interface. The video from ice floe 9 is limited due to ice obstructing the camera. After sampling filled 20 L carboys were then taken back to the ship to

pass the water over the MnO_2 fiber in the same way the CTD samples were processed. A single (>140 L) sample was taken from each of the ice floe's sampled during SD035.

Preliminary results

On shelf stations

Preliminary short-lived ^{224}Ra profiles appear consistent across the on shelf stations and with data collected during the SDA trials cruise (SD025) (Figure 9.6-1). Activities are generally higher at depth closer to the sediment water interface where Ra is added to the water column. The highest activities were observed at stations across the Larsen ice shelf (Figure 9.6-2). Note, that all data presented here are uncorrected for long-lived parent isotopes (^{228}Ra, ^{228}Th, ^{227}Ac) as well as detector efficiencies and blanks. This preliminary data therefore only gives a rough approximation of ^{224}Ra activities. Once the samples have been allowed to decay, repeated analyses are performed on-shore in the University of Leeds labs to make these corrections; all reported activities will be revised downwards due to these corrections.

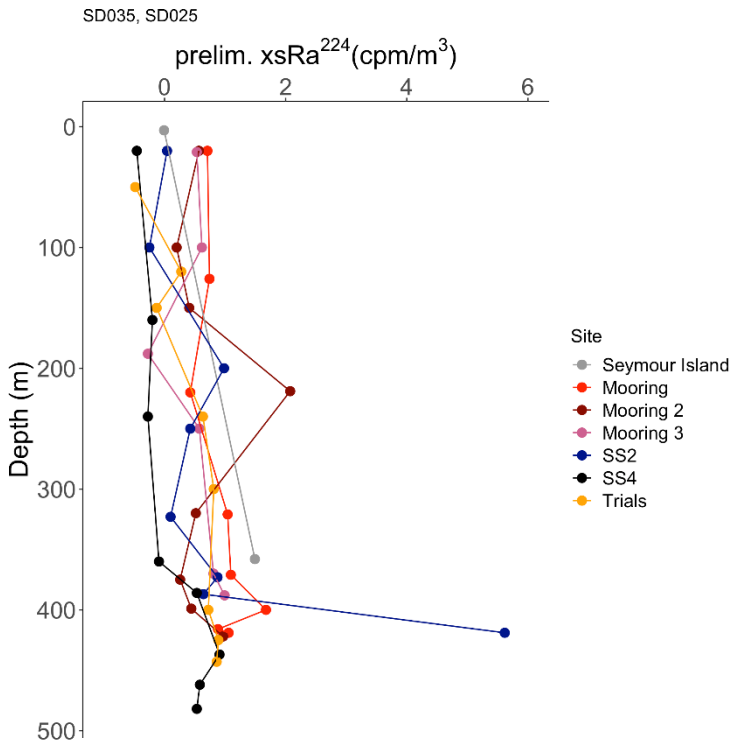

Figure 9.6-1: Depth profiles (uncorrected) at on shelf stations, data points from SD025 (Trials) are also shown for comparison. Trials data provided by A. Annett.

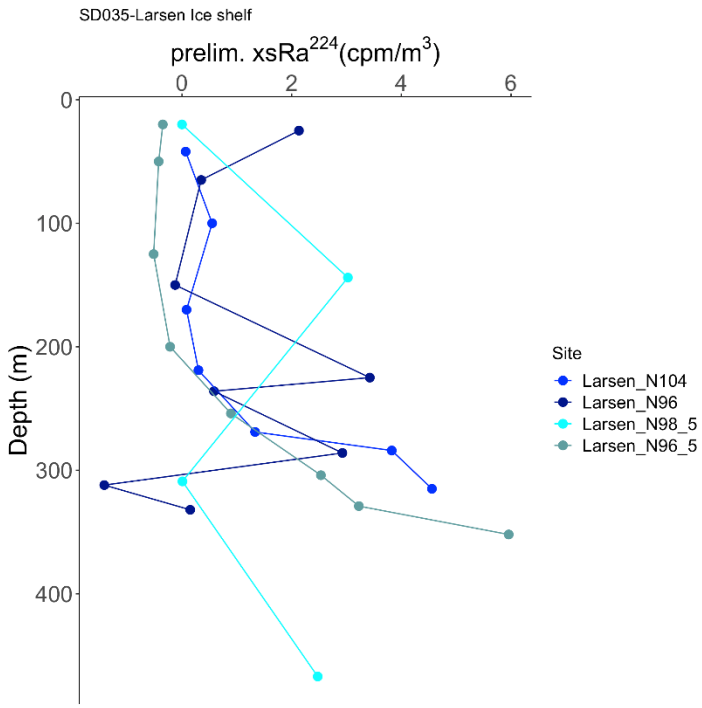

Figure 9.6-2: Stations near Larsen Ice Shelf.

Slope transect

Higher sampling resolution was conducted for the deeper casts leading onto the shelf (stations at the 2000 and 1500 m isobaths).

Radium-224 results from the slope transect (T5 to T8) showed similar activities to the shelf stations but with clearer increases in activity closer to the seafloor.

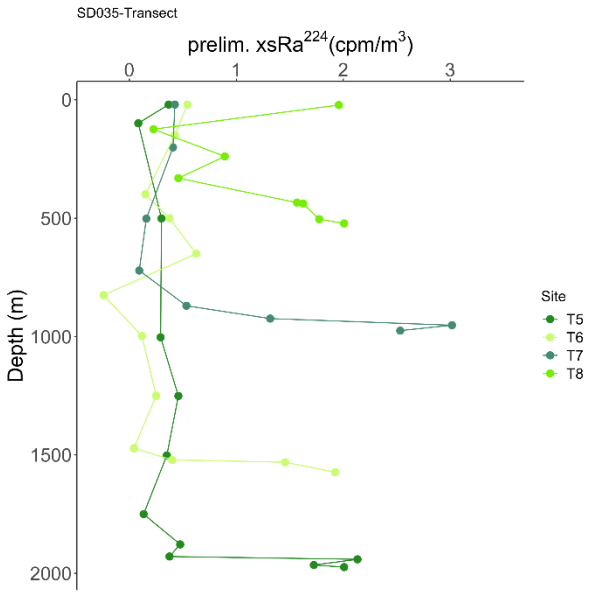

Figure 9.6-3: Comparison of uncorrected ^{224}Ra profiles from the transect onto the shelf slope.

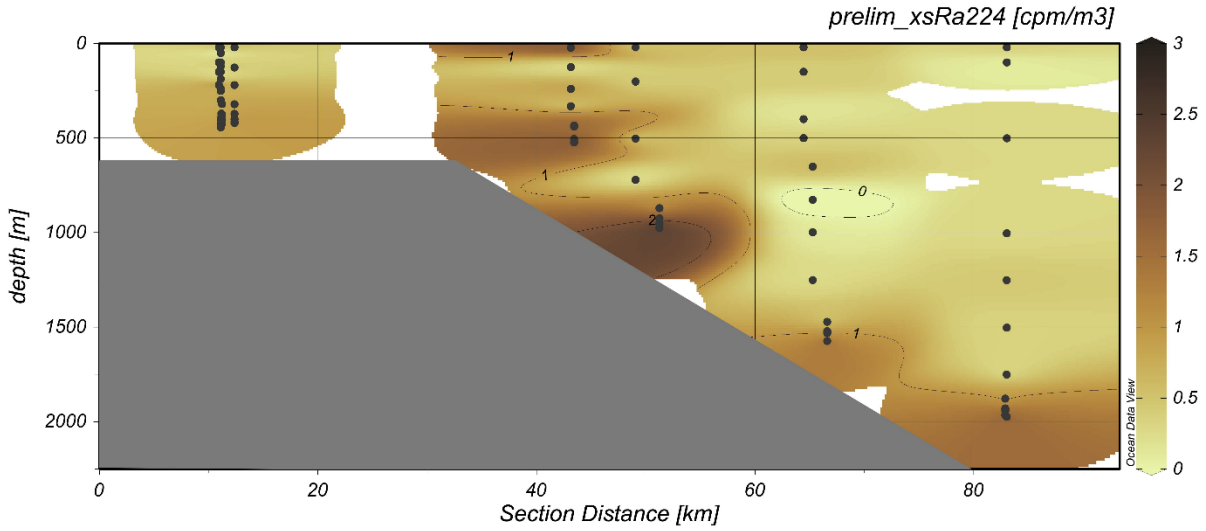

Figure 9.6-4: Contour plots of preliminary short-lived Ra^{224} data from the transect onto the shelf slope.

Two surface water samples on the transect and at Larsen show elevated surface activities, which may reflect different ^{228}Th activities, the parent isotope of ^{224}Ra and unlike Ra an element strongly influenced by particle concentrations.

9.7 Carbonate chemistry

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Rationale and objectives for measuring the marine carbonate system

Human activities have increased atmospheric CO_2 concentrations since the industrial revolution. These anthropogenic CO_2 emissions occur on top of an active natural carbon cycle that circulates carbon between the atmosphere, ocean, and land reservoirs. Understanding the behaviour of CO_2 in the ocean gives us information about how it is absorbed from the atmosphere and subsequently redistributed around the globe by ocean currents. The ocean is a vast storage of CO_2 due to high CO_2 solubility in seawater and CO_2 sequestration through transport into deep water masses that are no longer in contact with the atmosphere. In fact, the oceans have absorbed about 30% of the anthropogenic CO_2 emitted to the atmosphere since the industrial revolution. However, anthropogenic CO_2 is not evenly distributed throughout the oceans. While CO_2 concentration in the surface layers of the ocean increases as CO_2 increases in the atmosphere, its penetration into the deep ocean depends on the slow vertical mixing of the water column and the circulation of water. However, in some regions where vertical movement of water is relatively fast, such as the Southern Ocean, the time scale necessary for deep penetration of anthropogenic CO_2 is on the order of decades instead of centuries.

The Weddell Sea in particular is a key region to study the redistribution of ocean carbon and nutrients. It is a region where old water masses (Circumpolar Deep Water, or – as it is known locally – Warm Deep Water) are transformed by physical and biogeochemical processes at the surface. It also harbours important "hot spots" of dense water formation, which constitutes an important pathway of carbon to the deepest parts of the ocean. These dense water formation regions are located in the south-western Weddell Sea, where High Salinity Shelf Water forms during seasonal sea ice formation when sea ice grows in winter. The cold, saline water flows down the continental slope into the Weddell Sea basin, subducting underneath warmer waters. Locally, this dense water mass is named Weddell Sea Bottom Water.

As part of PICCOLO, we have collected seawater samples from the surface layer and throughout the water column for the analysis of dissolved inorganic carbon (DIC) and total alkalinity (TA). With these two measurements, we can quantify other components of the marine carbonate system, such as pH, pCO_2, and calcium carbonate saturation states. The data are used to study the role of carbonate chemistry in the transformation of carbon and to quantify the export of carbon to the deep ocean. Linking these data to other datasets acquired during the PICCOLO expedition, such as nutrient content and respiration rates, will allow us to better constrain biogeochemical processes regulating carbon transformation. The data are also used to calibrate various pH sensors on mooring lines and autonomous vehicles and pCO_2 sensors linked to the underway seawater supplies, which measured data at a higher resolution in time and/or space.

Sampling for DIC/TA

Sampling from the CTD rosette

Water samples for the determination of DIC and TA were drawn from the 20 L Niskin bottles on the stainless steel CTD rosette and collected in 250 ml glass bottles with ample rinsing and overflowing to avoid gas exchange with the air (SOP 1, Dickson 2007). With a few exceptions, three triplicate 250 ml samples were collected per cast. CTD samples were collected from all BGC casts and one Trace Metal Cast using the titanium CTD rosette (i.e. the GEOTRACES CTD station; Figure 9.7-1). On all CTD stations, samples were collected from all depth horizons, which for most stations was about 15 depths (Table 9.7-1). Sampling from leaking Niskin bottles was avoided by instead sampling from a non-leaking Niskin closed at the same depth, when possible. When this was not an option, the sample was collected regardless and a note was made of the leak. A total of 649 DIC/TA samples were collected from CTD rosettes. 542 of these (84%) were analysed on board, typically within 24 hours after sampling. In cases when analysis within 24 hours was not feasible, samples were fixed with saturated mercuric chloride solution (50 µl per 250 ml sample) and temporarily stored for later analysis. Due to time constraints, we were unable to complete the sample analysis on board for 5 CTD casts (107 samples). These samples were fixed and shipped back to the University of East Anglia (UEA) for analysis later in the year.

Table 9.7-1: Casts sampled for DIC/TA

Cast	Longitude	Latitude	Date/Time	Analysed on board?
3	-56.67374	-61.45432	22.01.24 15:03	Yes

7	-55.05332	-64.5763	27.01.24 18:02	Yes
9	-55.0681	-64.56342	28.01.24 07:10	Yes
18	-55.08344	-64.57536	30.01.24 08:17	Yes
19	-59.88118	-66.1362	31.01.24 09:12	Yes
23	-60.16804	-66.07224	31.01.24 20:24	Yes
28	-60.48266	-66.0563	01.02.24 07:21	Yes
33	-60.3399	-66.3822	01.02.24 16:33	Yes
36	-60.2236	-66.17418	01.02.24 22:53	Yes
39	-59.90096	-66.1341	02.02.24 06:38	Yes
43	-60.42906	-66.1177	02.02.24 13:08	Yes
44	-60.33306	-66.06724	02.02.24 16:18	Yes
46	-59.61344	-65.81126	02.02.24 22:29	Yes
48	-59.2957	-65.6265	03.02.24 06:46	Yes
52	-58.81898	-65.08304	03.02.24 17:25	Yes
54	-58.25876	-64.5886	04.02.24 06:38	Yes
68	-52.12044	-63.67914	06.02.24 17:49	Yes
69	-47.97386	-64.13444	07.02.24 13:04	Yes
71	-48.50488	-64.51864	08.02.24 08:28	Yes
76	-49.69378	-64.51364	09.02.24 08:18	Yes
81	-50.89084	-64.49202	10.02.24 08:11	Yes
86	-52.7331	-64.55122	11.02.24 06:03	Yes
87	-52.72304	-64.55588	11.02.24 08:02	Yes
93	-53.69616	-64.63006	12.02.24 08:04	Yes
101	-53.98972	-64.5539	13.02.24 07:41	Yes
108	-54.26868	-64.56892	14.02.24 07:51	Yes
114	-54.40354	-64.57374	15.02.24 07:43	Yes
120	-55.06586	-64.58812	16.02.24 07:48	Yes
125	-55.9921	-66.35066	19.02.24 07:46	Yes
129	-52.90082	-63.53592	23.02.24 22:56	No
132	-56.15398	-64.78394	25.02.24 11:13	No
133	-57.81402	-65.40894	26.02.24 06:07	No
134	-56.54252	-64.69876	29.02.24 18:11	No
136	-56.42786	-64.66118	01.03.24 07:46	No

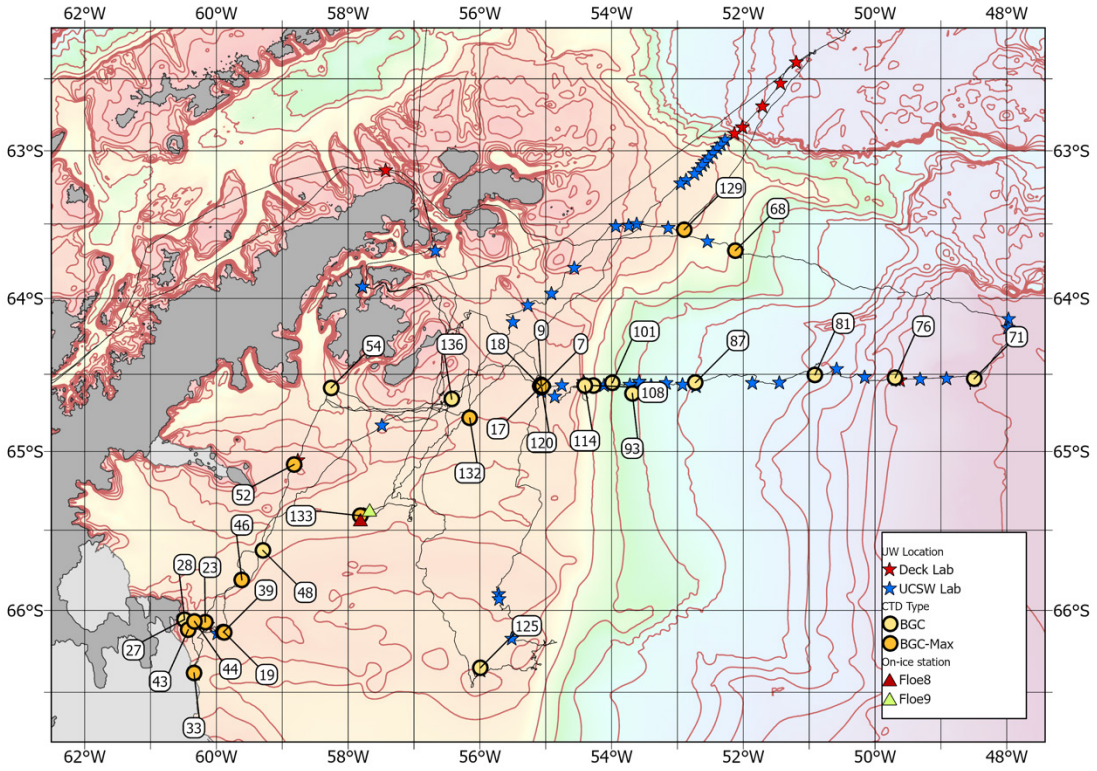

Figure 9.7-1: Map of sampling locations for DIC/TA.

Sampling from the underway seawater supply

Samples from CTD stations allow us to obtain discrete data at a chosen vertical resolution, but obtaining higher spatial resolution is dependent on the opportunity to deploy a CTD rosette, which requires significant ship time. This is why sampling from a ship's underway seawater supply can provide a great complementary dataset with a higher spatial resolution in the surface ocean, without needing additional ship time.

Underway seawater samples at ~7 m depth were collected from two supplies: the tap in the uncontaminated seawater (UCSW) lab and the tap in the deck lab. The main purposes of the DIC/TA samples collected from the UCSW tap were a) to better understand the spatial variability, b) to constrain biogeochemical processes by linking the discrete sample data to the array of continuous seawater measurements and by simultaneously collecting nutrient and $\delta^{18}O$ samples, and c) to provide a quality check and/or calibration opportunity of the underway continuous pCO_2 and pH sensors. The main purpose of the DIC/TA samples collected from the deck lab tap was to provide quality check and/or calibration opportunity of additional pCO_2 and pH sensors installed there. For this purpose, nutrient samples were also collected simultaneously from the deck lab tap to more accurately determine the pCO_2 and pH from the DIC and TA content. Duplicate 250 mL DIC/TA samples were collected from all sampling time points for both underway seawater supplies, accumulating to a total of 150 underway seawater samples (120 from the UCSW and 30 from the deck lab). Most of these samples were fixed with saturated mercuric chloride solution (50 µl per 250 ml sample). 110 of the underway samples were analysed on board. The remaining samples (40) were shipped back to UEA.

We encountered a number of challenges with the uncontaminated seawater supply on board the SDA. These include excessive bubble in the lines, as well as clogging of the system by krill and sea ice. Due to the latter, the pole through which the seawater is collected at the bottom of the ship was only deployed and/or the pump was only turned on in sea ice-free conditions. As we encountered a lot of sea ice during the expedition, this meant that the underway system was often only operational when we were stationary at an oceanographic station. The sporadicity of when the underway seawater supply was on or off is reflected in the irregular sampling time points (Fig. 9.7-1). A more detailed description of the challenges related to the underway seawater supply, as well as how some of them were solved, is provided elsewhere in this report.

A highlight for the underway sampling activity was a high frequency sampling transect that took place between 24 and 25 February, 2024, going up the continental slope of the Antarctic Peninsula. Samples were initially collected every hour until the 3000 m isobath. From the 3000 m isobath onwards (going towards shallower bathymetry), samples were collected every 30 mins to capture the horizontal gradients in seawater properties driven by the Antarctic Slope Current.

Table 9.7-2: Date/Time and locations of seawater DIC/TA samples collected from the UCSW lab.

Date/Time [UTC]	Latitude	Longitude	Analysed on board?
24.01.24 20:18	-63.91992	-57.78775	Yes
24.01.24 23:18	-63.91967	-57.78283	Yes
30.01.24 19:00	-64.82955	-57.48633	Yes
31.01.24 09:02	-66.13578	-59.88173	Yes
31.01.24 10:20	-66.13607	-59.89008	Yes
31.01.24 11:00	-66.13562	-59.89682	Yes
31.01.24 19:08	-66.13941	-59.98882	Yes
01.02.24 19:21	-66.38632	-60.32503	Yes
05.02.24 11:02	-64.2777	-55.70138	Yes
05.02.24 13:02	-64.15436	-55.49707	Yes
05.02.24 15:02	-64.04227	-55.27089	Yes
05.02.24 16:59	-63.96496	-54.91251	Yes
05.02.24 19:00	-63.79333	-54.56554	Yes
05.02.24 22:08	-63.5121	-53.9369	Yes
05.02.24 23:00	-63.50845	-53.74039	Yes
05.02.24 23:26	-63.49758	-53.61766	Yes
06.02.24 01:01	-63.52325	-53.1405	Yes
06.02.24 03:10	-63.61471	-52.5436	Yes
06.02.24 08:04	-63.68577	-52.09771	Yes
07.02.24 11:17	-64.13384	-47.97168	Yes
07.02.24 17:14	-64.1921	-47.97932	Yes
07.02.24 23:03	-64.53634	-48.49928	Yes

08.02.24 01:06	-64.53073	-48.49927	Yes
08.02.24 07:16	-64.52914	-48.49582	Yes
08.02.24 20:47	-64.52462	-48.91394	Yes
08.02.24 23:10	-64.52915	-49.31455	Yes
09.02.24 03:40	-64.53101	-49.68215	Yes
09.02.24 19:00	-64.51589	-50.15696	Yes
10.02.24 00:13	-64.46319	-50.58167	Yes
10.02.24 17:31	-64.55198	-51.45165	Yes
10.02.24 21:51	-64.55425	-51.86297	Yes
11.02.24 12:36	-64.57581	-52.71756	Yes
11.02.24 17:35	-64.56491	-52.92228	Yes
11.02.24 21:37	-64.5546	-53.17177	Yes
12.02.24 01:09	-64.57067	-53.39931	Yes
12.02.24 03:40	-64.5846	-53.59528	Yes
12.02.24 13:09	-64.54686	-53.58007	Yes
12.02.24 22:44	-64.56631	-53.71993	Yes
13.02.24 21:37	-64.56963	-54.11358	Yes
14.02.24 21:31	-64.56865	-54.32762	Yes
15.02.24 02:48	-64.55644	-54.41099	Yes
15.02.24 14:17	-64.5469	-54.4228	Yes
15.02.24 20:29	-64.64309	-54.86366	Yes
15.02.24 22:47	-64.56871	-54.7547	Yes
16.02.24 02:50	-64.56346	-55.06389	Yes
16.02.24 13:29	-64.60931	-55.06802	Yes
17.02.24 12:47	-65.89623	-55.71471	Yes
17.02.24 14:37	-65.92751	-55.70863	Yes
17.02.24 21:23	-66.17133	-55.51564	Yes
20.02.24 14:46	-63.67796	-56.67623	Yes
24.02.24 18:30	-62.92281	-52.2752	No
24.02.24 19:02	-62.95414	-52.33781	No
24.02.24 19:30	-62.98015	-52.39464	No
24.02.24 20:02	-63.01045	-52.45837	No
24.02.24 20:36	-63.04308	-52.52318	No
24.02.24 21:08	-63.07232	-52.5815	No
24.02.24 21:32	-63.09526	-52.62365	No
24.02.24 22:05	-63.12886	-52.68491	No
24.02.24 22:35	-63.1561	-52.74081	No
24.02.24 23:04	-63.1561	-52.74081	No
24.02.24 23:30	-63.19926	-52.86848	No

25.02.24 00:06	-63.22106	-52.95105	No

Table 9.7-3: Date/Time and locations of seawater DIC/TA samples collected from the Deck lab.

Date/Time [UTC]	Latitude	Longitude	Analysed on board?
31.01.24 19:46	-66.08663	-60.13419	Yes
01.02.24 06:02	-66.05638	-60.48707	Yes
01.02.24 19:31	-66.38585	-60.32464	Yes
02.02.24 16:59	-66.06733	-60.33257	Yes
03.02.24 05:41	-65.62668	-59.29295	Yes
03.02.24 22:31	-65.0537	-58.76216	Yes
04.02.24 04:22	-64.58655	-58.26258	Yes
04.02.24 18:46	-64.58916	-58.24141	Yes
06.02.24 08:16	-63.68436	-52.09436	Yes
08.02.24 07:26	-64.52789	-48.49716	Yes
09.02.24 02:43	-64.53662	-49.61919	Yes
09.02.24 07:16	-64.52269	-49.69389	Yes
10.02.24 07:00	-64.50582	-50.91525	Yes
11.02.24 12:49	-64.57366	-52.71803	Yes
12.02.24 01:17	-64.57026	-53.39834	Yes
12.02.24 13:20	-64.54615	-53.57945	Yes
13.02.24 08:16	-64.5539	-53.99692	Yes
14.02.24 07:26	-64.57322	-54.27655	Yes
15.02.24 06:53	-64.5766	-54.40786	Yes
16.02.24 03:05	-64.56218	-55.06887	Yes
17.02.24 11:11	-64.56218	-55.06887	Yes
19.02.24 04:36	-66.36644	-55.98803	Yes
22.02.24 13:09	-65.30029	-64.29502	No
23.02.24 10:52	-63.13154	-57.4292	No
24.02.24 14:07	-62.38115	-51.19562	No
24.02.24 15:03	-62.52927	-51.43619	No
24.02.24 16:03	-62.68922	-51.70834	No
24.02.24 17:01	-62.83482	-52.01418	No
24.02.24 17:34	-62.87862	-52.13377	No
24.02.24 18:04	-62.87862	-52.13377	No

Sampling from the Aquamonitor on the moorings

The PICCOLO mooring was deployed during the SDA Science Trails expedition SD025. An Aquamonitor was mounted on the mooring, which was programmed a duplicate seawater

sample throughout the year. The mooring was recovered on the 28th of January, 2024, on SD035. Many of the tubing collecting the switching valve to the sampling bags had been dislodged during its deployment time. For more details on the deployment and recovery of the mooring, see Section 8 in this report. Ten of the SD025 Aquamonitor samples were analysed on board for DIC/TA on the VINDTAs.

The PICCOLO mooring was redeployed on 29th of January, 2024, and recovered again 18 days later, on the 16th of February 2024. The Aquamonitor had been programmed to collect duplicate samples every 2/3 days. A total of 7 time points were successfully sampled. Six of these were analysed for DIC/TA on the VINDTAs. Remaining volume in the bags was later sampled for other variables, such as nutrients. Any remaining volume is shipped to UEA.

Sampling bags on the Aquamonitor were pre-spiked with saturated mercuric chloride solution, prior to deployment, and so these samples did not require further treatment between recovery and analysis. Sampling bags filled with sample were stored in the 4˚C storage room until analysis.

Table 9.7-4: List of Aquamonitor samples from the SD025 PICCOLO mooring analysed for DIC/TA

Bag No.	**Date/Time of sample collection [UTC]**
2	18.02.2023 00:17
4	08.03.2023 16:17
6	27.03.2023 08:17
8	15.04.2023 00:17
9	03.05.2023 16:17
11	22.05.2023 08:07
28	18.10.2023 16:17
32	25.11.2023 00:17
35	01.01.2024 08:07
37	20.01.2024 00:07

Table 9.7-5: List of Aquamonitor samples from the SD035 PICCOLO mooring analysed for DIC/TA

Bag No.	**Date/Time of sample collection [UTC]**
2	01.02.2024 18:17
3	04.02.2024 07:07

5	06.02.2024 19:07
8	09.02.2024 07:07
11	14.02.2024 07:07
14	16.02.2024 19:17

Sampling on sea ice

As part of multidisciplinary coordinated sampling activities on two ice floes (Floe 08 and Floe 09), we collected ice core samples for DIC and TA measurements, as well as seawater samples below the sea ice and directly underneath the ice at the ocean-ice interface. Details on sampling methods are described in Section 7.1.3 of this report about *on-ice activities*.

Analysis of DIC/TA

Seawater samples were analysed for DIC and TA on two VINDTAs (Versatile Instrument for the Determination of Total inorganic carbon and total Alkalinity; version 3C, (#4 and #7). The VINDTA operates at 25°C, by keeping maintaining temperature in jacketed pipettes and pre-warming samples to 25°C in a water bath (Mintrop, 2004). CTD- and underway samples were analysed on both instruments (#4) and (#7).

The DIC content on the VINDTA was determined by coulometry (Johnson et al., 1987). Generally, we tried to analyse samples from a single CTD cast on a single instrument on a single coulometry cell. We had to make a few exceptions due to trouble shooting incidents and time constraints. The coulometry cell was changed every 20-24 hours. Two to three CRMs (Certified Reference Material, batch 208) were used per coulometric cell: one before, in the middle, and after the sample sequence run on that particular cell. Total alkalinity was measured by open cell potentiometric titration. The acid consumption up to the second endpoint is equivalent to the titration alkalinity. The system uses a Metrohm Titrino 719S for adding acid, an ORION-Ross pH electrode and a Metrohm reference electrode. The burette, the pipette (volume approximately 100 ml), and the analysis cell have a water jacket around them at 25 ˚C. The titrant (0.1 M hydrochloric acid, HCl) was made at UEA prior to the expedition.

As the Aquamonitor samples were collected in air-tight sampling bags, we had to adapt the procedure a little. Like all other samples collected in borosilicate glass bottles, we placed in the bags directly in the water baths. The tubing leading to the peristaltic pumps of the VINDTA was directly connected to the tubing attached to the sampling bags. As there was no way to collect a sample temperature using the temperature probe in the sampling bag itself, we collected a temperature measurement manually using a temperature probe in the TA titration cell. Once both the DIC and TA sample aliquots were taken from the bag, the bag was once again made air-tight and placed back in the 4 ˚C storage room for further sub-sampling for other variables (including nutrients).

The sea ice core DIC/TA samples were analysed on a different system on board by Vassilis Kitidis (see Section 7.1.3 in this report about *on-ice activities*, in which the processing of the sea ice core samples is described).

The performance of the VINDTA instruments was generally good. Problems we encountered included:

- Malfunctioning of the sensor in the TA cell that senses when it has completely filled with liquid sample. I.e. it would fail to detect that the cell was empty, which would lead to mistiming of the automated process. This was first addressed by cleaning the "full"-sensor with MQ, which helped temporarily. When it remained unreliable, we replaced the sensor with a new one, but the problem kept occurring from time to time. We eventually removed the sensor from its usual socket in the cell and placed it loosely into the same socket through which the seawater sample is "pushed" from the TA pipette into the TA cell. This solved the issue.

- AgCl crystal formation on the frit within the inner cell of the reference electrode, which is placed in the TA cell. The crystals were effectively reducing ion exchange between the inner and outer cell. This caused a sudden "jump" in the measured TA values; TA values increased by a relatively constant ~40 µmol kg^{-1}. This problem was resolved by removing whatever inner KCl solution was in the inner cell, using a syringe, and then replacing it with fresh KCl solution. The volume of KCl solution in the inner cell was replaced multiple times until the crystal had completely dissolved. In the meantime, we kept running test seawater samples, which allowed us to see the TA values decrease – and then completely return – to their expected values as the crystal dissolved. The AgCl crystal formation within the inner cell of the reference electrode is normal and is a result of oversaturation of the KCl solution. The presence of these crystals within the inner cell is, in itself, not an issue for TA measurements. However, when it covers the frit, it can reduce the necessary ion exchange between the inner and outer electrode and affect the TA determination. As the KCl solution is already at saturation (as is required for the functioning of the electrode), oversaturation of the KCl solution can quickly occur if there is enough evaporation. We therefore decided to ensure that the opening to the inner cell remained closed at all times to reduce chances of evaporation.

- Failure of the top valve of the TA pipette. Failure and the need to adjust or replace a valve on either side of the pipettes on a VINDTA is considered to be a serious challenge on a ship at sea, because the way the tubing sits within them determines the total volume of the pipette when it collects is aliquot from the sample. This volume needs to be known very precisely (to 4 decimal places), in order to accurately determine the density, and therefore the DIC or TA content, of the sample. This is why the volumes of the TA and DIC pipettes are calibrated before and after analysis of a batch of samples (i.e. all samples of a field season or expedition). This is done by measuring the weight of the volume dispensed from the pipettes. Normally, when the tubing around the pipettes needs adjusting or the valves need replacing, the pipette volume calibration is repeated before any sample analysis continues. As we cannot obtain the precision of mass measurements on a moving vessel, instant re-calibration was not an option. Waiting until re-calibration back on land would risk the accuracy of any sample analysed after the change in pipette volume, as the pipette volume would be irretrievable if another failure of the tubing and/or valves around the pipette would occur. One option was to collect volume calibration samples in suitable light-weight plastic bottles, which would then have to be weight (with and without calibration sample) back on land. Bottles would have to ensure no evaporation could occur. Luckily, we believe that the issue was

solved without changing the total volume of the TA pipette. After some test runs and an accidental overflow of the TA pipette into the tubing leading to the air pump, the top valve reliably worked again. Admittedly, we are unsure what the cause was of the original failure. For future expeditions, we recommend bringing suitable (lightweight, air-tight) sample volume calibration bottles that can be used to collect calibration samples to be weighed once returned to land.

Data processing

Raw data from the instruments are used in Python scripts to determine the DIC and TA content. For DIC, we use the total counts from the coulometer, which are converted to µmol kg^{-1} values using the mean counts per µmol of DIC determined from the certified DIC content of the CRMs and their coulometry counts measured on that particular coulometry cell. TA is determined using the .dat titration files and the Calkulate Python package (version 23.1, Humphreys & Matthews, 2022). The DIC and TA data are undergoing quality control.

The data for Aquamonitor samples from the mooring will need additional processing, as the sampling bags were pre-filled with 40 mL of CRM (batch 67) prior to deployment (in addition to the added mercuric chloride). This will need to be accounted for in further calculations. As the sampled volume was not consistent, the sampling bags were weighed before and after the addition of CRM, as well as between recovery and analysis to be able to determine the sampled volume.

Data availability

The data will become publicly accessible once the results have been published.

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9.8 Seawater oxygen isotope sampling

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Seawater oxygen isotope samples (seawater ^{18}O) have been collected during SD035, thanks to a programmatic collaboration between PICCOLO and BIOPOLE (BAS). Oxygen isotopes of seawater are a potentially useful tracer for water masses. The unique isotopic fingerprint of seawater ^{18}O can be used to distinguish the contribution of sea ice, glacial meltwater and/or meteoric sources in the PICCOLO region (Meredith et al., 2023, *Phil. Trans. R. Soc.*). Alongside with other parameters (salinity, nutrients, radium isotopes, iron isotopes, trace metals), $H_2{}^{18}O$ will provide additional information on sources of melt water supply and thus fluxes of nutrients and metal in the study area.

Samples for seawater isotopes were collected into 30 ml glass vials (rinsed 3x with a small sample volume), the vial's neck was briefly dried with blue roll. Vials were then sealed with a rubber stopper and aluminium crimp seal. All samples were stored at 4°C and were then transported via dark cool stow to the British Antarctic Survey.

Seawater ^{18}O samples were collected from different water sampling operations during PICCOLO. From each titanium-CTD cast, samples were collected in the trace metal clean lab for full-depth profiles of the water column, with the intention that dissolved Fe and Fe-isotopes samples being collected from these same GoFlo bottles can be paired with ^{18}O isotopes. On three occasions when no ti-CTD was deployed, samples were taken from the stainless steel CTD cast (*labelled: ss-CTD*).

Near surface seawater samples were collected from the ship's underway system – an Uncontaminated Seawater Supply in the uncontaminated seawater laboratory (*labelled: UW samples*). Each sample is tied to a collection time and date that is directly linked to a location via the ships event log. During a ~N-S transect from the BIOPOLE glider collection on to the shelf (approximately 3000m water depth Long. -62.68922, Lat. -51.70834) to sample location (approximately 500 m water depth, Long. -63.19926, Lat. -52.86848). UW samples were taken continuously in 30 minute intervals, alongside with samples for nutrients and DIC analysis. In addition to the underway water supply, isotopes samples were also collected every 30 minutes from the towfish system (labelled: *FISH*) in the trace metal clean lab alongside samples collected for trace metal and iron isotopes analysis. For both sample systems, each recorded time of collected is connected to a GPS locations, which is listed in excel sheet "UW_Uncontaminted_seawater_lab.csv". The spatial variability of sample collection points is directly connected on the ship's speed. Please be aware, sample ID numbers for UW samples are not continuous or in order.

For two locations (ice floe 8 and ice floe 9), ^{18}O isotopes samples were collected from melted ice cores as well as from water under the ice. Ice cores 5 and 4 were drilled on ice floe 8 and 9,

respectively. The cores were sliced in 15 cm sections and melted in the nutrient lab. For each depth, an oxygen isotope sample was taken (*labelled: ice core*). Through the ice holes, seawater samples of three depths (depth underneath the ice: 40m, 20m and subsurface) were obtained from trace metal free niskins (ice floe 8, hole 10 and ice floe 9, hole 14; labelled: *ice floe*); sample water was collected on the ice, samples processing took place in the trace metal clean lab. Additional triplicates of seawater isotopes samples were taken from BGC niskins from the ice-water interface (ice floe 8, hole 7 and ice floe 9, hole 16), samples were filled in the vials directly on the ice after recovering the niskin bottles.

In order to investigate time-varying changes in meltwater supply to the region over the course of one year, a mooring system was deployed in February 2023 during cruise SD025 programmed to collect a sample once every month (Location 64° 34.538' S, 55° 03.496' W). After the mooring recovery, the system was redeployed at the same location in February 2024 for two weeks, programmed to sample every 3 days. Subsamples for ^{18}O isotopes were taken from both deployments after the recovery of the mooring. Mooring samples have been treated with 40 µl mercury chloride prior to sample collection.

Refs: Meredith MP et al. 2023 Tracing the impacts of recent rapid sea ice changes and the A68 megaberg on the surface freshwater balance of the Weddell and Scotia Seas. *Phil. Trans. R. Soc. A* 381: 20220162. https://doi.org/10.1098/rsta.2022.0162

9.9 Chromophoric Dissolved Organic Matter (CDOM)

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Chromophoric (or Colored) Dissolved Organic Matter (CDOM; less frequently referred to as 'gelbstoff' or 'gilvin') is the light absorbing fraction of Dissolved Organic Matter (DOM) [1]. DOM represents the second largest carbon reservoir in the ocean (after DIC). It is produced by direct excretion from phytoplankton, sloppy feeding by zooplankton, the microbial loop and transformed by photochemical and thermogenic reactions. As such, it constitutes a dynamic component of the global carbon cycle with a substantial, 'refractory', component that is conserved and used as a tracer [2]. The objective of this work was to gather CDOM absorbance spectra which can provide additional information on the chemical composition, provenance and reactivity of dissolved organic matter [3-5]. CDOM absorbance typically decreases exponentially with increasing wavelength which is described by the function $\alpha_\lambda = \alpha_{\lambda 0} e^{-S(\lambda-\lambda 0)}$, where α_λ and $\alpha_{\lambda 0}$ are the absorbance at wavelength λ and λ0 respectively and S is the spectral slope from a non-linear fit of α_λ against λ [3].

CDOM was measured on samples from the stainless steel and under-ice CTD hydrocasts as well as ice-core meltwater. Absorbance spectra were collected using a 10 cm pathlength quartz cuvette and scanning spectrophotometer over the 200-800 nm wavelength range (VWR-UV3100PC).

While data analysis was incomplete at the time of writing this report, seawater and under-ice samples showed the exponential absorbance decrease with increasing wavelength that is typical of oceanic CDOM (Figure 9.9-1). However, ice-core CDOM spectra were characterized by

distinct absorbance peaks in the UVA and UVB parts of the spectrum. These absorbance maxima likely represent distinct mycosporine-like-amino-acids (MAA) which are produced by sea-ice biota for photoprotection. Early analysis of CDOM and AFC data suggests that these absorbance peaks had a discrete stratigraphy within the ice core and their relative abundance likely reflects the abundance of microbial, nano- and pico-planktonic algal groups in different ice horizons.

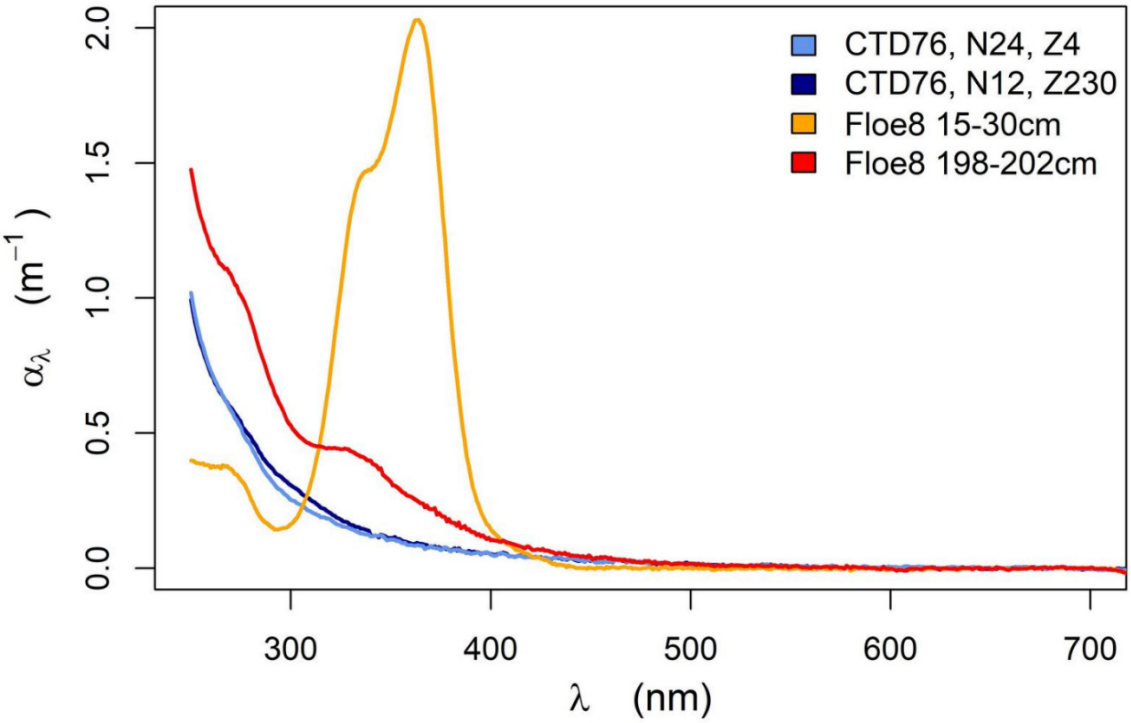

Figure 9.9-1: CDOM absorbance spectra for two samples from CTD76 and the ice core on Floe 8.

