IMOS

# marinematters

Integrated **Marine Observing** System

**ISSUE 25** | DECEMBER 2016

Senator Jonathon Duniam launches '*From Observations to Impact, the first decade of IMOS*'

Elephant seals collect crucial data for understanding the global climate

Underwater glider sets off from Perth to Sri Lanka in record-breaking mission

## East Australian Current measurements provide clues on climate and more

**The IMOS East Australian Current deep water moorings have just been retrieved and redeployed from a recent RV *Investigator* voyage after collecting data for 18 months.**

Rebecca Cowley, Marine National Facility

# director's corner

Welcome to the final edition of Marine Matters for 2016. IMOS celebrated its tenth anniversary with the launch of a 'decadal impact' document by Senator Jonathon Duniam on 11th November.

The Senator was acting on behalf of our Minister, Senator the Hon Simon Birmingham, who visited the IMOS Office back in August. IMOS only exists because of the tremendous support it receives from Australian Government through the National Collaborative Research Infrastructure Strategy (NCRIS), and we have welcomed opportunities to acknowledge this with members of the Federal Parliament and Cabinet.

A number of articles in this edition feature the role of IMOS in observing the global ocean, and the benefits Australia generates though being part of an international community.

The distinctive role IMOS plays in the southern hemisphere can be seen from tagged seals revealing how melting ice shelves in East Antarctica affect the global climate system, and sustained measurement of the East Australian Current (EAC) as an important limb of Pacific Ocean circulation. IMOS was also prominent at an international workshop on 'Building Regional Earth and Marine Observation Systems to Safeguard APEC Resources and Communities Workshop', putting our work into the context of an economic forum for the Asia Pacific region.

It is perhaps easy to take for granted the amazing data we access from international space agencies. We need to acknowledge this, and 'give back'. IMOS has key roles in providing high quality, in situ observations to help calibrate and validate these satellite measurements, and adding value to the global datasets in our region of expertise. Stories on ocean colour radiometry calibration at Lucinda Jetty and application of sea surface temperature (SST) products give emphasis to this relationship.

Closer collaboration between our national marine observing and data system, and the various numerical modelling communities, is proving to be increasingly productive. The third biennial Australian Coastal and Oceans Modelling and Observations Workshop (ACOMO) held at the Academy of Science in Canberra was highly successful. ACOMO is clearly filling an important niche in the national marine science system by providing a unique opportunity to bring together observing and modelling, from physics to ecosystems. As well as two outstanding keynote speakers, we were fortunate to have Dr Glenn Nolan, Secretary General of the European Global Ocean Observing System (EuroGOOS) in attendance. IMOS and EuroGOOS are two of thirteen regional alliances of the global ocean observing system, and we benefit tremendously by benchmarking against our most advanced peers.

In closing, I would like to wish you and your families a safe and happy festive season. Through the efforts of all in our community, IMOS finishes 2016 in very good shape.

*Tim Moltmann*

Gloria Salgado Gispert, Marine National Facility

## SENATOR JONATHON DUNIAM LAUNCHES
# *'From Observations to Impact, the first decade of IMOS'*

The new publication was launched in Hobart by Senator Jonathon Duniam in early November, and celebrates the first ten years of IMOS; particularly the impact it has created in places around the country and the partnerships it has enabled.


The Earth is a 'blue planet' with over 70% of its surface covered by ocean and Australia is a marine nation with the third largest ocean territory on Earth. The ocean is a natural resource that has delivered massive economic, social and environmental benefits to generations of Australians.

In 2006-7 the Australian Government's National Collaborative Research Infrastructure Strategy (NCRIS) provided the opportunity to create, for the first time ever, a single, national Integrated Marine Observing System (IMOS).

Such research infrastructure is needed to enable systematic and sustained observation of our marine environment at national scale. This is necessary if we are to understand the marine environment sufficiently well to be able to manage it sustainably for the benefit of future generations.

Senator Jonathon Duniam, who represented the Minister for Education and Training, Senator the Hon. Simon Birmingham, described IMOS as an 'international leader in ocean observing'.

"The achievements of IMOS over the past decade have been outstanding.

"From the rise in global ocean temperatures detected by the Argo array; to the tagging of Southern Ocean elephant seals that are collecting crucial climate data where other observing platforms can't go," said Senator Duniam.

Senator Duniam spoke of the value of such national collaborations.

"Our future competitiveness, not just the state of Tasmania but as a nation, relies upon the activities taking place throughout our universities and research centres," he said.

'From Observations to Impact' provides an introduction to IMOS, a brief history, an explanation of the need for IMOS, and a description of the national capability that has been created. However, as IMOS Director Tim Moltmann points out, the bulk of the publication is about impact, described from the perspectives of places, and partnerships.

Senator Jonathon Duniam with IMOS Director Tim Moltmann at the launch.

"The places that IMOS has delivered impact range from the high tropics to Antarctica, east coast and west, from harbours to the deep ocean," said Mr Moltmann.

"The partnerships that create impact come through working with industry and working with universities undertaking research training, through international collaboration to study a globally connected ocean, through working with centres of excellence in marine science and working with the major marine research programs addressing national priorities," he said.

The IMOS community thanks its stakeholders across Australia and globally for their interest, contributions and support to date. We hope everyone enjoys reading our publication and continues to share in our passion for high quality marine science with real world impact.

"The Australian Government has recently made an ongoing commitment to NCRIS and we look forward to delivering even greater impact in our second decade," said Mr Moltmann.

# Underwater glider sets off from Perth to Sri Lanka in record-breaking mission

The IMOS Ocean Glider Facility together with Rutgers University have deployed an ocean glider off Fremantle heading to Sri Lanka, a distance of 6,200 km. This is the longest journey of an ocean glider to-date.

IMOS, through the University of Western Australia which operates Australia's National Facility for Ocean Gilders, is proud to be part of the Challenger Glider Mission. The glider's successful crossing of the southern Indian Ocean has been an historic event. As it heads north to Sri Lanka and eventually back to South Africa it will complete a world first circumnavigation of the Indian Ocean basin.

IMOS Director, Tim Moltmann speaks of the collaboration with Rutgers University to undertake this ambitious plan.

"The Challenger Glider Mission is pushing the limits of the technology and helping us to learn just how much can be achieved through well planned missions involving multiple partners.

"It is enabling us to build capacity in ocean sciences around the Indian Ocean Rim, where development of the blue economy holds immense promise for the future," said Mr Moltmann.

"Open access to cost effective ocean information from autonomous technologies will be key to unlocking this potential," he said.

Data collected by the glider will be available through the Global Telecommunication System (GTS) and the intention is to integrate these data into the Australian Ocean Data Network (AODN) Portal, which makes vast amounts of ocean data freely available to the research community, industry and the general public.

The glider was launched in Fremantle (Australia) to travel to Galle (Sri Lanka), an estimated distance of 6,200km. It is expected to take about 8–10 months to make the journey, arriving in Sri Lanka after the monsoon in September 2017.

> *"Who knows what challenges the glider will face as she makes her way across this vast ocean frontier"*

Yasha Hetzel


The pre-launch celebration for underwater glider 'Challenger' (RU29) at the University of Western Australia's glider port before deployment on its first leg of a planned Indian Ocean circumnavigation. L to R: Chip Haldeman, Rutgers glider pilot; Nick D'Adamo, Intergovernmental Oceanographic Commission (IOC) of UNESCO and IOC IIOE-2 Coordinator; Scott Glenn, Rutgers Professor; Charitha Pattiaratchi, University of Western Australia Professor; Dr Christopher Back, Liberal Senator for WA and Chair, Senate Foreign Affairs, Defence & Trade Legislation Committee; and Dennis Stanley, UWA Glider Pilot.

The Challenger Glider Mission will capture and communicate unprecedented undersea data and help determine how changes in currents, temperatures and salinity affect weather patterns and give scientists a deeper understanding into the changing climate.

University of Western Australia Professor of Coastal Oceanography and leader of the IMOS Ocean Gliders Facility, Charitha Pattiaratchi, is part of the team navigating the Challenger glider.

"The research will be able to assist in predicating ocean trends in the future. This will be helpful for mariners and shipping routes, but most importantly it's to look at how the ocean climate is changing.

"We want to collect data across the ocean basins and see how the temperature and salinity changes with depth. We are then able to compare previous measurements taken 40 years ago and see how the ocean has changed," Professor Pattiaratchi said.

IMOS thanks its colleagues in Sri Lanka and South Africa for their cooperation.

"We look forward to building stronger collaborations with our colleagues in Indian Ocean science to develop the region's blue economy, said Mr Moltmann.

"Who knows what challenges the glider will face as she makes her way across this vast ocean frontier.

