RV *Investigator* Voyage Summary

Voyage #:	IN2016_T01		
Voyage title:	Continuity of Australian terranes into Zealandia: towards a geological map of the east Gondwana margin		
Mobilisation:	Hobart, 25 April 2016		
Depart:	Lautoka, 1900, Friday, 30 June 2016		
Return:	Hobart, 0400, Thursday, 14 July 2016		
Demobilisation:	Hobart, 15 July 2016		
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Principal Investigators:	Maria Seton, Nick Mortimer, Julien Collot (Geoscience) Nick Hardman-Mountford, CSIRO (Bio-optics/Biogeochemistry) Martina Doblin, UTS (Piggyback 1) Bonnie Laverock, UTS (Piggyback 2) Melita Keywood, CSIRO (Piggyback 3) Ann Thresher, CSIRO (Piggyback 4)		

Objectives and brief narrative of voyage

Scientific objectives

There are two scientific streams to this project:

a. ***Marine geology/geophysics.*** The main aim was to improve matches in the continental geology of eastern Australia, New Zealand and New Caledonia. Specifically, to test competing models for the continuity of east Gondwana Mesozoic igneous belts and terranes between eastern Australia, New Zealand and New Caledonia, contribute to the regional framework of petroleum basins on the northern Lord Howe Rise and establish the geological origin of the phantom "Sandy Island".

b. ***Bio-optics and biogeochemistry***. The objective was to characterize bio-optical and associated biogeochemical properties along the transect from optical sensors either profiled at CTD stations, deployed on autonomous profiling floats. Sensors were intended to measure: fluorometry, absorption, backscattering, attenuation, radiometry, oxygen, pH, temperature, salinity, nutrients. These sensor measurements would be supported by samples taken from water bottles on CTD casts (pigments, CDOM, phytoplankton absorption, suspended particles, nutrients, oxygen, carbon, salinity) to be used for context, validation and/or calibration.

The following piggyback projects were also carried out during this voyage:

c. ***Thermal performance of Marine microbes.*** (CI Martina Doblin, UTS)

The objective of this piggyback project is to examine the temperature tolerance, diversity and activity of upper ocean microbial communities from Lautoka to Brisbane. This involves collecting surface seawater along the ship's path, and conducting a series of microbial community characterisation assays using instrumentation that is normally only available in a land-based laboratory. After water collection, all of our investigations take place in a container lab on the ship. Data will come from the CTDs described above.

d. ***"Investigation into the microbial contribution to C, N and S cycling in the Coral Sea"*** **and "Spatial scale patterns in photo-physiology and primary productivity"** (CI Bonnie Laverock, UTS)

The aims of this piggyback project fall into four categories:

1. DMS/P production by phytoplankton and bacteria related to Coral Sea light conditions
2. Method development (*DMS measurements in seawater – gas chromatography vs. chemiluminescence detection)*
3. Nitrogen cycling supporting primary production in the Coral Sea
4. Spatial scale patterns in photo-physiology and primary productivity

e. ***Atmospheric underway measurements*** (CI Melita Keywood, CSIRO)

The scientific objective of this work is to investigate the chemical composition, size distribution, optical properties and cloud nucleating properties of marine aerosol over the southern hemisphere with the aim of quantifying regional contributions of aerosols to radiative forcing. There is currently very large uncertainty associated with the direct, semi-direct and indirect effect of aerosols on radiative forcing. A key feature in this regard is the influence on cloud properties of cloud condensation nuclei (CCN), the very small atmospheric aerosol particles necessary for the nucleation of every single cloud droplet. A recent analysis of the 35-year CCN concentration record at Cape challenges the current accepted wisdom of the role of dimethyl sulfide (DMS) on CCN

formation over the Southern Ocean. In particular, it appears that DMS oxidation is only significant during the summer months at Cape Grim, and in fact other sources and processes dominate throughout the rest of the year. That other sources and processes may be significant in CCN production and modulation has also recently been suggested in a review of the CLAW hypothesis. The identity of these sources remains an open question. The atmospheric underway experiments were a continuation of experiments carried out as part of the preceding voyage (IN2016_VO3).

f. ***Argo float deployments (Ann Thresher, CSIRO***)

7 ARGO floats were to be deployed during transit.

Date	Latitude	Longitude	Depth	Type
Fri 01 Jul 2016 01:00:53 +0000	19 09.60	174 55.20	2939m	ARGO float
Fri 01 Jul 2016 15:27:18 +0000	20 28.67	172 29.42	3089m	ARGO float
Mon 04 Jul 2016 00:05:34 +0000	21 13.39S	163 10.34E	3583m	ARGO float
Wed 06 Jul 2016 16:30:11 +0000	20 44.82S	159 51.10E	2137m	ARGO float
Thu 07 Jul 2016 14:23:05 +0000	23 25.18S	157 45.2180E	2181m	ARGO float
Fri 08 Jul 2016 00:20:43 +0000	24 52.00S	156 45.75E	2680m	ARGO float
Sat 09 Jul 2016 00:14:44 +0000	28 04.176S	156 00.22E	4813m	ARGO float

Voyage objectives

Geoscience

The original plan involved 4-6 dredges on the Fairway Ridge and Sandy Island area. The specific locations of potential dredge sites are shown on the original voyage plan image (Fig. 2) and are tied to a confidential seismic reflection profile and/or swath bathymetry data. As we had access to high-resolution swath data from the area from the Geological Survey of New Caledonia, there was no necessity to plan a detailed swath survey for each dredge site. The waypoints for the planned sampling locations are defined in table 1, with priority listing for the dredge sites. Exact dredge site locations are typically determined immediately prior to dredging based on factors such as wind conditions (strength and direction dictating possible dredging directions) and remaining science time available.

Table 1: Original Planned Dredge sites (based on Lautoka to Cairns voyage track)

Waypoint	Longitude	Latitude	Dredge site priority
Dredge 1	161.709506	-20.350414	1
Dredge 2	161.587761	-20.434766	1
Dredge 3	161.422881	-20.538931	1
Dredge 4	161.644005	-20.393789	2
Dredge 5	159.833103	-19.305847	1
Dredge 6	159.833103	-19.305847	2

Equipment. Dredges, winch, rock saw - all provided by MNF.

Swath bathymetry and ocean-bottom profiler (continuous collection)

Operations. We continuously collected bathymetric data and the North Fiji Basin will be crossed during the transit voyage, thus requiring no additional time to collect this important swath profile.

Equipment. Sub-bottom profiler and deep-water multibeam. This equipment has already been installed.

Gravity (continuous collection)

Operations. We continuously collected gravity data. There was no deviation necessary to obtain gravity measurements over the northwestern part of the Fairway Ridge as we were crossing this area as part of the dredging component of the survey.

Equipment. Gravimeter. This equipment was already installed on *Investigator*.

Bio-optics and Biogeochemistry

Operations. The voyage plan involved collecting daily CTD profiles and water samples to depths of 250m to characterise the water at time of deployment for pigment, nutrient, dissolved oxygen, dissolved inorganic carbon and total alkalinity concentrations. Deeper CTDs (up to 1000 m depth) were undertaken when coinciding with the deployment of Bio-Argo floats. Additional sensors we included on the CTD included chlorophyll and CDOM fluorometers, backscattering meter, beam transmissometer and dissolved oxygen sensor. The science team provided sensors that were not available through the MNF equipment pool. This included a LISST that was deployed on the main CTD and a suite of bio-optical sensors, which were deployed to 200m following each regular CTD cast and 300m following each deep (1000m) CTD cast, on a separate bio-optical instrument frame (the 'BOPak'). The bio-optical sensor suite included instruments measuring spectral absorption and attenuation (WETLabs ac-s), multispectral optical backscattering (WETLabs bb9, HOBILabs Hydroscat-6) and a Seabird 19plusv2 CTD with additional sensors measuring temperature, salinity, dissolved oxygen, chlorophyll fluorescence and PAR. Hyperspectral radiometry profiles were measured using a freefall Satlantic HyperPro to 10m depth, coincident with each daytime CTD station and, time permitting, coincident with afternoon ocean colour satellite overpasses (VIRRS).

Water samples taken during CTD sampling were filtered or chemically fixed on board according to standard operating procedures. Water samples were taken at 3 depths (surface, chlorophyll maximum, oxygen minimum) for the following analyses: HPLC pigments, particulate absorption (ap), particulate organic carbon (POC), total suspended solids (TSS), dissolved organic carbon (DOC), coloured dissolved organic matter absorption (aCDOM), flow cytometry and flow cam, dissolved inorganic carbon and total alkalinity. Additionally, analyses of all nutrients and dissolved oxygen were undertaken by the hydrochemistry facility for all water depths sampled.

The initial plan anticipated each deployment station taking 1.5 hours, with deployments taking place at 0930 and 1400 hours each day (when not conflicting with dredge operations). This plan was sensitive to the limited amount of science time available during the transit, so was curtailed to only one CTD per day except for the additional stations sampled during the 2 Bio-Argo float deployments. CTD and bio-optical deployments were generally achieved within 1.5 to 2 hrs. Remaining science time was updated daily during the voyage and a CTD station was not scheduled during the last day of the voyage (this also coincided with rough weather). Data and samples collected from the daily CTDs fed into a number of experiments being carried out as piggyback projects, listed below.

Piggyback Projects

Thermal performance of marine microbes. (CI Martina Doblin, UTS)

The objective of this piggyback project was to examine the temperature tolerance, diversity and biogeochemical function of upper ocean microbial communities from Lautoka to Hobart. This involved collecting seawater from the top and bottom of the mixed layer (i.e., surface and deep chlorophyll-a maximum, if present) and incubating microbial communities in a temperature gradient. The temperature gradient comprised 7 temperatures (ambient, ambient – 3, ambient – 6.5, ambient – 10 °C and ambient + 3, ambient +6.5, ambient + 10 °C).

A summary of our experiments is shown in Table 2.

Phototroph populations were enumerated and functional traits characterised on board using flow cytometry. Prochlorococcus, Synechococcus, diatoms, as well as picoeukaryotes were distinguished on the basis of their fluorescence (chlorophyll-a, phycoerythrin, PDMPO) and scatter properties.

Initial communities from each location were characterised in terms of their cell abundance and composition, as well as functional traits of cell volume, chlorophyll content, and frustule silicification.

Community carbon fixation and dissolved nutrient concentrations were also measured before and after incubation to assess the direct and indirect impacts of warming on biogeochemical functions of primary production and net nutrient uptake.

To evaluate the impact of resource limitation on temperature tolerance, the performance of natural microbial communities was contrasted with those that were supplemented with nutrients or light during temperature incubations. Surface communities were amended with dissolved nutrients (5 µmol nitrate, with phosphate, silicate, metals and vitamins added in equivalent f/2 culture medium ratios) before being incubated at surface irradiance (incident irradiance 600 µmol photons m^{-2} s^{-1}). In contrast, deep chlorophyll-a maximum communities were incubated at ambient and 'high' irradiance (~50 and ~200 µmol photons m^{-2} s^{-1}).

Table 2: Summary of microbial thermal performance experiments performed on board

CTD	Exp	Date	Depths
2	1	2-Jul-16	Sur + DCM
3	2	3-Jul-16	Sur
4	3	4-Jul-16	Sur
6	4	6-Jul-16	DCM
7	5	7-Jul-16	Sur
8	6	8-Jul-16	Sur + DCM
10	7	9-Jul-16	Sur
11	8	10-Jul-16	Sur
12	9	11-Jul-16	Sur + DCM

"Investigation into the microbial contribution to C, N and S cycling in the Coral Sea" **and "Spatial scale patterns in photo-physiology and primary productivity"** (CI Bonnie Laverock, UTS)

The aim of this piggyback was to combine biogeochemical observations of the microbial carbon, nitrogen and sulphur cycles with molecular data (from filtered DNA/RNA), in order to gain an understanding of the microbial "key players" contributing to marine primary production along the ship's transit path.

