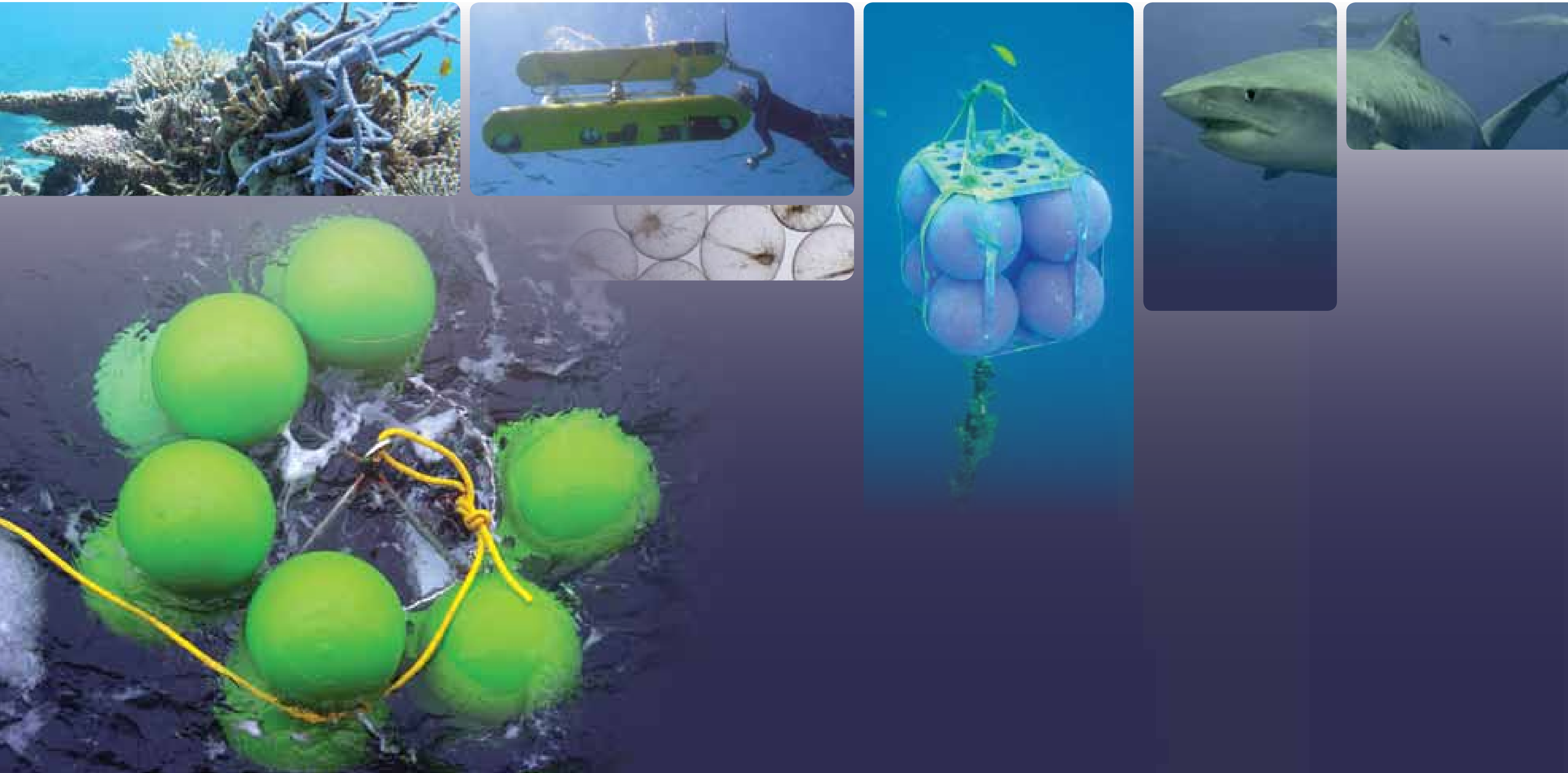
highlights 2010-2011

IMOS Integrated Marine Observing System



overview

Tim Moltmann
IMOS Director

After a very rapid ramp-up during the first three years of operation (2007-10), this fourth year has seen IMOS settle out to almost its full size under current funding arrangements. It is very exciting to reach this stage as we are now beginning to feel the momentum of ten Operating Institutions pulling in unison through national collaboration, providing observations and data streams at an unprecedented scale in the history of Australian marine and ocean-climate science.

