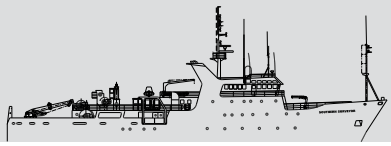


MARINE
NATIONAL FACILITY

2013 program

RV *Southern Surveyor*

CSIRO

voyage summary SS2013_t03

SS2013_t03

Transit voyage: Microbial oceanography of northern Australia; Mapping surface currents; Geographic limits of the Great Barrier Reef submerged reefs/Upper-slope swath mapping; Transect Measurements of Greenhouse Gases and Ozone in the Marine Atmosphere.

Voyage period

Start: 27/07/2013
End: 10/08/2013
Port of departure: Broome, Australia
Port of return: Brisbane, Australia

Responsible laboratory

Plant Functional Biology and Climate Change Cluster,
University of Technology, Sydney
PO Box 123 Broadway, NSW 2007, Australia

Chief Scientist

Dr Martina A. Doblin,
Plant Functional Biology and Climate Change Cluster,
University of Technology, Sydney

Scientific Objectives

Ship time on this transit voyage was allocated to four programs:

1. Microbial oceanography of northern Australia – primary program (36 hours), lead by UTS;
2. Global drifter program – lead by Dr Kiki Dethmers at the North Australia Marine Research Alliance (NAMRA-AIMS);
3. Swath mapping around the GBR, lead by Dr Robin Beaman (JCU) and Dr Gordon Keith (CSIRO);
4. Greenhouse gas measurement, lead by Dagmar Kubistin at UoW.

Each of the programs had their own scientific objectives, listed below prefixed with 1, 2, 3 or 4.

1-1. To determine the significance, diversity and seasonality of nitrogen fixation by microorganisms in the nitrogen limited waters of NW and NE Australia;

1-2. To examine the expression of light harvesting genes in phototrophic bacteria in different optical climates in the northern coastal and oceanic region of Australia;

1-3. To understand the biogeochemical role of eukaryotes with respect to N and Si uptake processes;

1-4. To understand the diversity and biogeochemical role of eukaryotes with respect to N uptake processes;

1-5. To reveal the species composition, photophysiology and carbon fixation of phytoplankton in optically complex coastal and ocean waters surrounding Northern Australia;

1-6. To obtain a new understanding of the processes involved in marine snow formation at different depths within the pristine waters of Northern Australia;

2-1. To determine the direction and velocity of subsurface currents across the Timor and Arafura Seas;

2-2. To obtain baseline parameters for developing a dispersal prediction model of derelict fishing gear;

2-3. To observe (and potentially retrieve) derelict fishing gear, in particular 'ghost nets';

2-4. To record and identify marine wildlife sightings across the Arafura and Timor Seas;

3-1. To determine the full spatial distribution of the Great Barrier Reef (GBR) shelf edge submerged reefs, i.e. can we identify their northern and southern limits?

3-2. To understand the detailed geomorphology of the submerged reefs and shelf edge features at these northern and southern limits;

3-3. To collect swath data in those parts of the upper-slope that currently have no swath data;

4-1. To make continuous measurements of carbon dioxide, methane, nitrous oxide, carbon monoxide and ozone as the RV *Southern Surveyor* travels along the chosen transect;

4-2. To assimilate measured data into a variety of atmospheric chemical transport, inverse and statistical models to improve our knowledge and understanding of atmospheric greenhouse gases and their sources and sinks.

Voyage Objectives

1.1. Deploy CTD-rosette to obtain vertical profiles of water column structure (temperature, salinity, dissolved oxygen, Photosynthetically Active Radiation, chlorophyll-*a* fluorescence, CDOM fluorescence), as well as photosynthetic rates and collect water samples for molecular biological assessment of the microbial community composition and function.

1.2. Undertake deck-board biogeochemical process studies, focusing on nitrogen and carbon fixation.

1.3. Undertake manipulative experiments to alter the quantity and quality of light available for photosynthesis and carbon fixation.

1.4. Undertake a CTD station in the deep water of the Coral Sea (CTD 23; 20°39'42.73"S, 154°29'56.59"E) if there is time.

2.1. Release 5 drifters at targeted locations along the voyage track.

2-2. Routinely conduct visual observations for marine animals and derelict fishing gear.

3-1. Map the submerged reefs along the GBR shelf edge, which lie adjacent to and just landward of the shelf break at approximately the 100 m contour, from the northern GBR in the Torres Strait then southwards following the 100 m contour along the shelf break towards the Swains Reefs.

3-2. Within the northern and central GBR sections, there are some priority sites along the shelf edge for exploratory (at continual transit speed) swath surveys within the 12 hours allocated, subject to safe navigation. These sites are (north to south):

Mantis Reef	143° 55.5'E	12° 16.3'S	
Tydeman Channel	144° 34.0'E	13° 58.0'S	
Ribbon 10/9 Channel	145° 41.9'E	14° 56.0'S	
Ribbon 8/7 Channel	145° 43.9'E	15° 07.5'S	
Ribbon 6/5 Channel	145° 44.9'E	15° 14.7'S	
Myrmidon Reef*	147° 22.6'E	18°15.0'S	*highest priority

3-3. Having followed the submerged reefs along the shelf break at the 100 m contour to about 21°S (the eastern limit of the Swains Reefs) or wherever the submerged reefs disappear, head out to the approximate 300 m contour and cross the Capricorn Channel at 400 m.

4-1. Undertake continuous underway measurements of greenhouse gases.

Results

1) **Microbial oceanography.** The microbial portion of this transit voyage was relatively successful. We were able to complete 11 deckboard incubations to quantify phytoplankton community carbon and nitrogen fixation, 11 full depth profiles of primary productivity (9 with size fractionated surface communities), 11 experiments with surface communities, conduct 6 experiments to assess aggregate formation, a further 9 experiments to assess the active incorporation of silica into diatoms and.

Charlotte Robinson (UTS PhD student) completed 12 vertical profiles of the upper ocean using a multi-wavelength light sensor to measure the degree of attenuation of blue, green and red light. She has also been measuring the photosynthetic activity of microbes to understand their capacity for growth using a fast repetition rate fluorometer. Measurements were made at fixed times of day to address diel effects on photosynthetic parameters. Simple measurements of the photochemical health of the phototrophic community were performed throughout the voyage and will yield diagnostic information indicative of nutrient stress.

Lauren Messer (UTS PhD student) completed N-fixation assays in collaboration with Charlotte's C-fixation assays at 11 stations, targeting potential nitrogen fixing microbes in surface waters (11 stations) and at the chlorophyll maximum (6 stations). Lauren also collected DNA/RNA samples from 21 stations to determine which microbial genes are actively involved in nutrient acquisition processes. During a transit through this region last October (ss2012_t07) we measured high rates of nitrogen fixation in surface waters, particularly in the Gulf of Carpentaria. During this voyage we expected the upper ocean to be stratified; instead we observed a well-mixed water column with potentially little nutrient limitation. Collectively this data set will help us to better understand the significance of nitrogen fixation in this region in relation to nutrient limitation, carbon fixation and the diversity and activity of the microbes mediating these processes.

Jaume Bibiloni (UTS PhD student) has been similarly harvesting microbes from hundreds of litres of seawater, only he is interested in photoheterotrophic bacteria that use unusual ways to make energy. His schedule has involved sampling in the early morning and late evening, and in deep waters below where most of the phototrophic microbes grow. In addition to samples collected from 23 stations, water samples from the underway system have been also collected, both afternoon and night, to investigate whether proteorhodopsin (PR) and bacteriochlorophyll-*a* (Bchl*a*) gene abundance/expression and distribution, change spatially. These samples, in conjunction with a series of monthly samples from 3 different IMOS mooring stations situated at Maria Island, Port Hacking and Stradbroke Island, which are being provided by collaborators at CSIRO, will provide a valuable database to investigate spatial and temporal changes

in community structure and photoheterotrophic activity within key Australian coastal oceanographic regions, which are currently being influenced by climate change.

Kirralee Baker (UTS PhD student) has been investigating the activity of diatoms, important microbes that underpin fisheries production in the ocean. She's been incubating seawater with a fluorescent marker that will enable her to understand how much silicate (a required nutrient for diatoms) has been incorporated into new cells. Samples were collected from a total of ten sites, where experiments were conducted using the surface waters at all of these sites and the chlorophyll maximum at four of these sites. The assays are being used to test the hypothesis that there is a relationship between water temperature and the degree of silicification in diatom communities.

Shalin Seebah (UTS Early Career Researcher) conducted roller tank experiments at 11 stations to investigate the potential for marine snow (large marine aggregate) formation in the waters along the transit. The custom-built roller tanks were filled with seawater, incubated for 72 hrs and marine snow formation recorded. Out of the 11 stations, only 2 stations formed marine snow. The sinking velocity of the formed aggregates were measured on-board. Shalin is interested in investigating the underlying mechanisms of marine snow formation since the majority of POC sinks out of the euphotic zone in this form. Therefore, seawater samples from different stations were fixed with formalin and brought back to the laboratory for post-voyage analyses. The concentration of transparent exopolymeric particles (TEP) which is an important component of marine snow will be quantified from these fixed samples and whether TEP concentration correlates with the formation of marine snow will be investigated.