A suite of biogeochemical measurements were taken at each CTD station; these included bacterial production rates (carbon cycling); nitrification rates (nitrogen cycling); and DMS/P concentrations and DMS/P lyase rates (sulphur cycling). Seawater was filtered in order to capture microbial cells for subsequent analyses involving microbial DNA and RNA. Additionally, photo-physiological measurements were used to estimate primary production at each CTD station and at underway points throughout the day; each of these time points was matched to a nutrient sample processed by the MNF's hydrochemist. Finally, a sulphur chemiluminescence device (SCD) was used to measure DMS concentrations, as a comparative method to the traditional gas chromatography (GC). Samples from each CTD were taken and run simultaneously on the SCD and GC.

Results

Geoscience

Seven dredge sites were attempted during the voyage - termed ECOSAT II as the voyage aims were a follow-on from voyage SS2012/v06 Eastern Coral Sea Tectonics (ECOSAT) - with seafloor material recovered in all 7 sites, 6 recovering rock material useful to the scientific aims. The dredge area comprised the canyon area on the Fairway Ridge close to the Lansdowne Bank, as originally planned. However, it was decided to make dredges 1 and 2 on the SE Fairway Ridge on and near a guyot volcano-like feature although this area was not in the original voyage plan. The original voyage plan included dredge sites at Sandy Island, based on a voyage track arriving in Cairns in North Queensland. The change of destination port to Hobart, combined with the limited amount of time allocated to dredging operations (c. 32 hours) and considerations of maximising the time available for both dredging and water sampling, the plan to dredge two sites near the phantom Sandy Island (NW of figure below) were abandoned in favour of a more detailed study of the Fairway Ridge. In all, seven dredges were made in three areas along the Fairway Ridge, instead of the six in two areas planned.

The rock dredging aspect of the voyage was a definite success. Useful rock was obtained in DR01-06, DR07 being the only dredge in which indurated rocks were not found, only biogenic ooze and soft limestone. An estimated 900 kg of seabed material was deposited on the deck and 102 kg of samples were taken off the ship for archiving and further study. We do not yet know if we can answer the main geoscientific research questions about northern Zealandia with the data and samples we have collected. This must await dating and chemical analysis of the ECOSATII rocks as well as interpretation of bathymetric data. However, the cruise component of the ECOSATII project has been an undoubted success and in many cases exceeded our expectations

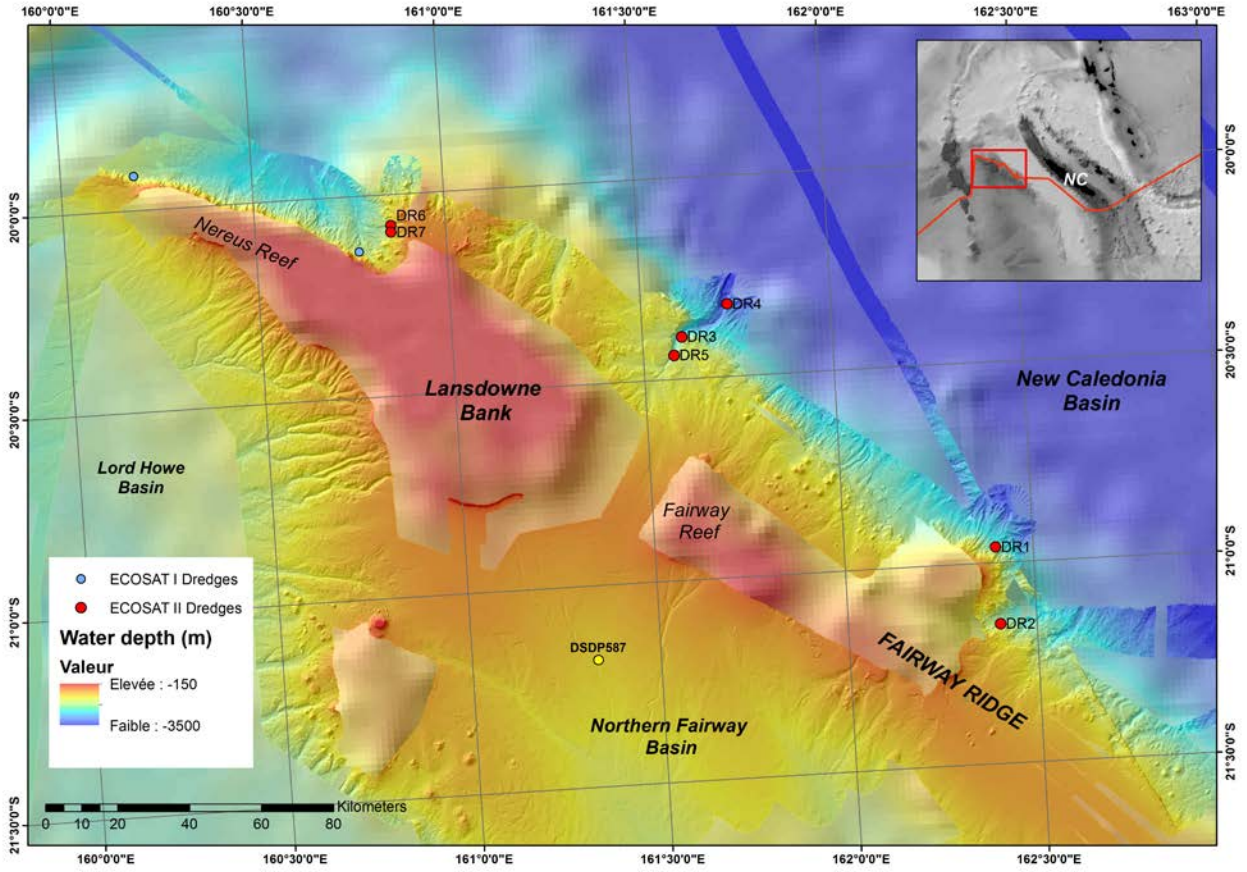


Figure 1: Overview map of the seven dredge sites (DR1 to DR7, in red) on the Fairway Ridge.

Table 3: Summary of Dredge Samples Collected

Dredge	Area	Location	Geological target	Est. long degE	Est. lat degS	Est. depth m	Rock kg	Main rock types	Minor rock types	Notes	Time on site (hrs)
DR01	SE Fairway Ridge	N spur on large guyot (satellite bathymetry). On seismic line 703A	Submarine volcano	162.4008	20.9612	2000	3	75% limestone, 25% volcanic breccia	Muddy foram ooze	Dredge got stuck for about an hour. Bites to 11 tonnes. Dredge bag was torn, probably lost rocks	3.50
DR02	SE Fairway Ridge	Head of canyon SE of volcano, SE side. On seismic line 703A	Fairway Ridge acoustic basement	162.4028	21.1526	1600	200	90% limestone, 10% volcanic breccia	Sandy foram ooze	Dredge got stuck for a few minutes. Bites to 7 tonnes.	3.75
DR03	Central Fairway Ridge	Middle part of canyon, east side. On seismic line 702C	Fairway Ridge acoustic basement	161.6035	20.3956	2150	400	60% limestone, 20% peb sst, 20% sandstone	White clay	Bites to 9 tonnes. Ship pulled backwards during dredge.	4.25

Dredge	Area	Location	Geological target	Est. long degE	Est. lat degS	Est. depth m	Rock kg	Main rock types	Minor rock types	Notes	Time on site (hrs)
DR04	Central Fairway Ridge	Lower part of canyon, floor and east side. On seismic line 702C	Strata above and below a seismic unconformity	161.7271	20.3204	3100	200	90% limestone, 10% igneous rocks	Mudstone	Bites to 8-10 tonnes	4.25
DR05	Central Fairway Ridge	Upper middle part of canyon, floor and east side. On seismic line 702C	Strata above and below a seismic unconformity	161.5806	20.4406	1900	30	95% limestone, 5% olive grey mudstone	Sponge and coral fragments	Bites in later part of dredge to 8-9 tonnes. Ship got pulled back, turned to port and dredge released	4.00
DR06	NW Fairway Ridge	N side of canyon crossing small fault on seismic line ZoNéCo04-4-06	Fairway Ridge acoustic basement	160.8573	20.0769	1500	35	95% limestone, 5% volcanic breccia	Mn crusts to 1cm thick	Couple of spikes at 7-8 tonnes and 12 tonnes when stuck on bottom	2.25
DR07	NW Fairway Ridge	Ridge S of canyon crossing small fault on seismic line ZoNéCo04-4-06	Fairway Ridge acoustic basement	160.8568	20.0937	1350	40	100% soft white limestone	A few pebbles	Not many pulls but dredge pulled back ship at end	2.50

If a successful dating and analysis programme is carried out, the various rock associations dredged can be integrated with other (e.g. seismic) data and a number of publication themes might eventuate:

- Basement geology of the Fairway Ridge based on the age and composition of granite and other clasts in cover sequence pebbly sandstones
- Newly discovered intraplate volcanic centres of northern Zealandia on the Fairway Ridge
- Late Cretaceous to Miocene lithostratigraphy of the northwest New Caledonia Basin
- Fairway Ridge Cenozoic limestone paleoenvironments and correlations with New Caledonia
- Age and petroleum source rock significance of Fairway Ridge carbonaceous mudstones

At present, no work is planned by the ECOSAT II team on the ooze, Mn crust or pumice samples, but these are available for study by others.

Figure 2: Example of preliminary rock sample descriptions – these samples were collected at dredge site #3

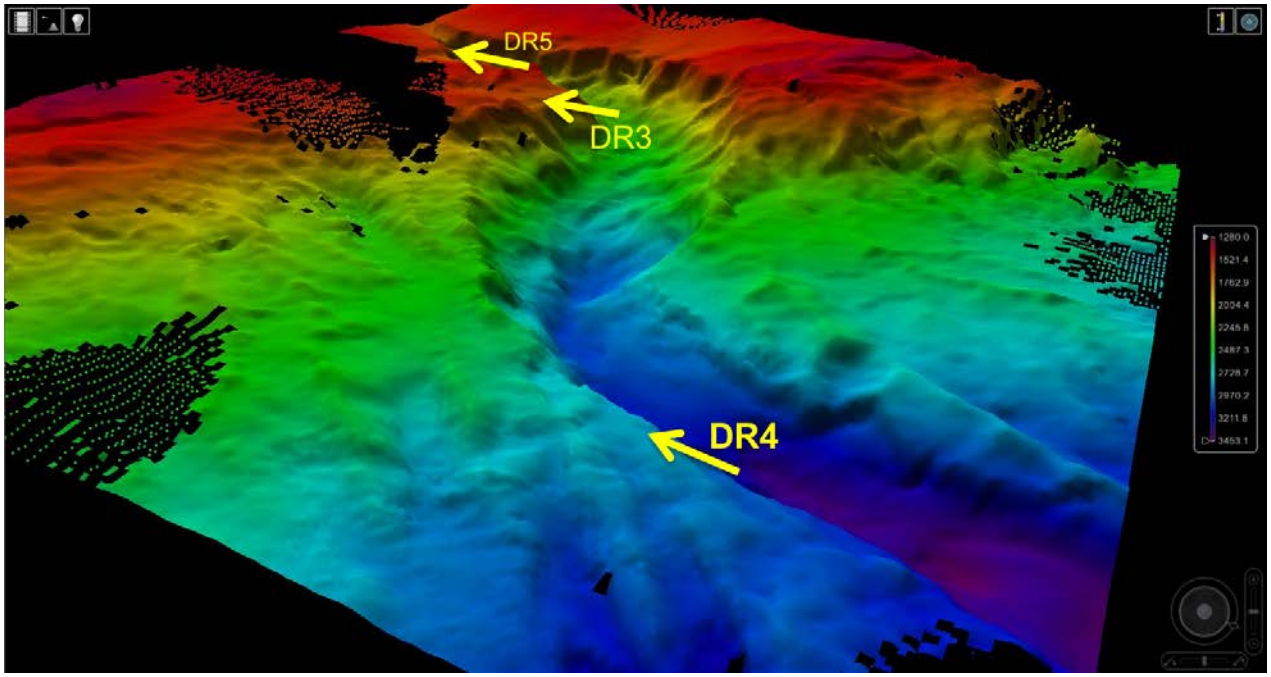


Figure 3: Caris screen shot of oblique 3D view looking up the prominent submarine canyon where dredges 3, 4 and 5 were made. Courtesy Frances Cooke.

