The Integrated Marine Observing System – delivering data-streams to support marine research and applications

Tim Moltmann[1], Roger Proctor[1,2], Katy Hill[1], Marian McGowen[1]

[1]*Integrated Marine Observing System, University of Tasmania, Private Bag 110, Hobart, Tasmania 7001.*

tim.moltmann@imos.org.au, roger.proctor@utas.edu.au, katy.hill@imos.org.au, marian.mcgowen@utas.edu.au

[2]*Proudman Oceanographic Laboratory, 5 Brownlow Street, Liverpool, L3 5DA, UK*

Abstract - The Integrated Marine Observing System (IMOS) is funded by the Australian Government through the National Collaborative Research Infrastructure Strategy (NCRIS) and the Education Investment Fund (EIF) to deliver data-streams from the Oceans around Australia. IMOS aims to meet the needs of the research community, address issues of national importance and contribute to international ocean observing programs. The strategic focus of IMOS is on the role of the oceans in the climate system, and the impact of major boundary currents on the continental shelf, ecosystems and biodiversity.

IMOS operates as a matrix of *Nodes* and *Facilities*. The scientific rationale for the observing system is determined by science *Nodes* that act as focal points for the scientific community and stakeholders to influence the design of the observing system. There is a Bluewater and Climate Node, and a number of Regional Nodes linked by a national backbone. IMOS *Facilities*, operated by a number of different institutions within the National Innovation System, are responsible for deploying IMOS infrastructure and delivering data streams for use by the Nodes and other stakeholders. The Facilities, not the Nodes, are funded under the IMOS system.

IMOS has built a national capability in using the newest technologies in ocean observing, some of which had not been previously used in Australia. Platforms utilized for sustained ocean observation in IMOS include Argo profiling floats, autonomous gliders, ships of opportunity, shelf and deep water moorings, coastal radar systems, sensor networks, acoustic tagging and monitoring system for fish and mammals, satellite remote sensing and an autonomous underwater vehicle.

Multiple platforms measure the same parameter to ensure time, space and depth scales are covered. For instance temperature is measured by Satellites which measure "skin" sea surface temperature (SST), Gliders which take profiles along transects across the shelf, Argo floats which provide broad-scale ocean temperature to 2000m, Ships of Opportunity which provide high density observations along ships tracks and shelf and deepwater moorings which provide long time series.

All IMOS data is freely available from the IMOS Ocean Portal. The IMOS Ocean Portal allows the marine science community to discover and explore the data streams coming from all of the Facilities. For more information and access to data, visit http://www.imos.org.au.

I. BACKGROUND

The Integrated Marine Observing System aims to observe the oceans around Australia to meet the national and international research needs. Australia has one of the largest marine jurisdictions of any nation on earth [1]. At over 14 million km^2 Australia's Exclusive Economic Zone (EEZ) is nearly twice the surface area of the Australian continent. It extends from the tropics to high latitudes in Antarctic waters and much of it is unexplored.

The surrounding Pacific and Indian Oceans strongly affect the continental climate-system at all time scales, from seasons to decades. The major ocean currents on its eastern, western, northern and southern boundaries, best known of these being the East Australian Current (EAC) and the Leeuwin Current (Fig.1) affect regional climatic conditions and help sustain the marine ecosystems. There is evidence that these currents are changing on decadal time scales [2] and have already impacted marine ecosystems.

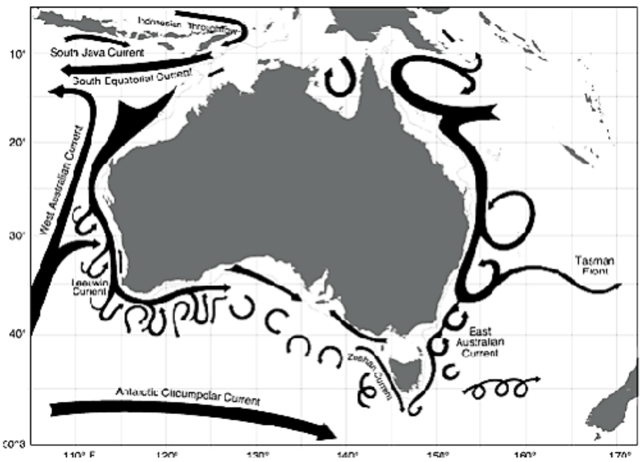

Figure 1 – boundary currents around Australia

One of the longest timeseries of marine data in Australia, a 40-year timeseries of sea surface temperature from Maria Island, Tasmania, one of the IMOS National Reference Stations, indicates, in Fig. 2 (taken from [2]), decadal

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oscillations superimposed on a rising trend in temperature, twice the global average, in part due to the increasing southerly extent of the EAC. Data, however, is sparse and neither the currents nor ecosystems have been monitored in a systematic way.

