highlights 2016–2017

IMOS
Integrated **Marine Observing** System

Photo: Asher Flatt

Director's Overview

Tim Moltmann
IMOS Director

This Annual Highlights document covers the eleventh year of operation. It has been a year of significance for IMOS as a national research infrastructure.

The 2016 National Research Infrastructure Roadmap was developed during this period and released in May 2017. The process to prepare a Research Infrastructure Investment Plan that will determine next stage investment was then commenced, and is ongoing.

These initiatives were set in train by the National Innovation and Science Agenda launched back in December 2015, and the IMOS community worked with its users and stakeholders during 2016 to develop a comprehensive forward plan so that we would be 'investment ready'. After several years of funding uncertainty, it was refreshing to again put focus and effort into longer-term forward planning.

The IMOS Five Year Plan (2017-22) was approved by the Board in September 2016. It was very encouraging to see the key elements of this forward plan reflected in the Roadmap. With a five-year 'investment plan' in place, backed by our users and stakeholders, IMOS has every reason to be positive about its future as a national research infrastructure with global reach and local impact.

This year, we have structured the Annual Highlights document into four sections, consistent with our Five Year Plan i.e. broadscale, backbone, regional and national.

Broadscale facilities play a vital role in connecting IMOS to the global ocean observing system. This brings tremendous benefits through access to additional observations, data and knowledge from many international collaborators. Understanding local issues such as future sea levels in Australia's coastal cities, and future ocean temperatures on the Great Barrier Reef, relies on access to this global information.

Backbone facilities provide a centrepiece for IMOS as a national collaborative research infrastructure. By focusing on building large datasets and long time series for widespread use and reuse, they create mechanisms for science communities to come together in ways that simply were not possible in the pre-NCRIS era. We now see the animal tracking community making great use of the 70 million detections of 125 species built up in a national database. We see the benthic ecology community making great use of 4 million, precisely georeferenced images collected by the Autonomous Underwater Vehicle facility. Importantly, we see these science outputs being used in policy and management e.g. to assess the State of the (Marine) Environment, and the status of threatened, endangered and protected species.

Regional facilities enable IMOS to intensify effort in areas of high social, economic and environmental value. They are central to the highly productive partnership that IMOS has fostered with the ocean modelling community. This is particularly important because decision makers need ocean forecasts and scenario models to determine what to do next. By making these more accurate and less uncertain, IMOS observations and data can impact the future. Annual highlights demonstrate the relevance of IMOS on the Great Barrier Reef, the New South Wales coast, the Great Australian Bight, and the West Australian coast.

National facilities enable IMOS to be much more than the sum of its parts. A fundamental component is our unerring focus on data discovery, access, use and reuse via the Australian Ocean Data Network (AODN). AODN is now officially recognised as Australia's ocean data facility, both nationally and internationally. Access to 'non-IMOS' data via AODN grew impressively over the past year, and this is key to how we will increase use and impact over time. IMOS *OceanCurrent* adds value to observations and data by providing daily products of interest to the scientific community as well as to other users, such as fishers, sailors and ocean swimmers.

All of the achievements of the past year were underpinned by continued, excellent performance of IMOS operating institutions. The program had 295 milestones for the year, of which 90% were achieved and a further 6% in progress at 30 June 2017. An outstanding effort by all of the scientific, technical and administrative staff involved in running the program on a day to day basis.

We hope you enjoy reading this IMOS Annual Highlights document for 2016-17, and thank you for your continued interest and support.

How does IMOS work?

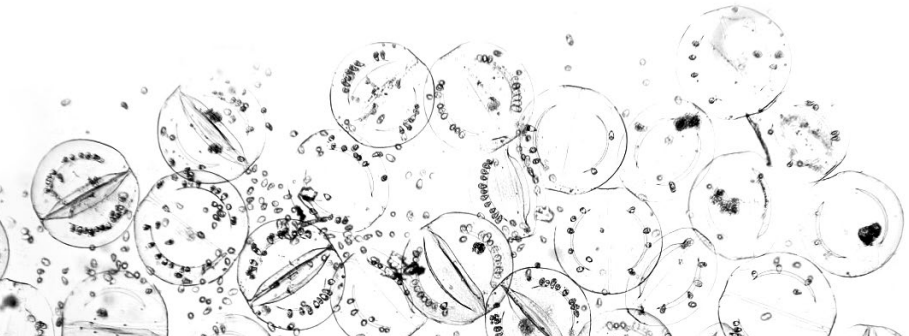
IMOS undertakes systematic and sustained observing of Australia's vast and valuable marine estate. All of its data is openly accessible to the marine and climate science community, international collaborators, and other stakeholders and users. It achieves this through a portfolio of platform-based **Facilities** to acquire the observations, an integrated set of science **Nodes** to design and guide the system, a program-wide focus on **Data** to enable ready access, use and reuse, and a growing number of **Research Partnerships** to drive uptake and impact.

Facilities

IMOS currently has a portfolio of ten Facilities that undertake systematic and sustained observing of Australia's marine environment, across scales (from open ocean, onto the continental shelf, and into the coast), and across disciplines (physics, biogeochemistry, and biology and ecosystems).

The current IMOS Facilities are:

1. Argo Floats
2. Ships of Opportunity
3. Deep Water Moorings
4. Ocean Gliders
5. Autonomous Underwater Vehicles
6. National Mooring Network
7. Ocean Radar
8. Animal Tracking
9. Wireless Sensor Networks
10. Satellite Remote Sensing



Nodes

The Australian marine science and stakeholder community is large, diverse, and dispersed. Nodes provide the means for IMOS to undertake national science and implementation planning, integrated across regions. They identify the major research themes and science questions, and determine what we need to observe, where, when and how. IMOS Node science and implementation plans have continued to be reviewed and developed over a number of years and provide a strong scientific underpinning for IMOS.