A good example of the opportunity presented by this national collaboration is how the recent La Nina has shown up in multiple observations – extreme events on the east coast, freshening in the Indonesian Throughflow, a marine heatwave down the west coast. References to these events are dotted throughout this document, but it is the emergence of a coherent national picture that is most interesting.

During 2010-11, the vast majority of deployments and recoveries were successfully completed. Virtually all new deployments and data streams planned for this year were successfully initiated.

There were 2,150 metadata records describing IMOS data streams in the Ocean Portal as at 30th June 2011, a 50% increase on last year. A further 6,000 data streams have also been made discoverable/accessible, by turning the IMOS information infrastructure into a broader Australian Ocean Data Network (AODN) that is capable of accessing not just IMOS-funded data, but all marine and ocean-climate data held by participating government and non-government organisations.

Perhaps the highlight of many in the 2010-11 year is the fact that we can identify almost 400 new projects, publications and conference presentations using IMOS data during the last 12 months. This is about 40% of scientific output to date. It has been anticipated that acceleration in use of IMOS data would occur over time, but it is highly satisfying to be able to measure it.

In summary, the IMOS community has delivered at a high level in 2010-11, and taken an important step in focusing as much on uptake and use of data, as on deployment and recovery of equipment. The tremendous momentum of a national, multi-institutional, integrated system is now palpable. Anticipated benefits are being realised, and new opportunities to harness this momentum are emerging.

Rob Harcourt, Macquarie University

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 ten 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.

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 – some in near-real time, and all as delayed-mode, quality-controlled data. These data streams, long time-series that are 'under construction', represent the actual research infrastructure being created and developed by IMOS.

IMOS observations are guided by science planning undertaken collaboratively across the Australian marine and climate science community. IMOS now has a National Science and Implementation Plan that draws on the intellectual strength of its six science Nodes – a 'Bluewater and Climate' Node focused on the open ocean, and five 'Regional Nodes' covering the continental shelf and coastal seas of Western Australia, Queensland, New South Wales, Southern Australia and Tasmania. Leaders of the Nodes come together to form a national steering committee that oversees the whole process, and IMOS science plans are subjected to international peer review on a rolling basis to ensure the planned science is world-class.

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 impact. The relationship between IMOS Facilities and major research themes shows both the multi-platform approach required to address major questions, and the broad utility of IMOS Facilities across research areas.

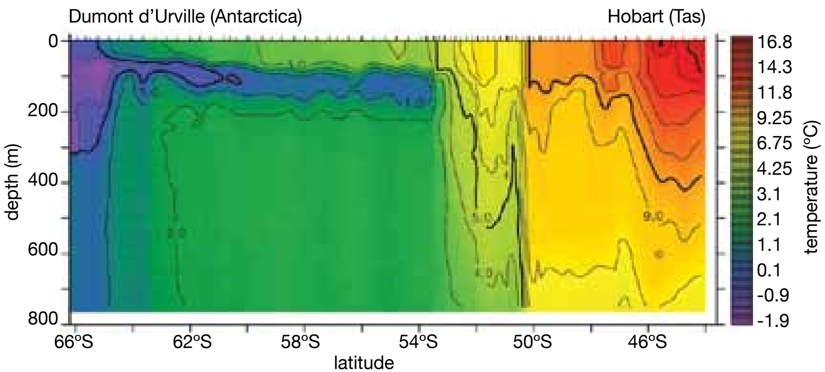
	Argo floats	Ships of opportunity	Deep water moorings	Ocean gliders	Autonomous underwater vehicles	National mooring network	Ocean radar	Animal tagging & monitoring	Wireless sensor networks	Satellite remote sensing
Multi decadal ocean change	✔	✔	✔	✔		✔		✔		✔
Climate variability	✔	✔	✔							✔
Major boundary currents	✔	✔	✔	✔		✔	✔			✔
Continental shelf processes				✔		✔	✔		✔	✔
Ecosystem responses		✔	✔	✔	✔	✔		✔	✔	✔


Iain Field, Macquarie University

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.

