highlights 2013-2014

IMOS Integrated **Marine Observing** System

Overview

Tim Moltmann
IMOS Director

This Annual Highlights document covers the eighth year of IMOS operation. Despite considerable uncertainty about future funding during this period, it is now clear that IMOS will continue to the end of its first decade of operation in mid-2016. It is pleasing to be able to focus on the benefits of sustained observing across this timeframe.

IMOS is now mature enough to be contributing to the evidence base used in preparing periodic assessments of ocean state at national and global scales, and we see many opportunities for this contribution to increase over time. With more data collected over longer periods, we are also better able to understand seasonal cycles and events. Using observations and data that simply did not exist before IMOS, new discoveries continue to accrue at a rapid rate. This is particularly true at finer scales where global effects translate into local issues of interest.

Most fundamentally, the 2013-14 annual highlights give a sense of how significant IMOS has become to the future of collaborative marine and climate science in Australia. Analysis of data from our first deepwater mooring deployment in East Australian Current looks fascinating, and reoccupation of this site in 2015 using the new RV *Investigator* is generating great excitement within the national community, and strong interest from international collaborators. Establishment of a new industry-research partnership in the Great Australian Bight is the first example of a large-scale program setting up in an area where IMOS has a mature regional observing system in place. We can clearly see both the benefits of IMOS to the research program, and the way in which observations and data for this region will be extended through the program for ongoing use and reuse. This is the shape of things to come.

IMOS is a complex system, and it takes the combined efforts of hundreds of people in multiple institutions around the nation to make it work on a daily basis. As one example, our various funding agreements with the Education Department included 235 milestones current during the 2013-14 year. Of this total, 89% were achieved in full with a further 8% in progress at 30 June 2014. An outstanding achievement by all involved.

Building on the reliable flow of new observations and data, science uptake and use continued to expand, including a large number of research projects and programs addressing priorities across a range of government, industry and societal needs. This provides hard evidence that IMOS is relevant and having impact in areas that are of significance to Australia as a 'marine nation'. The highlights for 2013-14 give us confidence that relevance and impact will further increase in coming years.

Tim Moltmann

How does it work?

IMOS is designed to be a fully integrated, national system, observing at ocean basin and regional scales, 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 with input from government, industry and other stakeholders. 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 and coastal processes; and Ecosystem responses. This annual highlights document is arranged by these 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
- Deepwater 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 these Facilities.

The IMOS 'circle diagram' which is designed to be read from inside to out, illustrates how the system is operated by selected institutions but available for use by the entire community through open data access, generating a wide range of outputs that are relevant across portfolios and sectors.

Tim Fountain, CSIRO

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 the global ocean circulation determine the distribution of these properties in the ocean.

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 XBTs in the upper 700m, and surface carbon fluxes), Moorings (deepwater and continental shelf), Ocean Gliders (to 1000m depth), Animal Tagging and Monitoring (in high latitudes), and Satellite Remote Sensing of sea surface temperature (SST), ocean colour and altimetry.

Alicia Navidad, CSIRO

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
✔	✔	✔	✔		✔		✔		✔	

2013-14 Highlights

IMOS has matured enough to make a contribution to the evidence base used in preparing periodic assessments of the ocean state at national and global scales. The Intergovernmental Panel on Climate Change (IPCC) released the 5th assessment report (AR5) 'Climate change 2013: the physical science basis' in September 2013. Australian users of IMOS data provided much of the significant ocean related science on which AR5 conclusions were based, including studies of ocean heat content, ocean salinity, carbon uptake, and sea level rise. In March 2014, the CSIRO and the Australian Bureau of Meteorology released their third State of the Climate report. Using climate observations it discusses the long-term trends in Australia's climate and the factors that influence it. Observations provided by IMOS contribute to the report findings for sea-surface temperature, ocean heat content, sea level, and ocean acidification in the Australian region.

Many of the important headlines of both these reports depended on ocean observations, including those collected by IMOS, and they detect how the ocean is changing in five key areas:

OCEAN SALINITY: measurements of ocean salinity delivered by the sustained broad-scale salinity observations from the global Argo float array demonstrates that the global water cycle has intensified.

SEA-SURFACE TEMPERATURE: IMOS provides streams of high quality, near real time SST observations from 14 vessels in previously un-validated regions around Australia. This remotely sensed SST data demonstrates that the sea-surface temperatures in the Australian region have warmed by 0.9°C since 1900.