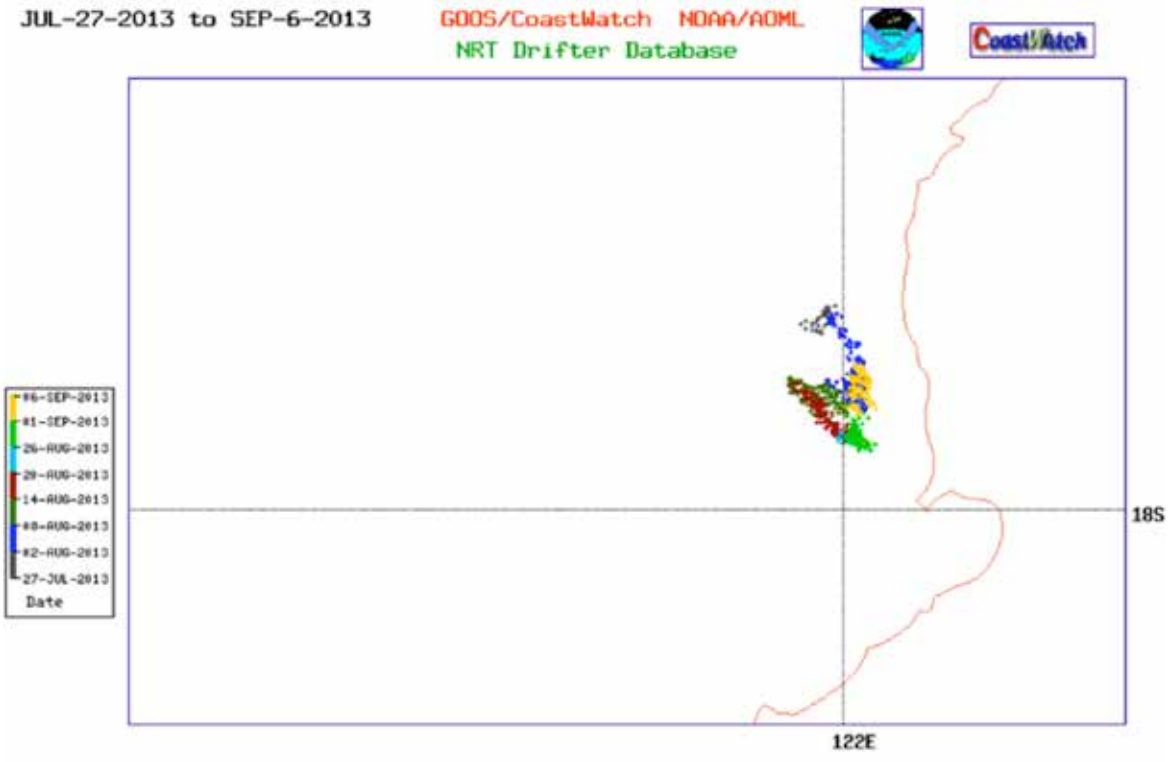
James McLaughlin (CSIRO Marine and Atmospheric Research, Perth, WA), collaborator on the Marine and Coastal Carbon Biogeochemistry Cluster, completed 11 productivity stations measuring ^{14}Carbon uptake by phototrophic plankton throughout the whole water column via photosynthesis versus irradiance incubations. In conjunction with James's assays, Martina performed experiments with ^{14}C designed to quantify how much dissolved organic carbon leaks out of cells. To better understand the light climate for photosynthesis, James collected samples to determine the role of suspended material in attenuating light within the euphotic zone. This work will contribute to the Marine and Coastal Carbon Biogeochemisty Cluster which aims to measure the productivity in coastal waters all around Australia, while also providing data to parameterise and validate biogeochemical models. James also organised the deployment of the Continuous Plankton Recorder to capture data on the community composition of phytoplankton and zooplankton along the transit.

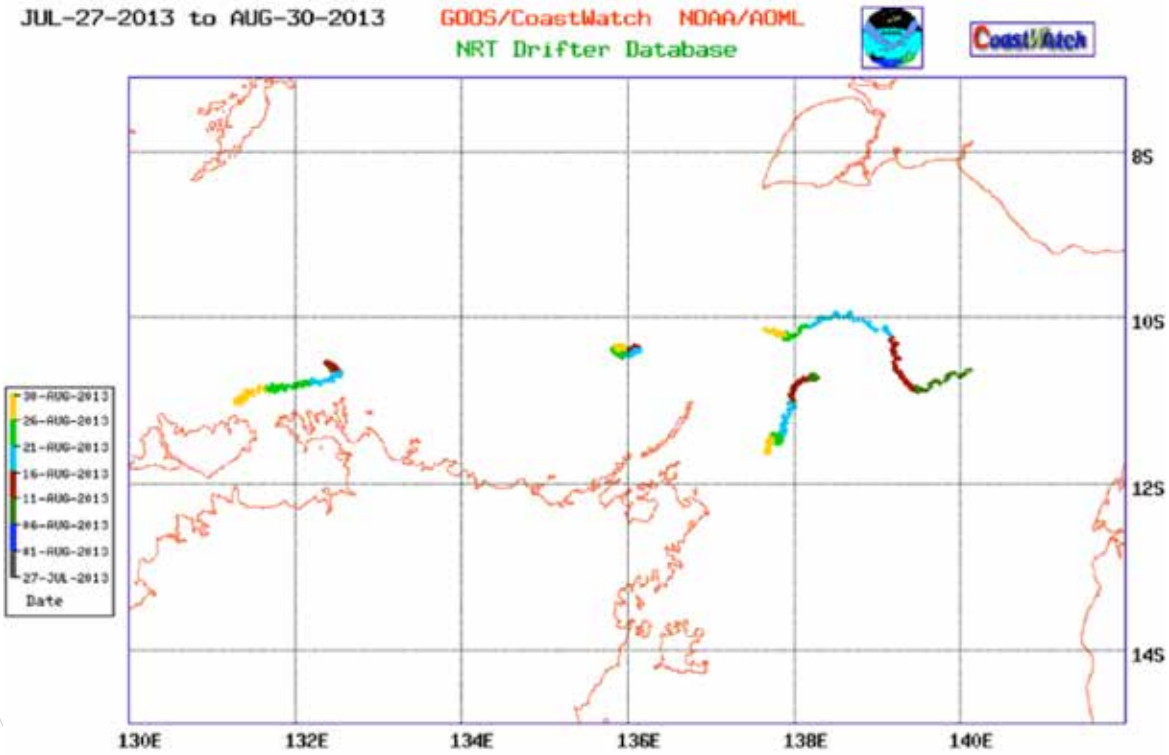
2) **Global drifter program.** With respect to objective 2, Kiki Dethmers launched 1 drifter near the Kimberley IMOS array (27/07/2013 at 11:27 UTC at 17 35.339 S and 121 51.616 E) and 4 further east in the Arafura Sea. Tracking data collected by the drifters on surface current direction and velocity will provide the baseline parameters for developing a dispersal prediction model of derelict fishing gear.

Four drifters were released in the Arafura Sea at:

Date	Lat (S)	Long (E)
31/07/2013	10 35.410	132 59.981
1/08/2013	10 40.401	135 59.807
2/08/2013	10 44.195	138 22.414
2/08/2013	10 45.645	140 49.236

Derelict fishing gear, with photographs of a drifter on the deck, being launched, and after deployment. The drifters are all actively transmitting positions as seen in the plots overleaf.





Drifter 1 (top) and drifters 2-5 (below).

In addition to deploying drifters, Kiki Dethmers made daily observations from the bridge for marine wildlife. During a total of 56 observation hours, 60 sightings were made of 15 identified and 5 unidentified species, accounting for approximately 300 individual animals, including cetaceans, sea snakes and birds. No ghost nets were observed during the voyage.

3) S**wath mapping around the GBR.** The results of the ss2013_t03 swath mapping and Topas subbottom profiling were generally considered a success, with some minor exceptions (see daily diary in Appendix). Both systems, for the most part, worked well, however in the northern GBR/Cape York area between latitude 9° 49'S to 12° 33'S, incorrect EM300 swath settings in the SIS acquisition software resulted in limited across track coverage and noisy data until the correct settings were applied. Therefore the objective to understand the northern limit of the GBR submerged reefs was inconclusive. However, the southern limit of the GBR submerged reefs has been extended to at least latitude 22 08'S, as numerous pinnacles 5-15 m high were observed to seaward to the Swains Reefs to depths of about 100 m. Therefore the GBR submerged reefs are currently observed over a distance of about 1000 km, certainly justifying their label as the world's longest fossil.

4) **Greenhouse gas measurement.** To characterise the sources and sinks of the major greenhouse gases in the Australasian region, continuous in situ measurements of the key greenhouse gases methane, carbon dioxide, nitrous oxide, as well as carbon monoxide and ozone were successfully performed during the transit SS2013_t03. The data were collected by using a fully automated Fourier Transform Spectrometer for CH_4, CO_2, N_2O, $\delta^{13}C$, CO and a UV absorption instrument for O_3. The time resolution was 3 min and 1 min, respectively. The preliminary data are shown in Appendix 3. Final calibration of the instrument once returned to Wollongong will allow finalization of the data.

Continental influenced air as well as marine background conditions were sampled during the SS2013_t03 transect from Broome to Brisbane. Strong enhancements in the trace gas concentrations were predominant when back trajectories indicate that the air mass has travelled over biomass burning regions. This unique dataset will now be compared with model estimates of the current understanding of the processes contributing to the growth and variability of greenhouse gases in the lower atmosphere.