Underway Geophysics

During the voyage, swath bathymetry (including backscatter), sub-bottom profiler and gravity data were collected continuously. Most useful was the swath bathymetry data, which allowed us to image large regions of previously unmapped seafloor fabric across both active and extinct plate boundaries in the North Fiji Basin and Tasman Sea, as well as major submarine landslide structures along the southwest margin of New Caledonia.

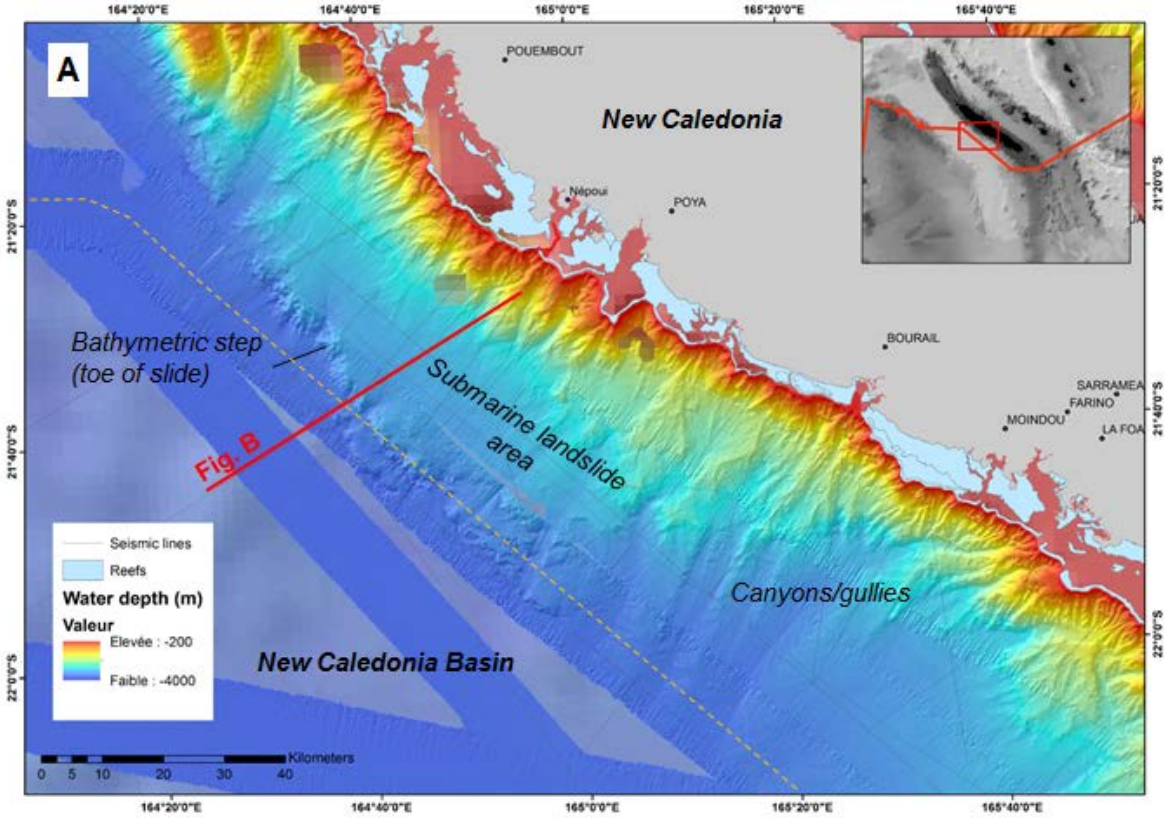


Figure 4: Map of New Caledonia southwestern slope multibeam bathymetry. The new IN2016T01 track (orange dotted line) purposefully imaged the deep water terraces and steps at the foot of the slope south and west of Népoui. The seafloor features are linked with a large submarine landslide mostly covered by sediments. The profile marked in red is presented in the more detailed geoscience-specific voyage report.

Bio-Optics and biogeochemistry

Two profiling floats equipped with bio-optical and biogeochemical sensors (Bio-Argos, table 4) were deployed in anticyclonic eddies. Sensors on the floats included SBE41cp CTD, SBE 61 dissolved oxygen optode and MCOMS chlorophyll fluorometer / optical backscatter meter with central wavelength 700nm. Additionally, float F0389 had a second MCOMS backscatter channel with central wavelength 532nm. Float F0393 was additionally equipped with MCOMS CDOM fluorometer instead of the second backscatter channel, WETLabs ECO-BB3 measuring optical backscatter at 3 wavelengths (400, 532, 700nm), WETLabs C-Rover (CRV) transmissometer and Satlantic OCR-504R/I, measuring upwelling radiance (R) and downwelling irradiance (I) at 4 wavelengths (412,443, 490, 555nm).

Table 4: Summary of deployment location and sensors for each of the Bio-Argo floats deployed

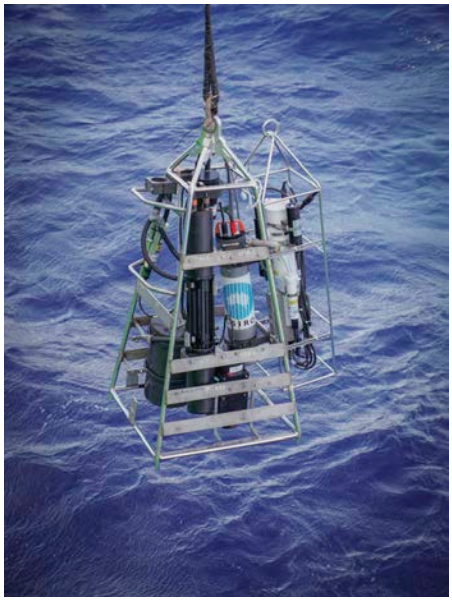
Float	**Deployment**			**Sensor Serial #**						
SBE NAVIS	Station	Latitude	Longitude	SBE 41CP	MCOMS	SBE 63	ECO-BB3	CRV	OCR504I	OCR504R
F0393	9	25° 49.1381 S	156° 01.1243 E	6017	0020	0682	1189	0072	0319	0018
F0389	11	31° 14.58 S	155° 23.49 E	6001	0027	0571	-	-	-	-

The BOPak frame was used to collect inherent optical property (IOP) and ancillary contextual data. Radiometry data was collected over the upper 10m simultaneously via a hand-deployed freefall profiler so was not included on the BOPak frame, however, a second multispectral backscatter meter was included to compare results between models. To accommodate this different range of sensors on the BOPak frame than had been deployed on previous *Investigator* voyages, some modifications were made to the frame. Additionally, a LISST was mounted on the main CTD frame. The instruments deployed and their serial numbers are provided in table 5.

Table 5: List of bio-optical sensors with serial numbers

Sensor	**Manufacturer**	**Serial #**
LISST	Sequoia Scientific	1542
Hydroscat (HS-6)	HOBILabs	HS040936
ac-s	WETLabs	88
DH4 (logger)	WETLabs	160
bb9	WETLabs	1352
SBE19plusV2	Seabird Electronics	19-7612
FL-NTU-RT	WETLabs	3992
Dissolved Oxygen	Seabird Electronics	43-3157
PAR	Biospherical Instruments	70587

Figure 5: Photo of the BOPak



Daily CTD casts were generally timed for 9.30am local time each day, allowing for local longitude rather than just time zone, with water collected from 8-10 depths. MNF instruments on the CTD frame included CTD, fluorometer, transmissometer, ECO-triplet (chlorophyll fluorescence, CDOM fluorescence and backscatter), PAR, dissolved oxygen sensor. The initial CTD cast failed on ascent due to water ingress to the cable. This fault was traced and repaired ahead of the second station. The BOPak was not yet ready for deployment, a consequence of the lack of mobilisation time in Fiji. The first four bio-optical stations suffered technical difficulties but a full suite of bio-optical measurements was obtained thereafter. No BOPak was deployed at station 1 (due to CTD failure) or station 12 (due to rough conditions). For a total of 13 stations, water samples were collected on 12 casts and bio-optical sensor measurements were obtained for 12 casts.

Samples for bio-optics at 3-4 depths: at the surface, subsurface chlorophyll maximum (Cmax) and around the dissolved oxygen minimum (D3), with an extra 25m sample for deep CTDs (see tables 6 and 7). Triplicate samples were taken for surface TSS, HPLC pigment / a_p samples at water depths used in microbial incubations (see below) and all DOC, a_{CDOM}, flow cytometry and flow cam samples. Samples are now awaiting lab analysis. Nutrients were measured at up to 8 regular depths (5, 10, 25, 50, 100, 150, 200, 250m) as well as non-regular depths coinciding with bio-optical samples. Four dissolved oxygen samples were taken per station at the same depths as bio-optical samples plus at 250m, except during deep CTDs where they were spread over a deeper range. For the last 2 stations, rougher conditions meant that the 'surface' sample was collected at 10m rather than 5m as large swells prohibited stopping the CTD any shallower.

Preliminary results

Both Bio-Argo floats were successfully deployed and commenced their programmed missions. However, after 2 days F0393 failed to surface for several days. Upon surfacing it became clear that the float had taken on water that was causing it to gain weight and to struggle to reach ascent buoyancy. New mission parameters were able to stabilize the float profiling but with loss of the ECO-BB sensor. The float was recovered off Brisbane on 13 Aug 2016 and has been sent back to the manufacturer for repair and servicing. F0389 is performing well, circulating between mesoscale structures and is showing interesting patterns of chlorophyll and particulate patchiness. These data will be quality controlled when calibration data from CTD samples become available. Plots of raw data and trajectories for these floats are shown in figure 6.

CTD casts showed a transition from stratified waters with a deep chlorophyll maximum (DCM) layer lying below the surface mixed layer in tropical waters (CTD1-7) to waters with chlorophyll distributions mixed throughout the upper water column in the subtropical / temperate waters towards Australia (CTD8-13). The exception to this was CTD3 which was in shallower water (547m) close to Noumea and showed chlorophyll distribution to be mixed throughout the surface layer. The DCM layers ranged in depth from 25m - 125m. Surface mixed layer depths ranged from 25m – 110m for the tropical stations and in the range 110m – 130m for other stations.

Table 6: List of CTD stations, position and samples obtained.

Local Date	Station #	Lat (deg min)	Lon (deg min)	Water Depth (m)	CTD #	BOPak #	CTD sensor samples	CTD bottle samples	Comments
1/07/16	1	19 09.47S	174 55.78E	2942	1	-	Y	N	CTD failed on ascent. BOPak not deployed
2/07/16	2	21 08.67S	171 17.68E	3040	2	1	Y	Y	DH4 battery case leaked. LISST not turning on. HS6 battery flat.
3/07/16	3	23 08.21S	167 04.87E	547	3	2	Y	Y	DH4 battery case tested on CTD then reinstalled on BOPak. LISST not turning on.
4/07/16	4	21 13.20S	163 10.10E	3582	4	3	Y	Y	bb9 installed but data corrupt (wrong baud rate).
5/07/16	5	20 19.68S	131 36.26E	1662	5	4	Y	Y	bb9 data corrupt (wrong baud rate)
6/07/16	6	20 00.38S	160 53.52E	1307	6	5	Y	Y	
7/07/16	7	21 57.80S	159 38.57E	1897	7	6	Y	Y	HS6 partial cast.
7/07/16	7a	22 04.06S	159 08.4E	2158	-	7	N	N	Additional cast to match satellite overpass
8/07/16	8	24 51.61S	156 45.99	2644	8	8	Y	Y	
8/07/16	9	25 49.143S	156 01.292E	4657	9	9	Y	Y	Deep cast (1000m, LISST removed) and deep BOPak (300m) ahead of Bio-Argo F0393 deployment
9/07/16	10	28 04.022S	155 59.44E	4809	10	10	Y	Y	
10/07/16	11	31 14.48S	155 23.49E	3935	11	11	Y	Y	Deep cast (1000m, LISST removed) and deep BOPak (300m) ahead of Bio-Argo F0389 deployment (immediately following)
11/07/16	12	34 58.64S	152 14.85E	4870	12	-	Y	Y	Too rough to deploy BOPak. CTD bottles 32 & 35 leaked but only used for surface filters.
12/07/16	13	39 01.40S	149 54.81E	4285	13	12	Y	Y	

Table 7: Water samples collected for bio-optical parameters from the CTD. Triplicate samples are indicated by 3 and single samples by 1. Depths with no samples are indicated by 0.

