MNF Voyage Summary

Voyage #:	IN2020_V08
Voyage title:	SOLACE - Southern Ocean Large Areal Carbon Export: quantifying carbon sequestration in subpolar and polar waters
Mobilisation:	Hobart, 0800 Monday 30 November to Tuesday 1 December 2020
Depart:	Hobart, 0800 Friday 4 December 2020
Return:	Hobart, 0800 Saturday 16 January 2021
Demobilisation:	Hobart, 0900 Saturday 16 January to Monday 19 January 2021
Voyage Manager:	Lisa Woodward
Chief Scientist:	Philip Boyd
Affiliation:	UTAS
Principal Investigators:	Michael Ellwood, Tom Trull, David Antoine, Rudy Kloser, Pere Masque
Project name:	
Affiliation:	ANU CSIRO Edith Cowan CSIRO Curtin University

VOYAGE SUMMARY

Voyage Summary

Objectives and brief narrative of voyage

Scientific objectives

The aims of the Southern Ocean Large Areal Carbon Export (SOLACE) project are as follows:

First, to improve water column measurement of the downward export flux of carbon of the biological pump using an integrated suite of new technological advances – from particle decomposition to mesopelagic vertical migrations.

Second, to integrate these improved estimates of the functioning of the biological export with bio-optical properties, used as proxies of biogeochemical (BGC) properties, and which can be remotely sensed using satellite sensors. A combination of conventional passive "ocean colour radiometry" and active "CALIOP" LIDAR (that 'sees through clouds' and also senses below the surface) will be validated on SOLACE to provide a comprehensive regional extrapolation of carbon export fluxes.

Third, to cross-link larger scale estimates of the biological pump (termed the BGP – biological gravitational pump - in a Review paper at Nature by Boyd, Claustre, Levy, Siegel and Weber, under revision) with those of PIPs (Particle Injection Pumps, Boyd et al., 2019, Nature) such as the Mixed Layer Pump (Llort et al., 2018) than can be assessed using profiling biological-floats (i.e., BGC-ARGO) as part of the US S. Ocean SOCCOM mission (www.soccom.edu), as well as the individual programmes of France, Australia and others.

Fourth, to link these S. Ocean findings with those of international programmes on this topic, working on N. Hemisphere analogues, via data synthesis and modelling (co-collaborator Dave Siegel, UCSB) to produce large areal maps of carbon export by both the BGP and PIPs. These programmes sit under the JETZON umbrella - http://jetzon.org/ .

COVID-19 protocols that had to implemented by the MNF prevented the planned participation on the SOLACE voyage of all international participants. These included researchers from WHOI (USA), AWI (Germany), GEOMAR (Germany) and NOC (UK).

Voyage objectives

1) A modular 3.5 day cycle of diverse water column activities from deployment and recovery of surface tethered free floating moorings (RESPIRE, particle sediment traps), to deployment from the ship of CTD, profiling cameras, net tows, ISP's, and water sampling to run lab based experiments. This cycle will be repeated 3 times at the subantarctic site (lower productivity and particle export) and 4 times at the polar site (bloom/bust and higher productivity and particle export). The mooring deployment / recovery is the most weather dependent event. Weather days will be factored in and may result in a modification of the number of cycles or

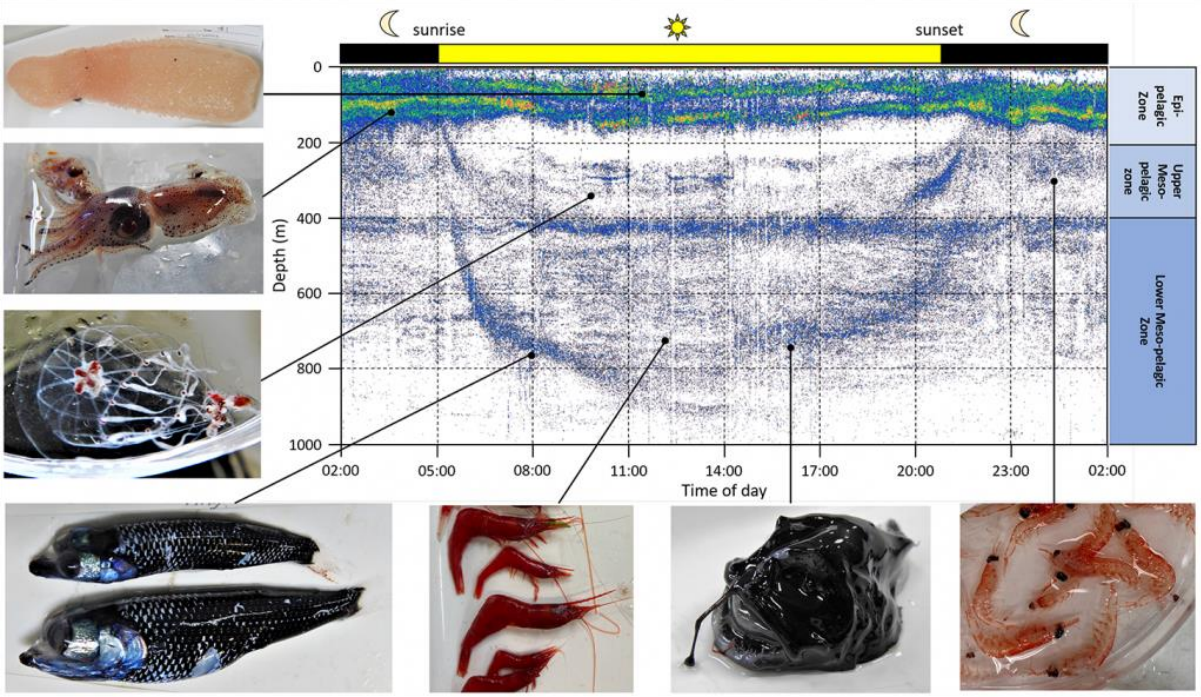
their duration. In order to fully meet the multiple aims of the voyage we will carry out additional sampling (to add to our time series) on 'weather days' that we do not use for bad weather.

2) Land-based satellite oceanography will be linked to shipboard bio-optical and optical sampling for validation (within the 3.5 day cycle of 1) above). It will be further underpinned by the deployment of gliders (from collaborators at CALTEC, USA) – one at each site (recovered post voyage downstream off New Zealand by another vessel). Weather should be of little influence for these deployment activities across the 45 day voyage.
3) Deployment of two state-of-the-art BGC-ARGO profiling floats with miniaturised UVP (Underwater Vision Profiler) on a 5 year mission. The floats telemeter datasets and their output will be modelled by collaborators in Spain. If weather conditions permit we may attempt to retrieve each BGC-ARGO for a data download (using 'Trull' device – see equipment manifest for details).
4) SOLACE sits under the JETZON umbrella - http://jetzon.org/ . The site is currently being developed and we are already (in anticipation of our voyage) contributing to metadata development and modelling initiatives.
5) Conduct aerosol and rain sampling:
    a. ASP to provide advance notice of incineration events and a final record of incineration events for the voyage to both the aerosols and atmospheric teams.
    b. Require access to aerosol sampling lab.
6) Cosmic ray measurements from underway instrument (Dr Grahame Rosolen, CSIRO).
7) Cloud Aerosol Precipitation Radiation Interactions eXperiment (CAPRIX) (Dr Alain Protat, BOM).
8) Completion of noise signature testing (MNF).
    a. This will be completed in Storm Bay immediately following departure and will be structured so as not to impact science equipment testing in Storm Bay and the voyage schedule.
9) To complement the CTD casts and regular BGC Argo floats, underway instrumentation will be running and will require some estimate of the mixed layer depth to support these observations. To give subsurface temperature structure while the ship is in transit, deployment of 12 x XBTs to observe subsurface properties while the ship is in transit between the 2 sites will be undertaken. These deployments are not permitted occur within Australian Marine Parks (AMPs).

Results

Objective 1 - A modular 3.5 day cycle of diverse water column activities

This cycle was successfully conducted on 7 occasions (3 subpolar and 4 polar waters) as specified in our voyage objectives. On each occasion we successfully deployed and recovered our surface-tethered free-drifting mooring. The summary figure below (taken from the SOLACE blog, see https://aappartnership.org.au/whos-who-in-the-zoo-micronekton-of-the-southern-ocean/) illustrates exciting linkages between our midwater camera deployments (PLAOS) and the trawls (RMT's) revealing which midwater biota are linked with day versus night patterns in bioacoustics as desciebed in the caption below.



ABOVE: Acoustic echogram at 18 kHz highlights the likely distribution of animals from 1000m to the surface over a 24-hour period at the sub-polar SOTS site; the yellow, green and red pixels shows regions of higher acoustic density whilst the blue and grey pixels show regions with lower acoustic density. This acoustic density is sometimes used a proxy for biomass. Animals found at different depths (from left-right) include; pyrosome, squid, jellyfish, fish, prawns, angler fish and krill. 📷 Svenja Halfter.

Objective 2 - Remote sensing (satellites and gliders)

The validation of satellite remote sensing (ocean colour) took place for most of the voyage through daily deployment of the DALEC (inherent optical properties) on a boom across the hours of daylight, and a noontime bio-optics vertical profile. Only one of the two gliders from CALTEC was deployed (the second glider had an electrical fault that could not be rectified). The first glider was deployed at SOTS and is still surveying the region, with a recovery due in April 2021. The glider team have been surveying around the BGC-ARGO float we deployed at the northern site (SOTS).

Objective 3 - Deployment of two BGC-ARGO floats

Both floats were successfully deployed – the first at the SOTS site and at the second at polar site (#2A) (56S 139E) and have been profiling daily since deployment on their 4-5 year missions. Calibration data was obtained for the new UVP6 (Underwater Vision Profiler 6) using a UVP5 and UVP6 deployed on each CTD cast during SOLACE. The floats are continuing to transit data back to IMOS in Hobart.

