RV *Investigator* Voyage Scientific Highlights and Summary

Voyage #:	IN2018_v01		
Voyage title:	Detecting Southern Ocean change from repeat hydrography, deep Argo and trace element biogeochemistry (PI Rintoul) & CAPRICORN (Clouds, Aerosols, Precipitation, Radiation, and atmospherIc Composition Over the southeRn ocean, PI Protat)		
Mobilisation:	Hobart, Tuesday, 9 January 2018		
Depart:	Hobart, 0900 Thursday, 11 January 2018		
Return:	Hobart, Wednesday, 21 February 2018		
Demobilisation:	Hobart, Thursday, 22 February 2018		
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Voyage Summary

Objectives and brief narrative of voyage

Scientific objectives

1. To quantify changes in Antarctic Bottom Water in the Australian Antarctic Basin.
Changes in temperature, salinity, volume, oxygen, CFC, nutrients and anthropogenic carbon in the abyssal layer will be quantified from full-depth repeat hydrography on three transects: along 140°E (the SR3 line), 150°E, and 132°E. CFCs and oxygen will be used to estimate changes in ventilation rate of the abyssal layer. Novel full-depth profiling floats (deep Argo) will allow the first broad-scale, continuous sampling of the abyssal layer. The deep Argo data will for the first time resolve the spatial scale of deep ocean change, as well as the seasonal and interannual variability that could alias signals of change derived from infrequent hydrography alone.

2. To quantify the evolving inventory of heat, freshwater, oxygen, CFCs, and carbon dioxide in the upper 2000 m and to infer changes in the ventilation rate of intermediate waters and ocean acidification.

Repeat hydrography, chemical tracers and Argo data will be used to track the evolution of ocean heat and freshwater content, quantify ocean carbon storage, and infer changes in ventilation from oxygen and CFC data. Changes in seawater carbonate chemistry, or ocean acidification, will be determined through comparison with historical section data. This is foundation data needed to track ocean acidification in the Southern Ocean and to assess likely impacts on the marine biota, including deep-sea coral communities and pelagic species.

3. To determine the distributions of trace metals and isotopes, their change with time, and the physical, chemical and biological processes controlling those evolving distributions.

Measurements of trace elements and isotopes (TEIs) are scarce in the Southern Ocean, particularly on repeat sections. We will measure iron and other trace elements over the full ocean depth using clean techniques. The distribution of trace elements will be combined with information on water mass properties and circulation and on biological processes to infer sinks and sources of trace elements. Measurements on the SR3 line will be compared to measurements in spring 2001 and late autumn 2008 to assess seasonal and longer-term changes. The proposed sections will also sample for TEIs in marine particles, and stable, radioactive and radiogenic isotopes that have not been measured before in this sector of the Southern Ocean. We will also sample for TEIs in aerosol particles using the RV Investigator's state-of-the-art aerosol sampling facilities and laboratories to evaluate the atmospheric contribution to trace element delivery to the remote Southern Ocean. Metagenomic analyses will be used to characterise the structure and function of the microbial community as a function of latitude and depth along the repeat transects.

4. To quantify cloud-aerosol-precipitation-radiation processes and interactions over the Southern Ocean and their variability as a function of latitude and large-scale context (CAPRICORN).

Errors in the representation of clouds and their interactions with aerosols produce too much absorbed shortwave radiation in climate models south of 50°S (up to 60 Wm^{-2} south of 55°S in the ACCESS model). These model challenges can be traced back to poor understanding of physical processes, which in turn cannot be studied in detail due to the lack of relevant observations. During this voyage detailed measurements of the cloud, aerosol, and precipitation properties, boundary layer structure, atmospheric state, and surface energy budget will be made using state-of-the-art instrumentation. The focus will be on understanding how those process work and how these properties and process change with latitude and the large-scale meteorological context.

5. To evaluate satellite cloud, aerosol, precipitation, and surface flux products over the Southern Ocean at different latitudes (CAPRICORN).

Given the obvious lack of operational observational networks in this region, satellite observations are needed to fully understand the cloud-aerosol-radiation-precipitation-ocean productivity interactions over the Southern Ocean, especially their seasonal and inter-annual variability. Global products derived from active and passive remote sensing instruments for clouds and aerosols (NASA A-Train mission, with CloudSat – CALIPSO) and rainfall (NASA/JAXA Global Precipitation Mission, GPM) are essentially not validated in this region, and in the case of rainfall are known to disagree. We will therefore collect as many observations as possible along the track of CloudSat-CALIPSO and within the swath of the GPM dual-frequency radar during this voyage. We will mostly do that during the transit from Antarctica back to Hobart, where we will adjust the ship location using orbital predictions.

6. To evaluate and improve the representation of these Southern Ocean cloud and precipitation properties and processes in the regional and global Australian ACCESS model (CAPRICORN).

Observations collected during this voyage, and better understanding of cloud – aerosol – radiation processes will be used to evaluate how well the Australian forecast model ACCESS simulates those processes and statistical properties. Sensitivity studies constrained by observational results will also be conducted to help improve this representation.

Voyage objectives

CTD/O2 rosette: Profiles of temperature, salinity, and oxygen through the full ocean depth will be obtained from the CTD along the SR3 section. This repeat line is particularly well-suited to documenting change in the deep ocean, as the Australian Antarctic Basin is the most well-ventilated deep basin (Orsi et al., 2002) and previous occupations of these lines have documented the most rapid rates of change observed in the Southern Ocean (Purkey and Johnson 2010, 2012, 2013; Aoki et al., 2005, 2013; Rintoul, 2007; Shimada et al., 2012; van Wijk and Rintoul, 2014). SR3 samples the bottom water formed in the Ross Sea and Adelie Land coast (the two major sources of bottom water in the Indian and Pacific Basins) close to the source of these waters. The southern end of the P11S section (150°E), upstream of the Adelie Land source, will be repeated to isolate the signal entering from the Ross Sea. A short section along 132E will allow changes since the last occupation of the line in the 1970s to be quantified.

Water samples collected with the 36 bottle rosette will be analysed on board for salinity, oxygen, chlorofluorocarbons (CFC-11, CFC-12, SF6), nutrients, dissolved inorganic carbon (DIC), and total alkalinity. Water samples will be filtered for metagenomic studies on shore. Water samples may also be returned to shore for analysis of pH, natural C-14 and C-13, pending a successful USA funding application. . The CAPRICORN team will also use these water samples to analyse the presence of potential ice nucleating particle material in the water.