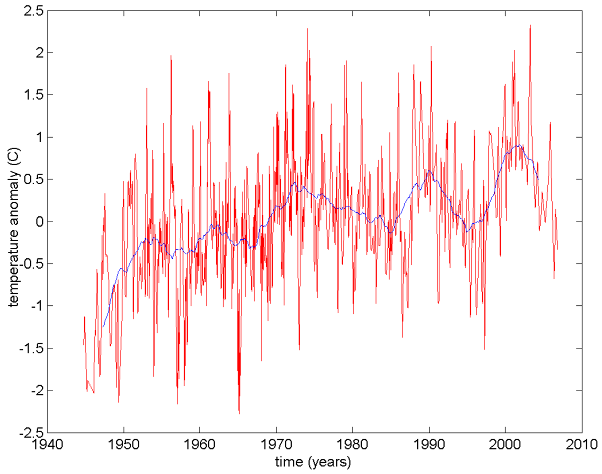

Figure 2 - Showing long term trend and decadal oscillations in the Maria Island sea surface temperature (from [2]).

IMOS Goals

IMOS is a nationally managed and distributed set of equipment established and maintained at sea, providing streams of in situ oceanographic data and information services that collectively will contribute to meeting the needs of marine research in both open oceans and coastal oceans around Australia. Combined with satellite data, it provides essential information to understand and model the role of the oceans in climate change, and data to initialize seasonal climate prediction models. If sustained in the long term, it will permit identification and management of climate change in the coastal marine environment. It will provide an observational nexus to better understand and predict the fundamental connections between coastal biological processes and regional/oceanic phenomena that influence biodiversity. While as an NCRIS project IMOS is designed to support research, the data streams are also useful for many societal, environmental and economic applications, such as management of marine natural resources and their associated ecosystems, support and management of coastal and offshore industries, safety at sea, marine tourism and defence.

The IMOS strategic research-goal is to assemble and provide free, open and timely access to streams of data that support research on:

- The role of the oceans in the climate system, and
- The impact of major boundary currents on continental shelf environments, ecosystems and biodiversity.

The scientific rationale for IMOS is set by six regional Nodes covering Queensland (QIMOS, including the Great Barrier Reef), New South Wales (NSWIMOS, southeastern Australia), Southern Australia (SAIMOS), Western Australia (WAIMOS), Tasmania and Bass Strait (TASIMOS), and the Bluewater and Climate (BWC) Node (Fig. 3). The intention is to have a single, national IMOS with Node emphasis appropriate to regional characteristics of the marine system. Nodes are linked through integrated Science Plans (available on the IMOS website) addressing five major research themes

- Multi-decadal Ocean Change
- Climate Variability and Weather Extremes
- Major Boundary Currents and Inter-basin Flows
- Continental Shelf Processes
- Biological Responses

Each Node has 50 to 100 members. The Node Leaders and the Director of the IMOS Office are members of the IMOS Steering Committee. Nine national Facilities under direction of the IMOS Office make the observations specified by the Nodes using different components of infrastructure and instruments, for example there are separate facilities for Argo floats, ships of opportunity, coastal radar, etc. The observing facilities include three for ***bluewater and climate observations*** (Argo Australia, Enhanced Measurements from Ships of Opportunity and Southern Ocean Time Series), three facilities for ***coastal currents and water properties*** (Moorings, Ocean Gliders and HF Radar) and three for ***coastal ecosystems*** (Acoustic Tagging and Tracking of fish and mammals, Autonomous Underwater Vehicle (AUV) and a biophysical sensor network on the Great Barrier Reef).

Figure 3 – IMOS Nodes and Facilities

The operators of the facilities are the major players in marine research in Australia. A satellite remote sensing facility assembles data for the region (sea surface temperature and ocean colour) and the electronic Marine Information Infrastructure (eMII) provides access to all IMOS data, enhanced data products, and web services in a searchable and interoperable framework. Recognizing the importance of access to data in eResearch, the Director of eMII also is a member of the IMOS Steering Committee. The value from this infrastructure investment lies in the nationally coordinated deployment of a wide range of equipment aimed at deriving critical data sets within a region that serve multiple applications.

