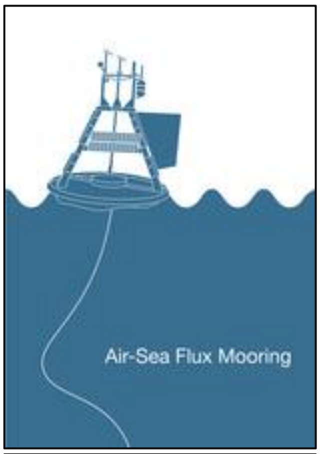
RV *Investigator* Voyage Plan

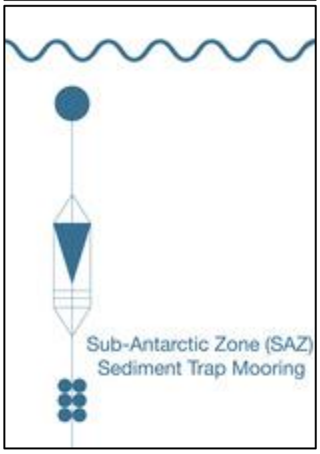
VOYAGE #:	IN2025_V02		
Version Number:	Final		
Voyage title:	**SOTS:** Southern Ocean Time Series automated moorings for climate and carbon cycle studies southwest of Tasmania		
Mobilisation:	Hobart, Monday, 24 March to Tuesday, 25 March 2025		
Depart:	Hobart, 0800 Wednesday, 26 March 2025		
Return:	Hobart, (~0900 - Time TBC) Wednesday, 16 April 2025		
Demobilisation:	Hobart, Thursday, 17 April to Friday 18 April 2025		
Voyage Delivery Coordinator and Voyage Manager:	Margot Hind	**Contact details:**	Margot.hind@csiro.au
Chief Scientist:	Elizabeth Shadwick		
Affiliation:	CSIRO	**Contact details:**	elizabeth.shadwick@csiro.au

Scientific objectives

Principal Investigator: Dr. Elizabeth Shadwick – CSIRO Env and AAPP

The Southern Ocean has a predominant role in the movement of heat and carbon dioxide into the ocean interior moderating Earth's average surface climate. The IMOS SOTS sub-facility uses a set of two automated moorings to measure these processes under extreme conditions, where they are most intense and have been least studied. The atmosphere-ocean exchanges occur on many timescales, from daily insolation cycles to ocean basin decadal oscillations and thus high frequency observations sustained over many years are required. The current context of anthropogenic forcing of rapid climate change adds urgency to the work.





Voyage objectives

The primary objective is to first deploy a new set of SOTS moorings (SOFS-14 and SAZ-27) and then recover the existing SOTS moorings (SOFS-13, and SAZ-26). Each of the SOTS moorings deliver to specific aspects of the atmosphere-ocean exchanges:

- the SAZ sediment trap mooring collects samples to quantify the transfer of carbon and other nutrients to the ocean interior by sinking particles and investigate their ecological controls.
- the Southern Ocean Flux Station (SOFS) mooring measures meteorological and ocean properties important to air-sea exchanges, ocean stratification, waves, currents and biological productivity and ecosystem structure. Water samples are collected for more detailed nutrient and plankton investigations after recovery.

Ancillary work will obtain supporting information on atmospheric and oceanographic conditions using CTD casts, and underway measurements.

1. Deploy SOFS-14 meteorology/biogeochemistry mooring
2. Deploy SAZ-27 sediment trap mooring
3. Recover SOFS-13 meteorology/biogeochemistry mooring
4. Recover SAZ-26 sediment trap mooring
5. CTD sampling (3 cast to 4550m, 2 to 600m) at the SOTS site, including collecting samples for nutrients, oxygen, dissolved inorganic carbon, alkalinity, and eDNA analyses
6. Ship meteorological observations at SOFS buoys for comparisons
7. Deployment of BGC-Argo Float (with additional UVP sensor recently refurbished after the SOLACE float was recovered).
8. Recovery of ACC-SWOT mooring at 55S site (deployed on the FOCUS IN2023_V07 voyage).
9. Deployment of BoM drifters at site of ACC-SWOT mooring recovery; CTD cast for post-calibration of recovered sensors.
10. Carry out underway air and water sampling and sensor measurements, including bio-optics and bio-acoustics

Voyage Priorities

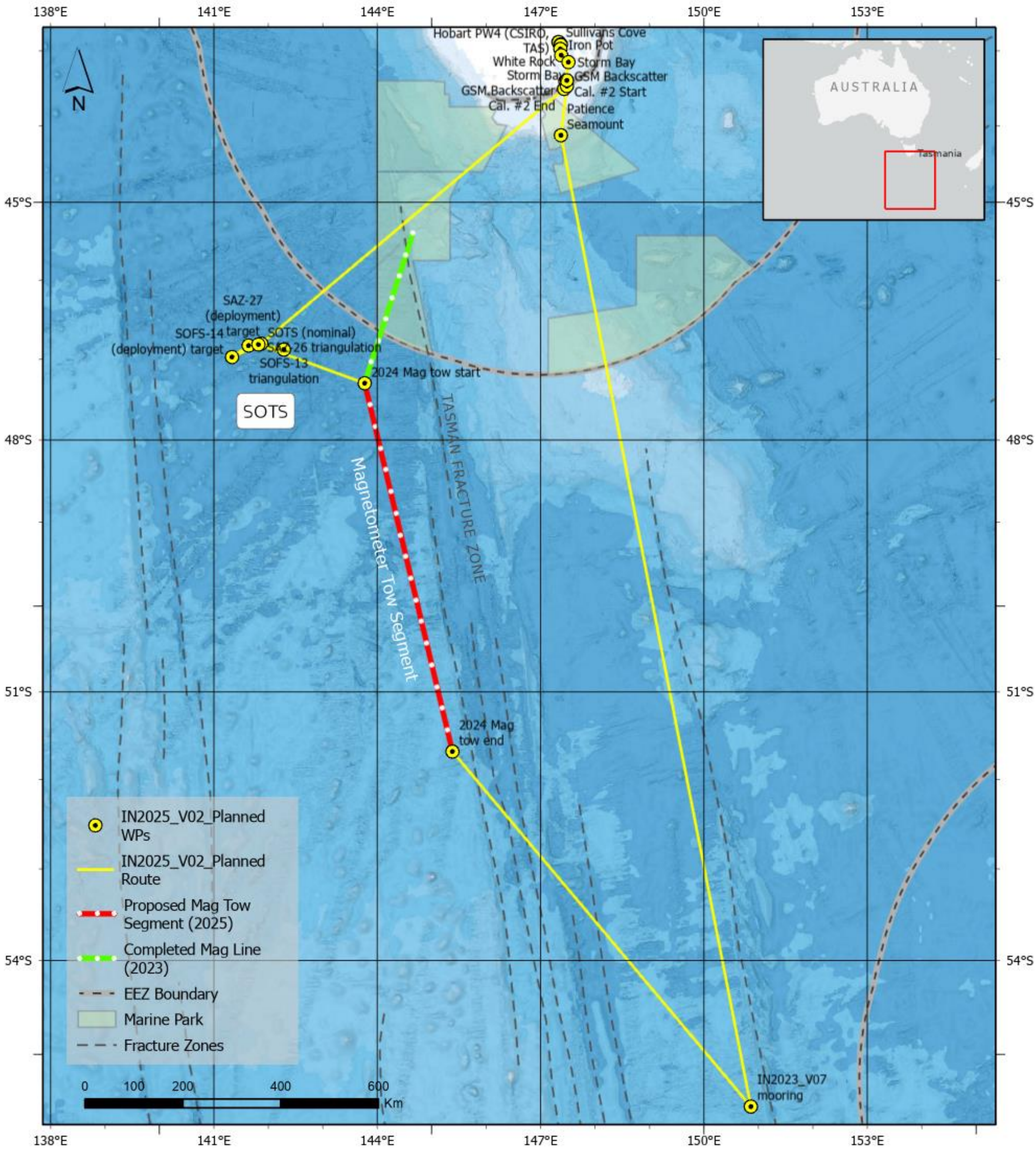
Note: The objectives listed above are not the priority ranking, because the list is designed for efficiency, using past voyage experience, to achieve all goals. In particular, deploying SOFS-14 as the first operation frees up deck space and increases efficiency. This sequence also optimises fatigue management (long day, spooling/rest day, short day, short day, long day), but is subject to change based on the weather conditions and other factors including the fatigue of the team.

