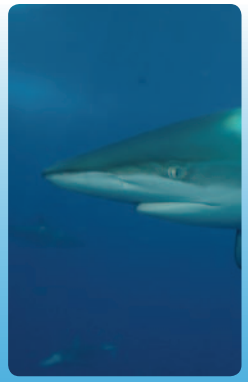
highlights 2011-2012

IMOS Integrated **Marine Observing** System



overview

Tim Moltmann
IMOS Director

The 2011-12 Annual Highlights document covers the fifth full year of IMOS operation, and the first year of extension beyond the initial NCRIS period, supported by an $18M per annum funding allocation made under the Marine and Climate Super Science initiative.

The vast majority of planned deployments and recoveries were successfully completed. A number of new deployments and data streams were initiated, including in the Kimberley and Pilbara regions of the North West, through $2M per annum cash co-investment by the Western Australian Government over three years. Overall progress against milestones was excellent. Of the 190 milestones under EIF and NCRIS, 91% were achieved with a further 7% substantially in progress at 30th June 2012.

Availability of data continued to build, and as at 30th June 2012 there were 2,143 metadata records created, all with data attached. IMOS has also received strong support and cooperation in taking responsibility for developing the Australian Ocean Data Network (AODN), demonstrating the benefits of having a national marine information infrastructure in place.

Since September 2011, the new IMOS *OceanCurrent* web site has been producing daily maps of surface currents and temperature using near real time observations from Argo floats, satellite altimetry, satellite sea surface temperature and, more recently, from ships of opportunity, ocean radars and satellite ocean colour. *OceanCurrent* has been very successful as a mechanism for uptake and use in both the scientific and user communities.

Science uptake of IMOS observations and data streams continued to grow during 2011-12 in line with expectations. For the second consecutive year, publications and reports using IMOS data grew by 40% per annum, to ~1,500 in total (cumulative). This includes 110 postgraduate projects, and 250 journal publications including those in press.

Importantly, it also includes 145 research projects and programs that are producing science outputs addressing priorities across a range of Government portfolios, industry sectors and societal needs.

In summary, the IMOS community has again worked effectively to deliver at a demonstrably high level in the 2011-12 year. Important steps have been taken in hardening the observational capability and the information infrastructure, and in growing the science uptake and production of relevant outputs. Indications are that all of these factors continue to trend positively in the first quarter of 2012-13. However the IMOS community cannot continue to deliver at this level without a clear signal of funding support beyond June 2013.

Scott Bainbridge, Australian Institute of Marine Science

How does it work?

IMOS is designed to be a fully-integrated, national system, observing at ocean-basin and regional scales, and covering physical, chemical and biological variables.

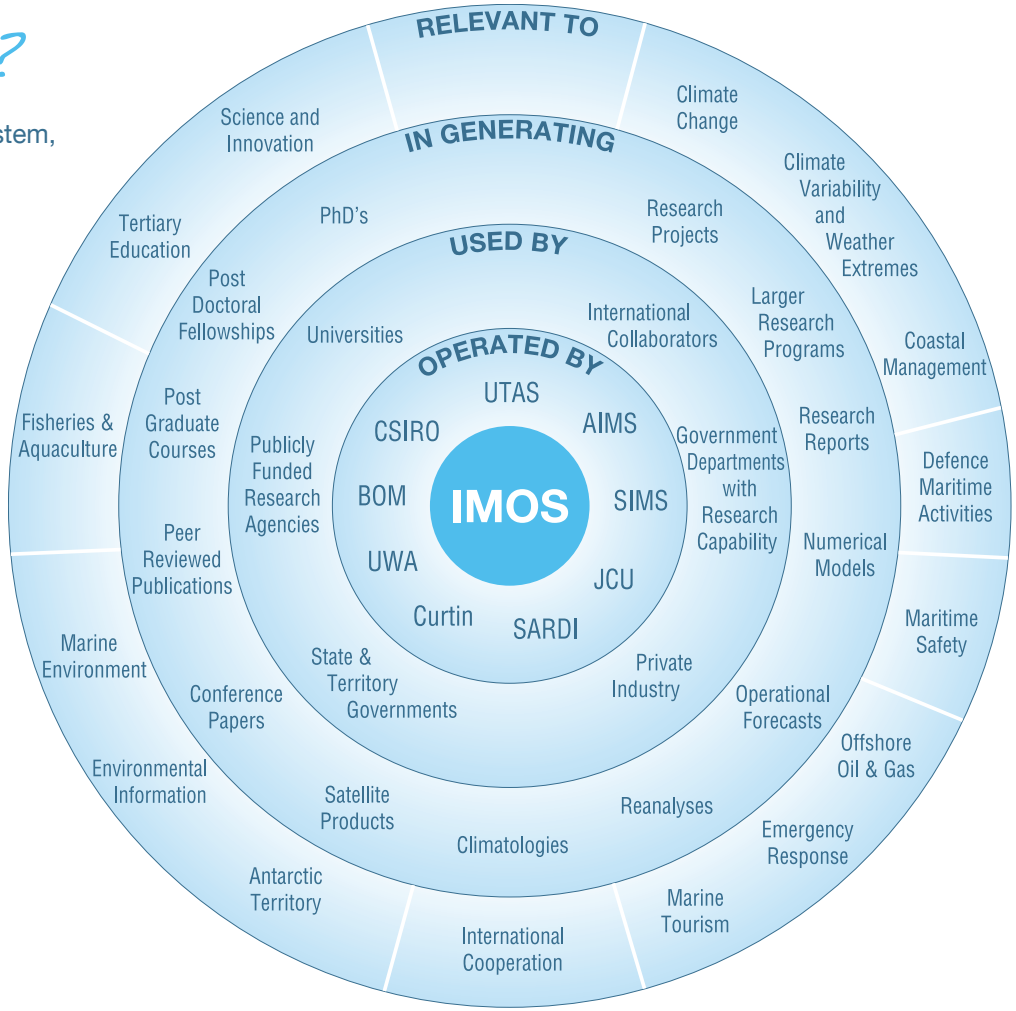
IMOS Facilities, operated by nine different institutions within the National Innovation System, are funded to deploy equipment and deliver data streams for use by the entire Australian marine and climate science community and its international collaborators.

