highlights 2009-2010

IMOS Integrated **Marine Observing** System







welcome

Tim Moltmann
IMOS Director

Australia's Integrated Marine Observing System (IMOS) was established in 2007 under the National Collaborative Research Infrastructure Strategy (NCRIS), with initial funding of $50M and co-investment of $44M from partners. It has successfully deployed a range of observing equipment in the oceans around Australia, making all of the data freely and openly available through the IMOS Ocean Portal for the benefit of Australian marine and climate science as a whole.

IMOS is in the process of becoming bigger and better. With the injection of an additional $52M from the Education Investment Fund (EIF) in 2009, and up to $66M in further co-investment, it will be able to deliver a greater range of ocean data, to more stakeholders, for longer.

The IMOS community has proved that Australia has the capability and capacity to deliver national, collaborative, research infrastructure in the form of an in-situ ocean observing system. There have been many deployment and recovery successes over the past year, with completion of the high risk but high return Southern Ocean Time Series deployment being a particular highlight. The rapid response of a number of IMOS Facilities to the additional opportunities provided by EIF funding was also truly impressive, demonstrating a genuine building of ocean observing capacity within Australian marine and climate science.

Uptake and use of data has strengthened considerably over the last twelve months, and will grow exponentially over time as more data becomes available. Multiple pathways to uptake and use are being established – through research education and training, research projects and programs, analyses and products, and modelling and forecasting systems. In the year under review, it was particularly pleasing to see IMOS data streams underpinning a number of new Super Science Fellowships awarded by the Australian Research Council.

I welcome you to this IMOS Annual Highlights document, the first of many to come.

Photo: 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/webportal/) allows marine and climate scientists and other users to discover and explore data streams coming from the Facilities. The Ocean Portal has been operational for over 12 months, with data streams now available from all 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. This is a large, diverse, dispersed community, and it makes sense to develop the science planning through a series of integrated 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 Node 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, Major boundary currents, Continental shelf processes, and Biological 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				✔		✔	✔		✔	✔
Biological responses		✔	✔	✔	✔	✔		✔	✔	✔

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.

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
✔	✔	✔	✔		✔		✔		✔

2009-10 Highlights

The Argo facility delivered approximately 10,000 ocean temperature/salinity profiles this year, and since inception has delivered over 32,000 profile/trajectory files to IMOS and the international Argo data set. The global Argo program was recognised at the OceanObs'09 Conference as the single most significant advancement in in-situ ocean observing over the last decade, as well as setting benchmarks for data sharing, documentation and quality control, supporting the dual purpose of short-term forecasting sciences and long-term climate/ocean monitoring.

Australian researchers have used historical records and Argo Float data to discover that ocean salinities show an intensified water cycle. The new research was published in August this year; it also confirms that surface warming of the world's oceans over the past 50 years has penetrated into the oceans' interior changing deep-ocean salinity patterns.

A Surface Ocean Carbon Dioxide Atlas is being assembled from all available measurements in the global oceans. It will contain over 9.5 million quality controlled observations, including data from the *l'Astrolabe* Ship of Opportunity line across the Southern Ocean. Coverage in the Australian region is sparse, and the IMOS surface carbon flux data will be invaluable for measuring long term trends in ocean CO_2 sinks in the Southern Hemisphere.

All images: CSIRO

Photo: 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 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.

Photo: 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
✔	✔	✔							✔

2009-10 Highlights

IMOS successfully deployed the first weather buoy in the remote Southern Ocean in March 2010. Moored in water 4.6km deep, 580km southwest of Tasmania at 46.75S, 142E, the Southern Ocean Flux Station (SOFS) is now transmitting hourly observations of wind, temperature, humidity, air pressure, sunlight and rain. It is giving real time insights into conditions “down south”, as well as helping to build a long-term record in this climatically important region of the world ocean. Real time data plots are available through the IMOS Ocean Portal. The $1M SOFS buoy was built by Woods Hole Oceanographic Institution in the USA and is operated by the Bureau of Meteorology as part of the Deep Water Moorings Facility.

Photo: Joe Adelstein, University of Tasmania

Successful deployment of the SOFS buoy is a significant engineering achievement in itself given extreme conditions the buoy has to withstand. While the Southern Ocean plays a significant role in the global climate system, there is a paucity of sustained in situ observations, and the SOFS buoy will be a valuable contribution to building the climate record and understanding climate variability.