The overall priority is successful SOTS moorings deployment, recovery, and collection of calibration/validation samples (SOTS objectives 1 – 6), followed by objective 7. After these, the objectives to support IN2020_V07 (8 and 9), are the next priority, with supplementary and piggyback project operations are prioritised lower, however careful consideration has been applied during planning and will be applied during voyage management at sea, in order to optimise timing of operations for maximum outcomes across all projects.

Activity plan for first 24-48 hours of voyage

Day	Date	Time	Activity
Wed	26 Mar	0800	Depart PW04
Wed	26 Mar	1000	In Adventure or Storm Bay, toolbox talk planning & testing: Moorings (Test fire/training Pneumatic Line Thrower), SOFS anchor lift
Wed	26 Mar	1300	Begin transit to the SOTS site (completing seagoing inductions, muster drill, voyage management team meeting and general voyage preparations)
Wed	26 Mar	1600	Perform Test CTD as soon as seawater is 1000m deep and then deploy CPR to tow down to SOTS

Voyage track example



Waypoints and stations

SITE	DEGREES DECIMAL MINUTES LATITUDE	DEGREES DECIMAL MINUTES LONGITUDE	DISTANCE (NM)	TOTAL DISTANCE (NM)	STEAMING TIME (HRS)	TOTAL STEAM (HRS)
Hobart PW4 (CSIRO, TAS)	42° 53.170' S	147° 20.320' E	0.0	0	0.0	0
Sullivans Cove	42° 53.026' S	147° 20.356' E	0.1	0.1	0.0	0.0
Battery Pt	42° 53.027' S	147° 20.701' E	0.3	0.4	0.1	0.1
Garrow	42° 54.872' S	147° 22.972' E	2.5	2.9	0.5	0.6
Hobart PBG	42° 55.411' S	147° 22.972' E	0.5	3.4	0.1	0.7
White Rock	42° 58.582' S	147° 22.499' E	3.2	6.6	0.3	1.0
Iron Pot	43° 03.687' S	147° 23.440' E	5.2	11.8	0.5	1.5
Storm Bay	43° 09.149' S	147° 31.376' E	8.0	19.7	0.8	2.3
GSM Backscatter Cal. #2 Start	43° 24.478' S	147° 27.939' E	15.5	35.3	1.6	3.9
GSM Backscatter Cal. #2 End	43° 30.632' S	147° 26.618' E	6.2	41.5	0.8	4.6
Patience Seamount *Piggyback to be completed on return trip	44° 07.458' S	147° 23.080' E	36.9	78.5	3.7	8.3
SOTS (nominal)	46° 48.200' S	141° 53.040' E	281.9	360.3	28.2	36.5
SOFS-14 (deployment) target	46° 58.320'S	141° 20.864'E	19.1	379.5	1.9	38.4
SAZ-27 (deployment) target	46° 49.662'S	141° 39.054'E	21.8	401.3	2.2	40.6
SOFS-13 triangulation	46° 52.691'S	142° 18.011'E	32.2	433.5	3.2	43.8
SAZ-26 triangulation	46° 48.884'S	141° 49.896'E	14.4	460.8	1.4	46.6
2024 Mag tow start	47° 17.913' S	143° 46.983' E	88.6	549.3	8.9	55.4
2024 Mag tow end	51° 40.999' S	145° 23.647' E	270.6	820.0	27.1	82.5
IN2023_V07 mooring	55° 32.544' S	150° 52.332' E	302.7	1122.7	30.3	112.8
GSM Calibration Line #3 END	43° 28.370' S	147° 29.713' E	736.3	1859.0	73.6	186.4
GSM Calibration Line #3 START	43° 23.824' S	147° 29.656' E	4.5	1863.6	0.6	187.0

SITE	DEGREES DECIMAL MINUTES LATITUDE	DEGREES DECIMAL MINUTES LONGITUDE	DISTANCE (NM)	TOTAL DISTANCE (NM)	STEAMING TIME (HRS)	TOTAL STEAM (HRS)
Storm Bay	43° 09.149' S	147° 31.376' E	14.7	1878.3	1.5	188.4

Time estimates

DATE	TIME	ACTIVITY
Wed 26	Mar	0800 – Depart PW04 1000 – In Adventure or Storm Bay, test the following: mooring anchor dual lift, CTD, … 1230 – 1300 Outbound: Calibrate backscatter of EM710 on GSM Line #2 @8kts 1300: Muster drill for all science party 1300 – Begin transit to SOTS (CTD when in water >1000 m deep). Deploy CPR following completion of 1000m CTD
Fri 28	Mar	0600: Arrive SOTS site (dependant on weather conditions) Deploy Jansen/Downie Float (nominally 47S, 142E) 0800-1200: SOTS CTD cast to 600m (pre-deployment calibration of SOFS-13 sensors) 1400: collect ship sensor observations close to SOFS-13 1630-1700: SOFS-14 Deployment Meeting 1900-2400: Ship drift assessment at SOFS-14 site
Sat 29	Mar	0400-0600 Reposition ship to SOFS-14 deployment start (~19 miles down-weather) 0645 SOTS: Toolbox on Bridge for SOFS-14 mooring deployment 0600-2000 SOTS: Deploy SOFS-14 mooring 2000-2400 SOTS: Triangulate SOFS-14 anchor, collect ship sensor observations close to SOFS-14
Sun 30	Mar	Rest/Spooling Day: Collect ship sensor observations close to SOFS-14 0800-1200: CTD Cast to 4550m (pre-deployment calibration of SAZ-27 sensors, SOTS sampling #1) 1000-1400: Spool on SAZ-27 1400-1600: recover Jansen/Downie Float with recovery scoop/net 1500-2300: ship sensor observations close to SOFS-14
Mon 31	Mar	0200-0600 SOTS: Transit to SAZ-27 deployment start (15 miles down-weather from target) 0645 SOTS: Toolbox on Bridge for SAZ-27 mooring deployment

DATE	TIME	ACTIVITY
		0600-1500 SOTS: Deploy SAZ-27 mooring 1500-1800 SOTS: Triangulate SAZ-27 anchor location
Tue 01	Apr	0400-0600 Transit to SAZ-26 recovery site (1 mile down-weather from anchor location) 0645 Toolbox on Bridge for SAZ-26 mooring recovery 0600-1800 Recover SAZ-26 mooring
Wed 02	Apr	0600-0800 SOTS: Transit to SOFS-13 site – ship mooring comparison and inspection of the SOFS-13 float 0800-1800 SOTS: Spool off SAZ-26 mooring – deck ops only 1000-1200 SOTS: Ship-buoy met comparison at SOFS-13 1200-1600 SOTS: CTD cast to 4000m (SOTS sampling #2) 1600-2200 SOTS: Ship-buoy met comparison at SOFS-13
Thu 03	Apr	0400-0600 SOTS: Transit to SOFS-13 recovery site (1 mile down-weather from surface float location) 0645 SOTS: Toolbox on Bridge for SOFS-13 mooring recovery 0600-2000: Recover SOFS-13 2000: Begin transit to magnetometer tow line (clear deck, and spool off SOFS-13 while underway)
Fri 04/Sat 05	Apr	Magnetometer tow, deploy drifters (nominal site 55S, 150E)
Sun 10	Apr	0400-0600 Transit to ACC-SWOT recovery site (1 mile down-weather from anchor location) 0645 Toolbox on Bridge for ACC-SWOT mooring recovery 0600-1800 Recover ACC-SWOT mooring 2000 – 2400 CTD cast at ACC-SWOT site; deployment of BoM drifters, deployment of Argo Float
Mon 11	Apr	CTD cast 600 m (post-recovery calibration of SOFS/SAZ/ACC-SWOT sensors); begin transit to Hobart
Tue 12	Apr	Transit
Wed 13	Apr	Arrive Hobart (via Patience Seamount to complete Scoulding project)
Thu 14	Apr	Bad weather allowance
Fri 15	Apr	Bad weather allowance
Wed 16	Apr	Bad weather allowance