IMOS observations are guided by science planning undertaken collaboratively across Nodes of the Australian marine and climate science community. There are five major research themes that unify IMOS science plans and related observations: Multi-decadal ocean change, Climate variability and weather extremes, Major boundary currents and interbasin flows, Continental shelf processes, and Ecosystem responses. This Annual Highlights Document is arranged by the major research themes, to provide a clear focus on relevance and impact.

The observations and data streams are collected via ten technology platforms, or Facilities:

- Argo floats
- Ships of opportunity
- Deep water moorings
- Ocean gliders
- Autonomous underwater vehicles
- National mooring network
- Ocean radar
- Animal Tagging and Monitoring
- Wireless sensor networks
- Satellite remote sensing

The IMOS Ocean Portal (http://imos.aodn.org.au) allows marine and climate scientists and other users to discover and explore data streams coming from all of the Facilities.



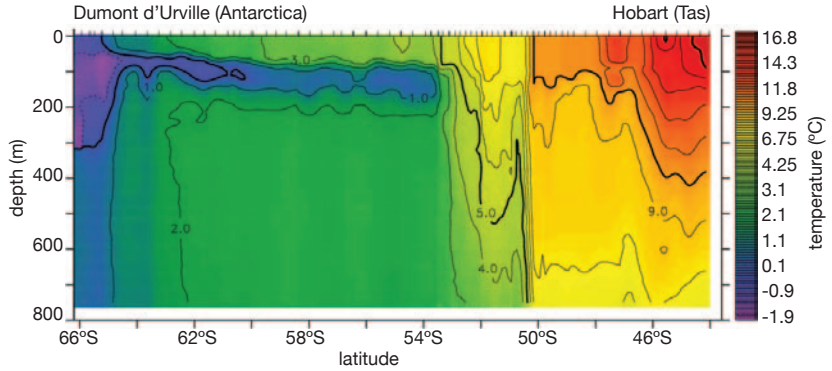
In the diagram above, we show how IMOS is being implemented through the Operating Institutions, and used by the entire sector to generate a wide range of science-based outputs that are relevant across multiple societal drivers.

Andrew Bowie, Antarctic
Climate and Ecosystems CRC

Multi-decadal ocean change

Tracking and understanding the processes by which heat and carbon are sequestered into the global oceans is essential for monitoring rates of global change, and for informing Earth System Models that are being used to project future climate. Tracking and understanding ocean salinity is also essential for monitoring changes in the global hydrological cycle, as most precipitation and evaporation occurs over the ocean surface where few historical observations are available. To complete the picture, observations of global ocean circulation determine the distribution of these properties in the ocean, including at depth.

Within IMOS, estimates of multi-decadal change are drawn from observations of temperature, salinity, carbon and general ocean circulation delivered by Argo Floats (to 2000m depth), Ships of Opportunity (expendable bathythermographs or XBT's in the upper 700m, and surface carbon fluxes), Moorings (deepwater in the Southern Ocean, long-term reference sites on the shelf), Ocean Gliders (to 1000m depth), Animal Tagging (in high latitudes), and Satellite sea surface temperature (SST), ocean colour, and altimetry.



Temperature section across the Southern Ocean from XBT's.
Credit: Scripps High Resolution XBT program

Argo floats	Ships of opportunity	Deep water moorings	Ocean gliders	Autonomous underwater vehicles	National mooring network	Ocean radar	Animal tagging & monitoring	Wireless sensor networks	Satellite remote sensing	IMOS *OceanCurrent*
✔	✔	✔	✔		✔		✔		✔	

2011-12 Highlights

The global fleet of Argo profiling floats is critical to observing continuing changes to salinity in the upper oceans. Australian researchers have detected a clear change in salinity in the world's oceans, signaling an acceleration in the global rainfall and evaporation cycle.

The research combined 50-year observed global surface salinity changes with changes from global climate models and observed ocean salinity changes from Argo to explore the relationship between salinity, rainfall and evaporation in climate models. The research determined the water cycle has intensified by four percent from 1950-2000: this is twice the response projected by current generation global climate models. The salinity shifts in the ocean confirm that the climate and global water cycle have changed. These changes suggest that arid regions have become drier and high rainfall regions have become wetter in response to observed global warming. Changes in the global water cycle and the corresponding redistribution of rainfall will affect food availability, stability, access and utilization.

The Southern Ocean is important to climate and carbon cycling because of its highly energetic interactions with the atmosphere. Data from the Southern Ocean Time Series (SOTS) mooring is used to quantify the energy and carbon exchanges between the atmosphere and ocean, and the rate of carbon transfer into the ocean interior.