Within IMOS, estimates of multi-decadal change are drawn from 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
✔	✔	✔	✔		✔		✔		✔

2010-11 Highlights

Ocean observations are essential to validate climate models to ensure we have confidence in future climate projections. Australian researchers use temperature measurements from Expendable Bathythermographs and Argo floats to validate the rate and distribution of ocean warming in the models. They have found that the oceans in climate models are not warming as fast as they should be according to the observations. This is due to ocean models 'over mixing', spreading heat too deeply and overestimating the role of anthropogenic aerosols in offsetting upper ocean warming.

IMOS is funding new technologies that provide insights into regions we have not been able to observe before. Ice capable Argo floats and elephant seals equipped with sensors are providing invaluable data from under the ice shelves, helping to understand ocean-ice shelf interactions, and how this impacts on ice shelf stability and ocean circulation. The first observations of the calving of the Mertz Glacier Tongue in February 2010, were obtained from two tagged Elephant Seals from Macquarie Island. The seals investigated the new iceberg that had formed and then proceeded to occupy Commonwealth Bay from March through April during the summer/autumn transition. Collecting environmental data as they dived, the seals documented the overturning of the summer mixed layer in preparation for the new season's dense shelf water formation. The data provided an independent assessment of sea ice production in the Commonwealth Bay polynya and is now being used to validate satellite-derived estimates.

CSIRO

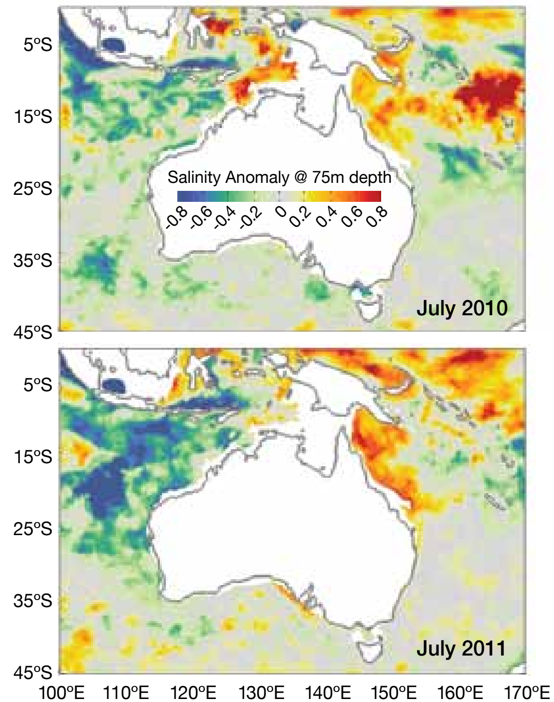
Danny McLaughlan, CSIRO

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 Nino/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:

- broadscale 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.



The difference in salinity between 2010 and 2011 in the Indian Ocean due to the La Nina event.

Credit: OceanMAPS, BLUElink

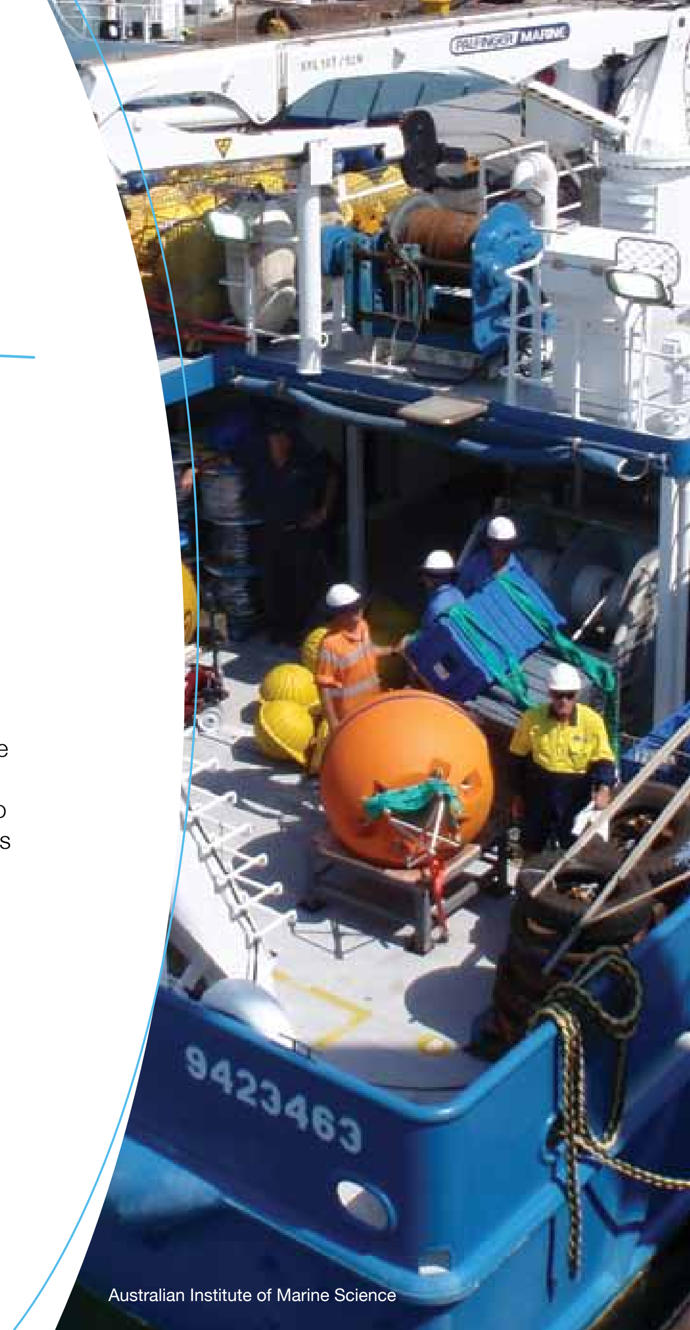
Argo floats	Ships of opportunity	Deep water moorings	Ocean gliders	Autonomous underwater vehicles	National mooring network	Ocean radar	Animal tagging & monitoring	Wireless sensor networks	Satellite remote sensing
✔	✔	✔							✔