Implementation of IMOS facilities began in 2007 under NCRIS funding. The recent additional EIF funding has allowed IMOS to enhance the measurement capability in a number of ways:

- an increased capacity to measure the southern ocean through a) the deployment of more Argo floats many equipped to go under ice, b) surface flux measurements from moorings and ships of opportunity, c) a deep water array measuring transport of Antarctic water to the Southern Ocean, d) utilizing seals with attached ctd devices, ‘live argo floats’, e) repeat glider transects;
- full depth monitoring of the Indonesian Through Flow and of boundary currents in the EAC and the Leeuwin Current;
- increased biogeochemical sampling at National Reference Stations in shelf and coastal waters.

A Significant proportion of the planned infrastructure has now been deployed. And free and open access to IMOS data streams in near real time is available through the IMOS Ocean Portal (Fig.4) accessible through the IMOS website.

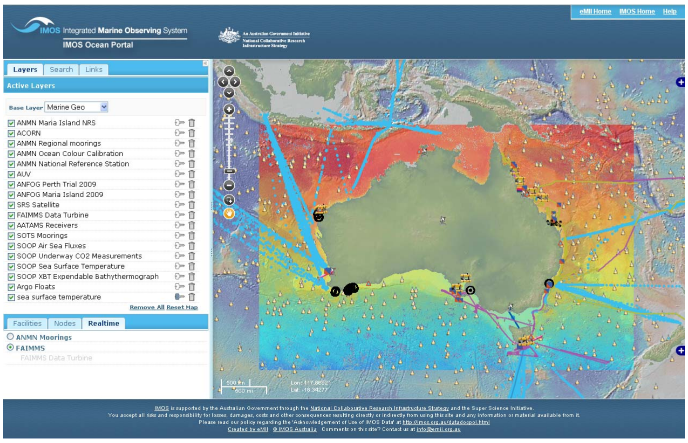

Figure 4 – View of the IMOS Ocean Portal

Marine data and information are the main products of IMOS and data management is therefore a central element to the project's success. eMII provides a single integrative framework for data and information management that will allow discovery and access of the data by scientists, managers and the public. The initial strategy has focused on defining specific data streams and developing end-to-end protocols, standards and systems to join the related observing systems into an unified data storage and access framework.

The IMOS information infrastructure, a robust working infrastructure for end-to-end data management, provides search, discovery and access to IMOS data. The components consist of:

- A distributed data storage network
- A GeoNetwork metadata catalog holding ISO 19115/19139 standard records (MEST)
- An ocean portal for map-view access to the data (Fig.4), providing
    - A national facility view of data
    - A regional node view of data
    - A real-time view of data
    - A search and discovery view of data

Data may be downloaded either through the portal or from the MEST and all components are built on open source software and to international standards. A distributed data storage system has been developed in association with the Australian Research Collaboration Service (ARCS). This has involved utilizing the ARCS Data Fabric, a ‘cloud’ storage system, i.e. the location of data across multiple platforms is invisible to the user. Data storage facilities have been set up at the regional high performance computing centres within four of the IMOS regional nodes (WAIMOS, SAIMOS, NSWIMOS and QIMOS) linked through the Australian Academic and Research Network fibre optic backbone (10GBit Bandwidth), with additional storage and system monitoring in Tasmania at the Tasmanian Partnership for Advanced Computing.

Recognizing that a significant proportion of IMOS data is either gridded (satellite, high frequency (HF) radar) or in timeseries form (Argo, ships of opportunity, gliders, moorings, networked sensors) and could sensibly be written into a self describing format (CF compliant netCDF) meant that advantage could be taken of emerging web services to access these data through OPeNDAP/THREDDS servers. Both netCDF format data and non-netCDF format data (e.g. AUV imagery) can be accommodated within the ARCS Data Fabric.

II. FACILITIES

Argo Australia is a program that provides observations of the oceans around Australia by maintaining an array (>220) of autonomous profiling floats. Argo floats measure temperature and salinity from 2000 m depth to the surface every 10 days. Some also measure oxygen. Data is supplied within 24 hours via the real-time data stream and highly quality-controlled data is available after 6 months as part of the delayed mode data stream. Argo provides the essential and in situ data for ocean and climate research and prediction/re-analyses.

