Australia's Marine National Facility

VOYAGE SUMMARY ss2012_v04

Observations of remarkable eastward flows and eddies in the subtropical southeast Indian Ocean

Voyage period:

11/08/2012 to 14/08/2012 & 24/08/2012 to 09/06/2012

Port of departure:

Fremantle, Australia

Port of return:

Fremantle, Australia

Responsible laboratory:

Institute for Marine and Antarctic Studies

University of Tasmania, Churchill Avenue, Sandy Bay Australia

Chief Scientist(s)

Dr Helen Phillips, Dr Pete Strutton, Prof Nathan Bindoff (not on voyage)

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Scientific Objectives

Our work will include a suite of CTD, microstructure, surface drifter and float observations, and a mooring that will contribute to answering a first-order gap in our understanding of the large-scale currents in the subtropical southeast Indian Ocean. The presence of a near-surface, eastward flow across the South Indian Ocean is a remarkable aspect of the upper-ocean circulation because it flows against the westward direction from Ekman and Sverdrup theory for this region. The flow often appears as a set of distinct currents and jets. These currents have been detected in observations and simulated in some numerical models. However the underlying mechanisms driving the eastward surface currents and their eventual interaction with the Leeuwin Current and downwelling remains unclear. Furthermore, they appear to be linked to the Indonesian Throughflow and Southern Ocean water masses formed south of Australia. Our primary goal in this work is to make new observations of the physical and biogeochemical structure of the eastward flows in the region between existing observations and the Australian coast, where their fate is unknown. This region is filled with energetic eddies generated by the Leeuwin Current. Our observations will also provide insight into the nature of the interaction of these eddies with the circulation and productivity of the interior Indian Ocean. Dynamical understanding of the Indian Ocean circulation is central to the outstanding problem in ocean climate projections of correctly including surface processes to project the spatial patterns of heat uptake, steric sea-level rise, and storage of carbon dioxide.

Voyage Objectives

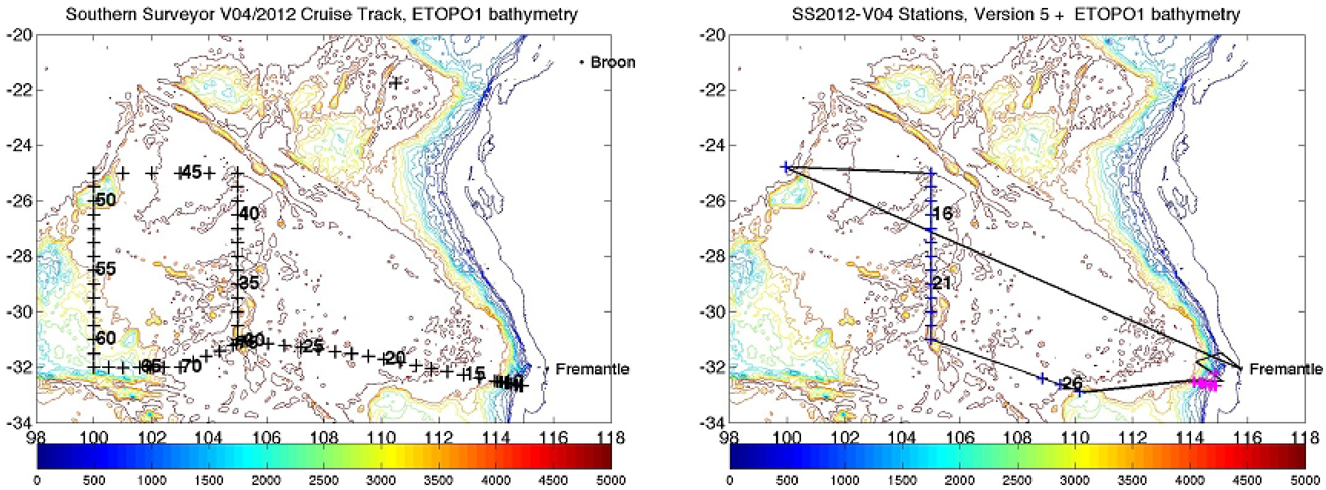
1. Map the vertical and meridional extent of the South Indian Countercurrent, and the underlying westward flows, east of 95E.
2. Identify the source waters of the westward flow beneath the SICC and broader eastward flow.
3. Characterise the 3-dimensional physical and biogeochemical structure of the Leeuwin Current eddies.
4. Establish a moored reference station to sample surface atmospheric fluxes and upper-ocean density, velocity and biogeochemistry.

Results

Our achievement of the objectives was seriously compromised by the engine failure on our voyage and the loss of 10 days in the science plan. Figure 1 illustrates the modification of the track as a result of the lost time. The pieces of the plan that were lost are:

1. Repeat of WOCE line I5 out to 100E with full depth CTDs
2. Full depth CTDs along 100E from 32S to 25S at 30nm spacing
3. Full depth CTDs along 25S from 100 to 105E at 50nm spacing
4. Observations below 2000m on all of the stations we were able to do

In spite of these losses we were able to meet part of each of the original objectives, as described below.



Original Voyage Track **Actual Voyage Track**

Figure 1 Voyage track of the original plan, including 89 full depth CTDs (left panel), and the modified track after engine failure, including 14 full depth CTDs (pink) and 20 2000m CTDs (blue; right panel). Colour contours are ETOPO5 bathymetry.

1. Map the vertical and meridional extent of the South Indian Countercurrent, and the underlying westward flows, east of 95°E.

The 105°E CTD line provides a high-resolution snapshot of the vertical and meridional structure of the South Indian Countercurrent, underlying westward flows and eddy field. Figure 2 shows a satellite view of the depth-integrated velocity field combining sea surface height anomalies (from AVISO) and a mean dynamic topography (Vianna et al. 2007). The large warm-core eddy at the northern end of the CTD line shows rapid anti-clockwise circulation around the eddy, with weaker eastward flows to the south of the line. The method of Ridgway and Dunn (2010) will be used to isolate the eddy signal from the underlying eastward (westward) surface (sub-surface) flows.

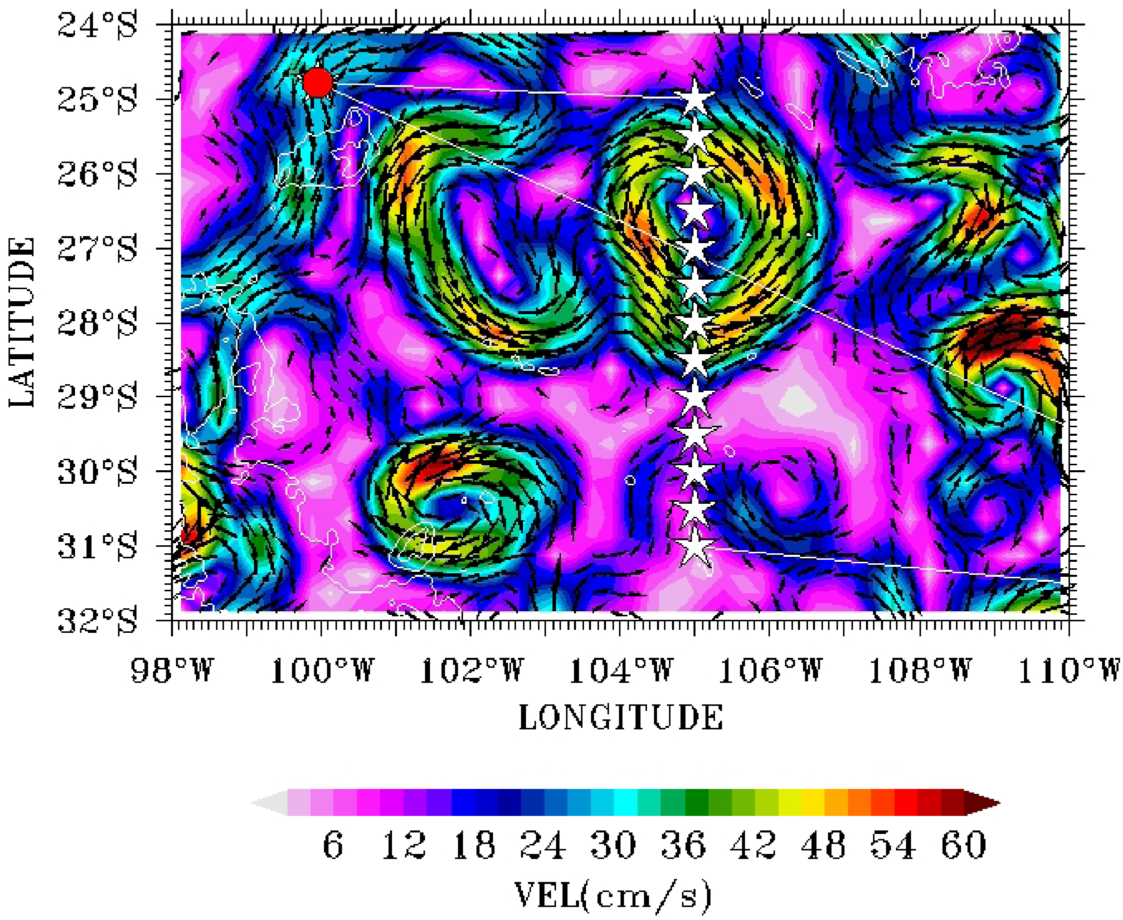


Figure 2: Geostrophic velocity from SSH anomaly on 24/8/2012 added to mean dynamic topoography (Vianna et al. 2007). Shading is speed (cm/s), vectors indicate direction when speed >10cm/s. Also shown are positions for the RAMA 25S mooring (red dot) and CTD stations (white stars). Figure by Viviane Menezes.

Our in situ observations of the flow field include shipboard ADCP (SADCP), lowered ADCP at each station, and 20 surface drifters deployed in pairs along the line. The currents observed from SADCP along 105°E are shown in Fig. 3. The eddy can be seen in the zonal component of velocity (top panel) as westward flow near 26°S and eastward flow near 27°S, both extending to at least 600m depth. The strong southward flow (bottom panel) near 27.5°S is also associated with the eddy. South of 28°S, there are alternating eastward and westward flows in the upper 300m. There is a suggestion of weak westward flow beneath the eastward flow near 31°S.

