IMOS
marinematters
Integrated **Marine Observing** System

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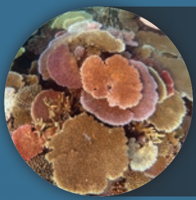


Oceanographic drivers of bleaching in the Great Barrier Reef: from observations to prediction.

New grant to support NSW-IMOS by facilitating cross-disciplinary integration of IMOS data.

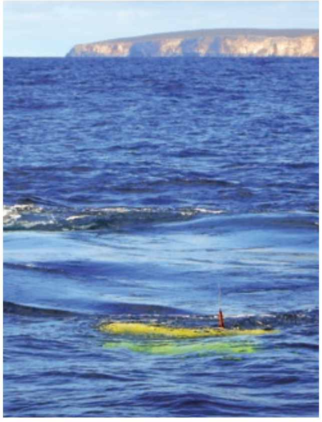
IMOS deployed four ocean gliders concurrently in the same region for the first time, alongside our deep water mooring array.

The IMOS Autonomous Underwater Vehicle returns to South Australia.

After 10 years the AUV Sirius has returned to SA to expand the IMOS integrated benthic monitoring program in the region.

G. Grammer, SARDI Aquatic Sciences

director's corner



Welcome to the latest edition of Marine Matters.

Headline news is the 2018 Budget announcement that the Government will provide an additional $1.9 billion over 12 years from 2017–18 ($393.3 million over five years) to implement the Research Infrastructure Investment Plan, informed by the 2016 National Research Infrastructure Roadmap.

This is a profoundly important decision for IMOS as a national collaborative research infrastructure. It means that, subject to ongoing strong performance and future national priorities, IMOS will be sustained over the long term.

Implementation of the Research Infrastructure Investment Plan has two components.

Firstly, IMOS operational funding already approved for 2018–19 ($16.46M) will be extended for another four years (to 2022-23) with indexation. This provides much anticipated certainty over the medium term that will be very welcome for our operating institutions and their staff, and for our various partners and co-investors. They have all stood by IMOS during uncertain times, and we look forward to repaying that faith.

Secondly, IMOS will be boosted by $22M of new investment from the Australian Government. This will allow us to address deferred capital replacement issues and undertake future capital refreshment in a planned and managed way. It will also allow new activities to be commenced. This is very exciting, as the capacity to take up new scientific and technological opportunities has been extremely limited in recent years due to the funding situation.

The IMOS Office and Governing Board are well prepared to respond. The Five Year Plan (2017–22) approved by the Board in September 2016 will guide us through next steps, augmented by additional consultation with the science community and the user and stakeholder base over coming months.

We are extremely grateful for the tremendous support provided by Australian Government through NCRIS. Our thanks go to the Minister for Education and Training and Minister for Jobs and Innovation who jointly launched the Government's response. Our colleagues in the Department of Education and Training, and the Department of Industry Innovation and Science, have worked tirelessly to support us. Australia's Chief Scientist Dr Alan Finkel AO showed great leadership through development of the 2016 Roadmap and beyond.

The IMOS community has been given a wonderful opportunity to continue supporting great marine science, research and education in the national interest. I'm sure I speak on behalf of all in saying that we intend to grasp it with both hands.

I hope you enjoy reading the edition of Marine Matters.

Tim Moltmann

Lea Walpole

IMOS data used to assess Bluelink's regional and coastal modelling

WRITTEN BY: MARIAN WILTSHIRE, EMLYN JONES (CSIRO) AND GARY BRASSINGTON (BOM)

Bluelink is a partnership between Defence, CSIRO and the Bureau of Meteorology (BoM). The dual purpose goal of the Bluelink partnership is to maintain global, regional, and littoral ocean forecast systems to support Defence applications; and to maintain a national ocean forecasting capability to help manage Australia's diverse area of maritime operations.

Ocean conditions can be unpredictable. This unpredictability creates risk and uncertainty for industries and sectors that rely on the ocean, especially our maritime and naval industries.

Bluelink addresses this challenge by using a variety of observational data streams from numerous sources to create a comprehensive suite of ocean forecasts that predict all types of marine weather scenarios, from local beach conditions to oceanic interactions on a global scale.

Over the past two years Bluelink's regional forecasting system (ROAM-Ocean), has been applied to more than 100 domains in the Australian region and performed over 3,900 individual model simulations. ROAM-Ocean is nested within the Ocean Model, Analysis and Prediction System (OceanMAPS) an operational global ocean model and assimilation system.

OceanMAPS is the global ocean forecasting component of Bluelink and is forced with atmospheric fields from the Australian Community Climate and Earth-System Simulator (ACCESS). To ensure accurate predictions of the physical state of the ocean, observations taken from the sea (in-situ) and the and space (via satellite) are processed and ingested into the prediction system via a process called data assimilation, to create accurate, near-real time estimates of circulation. More specifically, OceanMAPS assimilates multiple satellite platforms for sea surface temperature and altimetry as well as in situ platform (e.g., Argo, XBT, CTD). OceanMAPS is a Category 1 system operated by BoM, forming the backbone of the national ocean forecasting system producing daily forecasts out to seven days.

Both OceanMAPS and ROAM-Ocean are routinely assessed against withheld in-situ observations (e.g. gliders, moorings and radars). OceanMAPS forecasts are assessed against unassimilated reference observations from the global ocean observing system [e.g., Argo, drifting buoys (SST and currents) and Jason-altimetry] and compared with other international systems from the UK, France, Canada and the USA. The results are accessible via an internet service (**http://130.56.244.252/monitoring/index.php?pg=class4_stats**) in near real-time and summary charts are published annually. Each of the ROAM-Ocean simulations is automatically assessed against IMOS observations (including data from Satellite Sea Surface Temperature, Argo floats and Ocean Gliders) using software (EnKF-C, **https://github.com/sakov/enkf-c**) developed by Pavel Sakov (BoM).