OCEAN HEAT CONTENT: ocean heat is observed by the global Argo float array, and the data reveals that 93% of the extra heat energy stored by the earth since 1970 is found in the ocean.

SEA LEVEL: satellites monitoring the height of the ocean (called altimeters) are the tool of choice for studying sea level rise. Precise measurement from space pushes these satellite systems to their limits and some high quality measurements from within the ocean are required. State-of-the-art GPS buoys maintained by IMOS provide the only altimeter calibration and validation sites in the Southern Hemisphere. The satellite data shows that the global mean sea level increased throughout the 20th century and in 2012 was 225mm higher than in 1880.

OCEAN ACIDIFICATION: IMOS maintains three acidification time-series stations around Australia as well as measurements from volunteer observing ships. Observations of ocean acidity show that levels have increased since the 1800s due to increased CO_2 absorption from the atmosphere.

Darren Moore

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. These observations come from Argo Floats, Ships of Opportunity (XBT, SST and air–sea fluxes), Deep Water Moorings (Southern Ocean flux station) and Satellite Remote Sensing SST and altimetry.

Scott Bainbridge, Australian Institute of Marine Science

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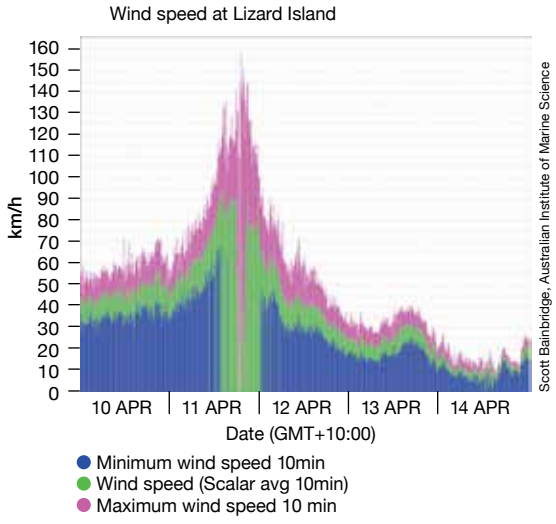
✔	✔	✔							✔	✔

2013-14 Highlights

Sea surface temperature data from Argo floats, ships of opportunity and satellite remote sensing have been used by scientists from the Bureau of Meteorology to tease apart the effect of the Indian Ocean Dipole (IOD) and the El Niño-Southern Oscillation (ENSO) on cool season rainfall across the eastern seaboard of Australia. The strong relationship between eastern Australian winter–spring rainfall and tropical modes of variability such as ENSO does not extend to the heavily populated coastal strip east of the Great Dividing Range in southeast Australia, where correlations between rainfall and tropical SST variations are insignificant during June–October. The IOD is found to have a strong influence on zonal wind flow during the winter and spring months, with positive IOD increasing both onshore winds and rainfall over the coastal strip, while decreasing rainfall elsewhere in southeast Australia. The IOD thus opposes the influence of ENSO over the coastal strip, and this is shown to be the primary cause of the breakdown of the ENSO–rainfall relationship in this region. Understanding our ocean-influenced climate and weather is essential as Australia's urbanised population lives predominantly in coastal cities, and is highly sensitive to events such as drought, flood, cyclones and storms.

In April 2014, tropical Cyclone *Ita* carved a path from the Solomon Islands across Papua New Guinea and through northern Queensland finally making landfall near Cape Flattery, as a Category-4 system. The system passed over the IMOS wireless Sensor Networks located at Lizard Island, Orpheus Island and Davies Reef. The data from the Lizard Island station is proving extremely valuable in cross-checking the intensity and impacts of severe Tropical Cyclone Ita. The data will greatly assist the Bureau of Meteorology in post-event analysis and provide a complete picture of the pressure gradients and wind strengths experienced as *Ita* moved over the island. Given *Ita's* eye-wall essentially passed over the Lizard Island weather station there is the rare opportunity to drill down into data recorded from within the core of a severe tropical cyclone. The data gathered about Cyclone *Ita* demonstrates the value in having observing infrastructure in place to provide real time data to inform both the scientific and emergency response communities.



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 interbasin 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 interannual and longer time scales, 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 Remote Sensing altimetry and SST providing broad spatial and temporal resolution.

