# RV *Investigator* Voyage Plan

| | | | |
|---|---|---|---|
| **Voyage #:** | **IN2018_V01** | | |
| **Voyage title:** | Detecting Southern Ocean change from repeat hydrography, deep Argo and trace element biogeochemistry & CAPRICORN | | |
| **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 | | |
| **Voyage Manager:** | Tegan Sime | **Contact details:** | 03 6232 5414 |
| **Chief Scientist:** | Steve Rintoul | | |
| **Affiliation:** | CSIRO & ACE CRC | **Contact details:** | 0475 950 794 |
| **Principal Investigators:** | Alain Protat | | |
| **Project name:** | CAPRICORN | | |
| **Affiliation:** | Bureau of Meteorology | **Contact details:** | : +61 3 9669 8128 |
| **Principal Investigators:** | Andrew Bowie | | |
| **Affiliation:** | IMAS-UTAS/ACE CRC | **Contact details:** | 0419 389 316 |
| **Principal Investigators:** | Bronte Tilbrook | | |
| **Affiliation:** | CSIRO & ACE CRC | **Contact details:** | 0407 688 832 |
| **Principal Investigators:** | Lev Bodrossy | | |
| **Affiliation:** | CSIRO | **Contact details:** | (03) 6232 5456 |

## 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 two transects: along 140°E (the SR3 line). 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).

## Operational Risk Management

No potentially high risk work has been identified outside standard operations.

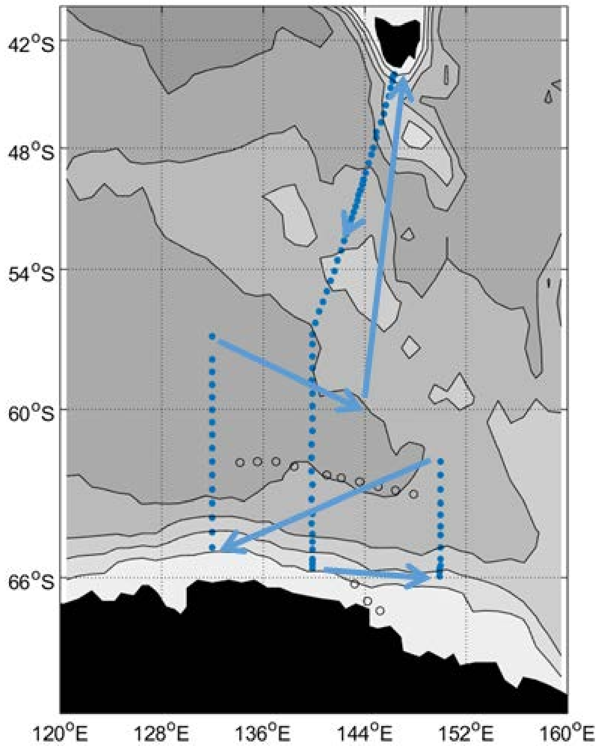
## Overall activity plan including details for first 24 hours of voyage

CTD operations will begin at the northern end of the SR3 repeat hydrography line along nominally 140°, on the Tasmanian continental shelf.  We will carry out CTD stations along the line from north to south. Trace metal rosette (TMR) casts (approximately 27 in total) will be carried out every 2 stations; of which 8 will be 'super-stations' that include separate deep casts to sample for marine particles using  in situ pumps (ISP).  For the other 'normal' stations, 11 will be shallow (to 1500 m) and 8 will be deep (full water column). We will also sample for trace elements in aerosol particles along the transect. Most of the atmospheric sampling for the CAPRICORN project will be done while the ship is working along the primary voyage track, but short diversions may be made to take advantage of coincident measurements with satellite or aircraft overflights.

First 24 hours:  Steaming time to the first station at (44S, 146.23E) is approximately 8 hours. The CTD stations are closely spaced over the continental slope (3.5 to 20 nm spacing) and occupying these stations will use the first 24 hours at sea. One or more TMR cast may also be carried out in the first 24 hours.

CAPRICORN instruments will collect continuous observations during the voyage. The main requirement from our team is to point the ship bow into the wind as often as possible to avoid contamination of the atmospheric measurements from ship exhaust. Four sondes will be launched at more or less regular 6h intervals during the first 24 hours.

## Voyage track example




Voyage track for IN2018_V01.  The vessel will occupy stations from north to south along the WOCE/GOSHIP SR3 line (nominally 140E); then steam east to occupy station from south to north along 150E; then steam southwest to 132E and occupy stations from south to north along this longitude. Closed circles indicate primary CTD stations. Open circles indicate possible additional stations to be occupied, if time and sea ice conditions permit. After completing the final CTD station at the top of the 132E line, the vessel will steam various courses on the transit back to Hobart, carrying out work for the CAPRICORN project.