The **Ship of Opportunity** Facility (SOOP) conducts a set of integrated, repeat underway observing systems on research vessels and volunteer ships in Australian regional seas that link physical, chemical and biological oceanography. The target regions are the boundary current systems off Eastern and Western Australia, the Southern Ocean, the shelf seas across northern Australia, and the Great Barrier Reef. The observations span spatial scales from eddies to basin width and timescales from seasonal to decadal. There are several sub-Facilities, each dealing with a different aspect of measurement:

a) *Multidisciplinary Underway Network* - using commercial shipping lines to add biogeochemical observations to the existing expendable bathythermograph (XBT) lines. This will improve coverage, enabling researchers to monitor the transport of mass, heat and freshwater in Australia's major boundary currents and their relation to ecosystems. Biogeochemical sensors will be added to the National Marine Research Facility, RV *Southern Surveyor* to monitor the sensitivity of biogeochemical cycling to climate change, and to measure CO_2 uptake in critical areas. Continuous Plankton Recorder (CPR) devices, capable of recording species-level data of phytoplankton and zooplankton, are installed on two lines to establish links between planktonic ecosystem structure and large-scale physical variability. One line runs down the core of the East Australia Current and the second across the Southern Ocean to Antarctica. The State Government of Victoria recently enhanced this sub-facility to include an autonomous marine monitoring system on the Bass Strait ferry, the Spirit of Tasmania 2. The sensors record temperature, salinity, chlorophyll-a and turbidity. A recent addition to this facility is the installation on research vessels (RV *Southern Surveyor*, RV *Aurora Australis*) and large fishing vessels of acoustic equipment to carry out repeated acoustic transects collecting bio-acoustic measurements which give estimates of mid-trophic organism distribution and abundance around the Australian Exclusive Economic Zone shelf, slope and oceanic environments.

b) *Sensors on tropical research vessels* - increase the monitoring of the Great Barrier Reef and the western Coral Sea. The research vessels *Cape Ferguson* and *Solander* have been upgraded to include thermosalinograph and chlorophyll-a sensors, with the total suite of sensors able to record temperature, salinity, fluorescence, light absorption and irradiance. These research vessels undertake repeated transects in the target areas as well as individual cruise tracks.

c) *Sea Surface Temperature (SST) Sensors* - In order to improve calibration and validation of satellite SST in the Australian region, there is a need for high quality *in situ* SST observations with greater timeliness, spatial and temporal coverage. Typically, SST observations from the ships of opportunity program (SOOP) in the Australian region are either of uncertain accuracy or difficult to access in a timely manner, and have therefore not been used for near real-time validation of satellite SST observations. Through IMOS, new streams of high quality, near real-time (within 24 hours), SST observations from eight vessels in the Australian region have become available on the IMOS data portal and the Global Telecommunications System. By the end of 2010 new data streams from a further six Australian vessels will be added to the project.

d) *Real-Time Air-Sea Fluxes* - sensors have been installed on RV *Southern Surveyor* and RV *Aurora Australis* to produce high quality, real-time measurements of air sea fluxes (the transfer of heat and freshwater between the atmosphere and the sea). Improved knowledge and mapping of air-sea fluxes is one of the great challenges of climate research. Data is being collected for studying the role of the ocean on climate variability, carbon levels, ecosystems and coastal environments.

The Australian Bluewater Observing System (ABOS) targets the coordination of national efforts in the sustained observation of open ocean properties to meet the needs of the Bluewater and Climate Node and various Coastal Node plans, with particular emphasis on observations important to climate and carbon cycle studies. The Facility consists of three elements:

i) *Southern Ocean Time Series (SOTS)* **-** multiple moorings deployed in the Subantarctic Zone southwest of Tasmania. The emphasis is on inter-annual variations of upper ocean properties and their influence on exchange with the deep ocean and includes physical, chemical, and biogeochemical observations.

ii) *Air-Sea Flux Stations (ASFS)* – the Southern Ocean Flux Station (SOFS) at the SOTS site.

iii) *Deepwater Arrays sub-facility (DA)* **-** Observations of deep ocean currents and properties needed to monitor ocean circulation and property variability in the ocean surrounding Australia and provide estimates of the ocean contribution to the regional and global circulation, heat and freshwater content and change. This includes observational programs based on moored conductivity-temperature-depth sensors and current meter arrays in deep waters that are specifically targeted to monitor formation of Antarctic Bottom Water, inter-basin exchange and major boundary currents. The Deepwater array sites include :

a) the Adelie Land Coast deep shelf to observe outflows of newly forming Antarctic Bottom water – *the Polynya array.*

b) Timor Passage and Ombia Strait, to monitor the inter-basin Indian-Pacific Ocean exchange and the upper limb of the global overturning circulation – *the Indonesian Through Flow (ITF) array.*

c) east coast of Australia, near Brisbane, to monitor the East Australian Current transport – *the EAC array*.

The **Australian National Facility for Ocean Gliders** (ANFOG) maintains a fleet of continental shelf and deep water gliders to obtain sustained data streams to monitor eddies, boundary currents and coastal seas. Ocean gliders are autonomous vehicles designed to operate in water depths up to 1000 m. By changing its buoyancy, the glider is able to descend and ascend. Two different types of gliders are in operation. The Slocum glider is designed to operate to a maximum depth of 200m and a maximum endurance of 30 days, whilst the Seaglider is able to operate to a maximum depth of 1000m and a maximum endurance time of up to 6 months. Both gliders have the same suite of sensors to measure conductivity (for salinity), temperature, dissolved oxygen, fluorescence, turbidity and coloured dissolved organic matter (CDOM) with depth.