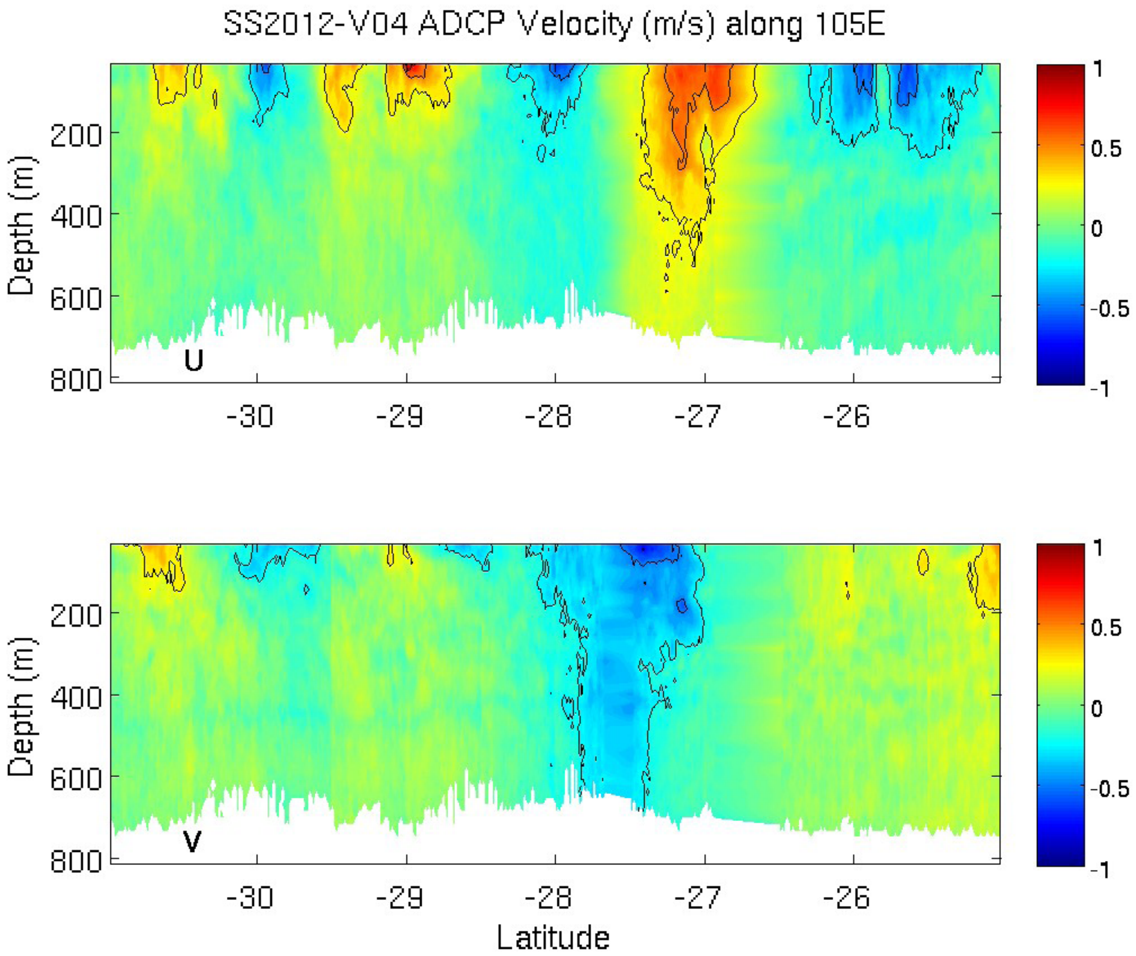


Figure 3: Absolute velocity (m/s) from shipboard ADCP along 105 E. Black contours denote 0.25, 0.5 and 0.75 m/s. Eastward (northward) component is shown in top (bottom) panel.

Our intention was to complete an additional meridional line at 100°E in order to compare the change in structure of the flow field between 100 and 105°E. We also intended to measure the flow field to the sea floor but we only had time to do CTD profiles to 2000 m. Neither of these parts of objective 1 was possible due to engine failure, but may be able to be achieved on the return voyage in 2013.

Degree of success: 40%.

2. Identify the source waters of the westward flow beneath the SICC and broader eastward flow.

Watermass properties of the zonal flows along 105°E will be identified primarily through analysis of temperature, salinity and oxygen profile data from CTD, combined with velocity data from ADCP. Additional information from 4 Iridium Argo profiling floats, equipped with Anderaa optodes, and existing Argo floats will provide broader spatial and temporal context for the shipboard snapshot. The biological and biogeochemical observations along this line were extensive and include full depth fluorometer attached to the CTD, full depth nutrients from bottle samples, chlorophyll a at 8 depths in the upper 200m, and biological sampling and analysis as outlined below under “Additional achievements”.

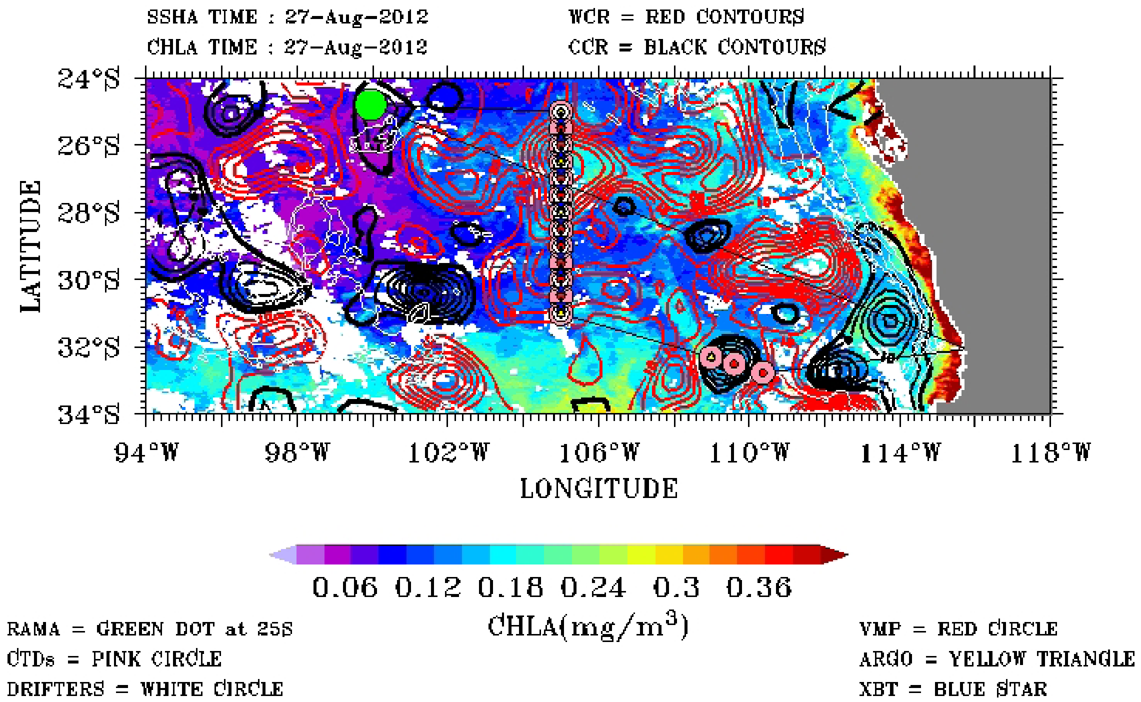


Figure 4: Chlorophyll a (mg/m3) from satellite observations (27/8/2012; colour shading). Contours are sea surface height anomaly on 27/8/2012 added to mean dynamic topography from Vianna et al. 2007 (black for clockwise circulation, red for snti-clockwise). RAMA mooring, shipboard observations and deployment location of drifting systems is as indicated in the legend. Figure by Viviane Menezes.

Figure 4 shows the location of shipboard sampling and deployment of drifting systems that will contribute to watermass identification, overlaid on satellite Chla colour shading, and sea surface height countours.

We anticipate that the 2000 m maximum depth will be sufficient to capture most of the subsurface westward flows, although we will miss the deep and bottom water signatures which would have provided a new estimate of change in the properties of these key watermasses to update the time series from the repeated occupations of the I5 32°S section.

Degree of success: 40%

3. Characterise the 3-dimensional physical and biogeochemical structure of the Leeuwin Current eddies.

The large warm-core eddy at the northern end of the 105°E section was comprehensively sampled both with the station data described at objective 2, and with high-density XBT and underway sampling. Three Iridium Argo profiling floats were deployed at the outer edges and in the centre of the eddy. The central profiling float was equipped with biological sensors (FLBBCD-AP2) and was programmed to profile to 300 m 4 times per day and to 2000 m every 3 days to obtain deep temperature, salinity and dissolved oxygen measurements.

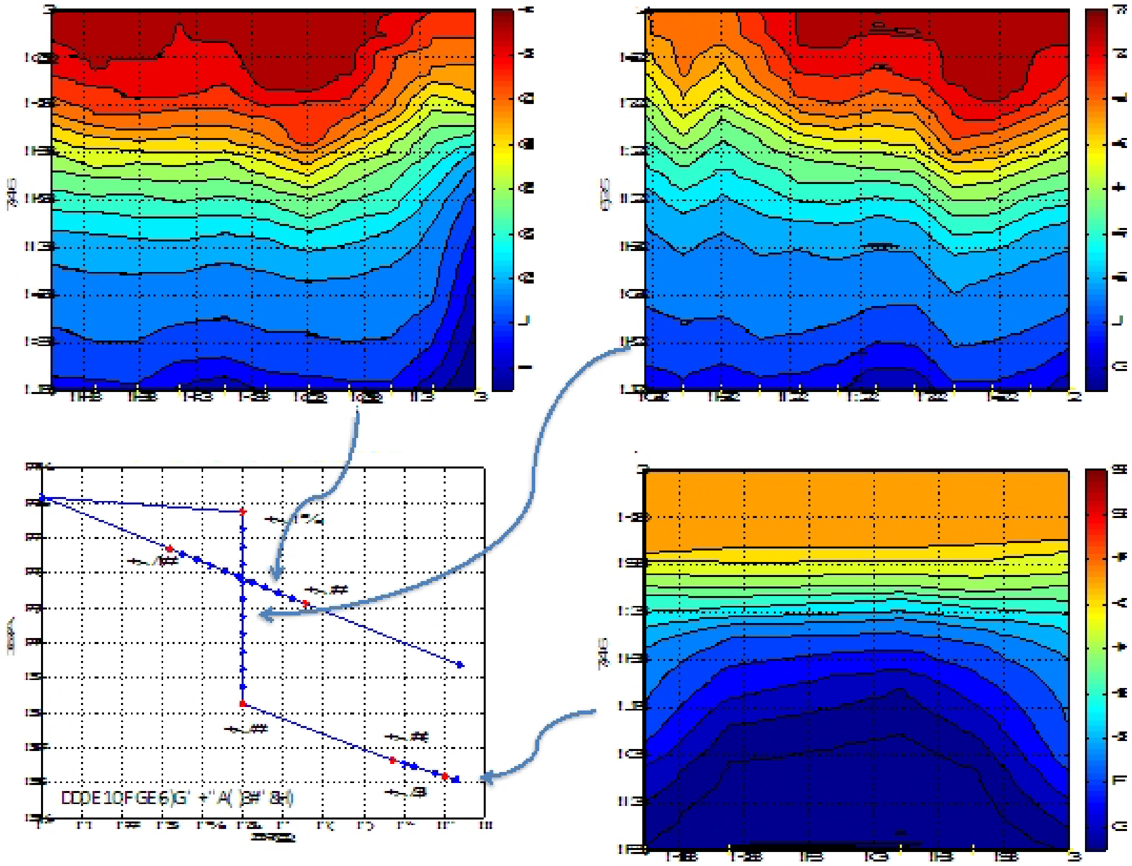


Figure 5 : Temperature sections (°C) from XBT transects across the warm core eddy at the northern end of 105°E (a-east to west, b-north to south), and across a cold core eddy near 109°E (d-west to east). Location of XBTs in each section is shown in panel c.

Figure 5 shows the temperature sections obtained from XBT profiles across the warm core eddy on the westward transit to the mooring (Fig. 5a) and working southward along 105°E (Fig. 5b). The XBTs on the 105°E line were spaced halfway between CTD stations giving 15 nm resolution of the upper ocean temperature structure (CTD data not available at the time of writing).

Following completion of the 105°E line, we identified a cold-core eddy not far off our route to Fremantle. We made 3 CTD/LADCP stations to 2000 m across the eddy at the edges and centre. Samples were taken for chlorophyll a and the full suite of biological analyses. XBTs were dropped at 15 nm spacing between the CTDs (Fig. 5d), and an Iridium Argo float equipped with Aanderaa optode and FLBBCD-AP2 sensor, and programmed for rapid profiling, as described for the warm-core eddy, was deployed at the centre. We attempted a second transect of this eddy, from south to north at roughly 90° to the first transect, but the conditions were too rough and we steamed slowly back to Fremantle.

Note the remarkably uniform temperature structure over the upper 150 m of the cold-core eddy (Fig. 5d) and the strong doming of the subsurface isotherms. A major emphasis of our analysis will be comparing the biophysical structure of the warm- and cold-core eddies.