Objective 4 - Contributions to metadata development and modelling initiatives for JETZON

The SOLACE voyage will provide invaluable datasets to initiate modelling work with collaboratos in Spain and New Zealand.

Objective 5 Aerosol and rain sampling

Aerosol sampling was very successful. Rain sampling – as is sometimes the case – was more patchy.

Objective 6 - Cosmic ray measurements

Were completed successfully.

Objective 7 – CAPRIX

The objectives of the CAPRIX project have been partially met. Good observations of rainfall have been collected, but failure of the cloud radar will not allow for the aerosol / cloud objectives to be met.

Objective 8 - Noise Signature testing (MNF)

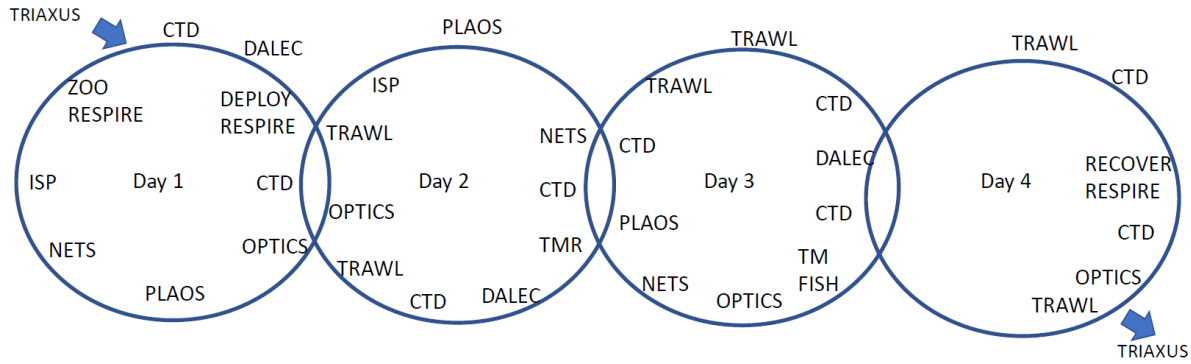
Was completed successfully in Storm Bay on 4 December 2020.

Objective 9 - Underway measurements and XBT's

Underway sampling took place through out the voyage, with the only issue being some technical glitches with the MIMS mass spectrometer used to measure Net Community Production (Tyler Rohr, CSIRO). XBT's were successfully deployed by the MNF support team and Tyler Rohr. The routine running of multi-frequency acoustics and of mapping took place throughout the voyage.

Voyage narrative

Following 3 days alongside to permit COVID-19 testing/isolation of the ships officers, crew, science party and support staff, RV *Investigator* departed from Hobart on the morning of 4 December 2020. After ship (noise signature issues) and science equipment testing in Storm bay the vessel headed SW towards the first process site (in the vicinity of the Southern Ocean Time Series (SOTS) mooring array, 47S 141.43E) stopping en route at a site within the Marine Park (44.46S 145.24E) to sample midwater biota during the day and nighttime periods. Following an initial CTD survey near the SOTS site the first of three repeat 3.5 days commenced at 47S 141.43E on Wednesday 9 December. A summary of the sequence of events for each repeat cycle is shown below. Cycle 2 commneced on 13 December and concluded 16 December, and the third and final cycle near the SOTS site was from 17 December until 20 December, after which we headed South to locate a suitable polar location for the next phase of the voyage. We were provided with custom maps of satellite ocean colour overlaid with altimetry by Benoit Legresy, this along with our pre-voyage desktop study greatly assisted findinga suitable locale in polar waters.



Generic summary of the sequence of activities on days 1 to 4 of the repeat cycle. Each cycle was bookended, before and after, by a Triaxus tow (when weather permitted) or a CTD survey. The sequence of each days events commences with the activity outside the top of each circle and concludes with the event in the top left of the circle (inside it). So on day 1 above, a CTD is the first event, then DALEC, then DEPLOY RESPIRE, and the last event is ZOORESPIRE, before moving to day 2 (PLAOS).

We transited South and carried out a joint XBT and CTD survey to locate a suitable polar site (56S 139E) at which to carry out quasi-lagrangian sampling (with a 'drifting waypoint' using a BOM holey sock drogued drifter). Repeat cycles 4 and 5 were conducted between 24 and 27 December, and 28 to 31 December, respectively. This polar site have very high concentrations of gelatinous zooplankton (salps), so much so that they were hindering deployment of nets and trawls. For this reason, we decided to re-locate further to the SE (based on the location of a low surface flow/higher chlorophyll site from the satellite maps being provided by Benoit Legresy (CSIRO)). Polar site #2B was at 58S 141.11E, and as at polar site 2A we deployed another BOM holey sock drogued drifter that we used as our 'drifting way point' for repeat cycles 6 and 7 (1-4 january 2021; 5-8 January 2021). Having completed the 7 repeat cycles and fulfilled our objective 1, we used the 9 and 10 of January to 'fill in' several activities that were particularly weather sensitive (e.g. PLAOS camera) and which had been postponed during cycles 6 and 7. We departed northwards late of January 10 and en route we carried out a > 24 h Triaxus tow (commencing on 12 Januray at 51.29S 144.16E) for Benoit Legresy (CSIRO) – to coincide with a SWAT (altimetry satellite) overpass. The Triaxus was recovered on the morning of 13 January, and we headed for Hobart with underway sampling being completed late on 13 January. We docked in Hobart at 0800 h on Friday 15 January 2021, 24 h ahead of schedule.

Outreach, education and communications activities

During SOLACE we ran a blog in conjunction with CSIRO, MNF and AAPP (Australian Antarctic Programme Partnership). The link below has >15 blogs written by the science party (from voyage leader through to early career researchers) and the MNF team, on both scientific findings through to reflections of life at sea. The blog was well received by many of the researchers in partner international organisations within the JETZON programme, as well as researchers within the AAPP who helped host the blog.

https://aappartnership.org.au/welcome-aboard-solace-voyage-blog/

The following are links to media coverage of the SOLACE voyage.

- 'It's exciting to finally get going', ABC Radio, 04 December 2020
- *Solace seeking in the Southern Ocean,* Amelia Nichele, Cosmos Magazine, 15 December 2020
- *Robot fleet dives to investigate marine snow, deep sea creatures discovered,* Isabella O'Malley, Weather Network, 05 January 2020 (syndicated across multiple publications)
- *Scientists probe ocean twilight zone*, Ethan James, Australian Associated Press, 16 Jan 2021 (syndicated across multiple publications)
- *Meet the creepy critters of the Southern Ocean's 'twilight zone',* Lucy Macdonald, ABC News, 15 January 2021
- *Robot Fleet Dives in "Marine Snow" for Climate Answers,* Sci Tech Daily, 12 December 2020
- *Australian Robots Are Exploring to the Deep Sea to Study Marine Snow,* Dharna Noor, Gizmodo, 25 December 2020

Summary

Based on post-voyage feedback I have received the voyage was both successful and enjoyable. Despite not having the full complement of SOLACE scientist (no internationals due to COVID restrictions), we met all of our scientific objectives. Although the voyage involved many complex over the side activities, with the exception of one glider that did not operate (electronic fault) and some broken TM Niskin bottles (collision with stern) we had a productive and safe voyage. The deployment of the BGC-ARGO floats and the ongoing glider mission have helped to extend the achievements of the SOLACE voyage. Individual voyage reports for each of the participating groups are archived in Appendix 1. We anticipate that there will be some exciting breakthroughs – in particular in better linking mesopelagic ecology and biogeochemistry – as a result of this voyage. As a result of such advances we can use SOLACE datasets to train the new generation of researchers in new holistic ways to study the oceans' Twilight Zone.

Marsden Squares

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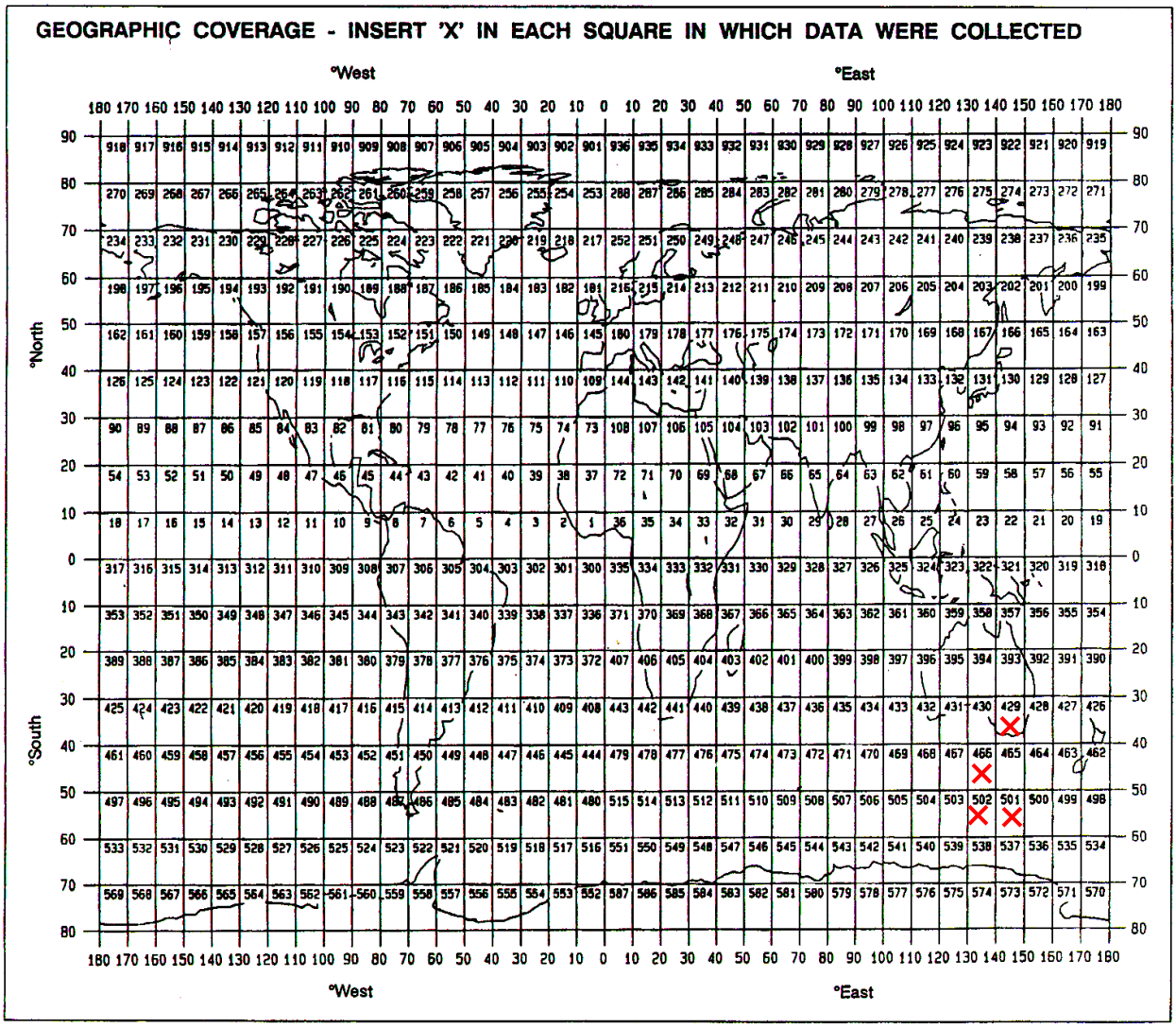
GEOGRAPHIC COVERAGE - INSERT 'X' IN EACH SQUARE IN WHICH DATA WERE COLLECTED
°West
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Moorings, bottom-mounted gear and drifting systems

