THE AUSTRALIAN NATIONAL MOORING NETWORK

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1. INTRODUCTION

The Australian National Mooring Network (ANMN) is one of 11 facilities of the Integrated Marine Observing System (IMOS) (http://www.imos.org.au). IMOS is a distributed set of equipment and data-information services designed to meet the needs of Australian researchers. The facilities are mandated to provide the infrastructure for research and in the case of IMOS - as data is the product – infrastructure means data. Infrastructure deployed by the ANMN monitors oceanographic and biological phenomena on Australia's continental shelf. The network is composed of a series of National Reference Stations (NRS) at sites around the countries inner continental shelf as well as regional sensor arrays.

1.1 Governance

The research agenda for IMOS is set in consultation between the IMOS director, the board and science nodes. The nodes are regional committees that meet regularly and are composed of many of Australia's senior marine researchers. To support the nodes' science agenda, the facilities, which have budget responsibility, liaise with the nodes over cost and practicalities of the science direction. As the largest IMOS facility the ANMN develops, installs and maintains infrastructure for most of the nodes. Within the ANMN there are 7 sub-facilities and, similar to other components of IMOS, governance responsibility is shared between various organisations. IMOS is essentially a partnership between different research and management institutions, which are termed operators in the IMOS structure, for the delivery and management of data to the research community. Nationally, the program is coordinated by the IMOS Office, which is hosted by the University of Tasmania (UTAS).

21-25 September 2009, Hall, J., Harrison D.E. and Stammer, D., Eds., ESA Publication WPP-306, 2010.

The sub-facilities of the ANMN and their host organisations (in brackets) are as follows: NRS – Coordination & Analysis (Commonwealth Science and Industry Research Organisation - CSIRO), Western Australia (CSIRO), Passive Acoustic Observatories (Curtin University of Technology), Queensland and Northern Australia (Australian Institute of Marine Science - AIMS), New South Wales (Sydney Institute of Marine Science - SIMS), South Australia (South Australian Research and Development Institute - SARDI) and Satellite Ocean Colour – Calibration & Verification (CSIRO).

2. NATIONAL REFERENCE STATIONS

The NRS form the backbone of the ANMN, providing context to other studies with a time series of datasets to monitor climate change both through oceanographic and biological processes. Consisting of nine sites, in depths between 50 and 110m, the stations are located along Australia's coastal boundary currents (Fig. 1). The NRS are fixed locations where both water samples are taken and where multiple instrumented moorings are located in close proximity to each other. The system builds on three existing sites where water quality data have been regularly collected, in some cases monthly, since the 1940s. Physical, chemical and biological parameters are collected at each site from both sensors, based around the WetLabs Water Quality Meter (WQM), and monthly or quarterly water samples from Niskin bottles, plankton nets and castes with a conductivity, temperature and depth (CTD) meter [1].

WQMs are a relatively new multi-sensor, which measure CTD, dissolved oxygen, fluorescence and turbidity. They were chosen for the coastal work of the ANMN due to their integrated antifouling systems, on-board processor - that both logs and averages data - and ability to integrate with telemetry systems. Although all data is retrieved when the moorings are serviced on a quarterly basis, a sub-set of averaged data is now being telemetered hourly from the Maria Island NRS http://imos.aodn.org.au/webportal/.

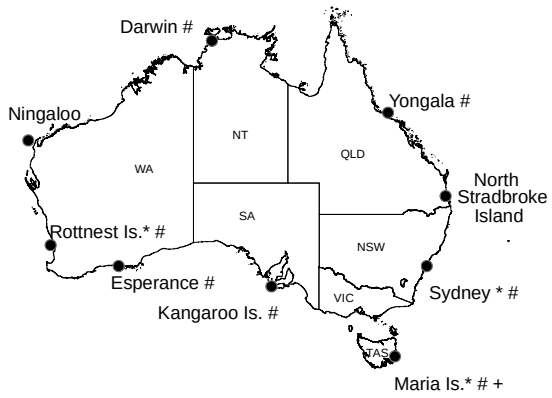

*Figure 1. NRS location status 2009, * indicate historical site, # indicates sub-surface mooring infrastructure deployed, + surface telemetry gear deployed*

For telemetry, averaged data is transferred from the sensors on the sub-surface mooring to a surface float using Teledyne benthos acoustic modems. Within the electronic package in the float, a Campbell logger collates this data along with other sensor information from a Vaisala weather station (top of mast in Fig. 2), Seabird SBE39 (measuring sea surface temperature) and a Motion Reference Unit (measuring significant wave height), into a file structure which is then sequentially transmitted using Iridium Satellite Short Burst Data transmission. The telemetry system is to be extended to other sites over the next two years. .