Degree of success: 85%.

Deep data in the eddies are missing, and we were unable to conduct a complete survey of the cold-core eddy. The XBTs provided by MNF made a significant impact on our ability to map the eddy structures.

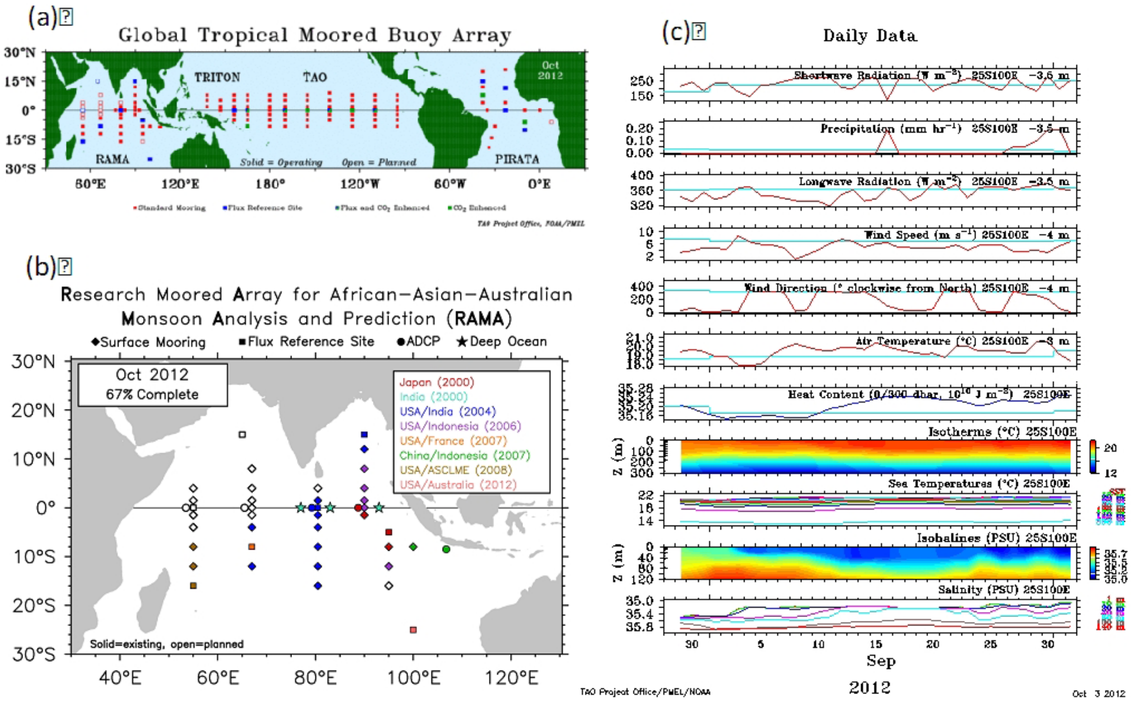


Figure 6: The location of the RAMA 25S mooring in the context of the Global Tropical Moored Buoy Array (a), of which RAMA is the subset for the Indian Ocean (b). Sample daily output from surface and subsurface sensors from deployment to October 3rd 2012 (c).

4. Establish a moored reference station to sample surface atmospheric fluxes and upper-ocean density, velocity and biogeochemistry.

This objective was completed. Australia is now a contributor to the RAMA array, the Indian Ocean component of the Global Tropical Moored Buoy Array. Fig. 6a shows the distribution of moorings in the Indian (RAMA), Pacific (TAO/Triton) and Atlantic (Pirata) oceans. Progress of the RAMA array and contributors (Fig. 6b) and a sample of the daily-averaged data (Fig 6c) are also shown. The full resolution data from the mooring will be recovered in 2013 by RV Southern Surveyor. A replacement mooring will be deployed if we can obtain a commitment to recover the mooring in 2014 (application for time on RV Investigator in 2014/15 has been submitted).

Degree of success: 100%

Additional achievements

1. At the start and end of the voyage, we were able to make underway transects of the Leeuwin Current and Leeuwin Undercurrent. We made 6 transects in zig-zag patterns between Fremantle and the 32S I5 line, collecting shipboard ADCP, thermosalinograph and underway fluorometer. These data will provide a snapshot of the Leeuwin Current system and a ground-truthing of model simulations and climatologies that can then be used to explore interannual and longer variability, and questions about the water pathways that feed these currents.

2. A significant success of the voyage, not foreseen in the voyage plan, was the expansion of the piggy-back project of Eric Raes into a 3-person biological sampling team from Anya Waite's UWA group (Raes, McInnes-Texas A&M, and Olsen). The integration of biological, biogeochemical and physical measurements of the eastward flows and Leeuwin Current eddies will dramatically improve our understanding of the system as a whole.
   The main aim was to test whether nitrogen fixation, carried out by the diazothroph community, is a key driver of planktonic CO_2 absorption in the largely unstudied eastern Indian Ocean. The biochemical N_2 fixation pathway would bypass the N limitation and in fact refuel the oligotrophic surface waters. The occurrence of N_2-fixing microorganisms in low nutrient and stratified oceanic habitats is well documented and increasing knowledge on their phylogenetic diversity, distribution, productivity and size has led to massive increases in the estimates of global N_2 fixation rates.

Samples at each biological N_2-fixation station were taken for:

- Chlorophyll a and Phytoplankton pigment composition analysis
- Phytoplankton identification
- Particulate Organic Carbon and Nitrogen (PON/POC depth profile to 2000m)
- δO18 (depth profile to 2000m)

Our goals were to:

A. **Measure N2-fixation rates in the eastern Indian Ocean and compare these rates with vertical nitrate fluxes from the deep sea** (Raes et al.)

The data forthcoming from this study will represent the first regional estimates of N_2-fixation rates at spatial scales above the mesoscale of the coastline of Western Australia and extending well into the eastern Indian Ocean (to 100 E). The magnitude and impact of N_2 fixation on ocean productivity was estimated using both well-established protocols Montoya (1996) and more recent methods Mohr (2010). Twenty biological fixation stations, including warm and cold core eddies, were sampled at the surface and oxygen minimum feature in the photic zone.

Degree of success: 80%.

N_2 fixation data is yet to be analysed but conservatively we can be confident as we have been using two well-established methodologies. The missing 20% is related to the loss of stations due to engine problems.

Output: The results of this study will be written as a manuscript, with the title "In situ N_2 fixation rates, closing the gap for the Eastern Indian Ocean''. Targeted journals will be Marine Ecology Progress Serries (MEPS) and PLOS one, a peer reviewed open access journal.

B. **Estimate diurnal variability of N_2 fixation** (Olsen et al)

The data forthcoming from this study represent the first diurnal nitrogen fixation rates and estimations for the visited region. Sampling time and incubations were setup to have a detailed resolution of the circadian rhythm of the N2 fixing community. Furthermore, multiple 24 hour experiments were done to accurately determine the dark vs night N_2 fixation rates.

Degree of success: 80%.

Output: The results of this study will be written as a manuscript, with the title "Circadian rhythm of N_2 fixation communities in the Eastern Indian Ocean''. Targeted journals will be Marine Ecology Progress Serries (MEPS) and PLOS one, a peer reviewed open access journal.

C. **Quantify and determine the active C and N fixing communities using fluorescence in situ hybridization** (Mcinnes et al).

This innovative molecular technique allows us to bypass cumbersome incubation techniques. Nif H and Rubsico are in situ targeted with mRNA-fluorescence probes to identify the C and N fixing communities. Special attention was given to the circadian rhythm of the different N_2 fixing communities in cold and warm core eddies. This data set will be compared with the in situ N_2 fixation incubation measurements. Analysis of environmental FISH data has commenced at the Centre for Microscopy, Characterisation and Analysis, Perth, UWA.

Degree of success: 80%.

Output: The results of this study will be written as a manuscript, with the title "Carbon and nitrogen fixation measured via gene expression in the Indian Ocean''. Targeted journals will be the Journal of Microbial Ecology, Marine Ecology Progress Serries (MEPS) and PLOS one, a peer reviewed open access journal.

D. **Identify N_2 fixing phylogenetic groups (Raes and Mcinnes)**

Environmental water samples were taken at multiple depths to determine the community of fixating, nitrifying, ammonifying and denitrifying microorganisms. A microarray (Roh et al., 2010) developed by the group of co-supervisor Peter Thompson (CSIRO Hobart) will be used to determine the presence of the Nif H gene. Abundance will be analysed using quantitative polymerase chain reaction amplification. Yet again, the forthcoming data from this study will be the first of its kind for this region and will improve our understanding of the Eastern Indian Ocean.

Degree of success: 80%.

Output: The results of this study will be written as a manuscript, with the title "A Phylogenetic N budget for the Eastern Indian Ocean''. Targeted journals will be the Journal of Microbial Ecology, Marine Ecology Progress Serries (MEPS).

Overall outcomes and benefits

The gathered information will be valuable to inform marine management on the importance of N fixation for Australia's future climate. This study will be conducted in the Eastern Indian Ocean, a region whose N dynamics are largely unstudied. The data following from this study will therefore contribute as a major piece of new information towards the understanding of the Indian Ocean and close a gap in global N fixation rates.

This study will allow multiple comparisons:

- Old and New isotope tracer techniques (N-fixation measurements)
- molecular methods and isotope tracer techniques (N-fixation and C-fixation measurements)
- latitudinal variation (C and N fixation)

All experiments were conducted and executed according to (Mohr et al., 2010, Dugdale and Goering, 1967, Goering et al., 1966, Montoya et al., 1996) and Protocols for the Joint Global Ocean Flux Study (Knap et al., 1994). Absolute nitrogen uptake rates (ρ in nmol N.L-1.h-1) will be calculated following Dugdale and Goering (1967). F-ratios will be calculated according to Epply and Peterson (1979).

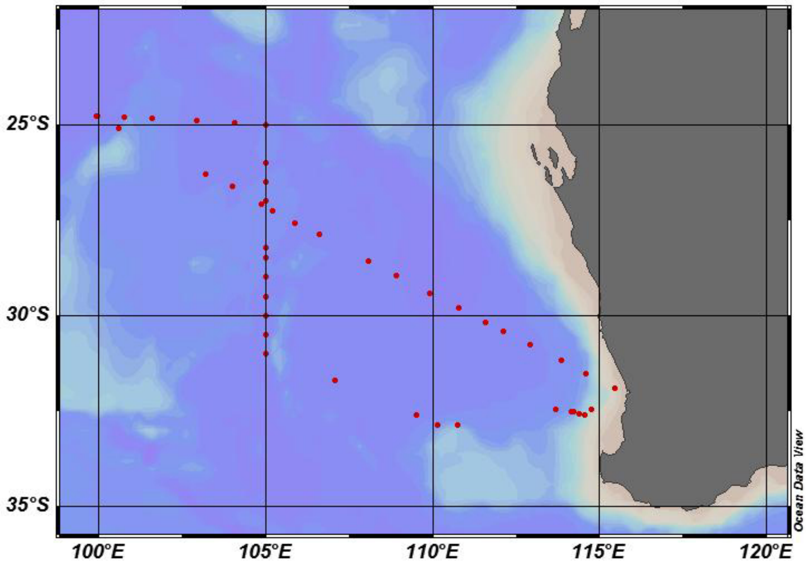


Figure 7: In situ Biological nitrogen fixation stations (red dots) along voyage track.

References

Dugdale, R. & Goering, J. 1967. Uptake of New and Regenerated Forms of Nitrogen in Primary Productivity. *Limnology and Oceanography*, 196-206.

Goering, J. J., Dugdale, R. C. & Menzel, D. W. 1966. Estimates of in Situ Rates of Nitrogen Uptake by Trichodesmium Sp. In the Tropical Atlantic Ocean. *Limnology and Oceanography*, 614-620.