"We wish her, and her pilots and technical support staff, the very best of luck," he said.

Charitha Pattiaratchi, University of Western Australia

# Elephant seals collect crucial data for understanding the global climate

The Antarctic and surrounding Southern Ocean are one of the most important, yet least observed of marine habitats. 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. The seal tagging component of IMOS is made possible with logistical support and funding from the Australian Government's Australian Antarctic Program.

Recently, 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 led by Dr Guy Williams from the Institute for Marine and Antarctic Studies and Antarctic Climate and Ecosystems CRC, raised questions about potential future changes in the global ocean and climate systems.

"Antarctica and the Southern Ocean are like a beating heart, producing deep and powerful currents of cold water that drive global ocean mixing and regulate atmospheric temperatures," Dr Williams said.

"These currents begin with intense sea ice formation around the Antarctica in winter, which creates cold, salty and dense water that sinks and flows away from the continent in enormous volumes."

"If this production of Antarctic bottom water weakens, it leads to changes in global ocean circulation patterns that can lead to changes in the global climate."

In 2011, the same team of researchers discovered an important fourth source of this cold, salty and dense water, known as Antarctic bottom water, off Cape Darnley in East Antarctica. The latest research included an additional two years of data and shows that Prydz Bay makes an important secondary contribution to Cape Darnley bottom water.

"However we found that the contribution from Prydz Bay is less salty and dense due to the influence of fresh water by nearby ice shelves," Dr Williams said.

"We can easily imagine that the production of these global ocean currents will slow as the rate of ice shelf melting all around Antarctica continues to increase."

This study would have been impossible without help from the seals, who gather oceanographic data from areas that tend to be very difficult to access in research ships. Seals have the advantage of continuing to forage and record ocean properties through the winter, exploiting small cracks and leads in the sea ice cover to breathe and allow for data transmission.

"The seals are doing an outstanding job and the result is an important advance in our understanding of the global ocean system," Dr Williams said.

Clive McMahon, SIMS

NEWS

# Europe and Australia, collaborating to observe the global ocean

International collaboration to implement the Global Ocean Observing System (GOOS) has recently been in the spotlight, in Canberra and Hobart. Dr Glenn Nolan, Secretary General of EuroGOOS, came to Australia to speak at ACOMO 2016 and then visited the IMOS Office.

EuroGOOS and IMOS are two of the thirteen GOOS Regional Alliances, which collectively provide an important mechanism to implement global ocean observing through national and regional programs.

'There are both similarities and differences between our systems,' said IMOS Director Tim Moltmann.

'There is tremendous benefit in working with Glenn and his colleagues to learn about the approaches they are taking in Europe, and to share our experiences in the Australasian region.

'Our systems grow stronger through closer collaboration, and we can contribute more to the global effort as a result,' he said.

Capacity development, end user engagement, and communication were key themes emerging from presentations given by Dr Nolan and discussions that followed. It was also interesting to hear about the role of EuroGOOS in the European Commission's Copernicus Marine Environment Monitoring Service. Australia has recently established a Copernicus Data Hub through Geoscience Australia, providing an exciting new mechanism for collaboration in the application and use of next generation satellite data.

IMOS Director Tim Moltmann with Dr Glenn Nolan (right), Secretary General of EuroGOOS.

"It has been tremendously useful to learn about the capabilities, networks and initiatives underway in Australia through IMOS and AODN. This will enable new collaborations in ocean observation between Australia and Europe in the coming years and strengthen the activities of the GOOS Regional alliances," said Dr Glenn Nolan.

The Council of GOOS Regional Alliances comes together at a Forum held every two years, with the next one scheduled for the second half of 2017. IMOS is currently chairing the Council, with EuroGOOS being Vice Chair, so Dr Nolan's visit was well-timed in terms of planning future collaborative activity.

*"Our systems grow stronger through closer collaboration, and we can contribute more to the global effort as a result"*

Lea Walpole

# Marine STEM in action at the Shine Dome

The third biennial Australian Coastal and Oceans Modelling and Observations Workshop (ACOMO 2016) was held on the 11th and 12th October 2016, at the Shine Dome, Australian Academy of Sciences, Canberra.

The meeting brought together over 90 participants from research organisations, universities and private industry across Australia, as well as attendees from international organisations.

The event was focused on putting Marine science, technology, engineering and mathematics (STEM) into action. Discussing how we can best use smart sensors, robotic instruments, research vessels, super computers, and numerical models to examine complex problems in marine science with real impact: in understanding the state of our oceans, the variability of our climate, and the health of fisheries and reefs across Australia.

The third ACOMO workshop brought together the IMOS national observations community with various modelling communities and focused on five related themes;

- boundary currents;
- near-shore and coastal processes,
- polar dynamics and processes,
- biogeochemistry and ecosystem modelling, and
- end user applications in oceanography.

The series of biennial ACOMO workshops was started by IMOS in 2012 with the aim to push at the boundaries of model-data fusion. The long term vision is for whole of ecosystem models that assimilate data from sustained observing systems, with practical application for the benefit of industry, government and society.

In line with this direction for ACOMO to progressively embrace a more whole-of-system view, the 2016 workshop included sessions on biogeochemistry and ecosystems, and on polar dynamics and processes. The extension into the ecosystem modelling included two keynote speakers. Simon Jennings is Lead Advisor at the Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, UK and Honorary Chair of Environmental Sciences at the University of East Anglia. Simon provided a review of modelling from primary production to fish production, highlighting model inter-comparison and the need for systematic ecosystem observing. Chris Edwards from University of California Santa Cruz presented a state-of-the-art approach to assimilation of data into modelling of the California Current ecosystem.

Another important topic covered in this workshop was a discussion on the need of a National Modelling System for Australia, as articulated in the National Marine Science Plan. Some of the issues discussed included user engagement, exploiting multiple modelling approaches, coupling of models, channeling of regional expertise for national benefit, technical readiness levels, and infrastructure to serve model output. There was considerable enthusiasm for continuing this national discussion.

To view the agenda, abstracts and presentations of ACOMO 2016 visit the workshop page (http://imos.org.au/acomo2016_agenda.html).

The ACOMO workshop was organized by IMOS and sponsored by the Australian Institute of Marine Science, The University of Western Australia, Sydney Institute of Marine Science, the Antarctic Climate & Ecosystems CRC, CSIRO, Western Australian Marine Science Institution and the University of New South Wales.

Adi Chopra

NEWS

# IMOS part of international APEC workshop in Canberra

The Asia-Pacific Economic Cooperation (APEC) Workshop "Building Regional Earth and Marine Observation Systems to Safeguard APEC Resources and Communities" was held at the Australian Academy of Science on 27-30 September.

The workshop focused on the role of earth and marine observing in addressing global and regional challenges. It was attended by 17 of the 21 APEC economies, as well as the Pacific Islands Forum. This is a clear indication of the importance of this topic to the region.

The workshop was part of the "Building Regional Earth and Marine Observation Systems to Safeguard APEC Resources and Communities" Project. The objective of this project is to develop a framework to strengthen cooperation in Earth and Marine Observing (EMO) to safeguard APEC resources and communities.

The workshop was organised to gather representatives from government, technical experts, academia and private sector with a strong interest in the Asia-Pacific to:

- educate the APEC members on the benefits of using EMO information to support APEC policy and industry priorities; and
- seek regional agreement on EMO priorities and an approach, including identifying funding opportunities and agreement on principles and next steps.

IMOS Director Tim Moltmann attended the workshop as a representative of the marine science and research community, through his role as the Director of Australia's national marine observing system which is globally recognised as regional alliance of the Global Ocean Observing System.

"It was very exciting to be involved in a discussion about earth and marine observing in the context of an economic forum: highlighting the importance of marine observing in delivering value to a blue economy," said IMOS Director Tim Moltmann.

The Honourable Craig Laundy, Member of the Australian Parliament, and Assistant Minister for Industry, Innovation and Science recognised the benefits from data use in his address at the Workshop Dinner.

"In Australia, it's estimated that the net value of more accurate, more timely and more frequent weather forecasts, through data gathered by Australia's Integrated Marine Observing System, is estimated to be at least A$616 million and the benefit to cost ratio is more than 22," said The Hon Craig Laundy.

"These benefits are realised by a very diverse set of industry sectors, including agriculture, aviation, tourism and recreation, petroleum, mining, property and insurance."

The workshop also presented a platform to explore future opportunities for collaboration in marine observing in the Asia Pacific region.

"We identified opportunities for enhanced cooperation in the Pacific Islands region where maritime safety and emergency preparedness are essential to prosperity and wellbeing. And we identified opportunities to work more closely with partners in the east Asian region for mutual benefit. We hope to be able to realise these opportunities in the future" said Mr Moltmann.