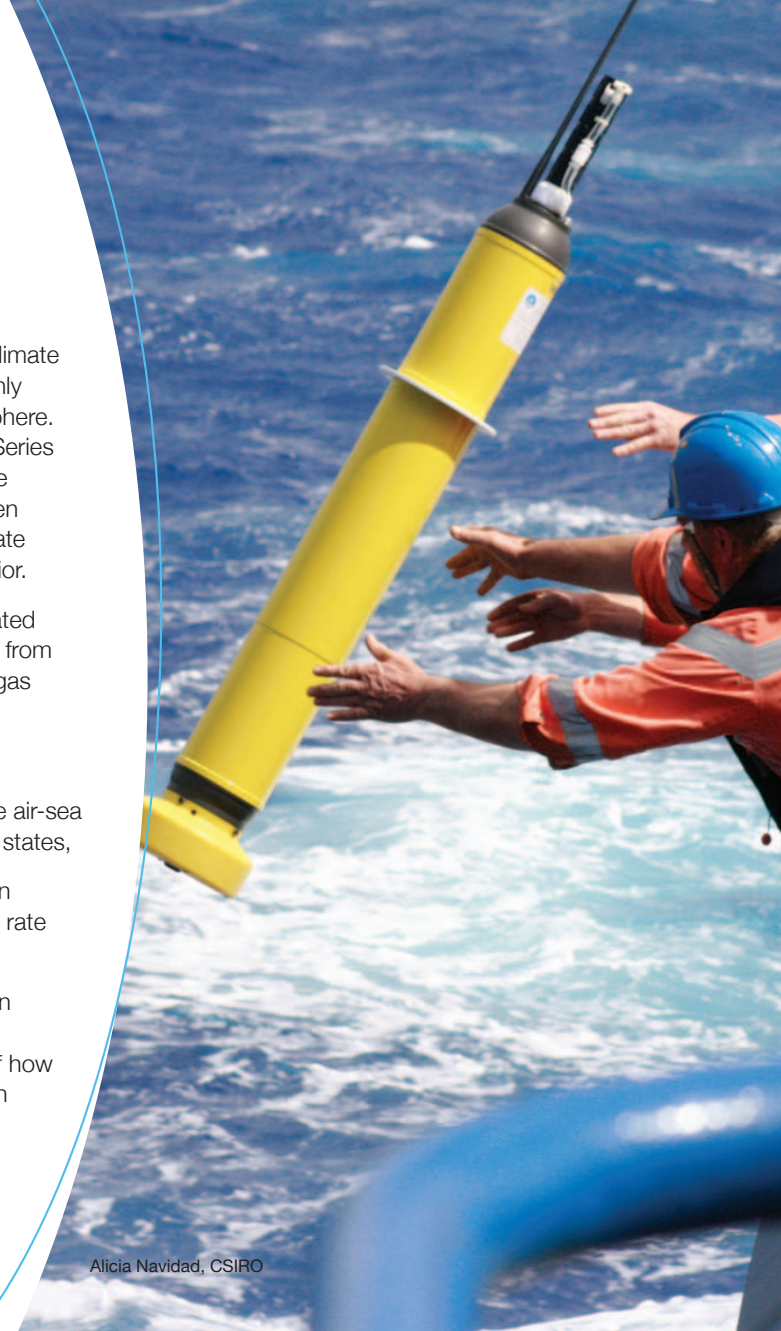
Over the 2010-11 deployment, estimated net community production, calculated from dissolved oxygen and dissolved total gas sensors, averaged 280 mg m^{-2} day^{-1}.

This estimate is critical to:

> quantifying gas exchange across the air-sea interface under high wind and wave states,

> understanding how biological carbon dioxide consumption influences the rate of CO_2 transfer into the ocean, and

> quantifying the relationships between mixed layer depth and biological production, to inform assessment of how future changes in ocean stratification will affect marine ecosystems.



Alicia Navidad, CSIRO

Eric Schulz, Bureau of Meteorology

Climate variability and weather extremes

There are three major, coupled ocean-atmospheric modes which account for a significant portion of Australian seasonal climate variability – El Niño/Southern Oscillation (ENSO), Indian Ocean Dipole (IOD) and Southern Annular Mode (SAM). Upper ocean thermal distribution is the largest source of predictability at seasonal timescales for all coupled modes, due to the large thermal inertia of the ocean and its predictable dynamics. Observations needed to understand upper ocean thermal distribution and inform seasonal and climate models include:

- broad scale upper ocean temperature and salinity structure,
- well resolved time-series in the equatorial oceans, and
- global wind, air-sea exchange (fluxes), and sea level measurements.

Within IMOS, these observations come from Argo Floats, Ships of Opportunity (XBT, SST and air-sea fluxes), Deep Water Moorings (Southern Ocean flux station) and Satellite SST and altimetry.