2010-11 Highlights

The El Niño-Southern Oscillation has widespread effects on the Australian climate and ocean processes. During 2010/11 a strong La Nina event formed in the Tropical Pacific, bringing increased rainfall over Asia and Australia. The impact of this increased rainfall was seen in measurements made during the deployment of IMOS deep water moorings in the Indonesian Throughflow, where a fresh layer of water was seen down to 50m. Observations from Argo floats followed the path of the fresher water as it flushed through into the Indian Ocean.

In April this year, IMOS successfully retrieved the Southern Ocean Flux mooring (46.7°S, 142°E), which is providing world-first data from this important but challenging area of the global ocean. Data has now been collected on the transfer of heat and gases between the atmosphere and ocean, which is being used for validating climate models such as Australia's Community Climate and Earth System Simulator (ACCESS). A second IMOS funded mooring is being built so that the site can be continuously occupied in the future.

When tropical Cyclone Yasi crossed the Great Barrier Reef in February this year, information about the meteorological and ocean conditions were available in real time from the IMOS sensor network on the reef. As surface wind speeds exceeded 160km/hr, the cyclone injected energy into the ocean, causing it to mix surface waters down as deep as 200m and dramatically reducing surface water temperatures.



Australian Institute of Marine Science

Australian Institute of Marine Science

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.

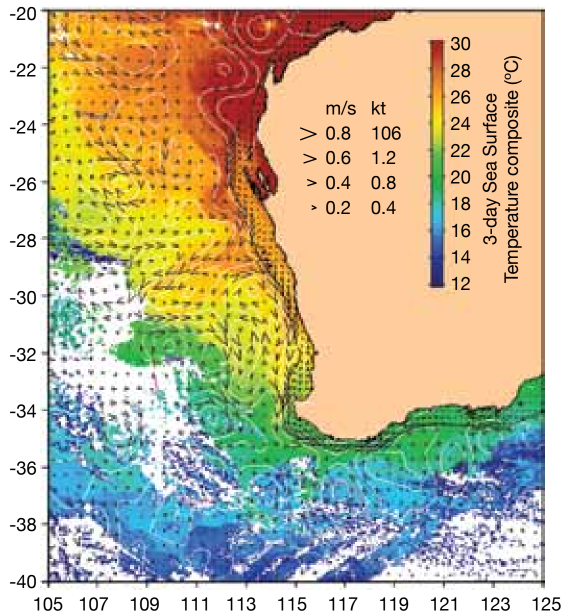
Monitoring boundary currents demands multiple observational techniques within IMOS. Shelf and deep water Moorings are being deployed in the narrowest and most coherent sections of the Indonesian Throughflow and EAC, to monitor full depth transport. Ocean Gliders, Ocean Radars and National Reference Station Moorings are being used to look at circulation on the continental shelf. Argo Floats and Ships of Opportunity are providing large scale context, with Satellite altimetry and SST providing broad spatial and temporal resolution.

