RV *Southern Surveyor*

2013 program

MARINE
NATIONAL FACILITY

voyageplan
ss2013_v04

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

Itinerary

Mobilise Fremantle 0800hrs, Monday 1st July, 2013
Depart Fremantle 1800hrs, Monday 1st July, 2013
Arrive Broome 0800hrs, Friday 26th July, 2013 and demobilise

Principal Investigators

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CSIRO

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 against the coast 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

This voyage is the combination of a recovery and re-deployment of the RAMA mooring at 25S, 100E and an additional 10 days at sea to complete the objectives of SS2012_V04 that were compromised by the engine failure suffered by R.V. *Southern Surveyor* during that voyage. The extent to which the original objectives were achieved, and a list of the activities that were lost is summarised in the letter from Nathan Bindoff to Ron Plaschke dated 1st November 2012 (attached).

With the voyage time allowed, and to achieve as much of the original science plan for SS2012_V04 as possible, our operational objectives for SS2013_V04 are:

1) Recover and re-deploy the RAMA 25S flux reference station to continue for a second year the observations of surface atmospheric fluxes and upper-ocean density, velocity and biogeochemistry.

2) Repeat WOCE line I5 out to 105E with full depth CTDs

3) Full depth CTDs along 100E from 31S to 25S at 30nm spacing

4) Full depth CTDs along 105E from 31S to 25S at 30nm spacing

5) Full depth CTDs along 25S from 100 to 105E at 60nm spacing if time permits

6) Full depth CTDs along WOCE line I5 from 100 to 105E at 60nm spacing if time permits

7) CTD profiles to 2000m across one warm core and one cold core eddy

8) Deployments of 5 EM-APEX profilers to measure the velocity structure in eastward flows and eddies, nominal positions shown in Figure 1

9) Deployment of 7 Argo floats from CSIRO at the nominal locations marked in Figure 1, contributing to the global Argo Program http://www.argo.ucsd.edu/ .

10) Deployment of 20 surface drifters provided by NOAA, USA at the locations shown in Figure 1. This is a contribution to the global surface drifter program http://www.aoml.noaa.gov/phod/dac/index.php, will provide information on the broad scale surface circulation in our region of interest, and will provide ground-truthing for CSIRO's Bluelink model http://www.bom.gov.au/bluelink/

These operational objectives will allow us to meet our original science objectives:

1) Map the vertical and meridional extent of the South Indian Counter current, and the underlying westward flows, east of 95E (40% complete in 2012 with only one north-south line).

2) dentify the source waters of the westward flow beneath the SICC and broader eastward flow (40% complete in 2012 with only one north south line).

3) Characterise the 3-dimensional physical and biogeochemical structure of the Leeuwin Current eddies (about 85% complete).

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

Priorities of the measurement program depend on circumstances during the voyage. Some trade off is possible between the number of CTDs and the survey of eddies in the event of equipment problems or bad weather beyond the current allowance of 1 day. The RAMA mooring has the highest priority, followed by the deployment of floats and drifters, the 105E line, the 100E line, and the survey of eddies. The lowest priority is the CTD profiles on the east west lines at 25S and 31S. The voyage aims to complete all aspects of the work satisfactorily.

A number of shipboard measurement programs and analyses of water samples will be undertaken as well as the shipboard activities listed above (see piggy-back projects and hydrographic analyses).