Though nationally co-ordinated, each site is regionally managed by the relevant sub-facility. The exceptions to this governance structure are the Maria Island and North Stradbroke Island NRS, which are directly managed by the NRS – Coordination & Analysis sub-facility. The Maria Island NRS is also know as the Maria Island Time Series (MITS) and is the longest high quality time series from the Southern Hemisphere, continuously monitoring the East Australian Current (EAC) extension from 1944 to the present day [2].

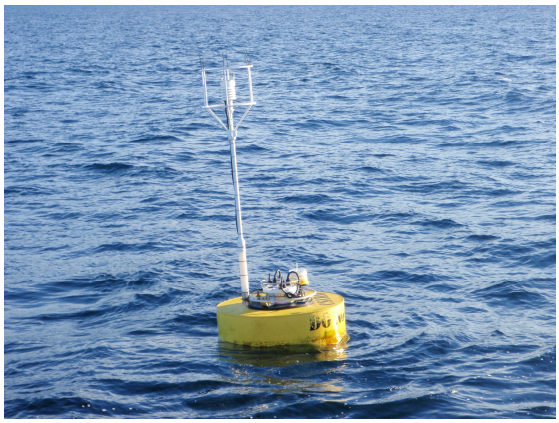

Figure 2. Maria Island NRS telemetry surface float

The site has been used as one of the test beds for technological developments, such as sensor integration for iridium satellite telemetry, and extensive beta testing of the WQMs for their NRS application.

3. WESTERN AUSTRALIA

The Western Australian sub-facility operates three NRS sites, deployed over a continental scale at Esperance, Rottnest and Ningaloo; the Rottnest NRS is one of the three long-term monitoring sites [3]**.** Western Australia also maintains two shelf moorings arrays; the first is deployed around the Perth Canyon, which is a bathymetric intrusion into the continental shelf just offshore from the Rottnest NRS. The second array is just north of Perth, off Two Rocks, and is deployed as a cross shelf transect. These arrays provide data to monitor the variability in the Leeuwin and continental shelf currents both in-terms of alongshore and cross-shore structures as well as oceanographic processes, such as upwelling, within the Perth Canyon.

The Two Rocks transect consists of five moorings deployed at intervals from the 50m to the 500m isobath. Instruments deployed include 190kHz and 75kHz Acoustic Doppler Current Profilers (ADCP) to measure current velocities, and thermistor chains of SBE 39 temperature and pressure sensors. Sable locator beacons are also deployed on those moorings with ADCPs. The Perth Canyon array is similar to the Two Rocks transect with a 190khz ADCP deployed near the head of Canyon in 200m depth, and two thermistor chains of SBE 39's to a depth of 500m. Both arrays also include RBR DR-1050 pressure sensors located near the bottom of the moorings for accurate barotropic pressure recording. Care was taken during the design of the arrays to ensure that sensors on the various moorings were consistently deployed across similar depths to avoid confounded transect comparisons of the water column.

4. QUEENSLAND AND NORTHERN AUSTRALIA

The Queensland and Northern Australia sub-facility consists of two NRS sites at Yongala and Darwin and four pairs of array moorings located north to south along the Great Barrier Reef (GBR). For the array moorings, each of the 4 pairs has an outer mooring on the continental slope in water greater than 200m and an on-shelf mooring sitting in shallower water around 30-70m deep. Like other ANMN moorings, the array deploys a range of instrumentation including ADCPs and WQMs. Three of the four shelf moorings will also have surface buoys to measure meteorological and radiation observations in real-time. The sub facility's objective is to observe the cross-shelf exchange of water between the Coral Sea and the GBR. Water moving along and onto the GBR will be measured by monitoring the southward flowing EAC and the northward Hiri western boundary current. The moorings located in the southern GBR monitor the strength of currents related to upwelling events detectable on the Capricorn-Bunker Shelf, which supply deep, nutrient-rich water to the reef (also see Steinberg *et al* in this volume).

5. ACOUSTIC OBSERVATORIES

The Passive Acoustic Observatories sub-facility has deployed arrays of acoustic listening stations that passively record sounds from the ocean. The stations provide baseline data on ambient oceanic noise, detection of fish and mammal vocalizations linked to ocean productivity, whale migration patterns and detection of underwater events. Through an analysis of these signals, it is possible to both identify different species and assess the number of animals present within the range of acoustic observation. Animals can also be located in space if they are close to an observatory or a bearing obtained if they are distant, by a horizontal array of sea noise loggers.