Knap, A., Michaels, A., Close, A., Ducklow, H. & Dickson, A. 1994. Protocols for the Joint Global Ocean Flux Study (Jgofs) Core Measurements, Jgofs, Reprint of the Ioc Manuals and Guides No. 29. UNESCO, 19, 1.

Mohr, W., Großkopf, T., Wallace, D. W. R. & LaRoche, J. 2010. Methodological Underestimation of Oceanic Nitrogen Fixation Rates. Plos One, 5, e12583.

Montoya, J. P., Voss, M., Kahler, P. & Capone, D. G. 1996. A Simple, High-Precision, High-Sensitivity Tracer Assay for N (Inf2) Fixation. *Applied and environmental microbiology*, 62, 986-993.

Ridgway, K. R. and J.R. Dunn (2010). Using satellite altimetry to correct mean temperature and salinity fields derived from Argo floats in the ocean regions around Australia. Deep-Sea Research I, 57, 1137-1151, doi:10.1016/j.dsr.2010.05.010.

Vianna, M. L., V. V. Menezes, and D. P. Chambers (2007), A high resolution satellite-only GRACE-based mean dynamic topography of the South Atlantic Ocean, Geophys. Res. Lett., 34, L24604, doi:10.1029/ 2007GL031912.

Voyage Narrative

August 10, 2012

(NB: Perth local time is used in the narrative)

Participants were met at 15:00 on 10th August at Victoria Quay, Gate D by Lisa Woodward (MNF Operations Officer) and escorted to the ship. Loading and tying down of gear continued through the afternoon and evening.

The next morning we continued readying for the voyage while we waited for the Pilot. Our 10am booking was repeatedly moved, due to our low pecking order relative to the massive container and cargo vessels that filled the port. We finally cast off at 14:00 on Saturday the 11th August.

The media release for our voyage generated some interest. We were contacted on our departure day by ABC radio Hobart. However, the interview didn't proceed because the Tasmanian Forest Agreement release took the limelight.

After rounding the northern end of Rottnest Island we headed south to our CTD test station in 1365m of water at 32.22S, 114.85E, at the head of the Perth Canyon. We were shown the operation of the CTD control software, deployment/recovery method, and water sampling techniques for salinity, oxygen and nutrients. The biology group (Strutton, Raes, McInnes and Olsen) looked after the samples they needed and didn't require any help from the CTD watch.

We continued south and back inshore to the top of the shelf in 50m water at the start of the I5 line. The shipboard ADCP was running continuously from Fremantle (and the entire voyage) so we obtained 2 cross-shelf diagonal transects of the Leeuwin and Leeuwin Undercurrent between the shelf and 1365m depth, and a third along the I5 line. The data collection began in earnest at the first I5 station in 152m depth at 32.68S, 114.91E. We did not begin work with the VMP at this point because the CTD operations and sampling were still unfamiliar to most of the party, the sea state was rough and we felt it prudent to keep the vulnerable VMP in its box until we could give it a better chance of surviving a deployment.

For the shallow shelf and slope stations we were able to share the 18 10-litre bottle samples (19 once the ISUS nitrate sensor was removed at the 1000m depth contour, after CTD #6) between the salinity, oxygen, nutrient and biology samples. With the hydrochemistry team, we settled on a bottle sample analysis plan of up to 12 salinity and oxygen samples at each station, and nutrients from all bottles. Samples for chlorophyll were taken at 6-8 depths between the surface and 200m and were analysed by Strutton. The biology sampling required 30-litres at the sea surface and at the oxygen minimum layer, shared amongst Raes, McInnes and Olsen. Once the water depth exceeded 2000m and there weren't enough bottle samples for everyone, we began to do a shallow cast to 200m for biology only, prior to a full depth CTD for physics. This was only required twice per day, at an early morning and evening station.

August 12, 2012

At CTD #7 at 21:40 12th August the conditions became too rough for CTD work. Winds were up to 40 knots and the swell was large so we hove-to on station until conditions improved. The biologists trialled bucket sampling to continue their 24-hour experiments but even this proved difficult in the conditions. Winds remained strong for most of the night and we were unable to resume CTD work until 08:00 (Perth) on Monday 13th August.

August 13, 2012

At 20:36 13th August, when CTD #12 was at 2600 dbar going down, the Captain ordered the CTD back on deck because of a problem in the engine room. Cylinder 1 was found to have a serious problem. The engine was shut down completely and we relied on thruster power (moving astern at 1.5 knots but comfortable) until the engineers were able to isolate cylinder 1 and bring the rest of the engine back on line. A blackout occurred during this time, which was extremely eerie but not hazardous because the conditions were calm again. We then began our journey back to Fremantle, 80 nm away, making around 5 knots on half power. We arrived in Fremantle at approximately 20:00 (Perth) on Tuesday 14th August (3 days after we departed).

There were problems with CTD sensors at most of the stations. In particular there was a large temperature offset between the primary and secondary sensors. It took many casts to isolate and resolve the problem by swapping sensors and cables. The first cast with 2 good temperature sensors was not until we set out again after the engine problem.

With science on hold and frenetic activity in the engine room, the science party caught up on work from home, met deadlines that would have been missed, made contact with colleagues at UWA and Murdoch (esp. Anya Waite and Lynnath Beckley), and spent time ashore exploring Fremantle and surrounds. A highlight was the introduction of Aussie Rules to 2 Americans and one ambivalent Australian at a Fremantle/Richmond match at Subiaco. We were able to stay aboard the ship and continued to enjoy the meals prepared by the catering team. Forays in search of fast internet access were a common pastime.

The engine troubles and solutions will have been described reliably elsewhere. Suffice to say, the engineers and contractors did an awful lot of work, spare parts were flown in from the other side of the world, and the engine had a major re-build. The Chief Engineer was satisfied with the final result and we set to sea again.

August 24, 2012

We departed Fremantle, again, at approx. 07:00 on Friday 24th August after 10 days in port. We revised our science objectives to produce a plan that could be achieved in the remaining 12 days. The MNF management were extremely helpful and flexible in the return date and port, offering us more time at sea from the planned port period in Darwin. Many of the science party had commitments to return to close to the end of the voyage and we decided to be back in port early on the 6th September at the latest, returning to Fremantle instead of Broome. The time saved in returning to Fremantle instead of Broome from the southern end of the 105E line was 66 hours, equivalent to doing 14 CTDs to 2000m at 30 nm spacing (i.e. the entire 105E line in the revised voyage plan).

From Fremantle we headed straight for the RAMA mooring site at 25S, 105E. The transit took just under 4 days. On the way, samples of surface water for biology were taken regularly through the flow-through hose in the wet lab. We crossed a cold-core eddy at the beginning of the transect with underway systems, and the large warm-core (stationary) eddy at the northern end of the 105E line with underway and XBTs (11 XBTs at 20nm spacing).

August 28, 2012

We arrived at the nominal mooring site, a flat-bottom area (according to Smith and Sandwell bathymetry) near 25S, 100E, at 04:00 on 28th August. We conducted a bathymetry survey around the nominal site with an XBT profile and a historical CTD profile (DOTSS 2000) to correct the sounder depths for sound velocity. The bathymetry was found to be suitable for the deployment.

At the mooring site we did a full depth CTD (#15), which was back on deck at noon 28th August. The mooring deployment followed. It went very smoothly and the anchor was released at 17:15. We steamed slowly to within a mile of the mooring to check the data transmission during the 12-hour rapid transmission window following deployment. The celebratory mood was dispelled by the news that the subsurface instruments were not reporting. All had been working fine on deck. Patrick outlined the options for identifying and correcting the problem to the management team. These included a small boat visit to the mooring so Patrick could plug his computer into the comms cable to check for data and then reset the system, and if this failed, either a partial recovery of the surface buoy under tension, or a full recovery and redeployment. Both recovery options would have to be delayed until the following morning. The most likely problem was a short in the connection of the conducting cable to the surface buoy.

We had a toolbox meeting in preparation for the small boat operation in the remaining hour of daylight. However, following this the Captain decided that conditions were too rough and we would wait until morning.

We began VMP operations at the mooring site, lowering the VMP by hand through a block on the CTD A-frame, and hauling it back by running the rope from the block back to the pot hauler on the starboard aft deck. We did 3 dips of the VMP to the maximum depth possible with the 400m rope, drifting a little away from the mooring site to keep the rope out from beneath the ship. After the VMP, we returned to a position as close as possible to the mooring to re-check transmissions. Patrick received intermittent signals from each of the subsurface sensors except the deepest, only one or two reporting in each transmission. Colleagues in Seattle were receiving the same transmissions via satellite. We decided that since all of the surface sensors were working and transmitting, and the subsurface sensors were clearly working, recording data, and occasionally transmitting, this was a satisfactory deployment result. Devoting a full day or more to recovery and redeployment would have severely compromised the achievement of our reduced objectives and we decided to move on after completing a 2000m CTD (#16) for biology and physical samples, and deploying Argo 5486. We departed the mooring site at 02:27 on 29th August and steamed toward the top of the 105E line at 25S (a 27 hour transit).

August 30, 2012

We arrived at the northern end of the 105E line at 05:00 on 30th August, and worked down the line over a period of 3 days. At each station, 30nm apart, we did 3 dips of the VMP, followed by a CTD/LADCP cast to 2000m. Water samples from each cast were shared between physics and biology requirements. Surface samples for biology were taken from the flow-through hose. Across the warm-core eddy still centred on the northern part of the 105E line, we did an XBT cast between each CTD (12 XBTs 30nm apart, giving temperature profiles every 15nm when combined with CTD). Four Argo floats with Iridium communications and oxygen sensors, including one with FLBBCD-AP2 biology sensors, were deployed at CTD stations along 105E (Hull #s 4926, 6296-FLBB, 4927 and 4928).

The FLBB float was deployed close to the centre of the warm-core eddy at CTD#21. Twenty surface drifters from the NOAA Global Surface Drifter Program were deployed in pairs along 105E. The deployment method of the VMP had to be modified after the first VMP on the line was aborted due to the line drifting under the ship (both while holding station and while allowing the ship to drift downwind of the line). We moved the operation to the aft deck, running the rope through a small block suspended from the aft A-frame. The process became much simpler and safer than working from the CTD A-frame. The VMP was allowed to free-fall on deployment with minimal friction on the rope. Recovery was with the pot hauler, as before. Depending on the current and wind, it was sometimes necessary for the ship to move slowly ahead to keep the line astern of the ship. This reduced the depth reached by the VMP since some of the line was taken up by the horizontal distance between the ship and the VMP.

September 2, 2012

At 05:00 on 2nd September we completed the 105E line and steamed to the edge of a cold-core eddy centred near 109.5E, 32.6S. We did 3 CTDs across the eddy (CTD #31-33), at the edges where the satellite sea surface height anomaly was close to zero, and at the centre. No VMP profiles were made at these stations because the weather had deteriorated, winds were at 30 knots most of the time and the swell was increasing. The conditions were approaching the limit at which we could safely do CTD stations. The second Argo float with FLBBCD-AP2 and oxygen sensors (hull # 6215) was deployed at the centre of the eddy at CTD #32. We spaced 8 XBTs at 15nm across the eddy between the CTD stations. XBTs were deployed through the hatch in the fish-sorting lab because of the strong winds and waves breaking on deck. The final XBT cast at the eastern edge of the cold-core eddy was aborted because 3 tries could not get a profile deeper than 300m. Presumably the wire was being blown against the hull of the ship. We reached the eastern edge of the eddy at 17:00 on 3rd September.