Voyage Track

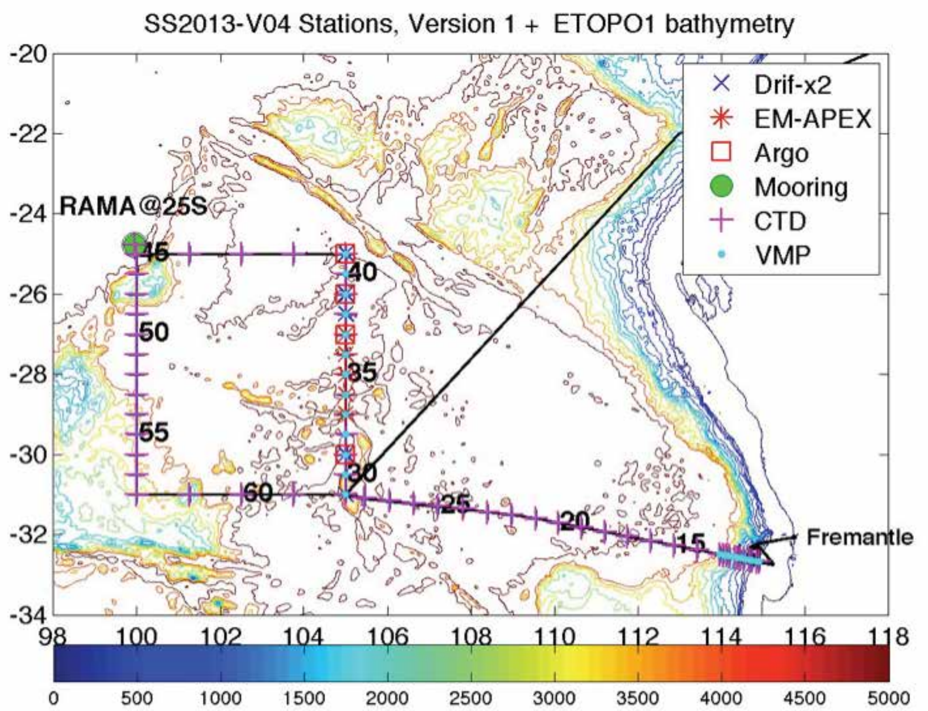


Figure 1. Proposed voyage track (black line) and nominal locations of RAMA mooring, profiling float and paired surface drifter deployments. Contours are bathymetry from ETOPO1, contoured every 100 m depth.

Time Estimates

Transit (at 10 knots)

Fremantle to Test CTD (32.23S, 114.85E) 47nm = 4.7 hours

Test CTD to inshore start of ADCP transect along I5 (32.74S, 115.26E) 37nm = 3.7 hours

Inshore end of I5 to CTD1 (32.68S, 114.91E) 18nm = 1.8 hours

Final CTD station (31.00S, 105E) to Broome 1225nm = 122 hours

Total: 5.5 days

Research

CTD station time 67 CTDs at 3.5 hours each = 234.5 hours

Mooring deployment = 48 hours

Transit between CTD stations 1580 nm = 158 hours

Transit across eddies (1 additional transect across 2 eddies of diameter ~150nm) 300nm = 30 hours

Total: 19.6 days

Contingency

1 day

Total 26.1 days

(1.5 days too long, but may require less than 48 hours at mooring, and can delete CTDs on east-west lines)

Piggy-back Projects

Upper-ocean mixing estimates using a VMP-200 microstructure profiler
Dr Ming Feng (not participating in the voyage)

CSIRO Marine and Atmospheric Research, Underwood Avenue, Floreat WA

Dr Feng has loaned us his microstructure profiler and provided training in its use to Dr Helen Phillips. Profiles of microstructure (or turbulence) in the upper 300-400 m of the water column will contribute significantly to Objective 1, providing an estimate of ocean mixing across the interface between the near-surface eastward flows and subsurface westward flows. We will lower the tethered profiler at every CTD station along the 105E line and at 13 stations coming off the shelf along the WOCE I5 line as we cross the Leeuwin Current. Fall rate of the profiler is about 80 cm/s so 3 round-trips to 300 metres will take about 37 minutes. The rope tether is streamed out so that the profiler free-falls through the water. There is a danger of cutting the rope with propellers. On SS2012_V04 we ran the rope from a rope basket up through a small, free-running block suspended from a stern A-frame block and down to the profiler. When the profiler was sinking, the rope ran free out of the rope basket. For recovery we used the pot hauler and fed the rope back into the rope basket. Sometimes, the ship needed to be slightly underway to ensure the rope was always behind the ship.

Primary productivity in the southeast Indian Ocean
Assoc. Prof. Pete Strutton (not participating in the voyage, samples to be collected by Viviane Menezes, IMAS)

IMAS, University of Tasmania, Private Bag 129, Hobart, TAS 7001

Water samples will be taken from the Niskin bottles at 8 depths over the top 200m of the ocean. Depths will be determined by the downcast traces at each CTD station.

PhD student Viviane Menezes (UTAS), and possibly Nicola Maher (UNSW) and Stefan Riha (UNSW) will be trained in Hobart on the operation of Strutton’s fluorometer to perform the analysis for Chlorophyl a on board. Additional samples will be frozen for on-shore HPLC analysis to investigate the types of phytoplankton contributing to the chlorophyl signal.

Nitrogen uptake and fixation in the eastward flows feeding the Leeuwin Current System
Eric Raes, Research Assistant (not participating in voyage, samples to be taken by Hanni Olsen, UWA)

Oceans Institute, M470 University of Western Australia, 35 Stirling Hwy, Crawley, 6009, WA

Background: The ocean's production capacity is thought to be driven by the biological availability of dissolved inorganic nitrogen. The oligotrophic conditions of the West coast of Australia limit both fisheries production and the capacity to mitigate the greenhouse effect via CO2 absorption. In this study we want to quantify the ability of plankton known as nitrogen-fixers (diazothrophs) to absorb CO2 by stimulating the biological reduction of N2 using the iron rich enzyme nitrogenase. The biochemical N2 fixation pathway would bypass the N limitation and in fact refuel the oligotrophic surface waters.