Voyage Narrative

The voyage departed on time on Saturday 27 July. The pumps for the aerosol sampling were already operational and did not get turned off until after we had returned to port in Brisbane. After dinner, Kiki Dethmers launched a drifter, closely followed by the CPR which was fitted with a new cassette and deployed using the aft A-frame. The microbial ecologists went through their water budget and sampling routine and the remainder of the science gear was set up, ready for our first CTD at 06:30 the next morning. The first CTD operation occurred on Sunday 28 July, closely followed by the deployment of the multispectral light meter. The second CTD operation occurred in the afternoon – there was generally low phytoplankton biomass and no obvious signs of a subsurface chlorophyll-maximum or the diazotroph, *Trichodesmium erythreum*. All microbial samples were collected and protocols for setting up nitrogen and carbon fixation assays, aggregation tanks, silica uptake assays and P vs I measurements ironed out. This routine of one morning CTD operation followed by the multispectral light meter profile, and one afternoon CTD operation went from Sunday to Friday, with a hiatus on Saturday 3 August when we transited the Torres Strait. On Sunday 4 August (adjacent to the Cape York peninsula), we did an early morning CTD cast and collected surface water with buckets to allow the swath mapping to start. On Monday 5 August, the microbial team did a morning and an afternoon CTD, but the routine for the remainder of the voyage was for two back to back CTD operations in the morning where water was captured for deckboard carbon and nitrogen fixation incubations. On Friday 9 August we also managed to complete a relatively deep cast in the East Australian Current north of Fraser Island. We had some issues with the forward CTD cable with some data lost on two CTD casts. The CTD was then switched to the aft cable on which we had no problems, and the forward one was fixed.

Summary

Given what was achieved, the voyage was a success. We had generally good weather, although it was windier than anticipated and there was one night where winds were over 40 knots. This did not appear to affect any of our deckboard incubations. Our equipment generally functioned well, although we experienced difficulty with the laboratory module of the Fast Repetition Rate fluorometer which meant we could not do a full analysis of the phototrophic microbes as originally intended. In addition, the settings on the swath mapper were not optimal in the Cape York region, and consequently yielded limited information. However, the objectives for the drifter and aerosol investigations were fully achieved.

Project:

Marine and Coastal Carbon Biogeochemistry Cluster
(CSIRO Wealth from Oceans Flagship)

Coordinating body:

University of Technology, Sydney

Principal Investigators:

A. *Dr Martina A. Doblin,* Plant Functional Biology and Climate Change Cluster, University of Technology, Sydney, PO Box 123 Broadway, NSW 2007, Australia.

B. *Dr Justin Seymour,* Plant Functional Biology and Climate Change Cluster, University of Technology, Sydney, PO Box 123 Broadway, NSW 2007, Australia.

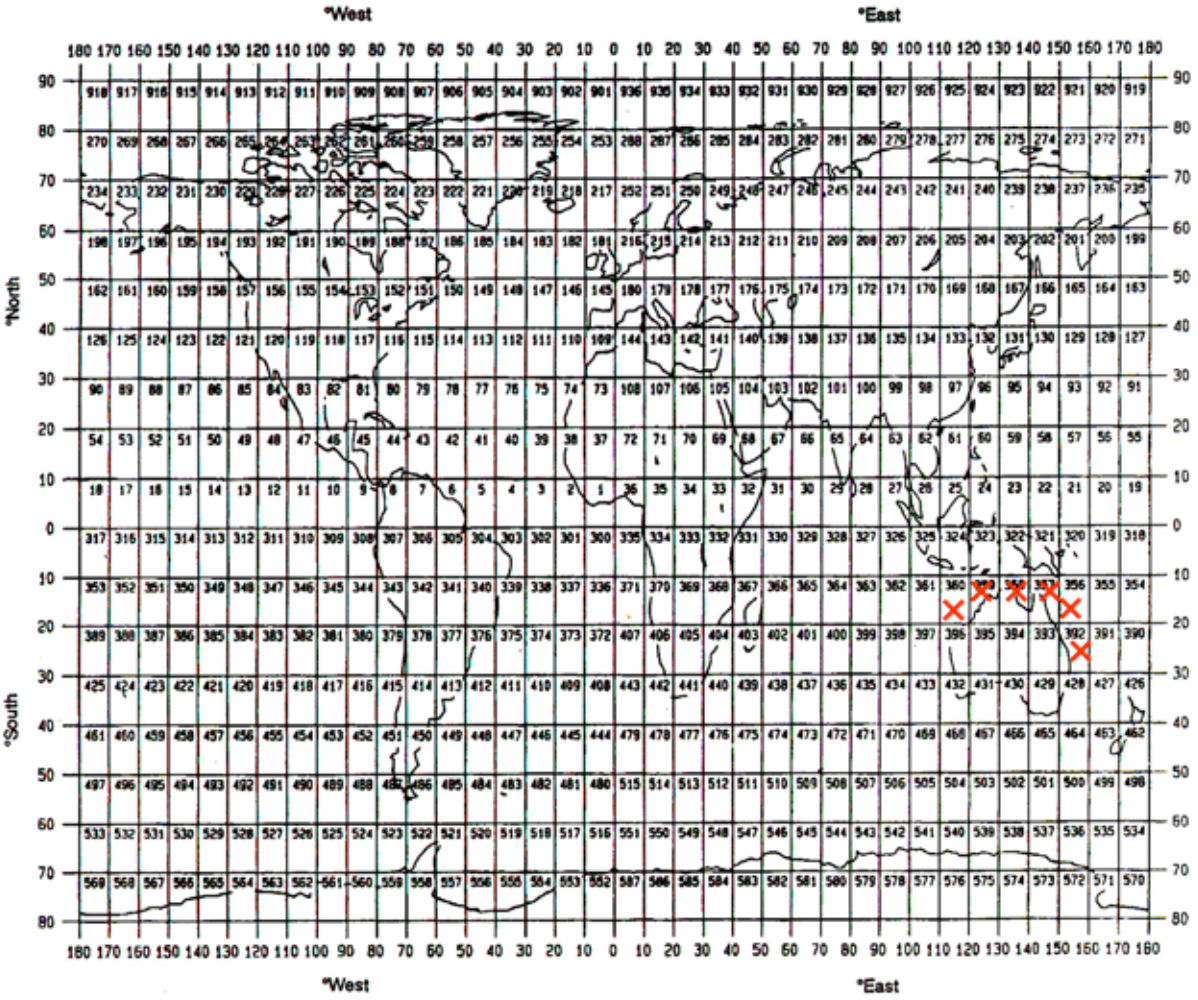
C. *Dr Kiki Dethmers,* North Australia Marine Research Allience – AIMS, Darwin, NT

D. *Dr Robin Beaman,* James Cook University, Townsville, QLD

E. *Dr Dagmar Kubistin,* University of Wollongong, NSW

F. *Mr James McLaughlin,* CSIRO Marine and Atmospheric Research, Perth WA

GEOGRAPHIC COVERAGE - INSERT 'X' IN EACH SQUARE IN WHICH DATA WERE COLLECTED



MOORINGS, BOTTOM MOUNTED GEAR AND DRIFTING SYSTEMS									
Item No.	PI	Approximate position						Data Type	DESCRIPTION
		Latitude			Logitude				
		deg	min	N/S	deg	min	E/W		
1	C	17	35.339	S	121	51.616	E	D05	Surface drifter, position (latitude, longitude), deployed but not recovered
2	C	10	35.410	S	132	59.981	E	D05	
3	C	10	40.401	S	135	59.807	E	D05	
4	C	10	44.195	S	138	22.414	E	D05	
5	C	10	45.645	S	140	49.236	E	D05	