CTD Configuration

	PLEASE SELECT:
Fundamentals	
Which CTD rosette to be used for this voyage (24 or 36 Niskin bottles):	36
Likely total number of casts:	6
Likely maximum depth of deepest cast:	4550 m
Standard CTD Configuration - Instrumentation (maximum 6 auxiliary channels plus 2 x DO) 6000m	
1 x SBE9+ (CTD) 2 x SBE3P Temperature Sensors 2 x SBE4C Conductivity Sensors 2 x SBE5T pumps	Yes
2 x SBE43 Dissolved Oxygen Sensors	Yes
1 x Tritech PA200/500 Altimeter	Yes
1 x Biospherical QCP2300HP PAR Sensor	Yes
1 x Wetlabs C-Star 25cm Transmissometer	Yes
1 x Wetlabs ECO FLCDRTD Fluorometer – CDOM (370/460nm)	No
1 x Wetlabs ECO FLBBRTD Fluorometer – Chlorophyll-a & Backscatter (2 x channels - 470/695nm)	Yes
Alternative Instruments (Instruments highlighted in grey can be substituted from standard configuration)	
Seapoint Turbidity Meter – Nephelometer	
Chelsea Aquatracka III (430/685nm) Fluorometer – Chlorophyll-a	
Seabird SUNA – Ultraviolet Nitrate Analyzer (**Serial Connection - 2000m**)	
Standard LADCP Configuration – Instrumentation: 6000m	
1 x Teledyne 300 kHz LADCP (Slave - Up) 1 x Teledyne 150 kHz LADCP (Master - Down) 1 x 48V Deep Sea Battery	No
Alternative LADCP Configuration - Instrumentation: 6000m	
1 x Teledyne 300 kHz LADCP (Slave - Up) 1 x Teledyne 300 kHz LADCP (Master - Down) 1 x 48V Deep Sea Battery	No
Hydrochemistry Analyses	
Salinity	Yes
Dissolved Oxygen	Yes
Nutrients: Nitrate	Yes
Nutrients: Phosphate	Yes
Nutrients: Silicate	Yes
Nutrients: Nitrite	Yes

	PLEASE SELECT:
Nutrients: Ammonia	No

Piggyback projects

1. Monitoring the recovery of a globally unique deep-sea eel aggregation in the Huon Marine Park

Principle Investigator: Ben Scoulding

This piggyback project supports a CSIRO project funded by the Director of National Parks, entitled 'Recovery of deep-sea fish aggregations in marine parks: Key Natural Values quantitatively monitored under Parks Australia's MERI program'. It is a repeat of the successful Piggyback projects conducted on IN2023_V03 and IN2024_V02. We aim to conduct a short acoustic survey of Patience Seamount within the 'Huon' Marine Park (Huon MP) south of Tasmania. The Huon MP has been identified as the only known location of a spawning aggregation of the basketwork eel, *Diastobranchus capensis* – a globally distributed and ecologically important deep-sea species. As such it represents a key natural value in Australia – one with a hypothesised trajectory of 'improving status' following decades long impact from bottom trawling before the Huon MP was established. The spatial concentration of eels in the aggregation (~2-3 km^2) and their high acoustic reflectivity are highly attractive characteristics that will enable the aggregation to be measured quantitatively with a hydroacoustic sensor (echosounder) and with very little further extractive sampling. In addition to the acoustic survey of Patience Seamount we will deploy MNFs deep-water towed camera into the eel aggregation on Patience Seamount. The camera platform gives real-time video through a fibre-optic cable allowing a consistent height above the seabed to be maintained and has been successfully used to survey the aggregation in the past (IN2018_V06 and IN2024_V02). Stereo camera measurements will allow measures of fish length and orientation while providing a census of species. Concurrent operation of the RV *Investigator*'s EK80s echosounders during the deployment of the deep-water towed camera platform can identify the aggregations to be targeted.

Objectives
1. Conduct a pre-defined (see Table and Figure below) acoustic survey of Patience Seamount within the Huon Marine Park.
2. Validate acoustic observations by deploying MNFs deep-water towed camera (DTC) into the eel aggregation on Patience Seamount.
3. Collect in situ target strength measurements (the amount of sound reflected by individual fish) from an autonomous echosounders fitted to the DTC.

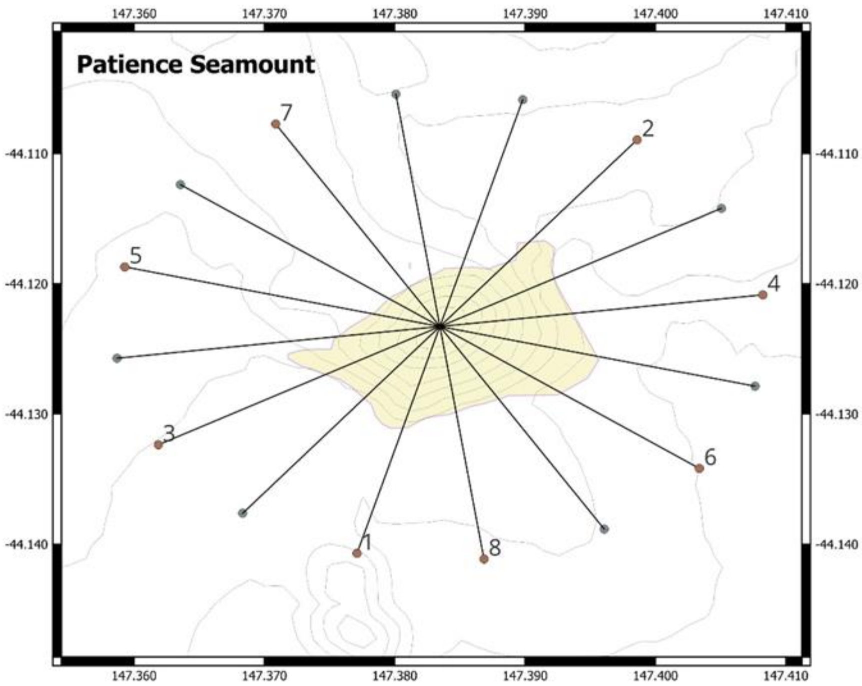
Plan
The objectives will be achieved by remotely supporting the MNF teams (GSM/SIT) onboard the RV Investigator (i.e. an onshore scientist will support MNF in real-time during the voyage). We will work closely with MNF staff prior to, and during the voyage. Pre-defined acoustic transects will be provided to GSM and acoustic data will be collected following IMOS protocols with the vessel travelling at 10 knots. Acoustic data will be collected using the RVIs hull mounted EK80 echosounders, operating at 18 and 38 kHz only.

To the best of our ability, we will provide pre-defined tow lines for the DTC based on existing MBES data (done in consultation with the SIT team) before the voyage, however, the exact lines may differ depending on the precise location of the aggregation. To support the collection of in situ target strength measurements we would work closely with the SIT team to install an autonomous echosounder on the DTC. This is a repeat of the deployments conducted during IN2024_V02.