The **Autonomous Underwater Vehicle** (AUV) facility provides precisely navigated time series measurements of benthic imagery using AUVs at selected reference stations on Australia's shelf. The AUVs provide a critical observational link between oceanographic and benthic processes. The facility generates physical and biological observations of benthic variables that cannot be cost-effectively obtained by other means. Data streams produced include precisely geo-referenced benthic imagery, multibeam swath bathymetry, Conductivity, Temperature, Depth (CTD) profiles and fluorometer data measuring chlorophyll-a and CDOM, turbidity (scattering in red) and photosynthetically active radiation (PAR), at the benthic reference sites.

The **Australian Mooring Network** (AMN) facility infrastructure is composed of nationally distributed systems of coastal and continental shelf moored sensors and associated biogeochemical (BGC) water sampling. The multiple datasets collected measure physical, chemical and biological parameters of coastal waters. The nine National Reference Stations (NRS) increase the number of long term time series observations both in terms of variables recorded, temporal distribution and geographical extent. Passive acoustic listening station arrays are located at three NRS sites providing baseline data on ambient oceanic noise, detection of fish and mammal vocalizations and detection of underwater events. The regional moorings monitor the interaction between boundary currents and shelf water masses and their consequent impact upon ocean productivity (e.g. Perth Canyon upwelling; Kangaroo Island upwelling) and ecosystem distribution and resilience (e.g. Coral Sea interaction with the Great Barrier Reef). A new NRS in Queensland, off the coast of North Stradbroke Island, complements new shelf moorings and deepwater moorings designed to monitor the transport of the EAC. Shelf moorings are organised on a regional basis for Queensland and Northern Australia, New South Wales, Southern Australia, Western Australia, and Tasmania.

The **Australian Coastal Ocean Radar Network** (ACORN) facility operates a network of HF ocean radar stations within Australia. The Facility is installing 6 pairs of stations at the following sites:

a) QLD Great Barrier Reef – around Heron Island
b) SA Gulfs – around the entrance to the Gulfs
c) WA Turquoise Coast between Seabird and Cervantes
d) WA Rottnest Shelf
e) SA Bonney Coast off Mt Gambier
f) NSW Coffs Harbour.

Of these, (a)-(d) are in place and working, and (e) and (f) are scheduled for installation in 2010. The primary data are maps of surface currents, with wave directional spectra, significant wave heights and wind directions observations also being available.

The Australian Acoustic Tagging and Monitoring System (AATAMS) has two objectives: The first is to create a national acoustic receiver network for the Australian research community thereby facilitating large scale, collaborative research using acoustic tagging methods. Acoustic monitoring is a powerful tool for observing animals in coastal and continental shelf ecosystems. Networks of receivers, all around Australia, allow animals to be monitored over scales of 100s of metres to 100s of kilometres. AATAMS is making an important contribution to the Ocean Tracking Network (OTN), a global partnership and co-investor in AATAMS. The second is to enhance the Australian research community's ability to detect ecosystem responses to change in the marine environment by measuring key demographic parameters and foraging movements of select top predators in the Southern Ocean. Miniaturized loggers with high resolution sensors are deployed on large marine vertebrates (typically 30 per year). This directly enhances the collection of oceanographic data in the Southern Ocean and in Australian boundary currents by providing profiles of temperature and salinity from regions of the Southern Ocean and coastal shelf regions that are difficult to sample by other means (e.g. beneath the winter sea ice and across cross-shelf currents), and by relating predator movements and behaviour to fine-scale ocean structure and variability.

Facility for the Automated Intelligent Monitoring of Marine Systems (FAIMMS) was set up as a test case for deploying new types of observing systems ('smart' sensor networks), so far four sites have been successfully set up and in doing so the Facility has created the world's first coral reef wireless sensor network. Sensor Networks are being deployed at seven sites along the Great Barrier Reef from Heron and One Tree Islands in the South to Lizard Island in the North.