Table 9.9-1: CDOM sampling during SD035 (PICCOLO).

CTD_no	Date	Time	Lat	Lon	Niskin	Depth
3	22/01/2024	14:42:00	-61.4547	-56.6768	2	456.896
					4	409.3836
					6	356.0794
					8	300.0248
					10	249.9071
					12	224.8959
					13	199.7162
					14	49.44057
					15	17.36511
					18	14.72362
					19	10.08954
					21	6.422297
					22	4.735405

					24	3.946676
5	26/01/2024	16:49:00	-64.0965	-56.1457	5	204.9
					7	60.119
					11	36.905
					14	22.551
					15	14.404
					18	11.293
					19	7.321
					23	2.781
7	27/01/2024	17:34:00	-64.5757	-55.0534	2	417.85
					4	368.627
					5	334.833
					8	275.222
					9	242.733
					10	200.091
					13	53.195
					15	35.825
					17	22.845
					18	14.866
					19	8.884
					21	4.931
					24	2.142
8	28/01/2024	04:56:00	-64.5604	-55.0606	5	203.382
					11	33.717
					24	2.566
					22	2.555
9	28/01/2024	06:50:00	-64.5699	-55.0673	2	456.896
					4	409.3836
					6	356.0794
					9	300.0248
					10	249.9071
					13	224.8959
					14	199.7162
					15	49.44057
					18	17.36511
					21	14.72362
					24	10.08954
16	30/01/2024	04:53:00	-64.5876	-55.0859	5	201.946
					8	35.868
					11	35.857
					24	2.311
18	30/01/2024	07:58:00	-64.5754	-55.0834	2	423.626
					4	353.894
					6	303.121
					8	252.54

					10	201.826
					14	75.364
					15	51.105
					18	33.93
					19	22.856
					21	12.864
					22	6.701
					24	2.86
19	31/01/2024	08:54:00	-66.1358	-59.8817	2	316.166
					4	264.86
					8	202
					10	181
					6	152
					5	122.857
					12	80.343
					14	47.988
					15	22.795
					18	16.609
					19	11.52
					21	6.573
					22	3.539
					24	2.331
28	01/02/2024	04:49:00	-66.0564	-60.4871	2	336.382
					4	292.913
					8	221.815
					13	201.518
					6	160.971
					5	140.718
					12	111.344
					9	80.985
					14	53.682
					16	35.513
					18	23.398
					19	15.384
					21	9.434
					24	2.202
33	01/02/2024	16:15:00	-66.3823	-60.3405	2	471.278
					8	368.159
					9	353.849
					16	18.395
					24	2.388
38	02/02/2028	04:54:00	-66.1338	-59.8922	5	202.276
					11	23.118
					22	1.852
					24	1.841

39	02/02/2028	06:24:00	-66.1338	-59.8965	1	315.542
					3	265.001
					5	252.792
					7	227.273
					11	126.118
					12	100.808
					14	47.205
					16	21.13
					18	12.983
					19	8.909
					21	4.685
					24	1.969
48	03/02/2024	04:53:00	-65.6271	-59.2911	1	420.971
					3	385.925
					7	303.517
					8	252.721
					11	201.976
					13	80.459
					16	54.384
					18	35.971
					19	23.851
					20	12.786
					22	6.699
					24	1.929
54	04/02/2024	06:23:00	-64.5884	-58.2599	1	488.329
					3	437.305
					7	285.467
					8	232.709
					10	202.207
					12	141.468
					13	100.965
					14	78.71
					15	52.435
					17	35.261
					19	22.142
					20	13.297
					22	7.064
					24	1.892
68	05/02/2024	16:58:00	-63.6792	-52.1204	6	962
					7	500
					8	500
					17	200
					22	16
71	05/02/2024	07:13:00	-64.5294	-48.4955	1	3932
					3	3890

					6	2000
					7	1000
					9	250
					11	200
					12	140
					13	90
					15	80
					19	38
					21	22
					22	11
					24	2
76	09/02/2024	07:12:00	-64.5235	-49.695	1	3466
					3	3425
					5	3265
					7	2300
					9	1300
					10	798
					12	230
					13	200
					15	110
					17	72
					19	42
					22	13
					24	4
81	10/02/2024	00:00:00	-64.4923	-50.8911	1	3009
					3	2957
					4	2748
					7	1252
					9	354
					10	284
					13	100
					14	54
					15	35
					18	23
					21	9
					24	2
87	11/02/2024	07:15:00	-64.5541	-52.7279	1	2492
					3	2452
					5	2300
					7	995
					8	500
					10	200
					12	140
					13	106
					15	71

					17	47
					20	17
					22	9
					23	2
93	12/02/2024	07:25:00	-64.6092	-53.6554	1	1900
					3	1850
					5	1500
					8	680
					10	500
					12	150
					14	105
					15	70
					17	46
					19	30
					22	9
					24	2
101	13/02/2024	07:09:00	-64.5553	-53.9878	1	1445
					3	1400
					5	1300
					7	800
					8	600
					11	200
					12	150
					15	45
					18	30
					21	11
					22	6
					24	2
108	14/02/2024	05:51:00	-64.5553	-54.2553	1	960
					3	910
					4	850
					5	700
					9	350
					11	180
					13	120
					15	36
					18	23
					19	15
					21	9
					24	2
114	15/02/2024	07:27:00	-64.5789	-54.6089	1	550
					3	500
					5	470
					9	230
					12	88

					13	70
					14	59
					17	39
					18	25
					20	14.7
					21	8
					23	2
120	16/02/2024	07:35:00	-64.5865	-55.0624	1	420
					3	385
					6	300
					9	210
					14	52
					15	35
					18	23
					19	15
					21	8
					24	2
124	19/02/2024	05:52:00	-66.3594	-55.9875	1	335
					3	285
					5	235
					7	200
					8	135
					10	110
					12	90
					14	58
					18	40
					19	26
					22	8
					24	2
132	25/05/2024	10:58:00	-64.7839	-56.154	1	402
					3	362
					5	300
					7	200
					10	150
					13	100
					15	80
					18	50
					20	20
					23	5
133	26/02/2024	05:54:00	-65.4088	-57.8139	1	410.453
					2	370.212
					4	279.646
					7	100.083
					9	50.004
					10	33.989

					13	22.999
					17	15.054
					19	6.073
					21	2.068
134	29/02/2024	17:52:00	-64.6984	-56.5474	1	338.588
					3	324.062
					7	19.615
					10	9.396
					13	5.866
					16	2.139
136	01/03/2024	07:31:00	-64.6618	-56.4276	1	382.011
					5	320.249
					10	199.735
					14	87.438
					18	38.393
					22	8.498
					24	1.919

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9.10 Abundance and composition of microbial plankton communities by flow cytometry and microscopy

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Objective

To determine the distribution, abundance and community structure of micro-, nano- and picophytoplankton and heterotrophic bacteria from CTD casts by flow cytometry and microscopy.

Phytoplankton community structure and abundance by flow cytometry.

Fresh seawater samples were collected in clean 250 mL polycarbonate bottles using a Seabird CTD system containing a 24 bottle rosette of 20 L Niskin bottles from 200 m to the surface at predawn primary productivity and biogeochemistry CTD casts. Seawater samples were also provided in 2 mL cryovials from the trace metal-free Niskin bottles from the trace metal CTD casts. Samples were stored in a refrigerator and analysed within 2 hours of collection. Fresh samples were measured using a Becton Dickinson FACSort flow cytometer which characterised and enumerated pico- and eukaryote phytoplankton (Note: prokaryote phytoplankton were not present), based on their light scattering and autofluorescence properties. Data were saved in listmode format and analysed during the cruise. Table 9.10-1 summarises the CTD casts sampled and analysed during the cruise.

Heterotrophic bacteria community structure and abundance by flow cytometry.

Samples for bacteria enumeration were collected in clean 250 mL polycarbonate bottles using a Seabird CTD system containing a 24 bottle rosette of 20 L Niskin bottles from 200 m to the surface at predawn primary productivity CTD casts and biogeochemistry CTD casts. Seawater samples were also provided in 2 mL cryovials from the trace metal-free Niskin bottles from the trace metal CTD casts from near the seabed to the surface. 0.5 mL samples were fixed with glutaraldehyde solution (Sigma-Aldrich, 50%, Grade 1. 0.5% final concentration, minimum of 30 mins at 4°C) within half an hour of surfacing. Samples (see below) were stained for 1 h at room temperature in the dark with the DNA stain SYBR Green I (Thermo-Fisher) in order to separate particles in suspension based on DNA content and light scattering properties. This enabled bacteria to be discriminated from other particles and enumerated. Samples were analysed flow cytometrically, within 3 hours of surfacing. Stained samples were measured using a Becton Dickinson FACSort flow cytometer. Data were saved in listmode format and analysed during the cruise. Table 9.10-1 summarises the CTD casts sampled and analysed during the cruise.

Table 9.10-1: CTD casts sampled for phytoplankton and heterotrophic bacteria community structure & abundance. Depths below 200 m are bacteria only.

DATE	EVENT	STN	CTD	CTD type	TIME on deck (GMT)	LAT N	LON E	DEPTHS/*NISKIN BOTTLES*
22/01/24	3	Test1	3	BGC	15:45	-61.4	-56.68	3 4 6 11 15 18 50 200 *24 22 20 19 18 15 14 13*
22/01/24	4	Test1	4	TM	17:07	-61.45	-56.66	20 30 39 60 75 100 125 150 175 200 250 300 350 403 428 453 *23 21 19 17 15 14 13 12 11 10 9 7 5 3 2 1*

26/01/24	5	Test2	5	PP	17:25	-64.10	-56.15	3 7 11 14 22.3 36.5 60 200 *23 19 18 15 14 11 7 5*
27/01/24	13	M1	7	BGC	18:41	-64.58	-55.05	2 5 9 15 23 35 53 198 *23 21 20 18 16 14 13 10*
28/01/24	18	M1	8	PP	05:35	-64.56	-55.61	2.5 5 9 15 23 35 53 200 *24 19 18 15 23 11 7 5*
28/01/24	19	M1	9	BGC	07:43	-64.57	-55.07	2.7 5.8 10 17 26 38 60 199 *23 22 20 19 17 16 14 13*
28/01/24	20	M1	10	TM	09:10	-64.53	-55.53	20 25 35 42 75 100 150 220 260 272 321 347 372 *23 21 19 17 16 15 13 12 9 7 6 4 2*
29/01/24	30	M1	13	TM	09:04	-64.58	-55.08	20 30 50 75 100 150 200 275 363 388 413 *24 16 15 14 13 12 11 9 7* 6 5
30/01/24	41	M2	16	PP	05:26	-64.59	-55.09	2.2 5.6 9.5 14.8 23.4 35.4 52.5 200 *24 19 18 15 14 11 7 5*
30/01/24	43	M2	18	BGC	08:45	-64.58	-55.08	2.8 7 13 22 31 50 75 200 *23 22 20 19 17 15 14 12*
31/01/24	44	N104	19	BGC	09:43	-66.14	-59.88	2.3 3.5 6.4 11.4 16.5 22.5 47 80 122 152 181 202 *23 22 20 19 17 16 14 11 5 6 10 7*
31/01/24	45	N104	20	TM	11:03	-66.14	-59.89	20 24.5 37 42 56 70 100 140 170 213 263 288 313 *23 19 17 16 14 13 12 11 10 9 5* 3 1
01/02/24	59	N96	26	PP	05:20	-66.06	-60.49	2 3 6 11 16 27 53 203 *24 19 18 15 14 12 8 6*
01/02/24	61	N96	28	BGC	07:49	-66.06	-60.48	2 5 9 15 23 35 53 80 110 139 159 200 *23 22 20 19 17 16 14 9 12 5 6 13*
01/02/24	62	N96	29	TM	09:09	-66.06	-60.48	20 25 30 50 65 80 150 180 200 225 233 283 308 313 *23 19 18 17 16 15 13 12 11 9 7 5 3 1*
01/02/24	62	N96	33	BGC	17:14	-66.38	-60.34	2 4.7 8.2 12.3 18.2 135 200 *23 21 19 18 16 14 13*
01/02/24	62	N96	34	TM	18:37	-66.39	-60.33	20 30 50 75 100 120 145 175 200 250 310 350 415 440 464 *23 21 19 18 17 16 15 13 12 11 9 7 5 3 1*
02/02/24	78	N104	38	PP	05:27	-66.13	-59.89	1.8 3 5 10 15 23 50 200 *24 19 18 15 14 11 6 5*
02/02/24	79	N104	39	BGC	06:59	-66.13	-59.90	2 3 5 9 13 21 47 100 125 150 175 200 *23 22 20 19 17 16 14 112 11 10 9 8*

02/02/24	80	N96_5	40	TM	09:27	-66.13	-60.39	20 25 35 40 50 70 125 180 200 249 299 324 349 *23 19 18 17 16 15 13 12 9 7 5 3 1*
02/02/24	84	N96_5	43	BGC	13:31	-66.12	-60.43	2 3 6 10 17 25 *23 22 21 19 17 15*
02/02/24	87	N101	45	TM	18:00	-66.07	-60.33	20 30 60 75 90 100 170 200 260 285 335 360 385 *23 20 17 16 15 14 12 11 9 7 5 3 1*
03/02/24	91	SS2	47	PP	05:33	-65.63	-59.29	1.7 8 14.5 26 40 59 200 *23 19 18 15 14 11 7 5*
03/02/24	92	SS2	48	BGC	07:14	-65.63	-59.30	1.8 7 13 24 36 55 70 80 120 200 *23 22 20 19 17 15 14 13 12 11*
03/02/24	94	SS2	49	TM	08:12	-65.63	-59.30	20 35 50 75 100 250 300 317 367 392 417 *23 21 17 16 14 11 9 7 5 3 1*
03/02/24	99	SS3	52	BGC	17:46	-65.08	-58.82	2.1 5 9 13 18 30 40 50 100 200 *23 21 19 17 15 14 13 12 9 5*
04/02/24	103	SS4	53	PP	05:29	-64.59	-58.26	1.9 7 13 22 35 52 78 200 *24 19 18 15 14 11 8 6*
04/02/24	104	SS4	54	BGC	07:12	-64.59	-58.26	1.8 7 13 22 35 52 78 100 140 200 *23 22 20 19 17 16 14 13 12 10*
04/02/24	105	SS4	55	TM	08:06	-64.59	-58.26	20 25 50 150 200 300 382 437 462 *21 17 16 13 11 9 7 5 3 1*
07/02/24	128	GT	69	TM	16:05	-64.13	-47.97	20 70 100 140 220 483 725 970 1265 1560 1855 2153 2735 3030 3320 4000 4070 *23 21 19 18 17 16 15 13 12 11 10 9 7 6 5 3 1*
08/02/24	133	T1	70	PP	06:21	-64.53	-48.50	1.6 10.5 21.5 36 56 84.5 130 200 *23 19 16 15 14 11 7 5*
08/02/24	134	T1	71	BGC	09:57	-64.53	-48.50	2 11 22 38 59 80 90 140 200 *23 22 20 19 17 16 14 12 11*
08/02/24	135	T1	72	TM	13:20	-64.50	-48.53	20 60 75 120 200 500 1000 1250 2000 2500 3000 3500 3700 3870 3900 3919 *23 22 19 18 17 16 15 13 11 10 9 8 7 5 3 1*
09/02/24	142	T2	75	PP	06:26	-64.53	-49.71	4 13 24 42 66 100 150 200 *24 19 18 15 13 11 7 5*
09/02/24	143	T2	76	BGC	09:12	-64.52	-49.69	4 7 13 19 27 42 63 72 95 110 150 200 *24 23 22 21 20 19 18 17 16 15 14 13*

09/02/24	144	T2	77	TM	13:10	-64.53	-49.61	20 65 81 125 230 500 1000 2000 2500 3378 3433 3487 3508 3533 *23 21 18 17 16 15 13 11 10 9 7 5 3 2*
10/02/24	151	T3	80	PP	06:17	-64.52	-50.95	3.5 7 13 24 36 55 80 200 *24 19 18 15 14 11 7 5*
10/02/24	152	T3	81	BGC	09:13	-64.50	-50.91	2 5 9 15 23 35 54 100 150 204 *23 22 20 19 17 16 14 13 12 11*
10/02/24	153	T3	81	TM	12:10	-64.45	-50.86	20 50 70 100 150 200 250 750 1250 1750 2195 2744 3028 3078 3094 3110 *23 21 19 18 17 16 15 13 12 11 10 9 7 5 3 1*
11/02/24	160	T4	86	PP	06:20	-64.55	-52.53	2 9 17 30 47 71 106 200 *24 19 18 15 14 11 7 5*
11/02/24	161	T4	87	BGC	09:05	-64.55	-52.73	2 9 17 30 47 71 106 140 200 *23 22 20 19 17 16 13 12 10*
11/02/24	163	T4	88	TM	13:33	-64.59	-52.72	20 45 100 150 200 450 500 750 1000 1500 2000 2309 2456 2484 2504 *23 19 18 17 16 15 113 12 11 10 9 8 5 3 1*
12/02/24	171	T5	92	PP	06:38	-64.61	-53.66	2.3 9 17 30 46 70 105 200 *24 19 18 15 14 11 7 5*
12/02/24	172	T5	93	BGC	08:57	-64.62	-53.68	2 9 17 30 46 70 105 150 200 *23 22 20 19 17 16 14 12 11*
12/02/24	173	T5	94	TM	12:25	-64.54	-53.58	20 45 75 100 150 200 350 500 700 1000 1250 1500 1750 1900 1927 1952 1972 *23 21 19 18 17 16 15 13 12 11 10 9 8 7 5 3 1*
13/02/24	182	T6	100	PP	06:24	-64.56	-53.99	2 6 11 19 30 45 70 200 *24 19 18 15 14 11 7 5*
13/02/24	183	T6	101	BGC	08:24	-64.56	-53.99	2 6 11 19 30 45 70 150 200 *23 22 20 19 17 16 14 12 11*
13/02/24	185	T6	102	TM	11:28	-64.56	-53.99	20 48 70 97 150 200 350 500 600 1000 1250 1400 1474 1525 1549 565 *22 21 19 18 16 15 13 12 11 10 9 8 7 5 3 1*
14/02/24	194	T7	107	PP	06:24	-64.56	-54.26	1.6 8 14 25 39 59 88 200 *24 19 18 15 14 11 7 5*
14/02/24	195	T7	108	BGC	08:27	-64.57	-54.28	2 5 9 15 23 36 53 120 180 200 *23 22 20 19 17 16 14 13 11 10*

14/02/24	196	T7	109	TM	10:05	-64.55	-54.27	20 30 60 80 100 150 200 350 460 500 600 700 750 837 888 914 933 *23 21 20 19 18 16 15 13 12 11 10 9 8 7 5 3 1*
15/02/24	205	T8	113	PP	06:33	-64.58	-54.41	1.7 8 14 25 39 59 88 200 *24 19 18 15 14 11 7 5*
15/02/24	206	T8	114	BGC	08:10	-64.57	-54.40	2 8 14.7 25 39 59 70 88 120 *22 21 20 18 16 15 13 12 11*
15/02/24	207	T8	115	TM	09:25	-64.57	-54.41	20 30 50 100 150 200 230 300 350 400 490 514 534 *23 18 17 16 15 13 11 10 9 7 5 3 1*
16/02/24	216	M	119	PP	06:36	-64.58	-55.04	2 5 8 15 23 35 52 200 *24 19 18 15 14 11 7 5*
16/02/24	217	M	120	BGC	08:14	-64.59	-55.06	1.8 5 8 15 23 35 52 85 200 *23 22 20 19 17 16 114 13 11*
16/02/24	218	M	121	TM	09:16	-64.59	-55.08	20 60 80 100 153 200 220 300 351 376 400 *23 17 16 15 13 10 9 7 5 3 1*
19/02/24	240	ICE1	124	PP	06:24	-66.36	-55.99	2.6 8 14 26 40 58 90 200 *24 19 18 15 14 11 7 5*
19/02/24	241	ICE1	125	BGC	08:14	-66.35	-55.99	2 8 14 26 40 50 58 90 110 120 135 200 *23 22 20 19 17 16 15 12 10 9 8 7*
19/02/24	242	ICE1	126	TM	09:20	-66.35	-56.00	20 49 56 75 100 150 200 250 308 332 351 *23 21 19 16 14 12 9 7 5 4 2*
25/02/24	258	Float	132	BGC	11:36	-64.78	-56.15	5 10 20 30 50 60 80 100 120 150 200 *23 22 20 19 18 17 15 13 12 10 7*
26/02/24	266	ICE2	133	BGC	06:31	-65.41	-57.81	2 3 6 10 15 23 34 50 75 100 150 200 *21 20 19 18 17 13 10 9 8 7 6 5*
01/03/24	293	SUPER	135	PP	06:30	-64.66	-56.42	1.8 8 14 25 39 55 88 200 *24 19 18 15 14 11 7 5*
01/03/24	294	SUPER	136	BGC	08:11	-64.66	-56.43	1.8 8 14 25 39 59 88 120 170 200 *23 22 20 19 18 16 14 13 11 10*
01/03/24	295	SUPER	137	TM	09:10	-64.66	-56.43	20 40 60 80 100 150 200 275 315 343 367 384 *23 19 17 15 13 12 9 8 7 5 3 1*

Additional flow cytometry.

Enumeration of algae and bacteria in respiration incubation experiments

Live 5 mL samples, collected in centrifuge tubes were provided by Isabel Seguro of the University of East Anglia to test the efficiency of 2 and 0.8 µm filtration at the beginning of her INT respiration experiments. Samples were treated and analysed as per phytoplankton and bacteria community structure samples in previous sections. See relevant section (10.1) in this cruise report for summary of incubation experiments.

Enumeration of algae and bacteria in trace metal incubation experiments

Live 4 mL samples, collected in centrifuge tubes were provided by Neil Wyatt of the University of Plymouth to test for bottle effects and to measure growth and effects of treatments on cell size and pigment fluorescence at the beginning and end of bioassay incubation experiments. Samples were treated and analysed as per phytoplankton and bacteria community structure samples in previous sections. See relevant section (10.2) in this cruise report for summary of bioassay incubation experiments.

NOTE: Occasional samples were also analysed for other cruise participants for algae and/or bacteria to test for bottle effects in incubations or test the efficacy of filtration processes.

Other activities

Ice and under ice sampling

There were 3 main ice-associated activities: Collection of a large piece of brown-coloured ice (0.5-0.7m^3) using a metal cargo cage and crane on 25th February (Figure 9.10-1A) and ice coring and through-ice water sampling with Niskin bottles at 2 ice floes (Table 9.10-2). For the brown ice a 1.14kg sample of the ice was thawed in the dark at room temperature. As >250 mL samples of thawed ice became available, 250 mL samples were preserved with Lugol's iodine solution for subsequent analysis by microscopy and FlowCam back in the UK. Samples were also preserved with glutaraldehyde for analysis of algae and bacteria by flow cytometry. An initial microscopic examination of the thawed samples showed that they contained extremely high numbers of centric diatoms (Figure 9.10-1B).

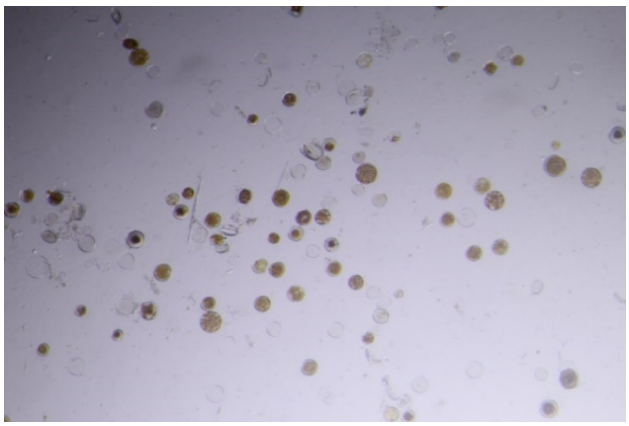

Figure 9.10-1: A, left, brown ice collection; B, right, thawed brown ice showing circular centric diatoms in the size range 40-120µm.

Two ice cores, collected by Ian Brown and Elise Droste were analysed for algae and bacteria. 2.5 mL samples were preserved with glutaraldehyde and left to fix overnight before analysis. 0.5 mL of each sample was stained with Sybr Green 1 DNA dye for quantification of bacteria and the remaining sample was analysed without further amendment for algal analysis. Table 9.10-2 below summarises samples collected from the ice cores. For the under ice Niskin bottle sampling, Samples were collected for flow cytometry and for microscopy from the Niskin bottles into clean 250 mL bottles and returned to the ship. Samples for flow cytometry were analysed as for the CTD rosette bottle samples. Samples were also preserved with Lugol's iodine for subsequent microscopic analysis back in the UK. Table 9.10-2 summarises the samples analysed for algae and bacteria by flow cytometry.

Table 9.10-2: Summary of ice-related activities for which flow cytometry samples were analysed.

DATE	EVENT	STN	CTD /Core	CTD type	LAT N	LON E	DEPTHS CTDs m, Cores cm
25/02/2024	264	BrownIce	-	-	-65.102	-56.967	-
26/02/2024	266	IceFloe8	IF8_08 IF8_11	BGC	-65.409	-57.814	0, 1, 5.8, 20, 30
26/02/2024	266	IceFloe8	IF8_04 IF8_05	TM	-65.409	-57.814	6.5, 20, 40
26/02/2024	266	IceFloe8	Core 7	-	-65.409	-57.814	0-15, 15-30, 30-43, 60-75, 75-90, 90-105, 112-127, 142-157, 152-168, 168-172, 172-187, 198-202, 202-217
27/02/2024	273	IceFloe9	IF9_05 IF9_06	BGC	-65.367	-57.673	0, 6.1, 11.1, 20, 30.3
27/02/2024	273	IceFloe9	IF9_03 IF9_04	TM	-65.367	-57.673	6.5, 20, 40
27/02/2024	273	IceFloe9	Core 6	-	-65.367	-57.673	15-30, 30-45, 45-60, 88-105, 105-120, 120-135

Microplankton Community Size Structure and abundance

1 – Sample preservation for microscopy

250 mL seawater samples from 97, 55, 33, 14, 4.5, 1% and 0.1% of surface light were collected daily from predawn primary production CTD casts. Water was collected directly into glass amber bottles and, back in the Main Lab. 5 mL of acid Lugol's solution was added to preserve the plankton. Samples were then stored in the walk-in cold room at 4°C. Back in the UK, samples will be analysed by microscopy to provide a to provide detailed information on taxonomic composition, size distribution and abundance.

Table 9.10-3: Details of samples preserved for microscopic analysis of plankton community structure.

DATE	CTD	LAT N	LON E	DEPTH SAMPLED (m)	% light
26/01/2024	5	-64.096	-56.146	3	97
26/01/2024	5	-64.096	-56.146	7	55
26/01/2024	5	-64.096	-56.146	11	33
26/01/2024	5	-64.096	-56.146	14	14
26/01/2024	5	-64.096	-56.146	22.3	4.5
26/01/2024	5	-64.096	-56.146	36.5	1
26/01/2024	5	-64.096	-56.146	60	0.1
26/01/2024	5	-64.096	-56.146	200	-
28/01/2024	8	-64.564	-55.606	2.5	97
28/01/2024	8	-64.564	-55.606	5	55
28/01/2024	8	-64.564	-55.606	9	33
28/01/2024	8	-64.564	-55.606	15	14
28/01/2024	8	-64.564	-55.606	23	4.5
28/01/2024	8	-64.564	-55.606	35	1
28/01/2024	8	-64.564	-55.606	53	0.1
28/01/2024	8	-64.564	-55.606	200	-
30/01/2024	16	-64.588	-55.086	2.2	97
30/01/2024	16	-64.588	-55.086	5.6	55
30/01/2024	16	-64.588	-55.086	9.5	33
30/01/2024	16	-64.588	-55.086	14.8	14
30/01/2024	16	-64.588	-55.086	23.4	4.5
30/01/2024	16	-64.588	-55.086	35.4	1
30/01/2024	16	-64.588	-55.086	52.5	0.1
30/01/2024	16	-64.588	-55.086	200	-
01/02/2024	26	-66.056	-60.487	2	97
01/02/2024	26	-66.056	-60.487	3	55
01/02/2024	26	-66.056	-60.487	6	33
01/02/2024	26	-66.056	-60.487	11	14
01/02/2024	26	-66.056	-60.487	16	4.5
01/02/2024	26	-66.056	-60.487	27	1
01/02/2024	26	-66.056	-60.487	53	0.1
01/02/2024	26	-66.056	-60.487	203	-
02/02/2024	38	-66.134	-59.892	1.8	97
02/02/2024	38	-66.134	-59.892	3	55
02/02/2024	38	-66.134	-59.892	5	33
02/02/2024	38	-66.134	-59.892	10	14
02/02/2024	38	-66.134	-59.892	15	4.5
02/02/2024	38	-66.134	-59.892	23	1
02/02/2024	38	-66.134	-59.892	50	0.1

02/02/2024	38	-66.134	-59.892	200	-
03/02/2024	47	-65.627	-59.291	1.7	97
03/02/2024	47	-65.627	-59.291	8	55
03/02/2024	47	-65.627	-59.291	14.5	33
03/02/2024	47	-65.627	-59.291	26	14
03/02/2024	47	-65.627	-59.291	40	4.5
03/02/2024	47	-65.627	-59.291	59	1
03/02/2024	47	-65.627	-59.291	90	0.1
03/02/2024	47	-65.627	-59.291	200	-
04/02/2024	53	-64.586	-58.263	1.9	97
04/02/2024	53	-64.586	-58.263	7	55
04/02/2024	53	-64.586	-58.263	13	33
04/02/2024	53	-64.586	-58.263	22	14
04/02/2024	53	-64.586	-58.263	35	4.5
04/02/2024	53	-64.586	-58.263	52	1
04/02/2024	53	-64.586	-58.263	78	0.1
04/02/2024	53	-64.586	-58.263	200	-
08/02/2024	70	-64.53	-48.50	2	97
08/02/2024	70	-64.53	-48.50	11	55
08/02/2024	70	-64.53	-48.50	22	33
08/02/2024	70	-64.53	-48.50	36	14
08/02/2024	70	-64.53	-48.50	56	4.5
08/02/2024	70	-64.53	-48.50	85	1
08/02/2024	70	-64.53	-48.50	130	0.1
08/02/2024	70	-64.53	-48.50	200	-
09/02/2024	75	-64.53	-49.71	4	97
09/02/2024	75	-64.53	-49.71	13	55
09/02/2024	75	-64.53	-49.71	24	33
09/02/2024	75	-64.53	-49.71	42	14
09/02/2024	75	-64.53	-49.71	66	4.5
09/02/2024	75	-64.53	-49.71	100	1
09/02/2024	75	-64.53	-49.71	150	0.1
09/02/2024	75	-64.53	-49.71	200	-
10/02/2024	80	-64.52	-50.95	3.5	97
10/02/2024	80	-64.52	-50.95	7	55
10/02/2024	80	-64.52	-50.95	13	33
10/02/2024	80	-64.52	-50.95	24	14
10/02/2024	80	-64.52	-50.95	36	4.5
10/02/2024	80	-64.52	-50.95	55	1
10/02/2024	80	-64.52	-50.95	80	0.1
10/02/2024	80	-64.52	-50.95	200	-
11/02/2024	86	-64.55	-52.53	2	97
11/02/2024	86	-64.55	-52.53	9	55
11/02/2024	86	-64.55	-52.53	17	33
11/02/2024	86	-64.55	-52.53	30	14

11/02/2024	86	-64.55	-52.53	47	4.5
11/02/2024	86	-64.55	-52.53	71	1
11/02/2024	86	-64.55	-52.53	106	0.1
11/02/2024	86	-64.55	-52.53	200	-
12/02/2024	92	-64.61	-53.66	2.3	97
12/02/2024	92	-64.61	-53.66	9	55
12/02/2024	92	-64.61	-53.66	17	33
12/02/2024	92	-64.61	-53.66	30	14
12/02/2024	92	-64.61	-53.66	46	4.5
12/02/2024	92	-64.61	-53.66	70	1
12/02/2024	92	-64.61	-53.66	105	0.1
12/02/2024	92	-64.61	-53.66	200	-
13/02/2024	100	-64.56	-53.99	2	97
13/02/2024	100	-64.56	-53.99	6	55
13/02/2024	100	-64.56	-53.99	11	33
13/02/2024	100	-64.56	-53.99	19	14
13/02/2024	100	-64.56	-53.99	30	4.5
13/02/2024	100	-64.56	-53.99	45	1
13/02/2024	100	-64.56	-53.99	70	0.1
13/02/2024	100	-64.56	-53.99	200	-
14/02/2024	107	-64.56	-54.26	1.6	97
14/02/2024	107	-64.56	-54.26	8	55
14/02/2024	107	-64.56	-54.26	14	33
14/02/2024	107	-64.56	-54.26	25	14
14/02/2024	107	-64.56	-54.26	39	4.5
14/02/2024	107	-64.56	-54.26	59	1
14/02/2024	107	-64.56	-54.26	88	0.1
14/02/2024	107	-64.56	-54.26	200	-
15/02/2024	113	-64.58	-54.41	1.7	97
15/02/2024	113	-64.58	-54.41	8	55
15/02/2024	113	-64.58	-54.41	14	33
15/02/2024	113	-64.58	-54.41	25	14
15/02/2024	113	-64.58	-54.41	39	4.5
15/02/2024	113	-64.58	-54.41	59	1
15/02/2024	113	-64.58	-54.41	88	0.1
15/02/2024	113	-64.58	-54.41	200	-
16/02/2024	119	-64.58	-55.04	2	97
16/02/2024	119	-64.58	-55.04	5	55
16/02/2024	119	-64.58	-55.04	8	33
16/02/2024	119	-64.58	-55.04	15	14
16/02/2024	119	-64.58	-55.04	23	4.5
16/02/2024	119	-64.58	-55.04	35	1
16/02/2024	119	-64.58	-55.04	52	0.1
16/02/2024	119	-64.58	-55.04	200	-
19/02/2024	124	-66.36	-55.99	2.6	97

19/02/2024	124	-66.36	-55.99	8	55
19/02/2024	124	-66.36	-55.99	14	33
19/02/2024	124	-66.36	-55.99	26	14
19/02/2024	124	-66.36	-55.99	40	4.5
19/02/2024	124	-66.36	-55.99	58	1
19/02/2024	124	-66.36	-55.99	90	0.1
19/02/2024	124	-66.36	-55.99	200	-
25/02/2024	-	-65.10	-56.97	Brown ice	-
25/02/2024	-	-65.10	-56.97	Brown ice	-
25/02/2024	-	-65.10	-56.97	Brown ice	-
25/02/2024	-	-65.10	-56.97	Brown ice	-
26/02/2024	Pump	-65.41	-57.81	Interface	-
26/02/2024	240226_C08	-65.41	-57.81	1	-
26/02/2024	240226_C08	-65.41	-57.81	5.8	-
26/02/2024	240226_C11	-65.41	-57.81	20	-
26/02/2024	240226_C11	-65.41	-57.81	30	-
27/02/2024	Pump	-65.37	-57.67	Interface	-
27/02/2024	240227_C05	-65.37	-57.67	6.1	-
27/02/2024	240227_C05	-65.37	-57.67	11.1	-
27/02/2024	240227_C06	-65.37	-57.67	20	-
27/02/2024	240227_C06	-65.37	-57.67	30.3	-
01/03/2024	135	-64.66	-56.42	1.8	97
01/03/2024	135	-64.66	-56.42	8	55
01/03/2024	135	-64.66	-56.42	14	33
01/03/2024	135	-64.66	-56.42	25	14
01/03/2024	135	-64.66	-56.42	39	4.5
01/03/2024	135	-64.66	-56.42	55	1
01/03/2024	135	-64.66	-56.42	88	0.1
01/03/2024	135	-64.66	-56.42	200	-

Reverse filtration and sample preservation for FlowCam analysis

11L seawater samples from 97, 55, 33, 14, 4.5 and 1% of surface light (DCM (deep chlorophyll maximum)) were collected daily from biogeochemistry CTD casts which directly followed predawn primary production CTD casts. Water was collected into rinsed polyethylene carboys and brought into the Main Lab. 50mm diameter plastic pipes with 50 µm mesh fitted to the end were inserted into the carboys and then siphon tubes were inserted into the filtering pipes. Seawater was then siphoned out of the carboys through the 50µm mesh, a technique known as reverse filtration, leaving a concentrated seawater sample containing plankton >50 µm in size. Samples were topped up to 200 mL using the seawater filtrate and transferred to amber glass bottles, followed by 4 mL of Lugol's solution to preserve the plankton. Samples were then stored in the walk-in cold room at 4°C. Back in the UK, samples will be analysed using a FlowCam to provide information on taxonomic composition, size distribution and abundance.

Table 9.10-4: Details of microplankton reverse filtration samples

DATE	CTD	LAT N	LON E	DEPTH SAMPLED (m)	LIGHT DEPTH %
22/01/2024	3	-61.455	-56.677	3	97
22/01/2024	3	-61.455	-56.677	4	55
22/01/2024	3	-61.455	-56.677	6	33
22/01/2024	3	-61.455	-56.677	11	14
22/01/2024	3	-61.455	-56.677	15	5
22/01/2024	3	-61.455	-56.677	18	1 DCM
28/01/2024	9	-64.570	-55.067	2.7	97
28/01/2024	9	-64.570	-55.067	5.8	55
28/01/2024	9	-64.570	-55.067	10	33
28/01/2024	9	-64.570	-55.067	17	14
28/01/2024	9	-64.570	-55.067	26	5
28/01/2024	9	-64.570	-55.067	38	1 DCM
30/01/2024	18	-64.575	-55.085	3	97
30/01/2024	18	-64.575	-55.085	7	55
30/01/2024	18	-64.575	-55.085	13	33
30/01/2024	18	-64.575	-55.085	22	14
30/01/2024	18	-64.575	-55.085	31	5
30/01/2024	18	-64.575	-55.085	50	1 DCM
01/02/2024	28	-66.056	-60.483	2	97
01/02/2024	28	-66.056	-60.483	5	55
01/02/2024	28	-66.056	-60.483	9	33
01/02/2024	28	-66.056	-60.483	15	14
01/02/2024	28	-66.056	-60.483	23	5
01/02/2024	28	-66.056	-60.483	35	1 DCM
02/02/2024	39	-66.134	-59.896	2	97
02/02/2024	39	-66.134	-59.896	3	55
02/02/2024	39	-66.134	-59.896	5	33
02/02/2024	39	-66.134	-59.896	9	14
02/02/2024	39	-66.134	-59.896	13	5
02/02/2024	39	-66.134	-59.896	21	1 DCM
03/02/2024	48	-65.627	-59.296	1.8	97
03/02/2024	48	-65.627	-59.296	7	55
03/02/2024	48	-65.627	-59.296	13	33
03/02/2024	48	-65.627	-59.296	24	14
03/02/2024	48	-65.627	-59.296	36	5
03/02/2024	48	-65.627	-59.296	55	1 DCM
04/02/2024	54	-64.588	-58.260	1.8	97
04/02/2024	54	-64.588	-58.260	7	55
04/02/2024	54	-64.588	-58.260	13	33
04/02/2024	54	-64.588	-58.260	22	14
04/02/2024	54	-64.588	-58.260	35	5

04/02/2024	54	-64.588	-58.260	52	1 DCM
08/02/2024	71	-64.530	-48.495	2	97
08/02/2024	71	-64.530	-48.495	11	55
08/02/2024	71	-64.530	-48.495	22	33
08/02/2024	71	-64.530	-48.495	38	14
08/02/2024	71	-64.530	-48.495	59	5
08/02/2024	71	-64.530	-48.495	80	1 DCM
09/02/2024	76	-64.523	-49.694	7	97
09/02/2024	76	-64.523	-49.694	13	55
09/02/2024	76	-64.523	-49.694	19	33
09/02/2024	76	-64.523	-49.694	42	14
09/02/2024	76	-64.523	-49.694	72	5
09/02/2024	76	-64.523	-49.694	95	1 DCM
10/02/2024	81	-64.504	-50.912	2	97
10/02/2024	81	-64.504	-50.912	5	55
10/02/2024	81	-64.504	-50.912	9	33
10/02/2024	81	-64.504	-50.912	15	14
10/02/2024	81	-64.504	-50.912	23	5
10/02/2024	81	-64.504	-50.912	35	1 DCM
11/02/2024	87	-64.554	-52.728	2	97
11/02/2024	87	-64.554	-52.728	9	55
11/02/2024	87	-64.554	-52.728	17	33
11/02/2024	87	-64.554	-52.728	30	14
11/02/2024	87	-64.554	-52.728	47	5
11/02/2024	87	-64.554	-52.728	71	1 DCM
12/02/2024	93	-64.624	-53.685	2	97
12/02/2024	93	-64.624	-53.685	9	55
12/02/2024	93	-64.624	-53.685	30	14
12/02/2024	93	-64.624	-53.685	46	5
12/02/2024	93	-64.624	-53.685	70	1 DCM
13/02/2024	101	-64.555	-53.988	2	97
13/02/2024	101	-64.555	-53.988	6	55
13/02/2024	101	-64.555	-53.988	11	14
13/02/2024	101	-64.555	-53.988	19	33
13/02/2024	101	-64.555	-53.988	30	14
13/02/2024	101	-64.555	-53.988	45	1 DCM
14/02/2024	108	-64.574	-54.278	2	97
14/02/2024	108	-64.574	-54.278	5	55
14/02/2024	108	-64.574	-54.278	9	14
14/02/2024	108	-64.574	-54.278	15	33
14/02/2024	108	-64.574	-54.278	23	14
14/02/2024	108	-64.574	-54.278	36	1 DCM
15/02/2024	114	-64.575	-54.405	2	97
15/02/2024	114	-64.575	-54.405	8	55
15/02/2024	114	-64.575	-54.405	14.7	14

15/02/2024	114	-64.575	-54.405	25	33
15/02/2024	114	-64.575	-54.405	39	14
15/02/2024	114	-64.575	-54.405	59	1 DCM
16/02/2024	120	-64.586	-55.062	1.8	97
16/02/2024	120	-64.586	-55.062	5	55
16/02/2024	120	-64.586	-55.062	8	14
16/02/2024	120	-64.586	-55.062	15	33
16/02/2024	120	-64.586	-55.062	23	14
16/02/2024	120	-64.586	-55.062	35	1 DCM
19/02/2024	125	-66.352	-55.991	2	97
19/02/2024	125	-66.352	-55.991	8	55
19/02/2024	125	-66.352	-55.991	14	14
19/02/2024	125	-66.352	-55.991	26	33
19/02/2024	125	-66.352	-55.991	40	14
19/02/2024	125	-66.352	-55.991	58	1 DCM
01/03/2024	136	-64.66	-56.43	1.8	97
01/03/2024	136	-64.66	-56.43	8	55
01/03/2024	136	-64.66	-56.43	14	14
01/03/2024	136	-64.66	-56.43	25	33
01/03/2024	136	-64.66	-56.43	39	14
01/03/2024	136	-64.66	-56.43	55	1 DCM

9.11 Chlorophyll sampling and analysis

Authors: Bethany Wilkinson[1], Tom Bell[1]

[1]Plymouth Marine Laboratory, Plymouth, UK

To measure the chlorophyll-a in the water, water was taken from taken from pre-dawn primary production CTD casts at light percentages 0.1%, 1%, 4.5%, 14%, 33%, and surface (presumably 100%). The water was collected using bottles covered in black tape to block light out. 100 mL of water was then used with a vacuum filter rig, which filtered the water onto 20 µm, 2 µm, and 0.1 µm polycarbonate filters. These filters were placed into 15 mL falcon tubes, and frozen in -80°C freezer until analysis.