Underway CO_2 and O_2: Continuous underway measurements (approx. 2- minute resolution) will be made to estimate the air-sea flux of along the ship track, with intermittent water samples collected and analysed for DIC, total alkalinity and oxygen for calibration.

SADCP/LADCP: Continuous measurements of velocity will be collected along the ship track using the 75 kHz and 150 kHz shipboard ADCPs. A lowered ADCP (LADCP) will collect horizontal velocity measurements at each station from the CTD package.

Deep Argo: 11 floats capable of profiling through the full ocean depth will be deployed, as part of a US – Australia – Japan – France pilot experiment. This will be the first broad-scale deployment of this new technology. Floats will typically be deployed immediately after completion of a CTD on the site.

Biogeochemical floats: Twelve profiling floats including biogeochemical sensors for nitrate, oxygen and pH will be deployed, as part of the international Southern Ocean Climate and Carbon – Observations and Modelling (SOCCOM) project. One bio-Argo float will be deployed for Pete Strutton (UTAS). Floats will typically be deployed immediately after completion of a CTD on the site.

Trace metals and isotopes: An autonomous 12 bottle trace metal-clean rosette (TMR) system and 6-8 in situ pumps (ISPs) will be used to collect GEOTRACES TEI samples in dissolved and particulate phases. Clean sampling and analytical container laboratories will allow for shipboard processing, experiments and some near real-time analyses of iron at sea. The majority of the analyses will take place ashore after the voyage using sophisticated instrumentation not suited for shipboard use.

Radiosonde launches (CAPRICORN): Weather balloons equipped with standard radiosondes will be launched every 6 hours for the whole duration of the voyage to regularly measure the meteorological state of the atmosphere. There is no hard requirement on launching at exactly 6 hours intervals. Since the launches need to have the ship into the wind we will launch sondes at the same times as CTDs. The radiosonde data will be sent to the Global Telecommunications System (GTS) and assimilated in global forecast models and regional version of ACCESS.

Aircraft overflights (CAPRICORN): The NCAR G-V aircraft (based in Hobart) equipped with in-situ and remote sensing instrumentation will overfly RV Investigator a few times (at least 3) as part of the international SOCRATES experiment. We will let the master, voyage manager, and science team know when that happens at least a day in advance. We will communicate with the aircraft during operations through their chat room. The back-up solution will be to use VHF radio. The procedure has been discussed between the ship manager (Marcus Ekholm), the MNF voyage manager, the CAPRICORN PIs (A. Protat and J. Mace), and the NCAR operations manager (Cory Wolff).

Satellite track chasing (CAPRICORN): we will optimize time spent with the swath of the satellite GPM radar and along the track of the CloudSat-CALIPSO cloud radar-lidar combination, by slightly adjusting the heading of the ship, mostly during the transit back to Hobart. We will communicate and negotiate these changes with the master, voyage manager, and science team a few days in advance (heads up 3 days before the actual date, update a day before the actual date with the final orbital information).

Continuous CAPRICORN observations: all other observations to address the CAPRICORN objectives will be continuous observations either from the main mast (surface fluxes, met observations, rainfall), foredeck (stabilized platform container), back deck (915 MHz wind profiler), Level 2 aft deck (Doppler wind lidar and ceilometer),Level 4 observation deck (suite of instruments strapped to the railings, MNF radiation packages and met observations), Level 5 observation deck (instruments strapped to railings), and aerosol and air chemistry labs (MNF baseline and user supplied instruments).

Results

1. To quantify changes in Antarctic Bottom Water in the Australian Antarctic Basin.

All stations were completed on the three repeat sections at 140E, 150E and 132E and additional work was done on the Antarctic continental shelf and on a 4th repeat section (WOCE/CLIVAR S4) along 62°S. The new data set will allow changes to be quantified in Antarctic Bottom Water with greater detail than previously possible. In particular, the different transects will allow us to distinguish the contribution from changes in the two sources of bottom water to the Australian Antarctic Basin (the Ross Sea and Adelie Land Bottom Water). Eleven deep Argo floats were deployed. The floats, the first deployed in the Southern Ocean, will provide monthly measurements of the evolution of full-depth water properties for the next five years. The float profiles will quantify seasonal and interannual variability in deep and bottom waters for the first time, information that is essential for interpretation of longer-term trends. All float deployments were successful and the floats are transmitting profiles.

Vertical sections of potential temperature, salinity, and oxygen along the SR3 transect near 140°E are shown in Figures 1-3, and the potential temperature – salinity diagram for all stations is shown in Figure 4. Preliminary assessment indicates the quality of the data collected is of very high quality.

2. To quantify the evolving inventory of heat, freshwater, oxygen, CFCs, and carbon dioxide in the upper 2000 m and to infer changes in the ventilation rate of intermediate waters and ocean acidification.

This objective was fully met. Profiles of temperature, salinity, oxygen, CFCs and carbon parameters were collected at 106 stations covering the full water column. This comprehensive data set will be used to diagnose ocean circulation and ventilation rates and changes in the ocean inventory of climate-relevant parameters such as heat, freshwater and anthropogenic carbon dioxide. Several parameters were measured for the first time in this sector of the Southern Ocean (e.g. SF_6). Floats and drifters deployed on the voyage (1 bio-optical floats, 11 biogeochemical floats, and 4 surface carbon drifters) will also contribute to this objective.

The first results from the measurements of total carbon and alkalinity are promising. The effect of the extension of the East Australian Current (EAC) presents a stronger signature than in previous visits to the line, with surface waters depleted in carbon and richer in alkalinity covering the area south of Tasmania. Close to the Tasman shelf at intermediate and deep layers, there are waters rich in carbon and alkalinity which could be related to incoming waters from the Tasman Sea. Another interesting result was found south of the Polar Front and towards the Antarctic shelf, where surface waters present lower carbon and alkalinity than in previous years. This result could be indicative of a lapse in of the intensification of the upwelling of deep waters previously reported and the restoration of the normal behaviour of the upwelling. Finally, the sampling on the shelf for the SR03 and adjacent sections allowed us to better track the different bottom waters formed in the basin which seem to have a stronger signal than in 2011, at least in alkalinity values. All of these are preliminary results in need of deeper discussion and to be contrasted with other sampled parameters.