Station	Depth	Description	Parameter						
#	m		HPLC / ap	TSS	POC	aCDOM	DOC	Flow cam	Flow cyto
1	-		0	0	0	0	0	0	0
2	5	Surface	3	1	1	3	3	3	3
	100	Cmax	3	1	1	3	3	3	3
	200	D3	1	1	1	3	3	3	3
3	5	Surface	3	3	1	3	3	3	3
	25	Cmax	1	1	1	3	3	3	3
	100	D3	1	1	1	3	3	3	3
4	5	Surface	3	3	1	3	3	3	3
	100	Cmax	1	1	1	3	3	3	3
	150	D3	1	1	1	3	3	3	3
5	5	Surface	3	3	1	3	3	3	3
	80	Cmax	1	1	1	3	3	3	3
	100	D3	1	1	1	3	3	3	3
6	5	Surface	1	3	1	3	3	3	3
	125	Cmax	3	1	1	3	3	3	3
	175	D3	1	1	1	3	3	3	3
7	5	Surface	3	3	1	3	3	3	3
	50	Cmax	3	1	1	3	3	3	3
	100	D3	1	1	1	3	3	3	3
8	5	Surface	3	3	1	3	3	3	3
	125	Cmax	3	1	1	3	3	3	3
	130	D3	1	1	1	3	3	3	3
9	5	Surface	1	3	1	3	3	3	3
	25		1	0	0	0	0	0	0
	60	Cmax	1	1	1	3	3	3	3
	160	D3	0	1	1	3	3	3	3
10	5	Surface	3	3	1	3	3	3	3
	75	Cmax	3	1	1	3	3	3	3
	175	D3	1	1	1	3	3	3	3
11	5	Surface	3	3	1	3	3	3	3
	25		1	0	0	0	0	0	0
	175	Cmax	3	1	1	3	3	3	3
	225	D3	1	1	1	3	3	3	3
12	5 or 10?	Surface	3	3	1	3	3	3	3
	110	Cmax	3	1	1	3	3	3	3
	130	D3	1	1	1	3	3	3	3
13	5 or 10?	Surface	3	3	1	3	3	3	3
	125	Cmax	1	1	1	3	3	3	3
	150	D3	1	1	1	3	3	3	3

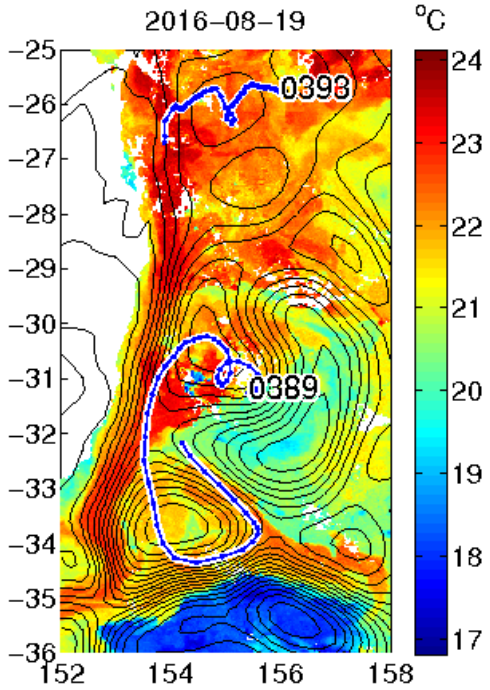
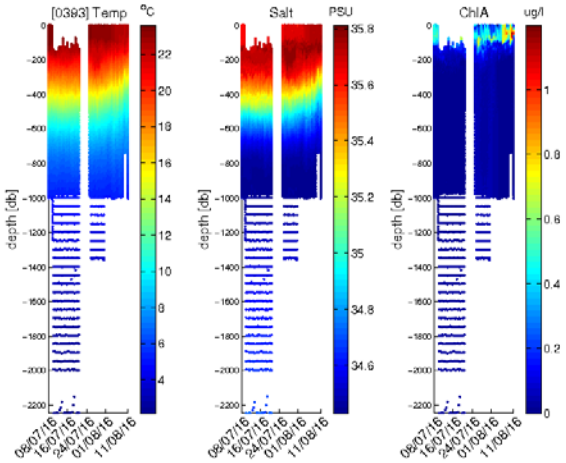
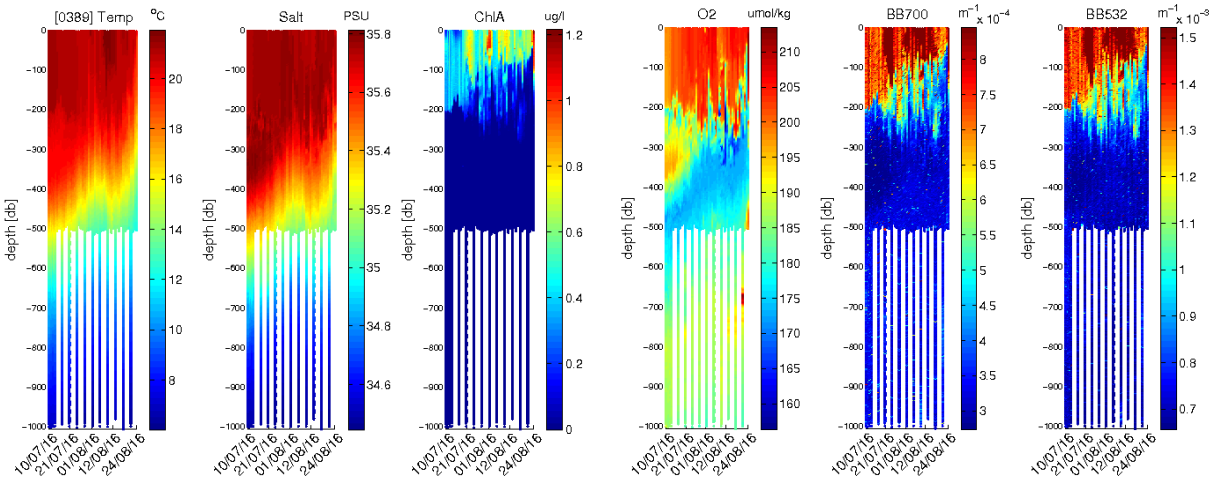


Figure 6: (a) Trajectories of Bio-Argo floats deployed overlaid on satellite altimetry contours and SST map. (b) Example raw data from F0393. (c) Raw data from F0389.





Thermal performance of marine microbes. (CI Martina Doblin, UTS)

A total of 9 experiments were successfully performed as we transited from Fiji to Hobart. Flow cytometry counts of phototrophs (in unfixed samples) were completed on board. Analysis of fixed samples for heterotrophic bacteria and viruses will take place at the University of Technology Sydney following the voyage. Carbon fixation assays were also successful, but an issue with the scintillation counter prevented the counts from being completed during the voyage. All of the dissolved nutrient analyses were achieved with the support of the MNF hydrochemist.

While we still have a lot of data to examine, some preliminary results are presented below in Figure 7.

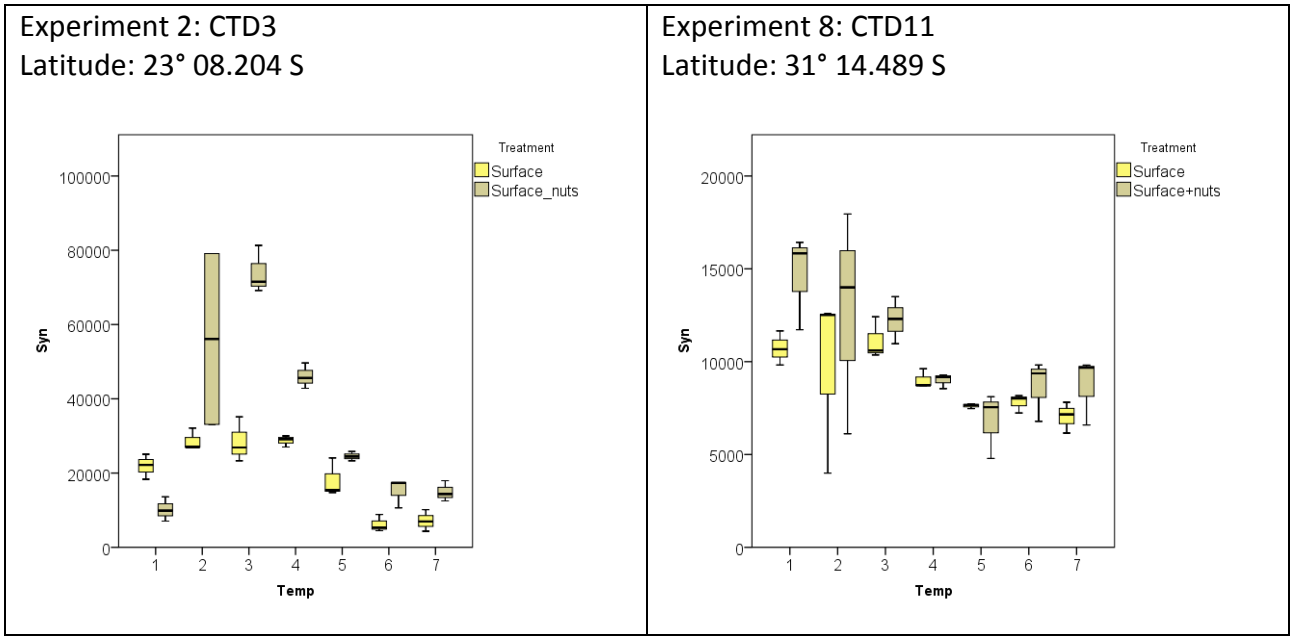


Figure 7: Abundance of Synechococcus sp. after 24 h incubation at 7 different temperatures. Temperature 4 is ambient, Temperature 1, 2 and 3 are hotter than ambient, and Temperature 5, 6 and 7 are cooler than ambient.

"Investigation into the microbial contribution to C, N and S cycling in the Coral Sea" **and "Spatial scale patterns in photo-physiology and primary productivity"** (CI Bonnie Laverock, UTS)

Of the 13 CTDs deployed throughout the voyage, 10 were sampled successfully for DMS/P concentrations, nitrification rates, bacterial production rates, DMSP lyase rates, DNA and RNA. While the majority of data for this project will arise from samples processed post-voyage, initial measurements indicate differences in the microbial biogeochemistry between CTD locations (e.g. Fig. Z). Subsequent analyses will focus on comparing these biogeochemical data with the abundances and activities of specific microbial functional groups (e.g. DMSP degrading bacteria), in order to assess the key biogeochemical players in different oceanographic provinces. This will contribute significantly to our understanding of the environmental factors driving microbial diversity and function in the marine environment; and what these functions mean for the primary producers underpinning the marine food web.