To analyze the chlorophyll-a content present in the filters, 10 mL of acetone was added to the filter and then left for up to 24 hours in a -20°C freezer. The samples were then taken out of the freezer and kept dark for at least an hour to allow them to come up to room temperature. The RFU (raw fluorescence value) was then measured using a Turner Trilogy fluorometer. These results were processed against a standards calibration to gain the chlorophyll-a concentration in µg L^{-1}.

After some discussion, additional samples were taken and added per CTD cast, with water now also being taken at 200 m, and then samples were also taken as triplicates, with one set of

triplicates from a random depth per cast. This depth was one that was already part of sampling, and taken from the same bottle, to determine any variability within the instrument, and human error when analysing for chlorophyll-a. The standards used for the calibration range were also increased, extending the calibration range.

Samples were also taken from the ice floe stations – a smaller CTD cast was deployed, and samples were collected the same way in darkened bottles. These were processed, filtered, and analysed the same as the rest of the samples. A small portion of melted brown ice was also filtered and analysed. In total, 18 Primary Production CTDs were sampled, 2 ice floes, and 1 set of brown ice, bringing the total number of water samples filtered to be 146, and number of filters analysed is 438.

Figure 9.11-1 shows the total measured chlorophyll from sample analysis versus the fluorescence measured by the in-situ stainless CTD fluorometer. Two specific groups are highlighted in different colours – the Larsen B CTDs show a deviation from the rest of the results, but are internally consistent. The Ice Station CTD is indistinguishable from the rest of the CTDs, but has been singled out because of the size distribution of the plankton (Figure 9.11-2). Figure 9.11-2 shows the size fractionated measured chlorophyll, with each point a single depth per station. Two anomalous sample sets are evident: Larsen B CTDs (Sample #s ~20-30), and the Ice Station CTD (Sample # ~120), which contain a higher proportion of chlorophyll in the largest (>20 µm) size fraction compared to all other CTDs.

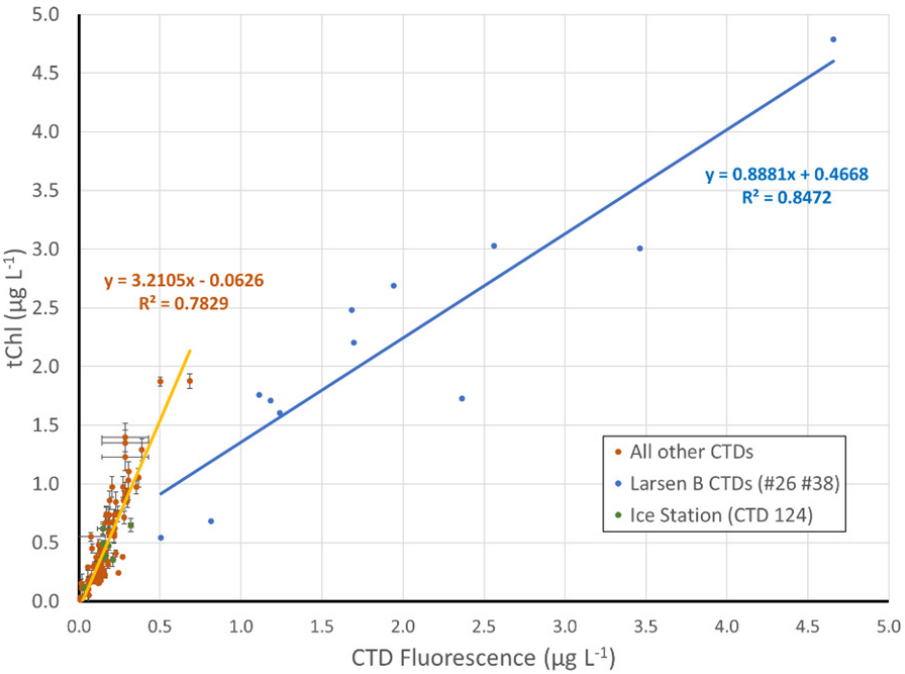

Figure 9.11-1: Stainless steel CTD fluorescence versus total chlorophyll concentration during the PICCOLO field campaign.

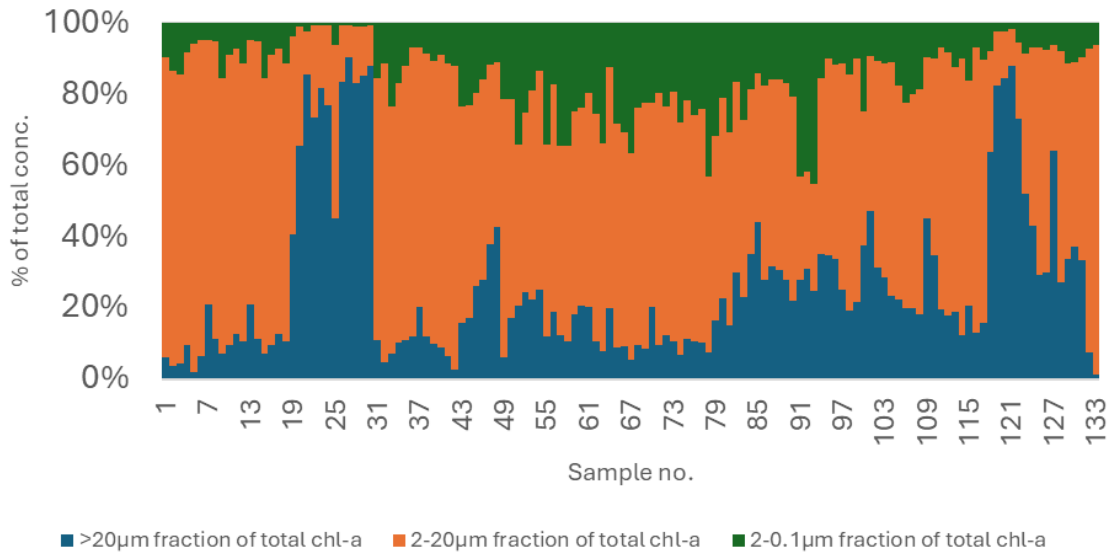

Figure 9.11-2: Size fractionated chlorophyll concentration (as a percent of total) for all samples collected during the PICCOLO field campaign.

9.12 Biogeochemistry: POC, PIC and Silicate

Authors: Flo Atherden, Emily Rowlands

[1]*Ecosytems Team, British Antarctic Survey, Cambridge, UK*

Rationale

Water samples for Particulate organic carbon (POC), particulate inorganic carbon (PIC) and silica (biogenic and lithogenic) analysis were taken from the CTD to determine their concentrations across different water masses mixing on and off the shelf, as well as gain an understanding of attenuation throughout the water column. The ratio of POC:PIC can indicate whether calcifying organisms are dominating the particulate flux. Biogenic and Lithogenic analyses allow for determining whether silica is of biological origin (e.g. diatoms) or from other sources (e.g. Icebergs). A high biogenic silica content can indicate diatoms are major contributors to the POC flux. The POC content of the bottom of the water column and POC measurements within the top 200 m (to inform primary production analyses onboard) were of particular interest. The POC data will also be used to help calibrate beam attenuation measurements.

Methods

In the main, 8 depths per biogeochemistry cast were chosen. Depths chosen consistently covered the surface, DCM and bottom, with other depths chosen to fill in the water profile, sample different water masses, capture interesting points from the beam attenuation, and sample other depths in the top 200m which coincide with the primary production cast. Where possible another consistent depth of 200 m was sampled. 9 L of water per depth was sampled from the biogeochemistry CTD using rubber tubing and 10 L carboys. Carboys were rinsed three times with water from the required depth before sampling. Additional samples were taken from

the on-ice work, wherein 500 ml from each on-ice niskin was filtered for POC, and 1500 ml from the interface was filtered for POC, PIC and silica (500 ml each) (Table 9.12-1).

Filtration

samples for POC, PIC and silica were filtered under ~ 20 psi. To minimise the potential contamination from the deck lab, filtration cups were covered with polyethylene sampling bags during filtration. Metal tweezers for handling filtered were cleaned with isopropanol. For POC and PIC analyses, water was filtered onto a pre-ashed, pre-weighed 25 mm GF/F filter. POC replicates were taken where time allowed (Table 9.12-1). POC and PIC samples were run on both the plastic and glass filtration rig. Samples were folded and returned to tin foil, and loosely wrapped up to allow the filters to dry for 24 hours, after which samples were sealed, collected into samples bags and stored at -20 °C. Two different blanks for POC analyses were performed. A blank where 800-2000 ml of Milli-Q was filtered onto a pre-weighed, pre-ashed 25 mm GF/F. Another blank (to record the dissolved carbon) was obtained by placing two 25 mm GF/F on top of each other. The top GF/F was the sample for POC analysis, and the bottom sample contained dissolved carbon. In general, these blanks were performed on mid/bottom of the water column as it significantly increased filtration time. To ensure that the top POC GF/F sample was not compromised, and enough material was collected, the bottom (dissolved carbon) GF/F was removed after 600-900 ml and more water was filtered onto the top POC GF/F (with the additional volume of water varying per station). Silicate samples were filtered onto 25 mm polycarbonate filters (pore size 0.6 um). These samples were always run on the plastic rig to prevent contamination with the glass filtration rig. Samples were stored in petri dishes and left to dry out for 24 hours. Samples were sealed with parafilm and stored at -20 °C.

Filters will be analysed back at British Antarctic Survey, Cambridge.

Issues encountered

1) Initially the air con/heater was blowing directly over the filtration rig, which caused issues with replacing/applying filters, as well as raising concerns over possible contamination of samples. However, this was fixed/minimised by reducing airflow and adjusting the direction.
2) One of the vacuum carboys (now marked accordingly) was damaged such that it collapsed under pressure. Consequently, it was not used and should not be used in future.

Table 9.12-1: Sampling dates, locations and methods for POC, PIC and Silica filtration

Date	Station	Sample method	CTD #	Analyses	No. Depths	Comment
27/01/2024	Mooring 1	CTD	7	POC, PIC, Silica	8	
30/1/2024	Mooring 3	CTD	18	POC, PIC, Silica	8	
31/1/2024	Nicholls 104	CTD	19	POC, PIC, Silica	8	Also named Larsen 1
01/2/2024	Nicholls 96	CTD	28	POC, PIC, Silica	8	
01/2/2024	Nicholls 98.5	CTD	33	POC, PIC, Silica	4	

02/02/24	Nicholls 104	CTD	39	POC, PIC, Silica	8	Also named Larsen 1
02/02/24	Nicholls 96.5	CTD	43	POC, PIC, Silica	6	
03/02/24	SS2	CTD	48	POC, PIC, Silica	8	
03/02/24	SS2	CTD	49	POC	3	POC from TM cast
04/02/24	SS4	CTD	54	POC, PIC, Silica	8	
08/02/24	T1	CTD	71	POC, PIC, Silica	8	
09/02/24	T2	CTD	76	POC, PIC, Silica	8	
10/02/24	T3	CTD	81	POC, PIC, Silica	8	POC replicates taken
11/02/24	T4	CTD	87	POC, PIC, Silica	8	
12/02/24	T5	CTD	93	POC, PIC, Silica	8	
13/02/24	T6	CTD	101	POC, PIC, Silica	8	
13/02/24	T6	CTD	102	POC	3	POC from TM cast
14/02/24	T7	CTD	108	POC, PIC, Silica	8	POC replicates taken
15/02/24	T8	CTD	114	POC, PIC, Silica	8	
16/02/24	Mooring	CTD	120	POC, PIC, Silica	8	
19/02/24	Ice Station	CTD	125	POC, PIC, Silica	8	
25/02/24	Stn 132	CTD	132	POC, PIC, Silica	8	
26/02/24	Nr Ice BGC	CTD	133	POC, PIC, Silica	8	
26/02/24	Floe 8	Ice Niskin	NA	POC	4	
26/02/24	Floe 8	Interface	NA	POC, PIC, Silica	1	
27/02/24	Floe 9	Ice Niskin	NA	POC	4	
27/02/24	Floe 9	Interface	NA	POC, PIC, Silica	1	
01/03/24	Super Station	CTD	136	POC, PIC, Silica	8	

10. Onboard Experiments and Analyses (Rate Measurements)

10.1 Microbial respiration

Authors: Isabel Seguro[1], Natalia Osma[2], Gui Bortolotto[3], Carol Robinson[1]

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The work of the microbial respiration team contributes to addressing three hypotheses within PICCOLO work packages 2 and 5:

H2.3 Dissolved organic matter (DOM) with a low carbon:nitrogen ratio promotes carbon dioxide production from dissolved organic carbon by bacterioplankton

H2.4 Strong biological activity determines the ocean carbon sink during and upon ice melt

H5.1 Annual carbon removal from the surface Weddell Sea is ranked: 1. POC, 2. DOC, 3. DIC

H5.2 Bacterial respiration is the most important biogeochemical process defining surface CO_2

Specific Objectives

1. Determine bacterial respiration as the respiration attributable to the 0.1-0.8 µm size fraction using three methods - the reduction of a tetrazolium salt (2-para(indophenol)-3(nitrophenyl)-5(phenyl) tetrazolium chloride-INT) (INT_R) and both the classical electron transport system (ETS) method and an enzyme kinetic model (EKM) incorporating pyridine nucleotide concentrations
2. In collaboration with project partner Boris Koch (AWI) determine the carbon:nitrogen:phosphorus ratio of dissolved organic material (DOM) and the concentration of dissolved organic carbon (DOC) of WDW, WW, summer surface water and AABW
3. In collaboration with Ruth Airs and Ian Brown (PML) who are measuring bacterial production, derive bacterial growth efficiencies and assess any influence of DOM stoichiometry
4. In collaboration with the physics team, estimate the upper limit for DOC export from the surface and transport into AABW
5. Determine the proportion of plankton community respiration attributable to the 0.1-0.8 µm and 0.8-2.0 µm size classes using INT_R and ETS and assess how this is influenced by environmental conditions including ice melt
6. Determine the relationship between plankton respiration derived from dissolved oxygen consumption (CR_{O2}), INT_R and ETS and assess the influence of plankton community structure and the stoichiometry of DOM
7. In collaboration with Ruth Airs and Ian Brown who are measuring primary production, estimate net community production and the proportion of carbon available for export
8. Measure dissolved oxygen in order to calibrate the oxygen sensors on the two CTDs and ultimately the oxygen sensors on the gliders, BGC Argo float and seal tags in order to derive oxygen consumption over a range of time and space scales
9. Communicate the importance of plankton respiration, and especially bacterial respiration in the Southern Ocean, to the general public via social media.

Methods

Community respiration derived from the decrease in dissolved oxygen concentration (CR_{O2})

CR_{O2} was determined as the decrease in dissolved oxygen concentration of a water sample incubated in the dark for up to 24h (Robinson et al., 2002; Serret et al., 2015). Water samples were collected into 10L carboys from each of six depths from the pre-dawn CTD cast (02:00 to 03:00 UTC) corresponding to surface irradiance 97 %, 33 %, 4.5 %, deep chlorophyll maximum (DCM) or 1 %, 0.1% and 200 m. Ten gravimetrically calibrated ~55 ml glass bottles were carefully filled with water from each depth. Five bottles were 'fixed' at the start of the incubation ("zero time samples") with 0.5 ml of manganese sulphate and 0.5 ml of a solution of sodium iodide/sodium hydroxide. The other five bottles were placed underwater in temperature-controlled incubators for 24 hours ("dark samples"). We aimed to have the incubation

temperatures within ±0.5 °C of the in situ temperature. Bottles were removed from the incubators after 24 hours and fixed with $MnSO_4$ and NaI/NaOH. Dissolved oxygen concentration was measured by automated Winkler titration using a Metrohm 765 Dosimat titrator to a photometric end point (Carritt & Carpenter, 1966). Plankton community respiration was calculated as the difference in oxygen concentration between the means of the "zero" and "dark" measurements. 19 water column profiles were completed. Samples were also collected for community respiration measurements from the melted brown sea ice and using a peristaltic pump from just beneath the ice floes. In order to test for linearity of oxygen consumption over time and to increase the likelihood of measuring very low respiration rates, two four-day time series experiments were undertaken with respiration measured at time points of 24, 48, 72 and 96 hours. Sampling times, Niskin bottles and positions are given in Table 10.1-1.

Community and size fractionated respiration derived from the reduction of INT (INT_R)
Water samples were collected from the same six depths as CR_{O2}. Five dark glass bottles were filled with 240 ml from each 10 L carboy. Two replicates were immediately fixed by adding 6 ml of formaldehyde (1 % w/v final concentration) and used as killed controls. Twenty minutes later all five replicates were inoculated with 6ml of a sterile solution of 7.9 mM 2-(ρ-iodophenyl)-3-(ρ-nitrophenyl)-5phenyl tetrazolium salt (INT) to give a final concentration of 0.2 mM. The solution was prepared for each experiment using Milli-Q water. Samples were incubated in the same temperature-controlled incubators as for CR_{O2} for 2 - 3 hours and then fixed by adding formaldehyde, as for the killed controls. The samples were sequentially filtered through 2.0, 0.8 and onto 0.1 µm pore size polycarbonate filters. The filters were then stored frozen in 1.5 ml cryovials at –80ºC until return to UEA. See Table 10.1-1 for a list of samples collected.

Time-course experiments were carried out at three depths (Surface, DCM, 200 m). Three replicate controls and fifteen replicate samples were incubated at 1, 2, 4, 6, and 8 hours in order to know the optimal incubation time for the experiments. The CRINT (i.e. the sum of respiration of all fractions) and BRINT (considered as the respiration of the 0.1-0.8 µm fraction) were measured onboard following Martínez-García et al. (2009).

Community characterisation
Samples were also collected for flow cytometric analysis of the communities in the experimental size fractions from the surface (~5m depth), DCM and 200m. This analysis was undertaken onboard by Glen Tarran (Plymouth Marine Laboratory).

Community and size fractionated respiration measured with the classical ETS method
Water samples were collected from the predawn CTD cast into 20 L carboys from Niskin bottles fired at the same six depths (surface, 33% light, 4.5% light, 1% light /DCM, 0.1% light and 200 m) as CR_{O2} and INT_R. The carboys were flushed twice with the sample seawater and placed in the 11.5 ºC constant temperature room. Between 10-20 L of seawater, depending on the depth, were filtered through 3 pore size filters (2.0 µm, 0.8 µm and 0.1 µm), thus allowing the estimation of the contribution of each component of the plankton community to the total respiration. Once the filtration was completed, the volume was measured with a 1 L measuring cylinder. The filters were snap-frozen in liquid nitrogen (-196 ºC) and stored at -80 ºC. Samples will be transported back to the UK in the ship for subsequent kinetic analyses of the electron transport activity (ETS) following the Owens and King (1975) protocol. See Table 10.1-1 for a list of samples collected.

Community and size fractionated respiration derived from pyridine nucleotide concentrations and an enzyme kinetic model

The same procedure as that described for the classical ETS method was followed for water collection and sample processing although, in this case, the filtration volumes ranged between 20-60 L. These filters will be analysed in the land-based lab (UEA, UK) for the intracellular concentration of pyridine nucleotides (Wagner and Scott, 1994, as modified by Osma et al., 2016) in order to apply a kinetic model that uses the potential respiratory activity (ETS), kinetic enzymatic constants and the concentration of intracellular substrates to estimate actual respiration rates. See Table 10.1-1 for a list of samples collected.

Community respiration derived from the decrease in dissolved oxygen concentration (CR_{O2})

Plankton community respiration was measured from 19 pre-dawn casts and 2 ice floe stations (Figure 10.1-1).

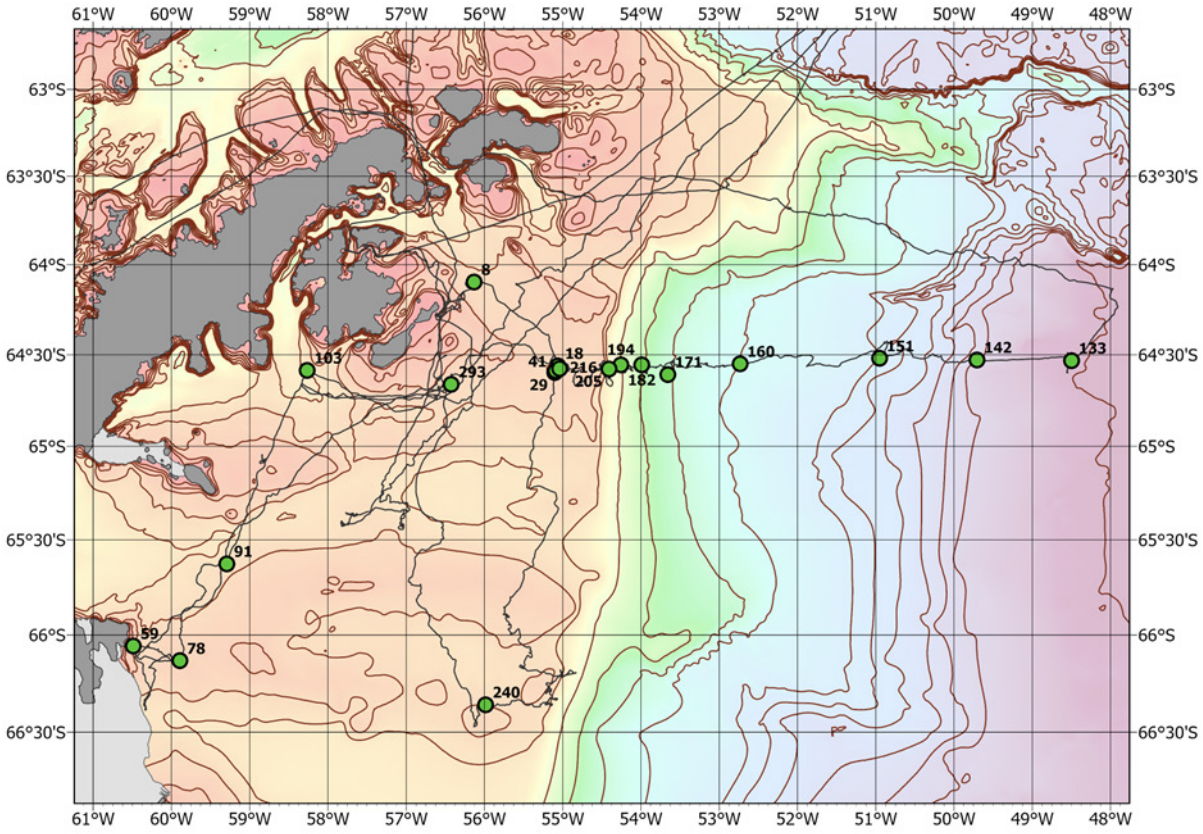

Figure 10.1-1: Cruise track showing positions of respiration measurements.

Example profiles from the shelf (CTD #53), transect (CTDs #100 and 113) and the mooring station (CTD # 119) are shown in Figure 10.1-2.

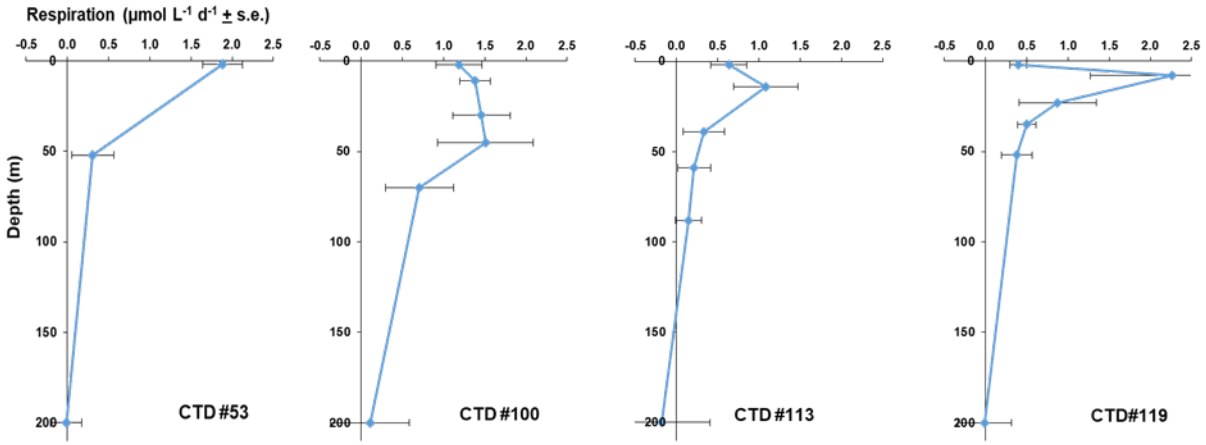

Figure 10.1-2: Example profiles of plankton community respiration.

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Table 10.1-1: CTD samples collected.

DATE	TIME (UTC)	CTD CAST	STATION	LAT (+ve N)	LON (+ve E)	NISKINS SAMPLED	PARAMETERS
22/01/2024	14:42	3	TEST1	-61.45469	-56.67683	24, 15, 13, 1	DOM, INT_R time series
21/01/2024	16:21	4	TEST1	-61.45278	-56.66144	12, 16, 20, 22, 23	Dissolved O_2
26/01/2024	16:49	5	TEST2	-64.0968	-56.13074	1, 2, 3, 4, 6, 8, 10, 12, 13, 17, 20, 21	ETS
26/01/2024	16:49	5	TEST2	-64.0968	-56.13074	5, 7, 11, 14, 15, 18, 19, 23	Dissolved O_2, CR_{O2}, INT_R, DOM
27/01/2024	17:37	7	MOORING	-64.57567	-55.05344	2, 4, 5, 8, 9, 10, 13, 15, 17, 19, 21, 24	Dissolved O_2
28/01/2024	04:56	8	MOORING2	-64.56036	-55.06062	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
28/01/2024	04:56	8	MOORING2	-64.56036	-55.06062	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
28/01/2024	06:50	9	MOORING	-64.56992	-55.06725	2, 6, 9, 12, 13, 14	Dissolved O_2
28/01/2024	08:27	10	MOORING	-64.53534	-55.07961	2, 6, 9, 12	Dissolved O_2
29/01/2024	08:21	13	MOORING	-64.58495	-55.07743	5, 9, 12, 13, 24	Dissolved O_2
30/01/2024	04:54	16	MOORING3	-64.58763	-55.08591	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
30/01/2024	04:54	16	MOORING3	-64.58763	-55.08591	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
30/01/2024	07:58	18	MOORING	-64.57537	-55.08344	2, 4, 6, 10, 15, 24	Dissolved O_2
31/01/2024	10:11	20	N104	-66.13611	-59.88765	2, 8, 13, 17, 20, 23	Dissolved O_2
31/01/2024	20:11	23	N102	-66.07234	-60.16907	2, 4, 12, 13, 15, 24	Dissolved O_2
01/02/2024	04:47	26	NIC96	-66.05637	-60.48707	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM

01/02/2024	04:47	26	NIC96	-66.05637	-60.48707	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
01/02/2024	07:07	28	N96	-66.05631	-60.48266	4, 5, 12, 13, 16	Dissolved O_2
01/02/2024	08:21	29	N96	-66.05626	-60.47978	2, 9, 12, 15, 16, 23	Dissolved O_2
02/02/2024	04:54	38	NIC104	-66.13378	-59.89225	1, 2, 3, 4, 7, 8, 10, 12, 13, 17, 20, 21	ETS, EKM
02/02/2024	04:54	38	NIC104	-66.13378	-59.89225	5, 6, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
02/02/2024	06:20	39	NIC10	-66.13386	-59.89469	1, 3, 8, 15	Dissolved O_2
02/02/2024	17:10	45	N101	-66.06733	-60.33257	4, 8, 12, 15, 17, 24	Dissolved O_2
03/02/2024	04:54	47	SS2	-65.62708	-59.29106	1, 2, 3, 4, 6, 8, 10, 12, 13, 17, 20, 21	ETS, EKM
03/02/2024	04:54	47	SS2	-65.62708	-59.29106	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
03/02/2024	06:31	48	SS2	-65.62652	-59.29569	13, 14, 15	Dissolved O_2
04/02/2024	04:58	53	SS4	-64.58644	-58.26346	1, 2, 3, 4, 9, 10, 20, 21	ETS, EKM
04/02/2024	04:58	53	SS4	-64.58644	-58.26346	5, 6, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
06/02/2024	17:32	68	CALIBRATION2	-63.67915	-52.12045	1, 2, 3, 4, 10, 11, 12, 24	ETS, EKM
06/02/2024	17:32	68	CALIBRATION2	-63.67915	-52.12045	8,17	INT_R, DOM
07/02/2024	11:47	69	GEOTRACES	-64.13382	-47.97171	1, 3, 5, 7, 10, 12, 15, 16, 19, 21, 23	Dissolved O_2
08/02/2024	05:46	70	T1	-64.53265	-48.49578	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
08/02/2024	05:46	70	T1	-64.53265	-48.49578	5, 7, 8, 14, 16, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
08/02/2024	07:13	71	T1	-64.52934	-48.49552	1, 9, 11	Dissolved O_2
09/02/2024	05:48	75	T2	-64.52885	-49.70508	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
09/02/2024	05:48	75	T2	-64.52885	-49.70508	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM

09/02/2024	07:12	76	T2	-64.52275	-49.69395	1, 3, 5, 12, 13	Dissolved O_2
09/02/2024	10:37	77	T2	-64.5314	-49.60718	2, 7, 11, 16, 21, 23	Dissolved O_2
10/02/2024	05:47	80	T3	-64.52022	-50.95213	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
10/02/2024	05:47	80	T3	-64.52022	-50.95213	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
11/02/2024	05:52	86	T4	-64.55078	-52.73381	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
11/02/2024	05:52	86	T4	-64.55078	-52.73381	5, 7, 11, 14, 18, 23	Dissolved O_2, CR_{O2}, INT_R, DOM
11/02/2024	05:52	86	T4	-64.55078	-52.73381	23	CR_{O2} time series experiment
12/02/2024	06:08	92	T5	-64.60919	-53.65531	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
12/02/2024	06:08	92	T5	-64.60919	-53.65531	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
12/02/2024	10:46	94	T5	-64.5417	-53.58619	2, 8, 12, 15, 24	Dissolved O_2
13/02/2024	05:49	100	T6	-64.55577	-53.99056	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
13/02/2024	05:49	100	T6	-64.55577	-53.99056	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
14/02/2024	05:47	107	T7	-64.5553	-54.25709	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
14/02/2024	05:47	107	T7	-64.5553	-54.25709	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
15/02/2024	06:05	113	T8	-64.57891	-54.40824	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
15/02/2024	06:05	113	T8	-64.57891	-54.40824	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
16/02/2024	06:10	119	MOORING4	-64.57774	-55.04009	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 21, 23	ETS, EKM
16/02/2024	06:10	119	MOORING4	-64.57774	-55.04009	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM

16/0/2024	06:10	119	MOORING4	-64.57774	-55.04009	22	CR_{O2} time series experiment
16/02/2024	07:34	120	MOORING4	-64.58598	-55.06117	3, 5	ETS
16/02/2024	07:34	120	MOORING4	-64.58598	-55.06117	1, 3, 11	DOM
16/02/2024	08:34	121	MOORING	-64.59402	-55.0774	2, 6, 11, 13, 18, 22	Dissolved O_2
19/02/2024	05:50	124	ICE STATION1	-66.36028	-55.9877	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
19/02/2024	05:50	124	ICE STATION1	-66.36028	-55.9877	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
19/02/2024	08:40	126	ICE STATION1	-66.34583	-55.99897	8, 10, 13, 17, 22	Dissolved O_2
23/02/2024	22:37	129	Calibration 3	-63.53921	-52.8961	1, 2, 3, 4, 6, 7, 9, 11, 12, 14, 15, 16, 18, 21	Dissolved O_2
25/02/2024	10:58	132	FLOAT1	-64.78393	-56.15397	1, 3, 5, 7, 10, 12, 13, 15, 17, 18, 19, 20, 22, 23, 24	Dissolved O_2
26/02/2024	05:50	133	ICESTATION	-65.40871	-57.81378	11, 12, 14, 15, 23, 24	ETS, CR_{O2}, INT_R, DOM
26/02/2024	09:38		ICEFLOE8	-65.4145	-57.81338		DOM from 4 Niskins, ETS, CR_{O2}, INT_R from peristaltic pump
25/02/2024	12:14		Brown ice	-65.1017	-56.9669		CR_{O2}, INT_R
26/02/2024	06:00		Diluted brown ice	-65.1017	-56.9669		ETS, INT_R
27/02/2024	16:27		ICEFLOE9	-65.3662	-57.674		DOM from 4 Niskins, ETS, CR_{O2}, INT_R from peristaltic pump
01/03/2024	06:00	135	SUPERSITE	-64.66287	-56.42403	5, 7, 11, 14, 18, 24	Dissolved O_2, CR_{O2}, INT_R, DOM
01/03/2024	06:00	135	SUPERSITE	-64.66287	-56.42403	1, 2, 3, 4, 6, 9, 10, 12, 13, 17, 20, 21	ETS, EKM
01/03/2024	07:30	136	SUPERSITE	-64.6618	-56.4275	1, 6, 10	DOM
01/03/2024	07:30	137	SUPERSITE	-64.65921	-56.42954	2, 6, 10, 14, 18, 21	Dissolved O_2

10.2 Iron bioassay experiments

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Factorial micronutrient and light addition experiments (n = 7; denoted Ex1-7) were performed during SD035 to investigate how spatial and temporal changes in micronutrient (Fe and Mn) and light availability influenced phytoplankton physiology, growth, community structure and macronutrient drawdown stoichiometry. The experimental methods were similar to those employed previously in the HNLC Southern Ocean (Wyatt et al., 2023). A complete list of sampling locations is provided in Table 10.2-1.

Table 10.2-1: Sampling locations, sampling methods, start and end times for micronutrient addition bioassay experiments during SD035.

Experiment id	Latitude	Longitude	Sampling CTD #	Collection depth (m)	Start date	End date
Ex1	-64.5308	-55.0805	CTD 010	20	28/01/2024	03/02/2024
Ex2			CTD 020	20	31/01/2024	06/02/2024
Ex3	-64.5043	-48.53146	CTD 072	75	08/02/2024	14/02/2024
Ex4	-64.58599	-52.71614	CTD 088	20	11/02/2024	21/02/2024
Ex5	-64.57147	-54.41243	CTD 115	20	15/02/2024	17/02/2024
Ex6	-62.33076	-50.98817	CTD 131	20	24/02/2024	01/03/2024
Ex7	-65.4145	-57.81338	Ice Floe 008, cast 3	5 + 8	26/02/2024	03/03/2024

Strict controls were required to avoid the contamination of incubation bottles, sampled seawater water and nutrient spikes. All incubation bottles were passed through a vigorous cleaning process involving a week-long soak in 1 M HCl followed by Milli-Q rinsing and storage with Milli-Q prior to sailing. Separately, all incubation bottles were rinsed with 5 % HCl and rinsed with Mill-Q water between experiments. The trace metal spikes were prepared from high purity salts prior to sailing. For Ex1-6, seawater was collected using a trace metal clean CTD rosette fitted with 24 GoFlo type bottles (see trace metal sampling Section 9.5). For Ex7, seawater was collected from under Ice Floe 008 using 2 x 5 L trace metal clean GoFlo type bottles deployed on a wire and lowered through a pre-drilled ice hole (see Section 7.1.5). Bottle filling and all manipulation steps including spiking and sub-sampling were performed in a Class-100 clean air laboratory.

Water for the experiments was transferred unfiltered into 250 mL polycarbonate bottles (Nalgene) for all incubation experiments. Incubation bottles were filled in a random order with triplicate samples for initial measurements collected at the beginning of the filling process. The average for time for collecting initial samples and filling of incubation bottles was 35 minutes. In addition to an unamended control, separate bottles were amended with 2 nM Fe and then further bottles with 2 nM Mn in factorially designed experiments. For experiments Ex2, 3 & 7, the

experiment was conducted under both 'surface' and 'low' light conditions. Experimental treatments in Ex1, 4, 5 & 6 were conducted as biological triplicates with Ex2,3 & 7 as duplicates.

Following micronutrient amendment, all bottles were parafilm-sealed before transfer into a temperature-controlled incubator set to approximately local sea surface temperature. A HOBO temperature logger confirmed temperature across the incubations was -1.44 ± 0.2 °C. The 'surface' light bottles were illuminated by a single light bank set to a local day/night cycle that changed during the cruise from 20 and 4 h to 18 and 6 h, respectively. The light bank was covered with a filter (Lee Filters; Bright Blue 141) to replicate the surface ocean light spectra. The 'low' light bottles were placed inside a purpose-built frame encased with a second filter (Lee Filters; 1.2ND 4 stop 299). Photosynthetically active radiation received by the 'surface' bottles was measured at ~ 33 µmol m^2 s, whilst transmission at 440 nm to the 'low' light bottle was measured at 5 %, respectively. An under-ice experiment (Ex7) was conducted at both surface light and 0.1% light transmission.

Samples for analysis of chlorophyll fluorescence (FRRf) were collected from all experiments at 48 h. After 6 days, samples were taken from for FRRf, chlorophyll, macronutrients, flow cytometry, alongside preservations of samples for later identification of phytoplankton community structure by microscopy, at which point the experiments were terminated except for Ex5 (2 days) and Ex4 (10 days). Preserved samples were collected from a combined sample of the replicate bottles within a treatment.

Preliminary results indicated that apparent Fe limitation of Weddell Sea phytoplankton was dependent upon the geographical location sampled and local supply of Fe, with some cases of likely secondary responses to additional Mn.

References

Wyatt, N.J., Birchill, A., Ussher, S., Milne, A., Bouman, H.A., Shoenfelt Troein, E., Pabortsava, K., Wright, A., Flanagan, O., Bibby, T.S., Martin, A., and Moore, C.M. (2023). Phytoplankton responses to dust addition in the Fe–Mn co-limited eastern Pacific sub-Antarctic differ by source region. Proceedings of the National Academy of Sciences, https://doi.org/10.1073/pnas.2220111120.

10.3 DOM photochemistry

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Dissolved Organic Matter (DOM) represents the second largest pool of carbon in the ocean, equivalent to the total amount of carbon in the atmosphere [1]. In sunlight, particularly under ultraviolet radiation, DOM can undergo photochemical transformations that release climate-active trace gases such as CO, CO_2, reactive oxygen species and nutrients such as NH_4^+ and NO_2^- [2-4]. In PICCOLO, we were interested in the photoproduction of CO_2 from the DOM matrix as a process which can modulate seawater CO_2 concentration and by extension its air-sea flux and carbon storage. The relevant photochemical reactions increase exponentially under

ultraviolet (UV) light and are therefore particularly relevant in the Southern Ocean carbon cycle because of stratospheric ozone depletion which exceeded 25 $\times 10^6$ km^2 in September 2023.

In total, fourteen irradiation experiments were carried out in a custom-built solar simulator which ensured consistent light levels (see Figure 10.3-1)

The incubator was fitted with long-pass wavelength filters that allowed three different treatments: a) a UV+visible treatment, b) a visible only treatment and c) a dark control [3]. Water was collected using the CTD hydrocast (20 L) and filtered sequentially through 142 mm diameter GF/D (2.7 µm nominal pore size glass fiber), GF/F (0.7 µm) filters and finally an ACROPAK 200 filter (0.8/0.2 µm). Subsamples were transferred to 1 L quartz flasks which were placed in the solar simulator and incubated for 48 hours. The concentration of dissolved inorganic carbon (DIC), total alkalinity (TA), pH and CDOM absorbance were determined after 24 and 48 hours of irradiation following established methods [5, 6].