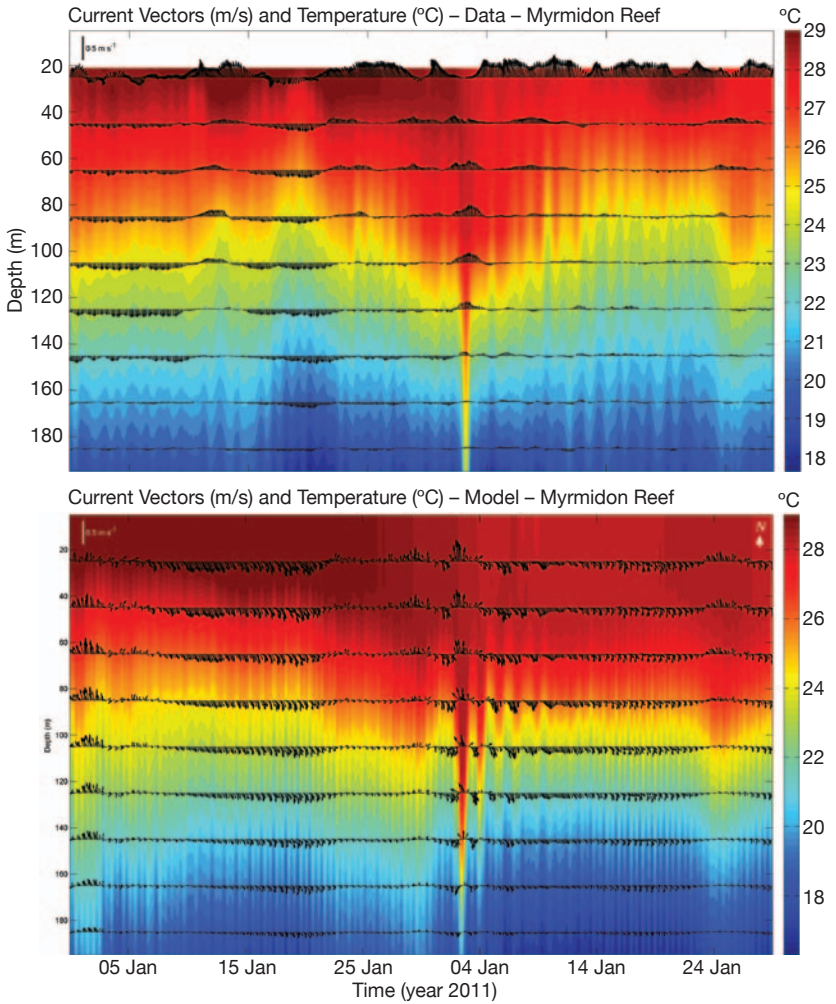
Rob Wiltshire, University of Tasmania

Argo floats	Ships of opportunity	Deep water moorings	Ocean gliders	Autonomous underwater vehicles	National mooring network	Ocean radar	Animal tagging & monitoring	Wireless sensor networks	Satellite remote sensing	IMOS *OceanCurrent*
✔	✔	✔							✔	✔

2011-12 Highlights

The Southern Ocean Flux Station (SOFS) has produced the first ever annual air-sea flux time series in the Southern Ocean. The data has revealed an air-sea flux regime that is rich in extreme heat loss events and has a small, annual net heat loss from the ocean to the atmosphere. Further analysis of data from the ongoing series of deployments of the SOFS mooring will enable a more detailed determination of the ocean-atmosphere interaction in the largely under sampled Southern Ocean.

IMOS observations are providing a detailed insight into the workings of the ocean, and particularly how marine ecosystems respond to extreme events. Severe Tropical Cyclone Yasi made landfall in northern Queensland, Australia on 3rd February 2011. It was the most powerful tropical cyclone to cross the Australian Coast in a century. As the system moved south-westwards towards the Australian coast, it passed over IMOS moorings located near the continental shelf break northeast of Townsville. The observational data from these moorings provided the opportunity to compare observations of this extreme event with a newly developed 3D hydrodynamic model of the whole of the Great Barrier Reef. Concurrent time series from the observations and model reveal low frequency variability that are reproduced reasonably well by the model. The model also reproduced the observed 10ºC warming of water at 200m caused by the passing of Tropical Cyclone Yasi. The magnitude of this event is quite remarkable.



Hemerson Tonin, Australian Institute of Marine Science

Craig Macaulay, CSIRO

Major boundary currents and interbasin flows

The waters around Australia form a complex intersection of the Pacific and Indian Oceans. There are two major boundary current systems; the East Australian Current (EAC) on the east coast and the Leeuwin Current on the west coast. There are also two major inter-basin flows connecting these ocean regions; the Indonesian Throughflow, between the western Pacific and the northeast Indian Ocean, and the Tasman Outflow by which the EAC penetrates into the Indian Ocean. These current systems have a central role in transferring heat, salt and nutrients into the coastal region. They vary on inter-annual and longer timescales, influenced by the major modes of climate variability (e.g. ENSO). The boundary current systems are therefore crucial to understanding local manifestations of global ocean processes and their influence on regional marine ecosystems.

Monitoring boundary currents demands multiple observational techniques within IMOS. Shelf and deep water Moorings are being deployed in the narrowest and most coherent sections of the Indonesian Throughflow and EAC, to monitor fluxes of heat, mass and salt.

Ocean Gliders, Ocean Radars and National Reference Station Moorings are being used to look at boundary current dynamics and their interaction with circulation on the continental shelf. Argo Floats and Ships of Opportunity are providing broad scale context and drivers, with Satellite altimetry and SST providing broad spatial and temporal resolution.

Australian Institute of Marine Science

Argo floats	Ships of opportunity	Deep water moorings	Ocean gliders	Autonomous underwater vehicles	National mooring network	Ocean radar	Animal tagging & monitoring	Wireless sensor networks	Satellite remote sensing	IMOS *OceanCurrent*
✔	✔	✔	✔		✔	✔			✔	✔