# What is IMOS and why do we need it?


In our latest 'IMOS in MOcean' video, IMOS Director, Tim Moltmann, explains how IMOS is a unique collaboration of Australia's leading research organisations, deploying a network of advanced technologies to deliver data about Australia's oceans.

Tim gives an overview of what IMOS is and why Australia (and the world) needs it. Tim then explains how IMOS undertakes systematic, sustained, and scientifically-robust observations of Australia's vast and valuable ocean estate and converts these observations into data, time series, products and analyses that can be used and reused for broad societal benefit.

Visit the IMOS in MOcean collection: imos.org.au/imosinmocean.html

# IMOS communicators head to sea on the RV *Investigator*

The IMOS Communication Managers Marian Wiltshire and Warrick Glynn joined a five-day Transit voyage on board the Marine National Facility RV *Investigator* in August.

Whilst the main objective of the voyage was to move the RV *Investigator* from Hobart to Sydney ahead of its next science voyage, some science did take place whilst we were at sea.

Associate Professor Andrew Bowie, a Chemical Oceanographer with the Antarctic Climate & Ecosystems CRC ran a supplementary project examining the natural iron fertilisation of the oceans around Australia. The project will facilitate an integrated ship-based atmospheric observational program for trace elements in oceans around Australia.

IMOS collects a number of continuous observations with the RV *Investigator* including underway $CO_2$ measurements, sea surface temperature, real-time air-sea fluxes, bio-acoustic data and deploys a Continuous Plankton Recorder to collect plankton samples. Warrick and I were able to locate, with the assistance of Stephen Thomas of the MNF, all of the equipment that take observations for IMOS, and look at the bioacoustic data in the operations room with Amy Nau.

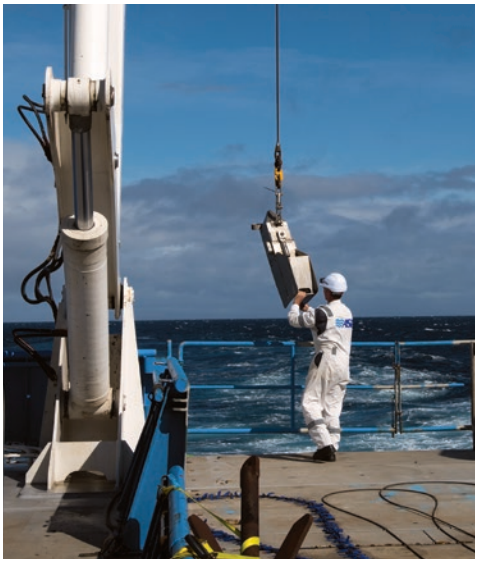
We also assisted in the deployment of an expendable bathythermograph (XBT) and the Continuous Plankton Recorder (CPR). This gave us an introduction to the on board protocols for the deployment of even small pieces of equipment, and how important the interaction between the ship's crew, the MNF support staff and the scientists is to ensure a successful and safe deployment. The RV *Investigator* also deploys our deep water moorings at the Southern Ocean Time Series site and the East Australian Current (EAC) array off the coast of Brisbane, and our experience on this voyage gives us a new appreciation for the complexity and difficulty of these deployments.

Our short voyage aboard Australia's only blue-water research vessel was fascinating, from watching how the scientists and crew work, to understanding how the IMOS observations are collected and where the equipment is located. We would like to thank the Ship's crew, MNF staff (in particular Tegan Sime, Ron Plaschke and Matt Marrison) and our fellow participants for an amazing trip.


Warrick Glynn, Marine National Facility

Marian and Warrick under the A-frame on the back deck.

Marian Wiltshire, Marine National Facility



Warrick Glynn, Marine National Facility

Above: A member of the ship's crew deploying the IMOS CPR. Right: Stephen Thomas of the MNF with the IMOS *In Situ* SST Autonomous Radiometer that measures sea surface temperature.

# IMOS Project Officer visits IMOS infrastructure in the tropical north

Emma Sommerville, Project Officer at the IMOS Office, visited the Australian Institute of Marine Science (AIMS) for a week in September 2016 to gain a better understanding of AIMS operations and strengthen relationships with IMOS Sub-Facility leaders and other staff involved with IMOS.

Emma spent the first couple of days visiting the Institute's facilities and talking to researchers and technical staff, and then two days on-board the RV *Cape Ferguson*, with her visit funded through a University of Tasmania career development scholarship.

The Townsville AIMS site facilities toured included the National Sea Simulator, the field operations area, moorings workshops, analytical laboratories, the data centre, the coral coring laboratory and the Townsville satellite ground station.

Emma spoke with various scientists and heard about research on the AIMS Long-term Monitoring Programme, micro plastics, reef predator movement and ecology, marine heatwaves, oceanography, reef health, climate change, and also technology development.

She spoke with AIMS researchers; Craig Steinberg, Jessica Benthuysen, Scott Bainbridge and Michelle Heupel to gain insight into just how key the IMOS programme is to their research and the excellent science they are able to produce from the data, including how it feeds into the eReefs model. Additionally, talking with professional and technical staff on operations and infrastructure, moorings and data management gave her a solid understanding of the breadth and scope of the Institute.

The highlight of the trip was the weekend spent on board the RV *Cape Ferguson* to service the Yongala National Reference Station, which was the start of a 16-day trip for the field team who were continuing on to service the southern Great Barrier Reef IMOS moorings. Saturday was spent loading the vessel, preparing the equipment and steaming to the tip of Cape Bowling Green to overnight. The mooring turnaround took most of Sunday, and involved swapping over the bottom frame first, then the surface float and taking CTD profiles and water samples whilst at the site. The field team and crew were very professional and Emma enjoyed being out at sea, feeling that she now has a new appreciation for what it actually means to achieve a 'mooring turn-around' milestone!

The trip succeeded in giving Emma a greater understanding of AIMS operations and in developing closer working relationships with the AIMS IMOS staff, which will hopefully spring up further collaborative opportunities.

"With my background in marine science, I really enjoyed talking to all the wonderful scientists and hearing about the research they are doing. It was very valuable to see IMOS operational activities in action, and I have a more rounded view of the opportunities and challenges of working in the tropical marine environment, which will help me manage these activities and milestones."

Thanks to Craig Steinberg and the rest of the AIMS staff for hosting Emma during her visit.