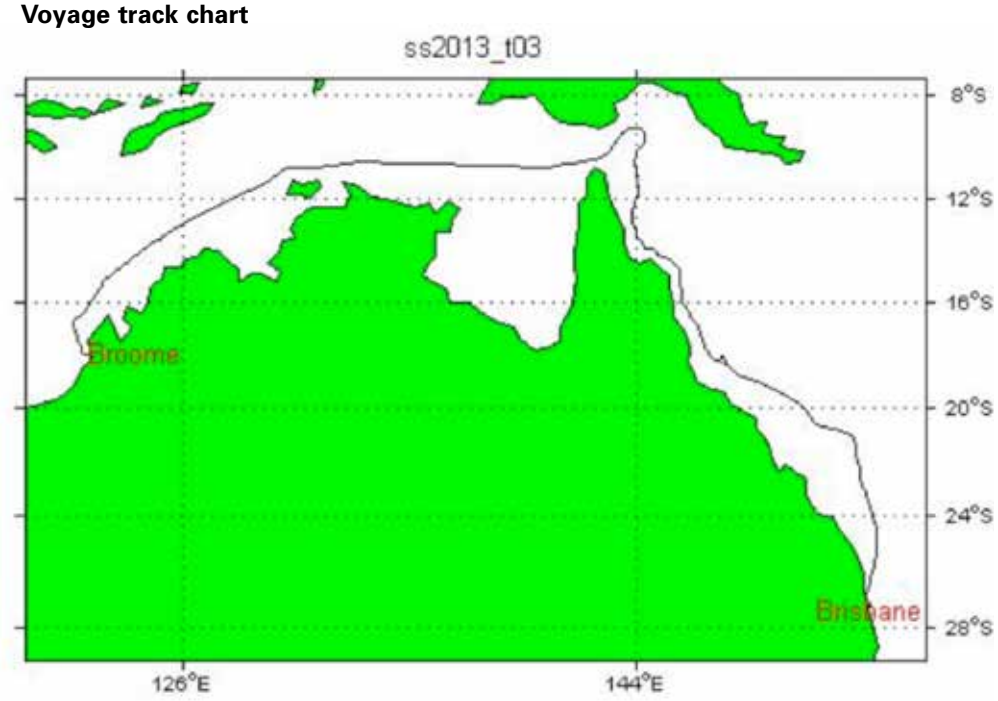
SUMMARY OF MEASUREMENTS AND SAMPLES TAKEN					
Item No.	**PI**	**No.**	**Units**	**Data Type**	**DESCRIPTION**
Phytoplankton pigments	A,B	21 CTDs	2-6 depths	B02	Samples of the phytoplankton community (2 L) at discrete CTD depths and at T0 and Tfinal of deckboard experiments were filtered onto 0.7 µm glass fibre GF/F filters and snap frozen for later analysis (at UTS) of HPLC pigment composition.
POC	A,B	11 CTDs	1-2 depths 15 samples	B71	Samples of water (≥2 L) at discrete CTD depths at some stations were filtered onto pre-ashed 0.45 µm glass fibre filters and snap frozen for later analysis of total particulate carbon and nitrogen as well as natural abundance of $\delta^{13}C$ and $\delta^{15}N$.
DOC	A	11 CTDs	1-2 depths 15 samples	B72	Samples of water at the surface of some CTD stations ("Optical casts") were filtered through 0.2 µm membrane filters and preserved for later analysis (at CSIRO CMAR) of dissolved organic carbon.
Humic-like substances	A	14 CTDs	1-2 depths 15 samples		Samples of water at the surface of some CTD stations were stored in plastic acid washed bottles and frozen for later HLS analyses at UTS.
flow cytometry (CTD and underway)	A,B	21 CTDs	2-6 depths	B08/ B07	Aliquots of seawater at discrete depths at each CTD station were preserved in glutaraldehyde (1% final concentration) and snap frozen for later analysis by flow cytometry of community composition and abundance.
DIC	A	17 CTDs	1-2 depths 29 samples	B72	Samples from the CTD and underway system were collected, fixed with mercuric chloride and shipped to CSIRO CMAR for TCO2 and DIC analysis.
Samples for light microscopy	A	17 CTDs	1-2 depths 34 samples	B08	Samples of water (1 L) at the surface of some CTD stations were preserved in Lugols solution for light microscope counts at UTS.
CDOM	A,B	11 CTDs	5 samples	H90	Samples of water at the surface at some CTD stations were filtered through 0.2 µm membrane filters and preserved for later spectrophotometric analysis of the contribution of CDOM to the absorption of light in the water column.
TSS	F	7 CTDs	8 samples	P01	Samples of water (2 L) at the surface at some CTD were filtered onto pre-ashed and weighed 0.45 µm glass fibre filters and frozen at -20 °C for later analysis (at CSIRO CMAR).
Particulate absorption	A	11 CTDs	20 samples	B71	Samples of water at the surface at some CTD stations were filtered onto 0.7 µm glass fibre (GF/F) filters and snap frozen for later spectrophotometric analysis (at UTS) of the absorption of light by phytoplankton and other particulate detrital matter.
Dissolved Nutrients (Deckboard experiment)	A,B	11 CTDs	50 samples	H23-26	Aliquots of water from CTDs and experimental bottles at Tfinal were collected in plastic vials and analysed on-board by the hydrochemist.
Phytoplankton photophysiology (CTD and deckboard experiment)	A	15 CTDs	24 samples	B02	Phytoplankton photophysiology (Fv/Fm and σ_{PSII}) was measured on aliquots of water from the surface of CTD stations and deckboard experiment samples using a Fast Repetition Rate Fluorometer (FRRf), respectively.
Phytoplankton community productivity	A,F	11 CTDs	4-6 depth P vs	B01	Photosynthetic rates of the phytoplankton community at multiple depths was measured by enriching phytoplankton samples with trace quantities of ^{14}C-labelled bicarbonate and measuring the uptake of inorganic carbon at 7 different light intensities. Samples were incubated in a lab-based incubator at in situ light and temperature conditions for 1 h.
DNA	A,B		30 samples	B72	Seawater was filtered using peristaltic pumps to capture particulate material on 0.2 micron membranes.

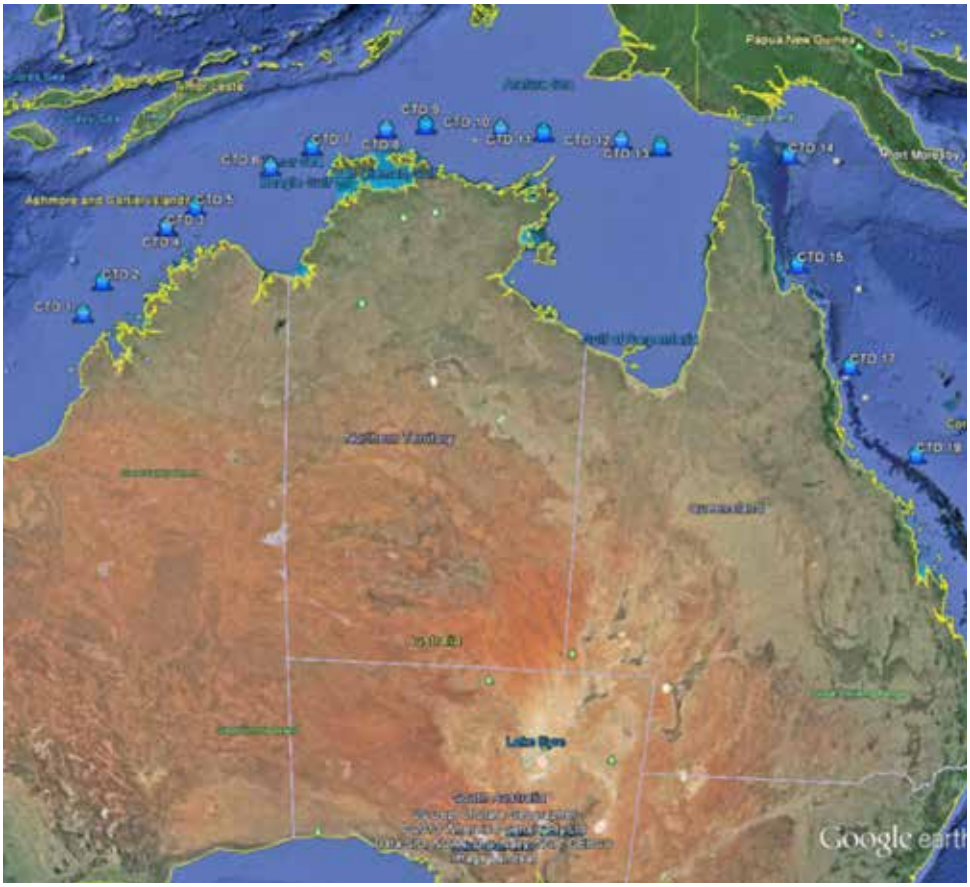
SUMMARY OF MEASUREMENTS AND SAMPLES TAKEN (continued)					
Item No.	**PI**	**No.**	**Units**	**Data Type**	**DESCRIPTION**
RNA	B	5174	30 samples	B72	Seawater was filtered using peristaltic pumps to capture particulate material on 0.2 micron membranes within 15 min of collection. Additional samples were collected from the continuous underway system and CTDs where Nfix/Cfix experiments were completed.
Swath	D	5170	km	G74	Kongsberg EM300 multibeam data collected during the transit
Topas	D		km	G75	Topas sub-bottom profiler data collected during the transit

Curation Report

Item No.	DESCRIPTION
Swath	Kongsberg EM300 multibeam data held by Robin Beaman, School of Earth and Environmental Sciences, James Cook University, PO Box 6811, Cairns QLD 4870 email: robin.beaman@jcu.edu.au
Topas	Topas sub-bottom profiler data held be held by Robin Beaman, School of Earth and Environmental Sciences, James Cook University, PO Box 6811, Cairns QLD 4870 email: robin.beaman@jcu.edu.au

Voyage track chart





General ocean area(s): Timor Sea, Arafura Sea, Gulf of Carpentaria, Torres Strait, Coral Sea

Personnel list

Scientific Participants

Name	Affiliation	Role
1. Dr. Martina Doblin	UTS	Chief Scientist
2. Ms Lauren Messer	UTS	PhD Student
3. Ms Charlotte Robinson	UTS	PhD Student
4. Mr Jaume Bibiloni Isaksson	UTS	PhD Student
5. Ms Kirralee Baker	UTS	PhD Student
6. Dr Shalin Seebah	UTS	Post-doc
7. Mr James McLaughlin	CMAR	Research fellow / Alternate Chief Scientist
8. Dr Kiki Dethmers	NAMRA-AIMS	Chief Investigator
9. Dr Robin Beaman	JCU	Chief Investigator/Swath
10. Mr Gustavo Hinestrosa	USyd	PhD Student/Swath
11. Lisa Woodward	CMAR/MNF	Voyage Manager
12. Rod Palmer	CMAR/MNF	Electronics Support
13. Anoosh Sarraf	CMAR/MNF	Computing Support
14. Sue Reynolds	CMAR/MNF	Hydrochemistry Support

UTS – University of Technology Sydney; **MNF** – Marine National Facility;
CMAR – CSIRO Marine and Atmospheric Research;
JCU – James Cook University; **USyd** – University of Sydney

Marine Crew

Name	Role
Mike	Master
John	
Simon	
Nick	Chief Engineer
Mick	First Engineer
Mick	Second Engineer
Graham	Bosun
Doug	IR
Pete	IR
Kel	IR
Rod	IR
Beck	Chief Cook
Aaron Buckleton	Cook
Cassie	Chief Steward

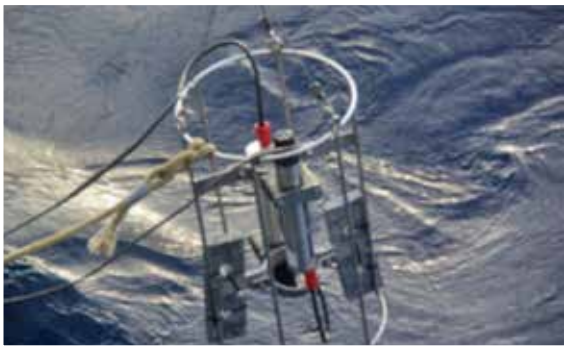
Acknowledgements

We are grateful to the crew of the R.V. *Southern Surveyor* who assisted with our sampling program. Lisa Woodward, Rod Palmer and Anoosh Sarraf (CSIRO) were great with their operational and technical support, helping to train and assist the scientists with CTD operations. We would also like to thank the Marine National Facility (CSIRO) for allowing us the opportunity to participate in a transit voyage. It has helped support 5 PhD student projects, 1 Early Career Researcher, and has contributed to the Marine and Coastal Carbon Biogeochemistry Cluster, a CSIRO partnership with multiple universities and research organisations.