Item Name, Identifier (e.g. serial number)	Principal Investigator (see Title Page)	APPROXIMATE POSITION (as degrees, decimal minutes)						DATA TYPE enter code(s) from list in Appendix A	DESCRIPTION
		LATITUDE			LONGITUDE				Identify, as appropriate, the nature of the instrumentation, the parameters measured, the number of instruments and their depths, whether deployed and/or recovered, dates of deployments and/or recovery, and any site identifiers.
		deg	min	N/S	deg	min	E/W		
RESP01	Philip Boyd	47	04	S	141	23	E		RESPIRE particle incubator and interceptor (3 depths, 150, 200 and 250 m) measuring dissolved oxygen (optode) and collecting particles for POC, PON. 3 PIT sediment traps were deployed at 170, 220 and 270 m and collected sinking particles for POC, PON, omics, and particle characterisation (see voyage report in Appendix D for more details).
RESP02	Philip Boyd	47	05	S	141	22	E		RESPIRE particle incubator and interceptor (3 depths, 150, 200 and 250 m) measuring dissolved oxygen (optode) and collecting particles for POC, PON. 3 PIT sediment traps were deployed at 170, 220 and 270 m and collected sinking particles for POC, PON, omics, and particle characterisation (see voyage report in Appendix D for more details).

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		deg	min	N/S	deg	min	E/W		
RESP03	Philip Boyd	47	05	S	141	21	E	B90	RESPIRE particle incubator and interceptor (3 depths, 150, 200 and 250 m) measuring dissolved oxygen (optode) and collecting particles for POC, PON. 3 PIT sediment traps were deployed at 170, 220 and 270 m and collected sinking particles for POC, PON, omics, and particle characterisation (see voyage report in Appendix D for more details).
RESP04	Philip Boyd	55	55	S	139	08	E	B90	RESPIRE particle incubator and interceptor (3 depths, 150, 200 and 250 m) measuring dissolved oxygen (optode) and collecting particles for POC, PON. 3 PIT sediment traps were deployed at 170, 220 and 270 m and collected sinking particles for POC, PON, omics, and particle characterisation (see voyage report in Appendix D for more details).
RESP05	Philip Boyd	55	49	S	138	44	E	B90	RESPIRE particle incubator and interceptor (3 depths, 150, 200 and 250 m) measuring dissolved oxygen (optode) and collecting particles for POC, PON. 3 PIT sediment traps were deployed at 170, 220 and 270 m

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		deg	min	N/S	deg	min	E/W		
									and collected sinking particles for POC, PON, omics, and particle characterisation (see voyage report in Appendix D for more details).
RESP06	Philip Boyd	58	05	S	141	15	E	B90	RESPIRE particle incubator and interceptor (3 depths, 150, 200 and 250 m) measuring dissolved oxygen (optode) and collecting particles for POC, PON. 3 PIT sediment traps were deployed at 170, 220 and 270 m and collected sinking particles for POC, PON, omics, and particle characterisation (see voyage report in Appendix D for more details).
RESP07	Philip Boyd	57	58	S	141	21	E	B90	RESPIRE particle incubator and interceptor (3 depths, 150, 200 and 250 m) measuring dissolved oxygen (optode) and collecting particles for POC, PON. 3 PIT sediment traps were deployed at 170, 220 and 270 m and collected sinking particles for POC, PON, omics, and particle characterisation (see voyage report in Appendix D for more details).

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		deg	min	N/S	deg	min	E/W		
TASBIO01	Philip Boyd	47	06	S	141	22	E	D06	BGC-ARGO profiling float deployed on 5 year free-drifting mission, transmitting data from 2000 m vertical profiles every 10 days from the following sensors, T,S, Oxygen, pH, chlorophyll fluorescence, backscatter, and UVP (underwater vision profiler).
TASBIO02	Philip Boyd	55	49	S	138	44	E	D06	BGC-ARGO profiling float deployed on 5 year free-drifting mission, transmitting data from 2000 m vertical profiles every 10 days from the following sensors, T,S, Oxygen, pH, chlorophyll fluorescence, backscatter, and UVP (underwater vision profiler).
KONISBERG01	Philip Boyd	47	05	S	141	22	E	D90	Konisberg ocean glider deployed on a month mission, piloted by Andrew Thompson's lab (CALTEC, USA). Transmitting data from a range of depths (mission dependent) every few days from the following sensors, T,S, Oxygen, pH, chlorophyll fluorescence, backscatter.

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		deg	min	N/S	deg	min	E/W		
SURFER1	Philip Boyd	55	55	S	138	08	E	D05	BOM holey-sock drogues surface drifter with GPS beacon – deployed as a 'drifting waypoint' and then left to drift as part of WMO drifter programme run by BOM.
SURFER2	Philip Boyd	58	02	S	141	15	E	D05	BOM holey-sock drogues surface drifter with GPS beacon – deployed as a 'drifting waypoint' and then left to drift as part of WMO drifter programme run by BOM.
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Summary of data and samples collected

Notes – Details of all sampling approaches are provided under the individual voyage reports in appendix 4, and in an Excel spreadsheet that transcribes the RV Investigator bridge log and provides times, dates and positions of all of the deployments (and recoveries) of activities listed below for each of the 7 repeat cycles. * by PI names in the column below denotes PI's who retired (Rudy Kloser), partially retired (Tom Trull), or who left Australian science (Pere Masque), and who were deputised by Caroline Sutton/Ben Scoulding, Tyler Rohr/Elizabeth Shadwick, or Zanna Chase, respectively.

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TMR	Michael Ellwood	7 repeat cycles	Trace metal concentrations	H30	Vertical water sampling and profiles (T,S), Sample analysis for trace metal concentrations
ISP	Michael Ellwood	7 repeat cycles	Trace metal concentrations	H30	Vertical particle sampling at multiple discrete depths, Sample analysis for particulate trace metal concentrations and other major elements.
TM fish	Michael Ellwood	7 repeat cycles	Trace metal concentrations	H30	Horizontal sampling at 4 m depth towed off a midships boom at 4-5 knots for trace metals, Sample analysis for trace metal concentrations
IOP	David Antoine	7 repeat cycles	Bio-optical characteristics	H17	Vertical profile of inherent optical properties in upper 200 m of water column using the AC9.

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CTD casts	David Antoine	7 repeat cycles	Dissolved and Particle concentrations	B71	Discrete sampling at multiple vertical depths for CDOM, POC and phytoplankton pigments.
Above Water Radiometry (DALEC)	David Antoine	Daily deployment	Bio-optical characteristics	M02	Above Water Radiometry, continuous recording – upwards and downwards looking sensors mpunted on their own frame.
CTD casts	David Antoine	7 repeat cycles	Image analysis	B90	Continuous sampling with UVP6 and UVP5 underwater imaging systems mounted on CTD frame.
Underway sampling	David Antoine	7 repeat cycles	Dissolved and Particle concentrations	B71	Discrete sampling for CDOM, POC and phytoplankton pigments.
PLAOS camera and acoustics system	Rudy Kloser	7 repeat cycles	Acoustics	B28	Continuous sampling at multiple frequencies for PLAOS acoustic data.
PLAOS camera and acoustics system	Rudy Kloser	7 repeat cycles	Optical imagery	B90	Continuous sampling at multiple frequencies for PLAOS optical data.