The **Satellite Remote Sensing** Facility (SRS) integrates data from reception stations around Australia acquiring data from environmental satellites and serves derived data products (of Sea Surface Temperature and Ocean Colour) to the Australian research community. This delivery is carried out through the Australian Oceans Distributed Active Archive Centre (AODAAC) data access infrastructure within the IMOS portal. Satellite remote sensing of the sea surface has proven to be a powerful observational technique, and is the only means to provide a truly synoptic view of large areas of the ocean at a moment in time. In addition an Ocean Colour Calibration and Validation Station at Lucinda Jetty, QLD, is maintained for Case 1 waters, with the ability to support validated data production for Case 2 waters. Two Altimetry Calibration and Validation Stations in Bass Strait and Storm Bay, Tasmania complete the SRS activity.

The **eMarine Information Infrastructure** (eMII) provides a single integrative framework for data and information management, discovery and access for IMOS data, through the IMOS Ocean Portal, with increased emphasis on data integration (observations and models) and value-adding. eMII hosts, manages and archives the data (raw and / or processed) from the IMOS facilities and supports the exploitation of these data by the IMOS nodes. eMII provides the standards, protocols and systems to integrate the data and related information into a single framework and provides the tools to allow end users (i.e. researchers, managers and the public) to access and utilise the data.

Extensive descriptions of Facility operations can be found on the IMOS website.

Given the commitment to the Facility and Node structure, the IMOS Strategy (2009-2013) will be to drive a national, collaborative approach to sustained ocean observing, designed to answer big science questions posed through the Nodes. Integration across time, space and depth scales, across physics, chemistry and biology, and between observing and modelling, will be further developed. The aim will be to enable open and timely use of data streams via an Australian (ocean) research data commons. Strong, mutually-beneficial partnerships between the institutions that make up the marine and climate component of the National Innovation System will be fundamental. The ten strategic priorities are:

1) Ongoing development of a coherent, well-positioned Bluewater and Climate Node
2) Impact and delivery through improving model output
3) Providing a national backbone for observing boundary currents
4) Ongoing development of Regional Nodes
5) Continuing to build institutional strengths into national capability
6) Exploring the potential for whole-of-system approaches
7) Driving down the cost per observation
8) Creating and developing the information infrastructure
9) Ensuring the data is used
10) Partnering for sustained ocean observing.

Detailed descriptions of these priorities are found in the IMOS 5 Year Strategy [3].

III. EXAMPLES OF DATA-STREAMS SUPPORTING MARINE RESEARCH AND APPLICATIONS

1. *Gravity currents from glider measurements off Perth Canyon, WA.*

From a series of transects, with a Slocum glider, new insights into the processes active in the Two Rocks / Rottnest Island / Perth Canyon region have been obtained. Repeat transects between January and March 2009 (transect route shown in Fig. 5) show the development of an evaporation - driven high salinity layer which cascades across the shelf into the deep ocean.

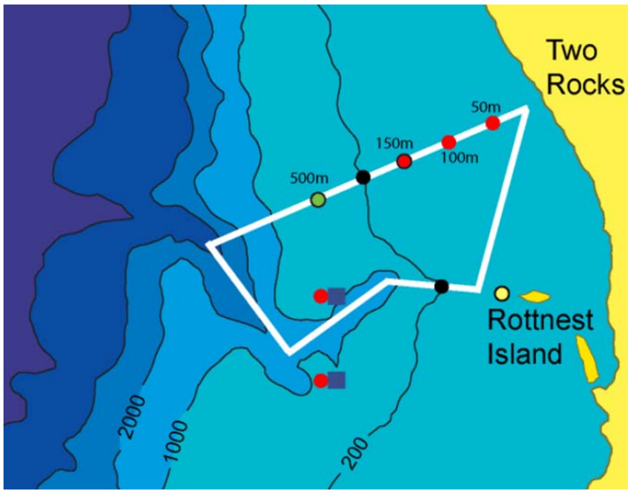

Figure 5 – Glider Transect

Transects (from coast to ocean) of salinity are shown for 22 February, 14 March and 21 March 2009 in Fig.6 (a-c). On the 22 February hot weather and evaporation leads to the formation of higher salinity water close to the coast. By the 14 March this established a gravity-driven bottom water plume on the shelf which, by 21 March had reached the edge of the continental shelf.