Martina A. Doblin
Chief Scientist

Figures

The microbial team sampling and undertaking their experiments.



Geographic limits of the Great Barrier Reef submerged reefs/Upper-slope swath mapping

The submerged or drowned reefs of the Great Barrier Reef (GBR) have been described as the world's largest fossil. Their existence was identified through singlebeam profiles along the GBR shelf edge in the 1980-90s. However their spatial extent and geomorphic detail remained unknown until new multibeam data revealed a pattern of inner and outer shoals parallel to the shelf break between about 40-70 m depth. Then in 2007, a *Southern Surveyor* expedition between Cooktown and Hydrographers Passage greatly added to the available multibeam data along the GBR shelf edge, confirming a near-continuous submerged reef stretching about 650 km. The shelf edge features included terraces, pinnacles, ridges and channels, interpreted as fringing reefs, patch and barrier reefs and tidal channels respectively.

The submerged reefs seaward of the Ribbon Reefs exist on a narrow (<500 m), relatively steep shoulder to a shelf break around 86 m, whereas submerged reef features are more developed on the wide (several km), gently-sloping shelf edge to the south with a shelf break around 102 m. AUV imagery collected from the 2007 expedition showed that the submerged reef features had extensive mesophotic coral ecosystems (MCEs), supporting diverse communities of hard and soft corals, sponges and other benthic fauna. Combined with subsequent expeditions, these data have shown that coral diversity on these deep reefs is much greater than previously thought, and includes many species not previously recorded from the GBR (Bridge et al., 2012b).

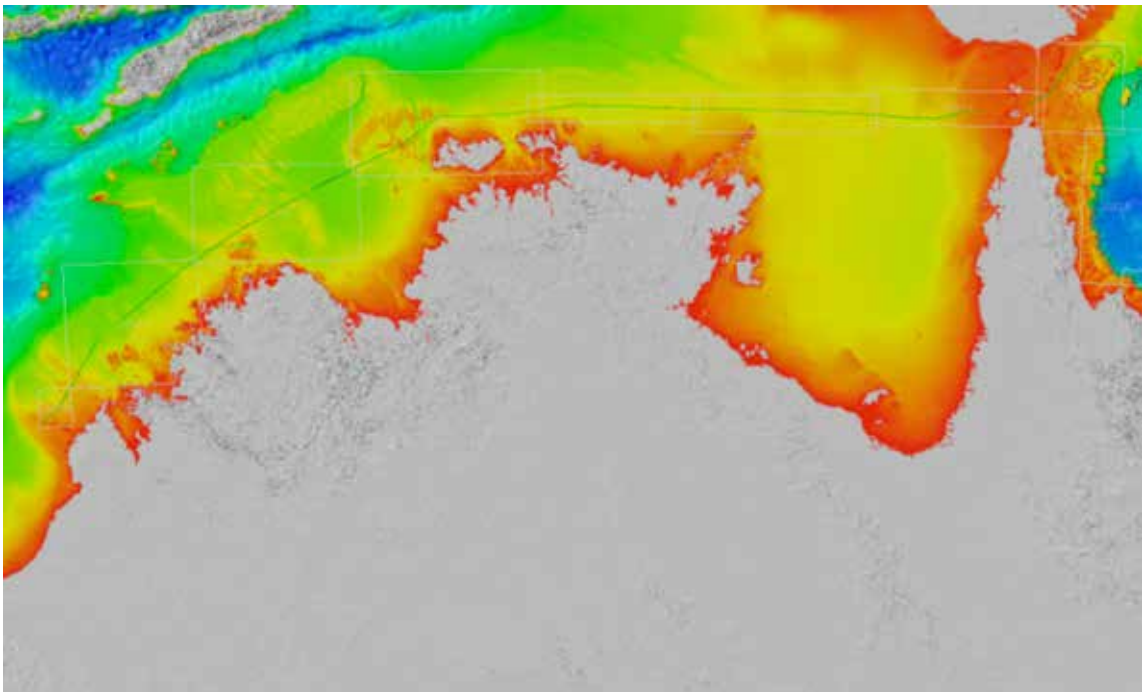


Figure 1. Swath coverage along northern Australia, from Broome to the Torres Strait.

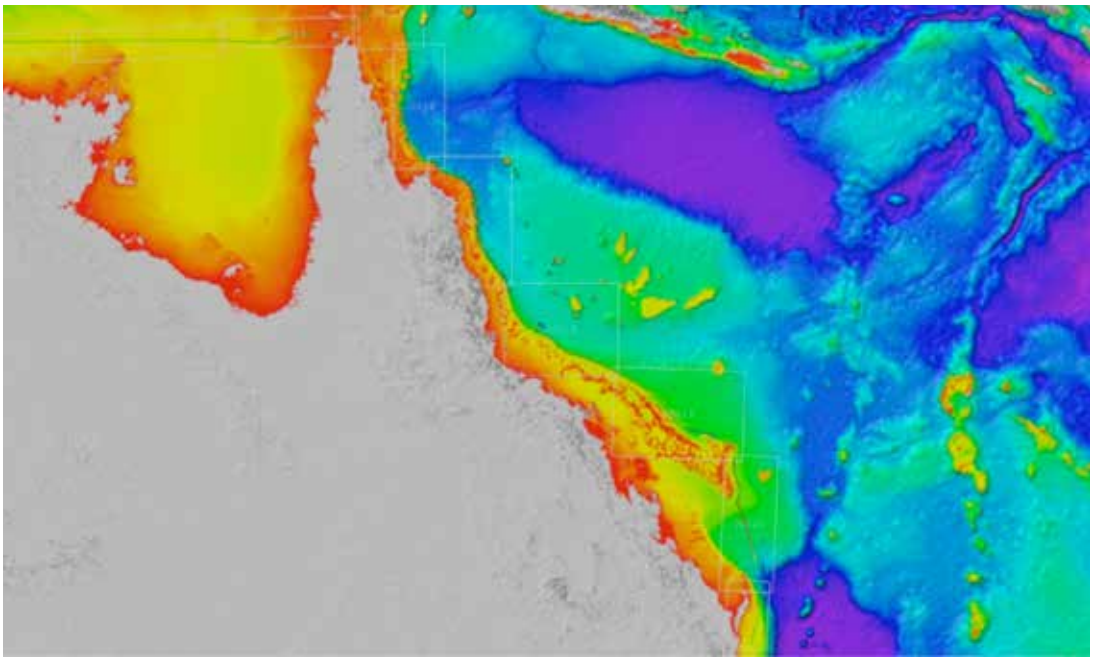
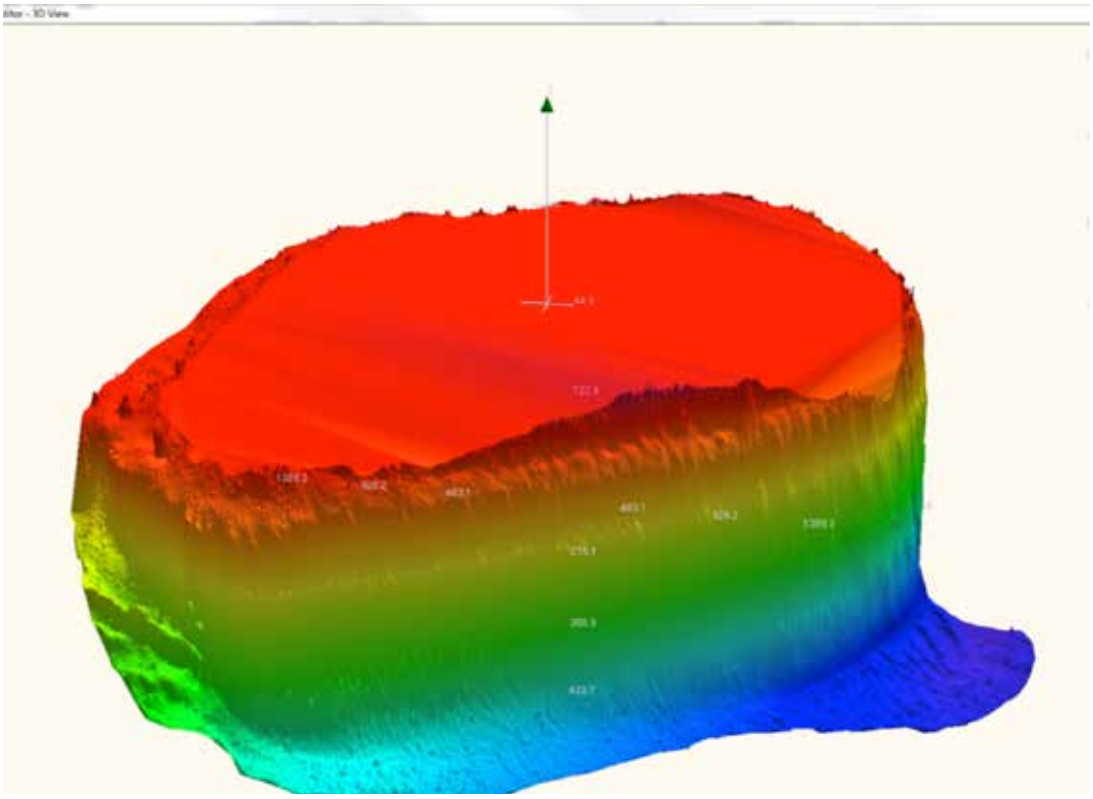


Figure 2. Swath coverage along the GBR shelf edge and upper slope, from Torres Strait to Brisbane.