## Waypoints and stations

Most of the stations to be occupied are repeats of historical stations, to allow estimates of change over time to be made. Therefore it is important that the stations are carried out at the specified positions (to within 2 nm), to the extent that conditions allow. However, it is not necessary to spend extra time to occupy the exact spot.

| station # | latitude (decimal) | longitude (decimal) | distance (nm) | total distance (nm) | steam time (hrs @ 10 kn) | total steam (hrs) |
|---|---|---|---|---|---|---|
| Hobart | -42.87 | 147.35 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | -44.00 | 146.32 | 130.0 | 130.0 | 13.0 | 13.0 |
| 2 | -44.05 | 146.29 | 3.3 | 133.3 | 0.3 | 13.3 |
| 3 | -44.12 | 146.22 | 5.2 | 138.4 | 0.5 | 13.8 |
| 4 | -44.38 | 146.19 | 15.7 | 154.1 | 1.6 | 15.4 |
| 5 | -44.72 | 146.05 | 21.3 | 175.4 | 2.1 | 17.5 |
| 6 | -45.22 | 145.85 | 31.2 | 206.5 | 3.1 | 20.7 |
| 7 | -45.70 | 145.66 | 29.9 | 236.4 | 3.0 | 23.6 |
| 8 | -46.17 | 145.47 | 29.3 | 265.7 | 2.9 | 26.6 |
| 9 | -46.65 | 145.25 | 30.2 | 295.9 | 3.0 | 29.6 |
| 10 | -47.15 | 144.91 | 33.1 | 329.0 | 3.3 | 32.9 |
| 11 | -47.47 | 144.90 | 19.2 | 348.2 | 1.9 | 34.8 |
| 12 | -48.00 | 144.67 | 33.1 | 381.3 | 3.3 | 38.1 |
| 13 | -48.32 | 144.53 | 20.0 | 401.3 | 2.0 | 40.1 |
| 14 | -48.78 | 144.32 | 28.8 | 430.2 | 2.9 | 43.0 |
| 15 | -49.27 | 144.09 | 30.8 | 460.9 | 3.1 | 46.1 |
| 16 | -49.61 | 143.93 | 21.3 | 482.3 | 2.1 | 48.2 |
| 17 | -49.89 | 143.80 | 17.5 | 499.8 | 1.8 | 50.0 |
| 18 | -50.16 | 143.66 | 17.1 | 516.9 | 1.7 | 51.7 |
| 19 | -50.40 | 143.53 | 15.2 | 532.1 | 1.5 | 53.2 |
| 20 | -50.68 | 143.42 | 17.3 | 549.4 | 1.7 | 54.9 |
| 21 | -51.01 | 143.27 | 20.6 | 570.0 | 2.1 | 57.0 |
| 22 | -51.26 | 143.13 | 15.9 | 585.9 | 1.6 | 58.6 |
| 23 | -51.54 | 142.99 | 17.6 | 603.5 | 1.8 | 60.4 |
| 24 | -51.81 | 142.84 | 17.1 | 620.7 | 1.7 | 62.1 |
| 25 | -52.08 | 142.71 | 16.9 | 637.6 | 1.7 | 63.8 |
| 26 | -52.37 | 142.53 | 18.6 | 656.2 | 1.9 | 65.6 |
| 27 | -52.67 | 142.39 | 18.7 | 674.9 | 1.9 | 67.5 |
| 28 | -53.13 | 142.14 | 29.0 | 703.9 | 2.9 | 70.4 |
| 29 | -53.58 | 141.86 | 28.8 | 732.7 | 2.9 | 73.3 |
| 30 | -54.07 | 141.60 | 30.8 | 763.5 | 3.1 | 76.4 |
| 31 | -54.53 | 141.33 | 29.2 | 792.7 | 2.9 | 79.3 |
| 32 | -55.02 | 141.02 | 31.3 | 824.0 | 3.1 | 82.4 |
| 33 | -55.50 | 140.73 | 30.5 | 854.5 | 3.0 | 85.4 |
| 34 | -55.93 | 140.41 | 28.0 | 882.4 | 2.8 | 88.2 |
| 35 | -56.43 | 140.10 | 31.7 | 914.2 | 3.2 | 91.4 |
| 36 | -56.93 | 139.85 | 31.1 | 945.3 | 3.1 | 94.5 |
| 37 | -57.35 | 139.88 | 25.2 | 970.5 | 2.5 | 97.1 |
| 38 | -57.85 | 139.85 | 30.0 | 1000.5 | 3.0 | 100.1 |