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
✔	✔	✔	✔		✔	✔			✔

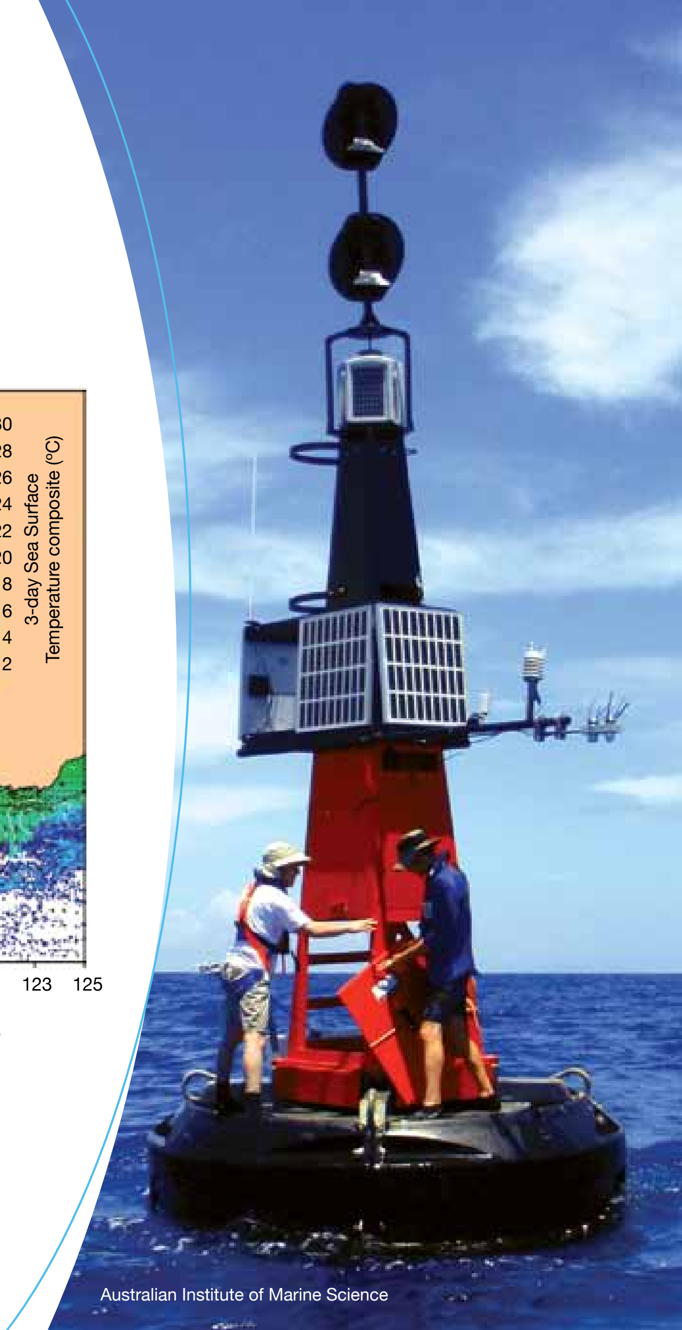
2010-11 Highlights

The effects of one of the strongest La Nina events on record were widespread in the oceans around Australia, in particular along the west coast, where ocean temperatures were warmer than normal. The La Nina event in the tropical Pacific increased the flow of water through the Indonesian Throughflow and hence strengthened the Leeuwin Current, bringing warmer water southwards. Data from IMOS moorings offshore of Perth showed surface water temperatures four degrees higher than normal in March 2011. The spatial extent of the warming is also visible in satellite Sea Surface Temperature data.

On the other side of the country, research into all aspects of the East Australian Current (EAC) was highlighted this year, through a special issue of the journal Deep Sea Research. One of the research papers observed the development and separation of an EAC warm-core eddy using a variety of IMOS data-streams from Argo floats, CO_2 measurements from Ships of Opportunity, an ocean glider and the Sydney mooring array.



Satellite sea surface temperature composite off Western Australia in December 2010.
Credit: CSIRO



Australian Institute of Marine Science

Australian Institute of Marine Science

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 ecosystem 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).