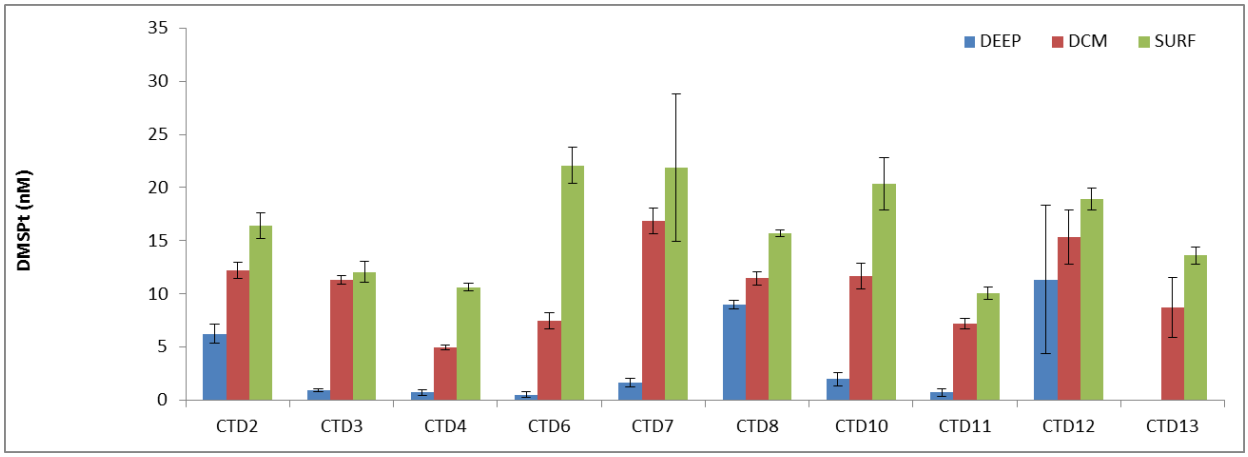


Figure 8: DMSP concentration (nM) measured at three water depths (surface (surf), chlorophyll maximum (DCM) and sub-mixed layer depth (deep)) using purge-and-trap gas chromatography with flame photometric detection (GC-FPD).

Atmospheric underway measurements

The INV2016_T01 transit voyage has seen the deployment of several pieces of aerosol instrumentation to investigate the chemical composition, size distribution, optical properties and cloud nucleating properties of marine aerosol over the southern hemisphere. These parameters are important in the quantification of regional contributions of aerosols to radiative forcing, and will help to improve meteorological and climate change models. With a few exceptions, the instrumentation has operated with only minor issues and a wealth of data has been successfully collected.

Two mass spectrometer systems were used to investigate the chemical composition of aerosols. Particle composition was analysed through the use of an ACSM, which provides online, high resolution chemical analysis of particles. Early data analysis shows mass concentrations of sulphate, with lower levels of organics, chlorine and ammonium. These results are consistent with the sea spray generated aerosol which are expected to be the primary source of aerosols in the open ocean. There were some periods of very high organic mass concentrations due to non-optimum wind conditions causing the diesel exhaust to blow over the sampling inlet. However, this effect was kept to a minimum due to careful ship directions placement during CTD deployments. A PTRMS system was used to perform analysis on water soluble species including DMS, however further data analysis is required before this data will be understood. Offline PM1 filter and VOC collections systems were also employed to allow for further chemical analysis at a later date.

Particle sizing measurements were performed utilizing two scanning mobility particle sizer (SMPS) systems, a NAIS, and an aerodynamic particle sizer (APS). The combination of equipment allowed for real time particle size measurements continuously from 0.5 nanometers up to 20 micrometres. The NAIS was also used to track potential particle formation events, however early analysis has not yielded any conclusive results. Particle concentrations were measured through a condensation particle counter (CPC) and were typically in the range of 200 – 300 particles per cubic centimetre of air when sampling clean ocean air. As a comparison a relatively clean city such as Brisbane will see concentrations ten times this value.

Aerosol cloud condensation properties were measured through the use of a cloud condensation nuclei counter (CCNC) and a volatility hygroscopicity tandem differential mobility analyser (VHTDMA). The CCNC concentrations were generally only slightly lower than the CPC readings, indicating that the vast majority of particles measured are potential cloud condensation nuclei. This result is expected as sea salt is very hygroscopic and will readily form cloud droplets given suitable circumstances. The VHTDMA system analysed the volatility and hygroscopicity of particles, which are important parameters in determining if a particle can become a cloud condensation nucleus.

There were no major issues encountered during the voyage for aerosol monitoring. The only worthy note is that both the PTRMS and VOC sequencer only sampled for the first week of the voyage, as they had been sampling continuously since the start of the previous INV2016_V03 voyage and ran out of some necessary consumables for continued operation.

Voyage Narrative

The overall voyage can be broadly divided into three legs:

- Four days of transit from Lautoka to the dredge area on the Fairway Ridge, with daily water sampling stations, Argo deployment and continuous swath mapping.
- Three days of swath mapping and rock dredging in the Fairway Ridge Study Area, with water sampling carried out opportunistically between dredge operations.
- Seven days of transit from the Fairway Ridge to Hobart, during which both Argo floats and Bio-Argo floats were deployed, as well as daily water sampling.

Weather was predominantly benign allowing the ship to make rapid progress (typically around 12 knots), with the exception of the final 3-4 days when the weather closer to Hobart deteriorated.

Leg 1: Lautoka to Fairway Ridge

Departure from Lautoka was around 1900 on 30/6/2016.

The initial plan was to collect CTDs to 250 m depth, twice per day (~0930 and 1400), with the timing of the morning CTD adjusted each day to ensure consistent local time at the sampling station. The first CTD station was problematic – first, the cast was delayed by one hour due to a problem with the ships engines (meaning the ship could not be kept sufficiently stable in the water for CTD deployment); then, the CTD experienced a failure upon reaching the 250 m maximum depth, such that no water samples were collected. Following these issues, a decision was taken to abandon the afternoon CTD (while the CTD cables were reterminated by the MNF technicians) and switch to a plan of one morning CTD per day, to ensure greater geographical coverage within the available time. Operations went much more smoothly on subsequent days, with deployment of CTDs at three sites as well as a bio-optics cast and a hand-held HyperPro radiometer. The HyperPro was also deployed for afternoon casts, requiring significantly less time than the CTD and Bio-optics deployment, and allowing measurements to coincide with satellite overpass times for optimum calibration between data sets.

Swath mapping of the North Fiji Basin revealed a number of interesting tectonic structures, including three interpreted divergent plate boundaries and numerous volcanic edifices. After passing the southern tip of New Caledonia, the voyage track was modified to pass along the foot of the slope along the southwest margin of New Caledonia, with the swath bathymetry data mapping, for the first time, the toe of a major slump structure.

Three Argo floats were deployed during this leg, two in the North Fiji Basin and one in the New Caledonia Trough area.

Leg 2: Fairway Ridge Dredge Sites

Swath mapping and dredging was carried out along the Fairway Ridge study area from 4/7/2016 to 6/7/2016 at a total of seven sampling sites. A total of seven dredges were conducted in three areas, spread across the three days. The amount of swath mapping required was minimal due to the availability of existing swath maps and seismic profiles provided by the Geological Survey of New Caledonia. However, significant new swath data were collected in the second dredge area, mapping the lower reaches of a major canyon system which was selected as the target for dredge #4. Dredging operations were predominantly carried out during darkness, but this did not present any issues, the crew performing their duties faultlessly. The only issue was a software glitch which prevented the science team from accurately monitoring the cable tension and wire out for the initial dredges – this was subsequently fixed by the MNF support staff.

Of the seven dredges, all seven successfully recovered material from the seafloor. On the first dredge, the chain link bag was damaged (with three links broken at the bottom of the bag), so that only a few small boulders remained, but this small sample size nonetheless contained both volcaniclastic breccia and limestone. Dredge #3 was particularly successful, recovering a wide range of lithologies – preliminary interpretation suggests that the granites pebbles, conglomerates and other sedimentary rocks will allow correlation with rocks in New Zealand and New Caledonia, which would satisfy the primary objective of geoscience project.

In between the dredging, morning CTDs and Bio-optics deployments were carried out (though at times to work around the dredging operations where necessary). The handheld HyperPro radiometer was used during dredging, but deployed from the side of the ship rather than the stern for safety reasons.

Due to time limitations and the success of initial dredges on the Fairway Ridge, a decision was taken to concentrate dredging efforts on the Fairway Ridge and sacrifice any attempt to collect samples from Sandy Island as originally planned. This decision saved around 7 hours from the overall voyage track, subsequently allowing an additional two days of CTD collection in addition to one more dredge than had originally been anticipated. If the end port of the voyage was Cairns or Brisbane as originally planned, we may have made a different decision on excluding Sandy Island from the dredging operations.

Leg 3: Fairway Ridge to Hobart

Following completion of seven dredges, priority switched to the collection of CTDs and deployment of Bio-Argo floats.

The target for the Bio-Argo floats were the centres of ocean eddies located east of the Australian east coast, and identified from recent sea-surface height maps derived from satellite altimetry. A course was plotted to the centre of ‘Eddy #1’ roughly 270 nm northwest of Brisbane, where the first Bio-Argo float was deployed, preceded by a deep CTD (to a depth of 1000 m).

A second eddy was identified 370 nm to the south, and chosen as the location to deploy the second Bio-Argo float. A southwards course heading towards this feature was designed to collect useful swath data over the extinct spreading ridge running down the axis of the Tasman Sea, guided by the fabric imaged in satellite derived gravity data. The second Bio-Argo was deployed at the location of ‘Eddy #2’ in the early hours of 10/7/2016, together with a 1000 m depth CTD and Bio-Optics cast. By the end of this day, confirmation was received that both Bio-optics floats were functioning and successfully transmitting data as planned.

With limited remaining science time and worsening weather forecast, the track to Hobart was reasonably direct, with some waypoints added to further map the tectonic fabric around the Tasman Sea extinct spreading ridge. The final CTD station and hand-held radiometer deployments took place on 12/7/2016.