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RMT trawls	Rudy Kloser*	7 repeat cycles	Fish	B65	Vertical midwater trawls at 0-200, 0-500 or 0-1000 m.
RMT trawls	Rudy Kloser	7 repeat cycles	Plankton	B65	Vertical midwater trawls at 0-200, 0-500 or 0-1000 m.
XBT deployments	Tom Trull*	12	T and S	H13	Opportunistic deployment of XBT's while the vessel was transiting (recorded in digitised ship log – accompanying spreadsheet to this voyage report).
Underway sampling	Tom Trull	Discrete samples throughout the voyage	Dissolved and Particle concentrations	B71	Water and particle samples collected from the underway seawater supply are returned to CSIRO Marine and Atmospheric Research for chemical analyses and then discarded following quarantine protocols.
CTD casts	Tom Trull	7 Repeat cycles	Dissolved and Particle concentrations	B71	Water and particle samples collected from the CTD are returned to CSIRO Marine and Atmospheric Research for chemical analyses and then discarded following quarantine protocols.
Underway sampling	Tom Trull	Continuous throughout the voyage	Net Community Production	B01	Using chemical samplers (MIMS; CO_2 coulometry)

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CTD casts	Pere Masque*	7 Repeat cycles	Radionuclides	H90	Water and particle samples collected from the CTD are returned to IMAS for processing (by Zanna Chase for Pere Masque)
TMR casts	Pere Masque	7 Repeat Cycles	Radionuclides	H90	Water and particle samples collected from the CTD are returned to IMAS for processing (by Zanna Chase for Pere Masque)

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Triaxus	Philip Boyd	7 repeat cycles	Phyical, chemcial and bio-optical datasets	D90	Towed undulating CTD profiles from 10 to 200 m depth for the following sensors – T,S, Oxygen, Nitrate, particles (LOPC), chlrophyll, backscatter, Photosynthetic competence (Fv/Fm).
Underway sampling	Philip Boyd	7 repeat cycles	Ative fluorescence	H71	Continuous sampling using a FIRE sampler for measurement of Fv/Fm from the ship's underway system.
TMR	Philip Boyd	7 repeat cycles	Net primary production	B01	Water samples for radio-isotope innoculation and incubation in the MNF deckboard incubators.
CTD casts	Philip Boyd	7 repeat cycles	Chlorophyll, and particles	B02	Discrete sampling in the upper 300 m for phytoplankton biomass.
Zooplankton nets	Philip Boyd	7 repeat cycles	Zooplankton stocks	B09	Vertical hauls using Bongo nets to assess the column integrated biomass and species composition of mesozooplankton.
ZOORESPIRE	Philip Boyd	7 Repeat cycles	Zooplankton respiration	B09	Vertical deployment of an instrument to capture zooplankton and measure their respiration rates at in situ temperature and pressure.

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ISP	Philip Boyd	7 Repeat cycles	Marine Particles	B71	Lab-based Incubations of marine particles to explore their biogeochemical signatures
Aerosol sampler	Philip Boyd	7 Repeat cycles	Atmospheric dust	M71	Atmospheric dust sampling (for trace metals)
Rain sampler	Philip Boyd	7 repeat cycles	Rain	M90	Rainfall samples (for trace metals)
					Please continue on a separate sheet if necessary

Item Name, Identifier (e.g. serial number)	Principal Investigator (see Title Page)	NO (see above)	UNITS (see above)	DATA TYPE Enter code(s) from list in Appendix A	DESCRIPTION Identify, as appropriate, the nature of the data and of the instrumentation/sampling gear and list the parameters measured. Include any supplementary information that may be appropriate e.g. vertical or horizontal profiles, depth horizons, continuous recording or discrete samples, etc. For samples taken for later analysis on shore, an indication should be given of the type of analysis planned, i.e. the purpose for which the samples were taken.

Item Name, Identifier (e.g. serial number)	Principal Investigator (see Title Page)	NO (see above)	UNITS (see above)	DATA TYPE Enter code(s) from list in Appendix A	DESCRIPTION Identify, as appropriate, the nature of the data and of the instrumentation/sampling gear and list the parameters measured. Include any supplementary information that may be appropriate e.g. vertical or horizontal profiles, depth horizons, continuous recording or discrete samples, etc. For samples taken for later analysis on shore, an indication should be given of the type of analysis planned, i.e. the purpose for which the samples were taken.
					Please continue on a separate sheet if necessary

Curation Report

Item #	Description	Storage	Access	Custodian
1.	Dissolved and particulate trace metal concentration and isotope data	Data stored with data custodian and Geotraces database	Contact custodian for data michael.ellwood@anu.edu.au	Michael Ellwood, ANU
2.	Pigments (RESPIRE and sediment trap samples)	Samples waiting for analysis at CSIRO Hobart	matthieu.bressac@imev-mer.fr or philip.boyd@utas.edu.au	Matthieu Bressac, Laboratoire d'Océanographie de Villefranche Philip Boyd, UTAS
3.	Particulate Organic Carbon, Biogenic Silica, Particulate Organic Phosphorus (RESPIRE and sediment trap samples)	Samples waiting for analysis - stored at IMAS	matthieu.bressac@imev-mer.fr or philip.boyd@utas.edu.au	Matthieu Bressac, Laboratoire d'Océanographie de Villefranche Philip Boyd, UTAS
4.	Samples for Metagenomic (RESPIRE and sediment trap samples)	Samples waiting for analysis - stored at IMAS	matthieu.bressac@imev-mer.fr or philip.boyd@utas.edu.au	Matthieu Bressac, Laboratoire d'Océanographie de Villefranche Philip Boyd, UTAS
5.	Polyacrylamide gels (Sediment trap samples)	Analysed - data stored with data custodians	matthieu.bressac@imev-mer.fr or	

Item #	Description	Storage	Access	Custodian
			philip.boyd@utas.edu.au	Matthieu Bressac, Laboratoire d'Océanographie de Villefranche Philip Boyd, UTAS
6.	Coloured Dissolved Organic Matter Samples	Samples have been analysed, data pending QAQC	Contact custodian for data david.antoine@curtin.edu.au	David Antoine, Curtin University
7.	Particulate Organic Carbon (flow sorted)	Samples waiting for analysis. Stored at Curtin University	Contact custodian for data once samples are analysed david.antoine@curtin.edu.au	David Antoine, Curtin University
8.	Above Water Radiometry (DALEC)	Data stored with data custodian	Contact custodian for data david.antoine@curtin.edu.au	David Antoine, Curtin University
9.	Underwater Video Profiles (UVP)	Data stored with data custodians	Contact custodians for data leo.lacour@takuvik.ulaval.ca or marc.picheral@obs-vlfr.fr	Leo Lacour, University Laval Marc Picheral, Laboratoire d'Oceanologie de Villefranche
10.	Absorption and Attenuation measurements (AC-9)	Data stored with data custodian	Contact custodian for data david.antoine@curtin.edu.au	David Antoine, Curtin University

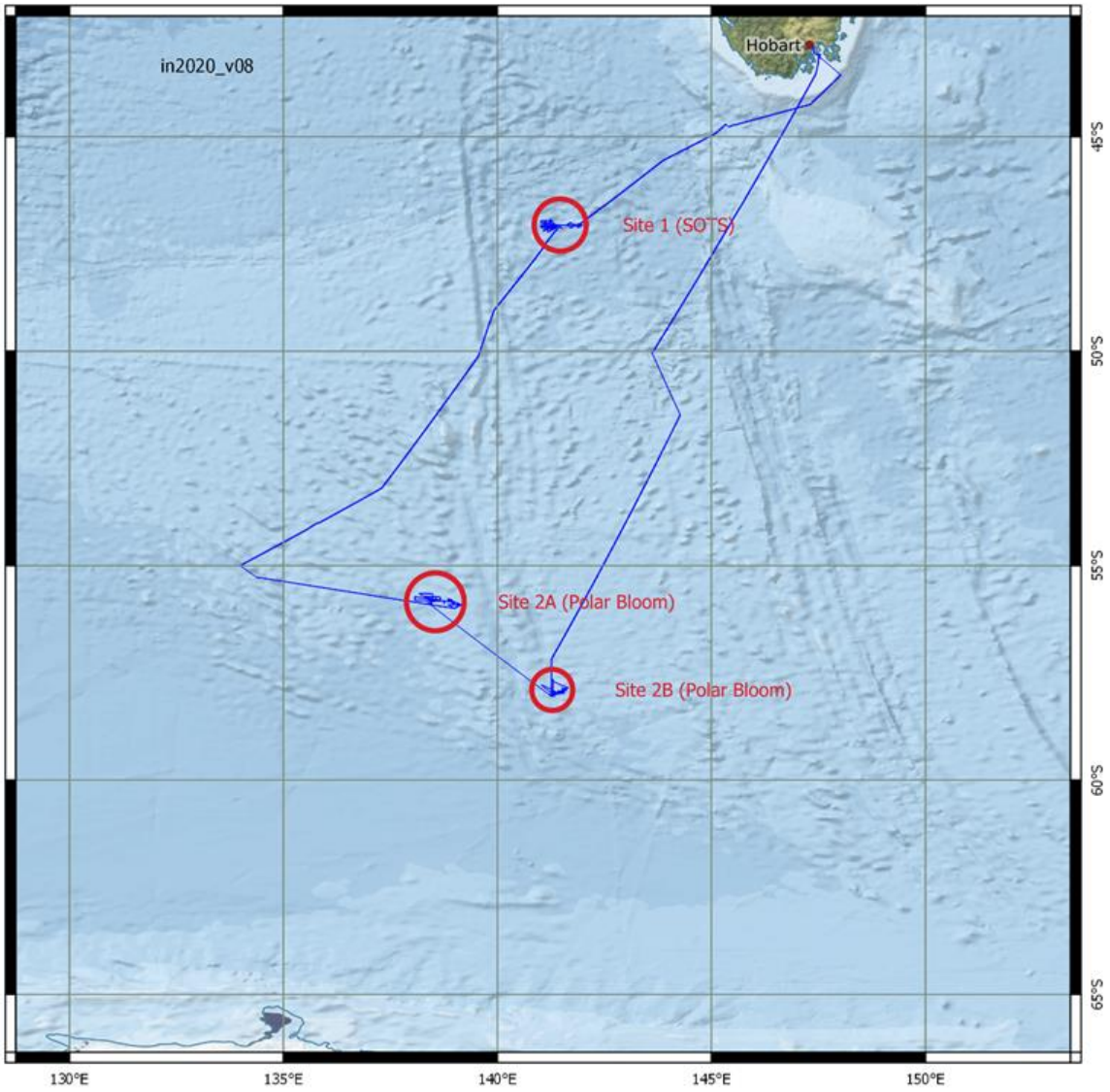
Item #	Description	Storage	Access	Custodian
11.	Inherent Optical Properties (IOP Package)	Data stored with data custodian	Contact custodian for data david.antoine@curtin.edu.au	David Antoine, Curtin University
12.	RMT frozen : Fish Samples	ANFC CSRIO : Lab T1199	Caroline Sutton	Alistair Graham