Swath coverage around the detached Myrmidon Reef on the central GBR margin.

Tables

Table 1: ss2013_t03 Samples collected

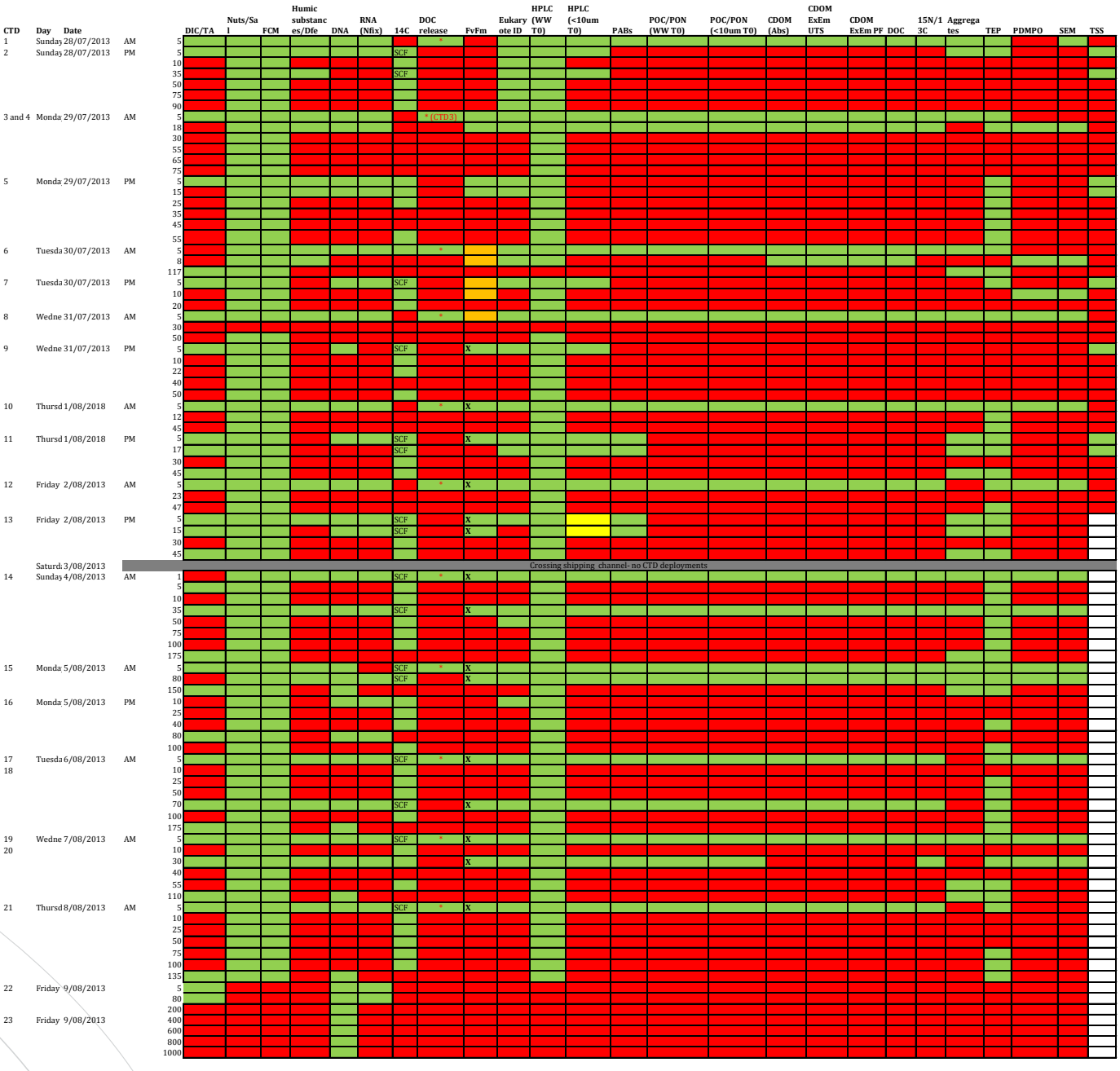


Table 2: ss2013_t03 Samples collected

SAMPLE	DAY/NIGHT	ACID_NUCL	DATE	LOCAL TIM	UTC
1.1	Night	RNA	30-Jul-13	21:59	12:59
1.2	Night	RNA	30-Jul-13	21:59	12:59
1.3	Night	RNA	30-Jul-13	21:59	12:59
1	Night	DNA	30-Jul-13	21:59	12:59
2.1	Night	RNA	31-Jul-13	21:19	12:19
2.2	Night	RNA	31-Jul-13	21:19	12:19
2.3	Night	RNA	31-Jul-13	21:19	12:19
2	Night	DNA	31-Jul-13	21:19	12:19
3.1	Night	RNA	01-Aug-13	21:48	12:48
3.2	Night	RNA	01-Aug-13	21:48	12:48
3.3	Night	RNA	01-Aug-13	21:48	12:48
3	Night	DNA	01-Aug-13	21:48	12:48
4.1	Night	RNA	02-Aug-13	22:07	12:07
4.2	Night	RNA	02-Aug-13	22:07	12:07
4.3	Night	RNA	02-Aug-13	22:07	12:07
4	Night	DNA	02-Aug-13	22:07	12:07
5	Day	DNA	03-Aug-13	7:35	21:35
5.1	Day	RNA	03-Aug-13	7:35	21:35
5.2	Day	RNA	03-Aug-13	7:35	21:35
5.3	Day	RNA	03-Aug-13	7:35	21:35
5.4	Day	DNA	03-Aug-13	7:35	21:35
6.1	Day	RNA	03-Aug-13	15:30	5:30
6.2	Day	RNA	03-Aug-13	15:30	5:30
6.3	Day	RNA	03-Aug-13	15:30	5:30
6.4	Day	DNA	03-Aug-13	15:30	5:30
6	Day	DNA	03-Aug-13	15:30	5:30
7.1	Night	RNA	03-Aug-13	21:42	11:42
7.2	Night	RNA	03-Aug-13	21:42	12:42
7.3	Night	RNA	03-Aug-13	21:42	13:42
7	Night	DNA	03-Aug-13	21:42	11:42
9.1	Night	RNA	04-Aug-13	20:50	10:50
9.2	Night	RNA	04-Aug-13	20:50	10:50
9.3	Night	RNA	04-Aug-13	20:50	10:50
9	Night	DNA	04-Aug-13	20:50	10:50
10.1	Day	RNA	05-Aug-13	15:49:53	5:49:53
10.2	N/A	N/A	N/A	N/A	N/A
10.3	Day	RNA	05-Aug-13	15:49:53	5:49:53
10	Day	DNA	05-Aug-13	15:49:53	5:49:53
11.1	Night	RNA	05-Aug-13	22:16:55	12:16:55
11.2	Night	RNA	05-Aug-13	22:16:55	12:16:55
11.3	Night	RNA	05-Aug-13	22:16:55	12:16:55
11	Night	DNA	05-Aug-13	22:16:55	12:16:55
12.1	Day	RNA	06-Aug-13	15:42:06	5:42:06
12.2	Day	RNA	06-Aug-13	15:42:06	5:42:06
12.3	Day	RNA	06-Aug-13	15:42:06	5:42:06
12	Day	DNA	06-Aug-13	15:42:06	5:42:06
13.1	Night	RNA	06-Aug-13	21:09	11:09
13.2	Night	RNA	06-Aug-13	21:09	11:09
13.3	Night	RNA	06-Aug-13	21:09	11:09
13	Night	DNA	06-Aug-13	21:09	11:09
14.1	Day	RNA	07-Aug-13	15:12	7:12
14.2	Day	RNA	07-Aug-13	15:12	7:12
14.3	Day	RNA	07-Aug-13	15:12	7:12
14	Day	DNA	07-Aug-13	15:12	7:12
15.1	Night	RNA	07-Aug-13	21:03	11:03
15.2	Night	RNA	07-Aug-13	21:03	11:03
15.3	Night	RNA	07-Aug-13	21:03	11:03
15	Night	DNA	07-Aug-13	21:03	11:03
16.1	Day	RNA	08-Aug-13	15:05	5:05
16.2	Day	RNA	08-Aug-13	15:05	5:05
16.3	Day	RNA	08-Aug-13	15:05	5:05
16	Day	DNA	08-Aug-13	15:05	5:05
17.1	Night	RNA	08-Aug-13	22:08	12:08
17.2	Night	RNA	08-Aug-13	22:08	12:08
17.3	Night	RNA	08-Aug-13	22:08	12:08
17	Night	DNA	08-Aug-13	22:08	12:08

APPENDICES

Appendix 1 – Science Report

Voyage SSt03/2013

Microbially-mediated biogeochemistry of northern Australia

Dr Martina Doblin, University of Technology, Sydney, Ultimo, NSW (Chief Scientist)

Mr James McLaughlin, CSIRO Marine and Atmospheric Research,
Perth, WA (Deputy Chief Scientist)

Itinerary

Departed Broome, 16:00
Saturday, 27 July 2013
Arrived Brisbane, 12:00
Saturday, 10 Aug 2013

Contribution to Australia's national benefit:

The accumulation of fossil-fuel-derived CO_2 in the sea and associated shifts in ocean temperature, circulation, stratification, nutrient input and oxygen content, is leading to major changes in the functioning of globally important biogeochemical cycles that sustain life on Earth (Riebesell et al. 2000; Hutchins et al. 2009). Given the enormous ecosystem services we derive from the global ocean (estimated at $8.4 trillion per year; Costanza et al. (1997) and that the ocean contributes approximately $42 billion to the Australian economy (The AIMS index of marine industry (2011)), this research is significant.