3. To determine the distributions of trace metals and isotopes, their change with time, and the physical, chemical and biological processes controlling those evolving distributions.

The GEOTRACES component of the voyage completed all its primary objectives along SR3, and added additional components with samples taken along the shelf, 150E, S4 and 132E sections. All sample analysis will be shore-based and will take place in 2018 in the IMAS/ACE CRC laboratories at the University of Tasmania (with a smaller subset of samples to be shipped overseas to collaborating labs). The primary focus of the GEOTRACES team was on the distributions of micronutrient trace elements (such as iron) to elucidate trace element and isotope sources and sinks, relationships with water mass characteristics, dissolved/particulate interactions, cross-shelf/slope gradients, and the coupling/decoupling with major nutrient cycles. The GEOTRACES team expanded its work on previous occupations of SR3 by adding parameters such as: trace elements and isotopes in marine particulates, radiogenic and radioactive isotopes, trace metal organic ligands and 3He.

Key carbon and nutrient cycling processes within the Southern Ocean (SO) are microbially driven and ecologically regulated as a balance between surface photosynthetic CO2 fixation and remineralisation by heterotrophic bacteria/archaea within the twilight and dark ocean. Despite their pivotal role, most of the SO microbial community structure, particularly within the pelagic dark oceans, remains unexplored. This study aims to map the SO microbes as a function of latitude and depth along the repeat transects and explore the potential roles of ocean circulation and hydrologically distinct water masses in structuring the SO microbial community. Epi-, meso- and abyssal pelagic seawater samples were collected during the IN2018_V01 voyage, and filtered to obtain the corresponding microbial samples. The samples were deep frozen at and transported back onshore for planned metagenomics (high throughput 16S and 18S ribosomal RNA gene tag sequencing) analysis to study the bacterial, archaeal and micro-eukaryotes community structure and composition within the different Southern Ocean water masses. The microbial community structure will be statistically correlated with hydrographic metadata to elucidate the key factors driving microbial community variation between the water masses.

4. To quantify cloud-aerosol-precipitation-radiation processes and interactions over the Southern Ocean and their variability as a function of latitude and large-scale context (CAPRICORN).

This objective was fully met. Most instruments operated nominally and continuously, allowing for all parts of the research program to be completed in the coming years. The large-scale was extremely well captured by the numerous radiosonde launches (over 95% successful, which in itself is a great success given the challenging environment). Joint datasets with the NCAR G-V aircraft were also collected, which will allow for additional process and validation studies to be conducted.

5. To evaluate satellite cloud, aerosol, precipitation, and surface flux products over the Southern Ocean at different latitudes (CAPRICORN).

This was another major success of the voyage. We collected precipitation data during seventeen (17) NASA GPM overpasses that included rain, snow or mixed-phase precipitation (see Table 1 below). Overall, aerosol instrumentation also worked very well, allowing for a detailed characterization of aerosol size distribution, composition, and concentration. Surface flux measurements were also successfully collected, which will complement the results obtained from the 2016 CAPRICORN voyages for higher latitudes and additional surface wind speed regimes (Barthi et al. 2018ab, submitted).

Table 1. GPM Overpasses of the RV Investigator during the 2018 CAPRICORN Voyage when precipitation was being observed at the ship. In total there were 56 passes of the GPM core satellite where the subsatellite track passed within 300 km of the Investigator during the 2018 CAPRICORN voyage.

Time (UTC)	Orbit	Distance (km)	Latitude (°)	Longitude (°)	Precip at Ship
1/18/18 14:00	22105	299.94	-50.40	143.53	Rain showers
1/22/18 20:00	22172	124.76	-54.53	141.33	Rain Showers
1/25/18 19:00	22218	87.65	-58.85	139.84	Stratiform rain
1/26/18 13:00	22229	12.84	-59.35	139.85	Stratiform Snow
1/28/18 13:00	22260	60.11	-61.85	139.85	Stratiform Snow
1/29/18 14:00	22276	83.44	-63.35	139.83	Snow showers
1/29/18 15:00	22278	178.74	-63.35	139.83	Snow showers
1/30/18 13:00	22291	150.95	-64.21	139.83	Stratiform Snow
2/7/18 11:00	22414	110.98	-63.05	146.45	Stratiform Snow
2/8/18 13:00	22432	161.02	-62.58	142.05	Stratiform rain
2/9/18 11:00	22445	177.39	-62.17	138.41	Snow showers
2/12/18 10:00	22491	219.76	-64.45	132.08	Stratiform Snow
2/12/18 13:00	22494	74.44	-64.45	132.08	Stratiform Snow
2/13/18 10:00	22507	171.02	-63.00	132.11	Snow showers
2/15/18 13:00	22541	71.1	-58.97	132.03	Rain Showers
2/16/18 8:00	22552	121.95	-57.52	132.00	Drizzle
2/17/18 7:00	22567	47.93	-56.77	136.97	Snow showers

6. To evaluate and improve the representation of these Southern Ocean cloud and precipitation properties and processes in the regional and global Australian ACCESS model (CAPRICORN).

Following the successful collection of cloud, precipitation and aerosol data during the voyage, the Bureau of Meteorology and the UK Met Office have agreed to produce high-resolution, regional, and climate (AMIP-style) simulations for the whole CAPRICORN period, using ACCESS and the original UM model, using the relocatable version. The main objective of the sensitivity tests will be to restrict in the cloud parameterization the production of ice to allow for more supercooled water from the available water vapour in Southern clouds observed during the voyage. Cloud, aerosol, and precipitation observations will be jointly used to make sure that improvements do not result from compensating errors as has been observed in the past (improving surface radiation in the UM model at the expense of cloud properties for instance).

Voyage Narrative

The voyage left Hobart at 0900 on 11 January 2018. We arrived at the first station at 1800 on 12 January, in 300 m of water on the Tasmanian continental shelf. This station marked the start of our first transect, the SR3 line along nominally 140°E. This section was first occupied as part of the World Ocean Circulation Experiment (WOCE) in 1991. The IN2018_V01 transect is the 10th complete reoccupation of the section over the past 27 years, making it one of the most complete time series of changes in water properties and circulation in the Southern Ocean.

On 13 January we were diverted to Hobart to offload an ill crew member. Approximately 45 hours were needed to complete the medical evacuation and return to the SR3 line. After consultation with MNF, it was agreed to delay the return date of the voyage from 21 February to the evening of 22 February to recoup some of the lost time.