Data

A key element of IMOS is that all observations are turned into quality controlled Data that can be discovered, accessed, downloaded, used and reused in perpetuity. Datasets and time series are essentially the research infrastructure that is being created and developed. This has been achieved by having a separate Data Facility, the Australian Ocean Data Network (AODN), that is responsible for building and maintaining a national marine information infrastructure. The infrastructure includes a geospatial portal as well as a metadata system, file formats, controlled vocabularies, file storage, servers, web services, and data tools.

Research Partnerships

The societal benefits of investment in IMOS are realised through uptake and use of observations and data to undertake marine and climate science that has relevance and impact. To some extent this emerges quite naturally through the IMOS Facility and Node structure, which is based on broad engagement across the Australian marine and climate science community. However, IMOS must also be explicitly responsive to current and emerging national priorities. Partnerships with major Australian research initiatives that require marine observations and data provide a mechanism for prioritisation and focus.

In this document, we highlight science impacts from IMOS infrastructure in four sections – broadscale, backbone, regional and national.

Photos: Julian Uribe-Palomino, CSIRO

Broadscale

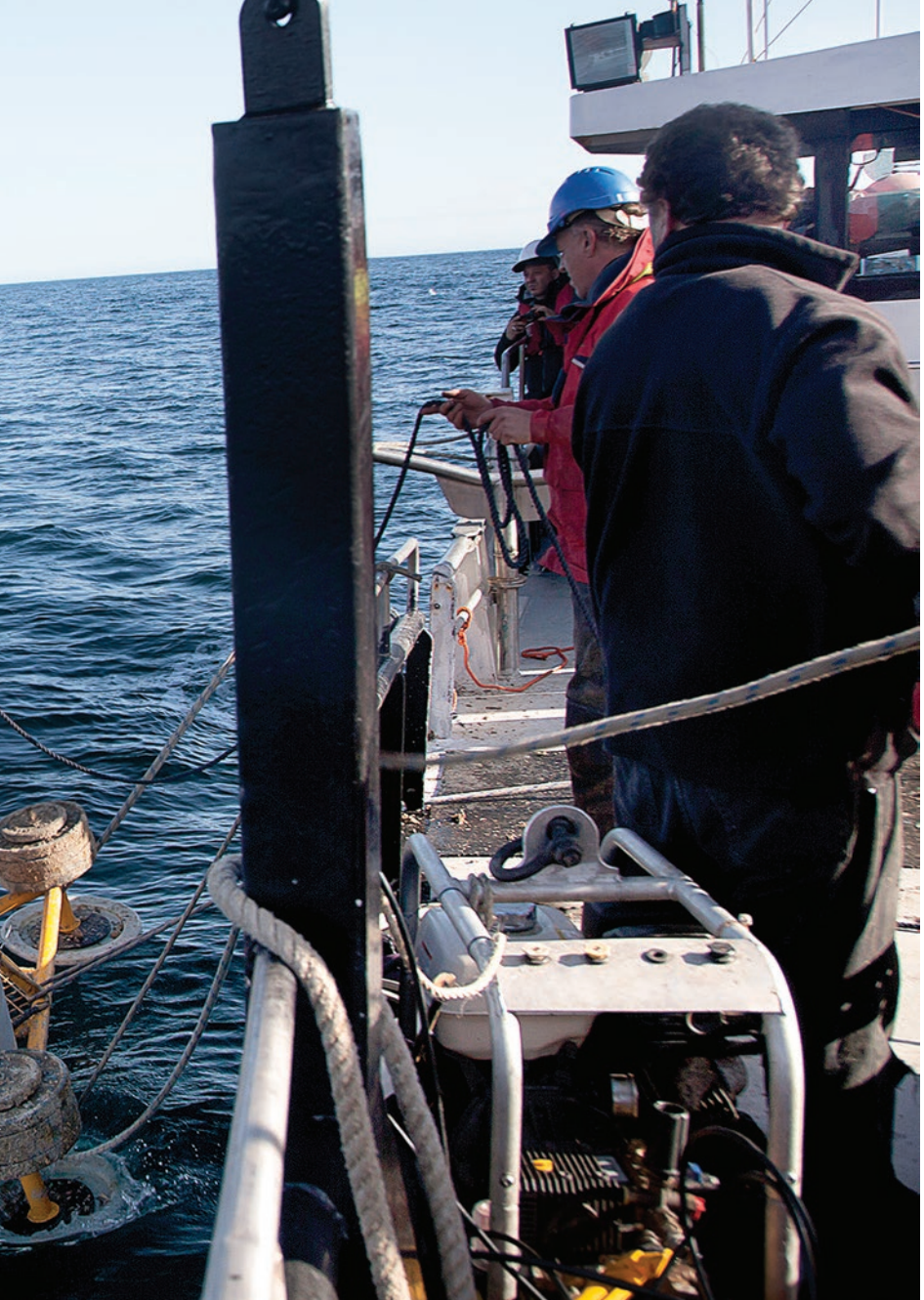
Observations from the open ocean are essential for improving our understanding of the ocean's role in climate and for tracking the evolution of climate change on decadal time-scales. Australia's highly variable climate is sensitive to conditions in the surrounding oceans and measurements of the open ocean provide the primary source of information used to anticipate floods and droughts associated with climate modes like El Niño and the Indian Ocean Dipole. Broadscale observations are also critical for ocean prediction on time-scales of days to weeks.

The IMOS broadscale observing infrastructure delivers sustained observations that cover the open ocean, providing researchers with the data to observe, understand and predict the oceans surrounding Australia from the tropics to Antarctica. The ocean is a globally connected system, and marine observing is an international endeavour. The broadscale facilities also provide much of Australia's contribution to the Global Ocean Observing System (GOOS), and related basin-scale coordination efforts in the Southern Ocean, Indian Ocean and Pacific Ocean.

The IMOS broadscale portfolio currently includes:

- Argo profiling floats,
- Satellite Animal Tracking,
- Ships of Opportunity, for physics,
- Ships of Opportunity, for biochemistry and biology and ecosystems, and
- Satellite Remote Sensing, calibration/validation/reception and national products.

Photo: Carlie Devine, CSIRO



2016–17 Impact

Sea level rise – The potential impact of sea level rise is well documented with around 250,000 Australian homes and much of the related transport, energy, communication and waste infrastructure vulnerable to a 1.1 metre sea level rise.