The occurrence of nitrogenase activity by N2-fixing microorganisms in low nutrient and stratified oceanic habitats is well documented and first sightings date back to the voyages of Captain Cook (Beaglehole et al., 1974) and C. Darwin (Darwin, 1889). Increasing knowledge, however, on the phylogenetic diversity of N2 fixing organisms in the oceans (Stacey et al., 1992, Mehta and Baross, 2006), their distribution and global N2 fixation rates have caused a paradigm shift in understanding the global N cycle (Delwiche, 1970, Montoya et al., 2004, Deutsch et al., 2007). The diazothrophic organisms have taken up a significant role in ocean biogeochemistry nowadays and marine nitrogen fixation has become a core component in ocean and atmospheric CO2 coupling (Falkowski, 1997, Douglas G, 2001).

This study will, furthermore, follow the fixed N into the deep sea thereby; 1) evaluating the potential influence of N2 fixation on the absorption of CO2 in the ocean via sedimentation and 2) quantify the ability of fixed N to move up the food chain.

Ship based N-fixation and uptake measurements during the voyage:

If feasible we would like to collect physical and biological parameters using the ship's Seabird SBE911 conductivity-temperature-depth (CTD) profiler at the surface and the O2 minimum feature in the photic zone (situated at approximately 150 m depth). Water budget would be 30 L for each depth.

If no CTD's casts will be feasible then we are able to collect our water samples from the surface flow through situated in the wetlab.

Samples will be taken for:

1. Chlorophyll a / HPLC
2. Primary productivity, following isotopic tracer incorporation into the particulated matter
3. Dissolved inorganic nitrogen uptake measurements using standard 15N protocols
4. N2-fixation rates using 15N gas as an injected tracer to measure fixation rates
5. A microarray, to determine the community of fixating, nitrifying, ammonifying and denitrifying microorganisms (Roh et al., 2010).

We would require the isotopic lab opposite the comms room, one bench in the fish lab for filtration and 5 nally bins for on deck incubations along with usage of the fire hose for a continous water flow.

Outcomes/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.

Offshore sources of high nitrate, low oxygen upper ocean waters
Dr Peter Thompson (not participating in the voyage, samples to be taken by Hanni Olsen, UWA)

CSIRO Marine and Atmospheric Research, Hobart, TAS 7001, Australia

Aim to determine whether the thin layer of high nitrate and low DO found near 24-25S, 112E in 2007 is also found further offshore. Based on some historic DO data I have identified 2 possible routes/locations for this feature. One is further west towards Africa and the other stretching north towards the Bay of Bengal. The nutrients are important for the productivity of the west coast of Australia so it would be useful to determine their source. Some random sampling is probably required to establish a background but ideally sampling would target these features. This is most easily handled by firing a bottle in any thin layer of low (~ 30 uM or more below normal) DO in the top 250m. These are usually pretty obvious if you are watching the profile as the CTD goes down.

At the same time the thin layer of nitrate suggests some unusual nitrification activity and the molecular team would like some samples to analyse for N genes and to sequence the DNA. If filtering is already being undertaken by other science party members then the required equipment would already be available to undertake this work. Post filtering the sample would (normally) go into a dewar full of liquid nitrogen.

Since only one person from Anya Waite's group will be participating on the voyage this time it may not be possible to complete this work. We will do it if we have time.

Argo float deployments

The activities associated with this project will be coordinated by Helen Phillips.

We will deploy 12 profiling floats: 5 EM-APEX to study the velocity structure in eastward flows and eddies, and 7 Argo floats from CSIRO, contributing to the global Argo Program http://www.argo.ucsd.edu/ . Nominal deployment locations are shown in Figure 1, and are clustered along the 100E and105E lines. The floats will be deployed while the ship is moving slowly off a CTD station.

Surface drifter deployments

The activities associated with this project will be coordinated by Helen Phillips.