Microbes are central players in the Earth's biogeochemical cycles, with small changes in function having potentially large consequences for the Earth-climate system (Taucher and Oschlies 2011). The outcomes of this research will have significant impact because it will increase the accuracy of predictions on the future delivery of ecosystem services, critical information that can be used to inform decision making about the sustainable use of Australia's ocean resources, aligning directly with goals of the Priority goal of "Responding to climate change and variability" and "Sustainable use of Australia's biodiversity" with the National Research Priority "An environmentally sustainable Australia".

As a result of this voyage:

1. We have a better understanding of:

– The rates of nitrogen fixation around north-eastern Australia, and the microbes responsible.

– Rates of photosynthesis and carbon fixation and the stock of dissolved and particulate carbon, including transparent exopolymeric substances that have the potential to form marine snow.

– The abundance of diatoms and the degree of silica incorporation into cells.

– The abundance and identity of key groups of photoheterotrophic bacteria that use light energy to break down organic matter, and subseqeuntly have a significant influence on ocean carbon cycling.

– Velocity and direction of surface currents in the Arafura Sea – Gulf of Carpentaria region, and the abundance of greenhouse gases in the atmosphere.

2. We have found:

– Little evidence of the nitrogen fixing cyanobacterium *Trichodesmium erythraeum* in surface waters during the transit, likely due to strong wind-induced mixing.

– Variable rates of primary productivity (carbon fixation) and dissolved organic carbon production.

– Relatively low incidence of marine aggregate formation (only 2 of 11 roller tank experiments).

3. We have mapped about 66% of the Great Barrier Reef (GBR) shelf break from Torres Strait to the Swains Reefs along the 100 m contour, thereby extending the known southern limit of the GBR submerged (drowned) reefs along the shelf break to about 1000 km in distance. We have also mapped the distribution of greenhouse gases and ozone in the coastal atmosphere.

4. We have commenced a program to understand the microbially-mediated biogeochemical transformations in waters around Australia, helping to inform biogeochemical and ecosystem models to help predict future changes in ecosystem function.

Appendix 2 – Daily diary of the swath/Topas data recording

Sat 27th July 2013

Wind 10 kn from 120°.Sea state 2. Nil swell
1900 in position 17° 42.6'S 121° 54.6'E

We departed from Broome at 1600, sailing out into the calm waters of the Arafura Sea on a sunny day. Within sight of land we saw our first whales, a pod of smaller Humpback whales. After safety briefings, we concentrated in getting the EM300 swath gear working. Initially, the harddrive of the processing computer had failed, but was fixed on setting up a replacement harddrive. The comports for the sensor inputs were then configured differently. There was no sound velocity input from the transducer. MNF technicians worked late to try and solve each issue. The Topas system remained off overnight.

Sun 28th July 2013

Wind 12 kn from 150°. Sea state 3. Nil swell
1900 in position 14° 46.6'S 123° 24.4'E

Overnight we transited about 60 km west of Lacepede Peninsula heading northward. Sea conditions still smooth. Just after midnight we had a breakthrough in the problems with the EM300 swath system, when we got the processor harddrive to work with the correct comports, but still with the incorrect sound velocity data input. With swath data coming in now, we could start focusing on the post-processing in the Caris HIPS software. At 1052, MNF techs solved the SV input problem and we loaded a new SV profile into the SIS acquisition software. Through the day we continued along the Kimberley coastline, about 100 km to the south-east. At 1440, we started the Topas subbottom profiler. Data quality are very good with penetration up to 40 m depth below seabed.

Mon 29th July 2013

Wind 11 kn from 130°. Sea state 3. Nil swell

1900 in position 12° 55.1'S 126° 10.6'E

We continued tracking north-east about 100 km off the Kimberley coastline. Both EM300 swath and Topas systems running well with no problems. All swath lines were being post-processed in near realtime within the Caris HIPS software. Seafloor detail is relatively smooth with depths of about 90 m with occasional dunes overlying hard substrate. Towards the end of daylight, we were off the Van Cloon Bank at the north-eastern end of the Kimberley coastline. Here, the seafloor showed a rough, reefal substrate interspersed with softer sediments infilling old river channels. Topas data are very impressive, with cross-bedded strata revealed to depths of 40 m in profile.

Tues 30th July 2013

Wind 12 kn from 087°. Sea state 4. Low swell
1900 in position 10° 54.4'S 130° 00.9'E
Overnight we continued across the Timor Sea towards the east, about 120 km north of the Kimberley coastline. Seabed depths were about 90 m with hardground and the occasional palaeochannel, infilled with sediments. By morning we were north of Joseph Bonaparte Gulf into the Timor Sea proper. Flat topped shoals were scattered amongst the generally flat seafloor, gradually becoming shallower towards the east. By 1900 we were 50 km north of Melville Island in depths of about 70 m. Seafloor still mostly flat with occasional rocky plateau interspersed with palaeochannels.

Subbottom profiles in places showed dramatic cross-bedding strata. Unlikely to be modern, so these would be dunes infilling depressions and cemented with a hard surface. Weather is becoming rougher with a slight effect on the data quality.

Wed 31th July 2013

Wind 19 kn from 120°. Sea state 4. Nil swell
1900 in position 10° 35.8'S 133° 26.3'E

We have continued easterly across the Arafura Sea, crossing a relatively flat seabed north of Melville Island and the Cobourg Peninsula. During the night, the winds picked up resulting a slight degrading of the Topas data, with the bottom tracking losing its ability to find the bottom. As winds eased, bottom tracking improved. North of the Cobourg Peninsula, slight pockmarks were observed associated with buried palaeochannels. In the swath data, these were seen as clusters of elongate 20-40 m wide, shallow depressions in depths of about 60 m. In the Topas data, we could see the same pockmarks in the seabed above the channels. The pockmarks are subtle and easy to remove in the post-processing, so care is being taken to retain the bathymetry data over these pockmarks.

Thur 1st August 2013

Wind 18 kn from 122°. Sea state 4. Nil swell
1900 in position 10° 42.0'S 137° 09.1'E

Overnight, we continued tracking about 130 km north of Arnhem Land, heading towards the Wessel Islands still in the Arafura Sea. Both EM300 swath and Topas systems were working well. Depths are about 60 m and relatively flat, with occasional low dips in the seafloor where buried river channels were found in the Topas data. Despite the relatively flat seafloor, the sub-surface is incredibly complex, with three distinct units lying above a deeper reflector, below which no sub-surface strata could be seen. The top unit is likely Holocene marine sediments infill, causing the flat seafloor. Below this are the complex second and third units, which together form a 20 m plus thickness of palaeochannels, crossbedded strata, channel infill and possibly faults.

Fri 2nd August 2013

Wind 13 kn from 154°. Sea state 4. Nil swell
1900 in position 10° 49.7'S 140° 34.2'E

We have continued across the top of the Gulf of Carpentaria towards the Torres Strait through the night then day. By evening we were 170 km west of the Torres Strait in good weather conditions. The multibeam and Topas systems continue to work well with no issues at all. Data quality also are very good, with backscatter showing as higher reflectance across rough seabed features or associated with low-relief channels, which show up very well in the Topas data. Subbottom penetration is up to 30 m with continuous units of sediment traced across the survey lines. At 1100 we had our first meeting regarding the swath surveying in the Great Barrier Reef. The Cape York area is the highest priority for shelf edge surveying, but due to lack of time and the poor charting it is unlikely that we will go near the shelf edge.

Sat 3rd August 2013

Wind 22 kn from 145°. Sea state 4. Low swell
1900 in position 9° 17.1'S 143° 46.4'E

We continued heading easterly overnight towards the Torres Strait, weather conditions OK. All systems were operating OK. By morning we had started the transit through the Torres Strait in shallow depths of about 20 m. The swath data were quite poor due to the shallow depths, which continued through the day. At 1704, SIS crashed. We spent about 9 min getting the system started, which worked OK after 1713. We also discovered that Topas had stopped and on checking the processed seg files on the Topas computer, found they had not been written to since about 2216 on Friday 2nd August, due to a full harddrive. We spent an hour moving old files off the Topas harddrive then restarted Topas at 1845. Through the evening we continued up Great Northeast Channel to the start of the Great Barrier Reef survey.