The vessel worked south along the SR3 line, carrying out CTD stations every 30 nm, with closer station spacing over sloping topography and in frontal zones. At roughly every other station, the Trace Metal Rosette (TMR) was deployed to collect samples for trace elements and isotopes requiring clean sampling techniques (e.g. iron). About every two degrees of latitude, a string in situ pumps were deployed, for sampling of particulates at 8 depths between the sea surface and sea floor. The pumps filtered about 1000 litres of sea water at each stop.

At each station, the CTD was used to collect profiles of temperature, salinity, oxygen, transmission, photosynthetically active radiation, fluorescence, backscatter, and velocity from a lowered acoustic Doppler current profiler (LADCP). Water samples from the CTD rosette were collected for analysis of salinity, oxygen, nutrients, dissolved inorganic carbon, alkalinity, and chlorofluorocarbons (CFCs) at most stations. Samples were collected for pH, radiocarbon (^{14}C), chlorophyll, HPLC, POC, metagenomics, radiogenic elements, ice condensation nuclei, and calcium/magnesium ratio at a subset of stations.

A variety of measurements were made while the ship was underway, including velocity from the shipboard 75 kHz ADCP (the 150 kHz ADCP unfortunately failed prior to our voyage and was not able to be used during the voyage) and temperature, salinity, oxygen, fluorescence, pCO2 and nutrients from the ship's intake line. Underway atmospheric observations included the usual meteorological variables measured by the ship (wind, air temperature, humidity, rainfall, barometric pressure) and a large number of instruments measuring aerosols, atmospheric chemistry and cloud properties for the CAPRICORN program. At some stations, the ship remained on station to allow an extended period of atmospheric observations. These operations were coordinated with overflights by satellites and a heavily-instrumented NASA aircraft operating out of Hobart during the duration of the voyage as part of the international SOCRATES program.

We deployed a total of 29 floats and drifters during the voyage, generally as we left a CTD station. The floats included 11 biogeochemical Argo floats for the U.S. Southern Ocean Carbon and Climate Observations and Modelling (SOCCOM) program, one biological Argo float for Dr Pete Strutton of UTAS, and two Argo floats for the CSIRO Argo program. Four surface drifters measuring carbon dioxide in surface waters were deployed for Japanese colleagues. We also deployed the first array of deep Argo floats in the Southern Ocean, including 5 “Deep SOLO” floats from the USA, 3 “Deep Ninja” floats from Japan, and 3 “Deep ARVOR” floats from France. All floats were deployed successfully and are transmitting data as planned.

Work resumed on 15 January. The SR3 line was completed without further incident and with little time lost to weather. The final station on the Antarctic continental shelf was completed on 2 February, ahead of schedule thanks to good weather, efficient ship-board operations, and quicker-than-expected transit times.

Stations on the Antarctic continental shelf near the Mertz Glacier had been flagged as high priority in the Voyage Plan, if sea ice and weather conditions allowed. Sea ice images suggested that it was worth a try and we steamed east then south, approaching the Mertz. We were aiming to sample the “Adelie Depression,” a deep trough on the continental shelf. Dense water formed in winter is trapped in the trough, allowing the properties of the dense winter water to be sampled in summer. The vessel had a clear run deep onto the continental shelf. Unfortunately, a band of sea ice had moved north and prevented us from getting south of 66°28’S, just short of the Antarctic Circle, and more importantly, still 18 nm short of the deep trough we sought to sample.

The ship completed a short section of 6 CTD sections while retracing our course from our southernmost point back to the edge of the continental shelf.

On 4 February, we left the continental shelf to deploy a Deep Ninja float in deeper water near 145°E and continued east to begin the second transect along 150°E. Like SR3, this section has been occupied a number of times over the past few decades. We were prevented from sampling the southernmost stations on the line by a heavy band of sea ice, but completed all the remaining stations on the line by 7 February.

Stations along the S4 repeat section, an east-west line between 62°S and 63°S, had been flagged in the Voyage Plan as being high priority if time permitted. This latitude band was also of high interest for the CAPRICORN team. As we were still ahead of schedule, we agreed to occupy stations along the S4 line as we made our way west to the final transect at 132°E.

On 9 February, we experienced our first significant gear failure. The small winch used (in conjunction with one of the CTD winches) to do full-depth TMR casts failed. While a number of alternatives were explored, no solution was found and no more full-depth TRM casts were completed. While all of the deep TMR casts in the original Voyage Plan had been completed at that stage, it was unfortunate to miss the opportunity to sample deep and bottom waters for trace elements on the 132°E line. (The small “Rockcrusher” winch as already a fall-back solution. The original plan to use 6000 m of new Dyneema line spooled onto a different winch was abandoned after the first test, when the rope jumped the sheave. This system had been implemented by the MNF in an attempt to meet the significant increase in TM cast depth capability requested for this voyage and there hadn't been an available opportunity to test the system before we sailed.)

Bad weather on 10 February delayed us by 11 hours, but we completed the S4 line the following day. As bad weather was forecast for the southern end of the next section at 132°E, we decided to work our way south along the line from 62.5°S. The weather did indeed pass through before we reached the southern end of the section, completing the southern-most station in 300 m of water on the Antarctic continental shelf on 13 February.

The vessel transited north to resume stations at 62°S, slowed somewhat by strong winds and short, steep seas. The last CTD station on the 132°E line (CTD #106), and final deep Argo float and surface carbon drifter deployments, were completed on the morning of 17 February.

We then headed east to a region of high biological productivity identified in satellite imagery to complete further sampling for the CAPRICORN program. The vessel remained on station for 4 hours of aerosol and atmospheric sampling, during which a CTD was completed to obtain water samples for analysis of ice condensation nuclei. This work was coordinated with an overflight by the NASA G5 aircraft. We stopped for the final time to complete another CAPRICORN station on 20 February, this time in a low productivity zone. The transit home to Hobart was aligned with a ground track of the CALIPSO satellite.

The vessel met the pilot at 0900 22 February.