Twenty surface drifters are being sent to us from NOAA, USA. They will be delivered in the same container as the mooring. They will be deployed along the 105E line as shown in Figure 1. This is a contribution to the global surface drifter program http://www.aoml.noaa.gov/phod/dac/index.php. The drifter tracks and measurements of sea surface temperature and air pressure will provide information on the broad scale surface circulation in our region of interest, and will provide ground-truthing for the Australian Bluelink model http://www.bom.gov.au/bluelink/

Southern Surveyor Equipment

Scientific Equipment
- Seapath Seatex 200
- Simrad EA500 (12kHz)
- ADCP

Laboratory and other Facilities
- General purpose laboratory (includes fume hoods, fridge, freezer)
- Hydrochemistry laboratory
- Wet laboratory/CTD room and use of the flow-through for underway water collection
- Productivity/isotopic lab opposite the comms room, the freezer and one of the fridges in this lab
- 5 nally bins for on deck incubations (supplied by UWA) along with usage of the fire hose for a continous water flow
- -800c freezer
- Walk in freezer

Winches, A-frames and Crane
- CTD/Hydro winches each with 5,000m of 8mm single core conducting cable
- Hydrographic A-frame
- Stern A-frame (SWL 15 tonnes) – for mooring work, and for lowering the VMP-200 aft
- 7.0 tonne knuckleboom crane
- Gilson winches (15 tonne, 5 tonne)
- Pot hauler, rope basket and small, free-wheeling block to pay out and haul back the VMP-200 rope.
- Net drum
- Coring winches
- Big crane fore of the doghouse

Data Products
- ADCP: standard data provided as 20 minute averages.
- Underway data in netCDF format
- Ship attitude – heave, pitch, roll and heading
- Data from winch sensors (tension, winch speed and wire out)
- Bridge log (photocopy)
- CTD log

Specialised Electronic Equipment
- Acoustic Pinger
- 12kHz Acoustic Receive Transducer (low power, wide beam)
- General Purpose Depth Sensor

Conductivity, Temperature and Depth Profiling (CTD)
- CTD (Seabird SBE 911 plus)
- CTD Rosette
- 10 litre Niskin bottles
- Transmissometer (to 6,000m depth)
- Profiling fluorometer – requires user support for calibration during voyage (6,000m depth)
- Light (PAR) (to 6000m depth)
- Dissolved oxygen (to 6,000m depth) – requires MNF hydrochemistry support for calibration.
- Lowered ADCP (to 6,000m depth) – requires users support for data processing and interpretation.
- MNF Isus Nitrate sensor (to 1,000m depth – will be removed from the rosette at the last shelf station before the water depth reaches 1000m.)

Chemical Analyses

- Salinity – 12 samples per cast
- Oxygen – 12 samples per cast
- Nitrate + Nitrite
- Nitrite
- Reactive silicate
- Ortho-phosphate
- NH4

Other Equipment and Facilities

- Underway fluorometer to measure sea surface fluorescence. User support required
- Underway thermosalinograph
- Meteorological data
- Milli-Q water supply

User Equipment

ATLAS Mooring (Fig. 1). Itemised list of equipment will be provided by the mooring technician from PMEL. Attachment provides information about standard mooring design and deployment procedure for PMEL moorings.

12 x profiling floats (Argo-type floats) to be shipped either

- in pairs, in 2 boxes of approx. 207cm x 57cm x 42cm, weight approx 95Kg
- or individually in 4 boxes of approx. 206cm x 38cm x 43cm, weight approx 52kg

20 x surface drifters provided by NOAA, USA. Will arrive in same container as mooring gear. See http://www.aoml.noaa.gov/phod/dac/gdp_doc.php for a picture of a drifter deployment and other details.

1 x VMP-200 microstructure profiler (in pelican rifle case – 19.6kg, 129x42x20cm) and 400m-long rope on spool. See http://www.rocklandscientific.com/Products/TurbulenceInstrumentation/VMP200/tabid/129/Default.aspx for details of instrument.

Filtration tower (to be installed in the fish lab) – 70cm(h) X 50cm(w)

Fluorometer (to be installed in the fish lab) - 50cm(h) X 50cm(w)

Chemicals to be brought on board

- Acetone
- Ammonium Chloride NI5
- Ethanol 99.7%
- Hydrochloric Acid 32%
- Lugol's Iodine solution
- Sodium bicarbonate 13C
- Sodium Nitrate N15
- Paraformaldehyde
- Phosphate buffered saline
- Liquid nitrogen dewar