Sun 4th August 2013

Wind 24 kn from 130°. Sea state 4. Low swell
1900 in position 12° 18.9'S 143° 56.2'E

After transiting the Torres Strait through the night, we exited into the northern Great Barrier Reef around 0200, following a 400 m contour plan. Sailing southward along the outside of the reef, we encountered rougher seas due to the increase in wind speed from the Coral Sea. Swath data quality remained OK along the Bligh Trough. By 0800, with better light, we sailed closer to the shelf edge and followed the reef which was only several 100 m to the west of us. Swath data showed no obvious signs of drowned reefs and the seafloor appeared to gradually drop with no terraces or reef features obvious towards the shallows. By early-afternoon, we were opposite Raine Island, transiting along the 400-1000 m contour. Topas data was considerably worse, with no real data of use. Swath data became quite poor on Deep mode, despite that mode matching the depth zone. Better quality data were obtained with Very Deep mode. The SIS acquisition software crashed several times. Around 2100 we resolved the swath data issues by selecting Manual mode, which considerably improved the data quality.

Mon 5th August 2013

Wind 18 kn from 125°. Sea state 4. Low swell
1900 in position 14° 47.7'S 145° 44.0'E

Overnight we traced the edge of the GBR, following the approximate 400 m contour. The swath system had the occasional crash, where no data were collected. Topas data remained poor until Gustavo managed to configure the profiler in Chirp mode. By morning we were off Tydeman Reef in about 100 m depth, surveying up onto the shoulder to seaward of the reef wall. We could easily see the reef exposed with occasional rock boulders on the reef flat. Seafloor morphology was fascinating with numerous canyon heads fed from a steep wall in front of the main reefs. We have the hint of coral pinnacles around the 50 m mark indicating drowned reefs so there is possible confirmation the drowned reefs are found to seaward of the main reefs on this narrow shoulder. We passed Lizard Island around 1800 with the survey continuing along the shelf edge at nightfall.

Tues 6th August 2013

Wind 7 kn from 108°. Sea state 3. Low swell

1900 in position 18° 14.7'S 147° 23.9'E

We had a very successful overnight along the Great Barrier Reef shelf margin surveying the heads of submarine canyons offshore from Cooktown. As the ship got closer to Cairns in the morning, the ship closed the 100 m contour and swathed the edge of the shelf edge in a south-easterly direction. Clear evidence of the lowstand shoreline was seen with a consistent 100 m scarp and terrace along the shelf edge. Topas data continued to be good quality. By late afternoon we approached Myrmidon Reef, an odd detached reef set out from the main reef matrix. Here we did a clockwise lap around Myrmidon Reef to survey the steep reef wall. Again, there was an obvious 100 m terrace, then a steep scarp, a 60 to 70 m terrace, then another steep scarp up to the modern reef growing from around 30 m. We then continued offshore to the Queensland Trough and returned at 90° to the slope, collecting good quality Topas data. The remaining night was a transit survey along the 100 m contour.

Wed 7th August 2013

Wind 8 kn from 190°. Sea state 3. Low swell

1900 in position 20° 03.5'S 150° 45.5'E

Overnight, we continued to sail along the shelf edge keeping to the 100 m contour. We passed by the head of the Bowl Slide, a huge underwater landslide, that starts at 100 m and drops debris over 700 m into the adjacent Queensland Trough. The shelf edge southeast of this feature was mostly straight with subtle terrace features. Through the day, the weather improved with light winds and low waves. Towards the afternoon, we approached Hydrographers Passage and noted large numbers of pinnacles around 110 m, just below the shelf break. These pinnacles continued right along Hydrographers Passage and into the northern Swains Reefs. Both the swath and Topas systems continued to run well in these relatively shallow waters.

Thur 8th August 2013

Wind 8 kn from 190°. Sea state 4. Moderate swell

1900 in position 20° 03.5'S 150° 45.5'E

Through the night, the ship moved into deeper waters, around 300 m, north of the Swains Reefs due to the uncertain nature of the reefs along the section of the GBR. By 0800, we had rounded the north-eastern limit of the Swains Reefs and continued tracing the 100 m contour along the western side of the Swains. The depths around this 100 m contour were very consistent, indicating a wide flat platform extending out from the reefs, but with no real indication of a 100 m scarp as had been seen earlier in the voyage along the GBR shelf edge. Instead, this wide platform was covered in numerous pinnacles, some up to 15 m high, scattered all over the platform. These pinnacles were observed right along the eastern Swains margin. Both the EM300 and Topas systems continued to work well. By 1700, we had completed surveying the GBR shelf edge and commenced our transit across the Capricorn Channel towards the Fraser coast.

Fri 9th August 2013

Wind 16 kn from 165°. Sea state 4. Moderate swell
1900 in position 25° 13.6'S 153° 35.3'E

Weather conditions deteriorated through the night so that by midnight, winds were gusting over 35 knots and seas were considerably higher. The quality of the swath and Topas data became more marginal with the worsening weather. We crossed the Capricorn Channel and by 0600 were positioned over the Tasman Basin for a deep CTD cast. On completion, we headed towards the Fraser shelf and then had problems getting the EM300 machine to work. A complete shutdown and reboot started the machine and we commenced surveying the Gardner Bank at 1230. This bank had previously been targeted for swath surveying to understand the extent of the hard-ground features in a predominantly sandy environment. By 1815, we had completed surveying Gardner Bank and started our final transit towards Brisbane along the Fraser shelf.

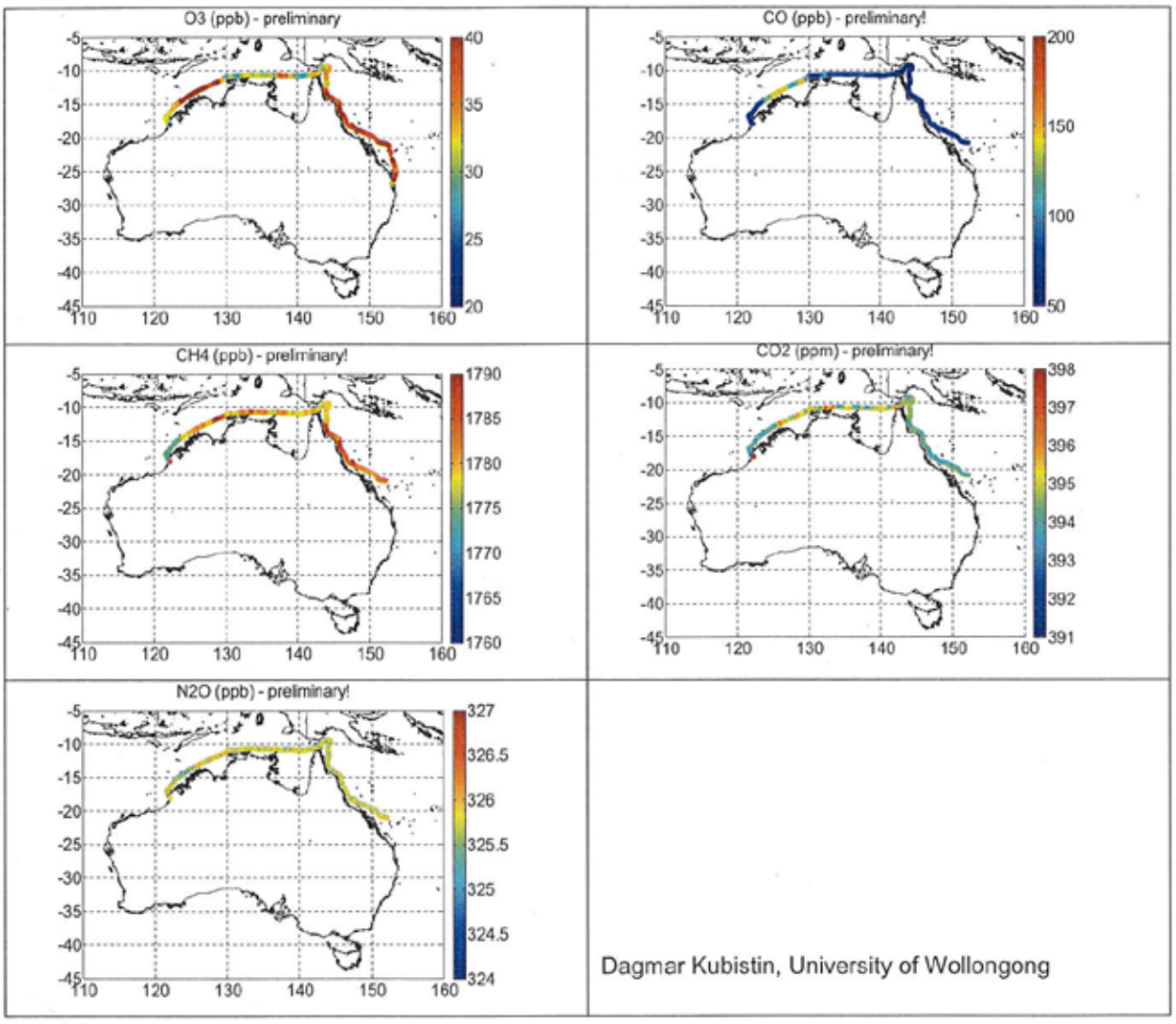
Sat 10th August 2013

Wind 10 kn from 165°. Sea state 2 Nil swell
1900 in position 27° 26.7'S 153° 0.4.6'E

During the overnight transit towards Brisbane down the Fraser shelf, we completed the swath and Topas survey around 0200 opposite the Sunshine Coast. All bathy data were fully cleaned in Caris HIPS software and saved for archiving. The remainder of the transit included the pilotage through Moreton Bay and into the Port of Brisbane, tying alongside the Cairncross Forgacs shipyard on the Brisbane River at 1200.

Appendix 3 – Measurements of greenhouse gases and ozone in the marine atmosphere

The following plots show the preliminary data and spatial coverage of greenhouse gases and ozone along the voyage track, contributing important information to the limited data coverage in the southern hemisphere. This unique dataset will help to improve our understanding of the growth and variability of these climate relevant trace gases.



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
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

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
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
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