We planned to make a second transect of this eddy with underway instruments (and additional CTDs if conditions permitted) by steaming to the southern edge of the eddy and making a transect from south to north perpendicular to the first transect. This course was into 40 the knot winds with stronger gusts, a heavy swell and rough seas. We persisted on this course to the southwest, making only 5 knots. Through the night it became clear that we wouldn't have time to make a full transect of the eddy, the weather was not abating, and no CTDs would be possible. On discussion with the Captain at 02:30 on 3rd September, when we also learnt the ship was taking on water through vents to the Green Room and the escape hatch at the forward end of the corridor outside the mess, we decided to abandon this 2nd transect of the eddy and head to Fremantle. Any remaining voyage time would be used making underway transects across the Leeuwin Current. The ride was much more comfortable once we put wind and swell behind us.

September 5, 2012

From 01:30 on 5th September to approx. 22:00 5th September, we made 3 ADCP transects between 3500m depth to the top of the slope near 100m depth. We worked from south to north from the latitude of the I5 section to north of Rottnest Island. We were not able to exactly repeat the I5 transect made at the beginning of the voyage because that would have put us beam on to the still large swell.

The pilot came on board at approx. 18:20 on 5th September and we docked at Victoria Quay around 07:00.

Summary

The collection of data that we have obtained is extensive and diverse. There are new and significant results to be obtained from each of the disciplines represented in the data (physical, chemical and biological oceanography, and meteorology). The greatest achievements are likely to come from a synthesis of all of these results into a wholistic assessment of the processes at work in the southeast Indian Ocean. There are key elements of the system that we were not able to sample due to the breakdown (the circulation and watermass structure below 2000m, the zonal change in circulation and properties between 100 and 105E). It would be terrific to be able to recover these components of the study when we return to the mooring in 2013.

Principal Investigators

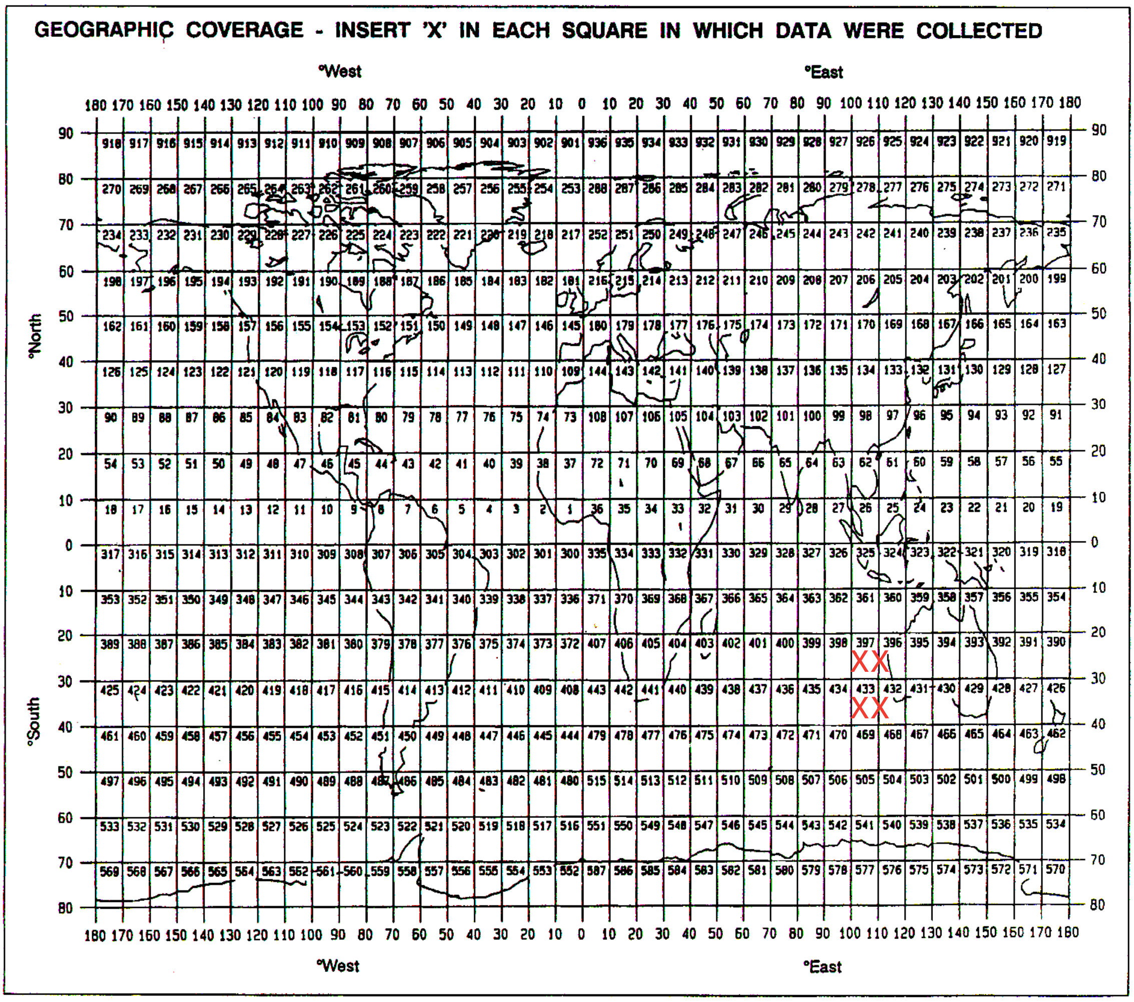
A. Dr Helen Phillips, IMAS, University of Tasmania, Churchill Avenue, Sandy Bay 7005, Australia

B. A/Prof Pete Strutton, IMAS, University of Tasmania, Churchill Avenue, Sandy Bay 7005, Australia

C. Mr Eric Raes, Oceans Institute, University of Western Australia

Marsden Squares

A red "x" indicates where data was collected.



MOORINGS, BOTTOM MOUNTED GEAR AND DRIFTING SYSTEMS

ITEM NO	PI	APPROXIMATE POSITION						DATA TYPE	
		LATITUDE			LONGITUDE				
	SEE PAGE ABOVE	DEG	MIN	N/S	DEG	MIN	E/W	ENTER CODES FROM LIST ON LAST PAGE	DESCRIPTION
1	A	24	48.0	S	99	57.3	E	M06, H72,H17,D90	ATLAS flux reference station mooring. See http://www.pmel.noaa.gov/tao/proj_over/mooring.shtml for detailed information
2	A	24	46.8		99	56.4		H11,D5	Argo 5486 (Argos comms)
3	A	25	0.6		105	0.0		H11,D5,H21	Argo 4926 (Iridium comms, Anderaa optode)
4	A	25	0.6		105	0.0		D5	Surface Drifter 109270
5	A	25	0.6		105	0.0		D5	Surface Drifter 109331
6	A	26	0.0		105	0.0		D5	Surface Drifter 109561
7	A	26	0.0		105	0.0		D5	Surface Drifter 109563
8	A	26	30.6		105	1.2		D5	Surface Drifter 109251
9	A	26	30.6		105	1.2		D5	Surface Drifter 109543
10	A	27	1.2		105	0.0		H11,D5,H21,H17,B6	Argo 6296 (Iridium, Anderaa, FLBBCD-AP2)
11	A	27	1.2		105	0.0		D5	Surface Drifter 109245
12	A	27	1.2		105	0.0		D5	Surface Drifter 109412
13	A	27	31.2		105	1.8		D5	Surface Drifter 109255
14	A	27	31.2		105	1.8		D5	Surface Drifter 109423
15	A	28	0.6		105	0.0		D5	Surface Drifter 109256
16	A	28	0.6		105	0.0		D5	Surface Drifter 109414
17	A	28	0.0		105	0.0		H11,D5,H21	Argo 4928 (Iridium, Anderaa optode)
18	A	28	30.0		105	0.0		D5	Surface Drifter 109425
19	A	28	30.0		105	0.0		D5	Surface Drifter 109636
20	A	29	0.6		105	0.0		D5	Surface Drifter 109253
21	A	29	0.6		105	0.0		D5	Surface Drifter 109567
22	A	30	0.6		105	0.0		D5	Surface Drifter 109252
23	A	30	0.6		105	0.0		D5	Surface Drifter 109569
24	A	31	0.6		105	0.6		H11,D5,H21	Argo 4927 (Iridium, Anderaa optode)
25	A	31	0.6		105	0.6		D5	Surface Drifter 109545
26	A	31	0.6		105	0.6		D5	Surface Drifter 109568
27	A	32	37.8		109	30.0		H11,D5,H21,H17,B6	Argo 6215 (Iridium, Anderaa, FLBBCD-AP2)

SUMMARY OF MEASUREMENTS AND SAMPLES TAKEN

ITEM NO.	PI	NO	UNITS	DATA TYPE	DESCRIPTION
1	A,B	33	Stations	H10,H17,H21,	CTD casts – salinity, temperature, pressure, dissolved oxygen, fluorescence
2	A,B	7	Stations	H24	Nitrate profiles from ISUS sensor on shelf/ slope CTD stations (max depth 1000m)
3	A	33	Stations	D71	Lowered ADCP – velocity profiles
4	A,B	33	Stations	H9,H21,H22,H24, H25,H26	Bottle samples – salinity, temperature, dissolved oxygen, nutrients (nitrate, nitrite, silicate, phosphate)
5	B	33	Stations	B2	Bottle samples – chlorophyll a, 6-8 samples over the upper 200m
6	C	33	Stations	B71,B90	Bottle samples – biology at the sea surface and in the oxygen minimum layer above 200m, samples analysed for N uptake, N fixation (2 methods), N uptake through 24 hour incubation, POC, PON, delO18, taxonomy, microarray and HPLC.
7	A	14	Stations	D90	VMP200 casts – vertical microstructure profiles (set of 3 casts to the maximum depth possible with a 400m line, usually approx.. 300m)
8	A	34	Casts	H11	XBTs (deep blue) – temperature to approx. 900m, 4 casts had bad data
9	C	35	Stations	B2,B71,B90	Surface water intake measurements (denoted FT in event log, Appendix 2) – biological analyses as for CTD bottle data, item 6
10	C	4	Stations	B2,B71,B90	Bucket samples of surface water - biological analyses as for CTD bottle data, item 6
11	A		Nautical miles	H71	Thermosalinograph – surface salinity and temperature
12	B		Nautical miles	H17	Underway fluorometer
13	A		Nautical miles	M6	Standard meteorological measurements
14	A		Nautical miles	D71	Shipboard ADCP (75 kHz)

CURATION REPORT

ITEM NO.	DESCRIPTION
1	CTD profiles
2	ISUS nitrate profiles
3	LADCP profiles
4	Bottle data – T, S, O2
5	Bottle data – chlorophyl a
6	Bottle data – biology
7	VMP profiles
8	XBT profiles
9	Surface intake – biology
10	Bucket samples – biology
11	Thermosalinograph
12	Underway fluorometer
13	Standard meteorology
14	Shipboard ADCP
15	Argo float data – automatically sent to the Global Argo Data Repository (http://www.nodc.noaa.gov/argo) in near-real time, where it is publically available
16	Surface drifter data – data is publicly available from the Global Drifter Program (http://www.aoml.noaa.gov/phod/dac/index.php)
17	RAMA mooring data – data is publicly available from the NOAA web site http://www.pmel.noaa.gov/tao/disdel/disdel-rama.html