RV *Cape Ferguson*

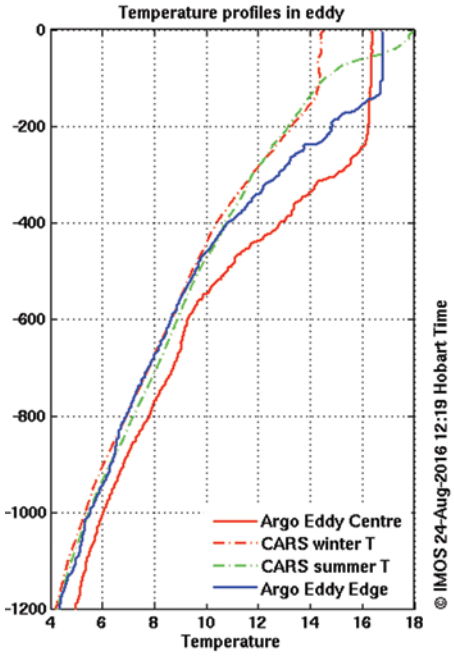


The Yongala National Reference Station

Emma Sommerville, IMOS

# EAC Eddies are coming to Tasmania

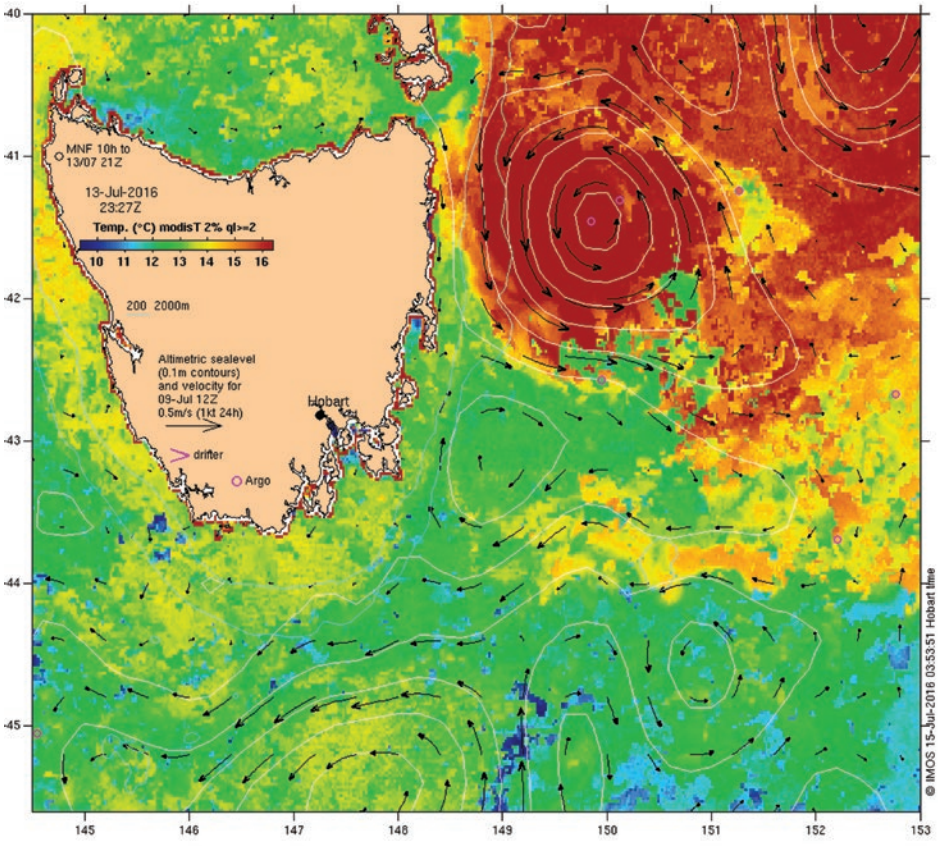
Around the globe 2015 was an exceptionally warm year for both land and ocean temperatures. For Tasmania though, the heat continued with sea surface temperatures off the east coast hotter than ever this year.




Much of the warming can be attributed to the unusual presence of East Australian Current (EAC) eddies south of Bass Strait. For example (below right) the eddy off NE Tasmania encountered by the Orange Roughy survey team during July this year. Eddies have been tracked travelling down the coast of Tasmania before – what is unusual is the dramatic increase in the size and frequency of these eddies over the last few years.

The influence of these eddies goes well beyond the sea surface temperature. Argo floats sampled the eddy both at its centre and at its outer edge near the continental slope (top right). Temperatures at the centre of the eddy were more than 2° warmer than the year round average between 100 and 400m depth, and almost 1° warmer down to 1200m depth. How much the eddy properties impinge on the shelf is highly dependent on the size and path of each eddy but with their greater frequency and size, these eddies will inevitably impact coastal waters.

In July of both 2015 and 2016 there were large eddies off the north east of Tasmania impacting on the eastern Orange Roughy spawning ground during their spawning time. The eddy velocities of over 2 knots persisted for much of the survey[1] in July this year. How the spawning ground preference and larvae are impacted by the increased temperatures and velocities due to the eddies is unknown at this stage but given that it has occurred now two years in a row we may well find out in the future. Transport within the EAC extension has increased between 1948 and 2014 and is predicted to increase further with climate change. The observed trend in eddy activity over the last 24 years, particularly off Tasmania, is in agreement with the direction of the trend predicted with climate change.




Images from IMOS *OceanCurrent*

1 The Orange Roughy survey is part of the SETFIA/AFMA/CSIRO ongoing monitoring program.

# Southern Australian Integrated Marine Observing System (SAIMOS)

## Wealth of oceanographic data collected by sea lions in the Great Australian Bight.

Fred Bailleul, SARDI

Male Australian sea lion equipped with a CTD-SRDL.

**WRITTEN BY:** FREDERIC BAILLEUL, SIMON GOLDSWORTHY, CLIVE MCMAHON AND ROBERT HARCOURT

The Great Australian Bight (GAB) represents a complex oceanographic system strongly influenced by the circulation of diverse water masses. In the east a seasonal coastal upwelling underpins Australia's largest fishery (by volume), as well as diverse apex predator communities. Large regional and national efforts have been directed towards the modelling of physical oceanographic processes in the GAB to better understand the response of the upwelling system to change. However, efforts to characterise the region have been hampered by the lack of in situ measurements, especially in remote areas and during winter months.

The standard data needed to study ocean circulation are vertical profiles of temperature and salinity, from which the density of seawater can be deduced, and vertical profiles of fluorescence and irradiance provide an indication of primary production. These data are traditionally collected with diverse sensors deployed on research vessels, on moorings, gliders or autonomous Argo profilers. Each of these approaches can be logistically and/or financially difficult to implement especially on a large spatio-temporal scale.

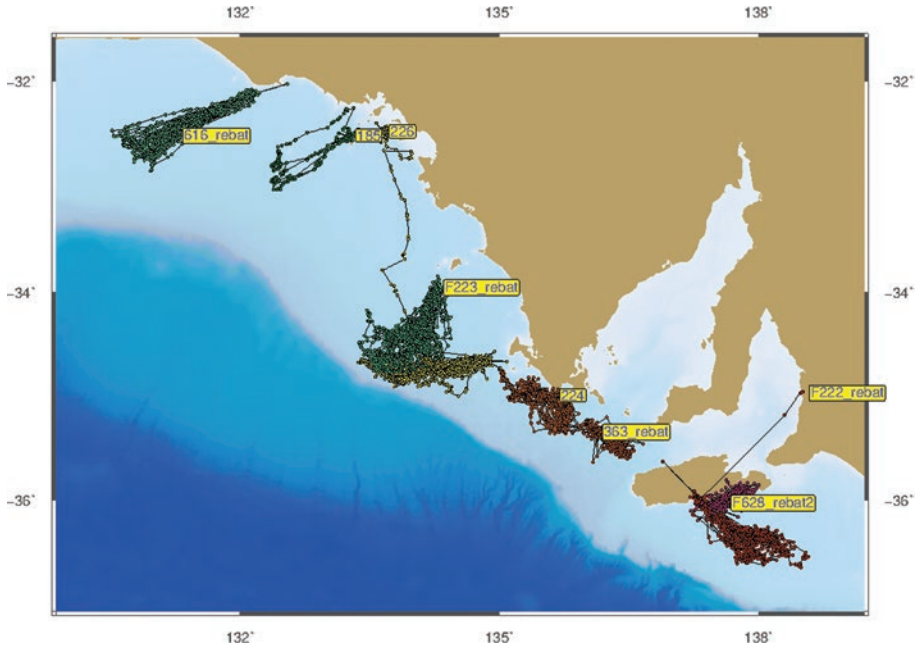
The southern coastline of Australia is home to around 90% of the world's population of the Australian sea lion, which is a benthic forager in continental shelf waters year-round. As platforms for instrumentation, they provide an unprecedented opportunity to gather data on the oceanographic environment at a high spatio-temporal resolution. Since 2007, over 50 sea lions (about 7 deployments per season) have been equipped with Argos-Conductivity-Temperature-Depth recorders collecting cross-shelf temperature and salinity profiles over a 1,000 km of shelf. More recently, individuals have been equipped with a new generation of tags that include both fluorescence and irradiance sensors, measurements which in conjunction with CTD data, can

*The southern coastline of Australia is home to around 90% of the world's population of the Australian sea lion, which is a benthic forager in continental shelf waters year-round.*

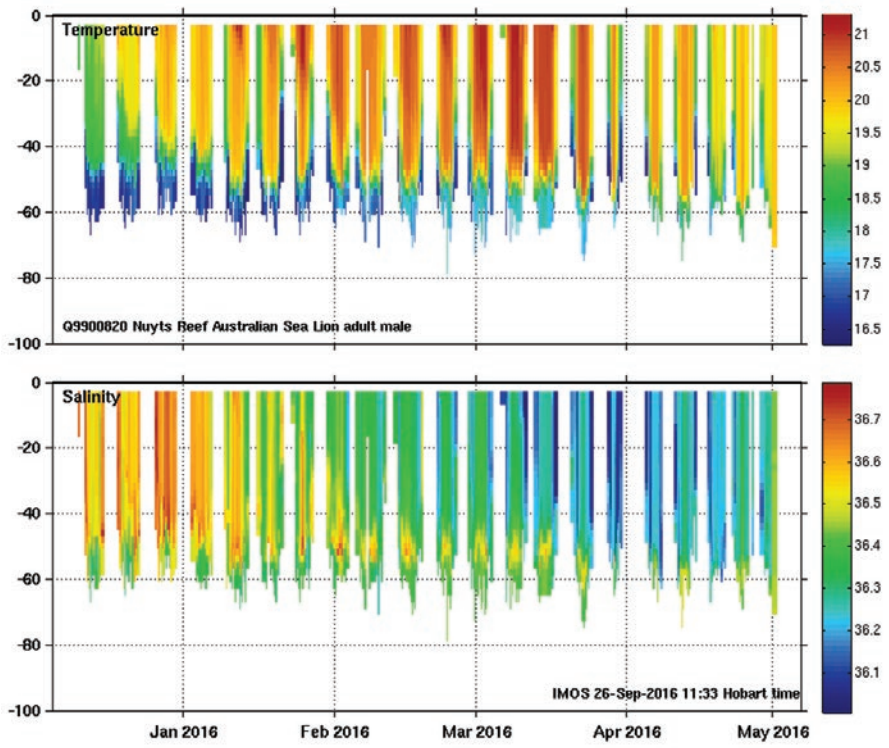
be used to estimate primary production. Sea lion instrumentation has provided a viable and cost-effective method of sampling near real-time hydrographic properties in the GAB region. In 2016, one tag recorded ~5300 profiles over the continental shelf over a six-month period.