| station # | latitude (decimal) | longitude (decimal) | distance (nm) | total distance (nm) | steam time (hrs @ 10 kn) | total steam (hrs) |
|---|---|---|---|---|---|---|
| 39 | -58.35 | 139.85 | 30.0 | 1030.5 | 3.0 | 103.1 |
| 40 | -58.85 | 139.84 | 30.0 | 1060.5 | 3.0 | 106.1 |
| 41 | -59.35 | 139.85 | 30.0 | 1090.5 | 3.0 | 109.1 |
| 42 | -59.85 | 139.86 | 30.0 | 1120.5 | 3.0 | 112.1 |
| 43 | -60.35 | 139.85 | 30.0 | 1150.5 | 3.0 | 115.1 |
| 44 | -60.85 | 139.85 | 30.0 | 1180.5 | 3.0 | 118.1 |
| 45 | -61.35 | 139.84 | 30.0 | 1210.5 | 3.0 | 121.1 |
| 46 | -61.85 | 139.84 | 30.0 | 1240.5 | 3.0 | 124.1 |
| 47 | -62.36 | 139.84 | 30.6 | 1271.1 | 3.1 | 127.1 |
| 48 | -62.85 | 139.85 | 29.4 | 1300.5 | 2.9 | 130.1 |
| 49 | -63.35 | 139.83 | 30.0 | 1330.5 | 3.0 | 133.1 |
| 50 | -63.87 | 139.85 | 31.2 | 1361.7 | 3.1 | 136.2 |
| 51 | -64.21 | 139.84 | 20.4 | 1382.1 | 2.0 | 138.2 |
| 52 | -64.55 | 139.85 | 20.4 | 1402.5 | 2.0 | 140.3 |
| 53 | -64.81 | 139.86 | 15.6 | 1418.1 | 1.6 | 141.8 |
| 54 | -65.07 | 139.86 | 15.6 | 1433.7 | 1.6 | 143.4 |
| 55 | -65.40 | 139.85 | 19.8 | 1453.5 | 2.0 | 145.4 |
| 56 | -65.43 | 139.85 | 1.8 | 1455.3 | 0.2 | 145.5 |
| 57 | -65.53 | 139.85 | 6.0 | 1461.3 | 0.6 | 146.1 |
| 58 | -65.57 | 139.85 | 2.4 | 1463.7 | 0.2 | 146.4 |
| 59 | -65.71 | 139.85 | 8.4 | 1472.1 | 0.8 | 147.2 |
| 60 | -65.95 | 149.90 | 248.0 | 1720.1 | 24.8 | 172.0 |
| 61 | -65.83 | 149.90 | 7.2 | 1727.3 | 0.7 | 172.7 |
| 62 | -65.72 | 149.91 | 6.6 | 1734.0 | 0.7 | 173.4 |
| 63 | -65.61 | 150.00 | 7.0 | 1740.9 | 0.7 | 174.1 |
| 64 | -65.40 | 150.00 | 12.6 | 1753.5 | 1.3 | 175.4 |
| 65 | -65.00 | 149.99 | 24.0 | 1777.5 | 2.4 | 177.8 |
| 66 | -64.60 | 150.00 | 24.0 | 1801.5 | 2.4 | 180.2 |
| 67 | -64.30 | 150.00 | 18.0 | 1819.5 | 1.8 | 182.0 |
| 68 | -63.90 | 150.00 | 24.0 | 1843.5 | 2.4 | 184.4 |
| 69 | -63.50 | 150.00 | 24.0 | 1867.5 | 2.4 | 186.8 |
| 70 | -63.00 | 150.00 | 30.0 | 1897.5 | 3.0 | 189.8 |
| 71 | -62.50 | 150.00 | 30.0 | 1927.5 | 3.0 | 192.8 |
| 72 | -62.00 | 150.00 | 30 | 1957.5 | 3.0 | 195.8 |
| 73 | -65.00 | 132.00 | 514.0 | 2471.5 | 51.4 | 247.2 |
| 74 | -64.50 | 132.00 | 30.0 | 2501.5 | 3.0 | 250.2 |
| 75 | -64.00 | 132.00 | 30.0 | 2531.5 | 3.0 | 253.2 |
| 76 | -63.50 | 132.00 | 30.0 | 2561.5 | 3.0 | 256.2 |
| 77 | -63.00 | 132.00 | 30.0 | 2591.5 | 3.0 | 259.2 |
| 78 | -62.50 | 132.00 | 30.0 | 2621.5 | 3.0 | 262.2 |
| 79 | -62.00 | 132.00 | 30.0 | 2651.5 | 3.0 | 265.2 |
| 80 | -61.50 | 132.00 | 30.0 | 2681.5 | 3.0 | 268.2 |
| 81 | -61.00 | 132.00 | 30.0 | 2711.5 | 3.0 | 271.2 |
| 82 | -60.50 | 132.00 | 30.0 | 2741.5 | 3.0 | 274.2 |
| 83 | -60.00 | 132.00 | 30.0 | 2771.5 | 3.0 | 277.2 |
| 84 | -59.50 | 132.00 | 30.0 | 2801.5 | 3.0 | 280.2 |
| 85 | -59.00 | 132.00 | 30.0 | 2831.5 | 3.0 | 283.2 |