The filtration regime proved effective at suppressing plankton and microbial numbers for all but one experiments (#14). Experiment #14 was carried out with a sample of 'brown ice meltwater', a body of ice discoloured by algal growth on the underside. Automated Flow Cytometry (AFC) of selected samples from this experiment showed a distinct cluster of ~1µm diameter, high-nucleic acid bacteria which were extremely abundant after 24 hours of incubation in all treatments, but particularly in the dark treatment (up to 4×10^7 mL^{-1}). The unfiltered melt-water sample had a mixed microbial and eukaryote assemblage prior to irradiation. The sample also had very high CDOM absorbance – the spectrophotometric cuvette was changed to 1 cm pathlength instead of the standard 10 cm for all other samples. Ordinarily, a 1 cm cuvette is used in freshwater and estuarine environments where organic carbon loads are at least an order of magnitude higher. It is conceivable that a small proportion of microbes or microbial spores passed through the filters at all times, but only showed explosive growth in this sample due to the elevated nutrients and DOM load. [7]

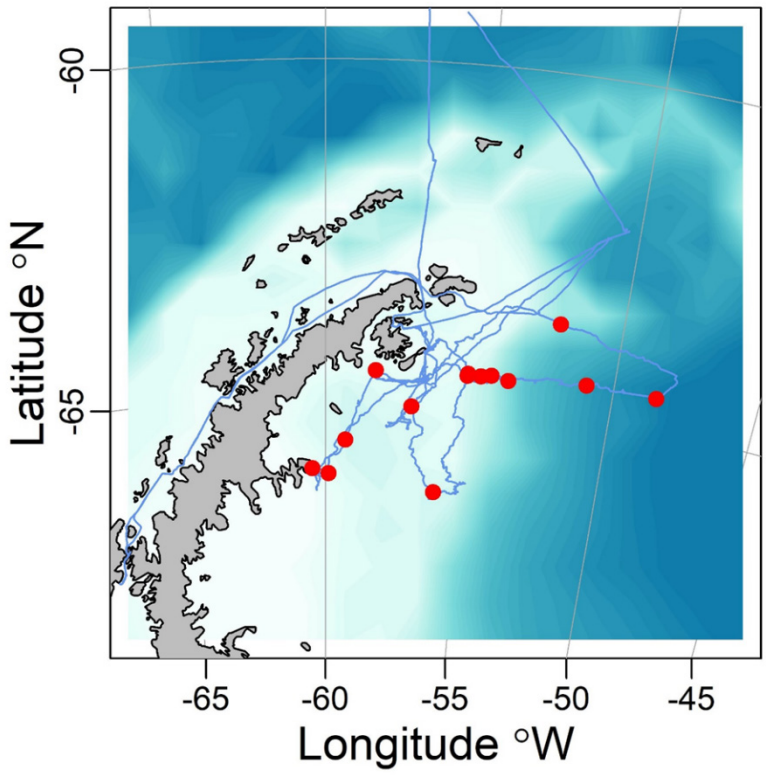

Figure 10.3-1: Location of DOM photochemical experiments (red dots) on SD035 cruise track.

Table 10.3-1: Photochemical experiments on SD035

Experiment	Latitude (°N)	Longitude (°E)	CTD	Niskin	Depth
Photo01	-64.56036	-55.0606	8	22	2
Photo02	-64.58761	-55.0859	16	8	52.5
Photo03	-66.05638	-60.4871	26	24	2
Photo04	-66.13378	-59.8922	38	22	2
Photo05	-65.62709	-59.2911	47	22	26
Photo06	-64.58644	-58.2635	53	22	2
Photo07	-63.67915	-52.1204	68	7	500
Photo08	-64.53265	-48.4958	70	22	2
Photo09	-64.52027	-50.9522	80	22	200
Photo10	-64.60919	-53.6554	92	22	70
Photo11	-64.55531	-54.2553	107	22	14
Photo12	-64.57889	-54.6089	113	22	14

Photo13	-66.35942	-55.9875	124	22	58
Photo14	-65.10174	-56.967	BROWN ICE		

1. Hansell, D.A. and M.V. Orellana *Dissolved Organic Matter in the Global Ocean: A Primer*. Gels, 2021. **7**, DOI: 10.3390/gels7030128.

2. Kitidis, V., et al., *Photochemical production of ammonium in the oligotrophic Cyprus Gyre (Eastern Mediterranean)*. Biogeosciences 2006. **3**: p. 439-449.

3. Kitidis, V., et al., *Oxygen Photolysis in the Mauritanian Upwelling: Implications for Net Community Production*. Limnology and Oceanography, 2014. **59**(2): p. 299-310.

4. Kitidis, V., et al., *Carbon Monoxide Emission from a Mauritanian Upwelling Filament*. . Marine Chemistry, 2011. **127**: p. 123-133.

5. Kitidis, V., et al., *Surface ocean carbon dioxide during the Atlantic Meridional Transect (1995-2013); evidence of ocean acidification*. Progress in Oceanography, 2017. **158**: p. 65-75.

6. Kitidis, V., et al., *Variability of chromophoric organic matter in surface waters of the Atlantic Ocean*. Deep-Sea Research Part Ii-Topical Studies in Oceanography, 2006. **53**(14-16): p. 1666-1684.

7. Hansen, A.M., et al., *Optical properties of dissolved organic matter (DOM): Effects of biological and photolytic degradation*. Limnology and Oceanography, 2016. **61**(3): p. 1015-1032.

10.4 Phytoplankton and bacterial production; Dissolved organic carbon exudation

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Background and Objectives

Primary production, or the rate of uptake of dissolved inorganic carbon for photosynthesis is a key measurement contributing to the hypotheses of PICCOLO work package 2, which aimed to quantify the contribution of phytoplankton and bacterial processes to the uptake, transformation and remineralisation of carbon, and determine the constraints on production and respiration imposed by iron and light. Primary production is expected to be largely controlled by the availability of dissolved iron in the photic zone, which is limiting in vast areas of the Southern Ocean. Direct measurements of primary production are sparse in the Weddell Sea, and those that exist are mainly confined to SE (Brocket, 1985; Balaguer et al. 2023) E (El-Sayed & Taguchi 1981), and NW regions (Romanov et al. 2022). Response curves of photosynthesis to irradiance, from which various informative parameters can be derived important for remote sensing algorithms are even more scarce for the region.

Bacterial production encompasses the uptake of radiolabelled leucine for protein synthesis, and can be converted to units of carbon uptake by applying appropriate conversion factors. Bacterial production is an uncommon measurement for the Weddell Sea with values available for the NW region alone (Vaque et al. 2002). Bacterial production is an important measure contributing to the remineralisation of carbon, and essential for calculation of bacterial growth efficiency which is poorly understood for Antarctic polar waters.

The partition of carbon taken up by phytoplankton into dissolved or particulate forms is a key parameter for determining the remineralisation of carbon versus that available for export. Dissolved organic carbon (DOC) is the largest and most bio-reactive pool of carbon in the ocean (Hansell et al. 2009), with bacterioplankton being the main consumers. Changes in the processes regulating DOC production and removal affect seawater CO_2 levels and organic carbon export. Exudation of DOC by phytoplankton and its production by other food web processes e.g. grazer activity are the main contributors to the DOC pool.

During the PICCOLO cruise SD035, from pre-dawn CTD casts measurements were taken for primary production using 14C incubations under artificial light, PI curves using an ICES light source and a shaded bottle array yielding 12 light intensities, bacterial production and DOC exudation. DOC exudation experiments as a function of light intensity were also carried out during a transect from the Weddell gyre onto the Western Antarctic Peninsula shelf.

Sampling

CTD casts were performed pre-dawn, so a light profile was not available to calculate light depths. Sampling depths were selected using the deep chlorophyll maximum as the 1% light depth, and other light depths calculated accordingly. Samples were taken at light depths of 97%, 33%, 14.5%, 4.5%, 1% and 0.1%. Water was sampled into pre-rinsed, dark plastic bottles (2 L), and kept at in-situ temperature during manipulation for the methods described below. Details of the CTDs sampled, and sampling depths can be found below (Tables 10.4-1 and 10.4-2).

Table 10.4-1: Details of CTDs sampled.

Event number	CTD number	Station	Date	Latitude	Longitude	Water depth (m)
18	8	Mooring	28/01/2024	-64.56036	-55.06062	432
41	16	Mooring	30/01/2024	-64.58763	-55.08591	430
59	26	N96	01/02/2024	-66.05637	-60.48707	338
78	38	N104	02/02/2024	-66.13378	-59.89225	322
91	47	SS2	03/02/2024	-65.62708	-59.29106	430
103	53	SS4	04/02/2024	-64.58644	-58.26346	499
133	70	T1	08/02/2024	-64.53265	-48.49578	3987
142	75	T2	09/02/2024	-64.52885	-49.70508	3541
151	80	T3	10/02/2024	-64.52022	-50.95213	3043

160	86	T4	11/02/2024	-64.55078	-52.73381	2543
171	92	T5	12/02/2024	-64.60919	-53.65531	1983
182	100	T6	13/02/2024	-64.55577	-53.99056	1485
194	107	T7	14/02/2024	-64.5553	-54.25709	997
205	113	T8	15/02/2024	-64.57891	-54.40824	525
216	119	Mooring	16/02/2024	-64.57774	-55.04009	425
240	124	IceStation1	19/02/2024	-66.36028	-55.9877	326
293	135	Supersite	01/03/2024	-64.66287	-56.42403	396

Table 10.4-2: Details of depths sampled.

CTD no	**Light depths**					
	97	**33**	**14**	**4.5**	**1 (DCM)**	**0.1**
	Sampling depth (m)/Bottle number					
008	2.5/24	9/18	15/15	23/14	35/11	53/7
016	2.2/24	9.5/18	14.8/15	23.5/14	35.5/11	52.5/7
026	2/24	6/18	11/15	16/14	27/11	53/7
038	1.8/24	5/18	10/15	15/14	23/11	50/6
047	1.7/24	14.5/18	26/15	40/14	59/11	90/7
053	1.8/24	13/18	22/15	35/14	52/11	78/6
070	1.6/23&24	21.5/16	36/15	56/14	84.5/11	130/7
075	4/24	24/18	42/15	66/14	100/11	150/7
080	3.5/23&24	13/18	24/15	36/14	55/11	80/7
086	2.5/24	17/18	30/15	47/14	71/11	106/7
092	2.3/23&24	17/18	30/15	46/14	70/11	105/7
100	2/24	11/18	19/15	30/14	45/11	70/7
107	1.6/23&24	14/18	25/15	39/14	59/11	88/7
113	1.7/24	14/18	25/15	39/14	59/11	88/7
119	2/20,22,24	8/18	15/15	23/14	35/11	52/7
124	2.6/23&24	14/18	26/15	40/14	58/11	90/7

135	1.8/24	14/18	25/15	39/14	59/11	88/7

Primary Production

Primary production rates were measured using two methods: i) simulated in situ incubations under artificial light (light source), maintained at *in situ* temperature via a closed loop of circulating Hexid coolant, cooled by a T-PAC chiller (type). For simulated in situ incubations, incident light was attenuated to match the chosen light depths of 97%, 33%, 14%, 4.5%, 1% and 0.1 % by using combinations of light filters (Lee Filters 210 and HT061, Stage Electrics), wrapped around clear plastic tubes into which the incubation bottles were inserted. The tubes were then floated in the cooled incubation tank below the light source. ii) Photosynthesis-Irradiance (PI) curves using ICES light source and ICES incubation bottles which are supplied shielded to create 12 light intensities ranging from dark to full irradiance. The PI curve incubations were carried out within a perspex incubation chamber cooled via underway water at in *in situ* temperature.

Method detail

Primary production; Simulated in situ incubations: Sea water from each of the 6 PAR depths was transferred into 70ml acid washed polycarbonate bottles, minimizing headspace. Each depth consisted of three replicates plus one fully blacked out. Each bottle was spiked with 10µCi (370kBq) $NaH^{14}CO_3$. Dispensing and addition of the label was carried out swiftly before bottles were transferred to the incubator, within tubes with corresponding light percentage density filters for the sampling depth. Incubations were carried out for 24 hours with continuous light and temperature maintained by a closed loop of chilled Hidex coolant. To terminate the incubations, the samples were sequentially filtered through 47mm polycarbonate membrane filters (20µm, 2µm, 0.1 µm) under low vacuum. Filters were then fumed for 12 hours with fuming HCL in a dessicator. Finally ProSafe FC+ scintillation cocktail was added to the filters and stored in the dark for 12 hours prior to analysis for 14C using a Hidex 300 scintillation counter on board ship.

PI curves: Seawater from either the deep chlorophyll maximum or surface was transferred to 12 acid-washed ICES incubation bottles. Each bottle was spiked with 10µCi (370kBq) $NaH^{14}CO_3$. Bottles were fixed to a carousel which orientated their flat surface towards the incident light. The carousel was submerged in underway water in a Perspex tank, illuminated from above. Underway seawater flowed continuously through the tank to maintain the temperature at *in situ* conditions. Incubations were carried out for 90-120 minutes, and terminated by filtering samples sequentially through 47 mm polycarbonate membrane filters (20µm, 2µm, 0.1 µm) under low vacuum. Filters were then fumed for 12 hours with fuming HCL in a dessicator. Finally ProSafe FC+ scintillation cocktail was added to the filters and stored in the dark for 12 hours prior to analysis for 14C using a Hidex 300 scintillation counter on board ship.

Dissolved organic carbon release

Bulk community dissolved organic carbon release was determined by spiking seawater samples with $NaH^{14}CO_3$ and measuring how much of the label was released to the dissolved phase following uptake for photosynthesis. Sea water from each of the 6 PAR depths was transferred into 70 ml acid washed polycarbonate bottles, using a single bottle per depth. In addition, one

bottle was filled with DCM seawater filtered through 0.2 µm syringe filter (Whatman), as a blank. Each bottle was spiked with 10 µCi (370kBq) $NaH^{14}CO_3$. The bottles were transferred to the incubator, within tubes with corresponding light percentage density filters for the sampling depth. Incubations were carried out for 24 hours with continuous light and temperature maintained by a closed loop of chilled Hidex coolant. To terminate the incubations, 3 x 5 mL aliquots of seawater from each bottle was filtered through a 0.2 µm syringe filter into three plastic scintillation vials, which were then acidified with addition of 100 µL 50% HCl. Samples were left for 12 h, then bubbled with air, before adding 15 mL ProSafe FC+ scintillation cocktail. Samples were left for a further 12 h in the dark before activity of 14C was measured using Hidex 300 scintillation counter on board ship.

DOC Experiments:

During the transect from the Weddell gyre onto the shelf (CTDs 70 to 119), DOC experiments were performed to determine the impact of light and iron on DOC exudation. During the pre-dawn CTD, water from the DCM was added to 12 ICES bottles which were shaded to create light environments ranging from surface light intensity to darkness. Each bottle was spiked with 10 µCi (370kBq) $NaH^{14}CO_3$. The bottles were transferred to the incubator, orientated within clear tubes so the flat face of the bottles was facing the incident light. Incubations were carried out for 24 hours with continuous light and temperature maintained by a closed loop of chilled Hidex coolant. To terminate the incubations, 3 x 5 mL aliquots of seawater from each bottle was filtered through a 0.2 µm syringe filter into three plastic scintillation vials, which were then acidified with addition of 100 µL 50% HCl. Samples were left for 12 h, then bubbled with air, before adding 15 mL ProSafe FC+ scintillation cocktail. Samples were left for a further 12 h in the dark before activity of 14C was measured using Hidex 300 scintillation counter on board ship.

Microbial Production

Microbial production was estimated by measuring incorporation of radio labelled leucine.

Method detail

Whole community production (rate of leucine incorporation)

Whole community production was measured at all depths sampled (Table 10.4-2). For each depth, triplicate samples were taken plus one trichloroacetic acid (TCA) killed control (final concentration of TCA was 5%; 85 µL 100 % TCA added). Micro-centrifuge tubes containing 1.7ml sample were used for the incubations. Each was spiked with 5 µL 3H-leucine to give a final concentration of 43 nmol L^{-1}. Incubations were conducted at *in situ* temperatures in the dark for two hours and terminated by the addition of TCA to a final concentration of 5% (85 µL 100 % TCA). Processing was carried out according to Smith and Azam (1992): Samples were centrifuged (14000 rpm for 10 mins at 2 °C, Eppendorf centrifuge) then aspirated. To wash the pellet, 1.7 mL 5 % TCA was added to each tube and vortexed. Samples were re-centrifuged (10 mins at 14000 rpm, 2 °C), then aspirated prior to addition of 1.7 mL ProSafe FC+ scintillation cocktail. Samples were left in the dark overnight before analysis for 3H activity using a Hidex 300 scintillation counter on board ship.

Smith DC, Azam F (1992) A simple, economical method for measuring bacterial protein synthesis rates in seawater using 3H-leucine. Mar Microb Food Webs 6:107–114

Production measurements from ice samples

A summary of ice sampling carried out on SDA035 for production work is given below (Table 10.4-3).

Table 10.4-3: Details of ice sampling.

Event number	Date	Latitude	Longitude	Station id	Event description	Samples description
257	24/02/2024 to 25/02/2024	-62.3102 to -63.2222	-50.9212 to -52.9256	N/A	Tow fish	Filtered seawater collection for melting sea ice
264	25/02/2024	-65.1017	-56.9669	N/A	Sea-Ice collection	Brown sea ice collected from ship via crane
268	26/02/2024	-65.4145	-57.8134	Floe8	On-ice work	Interface water, ice core section (bottom)
273	27/02/24	-65.3662	-57.674	Floe9	On-ice work	Interface water, ice core section (bottom)

Sea-ice collection from SDA

To collect sea ice from the SDA, the ship steered into sea ice in order to break it into smaller manageable sections, and to enable observation of the underside of the ice. A deck party identified suitable chunks of ice to bring onto deck. Requirements were: observable colouration of the sea ice by phytoplankton; sea ice chunk of a suitable size and shape to be brought onboard. A metal cage was deployed attached to a deck crane. The cage was lowered under the desired chunk of sea ice and captured in the cage. The sea ice was then brought on deck, where it was photographed and subsampled. Subsamples of ice were taken by using a clean hammer and chisel, and an ice saw. 1.458 Kg of sea ice was added to 12 L of filtered seawater in a carboy. The carboy was left in the dark at 4°C for 12 h for the ice to melt.

Once melted the ice soup was distributed among scientists for analyses. Primary production, PI curve, bacterial production and DOC exudation were carried out as described above. Samples were incubated under 1 % light for primary production measurements.

On-Ice sampling

On ice floes 8 and 9 (Table 10.4-3), interface water at the ice-water interface was sampled via a peristatic pump into an acid-washed amber plastic bottle. Interface water was transported back to the ship, and used immediately for primary production, PI curve and bacterial

production incubations, as described above. The light level at the ice-water interface was estimated from light measurements (Bob Brewin), and determined to be approximately 0.1 % for floe 8 (ice thickness 2 m) and 1% for floe 9 (ice thickness 1.5 m). These were the light intensities used for production incubations for samples from each ice floe, respectively.

Ice cores were taken using an auger attached to an electric drill. The bottom 20 cm (1 Kg) of the ice core was taken for production incubations and melted in 4 L of filtered seawater collected from the Tow fish (Event 257), at 4 °C, overnight. Once melted, the mixture was used for primary production, bacterial production and PI curve incubations as described above. Incubation light intensities were 0.1 % for Floe8 and 1% for Floe9, as determined by optical measurements *in situ*.

10.5 Zooplankton experiments

10.5.1 Iron cycling through krill

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Background

Zooplankton play an important role in the marine carbon cycle as they compact the organic carbon from small, dispersed algae into large dense fecal pellets that are more likely to sink to the ocean interior than the algae themselves. However, the fecal pellets also contain nutrients (e.g. nitrogen-N, phosphate-P, silicate-Si, iron-Fe) that are likewise exported from the upper ocean, which can potentially terminate algae growth when the nutrient resupply is limited. A recent paper by Le Mézo and Galbraith (2021) shows that this is especially relevant for the micronutrient iron, which is little assimilated or excreted by zooplankton but instead directly channelled from the ingested food into the fecal pellets. The ratios of N : C and P : C are usually lower in the fecal pellets than in the algae (due to the animal's higher assimilation efficiency for N and P than C), but this is the opposite for Fe. Fecal pellets of zooplankton, fish and whales have often orders of magnitude higher Fe : C ratios than the algae themselves, which suggests that the animals drive a strong iron pump that exceeds the carbon pump (Le Mézo and Galbraith, 2021).

However, the high Fe : C rations measured in freshly produced zooplankton fecal pellets might be misleading. For instance, dissolved iron can be released from the fecal pellets before they leave the upper mixed layer and therefore contribute to the pool of recycled iron in surface waters. Also, zooplankton often feed disproportionally on the larger size fractions of algae that can be especially enriched in Fe due to their large storage capabilities (Marañón et al. 2013). Therefore, the Fe : C ratio of the total particulate organic matter (classified as 'food' by Le Mézo and Galbraith, 2021) might not be representative for the food ingested by zooplankton.

Neither the *in situ* Fe : C ratios of different algal size fractions, nor the release of dissolved iron from zooplankton fecal pellets has so far been studied in the Southern Ocean. However, 24 h-incubations of freshly caught krill onboard ship have resulted in relatively high rates of dissolved iron (dFe) release, especially for krill that had been feeding on diatoms (up to 5 nmol dFe krill^{-1} d^{-}

[1], Schmidt et al. 2016). Whether this iron was excreted by the krill themselves or derived from the fecal pellets produced during the incubations, remained unknown.

Objectives and highlights of the PICCOLO cruise

One aim of WP3 within the PICCOLO project is to refine the current knowledge about the role of Antarctic krill in the Southern Ocean iron cycle by considering (1) their potential food, (2) their body tissue and (3) their fecal pellets. Our highlight from the PICCOLO cruise is the large set of samples that was collected for subsequent dissolved and particulate trace metal analysis including 34 casts of surface water size-fractionated into pico-, nano- and microplankton; ~20 krill sampling events and 7 fecal pellet incubation experiments. The special scientific value of this sample set comes from the spatial heterogeneity of the study locations including shelf, shelf-break, and open ocean as well as ice-free and ice covered-regions with strong gradients in the dissolved iron inventories (see details in Section 9.5). Co-leader of WP 3, Angus Atkinson, has acquired additional funding for 10-months of staff time to support the trace metal analysis of these samples after arrival in the UK.

Pre-cruise acid washing of filters and equipment at the University of Plymouth (UoP)

Before packing for the cruise, all equipment for trace metal work was acid washed at the University of Plymouth, including carboys, buckets, filtration sets, Nalgene vials, petri dishes, falcon tubes, sampling spoons, forceps etc. The acid washing process usually comprised the following steps: an initial wash with Milli-Q water, a 2-week soak in a strong acid (10% HCl), followed by a 1-week soak in a weak acid (1 or 3% HCl), a thorough rinse with Milli-Q, drying in a laminar flow cabinet and double-bagging and labelling for transport. Nuclepore filters of five different pore sizes (0.2, 2, 5, 10, 20 µm) were acid washed as described above, rinsed with Milli-Q until neutral pH and shipped to the Southern Ocean within tubs filled with Milli-Q. Two different types of filter blanks will be analysed; those that remained in the tubs throughout the cruise and are returning to the UK in Milli-Q (= analytical blanks of the ICPMS procedure) and those that were placed in the filtration rag to filter 100 ml of Milli-Q onboard and are shipped home dry in a Nalgene vial at -20°C (= onboard handling blanks).

Size-fractionation of potential food

The water for the size-fractionation derived from the trace-metal clean CTD or trace-metal clean fish onboard, or from the trace-metal clean Niskin bottle on-ice (see Section 9.5). In total, 34 water samples were size-fractionated (Table 10.5.1-1). Most of the TM CTD samples derived from 20 m water depth or, in a few cases, from the deep chlorophyll *a* (Chl *a*) maximum. These water depths were also sampled for macronutrients, flow cytometry, lugol samples and total particulate iron (among others), either simultaneously from the TM CTD or a few hours earlier from the BGC CTD. Where possible, additional surface water samples were taken via the trace metal fish (~3 m water depth) or the on-ice Niskin bottles (5 and 8 m depth). Usually, the total amount of water available from a cast was ~10 L. This water was divided into two 4 L sub-samples. Nuclepore filters (47 mm) of 3 pore sizes were used to sample standardised fractions of pico- (0.2-2 µm), nano- (2-20 µm) and microplankton (> 20 µm). The additional filter size of 10 µm was used to allow for comparisons with previous studies in the Southern Ocean, e.g. the JR 82 cruise and the CUSTARD cruise, that used 10 or 12 µm pore sizes instead of 20 µm for size-fractionated Chl *a* analysis. The filtrations took place in a 'clean air' laboratory container from the National Marine Equipment Pool. The water was filtered sequentially, and the filters are

stored in Nalgene vials in -20 or -80°C freezers until further analysis. For each cast and pore size, two replicates were filtered: one for particulate iron (stored at -20°C), the second for total nitrogen (stored at -80°C). Any remaining water beyond the required 8 L was filtered for lipid biomarker analysis on a 47mm GF/F filter, using a glass filtration set in controlled temperature room 1 (CT1, ~5.5°C), and frozen at -80°C.

Potential problems: (1) Occasionally, there was a time gap of several hours between CTD water sampling and water filtration due to the logistics involved in sampling 24 rosette bottles for various parameters. During this time the water temperature within the rosette bottle might have increased by several degrees. (2) Ideally, we would analyse size fractionated POC alongside the size-fractionated iron, to allow the calculation of Fe : C ratios for each of the size-fractions. However, while nuclepore filters have the advantage of being available in a range of highly uniform pore sizes (in opposite to GF filters that are less precise in pore size and rarely cover larger pore sizes), they are made of polycarbonate which restricts their use for carbon analysis. The other alternative, analysing size fractionated Chl *a*, might be misleading due to the significant contribution of heterotrophic bacteria to the total biomass within the smallest size fraction (0.2-2 µm). Also, Chl *a* and other pigments might have been more sensitive than total nitrogen to the enhanced light intensity and temperature in the NMF container where the filtrations took place.

Sampling of krill

Krill was sampled with an RMT 8, which has two nets that can be opened and closed for specific acoustic targets in the upper water column (see Section 12.1 '*RMT 8 fishing',* Sophie Fielding). The first net (Net 1) is usually deployed at greater depth and for a longer time interval than the second net (Net 2). When on deck, the animals from both cod ends were immediately washed into buckets filled with filtered sea water and transported into CT1. About 20-60 specimens were immediately frozen at -80°C for subsequent stomach content- and particulate iron analyses.

The preparation of 'super-clean' incubation water

A trial fecal pellet incubation experiment was conducted in the shelf region of the Weddell Sea, against the background of relatively high ambient dFe concentrations in the incubation water (*Test 1*). With the lack of significant differences in dFe between incubation water with and without pellets, we concluded that the experiments require incubation water that contains low dFe concentrations. We therefore sampled 25 L of surface water from an oceanic station using the TM fish (Fish003, Event 130, 07/02/2024). This water was filtered through a 0.2 µm cartridge filter and stored in a carboy wrapped in black bin liners, in the scientific freezer (-0.5°C). The same water was used for all six subsequent pellet incubation experiments. Before the set-up of a new experiment, a 1 L subsample of this water was filled into a wash bottle for subsequent use in the experiments.

Fecal pellet incubation experiments

For the incubation experiments, we preferentially used krill from Net 2, which were usually in better conditions when arriving on deck (see Table 12.1-1 for RMT8 deployment details). An exception was event SD035-278, where the fewer krill in Net 1 appeared livelier and were used for the experiments. The most healthy-looking krill were transferred with a large plastic spoon into smaller buckets filled with trace metal-clean water. Usually about 300 krill of different sizes were spread across 6-8 ten litre buckets and transferred to the scientific freezer (-0.5°C). After

~1 h, all krill were removed from the buckets and the pellets within the buckets were allowed to settle. In a laminar flow hood (flow setting: medium), pellets were picked from the bottom of the buckets using a 5 ml plastic pipette and placed into one of nine petri dishes. Each petri dish received a few pellets from each bucket at random. The petri dishes were labelled K1, K2 … K9 and photographs were taken of each dish for subsequent pellet volume estimates. Each of the petri dishes was emptied into a 55 ml Falcon tube and the water surrounding the pellets was slowly drained, trying to avoid the loss of any pellets. Once the water was completely removed, the nine Falcon tubes with pellets and three empty tubes were filled with the 'super-clean' incubation water. The lids of the Falcon tubes were tightly closed, the tubes wrapped in parafilm and placed on a laboratory roller (Munro Scientific Equipment, ~5 rpm) to keep the pellets in suspension during the 1-2 days of incubation. The tube roller was placed in the scientific fridge at ~3°C, in the dark.

Experiments 1 and 2 were considered *Test* experiments for iron-clean handling and the overall set-up of the experiments (see Table 10.5.1-2). Therefore, the dissolved iron concentrations in sub-samples of the incubation water with and without pellets were analysed directly onboard by Neil Wyatt (NW). Results of the second *Test* experiment (Exp. 2) looked promising with four of the five pellet incubations showing higher dFe concentrations than the three blank incubations. From there on, the pellet incubation experiments increased in complexity with the last three experiments (Exp. 5, 6 and 7) being sampled identically as follows: Three tubes with pellets were terminated after each ~15 h, ~30 h and 40 h of incubation, and three tubes without pellets after ~40 h. For each Falcon tube, the parafilm was removed and the tube was carefully rinsed with Milli-Q to wash-off potentially attached iron. Once the pellets had settled in the conical bottom of the tube, the tube was opened, and 40 ml of the incubation water was filtered through a 0.2 µm filter into a dFe sample bottle (provided by NW) without decanting any pellets. These dFe bottles were labelled and handed to Angie Milne for acidification and return transport to UoP. The remaining 15 ml of incubation water in each Falcon tube were filtered into a macronutrient sample bottle (provided by Sarah Breimann), combining a total of 45 ml for the three replicate tubes per timepoint. For Exp. 3-5, the macronutrients were immediately analysed by SB, while for the remaining two experiments (Exp. 6 and 7), bottles were frozen at -20°C and analysed within the next few days. Once all the incubation water had been filtered and the sample bottles were removed from the filtration rig, the pellets were washed with 'super-clean' incubation water onto the same 0.2 µm filter. The filter was placed in a Nalgene vial and stored at -20°C together with the empty Falcon tube, for return transport to UoP. A fourth blank Falcon tube was sampled for macronutrients and bacteria without filtration. The bacteria were analysed onboard via flow cytometry (Glen Tarran).

Table 10.5.1-1: Size-fractionated filtration for particulate Fe (pFe), total nitrogen (TN) and lipid biomarkers ($IPSO_{25}$, fatty acids and sterols). Background information on Station ID, sampling date, sampling depth, and sample volume (in Litre). size-fractions: >20 µm, 20-10 µm, 10-2 µm, 2-0.2 µm.

Date	Event No.	Station ID	Depth	Bottle	pFe/ TN >20 µm	pFe/TN 20-10 µm	pFe/TN 10-2 µm	pFe/TN 2-0.2 µm
22/01/2024	**SD035-4**	Test1	20 m	24	4	4	2	0.65
22/01/2024	**SD035-4**	Test1	30 m	21	4	4	2	0.5
22/01/2024	**SD035-4**	Test1	75 m	?	4	4	2.67	0.7
27/01/2024	**SD035-12**	Fish01	2-3 m		4	4	4	0.79
28/01/2024	**SD035-20**	Mooring	34 m	18,19	4	4	2	0.4
29/01/2024	**SD035-30**	Mooring	30 m	17	4	4	4	1.15

29/01/2024	**SD035-30**	Mooring	20 m	19	4	4	4	1.5
31/01/24	**SD035-45**	N104	24 m	21	4	4	2	2
01/02/24	**SD035-62**	N96	25 m	21	4	4	4	1
01/02/24	**SD035-71**	N98	20 m	22	4	4	4	1.05
02/02/24	**SD035-80**	N96	24 m	21	4	4	2	0.38
02/02/24	**SD035-87**	N101	24 m	21	4	4	3	0.21
03/02/24	**SD035-94**	SS2	DCM	19	4	4	4	1
04/02/24	**SD035-105**	SS4	20 m	23	4	4	4	1
05/02/24	**SD035-120**	Fish02	2-3 m		4	4	4	1
06/02/24	**SD035-124**	Calib2	27 m	?	4	4	4	0.97
07/02/24	**SD035-130**	Fish03	2-3 m		4	4	4	0.99
08/02/24	**SD035-135**	T1	20 m	23,24	4	4	2	0.44
09/02/24	**SD035-144**	T2	20 m	22	4	4	4	1.02
09/02/24	**SD035-144**	T2	DCM	19	4	4	4	2
10/02/24	**SD035-153**	T3	20 m	24	4	4	4	2
11/02/24	**SD035-162**	T4	20 m	24	4	4	4	2
12/02/24	**SD035-173**	T5	20 m	24	4	4	4	2
13/02/24	**SD035-184**	T6	20 m	24	4	4	4	2
14/02/24	**SD035-196**	T7	20 m	24	4	4	4	2
15/02/24	**SD035-207**	T8	20 m	24	4	4	4	2
16/02/24	**SD035-218**	Mooring	20 m	24	4	4	4	2
19/02/24	**SD035-242**	IceSt1	20 m	24	4	4	4	2
24/02/24	**SD035-256**	BiopoleGl	20 m	24	4	4	4	2
24/02/24	**SD035-257**	Fish18	2-3 m		4	4	4	2
24/02/24	**SD035-257**	Fish27	2-3 m		4	4	4	2
26/02/24	**SD035-268**	Icefloe8	5, 8 m		3.4	3.4	3.4	1.7
27/02/24	**SD035-273**	Icefloe9	5, 8 m		4	4	3	1
01/03/24	**SD035-295**	Supersite	20 m	24	4	4	4	2

Table 10.5.1-2: Overview of fecal pellet excretion experiments.

RMT krill sampling	**Event No.**	**Exp**	**Time point 0**	**Time point 1**	**Time point 2**	**Time point 3**	**Time point 3 (Blank)**
			pellet samples	dFe, pFe, empty tubes, nutrients			dFe, pFe, empty tube, nutrients
31/01/2024	**SD035-56**	E 1					
03/02/2024	**SD035-101**	E 2					

11/02/2024	**SD035-165**	E 3	2		20 h	38 h	38 h
14/02/2024	**SD035-203**	E 4	3		34 h	42 h	41 h
17/02/2024	**SD035-236**	E 5	3	14 h	31 h	38 h	38 h
25/02/2024	**SD035-260**	E 6	3	14 h	32 h	41 h	40 h
28/02/2024	**SD035-278**	E 7	3	16 h	29 h	38 h	37 h

Experiments 1 and 2 (E1, E2) were test-runs to check for Fe-clean handling and sampling via dissolved iron (dFe) measurements onboard. Time-points 1-3 indicate the number of hours the experiments did run for. For each time-point, three replicate 55 ml centrifuge tubes that contained krill fecal pellets were sampled. Additional blank samples without fecal pellets were taken at the end of the experiment. For each time point, the incubation water was first filtered through a 0.2 µm nucleopore filter and 40 ml of filtered incubation water was collected for dFe and 15 ml for macronutrient analysis, while the 0.2 µm filter was frozen for particulate iron (pFe) analysis. An unfiltered blank was sampled for macronutrients and bacteria. Macronutrient analyses were carried out on 30 ml of combined water from the same time point and sample type (10 ml from each replicate sample of either blanks or incubations with pellets).

10.5.2 Zooplankton preservation experiments

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Rationale

This experiment aims to determine the effect of formalin preservation in sediment traps on the lipid chemistry of zooplankton which actively swim into the trap (swimmers). Swimmers are not part of the carbon flux but can give an indication of the community present around the trap. Traps are also able to sample animals which may be underrepresented in nets (e.g. pteropods, gelatinous zooplankton). Understanding the effect of prolonged formalin preservation may facilitate further analysis of swimmers (lipid analysis), beyond identification and size measurements.

Method

A dedicated mammoth net took place for this experiment on 13/2/2024 (Event # 190) (Table 10.5.1-1). A cohort of zooplankton was picked and immediately frozen at -80°C, a second cohort, aiming to demonstrate the immediate effects of formalin preservation, was then placed in 5 ml Eppendorf tubes and preserved with 4 % formalin used for sediment traps (see Section 14). After 24 hours, this second cohort was then removed from the formalin, with individual zooplankton placed in filtered sea water for 5 minutes (to 'wash' the sample), then placed in clean Eppendorf's and frozen at -80°C. The remaining zooplankton in the nets were preserved in sediment trap specific formalin. Lipid analysis will be conducted on the remaining zooplankton back at British Antarctic Survey, Cambridge. With extra cohorts analysed at different time points (e.g. 6 months, 1 year) to determine the long-term effects of formalin preservation on lipid

chemistry. See table 10.5.1-2 for a summary of which species and stage was taken from each net and their treatment.

Table 10.5.1-1: Dedicated mammoth net set up. Mesh size for each net 300 µm.

Net Number	Depth range (m)
1	1000-500
2	500-250
3	250-125
4	125-62.5
5	62.5-0

Table 10.5.1-2: Zooplankton initially picked for immediate freezing as well as 24 hours in formalin, the rest of the net was preserved in sediment trap specific formalin.

Net	Genus	Species	Stages	No. of individuals per replicate	No. of replicates	Treatment
5	*Calanoides*	acutus	CVIF	3	2	Frozen
5	*Calanoides*	acutus	CVIF	3	NONE	24 hour formalin
5	*Calanoides*	acutus	<= CV	3	4	Frozen
5	*Calanoides*	acutus	<= CV	3	2	24 hour formalin
4	*Calanoides*	acutus	CVIF	3	4	Frozen
4	*Calanoides*	acutus	CVIF	3	2	24 hour formalin
4	*Calanoides*	acutus	<= CV	5	6	Frozen
4	*Calanoides*	acutus	<= CV	5	3	24 hour formalin
3	*Calanoides*	acutus	CVIF	3	4	Frozen
3	*Calanoides*	acutus	CVIF	3	2	25 hour formalin
3	*Calanoides*	acutus	<= CV	5	3	Frozen
3	*Calanoides*	acutus	<= CV	5	3	24 hour formalin
3	*Metridia*	lucens	CVIF	5	6	Frozen
3	*Metrida*	lucens	CVIF	5	3	24 hour formalin
3	*Rhincalanus*	gigas	MIX	3	2	Frozen
3	*Rhincalanus*	gigas	MIX	3	2	24 hour formalin
2	*Calanoides*	acutus	<=CV	5	3	Frozen
2	*Calanoides*	acutus	CVIF	5	1	Frozen
2	*Calanoides*	acutus	CVIF	5	2	Frozen
2	*Calanoides*	acutus	CVIF	5	3	Frozen
2	*Calanoides*	acutus	CVIF	5	6	24 hour formalin
1	*Calanoides*	acutus	CVIF	5	3	Frozen
1	*Calanoides*	acutus	CVIF	5	3	24 hour formalin
1	*Calanoides*	acutus	<=CV	5	3	Frozen
1	*Calanoides*	acutus	<=CV	5	3	24 hour formalin

11. Seal Tagging

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Background and objectives

Seal tagging activities on cruise SD035 were driven by two objectives. Firstly, to collect behavioural and movement data of three top predators and to collect simultaneously environmental data of the western Weddell Sea. The goal was to deploy up to 19 CTD-Satellite Relay Data Loggers (CTD-SRDL, SMRU Instrumentation Group, University of St Andrews). These CTD-SRDLs collect up to 4 CTD profiles a day (Boehme et al., 2009). Some CTD-SRDLs had additional sensors. 7 were equipped with additional fluorometry and light level sensors (F-CTD-SRDL) and 8 with dissolved Oxygen sensors (O-CTD-SRDL). The species intended for deployment of tags were Southern Elephant seals (SES), Weddell seals (WES) and Crabeater seals (CRA). The range of species will help us to investigate how different top predators utilise this region. These seal species moult (replace their fur in a natural physiological event) in late summer and the aim here was to catch seals at the end of their annual moult. CTD-SRDLs would then be glued to the fur using Loctite© 422 (Henkel), so that the tags may remain attached to the animal up to their next moult. It has been anticipated that these seals will spend the winter in the study region, diving to different depths depending on the species. Their dives will provide depth profiles of temperature and salinity, with the addition of fluorescence and dissolved oxygen for some CTD-SRDLs. This data will be transmitted in near real-time to the ARGOS satellite system together with behavioural information, i.e. dive depths and durations. A location estimate is provided by the ARGOS satellite system. The spatial and temporal resolution of this dataset will enable us to investigate the oceanographic processes during the autumn and winter period in this area.

The initial objective was to tag as many SES and WES as possible since they are expected to dive deeper. However, the former species normally uses land that is free from ice for moulting, meaning that, in the Western Weddell Sea they were only expected to be found in the islands (e.g., James Ross Islands) near the coast to the west. Surprisingly, one SES was found resting on an ice floe and tagged with an O-CTD-SRDL (Figure 11-1). Many crabeater seals were observed at the beginning of the period allocated for potential seal tagging activities, but initially ignored in an attempt to maximize the tagging of WES and SES.

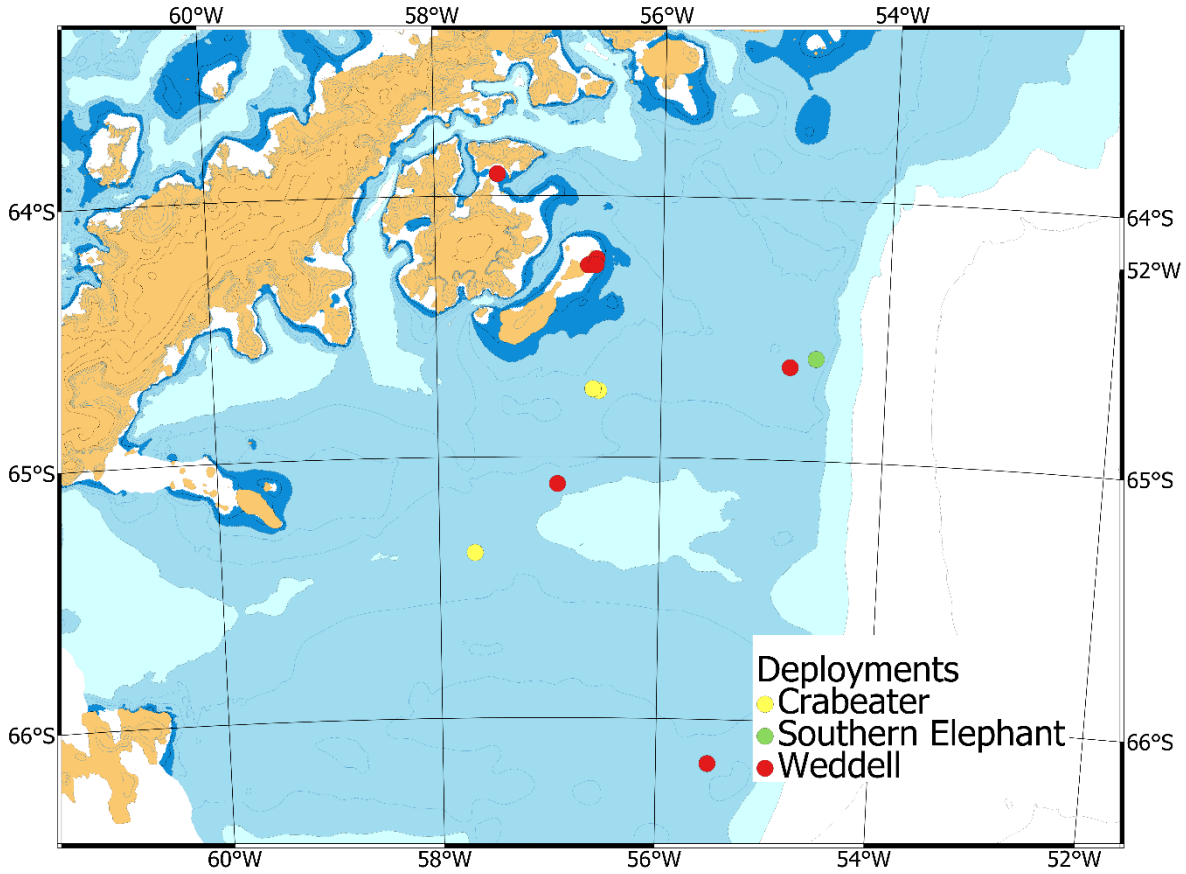

Figure 11-1: Seal tagging locations by species in the western Weddell Sea. Depth indicated by shades of blue.