An important recent development is the integration of the satellite animal tracking (SealCTD) data into the IMOS *OceanCurrent* web portal (see http://oceancurrent.imos.org.au/aatams.php), providing simple point and click access to 10 day CTD profiles, detailed temperature (T) and salinity (S) plots of individual profiles, TS plots by dive and depth, and time series plots. Data are used in the validation of regional physical models (e.g. the Coupled-Ocean-Atmosphere-Wave-Sediment Transport Modelling System, which is integrated to exchange data fields between the ocean model ROMS, the atmosphere model WRF, the wave model SWAN, and the sediment capabilities). Over the next year, much of these data will be integrated into key outputs describing the regional oceanographic processes, variation in mixed layer and euphotic depths, and subsurface productivity as part of the GAB Research Program.

The satellite animal tracking program in the GAB provides an excellent example of appropriate technology and platform to collect cost-effective observations from remote regions, and has provided sustained (annual) observations over 1,000 km of shelf in the SAIMOS region for the last ten years. These data provide the only source of near real-time subsurface observations from regions in the GAB that are ecologically important to top predators and fishery production, and represent a pertinent example of the type of biophysical integration that IMOS strives to achieve.




Tracking data from deployments conducted on 8 males in 2016. Picture from the Sea Mammal Research Unit website http://www.smru.st-andrews.ac.uk




Example of temperature and salinity data provided by a male sea lion in the Nuyts archipelago in 2016. Picture from the IMOS *OceanCurrent* web portal (see http://oceancurrent.imos.org.au/aatams.php)

# Deep water moorings: East Australian Current measurements provide clues on climate and more

Dr Bernadette Sloyan, CSIRO researcher and leader of the IMOS Deep water arrays sub-facility, and her colleagues have just returned from a voyage on the RV *Investigator* to retrieve the IMOS East Australian Current (EAC) deep water moorings, which have been collecting data for 18 months.

Each instrument along the mooring line is brought into the ship and returned to the CSIRO laboratory in Hobart where the data are downloaded, quality controlled and then made available by IMOS for researchers to analyse.

During the voyage, a replacement set of new moorings with calibrated instruments are redeployed so that they can continue to collect data for another 18-month period. By turning over the moorings in this way, IMOS is collecting a sustained time-series of observations of the East Australian Current across its entire extent, and of sufficient duration, to understand seasonal, interannual and decadal signals.

Dr Sloyan was pleased with the recovery rate of intact, functioning instruments and said that initial indications are that the data obtained from the moorings is of high quality.

"In the 18 months from now until we go out again to retrieve the instruments we've just put out, we'll be working hard to get the just recovered data into shape so that we can begin to make sense of it," said Dr Sloyan.

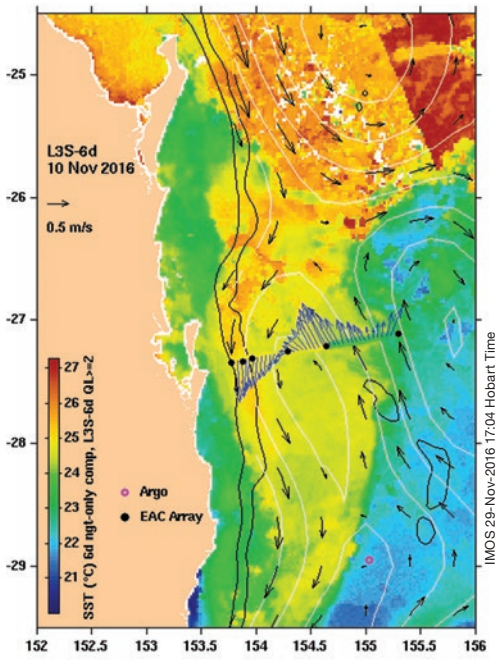
"And it's not only my group who will be looking at the results; anyone, anywhere in the world will be able to access this data and perform their own analyses on it, drawing their own conclusions about the implications for Australia and beyond," she said.

The EAC moves large amounts of water down the east coast of Australia, each second transporting more than 25 million cubic metres, the equivalent of 10,000 Olympic swimming pools, southwards. This southward movement of warm EAC water influences Australian weather and climate and its interaction with the coastal ocean has a profound effect on the region's marine ecology.

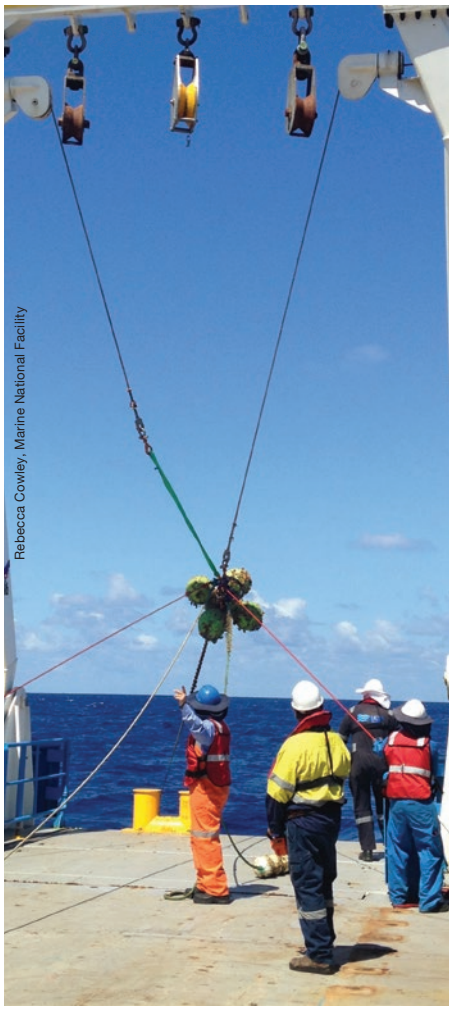
The RV *Investigator* is equipped with an instrument that enable tracking of the real-time upper ocean (0-500m) ocean currents – an acoustic Doppler current profiler (ADCP). Maps produced by the ADCP provide a record of sub-surface conditions at a given time which can then be correlated with other underway observations.

Describing the voyage as successful, Dr Sloyan praised the skills of the ship's crew and the collaboration between IMOS, CSIRO and the Marine National Facility which operates the RV *Investigator*.

"To pull off a successful operation like this, you need all of the elements to come together and that means the marine observation infrastructure, the scientists who design and carry out the deployment and of course the ship and its talented Master, officers and crew," said Dr Sloyan.




Sea surface temperature of the EAC at the time of the voyage. The black dots are the location of the EAC moorings and the blue arrows along the mooring line is the near surface velocity from the ship ADCP taken during the voyage. Image from IMOS *OceanCurrent*.




Retrieving one of the mooring components.