| station # | latitude (decimal) | longitude (decimal) | distance (nm) | total distance (nm) | steam time (hrs @ 10 kn) | total steam (hrs) |
|---|---|---|---|---|---|---|
| 86 | -58.50 | 132.00 | 30.0 | 2861.5 | 3.0 | 286.2 |
| 87 | -58.00 | 132.00 | 30.0 | 2891.5 | 3.0 | 289.2 |
| 88 | -57.00 | 132.00 | 60.0 | 2951.5 | 6.0 | 295.2 |
| CAPRICORN | -60.00 | 144.00 | 417.0 | 3368.5 | 41.7 | 336.9 |
| Hobart | -42.87 | 147.35 | 1035.0 | 4403.5 | 103.5 | 440.4 |

## Time estimates

The following time estimates are based on a steaming speed of 10.5 knots.

If the full allowance for weather/ice/equipment delays is not required, additional stations may be added on the Antarctic continental shelf near the Mertz glacier (ice permitting) and/or along the GOSHIP S4 repeat hydrography line (nominally 62°S), as shown on the voyage track map.

Station times have been estimated in two ways, both of which give similar answers: based on experience on Aurora Australis in the Southern Ocean over the past decade, and based on station times calculated from IN2016_V03 (we fit a line to cast time vs depth, and added 20 minutes for set-up on station and departure). We have used the IN2016_V03 times; as that voyage experienced delays due to wire and spooling issues, this should be conservative. See attached spreadsheet for additional details of sampling locations and timing.

TMR = trace metal rosette; ISP = in situ pump

| Date | Time (days) | Total time | Activity |
|---|---|---|---|
| 9-10 Jan | 2.0 | 2.0 | Mobilisation |
| 11 Jan | 0.5 | 2.5 | Transit to first station |
| | 19.1 | 21.6 | SR3: CTD + TMR/ISP + steaming |
| | 0.4 | 22.0 | SOCCOM float deployments (12 @ 1 hr) |
| | 1.0 | 23.0 | Deep Argo float deployments (11@ 2 hrs) |
| | 1.0 | 24.0 | Transit to 150E section |
| | 2.5 | 26.5 | 150E CTD section (CTD + TMR/ISP + steam) |
| | 2.0 | 28.5 | Transit to 132E section |
| | 4.2 | 32.7 | 150E CTD (CTD + TMR/ISP + steam) |
| | 5.8 | 38.5 | Transit home |
| | 2.0 | 40.5 | Extra transit on return for satellite track chasing (CAPRICORN) |
| | 3.5 | 44.0 | Weather/ice/gear delays |
| 22 Feb | 1.0 | 45.0 | Demobilisation |

## Piggy-back projects (if applicable)

No piggy-back projects on this voyage.

## *Investigator* equipment (MNF)

Equipment, facilities and support staff required from MNF are summarised in the tables below. The following containers are needed. All vans need power; a data cable is needed to the TM3 (the TMR storage container).

- MNF Trace metal analysis van ('blue' van – TM1)
- MNF Trace metal sampling van ('white van – TM2)
- MNF Trace Metal Rosette (TMR) storage container (TM3)
- "Education" van used for in-situ pump (ISP) storage on aft deck. Helium cylinders and/or large deep Argo floats may also be stored in this van.

A total of 5 gas cage pallets are needed (3 for helium, 1 for nitrogen (for CFC), 1 for nitrogen (Carbon team).

## User Equipment

Containers/lab vans required:

- User-supplied CFC analysis van
- CAPRICORN: container to store spares in the hold
- Carbon team 20' container used for storage during voyage (stored in hold).