Summary

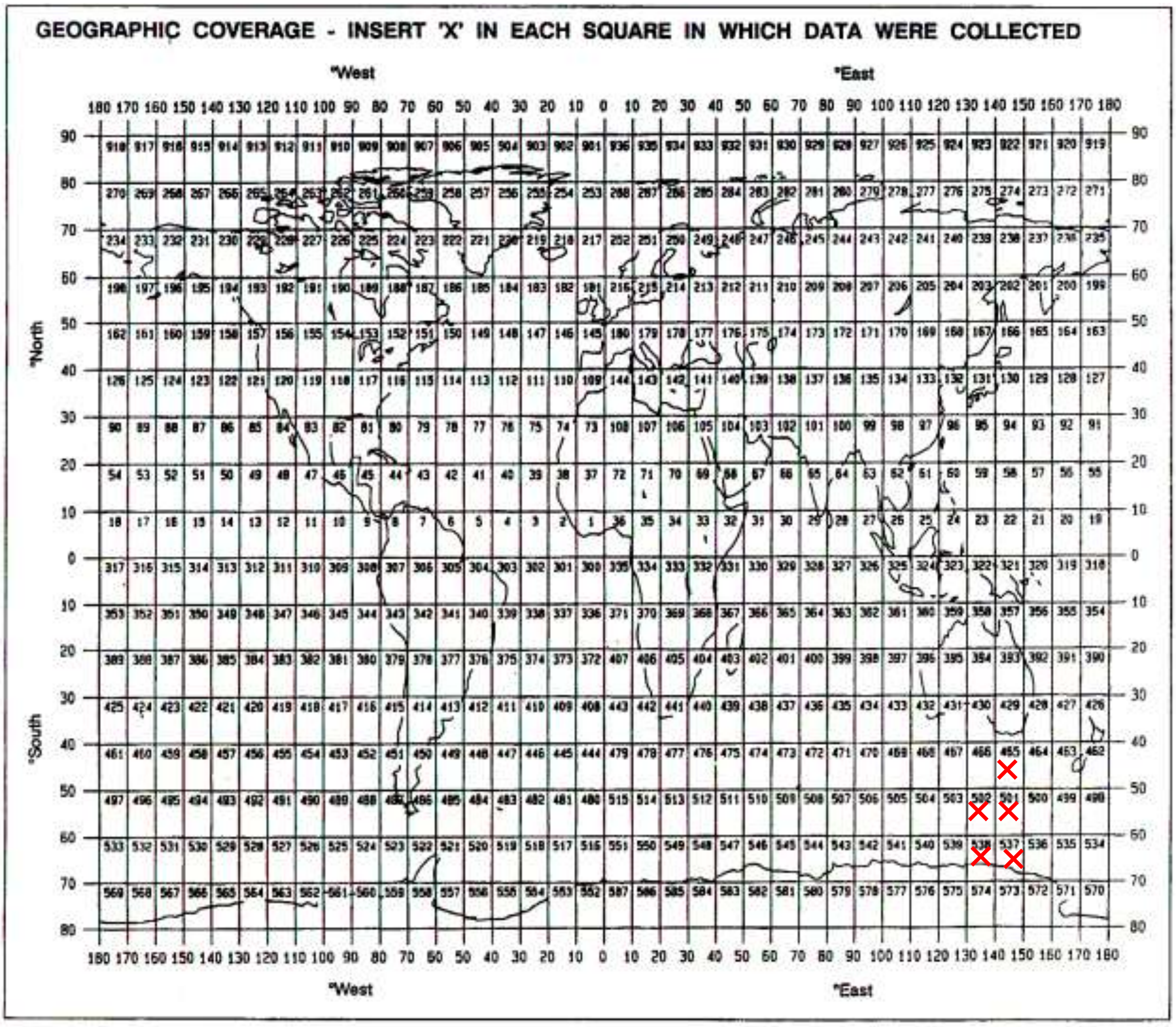
The voyage was a great success, with all objectives achieved or exceeded. We have collected the most comprehensive and highest quality data set yet obtained from this region. We achieved much more than planned, thanks to generally good weather, smooth ship-board operations, excellent support from MNF staff and the ship's officers and crew, and effective cooperation between scientific programs that allowed efficient use of the ship time available.

Some summary statistics:

- > 4500 nm travelled
- 108 CTD stations (88 in the original voyage plan)
- 52 Trace Metal Rosette casts (27 planned)
- 11 in situ pump stations (8 planned)
- 29 floats and drifters deployed (all successful)
- 224 radiosondes launched
- 17 NASA GPM overpasses with precipitation
- Many "firsts" (e.g. first Deep Argo deployments and first measurements of many properties in this part of the Southern Ocean, including SF_6, ammonium and many atmospheric parameters, first cloud, aerosol, radiation, and precipitation observations south of 55 South).
- Many high quality underway and atmospheric data sets

Marsden Squares

Move a **red "x"** into squares in which data was collected



Moorings, bottom mounted gear and drifting systems

Item No	PI See page above	APPROXIMATE POSITION						DATA TYPE enter code(s) from list on last page	DESCRIPTION
		LATITUDE			LONGITUDE				Identify, as appropriate, the nature of the instrumentation the parameters (to be) measured, the number of instruments and their depths, whether deployed and/or recovered, dates of deployments and/or recovery, and any identifiers given to the site.
		deg	min	N/S	deg	min	E/W		
1	Rintoul (for all)	60	21	S	139	51	E	D05	Surface carbon drifter
2		63	54	S	150	00	E	D05	Surface carbon drifter
3		60	02	S	132	13	E	D05	Surface carbon drifter
4		56	58	S	132	10	E	D05	Surface carbon drifter
5		45	14	S	145	51	E	D06	Argo float
6		49	37	S	143	56	E	D06	Argo float
7		60	51	S	139	51	E	D06	Biological Argo float (Strutton)
8		48	19	S	144	31	E	D06	Biogeochemical Argo float (SOCCOM)
9		53	35	S	141	51	E	D06	Biogeochemical Argo float (SOCCOM)
10		55	30	S	140	43	E	D06	Biogeochemical Argo float (SOCCOM)
11		58	22	S	139	51	E	D06	Biogeochemical Argo float (SOCCOM)
12		60	22	S	139	51	E	D06	Biogeochemical Argo float (SOCCOM)
13		62	51	S	139	51	E	D06	Biogeochemical Argo float (SOCCOM)
14		64	49	S	139	52	E	D06	Biogeochemical Argo float (SOCCOM)
15		65	25	S	150	00	E	D06	Biogeochemical Argo float (SOCCOM)
16		62	00	S	149	59	E	D06	Biogeochemical Argo float (SOCCOM)
17		63	30	S	132	06	E	D06	Biogeochemical Argo float (SOCCOM)
18		58	30	S	132	01	E	D06	Biogeochemical Argo float (SOCCOM)
19		60	51	S	139	52	E	D06	Deep Argo float (deep SOLO)
20		61	30	S	132	00	E	D06	Deep Argo float (deep SOLO)
21		60	02	S	132	13	E	D06	Deep Argo float (deep SOLO)
22		58	30	S	132	00	E	D06	Deep Argo float (deep SOLO)