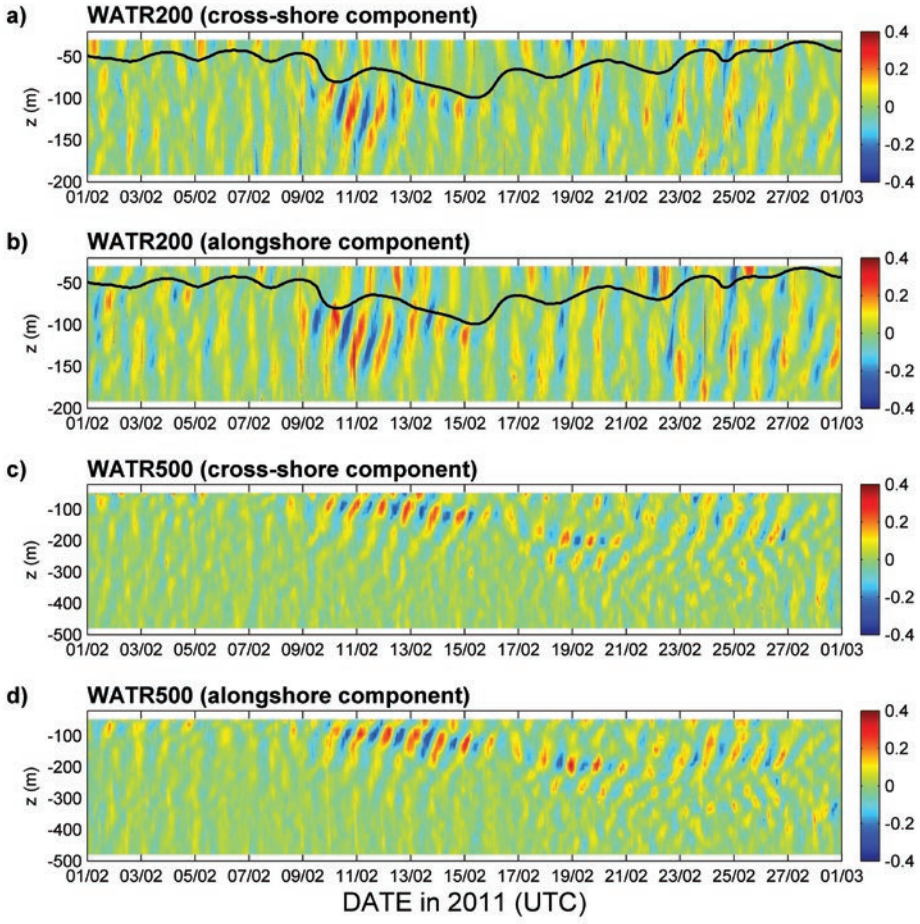
# Ocean radar, national mooring network and satellite remote sensing:

## Daily sea breeze has major implications for circulation and vertical mixing along the Rottnest continental shelf and offshore regions

In south-west Australia, in the absence of strong tidal forcing, ocean dynamics (e.g. mixing and upper ocean circulation) are dominated by wind effects that are strongly influenced by the diurnal land-sea breeze cycle. The location of the region, close to the 30° latitude – defined as the 'critical' latitude – means that the effects of earths' rotation are amplified at forcing periods close to 24 hours. Thus the forcing from the land-sea breeze and the response of the effect due earths' rotation (the Coriolis effect) have the same period resulting in a resonance effect.

Observations of upper ocean dynamics, offshore Rottnest Island, from a range of IMOS platforms including surface currents using HF Radar, moorings and satellite remote sensing data have been used in a recently published study that has examined the effects of this resonance. Ocean dynamical theory indicated that the effects of the wind should be limited to depths less than 70m in this region. 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 (see Figure at right).

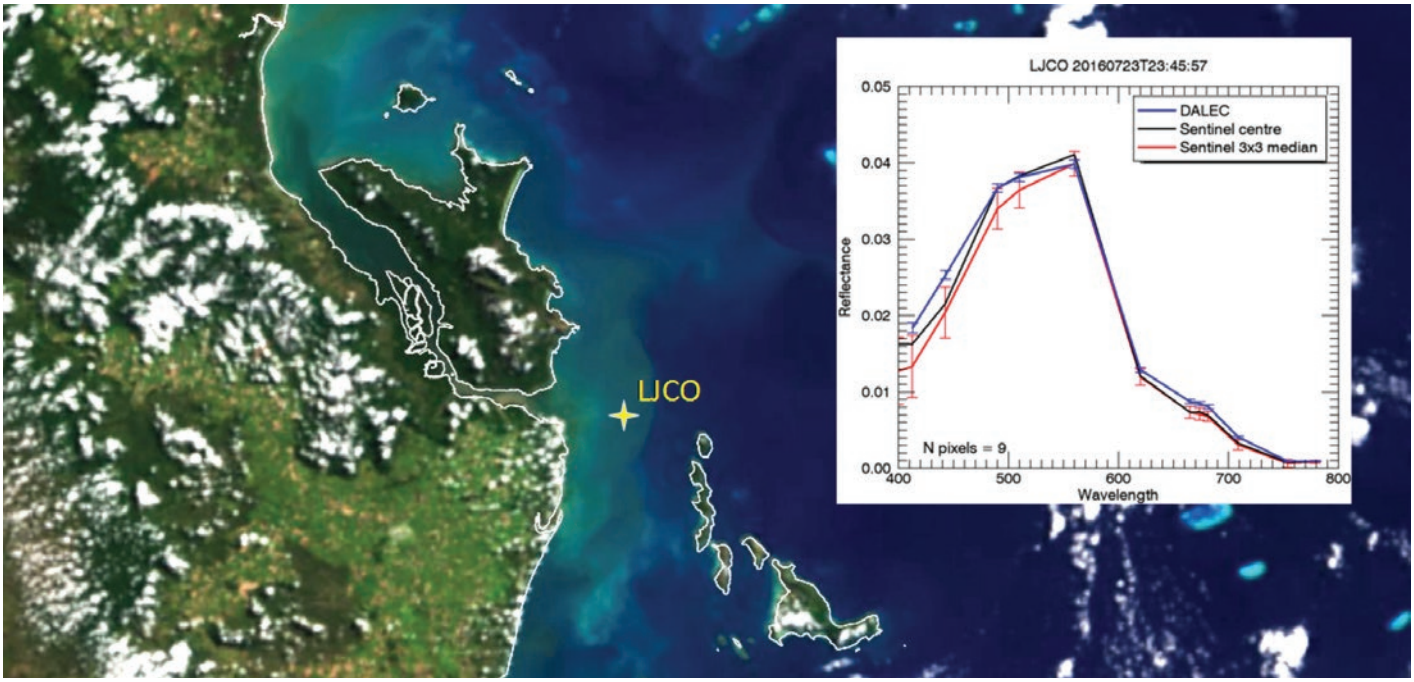
The associated current speeds exceeded 0.30 $ms^{-1}$ comparable with speeds recorded in the Leeuwin Current. The resonance effect also induced internal waves that resulted in the diurnal vertical movement of temperature isotherms by up to 60 m which also induced upwelling of cold water onto the continental shelf with a diurnal period. In stratified systems, vertical density gradients prevent transport of nutrients to the surface layer and resulting in low primary production. The resonant processes identified using the IMOS data provide a mechanism that is able to transport nutrients to the upper ocean that is important for the local primary production and thus to local fishery resources.




Vertical profiles of the high-frequency currents (ms-1) from the shelf mooring (WATR200, Fig a,b) and the deep mooring (WATR500 Fig c,d) at Two Rocks in February 2011 revealed a diagonal banding in the upper 200-300m. At each depth level, a daily change in direction (alternating between positive and negative) was observed in both cross-shore and alongshore components indicating circular motion. Note that the panels have different depth scales.

# Satellite Remote Sensing: IMOS supporting validation of Seninel-3A

Over the past few months Ocean Colour validation activities at the Lucinda Jetty Coastal Observatory (LJCO) have been ramped up to support the European Space Agency (ESA) and European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) in their efforts to evaluate the performance of the Ocean and Land Colour Instrument (OLCI) on board the Sentinel-3A satellite.




Sentinel-3A OLCI true colour composite acquired on 23rd of July 2016 over LJCO and preliminary spectral comparison with the DALEC spectro-radiometer.

Sentinel-3A was launched in February this year and is a first of a series of identical satellites (Sentinel-3B, 3C) that will provide Australia with unprecedented data quality and continuity for the next 15 to 20 years. OLCI scans the Earth's surface in 21 spectral bands (400-1020 nm) at a nominal spatial resolution of 300 m. The simultaneous operation of two satellites at a time (e.g. 3A and 3B) in descending orbits ±140 degree out of phase will significantly improve revisit times and spatial coverage. Sentinel-3B is scheduled for launch in November 2017.

Dedicated Ocean Colour Sentinel-3 Validation Teams (S3VT-OC) around the world are currently quantifying the accuracy of Sentinel-3A OLCI geophysical (Level 2) products, which are not yet released to the public. Under IMOS the Australian Ocean Colour S3VT led by Thomas Schroeder (CSIRO) is currently comparing OLCI radiometric products with concurrent ground observations collected at the LJCO. Specifically, the hyper-spectral sea surface reflectance measurements of DALEC and multi-spectral SeaPRISM observations embedded into AERONET (Aerosol Robotic Network) Ocean Colour are used for this comparison.

"Ongoing in-situ optical and water quality measurements from Australia are critical to quantifying the performance of OLCI in the southern hemisphere – now and in the future", says Marc Bouvet from the European Space Agency and co-chair of the S3VT-OC.

"First radiometric comparisons over Lucinda Jetty are very encouraging", says Ewa Kwiatkowska from EUMETSAT also co-chair of the S3VT-OC, "and inform us, in this critical phase before the public release of data, about the quality of the atmospheric correction, an important ocean colour pre-processing step from which all higher-level ocean colour products are derived" (see figure above).