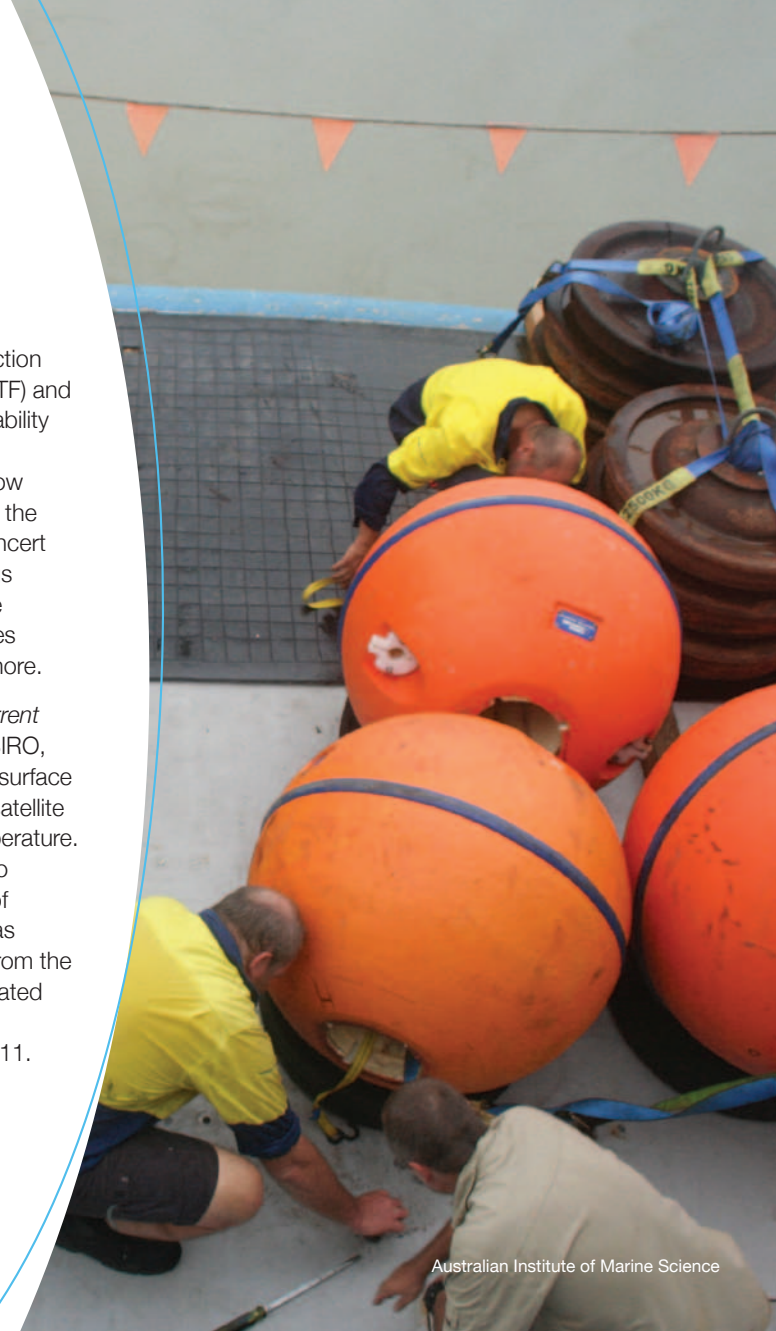
2011-12 Highlights

The deployment of the East Australian Current (EAC) mooring array in April 2012 completed the IMOS deep water mooring arrays and means that IMOS is now observing Australia's deep oceans at key locations from the tropics to Antarctica.

This deep water mooring array complements existing IMOS observations being taken off the Great Barrier Reef, the New South Wales coast, and the east coast of Tasmania that monitor components of the EAC. With this final piece of the jigsaw in place, Australian scientists will for the first time in history have the ability to accurately measure transport of mass, heat and salt at three locations from the tropics to the Southern Ocean, to see how it is changing over time, and to understand what these changes might mean for marine ecosystems and coastal populations along the eastern seaboard.

Last year, we reported how an increased Indonesian Throughflow due to the La Niña event had caused a strengthening of the Leeuwin Current. The recently deployed Kimberley and Pilbara mooring arrays will help to explain the nature of the connection between the Indonesian Throughflow (ITF) and the Leeuwin Current, by observing variability in shelf currents and coastally trapped waves along the northwest shelf and how they relate to observations at the ITF to the north, and off Perth to the South. In concert with broader observations, the moorings will help deduce the relative importance of this northwest shelf connection verses variability in Indian Ocean currents offshore.

The newly established IMOS *OceanCurrent* website builds on historical work by CSIRO, and has been producing daily maps of surface currents and temperature using Argo, satellite altimetry, and satellite sea surface temperature. During the past year it was expanded to include near real time data from ships of opportunity and ocean radars, as well as satellite ocean colour. The daily maps from the IMOS *OceanCurrent* website demonstrated that both of Australia's major boundary currents were stronger than usual in 2011.



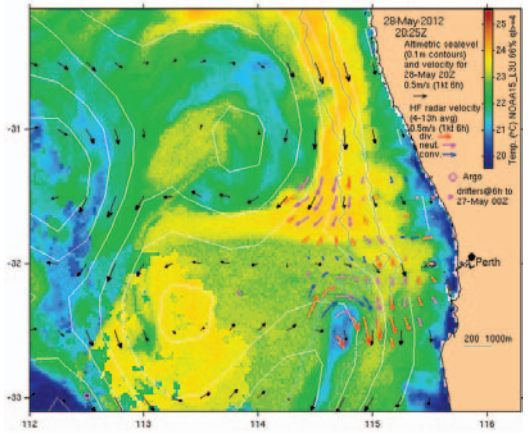
Australian Institute of Marine Science

Dan Atwater, James Cook University

Continental shelf processes

Australia has a large and varied continental shelf environment; broad and shallow in the tropical north and narrow on the sub-tropical east and west coasts. There are key processes occurring across this environment that provide a focus for observing connections between global ocean processes, boundary currents and biological responses on the continental shelf. These include encroachment of warm and cold-core eddies, upwelling and down-welling systems, coastal currents, and wave climates.

IMOS is providing an extensive, national backbone around the continental shelf, as well as more intensive observations in regions of socio-economic and ecological significance e.g. coral reefs, biodiversity hotspots, population centres, and regional development hubs. The backbone comprises a network of National Reference Station Moorings, and national access to Satellite remote sensing products, along with the IMOS national information infrastructure. The more intensive, region-specific observations include a combination of Shelf Moorings, coastal Ocean Gliders, Ocean Radar (for currents and waves), and Wireless Sensor Networks (on the Great Barrier Reef).



IMOS *OceanCurrent*

Argo floats	Ships of opportunity	Deep water moorings	Ocean gliders	Autonomous underwater vehicles	National mooring network	Ocean radar	Animal tagging & monitoring	Wireless sensor networks	Satellite remote sensing	IMOS *OceanCurrent*
			✔		✔	✔		✔	✔	✔

2011-12 Highlights

Ocean gliders have revealed the journey of Bass Strait water from the Tasman Sea to the Indian Ocean. The ocean gliders profiled a 200-metre tall, 40 kilometre wide disc of water that originated in Bass Strait and, amazingly remained undiluted as it travelled hundreds of kilometres.