Item #	Description	Storage	Access	Custodian
		Permit number: 0003795507		
13.	RMT frozen : Invertebrate samples	ANFC CSRIO : Lab T1199 Permit number: 0003795507	Caroline Sutton	Alistair Graham
14.	RMT frozen : invertebrate prawns	IMAS UTAS : Lab T1270 Permit number: 0003795507	Caroline Sutton	Pam Qualye
15.	RMT preserved specimens	CSIRO	Caroline Sutton	Caroline Sutton
16.	RMT shipboard and biological data	Marine National Facility	Caroline Sutton	Dave Watts
17.	PLAOS acoustic data	CSIRO and MNF	Ben Scoulding	Ben Scoulding
18.	PLAOS optical data	CSIRO and MNF	Ben Scoulding	Ben Scoulding
19.	RV Investigator acoustic data	MNF	Ben Scoulding	MNF
20.	RV Investigator underway and Triaxus data	MNF	Richard Atkinson	MNF

Item #	Description	Storage	Access	Custodian
21.	RV Investigator Triaxus towbody data	MNF	Richard Atkinson	MNF

Item #	Description	Storage	Access	Custodian
22.	DIC/ALK : Water samples collected from the CTD	Returned to CSIRO Marine and Atmospheric Research for chemical analyses and then discarded following quarantine protocols.	Data will be made accessible through CSIRO (with me the point of contact) and through the AAPP BGC project	Elizabeth Shadwick (elizabeth.shadwick@csiro.au)
23.	POC : Particles samples collected from the CTD.	Returned to CSIRO Marine and Atmospheric Research for chemical analyses and then discarded following quarantine protocols.	Data will be made accessible through CSIRO (with me the point of contact) and through the AAPP BGC project	Elizabeth Shadwick (elizabeth.shadwick@csiro.au)
24.				
25.				
26.				
27.				
28.				
29.				
30.				

Track Chart


in2020_v08
Hobart
Site 1 (SOTS)
Site 2A (Polar Bloom)
Site 2B (Polar Bloom)
45°S
50°S
55°S
60°S
65°S
130°E
135°E
140°E
145°E
150°E

Acknowledgements

I wish to acknowledge the assistance provided by the SOLACE Shoreside team before and during the voyage. Dr's Elizabeth Shadwick, Benoit Legresy, Steve Rintoul and Tom Trull (CSIRO) with advice on sampling at the SOTS site and on satellite altimetry data and insights into the physical oceanography of the region. Prof. Peter Strutton (IMAS) and Dr. Christina Schallenberg (IMOS) provided guidance on the pre-deployment and deployment fo the BGC-ARGO floats, Prof. Andrew Thompson and his team provided us with two Konisberg gliders and his lab are 'flying' them currently around the S. Ocean. Marc Piceral and Leo Lacour helped to remotely configure the 2 BGC-AGO floats before deployment, and also offered trouble shooting advice on the UVP5 and 6 instruments deployed on the vessels CTD rosette.

It goes without saying that we are very grateful to the ASP vessel company and to the MNF support teams both on board but also shoreside, and thank them for their care and stewartship prior to the voyage with the COVID procedures.

Signature

Your name:	Philip Boyd
Title:	Chief Scientist

Appendix B – Photographs

Please see Appendix D and the blog (Appendix c) for photographs and their context within the individual voyage reports.

Appendix C – [Press and media coverage]

https://aappartnership.org.au/welcome-aboard-solace-voyage-blog/

- 'It's exciting to finally get going', ABC Radio, 04 December 2020
- *Solace seeking in the Southern Ocean,* Amelia Nichele, Cosmos Magazine, 15 December 2020
- *Robot fleet dives to investigate marine snow, deep sea creatures discovered,* Isabella O'Malley, Weather Network, 05 January 2020 (syndicated across multiple publications)
- *Scientists probe ocean twilight zone*, Ethan James, Australian Associated Press, 16 Jan 2021 (syndicated across multiple publications)
- *Meet the creepy critters of the Southern Ocean's 'twilight zone',* Lucy Macdonald, ABC News, 15 January 2021
- *Robot Fleet Dives in "Marine Snow" for Climate Answers,* Sci Tech Daily, 12 December 2020
- *Australian Robots Are Exploring to the Deep Sea to Study Marine Snow,* Dharna Noor, Gizmodo, 25 December 2020

While the SOLACE team just returned from a 6-week voyage on board the CSIRO's research vessel "Investigator", the two biogeochemical-Argo floats (BGC-Argo) deployed during the voyage will continue exploring the Southern Ocean on their own.

These autonomous robots are drifting with the currents and profile day and night through the water column, whatever the weather conditions. One float is evolving in sub-polar waters, 800 km south west of Hobart, while the other one explores cold polar waters further south (see Fig. 1). By navigating on each side of the Polar Front, both floats are experiencing very different environments, which offers the opportunity to compare different ecosystems, especially their contribution to carbon sequestration.

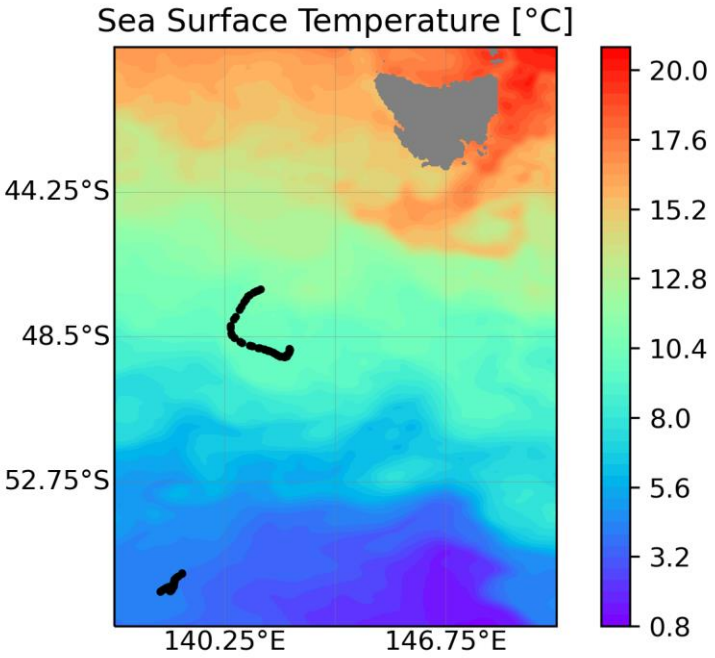


Figure 1. Trajectory of the floats superimposed on a map of sea surface temperature (January 23rd 2021).

These BGC-Argo floats are the first of their kind to be deployed with such a constellation of bio-optical sensors (see Fig.2). They provide, in near real-time, measurements of algal concentration, suspended matter, oxygen, nutrients, downwelling irradiance and pH of the sea water. In addition to these essential biogeochemical variables, the floats carry a miniaturized camera (called UVP6) which captures images of non-living particles and zooplankton evolving in the water column. This new generation of floats with state-of-the-art sensor setup is just beginning to reveal how ocean life is contributing to the regulation of atmospheric CO_2 levels and climate.

Appendix D – [Individual voyage reports from SOLACE projects]

Voyage Report – Antoine Project

The Antoine project (Curtin University), represented by Charlotte Robinson on-board, carried out a comprehensive survey of optical and biogeochemical properties of seawater and particles throughout the entire voyage. The overall objectives being to improve satellite algorithms for deriving and monitoring estimates of organic carbon concentrations and biomass of different phytoplankton functional types which have various roles in carbon cycling, as well as deriving simple optical relationships between optical parameters e.g. backscattering and phytoplankton specific carbon concentration for application to in-water monitoring. This was done through the daily deployment of the DALEC radiometer above the water and inherent optical package in the water as well as sampling from the underway seawater supply and CTD deployments. The DALEC (Dynamic Above Water Radiance and Irradiance Collector) measures light in visible wavelengths coming from the from sea and sky. It Is effectively recording the same data that ocean colour satellites do, but at

more wavelengths, and observing a smaller footprint (2 m diameter vs 4 km width of a satellite pixel). Because the Southern Ocean is so cloudy, it is hard to get lots of satellite data to match up to observations we make in water or with samples we collect. This provides us with a semi-continuous 'satellite record' that we can use to test, compare and improve satellite algorithms. The inherent optical property frame measures the absorption and scattering of light at different visible wavelengths. We also have a CTD (temperature and salinity), fluorometers measuring fluorescence and a transmissometer measuring the concentration of particles on the package. These measurements allow us to test relationships between biology/biogeochemistry sampled by the fluorometer and transmissometer and also samples taken from the underway seawater system and main CTD casts. We collected samples of the phytoplankton biogeochemistry (carbon), pigments and absorption properties from the CTD and underway seawater system to compare with the optical measurements and help build relationships between the optics and biogeochemistry.

IN2020_v08 Voyage Report

Robert Strzepek

Overview of Measurements

I collected and analyzed seawater samples to characterize phytoplankton physiology. Along with Pauline Latour (UTAS) and Sam Eggins (ANU), the 'Incubator, Inc' group performed 6 deckboard incubations to examine what factors (iron, manganese, light) affect phytoplankton growth and physiology.