Australian Institute of Marine Science

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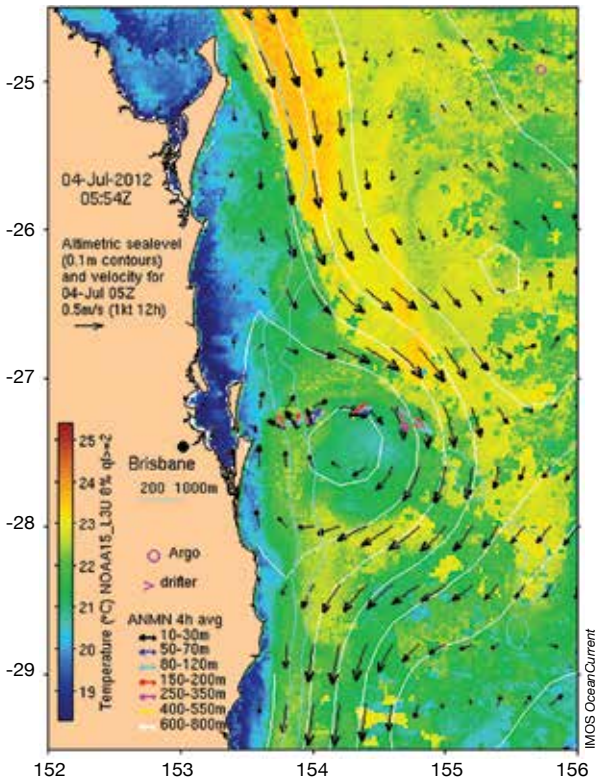
✔	✔	✔	✔		✔	✔			✔	✔

2013-14 Highlights

The East Australian Current (EAC), off eastern Australia, is the complex and highly energetic western boundary current system of the South Pacific subtropical gyre. The EAC is the dominant mechanism for the redistribution of heat between the ocean and atmosphere in the Australian region. Changes in the dynamics and strength of the EAC due to large-scale forcing changes may potentially result in significant regional climate and marine ecosystem changes in Australia and along the eastern Australian seaboard, respectively. IMOS deployed, off Brisbane, seven full-depth ocean moorings along a 200 km line from the continental shelf to the deep abyssal ocean from April 2012 to September 2013. This was the first successful in-situ monitoring of the complete EAC. Analysis of the data show that the EAC during this 18-month period had a mean southward transport of 25.3 Sv (1 sverdrup = 10^6 m^3 s^{-1}) and southward heat flux of 1.6 PW (1 petawatt = 10^{15} W). The IMOS mooring data also show that the location of the EAC is highly variable; the EAC can be found at any location along the mooring line and that it can move position rapidly. The data obtained from the IMOS EAC mooring array will be used by numerous researchers to more fully understand the complexities of this important western boundary current.

Using observations and data that simply did not exist before IMOS, new discoveries continue to accrue at a rapid rate, particularly in how the variability of the major boundary currents affect regional areas of interest. The EAC strongly influences the dynamics on the nearby shelf, and in particular the cross-shelf transport and uplift through the bottom boundary layer. IMOS shelf mooring data has been used to investigate bottom cross-shelf transport, both upstream and downstream of the EAC separation zone. Net bottom cross-shelf transport was onshore at all locations, whilst uplifts in the bottom boundary layer (onshore transport) were more intense and frequent upstream of the separation zone. IMOS ocean glider and HF radar observations identified a biological response – with elevated coastal chlorophyll concentrations – to a strong uplift of water associated with EAC encroachment onto the shelf. These results provide evidence of the EAC's role as a driver of variability in the continental shelf waters, which can be used in fisheries and marine ecosystem management.



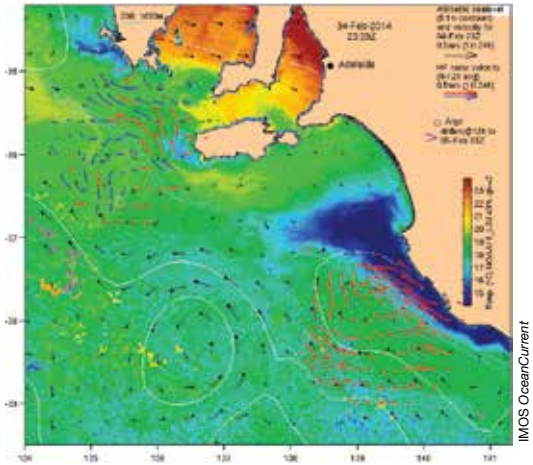
SST image of the EAC with current meter data from the EAC deep water mooring array.

Dan Atwater, James Cook University

Continental shelf and coastal processes

Australia has a large and varied continental shelf environment; broad and shallow in the tropical north and narrow on the subtropical 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 downwelling 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

SST image of an extreme Bonney Coast upwelling with surface velocities measured by the South Australian HF radars.