Global mean sea level has been rising at a faster rate during the satellite altimetry period (1993–2014) than previous decades, and is expected to accelerate further over the coming century. However, the accelerations observed over century and longer periods have not been clearly detected in satellite data spanning the past two decades.

A recent study that incorporated IMOS satellite altimeter time series data, has shown the factors contributing to sea-level rise (called contributions) have increased by half since 1993, largely due to an increased contribution from Greenland's ice. This result increases confidence in our altimetry observations (including the associated calibration and validation supported by IMOS) and improves our understanding of recent changes and emerging increases to the rate of sea-level rise.

Ocean circulation – The Southern Ocean surrounding Antarctica is one of the most important, yet least observed parts of the global ocean. Connecting all the world's oceans, the physical structure of the Southern Ocean profoundly influences world climate and ecology, and plays a key role in global climate.

IMOS has been tagging elephant seals since 2011 to collect important data on ocean properties throughout the Antarctic winter – data previously unavailable but crucially important to oceanographic and climate studies. A study using IMOS data from elephant seals, discovered that fresh water from Antarctica's melting ice shelves slows the production of powerful deep-water ocean currents responsible for regulating global temperatures.

The findings of the research raised questions about potential future changes in the global ocean and climate systems. If the production of Antarctic bottom water weakens, it leads to changes in global ocean circulation patterns that can ultimately change the global climate.

Ocean uptake of carbon – Understanding how the oceans absorb carbon dioxide is critical for understanding the global climate system and predicting climate change.

IMOS data has contributed to a new version of the Surface Ocean CO_2 Atlas (SOCAT). SOCAT version 3 brings together 14.7 million quality controlled, surface ocean carbon dioxide observations from 1957 to 2014 for the global oceans and coastal seas. The new version has created a 58-year data record with additional data sets for recent years, and also included calibrated surface ocean measurements from alternative sensors and platforms, such as moorings and drifters, in remote and less remote ocean regions.

High profile scientific applications of SOCAT include quantification of the ocean sink for atmospheric carbon dioxide and its long-term variation, detection of ocean acidification, as well as evaluation of coupled-climate and ocean-only biogeochemical models.

Ocean warming – The Subtropical South Pacific is one of the Earth's major heat accumulators and accounts for up to a quarter of the global ocean heat increase.

A recent study has performed a comprehensive analysis of satellite and in situ measurements (including data from the IMOS Argo array) to report that a significant deep-ocean warming occurred in the subtropical South Pacific Ocean over the past decade (2005-2014). Heat accumulation is due to a decade-long intensification of wind-driven convergence, possibly linked to persistent La Niña-like conditions.

We need to better understand the uptake of heat and the response of the Pacific-Indian tropical oceans to climate change given their role as complex drivers of seasonal, inter-annual and decadal variability, particularly in the variability of tropical cyclones, heatwaves and droughts.

Clive McMahon, Sydney Institute of Marine Science

Backbone

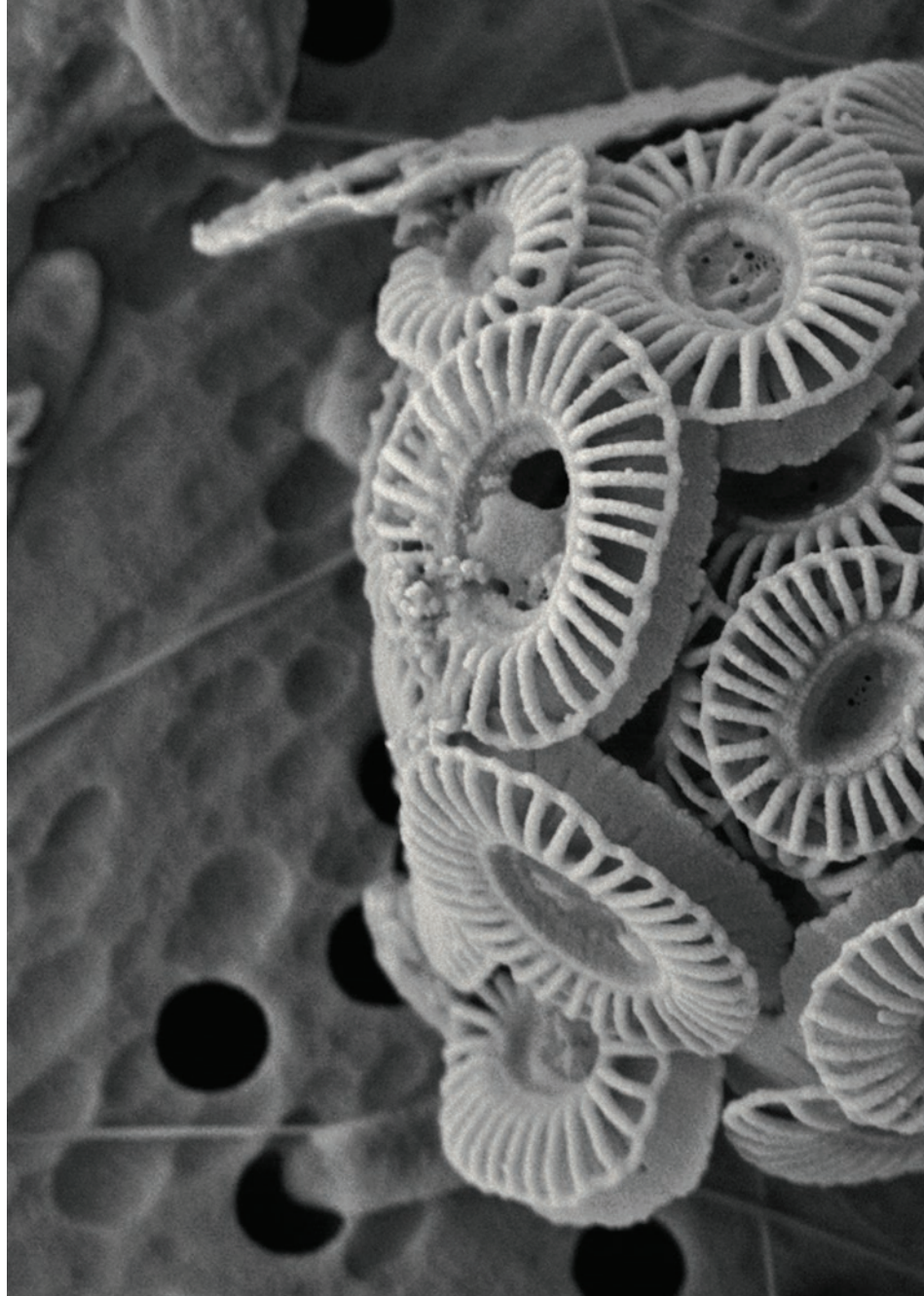
Backbone facilities play a central role in IMOS, linking the broadscale to the regional, and providing whole-of-program capability that goes beyond a 'sum of regions' approach.