Personnel List

Participant	Affiliation	Position
Eric Schulz	Bureau of Meteorology	Chief Scientist
Nathan Bindoff	IMAS, Univ. Tas.	Alternative Chief Sci./ Science Watch Leader
Helen Phillips	IMAS, Univ. Tas.	Science Watch Leader
Viviane Vasconcellos de Menezes	IMAS, Univ. Tas.	CTD Watch/ Chlorophyl analysis
Patrick Berk	PMEL, NOAA, USA	Mooring technician
Hanni Olsen	University of W.A.	Biology
Stephanie Downes	Australian National Uni	CTD Watch
Stefan Riha	UNSW and ARC CoE for Climate Systems Science	CTD Watch/assist with biology
Nicola Maher	UNSW and ARC CoE for Climate Systems Science	CTD Watch/assist with biology
Dave Terhell	CMAR	MNF Voyage Manager
Peter Hughes	CMAR	MNF Hydrochemistry Support
Sue Reynolds	CMAR	MNF Hydrochemistry Support
Alicia Navidad	CMAR	MNF Hydrochemistry Support
Karl Forcey	CMAR	MNF Electronics Support
Hiski Kippo	CMAR	MNF Computing Support

Dr Eric Schulz
Chief Scientist

Dr Helen Phillips
Sampling Coordinator

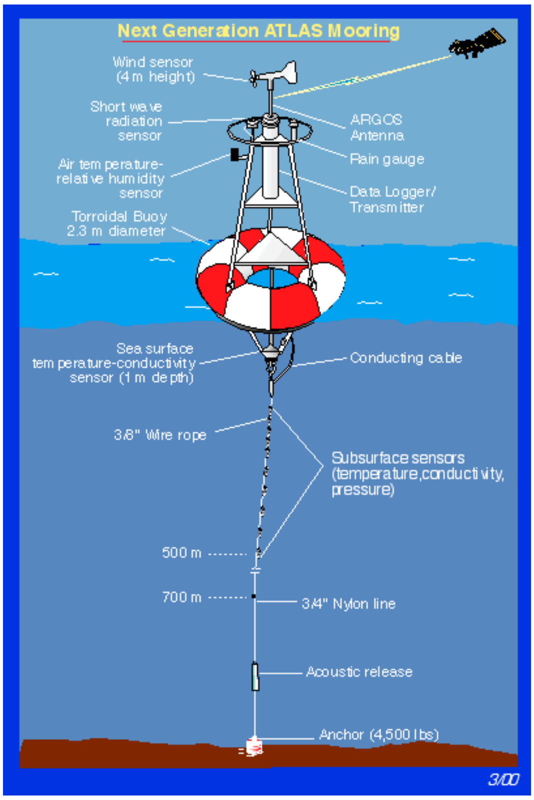


Figure 2. Design of RAMA 25 S mooring to be deployed in approx. 4000 m water depth.

Appendix 1

Letter from Bindoff to Plaschke re time lost on SS2012_V04 (2 pages)

1st November 2012

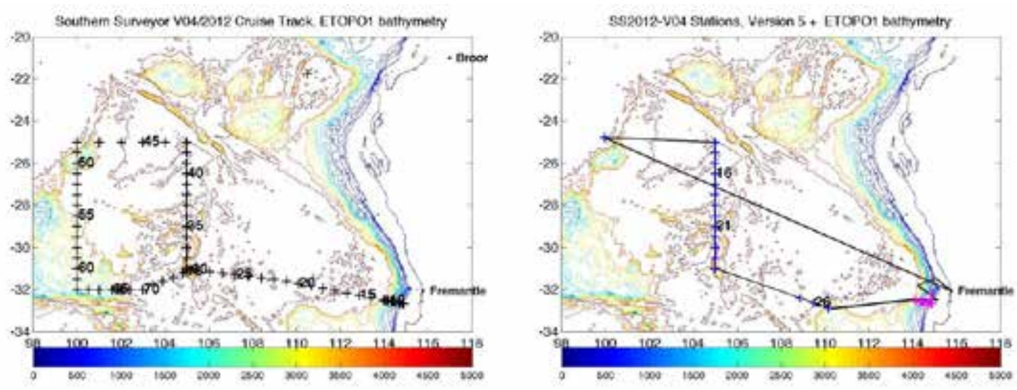
Mr Ron Plaschke
Director
Marine National Facility
CSIRO Marine and Atmosphere
GPO Box 1538
Hobart 7001
Tasmania

Dear Ron

Re: SS04/2012 Observations of remarkable eastward flows and eddies in the subtropical southeast Indian Ocean

This letter is to follow up on our phone conversations in late August regarding the 10 days of vessel downtime experienced on this voyage. As you will appreciate, due to the engine problems and unplanned port call, not all the voyage objectives could be achieved as planned. Figure 1 below illustrates the revised voyage track and the parts of the original plan which were lost including:

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



Original voyage track in voyage plan

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).