Photo: Joe Adelstein, University of Tasmania

Photo: 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.

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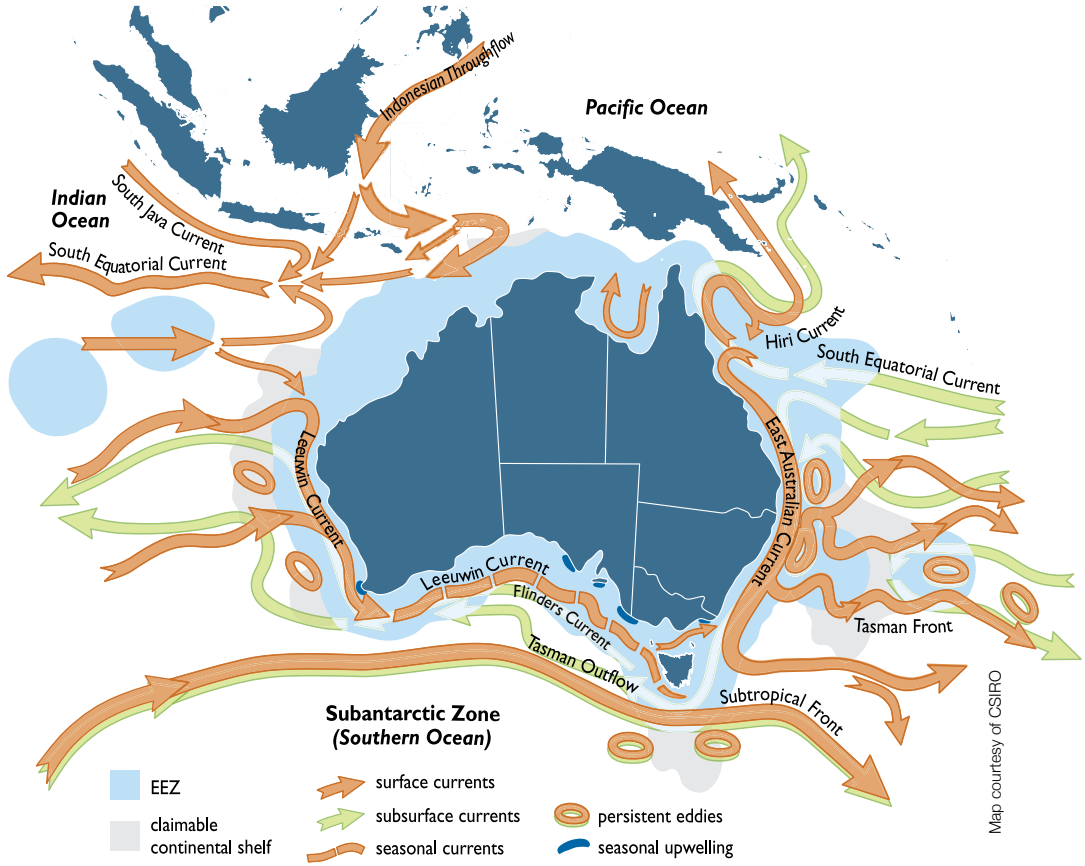
✔	✔	✔	✔		✔	✔			✔

2009-10 Highlights

The Indonesian Throughflow Shelf Transect Moorings (comprised of four moorings extending from the Timor Trough to Joseph Bonaparte Gulf) were deployed in June by the National Mooring Network Facility. This was an important first step in enhanced monitoring of northern Australian waters. These shelf moorings will complement planned Deep Water Moorings that will be deployed in the Timor Passage and Ombai Strait to monitor inter-basin Indian-Pacific Ocean exchange.

The Ocean Gliders Facility achieved its goal of deploying 5 gliders simultaneously; in Western Australia, South Australia, New South Wales and Tasmania. The Ocean Gliders Facility has also expanded the national fleet over the past year with additional EIF funds. New Seaglider routes have been established in the Southern Ocean and Coral Sea. The Southern Ocean glider spent 76 days at sea travelling back from the Southern Ocean Time Series site (approximately 600 km from Tasmania). Data from this route will allow researchers to better understand Southern Ocean influence on Australian climate and marine ecosystems. The first glider to traverse the Coral Sea was deployed in June this year.



This glider has already completed 484 dives, collecting more data about conditions in the region after three months than the sum of all historical shipboard surveys. This Seaglider will be used to observe the divergence between the EAC and the Hiri Current.