We need accurate and reliable algorithms to support OLCI's global data services, science and applications. The contribution of IMOS is crucial because the southern hemisphere has been severely under-sampled. "The IMOS ocean colour validation support is greatly appreciated by ESA and EUMETSAT and will ultimately help to identify and understand potential regional biases in OLCI-derived water products", says Marc Bouvet.

Over the coming months the Australian S3VT under IMOS will continue to contribute optical and water quality observations for inclusion into ESA's MERMAID data base that is used for algorithm validation and development and will provide a more comprehensive assessment of OLCI geophysical products over Lucinda.

# National Mooring Network: Ocean symphonies aid marine animals in finding food

This IMOS news article has been adapted from a Curtin University media release.

A cacophony of underwater noise in the Perth Canyon, detected each evening with acoustic receivers, is most likely produced by small fishes.

IMOS Acoustic Observations Sub-Facility leader, Associate Professor Robert McCauley of Curtin University, has been deploying sea noise recording instruments into the deep ocean in the Perth Canyon west of Fremantle for nearly 20 years. For all of this time they have been listening to a cacophony of noise every evening; however, the source of that noise was unknown.

Recently, McCauley and an associate, Dr Doug Cato from the University of Sydney and the Defence Science and Technology Group, have published an article in the Journal of the Acoustical Society of America suggesting that the noise they have been detecting is most likely produced by small fishes.

In the Perth Canyon each evening, timed around sunset, lantern fish (family Myctophidae) rise from their daytime resting places at 200 to 500 metre depth, to forage in the top 160 metres of the water column. Once the fish reach their foraging depth there is a massive increase in noise throughout the Perth Canyon which lasts until about 5 hours after sunset but may continue until sunrise at a lower level.

The researchers argue this noise – a chorus – is produced by these small lantern fish. Although small, lantern fishes are one of the most common fish in the oceans. They have all sorts of novel sensing systems, including a system of flashing lights along their body (hence the name lantern fish), sophisticated hearing systems and good vision for the low light world they live in.

Robert McCauley

Sea noise recording mooring ready to be deployed.

The work done by McCauley and Cato shows that at a small scale within the Perth Canyon, and at a seasonal scale, the behaviour of the choruses matches where all the small planktonic food is and when they are most likely to be found. The lantern fishes will be preferentially targeting the places where the highest amounts of food are. The researchers argue that perhaps these small fishes are using these sounds during their feeding behaviour, which results in the location and levels of sound produced following trends in when and where all the food is.

The choruses occur at a massive scale, well beyond the researchers' sample range, which was almost 40 km along the 300 m depth contour and 15 km to seaward of this. This means the choruses act as giant beacons in the ocean, advertising places where there are lots of small food. While they have not measured the outside range at which the Perth Canyon choruses can be detected, the researchers estimate that these 'beacons' may be acting in the ocean at the many tens of kilometres scale, which they state are conservatively in the 30 to 60 km range, or most likely more. This makes the ocean a slightly smaller place where help is at hand in finding food, for all the animals which can hear the choruses, such as whales, dolphins, seals, tuna and many other fishes.

Support for this work has been through Environment Australia, Australian Defence, and since 2008, IMOS.

# Postgraduate Student | **Haifeng Zhang**

**PROJECT TITLE:**

## Investigating sea surface temperature diurnal variation over the tropical warm pool region

*The University of New South Wales at Australian Defence Force Academy (UNSW Canberra @ ADFA)*


Sea surface temperature diurnal variation, or diurnal warming, normally refers to the daily temperature rise in the upper few meters of the ocean. Diurnal warm layers have typical temperature differences relative to the body of water below in the order of 0.5-3°C. However, in some extreme cases such as when the wind is very calm and solar radiation is very strong, the differences can reach values up to 7-8°C. It is expected that the proper inclusion of sea surface temperature diurnal variation effects in air-sea coupled models, numerical weather prediction models, and climate models can enhance the model accuracy.

Therefore, a comprehensive study of the spatial extent, frequency and amplitude of diurnal warming events is essential, particularly over the tropical warm pool region (90°E-170°E, 25°S-15°N) given its special location and role in global climate.

University of New South Wales student Haifeng Zhang's PhD project is using IMOS satellite and modelled data to focus on the description of the general features (Zhang et al., 2016a) and seasonal patterns (Zhang et al., 2016b) of diurnal variation events, the relationship between diurnal variation events and the driving meteorological variables (winds, solar radiation, etc.) It also has evaluated empirical diurnal variation models, physical diurnal variation models, and air-sea coupled model with diurnal variation scheme implemented.

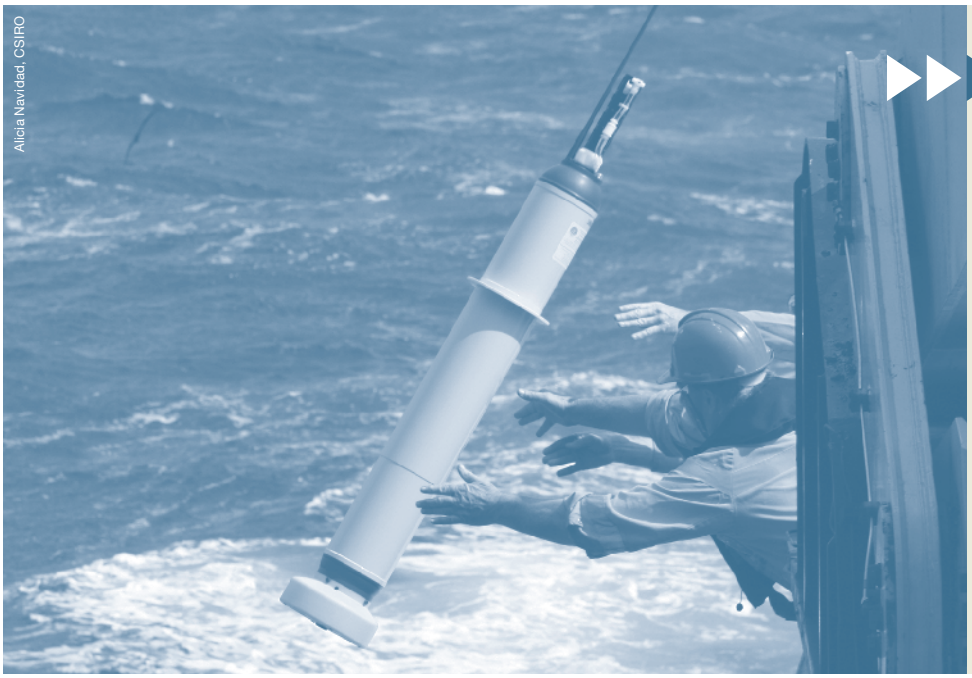
Initial results have shown the large amplitude (up to 6-8°C) and high frequency (especially in the austral summer) of sea surface temperature diurnal variation events over the tropical warm pool region.

The more important role of morning winds, in comparison to 24-hour mean winds, has also been highlighted, which could be useful for diurnal variation model improvement. A future research will investigate the relationship between diurnal variation events and other meteorological phenomena, such as Madden-Julian Oscillation and precipitation.