Item No	PI See page above	APPROXIMATE POSITION						DATA TYPE enter code(s) from list on last page	DESCRIPTION
		LATITUDE			LONGITUDE				Identify, as appropriate, the nature of the instrumentation the parameters (to be) measured, the number of instruments and their depths, whether deployed and/or recovered, dates of deployments and/or recovery, and any identifiers given to the site.
		deg	min	N/S	deg	min	E/W		
23		56	58	S	132	10	E	D06	Deep Argo float (deep SOLO)
24		63	21	S	139	50	E	D06	Deep Argo float (deep Ninja)
25		65	00	S	145	30	E	D06	Deep Argo float (deep Ninja)
26		63	30	S	150	00	E	D06	Deep Argo float (deep Ninja)
27		64	13	S	139	50	E	D06	Deep Argo float (deep ARVOR)
28		64	36	S	150	00	E	D06	Deep Argo float (deep ARVOR)
29		63	05	S	132	06	E	D06	Deep Argo float (deep ARVOR)

Summary of Measurements and samples taken

Item No.	PI see page above	NO see above	UNITS see above	DATA TYPE Enter code(s) from list at 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.
1	Rintoul	108	Profiles	H10, H16, H17, D71	CTD vertical profiles of water properties (temperature, salinity, oxygen, PAR, transmissometer, lowered ADCP, backscatter, fluorescence
2	Rintoul	102	Profiles	H09, H73	CFC profiles collected at 102 stations
3	Rintoul	108	Profiles	H09, H21, H22, H24, H25, H76,	Water bottles sampled for oxygen, nutrients (nitrate, nitrite, phosphate, silicic acid, ammonia, salinity, oxygen) at 108 profiles
4	Bowie	52	Stations	H30	Trace metal rosette (TMR) (52 stations, including 1 test cast; 2224 samples); see metadata
5	Bowie	11	Stations	H30	ISP (11 stations; 86 total pump deployments ; 1032 filter samples); see metadata
6	Bowie	39	Stations	H30	Radiogenic CTD sampling (39 stations ; 171 samples); see metadata
7	Bowie	3	Stations	H33	3He CTD sampling (3 stations; 24 total samples); see metadata
8	Bowie	15	Samples	M71	Aerosol samples for trace elements; see metadata
9	Bowie	7	Samples	M71	Precipitation samples for trace elements; see metadata
10	Bowie	11	profiles	H30,H32	In situ pump profiles
11	Tilbrook	1940	Bottles	H74	Total CO2 measurements on bottles sampled from 106 CTD casts
12	Tilbrook	1940	Bottles	H27	Alkalinity measurements on bottles sampled from 106 CTD casts
13	Tilbrook	65	Bottles	H74	Total CO2 measurements on bottles sampled from the underway seawater line
14	Tilbrook	65	Bottles	H27	Alkalinity measurements on bottles sampled from the underway seawater line
15	Bodrossy	480	samples	B07	Filtered sea water samples for microbial genomics analyses
16	Bodrossy	170	samples	B07	Filtered sea water samples, flow cytometry and nutrient samples from a shipboard microcosm experiment
17	Protat	Continuous	dBZ, ms-1	M01	BASTA cloud radar: vertical profiles of radar reflectivity and Doppler velocity

Item No.	PI see page above	NO see above	UNITS see above	DATA TYPE Enter code(s) from list at 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.
18	Protat	Continuous	m^{-1}, unitless	M01	RMAN-510 aerosol and cloud lidar: Vertical profiles (1min, 25m) of calibrated lidar co-polar and cross-polar backscatter
19	Mace	Continuous	g m^{-2}	M01	Microwave Radiometer (MWR): Liquid Water Path, Water Vapour Path
20	Alexander	Continuous	dBZ, ms-1	M01	MRR-PRO micro-rain radar: Vertical profiles (1min, 50m) of 24 GHz radar reflectivity, Doppler velocity, and Spectral Width
21	Schofield	Continuous	m-1	M01	mini MPL scanning Lidar: Vertical profiles (1min, 15m) of calibrated lidar co-polar and cross-polar backscatter
22	Schofield	Continuous	unitless	M01	MAX-DOAS: aerosol scattering properties (in-situ)
23	Brown	Continuous	dBZ, ms-1	M01	UHF wind profiler: Vertical profiles of reflectivity, Doppler velocity, and Spectral Width
24	Brown	Continuous	m-1, ms-1	M01	Doppler wind lidar: Vertical profiles of clear air reflectivity, Doppler velocity, and Spectral Width
25	Brown	Continuous	unitless	M01	Lidar Ceilometer: cloud base heights (4 layers max)
26	Brown	224		M01	Radiosondes: profiles of p, T, RH, winds
27	Klepp	Continuous	m-3	M01	OceanRain Disdrometer: Drop size distributions (1min, size range : 0.1 to 22 mm, 128 size bins) and Time series (1min) of precipitation rate (rainfall, snow, mixed)
28	Monty	Continuous		M01	Ssonic anemometer + fast humidity sensor: turbulent surface fluxes
29	Ristovski	Continuous		M01	VH-TDMA: Aerosol hygroscopic growth factors and volatility at 250°C at Dp =40, 100 and 150 nm. 18 min (raw) 1 hr (processed); 3 sizes (bin width ~10% of Dp)
30	Ristovski	Continuous	$\mu g.m^{-3}$	M01	Tof-ACSM: aerosol chemical composition (0.1 < DP < 1 µm), 10 min resolution
31	DeMott	21 – 62 hr integrated	L^{-3}	M01	Ice Spectrometer: Ice nuclei number concentrations and freeze temperature distribution. 21 – 62 hr integrated filters
32	DeMott	Continuous	L^{-3}	M01	CFDC: Ice Nuclei number concentrations. 1 sec (raw), 2-5 min (processed)

Item No.	PI see page above	NO see above	UNITS see above	DATA TYPE Enter code(s) from list at 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.
33	DeMott	Continuous	L^{-3}	M01	WIBS-4A: Atmospheric bio-aerosol. 1 sec (raw), 1-5 min (processed); Size distributions >0.8 µm
					Please continue on separate sheet if necessary

Curation Report

Delete section if not applicable.