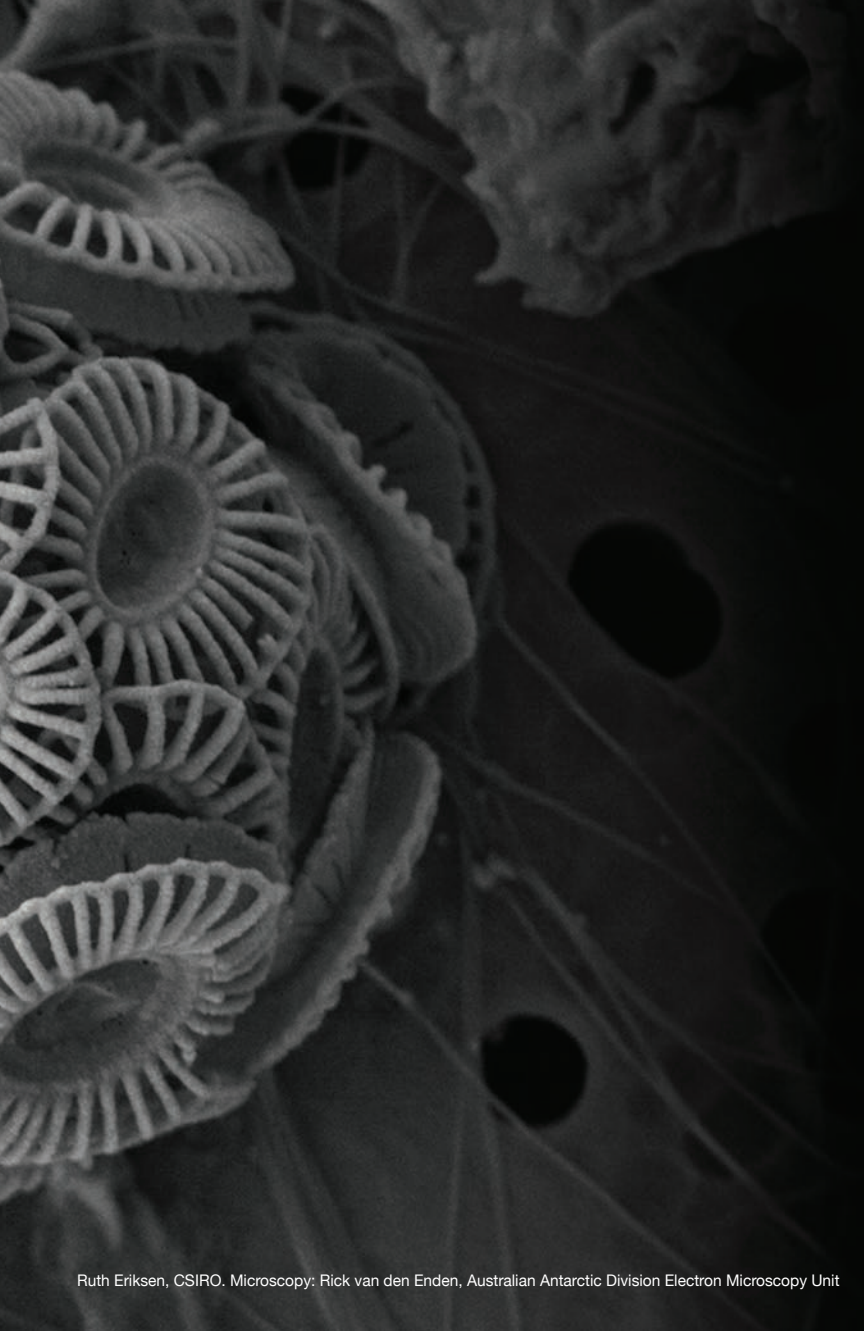
Within IMOS this manifests in a capability to monitor major boundary currents, such as the East Australian Current. It manifests in the ability to develop long term, high frequency time series to address significant questions, such as uptake of CO_2 in the Southern Ocean, and variability and change in the physical and biogeochemical properties of Australia's coastal seas. Lastly, it manifests in an integrated suite of national facilities to study marine biology and ecosystems, and their interaction with biogeochemical and physical processes. Emphasising biology and ecosystems in the backbone is a strategic choice. It is based on an assessment that IMOS will make a much greater difference in sustained ecological observing by playing the role of national integrator and aggregator, guided by priorities around bioregional planning and management, assessing the state of the marine environment, and managing long ranging, cross-jurisdiction species, both commercially exploited and threatened/protected.

Photo: Andrew Bowie, Antarctic Climate & Ecosystems CRC and Institute for Marine and Antarctic Studies

The IMOS backbone portfolio currently includes:

- Deep Water Moorings (transport arrays),
- Deep Water Moorings (time series),
- National Reference Station Network (including ocean acidification and passive acoustics),
- Acoustic Animal Tracking, and
- Autonomous Underwater Vehicles (AUV).