**Rintoul:**

| **Item name** | **Supporting information** |
|---|---|
| Gas Chromatographs (2) | CFC measurements: In lab van from USA, power and water requirements to be specified. Data feed from ships logging system required. |
| Wetlabs FLBB | As deployed on leg 1 of IN2016_V03; requires two auxiliary channels on CTD |

**Protat:**

| **Item name** | **Supporting information** |
|---|---|
| 95 GHz cloud radar | In the fore deck stabilized platform container (BOM) |
| Lidar | In the fore deck stabilized platform container (BOM) |
| Micro-rain radar | Strapped on railing of Level 4 observation platform (AAD). |
| Mini-MPL scanning lidar | Under discussion with MNF (Deck 4 or 5 observation platform). |
| MAX-DOAS | Under discussion with MNF (Deck 4 or 5 observation platform); needs to be near mini-MPL scanning lidar. |
| Microwave radiometer | Strapped on railing of Level 4 observation platform (Univ. Utah). |
| Microwave profiler | Strapped on railing of Level 4 observation platform (BOM). |
| UHF wind profiler | On the aft deck (see deck layout). |
| Doppler wind lidar | Level O2, aft (see deck layout). |

| Item name | Supporting information |
| --- | --- |
| Ceilometer | Level 02 aft deck adjacent to Doppler wind lidar (NCAR) |
| Radiosondes + helium | Location of helium storage still under discussion: a combination of 2 bottles in racks in Sheltered Science area and bottles in gas cages (possibly one cage in Sheltered Science area). |
| OceanRAIN disdrometer | Main mast, second highest platform preferred (OceanRAIN project manager, Christian Klepp). Three instruments (disdrometer, detector and anemometer) along with data logger in dry lab. 40 m single-cable length. (Univ. Hamburg) |
| Surface Flux package | Front mast Sonic anemometer from Univ. Melbourne, maybe also a fast humidity sensor. We will rely on the MNF baseline instruments as well. |
| VH-TDMA | This instrument provides real time data on aerosol composition and hygroscopic properties; will be placed in the Air Chemistry laboratory (QUT) |
| Particle sizer (SMPS) | This instrument provides data on the aerosol size distribution, linking the existing RV Investigator SMPS and the APS (CSIRO). Successfully deployed on numerous previous voyages in the aerosol lab. Uses sealed radioactive sources |
| Particle sizer (APS) | This instrument provides data on the aerosol size distribution, extending the range provided by the SMPS instrument into the micron size (CSIRO). Successfully deployed on previous voyages in the aerosol lab. |
| Particle counter (CPC) | Aerosol lab – successfully deployed on two voyages- requires remote desktop access to instrument- will have butanol as working liquid (CSIRO) . This expands existing permanent instrumentation on the vessel |
| Chemical Ionisation Mass Spectrometer (CIMS) | Provides measurements of sulfuric acid and molecular clusters. Uses as x-ray tube as an ionization source. Successfully deployed on IN2016_V05. Will be deployed in either the whale obs room or the air chemistry lab. |
| PTRMS | Provides measurements of volatile organic compounds (VOCs). Not yet secured, but if available, will be mounted in the air chemistry laboratory. |
| Aerosol Chemical Speciation Monitor | Aerosol chemical composition. Mounted in the Air Chemistry Lab - successfully deployed on two voyages (CSIRO) |
| PM1 Aerosol sampler | Captures aerosol samples for later analysis of chemical composition. This utilizes infrastructure recently installed in the air chemistry and aerosol laboratories. |
| Continuous Flow Diffusion Chamber (CFDC) | Aerosol Lab – Primary components fit in user-supplied 19x24x49 inch aircraft-rated rack except a 5x7x10 inch icing water tank that can be secured to any structure at floor level. A chamber extends out of the open rack top to 56 inches total height from floor. Total weight is 370 pounds. Rack will secure to floor rails, as was done |