A majority of the ROAM-Ocean assessments take place along the shelf off southern Western Australia and northern New South Wales, using the repeat transects from the IMOS Ocean Gliders (both the deep water Sea Gliders and the more coastal Slocum Gliders).

Of key interest to the Bluelink partners are upper ocean dynamics and our ability to predict their evolution in time. Such dynamics include (but are not limited to) the surface mixed layer (mixed layer depth and temperature gradients), surface currents and the position of fronts and eddies.

More recently, Bluelink started to use data collected from the IMOS Ocean Radar sites (Newcastle, Coffs and Perth), whilst this assessment is still in a preliminary phase, the data will be used to assess the modelled current velocities.

The IMOS Ocean Glider data is extremely important for Bluelink because there are very few other observations available to assess the 3D structure and temporal frequency of models in shelf areas. The vertical resolution provided by the Ocean Glider data is especially useful in this respect.

Whilst the IMOS Ocean Glider data is proving important, it is somewhat difficult to use as it contains a lot of sub-meso-scale features which are notoriously challenging to predict in a model. A model can often generate these sub-mesoscale features, but they may not be in the right place at the right time. The prediction of sub-meso scale features is an area of active research, and as observing systems generate larger quantities of high resolution data, and modelling systems increase in resolution, such features may become skillfully forecast.

The Bluelink models and forecasts are shared with Defence, marine planners, and maritime industry and safety authorities, to help guide their activities at sea and near shore.

With a better understanding of Australia's oceans and beaches, innovative approaches can be created to understand the marine environment and support its sustainability, as well as boosting the efficiency and profitability of ocean-based industries and services. ■

NEWS

Oceanographic drivers of bleaching in the GBR: from observations to prediction

WRITTEN BY: CRAIG STEINBERG (AIMS)

Mass coral bleaching has occurred on the Great Barrier Reef (GBR) and Torres Strait in 2016 and 2017 as part of a continuous global bleaching event that started in late 2014 (NOAA). The combined effect has meant that the majority of the reef has been severely affected.

A new project is looking to understand how local or reef scale, regional and global oceanographic and meteorological processes influence the severity and spatial variability of thermally driven coral bleaching. By doing this a better appreciation of which parts of the reef are more tolerant (or fortunate) and therefore more likely to retain their health into the future can be used to better manage the GBR.

The three-year project is funded under the National Environmental Science Programme (NESP) Tropical Water Quality Hub and is being undertaken by researchers from Australian Institute of Marine Science (AIMS) and CSIRO in partnership with the Bureau of Meteorology (BoM) and National Oceanic and Atmospheric Administration (NOAA).

The project is structured in three main components:

1. Summary of oceanographic conditions during the 2015-17 bleaching years

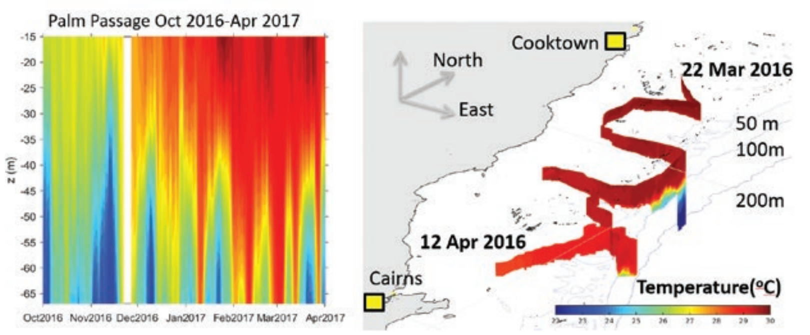
All available relevant environmental observations of the recent bleaching events will be gathered to be more easily discoverable to researchers and managers via a gateway/summary webpage. These include hundreds of temperature loggers deployed along the GBR by AIMS, weather stations and the use of IMOS remote sensing, moorings and glider deployments. This publicly available and quality-controlled data set will allow the most comprehensive understanding yet of how individual coral reefs faired.

2. Hydrodynamics of bleaching and improved understanding

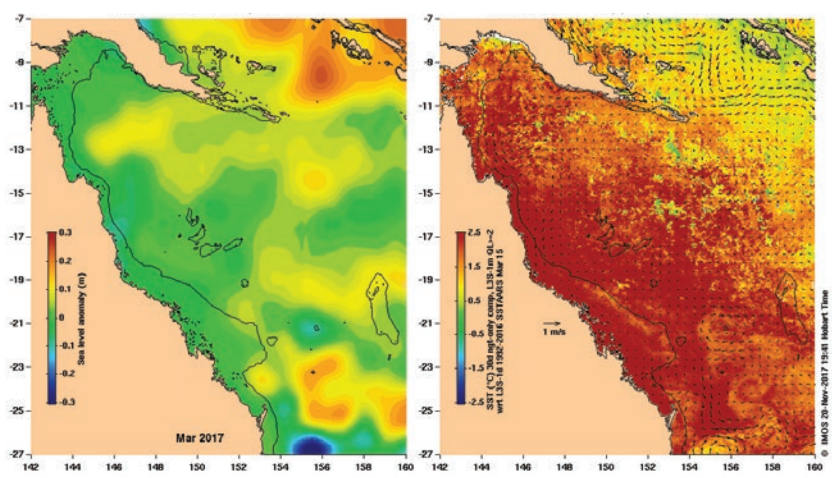
The data will be used to improve the current understanding of the relationship between heat stress and bleaching response from repeated in situ observations of coral health and also assess how well the eReefs models perform and analyse the hydrodynamic reasons behind the variations of response. 3D versions of remotely sensed bleaching products by NOAA's Coral Reef Watch and BoM ReefTemp will be produced.

3. Improved seasonal predictions of marine heatwaves in the GBR

A seasonal prediction capability for marine heatwaves will be developed in partnership with BoM. This is being developed as a tailored research product to assist GBR management of developing marine heat waves and will utilise BoM's next generation seasonal prediction model ACCESS-S. ■



Water column profiles of temperature from Palm Passage mooring for the period October 2016 to April 2017. Cool water bottom intrusions are evident through the summer period (left) and IMOS Glider temperature transects across the continental shelf between Cooktown and Cairns between 22 March and 12 April 2016 (right).