Ruth Eriksen, CSIRO. Microscopy: Rick van den Enden, Australian Antarctic Division Electron Microscopy Unit

2016–17 Impact

Global carbon cycle – The world's oceans have a remarkable capacity to absorb carbon dioxide. About one third of the carbon dioxide released by human activities has been absorbed in the ocean, with the Southern Ocean playing the most important role of any ocean and accounting for ~40% of the total.

In the Australian sector, the Subantarctic Zone (SAZ) exports large quantities of organic carbon from the surface ocean, despite lower algal biomass accumulation in surface waters than other Southern Ocean sectors. A recently published paper has presented the first analysis of diatom and coccolithophore assemblages and seasonality, as well as the first annual quantification of bulk organic components of captured material at the base of the mixed layer (500m depth) in the SAZ.

Sediment traps have been moored at a location southwest of Tasmania as part of the long-term SAZ project initiated by the Antarctic and Climate Cooperative Research Centre in 1997, which has become part of the IMOS Deep Water Moorings Facility. The study provides a unique, direct measurement of the biogeochemical fluxes and their main biological carbon vectors.

A deeper understanding of the biological and physical processes that control the carbon export in the SAZ is of critical importance to determine the role of the Southern Ocean in the global cycling of nutrients and climate.

Species distribution – Australia's marine estate is home to some of the world's most iconic marine species. However, the historical paucity of data about the distribution of one of these species, the white shark *Carcharodon carcharias*, makes it difficult to develop effective, evidence-based strategies for mitigating the risks associated with human encounters.

A recent study examined the movements of 89 tagged white sharks between December 2008 and May 2016, through the network of 343 IMOS acoustic receivers in Western Australia and South Australia. In all, 290 inter-regional movements, totalling 185 092 km were recorded for 73 of these sharks. Sharks commonly moved at a rate in excess of 3 km/h, even over

distances of thousands of kilometres. Detections indicated that white sharks may be present off most of the south and lower west coasts of WA throughout the year, although were more likely to be encountered during spring and early summer.

There was limited evidence for predictable return behaviour, however, the data suggests that continental-scale collaborative studies such as this are increasingly important for an improved understanding of the movement ecology of white sharks in south-western Australian waters.

Deep reefs – To conserve marine biodiversity and keep ecosystems healthy in Australia's vast ocean territory it is important to explore and map our marine estate to fill in knowledge gaps.

High resolution underwater images taken by the IMOS Autonomous Underwater Vehicle (AUV) have been used in a study to characterise the distribution and ecology of deep (30–90 m) reef sessile invertebrate assemblages from sub-tropical to temperate eastern Australia. The study estimated the cover of 51 preselected invertebrate types from over 1700 seafloor images from more than 105 km of transects across the study region.

Changes in community structure mostly correlated with primary productivity and the temperature climatology, while local scale variability in community composition was most related to depth. Documenting the changes in deep reef benthic community composition across latitudinal and environmental gradients in temperature Eastern Australia provides an essential benchmark to detect the effects of climate change in an area identified as a global hotspot for climate-driven ocean change.

Marine microbial biodiversity – IMOS data is contributing to the study of marine organisms at all trophic levels from apex predators down to microogranisms. Marine Microbial sampling occurs alongside our physical and chemical observations at the seven IMOS National Reference Stations around Australia. Since mid-2015, IMOS has partnered with Bioplatforms Australia to commence DNA sequencing of these samples to generate the large-scale datasets required to understand fundamental marine processes, and have a more complete understanding of marine microbial diversity and function.

A new study has used the data from three of the IMOS National Reference Stations spanning the east coast of Australia (at North Stradbroke Island in Queensland, Port Hacking in New South Wales and Maria Island in Tasmania) to observe the temporal patterns in Aerobic Anoxygenic Phototrophic Bacteria (AAnPB) dynamics.

Whilst this diverse group of aquatic microorganisms are ecologically important, the key environmental drivers underpinning their abundance and diversity are still largely undefined. Network analysis revealed that discrete AAnPB populations exploit specific niches defined by varying temperature, light and nutrient conditions in the Tasman Sea system, with evidence for both niche sharing and partitioning amongst closely related operational taxonomic units.

Microorganisms are the major biotic players in controlling the function of marine environments. The composition and biogeochemical functionality of these microbial assemblages underpins the ecology of marine ecosystems and mediates the ocean-atmosphere exchange of climatically important gases. Studies like these will help us understand the full potential of our oceans and estuaries, their health and resilience.

Photo: Andrew Fox, Rodney Fox Shark Expeditions

Regional

IMOS invests in Facilities responding to the needs of multiple regions around Australia. This allows for regional intensification of infrastructure in areas of high social, economic, and environmental value.

The IMOS regional Facilities undertake measurements of the major boundary currents, and continental shelf and coastal processes in Australian waters. They are aimed at determining the fundamental physics and biogeochemistry of shelf and coastal ocean circulation, and the influence of climate and climate change.

These Facilities are collectively contributing an unprecedented level of data in Australian shelf and coastal waters, which in turn is creating new opportunities for modelling, analysis and product development.

The IMOS regional portfolio currently includes:

- Ocean gliders,
- Ocean radar,
- Moorings network (continental shelf and coastal),
- Wireless sensor networks (Great Barrier Reef), and
- Satellite Animal Tracking.

Photo: Warrick Glynn, IMOS

2016–17 Impact

Shelf climatology – In order to maintain Australia's marine sovereignty, and improve security and safety, we need to better understand, monitor and predict sea state (winds, currents and waves) and extreme events in the marine environment.

A recently published data set collected by IMOS ocean gliders over 26 missions along the continental shelf of southeastern Australia, is made up of over 33,600 CTD profiles from the surface to water depths ranging 25–200 m. The data set provides unprecedented high resolution observations of the continental shelf waters adjacent to a western boundary current, straddling the region where it separates from the coast.

The study presents a high-resolution mean hydrography of the continental shelf along south-eastern Australia from repeat glider deployments over eight years. The data set provides for the first time gridded mean fields for temperature, salinity and density, but also dissolved oxygen and chlorophyll-a fluorescence indicative of phytoplankton biomass. This data will be invaluable for understanding shelf stratification, circulation, biophysical and bio-geochemical interactions, as well as for the validation of high-resolution ocean models.