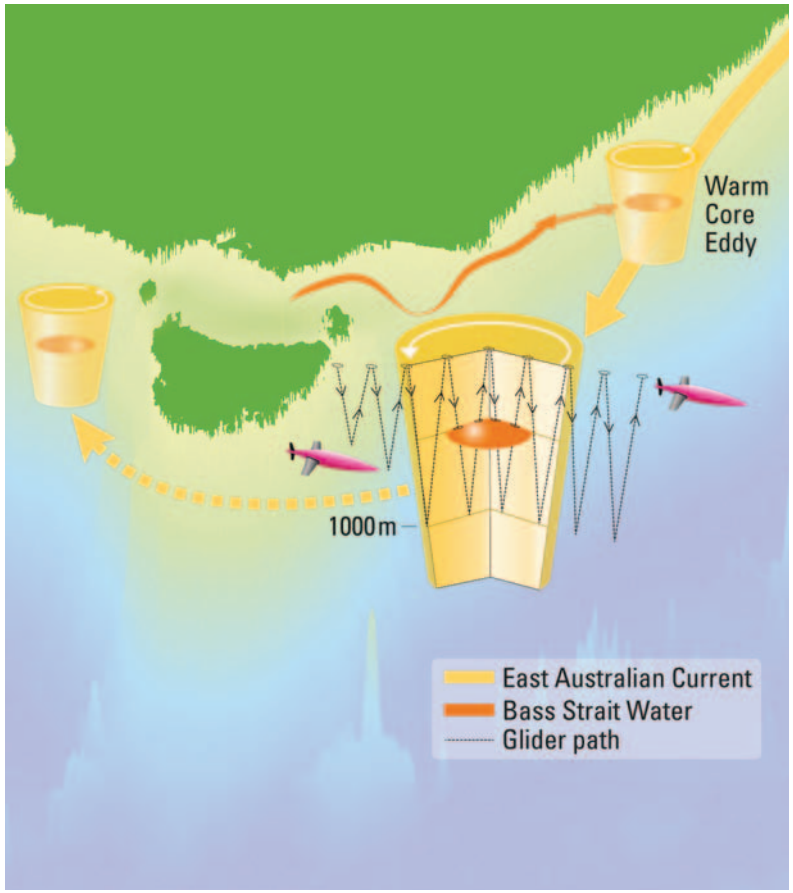
This new discovery is a clear example of the benefits arising from a significantly enhanced technical ability to explore our oceans and identify features relevant to marine ecosystems and climate.

Scientists have known that salty Bass Strait water, with its unique chemical signature, flows into the Tasman Sea north-east of Flinders Island, sinking to a depth of 400-800 metres in a feature referred to as the Bass Strait Cascade.

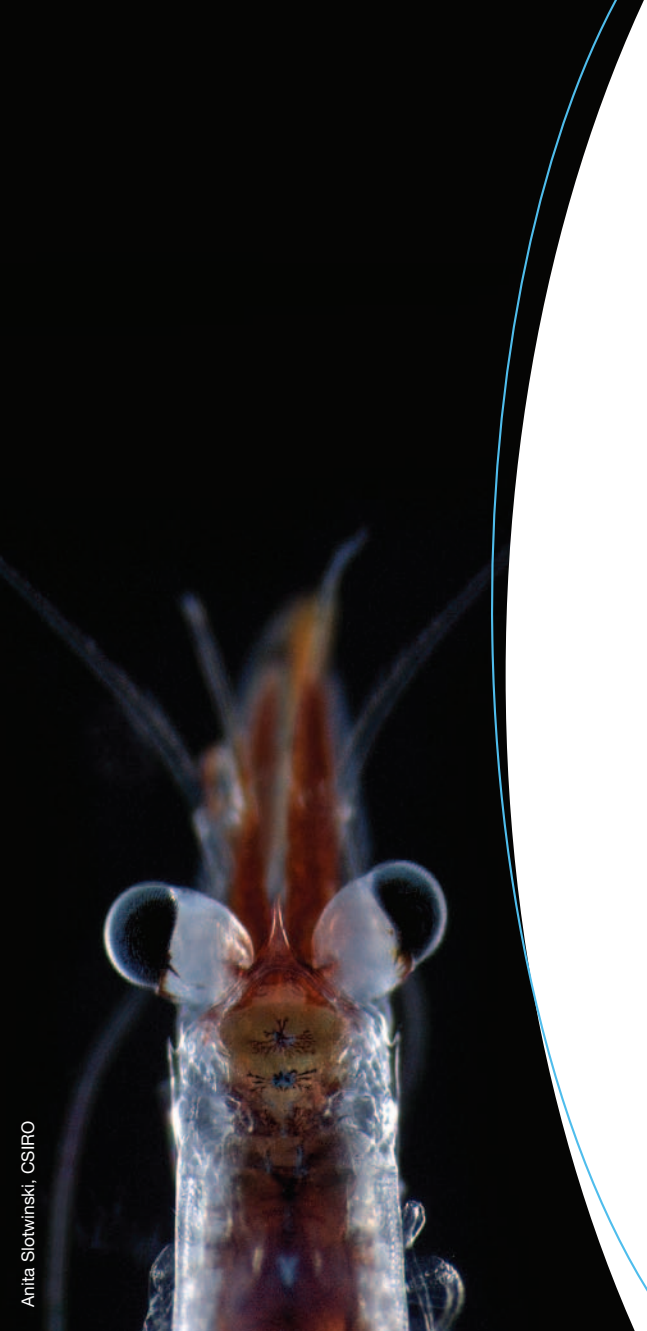
However, the porpoising action of the ocean gliders has given scientists data to a depth of 1000 metres and a detailed insight into anti-clockwise rotating warm-core eddies that regulate ocean conditions and influence ocean productivity.

Further measurements show that at least some of this Bass Strait water makes the journey past southern Tasmania and possibly thousands of kilometres into the Indian Ocean.