IMOS *OceanCurrent* images of the Coral Sea and GBR on 15 March 2017. Satellite altimetry 30 day sea level anomaly product (left) and the Monthly average SST anomaly with derived geostrophic velocity from altimetry overlain (right).

Neal Cantin, AIMS

Tabulate Acropora corals from John Brewer Reef, a midshelf reef in the Central GBR, at the beginning of in water bleaching survey transects following the peak of heat stress in April 1 2017. Moderate levels of bleaching with no visible mortality at this reef.

Developing improved plankton data products for the IMOS community

WRITTEN BY: JASON D. EVERETT (UNSW, SIMS), CLAIRE H. DAVIES (CSIRO) AND ANTHONY J. RICHARDSON (CSIRO)

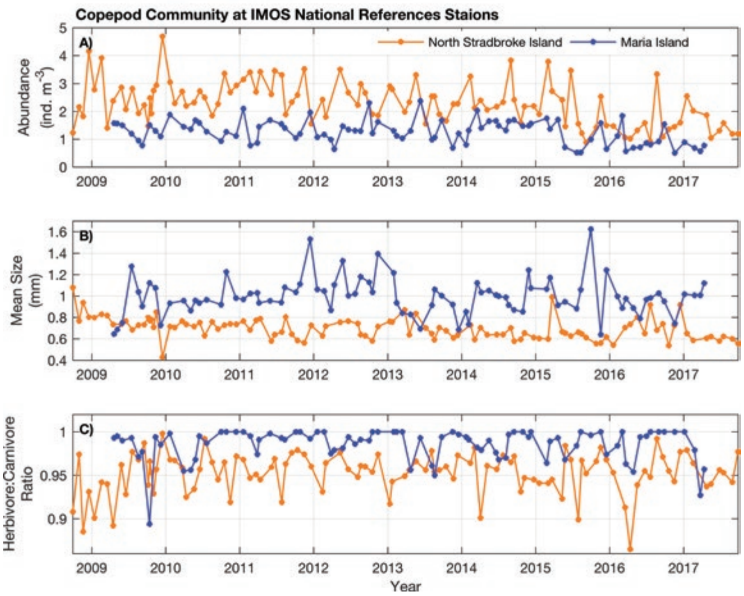
The key goal of the IMOS Zooplankton Ocean Observation and Modelling (ZOOM) Task Team is to bring modellers and observationalists together in order to maximise the collaborative research efforts being undertaken from the continuous IMOS and intermittent non-IMOS zooplankton observations.

Zooplankton observations are made at a range of spatial and temporal scales around Australia, and therefore provide us a unique opportunity to address sources of significant uncertainty in ecosystem models at multiple scales. However, due to the diverse types and nature of these zooplankton observations, the challenge of using these observations in models, and the different languages and backgrounds of the observational and modelling research communities, there has been relatively little uptake of these IMOS observations into biogeochemical and ecosystem models.

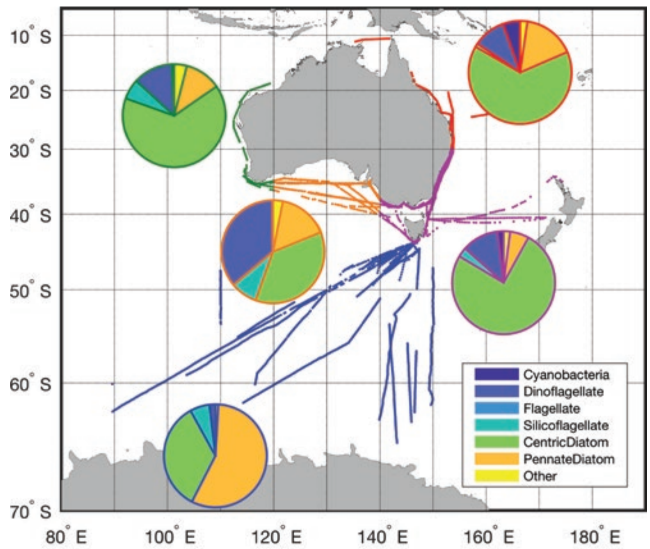
One of the focuses of the ZOOM Task Team has been to understand what data products are most useful for the modelling community to parameterise or assess their models. At our workshop in December 2017 a prioritised list of products was put together, and work has begun to deliver these products to the community via the Australian Ocean Data Network (AODN) Portal. The types of products being developed using National Reference Station (NRS) and Continuous Plankton Recorder (CPR) samples include:

1. Zooplankton biomass in units of carbon, nitrogen, wet weight and dry weight for all observations;
2. Mapped monthly climatology biomass fields around Australia;
3. Indexes of zooplankton diet preference (herbivore:carnivores), mean copepod size, phytoplankton and zooplankton species diversity, energy capture method (autotrophic:hetertrophic);
4. Summary tables of phytoplankton/ zooplankton abundance at higher taxonomic grouping (e.g. copepods, salps, larvaceans) for all sites and sampling periods.

These products are continuing to be developed throughout 2018 and will be released through the AODN Portal when ready. These products will be used by the ZOOM modelling group in late 2018 when we meet for the final time in order to "Confront Models with Data". The IMOS-ZOOM Task Team is co-convened by Jason Everett (UNSW) and Anthony J. Richardson (UQ/ CSIRO) and currently comprises more than 20 scientists from universities and government research organizations. ■



A time-series of copepods from the North Stradbroke Island (NSI) and Maria Island (MAI) National Reference Stations showing A) The abundance of copepods, B) Mean copepod size and C) Ratio of herbivore:carnivores. The figure shows a higher abundance (A) yet smaller size (B) of copepods at NSI. The copepod community at MAI is predominantly herbivorous with few carnivorous copepods appearing throughout autumn and winter (C). On average, NSI has a larger proportion of carnivorous zooplankton throughout the year.