Arrays are located in the Perth Canyon and Portland in South Australia with a final installation planned for Sydney, NSW. These sites have been chosen due to their biological interests; for example, the Perth Canyon is a focal feeding area for pygmy blue whales, *Balaenoptera musculus brevicauda*, on the Western Australian coast [4]. This particular array is also closely matched to the moorings being deployed in the canyon by the Western Australian sub-facility. This will allow for correlations between the acoustic data on biological processes with oceanographic data.

6. NEW SOUTH WALES

The New South Wales sub-facility is establishing a national reference transect of moorings and bio-geo-chemical measurements off Sydney, which includes all parameters measured by other NRS. Like the NRS sites at Maria and Rottnest Islands, data has been collected for over 70 years at Port Hacking in the south of Sydney. The NRS transect consists of three moorings in 65, 100 and 140m of water and four water sampling stations in 25, 50, 100 and 125m of water in an area downstream of where the EAC typically separates from the coast, and is hence often influenced by EAC eddies. The sub-facility has also deployed two moorings across the shelf at Coffs Harbour, upstream of the EAC separation point, and a single mooring at Jervis Bay, south of Sydney. The arrays will enhance the ANMN coverage along the coast of south-eastern Australia to provide long term monitoring of the continental shelf oceanography both upstream and downstream of the EAC separation point. Also, as the sub-facility is located in the most densely populated area of Australia, issues such as water quality, waste disposal, shipping hazards, harmful algal blooms and recreation are also of particular research interest (also see Roughan *et al* in this volume, and [5]).

7. SOUTH AUSTRALIA

The Southern Australian sub-facility is deploying six moorings to monitor the large seasonal coastal upwelling of water that occurs along the continental shelf during summer. This includes a NRS site at Kangaroo Island, located at a convergence point of isobaths to monitor upwelling/outflow events as well as long-term variations in the strength of the coastal current. The array also includes a slope mooring at the 600m isobath to measure the Flinders Current. The Flinders Current is in part driven by the Tasman Outflow, a remnant of the EAC, and also forms a link to the west where it becomes the Leeuwin Undercurrent. Three shelf moorings are located in the path of both upwelling and downwelling to measure the alongshore currents and exchange, and the planktonic systems as they evolve towards the St. Vincent and Spencer Gulfs and Eyre Peninsula. An outer shelf mooring examines outflows of saline rich water from coastal gulfs during winter as well as enhanced upwelling from the du Couedic Canyon. A substantial water sampling program is also undertaken to measure temperature, salinity, nutrients, phytoplankton, viruses and bacteria. The purpose of the sampling and mooring programs is to understand and monitor the boundary/shelf currents and ecosystems of the region.

8. SATELLITE OCEAN COLOUR CALIBRATION AND VALIDATION

The Satellite Ocean Colour Calibration and Validation (SOCCV) sub-facility is located on the Lucinda Jetty in Northern Queensland. Like other ANMN sub-facilities SOCCV will provide telemetered data streams. However, unlike the limited data provided through satellite or mobile

phone networks, the SOCCV has a broadband link and mains electricity. As the jetty itself is the longest in the Southern Hemisphere, extending 5.76km out into the GBR lagoon, this effectively makes the site a coastal cabled observatory. The observatory aims to ground-truth remotely sensed data from satellites. For tropical Queensland coastal waters data products that are derived from remote sensing for ocean colour tend to be inaccurate due to the optical complexity of the waters and the overlying atmosphere. The observatory will become the pre-eminent source for validation of coastal-ocean colour radiometry for biogeochemistry and climate studies in Australia. It will merge two different data streams: surface measurements of water radiance and the in-water measurement of their optical properties. The observatory site will also be used to provide satellite operators and data users with reliable calibration and validation data for satellite missions.

9. DATA MANAGEMENT

Along with all other IMOS facilities, data collected by the ANMN is open access. To allow this, data is provided in a timely manner to the IMOS data hosting and management facility, eMarine Information Infrastructure (eMII) (http://imos.org.au/emii.html), which is based at UTAS. IMOS also has a commitment to provide, where possible, real time data from sensors via telemetry. Both the delayed mode data, which includes all logged files from the various sensors and samples, and averaged telemetered data are archived within the Australian Ocean Data Network (AODN). Though eMII is based at UTAS in Hobart, AODN employs a distributed data storage and discovery network, based at various Australian research facilities around the country.

10. CONCLUSIONS

The theme of the facility is monitoring the behaviour and attributes of Australia's continental shelf boundary currents by combining elements of physical, chemical and biological oceanography. This makes it the largest and most scientifically diverse of the IMOS facilities.

The ANMN is set to expand in the future. This includes more sites established across the country, ADCPs for all NRS sites and additional mooring types that measure pCO_2. As the data from this massive investment in research infrastructure begins to flow the facility's real measure of success will be in the science generated to help us understand the waters of Australia's continental shelves.

10.1 Acknowledgments

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