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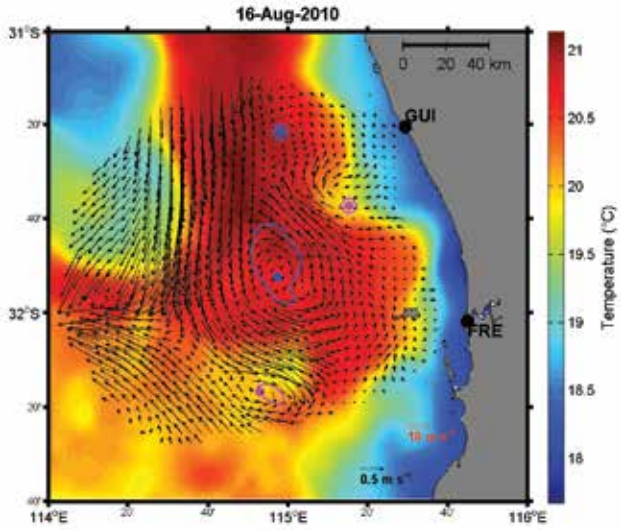
			✔		✔	✔		✔	✔	✔

2013-14 Highlights

IMOS provides a range of marine data streams using different platforms. Researchers are now able to use multi-platform data to understand continental shelf processes around Australia. A recent study into the structure of peddies (petite eddies or sub-meso scale eddies), which form along the continental shelf off Perth in regions of strong horizontal gradients in the currents used IMOS data streams from shelf moorings along the Two Rocks transect; surface currents from HF Radar; ocean gliders and SST and chlorophyll from satellites together with ship borne data collected from a RV *Southern Surveyor* voyage. The data indicated that the centres and perimeters of the eddy have different water properties to those of the adjacent ocean with colder water upwelling at the centre of the peddie, which was associated with high chlorophyll at the surface and sub-surface. Rapid upwelling rates of up to 100m per day were observed. Analysis of ~40 months of HF radar identified over 1500 peddies (768 cyclonic; 816 anti-cyclonic) with the majority occurring along the interface between the southward flowing Leeuwin and northward flowing Capes Current and along the perimeter of meso-scale eddies.

The daily IMOS *OceanCurrent* maps continue to help observe and understand shelf processes such as the Bonney Coast upwelling. Winds associated with the combination of low atmospheric pressure over south-east Australia and high pressure west of Tasmania in February 2014 caused an extremely strong upwelling event stretching from the Eyre Peninsula to Portland. The surface velocities associated with the upwelling were measured by both the South Australian HF radars, confirming expectations from basic theory and numerical modelling that the flow is essentially alongshore in the upwelling region, with just a small component directed offshore to drive the upwelling. The dynamics are very different, and more complex, outside the continental shelf in the deep ocean, where eddies exist and the wind-driven current is not constrained to follow the coast. Variation in upwelling events is important as upwelling sustains planktonic systems that support pelagic fish. These in turn provide the fundamental food source for higher predators including tuna, sharks, seals, seabirds and whales.



Charitha Pattiaratchi, University of Western Australia

Location of peddies off Perth on 16 August with HF Radar surface currents overlain on the satellite derived SST.

Rob Harcourt, Macquarie University

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 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 and on the sea floor. 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 Remote Sensing 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
	✔	✔	✔	✔	✔		✔	✔	✔	✔

2013-14 Highlights

IMOS data streams can sometimes deliver a surprise for researchers. The IMOS Continuous Plankton Recorder (CPR) was sampling the ocean between Brisbane and Sydney three weeks after a massive dust storm in 2009 that shrouded the entire east coast. The CPR sampling unexpectedly collected massive concentrations of black fungal spores. The bloom of a terrestrial fungus in Australia's coastal waters is an extremely rare event. Researchers are now trying to understand the possible impacts of a terrestrial fungus in the marine environment, in particular the potential toxic effects for coral, algae and fish.

Similarly, the annual surveys by the IMOS Autonomous Underwater Vehicle (AUV) of the benthic ecosystem at the Abrolhos islands has captured and documented the effect of the 2010-2011 'marine heat wave' on the west coast. Interestingly, whilst researchers found the initial devastation to the coral reefs was large, regrowth was surprisingly fast and widespread. Although the original plate corals have not recovered, other coral species have regenerated in their place, with approximately 50% of the lost area being replaced.