A map of the Continuous Plankton Recorder (CPR) phytoplankton observations around Australia (designated as coloured dots). The edge colour of each pie plot corresponds to the coloured dots of the tow locations. This plot uses the new phytoplankton data product of CPR phytoplankton data binned to higher taxonomic group. Even with this simple plot, we can see that diatoms are the dominant phytoplankton group around Australia, in the Southern Ocean (blue dots) Pennate Diatoms dominate over Centric Diatoms, whilst around the rest of Australia this is opposite. In the Great Australian Bight (Orange dots), dinoflagellates are abundant, whereas in the northeast (red dots) we see the presence of cyanobacteria (*Trichodesmium spp.*).

Frontal systems on the Australian north-west shelf

WRITTEN BY: CHARI PATTIARATCHI (UWA)

Ocean fronts, defined as regions of large horizontal gradients in water properties (temperature, salinity etc), are areas of high productivity globally. Recent satellite imagery from the north-west shelf indicates the existence of two types of fronts extending over 1000km from North-West Cape to Cape Leveque. The nearshore band of high chlorophyll (see top figure) is associated with a very cold band of water at the coast (see middle figure) that usually develops every May, persists throughout winter, and is evident in the SSTAARS climatology.

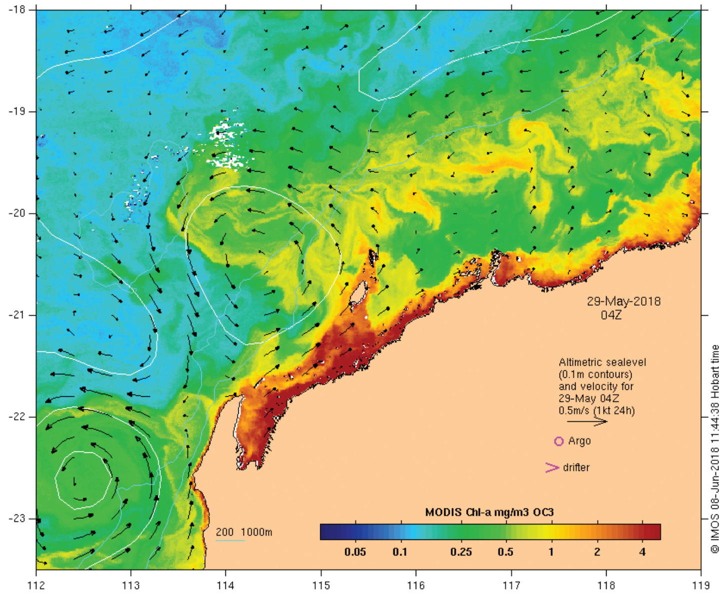
Water in shallow coastal regions become more saline over summer due to evaporation and with winter cooling the water becomes much denser than water further offshore. This cool, dense water then flows offshore along the bottom as a dense shelf water cascade which has been observed by ocean glider deployments in the region and other regions of Australia.

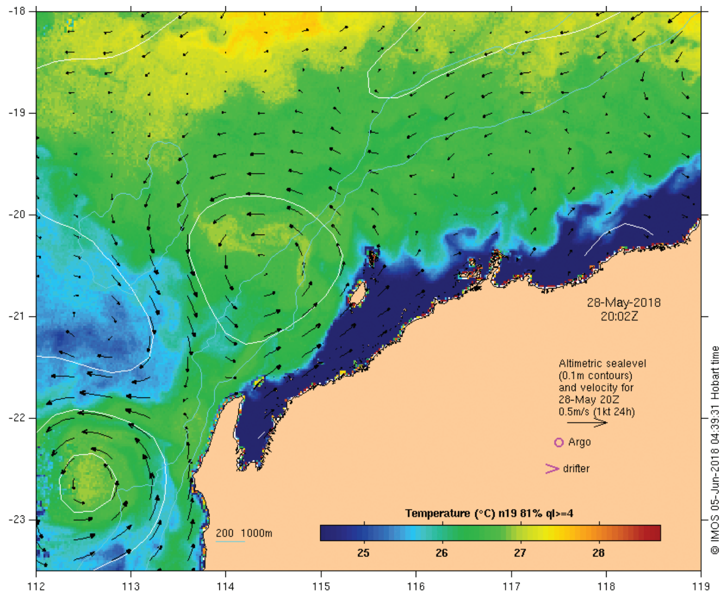
On continental shelves, fronts can also develop just through the reduction of tidal currents with depth without the influx of different water masses. Simpson and Hunter (1974) demonstrated that a front could develop where mixing due to tidal currents was no longer strong enough to overcome stratification. Many studies undertaken globally have shown that the ratio of the water depth to nearbed current speed cubed, $h/|U^3|$ is a good indicator of the location of tidal fronts, in particular where $\log10 (h/|U^3|) = 2.7$.

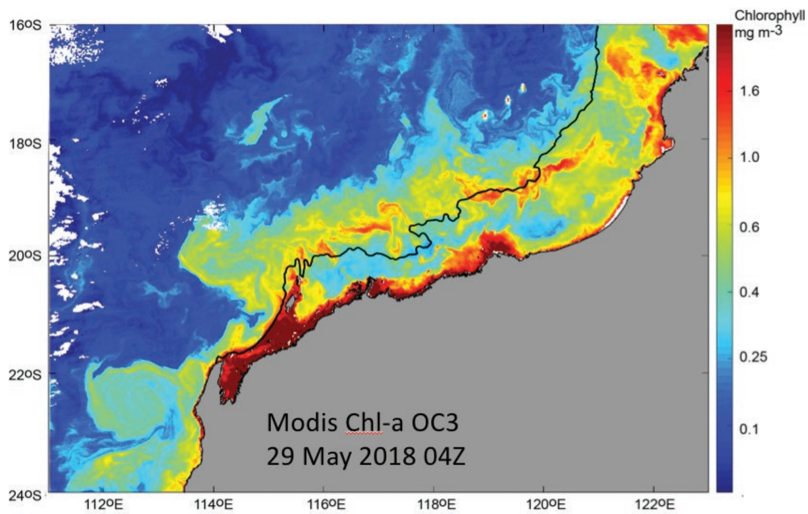
The band of higher chlorophyll found further offshore, suggesting the presence of a second front, lies in close proximity to the predicted Simpson and Hunter tidal front location (indicated with black line in the bottom figure).