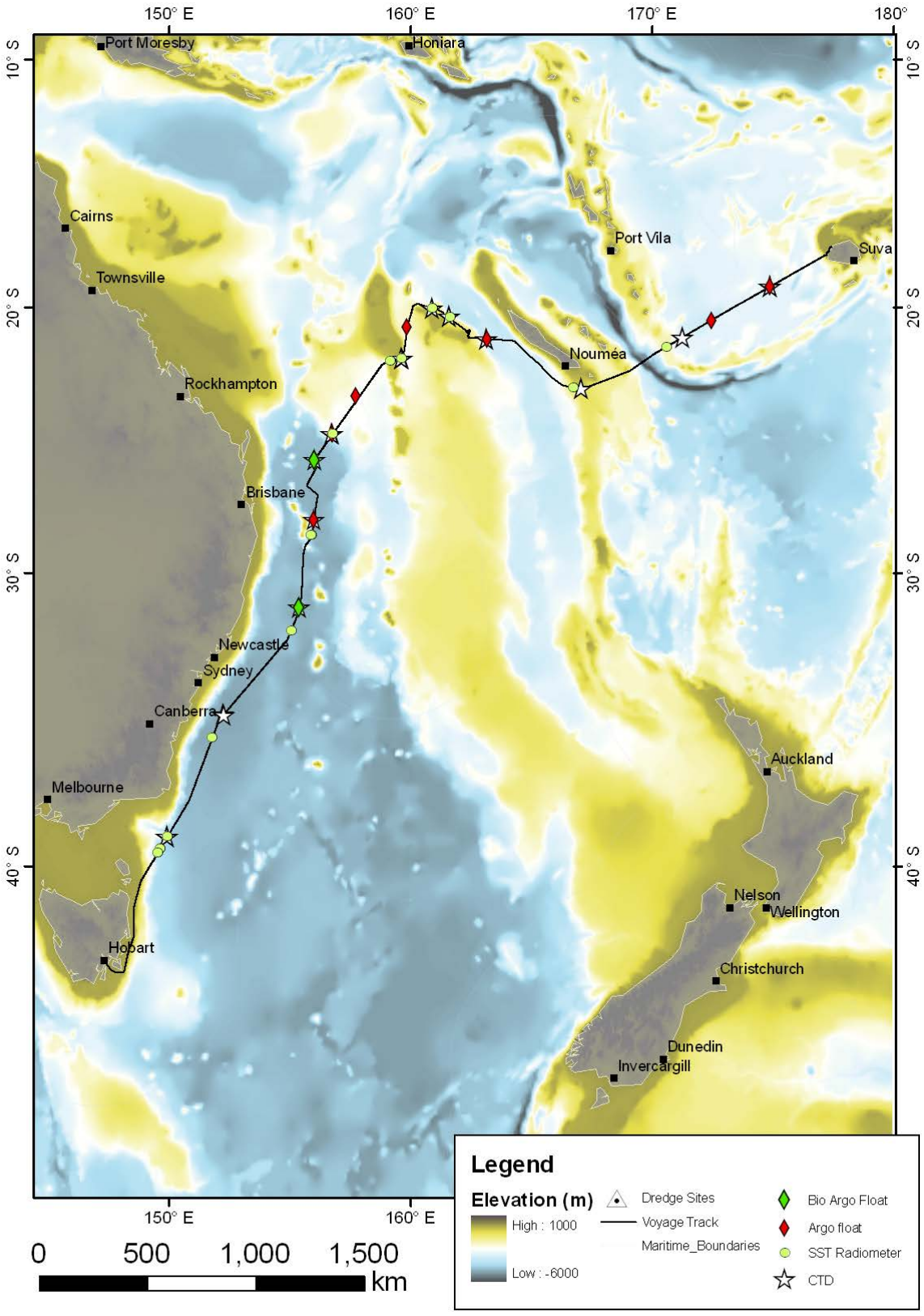
Summary

The scientists could not have asked for much more from this voyage (except time). The science carried out has been highly multidisciplinary, spanning geological sampling, seafloor mapping and underway geophysics, CTD sea-water sampling, measurement of the ocean's bio-optical properties, deployment of ARGO floats for long term ocean monitoring, and atmospheric measurements. Valuable scientific data were collected every day of the voyage, and the preliminary results show that this voyage was a great success by any standards, let alone for a transit voyage.

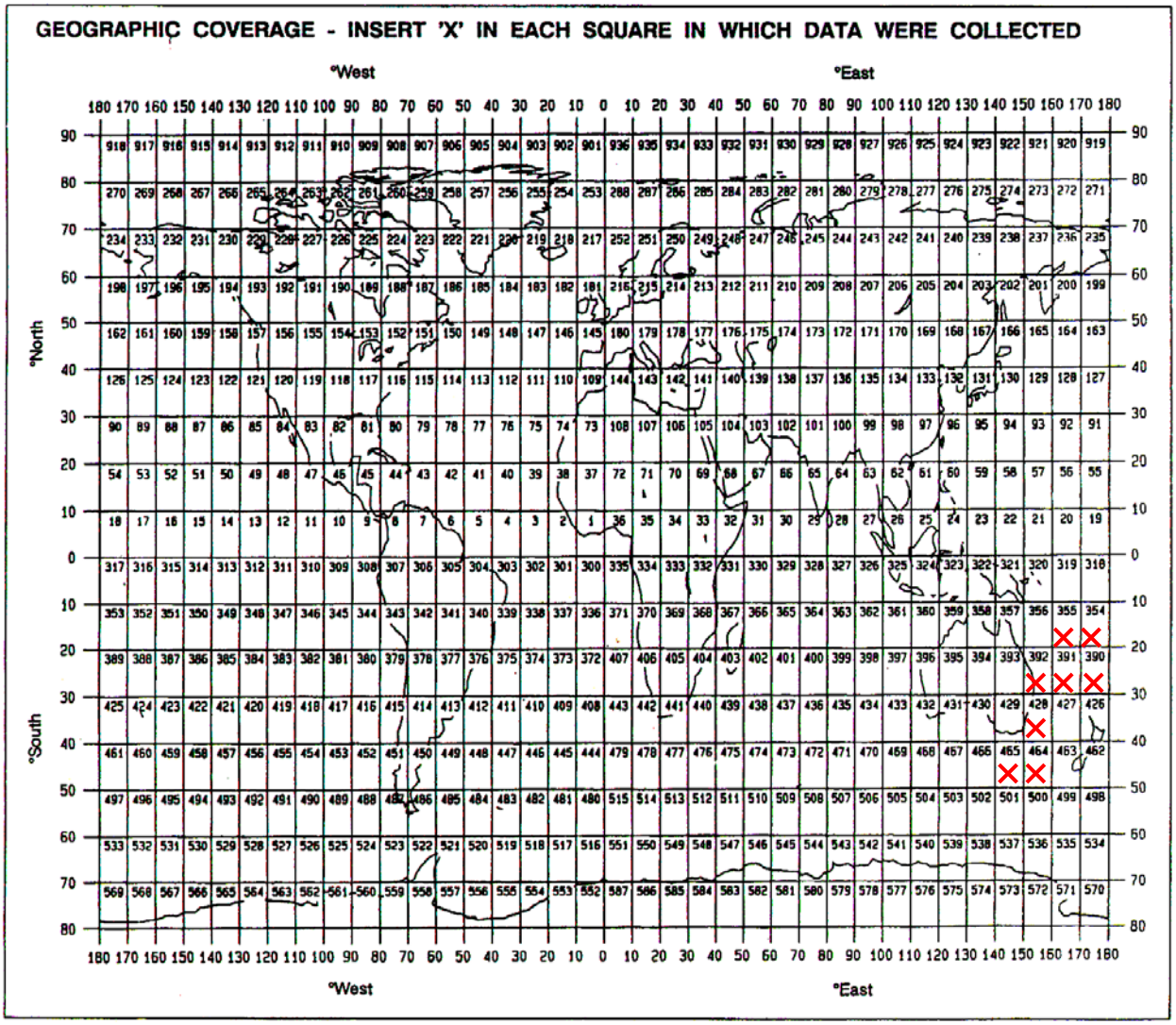
The primary aim of the geoscience team was to sample bedrock from the northern reaches of Zealandia, and this aim was successfully met. Our next step will be to conduct a program of laboratory analysis on our recovered rocks samples to determine their geochemistry, age of formation, and more clearly establish their origin within the breakup of Gondwana and the separation of Zealandia from Australia.

Properties of the water column were collected each day from July 1st to July 12th, providing a significant coverage of new observations across the ocean basins along a longitudinal profile between Fiji and Australia, and along a latitudinal profile running down the Tasman Sea. Argo and Bio-Argo floats were successfully deployed in the waters east of Australia, and data transmitted from these floats over the coming years will add significant value to our understanding of the ocean system around Australia.

Voyage Track



Marsden Squares



Moorings, bottom mounted gear and drifting systems

Item No	PI See page above	APPROXIMATE POSITION						DATA TYPE	DESCRIPTION
		LATITUDE			LONGITUDE				
		deg	min	N/S	deg	min	E/W		
1	Thresher	19	10	S	174	55	E	D06	Argo Float, Deployed 2016/07/01, 01:00 UTC
2	Thresher	20	29	S	172	30	E	D06	Argo Float, Deployed 2016/07/01, 15:30 UTC
3	Thresher	21	14	S	163	11	E	D06	Argo Float, Deployed 2016/07/04, 00:05 UTC
4	Thresher	20	45	S	159	51	E	D06	Argo Float, Deployed 2016/07/06, 16:30 UTC
5	Thresher	23	25	S	157	45	E	D06	Argo Float, Deployed 2016/07/07, 14:25 UTC
6	Thresher	24	52	S	156	46	E	D06	Argo Float, Deployed 2016/07/08, 00:20 UTC
7	Hardman-Mountford	25	49	S	156	1	E	D06	Bio Argo Float, Deployed 2016/07/08, 08:50 UTC; Float #F0393
8	Thresher	28	4	S	156	0	E	D06	Argo Float, Deployed 2016/07/09, 00:15 UTC
9	Hardman-Mountford	31	15	S	155	24	E	D06	Bio Argo Float, Deployed 2016/07/09, 22:20 UTC; Float #F0389

Summary of Measurements and samples taken

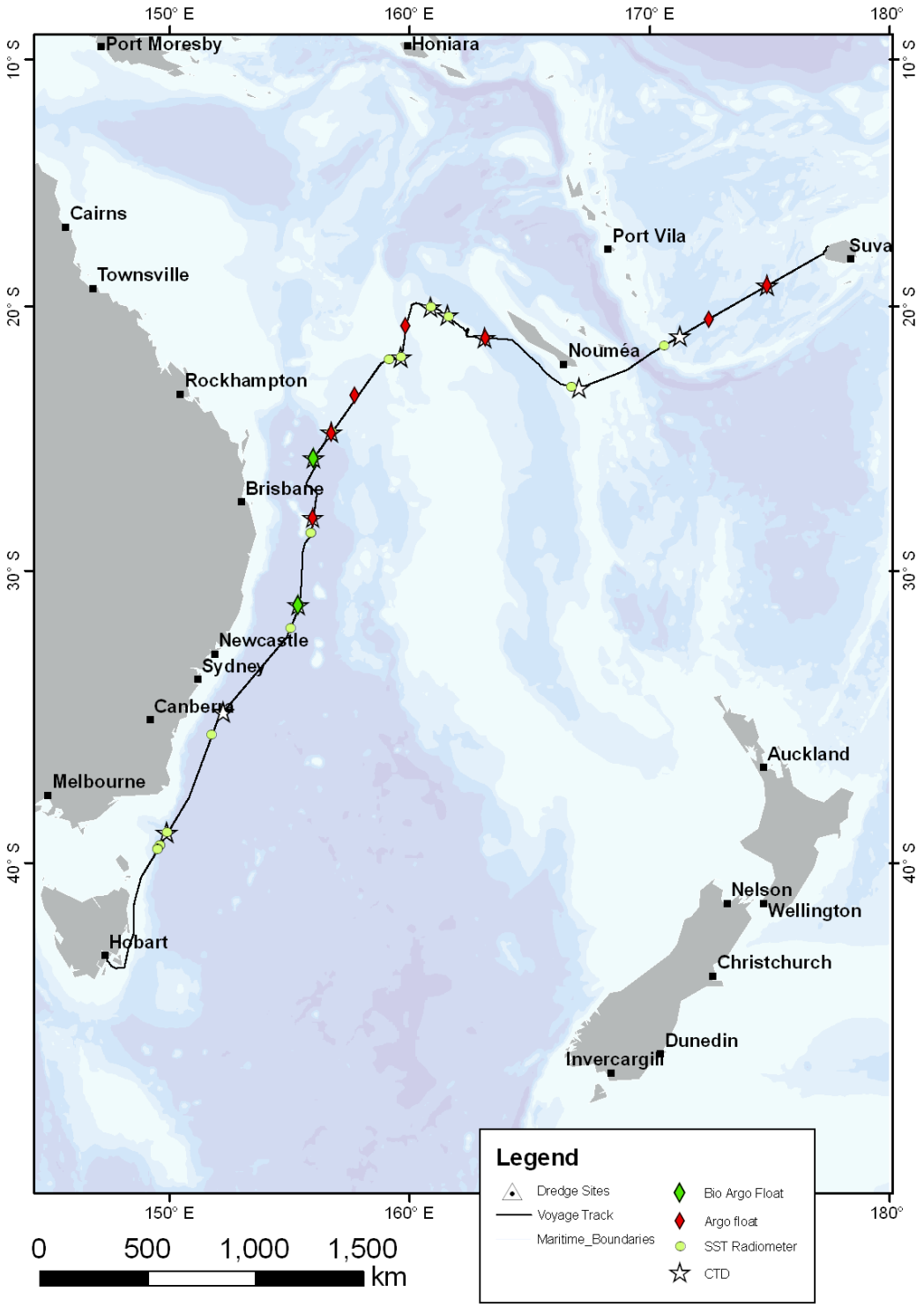
Item No.	PI	NO	UNITS	DATA TYPE	DESCRIPTION
1	Williams	7	Dredge Hauls	G01	Dredge Hauls from seven sites along the Fairway Ridge. A full listing is given in table 3. Samples taken to shore for further geochemical and geochronological analysis.
2	Williams	5500	km	G74	Swath Bathymetry (including backscatter) - continuous collection of data. Preliminary data used for dredge site planning. Data to be fully processed and analysed onshore.
3	Williams	5500	km	G27	Gravity – continuous collection of data, to be fully processed and analysed onshore.
4	Williams	5500	km	G75	Sub Bottom Profiler – continuous collection of data, to be fully processed and analysed onshore.
5	Hardman-Mountford	13	casts	H10	CTD Casts - continuous collection of sensor measurements on vertical profiles, water sampling at 8-10 discrete depths. A full listing is given in tables 6 and 7.
6	Hardman-Mountford	12	casts	H17	BOPak - continuous collection of bio-optical sensor measurements on vertical profiles.
7	Hardman-Mountford	21	casts	H17	SST Radiometer - continuous collection of bio-optical sensor measurements on vertical profiles.
8	Doblin	9	Experiment Sites	B01,B02,B08	Measurement of microbe performance from seawater samples placed under different thermal regimes. A full listing is given in table 2.
9	Laverock	180	samples	B07	Filtered seawater samples, collected on 0.22 um filters for DNA and RNA extraction and analysis. All samples to be processed onshore.
10	Laverock	360	samples	B07	Samples for bacterial production (carbon uptake), measured as tritiated leucine uptake rates. All samples to be processed onshore.
11	Laverock	180	data points	B07	Bacterial and archaeal nitrification rate measurements, measured on board using specotrophotometry.
12	Laverock	720	data points	B07	DMS/P concentrations and DMSP lyase rate measurements, measured on board using purge-and-trap gas chromatography with flame photometric detection (GC-FPC) and sulphur chemiluminescence (SCD).