The assessment of the level of completion of four main objectives of the voyage is:

1) Map the vertical and meridional extent of the South Indian Counter current, and the underlying westward flows, east of 95E (40% complete with the only one north-south line).

2) Identify the source waters of the westward flow beneath the SICC and broader eastward flow (40% complete with only one north south line).

3) Characterise the 3-dimensional physical and biogeochemical structure of the Leeuwin Current eddies (about 85% complete).

4) Establish a moored reference station to sample surface atmospheric fluxes and upper-ocean density, velocity and biogeochemistry (100% complete, recovery scheduled for 2013).

The objectives 1 and 2 were the most compromised and are in fact the main scientific objectives of the proposal. Both of these objectives were completed to the 40% level. In terms of scientific output these two objectives were the central to the main proponents science outcome of this voyage.

Although the engine breakdown clearly had a major impact on the voyage, the scientific team are pleased with the results achieved on the shortened voyage including the deployment of the RAMA mooring. We do however request the lost time that occurred on this voyage be added to the 2013 recovery of the RAMA mooring to enable the scientific objectives to be fully realised.

Should the MNF proposal by Eric Schulz, Phillips, Bindoff, Strutton, and McPhaden "Observing ocean-atmosphere interactions and ocean circulation on climate-relevant time scales in the southeast Indian Ocean" be successful, then I suggest the 2013 RAMA recovery and these additional 10 days of field program be adjoined to this proposal.

Yours Sincerely

Prof. Nathan Bindoff

cc. Dr Helen Phillips, Dr Eric Schulz, Dr Mike McPhadden, and Dr Peter Strutton.

Appendix 2

Mooring design and deployment procedure

PMEL Mooring Equipment and Operations

NOAA's Pacific Marine Environmental Laboratory (PMEL) is investigating the possibility of deploying, recovering or repairing ATLAS moorings from vessels operating in the Indian Ocean. This work is towards the implementation of the "Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction" (RAMA). RAMA will complement the "Tropical Atmosphere Ocean/Triangle Trans-Ocean Buoy Network" (TAO/TRITON) moored array for the Pacific Ocean and the "Pilot Research Moored Array in the Tropical Atlantic" (PIRATA) for the Atlantic Ocean, providing data essential for monitoring, understanding and the prediction of regional and global climate variability. RAMA is a key component of the Indian Ocean Observing System (IndOOS), designed by the IOGOOS/CLIVAR Indian Ocean Panel (IOP).

The follow pages outline the requirements necessary to maintain these moorings. The design lifetime of the moorings is 1 year, thus an ongoing commitment of resources is needed, with cruises to each site scheduled on an approximately annual basis. The map of planned sites (Figure 1) indicates up to 20 sites which could potentially be maintained, within the limitations of time and normal working areas of the ships. Our preference would be to maintain moorings at 3 to 10 sites on cruises of up to 30 days duration though regular servicing of even an individual site is of benefit to RAMA. Initial estimates of time on station would be 24 hours per site. With time this could be shortened as scientists and ship's crew become more accustomed to operating from the ship. Nighttime operations are possible, depending on the acceptance of the Commanding Officer.

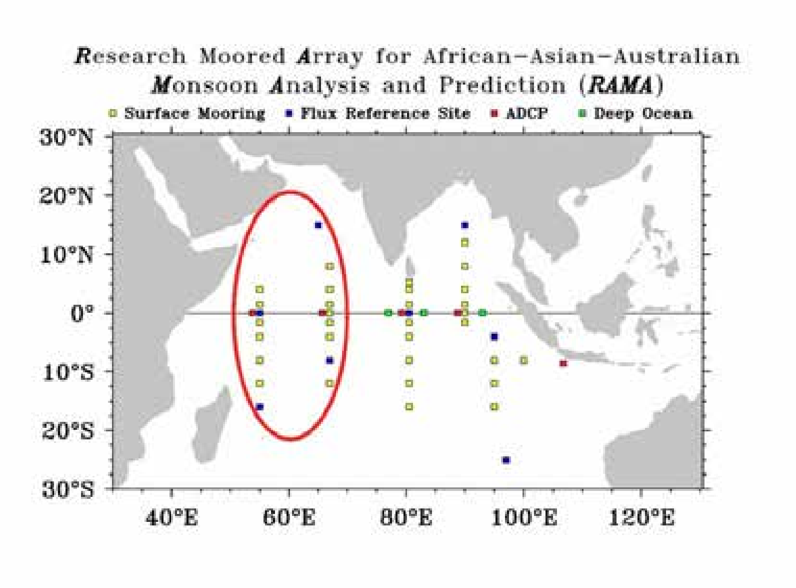


Figure 1

Depending on the number of sites visited and the amount of support available from the ship's personnel, PMEL would send one to three technicians to participate in the cruise. It is assumed that ship's personnel would be available to assist during deployment operations and during the transfer of equipment to and from the ship while in port. PMEL would also ask that the ship provide surface meteorology, upper ocean CTDs, and bathymetry information in the vicinity of the moorings.