Photo: 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 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).

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
			✔		✔	✔		✔	✔

2009-10 Highlights

The Wireless Sensor Networks Facility installed a network at Lizard Island in the northern Great Barrier Reef (GBR) this year, adding to existing networks in the southern (Heron and One Tree islands) and central (Orpheus Island, Davies, Myrmidon and Rib Reef) GBR. This installation represents the last major deployment for the Facility. The sensor networks will collect data related to the interaction of heat and light in coral bleaching, to understand the impact of upwelling from the Coral Sea upon the productivity of the GBR ecosystems.

IMOS observing systems on the Great Barrier Reef were used when the Chinese coal carrier *Shen Neng 1* ran aground on Douglas Shoal in the Southern Great Barrier Reef in April this year. Data from the IMOS Moorings, Wireless Sensor Networks and the Ocean Radar in the region were used to help understand the regional circulation during the grounding. This incident highlights the potential usefulness of IMOS data for operational as well as research purposes.

Shelf mooring capability has been significantly enhanced in South Australia, and this group achieved 100% return of equipment over the past year. Data from the shelf mooring array is underpinning a newly-established hydrodynamic and biogeochemical modelling facility for South Australia.

All photos: Australian Institute of Marine Science

Photo: Andrew Boomer, Sydney Institute of Marine Science (SIMS)

Biological 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. Biological 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 biological 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.

Photo: Rob Harcourt, Macquarie University

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2009-10 Highlights

The Animal Tagging and Monitoring Facility deployed 15 CTD tags on southern elephant seals at Macquarie Island earlier this year. This data enables both biologists and oceanographers to learn from the seals; to gain a much better understanding of how the environment influences foraging behaviour and success in relation to differences in the ocean around them. With this new method of collecting integrated data, IMOS will enable researchers to determine changes in the Southern Ocean, and influences they may have on this fragile ecosystem.

Photos: Andrew Boomer, SIMS

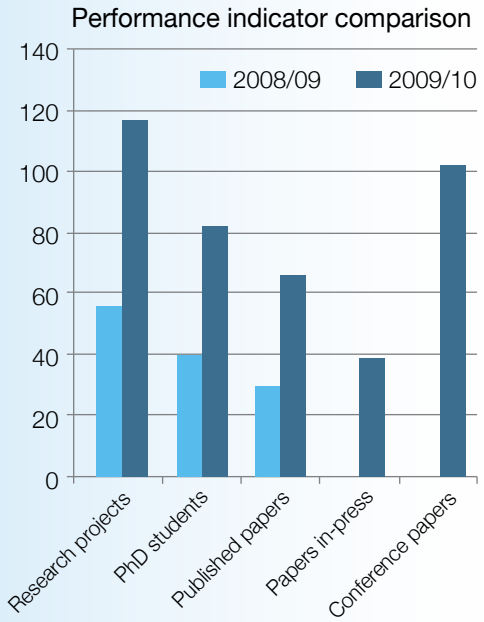
IMOS has established a national system of reference sites for repeated, sustained benthic surveying using an Autonomous Underwater Vehicle (AUV). Over the past year the AUV was deployed around Scott Reef, Rottnest Island, Jurien Bay, and the Abrolhos Islands in WA, and Freycinet, Tasman Peninsula and the Friars in Tasmania. Sites will be revisited at regular intervals by the AUV to collect a time series of measurements, documenting changes in benthic habitats and community composition over time. The AUV data will prove invaluable for monitoring change in these areas.

In New South Wales, output from the AUV facility is underpinning a new Australian Research Council Discovery project examining cost-effective autonomous systems for large scale monitoring of marine protected areas.