Two methods were used to quantify phytoplankton photosynthetic physiology:

1) Fast Repetition Rate fluorometry (FRRf).

a. Discrete sampling: A Light Induced Fluorescence Transients fluorometer (LIFT; Soliense) and a Chelsea Technologies Group FastOcean Sensor fitted with an Act2 laboratory system were used in the Controlled Temperature (CT) room to measure the maximum photochemical efficiency of photosystem II (PSII; F_v/F_m), the functional absorption cross section of PSII (σ_{PSII}), and photosynthetic electron transport rates (ρ) on blank-corrected and low light-acclimated (30 - 60 min.) water samples. These parameters were measured at three excitation wavelengths (445, 470 and 505 nm). Fluorescence versus irradiance curves were also performed with the FastOcean FRRF for select deckboard incubations.

b. Underway sampling: A Fluorescence Excitation and Relaxation (FIRE; Satlantic) measured surface water from the underway seawater system approximately every 30 seconds using a 450 nm excitation light source. There are some gaps in this dataset because either the FIRE was deployed on the Triaxus, or the operator was incompetent.

2) **Net Primary Productivity and Iron uptake.** Six *'simulated in situ'* (SIS) ^{14}Carbon / ^{55}Iron uptake incubations (SIS 1-6) were completed during the voyage, two at each site (SOTS, Southern Sites #1 and #2) (~ 500 samples total). For each incubation, 36 310 mL samples were prepared from water collected pre-dawn from 3 depths (15 – 87 M) using the trace metal rosette (TMR). The samples were incubated with tracer amounts of ^{55}Fe (0.2 nmol L^{-1}) and ^{14}C (20 µCi) in six light-attenuating mesh bags (simulating light levels from ~0.2 to 50 % of incident irradiance) at ambient seawater temperature (~3 or 10 °C) in the deckboard incubators for 24 hrs.

Samples for flow cytometry, trace metals, macronutrients and FRRF were also collected from these TMR casts.

The ^{14}C/^{55}Fe spiked bottles were then processed as follows:

- 2 size-fractionated (0.2, 2.0 and 20 µm porosity 47 mm polycarbonate (PC) filters), washed with TiEDTA citrate solution to remove extracellular iron and hence determine intracellular Fe:C ratios,

- 2 size-fractionated without the TiEDTA citrate wash to determine total particulate Fe:C ratios,

- 1 total (> 0.2 µm; no TiEDTA citrate wash), and

- 1 dark 'control' (> 0.2 µm no TiEDTA citrate wash).

Sample Collection

CTD sampling

Discrete measurements were made with the LIFT fluorometer from the euphotic zone (5 – 100 m) samples from the 'sampling' CTDs. Thanks to the CTD sampling team for these.

Deckboard Incubations

I assisted Pauline Latour and Sam Eggins (i.e., Incubators, Inc.) with four deckboard incubation experiments designed to examine the effect of iron, manganese, light, and the siderophore desferrioxamine B on phytoplankton growth and physiology. See their reports for details.

Spokes and flourishes of the Ferrous Wheel (SAFX)

I conducted two experiments that examined the relative rates of iron uptake and regeneration by the autotrophic (phytoplankton) and heterotrophic (bacterial) communities at SOTS and the Southern site #1. Seawater was collected with the TMR from the chlorophyll maximum at each site (~15 m at SOTS, and from the DCM at 87 m at the Southern site). Whole (bacteria and phytoplankton) and <0.8 µm (bacteria) samples were incubated either in the dark, or at ~50% incident irradiance in either the presence or absence of the photosynthetic inhibitor dichlorophenyl 1,2-dimethyl urea (DCMU). Treatments were incubated for three days and subsampled every 24 hrs for:

1) $^{55}Fe/^{14}C$ uptake

2) fast repetition rate fluorometry (FRRF)

3) flow cytometry

Microbial respiration of marine particles (Respiratory Quotient Measurements)

Microbial respiration of sinking marine biogenic aggregates is pivotal in determining the balance of carbon exported to depth. As organic particles sink through the water column, they are rapidly colonised by a consortia of heterotrophic bacteria resulting in fast and efficient respiratory turnover of the particulate organic matter contained. During aerobic respiration, organic carbon is oxidised resulting in localised depletion of oxygen and production of carbon dioxide. By measuring the relationship between O2 consumed and CO2 produced, the respiratory quotient (RQ) can be obtained, giving an accurate assessment of remineralisation efficiency. RQs are widely used in ocean ecosystem models and in calculations of carbon flux, however they are commonly assumed to be 1 . In reality, this ratio varies significantly and is dependent on the stoichiometry of the organic substrate and the degree of oxidation or metabolic pathway used during remineralisation. During the course of the voyage a total of 7 deployments of sediment and respire traps were carried out collecting samples from 3 different depths (150m, 200m and 250m) over each 3-day deployment period. Particles were harvested from these traps and placed in 4ml sample vials, each containing an O2 and a CO2 sensor. The sample vials were incubated for 3 days, at ambient seawater temperature, with readings taken for O2 and CO2 concentration every 6 hours. Following this all samples were processed for preservation with glutaraldehyde for further shore-side analysis. Including negative controls a total of 504 samples were collected and processed.

Shipboard analysis carried out by Philip Butterworth. Lead researcher and contact for this work: Fraser Kennedy.

Flow Cytometry

Phytoplankton are responsible for approximately 50% of primary production on Earth and build the foundation of marine food webs. The composition of phytoplankton communities has a strong influence on how key elements, such as carbon, nitrogen, and phosphorous, flow through biogeochemical reservoirs. More specifically, plankton ecological processes influence how much CO2 fixed in the surface of the ocean is transferred to depth via the biological carbon pump. This project uses high-resolution flow cytometry to investigate the composition of phytoplankton/bacteria communities in the Southern Ocean along the SOLACE voyage transect. Our goal is to link ecological insights gained via flow cytometry with the carbon pools and fluxes measured during the voyage. Ultimately, our data aims to improve our mechanistic understanding of the biological carbon pump to improve climate models. Samples for shore-based flow cytometry were collected from 12 CTD casts (292 water samples; 123 for phytoplankton and 169 for bacterial analysis) and from the ships underway system (72 water samples; 36 for phytoplankton and 36 for bacterial analysis). Following collection, all samples were preserved (in glutaraldehyde for bacterial samples and formalin:hexamine for phytoplankton samples) and flash-frozen in liquid N2 before storage at -80 °C.

Shipboard analysis carried out by Philip Butterworth. Lead researcher and contact for this work: Lennart Bach.

Micronekton Voyage Report

Voyage highlights

- Successfully sampled micronekton in the Southern Ocean using three complementary sampling tools (1) trawl, (2) acoustics and (3) optics.
- Successfully used these data to determine the migration patterns of the dominant micronekton taxa across three Southern Ocean sites.
- This was the first example of using the broadband capabilities of the PLAOS to distinguish between broad types of micronekton.
- For the first time we will depart from a voyage with a fully analysed dataset ready for inclusion in a scientific peer reviewed article.
- Established links with fellow researchers to progress this area of research on return to Hobart.
- Themisto

RMT Biological Sampling

An RMT16 (16 m2 mouth area when fishing) midwater trawl was deployed 53 times to characterise micronekton species diversity in three integrated depth strata: 0-200 m (epipelagic zone) and 200-400 (upper mesopelagic zone) and 400-1000 m (lower mesopelagic zone. These depths were repeatedly sampled during the Day and Night at the three main sites: SOTS, 55S and 58S. In addition, trawls targeting obvious scattering layers identified by the ship's acoustic were undertaken opportunistically at each site. A single integrated exploratory trawl was conducted en route to the to the SOTS site in the Tasman Fracture Marine Protected Area (44 43.3 S, 145 21.18 E). Table xx shows the number and location for the trawls.

The RMT16 was deployed on the General-Purpose wire and monitoring of the depth of the net during trawls was via USBL beacon fixed to the net tow bar. A net controller also mounted on the tow bar controlled the opening of the net mouth and this instrument logged depth during a trawl. The real-time depth monitored from the USBL beacon and that downloaded from the controller after a trawl were generally in agreement and the planned depth strata were successfully reached and remained discrete. The net controller was at times unreliable particularly at the beginning of the voyage and as a result there were seven aborted trawls where the net did not open. Thanks to the competency and dedication of MNF's instrumentation crew Steve and Ian, the net controller remained operational. Early on at the SOTS site the net was often damaged and required small repairs after each deployment. On one deployment (Deployment 11) it was badly ripped and required five hours of stitching and repairs. On another deployment the top bar was badly bent and replaced. The replacement top bar was bent on the Deployment 53 and the net the was retired. We are grateful to Mark Lewis who ensured that the net was operational allowing us to complete our set replicates. Without his constant attention the net simply would not have made the entire voyage and it would have been replaced with the smaller RMT8 net.

The RMT16 sampled a wide range of size classes and catches were generally in very good condition. Fishes, crustaceans, cephalopods and gelatinous zooplankton were identified in catches and shipboard identifications were to the lowest possible level of classification.