Laboratory Space: Interior lab space is required for instrument testing and setup. A small amount of bench space (~2 m) is necessary for instrument checkout and a satellite-uplink monitoring station used to receive transmissions from the buoy. A cable is run from the laboratory space to an outside antenna in an area that would allow an unobstructed view of our surface mooring during deployment operations. This "line of sight" path to the buoy allows for the reception of Argos transmissions while monitoring the instrumentation.

Deck Space: The mooring hardware will require outside storage on the working deck. For three moorings about 50 m² of deck space is necessary to store the reels of rope, anchors, buoys, towers, and hardware. Space is also necessary to test our instrumentation before their deployments (Figure 2). We will need to have additional space to assemble a buoy before operations begin.

Figure 2. Surface instruments setup for system checks on the weather deck.

Communications: Email or Fax capability between the ship and PMEL is highly desirable. Communications between the lab and the ship is essential to confirm good data transmission or notification of instrumentation or hardware malfunction.

Bathymetry: A depth sounder with 6000 meter range and recording capability is required. An accurate bathymetric survey of the deployment area is necessary and an automated 2-D map generated prior to deployment is desirable. A reasonably flat target area is required, preferably at least 2 nm square. Depth variations in the drop site should be no more than 80 meters over 2 nm.

Deployment Operations: The RAMA surface moorings are deep ocean taut-line moorings with a scope (the ratio of mooring length to water depth) of 0.985. There is some flexibility in deployment methods and operations can be tailored to the characteristics of an individual vessel. A discussion with the ship's officers and scientific party will take place before operations to plan deployment procedures.

The use of a crane or A-frame, or both, is essential. The buoy will be assembled on the ship prior to deployment and is typically picked up by a crane, swung over the side of the ship, and lowered into the water using a release hook (Figure 3). The line attached to the bottom of the buoy is fair-lead around the stern of the ship and through an A-frame to a capstan. The line is slowly let out with the buoy drifting off the stern while sensors are attached to the mooring line. Figure 4 shows an alternative method of buoy deployment using an A-frame.

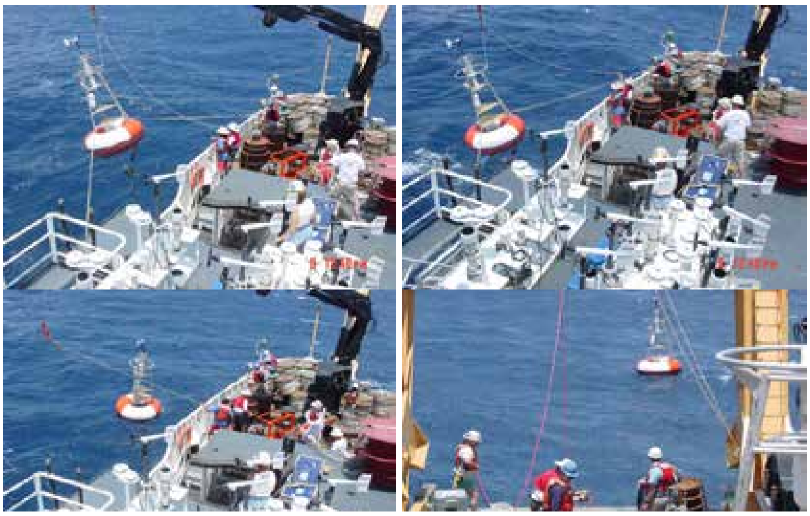


Figure 4.

Ship Equipment Required:

A crane with a lifting capacity of 2950 kg and a reach that extends outboard for use in deployment of the surface buoys.

A stern A-Frame with a lifting capacity of 6300 kg, a height of 6 m with a width of at least 3 m at it’s base is desirable (Figure 5).