Ocean radar data is providing a unique view of coastal shelf processes as it is now being included in the daily maps delivered via IMOS *OceanCurrent*. An intense cold core eddy off Perth, Western Australia in early June provided an excellent example of the power we are beginning to realize by bringing together multiple data streams in near real time. The tight radius of the eddy was well resolved by the radar, and the correspondence of the radar data with the SST imagery was clear.



Louise Bell, CSIRO Creative Services



Anita Slotwinski, CSIRO

Ecosystem responses

Australia's large ocean territory, from the tropics to the Antarctic, encompasses a diverse range of marine ecosystems. IMOS is seeking to take an integrated approach, whereby measurements ranging from biogeochemistry through lower to higher trophic levels are undertaken across particular systems.

At basin scale, our initial focus is in the highly dynamic Southern Ocean. Seasonal changes in circulation, stratification and ice cover boost ecosystem production making this one of Australia's richest pelagic ecosystems, supporting the greatest density and biomass of apex predators to be found in Australian waters.

At regional and local scales, major boundary currents and continental shelf processes around Australia play a vital role in regulating the productivity, abundance, and distribution of marine ecosystems, both in the water column (pelagic) and on the sea floor (benthic). The warm boundary currents are generally nutrient poor, leading to marine systems of relatively low productivity. However, continental shelf processes, including cold-core eddies and upwelling systems, cause localised peaks in productivity. These "hotspots" are critical to supporting highly diverse fish, seabird, marine mammal and sea turtle populations within regions.

Ecosystem responses to variability and change need to be considered at all levels of the food web (trophic levels), from primary producers to apex predators. IMOS is observing ecosystem responses through an extensive, national backbone comprised of Ships of Opportunity (continuous plankton recorders, and echo-sounders to estimate biomass), a network of National Reference Station Moorings, and national access to Satellite ocean colour, along with the IMOS national information infrastructure. More intensive, region-specific observations include a combination of Animal Tagging and Monitoring (acoustic arrays and satellite tagging), Autonomous Underwater Vehicles (undertaking benthic surveys), deep water and shelf Moorings (Southern Ocean Time Series, acidification moorings, noise loggers), Ocean Gliders, and Wireless Sensor Networks.

Argo floats	Ships of opportunity	Deep water moorings	Ocean gliders	Autonomous underwater vehicles	National mooring network	Ocean radar	Animal tagging & monitoring	Wireless sensor networks	Satellite remote sensing	IMOS *OceanCurrent*
	✔	✔	✔	✔	✔		✔	✔	✔	✔

2011-12 Highlights

IMOS is working with a number of research projects that will influence development of the observing system into the future. In a project with the National Environmental Research Program (NERP) Marine Biodiversity Hub, IMOS is providing data for use in development of a set of National Marine Ecological Indicators to monitor and evaluate the state of Australia's marine environment.

Qualitative models have been developed of key ecological features, based on our understanding of how they work. From these models, the key drivers, threats, and indicators are identified. These models are currently being tested with data from IMOS and the Australian Ocean Data Network delivering to the identified drivers, threats and indicators.

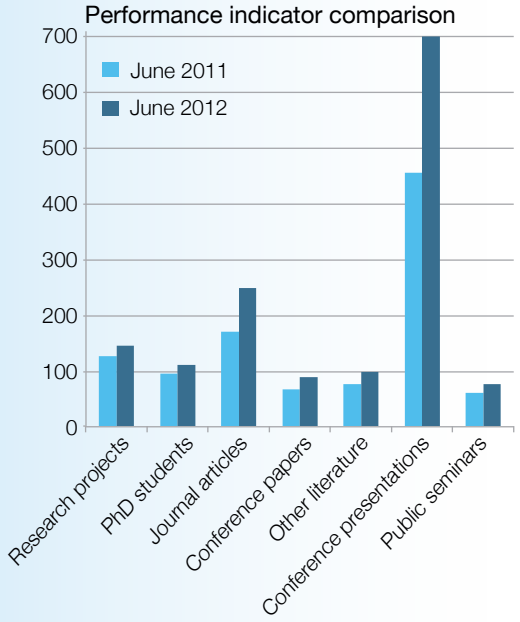
Picoplankton are small photosynthetic cells that contribute the majority of chlorophyll biomass and productivity in the world's oceans. Picoplankton abundance is measured through biogeochemical sampling that occurs at the nine National Reference Stations around five distinct regions of the Australian coastal zone. The observations have shown that seasonal patterns in abundance were evident from stations at Rottnest Island (WA), Yongala and North Stradbroke Island (QLD), Maria Island (TAS) and Port Hacking (NSW), principally due to seasonality in the flows of the Leeuwin and East Australian Currents. Additionally, major shifts in picoplankton abundance were found following extreme weather (such as the marine heat wave in WA and flood plumes in QLD) and dust deposition events.

IMOS is developing a number of tools that will assist ecosystem research in Australia. The animal tagging and monitoring database is providing Australian researchers with an unprecedented ability to look at the national distribution of marine species. Comprehensive web-based atlases are also under development for phytoplankton and zooplankton, covering the taxonomy, distribution and general ecology of many species. These atlases will build on previously available information and incorporate new information gained from the nine IMOS National Reference Stations along with data from IMOS Continuous Plankton Recorders on ships of opportunity.