Item #	DESCRIPTION
1.	Archived at Clivar and Carbon Hydrographic Data Office (CCHDO) and Australian Oceanographic Data Centre (AODC)
2.	Archived at Clivar and Carbon Hydrographic Data Office (CCHDO) and Australian Oceanographic Data Centre (AODC)
3.	Archived at Clivar and Carbon Hydrographic Data Office (CCHDO) and Australian Oceanographic Data Centre (AODC)
4.	Archived at GEOTRACES Data Assembly Centre (BODC), IMAS Data Portal, CSIRO Data Access Portal
5.	Archived at GEOTRACES Data Assembly Centre (BODC), IMAS Data Portal, CSIRO Data Access Portal
6.	Archived at GEOTRACES Data Assembly Centre (BODC), IMAS Data Portal, CSIRO Data Access Portal
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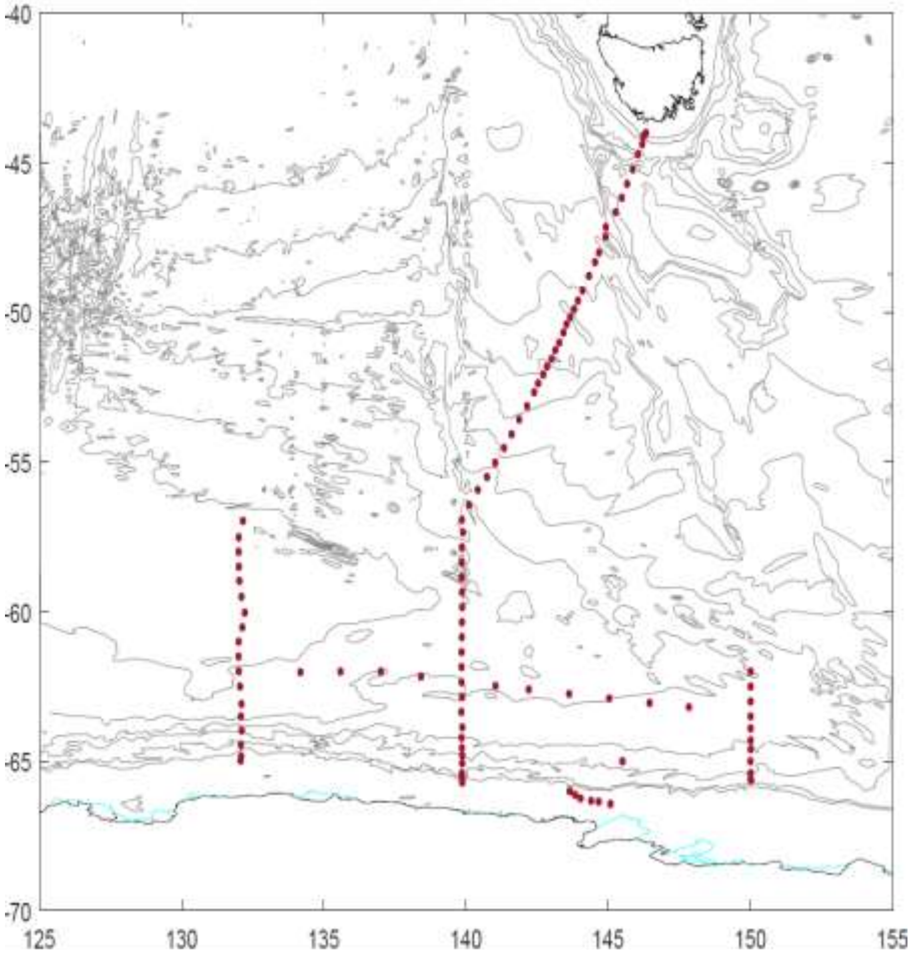
11.	Archived at Clivar and Carbon Hydrographic Data Office (CCHDO) and Australian Oceanographic Data Centre (AODC)
12.	Archived at Clivar and Carbon Hydrographic Data Office (CCHDO) and Australian Oceanographic Data Centre (AODC)
13.	Archived at Clivar and Carbon Hydrographic Data Office (CCHDO) and Australian Oceanographic Data Centre (AODC)

Item #	DESCRIPTION
14.	Archived at Clivar and Carbon Hydrographic Data Office (CCHDO) and Australian Oceanographic Data Centre (AODC)
15.	CSIRO Oceans & Atmosphere
16.	CSIRO Oceans & Atmosphere
17 - 33	CSIRO / MNF DAP

Track Chart



Personnel List

	Name	Role	Organisation
1.	Tegan Sime	Voyage Manager	CSIRO MNF
2.	Ian McRobert	SIT Support	CSIRO MNF
3.	Aaron Tyndall	SIT Support	CSIRO MNF
4.	Steve Van Graas	DAP Support	CSIRO MNF
5.	Francis Chui	DAP Support	CSIRO MNF
6.	Matthew Eckersley	Doctor	CSIRO MNF
7.	Christine Rees	Hydrochemist	CSIRO MNF
8.	Stephen Tibben	Hydrochemist	CSIRO MNF
9.	Kendall Sherrin	Hydrochemist	CSIRO MNF
10.	Kristina Paterson	Hydrochemist	CSIRO MNF
11.	Steve Rintoul	Chief Scientist/CTD watch	CSIRO / ACE CRC
12.	Mark Rosenberg	CTD watch	ACE CRC
13.	Esmee van Wijk	CTD watch	CSIRO / ACE CRC
14.	Benoit Legresy	CTD watch	CSIRO / ACE CRC
15.	Katherine Tattersall	CTD watch	CSIRO
16.	Sophie Bestley	CTD watch	CSIRO
17.	Mark Warner	CFC	U. of Washington
18.	Dan Anderson	CFC	U. of Washington
19.	Kate Berry	Carbon	CSIRO/ACECRC
20.	Abe Passmore	Carbon	CSIRO/ACECRC
21.	Craig Neill	Carbon	CSIRO
22.	Paula Conde Pardo	Carbon	ACE CRC
23.	Leo Mahieu	Carbon	CSIRO
24.	Joshua Denholm	Carbon	CSIRO
25.	Andrew Bowie	GEOTRACES	IMAS-UTAS/ACE CRC
26.	Melanie East	GEOTRACES	ACE CRC
27.	Pier van der Merwe	GEOTRACES	ACE CRC
28.	Morgane Perron	GEOTRACES	IMAS-UTAS
29.	Matt Corkill	GEOTRACES	ACE CRC
30.	Tom Holmes	GEOTRACES	ACE CRC
31.	Christine Weldrick	GEOTRACES	ACE CRC
32.	Pauline Latour	GEOTRACES	
33.	Swan Li San Sow	Meta-genomics	CSIRO
34.	Jay Mace	CAPRICORN co-chief scientist – BOM cloud radar, lidar, MWR, MRR-PRO	University of Utah
35.	Ruhi Humphries	CAPRICORN co-chief scientist – Aerosols	CSIRO
36.	Chiemeriwo Godday Osuagwu	CAPRICORN – Aerosols	Queensland University of Technology
37.	Kathryn Moore	CAPRICORN – Ice Nuclei	Colorado State University
38.	Dan Buonome	CAPRICORN – Radiosondes, Wind profiler, Doppler lidar	NCAR, Boulder
39.	Isabel Suhr	CAPRICORN – Radiosondes, Wind profiler, Doppler lidar	NCAR, Boulder