The following types of biological samples from the RMT16 deployments were retained:

- Fish, crustacean, cephalopod and gelatinous zooplankton taxonomic specimens: preserved in formalin solution or ethanol;
- Fish muscle tissue sample for DNA barcoding: preserved in ethanol;
- Whole fish samples for swimbladder examination: preserved in formalin solution or frozen (-20˚C);
- Whole fish samples for further post-processing: frozen (-20˚C);
- Fish muscle tissue samples for stable isotopes analysis: frozen (-20˚C);
- Composite whole crustacean samples for stable isotopes analysis: frozen (-20˚C);

Cephalopod muscle tissue samples for stable isotopes

Table 1

Site	Depth Stratum	Day	Night
Tasman Fracture MPA	Integrated		1
SOTS	Epipelagic	2	3
	Upper Mesopelagic	3	2
	Lower Mesopelagic	3	2
	Targeted scattering layer		2
55S	Epipelagic	2	2

	Upper Mesopelagic	2	2
	Lower Mesopelagic	3	2
	Targeted scattering layer		1
58S	Epipelagic	2	2
	Upper Mesopelagic	2	2
	Lower Mesopelagic	2	2
	Targeted scattering layer		2
Aborted trawls		7	

PLAOS

Acoustic and optical data were collected using CSIRO's profiling lagrangian acoustic optical system (PLAOS). Lagrangian refers to the motion of the PLAOS in space and time as it profiles the water column from 0 to 1000 m at a descent rate of ~0.5 ms-1. The PLAOS remains tethered to the vessel but can free fall until it reaches the desired depth when it is slowly retrieved. Only data collected on the downcast is considered in the analysis. The PLAOS houses two Simrad WBT tubes with one connected to 38 and 120 kHz downwards looking transducers and the other connected to a 200 kHz sideways facing transducer. The 38, 120 and 200 kHz echosounders transmitted broadband pulses (35-45 kHz, 90-160 kHz, 160-260 kHz respectively) of sound into the water column at ~5 Hz. All echosounders recorded data continuously to a range of 100 m. Additionally, the PLAOS is equipped with several optical systems, namely a vertical video camera (which records data continuously), a pair of vertically orientated SLR cameras and an oblique SLR camera (which take alternate photos every 2 seconds). During the SOLACE voyage we focused our attentions on the 38 and 120 kHz echosounder data and the oblique camera images. In part this was because these proved to be the most reliable systems (with the video and vertical cameras failing early in the voyage), but also the desire to have a fully analysed dataset on completion of the voyage. Table xxx provides an overview of the PLAOS deployments throughout the SOLACE voyage for each site and cycle by day and night.

Table 2. Summary of PLAOS deployments.

Site	Cycle	Number of stations	
		Day	Night
SOTS	1	1	1
	2	2	2
	3	3	1
55S	1	2	1
	2	1	2
58S	1	2	2

2 4 1

Together with the trawl (discussed above) these systems were used to describe the vertical distribution of micronekton at the three study sites by day and night. Parts of the micronekton community migrate daily from the mesopelagic zone (200-1000 m) to the epipelagic zone (0-200 m) and are responsible for the active transport of carbon from the surface waters down to a depth of around 1000 m. Therefore, they play an important role in the biological pump and understanding their distribution and movement patterns is important to understanding the system. The acoustic data provided depth stratified (binned every 10 m) target counts from 0-1000 m. Each of these acoustically detected targets were classified based on their acoustic response. This allowed us to infer something about the probable target type. For example, certain responses are indicative of gas-filled targets (e.g. fish with swimbladders) whilst others indicate fluid filled targets (e.g. crustaceans). As well as providing the occasional 'best of image' the oblique camera delivered counts from 0-1000 m (binned every 100 m) to a higher taxa resolution. The high-resolution images allowed us to group species by type (e.g. prawn, medusa and chaetognath) and describe precisely the depth at which the image was captured. Together these data have enabled us to describe in detail the micronekton communities at three study sites in the Southern Ocean. We now have a better understanding of which groups of animals are moving and how many of them are doing so. Coupled with the data collected by other researchers during the SOLACE voyage we hope to provide a more holistic understanding of the carbon pump in the Southern Ocean.

The micronekton team would like to extend our thanks to the MNF support team who have kept us in data throughout the voyage through equipment repair, deployments and day to day operations. Mark, Ian and Steve it wouldn't have been possible without you.

Trace metal cycling on the SOLACE voyage

Aim: Characterise the iron and the trace metal status of the SOTS site (47 °S) and two sites south of the Polar Front to understand the connection between dissolved iron supply, primary productivity and carbon export.

Sample collection and onboard sample analysis

During the voyage, the MNF trace metal rosette was used to collect shallow (0-500 m) and deep (0-1500m) water casts for trace metals and their isotopes. In addition, water was drawn for primary production (^{14}C), iron uptake (^{55}Fe), and nutrients (Figure 1). A total of 14 TMR casts conducted during the voyage.

Dissolved iron measurements were made at sea. Dissolved iron concentrations were generally low in the upper water column (range 100 -300 pM) and increased with depth. There appeared to be a connection between iron supply and phytoplankton bloom activity at the second southern site (~58S; 141E).

Particulate trace metal and isotope samples were collected using six in situ pumps for trace metals and isotope analysis. These profiles were collected between 40 and 500 m. A total of 10 deployments were undertaken during the voyage.

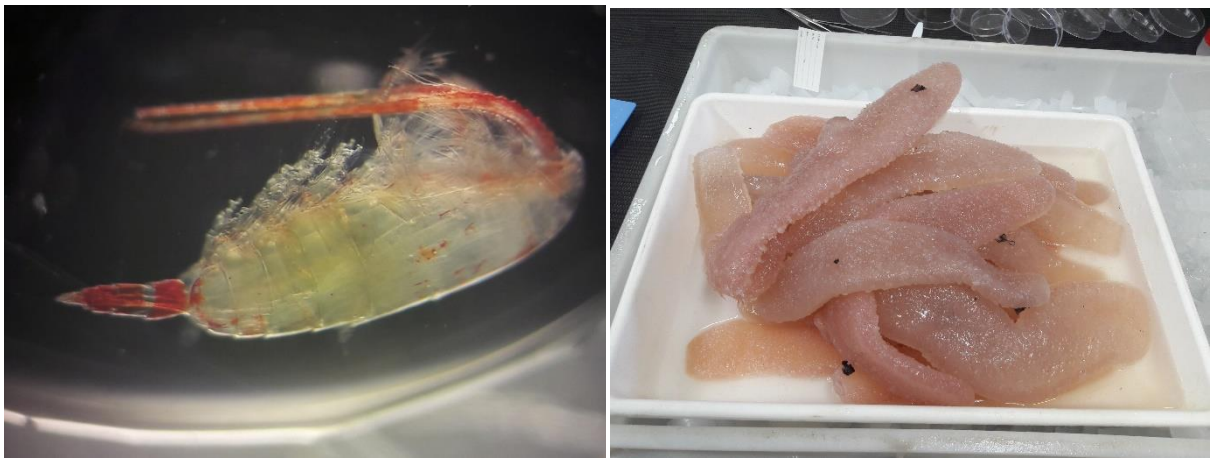
CTD samples were collected for hydrogen peroxide analysis to understand its role in iron redox cycling in the euphotic zone. Hydrogen peroxide concentrations ranged between 10 and 27 nM within the upper euphotic zone. Higher concentrations were measured at the SOTS site and low concentrations at the two southern sites.

Team zooplankton: Copepods, salps and amphipods!

Team zooplankton (PhD candidate Svenja Halfter and student Margot Hind) sampled the upper water column at the three sites regularly within the 3.5-day cycles. After the Bongo net deployments failed at the first site (SOTS), we switched over to the Neuston net (335 µm) with attached flowmeter. We usually tow the net at the depth of 200 m with the ship's speed between 0.5 – 1 knot for 10 min, before the net was hauled in at 15 m/min. The samples were either frozen for analysis of the species composition back home at IMAS or animals were selected for incubations.

At SOTS (47˚S), the zooplankton community was dominated by the tunicate *Pyrosoma atlanticum* and two copepod species *Neocalanus tonsus* and *Euchirella* spp. Pyrosomes usually inhabit subtropical waters and, in fact, we detected a subsurface intrusion of subtropical waters at this site with the Triaxus and CTD. In future, with increasing inflow of warmer waters that originate in the East Australian Current, we expect pyrosome swarms to be a common sighting for the subantarctic Southern Ocean during summer or autumn (e.g., in autumn 2019 on IN2019_V02).

We selected the copepods for faecal pellet and respiration incubations, for 24 and 8 hours, respectively, to determine the contribution of the two species for the passive downward carbon flux and respiratory flux. Furthermore, the water column was sampled 6 times during the 3 cycles (3xday/3xnight) for community composition analysis at this site.



Left: The copepod *Neocalanus tonsus* is very common in the subantarctic zone, right: pyrosome catch from the Rectangular Midwater Trawl net.

At the first southern site (55˚S), we changed our target zooplankton because the zooplankton/micronekton community was dominated by the salp *Salpa thompsoni*, which is the most common species in the Southern Ocean. Because of their fast growth and reproduction rates, they are able to exploit any phytoplankton growth and efficiently control algae standing stock.

We conducted salp carcass sinking velocity experiments in a settling column and decomposition incubations for 24 hours to estimate how much the salp bloom contributes to the downward carbon

flux. We also recorded length distribution and salp species composition and froze samples for further identification and carbon analysis back on land.

Salpa thompsoni from the Neuston net, before and after picking out of the algae that were also collected in the net.

At the second southern site (58˚S), we continued this sampling scheme. Additionally, we worked in collaboration with the micronekton team on the amphipod *Themisto gaudichaudii*. After targeted trawls (RMT 43 and 48) of strong acoustic features at 50-70 m water depth, a high abundance of *Themisto* (juveniles between 10-14 mm) was collected. Similar to the copepods at SOTS, we used the animals in respiration and faecal pellet incubations. At these two southern sites, the water column was sampled 12 times during the 4 cycles (6xday/6xnight) for community composition analysis.

Left: *Themisto gaudichaudii,* right: part of the catch from RMT 43.

Finally, throughout the voyage, samples of *S. thompsoni* gut material, and *Euchirella* spp. and *T. gaudichaudii* faecal pellets were used in RQ measurements to estimate bacterial decomposition rates of the material.