Coastal currents transporting different water masses can also contribute to the existence of fronts and the frontal location could also be related to the location of the Holloway current that flows towards the south-west. The offshore chlorophyll maximum, although much weaker than in the nearshore front, has affected about 1000km of the mid-shelf region.

Recent work by Thums et al. (2017) demonstrated that flatback turtles (*Natator depressus*) followed the location of the predicted Simpson and Hunter tidal front when migrating along the Kimberley Coast. ■







REFERENCES:

Simpson, J. H., and Hunter, J. R. (1974). Fronts in the Irish Sea. *Nature* 250, 404–6.

Thums M, Waayers D, Zhi H, Pattiaratchi CB, Bernus J & Meekan MG. 2017. Environmental predictors of foraging and transit behaviour in flatback turtles (*Natator depressus*). *Endangered Species Research*, 32, 333–349.

NSW-IMOS:

Research Attraction and Acceleration Program (RAAP) grant to support NSW-IMOS by facilitating cross-disciplinary integration of IMOS data.

The NSW node of IMOS, which is based at the Sydney Institute of Marine Sciences (SIMS), was recently awarded a Research Attraction and Acceleration Program (RAAP) grant through the NSW State Government's Office of the Chief Scientist and Engineer to support NSW-IMOS by facilitating cross-disciplinary integration of IMOS data.

The NSW-IMOS node uses the data from several IMOS National Facilities and Sub-Facilities including those operated by SIMS; the Autonomous Underwater Vehicle and Animal Tracking facilities along with the New South Wales Moorings sub-facility.

The new RAAP funding will provide logistical support to Ocean Radar and Ocean Glider operations in NSW, funding for vessel-time to support deployments and research, and most notably the salaries for three post-doctoral positions who will provide synergies across the IMOS facilities in NSW.

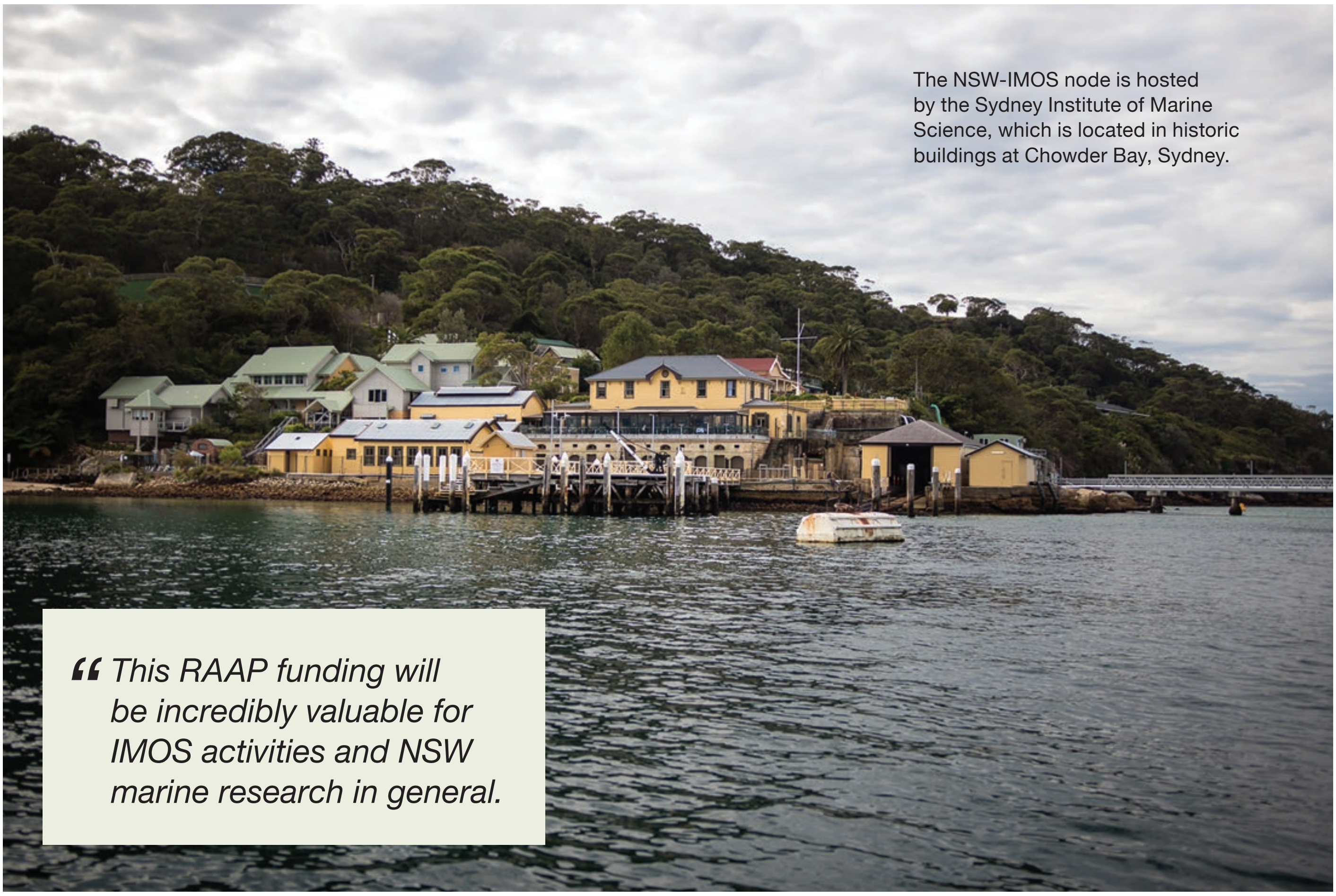
The first of the three post-doctoral positions will be focussed on improving understanding of marine microbial dynamics within the Australian marine environment by integrating data collected as part of the Bioplatforms Australia (BPA) Marine Microbes project (**http://www.bioplatforms.com/marine-microbes/**) with a rich set of oceanographic contextual data collected by IMOS.