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
			✔		✔	✔		✔	✔

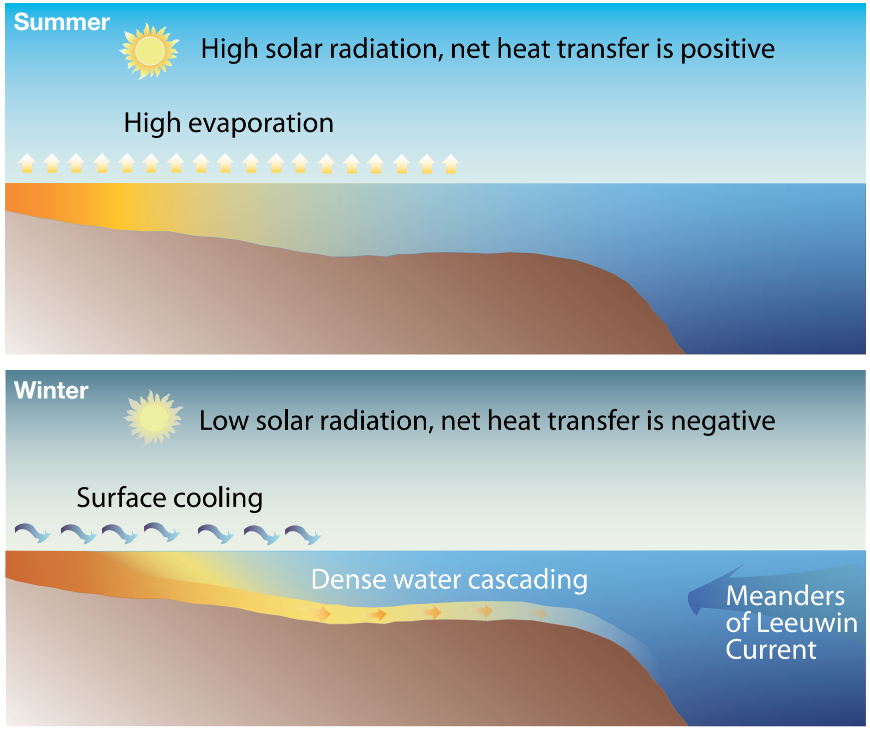
2010-11 Highlights

IMOS technology is providing new insights into processes around Australia's coast. We can now observe dense water shelf outflows that are formed when evaporation in summer and subsequent cooling towards winter produces dense saline waters that flow down the continental shelf slope, interacting with the ocean currents around the coast.

Off Perth, researchers have been able to use data from glider transects across the continental shelf to track the formation and fate of these dense flows, as well as how they are interacting with the Leeuwin Current system.

In South Australia, mooring data has been used to understand the processes that drive exchange between salty, dense waters from the Spencer Gulf and continental shelf waters. Researchers discovered that salty, dense "lenses" of water dubbed "Speddies" exited the Gulf, modulated by the tidal cycle.

In Bass Strait, a combination of glider and satellite data has been used to understand the fate of dense water formed in Bass Strait. Researchers found that dense Bass Strait water flows east meeting East Australian Current eddies. The dense water is picked up by eddies, forming a pocket of salty, high oxygen, high nutrient water in the middle of the eddy which is then transported offshore.



Development of seasonal dense shelf outflows; summer evaporation increasing salinity, and winter cooling increasing density forming the outflow.

Credit: Thisara Welhena, University of Western Australia.

Anita Slotwinski, CSIRO

Ecosystem responses

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 also 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.

Rob Harcourt, Macquarie University

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	✔	✔	✔	✔	✔		✔	✔	✔

2010-11 Highlights

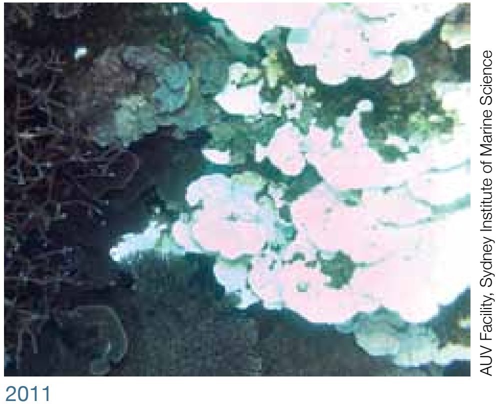
The La Nina event was also felt in Australia's ecosystems. Coastal warming associated with a strengthened Leeuwin Current caused a "marine heatwave" along the Western Australian coast, prompting widespread coral bleaching from Ningaloo Reef in the north to Rottnest Island in the south. IMOS provided before and after images of this coral bleaching event using the Autonomous Underwater Vehicle (AUV). IMOS has established a national system of reference sites for repeated, sustained benthic surveying, and this event highlights the importance of monitoring benthic ecosystems on a repeated basis.