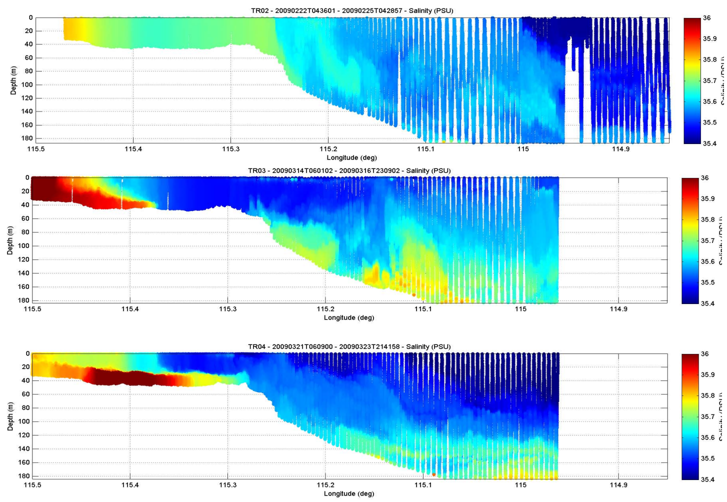

Figure 6 – Transects of salinity from coast (left) to ocean (right) from a Slocum glider (a) for 22 February (top), (b) 14 March (middle), (c) 21 March 2009 (bottom).

These glider deployments yielded in excess of 4000 CTD casts, providing the high resolution data in space and time needed for the discovery of features such as those seen in Fig. 6, features which would not be seen by more traditional methods of sampling.

2. Temperature profiles from CTDs on sea-lions in the Great Australian Bight, SA.

There are five species of sea lions worldwide and the Australian sea lion, which is only found in southern Australia, is one of the rarest, and as a threatened species it needs protection. But for that to be effective, much more needs to be known about how these animals live, where they travel and what they eat. Using satellite transmitters glued to the backs of seals produces information on the locations of these animals when they're at sea. This helps the understanding of foraging behaviour. Extending this technology and using top predators as 'living gliders' is providing hither-to unavailable information on their diving habits, and consequently on the vertical structure of the waters they inhabit. The CTD-SRDL tags, currently attached to 10 sea lions, include high-resolution temperature and conductivity sensors with accuracies of 0.01º C, and 0.01 mS/cm respectively. The tag performs up-casts depending on time and depth criteria that suit the deployment, sampling every 0.5 sec. With good satellite coverage four full temperature and salinity profiles will be transmitted each day.

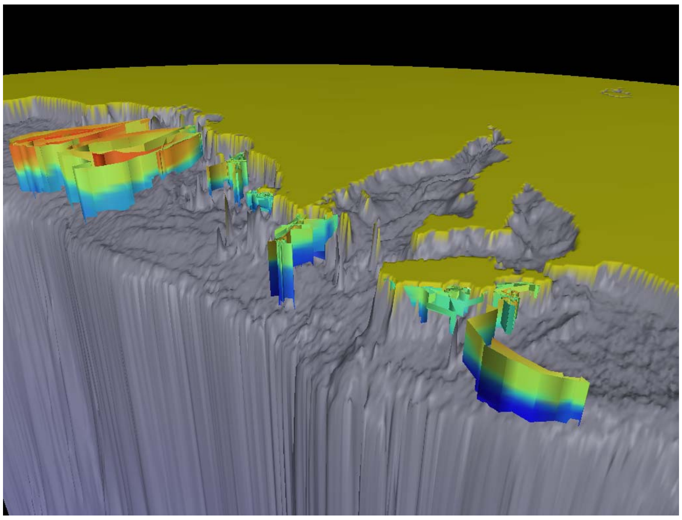

Figure 7 – vertical temperature structure measured by CTD units on sea lions.

Figure 7 shows an example of sea lions behaviour, and the recorded temperature profiles. Tracks to the shelf edge for feeding and back to the coast provide detailed vertical structure across the whole shelf. Wherever possible the CTD-SRDLs will be recovered from the sea lions for re-use.

The maritime expeditions of the Australian sea lions are now yielding data that are important to both biologists and oceanographers and refining our understanding of the intimate connections between the mechanics of the Earth's oceans, and the complex ecosystems which dwell within and upon them. Analysis of the information will also provide measures of relative foraging and reproductive success. These metrics will differ between species but are likely to include trip durations, trip distances and foraging trip mass changes, and offspring mass changes and survival where applicable. Combined foraging locations will also be provided as estimates of overall foraging activity to identify Areas of Ecological Significance. These data will also provide important information for ecosystem modelling on predator foraging ecology and top-down controls on lower trophic levels for ecologists and natural resource modellers. Furthermore these foraging location data will be used to assess foraging success in relation to temporal and spatial oceanographic variation of the region.

IV. INTEGRATION OF DATASETS

As more IMOS data streams become available the opportunity arises for integration of multi-parameter multi-disciplinary datasets to enable a more complete analysis of the environment to be made. One example of this will be combining information from measurement platforms in the Southern Ocean. A transect from Hobart, Tasmania to Dumont d'Urville in Antarctica provides the opportunity for combining IMOS measurements of surface and sub-surface properties and fluxes.