Eddy-shelf interactions – IMOS radar observations have proved to be a useful tool for examining ocean processes. One study used more than a year of high-resolution (1.5 km, hourly) surface velocity measurements from the IMOS ocean radar at Coffs Harbour to quantify the propagation of frontal eddies and meanders along the eastern coast of Australia.

The study used the surface current measurements from the ocean radars, in conjunction with data from IMOS moorings, and satellite observations. It was the first time that the characteristics and motion of frontal eddies in a western boundary current have been systematically observed at high resolution.

These cyclonic frontal eddies are a major mechanism for the transport and entrainment of nutrient rich coastal and deep waters, influencing physical and biological dynamics, and connectivity over large distances.

Photo: Emma Sommerville, IMOS

Influence of sea breezes – Researchers in Western Australia have used observations from a range of IMOS platforms including ocean radar, moorings and satellite remote sensing data from the Rottnest continental shelf to examine the influence of the strong land-sea breeze cycle on upper ocean dynamics. The study found that the daily sea breeze has major implications for circulation and vertical mixing along the Rottnest continental shelf and offshore regions.

The IMOS observations indicated that when southerly winds and land-sea breeze system dominated the wind regime, strong counterclockwise circular motions with periods of 24 hours penetrated to water depths greater than 300m. The resonant processes identified using the IMOS data provide a mechanism that is able to transport nutrients to the upper ocean which is important for local primary production and thus to local fishery resources.

Coral bleaching – Ocean warming has caused several major bleaching events on the world heritage listed Great Barrier Reef (GBR). The 2015-16 summer saw widespread coral bleaching along the GBR.

Data from the IMOS Wireless Sensor Networks provided daily real-time measures of temperature, bleaching stress and risk which helped guide survey and monitoring work. The analysed data documents the local and regional environmental factors that led to the bleaching event.

The IMOS data successfully predicted bleaching severity along the GBR with field surveys confirming the north (extensive bleaching) to south (moderate to no bleaching) patterns. The data also revealed that warmer temperatures continued well past the summer – temperatures remained 1ºC above normal from March through to June 2016. This late summer warming may have implications for the fate of corals that were exposed not only to record high temperatures, but to subsequent months of above-normal temperatures. The increased frequency of bleaching events highlights the importance of near real time observations to inform intervention.

Upwelling of cooler waters – Another study published recently examined cool, salty bottom water intrusions in the Central Great Barrier Reef. The study aimed to characterise their seasonal occurrence, the intensity of bottom cooling and duration, and to determine the physical mechanisms causing them.

The research identified the intrusions using six years of mooring observations from the IMOS mooring in the Palm Passage and linked them to fluctuations in the winds and source waters over the slope.

A complementary analysis using a regional hydrodynamic eReefs model for the Great Barrier Reef further revealed the roles of winds and density fields in forcing the shelf circulation during intrusion events.

Understanding the underlying causes of observed patterns in both coral bleaching events and the upwelling of cooler water is important for the management and use of the GBR under changing conditions.

Operational oceanography – To meet the challenge of managing Australia's fisheries and aquaculture, the science underpinning it must be collaborative and integrated to develop improved tools for managers for better decision-making.

In a new project, titled eSA-Marine, the first step towards an operational now-cast/forecast ocean predication system for South Australia has been made, underpinned by IMOS observations and data. The first phase of an operational model has been developed for Australia's southern shelves by nesting SARDI's high resolution (2.5 km grid) ocean model SAROM inside the Bureau of Meteorology's global 10 km grid operational now-cast/forecast model – Ocean MAPS.

The new operational web-based system will assist fisheries and aquaculture in the hazard management of harmful algal blooms/toxins, prediction of ocean weather and likely habitat of pelagic fish.