40.	Alexander Norton	CAPRICORN – miniMPL lidar, MAX-DOAS, surface fluxes	University of Melbourne (or Bureau of Meteorology)

Marine Crew

List all crew members and their position on the ship

Name	Role
Michael Watson	Master
Adrian Koolhof	Chief Mate
Andrew Roebuck	Second Mate
James Hokin	Third Mate
Gennadiy Gervasiev	Chief Engineer
Mark Ellicott	First Engineer
Ian McDonald	Second Engineer
Ryan Agnew	Third Engineer
John Curran	Electrical Engineer
Gary Hall	Chief Caterer
Emma Lade	Caterer
Keith Shepherd	Chief Cook
Paul Stanley	Cook
Jonathan Lumb	Chief Integrated Rating
Dean Hingston	Integrated Rating
Ryan Drennan	Integrated Rating
Murray Lord	Integrated Rating
Matthew McNeill	Integrated Rating
Kel Lewis	Integrated Rating
Darren Capon	Integrated Rating

Acknowledgements

Please insert applicable acknowledgements.

Signature

Your name	Stephen R. Rintoul
Title	Chief Scientist
Signature	
Date:	20/07/2018

List of additional figures and documents

Attach any numbered and titled figures here. Delete section if not applicable.

Appendix A CSR/ROSCOP Parameter CodeS

Appendix B Photographs

Photos from voyages assist with communication opportunities and for use in the MNF Annual Report. Photos should be in high resolution as a jpg, png or tif file if possible and include short captions and a credit. For the later this should be a person or an organisation.

If referring to significant equipment items in the text supply a photo or diagram so readers can gain a sense of what has been done. Include people in photos where possible and particularly when students are involved.

View recent Annual Reports for ideas on what type of pictures to supply.

Appendix C (title)

Appendix D (title)

Appendix E (title)

Appendix A - CSR/ROSCOP Parameter CodeS

	METEOROLOGY
M01	Upper air observations
M02	Incident radiation
M05	Occasional standard measurements
M06	Routine standard measurements
M71	Atmospheric chemistry
M90	Other meteorological measurements

	PHYSICAL OCEANOGRAPHY
H71	Surface measurements underway (T,S)
H13	Bathythermograph
H09	Water bottle stations
H10	CTD stations
H11	Subsurface measurements underway (T,S)
H72	Thermistor chain
H16	Transparency (eg transmissometer)
H17	Optics (eg underwater light levels)
H73	Geochemical tracers (eg freons)
D01	Current meters
D71	Current profiler (eg ADCP)
D03	Currents measured from ship drift
D04	GEK
D05	Surface drifters/drifting buoys

	MARINE BIOLOGY/FISHERIES
B01	Primary productivity
B02	Phytoplankton pigments (eg chlorophyll, fluorescence)
B71	Particulate organic matter (inc POC, PON)
B06	Dissolved organic matter (inc DOC)
B72	Biochemical measurements (eg lipids, amino acids)
B73	Sediment traps
B08	Phytoplankton
B09	Zooplankton
B03	Seston
B10	Neuston
B11	Nekton
B13	Eggs & larvae
B07	Pelagic bacteria/micro-organisms
B16	Benthic bacteria/micro-organisms
B17	Phytobenthos
B18	Zoobenthos
B25	Birds
B26	Mammals & reptiles
B14	Pelagic fish
B19	Demersal fish
B20	Molluscs
B21	Crustaceans

D06	Neutrally buoyant floats
D09	Sea level (incl. Bottom pressure & inverted echosounder)
D72	Instrumented wave measurements
D90	Other physical oceanographic measurements

	CHEMICAL OCEANOGRAPHY
H21	Oxygen
H74	Carbon dioxide
H33	Other dissolved gases
H22	Phosphate
H23	Total - P
H24	Nitrate
H25	Nitrite
H75	Total - N
H76	Ammonia
H26	Silicate
H27	Alkalinity
H28	PH
H30	Trace elements
H31	Radioactivity
H32	Isotopes
H90	Other chemical oceanographic measurements

B28	Acoustic reflection on marine organisms
B37	Taggings
B64	Gear research
B65	Exploratory fishing
B90	Other biological/fisheries measurements

	MARINE GEOLOGY/GEOPHYSICS
G01	Dredge
G02	Grab
G03	Core - rock
G04	Core - soft bottom
G08	Bottom photography
G71	In-situ seafloor measurement/sampling
G72	Geophysical measurements made at depth
G73	Single-beam echosounding
G74	Multi-beam echosounding
G24	Long/short range side scan sonar
G75	Single channel seismic reflection
G76	Multichannel seismic reflection
G26	Seismic refraction
G27	Gravity measurements
G28	Magnetic measurements
G90	Other geological/geophysical measurements

	MARINE CONTAMINANTS/POLLUTION
P01	Suspended matter
P02	Trace metals
P03	Petroleum residues
P04	Chlorinated hydrocarbons
P05	Other dissolved substances
P12	Bottom deposits
P13	Contaminants in organisms
P90	Other contaminant measurements