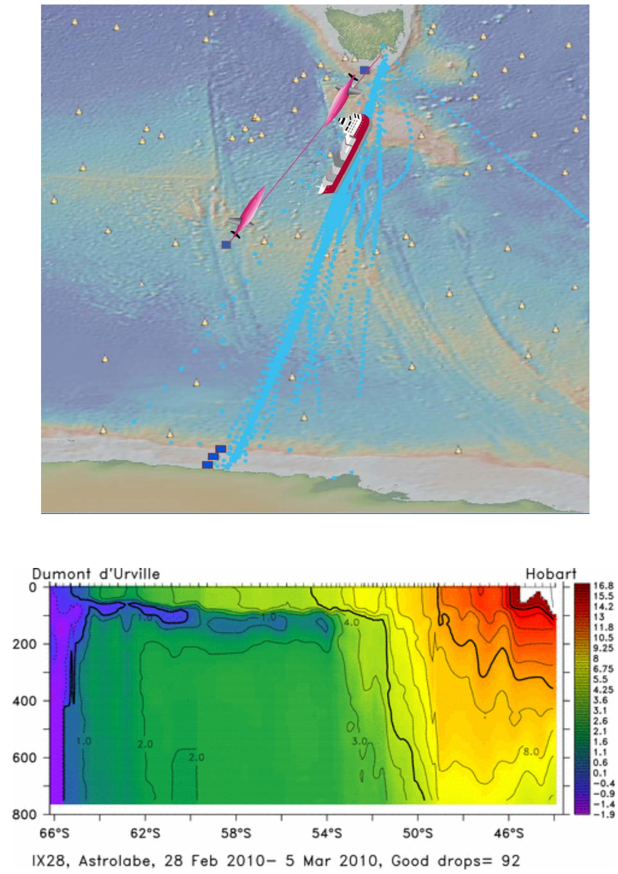

Figure 8 – Measurements from the Southern Ocean

Figure 8 shows the potential measurement platforms (top) and a recent transect of temperature structure measured by XBT from the *Astrolabe* (bottom). In addition to XBTs (blue dots), the *Astrolabe* also measures SST, surface fluxes, tows a

CPR for plankton and primary production biomass and is planned to carry acoustics to measure mid-water secondary production biomass. At the nearby ABOS (SOTS) mooring (blue square) water column bio-physical processes and air-sea fluxes are measured. Also shown are ARGO floats (yellow dots) measuring temperature, salinity, and sometimes oxygen profiles, a glider transect between the SOTS mooring and Hobart measures profiles of temperature, salinity, oxygen, chlorophyll-a and turbidity, and the deepwater mooring array at the Antarctic ice edge (three blue squares, the Polynya Array) measures transport of Antarctic bottom water into the Southern Ocean. These measurements are complemented by surface SST and Ocean Colour distributions from satellite remote sensing. The challenge will be to bring data from these different disciplines and sampling systems together in a coherent way, taking into account the different uncertainties associated with the instrumentation and space/time sampling.

V. SUMMARY

It is clear that IMOS data will contribute to increasing our understanding of the bio-physical and ecosystem dynamics and processes taking place in Australian regional seas and oceans and hence make a significant contribution to the Global Ocean Observing System (GOOS). The enhanced observing capability will also provide new information for data assimilating operational ocean models (e.g. BlueLINK), validation for model re-analyses, and help reduce model uncertainty. The ocean is predictable at varying time and space scales, depending on the processes involved; an assessment of the predictability of the ocean is needed, to determine uncertainties in ocean forecasts. Such an assessment can feed into observing system design, and hence improve ocean forecasting in the future.

The Conference Statement of OceanObs'09 (see www.oceanobs.org) calls for significant enhancement of internationally-coordinated observation of the global oceans, and notes that the resourcing required is fragile and insufficient. This is meant to highlight the fact that most sustained ocean observing programs are funded via time-bounded research budgets. More specifically, it calls for:

- Sustaining and completing the current global observing system design, which is largely physical
- Extending it into biogeochemistry and biology, and into regional and coastal ecosystems
- Increasing efforts in providing free, open and timely access to data and information, and
- Increasing efforts in human capacity building and education.

In the context of the OceanObs statement, IMOS is very well-positioned to provide Australia's contribution to the global ocean observing effort required over the next decade. This is well-recognised within the international community. Our task is particularly significant because Australia has a very large ocean territory per head of population. Our counterparts in the US and France have larger ocean territories, but also far, far greater resources at their disposal. Delivering benefit from recent national investment, ensuring that we do take a truly national approach, and strengthening our engagement in international programs and regional alliances, will be crucial for 'sustaining the benefits, realising the potential' of ocean information for Australian society.

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