Item No.	PI	NO	UNITS	DATA TYPE	DESCRIPTION
13	Laverock	720	data points	B08	Phytoplankton biomass and electron transfer rate estimates, measured on board using fast repetition rate fluorometry (fRRF).
14	Brown		underway		Atmospheric Chemistry and Aerosols

Curation Report

Item No.	DESCRIPTION
1. 1	**Rock samples** from the dredges were sent to three institutions for further work and/or archiving: - The University of Sydney, Australia (contact Simon Williams, Maria Seton): main repository for all dredge samples - GNS Science, Dunedin, New Zealand (contact Nick Mortimer): portions of volcanic breccias and basalt clasts for geochemical analysis and Ar-Ar dating. Portions of pebbly sandstone clasts, sandstones and mudstones for provenance study, including U-Pb dating of the granite clasts and sandstone detrital zircons. - Service de la Géologie de Nouvelle-Calédonie, Nouméa (contact Samuel Etienne, Julien Collot): portions of sedimentary rocks (limestones, sandstones and mudstones), part of igneous rock samples, volcanic breccias and recent biogenic oozes. The logbook of the cruise is kept with the repository at the University of Sydney.
2.	**Filters** for microbial analyses were transported back to the University of Technology Sydney (UTS) for processing (DNA/RNA extractions) and subsequent functional gene analyses. Contact : Bonnie Laverock, UTS
3.	**Samples** for bacterial production measurements were transported back to the University of Technology Sydney (UTS) for processing. Contact: Bonnie Laverock, UTS

Track Chart


150° E
160° E
170° E
180°
10° S
20° S
30° S
40° S
Port Moresby
Honiara
Cairns
Townsville
Port Vila
Suva
Nouméa
Rockhampton
Brisbane
Newcastle
Sydney
Canberra
Melbourne
Auckland
Nelson
Wellington
Christchurch
Dunedin
Invercargill
Hobart
Legend
Dredge Sites
Voyage Track
Maritime_Boundaries
Bio Argo Float
Argo float
SST Radiometer
CTD
0
500
1,000
1,500
km

Personnel List

	Name	Role	Organisation
1.	Lisa Woodward	Voyage Manager	CSIRO MNF
2.	Brett Muir	SIT Support	CSIRO MNF
3.	Ian McRobert	SIT Support	CSIRO MNF
4.	Frances Cooke	GSM Support	CSIRO MNF
5.	Tara Martin	GSM Support	CSIRO MNF
6.	Mark Rayner	Hydrochemistry	CSIRO MNF
7.	Anoosh Sarraf	DAP Support	CSIRO MNF
8.	Simon Williams	Chief Scientist	USyd
9.	Nick Mortimer	Alternate Chief Scientist	GNS
10.	Samuel Etienne	Stratigraphy	New Cal. Geol.Survey
11.	Joanne Whittaker	Geophysics	UTas
12.	Nick Herold	Climatologist	UNSW
13.	Serena Yeung	Geology	USyd
14.	Isabel Sauermilch	Geophysics	UTas
15.	Joanna Tobin	Geophysics	USyd
16.	Lena O'Toole	Geology	UNSW
17.	Nick Hardman-Mountford	Lead Investigator, Biooptics	CSIRO
18.	James McLaughlin	Bio-optics	CSIRO
19.	Charles Kovach	Bio-optics	NOAA
20.	Martina Doblin	Lead Investigator, Piggyback 1	UTS
21.	Allison McInnes	Bio-microbes	UTS
22.	Bonnie Laverock	Lead Investigator, Piggyback 2	UTS
23.	Elisabeth Deschaseaux	Bio-microbes	UTS
24.	Charlotte Robinson	Bio-microbes	UTS
25.	Doug Thost	Deputy Voyage Manager	CSIRO
26.	Reece Brown	Atmospherics	QUT

Marine Crew

Name	Role
John Highton	Master
Gurmukh Nagra	Chief Mate
Brendan Eakin	Second Mate
James Hokin	Third Mate
Chris Minness	Chief Engineer
Mark Ellicott	First Engineer
Mike Sinclair	Second Engineer
Ryan Agnew	Third Engineer
Shane Kromkamp	Electrical Engineer
Alan Martin	Chief Caterer
Kyra Lade	Caterer
Keith Shepherd	Chief Cook
Matt Gardiner	Cook
Jonathon Lumb	Chief Integrated Rating
Dennis Bassi	Integrated Rating
Chris Dorling	Integrated Rating
Paul Langford	Integrated Rating
Jarrod Ellis	Integrated Rating
Rod Langham	Integrated Rating
Peter Taylor	Integrated Rating
Nathan Milnes	First Electrical Engineer (supernumary)
Samuel Edwards	ASC Cadet
Patrick Grinham	Engineer Cadet
Aaron Wheeler	Temporary TIR

Acknowledgements

We are grateful to the MNF and ASP for assistance with mobilization and for excellent support at sea. We are heavily indebted to everyone onboard for their outstanding efforts - whether fixing equipment, doing the maths for our dredging plans, cleaning up the mess made by our rocks on the back deck, or making sure we had three great meals a day to keep us going. The atmosphere on board was always positive and welcoming, and we are privileged to have such a skilled and professional staff to support us 24 hours a day. A big thanks to Lisa for her endless patience, and Doug for taking wonderful photos that documented our journey.

We also acknowledge the support of our home institutions (The University of Sydney, GNS Science, SGNC, the University of Tasmania, the University of New South Wales, University of Technology Sydney, Queensland University of Technology, CSIRO and NOAA) for their support. The Geoscience Team acknowledges support from GNS Science and the Australian Research Council.

Signature

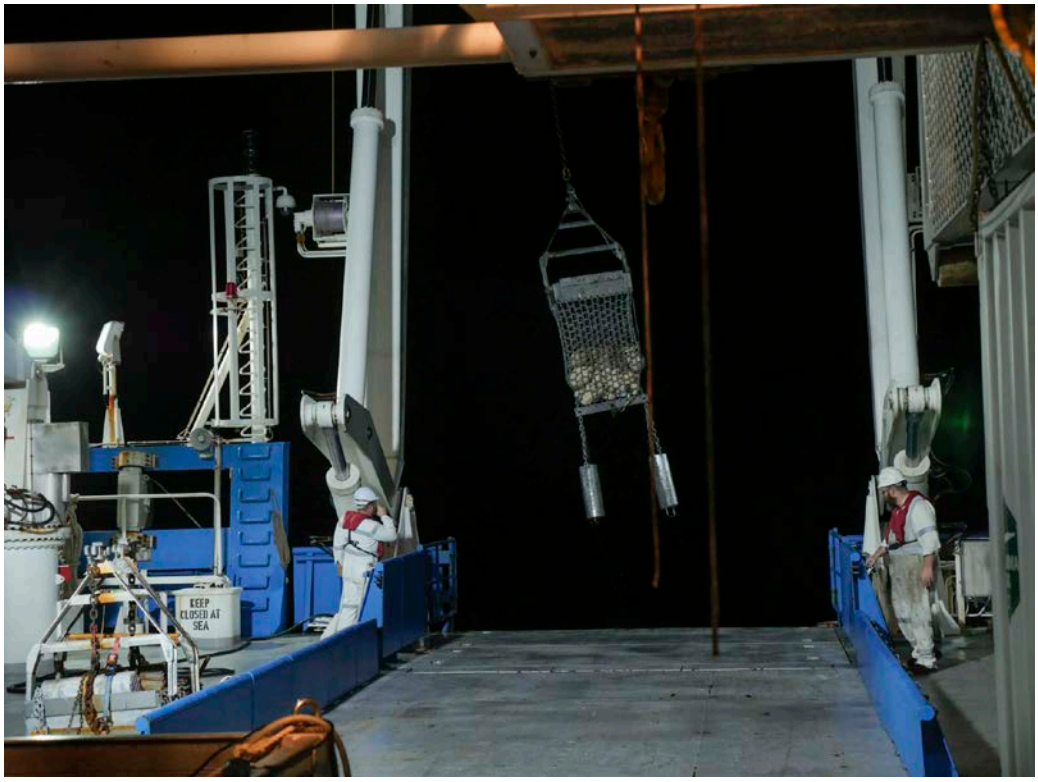
Your name	Simon Williams
Title	Chief Scientist
Signature	
Date:	12/9/2016