The hydroacoustic survey of Patience Seamount requires approx. 10 hours dedicated ship time (4 hours to complete the acoustic survey and 6 hours for camera operations) and is approx. a 30 nmi detour from the usual route taken to SOTS.

The hydroacoustic survey of Patience Seamount will be conducted on the return leg from SOTS to Hobart and can be conducted day or night.

Transect	Start_lon	Start_lat	End_lon	End_lat
1	147.3898	-44.1059	147.3771	-44.1407
2	147.3683	-44.1376	147.3986	-44.1089
3	147.405	-44.1142	147.3619	-44.1324
4	147.3587	-44.1257	147.4082	-44.1208
5	147.4076	-44.1279	147.3593	-44.1187
6	147.3636	-44.1124	147.4034	-44.1342
7	147.3961	-44.1388	147.3709	-44.1077
8	147.3801	-44.1054	147.3868	-44.1411



2. Evolution of the Seafloor of the Australian-Antarctic Southern Ocean

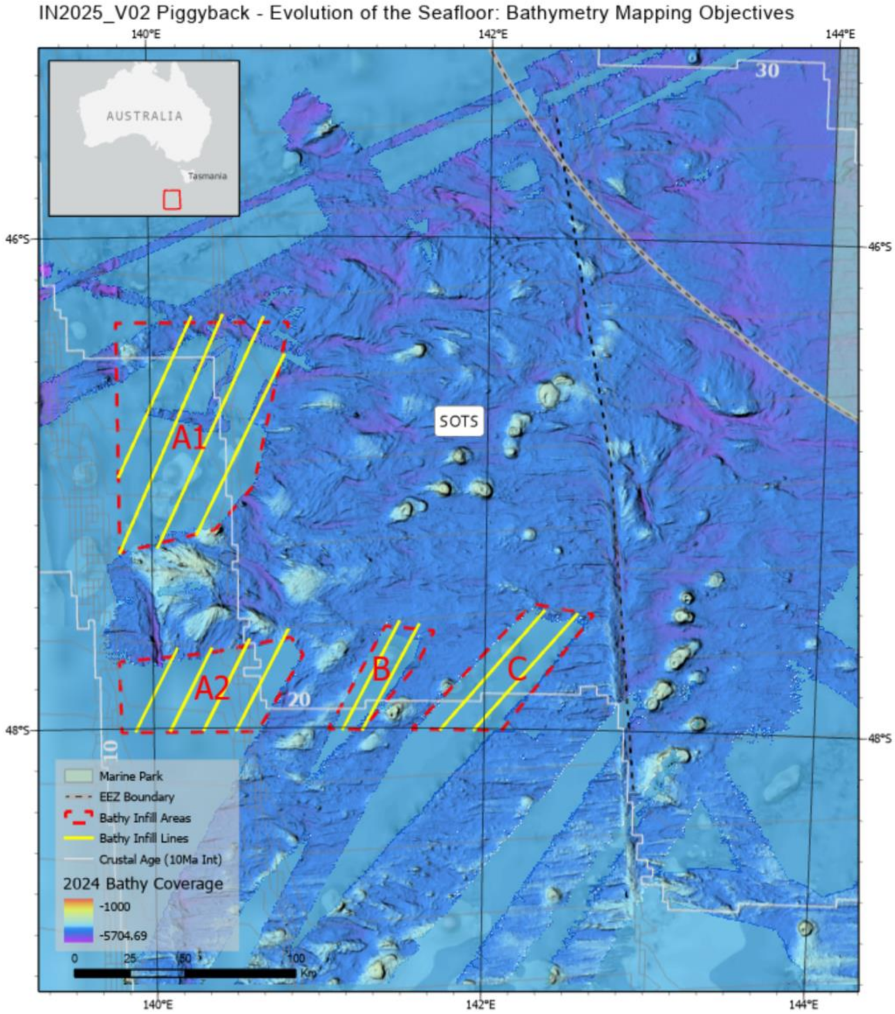
Principle Investigator: Philippe Vandenbossche

There are two primary objectives that will augment existing data in support of this research. Their priority is as follows:

1. Acquire towed magnetometer data between ~47.3°S, 143.78°E and ~51.7°S, 145.4°E (as illustrated on the planned voyage route map). This will cover an estimated seafloor age range of ~24 Ma to 10 Ma. Since no physical rock dating is known to exist in the study area, magnetic data will provide valuable indicative ages of the seafloor crust across this region of the Southern Ocean. The 2025 magnetometer transect is planned to be a continuation of the previously acquired data in 2023, and is estimated to extend ~271 nautical miles in a SSE direction from the previous line. Since no data was acquired in 2024, it remains the highest priority for this project in 2025.
2. Acquire multibeam bathymetry data in areas previously unmapped. Areas to primarily target lie to the west and south of the SOTS site as illustrated by areas A1, A2, B & C on the map below. This will extend the seafloor mapping coverage in the region, thereby providing valuable new bathymetry data that will be used to analyse the seafloor morphology and tectonic fabric (and contribute to the International Seabed 2030 initiative).

Fit with voyage plan

While the magnetometer towing is expected to form part of the transit there is expected to be a course deviation to achieve this (see planned voyage track above). The priority magnetometer survey line (indicated by the red and white dashed line on the voyage map) is estimated to add a transit deviation from the proposed track of 75 Km (or 40 NM), thus adding ~4 hours (at 10 knots) or ~6 hours with deployment and recovery. Multibeam mapping is divided into areas and can be targeted for periods when time in the schedule allows.



Map illustrating the bathymetry mapping objectives (areas A1, A2, B & C)

3. Southern Ocean Winter Cloud Interactions processes (SOWCLIP):

Principal Investigator: Alain Protat

Cloud microphysical properties produced from the competition between supercooled liquid and ice particles for water vapour in subfreezing cumulus clouds over the Southern Ocean and off the coast of Antarctica have been directly linked to errors in absorbed solar radiation at the sea surface, which have been further linked to uncertainty in predicting global climate sensitivity under CO2 warming and sea surface temperature biases in climate models.

Strikingly, the latest climate simulations using improved knowledge gained on the frequency of occurrence of supercooled liquid water from earlier voyages (IN2015_V02, IN2016_V02, IN2018_V01, IN2018_V02, IN2022_V03, IN2023_V03) indicate the existence of two distinct large surface shortwave radiation biases of opposite sign north or south of about 55°S latitude. From the IN2018_V01 and most recent IN2024_V01 observations collected closer to the coast of Antarctica, we have gathered evidence that emissions of aerosol precursors from over Antarctica produce very high concentrations of aerosols and different cloud properties from further north and from when air masses bring pristine air from the open ocean. However, our number of samples remain quite limited to draw statistically significant conclusions. Past voyages have further revealed a change in the thermodynamic profile of the atmosphere across the 55°S latitude, i.e., the

Antarctic Ocean polar front. At high latitudes the upper air soundings reveal that the free troposphere has a greater relative humidity supporting multiple cloud layers. The surface heat fluxes also vary strongly across this divide with suppressed sensible and latent heat fluxes across the high latitudes.

Our main objective is to collect a suite of aerosol, cloud, surface radiation and precipitation observations during IN2025_V02. This new dataset will be combined with the existing ones collected in the period 2016 - 2024 to continue to build a comprehensive understanding of the relationship between ocean productivity, aerosol formation, cloud microphysics, cloud dynamics, and link that understanding to rainfall properties and surface radiation. If at all possible, we would like to contribute to the early calibration effort of the cloud radar and lidar launched in space as part of the European Space Agency EarthCARE mission by collecting cloud radar – lidar and precipitation observations under the satellite track. We will use orbital predictions to identify potential opportunities without interfering with the SOTS operations.

We will launch radiosondes with an expected frequency of twice a day (with an option to add one more in interesting situations pending confirmation of budget). If suitable for the SOTS and ship crew, we'd suggest 8am / 8 pm local time as preferred launch times.