Methods

Initially, the seal tagging team was formed by four members, including three with previous experience in seal tagging activities. Different types of boats and the "Wor Geordie" were available to the team to approach the seals after positive identification from the bridge. The FRC was used for short trips from the ship to an ice floe, while the Erebus was used for longer trips including searching for seals in among ice floes. The Terror and the small Humber inflatables were very useful for searching and approaching seals along the coastlines.

Avian flu (H5N1) is now found in the northern Antarctic Peninsula presenting a risk to the seal team. An analysis of the potential of the team encountering an infected seal and this seal infecting one of the team was performed and concluded that this eventuality is extremely low, as there has been no firm evidence of mammal to mammal (including human to human) transmission anywhere, according to CDC reports. Nevertheless, the seal tagging team were fitted with FFP2 masks. Additionally, the only two members of the team responsible for physically handling the animals (LB and GB) wore oilskin trousers and jackets to facilitate the cleaning of the gear between tagging activities.

Seals were captured and chemically immobilised (i.e., anaesthetised) using Zoletil 100, an association of zolazepam and tiletamine (50 mg of each per millilitre of diluent). That anaesthetic acts as a tranquilizer, with mild analgesic effect. Catching and anaesthetizing

followed standard protocols used in the past and approved during the ethical review process. No problems were encountered.

Two methods were employed to catch the seals. The first involved the delivery of a pressurized dart delivered via a blowpipe (regulated in UK), which injected the anaesthetic drug Zoletil 100 at a dose of 0.8-1.0ml per 100kg into the muscle. Crabeater seals needed a slightly higher dose of 1.0-1.3ml per 100kg for complete sedation. After delivery the field party retreated to an appropriate, unthreatening distance making still sure that the seal had no access to water, while the Zoletil took effect to both allow the animal to succumb to the anaesthesia and to prevent it from entering the water. The level of sedation was checked after about 10 minutes. When the necessary level of sedation was achieved, the deployment procedure was initiated by placing a cloth bag over the seals head to reduce stimulation (regulated in the UK) while working. The second method involved catching the seal in a cloth bag which was pulled over the head of the seal. This bag also minimises the mobility of the seal's flippers and it can be more easily constraint. Zoletil 100 at a dose of 0.4-0.5ml per 100kg was then injected into the blood stream sedating the seal within 45-60 seconds. This enabled work under relatively light anaesthesia. Biometric measurements of length and girth were taken and a SRDL was glued to the fur on the head using a rapid setting cyanoacrylate glue (Loctite© 422, Henkel, regulated in the UK). Skin samples were collected from Weddell seals (regulated in UK) enabling us to track and identify the seal through DNA analysis without any ID tags (e.g. flipper tags) and also enables us to look at relatedness between the seals tagged in this campaign and in relation to seals tagged in other areas. A small faecal sample (10g) was obtained manually from the rectum using a spoon-like instrument (Hudak and Sette, 2019). The entire handling procedure took between 8 and 15 minutes in total. The seals were then observed until they sedation was sufficiently reduced to be released from our care. The total time from administration of anaesthetics to releasing the seal was generally less than 30 minutes.

The seals were expected to be still moulting at the beginning of the cruise, but to have finished nearer its end. Therefore, most effort was put towards the end of the cruise to catch seals to minimise the possibility of catching a seal that has not sufficiently moulted to attach a SRDL to its fur. Only one Weddell seal was caught relatively early in the cruise, which did not have the required new fur on its head. Crabeater seals are expected to perform relatively shallower dives with very few dives beyond 50m and were therefore tagged preferentially with F-CTD-SRDLs or CTD-SRDLs as the oxygen data from only close to the surface was not deemed to be useful.

A total of 2 SESs, 12 WESs and 6 CRAs were caught (Table 11-1). This work was approved by the ethical committee of the University of St Andrews, UK and got the permit BAS-S7-2023/13 for activities under Section 7 of the Antarctic Act 1994 to conduct this specialist activity in Antarctica by the UK Foreign & Commonwealth Office.

Faecal samples

Additional authorship: Emily Rowlands (British Antarctic Survey)

With the intend to investigate the presence of microplastics in the faeces of Antarctic seals, faecal samples were collected as part of tagging procedures, directly from the animal, when possible, or from the surrounding ground (i.e., scat sampling). That was usually done at the end of the tagging procedures, after the tag had been deployed and the animal was still under the effect of chemical immobilization.

For collection directly from the animal, one member of the seal tagging team held the posterior of the animal, holding by the hind flippers, in an elevated position, while another gently inserted a 25cm plastic spoon in the rectum of the animal (Figure 11-2). The spoon was then gently rotated and removed. The contents of the spoon were placed inside a glass jar by either shaking the spoon inside the jar or, when very little material was collected, by scrapping the spoon with a latex glove. On one occasion, the spoon insertion stimulated the animal to defecate and the sample was collected directly into the jar.

Figure 11-2: One member of the seal tagging collects faecal samples while another holds its hind flippers.

A stringent contamination protocol was adopted whereby all spoons were cleaned with Bioguard before being rinsed 3 x with milli-Q and wrapped in foil packets for transport to the field. Glass jars used to collect samples were also rinsed 3 x in milli-Q. Field blanks were collected sporadically. For this, during the collection of a faecal sample, another jar was opened and left to collect any airborne contamination before being sealed at the same time as the sample jar. Field blanks will be paired with procedural blanks in the lab. Samples of potential sources of contamination such as the polypropylene rope, other field equipment and clothing were collected to create a contamination library. The sampler stood downwind of the sample pot to minimise contamination from clothing etc.

Samples were placed in the -20° C freezer for transport. In a plastics clean laboratory in Cambridge, samples will undergo enzymatic and chemical digestive processes before being analysed via Focal Plane Array Fourier Transform Infrared spectroscopy. This analytical method allows the detection of microplastics down to 11 µm.

CTD-SRDL deployments

Western Weddell Sea – 15th February and 17th February

On 15th February, opportunistic seal searching was conducted from the bridge of the SDA, while in transit between sites relevant to other planned research activities. In that afternoon, a SES was found resting on the floating ice and he seal tagging team was deployed. The animal was successfully captured using a head-bag. The animal reacted well to the intravenous application of the anaesthetic (Zoletil©) and was clearly tranquilized while its breathing was monitored. It was then possible to verify that that animal had finished moulting and was adequate to be tagged. A CTD-SRDLs equipped with an oxygen sensor (#15903) was fixed to its fur. This is, to the best of our knowledge, the second ever elephant seal to be tagged on an ice floe. After checking that the animal had recovered from the effects of the drugs, the animal was observed going into the water and the seal tagging team went back aboard the SDA to continue searching for seals.

Later, on 15th February, another seal was observed also resting on an ice floe, this time a WES. A similar procedure as described above was employed, with the addition of collection of faecal (see *Faecal Samples* section) and skin samples. That animal was tagged with a F-CTD-SRDL (#15864).

Two days later, on 17th February, another WES was observed from the bridge of the vessel. The seal tagging was deployed on the inflatable boat, similar to the earlier tagging operations. The animal was captured with a head-bag and chemically immobilised, but at closer inspection it was verified that the moult had not finished. It was decided for not deploying a tag on that animal; however, a skin sample was collected.

Western Weddell Sea – 25th February and 27th February

Seal searching was conducted opportunistically, while transiting between sites relevant to the other planed research activities. It became clear that WES were not very common in the region, with most of the animals found being CRA.

In the afternoon of 25th March, two WES were tagged with O-CTD-SRDLs (#15899 and #15898), each on a separate ice floe. One of them was captured with a head-bag prior to application of Zoletil 100 and the other was captured after the application of a dart. Both animals responded well to the chemical immobilization and had skin samples collected.

Since it was clear that WES were difficult to find in the region, on 27th February it was decided to attempt the tagging of CRAs. A larger boat, the Erebus, was deployed with the seal tagging team and three members of the SDA crew. Attempts to capture CRAs were made on two CRAs each on a separate ice floe, which were unsuccessful due to both the size or structure of the floes and also to the behaviour of CRAs, that moved quickly towards the water before a capture could be done. A third CRA was captured that day using a dart, and a F-CTD-SDRL was successfully deployed (#15859).

On 27th February, when research activities related to sapling the water and ice on a large flat ice floe were underway, a CRA was found resting in the ice near the sampling sites. It was decided to attempt the tagging of that seal, which was successful (#15861). A dart was employed on the capture and a faecal sample was also collected. The animal responded well to the chemical immobilisation.

Western Weddell Sea – 1st March

It had been decided that on that day CRA seals would be targeted for seal tagging. In the afternoon, a large ice floe was found with many CRAs resting in close proximity to each other, and four tags were successfully deployed on those seals; two F-CTD-SRDLs (#15863; #15862) and two CTD-SRDLs (#15878; #15907). All animals were captured with the use of darts and all responded well to the chemical immobilisation. Faecal samples were collected from two of those animals.

Seymour Island – 2nd March

While dismounting the Seymour Island camp site, some WESs were seen resting on ice floes in the surrounding area. During the morning, the seal tagging team was deployed on a small inflatable boat (Humber) and approached one of them. A dart was used for chemical immobilization and the seal was successfully tagged with an O-CTD-SRDL (#15905). On that afternoon, and still during the operations to recover a research team camping at Seymour Island, a WES was spotted on the beach by the demobilisation personal. That WES was captured with a head-bag, chemically immobilised via intravenous application of Zoletil 100 and successfully tagged with an O-CTD-SRDL (#15901). Both animals responded well to the effect of drugs and faecal samples were collected from both.

After successful deployment of the second tag on that day, the seal tagging team decided to explore the shore to the northeast of the camp site. A young male SES was found resting on the sandy beach and captured using a head-bag. An initial dose of Zoletil 100 was administered intravenously, however during the capture it became clear that the animal was larger than initially estimated and an additional dose of the drug was immediately applied. The animal was successfully tagged with an O-CTD-SRDL (#15900). After the tagging of that SES, the seal tagging team was ready to return to the SDA, but when approaching the Humber a WES was surprisingly very close to the inflatable boat, only partially submerged. The seal tagging team promptly made the animal move completely out of the water, by positioning themselves between the sea and the seal allowing the animal to calmly move up the beach. That animal was successfully captured with the head-bag and a F-CTD-SRDL was deployed (#15860).

James Ross Island – 4th March

The seal tagging team was deployed on the Terror for searching for seals around the James Ross Island while other research activities were conducted nearby on Vega Island. Some WESs were seem swimming in the area and many were found resting on the rocky/sandy beach of a small peninsula known as The Naze. Five tags were deployed on WESs during that afternoon, one F-CTD-SRDL (#15950), two O-CTD-SRDL (#15904; #15902) and two CTD-SRDL (#15908; #15906). All seals were captured with the head-bag and responded well to the intravenous application of Zoletil 100. Faecal samples were collected from two of those.

While finishing the tagging procedures on the 5th and last WES, a tour ship was near the area and a group of tourists on kayaks approached the beach where the tagging had just happened. The tourists did not come ashore but observed and interacted with the seal tagging team from the water.

Table 11-1: Summary of seal capture and tagging information during cruise SD035. (Date presented as "dd-mmm-yy"; latitude and longitude in decimal degrees; SES = southern elephant seal; WES = Weddell seal; CRA – Crabeater seal; F = female; M = male.

Date	Tag	Type	Lat	Lon	Location	Species	Sex

15-Feb-24	15903	Oxy	-64.609	-54.628	Western Weddell Sea	SES	M
15-Feb-24	15864	Fluoro	-64.644	-54.857	Western Weddell Sea	WES	F
17-Feb-24	N/A	N/A	-66.169	-55.514	Western Weddell Sea	WES	M
25-Feb-24	15899	Oxy	-65.103	-56.927	Western Weddell Sea	WES	F
25-Feb-24	15898	Oxy	-64.265	-56.657	Western Weddell Sea	WES	M
27-Feb-24	15859	Fluoro	-65.366	-57.678	Western Weddell Sea	CRA	M
29-Feb-24	15861	Fluoro	-64.746	-56.559	Western Weddell Sea	CRA	F
1-Mar-24	15863	Fluoro	-64.739	-56.611	Western Weddell Sea	CRA	F
1-Mar-24	15862	Fluoro	-64.739	-56.611	Western Weddell Sea	CRA	F
1-Mar-24	15878	CTD	-64.739	-56.611	Western Weddell Sea	CRA	M
1-Mar-24	15907	CTD	-64.739	-56.611	Western Weddell Sea	CRA	F
2-Mar-24	15905	Oxy	-64.241	-56.583	Seymour Island	WES	F
2-Mar-24	15901	Oxy	-64.265	-56.657	Seymour Island	WES	M
2-Mar-24	15900	Oxy	-64.265	-56.591	Seymour Island	SES	M
2-Mar-24	15860	Fluoro	-64.265	-56.591	Seymour Island	WES	M
4-Mar-24	15904	Oxy	-63.915	-57.453	James Ross Island	WES	F
4-Mar-24	15950	Fluoro	-63.915	-57.452	James Ross Island	WES	F
4-Mar-24	15902	Oxy	-63.915	-57.452	James Ross Island	WES	F
4-Mar-24	15908	CTD	-63.915	-57.452	James Ross Island	WES	F
4-Mar-24	15906	CTD	-63.915	-57.450	James Ross Island	WES	F

SRDL performance

Pre-deployment quality check

All tags are calibrated by the manufacturer before shipping. However, it has proven to be useful to compare the tags to a ship based CTD system. All tags were therefore attached to the ship-based CTD frame lose to the ship-based CTD system for at least one CTD cast, to depths between 500 m and 2000 m. The metal frame as well as the attachment using cable ties is thought to affect the conductivity measurements, so that only data on the pressure and temperature sensors were collected. This data is then used in the Delayed-Mode Quality Control process when all data has been received through the ARGOS satellite system.

Lessons learned

The crew of the SDA was very supportive and allowed the use of all facilities. The FRC boat was ideal for quick deployment and movement between ice floes to approach already spotted seals. The Erebus was very well equipped for longer outings. The heated cabin made sure that the team did not became cold between tagging activities and the cabin roof was a good platform to look out for seals on ice floes. The Terror was surprisingly usable when working on the beach with essentially no limits to team size and equipment required. The cabin was big enough to keep up to 8 persons.

The Naze (Figure 11-3) is a small bay in Herbert Sound between James Ross Island and Vega Island. Comb Ridge is the northwestern border and is a shallow non-tidal sandbank. Between 8-10 Weddell seals were found to haul out on the beach with more seals occupying the waters surrounding the bank. This place seems to be frequently occupied by Weddell seals, which was confirmed by the land-based researchers. This seems to be an ideal location tagging of WES in

early March. The behaviour and horizontal movement of these seals could be very specific though and our data will show which areas these seals occupy.

Drones were used to help looking for seals amidst ice floes and along beaches. A DJI Mavic 2 drone was used, which helped to find seals within the rough surface of the ice floes of the western Weddell Sea. Identification was difficult however. A DJI Mavic 3 drone was used briefly and was more promising as the pilot was able to switch between different focal length of the camera enabling a wide view for finding seals and a zoomed in view for better identification of species.

Figure 11-3: The Naze to the left, Herbert Sound to the right with Vega Island in the back. Comb Ridge sticks out as a shallow sand bank and is easily accessible for seals (and by boat).

References

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12. Zooplankton Nets and Analyses

12.1 RMT8 fishing

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Gear

The RMT8 was used to collect specimens of Antarctic krill for the trace metal experiments. All hauls were target hauls. Evening fishing was preferred, where there was still light and swarms or layers were evident in the EK80. The new camera on the RMT8 net control system made target fishing significantly easier. Rather than specific swarms being targeted, locations for fishing were chosen because they had sufficient ice clear waters to tow a net for up to 1 nautical mile and had layers of krill in the EK80. The ship was asked not to use the bow thruster so that the acoustics remained clear during the haul.

Deployment/recovery

Deployments were made using the aft gantry. Two scientists and two Abs were in the deployment zone. The biowire fibre optic wire was used for all hauls. Once targets were seen, the ship backed up to the sea ice downwind of the target to give the longest path. The cod-ends were thrown in as the ship picked up speed to 2 knots. The net was typically lowered to 30-50 m waiting for a target in the acoustics. Once seen in the acoustics (target depths varied from 70 m to surface), the net was lowered or raised to just below the target depth. Once visual verification of krill was seen on the camera the net was opened. Note the light was not used on the camera system, preference was for natural light. If the net was towed through a krill swarm, it was left open for 30 seconds to 2 minutes depending on the density of krill. All RMT hauls targeting krill swarms were successful. The last haul was undertaken at night with few targets. Instead the surface 5 m of water was targeted. Likewise this was a successful catch.

Sample protocol

On retrieval of the catch the bucket containing the healthiest alive krill was taken to the cold room for Katrin Schmidt (see Section 10.5.1). The remainder of the catch was sorted, weighed and a length frequency undertaken on the krill (see Figure 12.1-1). Krill total length was measured on 100 fresh krill, using the standard BAS measurement from the anterior edge of the eye to the tip of the telson, with measurements rounded down to the nearest mm (Morris et al. 1988). Maturity stage was assessed using the scale of Makarov and Denys with the nomenclature described by Morris et al. (1988).

Where possible 4 bags of 25 Antarctic krill were frozen at -80 C for future analyses. These included events 101, 165, 203, 236, 260, 278. Krill from samples 56 and 58 were preserved in formalin for future identification (they contained non-Antarctic krill species).

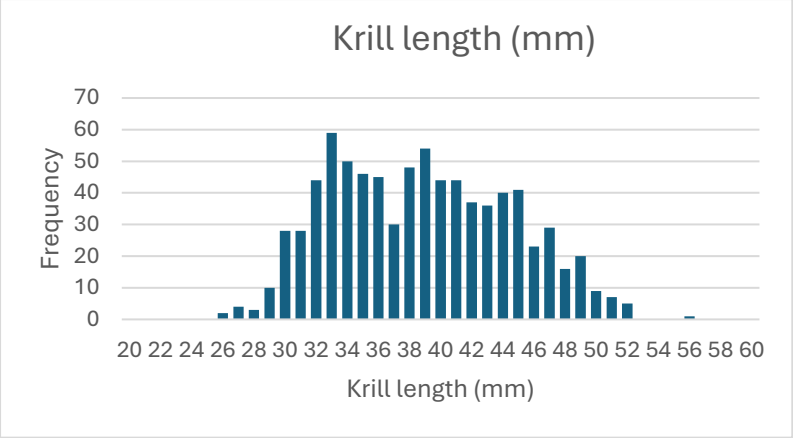

Figure 12.1-1: Krill length frequency analysis

Table 12.1-1: Details of RMT8 net catches

Time	Latitude	Longitude	Water depth	Event No.	Wire out	Net depth	Action	Comment
22/01/2024 21:51	-61.4449	-56.6508	476.42	6			offDeck	
22/01/2024 21:57	-61.4451	-56.642	487.29	6	74.00		inWater	
22/01/2024 22:02	-61.4453	-56.6348	492.05	6	25.20	30	net1 opened	Time and net depth approximate
22/01/2024 22:04	-61.4454	-56.6319	489.33	6	-5.20	15	net1 closed	Time and net depth approximate
22/01/2024 22:04	-61.4454	-56.6318	489.33	6	-5.50	15	net2 opened	Time and net depth approximate
22/01/2024 22:06	-61.4454	-56.629	491.98	6	-16.10	0	net2 closed	Time and net depth approximate
22/01/2024 22:07	-61.4455	-56.6276	495.03	6	-15.50		outWater	
22/01/2024 22:17	-61.4457	-56.6187	495.26	6	-17.50		onDeck	
31/01/2024 23:58	-66.0522	-60.487	338.25	56	-11.82		In water	Fishing 230 - 100, 100-surface
01/02/2024 00:18	-66.0592	-60.5099	305.81	56	249.51	230	Net 1 opened	
01/02/2024 00:28	-66.0627	-60.5196	300.26	56	148.31	100	Net 1 closed	
01/02/2024 00:30	-66.0634	-60.5215	300.33	56	139.10	100	Net 2 opened	
01/02/2024 00:50	-66.0699	-60.5441	257.41	56	-2.29	0	Net 2 closed	
01/02/2024 01:03	-66.0717	-60.5521	256.54	56	-17.61		Out of water	
01/02/2024 02:55	-66.0457	-60.4776	336.7	58	59.10	62	Net 1 opened	
01/02/2024 03:05	-66.0489	-60.4878	333.93	58	99.10	64	Net 1 closed	
01/02/2024 03:19	-66.0527	-60.5002	301.3	58	12.36	10	Net 2 opened	
01/02/2024 03:29	-66.0552	-60.5082	297.4	58	-1.01	1	Net 2 closed	

01/02/2024 03:40	-66.0569	-60.5135	299.98	58	-16.93		On deck	
03/02/2024 21:25	-65.049	-58.8431	270.9	101	-11.26	31	In water	
03/02/2024 21:32	-65.0528	-58.8418	267.3	101	30.05	31	Net 1 opened	
03/02/2024 21:32	-65.0529	-58.8418	268.22	101	30.05	31	Net 1 closed	Error in double clicking closed net quickly after
03/02/2024 21:33	-65.0533	-58.8416	268.49	101	30.05	32	Net 2 opened	Targeting krill swarms at 20 m and 10 m
03/02/2024 21:43	-65.0591	-58.8396	265.2	101	10.26	5	Net 2 closed	Successful net
03/02/2024 21:53	-65.0647	-58.8377	262.79	101	-19.00	5	Out of water	
11/02/2024 17:10	-64.5594	-52.9005	2478.98	165	-15.52	0	In water	Targeting a swarm
11/02/2024 17:20	-64.5602	-52.9092	2475.14	165	69.70	70	Net 1 opened	Targeting a swarm
11/02/2024 17:28	-64.5628	-52.9163	2471.38	165	92.75	70	Net 1 closed	Targeting a swarm
11/02/2024 17:32	-64.564	-52.9196	2470.63	165	46.84	47	Net 2 opened	Targeting a swarm
11/02/2024 17:46	-64.5659	-52.9339	2464.7	165	69.49	60	Net 2 closed	Targeting a swarm
11/02/2024 17:56	-64.5643	-52.9468	2459.96	165	-16.68		Out of water	Successful net
14/02/2024 22:59	-64.5847	-54.3112	874.6	203	-20.21		In water	Targeting a swarm
14/02/2024 23:05	-64.5844	-54.3169	859.12	203	30.16	33	Net 1 opened	Targeting a swarm
14/02/2024 23:07	-64.5845	-54.3188	854.1	203	25.35	18	Net 1 closed	Targeting a swarm
14/02/2024 23:08	-64.5847	-54.3197	851.16	203	20.44	20	Net 2 opened	Targeting a swarm
14/02/2024 23:09	-64.5849	-54.3206	848.62	203	20.44	18	Net 2 closed	Targeting a swarm
14/02/2024 23:25	-64.5864	-54.3333	815.96	203	-17.67		Out of water	Successful net
17/02/2024 23:25	-66.1659	-55.5102	444.2	236	-14.45		In water	Targeting a swarm
17/02/2024 23:34	-66.1672	-55.5192	444.83	236	57.08	79	Net 1 opened	
17/02/2024 23:36	-66.1674	-55.5216	447.33	236	80.02	79	Net 1 closed	
17/02/2024 23:38	-66.1674	-55.524	448.32	236	53.17	37.5	Net 2 opened	
17/02/2024 23:39	-66.1674	-55.5252	449.46	236	43.08	37.5	Net 2 closed	
17/02/2024 23:49	-66.1671	-55.5343	442.23	236	-17.94		Out of water	Successful net
25/02/2024 13:44	-64.8815	-56.5108	444.68	260	-18.04		In water	Targeting a swarm
25/02/2024 13:56	-64.886	-56.5202	439.41	260	10.27	10	Net 1 opened	
25/02/2024 13:57	-64.8865	-56.521	438.04	260	13.94	10	Net 1 closed	Krill observed on camera
25/02/2024 13:58	-64.887	-56.5216	434.59	260	14.47	20	Net 2 opened	Targeting krill swarms at 20 m - varying up and down around there

25/02/2024 14:05	-64.8901	-56.5267	423.75	260	30.70	20	Net 2 closed	Successful net
25/02/2024 14:14	-64.8933	-56.536	415.33	260	-13.93		Out of water	Successful net
29/02/2024 00:47	-64.7352	-56.5052	374.96	278	-4.67		In water	No swarms present
29/02/2024 01:24	-64.7296	-56.5409	371.56	278	-10.31		Out of water	Successful net

Table 12.1-2: Overview *of specimens collected by the RMT nets that were immediately frozen at -80°C for subsequent trace metal analysis at University of Plymouth.*

Date	Event No.	Net	Euphausiids	Copepods	Chaetognaths	Pteropods	Salps/ Jellies	Amphipods	Polychaetes	Mysids	Squid	Fish
31/01/2024	**56**	1	60		7		10					1
03/02/2024	**101**	2	35				10					
11/02/24	**165**	2	20					3	1			
14/02/24	**203**	2	20									
17/02/24	**236**	2	20									
25/02/2024	**260**	2	40									
28/02/2024	**278**	1	60				1	5				

12.2 Mammoth netting

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To sample copepods and determine the composition of mesozooplankton community across discrete depth layers in the Weddell Sea, a HydroBios MAMMOTH multinet was deployed at each CTD process station, and where possible both a day and night haul was made (see Table 12.2-1). The mammoth was deployed vertically from the Starboard Gantry on the Standard CTD cable. to a variety of depths, depending on the water depth. Nets 1-5 were fitted with 300 um mesh nets, and nets 6-9 were fitted with 100 um mesh nets.

The Mammoth was deployed in logging mode. This requires an “arming” depth to be achieved before the nets will close. In shelf waters, the arming depth was selected to be 10% less than the water depth given by the EA640 (which tends to over-predict water depth). A USBL beacon was attached to the Mammoth net to provide real-time depth monitoring.

The Mammoth was deployed from the starboard gantry at 0.6 m/s until it was at the arming depth, and then the next depth considered depending on water depth. Once at the bottom depth, the Mammoth net was hauled to the depth of the un-used nets firing depth at a rate of 0.1 m/s. Once above this the Mammoth net was hauled at a steady 0.3 m/s rate to the surface.

The focus was collecting samples with the 100 um mesh nets, but the system suggests to fit all nets and fire all nets. Therefore nets 1-5, unless specifically fishing to use the 300 um mesh, were closed within 3 m of each other at the bottom of each haul. The top four nets (the 100 um mesh), were set at the following depths: Net 9: 2-62.5m, Net 8: 62.5 – 125, Net 7: 125-250, Net 6: 250 to variable depth (max 1000m) on shelf allowing for water depth, arming depth and other net closures (see Table 12.2.1)

Large euphausiids and other zooplankton were picked from the sample and frozen for iron analysis, otherwise the whole sample was preserved in 4% formaldehyde for future taxonomic analysis (see Table 12.2-2).

The Mammoth system has an associated CTD and flow meter that measures flow rates and environmental variables and logs to an internal disk. This data was downloaded using the Oceanlab 3 software. The Oceanlab files for all deployments were exported as raw (.hbl and .hbc files) and *.txt files in the scientific work area of the SD035 cruise "leg" directory.

Issues encountered:

Deployment 14 was unsuccessful as the arming depth was not achieved.

Deployment 16 and 17 was attempted in 30-35 knot winds. The starboard deployment position makes the nets susceptible to winds and this is likely the limit for this

Deployment 155 – the electronic file is not available

Table 12.2-1: Mammoth nets and associated firing depths

Time	Latitude	Longitude	Water depth (m)	Event No.	Wire out (m)	Arming Depth (m)	Net Depths (m)	Action	Comment
22/01/2024 18:52	-61.4518	-56.6533	470.45	5	-2.25	415	400,390,380,370,360,350,300,200,50,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
22/01/2024 19:14	-61.4491	-56.6522	463.17	5	430.02	415	400,390,380,370,360,350,300,200,50,2	At bottom	
22/01/2024 19:48	-61.4459	-56.6515	466.31	5	-8.21	415	400,390,380,370,360,350,300,200,50,2	Out of Water	
27/01/2024 21:58	-64.5697	-55.0499	437.65	14	-0.15	415	412,409,406,403,400,397,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
27/01/2024 22:22	-64.5688	-55.0429	440.72	14	415.15	415	412,409,406,403,400,397,250,125,62.5,2	At bottom	
27/01/2024 23:07	-64.5682	-55.0276	437.83	14	-8.31	415	412,409,406,403,400,	Out of water	Arming depth not achieved, nets failed to trigger

							397,250,125,62.5,2		
28/01/2024 01:38	-64.5705	-55.0659	432.44	16	-8.31			In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
28/01/2024 01:48	-64.569	-55.0631	430.24	16	-9.52			Out of water	Net aborted due to wind
28/01/2024 02:02	-64.5661	-55.0594	436.09	17	-13.43			In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
28/01/2024 02:10	-64.5643	-55.0568	434.08	17	-10.58			Out of water	Net aborted due to wind
28/01/2024 19:52	-64.5763	-55.0568	436.4	26	-11.97	415	395,392,389,386,383,380,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
28/01/2024 20:12	-64.5772	-55.0554	433.17	26	402.37	415	395,392,389,386,383,380,250,125,62.5,2	At bottom	
28/01/2024 20:41	-64.5793	-55.0522	428.11	26	2.52	415	395,392,389,386,383,380,250,125,62.5,2	Out of water	
29/01/2024 01:50	-64.5755	-55.0455	432.58	28	-11.39	400	387,384,381,378,375,372,250,125,62,5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
29/01/2024 02:09	-64.5733	-55.0351	434.67	28	403.70	400	387,384,381,378,375,372,250,125,62,5,2	At bottom	
29/01/2024 02:44	-64.5677	-55.0156	431.21	28	-11.32	400	387,384,381,378,375,372,250,125,62,5,2	Out of water	
29/01/2024 23:07	-64.5858	-55.0813	422.18	40	-6.15	380	375,370,250,125,62.5,6,5,4,3,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
29/01/2024 23:18	-64.5862	-55.0807	420.15	40	225.22	380	375,370,250,125,62.5,6,5,4,3,2	At bottom	
29/01/2024 23:53	-64.5879	-55.0774	420.9	40	-9.24	380	375,370,250,125,62.5,6,5,4,3,2	Out of water	
31/01/2024 16:17	-66.137	-59.9005	321.34	51	-1.22	290	285,282,279,276,273,270,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
31/01/2024 16:35	-66.1372	-59.9003	321.57	51	301.56	290	285,282,279,276,273,	At bottom	Query net 9 sample lost on deck

							270,250,125,62.5,2		
31/01/2024 16:59	-66.1372	-59.9004	321.35	51	-7.33	290	285,282,279,276,273,270,250,125,62.5,2	Out of water	
02/02/2024 03:08	-66.134	-59.8918	322.58	77	-2.58	290	285,282,279,276,273,270,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
02/02/2024 03:23	-66.134	-59.8918	322.46	77	297.47	290	285,282,279,276,273,270,250,125,62.5,2	At bottom	
02/02/2024 03:51	-66.134	-59.8919	322.46	77	-12.47	290	285,282,279,276,273,270,250,125,62.5,2	Out of water	
02/02/2024 14:04	-66.1136	-60.4322	344.87	85	3.91	310	305,302,299,296,293,290,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
02/02/2024 14:12	-66.1134	-60.4321	344.82	85	163.80	310	305,302,299,296,293,290,250,125,62.5,2	At bottom	
02/02/2024 14:40	-66.1129	-60.4343	347.95	85	15.98	310	305,302,299,296,293,290,250,125,62.5,2	Out of water	
03/02/2024 03:34	-65.6271	-59.2911	431.5	90	17.15	390	385,382,379,376,373,370,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
03/02/2024 03:53	-65.6271	-59.2911	430.61	90	392.89	390	385,382,379,376,373,370,250,125,62.5,2	At bottom	
03/02/2024 04:27	-65.6271	-59.2911	430.37	90	-7.64	390	385,382,379,376,373,370,250,125,62.5,2	Out of water	
03/02/2024 11:37	-65.6231	-59.3046	433.41	98	19.79	390	385,382,379,376,373,370,250,125,62.5,2	In Water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
03/02/2024 11:52	-65.623	-59.3055	434.55	98	391.26	390	385,382,379,376,373,370,250,125,62.5,2	At bottom	
03/02/2024 12:20	-65.6221	-59.3072	434.07	98	-10.21	390	385,382,379,376,373,370,250,125,62.5,2	Out of water	
04/02/2024 03:01	-64.5866	-58.2624	499.51	102	21.30	450	445,442,439,436,433,	In Water	Nets 1-5 300 um mesh

							430,250,125,62.5,2		Nets 6-9 100 um mesh
04/02/2024 03:24	-64.5866	-58.2624	499.44	102	470.01	450	445,442,439,436,433,430,250,125,62.5,2	At bottom	
04/02/2024 04:14	-64.5865	-58.2626	499.28	102	-0.02	450	445,442,439,436,433,430,250,125,62.5,2	Out of water	
04/02/2024 17:21	-64.5895	-58.2462	497.68	111	-9.96	450	445,442,439,436,433,430,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
04/02/2024 17:41	-64.5893	-58.2455	498.05	111	460.02	450	445,442,439,436,433,430,250,125,62.5,2	At bottom	
04/02/2024 18:15	-64.5897	-58.2436	497.38	111	-0.67	450	445,442,439,436,433,430,250,125,62.5,2	Out of water	
07/02/2024 09:20	-64.1339	-47.9717	4094.35	127	19.84	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
07/02/2024 10:04	-64.1339	-47.9717	4094.1	127	1200.02	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	
07/02/2024 11:30	-64.1338	-47.9717	4093.82	127	-8.01	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	Out of water	
08/02/2024 02:56	-64.5333	-48.4963	3987.11	132	-9.65	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	In Water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
08/02/2024 03:40	-64.5327	-48.4958	3987.05	132	1200.02	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	
08/02/2024 04:58	-64.5327	-48.4958	3987.29	132	-12.29	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	Out of water	
08/02/2024 13:56	-64.4887	-48.5495	3965.87	137	11.43	1100	1060,1050,1040,1030,1020,1010,	In water	Nets 1-5 300 um mesh

							1000,250,125,62.5,2		Nets 6-9 100 um mesh
08/02/2024 14:35	-64.4884	-48.5498	3967.18	137	1200.02	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	
08/02/2024 15:49	-64.4884	-48.5498	3966.31	137	14.66	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	Out of water	
09/02/2024 03:21	-64.5309	-49.6825	3555.27	141	20.38	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
09/02/2024 03:58	-64.531	-49.6816	3555.34	141	1190.24	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	
09/02/2024 05:13	-64.5249	-49.6622	3550.67	141	-9.81	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	Out of water	
09/02/2024 13:27	-64.5186	-49.6324	3550.8	146	20.21	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
09/02/2024 14:03	-64.5177	-49.6306	3550.28	146	1199.10	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	
09/02/2024 15:17	-64.5182	-49.6298	3550.74	146	15.99	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	Out of water	
10/02/2024 12:34	-64.4376	-50.8785	3166.4	155	-9.96	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
10/02/2024 13:13	-64.4357	-50.8851	3170.29	155	1195.20	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	
10/02/2024 14:27	-64.4291	-50.8864	3132.28	155	15.98	1100	1060,1050,1040,1030,1020,1010,	Out of water	

							1000,250,125,62.5,2		
11/02/2024 13:52	-64.5627	-52.7266	2550.55	164	-12.40	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
11/02/2024 14:32	-64.56	-52.7312	2546.89	164	1197.94	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	
11/02/2024 14:50	-64.5592	-52.7325	2545.42	164	985.25	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	Out of water	
12/02/2024 03:10	-64.5826	-53.5935	2033.15	170	-10.19	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
12/02/2024 03:51	-64.5855	-53.5956	2032.09	170	1194.04	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	
12/02/2024 05:09	-64.5929	-53.6089	2026.71	170	-11.17	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	Out of water	
12/02/2024 19:34	-64.5315	-53.5869	2018.35	178	20.25	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
12/02/2024 20:15	-64.5305	-53.586	2018.29	178	1119.95	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	
12/02/2024 21:27	-64.5307	-53.5862	2019.01	178	-3.55	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	Out of water	
13/02/2024 03:00	-64.5557	-53.9774	1504.2	181	-13.66	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
13/02/2024 03:39	-64.5561	-53.965	1521.65	181	1200.02	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	

13/02/2024 04:59	-64.5523	-53.9462	1547.8	181	0.82	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	Out of water	
13/02/2024 17:45	-64.5709	-53.948	1546.82	189	20.69	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
13/02/2024 18:21	-64.5695	-53.9454	1550.84	189	1196.07	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	At bottom	
13/02/2024 19:36	-64.5633	-53.9402	1564.9	189	-7.69	1100	1060,1050,1040,1030,1020,1010,1000,250,125,62.5,2	Out of water	
13/02/2024 20:54	-64.5707	-54.1161	1280.83	190	-7.77	1050	1000,500,250,125,62.5,5,4,3,2,1	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh Nets for Flo Atherden
13/02/2024 21:30	-64.5698	-54.1139	1283.73	190	1146.52	1050	1000,500,250,125,62.5,5,4,3,2,1	At bottom	
13/02/2024 22:39	-64.5699	-54.1092	1291.98	190	-8.66	1050	1000,500,250,125,62.5,5,4,3,2,1	Out of water	
14/02/2024 01:40	-64.5844	-54.243	1029.03	193	-8.52	950	940,935,930,925,920,915,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
14/02/2024 02:18	-64.5865	-54.2424	1029.26	193	981.03	950	940,935,930,925,920,915,250,125,62.5,2	At bottom	
14/02/2024 03:21	-64.5889	-54.2399	1034.88	193	0.08	950	940,935,930,925,920,915,250,125,62.5,2	Out of water	
14/02/2024 14:22	-64.5677	-54.2505	1014.22	200	-8.00	800	795,792,789,786,783,780,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
14/02/2024 14:50	-64.5684	-54.2553	1002.94	200	828.57	800	795,792,789,786,783,780,250,125,62.5,2	At bottom	
14/02/2024 15:53	-64.5722	-54.2542	1001.47	200	-8.41	800	795,792,789,786,783,780,250,125,62.5,2	Out of water	

15/02/2024 01:55	-64.5601	-54.4215	523.2	204	-8.45	455	450,447,444,441,438,435,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
15/02/2024 02:15	-64.5585	-54.4187	545.66	204	476.05	455	450,447,444,441,438,435,250,125,62.5,2	At bottom	
15/02/2024 02:47	-64.5565	-54.4112	586.09	204	-12.20	455	450,447,444,441,438,435,250,125,62.5,2	Out of water	
15/02/2024 13:09	-64.555	-54.4214	539.91	211	-7.93	455	450,447,444,441,438,435,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
15/02/2024 13:31	-64.5523	-54.4209	547.98	211	510.02	455	450,447,444,441,438,435,250,125,62.5,2	At bottom	
15/02/2024 14:14	-64.5472	-54.4226	569.28	211	5.63	455	450,447,444,441,438,435,250,125,62.5,2	Out of water	
16/02/2024 01:41	-64.5698	-55.0602	440.53	215	-8.50	390	385,382,379,376,373,370,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
16/02/2024 02:02	-64.5685	-55.0626	430.48	215	395.22	390	385,382,379,376,373,370,250,125,62.5,2	At bottom	
16/02/2024 02:33	-64.5658	-55.0633	431.58	215	-12.10	390	385,382,379,376,373,370,250,125,62.5,2	Out of water	
19/02/2024 01:36	-66.3877	-55.9653	314.1	239	-9.81	290	275,272,269,266,263,260,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
19/02/2024 01:48	-66.3874	-55.9677	313.74	239	286.54	290	275,272,269,266,263,260,250,125,62.5,2	At bottom	
19/02/2024 02:11	-66.3865	-55.9701	315.19	239	0.90	290	275,272,269,266,263,260,250,125,62.5,2	Out of water	
19/02/2024 12:02	-66.3395	-56.0148	368.67	245	19.08	330	315,312,309,306,303,300,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
19/02/2024 12:18	-66.3402	-56.012	369.1	245	338.14	330	315,312,309,306,303,300,250,125,62.5,2	At bottom	