List of additional figures and documents

Appendix 1 Voyage Photos

Appendix 2 CSR/ROSCOP Parameter CodeS

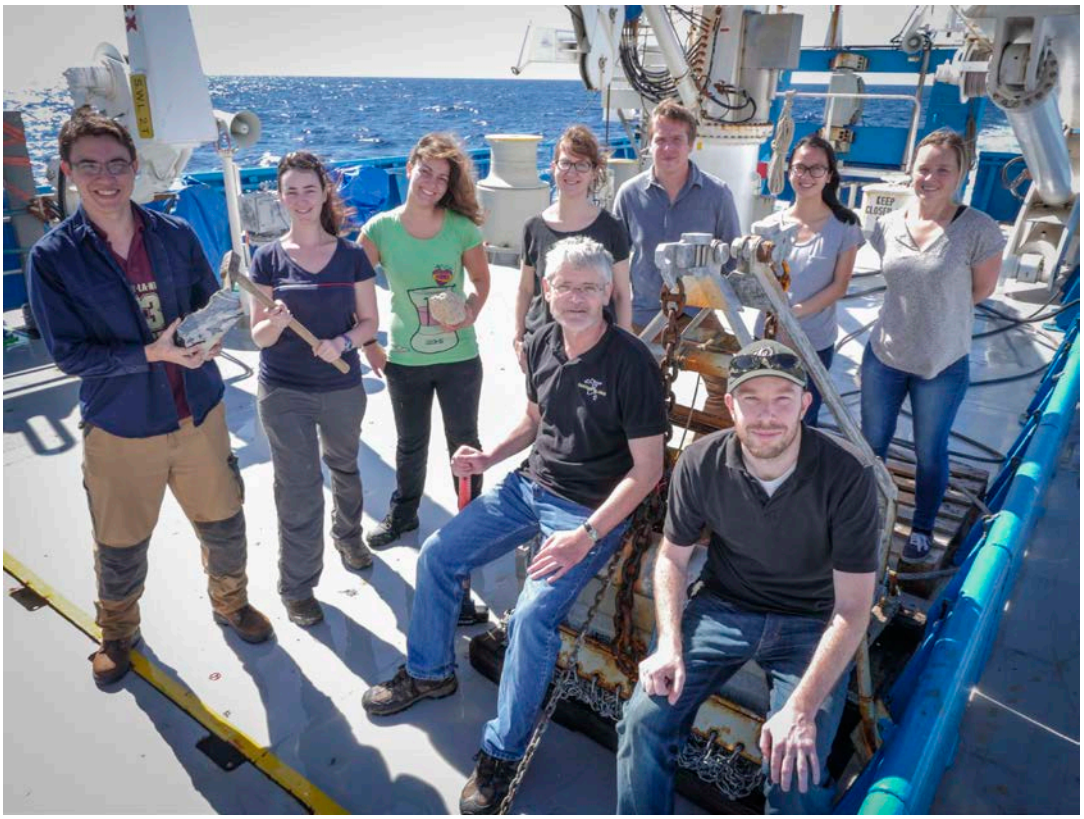
Appendix 1: Voyage Photos



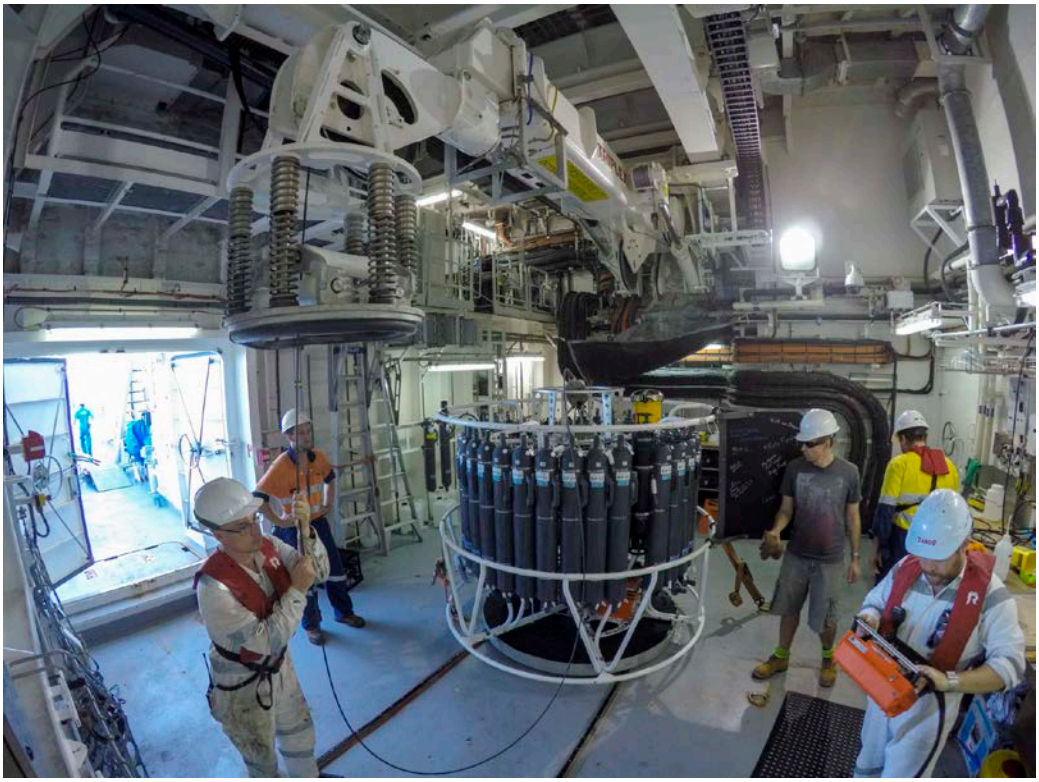
The rock dredge coming back on deck - with rocks in. [photo: Doug Thost]

Slicing up the samples with the rock saw. [photo: Doug Thost]

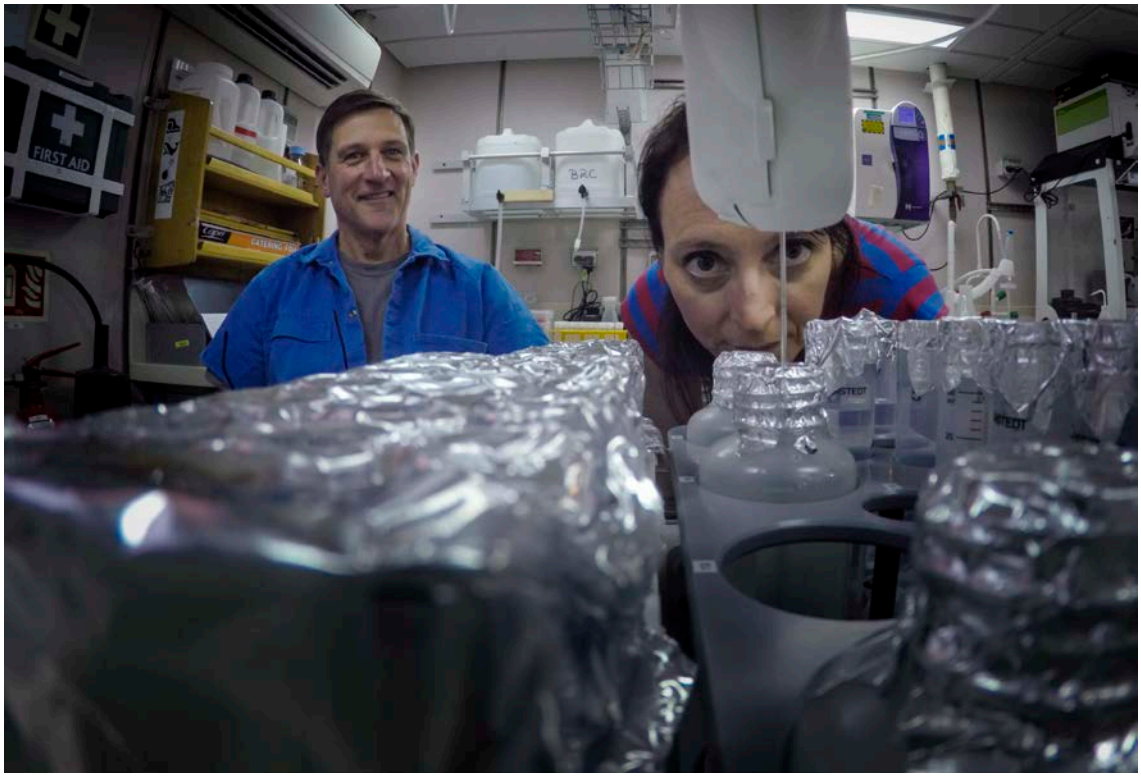
The Geoscience team, cataloguing the samples. [photo: Doug Thost]



The Geoscience team, posing for the camera. [photo: Doug Thost]

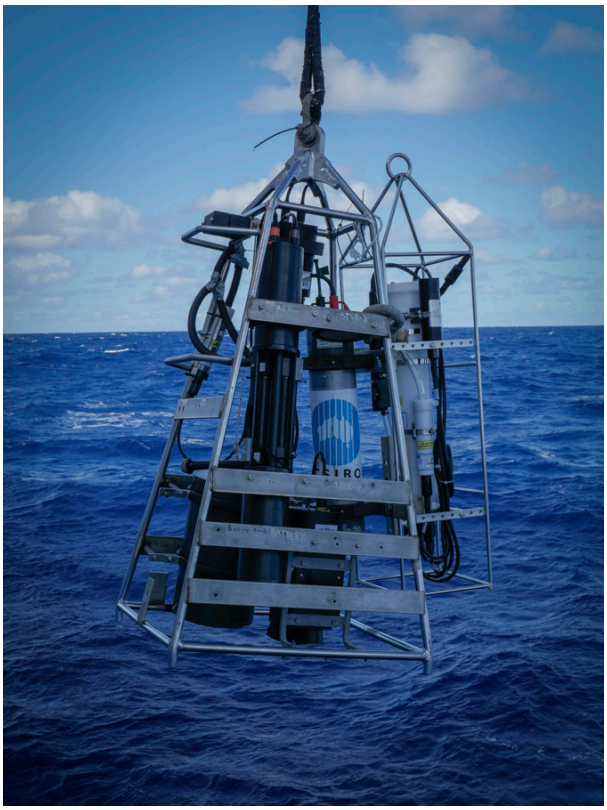


Preparing to deploy the CTD. [photo: Doug Thost]

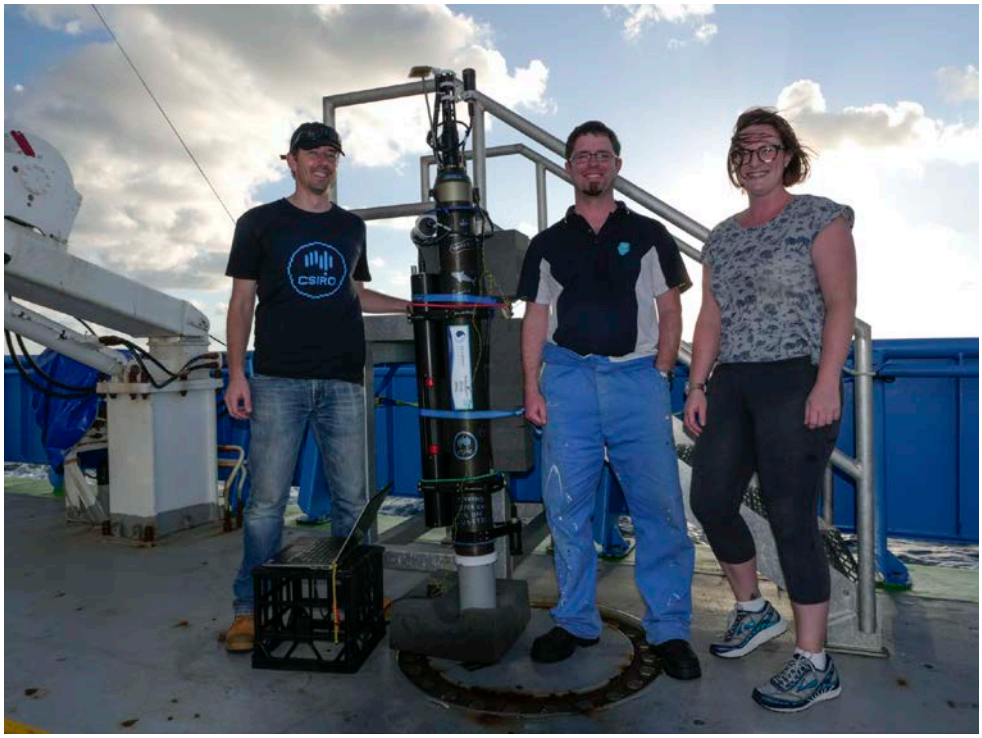


Martina and Mark in the lab. [photo: Doug Thost]

Preparing to deploy the bio-optical instrument frame (BOPak). [photo: Doug Thost]



The BOPak on its way into the water. [photo: Doug Thost]



Nick, James and Bonnie get ready to deploy a Bio Argo float. [photo: Doug Thost]

Deploying a Bio Argo float. [photo: Doug Thost]

Preparing polystyrene cups for deployment on the CTD. [photo: Doug Thost]

The science team on the front deck, back in Hobart. [photo: Nick Herold]

Appendix 2: 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
D06	Neutrally buoyant floats

	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
B28	Acoustic reflection on marine organisms

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

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