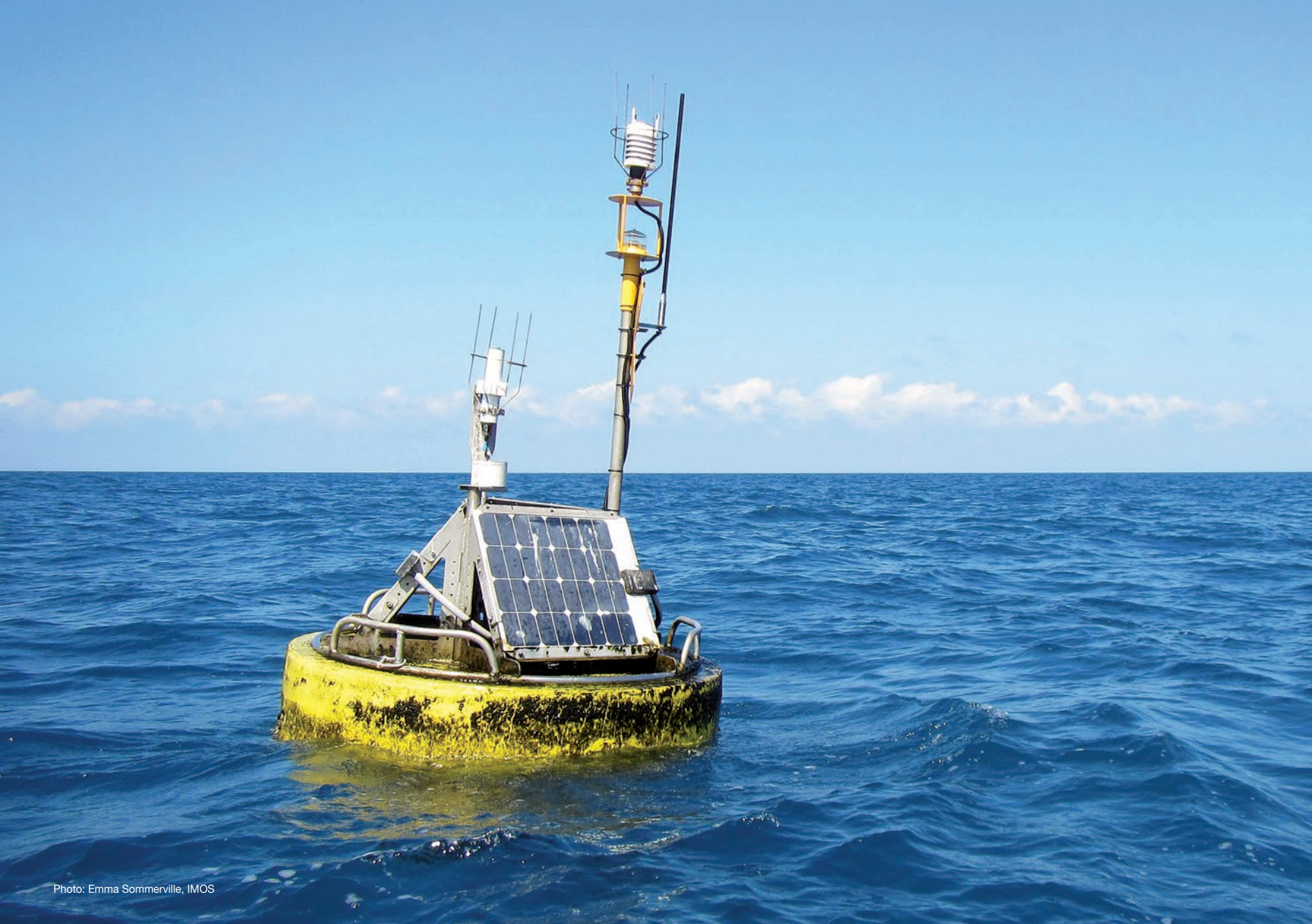


Photo: Emma Sommerville, IMOS

National

IMOS has a clear focus on national-level governance, management and delivery mechanisms. Key components include the Australian Ocean Data Network (AODN) and IMOS *OceanCurrent*.

Australian Ocean Data Network (AODN)

At the beginning of this year, the IMOS eMarine Information Infrastructure (eMII) Facility and the Australian Ocean Data Network (AODN) were merged into a single entity. IMOS has had responsibility for managing Australia's national ocean data facility since 2011, but for historical reasons, separate eMII and AODN infrastructures were being maintained. The marine information Facility of IMOS became the AODN from 1 July 2016.

Enabling open access to marine data, regardless of how its acquisition is funded, is considered to be core business for IMOS. This is key to how we will grow the use and impact of marine observations and data in the Australian marine environment over time.

Several improvements were made to the AODN information infrastructure this year, which is now hosted on Amazon Web Services. The sub-setting and aggregation of gridded data products (satellite Sea Surface Temperature and Ocean Colour; ocean radar surface currents) was significantly improved, with a near order-of-magnitude improvement in aggregation time. The export of single point time series was also implemented. The ingest of IMOS facility data has been streamlined by the establishment of 'pipeline' processes which test for conformance of a range of standards and speed the delivery of conforming datasets to publication. Enhancements to the Moorings Toolbox have improved processing and quality control, and it is now used by all IMOS moorings sub-facilities. The ability to download data in the form of shapefiles was added in response to user demand, to handle datasets such as benthic habitat maps and their interaction with GIS software.

Access to IMOS and 'non-IMOS' data via AODN grew impressively over the past year. The AODN now includes 174 data collections that can be discovered, accessed, sub-setted and downloaded. This is up from 133 data collections last year. Virtually all (94%) of the 41 new data collections are 'non-IMOS'.

Growth in AODN data collections was achieved through a portfolio of approaches. The AODN software 'stack' was implemented at new partner organisations such as Deakin University. AODN worked with partners such as the NSW Office of Environment and Heritage to begin making their data openly accessible. And through research partnerships, such as with the National Environmental Science Programme (NESP) Marine Biodiversity Hub, we ensure that new marine observations collected through Australian Government funded research programs are becoming accessible via AODN.

Photo: David Boadle, CSIRO

Photo: Warrick Glynn, Marine National Facility

IMOS *OceanCurrent*

The IMOS *OceanCurrent* website provides ready access to quick-look graphics of Australian ocean conditions, including sea surface temperature and ocean colour, overlaid with sea level contours and surface current velocities.

It sources data from a number of the IMOS facilities including Satellite Remote Sensing, Deep Water Moorings, National Mooring Network, Ocean Radars, Ocean Gliders and Argo. The daily IMOS *OceanCurrent* maps are highly valued by the IMOS science community and a broader stakeholder base.

Improvements over the past year include the addition of temperature and salinity profiles from ocean mammals ('SealCTDs').

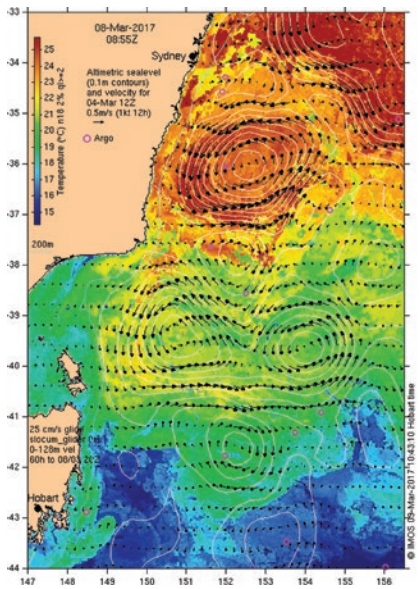
OceanCurrent is regularly used by marine scientists working at sea, on research voyages or when piloting ocean gliders. In one study published this year, IMOS *OceanCurrent* maps were used to contrast two eddies that had formed in the Eastern Australian Current whilst onboard the Marine National Facility *Investigator*.

The study presents the first depth observations of a small (~35 km in diameter) cold core eddy, which formed along the landward front of the East Australian Current (EAC). The researchers contrasted the observations with a typical larger (~160 km in diameter) cold core eddy.

The study made use of satellite remote-sensed observations of sea surface temperature (SST) and ocean colour on cloud-free days, processed and served through the IMOS *OceanCurrent* website, as well as in-situ observations that were collected from the dedicated research voyage aboard *Investigator*.