Voyage Track

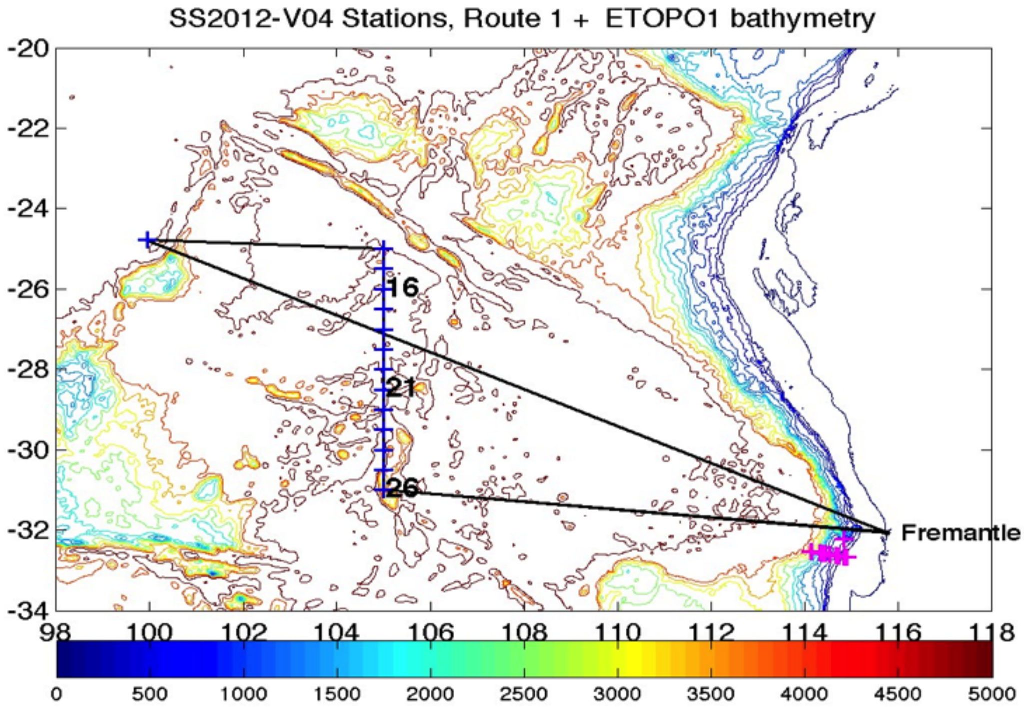


Figure 8: The first part of the voyage, prior to engine failure, consisted of departure from Fremantle, CTD stations denoted by the pink plus signs (working southward and westward), and return to Fremantle. The track for this part of the voyage is not drawn in. For the second part of the voyage, we departed Fremantle, followed the diagonal line to the farthest point (25S, 100E) where the mooring was deployed. We then worked eastward to 100E, southward to 31S, southeastward to transect a cold-core eddy, and finally eastward back to Fremantle via a zig-zag up the coast making underway observations of the Leeuwin Current system.

General Ocean Area(s)

Southeast Indian Ocean

Specific Area

25S-32S, 100E-Australia

Personnel list

Scientific Participants

Helen Phillips	IMAS, UTas	Chief Scientist & CTD/VMP/Floats
Peter Strutto	IMAS, UTas	Alternative Chief Scientist + CTD/Biogeochemistry
Jessica Benthuysen	CMAR	CTD Watch/VMP
Mark Rosenberg		CTD Watch + Moorings
Christopher Roach (PhD student)	IMAS, UTas	CTD Watch/VMP
Viviane Vasconcellos de Menezes (PhD student)	IMAS, UTas	CTD Watch/VMP
Eric Raes	UWA	Biology
Allison McInnes (PhD student)	Texas A&M Uni	Biology
Hanni Olsen (MSc student)	UWA	Biology
Patrick Berk	PMEL, NOAA	Moorings Technician
Dave Terhel	CMAR	MNF Voyage Manager
Rod Palmer	CMAR	MNF Electronics Support
Hugh Barker	CMAR	MNF Computing Support
Peter Hughes	CMAR	MNF Hydrochemistry support
Sue Reynolds	CMAR	MNF Hydrochemistry support

Marine Crew

Name	Role
John Barr	Master
Mick Tuck	Chief Mate
Paul Iddon	Secondmate
Nick Fleming	Chief Engineer
Paul Buffett	First Engineer
William Hollingworth	Second Engineer (11-23/8)
Mike Sinclair	Second Engineer (24/8-6/9)
Charmaine Aylett	Chief Stewar
Aaron Buckleton	Chief Cook
Leon Evans	Second Cook
Tony Hearne	Boatswain
John Allwood	Integrated Rating
John Baker	Integrated Rating
Reuben Ifill	Integrated Rating
Peter Taylor	Integrated Rating

Acknowledgements

Prof Nathan Bindoff led this project but was unable to participate in the voyage. He provided invaluable guidance and financial support for the voyage.

Dr Eric Schulz has made a substantial contribution to the development of proposals to MNF in support of this and future voyages to 25S, 100E.

Dr Mike McPhaden, PMEL/NOAA, USA provided the mooring instrumentation and the technician to deploy the mooring. He has also committed support for recovery and redeployment of the mooring in 2013, with the goal of maintaining this mooring as a long-term monitoring station in the RAMA array.

Dr Ming Feng loaned us the VMP200, enabling the microstructure measurements to be made. He will collaborate with us on the analysis of these data.

Nick Mortimer and colleagues at CSIRO, Floreat found us space to store spare mooring equipment until the 2013 recovery and redeployment.

MNF responded to the interruption of the voyage with generosity and good humour. They offered us considerable flexibility in redesigning our science plan to make the most of the time remaining to achieve as many of our objectives as possible.

Last but not least, the Captain and crew of RV Southern Surveyor were extremely helpful and worked hard to resolve any technical problems with the deployment of instruments. Their competence and good humour was very reassuring when the weather became challenging. We are particularly grateful for the effort and expertise of the engineering team in getting the ship back to sea as quickly as possible.

Helen Phillips
Chief Scientist

Appendices

Appendix 1 – Table of all observations collected

Appendix 2 – Mooring deployment report

Appendix 3 – Mooring design details

Appendix 1 - Table of all observations collected

Event	Station ID	Date (UTC)	Time (UTC)	Longitude	Latitude	Water depth	LADCP	Salts-O_2-Nutrients	Biology	Comments
1	CTD01	11-Aug-2012	13:44	114.85	-32.22	1365	y	y	y	test CTD cast
2	CTD02	11-Aug-2012	18:35	114.91	-32.68	152	y	y	y	
3	CTD03	11-Aug-2012	20:24	114.84	-32.66	230	y	y	y	
4	CTD04	11-Aug-2012	21:54	114.75	-32.65	483	y	y	y	
5	CTD05	11-Aug-2012	23:21	114.69	-32.63	611	y	y	y	
6	CTD06	12-Aug-2012	01:40	114.54	-32.60	822	y	y	y	
7	CTD07	12-Aug-2012	04:18	114.47	-32.59	969	y	y	y	
8	Bucket 7a	12-Aug-2012	10:53	114.40	-32.58	x	n	n	n	
9	Bucket 7b	12-Aug-2012	16:00	114.40	-32.57	x	n	n	n	
10	Bucket	12-Aug-2012	17:00	114.40	-32.57	x	n	n	n	
11	CTD08	13-Aug-2012	01:26	114.39	-32.57	1531	y	y	y	
12	CTD09	13-Aug-2012	04:39	114.34	-32.57	2171	y	y	y	
13	CTD10	13-Aug-2012	07:38	114.16	-32.53	2874	y	n	n	bio only CTD, match with CTD 11 for nuts
14	CTD11	13-Aug-2012	10:35	114.16	-32.54	2961	y	y	y	physics/nuts CTD
15	CTD12	13-Aug-2012	13:24	114.07	-32.51	3618	y	n	n	aborted - engine trouble
16	Bucket	13-Aug-2012	18:23	114.23	-32.51	x	n	n	n	
17	CTD13	14-Aug-2012	09:45	115.64	-31.97	x	n	n	n	TSG cal
18	FT1	24-Aug-2012	01:22	115.45	-31.91	x	n	n	n	
19	FT2	24-Aug-2012	06:24	114.58	-31.52	x	n	n	n	
20	FT3	24-Aug-2012	10:42	113.85	-31.19	x	n	n	n	
21	FT4	24-Aug-2012	15:59	112.93	-30.78	x	n	n	n	
22	FT5	24-Aug-2012	20:48	112.10	-30.41	x	n	n	n	
23	CTD14	24-Aug-2012	22:58	111.75	-30.25	x	n	n	n	TSG cal
24	FT6	25-Aug-2012	00:00	111.59	-30.18	x	n	n	n	
25	FT7	25-Aug-2012	05:18	110.78	-29.81	x	n	n	n	
26	XBT01	25-Aug-2012	07:37	110.41	-29.64	x	n	n	n	
27	FT8	25-Aug-2012	11:00	109.92	-29.42	x	n	n	n	
28	FT9	25-Aug-2012	16:09	108.90	-28.95	x	n	n	n	
29	FT10	25-Aug-2012	20:44	108.08	-28.58	x	n	n	n	
30	FT11	25-Aug-2012	21:24	107.96	-28.52	x	n	n	n	
31	FT12	26-Aug-2012	01:20	107.28	-28.21	x	n	n	n	

Event	Station ID	Date (UTC)	Time (UTC)	Longitude	Latitude	Water depth	LADCP	Salts-O_2-Nutrients	Biology	Comments
32	FT13	26-Aug-2012	05:15	106.59	-27.89	x	n	n	n	eddy XBT 1
33	XBT02	26-Aug-2012	05:19	106.57	-27.88	x	n	n	n	
34	FT14	26-Aug-2012	07:14	106.24	-27.73	x	n	n	n	eddy XBT 2
35	XBT03	26-Aug-2012	07:19	106.22	-27.72	x	n	n	n	
36	XBT04	26-Aug-2012	09:17	105.88	-27.57	x	n	n	n	
37	FT15	26-Aug-2012	09:20	105.88	-27.57	x	n	n	n	eddy XBT 3
38	XBT05	26-Aug-2012	11:16	105.55	-27.41	x	n	n	n	
39	FT16	26-Aug-2012	11:30	105.56	-27.41	x	n	n	n	eddy XBT 4
40	XBT06	26-Aug-2012	13:10	105.22	-27.26	x	n	n	n	
41	FT17	26-Aug-2012	13:11	105.22	-27.26	x	n	n	n	eddy XBT 5
42	XBT07	26-Aug-2012	15:14	104.88	-27.10	x	n	n	n	
43	FT18	26-Aug-2012	15:15	104.88	-27.10	x	n	n	n	eddy XBT 6
44	XBT08	26-Aug-2012	17:19	104.56	-26.95	x	n	n	n	
45	FT19	26-Aug-2012	17:20	104.62	-26.95	x	n	n	n	eddy XBT 7
46	FT20	26-Aug-2012	19:38	104.20	-26.78	x	n	n	n	eddy XBT 8
47	XBT09	26-Aug-2012	19:40	104.19	-26.78	x	n	n	n	
48	FT21	26-Aug-2012	21:42	103.99	-26.96	x	n	n	n	eddy XBT 9
49	XBT10	26-Aug-2012	21:49	103.85	-26.62	x	n	n	n	
50	FT22	26-Aug-2012	23:46	103.53	-26.47	x	n	n	n	eddy XBT 10
51	XBT11	26-Aug-2012	23:49	103.52	-26.46	x	n	n	n	
52	FT23	27-Aug-2012	01:44	103.19	-26.31	x	n	n	n	eddy XBT 11
53	XBT12	27-Aug-2012	01:46	103.18	-26.30	x	n	n	n	
54	FT24	27-Aug-2012	16:40	100.61	-25.09	x	n	n	n	
55	XBT13	27-Aug-2012	19:58	100.02	-24.82	x	n	n	n	
56	FT25	27-Aug-2012	22:15	99.96	-24.78	x	n	n	n	
57	CTD15	28-Aug-2012	04:16	99.96	-24.78	x	y	y	y	
58	VMP	28-Aug-2012	13:15	99.99	-24.78	5452	n	n	n	
59	CTD16	28-Aug-2012	17:40	99.94	-24.78	5455	y	y	y	
60	Argo-5486	28-Aug-2012	18:09	99.94	-24.78	5454	n	n	n	
61	FT26	28-Aug-2012	22:47	100.78	-24.82	x	n	n	n	
62	FT27	29-Aug-2012	03:07	101.60	-24.85	x	n	n	n	