Contact information: Svenja Halfter, Svenja.Halfter@utas.edu.au

Participant: Tyler Rohr

Activity Summary:

1. Equilibrator Inlet Mass Spectrometer (EIMS) operation
2. DIC/ALK/POC sampling
3. Glider deployment
4. Underway Chlorophyll sampling
5. UVP operations
6. Thorium sampling

Activity Descriptions:

Activity 1: Equilibrator Inlet Mass Spectrometer (EIMS) operation

Other Individuals involved: Elizabeth Shadwick (from shore), Erik Van Ooijen (from shore)

Description: An Equilibrator Inlet Mass Spectrometer (EIMS) was run continuously throughout the voyage on underway seawater fed into a bath in the underway. The eims measured the O_2/Ar ratio of gasses in the seawater which was passed through an equilibrator cartridge and fed to the mass spectrometer. The purpose of collecting the O_2/Ar ratio is to estimate Net Community Production, and important biological signal closely tied to carbon export.

Activity 2: DIC/ALK/POC Sampling

Other Individuals involved: Jakob Weis, Pauline Latour

Description: DIC, Alkalinity, and POC were sampled from roughly 12 CTD casts throughout the voyage, with 6 casts at the SOTS site, and three casts at each of the two southern sites. Generally, 12 depths were sampled for DIC/ALK and 6 depths were sampled for POC. DIC and Alkalinity were sampled in order to constrain the carbonate system (e.g. pH, pCO_2). Particulate Organic Carbon was sampled to help understand the biogeochemical composition of the upper water column along with the particulate carbon export flux.

Activity 3: Glider Deployment

Other Individuals involved: Stephen Thomas, Andy Thompson (from shore), Ross Healy (from shore)

Description: Both gliders were tested extensively on the wharf prior to the steaming south. Testing included a suite of simulation dives and comms tests were run in coordination with Andy Thompson and his team at Caltech. Both gliders were deemed ready to go by Andy and his team. One glider was deployed at the SOTS site successfully. Prior to deployment of the first glider it was assembled, and a second suite of simulation dives and comms tests were run in coordination with Andy. A second glider was attempted to be deployed at the first southern site but was unfortunately unsuccessful. The glider was not able to turn on. Over the following week I worked in conjunction with Stephen Thomas to trouble shoot the problem and repair the glider. This involved countless hours of unsuccessful "wanding" at the magnetic switch with a magnetic wand (the ostensible way to turn it on) along with various troubleshooting related to the comms connection before getting the go ahead from Andy to remove the pressure hull and access the electrics board. We worked with guidance from Ross Healy (Seaglider employee) to troubleshoot the electronics. Ultimately we traced the problem back to a bloom resistor below the power relay. The physical rupture in the resistor was quite large and likely preventing the processor from powering on. It is unclear why this resistor blew.

The purpose of the glider deployments was to dynamically profile the water column, allowing Andy and his team the pilot the vehicle to area of particular oceanographic interest with precision and resolution not possible from shipboard instrumentation.

Activity 4: Underway Chlorophyll sampling

Other Individuals involved: Jakob Weis

Description: Underway chlorophyll samples were taken extensively on the transect from SOTS to the first southern site and briefly on the transect from the second southern site. Samples were taken between every half hour and two hours depending on the suspected proximity to the site. These samples were taken to quickly access the biological state of the water underway and help us hone in on a site with high biological productivity.

Activity 5: UVP operations

Other Individuals involved: Charlotte Robinson (primary)

Description: A UVP5 and UVP6 were attached to the CTD and operated on most CTD deployments. The purpose of the UVPs was to measure the partical distribution in the water column.

Activity 6: Thorium sampling

Other Individuals involved: Jakob Weis (primary)

Description: Thorium samples were taken from 36 depths across the water column at SOTS. Most depths were collected on a single casts (21) with ~8 more filled in on two other casts. These samples were collected for Zanna Chase to better understand the trace element distribution at the SOTS.

Radioactive elements, like thorium, can be used as proxies for various biogeochemical processes (e.g. the disequilibrium between Th and Ur and can be used to estimated the particle export rate).

The gravitational carbon pump was investigated using two types of mesopelagic traps deployed on a free drifting mooring for 3 days (Table 1). The downward particle flux was sampled and characterized using sediment traps deployed at multiple depths (180, 230 and 280 m). Each sediment trap was composed of 4 collection tubes: (1) one tube contained a polyacrylamide gel to obtain intact sinking particles / aggregates (Fig. 1), (2) one tube was filled with a brine containing formaldehyde to measure the downward fluxes of particulate organic and inorganic carbon, particulate organic nitrogen, particulate organic phosphorus, biogenic silica, and pigments, (3) one tube filled with a RNAlater solution was used to collect and preserve samples for metagenomic analysis, and (4) one tube filled with filtered seawater was used to obtain sinking particles (and the associated bacterial community) for *in vitro* incubation experiments. In addition, bacterial remineralization of sinking particles was measured *in situ* using the RESPIRE particle interceptor/incubator (equipped with an oxygen optode) deployed on the same mooring line at three depths (200, 250 and 300 m). In total, seven successful deployments were performed; three deployments at the SOTS site in the subantarctic, and 4 deployments at the two polar sites (Table 1).

Table 1. Details of the deployments

Deployment ID	Cycle #	Deployment (UTC)	Latitude (°N)	Lontitude (°E)	Recovery (UTC)
SOL1	1	8/12/20 23:45	-47.08	141.39	11/12/20 23:45
SOL2	2	12/12/20 23:15	-47.09	141.37	15/12/20 22:30
SOL3	3	16/12/20 20:00	-47.08	141.37	19/12/20 22:30
SOL4	4	23/12/20 23:50	-55.92	139.14	26/12/20 22:15
SOL5	5	27/12/20 21:45	-55.80	138.62	30/12/20 22:00
SOL6	6	31/12/20 22:30	-58.05	141.26	3/1/21 22:00
SOL7	7	4/1/21 22:15	-57.98	141.37	7/1/21 22:00

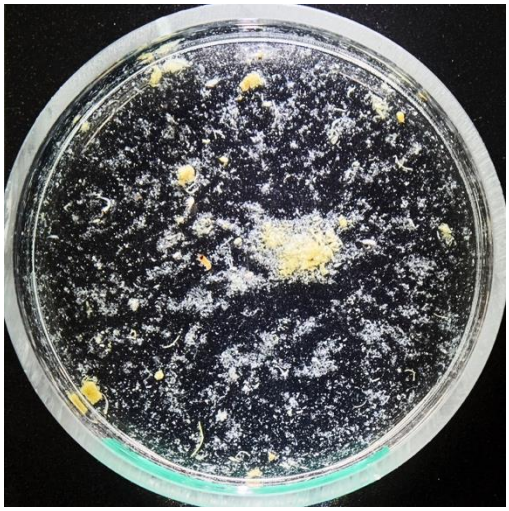


Figure 1. Photography of a polyacrylamide gel used to determine the nature and size distribution of the downward particle flux.

Voyage report

Incubation work

Phytoplankton growth is known to be limited by iron (Fe) in the Southern Ocean. More recently, the hypothesis that Mn may also co-limit phytoplankton growth has been raised. To test this hypothesis, two incubation experiments were done at both sites visited during the SOLACE voyage: one experiment was performed at SOTS and the second one at the south site (58°S). Briefly, surface trace metal clean seawater was collected from the trace metal rosette and divided into four treatments:

- Controls (no modification)
- +Fe (addition of Fe to reach at least 2 nM)
- +Mn (addition of Mn to reach at least 2 nM)
- +FeMn (to reach at least 2 nM of Fe and Mn)

At SOTS, the seawater was collected from 15 m. After metal additions, the bottles were incubated in the shipboard incubators for 7 days, inside mesh bags to simulate the light at 15 m. A mid-sampling point was done at day = 4 during which sub-samples were collected for measurement of photophysiology and macronutrients. At day = 7, sub-samples were collected for photophysiology, macronutrients, trace metal concentrations, chlorophyll-a and particulate organic carbon. The macronutrients and chlorophyll-a were analysed directly onboard.

At the south site, the same experiment was reproduced with seawater collected from the deep chlorophyll maximum (DCM), located at about 80 m. Additionally, the experiment was doubled to look at the effect of increasing light on the DCM communities and the interaction with Fe and Mn co-limitation. The “low light” experiment was incubated with additional mesh bags to reproduce the light present at about 80 m while the “high light” experiment was incubated in a single mesh bag (light at 15 m). Similarly, sub-samples were collected at day = 4 and day = 8 to collect data on the

photophysiology, macronutrients, chlorophyll-a and POC. During this second experiment, no trace metal samples were collected.

At both SOTS and the first southern site deck-board incubation experiments were conducted to examine the energetic role of extracellular carbonic anhydrase (eCA: an enzyme important in carbon uptake). In addition to controls, Fe replete and further Fe limited (induced by the addition of Fe-binding siderophore DFB) treatments were grown and their photophysiology examined in addition to samples for POC/PON, chlorophyll-a and flow cytometry being taken. These incubations were subsampled and eCA inhibited through the addition of acetazolamide (an eCA specific inhibitor). Results were then compared between cultures in which eCA was functional and inhibited in order to glean information on the importance of this enzyme in the Southern Ocean. At the second southern site a similar experiment was run to determine the long term influence of eCA inhibition on the phytoplankton community.

Atmospheric sampling

Aerosols play a key role in resupplying Fe to the anaemic Southern Ocean. To study this during SOLACE, dust samples were collected all along the voyage for trace metal measurements. Briefly, clean air is pumped from the front of the ship, when the boat is directly facing the wind. The pumped particles then deposit on a trace metal clean filter, located inside a clean hood in the aerosol lab. Two lines run in parallel and the filters are changed after a volume of 50 m^3 passes through the filters. These filters will then be analysed back onshore for trace metal concentrations at the Institute for Marine and Antarctic Studies (IMAS).

We also tried to collect rain samples as Southern Ocean rain is poorly studied. The rain sampler is located on level 5 at the front of the ship. It is constituted of a plastic funnel directly attached to a bottle for sample collection. Unfortunately, despite several trials, we did not manage to collect a proper rain sample as the rain seemed to fill the plastic bag protecting the bottles against contamination rather than the bottle itself (see picture below).

Pauline Latour