The second position will integrate a range of observational and modelling products in order relate coastal ocean dynamics with biological activity (phytoplankton, zooplankton forage fish and pelagic predators) in the East Australian Current region.

While the third project will develop deep learning approaches for quantitative and semantic understanding of marine imagery, typically collected by Autonomous Underwater Vehicle (AUV), Remotely Operated Vehicle (ROV) and towed camera systems.

NSW-IMOS Node Leader, Professor Justin Seymour is excited by the opportunities provided by this additional funding and capacity for IMOS activities in NSW.

"This RAAP funding will be incredibly valuable for IMOS activities and NSW marine research in general. The three new research positions made possible by this grant will not only deliver new research capacity to NSW-IMOS, but will provide excellent opportunities to bridge the gaps between facilities and disciplines and truly integrate IMOS activities within the state," says Professor Seymour.



The NSW-IMOS node is hosted by the Sydney Institute of Marine Science, which is located in historic buildings at Chowder Bay, Sydney.

> *"This RAAP funding will be incredibly valuable for IMOS activities and NSW marine research in general.*

Leah Wood, SIMS

WA-IMOS:

Marine Biodiversity Hub project examines the occurrence and distribution of marine wildlife in the Bremer Bay region

Rebecca Wellard, Curtin University

Pod of killer whales surfacing above the head of the Henry Canyon, south of Bremer Bay.

Approximately 70 kilometres south-east of Bremer Bay (119.4°E, 34.4°S) off southern Western Australia's coast lies a group of submarine canyons etched into the continental slope, plunging to depths of more than 1,000 metres.

Charismatic pelagic organisms such as cetaceans, sharks, seabirds and squid are known to concentrate in high abundance above these features. In particular, the canyons are the site of the largest reported seasonal aggregation of killer whales (*Orcinus orca*) in the Southern Hemisphere, with over 100 identified individuals in the local population, many of which are regularly sighted.

Existing data suggest that the majority of killer whale encounters occur west of the Bremer Marine Park, around the heads of the Knob and Henry Canyons. It is unclear, however, whether this area represents a discrete and unique killer whale hotspot or whether the park may support other aggregations, be they from separate individuals or the same animals frequenting the hotspot. Furthermore, the mechanisms underpinning ocean productivity in these otherwise relatively oligotrophic waters remain largely unresolved.

A collaborative National Environmental Science Programme (NESP) Marine Biodiversity Hub project led by University of Western Australia (UWA) has surveyed marine life across the region, both inside and adjacent to the Bremer Commonwealth Marine Reserve (CMR) which extends to the edge of the continental slope. The project received funding under the NESP Emerging Priorities scheme.

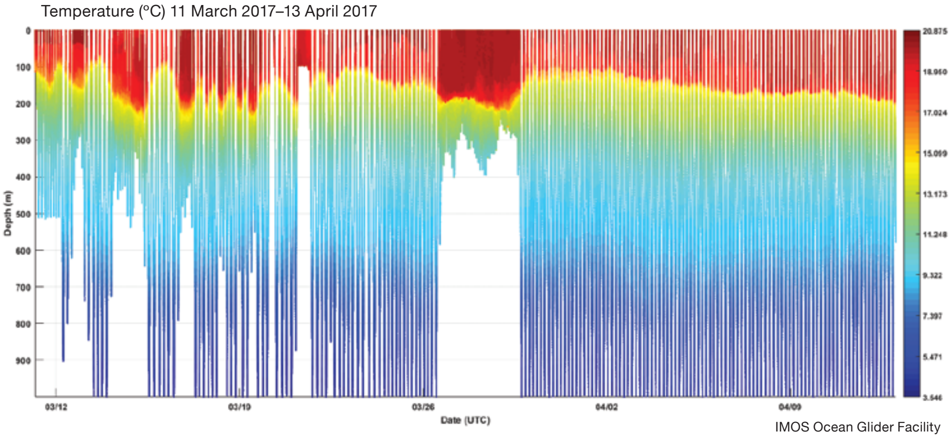
Between February and April 2017, the Bremer Marine Park and surrounds were surveyed using a combination of sampling platforms. These activities were supported by additional contributions from Parks Australia, the Ian Potter Foundation and IMOS.

Aerial surveys were conducted in March 2017 with two observers flying onboard a chartered aircraft. The survey team from Curtin University's Centre for Marine Science and Technology and UWA recorded the occurrence and distribution of large marine wildlife along transects that crossed the Bremer CMR and known aggregation area. An additional survey focussed on the aggregation area.

Sightings of marine megafauna included killer whales, sperm whales, long-finned pilot whales, large sharks and dolphins.