Event	Station ID	Date (UTC)	Time (UTC)	Longitude	Latitude	Water depth	LADCP	Salts-O_2-Nutrients	Biology	Comments
63	FT28	29-Aug-2012	10:16	102.92	-24.91	x	n	n	n	
64	FT29	29-Aug-2012	16:10	104.06	-24.96	x	n	n	n	
65	VMP	29-Aug-2012	22:15	105.00	-25.00	4937	n	n	n	
66	CTD17	30-Aug-2012	00:04	105.00	-25.00	4947	y	y	y	
67	Argo-4926	30-Aug-2012	00:13	105.00	-25.01	4989	n	n	n	
68	DRIFT-109270	30-Aug-2012	00:13	105.00	-25.01	x	n	n	n	
69	DRIFT-109331	30-Aug-2012	00:13	105.00	-25.01	x	n	n	n	
70	XBT14	30-Aug-2012	01:44	105.00	-25.25	x	n	n	n	
71	VMP	30-Aug-2012	04:18	104.99	-25.50	4842	n	n	n	
72	CTD18	30-Aug-2012	06:11	105.00	-25.50	4842	y	y	y	
73	XBT15	30-Aug-2012	07:56	105.00	-25.75	x	n	n	n	
74	VMP	30-Aug-2012	10:36	105.00	-26.00	5021	n	n	n	
75	CTD19	30-Aug-2012	12:26	105.00	-26.00	5016	y	y	y	
76	DRIFT-109561	30-Aug-2012	12:33	105.00	-26.00	x	n	n	n	
77	DRIFT-109563	30-Aug-2012	12:33	105.00	-26.00	x	n	n	n	
78	XBT16	30-Aug-2012	14:08	105.00	-26.25	x	n	n	n	
79	FT30	30-Aug-2012	16:04	105.00	-26.50	x	n	n	n	
80	VMP	30-Aug-2012	16:44	105.00	-26.51	4910	n	n	n	
81	CTD20	30-Aug-2012	18:55	105.02	-26.51	4924	y	y	y	
82	DRIFT-109251	30-Aug-2012	19:04	105.02	-26.51	x	n	n	n	
83	DRIFT-109543	30-Aug-2012	19:04	105.02	-26.51	x	n	n	n	
84	XBT17	30-Aug-2012	20:32	105.00	-26.75	x	n	n	n	
85	FT31	30-Aug-2012	22:49	105.00	-27.00	x	n	n	n	
86	VMP	30-Aug-2012	23:10	105.02	-27.00	4965	n	n	n	
87	CTD21	31-Aug-2012	00:53	105.00	-27.00	4975	y	y	y	
88	Argo-6296	31-Aug-2012	01:04	105.00	-27.02	4994	n	n	n	
89	DRIFT-109245	31-Aug-2012	01:04	105.00	-27.02	x	n	n	n	
90	DRIFT-109412	31-Aug-2012	01:04	105.00	-27.02	x	n	n	n	
91	XBT18	31-Aug-2012	02:27	105.00	-27.26	x	n	n	n	
92	VMP	31-Aug-2012	04:57	105.00	-27.51	4915	n	n	n	
93	CTD22	31-Aug-2012	05:41	105.01	-27.50	0	n	n	n	aborted - bad wire angle

Event	Station ID	Date (UTC)	Time (UTC)	Longitude	Latitude	Water depth	LADCP	Salts-O_2-Nutrients	Biology	Comments
94	CTD23	31-Aug-2012	07:46	105.03	-27.51	4929	y	y	y	
95	DRIFT-109255	31-Aug-2012	08:02	105.03	-27.52	x	n	n	n	
96	DRIFT-109423	31-Aug-2012	08:02	105.03	-27.52	x	n	n	n	
97	XBT19	31-Aug-2012	09:45	105.00	-27.75	x	n	n	n	
98	VMP	31-Aug-2012	12:34	105.00	-28.00	4937	n	n	n	
99	DRIFT-109256	31-Aug-2012	12:45	105.00	-28.01	x	n	n	n	
100	DRIFT-109414	31-Aug-2012	12:45	105.00	-28.01	x	n	n	n	
101	CTD24	31-Aug-2012	14:35	105.00	-28.00	4942	y	y	y	
102	Argo-4928	31-Aug-2012	14:35	105.00	-28.00	4942	n	n	n	
103	FT32	31-Aug-2012	16:15	105.00	-28.23	x	n	n	n	
104	XBT20	31-Aug-2012	16:21	105.00	-28.25	x	n	n	n	
105	XBT21	31-Aug-2012	16:26	105.00	-28.26	x	n	n	n	
106	VMP	31-Aug-2012	19:05	105.00	-28.50	4953	n	n	n	
107	CTD25	31-Aug-2012	21:20	105.00	-28.50	4958	y	y	y	
108	DRIFT-109425	31-Aug-2012	21:31	105.00	-28.50	x	n	n	n	
109	DRIFT-109636	31-Aug-2012	21:31	105.00	-28.50	x	n	n	n	
110	XBT22	31-Aug-2012	23:00	105.00	-28.75	x	n	n	n	
111	VMP	01-Sep-2012	01:34	105.00	-29.00	5134	n	n	n	
112	CTD26	01-Sep-2012	03:54	105.00	-29.00	5143	y	y	y	
113	DRIFT-109253	01-Sep-2012	04:04	105.00	-29.01	x	n	n	n	
114	DRIFT-109567	01-Sep-2012	04:04	105.00	-29.01	x	n	n	n	
115	XBT23	01-Sep-2012	05:41	105.00	-29.25	x	n	n	n	
116	VMP	01-Sep-2012	08:20	105.01	-29.51	4402	n	n	n	
117	CTD27	01-Sep-2012	10:32	105.00	-29.50	4672	y	y	y	
118	XBT24	01-Sep-2012	12:04	105.00	-29.74	x	n	n	n	
119	VMP	01-Sep-2012	14:34	105.00	-30.00	5384	n	n	n	
120	CTD28	01-Sep-2012	16:39	105.00	-30.00	5386	y	y	y	
121	DRIFT-109252	01-Sep-2012	16:49	105.00	-30.01	x	n	n	n	
122	DRIFT-109569	01-Sep-2012	16:49	105.00	-30.01	x	n	n	n	
123	XBT25	01-Sep-2012	18:22	105.00	-30.25	x	n	n	n	
124	VMP	01-Sep-2012	20:55	105.00	-30.50	4679	n	n	n	

Event	Station ID	Date (UTC)	Time (UTC)	Longitude	Latitude	Water depth	LADCP	Salts-O_2-Nutrients	Biology	Comments
125	CTD29	01-Sep-2012	22:36	105.00	-30.50	4666	y	y	y	
126	XBT26	02-Sep-2012	00:18	105.00	-30.75	x	n	n	n	
127	VMP	02-Sep-2012	03:04	105.00	-31.00	2952	n	n	n	
128	CTD30	02-Sep-2012	04:44	105.01	-31.01	2919	y	y	y	
129	Argo-4927	02-Sep-2012	04:45	105.01	-31.01	2919	n	n	n	
130	DRIFT-109545	02-Sep-2012	04:52	105.01	-31.01	x	n	n	n	
131	DRIFT-109568	02-Sep-2012	04:52	105.01	-31.01	x	n	n	n	
132	FT33	02-Sep-2012	15:57	107.09	-31.69	x	n	n	n	
133	XBT27	03-Sep-2012	01:34	108.74	-32.36	x	n	n	n	
134	CTD31	03-Sep-2012	04:16	108.89	-32.41	5318	y	y	y	
135	XBT28	03-Sep-2012	05:12	109.03	-32.46	x	n	n	n	
136	XBT29	03-Sep-2012	06:25	109.25	-32.54	x	n	n	n	
137	CTD32	03-Sep-2012	09:33	109.50	-32.62	5067	y	y	y	
138	Argo-6215	03-Sep-2012	09:40	109.50	-32.63	5000	n	n	n	
139	XBT30	03-Sep-2012	11:12	109.77	-32.72	x	n	n	n	
140	XBT31	03-Sep-2012	12:42	110.03	-32.82	x	n	n	n	
141	CTD33	03-Sep-2012	15:34	110.16	-32.87	5467	y	y	y	
142	XBT32	03-Sep-2012	16:36	110.29	-32.91	x	n	n	n	
143	XBT33	03-Sep-2012	16:46	110.29	-32.92	x	n	n	n	
144	XBT34	03-Sep-2012	16:51	110.28	-32.92	x	n	n	n	
145	FT34	03-Sep-2012	22:33	110.73	-32.86	x	n	n	n	
146	FT35	04-Sep-2012	15:56	113.68	-32.46	x	n	n	n	
147	FT36	04-Sep-2012	21:41	114.76	-32.45	x	n	n	n	

Appendix 2 - Mooring deployment report

Voyage Report IO6-12-ss

August 11th- September 6th, 2012
Freemantle – Freemantle, Australia
25S, 100E

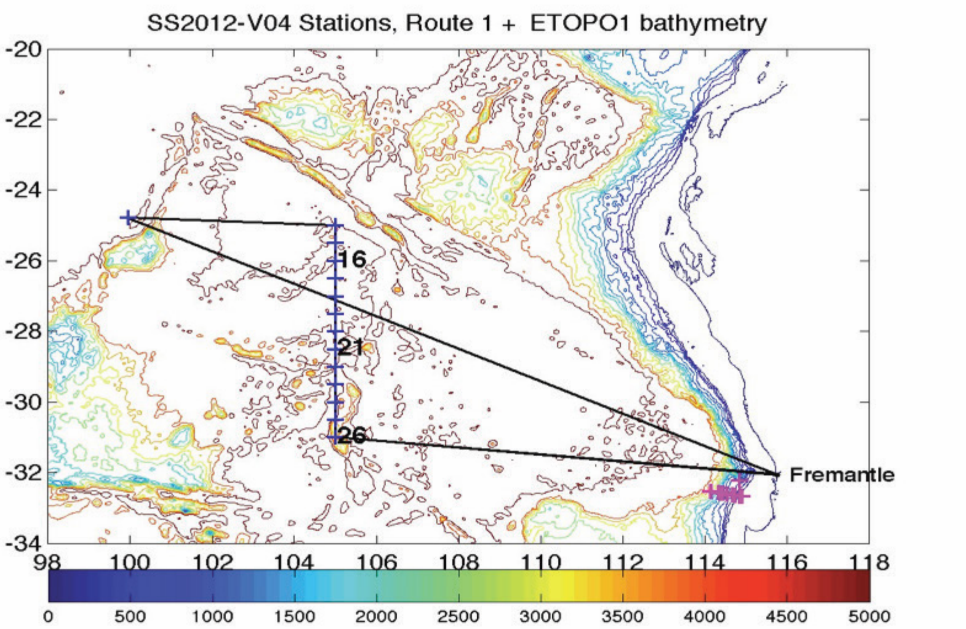
Patrick Berk, PMEL/NOA

Voyage Summary:

I met the R/V Southern Surveyor in Fremantle, Australia on August 11th, 2012. The ship had been loaded 10 days prior in Hobart, Tasmania, so no prep work was needed in port. I had expected to receive 2 Sonteks when I arrived at my hotel, but unfortunately a shipping error caused them to be lost in transit (more below). We departed the morning of the 11th and headed west. Our first task was a line of CTD's heading west until turning north up the 100E line. On the night of the 13th , 90 miles from Fremantle, we experienced debilitating engine failure. It was quickly determined that we needed to head back to port, so that's what we did. We were able to make 3-5 knots and arrived back in port the night of the 14th. Repairs took 9 days and we set back out on the 24th of August (details below). We took time in port to build and test the mooring on deck.