Rob Harcourt, Macquarie University

Performance indicators

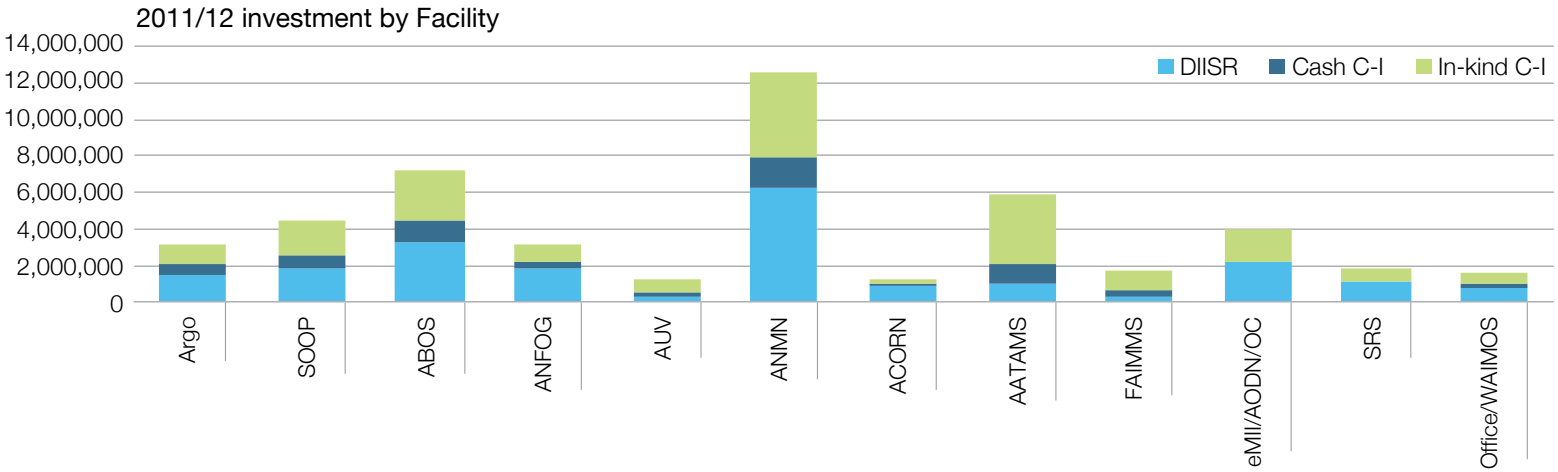
The uptake and use of IMOS data is measured by performance indicators related to research projects, postgraduate students, publications and presentations. They are fully listed on the IMOS website at **http://imos.org.au/imospublications.html**. Cumulative totals of the IMOS performance indicators at June 2011 and June 2012 are provided below:



Financial summary

Details of IMOS finances for 2011/12 are provided in the Annual Progress Report which is available for download at **http://imos.org.au/reports1.html**. A summary is provided below:

FINANCIAL OVERVIEW	NCRIS	EIF	Total
Balance at 1 July 2011	**6,288,354**	**6,320,510**	**12,608,864**
Department of Industry, Innovation Science, Research and Tertiary Education	0	18,000,000	18,000,000
Interest earnings	274,312	490,042	764,354
Income sub-total	**274,312**	**18,490,042**	**18,764,354**
Cash Co-investments	0	7,404,054	7,404,054
In-kind Co-investments	802,748	19,483,627	20,286,375
Total – Resources received	**1,077,060**	**45,377,723**	**46,454,783**
Capital/equipment purchases	493,214	5,512,989	6,006,203
Personnel	1,019,129	8,589,015	9,608,144
Other	341,390	5,198,595	5,539,985
Expenditure sub-total	**1,853,733**	**19,300,599**	**21,154,332**
Cash Co-investments	0	6,564,807	6,564,807
In-kind Co-investments	802,748	19,483,627	20,286,375
Total – Resources utilised	**2,656,481**	**45,349,033**	**48,005,514**
Balance at 30 June 2012	**4,708,933**	**6,349,200**	**11,058,133**



Operators

- Australian Institute of Marine Science
- Bureau of Meteorology
- Commonwealth Scientific and Industrial Research Organisation
- Curtin University
- James Cook University
- South Australian Research and Development Institute
- Sydney Institute of Marine Science
- University of Tasmania
- University of Western Australia

Co-investors

- Antarctic Climate and Ecosystems Collaborative Research Centre
- Astral Fisheries
- Australian Antarctic Division
- Australian Climate Change Science Programme
- Department of Commerce (WA)
- Department of Defence (Defence Science and Technology Organisation)
- Department of Economic Development, Tourism and the Arts (Tas)
- Department of Employment, Economic Development and Innovation (QLD)
- Department of Environment & Heritage (SA)
- Department of Environment, Climate Change and Water (NSW)
- Department of Environment and Natural Resources (SA)
- Department of Environment and Resource Management (QLD)
- Department of Fisheries (WA)
- Department of Primary Industries (Vic)
- Department of Trade and Investment (NSW)
- Environmental Protection Authority (Vic)
- Flinders University
- Geoscience Australia
- (ARC Research Network on) Intelligent Sensors, Sensor Networks and Information Processing Network
- iVEC (WA)
- *L'Astrolabe*
- Macquarie University
- Manly Hydraulics Laboratories
- Marine National Facility
- Marine Parks Authority (NSW)
- Monash University
- National Institute of Water and Atmospheric Research (NZ)
- National Oceanic and Atmospheric Administration (USA)
- Ocean Tracking Network (Canada)
- Parks Victoria
- Petuna Sealord
- Research Data Storage Infrastructure
- Royal Australian Navy (Directorate of Oceanography and Meteorology)
- Scripps Institution of Oceanography (USA)
- Sea Mammal Research Unit, University of St Andrews (UK)
- Sydney Water (NSW)
- Tasmanian Partnership for Advanced Computing
- Tropical Marine Network
- University of Melbourne
- University of New South Wales
- University of Sydney

UTAS

Australian Government
Department of Industry, Innovation, Science, Research and Tertiary Education

IMOS is supported by the Australian Government through the National Collaborative Research Infrastructure Strategy and the Super Science Initiative. It is led by the University of Tasmania on behalf of the Australian marine and climate science community.

www.imos.org.au

The Operators of the IMOS infrastructure are:

sims sydney institute of marine science

James Cook University Australia

Curtin University

Australian Government

Australian Institute of Marine Science

CSIRO

The University of Western Australia

Australian Government
Bureau of Meteorology

Government of South Australia

SARDI South Australian Research and Development Institute

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