Observational data sets depicting the 3-D structure of eddies are rare, and to date the dynamics of frontal eddies have primarily been diagnosed through modeling studies. The comprehensive data set revealing the 3-D structure and dynamics of two contrasting cyclonic eddies showed that not all cyclonic eddies are created equal. The smaller frontal eddy was significantly more energetic and productive than the mesoscale cyclone, despite its small size and short life. It was shown to be a very dynamic feature, rotating rapidly, extending to more than 1000 m in depth, and was highly productive. The researchers believe these features make a significant contribution to the productivity of the Tasman Sea region.

In addition to supporting research, *OceanCurrent* was used to inform Sydney to Hobart yachtsmen and competitors in the Rottnest Channel Swim, as well as to investigate connections between oceanographic conditions and a mass fish die-off at Mallacoota in April 2017.

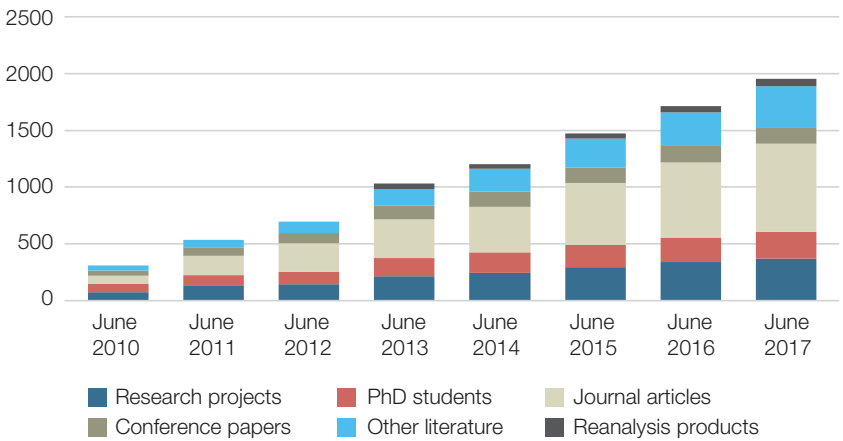


Performance Indicators & Financials

Performance Indicators

The uptake and use of IMOS data is measured in terms of research projects, postgraduate students, publications and products. These are fully listed on the IMOS website at **http://www.imos.org.au/imospublications.html.** Measured scientific output continued to grow impressively over the last year, as shown below:

Counting science outputs is useful, but it does not necessarily tell the full story of the impact IMOS is having. For example, the annual achievements highlighted in this document are drawn from fifteen publications as shown in the references. These fifteen papers had a total of 166 different authors from 82 institutions, both national and international, providing an insight into the breadth of use that IMOS is enabling.



Financial Summary

A summary of the IMOS finance for 2016-17 is provided below:

FINANCIAL OVERVIEW	2016–17	2015–16
Balance at beginning of financial year	**2,587,452**	**1,015,629**
Income		
National Collaborative Research Infrastructure Strategy (NCRIS)	15,573,697	13,963,000
Cash Co-investments	3,444,249	6,196,130
In-kind Co-investments	21,708,441	16,829,537
Total	**40,726,387**	**36,988,667**
Expenditure		
NCRIS Expenditure		
Capital / equipment purchases	1,919,532	2,486,979
Personnel	9,456,552	8,652,489
Other	4,161,228	4,187,175
Sub Total NCRIS	**15,537,312**	**15,326,643**
Cash Co-investments	3,091,357	3,260,664
In-kind Co-investments	21,708,441	16,829,537
Total	**40,337,110**	**35,416,844**
Balance at end of financial year	**2,976,729**	**2,587,452**

Partners

OPERATORS

> Australian Institute of Marine Science
> Bureau of Meteorology
> Commonwealth Scientific and Industrial Research Organisation
> Curtin University
> South Australian Research & 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

> Austral Fisheries
> Australian Antarctic Division
> Australian Longline
> Department of Defence
> Department of Primary Industries, NSW
> Department of State Growth, Tas
> Environmental Protection Authority, Victoria
> Flinders University
> Great Barrier Reef Marine Park Authority
> James Cook University
> Landbridge Group
> Marine National Facility
> Monash University
> National eResearch Collaboration Tools and Resources
> Office of Environment and Heritage, NSW
> Office of Science and Research, NSW
> Royal Australian Navy
> South East Trawl Fishing Industry Association Ltd
> Sydney Water Corporation
> University of Melbourne

INTERNATIONAL COLLABORATORS

> European Space Agency
> First Institute of Oceanography
> French Polar Institute
> Hokkaido University
> National Aeronautics and Space Administration
> National Center for Scientific Research, France (CNRS)
> National Institute of Water and Atmospheric Research, NZ
> National Oceanic and Atmospheric Administration, USA
> National Science Foundation, USA
> Ocean Tracking Network
> Scripps Institution of Oceanography, USA
> Sealord
> Sea Mammal Research Unit
> Shanghai Ocean University
> Southern Ocean Observing System
> University of Stockholm

RESEARCH PARTNERSHIPS

> Antarctic Climate & Ecosystems Cooperative Research Centre
> Australian Research Council
> BlueLINK Ocean Forecasting
> eReefs
> Fisheries Research and Development Corporation
> Great Australian Bight Research Program
> National Environmental Science Programme Earth Systems and Climate Change Hub
> National Environmental Science Programme Marine Biodiversity Hub
> Reef 2050 Integrated Monitoring and Reporting Program
> Western Australian Marine Science Institution

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NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

IMOS is a national collaborative research infrastructure, supported by Australian Government. It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent.

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PRINCIPAL PARTICIPANTS

University of Tasmania (Lead Agent)

Australian Government | Australian Institute of Marine Science

Australian Government Bureau of Meteorology

CSIRO

Government of South Australia

SARDI South Australian Research and Development Institute

The University of Western Australia

sims sydney institute of marine science

UTS

The University of Sydney

Macquarie University

UNSW Sydney

SIMS is a partnership involving four Universities.

ASSOCIATE PARTICIPANTS

Curtin University

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