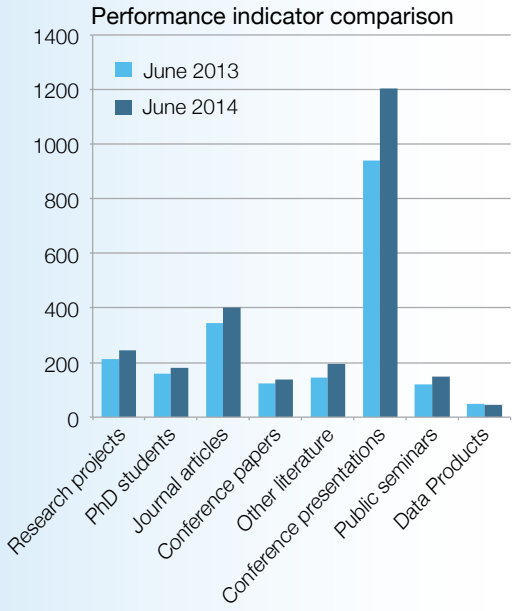
The new Great Australian Bight (GAB) Collaborative Research Science program is being undertaken by CSIRO, Marine Innovation Southern Australia (MISA) and BP. The four-year $20 million research program on the Great Australian Bight's ecosystems, marine resources and socio-economic importance will make extensive use of data from IMOS, and will further extend collection of data in the GAB from a variety of platforms including: gliders, moorings, biogeochemical sampling, tagged apex predators, acoustic receivers, ocean radar, bioacoustics, continuous plankton recorders and passive acoustic receivers. The data will be used in hydrodynamic ocean modelling, to identify hot spots of ecological activity, and assess spatial and temporal variation in food web dynamics. This is an excellent example of how much more we can achieve from a regional study when we have a sustained observing in place to build upon.

Metagenomic analysis of marine samples now provides an opportunity to undertake large-scale, spatially-explicit analyses to quantify and map patterns of microbial biodiversity. Since 2012 IMOS, in partnership with the Australian Marine Microbial Biodiversity Initiative, has been collecting microbial samples as part of the regular monthly water sampling at three east coast National Reference Station (NRS) sites. With the initial sampling providing preliminary data that demonstrates varied spatial and temporal patterns between bacterial taxa, the microbial sampling will now be expanded to all seven NRS sites around the country over the next year. This is an example of value adding to an existing long-term IMOS sampling program.

Kim Brooks, Australian Institute of Marine Science

Performance indicators

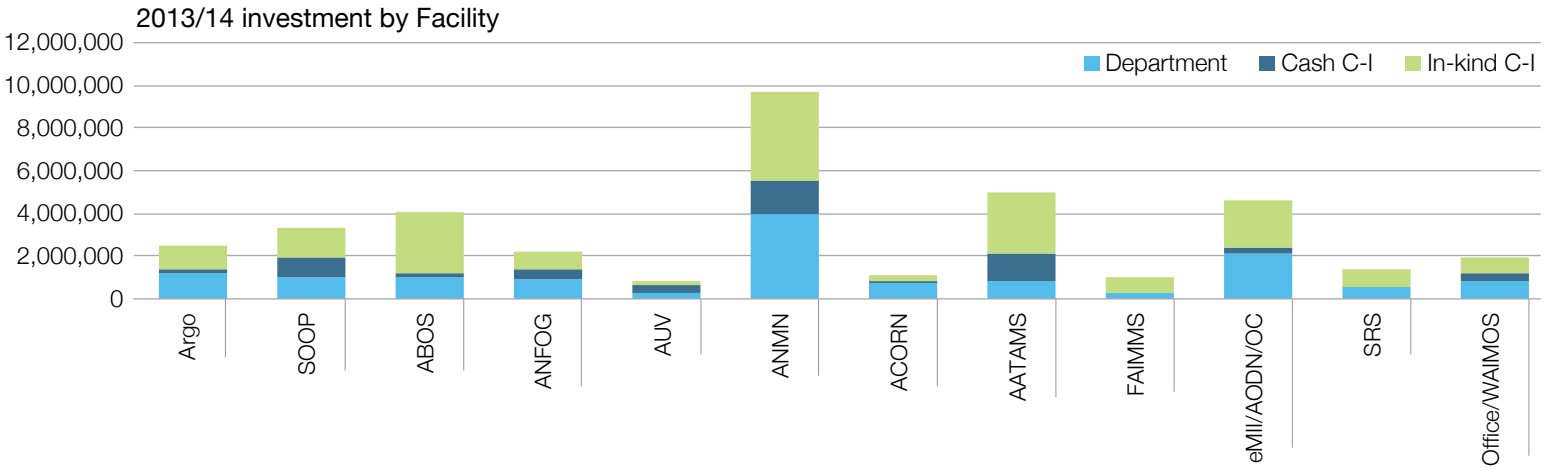
The uptake and use of IMOS data is measured by performance indicators related to research projects, postgraduate students, publications and presentations. They are fully listed on the IMOS website at **www.imos.org.au/imospublications.html**. Cumulative totals of the IMOS performance indicators at June 2013 and June 2014 are provided below:



Financial summary

Details of IMOS finances for 2013–14 are provided in the Annual Progress Report which is available for download at **www.imos.org.au/reports1.html**. A summary is provided below:

FINANCIAL OVERVIEW	2013-14	2012-13
Balance at beginning of financial year	**12,922,093**	**11,058,133**
Education Investment Fund	0	18,000,000
Collaborative Research Infrastructure Scheme	4,803,088	2,401,544
National Collaborative Research Infrastructure Strategy	11,513,351	0
Interest earnings	269,518	503,221
Income relating to Australian Government funds	**16,585,957**	**20,904,765**
Cash Co-investments	5,777,685	6,705,985
In-kind Co-investments	18,309,618	24,096,101
Total – Resources received	**40,673,260**	**51,706,851**
Capital / equipment purchases	1,637,785	3,976,663
Personnel	8,461,359	9,675,745
Other	3,590,315	5,286,349
Expenditure relating to Australian Government funds	**13,689,459**	**18,938,757**
Cash Co-investments	5,892,748	6,808,033
In-kind Co-investments	18,309,618	24,096,101
Total – Resources utilised	**37,891,825**	**49,842,891**
Balance at end of financial year	**15,703,528**	**12,922,093**



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 New South Wales, University of Sydney, Macquarie University, University of Technology Sydney)
- University of Tasmania
- University of Western Australia

Co-Investors

- Antarctic Climate and Ecosystems Collaborative Research Centre
- Austral Fisheries
- Australian Antarctic Division
- Australian Climate Change Science Program
- Australian National Data Service (ANDS)
- Australian Ocean Data Centre Joint Facility
- Charles Darwin University
- Darwin Ports Corporation
- Defence Science and Technology Organisation
- Department of Aquaculture Fisheries and Forestry (Queensland)
- Department of Environment and Heritage Protection (Queensland)
- Department of Environment and Natural Resources (SA)
- Department of Environment and Primary Industries (Victoria)
- Department of Fisheries, WA
- Department of Further Education Employment Science and Technology (SA)
- Department of Primary Industries, NSW
- Department of Science, Information Technology, Innovation and the Arts (Queensland)
- Department of State Growth, Tasmania
- Department of the Premier and Cabinet, WA
- Environmental Protection Authority Victoria
- First Institute of Oceanography (China)
- Flinders University
- French National Centre for Scientific Research (Centre National de la Recherche Scientifique, CNRS)
- French Polar Institute (Institut Polaire Français Paul Emile Victor, IPEV)
- Geoscience Australia
- Griffith University
- Marine National Facility
- Murdoch University
- National Computational Infrastructure (NCI)
- National eResearch Collaboration Tools and Resources (NeCTAR)
- National Institute of Water and Atmospheric Research, NZ
- National Oceanic and Atmospheric Administration, USA
- National Science Foundation, USA
- Ocean Tracking Network/ Dalhousie University (Canada)
- Oceanographic Field Services
- Office for Science and Research, NSW
- Office of Environment and Heritage, NSW
- Research Data Storage Infrastructure (RDSI)
- Royal Australian Navy
- Scripps Institution of Oceanography, USA
- Sea Mammal Research Unit, University of St Andrews, UK
- Sealords, NZ
- Southern Cross University
- Sydney Water Corporation
- Tasmanian Partnership for Advanced Computing
- Tropical Marine Network
- University of Melbourne
- University of Queensland

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

UNIVERSITY of TASMANIA

IMOS is a national collaborative research infrastructure, supported by Australian Government. It is led by University of Tasmania in partnership with the Australian marine & climate science community.

www.imos.org.au

The Operators of the IMOS infrastructure are:

sims sydney institute of marine science

The University of Western Australia

Australian Government
Bureau of Meteorology

Australian Government

Australian Institute of Marine Science

CSIRO

SARDI
South Australian Research and Development Institute

Curtin University

James Cook University Australia

Government of South Australia

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