### REFERENCES

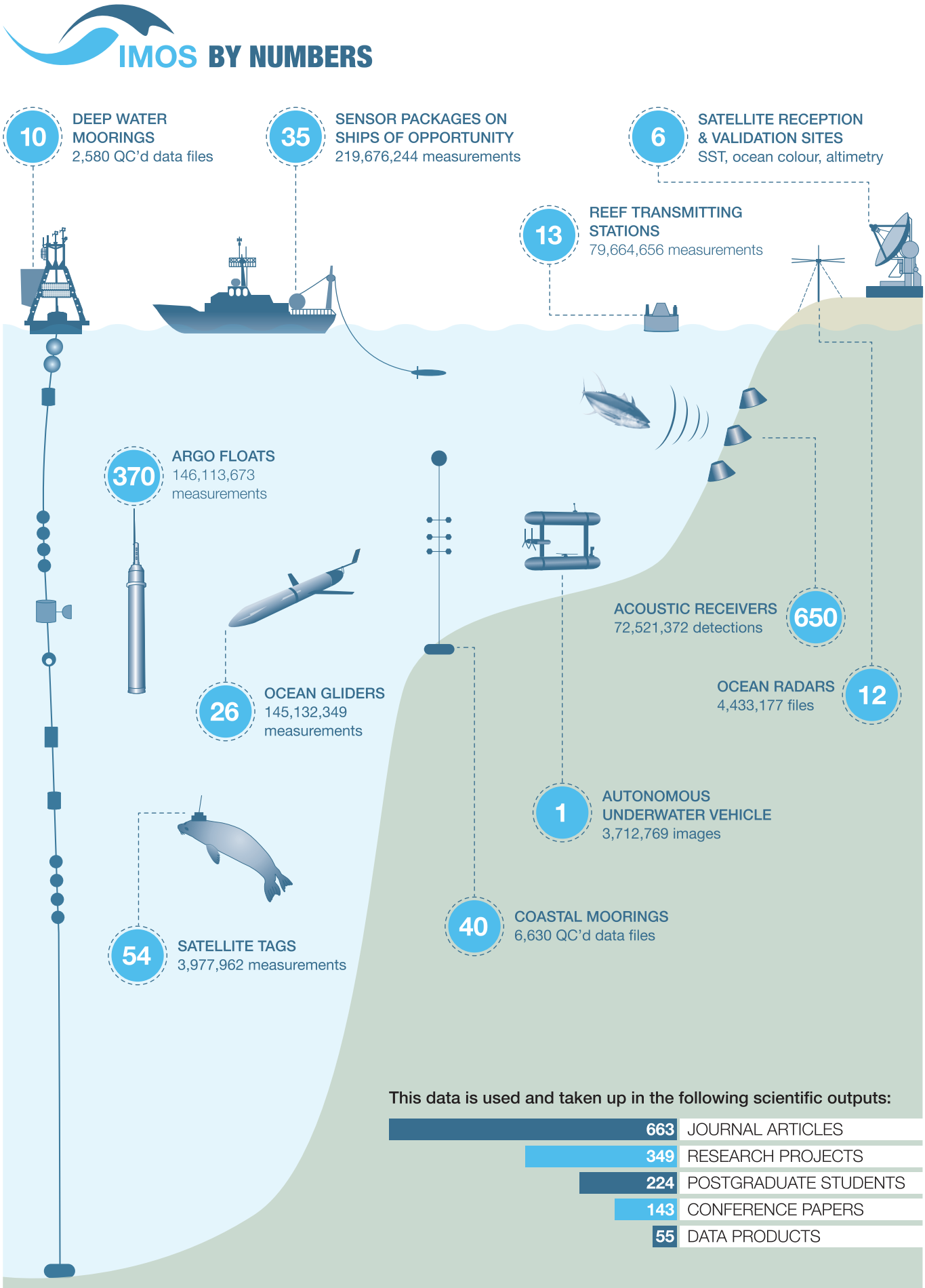
Zhang, H., H. Beggs, L. Majewski, H. Wang, and A. Kiss (2016a), Investigating sea surface temperature diurnal variation over the Tropical Warm Pool using MTSAT-1R data, Remote Sens. Environ., 183, 1–12, doi:10.1016/j.rse.2016.05.002.

Zhang, H., H. Beggs, X. H. Wang, A. E. Kiss, and C. Griffin (2016b), Seasonal patterns of SST diurnal variation over the Tropical Warm Pool, J. Geophys. Res., 121, doi:10.1002/2016JC012210.


Alicia Navidad, CSIRO

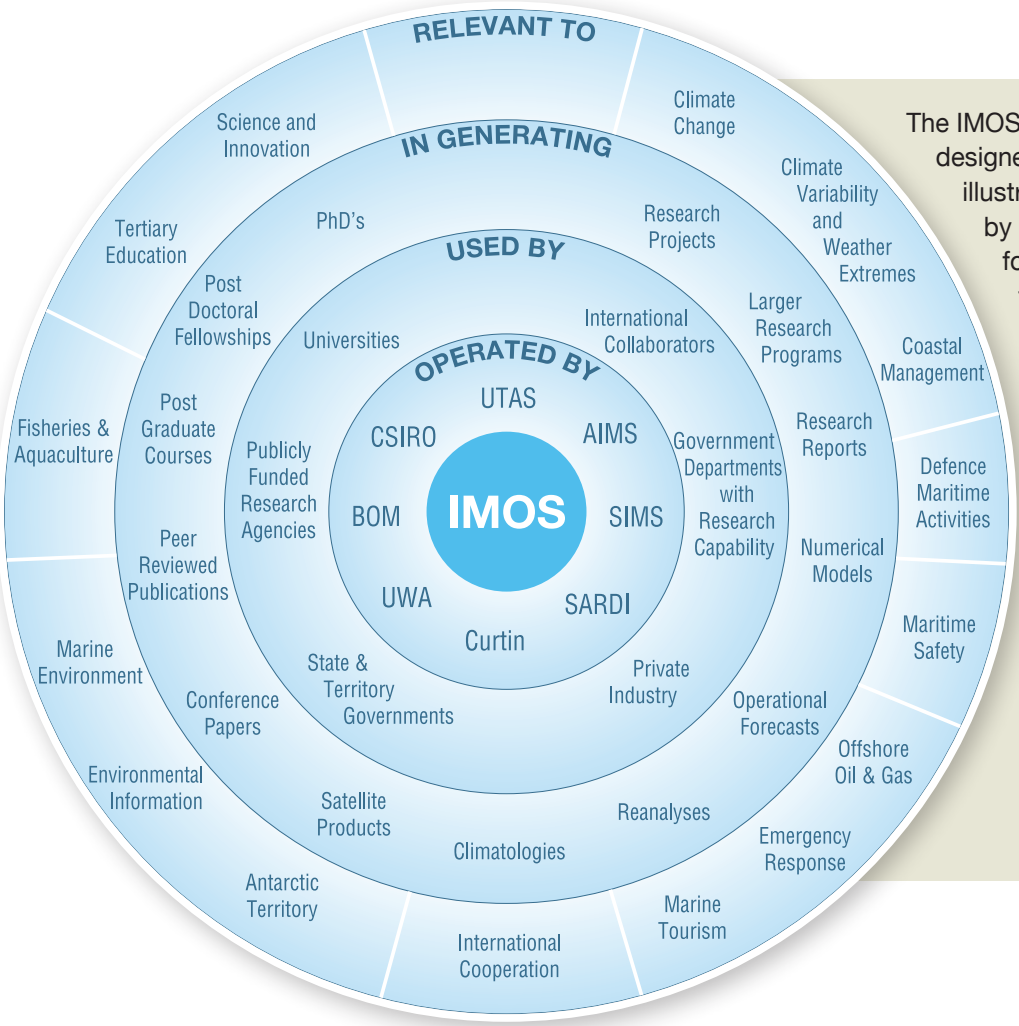
**IMOS has provided Australia with a step-change increase in its marine observing capability over the last decade.** This has involved establishing a portfolio of platform-based Facilities to acquire the observations, an integrated set of science Nodes to guide the design and drive the uptake, and a clear focus on data to enable ready access, use and reuse. The infographic at right, 'IMOS by numbers', demonstrates the variety of observing platforms IMOS uses to undertake systematic and sustained observations of Australia's marine environment. ▶▶▶

# IMOS BY NUMBERS




This data is used and taken up in the following scientific outputs:

| | |
|---|---|
| 663 | JOURNAL ARTICLES |
| 349 | RESEARCH PROJECTS |
| 224 | POSTGRADUATE STUDENTS |
| 143 | CONFERENCE PAPERS |
| 55 | DATA PRODUCTS |




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.

**The diagram has five layers:**

1. IMOS at the core,
2. the eight operating institutions,
3. the broader research community,
4. various pathways for uptake and use of IMOS data and products, and
5. portfolios of relevance and impact.


**Director**
Tim Moltmann
Tim.Moltmann@imos.org.au

**Project Manager**
Jo Neilson
Jo.Neilson@utas.edu.au

**Communications Manager**
Marian Wiltshire
Marian.Wiltshire@utas.edu.au

Warrick Glynn
Warrick.Glynn@utas.edu.au

communication@imos.org.au

**Scientific Officer**
Ana Lara-Lopez
Ana.Lara@utas.edu.au

**Project Officer**
Emma Sommerville
Emma.Sommerville@utas.edu.au

**Personal Assistant**
Donna Harris
d.harris@utas.edu.au

UNIVERSITY of TASMANIA

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

**General enquiries:**
Integrated Marine Observing System (IMOS),
University of Tasmania, Private Bag 110, Hobart, TAS, 7001
• +61 (03) 6226 7549 T • +61 (03) 6226 2107 F


**For more information about IMOS please visit the website www.imos.org.au**


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

Thanks to: Warrick Glynn, David Reilly, Emma Sommerville, Madeleine Cahill, Frederic Bailleul, Simon Goldsworthy, Clive McMahon, Robert Harcourt, Bernadette Sloyan, Charitha Pattiaratchi, Robert McCauley, Thomas Schroeder, and Haifeng Zhang.