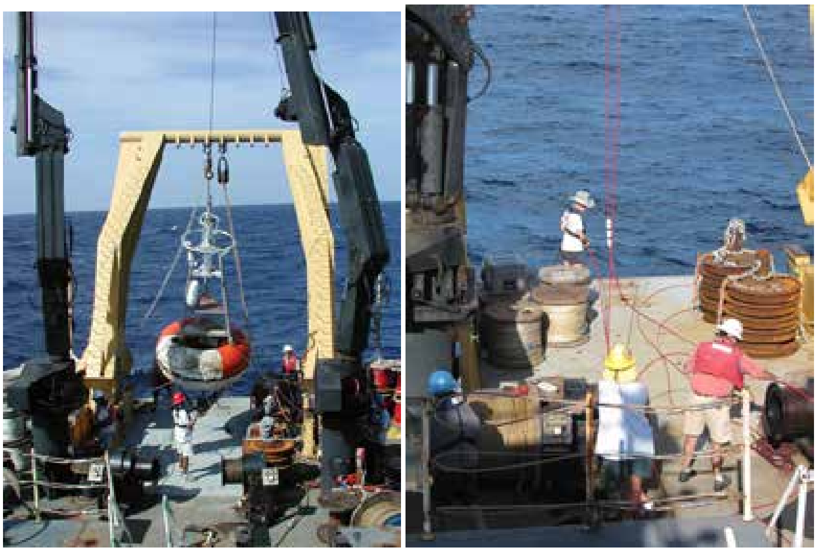


Figure 5.

Time on station: Approximately 24 hours are required for the site survey, deployment operations and data verification. More time could be needed depending on the extent of the bathymetric survey. A CTD to at least 1000 m should be performed, preferably after mooring deployment.

Acoustic Release Instrumentation: After deployment an acoustic hydrophone will be lowered into the water from the ship's deck to communicate with the acoustic release located above the mooring anchor. We use a Model 8011A EG&G Acoustic Deck Unit and a model 8242 acoustic release. PMEL will supply the Deck Unit for the cruise.

Shipment: Our shipment will be contained in one or more 40' shipping containers. The containers should be spotted on the dock next to the ship. A forklift will be necessary to unload the containers. If the ship's crane does not have the ability to lift or reach material on the dock, a dockside crane will be needed to transfer the equipment to the ship. The ship's crane must be able to move stored equipment to the working deck for deployment. Anchors should be stored near the A-frame as moving them at sea may be difficult.

Mooring Hardware: The surface buoys are a 2.4 meter toroidal buoy, constructed of fiberglass over foam. There are attachment points on the top and bottom of the buoy where metal frames (referred to as towers above the buoy and bridles below) are bolted into place. The towers are constructed of aluminum and the bridles are made of stainless steel. The 1 cm diameter, galvanized-steel mooring wire is jacketed with water tight polypropylene with a nominal outside diameter of 1.3 cm. The 8 strand plaited nylon rope has a diameter of 1.9 cm. Anchors are fabricated from scrap railroad wheels to total 2700 kg each for surface moorings. The railroad wheels are assembled on two shafts which are chained together before deployment. The working lines, blocks, reel stands and miscellaneous deck items will be provided by PMEL.

Listed below are weights, measures, and quantities of mooring hardware (including spares) that would be loaded onto the ship if 3 sites were to be maintained. **An accurate inventory suited to a particular cruise would be sent before the shipment leaves Seattle.**

Surface Mooring Hardware:

ITEM	SIZE (M)	WEIGHT (Kg)	QTY	TOTAL (Kg)
Toroid	2.3 meters diameter, 1 meter high	318	4	1272
Tower	Triangle 1.5 m base, 2.3 m high	61	4	244
Bridle	Triangle 1.5 m base, 1 m high	84	4	336
Wire Rope Reel	0.71 m diameter, 0.6 m wide	341	4	1364
Nylon Rope Reel	0.71 m diameter, 0.6 m wide (8 reels are estimated per mooring)	120	4	3840
Anchor	1.01 m diameter x 1.15 m high (2 per surface mooring)	1361	8	10912
Lead Weights	0.2 m x 0.14 m x 0.15 m (3 per buoy)	150	4	600
Misc. Hardware	Shipping container varies	590	2	1180

Instrumentation:

ITEM	SIZE (M)	WEIGHT (Kg)	QTY	TOTAL (Kg)
Surface Data-Logger	1.51 m x 0.56 m x 0.45 m	84	6	504
Acoustic Releases	0.81 m x 0.36 m x 0.25 m	48	6	288
Electronic monitoring box	0.91 m x 0.71 m x 0.46 m	34	1	34
Acoustic Deck Unit	0.51 m x 0.71 m x 0.36 m	32	2	64
Seacat	0.91 m x 0.25 m x 0.25 m	12	1	12
Sensor Modules	0.46 m x 0.46 m x 0.46 m	25	6	150
Misc parts box	0.91 m x 0.71 m x 0.46 m	34	1	34