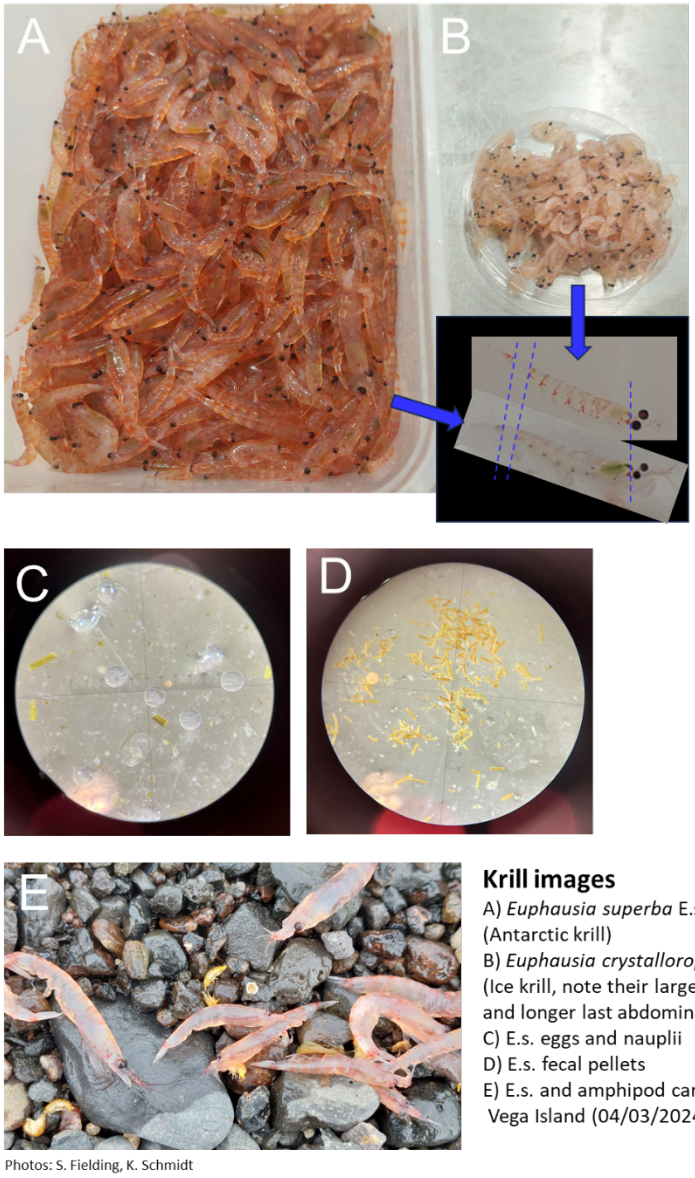
19/02/2024 12:49	-66.3408	-56.0136	368.35	245	10.37	330	315,312,309,306,303,300,250,125,62.5,2	Out of water	
29/02/2024 21:22	-64.699	-56.5295	361.58	290	5.23	330	310,307,304,301,298,295,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
29/02/2024 21:36	-64.6985	-56.5298	357.33	290	334.37	330	310,307,304,301,298,295,250,125,62.5,2	At bottom	
29/02/2024 22:01	-64.6986	-56.5297	357.71	290	3.95	330	310,307,304,301,298,295,250,125,62.5,2	Out of water	
01/03/2024 00:58	-64.6782	-56.4906	379.63	292	-1.75	330	310,307,304,301,298,295,250,125,62.5,2	In water	Nets 1-5 300 um mesh Nets 6-9 100 um mesh
01/03/2024 01:14	-64.6776	-56.4895	383.16	292	333.79	330	310,307,304,301,298,295,250,125,62.5,2	At bottom	
01/03/2024 01:43	-64.677	-56.4869	382.63	292	-0.01	330	310,307,304,301,298,295,250,125,62.5,2	Out of water	

Table 12.2-2: Overview of specimens collected by the Mammoth nets that were immediately frozen at -80°C for subsequent trace metal analysis at University of Plymouth.
(Eup-euphausids, Cops-copepods, Chat-chaetognaths, Ptero-pteropods, Salps-salps/jellies, Amp-amphipods, Poly-polychaets, Mys-mysids, Squ-squid)

Date	Event	Net	Eup	Cops	Chat	Ptero	Salps	Amp	Poly	Mys	Squ	Fish
22/01/2024	**5**	9	5				3					
29/01/2024	**28**	9	60									
		8				1						
		7					1					
03/02/2024	**90**	9	31				1	2				
03/02/2024	**98**	6		5			2					
		9	5									
04/02/2024	**102**	7	3									
		8	2									
		9	2									
07/02/2024	**127**	6		30		2	5					
		7					2					
08/02/2024	**132**	6					4					
08/02/2024	**137**	6		20	1							
		7				1						
		8	3				2			1		

		9	20									
09/02/2024	**141**	6	2	20			2					
		7	7				2				1	1
		8		15								
		9				2						
09/02/2024	**146**	6		15								
		7								1		
10/02/2024	**155**	6		15								
		7				1	4					
		9	2									
11/02/2024	**164**	6		40	1	1						
		7	1						10			
		9	4									
12/02/2024	**170**	6	1	35	5							1
		8	3									
		9		6								
12/02/2024	**178**	6		10	10							
		7		10		1			1			
13/02/2024	**181**	6	2	4								
		7	3	8								
		8	10	5								
		9	30			1						
13/02/2024	**189**	6		15								
		7		15		1						
14/02/2024	**193**	6		20	1							
		7	2		1							
		8	2									
		9	1									
14/02/2024	**200**	6		10		1						
		8	2		2				1			
15/02/2024	**204**	6	5		1							
		7	8	1	1							
		8	4									
16/02/2024	**215**	6	2	10								
		7	4	10		1			1			
		8	5									
		9	3									
19/02/2024	**239**	7	1									
		8	1									
19/02/2024	**245**	6			1							
		7					1					
		8					1					
29/02/2024	**290**	6	1									
		7			1							
01/03/2024	**292**	6	2	5								

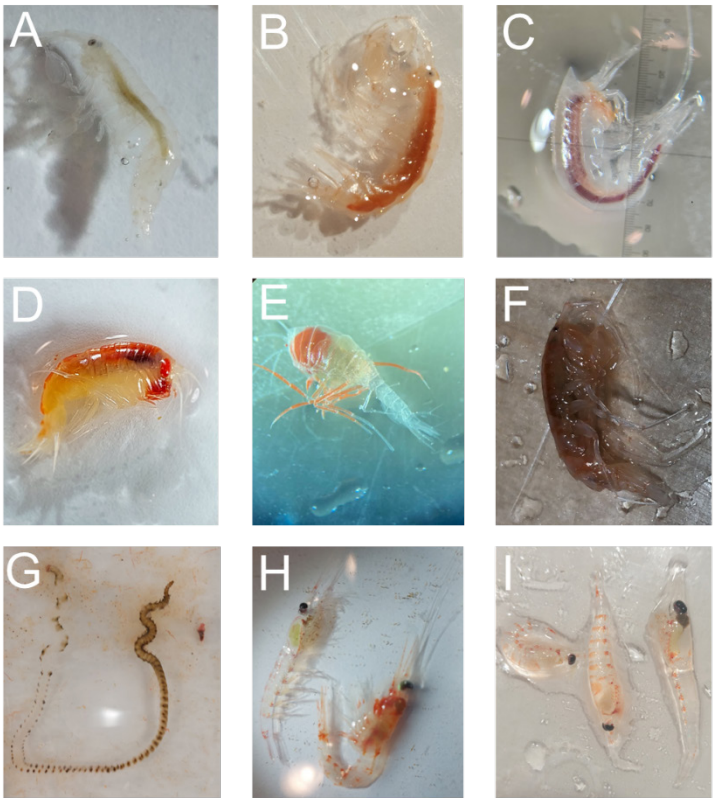
		7	3									
		8	2									



Krill images
A) *Euphausia superba* E.s. (Antarctic krill)
B) *Euphausia crystallorophias* E.c. (Ice krill, note their larger eyes and longer last abdominal segment)
C) E.s. eggs and nauplii
D) E.s. fecal pellets
E) E.s. and amphipod carcasses on Vega Island (04/03/2024)

Photos: S. Fielding, K. Schmidt

Figure 12.2-1: Krill images



*the amphipods were identified by A. Jażdżewska, H. Griffiths & H. Flores

Photos: S. Fielding, K. Schmidt

Other zooplankton

A-F) pelagic amphipods*, A) *Eusiridae*
B) *Eusiridae* (poss. *Eusirus microps*)
C) *Cyphocarididae* (poss. *Cyphocaris* spp.)
D) *Epimeriidae* (poss. *Epimeria macronyx*)
E) *Hyperiidea*
F) *Eusiridae*
G) polychaeta
H) mysid (right), note the reduced swimming legs compared to E.s. (left)
I) euphausiids (poss. *Thysanoessa macrura*)
J) *Glyptonotus antarcticus* (giant Antarctic isopod) carcass on Vega Island beach (04/03/2024)

Figure 12.2-2: Other zooplankton images

13. Seaglider Deployments

13.1 Seaglider Mission 67 overview

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Mission webpage

https://www.ueaglider.uea.ac.uk/mission67

Leg 1. Larson ice shelf

SG565 and SG673 were first deployed near the northern end of the Larson C Ice Shelf, at **Target S104** (Lat: -66° 8.0', Lon: -59° 53.0') on 31st Jan 2024. They were set on a transect towards the ice shelf and completed 21 and 22 dives respectively. The gliders were recovered on 1st Feb 2024.

SG 565 James Marr	**SG 673 Bottlenose**
Dive 1	Dive 1
Lat: -66° 9.21'	Lat: -66° 8.64'
Lon: -59° 54.21'	Lon: -59° 53.93'
2024-01-31	2024-01-31
18:57:59	15:45:38

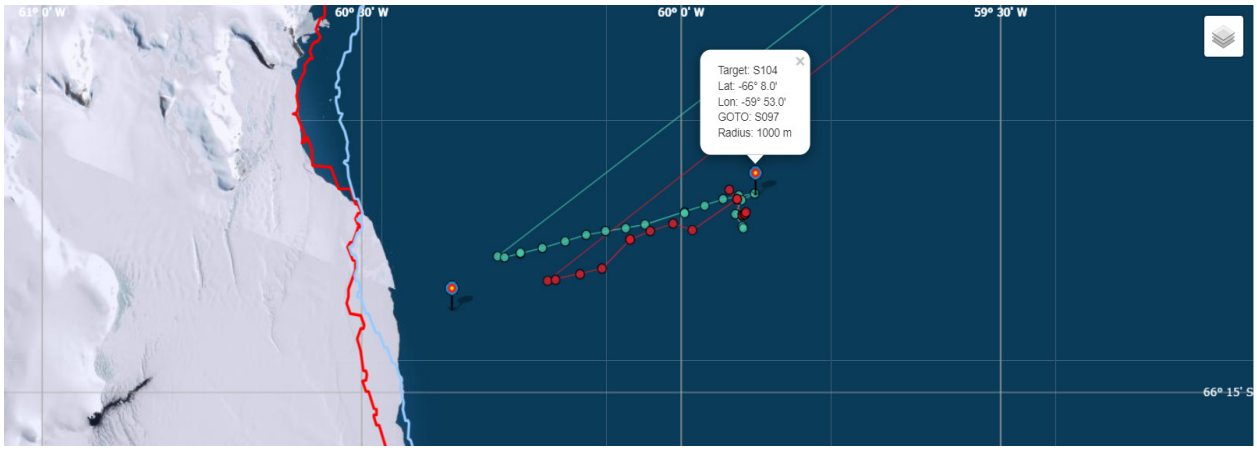


Figure 13.1-1: Mission 1. Transect of SG565 (green dots) and SG673 (red dots) towards Larson C Ice shelf.

The Seagliders were subsequently left on and in RECOVERY and issued a long TRSLEEP command ($TRSLEEP,3600) to be ready for future redeployments.

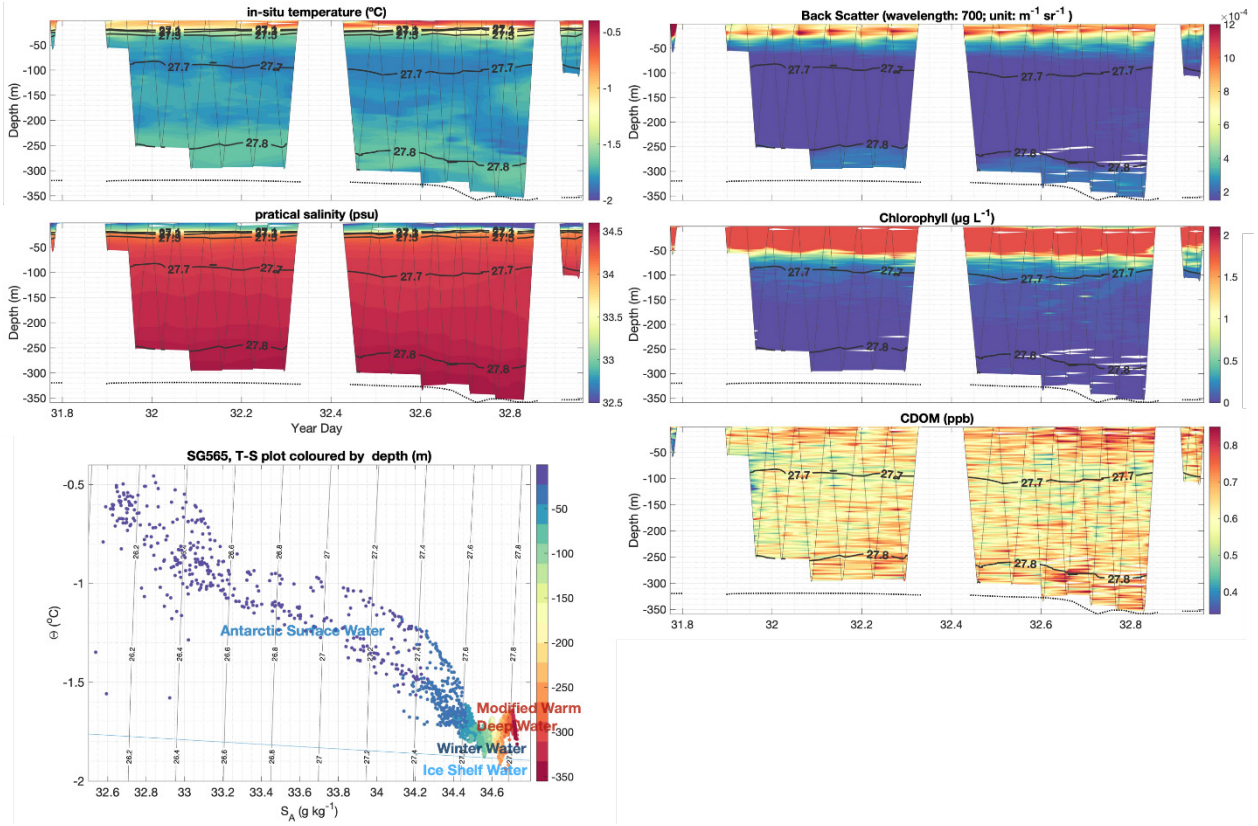


Figure 13.1-2: Time-depth plots and T-S plot using SG565 measurements. Thin dark grey lines are the glider trajectory in the water column. Thick black contours show the potential density. Dashed black line show the local bathymetry (BedMachine v3). Note that SG565 carries an oxygen optode whose calibration information is not currently compatible with the UEA glider toolbox, hence not shown in this report.

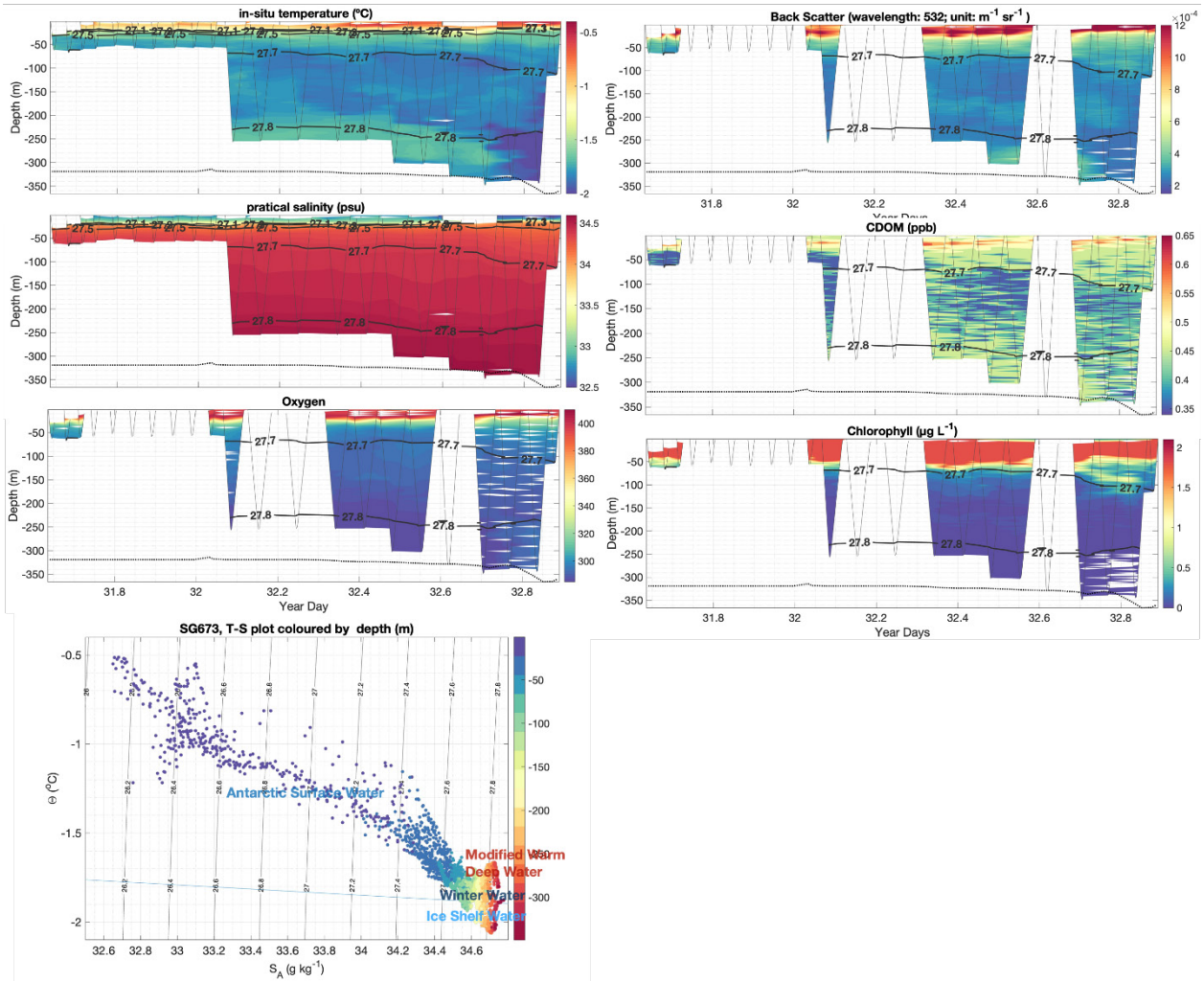


Figure 13.1-3: Time-depth plots and T-S plot using SG673 measurements. Thin dark grey lines are the glider trajectory in the water column. Thick black contours show the potential density. Dashed black line show the local bathymetry (BedMachine v3). Note, temperature and salinity measurements from SG673 present many small perturbations. A potential reason causing those perturbations is the bags for chemicals SG673 was carrying. Those bags might have affected the speed and position of SG673 in dives, leading to an unstable flow crossing the temperature and salinity cells, and consequently noisy measurements. Further quality control including a low-pass filtering is required for this glider.

Leg 2. Weddell shelf slope

SG673, SG565 and SG558 were re-deployed in the Weddell sea, at **Target VM1000** (Lat: -63° 40: Lon -52° 7) on 6th February 2024.

SG 673 Bottlenose	SG 565 James Marr	SG 558 Bella
Dive 22	Dive 23	Dive 1
Lat: -63° 40.66'	Lat: -63° 40.48'	Lat: -63° 40.73'
Lon: -52° 7.41'	Lon: -52° 8.39'	Lon: -52° 7.34'
2024-02-06	2024-02-06	2024-02-06
16:05:47	16:33:55	17:47:58

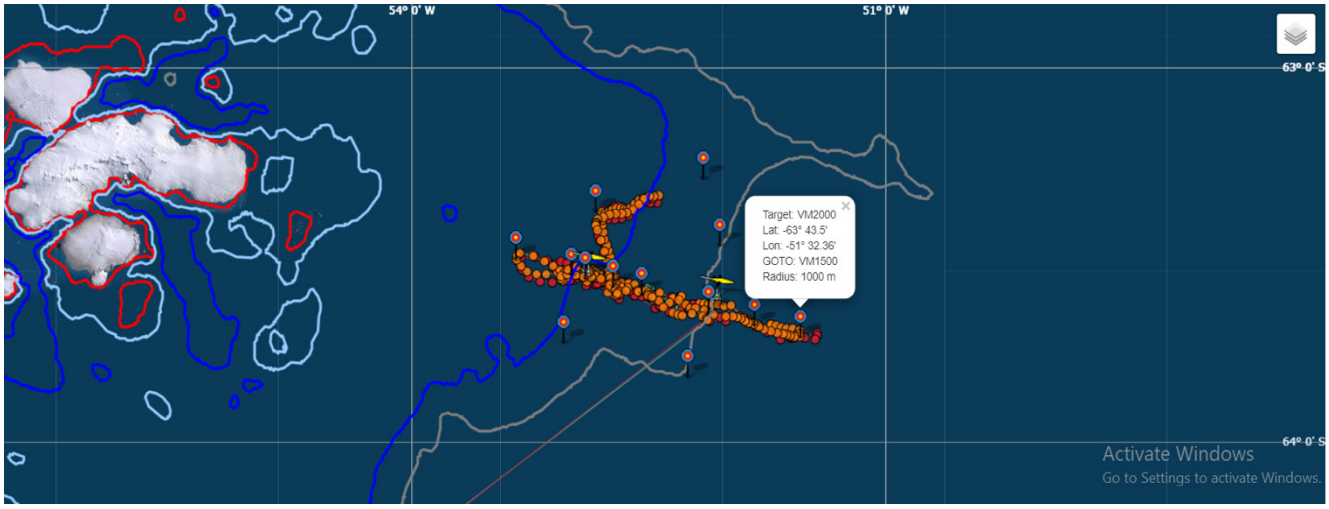
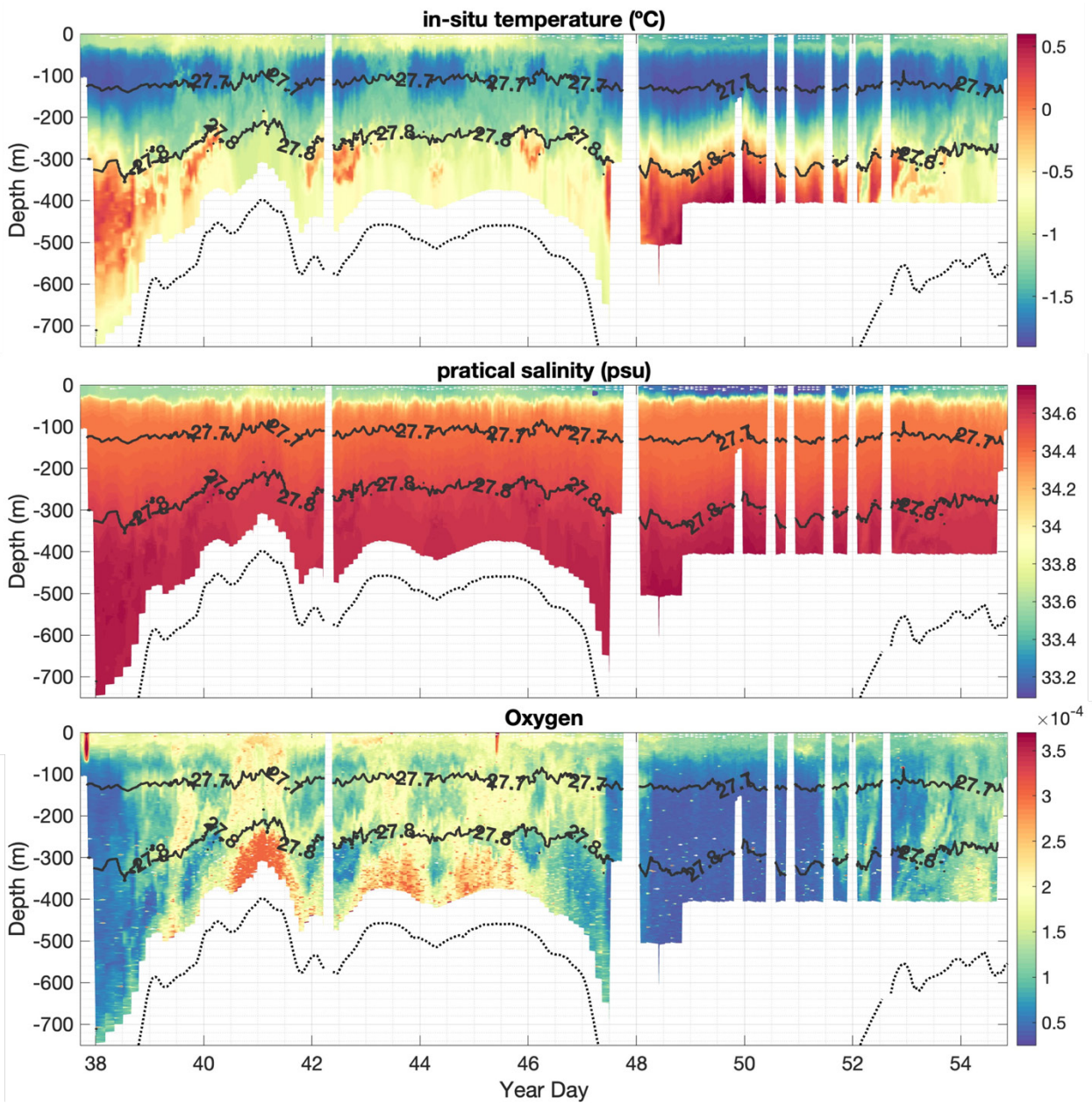
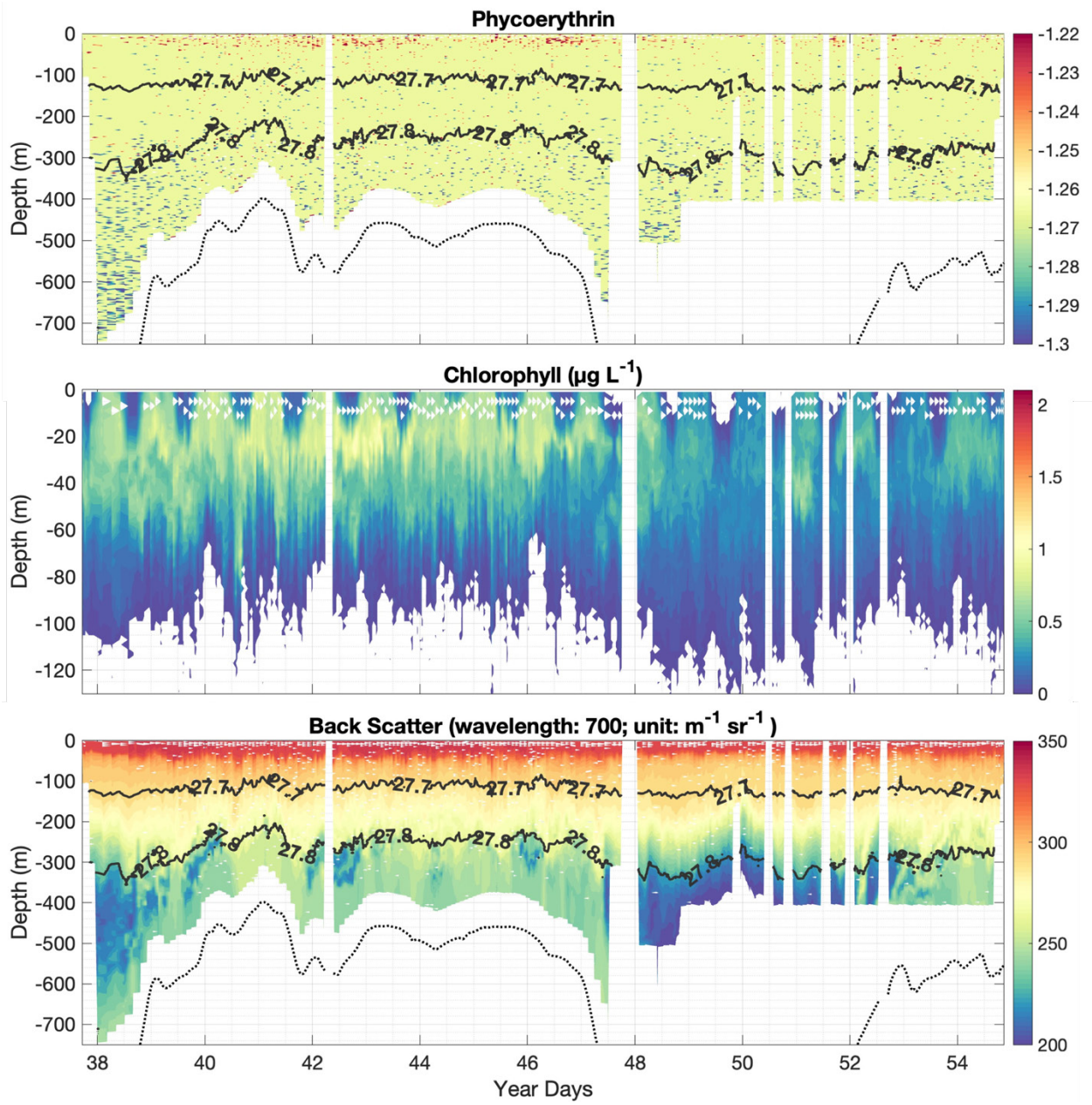


Figure 13.1-4: Mission 2. Transect of SG565 (green dots), SG673 (red dots) and SG558 (orange dots) on Weddell sea shelf break.

The Seagliders were piloted across the shelf east to west along a transect, occasionally flying North to avoid incoming sea-ice. The Seagliders were recovered on 23rd February 2024. Seaglider SG673 completed 158 dives, Seaglider SG558 completed 196 dives, Seaglider SG565 developed a communication fault since 19 dives (i.e., after dive #40) and continued diving, but was not recovered.


in-situ temperature (°C)
pratical salinity (psu)
Oxygen
Depth (m)
Year Day
0
-100
-200
-300
-400
-500
-600
-700
38
40
42
44
46
48
50
52
54
27.7
27.8
0.5
0
-0.5
-1
-1.5
34.6
34.4
34.2
34
33.8
33.6
33.4
33.2
×10-4
3.5
3
2.5
2
1.5
1
0.5


Phycoerythrin
Depth (m)
0
-100
-200
-300
-400
-500
-600
-700
27.7
27.8
-1.22
-1.23
-1.24
-1.25
-1.26
-1.27
-1.28
-1.29
-1.3
Chlorophyll (μg L-1)
Depth (m)
0
-20
-40
-60
-80
-100
-120
2
1.5
1
0.5
0
Back Scatter (wavelength: 700; unit: m-1 sr-1)
Depth (m)
0
-100
-200
-300
-400
-500
-600
-700
350
300
250
200
38
40
42
44
46
48
50
52
54
Year Days

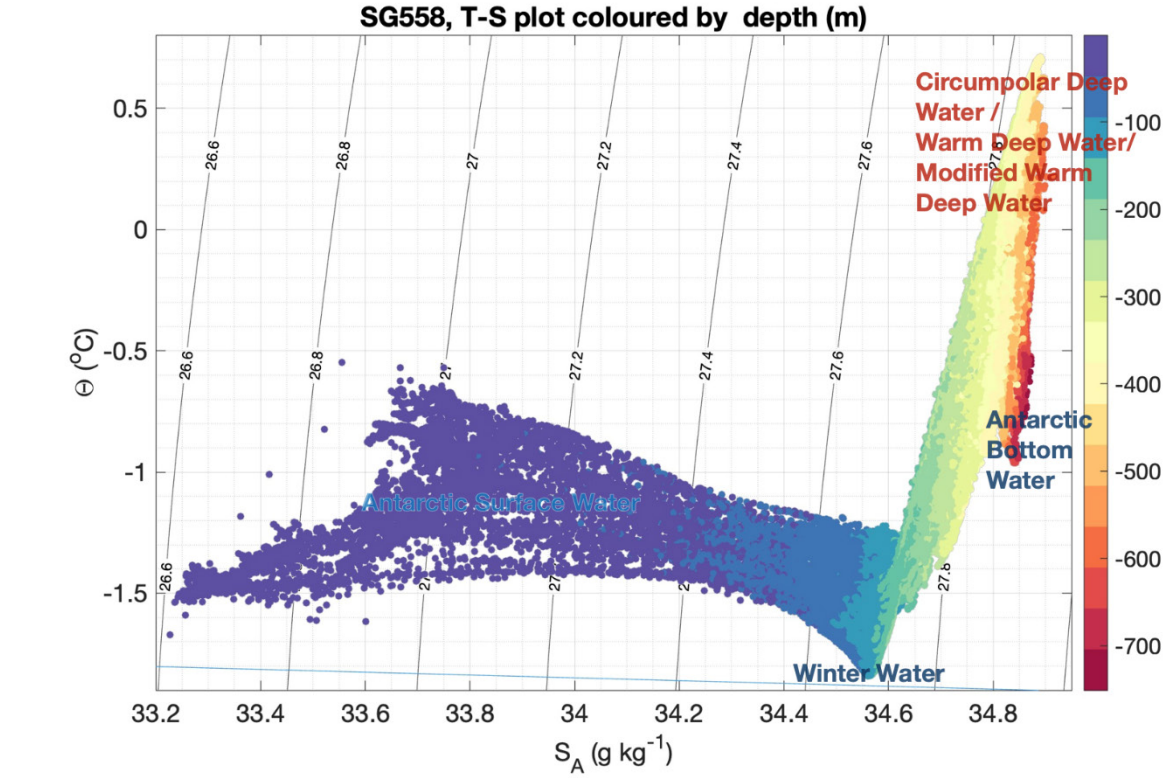


Figure 13.1-5: Time-depth plots and T-S plot using SG558 measurements. Dashed black line show the local bathymetry (BedMachine v3).

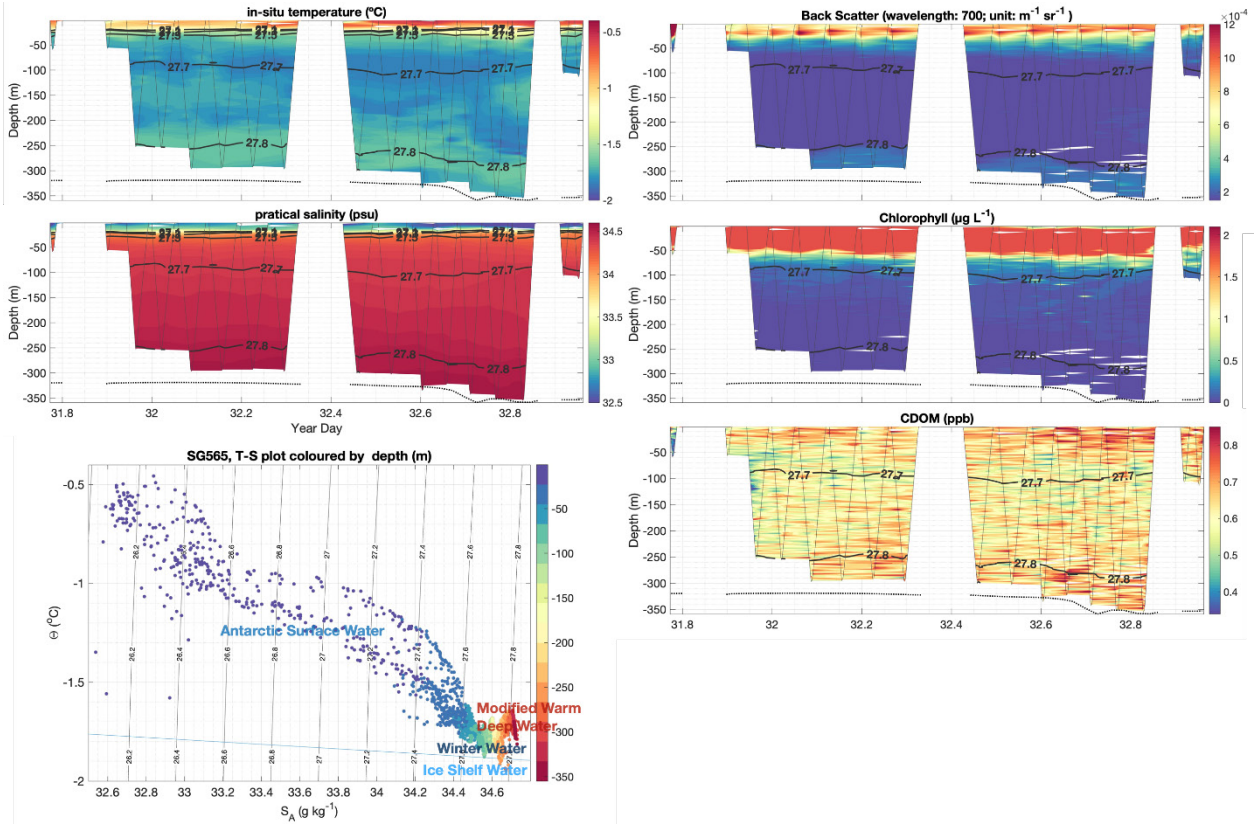
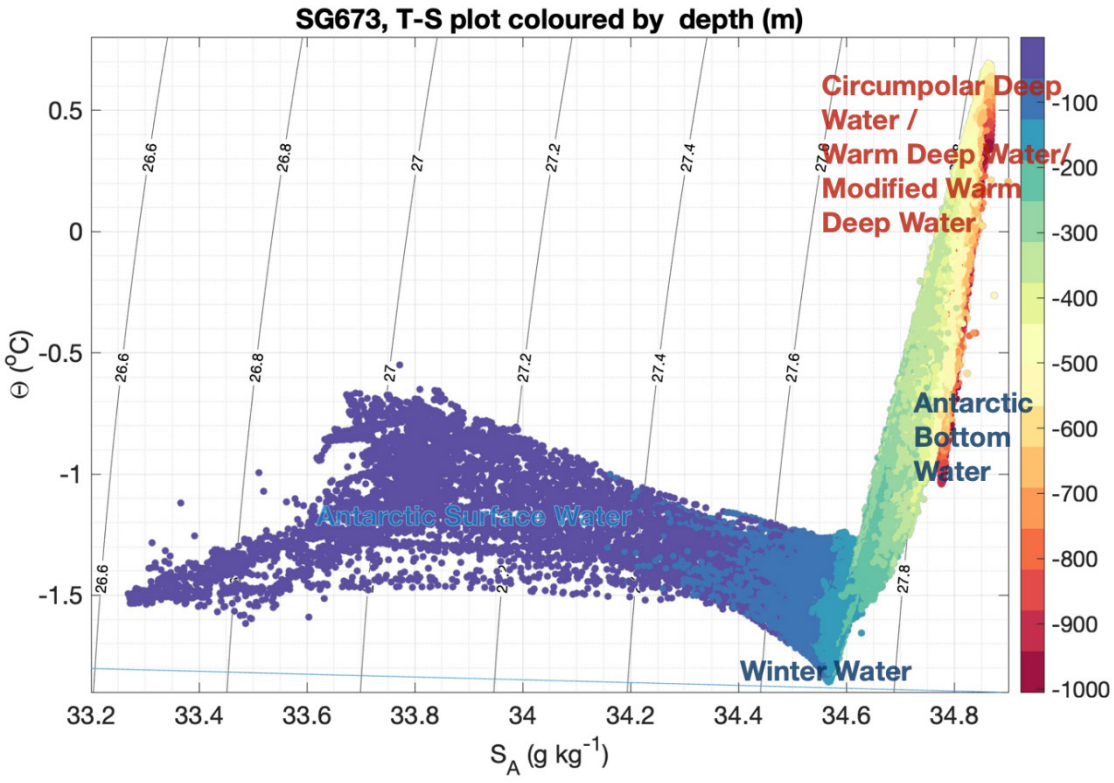
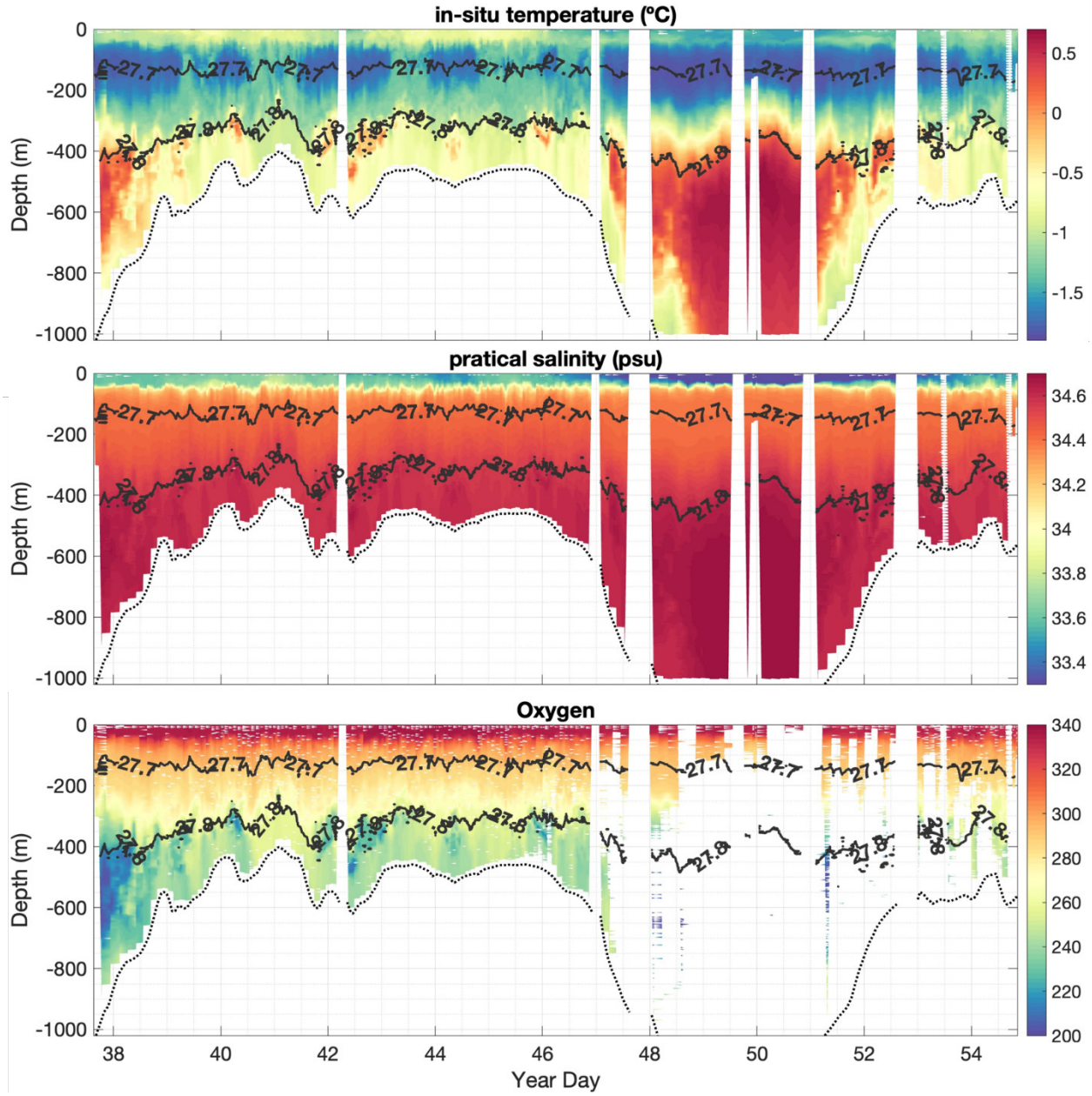


Figure 13.1-6: Time-depth plots and T-S plot using SG565 measurements. Thin dark grey lines

are the glider trajectory in the water column. Thick black contours show the potential density. Dashed black line show the local bathymetry (BedMachine v3). Note that SG565 carries an oxygen optode whose calibration information is not currently compatible with the UEA glider toolbox, hence not shown in this report.