Photo: Rob Harcourt, Macquarie University

Performance indicators

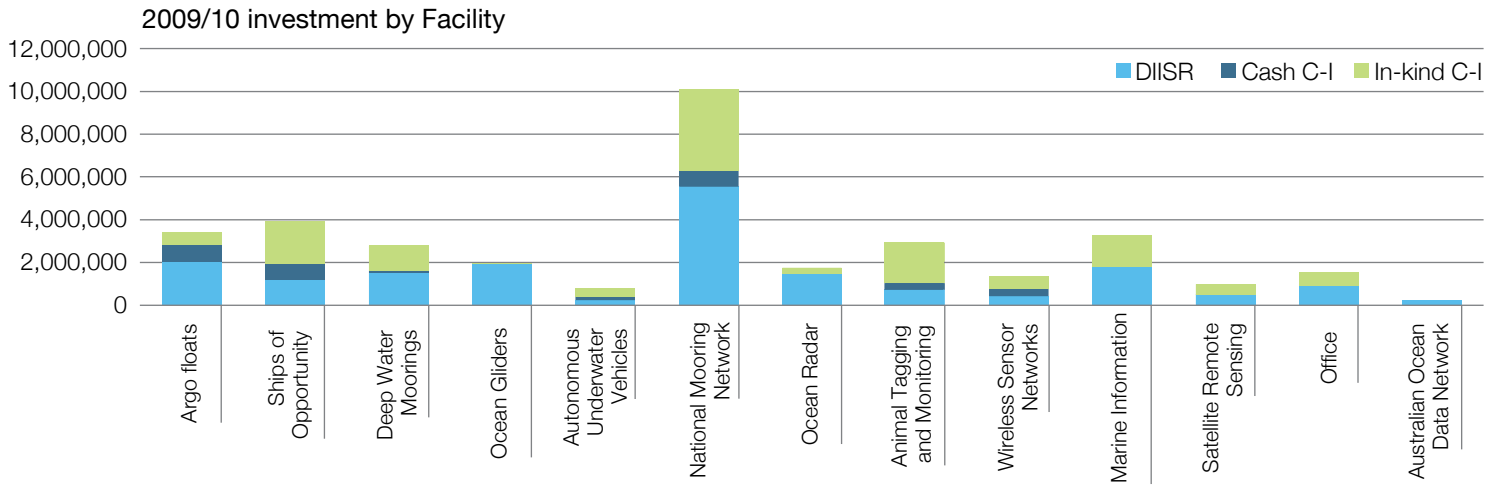
The uptake and use of IMOS data is measured by performance indicators related to research projects, postgraduate students and publications. They are fully listed in the Annual Progress Report which is available for download at **http://imos.org.au/reports1.html**. A comparison with last year's reported figures is provided below:



Financial summary

Details of IMOS finances for 2009/10 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 2009	**15,067,722**	**8,000,000**	**23,067,722**
Department of Innovation, Industry, Science and Research	8,478,000	8,000,000	16,478,000
Interest earnings	562,914	291,430	854,344
Income sub-total	**9,040,914**	**8,291,430**	**17,332,344**
Cash Co-investments	3,816,026	55,500	3,871,526
In-kind Co-investments	11,776,584	1,564,436	13,341,020
Total – Resources received	**24,633,524**	**9,911,366**	**34,544,890**
Capital / equipment purchases	3,835,633	3,892,081	7,727,714
Personnel	5,611,211	563,885	6,175,096
Other	3,443,420	1,090,945	4,534,365
Expenditure sub-total	**12,890,264**	**5,546,911**	**18,437,175**
Cash Co-investments	3,126,776	55,500	3,182,276
In-kind Co-investments	11,776,584	1,564,436	13,341,020
Total – Resources utilised	**27,793,624**	**7,166,847**	**34,960,471**
Balance at 30 June 2010	**11,907,622**	**10,744,519**	**22,652,141**



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 Collaborative Research Centre
- Australian Antarctic Division
- Australian Climate Change Science Programme
- Australian Ocean Data Centre Joint Facility
- Australian Research Collaboration Service
- Department of Economic Development, Tourism and the Arts (Tas)
- Department of Environment, Climate Change and Water (NSW)
- Department of Fisheries (WA)
- Department of Primary Industries (NSW)
- Department of Primary Industries (Vic)
- Department of State Development, Trade and Innovation (Qld)
- Flinders University
- (ARC Research Network on) Intelligent Sensors, Sensor Networks and Information Processing Network
- Interactive Virtual Environments Centre
- Macquarie University
- Manly Hydraulics Laboratories
- Marine National Facility
- Monash University
- Myriax
- Ocean Tracking Network (Canada)
- Queensland Cyber-Infrastructure Foundation
- Royal Australian Navy (Directorate of Oceanography and Meteorology)
- Scripps Institute of Oceanography (USA)
- Sea Mammal Research Unit (UK)
- Sydney Water
- Tasmanian Aquaculture and Fisheries Institute
- Tasmanian Partnership for Advanced Computing
- Tropical Marine Network
- University of New South Wales
- University of Sydney
- Vemco

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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