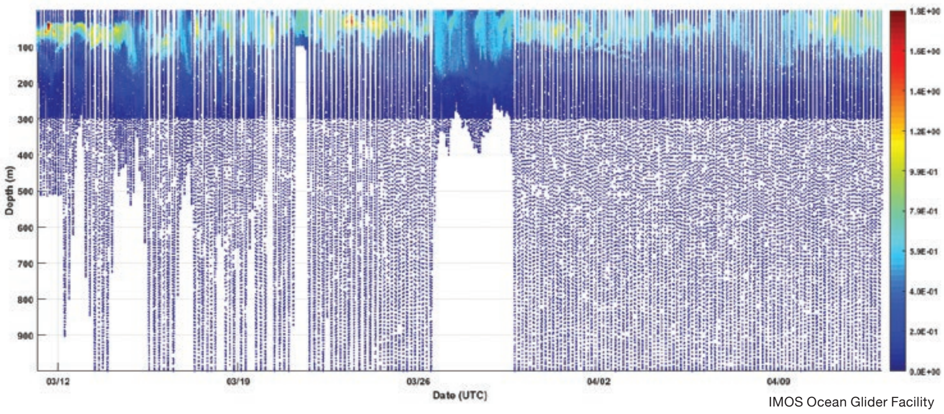
A 10-day mid-water baited remote underwater video systems (BRUVS) survey of the Bremer CMR and aggregation area led by UWA took place in February–March 2017. One hundred BRUVS deployments documented the diversity, abundance and biomass of pelagic sharks and fishes.

Temperature (°C) 11 March 2017–13 April 2017



IMOS Ocean Glider Facility

Temperature data gathered by the IMOS ocean glider. Thinner layers of warm surface waters as the glider moves further offshore into deeper water suggest a reduced influence of the Leeuwin Current, which flows eastward along the continental shelf.



IMOS Ocean Glider Facility

Chlorophyll *a* data gathered by the IMOS ocean glider. Chlorophyll *a* concentrations, a measure of the important phytoplankton at the base of the food chain, form a layer at approximately 50 m depth, but show a higher signal in the west of the transect.

Curtin University's Centre for Marine Science and Technology also conducted passive acoustic monitoring between February 2015- February 2016 at the edge of the continental shelf south of Bremer Bay. A further dataset was collected via a towed acoustic array in February 2016. The analysis of these datasets was commissioned by this NESP project.

Researchers from Marine Information and Research Group Australia spent 26 days in the offshore Bremer sub-basin between late February and April 2017. Vessel-based operations allowed the collection of photographic data and tissue samples from large megafauna. Unfortunately, the planned tagging activity of adult orcas was not completed due to challenging sea conditions.

An IMOS Ocean Glider was deployed in the Bremer offshore region in March 2017 for a six-week oceanographic investigation. After three weeks, the glider had made more than 150 'dives' to depths of up to 1000 metres, measuring sea temperature, salinity and biogeochemical parameters along repeat, sawtooth transects. It detected patterns in seawater temperature, salinity and oxygen content that appear to indicate different water masses overlying the canyons.

The knowledge gained during the 12-month project will support Australian Government decision-making to protect the environment and biodiversity and allow for sustainable use, and prioritise future research. This includes management decisions relating to the Bremer CMR, as well as the Albany canyon group and adjacent shelf break, which are identified as Key Ecological Features in the South-West Marine Bioregional Plan.

The final report for the project is available via the Marine Biodiversity Hub website: **https://www.nespmarine.edu.au/project/ep2-surveying-marine-life-canyons-bremer-bay**

Ships of Opportunity: Temperate Merchant Vessels

Tracking the first nurdle spill in Australia from a sewage treatment facility

WRITTEN BY RANDALL LEE (EPA VICTORIA) AND IAN BAIL (WANNON WATER AUTHORITY)

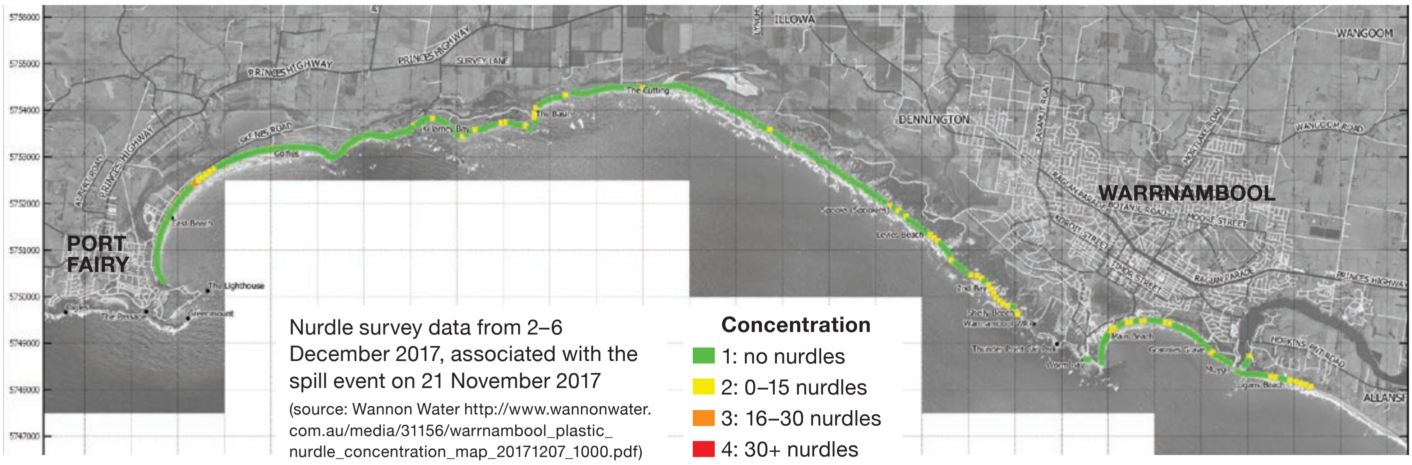
www.boomerangalliance.org.au/nurdles

Firstly, 'What are nurdles?' – They are plastic resin production pellets 2–5mm in size that are used for plastics manufacturing. Since 2010, nurdles have become a global issue, with groups overseas working to prevent the pellets spreading and washing up on beaches. They can be found in the digestive tracts of various marine animals. Nurdles cause physiological damage by leaching plastic additives and hydrophobic pollutants absorbed from seawater at levels many times higher than ambient concentrations.

When 15 billion nurdles were spilled in Hong Kong in 2012, dead sea birds and fish washed up with the pellets. In response to numerous nurdle spills within the San Franscisco Bay area, the US EPA commenced a nationwide enforcement program in 2011, focusing on the handling malpractice of plastics manufacturing companies.