The voyage track was reorganised at this point to return to Fremantle rather than Broome, since it would save 2 days of travel time. We also decided it was best to head straight to the mooring, deploy, and finish CTD's and other work on the way back. After an evening of surveying, the buoy was deployed successfully on the afternoon of August 28th. After deployment we were getting no transmission from anything on the inductive line. We considered a variety of options but determined that we didn't have time for a repair effort. Subsequently the majority of modules on the inductive line started reporting properly.

We spent the rest of the voyage doing CTD's, XBT's and VMP's. We returned to Fremantle at 6am, September 6th.



Revised Voyage plan

SUMMARY OF MOORING OPERATIONS

SITE	MOORING ID	OPERATION
25s 100e	RA091A	New Deployment

ON-DECK INSTRUMENT OR HARDWARE FAILURE *(PRE-DEPLOYMENT)*

SITE	MOORING ID	OPERATION
Sensor type	Serial No	Comments
Barometer	114864	Extra Characters in String
TC	11703	No Inductive Comms

Shipping notes:

(Any problems with loading, agents...)

The Southern Surveyor crew while in port in Hobart very graciously loaded the ship without PMEL presence. When I arrived onboard all gear was neatly stowed and secured. What was not in Fremantle when I arrived was the box of 2 sonteks that had been air shipped to my hotel. After 2 days of phone calls to FedEx, we determined that there had been an extended delay in Memphis, TN and the box was presumably in Singapore. I was told that the package had been loaded onto the plane to Perth and should arrive soon. This turned out to be completely false and when I called the next morning I found out that the Sonteks had been shipped by to the US. We sailed without them. We thought we had a second chance when the ship returned to port 4 days later. It turns out once again the box had gotten delayed in the US and was once again somewhere in Singapore. At this point FedEx admitted that they had lost it, and sent someone to physically search for the box. After many more phone calls and much more frustration it was determined that the package, which is hazmat, had inadvertently been sent on a non-hazmat route. Crew in Singapore refused to load the box onto the scheduled passenger airplane. The package was given up on and returned to PMEL.

Upon completion of the voyage we searched for storage options for our remaining gear that was impractical to send home. We finally were able to secure storage at the CSIRO facility outside Perth. 2 anchors (1 set), 9 empty reels and a reel stand are stored outdoors, and 1 reel of nilspin and 1 reel of working line are stored inside (building 15). Storage is located at:

CSIRO Marine And Atmospheric Research
Nearshore Research Facility
Underwood Av.
Floreat, WA 6014

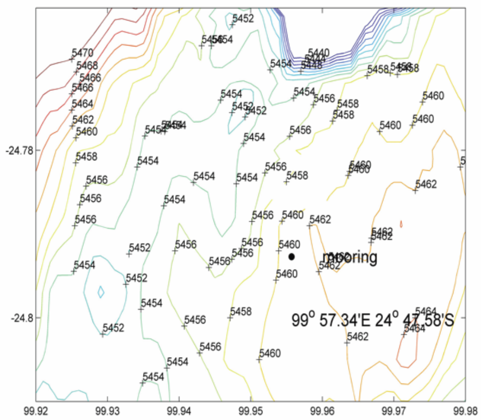
Our main contact there is Nick Mortimer, the Facility Manager.
Nick.Mortimer@csiro.au

Transportation was arranged with Green's Hiab

Noteworthy Operational Details:

We surveyed an approximately 4 mile square area the night before deployment. While the ship has a nice multibeam setup, there was no one on board who was able to process the multibeam data. Therefore we used the single 12khz sounder which automatically logged at 5 second intervals. We were able to interpolate fairly accurate bathymetry using those data. We also were able to turn on and log the multibeam data to hopefully be post processed back at CSIRO.

The Southern Surveyor has no central capstan so the mooring was pre-spooled onto a net drum ahead of time. This made the actual deployment quite simple since there was no stopping at any point once we reached the nylon. At the end of the nylon we had to stopper off and back spool on our cut piece of nylon.



Instrumentation and Hardware Notes:

(Missing nuts from shackles, tower missing rain mount...)

I was short a number of things in the hardware department. Most notably I was short on nylon. We had enough nylon to deploy the mooring where we wanted, but had essentially no extra (only 80m) as spare. I also had no lifting straps, ratchet straps or tag lines. The ships crew was able to round up everything we needed but it was disconcerting to show up to a ship ill prepared.

Software Notes: *(problems with Tweezers, Filemaker...)*

One of the laptops in the white box showed up dead. I charged it for a few hours but it wouldn't start up. It was an older, non-rugged laptop. 2nd, rugged laptop worked just fine.

Ship Notes or issues: *(SCS problems, problems with personnel or communications on board...)*

Overall the ship and it's crew all worked exceptionally. All winches, cranes and A-frames worked as they should.

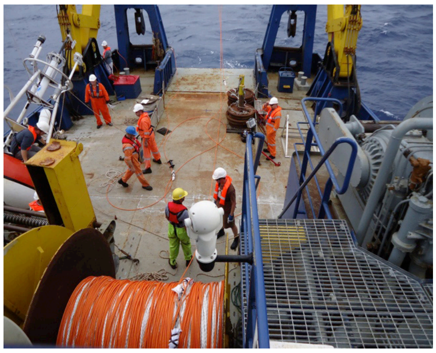
The one big exception was our breakdown on day 3. An oil line became clogged with a small piece of rubber and caused a bearing to overheat (>200 C). This took multiple cylinders of the engine offline. The engineers were able to bypass these cylinders to get us home at a decent speed (5kts). Unfortunately when we got back into port fixing the bearing was not the only issue. More pieces of rubber were found in others parts of the engine. A large section of the engine had to be dismantled and cleaned before we could proceed. Our repair time totalled 9 days.

Ancillary Projects: *(Attach summary of ancillary work - # of floats depl, etc)*

Over the course of the voyage we completed 34 ctd's, 33 xbt's, 14 vmp's and deployed 20 surface drifters, and 5 ARGO drifters. See attached documentation.

Recommendations:

If the southern surveyor is used again next year there are a few things to note. If the net drum is to be used again, then it would be nice to spool the nilspin onto the reel backwards, with the lower termination on the outside. This will avoid having to end-for-end the nilspin onboard. The ships crew also prefers anchors to be on pallets so that they can move them around with a pallet jack.



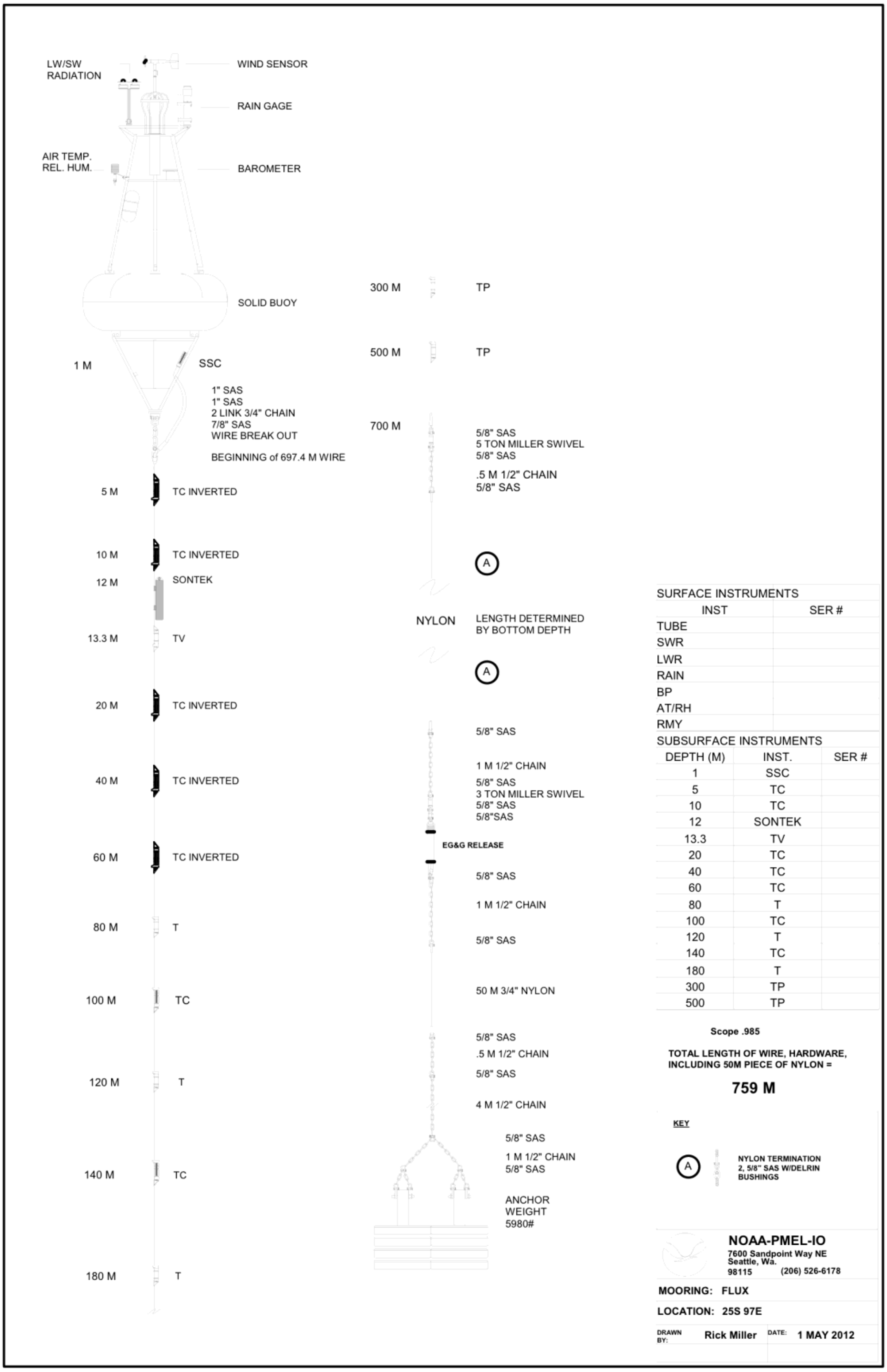
25S-97E

ADDRESS	TUBE CONFIG.	TEMP.	COND.	PRESS>	VELOC.	DEPTH	MODULE
0	SST/C	SST	C1			1m	SSC
1	TC	T1	C2			20m	TC
2	TC	T2	C3			40m	TC
3	TC	T3	C4			60m	TC
4	T	T4				80m	T
5	TC	T5	C5			100m	TC
6	T	T6				120m	T
7	TC	T7	C6			140m	TC
8	T	T8				180m	T
9	TP	T9		P9		300m	TP
10	TP	T10		P10		500m	TP
11	TC	T11	C7			10m	TC
12	T	T12				5m	TC
13	TV				V1	13.3m	TV

Figure 10: RAMA 25S mooring instrument allocation

Appendix 3 - Mooring design details

Figure 9: RAMA 25S mooring instrument layout



SURFACE INSTRUMENTS

INST	SER #
TUBE	
SWR	
LWR	
RAIN	
BP	
AT/RH	
RMY	

SUBSURFACE INSTRUMENTS

DEPTH (M)	INST.	SER #
1	SSC	
5	TC	
10	TC	
12	SONTEK	
13.3	TV	
20	TC	
40	TC	
60	TC	
80	T	
100	TC	
120	T	
140	TC	
180	T	
300	TP	
500	TP	