| Item name | Supporting information |
|---|---|
| | previously in the aerosol laboratory during IN2016_V02. N2 or compressed air gas is required (1 standard tank per week) and a small non-CFC refrigerant tank is needed for refrigeration systems. Running maximum of 19 amps at 110V (60 Hz) is ideally required, and power conversion is needed from the ship's 240V power source. The exact plan for that conversion is under discussion with MNF. Sample flow rate is 1.5 liters per minute, to be provided to the CFDC at some times from the aerosol lab inlet. An aerosol pre-concentrator (MSP Model 4240, 14"x 21"x 11"; 44 lbs, 8 A max @ 240 VAC on start-up and 5 A @ 240 VAC steady state) will be placed in the aerosol lab and connected to the CFDC system at other times via a separate sampling tube that was installed in 2016, still extending partly into the aerosol lab (our present understanding). This tube will be extended to make a connection to the aerosol concentrator.. (CSU) |
| Ice Spectrometer (IS) filters and filters for sequencing analyses | Sampling filter holders (one maximum per day of cruise) for offline IS measurements of ice nucleating particles can be secured to accessible rails outside on Deck05 , with a rain cover provided. A sample pump (240V, 0.8 A running) will be provided to be mounted within laboratory space, with a sample line running to the external filter sampler position. If it can be accommodated, a second air pump will feed a filter to be devoted to airborne next gen sequencing analyses. Finally, also if it can be accommodated, we would send a secured collector for rain samples. Sterilization and storage supplies will be provided. Filters will be stored in the walk-in freezer, and we ask for power to remain on this freezer on return to port, until a cryo-shipper arrives for shipment to the U.S. within a few days of return. (CSU) |
| WIBS-4A | 11.9"x15.1"x 6.75", 100 W, 13.6 kg; for fluorescent particle measurements, mounted in the aerosol lab with a sample inlet that is directed vertically (without bends) to connect to the multi-user aerosol inlet. (CSU) |

**Bowie:**

| Item name | Supporting information |
|---|---|
| Air Sampling Pump Controller (from MNF) | Sector control switch used to switch vacuum pumps on/off and enable sampling of air only when the ship is in a 'clean' sector (i.e., prevents contamination of samples by sampling air impacted by the ship's exhaust); requires Ethernet data feed of ship's met data |
| Aerosol sampling system (UTAS/CSIRO) | Includes pumps, flow meters, tubing and filtration holders |
| Laminar flow hood (UTAS) | For clean sampling and sample handling |
| Sampling bottles and filters (UTAS) | Seawater, aerosol and marine particles sampling |

| Item name | Supporting information |
|---|---|
| Laboratory ware and equipment | For experiments and sample processing at sea |
| Precipitation (Rain) Sampler | Polyethylene funnel and collection bottle, to be installed on 05 level outside of bridge equipment room (no power required), and opened manually during rain events |
| Flow injection samplers | Benchtop samplers for near real-time analysis of trace elements |
| spare trace metal rosette | Stored on O2 deck, in place where it can be lowered to aft deck if level |

**Tilbrook:**

| Item name | Supporting information |
|---|---|
| Coulometer | DIC measurement: wet clean lab, 240V 10 amp supply, 2.5m bench space, room T controlled 20-25C and rate of change in room T less than 1C per hour, fresh water tap and sink |
| Potentiometric titrator | Total Alkalinity measurement; wet clean lab, 2m bench space, 240V 10 amp supply, room T controlled 20-25C and rate of change in room T less than 1C per hour, fresh water tap and sink |
| Gas cylinders | Air, Nitrogen and CO2 (2 each, G size) in lab near coulometer. |
| Sample bottles | spare sample bottles in 2 cage pallets and spare equipment, preferably in an accessible container, to allow backup samples to be collected in case of equipment down time. |
| C-14 & C-13 samples | 3-4 m3 of room temperature storage space. On IN2016_v03, empty bottles were stored in the clean dry lab (under-bench space plus the large island bench), and full samples were then stored in the dirty wet lab as Argo floats were deployed. At the end of the voyage they were moved to the constant temperature lab (filled 2/3 of the room). Any one of the above 3 spaces would be adequate. |
| SOCCOM float pH samples | Preservation lab or similar store pH samples as on IN2016_V03 |
| C. Neill new DIC instrument | Third bench in wet clean lab. |

## Special Requests

- CTD needs to be operated with heave compensation engaged.
- Consistent with experience developed on IN2016_V03, the CTD should be lowered at 60 m/min, and raised at 70 m/min at depths shallower than 3500 m.
- CTD and other operations will be carried out 24 hours per day. Most of the science team will work 12 hour shifts. Food for a night meal needs to be set aside and reserved for the scientists working through the night. We also need to be able to put meals aside when CTD operations or sampling conflict with meal times.
- As discussed with MNF, we will use dual altimeters (a 500 kHz unit owned by MNF and a 200 kHz unit borrowed from Australian Antarctic Division)

**See attached summary of lab space needs and allocations.**

**Rintoul:**

- Power, water and data feed from ship's logging system needed for CFC lab van.
- Storage for 11 Deep Argo floats and 12 Biogeochemical Argo (SOCCOM) floats, in dirty wet lab or other space with easy access to deck for deployment (possibly use "Education" van on aft deck for 6 large deep Argo floats).