SG673




in-situ temperature (ºC)
pratical salinity (psu)
Oxygen
Depth (m)
Year Day
0
-200
-400
-600
-800
-1000
38
40
42
44
46
48
50
52
54
27.7
27.8
0.5
0
-0.5
-1
-1.5
34.6
34.4
34.2
34
33.8
33.6
33.4
340
320
300
280
260
240
220
200

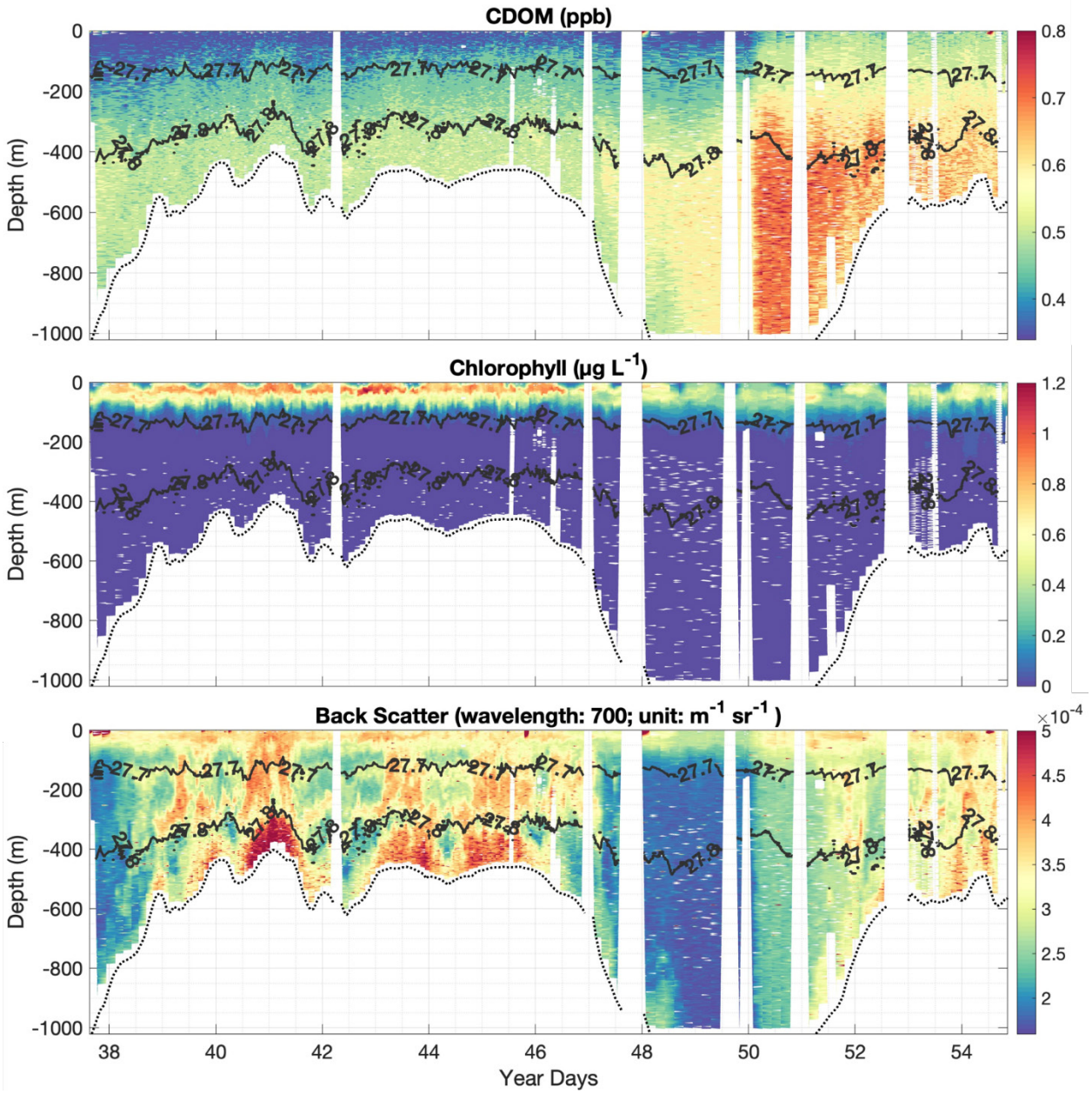


Figure 13.1-7: Time-depth plots and T-S plot using SG673 measurements. Thin dark grey lines are the glider trajectory in the water column. Thick black contours show the potential density. Dashed black line show the local bathymetry (BedMachine v3).

Leg 3. Weddell shelf super-station/Caravela deployment.

SG676 was deployed in the Weddell sea, at the Caravela supersite. The deployment location was **VM** (Lat: -64° 41.41'; Lon: -56° 35.1')

SG 676 VIMS
Dive 1
Lat: -64° 41.07'
Lon: -56° 34.58'
2024-02-29
13:26:13

The Seaglider was piloted in 'virtual mooring mode', meaning it dived at the same location continuously. It was deployed from 29th -30th February 2024 and completed a total of 18 dives. Multiple CTDs were conducted before this mission. The salinity of this glider, for an unknown, present abnormally low values (~31 psu). Further investigation of the data is needed.

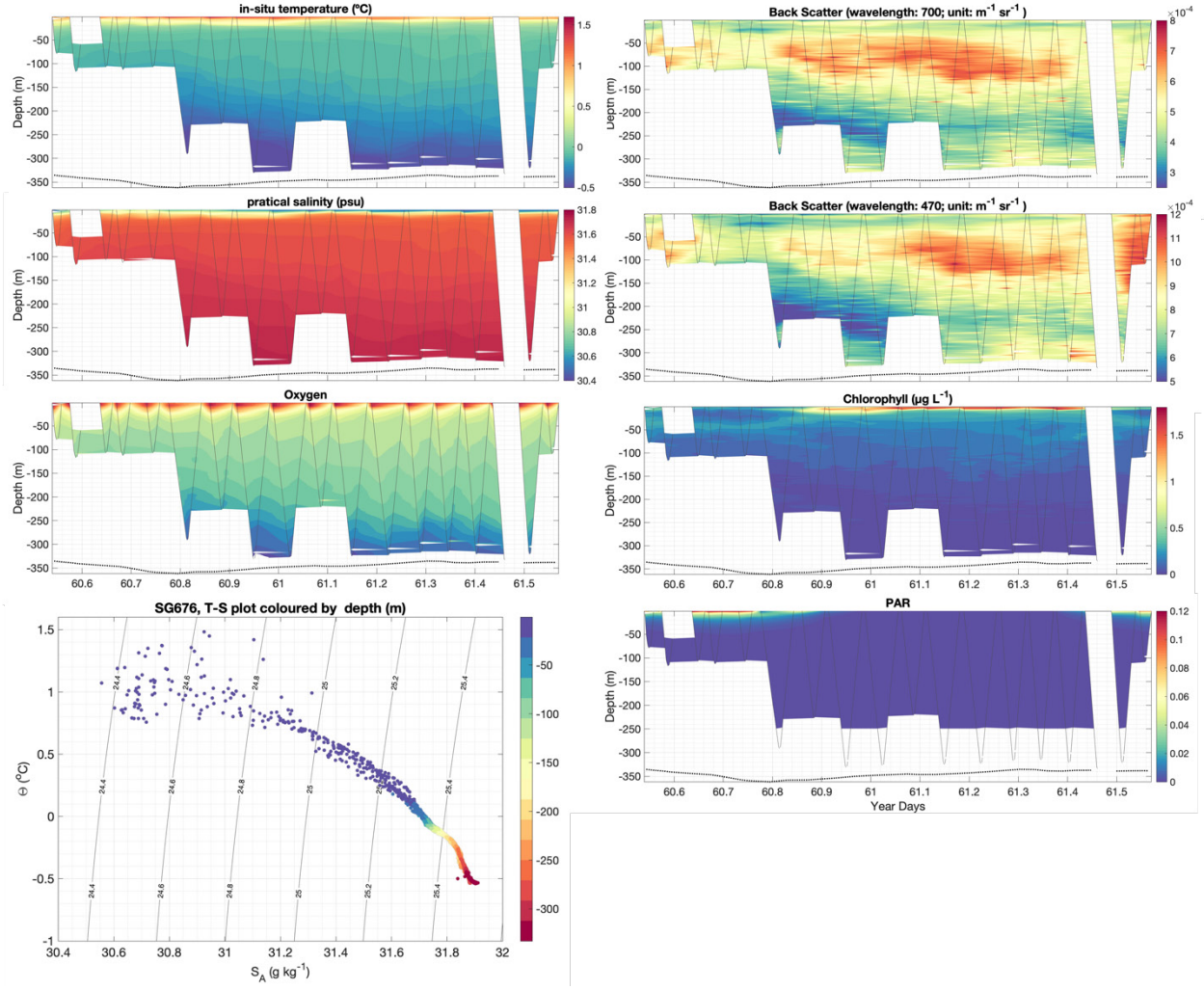


Figure 13.1-8: Time-depth plots and T-S plot using SG676 measurements. Thin dark grey lines are the glider trajectory in the water column. Thick black contours show the potential density. Dashed black line show the local bathymetry (BedMachine v3). Note that SG676 measured abnormally low salinity, which is highly likely caused by an error in calibration procedures. Further investigation is needed before using this dataset.

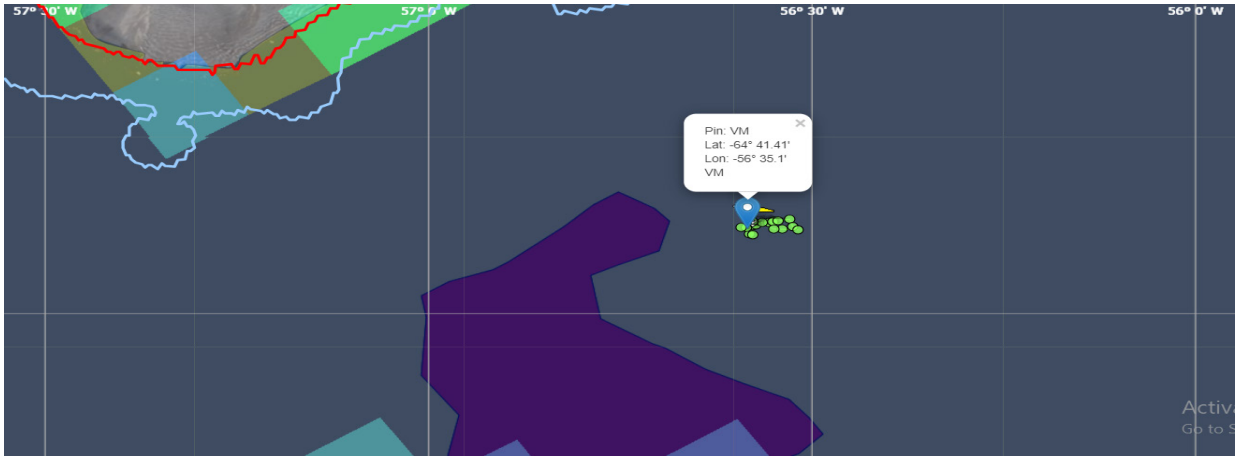


Figure 13.1-9: Mission 3. Caravela supersite SG676

Identified Problems

SG565 problems

SG565 developed a problem after its second deployment (Mission 2, Weddell shelf). It successfully communicated for 19 dives and then communication ceased. The cause of the problem is unknown and nothing apparent is shown in the last set of files received. The glider could be seen to continue along its current heading of about 80°, with surfacing every 3-4 hours as shown on the ARGOS tag transmissions. The glider continued along this bearing but was never recovered. The ARGOS tag stopped transmitting on 23rd February 2024.

SG673 problems

The pH logger sensor on SG673 developed a fault on dive 165 and was switched off ($LOGGERS,0). This was because the pH logger had stopped communicating with the Seaglider. It was switched on again for dive 177 to try and capture samples for the calibration cast, but was unsuccessful. The reason for this failure was likely due to the excessively full waste bags which were causing pressure on the sensor to Seaglider connections.
The pH sensor was poorly calibrated, with 4 depths on the deployment CTD cast and no calibration on recovery. Future use of the pH logger should consider more detailed calibration procedures.

Seaglider SG673 appeared to take measurements from every Seaglider dive while it was switched on. This data will be processed back at UEA. Limited TA/DIC samples were analysed to reference the pH measurements. A total of 3.9 litres of waste was collected in the Seaglider waste bags and removed on recovery.

SG558 problems

Seaglider SG558 appeared to take no measurements from any Seaglider dive. A probable air lock was encountered on the sensor prior to deployment. Flushing attempts were made and increases to the pump power were tested but the sensor was unable to be cleared. The sensor was deployed in the hope that the pressure (through depth) would clear the trapped air but this seems unsuccessful. No waste was collected in the Seaglider on recovery.

SG676 problems

Note that SG676 measured abnormally low conductivity throughout mission 3, leading to unrealistic salinity values. We suspect that is likely caused by an error in calibration procedures.

However, the sg_calib_constants.m show consistent values to the values that SG676's calibration certificates state. Further investigation is needed before using this dataset.

Calibration file problems

All sg_calib_constants.m files in the glider base station appear to have calibration coefficients stored in different formats to the UEA glider toolbox. Hence, the basestation and the UEA glider toolbox had several issues processing the datasets. Further discussion is required to identify which format is ideal for sg_calib_constants.m and a uniform modification should be applied to all sg_calib_constants.m files.

Glider Instrumentation

Imaginex ES853 Echosounder

SG565 and SG676 was outfitted with an Imagenex Model 853 Echosounder with Data Logger. Both are autonomous logging units meaning that the glider supplies the power to operate the sensors but the sensor data are stored on board the respective sensor with a very small subsample being sent to the Basestation via Iridium during a glider surfacing.

The ES853 echo sounder is a custom designed instrument manufactured by Imagenex. The unit has an acoustic frequency of 120 Hz, sampling to a range of 100 m with 0.5 m bin intervals and is pressure rated to a depth of 1000 m. The onboard transducer has a beam angle of 10° beam angle. The hardware amplifier has a configurable 20 or 40 dB gain option. The echo sounder can be deployed to log to internal memory or to an attached MS Windows based computer using the manufacturer's supplied software. When logging to internal memory, the echo sounder records data to its 2 GB built-in solid state memory card. When attached to a computer the echo sounder will ping as fast as it is capable, approximately 2 Hz. When set to stand-alone mode and logging to memory, the ping rate is 1 Hz. When in glider mode, a mode used when mounted onboard a Seaglider, data is logged to memory and the ping rate is 0.25 Hz.

SG673 and SG558 were fitted with Clearwater Lab-on-chip (LoC) loggers; SG673 being pH and SG558 Nitrate.

Clearwater LoC Nitrate sensor

The ClearWater nitrate analyser operates using colourimetric nitrate analysis (the Griess assay) on a microfluidic chip. Nitrate is reduced to nitrite by passing the fluid through a cadmium tube, after which it is mixed with the Griess reagent. The subsequent chemical reaction produces a purple coloured compound. The intensity of the colour is proportional to the concentration of nitrate, and is measured by absorbance spectrophotometry at 525 nm.

The Nitrate analyser contains a Lab-On-Chip microfluidic manifold that permits the selection of blank, sample and standard solutions, which are sequentially injected with the two reagents into the sensor absorption cells. The Lab-On-Chip contains three absorption cells: a 98 mm measurement cell (~0-10 µM NO), a 10 mm measurement cell (~5-100 µM NO) and a 1 mm measurement cell (> 100 µM NO). Each cell is equipped with 525 nm LEDs and photodiodes for optical absorbance detection.

For each sample analysed, the sensor automatically performs the following steps:

1. The blank solution, reagent 1 and reagent 2 are aspirated into the three syringes, merged at a confluence point and injected into the sensor absorption cells.
2. The pump is stopped for 60 seconds while mixing and colour development take place in the absorption cells.
3. Steps 1 and 2 are repeated for the sample (filtered inline using a 0.45 µm capsule filter) and standard solution, which are both followed by a cleaning step to prevent analytical drift.

The data are stored on an internal flash card for retrieval once the glider is recovered.

Clearwater LoC pH sensor

The ClearWater pH sensor operates using the standard spectrophotometric pH technique. A dye (purified m-Cresol Purple (mCP)) is mixed with a sample, and the resulting colour change is measured at two wavelengths (~435 nm and ~580 nm). Each sample measurement is blank-corrected and pH is calculated by the ratio of absorbances at the two wavelengths. This method is therefore immune to long-term drift caused either by changes in light source intensity or detector sensitivity. The pH sensor reports data on the total proton scale.
The pH sensor contains a Lab-On-Chip microfluidic manifold that is responsible for mixing the dye and samples. Once the sample is mixed it is pumped into a twin-wavelength optical cell, where a photodiode records the changes in light intensity. The sensor can achieve a pH measurement precision better than 0.001 and accuracy better than 0.009*.
In order to achieve high quality measurements the pH sensor has two thermistors used to monitor the temperature of the optical cell. These are carefully calibrated during the assembly of the sensor, however these are only valid over set ranges. For optimal measurements the range of temperatures the sensors are calibrated over will be determined with the end user at the stage of ordering.

For each sample analysed, the sensor automatically performs the following steps:
1. The fluidic channels are flushed with sample, and the blank light intensity recorded.
2. The sample and mCP dye are mixed together and pumped into the optical measurement cell.
3. Optical measurement is performed and pH is calculated (as per Yin et al. 2021).

RSI Micropod turbulence logger

SG579 was fitted with the submerged data logger hub and two micropod profilers.

The MicroPod Turbulence System consists of a submerged data logger (DataHub) that provides signal input for up to eight MicroPod modules. These can be any combination of MicroPod-S velocity shear modules and MicroPod-T fast response temperature modules. The DataHub can also provide optional analog and digital input channels to synchronously sample other instruments, e.g., current meters such as Nortek ADV or Vectrino, or electro-magnetic current meters. APPLICATIONS The MicroPod Turbulence System can either be deployed in the field or installed and manipulated in a laboratory tank or flume for turbulent flow characterization.

The MicroPods have also been integrated with autonomously operated ocean gliders, submarine vehicles, floats and mooring systems with the Datahub installed within the autonomous platform.

Launch and recovery procedures.

Five gliders taken aboard the RRS Sir David Attenborough for the PICCOLO SD035 cruise. four were launched (SG565, SG558, SG673 and SG676).

Small boat deployment and Recovery

SG565 and SG673 were first deployed near the northern end of the Larson C Ice Shelf (mission 1). SG676 was deployed at the Caravela supersite. These Seagliders were all launched and recovered (except SG676) with the use of a small boat (FRC, Fast Response Craft). The Seagliders were deployed individually as there was not enough room in the boat for both gliders. The Seagliders went through launch procedure (run "Sea Launch" commend) whilst still on board the RRS Sir David Attenborough. Once launch procedure had been completed and both the pilots and deployment team were happy that the glider was ok to launch, the gliders (while securely tied to their cradles) were loaded onto the FRC without their wings and tailfin attached. Once the FRC is safely on the water, the wings and tailfin were attached and the Seaglider was lowered into the water. A quick buoyancy test was performed and the Seaglider was then released. A RESUME command was issued by the piloting team and the FRC waited until the Seaglider had left the surface before returning to the SDA.

Figure 13.1-10: Deployment of Seaglider using small boat

The Seagliders were recovered in the same way. A small boat was deployed to retrieve the Seaglider. We dragged the glider out from water by grabbing its tail fins. We then hold the glider nearly vertically to allow it to drain. Once the water inside of glider has drained, we hauled back the glider into the FRC, place it safely on its cradle with its seatbelt on. The whole FRC is then recovered by a crane to the SDA. SG676 was recovered using the recovery loop (winch) method.

Winch deployment

The Seagliders were redeployed on 6th February 2024. The Seagliders deployed were SG558, SG565 and SG673. The Seagliders were redeployed at location VM2000.

The weather on 6th February 2024 was unsuitable for the easy launching of the FRC (40-50 Knt

wind, Beaufort 8) and an alternative deployment method was required. Upon inspection, and consultation with the ship's crew, a variety of different methods were assessed. It was decided that launching off the aft 'A frame' and into the wake of the ship was the best method. This provided stability (as it was mid-ship) and the calmest water, with the least swell. Each Seaglider was released using a 'Sea-catch' release system, launching the glider from a height of 2-3m.

Figure 13.1-11: Deployment of Seaglider using the winch

Recovery using a loop

Recovery from the Weddell Sea shelf mission (mission 2) and the Caravela supersite (mission 3) was performed using the Recovery loop, through the boarding deck below deck 3. This method was simple and should be considered on future cruises. The boarding deck is a small area below deck 3 and is used for boarding the vessel. It has large doors and a freeboard of about 3m. For Recovery we used a recovery loop through these doors to fasten a loop over the lifting point on a Seaglider. Once looped the Seaglider was lifted on-board with the use of a crane.

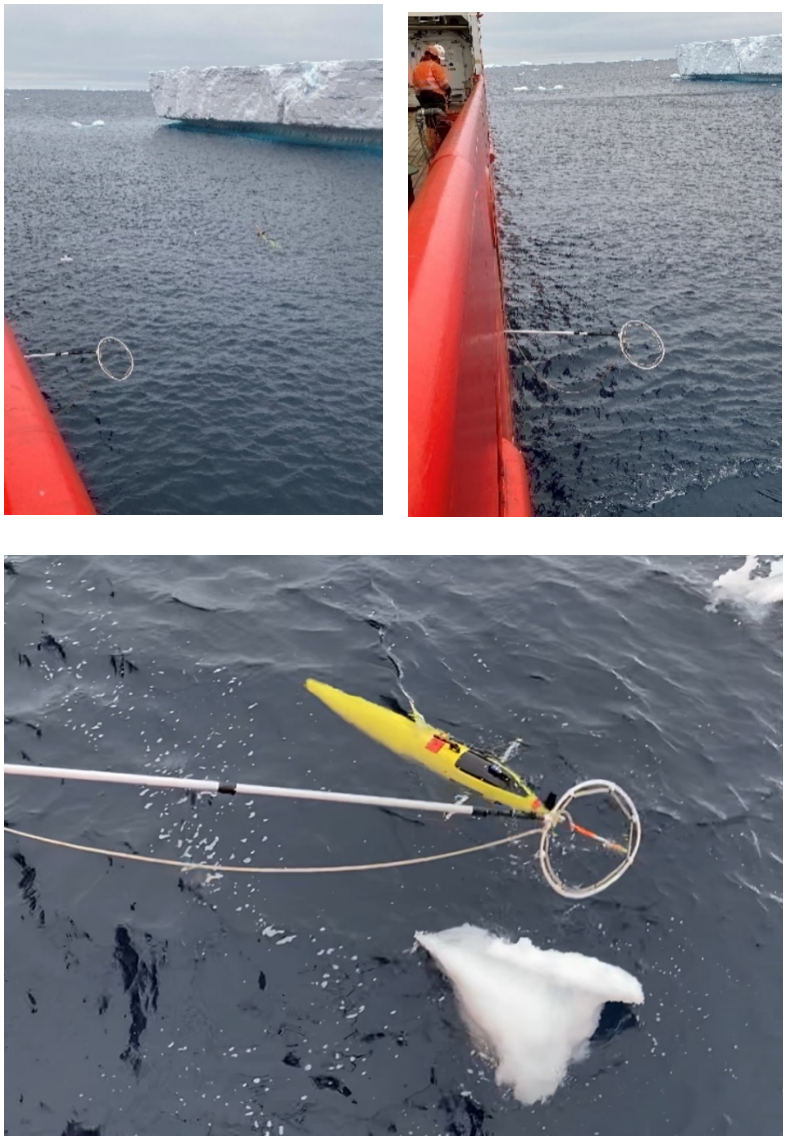


Figure 13.1-12: Recovery using recovery loop

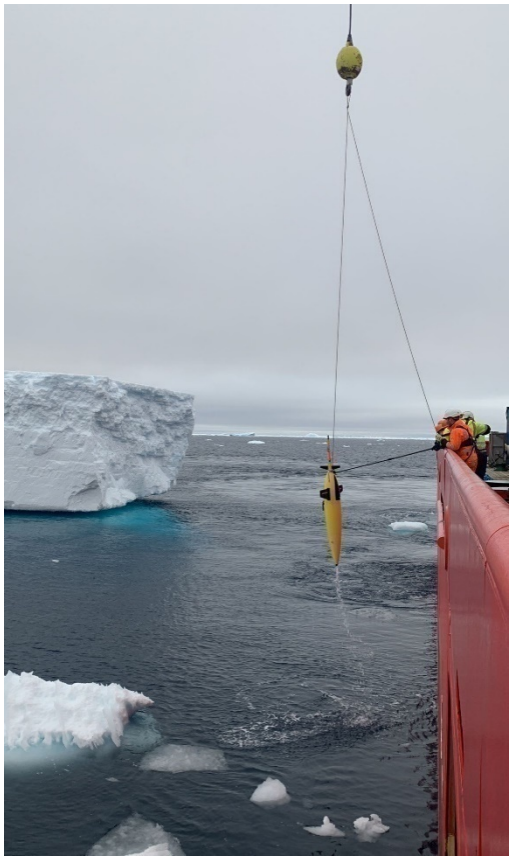


Figure 13.1-13: Seaglider lifted on board using ship's crane

Recovery of SG676 on 1st March 2024 was difficult. The Seaglider was sitting very low in the water. This makes the Seaglider very difficult to loop with a rope. As a result only the antennae was caught and the Seaglider was lifted out of the water with the antenna only. A rope was eventually positioned forward of the tailfin and the glider was successfully lifted onboard.

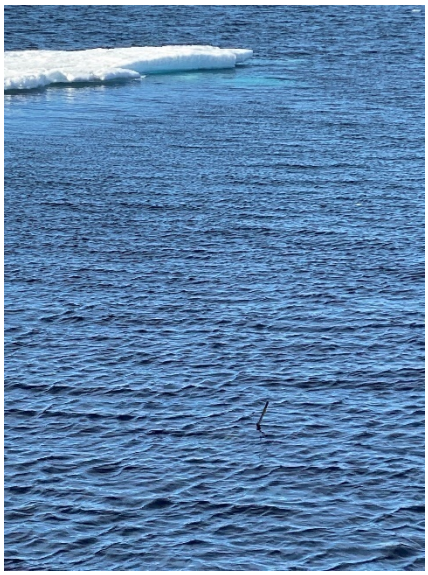


Fig 13.1-14: Seaglider SG676 sitting low in the water

It is recommended that maximum inflation of the bladder ($SM_CC,650) should be set in the cmdfile prior to recovery to ensure the Seaglider is as buoyant as possible to make loop recoveries easier.

13.2 Glider piloting: A pilot's perspective

Authors: Rob Hall[1] and UEA pilots[1]

[1]School of Environmental Sciences, University of East Anglia, Norwich, UK

Piloting

Four Seagliders were deployed during the field campaign, each with a difference suite of sensors (summarised in Table 13.2-1). Conductivity and temperature were sampled every 5 seconds on all gliders. Dissolved oxygen concentration and optical variables (WETLabs) were sampled every 5 seconds above 250 m and every 10 seconds below 250 m. PAR was sampled every 5 seconds above 250 m and turned off below 250 m. An exception to this rule was the dissolved oxygen concentration sensors on SG558 and SG673. These were limited to 10-second sampling, probably due to a conflict with the Lab-on-Chip (LoC) pH/nitrate sensor installed on these gliders. SG565 and SG676 were also each equipped with an echosounder. All sensors sampled at all depths and during both descent and ascent phases of the dive. For all four gliders, the altimeter was successfully used to make soundings of the seabed and set the depth of apogee; the typical bottom turn margin was 20 m.

Table 13.2-1: Summary of sensors and loggers on each deployed Seaglider.

Glider	SBE CT	[O_2]	WETLabs	PAR	LoC	ES
SG558	✓	AA4831	BBFL2IRB: Chl (695) PE (595) 700		Nitrate	
SG565	✓	CONTROS	BBFL2IRB: Chl (695) CDOM (460) 700			✓
SG673	✓	AA4831	BBFL2IRB: Chl (695)		pH	

			CDOM (460) 532			
SG676 (RevE)	✓	AA4831	BB2FLIRB: Chl (695) 470 700	✓		✓

Table 13.2-2: Summary of Seaglider deployments.

Glider	**Leg 1: Larsen**	**Leg 2: Shelf slope**	**Leg 3: Shelf**
SG558		Dives: 1-196	
SG565	Dives: 1-21	Dives: 22-40	
SG673	Dives: 1-22	Dives: 23-180	
SG565			Dives: 1-18

Leg 1: Larsen
SG565 and SG673 were initially deployed for 1 day (31 Jan-1 Feb 2024) occupying a 20-km section perpendicular to Larsen Ice Shelf in a small polynya (Leg 1; Table 13.2-2). Bathymetric depths were less than 400 m so once the gliders were safely diving to depth, the full water column was sampled.

Leg 2: Shelf slope
The primary deployment of the campaign was further north, over the Weddell Sea shelf slope. Here, SG558, SG565 and SG673 were deployed for 17 days (6-23 Feb 2024) occupying a 90-km section perpendicular to the shelf slope (Leg 2; Table 13.2-2). The bathymetric depth changed from 400 m at the western end of the section to 2000 m at the eastern end.

All three gliders were deployed over the 1000 m isobath and initially transited upslope. At the 650 m isobath SG558 and SG673 continued up-slope while SG565 returned down-slope.

Unfortunately, SG565 stopped communicating with the basestation after dive 40 (near the 1000 m isobath) but continued to transit east-north-east on its escape heading (60±10°) with a roughly four-hour dive cycle. Its geolocation was tracked using its auxiliary ARGOS tag until 25 Feb. It is suspected that the tag ran out of power on that date.

SG558 and SG673 were piloted in parallel and stayed within a few kilometres of each other for the whole deployment. After reaching the 400 m isobath on 10 Feb, the gliders returned down-slope but an increase in sea ice concentration required a diversion back onto the shelf. This diversion took them north to the 450 m isobath and then northeast to the 500 m isobath. Once

satellite imagery showed that the sea ice had moved offshore the gliders retraced their path back to the main 90-km section and continued down-slope. In total, the diversion took four days. On 18 Feb the gliders reached the 2000 m isobath and returned up-slope. They were recovered near the 500 m isobath on 23 Feb.

During the ascent phase of dive 165, the LoC pH sensor appeared to cause interference with the guidance and control cycle of SG673. The LoC sensor was thus turned off from dive 166 onwards. The sensor was re-tested during dive 177, just before recovery, but again it interfered with the guidance and control cycle during the ascent phase.

SG558 battery issues. The 15V battery on SG558 started anomalously low (12-12.5V during pumping at apogee) and the voltage started to drop more rapidly from 15 Feb. During dive 113 (16 Feb), while diving to 700 m, the '24V' voltage dropped to less that the default value of 11.5V and the glider went into recovery. The glider was then limited to 300 m for two dives then 500 m for 9 dives (dive 21 was to 600 m). During dive 125 (17 Feb) the '24V' voltage again dropped to less that the default value of 11.5V and the glider went into recovery. The glider was then limited to 400 m and the critical value reduced (eventually to 10V) to reduce the risk of the glider going into recovery under sea ice, which would lead to the loss of the glider.

On 19 Feb, two parameters were decreased for both SG558 and SG673 in order to reduce the length of time they would spend near the surface if they came up under sea ice. These were $CALL_TRIES,3 and $CALL_WAIT,30. At the same time $N_NOCOMM was doubled to 10. $UPLOAD_DIVES_MAX was also temporarily changed to 1 to reduce the transmission time while sea ice density was high.

Leg 3: Shelf

SG676 was finally deployed for 1 day (29 Feb-1 Mar 2024) occupying a 'virtual mooring' station on the shelf while the AutoNaut ASV Caravela collected near-surface and atmospheric data nearby (Leg 3; Table 13.2-2). Bathymetric depths were less than 350 m so once the glider was safely diving to depth, the full water column was sampled. Because the deployment was short and the water column shallow, dissolved oxygen concentration and optical variables were sampled every 5 seconds at all depths. Unfortunately, the echosounder had to be turned off from dive 3 onwards because it appeared to cause a glider error related excessive current draw.

13.3 PICCOLO Seaglider information

Authors: Gareth Lee[1], Daisy Pickup[1,#]

[1]School of Environmental Sciences, University of East Anglia, Norwich, UK
[#] Not on board

The following section contains information on all the gliders tested (SG579, SG545, SG558, SG673 and SG676) and deployed (SG545, SG558, SG673 and SG676) during the PICCOLO research cruise. The Seagliders were stuffed into a 20' container and loaded onto the RRS *Sir David Attenborough* in Harwich, UK on 7th October 2023. The container will return to UEA in June 2024.

SG673

CT sail (SBE Glider-APL (Sea))	#0357	slot1	
Optode (Aanderaa 4831)	#796	slot2, port7	port F
Wetlabs (BBFL2IRB)	#1729	slot3, port3	port C
pH (Clearwater Sensors)	#115	logger slot1, port5	port B
All up weight:	57.0242 Kg (with pH bags), 57.2414 Kg (without pH bags)		
Volmax:	56234 cc (without bags)		
Density of tank:	1.0268		
C_PITCH,	2799		
C_ROLL,	1809		
C_VBD,	3100		
Battery (15v)	95.92%		

SG558

CT sail (SBE Glider-APL (Sea))	#0363	slot1	
Optode (Aanderaa 4831)	#590	slot2, port5	port B
Wetlabs (BBFL2VMT)	#671	slot3, port6	port E
Nitrate (Clearwater Sensors)	#065	logger slot 1, port 7	port F
All up weight:	56.1255 Kg (with nitrate bags), 59.2429 Kg (without nitrate bags)		
Volmax:	55358 cc (without bags)		
Density of tank:	1.0268		
C_PITCH,	1743		
C_ROLL,	2924		
C_VBD,	2801		
Battery (15v)	96.2%		

SG676

CT sail (SBE Glider-APL (Sea))	#0304	slot1, ch10	
Optode (Aanderaa 4831F)	#886	slot2, ch6	port B
Wetlabs (BB2FLIRB)	#6008	slot3, ch3	port C
QSP 2150 PAR sensor	#50274	slot4,	port E
ES853 Echosounder	#9002	logger slot1	port D
All up weight:	55.3537 Kg		
Volmax:	53758cc		
Density of tank =	1.026590		
C_PITCH,	1880		
C_ROLL,	2347		
C_VBD,	2694		
Battery (15v)	99%		

SG565

CT sail (SBE Glider-APL (Sea))	#0201	slot1	
Oxygen Contros HydroflashO2	#DO 0816-006	slot2	port B
Wetlabs (BB2FLIRB)	#1406	slot3	port C
ES853 Echosounder	#9002	logger slot1	port D
All up weight:	53.8001 Kg		
Volmax:	53118 cc		
Density of tank =	1.0268		
C_PITCH,	2556		
C_ROLL,	2277		
C_VBD,	3001		
Battery=%	24V: 99.82, 10V: 99.61		

SG579

CT sail (SBE Glider-APL (Sea))	#0109	slot1	
RSI Datalogger	#127	logger slot 1	port B
RSI Micropod-S	# SN001-S		
RSI Micropod-T	# SN001-T		
All up weight:	57.4495 Kg		
Volmax:	56444 cc		
Density of tank =	1.0268		
C_PITCH,	2565		
C_ROLL,	1942		
C_VBD,	3165		
Battery=%	24V: 99.66, 10V: 98.21		

The Seagliders were unpacked and tested after the Drakes passage crossing. Initial self-tests and sim dives were performed.

Seaglider SG558 (Bella)

Self-test #49 was performed on 25th Jan 2024.
The following warnings and errors were observed.

546.390,SUSR,N,---- Self test FAILED or ABORTED! ----
546.498,SUSR,N,1 failures noted
546.576,SUSR,N,--> bathymetry maps failed
546.671,SUSR,N,Restoring original settings...

Battery state:
24V/high bus total = 5.507 AmpHr (15v)
10V/low bus total = 6.606 AmpHr (15v)

A series of 11 sim-dives followed to check the sensors and $NO3^-$ logger. The dives were intended to dive to 500m, but the Seaglider altimeter detected the 'bottom' at 200m and began apogee. This was a good test of the altimeter and 200m was enough to test the sensors. No errors or problems were observed and the SG558 was deemed ok to deploy.
Nitrate sensor issues were encountered. The Nitrate sensor developed an 'air lock' in transport and was unable to draw any sample.

Seaglider SG565 'James Marr'

Self-test #35 was performed on 17th Jan 2024.
The following warnings and errors were observed.

275.088,SUSR,N,1 failures noted
275.166,SUSR,N,--> bathymetry maps failed
275.258,SUSR,N,1 warnings noted
275.334,SUSR,N,--> non-default capture settings

Battery state:
24V/high bus total = 0.634 AmpHr
10V/low bus total = 0.667 AmpHr
229.107,HBATT,N,24V batt pack voltage = 26.03V
229.243,HBATT,N,10V batt pack voltage = 10.76V

A series of 5 sim-dives followed to check the sensors and ES853 Echosounder. No errors or problems were observed and the SG565 was deemed ok to deploy.

Seaglider SG673 'Bottlenose'

Self-test #13 was performed on 26th Jan 2024
The following warnings and errors were observed.

206.981,SUSR,N,1 failures noted
207.059,SUSR,N,--> bathymetry maps failed
Battery state:
24V/high bus total = 4.853 AmpHr
10V/low bus total = 8.864 AmpHr
109.035,HBATT,N,24V batt pack voltage = 14.36V
109.173,HBATT,N,10V batt pack voltage = 14.15V

A series of 11 sim-dives followed to check the sensors and LoC pH sensor. No errors or problems were observed and the SG673 was deemed ok to deploy.

Seaglider SG676 'VIMS glider'

Self-test #14 was performed on 18th Jan 2024
The following warnings and errors were observed.

408.385,SUSR,N,---- Self test FAILED or ABORTED! ----
408.392,SUSR,N,2 failures noted
408.396,SUSR,N,--> bathymetry maps failed
408.401,SUSR,N,--> SMS failed
408.405,SUSR,N,1 warnings noted
408.409,SUSR,N,--> Iridium registration

Battery state:
24V total = 0.705 AmpHr
10V total = 0.606 AmpHr
294.084,HBATT,N,24V batt pack voltage = 15.14V (min 15.14V)

294.092,HBATT,N,10V batt pack voltage = 15.00V (min 15.00V)
294.531,HST4,N,Updating parameter $FG_AHR_24V to 1.2793481
294.546,HST4,N,Updating parameter $FG_AHR_10V to 0.8925873

A series of 10 sim-dives followed to check the sensors and ES853 Echosounder logger. No errors or problems were observed and the SG676 was deemed ok to deploy.

Seaglider SG579 (Humpback)

Self-test # was performed on 28th Jan 2024.
This Seaglider didn't ever complete its initial self-test. The Seaglider re-booted after attempting to start the RSI logger.

2.865,SUSR,N,---- Checking sensors and data file creation ----
1.018,SSURF,N,Dive started Sun Jan 28 17:08:50 2024
(1706461730)
1.157,HRSIMT,N,sample start 9
131.903,HRSIMT,N,error starting sampling
383.055,HRSIMT,N,error starting sampling

Version 66.12/eAGLERAY Built: Apr 8 2019 13:22:09
Seaglider operating software developed by
Applied Physics Laboratory, University of Washington(APL)
Maintained by Kongsberg Maritime in conjunction with APL
Copyright 2003-2016, University of Washington
with serial and logger device sensor integration facilities

14. Floating Sediment Trap Deployments

Authors: Emily Rowlands[1], Flo Atherden[1], Gareth Flint[2], Katie Cartridge[2], Simon Ussher[3], Angela Milne[3]

[1]Ecosytems Team, British Antarctic Survey, Cambridge, UK
[2]Antarctic Marine Engineering, British Antarctic Survey, Cambridge, UK
[3]School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth, UK

Background

The floating trap consists of three stainless-steel carousels in succession on a line, deployed at 50, 100 and 150 metres with 50 metres of wire between each carousel. At the top of the trap array, a single small surface buoy is attached and at the bottom a 10 kg steel weight (Figure 14-1). An Iridium beacon was mounted on the buoy so the floating trap could be tracked and located.

Figure 14-1: Floating trap schematic

Each carousel contains 4 metal bottles (or a trace metal replacement) to collect sinking material, in order to measure the vertical movement of particles over selected short-term timescales and determine particle fluxes. Each bottle has a lid with the lids to each carousel being closed via a release messenger mechanism prior to recovery to prevent contamination during the recovering phase and ensure it is truly the specified deployment depths bring sampled. The trap was deployed off the aft deck using the mooring winch set-up. The ship was stationary during deployment and recovery to minimise tension on the wire. Swivels were added between each carousel.

Deployment

The floating sediment trap was deployed 6 times throughout the duration of the cruise (one of which was aborted due to a medical evacuation). For each deployment, a decision was made as to whether to allow the trap to free-float or deploy tethered to the ship based on ice conditions, bathometry, currents and whether steam time was ample for recovery of the trap. When tethered to the ship, the trap was attached to the light towing boom at approximately 5 metres from the ship.