4. Profiling Echosounder

Principle Investigator: Pete Jansen

Deployment and recovery of profiling echo sounder, attached to profiling float.

The open ocean provides ecosystem services of global importance. Our ability to make robust decisions to sustain the provision of these services in the face of environmental change and changing human pressures relies, in large part, on knowledge of ecosystem status and trends. Mesopelagic micronekton are increasingly appreciated as playing pivotal roles in ocean ecosystems but also remain a key area of uncertainty in current understanding of ocean ecosystem structure and function, with current global biomass estimates varying by a factor of 10 (1-18 Gt), due to a lack of information globally. Here we aim to address this knowledge gap by integrating commercially available, battery-powered, broadband, multi-channel echosounders into profiling floats, equivalent to Argo floats. To autonomously characterise the community composition and numerical abundance of mesopelagic micronekton. This will significantly advance conventional observational- methods (nets and satellites) that are unable to provide the synoptic view of micronekton dynamics at relevant temporal and spatial scales.

- Deploy profiling float weighing 50-70kg from A-frame using release line.
- Recovery of float from sea using recovering net from coring boom

Deployment plan:

Deployment on the 30th of March would work with mooring work, 1-7 day deployment would be good, deployment day or night ok, recovery would best duing daylight hours. Profiler has gps tracking which will be available to negotiate pickup.

Deployment of equipment on shallow CTD would be an advantage but not essential.

5. Natural Iron Fertilisation of the Southern Ocean: Linking terrestrial dust and bushfires to marine biogeochemistry

Principle Investigator: Andrew Bowie

This project will extend an integrated ship-based atmospheric observational program on RV Investigator that has been in operation on voyages in the Southern Ocean south of Australia since 2016. Shipboard observational data acquired in this project on the trace element composition of aerosol particles will be combined with ongoing land-based time-series measurements led by the Project PI, to support research to quantify the importance of the deposition of iron-rich aerosols from Australia into surface ocean waters and how they impact marine biogeochemistry and ocean ecosystem health. The project will sample and conduct experiments on atmospheric particles containing terrestrial dust and bushfire smoke that are transported south from Australia to the Southern Ocean. The observational data from this project will be shared with atmospheric and ocean modelling colleagues in Japan and the United Kingdom to optimise model predictions of the land–atmosphere–ocean iron cycle in the Southern Ocean using new parameterisations normalised for contemporary southern hemisphere conditions.

Project outputs include provision of the critical information on atmospheric iron deposition for ocean fertility and health, providing the science for predicting a key factor in the future impact of the oceans on climate. Project outcomes include provision of a scientific basis for managing the complex role of iron in sustaining marine ecosystem biodiversity and for informing government policy on ocean fertilisation as a carbon mitigation strategy.

The application supports the training and research of a postgraduate student from IMAS-UTAS.

This project will make use of the state-of-the-art atmospheric science capabilities on the RV Investigator. We will install an aerosol sampling system for the clean collection of particles in the ship's aerosol lab. This system consists of vacuum pumps, flow meters and in-line filtration systems. The manifold is connected to air intake lines fed from the sampling nozzle located ~10 m above sea level on the foremast at the bow of the vessel.

Samples will be collected on Whatman-41 filters which are suitable for different analytical needs. Filters will be changed approximately every 1-2 days, depending on the aerosol loading, flow rates and amount of time the air inlet is in a suitable 'clean' air sector and sampling takes place. The sector sampling switch records the date/times and waypoints when the wind is 'in sector'. A range of procedural and field exposure blanks will also be collected at sea. Sampled filters will be stored frozen and returned to the shore-based laboratory for further experiments and analyses. We will also opportunistically collect event-based clean rainwater samples using a polyethylene funnel and collection bottle when conditions allow, to quantify the trace metal deposition in the 'bulk' and 'wet' fractions.

6. Quantifying Dust Fluxes in the Southern Ocean Time Series using Thorium Isotopes in Seawater

Principle Investigator: George Rowland

This project aims to quantify the flux of mineral dust and associated nutrients supplied to the Southern Ocean using measurements of thorium in seawater. One isotope (^{232}Th) traces dust, while another (^{230}Th) is a time-keeper. The data will be used to assess agreement between different methods of dust flux estimation, including sediment traps and dust deposition models (which are associated with large uncertainties).

Extending a time series of thorium samples collected at the SOTS site will provide us with samples from five of eight years (2018–2025), allowing us to create a modern baseline dust flux estimate for the site and to test assumptions about thorium's geochemistry. Few data exist to investigate annual-multiannual changes in thorium concentrations: using this time series we can test whether estimates of thorium residence time, and therefore dust flux, are accurate. Comparing these recent annual-multiannual samples to legacy samples (from 1997) will also allow decadal scale differences in dust and thorium to be assessed. These research questions can be summarised as follows:

1. What is the magnitude of dust (and trace metal) flux to the SOTS site and ACC-SWOT sites and how does this vary over annual and decadal timescales?
2. How well do different measures of dust flux agree at the SOTS site?
3. Are changes in thorium concentrations consistent with residence time estimates?

Using low-contamination methods we will analyse 5–10 L of seawater per sample collected from the CTD rosette, quantifying dust fluxes through the whole water column, with a particular focus on resolving details in the upper ocean.

Logistics:

This project requires 10–15 samples of filtered seawater for a full-depth profile, collected from the (36 bottle) CTD rosette. 5–10 L of water per sample is required because thorium isotopes are ~10^{-15}–10^{-18} g/g in seawater. The upper water column will record more recent dust inputs and will be sampled at a higher resolution using 10 L samples (due to lower concentrations). A full-depth profile will thus require 75–100 L from 10–15 bottles from the water budget.

Filtered seawater will be acidified to pH < 1.8 using ~12–24 ml 10 M distilled hydrochloric acid (produced in the IMAS clean laboratory). The acidification will be conducted in a laboratory space suitable for handling acids, preferably with a laminar flow hood.

Permits

This voyage may or expects to traverse through the following Marine Parks:

- Tasman Fracture Marine Park
- Huon Marine Park

No operations are planned, except for approved underway science deployments/systems as per the following permits. An assessment of unplanned deployments (e.g. XBTs) is to be carried out onboard before commencing any operations.

  - Southwest Marine Parks: PA2020-00041-2 (variation PA2020-00041-8)
  - Southeast Marine Parks: PA2020-00041-1 (variation PA2020-00041-7)

Both permits preclude echosounders or other activities that may take, keep, move or interfere with a cetacean. Must act consistently with Part 8 of EPBC Regs 2000 for cetacean and whale watching approach distances and precautionary zones. Must not travel greater than 10 knots when cetaceans are likely to be present.

Other

- AAPP permit for import of samples – Permit 0008136576
- University of Tasmania permit for import of samples – Permit 0008684946

Signature

Your name	Elizabeth H. Shadwick
Title	Chief Scientist
Signature	
Date:	19 March 2025

List of additional figures and documents

a. Appendix A MNF Equipment

b. Appendix B User Supplied Equipment

c. Appendix C Hazardous Materials Manifest

Appendix A

Scientific equipment and facilities provided by the Marine National Facility

Some equipment items on the list may not be available at the time of sailing. Applicants will be notified directly of any changes. Indicate what equipment and facilities you require from the Marine National Facility by placing an **X** in the relevant box.