**Protat:**

- Power for all CAPRICORN instruments (see special requirements from P. DeMott, CSU, to MNF Ian McRobert for US instrument in the aerosol lab).
- Make sure all CAPRICORN instruments are all interrogating the MNF NTP server (same clock for all instruments).
- Data connection (backup, remote control and some live data feed to shore) for some instrumentation. We need to send about 200 kB images every 10 minutes. We need to provide the US PIs with the web live address of the MNF Investigator location so that they can track us.
- We would like to get access to the videoconferencing room to be able to brief the US PIs from SOCRATES in Hobart on the current situation at the ship location. Typically, there will be a weather briefing and a discussion with the US PIs once a day. This should last for about one hour. Additionally, when it is decided that the aircraft will overpass the ship, we will need to have another discussion of about one hour.
- We request that Jay Mace (CAPRICORN PI on the ship) has Internet access to be able to send summary images to Hobart every 10 minutes, update satellite orbital predictions, and liaise with the CAPRICORN ground PI (A. Protat) and US PIs in Hobart.

**Bowie:**

- Access to laminar flow hood in wet clean lab of the ship to sample from the trace metal clean underway supply system
- Access to laminar flow hood in dry clean lab for acidification of samples
- Storage for 24 fish bins with natural radiogenic isotope samples, e.g. in dry clean lab
- ASP – please provide advance notice of incineration events and a final record of incineration events for the voyage to the aerosols team.ASP – please provide advance notice of incineration events and a final record of incineration events for the voyage to the atmospheric team.
- Access to Milli-q system (in GP dry lab (clean))
- Access to aerosol sampling lab, GP wet lab (clean), blast freezer and controlled temperature lab

**Tilbrook:**

- Entire wet clean lab is needed for carbon measurements and sample processing as on IN2016_V03. Requires total of 32 x 10A power outlets, capacity to handle 6kW heating and maintain temperature variations to within 1C per hour in 20-25C temperature range. This lab was modified last year to be able to handle the needs of the carbon team. The fume hood is needed and the laminar flow hood is available for use, but there is little other free space in this lab. Need access every 2-3 days to the milliQ system in the General Purpose clean lab (dry).
- 20 foot container. Equipment is loaded and offload using a container. Stored on O2 deck for storage on board.

**Bodrossy:**

- two incubators in Clean Dry Lab, walk in fridge and shipboard incubator
- filtering station at the clean dry lab next to a sink (bench space to the right of the door when we enter the clean dry lab would be best).
- For the microcosm work, need some bench space at the wet lab with convenient access to the walk in fridge.

## Permits

Environmental authorisation needed for work south of 60S approved.

Permit for Tasman Fracture Commonwealth Marine Reserve approved.

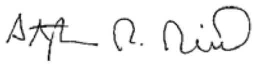
ACMA licence for the US NCAR 915 MHz wind profiler approved. Other active remote sensing instruments (BOM cloud radar, BOM lidar) have an ongoing ACMA licence.

## Personnel List

| | | | |
|---|---|---|---|
| 1. | Tegan Sime | Voyage Manager | CSIRO MNF |
| 2. | Ian McRobert | SIT Support | CSIRO MNF |
| 3. | Aaron Tyndall | SIT Support | CSIRO MNF |
| 4. | Peter Shanks | DAP Support | CSIRO MNF |
| 5. | Francis Chui | DAP Support | CSIRO MNF |
| 6. | TBC | Doctor | |
| 7. | Christine Rees | Hydrochemist | CSIRO MNF |
| 8. | Stephen Tibben | Hydrochemist | CSIRO MNF |
| 9. | Kendall Sherrin | Hydrochemist | CSIRO MNF |
| 10. | TBC | 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) |

## Signature

| | |
|---|---|
| **Your name** | Steve Rintoul |
| **Title** | Chief Scientist |
| **Signature** |  |
| **Date:** | 30 October 2017 |

## List of additional figures and documents

Proposed deck layout (Investigator_Rear_Deck_Planning_IN2018_V01_25sep2017.pptx)

Lab space allocation summary (lab summary table.docx)