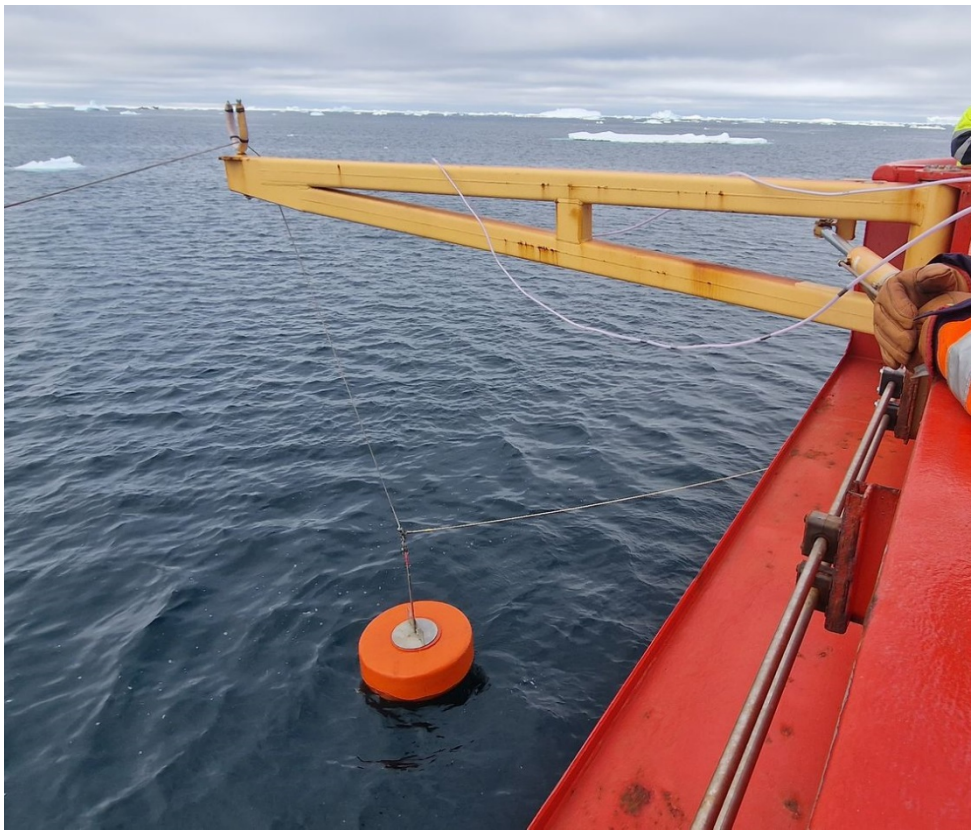


Figure 14-2: Floating trap deployment attached via the light tow boom

Table 14-1: All deployments of the floating sediment trap

Operation	Date	Time	Station ID	Event	Longitude	Latitude	Deployment duration	Free-floating

Floating trap deployment	04/02/2024	12:28:00	SS4	109	-64.58536	-58.23477	11 hours	No
Floating trap recovery	04/02/2024	23:52:00	SS4	109	-64.58536	-58.25510		
Floating trap deployment	07/02/2024	23:00:00	T1	131	-64.53655	-48.50012	18 hours	Yes
Floating trap recovery	08/02/2024	17:03:00	T1	131	-64.51460	-48.54881		
Floating trap deployment	16/02/2024	11:54:00	Mooring	221	-64.58017	-55.02203	24 hours	Yes
Floating trap recovery	17/02/2024	00:11:00	Mooring	221	-64.59638	-54.99506		
Floating trap deployment	19/02/2024	17:38:00	Ice station	249	-66.46453	-56.13142	No sample recovered	N/A
Floating trap recovery	19/02/2024	18:58:00	Ice station	249	-66.46005	-56.12970		
Floating trap deployment	27/02/2024	01:02:00		272	-65.38404	-57.71208	20 hours	Yes
Floating trap recovery	27/02/2024	21:34:00		272	-65.35887	-57.76291		
Floating trap deployment	29/02/2024	14:05:00	Supersite	284	-64.6764	-56.5806	22 hours	Yes
Floating trap recovery	01/03/2024	12:31:00	Supersite	284	-64.6764	-56.5806		

Sample processing

Bottles were allocated as follows from each carousel at each depth:

- 1 bottle for POC/PIC/Silicate analyses
- 1 bottle for microplastics/nanoplastic analyses
- 1 bottle for trace metal analyses
- 1 bottle for the analysis of phytoplankton and faecal pellets

POC/PIC/Silicate analyses

First, samples were decanted into 10L carboys and shaken well before being split into beakers ensuring 2 x 600 ml technical replicates for POC, PIC, Silicate samples respectively. Samples were filtered with a 25 mm vacuum pump filtration system. Pre-ashed and pre-weighed GF/F (25 mm) filters were used for PIC and POC analyses, Polycarbonate filters (25 mm, 0.6 um pore size) were used for biosilica analyses. When not decanting liquid, the filter cups were covered with polypropylene bags to prevent contamination via airborne particles.

After the processing of each sample, a small amount of milli-q was used to flush the filtration equipment of any remaining particles. Filters were then removed, folded into quarter and loosely sealed in foil to allow dry overnight in a clean space. Finally, filters were placed into the -20 freezer.

Microplastic/nanoplastic analyses

Post recovery samples were decanted into 10L carboys and shaken well before a sub-sample was taken for nanoplastics analyses. For this, 2 x technical replicates of 100 ml from each carboy were decanted into 50 ml falcon tubes and frozen at -20 °C for post-hoc fine scale filtration and gas chromatography-mass spectrometry (GCMS) analyses off the ship.

For microplastics analyses, the remainder of each sample was filtered using the 47 mm vacuum pump filtration system (flushed with milli-q before use). Samples were filtered on to 10-micron metal meshes. During filtering, in order to minimise contamination, aluminium foil was used to cover the filtration beakers when not transferring liquid. Two blank filters were exposed to the air each time liquid is poured to monitor the airborne contamination. One blank was placed to the left of the rig and one blank to the right of the rig.

All filters were preserved at -20°C for analysis in Cambridge using Focal Plane Array Fourier Transform Infrared (FPA FTIR) analyses. Metal meshes were used as this enables sample oxidation and digestion without transferring samples onto new filters.

Trace metal analyses

One of each set of 4 tubes was dedicated to trace metal collection (University of Plymouth - Milne and Ussher) after inserting clean polythene bags (rinsed x3 with ultrapure water and handled in a clean lab using gloves and cleanroom sleaves). The bags were held in place with o-rings around the top opening and lids lined in plastic and seated on an insert with a raised seat covered in a rubber matt to support the bags bottoms. The base of the trap sample tube had to be purged of air by half filling with clean seawater inserting the bag and then filling the bag with high purity water to push the air from the sides before placing the o-ring. Many samples became compromised as air caught under the bags was pressurised at depth causing the bags to burst. Samples that were uncompromised were poured into acid washed carboys, stored in refrigerator (0°C) and then vacuum filtered on an acid washed Savillex PFA filtration rig with acid washed 0.45 um 47mm polycarbonate (Nuclepore) filters. These filters were rinsed with milliQ ultrapure water to quantitatively transfer all the particles and rinse salts, folded and inserted into polypropylene 5 mL vials and frozen at -20°C.

Phytoplankton and Faecal pellet analyses

Post recovery, samples were decanted into 10L carboys. The samples were then split into 250 ml plastic bottles to produce 2 x technical replicates for phytoplankton and faecal pellet analyses. All samples were then preserved via spiking the sample with 36-37% formaldehyde to create a final concentration of 4%.

The remainder of the sample from each carboy was filtered through a 100-um mesh in order to capture any zooplankton/zooplankton carcases and preserved in 4% formaldehyde.

Fixed samples were stored at room temperature.

Troubleshooting

- During the first deployment (event 109) the trap lids didn't close, this was due to oversized thimbles on the wire ropes, preventing the messengers from working correctly, and was resolved by re-swaging the ends with smaller thimbles.
- Two of the three plastic bottles were lost during event 109. The polycarbonate bottles were not able to be manufactured in the same way as the metal bottles and were therefore fixed onto the carrousels in a slightly different way which we now know is not as robust. For future trace metal samples, one of the metal bottles was lined with a polypropylene bag secured with a tightly fitting o-ring and wire tied as a precautionary measure.
- Of the deployments with polypropylene lined bottles, some samples failed due to issues with the bags either ripping or being forced upwards due to trapped air in the cylinders. On the last deployment, the base of the trap sample tube had to be purged of air by half filling with clean seawater inserting the bag and then filling the bag with high purity water to push the air from the sides before placing the o-ring, this resulted in samples being recovered from all 3 depths.

15. BGC-Argo Float Deployment

Authors: Giorgio Dall'Olmo[1], Bob Brewin[2]

[1]National Institute of Oceanography and Applied Geophysics (OGS), Trieste, Italy
[2]University of Exeter, Exeter, UK

A NKE Provor CTS5 was deployed on 25 Feb 2024 at 11:48 UTC (lat: -64.78407 degN, lon: -56.15477 degS). The float was equipped with SBS CTD, Aanderaa oxygen optode, SBS ECO-FLBB (chlorophyll fluorescence and optical backscattering), a SBS ISFET pH sensor, and a SBS Suna UV spectrophotometer to estimate NO3 concentration. The float is equipped with an ice-avoidance algorithm composed of two parts: 1) a collision-detection system that aborts the ascent when the float's pressure does not vary after a specific amount of time and 2) an ice-sensing algorithm that aborts the ascent is the median temperature in the upper 40-15 dbar is lower than a specific threshold (nominally -1.65 degC). The float is a "jumbo float", i.e. it has an increased battery capacity. With the current configuration (i.e. vertical resolution of the different sensors) it should be able to collect more than 400 profiles. After a brief high-frequency part of its mission, it is now programmed to ground (a special spike system is present at the bottom of the float to anchor it to the sea bottom during the parking-grounding phase) at every cycle and profile every 10 days with an ice-sensing threshold of -1.3 degC (a conservative value to prevent the float from getting caught in surface ice). On 1 May 2024 (when we expect the surface ice to be fully formed) the ice-sensing temperature threshold will change to the nominal value of -1.65 degC. To allow the float to leave the shelf pushed by the currents, the float's mission will automatically change on 15 Feb 2025 to stop grounding and the ice-sensing algorithm will be de-activated (the ice-collision will remain active).

16. Optics Rig Deployments

Authors: Giorgio Dall'Olmo[1], Bob Brewin[2]

[1]National Institute of Oceanography and Applied Geophysics (OGS), Trieste, Italy
[2]University of Exeter, Exeter, UK

A profiling optical package ("optics rig") was deployed from the aft starboard crane at 36 locations (Figure 16-1) down to about 300 m. The package was equipped with the following instruments:

- SBS CTD (the pump and therefore the conductivity sensor malfunctioned from the start of the cruise)
- SBS DH8: a datalogger that recorded and timestamped data from all instruments
- SBS BB3: a three-channel (470, 532, 700 nm) optical backscattering meter
- RBR Tridente: a three-channel instrument with chlorophyll fluorescence, optical backscattering at 700 nm and CDOM fluorescence (the latter malfunctioned from the start of the cruise)
- In-situ Marine Optics SC6: a six-channel (380 - 700 nm) optical backscattering meter
- SBS ACS: a hyperspectral (400 - 750 nm) beam-attenuation and absorption meter
- FlowControl Sub (Sequoia Scientific): an automatic switch that allowed us to collect bulk ACs measurements during the descent part of the profile, and 0.2-um filtered (Acropack) ACS measurements during the ascending profile. These data will be used to determine the absorption and attenuation coefficients of suspended particles.
- Secchi depth: A 30 cm Secchi disk was attached to profiling rig. In all but a few cases (where only one up and down cast was conducted), the profiling rig was deployed twice (two casts, with a second cast often to between 20-30 m), and consequently, the depth of visual disappearance and reappearance (by eye) of the disk were measured twice (four measurements of Secchi depth at each station, sometimes more if multiple participants were involved, or if more than 2 casts were made). A Wire Length Measurement (WLM) sensor was attached to the aft-deck winch that calculated the length of wire released by the winch. This was zeroed when the disk was at the surface, and when the disk disappeared and reappeared the observer noted the depth from the WLM logger. Multiple participants (scientists and crew of research ship) took part. At each station, all Secchi depth data collected were averaged and a standard deviation computed as a proxy of the uncertainty in the Secchi depth. Protocols were identical to those described in Brewin et al. (2023).
- Forel-Ule colour: Two different Forel-Ule colour scales were used in the study. A LaMotte scale, which consists of a simple printed scale encased in perspex. Additionally, the Forel-Ule scale presented in Novoa et al (2014) was used. The measurements were collected visually (by eye), by comparing the colour of the water above a background of the white disk at roughly half the Secchi depth with the scales. Multiple measurements were made by scientists and crew. These were averaged and a standard deviation computed as a proxy of the uncertainty. Protocols were identical to those described in Brewin et al. (2023). Comments on conditions were also noted down in a logbook and are provided with the dataset (Figure 16-2).
- Sensing Secchi Disk: A small electronic sensing package (Arduino-based) was integrated into a 10 cm Secchi disk (Brewin et al. Under Review), for vertical profiling, that measures positioning (GPS), light spectra, temperature, and pressure. It was

charged and transferred data wirelessly, was encased in epoxy resin, and was used to derive vertical profiles of spectral light attenuation and temperature (Figure 16-3).

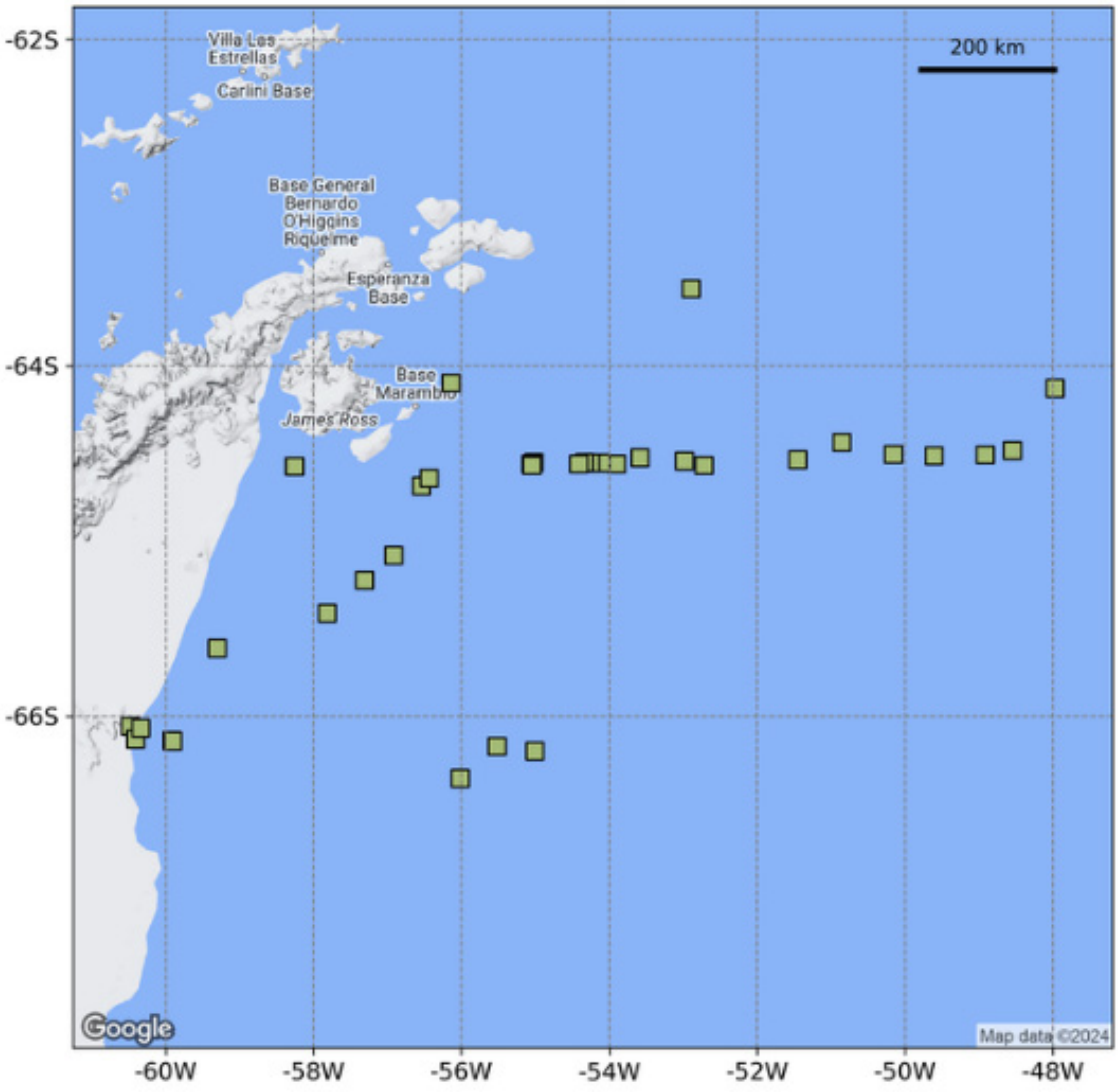


Figure 16-1: Map showing location of optics rig deployments.

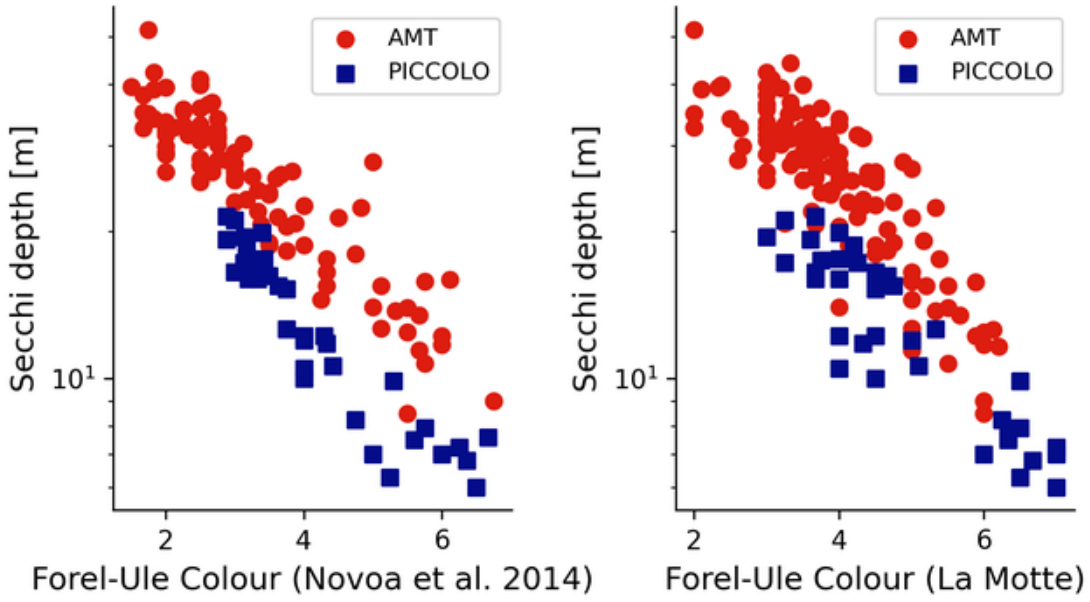


Figure 16-2: Secchi disk colour comparisons between optical rig deployments on SD035 and previous AMT data.

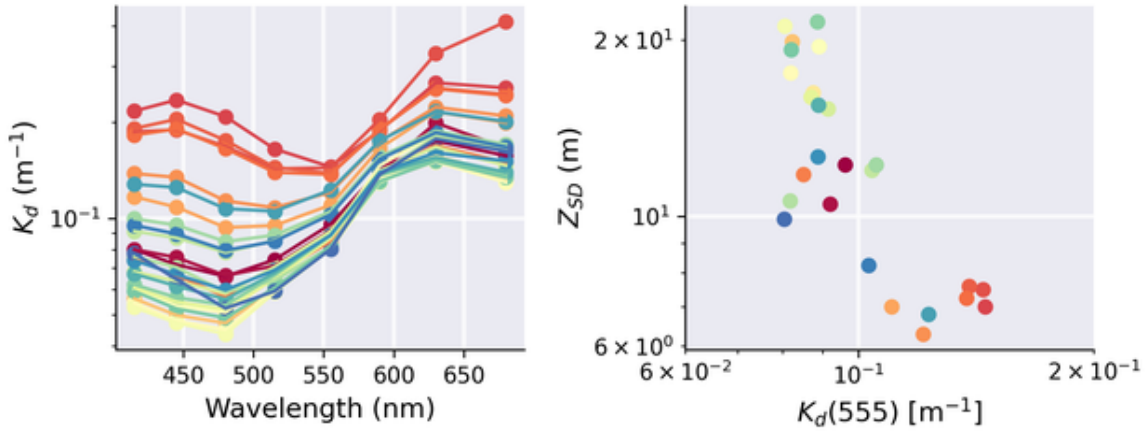


Figure 16-3: Sensing Secchi disk data collected during optical rig deployments.

17. Caravela Uncrewed Surface Vessel Deployment

Authors: Karen Heywood[1], Gareth Lee[1]

[1]*School of Environmental Sciences, University of East Anglia, Norwich, UK*

Caravela is a 5-metre long AutoNaut autonomous surface vessel. She is wave-propelled, and her sensors are powered by solar panels. AutoNaut Caravela is a self-powered, uncrewed surface vehicle (USV) developed and built by AutoNaut Ltd (https://www.autonautusv.com). The USV is designed to be a cost effective, low man-power scientific data collection platform, with zero emissions, extreme persistence and capability of surviving extreme weather conditions. Zero emission is achieved solely by wave and solar power. A patented Wave-propulsion Technology converts energy from the pitch and roll of the waves. AutoNaut is equipped with spring-loaded foils attached to the struts under the keel. These foils exploit the wave-induced vessel motion, caused by waves lifting the vessel up, out of the water and dropping it down again, to generate the forward propulsion. Under very calm weather conditions when the waves cannot alone propel the USV, an electrical thruster on the stern strut can be used. This USV is the 5-metre version with maximum speed up to about 2 knots, depending on the sea state.

The AutoNaut 5.0 is designed for versatility. It has a large carrying capacity for sensors, batteries and solar panels. The modularity of the design gives a flexible payload and for ease of transport the hull can break down into two halves.

Dimensions

Length	5.0m
Beam	0.8m
Displacement	280kg
Total Draft	0.8m
PV Panels	300Wp
Mast Height	1.5m
Hull Sections	2 sections bolted together for ease of transport.
Watertight Compartments	3
Lifting Points	2 point lift, fore and aft
Battery	Lithium Ion battery capacity designed to payload needs.
Payload Weight	500l / 130kg

Hull Composition

Hull Type	Monohull
Hull Material	Glass epoxy resin infusion
Internal Structure	Structural PU foam/ ply and glass composite sandwich
Mast	Woven carbon fibre, 1.5m above waterline

Caravela is equipped with Collision avoidance, a navigation light and AIS to minimize risk of collision. During the PICCOLO deployment, Caravela carried the following integrated sensors:

Meteorological sensors

AIRMAR 120WX Weather Station
Apogee CS301 – Pyranometer

Apogee SL-510 – Pyrgeometer
Rotronic HC2A – Temperature and humidity sensor

Underwater sensors

Nortek signature 1000 ADCP
Seabird pumped CT sensor - Fastcat

Caravela was designed to carry and release a Seaglider. For this campaign however, we were using the ship to deploy and recover the gliders. Instead we used the frame that the glider would normally sit in, to attach three stand-alone, self-powered sensors. They were carried beneath Caravela at a depth of about 0.7 m.

The sensors were:

- pH sensor (from Vassilis Kitidis, PML)
- Fluorescence sensor (from Giorgio Dall'Olmo, OGS)
- Pro Oceanus PRO-CV pCO_2 sensor (from Tom Bell, PML)

When measuring seawater pCO_2 during sampling on Caravela, a pump powered by the internal battery was used to push seawater through the sensor head. The sensor was set to perform an autozero as soon as sampling was initiated, and then every subsequent 12 hrs.

Figure 17-1: Seawater pCO_2 sensor attached to the underside of Caravela. The seawater pump is in front of the sensor (to the right in the picture), and the outlet tubing extends behind.

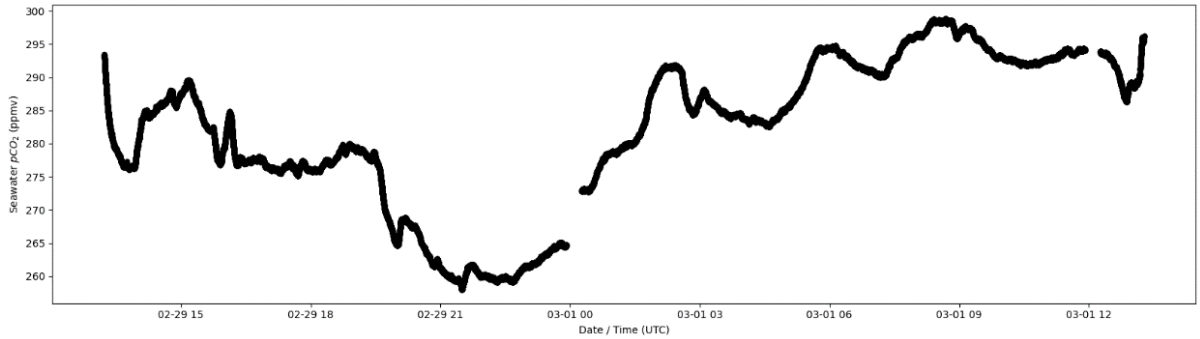


Figure 17-2: Raw pCO_2 data (autozero data excluded) collected during Caravela deployment.

Figure 17-3: Visual record of where the pH and seawater pCO_2 instruments were attached to Caravela.

Permission to deploy Caravela was required from the Maritime and Coastguard Agency. A very limited and brief deployment was approved, requiring local piloting from the bridge of the ship at all times (rather than autonomous or remote piloting, as is usually adopted).

Caravela was deployed from the ship on Thursday 29th February and recovered on Friday 1st March. She was piloted in turn by Gareth Lee and Karen Heywood from the SDA bridge, with the piloting team at UEA (Beth Siddle and Philip Leadbitter) shadowing in case of problems. Initially, we attempted to follow a square repeated track (waypoint track mode). However, the sea ice in the region was drifting quite rapidly through the study area, which meant constantly having to change the waypoints. Eventually we reverted to piloting in heading mode, choosing the desired heading based on the sea ice coverage shown in the ship's radar. This worked well even during darkness. There were some encounters with sea ice, but since Caravela's speed is moderate, there was no damage to the vessel. During the daytime, there was insufficient wind to generate waves, so the thrusters were used. The only problem encountered during the survey was that the battery readout in the RCW piloting software did not correctly indicate the remaining battery.

Figure 17-4: Deployment of Caravela from the SDA. The small boat was used to tow the USV away from the ship before release.

Figure 17-5: Deployment of Caravela using the SDA crane.

Figure 17-6: Caravela and the conditions during the deployment

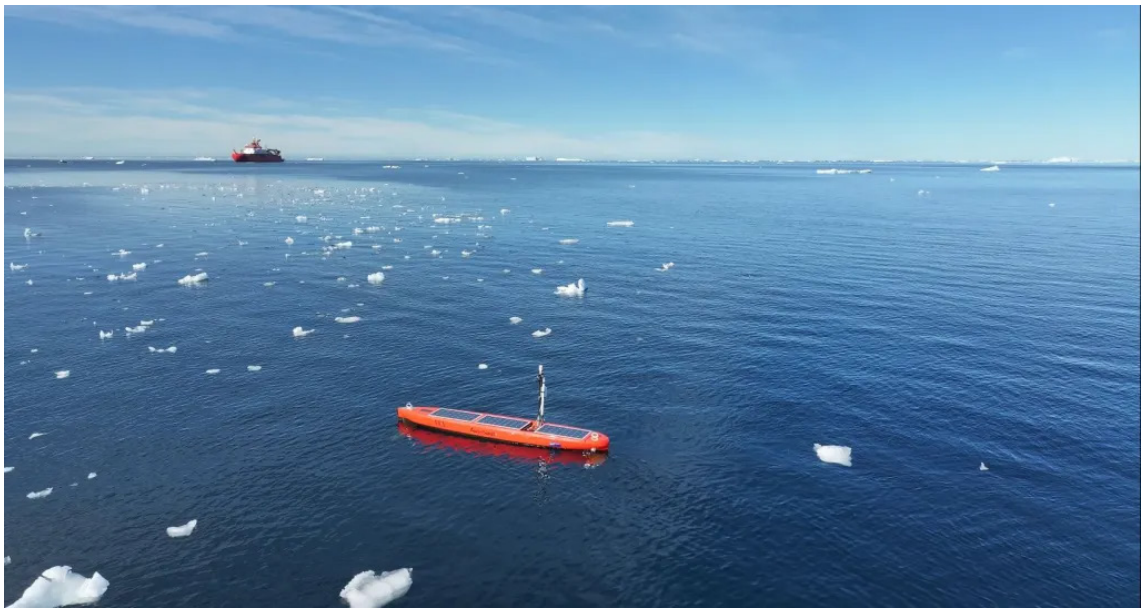


Figure 17-7: Caravela and the SDA showing the calm conditions during the first day

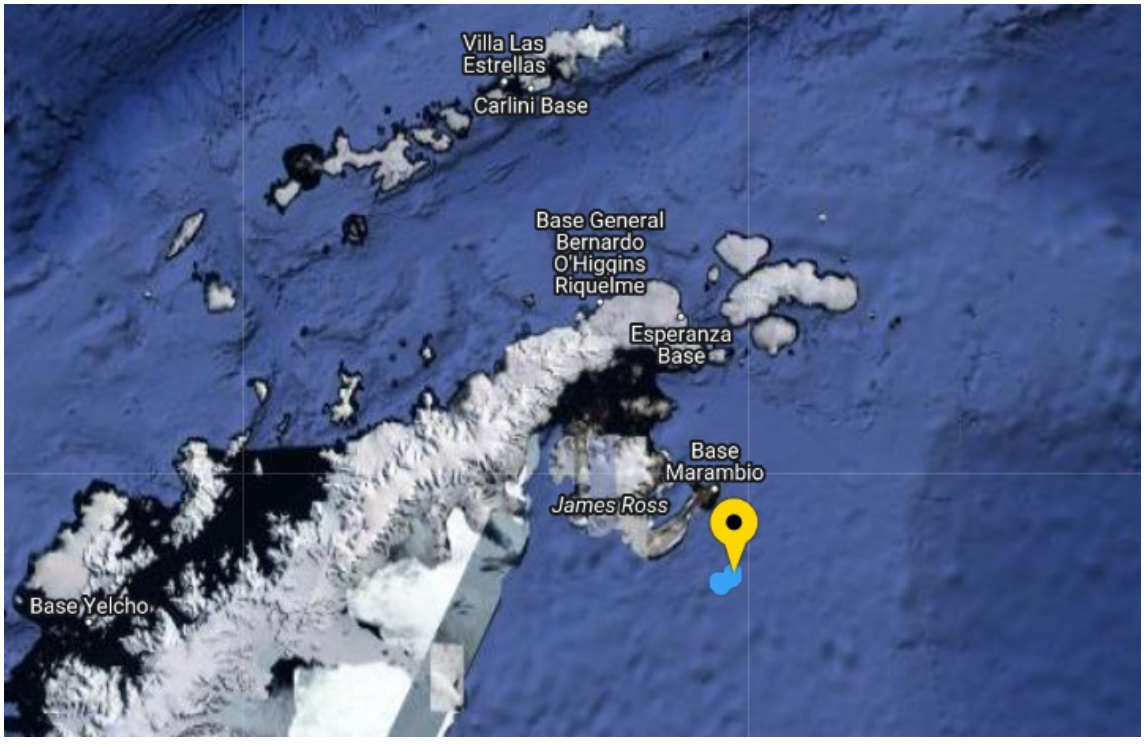


Figure 17-8: Overview map of Caravela's deployment location from the YellowBrick fixes

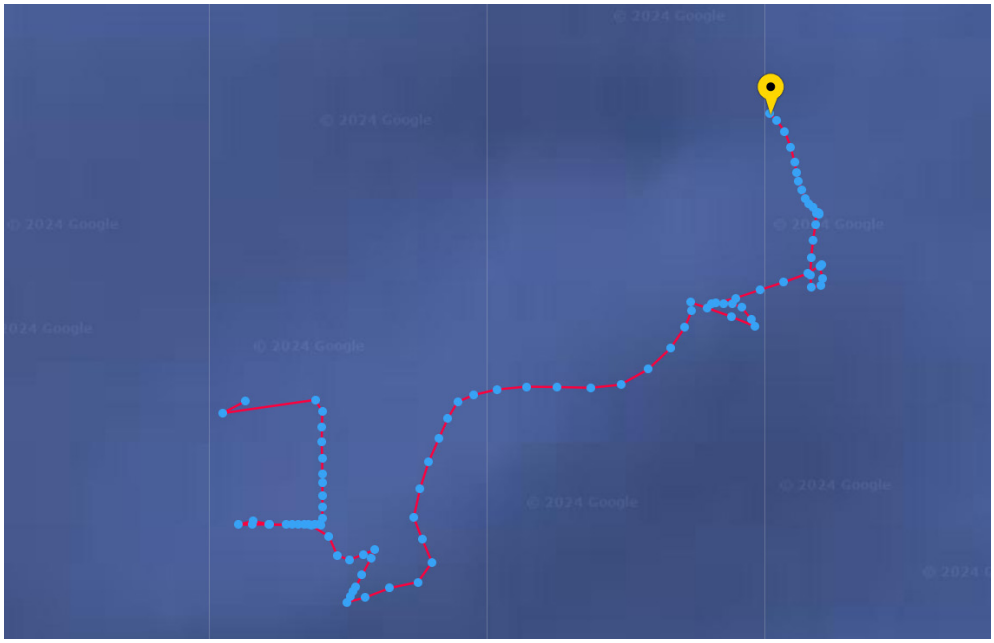


Figure 17-9: Detailed map of Caravela's track from the YellowBrick fixes

18. Multi Rotor RPAS Operations (Drone Flying)

Author: Carson McAfee (BAS)

[1]*Antarctic Marine Engineering, British Antarctic Survey, Cambridge, UK*

During the cruise Carson flew the DJI Mavic 2 Pro 47 times, accumulating 13 hours and 27 minutes flight time.

Table 18-1: Summary of drone flying

Date	Start time	End Time	Location	Note
29/01/2024	13:40	14:05	-64.57271, -55.09429	Practice Flight, SD035, Event 33
29/01/2024	14:33	14:53	-64.57271, -55.09429	Practice Flight, SD035, Event 34
29/01/2024	15:08	15:14	-64.57271, -55.09429	Practice Flight, SD035, Event 36
01/02/2024	16:13	16:32	-66.38209, -60.34028	Event 67, SD035, Larsen C
01/02/2024	16:33	16:50	-66.38219, -60.33992	Event 68, SD035, Larsen C
01/02/2024	16:55	17:18	-66.38335, -60.33645	Event 69, SD035, Larsen C
01/02/2024	17:37	17:59	-66.38592, -60.33459	Event 70, SD035, Larsen C
01/02/2024	18:03	18:24	-66.38638, -60.33010	Event 72, SD035, Larsen C
03/02/2024	18:49	19:08	-65.08306, -58.81896	Event 100. Filming an iceberg
16/02/2024	11:56	12:21	-64.58075, -55.02237	Event 222. Filming Sediment Trap.
16/02/2024	12:23	12:46	-64.58082, -55.01867	Event 223. Looking for mooring Ice Cover.
16/02/2024	12:47	13:10	-64.60604, -55.06649	Event 224. Looking for seals on ice flow.
16/02/2024	13:14	13:34	-64.60818, -55.06350	Event 226. Looking for mooring ice cover.
16/02/2024	21:38	22:01	-64.57651, -55.06202	Event 227. Watching Mooring recovery.
16/02/2024	22:03	22:25	-64.57373, -55.06320	Event 228. Watching Mooring recovery.
17/02/2024	13:22	13:35	-65.90916, -55.69836	Event 230. Looking for Seals

17/02/2024	13:39	13:50	-65.90141, -55.71133	Event 231. Looking for Seals
17/02/2024	17:10	17:27	-66.06041, -55.46778	Event 232. Looking for Seals
17/02/2024	17:28	17:45	-66.05962, -55.43250	Event 233. Looking for Seals
19/02/2024	17:14	17:37	-66.46672, -56.13227	Event 248. Testing Pix 4D Grid.
19/02/2024	17:44	17:53	-66.46405, -56.13124	Event 250. Testing Pix4D Grid.
19/02/2024	18:01	18:17	-66.46267, -56.13074	Event 251. Testing Pix4D Grid.
25/02/2024	20:49	21:04	-65.20415, -57.21326	Event 265. Seal Tagging on Floe.
26/02/2024	18:08	18:16	-65.41450, -57.81338	Event 268. Ice Floe 8. Survey Test Flight
26/02/2024	18:23	18:43	-65.41450, -57.81338	Event 268. Ice Floe 8. Survey Flight 1
26/02/2024	18:48	19:08	-65.41450, -57.81338	Event 268. Ice Floe 8. Survey Flight 2
26/02/2024	19:15	19:36	-65.41450, -57.81338	Event 268. Ice Floe 8. Survey Flight 3
26/02/2024	19:43	20:05	-65.41450, -57.81338	Event 268. Ice Floe 8. Survey Flight 4. Good one.
26/02/2024	21:02	21:22	-65.41450, -57.81338	Event 268. Ice Floe 8. Test Flight Lars.
26/02/2024	21:26	21:40	-65.41450, -57.81338	Event 268. Ice Floe 8. Scenic Flights and Pics.
27/02/2024	15:02	15:08	-65.36620, -57.67400	Event 273. Ice Floe 9. Survey Test Flight.
27/02/2024	15:13	15:15	-65.36620, -57.67400	Event 273. Ice Floe 9. Survey Test Flight.
27/02/2024	15:29	15:51	-65.36620, -57.67400	Event 273. Ice Floe 9. Survey Flight 1.
27/02/2024	15:57	16:17	-65.36620, -57.67400	Event 273. Ice Floe 9. Survey Flight 2.
27/02/2024	17:06	17:20	-65.36620, -57.67400	Event 273. Ice Floe 9. Survey Flight 3.
29/02/2024	12:11	12:33	-64.68290, -56.58203	Event 279. Live stream to bridge to watch deployment.
29/02/2024	12:35	12:54	-64.68290, -56.58203	Event 280. Live stream to bridge to watch deployment.
29/02/2024	12:55	13:16	-64.68290, -56.58203	Event 283. Live stream to bridge to watch deployment.
02/03/2024	17:48	17:53	Seymour Island	Preflight Survey of area.
02/03/2024	17:54	18:11	Seymour Island	Seymour Island Beach and Camp Survey PT1. Event 302 File.
02/03/2024	18:13	18:16	Seymour Island	Seymour Island Beach and Camp Survey PT2. Event 302 File.
02/03/2024	18:18	18:19	Seymour Island	Seymour Island Squid Survey. Event 302 File.
02/03/2024	19:47	20:05	Seymour Island	Elephant Seal Tagging. Event 303
03/03/2024	11:59	12:22	James Ross Island	Survey Flight. Seal Finding. Event 305.
03/03/2024	12:22	12:45	James Ross Island	Survey Flight. Seal Finding. Event 306.
03/03/2024	13:03	13:18	James Ross Island	Survey Flight. Event 307. Gui.
03/03/2024	13:20	13:42	James Ross Island	Survey Flight. Event 308.

The initial flights were done to collect scenic shots (video and stills) of the ship. The ship then requested flights for operational reasons, and then the science party started requesting flights for data collection and surveying. Other than one minor incident (detailed in *SD035 Report E&T_V3.pdf*), the flying program went well. "Pix4D Capture Pro" was used to automatically fly (and photograph) a designated survey area, and then software called "Open Drone Map" to stitch the images together (see Figures 18-1 and 18-2).

Figure 18-1: Stitched drone imagery from Ice Floe 9

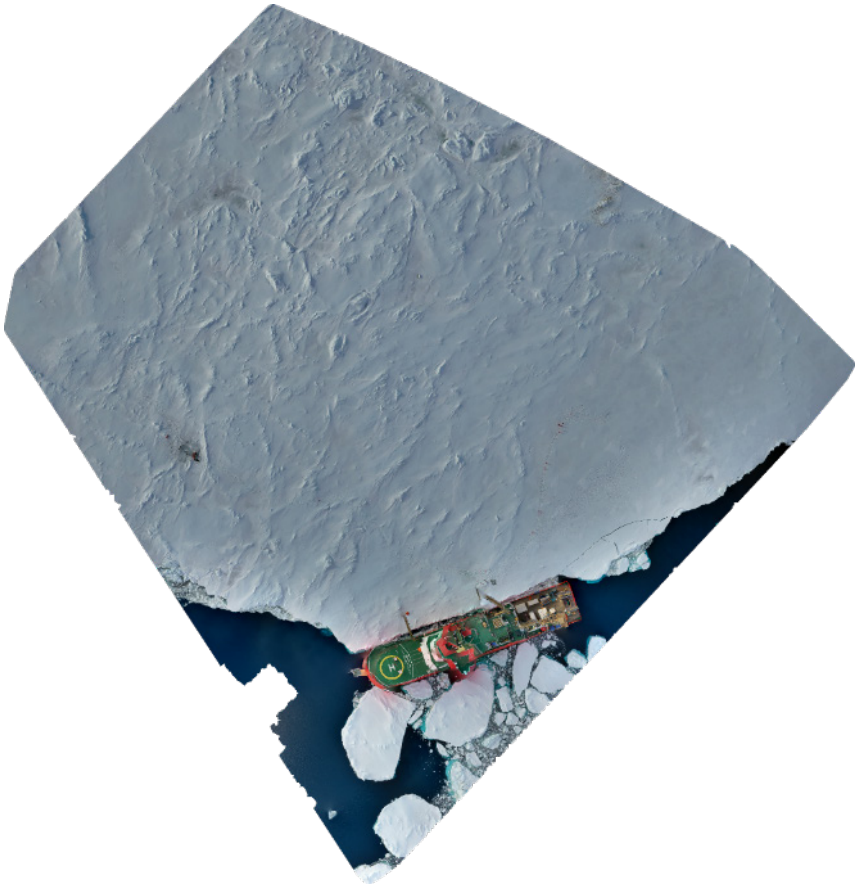


Figure 18-2: Stitched drone imagery from Ice Floe 8