STANDARD LABORATORIES AND FACILITIES		
NAME	**REQUIRED**	**NOTES/COMMENTS**
Aerosol Sampling Lab	X	• Please indicate the intended activity in this lab
Air Chemistry Lab	X	• Please indicate the intended activity in this lab
Preservation Lab		• Please indicate the intended activity in this lab
Constant Temperature Lab (Min temp: ~4°C / Max temp ~35°C)		• Please indicate the intended activity in this lab • Please indicate the required setpoint temperature
Underway Seawater Analysis Laboratory		• Please indicate the intended activity in this lab
GP Wet Lab (Dirty)		• Please indicate the intended activity in this lab
GP Wet Lab (Clean)		• Please indicate the intended activity in this lab
GP Dry Lab (Clean)		• Please indicate the intended activity in this lab
Sheltered Science Area		• Please indicate the intended activity in this area
Observation Deck 07 Level		• Please indicate the intended activity in this area
Internal Freezer (Dirty Wet lab) (Min temp -25°C / Max temp 0°C) Volume: >20m^3		• Please indicate the intended activity in this area • Please indicate the required setpoint temperature
Clean Freezer (Dirty Wet lab) (Min temp -25°C / Max temp 0°C) Volume: >2.5m^3 Co-located within the Internal freezer and separated by a door		• Please indicate the intended activity in this area • Please indicate the required setpoint temperature
Blast Freezer (Dirty Wet lab) (Min temp -30°C / Max temp 0°C) Internal volume >1.5m^3 Capable of reducing the temperature of 150kg of water from +20C to -30C in one hour.		• Please indicate the intended activity in this area • Please indicate the required setpoint temperature
Cool Room (Dirty Wet lab) (Min temp 0°C / Max temp 10°C)		• Please indicate the intended activity in this area • Please indicate the required setpoint temperature

STANDARD LABORATORIES AND FACILITIES		
NAME	**REQUIRED**	**NOTES/COMMENTS**
Ultra-Low Temperature Freezers x2 (Main Deck) Min temp -80°C / Max temp -80°C)		• Please indicate the intended activity in this area
YODA Freezers (x2) (Clean Dry lab) (Min temp -20°C / Max temp 10°C)		• Please specify if both or only one are needed • Please indicate the intended activity in this area • Please indicate the required setpoint temperature

STANDARD SAMPLING EQUIPMENT			
NAME	**ESSENTIAL**	**DESIRABLE**	**NOTES/COMMENTS**
Continuous Plankton Recorder (CPR)	X		*note: Use of this item must be flagged with the relevant CSIRO Oceans & Atmosphere team responsible for CPR cassette preparation and sample processing. Please discuss your planned CPR use with your VDC, who will assist in liaising with the CPR team.

SPECIALISED SAMPLING EQUIPMENT			
NAME	**ESSENTIAL**	**DESIRABLE**	**NOTES/COMMENTS** **(THESE ITEMS MAY REQUIRE ADDITIONAL MNF SUPPORT STAFF)**
TRIAXUS – Underway Profiling CTD			Triaxus is a pilotable towed vehicle capable of carrying a variety of instrumentation. Constant depth towing or undulating profiles (e.g. cyclic depth pattern from the surface to 200m) are possible. Towing speed depends on the tow profile, instrumentation payload and prevailing conditions. Typically, undulations from the surface to 200m are possible at 8knt, with slower speeds for deeper profiles and faster for constant-depth towing. Maximum achievable depth typically 300m to a distance of approximately 1.5km from the ship. Triaxus is normally configured with the following sensors as a minimum: • Dual temperature, conductivity and dissolved oxygen (SBE9plus and dual pumped

SPECIALISED SAMPLING EQUIPMENT			
NAME	ESSENTIAL	DESIRABLE	NOTES/COMMENTS (THESE ITEMS MAY REQUIRE ADDITIONAL MNF SUPPORT STAFF)
			temperature/conductivity/dissolved oxygen circuits) • PAR • Chlorophyll-A, CDROM, optical backscatter (Eco-triplet – 2000m Max) • Plankton counter (Laser Optical Plankton Counter) • Transmissometer Contact MNF for further details on other instrumentation and capability.
Desired towing profile:			
Additional instrumentation: (please supply, make and model and datasheets and a contact person for discussion on integration)			
Piston Coring System			
Gravity Coring System			
Multi Corer			
Kasten Corer			
Smith Mac Grab			
Rock Dredges			
Rock Saw			Requires trained science personnel
Seaspy Magnetometer	X		
Portable Pot Hauler			
Equipment to measure seawater sound velocity/CTD:			
XBT System	X		2 per day provided
Valeport Rapid SV			
Valeport Rapid CTD			
Valeport SVX2		X	

SPECIALISED SAMPLING EQUIPMENT			
NAME	ESSENTIAL	DESIRABLE	NOTES/COMMENTS (THESE ITEMS MAY REQUIRE ADDITIONAL MNF SUPPORT STAFF)
Trace Metal Rosette and Bottles			
Trace Metal In-situ Pumps (x6)			• See non-MNF owned section below for additional 2 units. • Science team to organise and pay for battery packs for this system (+ spare). • They can be sourced through a supplier such as 'Batteryworld Hobart' (Graham Cowie, 03 6272 3900) who has made these previously. • The science teams need to calculate how long they will be deployed and bring enough batteries to cover their deployment times. They are rated to 30 Amp hours, which equals to 36,000 litres of sea water being filtered.
Deep Towed Camera	X		
Drop Camera			
Sherman Epibenthic Sled			Stern ramp must be removed to operate this system.
Brenke Sled			
Hydro-Bios MultiNet (Mammoth) (1m x 1m) *(has replaced the EZ net)*			Please specify 100-micron, 335-micron, or 500-micron mesh Can be used in a vertical or horizontal operations
Surface Net (1m x 1m)			Please specify 335-micron, 500-micron, or 1,000-micron mesh
Bongo Net			750mm frame, 500-micron mesh net and 335-micron cod end
Beam Trawl			
MIDOC			Multiple opening/closing net system with cod ends- suitable for pelagic trawls
Pelagic Trawl System (net, doors)			Contact MNF to discuss net and mesh dimensions
Demersal Trawl System (net, doors)			Contact MNF to discuss net and mesh dimensions
RMT-8 (Rectangular Midwater Trawl)			8m2 mouth area Tow speed ≤2 knots

SPECIALISED SAMPLING EQUIPMENT			
NAME	ESSENTIAL	DESIRABLE	NOTES/COMMENTS (THESE ITEMS MAY REQUIRE ADDITIONAL MNF SUPPORT STAFF)
Utilises a single warp so can be deployed on the general-purpose towing wire in self-contained mode. Must be deployed with stern ramp covered.			
RMT-16 (Rectangular Midwater Trawl) Utilises a single warp so can be deployed on the general-purpose towing wire in self-contained mode. Must be deployed with stern ramp covered.			16m2 mouth area Tow speed ≤2 knots
Trawl Monitoring Instrumentation (ITI) (2,000m depth limit)			MNF to identify this need, dependent on pelagic or demersal trawling requirement
Stern ramp	EXPOSED	INSTALLED	MNF to identify this requirement

RESEARCH SUPPORT INFRASTRUCTURE			
NAME	ESSENTIAL	DESIRABLE	NOTES/COMMENTS
Saltwater Ice Machine (Dirty Wet lab)			
Radiosonde Receiver System	X		
Laboratory Incubators (Clean Dry lab)			
Deck Incubators			Temperature controlled deck incubators
Milli-Q System			
Sonardyne USBL System			
Float/Glider Recovery Net	X		Pete Janssen piggyback

Underway systems

ACOUSTIC UNDERWAY SYSTEMS			
NAME	ESSENTIAL	DESIRABLE	NOTES/COMMENTS
75kHz ADCP			

ACOUSTIC UNDERWAY SYSTEMS			
NAME	**ESSENTIAL**	**DESIRABLE**	**NOTES/COMMENTS**
150kHz ADCP			
Multi Beam Echo Sounder EM2040-MKII 200-700kHz (0 – 250m approx.)			
Multi Beam Echo Sounder EM124 12kHz (100m to full ocean depth)	X		
Multi Beam Echo Sounder EM712 70-100kHz (0 – 1000-m approx.)	X		
Sub-Bottom Profiler SBP29	X		
Scientific Narrowband/Broadband Echo Sounders EK80 (6 bands, 18kHz - -333kHz)	X		EK80s will be used in narrowband mode unless otherwise requested Quantitative measurements from scientific echosounders requires sphere calibration in the watermass of sampling
Multibeam Scientific Echo Sounder ME70 (70 - 100 kHz)			
Omnidirectional Echo Sounder SH90			
Gravity Meter		X	