Station planning spreadsheet

CTD equipment request sheet

Chemical manifests

Copies of permits

## 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.

### (i) Standard laboratories and facilities

| Name | Essential | Desirable |
|---|---|---|
| Aerosol Sampling Lab | X | |
| Air Chemistry Lab | X | |
| Preservation Lab | X | |
| Constant Temperature Lab | X | |
| Underway Seawater Analysis Laboratory | X | |
| GP Wet Lab (dirty) | X | |
| GP Wet Lab (Clean) | X | |
| GP Dry Lab (Clean) | X | |
| Sheltered Science Area | X | |
| Observation deck 07 level | | |
| Walk in Freezer | | |
| Clean Freezer | X | |
| Blast Freezer | X | |
| Ultra-Low Temperature Freezer | X | |
| Walk in Cool Room | X | |

### (ii) Specialised laboratory and facilities

May require additional support

| Name | Essential | Desirable |
|---|---|---|
| Modular Radiation Laboratory | | |
| Modular Trace Metal Laboratories – 'blue' analysis van TM1 | X | |
| Modular Trace Metal Laboratories – 'white' sampling van TM2 | X | |
| Trace Metal Rosette (TMR) storage container (TM3) | X | |
| Modular Hazchem Locker | | |
| Deck incubators | | |
| Stabilised Platform Container | X | |

### (iii) Standard laboratory and sampling equipment

| Name | Essential | Desirable |
|---|---|---|
| CTD - Seabird 911 with 36 Bottle Rosette | X | |
| CTD -Seabed 911 with 24 Bottle Rosette | X | |
| LADCP | X | |
| Sonardyne USBL System | | |
| Milli -Q System | X | |
| Laboratory Incubators | | |
| Heavy Duty Electronic Balance | | |
| Medium Duty Electronic Balance | | |
| Light Duty Electronic Balance | | |
| Surface Net | | |
| Bongo Net | | |
| Smith Mac grab | | |
| Dissecting Microscopes | | |

### (iv) Specialised laboratory and sampling equipment

May require additional support

| Name | Essential | Desirable |
|---|---|---|
| TRIAXUS – Underway Profiling CTD | | |
| Continuous Plankton Recorder (CPR) | | |
| Deep tow camera | | |
| Piston Coring System | | |
| Gravity Coring System | | |
| Multi Corer | | |
| XBT System | | |
| Trace Metal Rosette and Bottles | X | |
| Sherman epibenthic sled | | |
| Trace- metal in-situ pumps | X | |
| LADCP | | |
| Rock Dredges | | |
| EZ Net | | |
| Rock saw | | |
| Portable pot hauler | | |
| Beam Trawl | | |
| Trawl doors (pelagic or demersal) | | |
| Stern Ramp | | |
| Trawl monitoring instrumentation (ITI) | | |

| Name | Essential | Desirable |
|---|---|---|
| Radiosonde | X | |

### (v) Equipment and sampling gear requiring external support

May require additional support from applicants

| Name | Essential | Desirable |
|---|---|---|
| Seismic compressors | | |
| Seismic acquisition system | | |

### (vi) Underway systems

***Acoustic Underway Systems***

| Name | Essential | Desirable |
|---|---|---|
| 75kHz ADCP | X | |
| 150kHz ADCP | X | |
| Multi Beam echo sounder EM122 12kHz (100m to full ocean depth) | | |
| Multi Beam echo sounder EM710 70-100kHz (0-1000m approx.) | | |
| Sub-Bottom Profiler SBP120 | | |
| Scientific Echo Sounders EK60 (6 bands, 18kHz-333kHz) | X | |
| | | |
| Gravity Meter | | |
| Trace metal clean seawater supply | X | |

***Atmospheric Underway Sensors***

| Name | Essential | Desirable |
|---|---|---|
| Nephelometer | X | |
| MAAP (multi angle absorption photometer) | X | |
| SMPS (scanning mobility particle sizer) | X | |
| Radon detector | X | |
| Ozone detector | X | |
| Manifold instrumentation (intake temperature and humidity) | X | |
| Picarro spectrometer (analysis of $CO_2$/$CH_4$/$H_2O$) | X | |
| Aerodyne spectrometer (analysis of $N_2O$/CO/$H_2O$) | X | |
| O2 analyser | X | |
| Manifold instrumentation (intake temperature and humidity) | X | |
| CCN (Cloud Condensation Nuclei) | X | |
| CPC (Condensation Particle Counter) | X | |
| MOUDI (Micro-Orifice Uniform Deposit Impactors) | X | |
| NOx monitor | X | |

| Name | Essential | Desirable |
|---|---|---|
| Polarimetric Weather Radar | X | |

***Underway Seawater Instrumentation***

| Name | Essential | Desirable |
|---|---|---|
| Thermosalinograph | X | |
| Fluorometer | X | |
| Optode | X | |
| PCO2 | X | |