Data from National Reference Stations and the Ships of Opportunity Continuous Plankton Recorder Survey have been used to develop the first comprehensive assessment of phytoplankton and zooplankton assemblages in Australian and Southern Ocean waters. Since 2008, 450 plankton taxa have been identified at the nine national reference stations alone. This is an invaluable baseline dataset which will continue to grow, and assist understanding of change and variability into the future.

Observations of prey biomass; the small fish, squids and other small nekton which form the connection between the small plankton and large marine predators; has long been the missing link in our understanding and ability to model marine ecosystems. Observations of biomass using acoustic echo-sounders on Ships of Opportunity now provide a way to derive biomass estimates, which are being incorporated into ecosystem models. Initial estimates suggest that biomass in the Tasman Sea could be 10 times larger than previously thought.

Marine apex predators are sensitive to changes in the distribution and abundance of their prey, who respond to changes in lower trophic levels and to physical environments. Pelagic apex predators forage in areas of relatively high food availability called areas of ecological significance (AES). Areas of Ecological Significance are defined as regions where multiple species cluster. AES are being identified by integrating data from a number of tagged species with productivity and prey data. Observing AES's provides information on the spatial and temporal variability of their prey and the influence of mesoscale features such as fronts and eddies.

2010

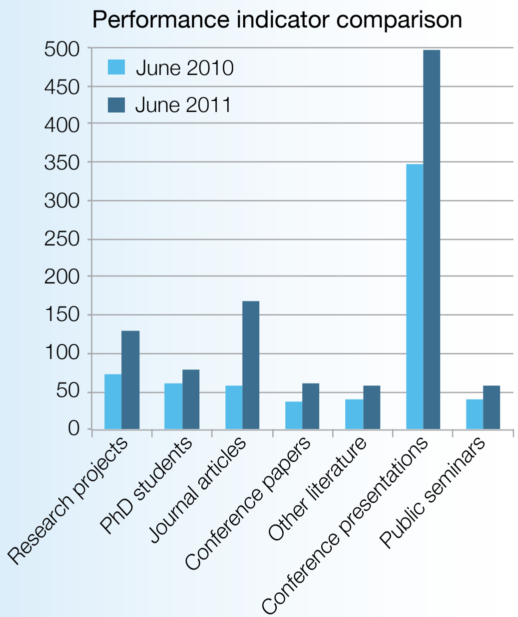


2011

AUV Facility, Sydney Institute of Marine Science

Performance indicators

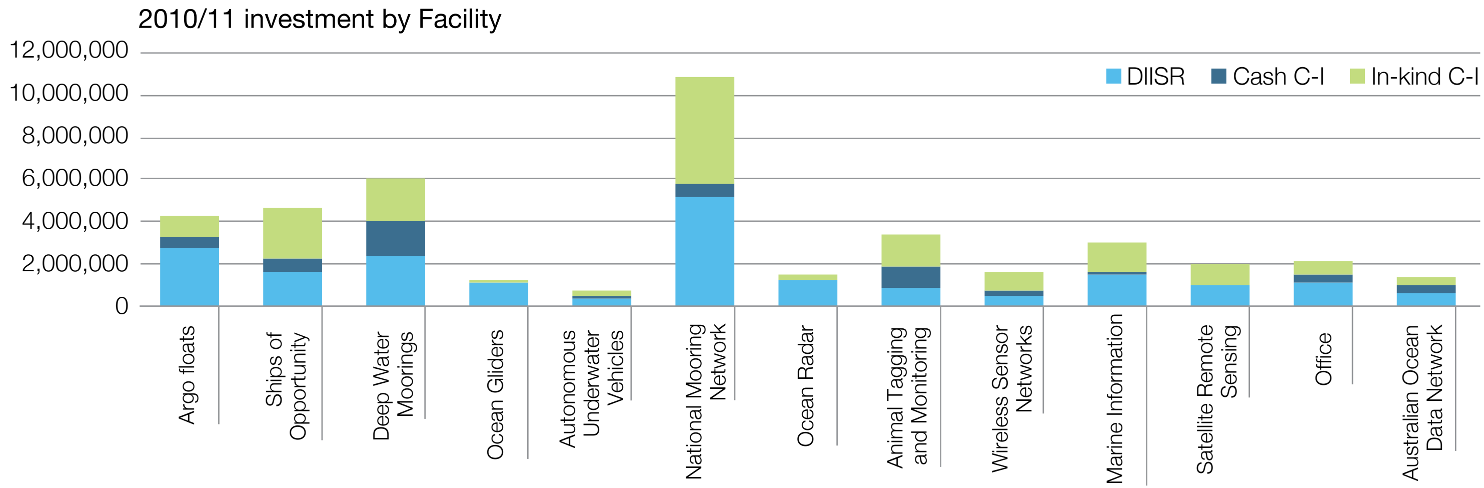
The uptake and use of IMOS data is measured by performance indicators related to research projects, postgraduate students and publications. They are fully listed in the Annual Progress Report which is available for download at **http://imos.org.au/reports1.html**. Cumulative totals of the IMOS Performance indicators at June 2010 and June 2011 are provided below:



Financial summary

Details of IMOS finances for 2010/11 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 2010	**11,907,622**	**10,744,519**	**22,652,141**
Department of Innovation, Industry, Science and Research	8,479,000	0	8,479,000
Interest earnings	431,377	338,135	769,512
Income sub-total	**8,910,377**	**338,135**	**9,248,512**
Cash Co-investments	3,736,038	2,285,819	6,021,857
In-kind Co-investments	13,063,390	3,630,222	16,693,612
Total – Resources received	**25,709,805**	**6,254,176**	**31,963,981**
Capital / equipment purchases	3,912,484	1,966,791	5,879,275
Personnel	6,638,538	1,637,186	8,275,724
Other	4,788,473	1,158,167	5,946,640
Expenditure sub-total	**15,339,495**	**4,762,144**	**20,101,639**
Cash Co-investments	2,926,188	2,285,819	5,212,007
In-kind Co-investments	13,063,390	3,630,222	16,693,612
Total – Resources utilised	**31,329,073**	**10,678,185**	**42,007,258**
Balance at 30 June 2011	**6,288,354**	**6,320,510**	**12,608,864**



Operators

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

Co-investors

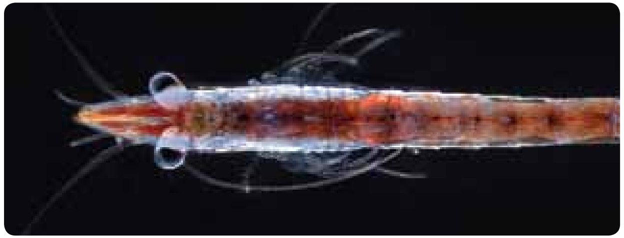
- Antarctic Climate and Ecosystems Cooperative Research Centre
- ARC Research Network on Intelligent Sensors, Sensor Networks and Information Processing
- Austral Fisheries
- Australian Antarctic Division
- Australian Climate Change Science Programme
- Australian eResearch Collaborative Services
- Defence Science and Technology Organisation, Department of Defence
- Department of Commerce, WA
- Department of Economic Development, Tourism and the Arts, Tas
- Department of Employment, Economic Development and Innovation, QldDepartment of Environment and Natural Resources, SA
- Department of Environment and Resource Management, Qld
- Department of Fisheries, WA
- Department of Trade and Investment, NSW
- Flinders University
- iVEC
- Macquarie University
- Marine National Facility
- Monash University
- National Oceanic and Atmospheric Administration, USA
- Ocean Tracking Network, Canada
- Oceanographic Field Services
- Office of Environment and Heritage, NSW (was Department of Environment, Climate Change and Water, NSW)
- Parks Victoria
- Petuna Sealords
- Queensland Cyber Infrastructure Foundation
- Royal Australian Navy
- Scripps Institution of Oceanography, USA
- Sydney Water
- Tasmanian Partnership for Advanced Computing
- Tropical Marine Network
- University of New South Wales
- University of Technology, Sydney
- University of Sydney
- Vemco

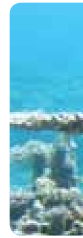
UTAS

Australian Government
Department of Innovation, Industry, Science and Research

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

Australian Government Geoscience Australia

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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