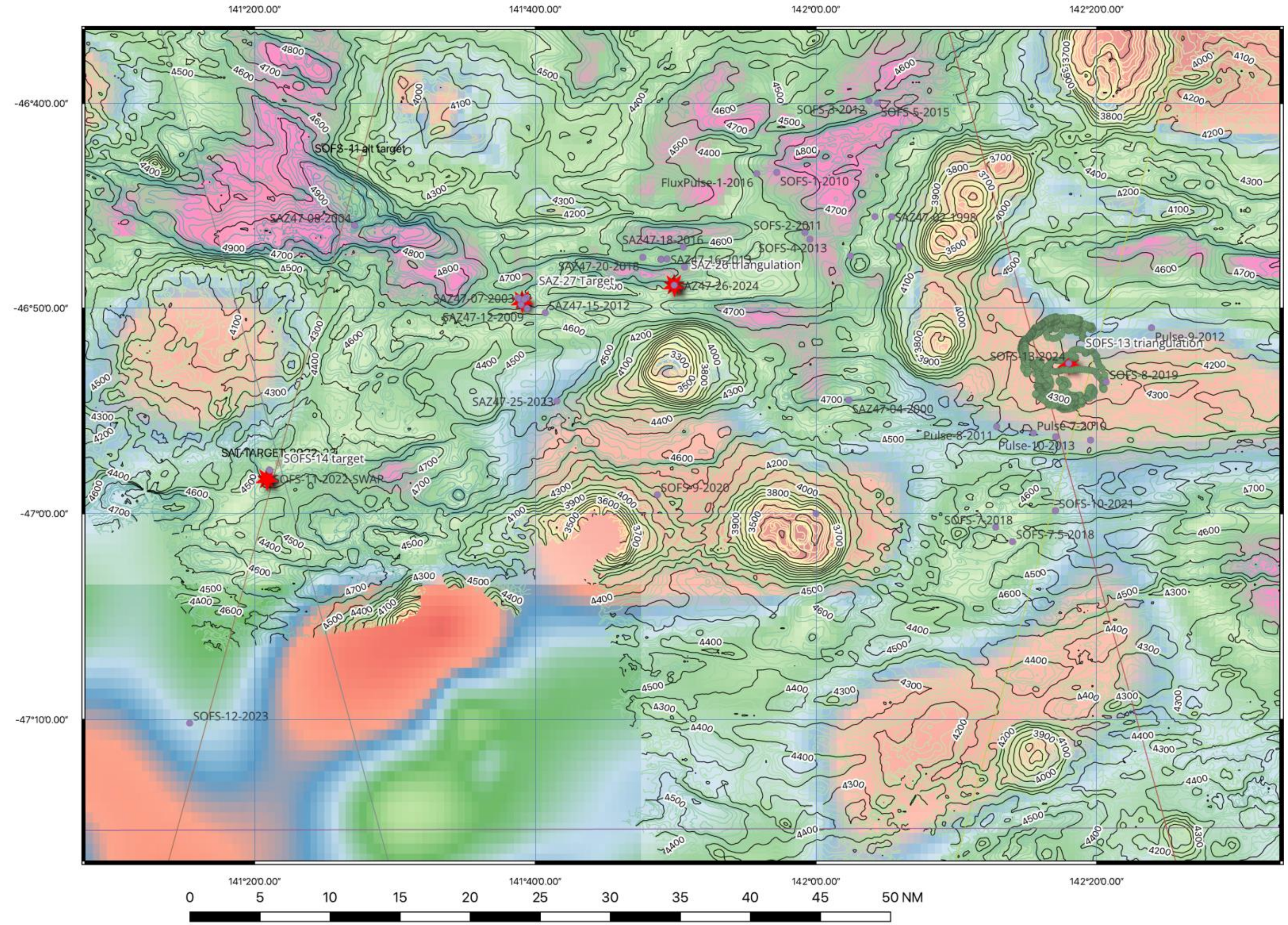
ATMOSPHERIC UNDERWAY SENSORS			
NAME	**ESSENTIAL**	**DESIRABLE**	**NOTES/COMMENTS**
Nephelometer	X		
Multi Angle Absorption Photometer (MAAP)	X		
Scanning Mobility Particle Sizer (SMPS)	X		
Radon Detector	X		
Ozone Detector	X		
Condensation Particle Counter (CPC)	X		
Picarro Spectrometer (analysis of CO_2/CH_4/H_2O)	X		

ATMOSPHERIC UNDERWAY SENSORS			
NAME	**ESSENTIAL**	**DESIRABLE**	**NOTES/COMMENTS**
Aerodyne Spectrometer (analysis of $N_2O/CO/H_2O$)	X		
Cloud Condensation Nuclei (CCN)	X		
Polarimetric Weather Radar	X		
Filter Aerosol Sampling units (FAS) x 3			Used for collecting physical aerosol samples on filters. FAS includes pumps, filter holders, flow controllers, totalizer, Very Sharp Cut Cyclone (VSCC) PM1 and PM2.5. • User to specify how many units are required (maximum 3 supplied by MNF). • User to provide own filters. • User to outline sampling requirements with MNF Seagoing Instrumentation Team (SIT) i.e. ship exhaust sample avoidance etc.

UNDERWAY SEAWATER SYSTEMS AND INSTRUMENTATION			
NAME	**ESSENTIAL**	**DESIRABLE**	**NOTES/COMMENTS**
Thermosalinograph			
Fluorometer			
Optode			
pCO2			

SEAWATER SYSTEMS			
NAME	**ESSENTIAL**	**DESIRABLE**	**NOTES/COMMENTS**
Trace metal clean seawater supply			
Scientific clean seawater supplied to laboratories			
Raw seawater available on deck and in laboratories			

Appendix A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141°40'0.00"
142°0'0.00"
142°20'0.00"
-46°40'0.00"
-46°50'0.00"
-47°0'0.00"
-47°10'0.00"
SOFS-11 alt target
SAZ47-08-2004
SOFS-3-2012
SOFS-5-2015
FluxPulse-1-2016
SOFS-1-2010
SOFS-2-2011
SOFS-4-2013
SAZ47-02-1998
SAZ47-18-2016
SAZ47-16-2019
SAZ-26 triangulation
SAZ47-20-2018
SAZ-27 Target
SAZ47-26-2024
SAZ47-07-2003
SAZ47-15-2012
SAZ47-12-2009
SOFS-13 triangulation
Pulse-9-2012
SOFS-13-2024
SOFS-8-2019
SAZ47-25-2023
SAZ47-04-2000
Pulse-8-2011
Pulse-7-2010
Pulse-10-2013
SOFS-14 target
SOFS-11-2022-SWAP
SOFS-9-2020
SOFS-10-2021
SOFS-7-2018
SOFS-7.5-2018
SOFS-12-2023
0 5 10 15 20 25 30 35 40 45 50 NM

Appendix B

User Supplied Equipment

Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	6 x sofs wire spools, 4 x saz rope spools	1200kg		Main deck
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	hydraulic feeder	250kg	150W x 60D x 160H cm	main Deck
Bureau of Meteorology	Alain Protat 0435 256 261 alain.protat@bom.gov.au	SOWCLIP	BASTA - 95 GHz cloud radar	~60 kg	(LxWxH) 70x40x70cm	(LxWxH) 120x70x100cm
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	Bullhorn mooring fairlead	100 kg	1m	Main deck
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	Mooring winch	1.5 tonne	2x1x1.5 m	Main deck / Sheltered Science Area
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	Half height open top moorings container	5 tonnes	20ft	Main deck
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	SOFS float and recovery cradle	2.5 tonnes	3x3 m	Main deck

Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	Mooring anchor stacks x 2	3 tonne and 2 tonne	3x1 m	Main deck
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	Full height container for storing and working on sediment traps	4.5 tonnes	20ft	Main deck
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	3 cage pallets of mooring equipment	500kg per cage 3 tonnes total	1 x 2 m each	Main deck
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	Deck mounted pneumatic line thrower (grappling gun)	50 kg	0.5 m	ESC 1
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	Acoustic release deck unit	5kg	0.5 m2	Operations Room
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	Hydraulic High Pressure Unit (HPU)	850kg	approx 120W x 100D x 140H (cm)	Sheltered workshop
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	2 x Air Spoolers, 1 x brake spooler	100kg each	approx 120W x 120D x 100H (cm)	Main deck secured to half height
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	tranisition box	300kg	150W x 150D x 100H cm	main deck
Elizabeth Shadwick / CSIRO moorings	**Jim La Duke** James.Laduke@csiro.au	Southern Ocean Time Series	Releases for SOFS / SAZ + spare	100KG.	120W x 70D x 40H cm	Main Deck

Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	1 pallet of blocks	400Kg	110W x 110D x 50H cm	Main deck
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	1 cage for gear	250kg		wet lab
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	5 x pallets for hydra- floats SWOT mooring	170kg each	120W x 220D x 40H cm	Main deck
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	2 tether cages	1740Kg	110W x 180D x 220H cm	Main deck
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	1 SAZ 45" ADCP float and frame	300kg	240w x 120D x 96H cm	Main deck
University of Utah	Jay Mace Jay.Mace@utah.edu	SOWCLIP	23 and 31 GHz Microwave Radiometer	~30 kg	(LxWxH) 100x25x25cm	Deck 5 railing
Colorado State University	Jessie Creamean	SOWCLIP	INP filter	Filter unit: ~300-400 g Rain hat: ~500 g Mass flow meter (MFM): 230 g Pump: 7.3 kg	Filter unit: 5.7 Ø ×16.2 cm Rain hat: ~40 Ø ×50 cm MFM: 181 x 70 x 51 mm Pump: 24 x 18 x 14 cm	Deck 5 (suggested)
Colorado State University	Jessie Creamean	SOWCLIP	DNA filter	SASS sampler: 3 kg Rain hat: ~500 g Tripod: ~2 kg	SASS sampler: 15.6 x 17.0 x 19.8 cm Rain hat: ~40 Ø ×50 cm	Deck 5 (suggested)

CSIRO	Peter Jansen	profing echo sounder	profiler with echo sounder attached	65 kg	0.1 x 1.5m	Main Deck secured to half height
Andrew Bowie	andrew.bowie@utas.edu.au	Air Sampling Pump Controller (from MNF)		4 kg	0.2 m3	Aerosol lab
Andrew Bowie	andrew.bowie@utas.edu.au	Aerosol sampling system (UTAS/CSIRO)		15 kg	1 m bench space	Aerosol lab
Andrew Bowie	andrew.bowie@utas.edu.au	Laminar flow hood (UTAS)		30 kg	1 m bench space	Aerosol lab
Andrew Bowie	andrew.bowie@utas.edu.au	Precipitation (Rain) Sampler		10 kg	1 m3	to be installed on 05 level outside of bridge equipment room (no power required)
Elizabeth Shadwick	elizabeth.shadwick@csiro.au	Southern Ocean Time Series	1 x Argo Float	20kg each	1950L x 260W x 260D (in crate)	Dirty Wet Lab
Bureau of Meteorology	Alain Protat 0435 256 261 alain.protat@bom.gov.au	SOWCLIP	RMAN Lidar	~110 kg	(LxWxH) 80x65x115cm	Deck 5 railing
Bureau of Meteorology	Alain Protat 0435 256 261 alain.protat@bom.gov.au	SOWCLIP	Micro Rain Radar	~20 kg	(LxWxH) 50x50x100cm	Deck 5 railing

Bureau of Meteorology	Alain Protat 0435 256 261 alain.protat@bom.gov.au	SOWCLIP	miniMPL	68 kg	Housing W - 64cm L - 64cm H - 90 cm	Deck 5 observation platform
Elizabeth Shadwick / CSIRO moorings	**Elizabeth Shadwick** elizabeth.shadwick@csiro.au	Southern Ocean Time Series	ESC1 moorings container	5 tonnes	20ft	main deck
AAD	Simon Alexander 0451 091 086 Simon.Alexander@aad.gov.au	SOWCLIP	Vaisala CT-25 ceilometer			Deck 5 railing
AAD	Simon Alexander 0451 091 086 Simon.Alexander@aad.gov.au	SOWCLIP	Parsivel-2 Disdrometer			Deck 5 railing
Elizabeth Shadwick	elizabeth.shadwick@csiro.au	Southern Ocean Time Series	4 x Surface Drifters	30kg each	4 in bigger cardboard box 1150L x 1150W x 900H	Dirty Wet Lab

Appendix C

Hazardous Materials Manifest

Hazardous Material Name	Manufacturer	Product ID (from SDS)	Project Title	Number of Containers /Cylinders	Container Size	Quanitity Unit	Total	Person Responsible	Email
Helium Gas	BOC		SOWCLIP	4	G	Cylinder	4 x G Cylinder	Alain Protat	alain.protat@bom.gov.au
mercuric chloride saturated solution			Southern Ocean Time Series	2	25	mL	50mL	Elizabeth Shadwick	elizabeth.shadwick@csiro.au
mercuric chloride seawater brine			Southern Ocean Time Series	63	250	mL	15750mL	Elizabeth Shadwick	elizabeth.shadwick@csiro.au
Partially depleted lithium batteries			Southern Ocean Time Series		50mm long 6mm diameter, stored in plastic tub	AA batteries	50mm long 6mm diameter, stored in plastic tub-AA batteries	Pete Jansen	peter.jansen@csiro.au

Equipment with Lithium Batteries	Tadiran	Tadiran High Energy Lithium Battery	Profiling Echo Sounder Piggy back	1	profiling float	Cylinder	1 profiling float-Cylinder	Pete Jansen	peter.jansen@csiro.au
Distilled HCl for rainwater samples	6M	6 M distilled HCl	Southern Ocean Time Series	1	125	mL	125mL	George Rowland	george.rowland@utas.edu.au
Distilled HCl for seawater samples	Supelco/Sigma Aldrich/MERCK/ IMAS clean laboratory	10 M Distilled HCl	Piggyback: Thorium isotopes in seawater	1	1000	mL	1000mL	George Rowland	george.rowland@utas.edu.au
Seawater – Hydrochloric Acid mixture	Supelco/Sigma Aldrich/MERCK/ IMAS clean laboratory	0.0158 M HCl – brine mixture	Piggyback: Thorium isotopes in seawater	20	10	L	200L	George Rowland	george.rowland@utas.edu.au
Seawater – Hydrochloric Acid mixture	Supelco/Sigma Aldrich/MERCK/ IMAS clean laboratory	0.0158 M HCl – brine mixture	Piggyback: Thorium isotopes in seawater	30	5	L	150L	George Rowland	george.rowland@utas.edu.au

MilliQ water – hydrochloric acid mixture	Supelco/Sigma Aldrich/MERCK/ IMAS clean laboratory	0.0158 M HCl diluted in purified water	Piggyback: Thorium isotopes in seawater	6	5	L	30L	George Rowland	george.rowland@utas.edu.au
MilliQ water – hydrochloric acid mixture	Supelco/Sigma Aldrich/MERCK/ IMAS clean laboratory	0.0158 M HCl diluted in purified water	Piggyback: Thorium isotopes in seawater	6	0.5	L	3L	George Rowland	george.rowland@utas.edu.au