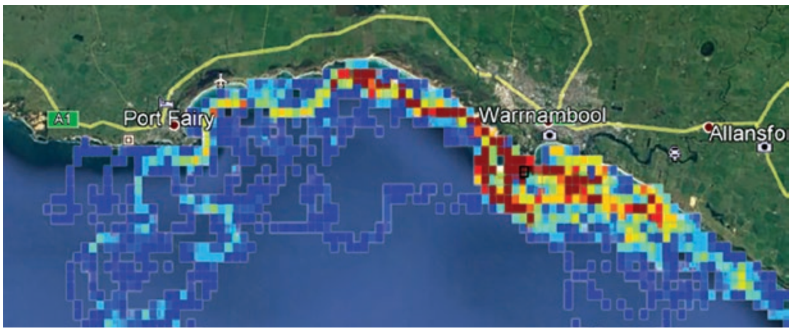
On November 21, 2017, the local water authority in South West Victoria, Wannon Water, reported to EPA Victoria that an illegal dump of nurdles had been received at its septage receival point, some of which then passed through its Warrnambool sewage treatment plant (STP) and into the ocean. This was considered to be the first nurdle spill incident in Australia through a STP. The strong emergency response and volunteer clean-up efforts on local beaches highlighted both the significant level of concern about the potential threat of nurdle contamination, and the limited hands-on experience of a local spill.

As the situation at Warrnambool developed, the nurdles were found to have also spread to Port Fairy's East Beach, resulting in increased clean-up efforts . Wannon Water employees and contractors, government agency staff and many volunteers, spent



Nurdle survey data from 2–6 December 2017, associated with the spill event on 21 November 2017

(source: Wannon Water http://www.wannonwater.com.au/media/31156/warrnambool_plastic_nurdle_concentration_map_20171207_1000.pdf)



VICMOM 10 day simulation for 21 November to 6 December 2017, showing probability of occurrence of nurdles discharged from the Warrnambool STP on 21 November 2017.

hours at the beach in the days and months after the spill, using buckets and sieves to separate and remove the tiny plastic pieces from the sand.

The statewide Victorian Marine Operational Model (VICMOM)* developed by CSIRO and EPA Victoria was employed for several weeks to provide 2–3 day forecasts on a daily basis to map nurdle dispersal and accumulations from the point of discharge. This information was used at the Incident Control Centre to optimize beach clean-up operations and provide messaging for recreational users. The resultant clean-up efforts were mapped and compared favorably to VICMOM's dispersion forecasts.

The Warrnambool spill was declared a Class 2 State Emergency at the end of November, and a multi-agency team set up to manage the ongoing response. Wannon Water implemented additional fine screening on the outlet of the STP in early December, satisfying an EPA Pollution Abatement Notice to prevent further contamination from the one-off event.

Reporting from Wannon Water on the clean-up efforts to the end of February 2018 confirmed that around 130 litres (approximately 3,000,000) of nurdles were captured within the STP, and that an additional 24.6 litres (570,000) had been collected from beaches through combined community volunteer and agency efforts. The response has so far cost Wannon Water around $350,000, and monitoring and clean-up will continue until the end of 2018.

For more information, and ongoing updates on the event go to: http://www.wannonwater.com.au/whats-happening/projects/nurdles-response.aspx

*VICMOM is a coupled oceanic (Bluelink) and atmospheric (ACCESS) product that has been downscaled to a series of 500m grid model domains to cover the Victorian coast. It was developed by the Environmental Modelling team (Mark Baird, John Andrewatha, Scott Condie and Bec Gorton) and EPA Victoria (Randall Lee). This region is recognized nationally as a significant gap area for marine observations, with the IMOS SOOP Facility Spirit of Tasmania 1 the sole supplier of in-situ marine water quality data in this region. ■

Deep water moorings

IMOS moorings continue to reveal the complexities of the East Australian Current

The RV *Investigator* departed from Brisbane in April to turn around the East Australian Current (EAC) deep water mooring array.

The East Australian Current (EAC) is wide and powerful and plays a crucial role in our east-coast climate and ocean ecosystems. But there are big gaps in our knowledge about this dynamic ocean current that can move from hugging the coast one day to being hundreds of kilometres out to sea the next.

IMOS has been observing this major boundary current since 2012 with an array of six full-depth moorings that measures the speed, salinity and temperature of the EAC.

Ocean observing at this scale is only possible by the major Australian marine national research infrastructure. The RV *Investigator* voyages that enable the maintenance of multi-year monitoring of the EAC are a collaboration between IMOS, the Marine National Facility who operate the vessel, and the scientists and engineers that operate the IMOS Deep Water Moorings Facility at CSIRO.

The East Australian Current carries up to 40 million cubic metres of water south each second, the equivalent of 16,000 Olympic swimming pools. It's almost 100 kilometres wide in parts and more than one and half kilometres deep in some areas.

The EAC is a complex and highly energetic western boundary system of the South Pacific Ocean off eastern Australia. It closes the South Pacific subtropical gyre, transporting heat, salt and other nutrients southward and onto the continental shelf.

Chief Scientist for this voyage, Dr Bernadette Sloyan, a CSIRO scientist and a leader of the IMOS Deep Water Mooring Facility, explains the importance of gathering the data about the EAC.

"We're all very comfortable with going to Brisbane in July and knowing the mean temperature will be this so I'll pack my clothes to do that. "

"But if we think about the mean conditions of the EAC in June or July or any other month of the year we really haven't had the ocean observations to do that."

"So, by combining the ocean observations from the moorings with models of different resolutions along our coast, we will be able to provide an understanding of what the mean conditions of the current are."

"Then when we see bigger changes, we can quantify how big that change is, and the variability, allowing us to start thinking about what's driving the changes that we see.

Warrick Glynn, IMOS

Dr Bernadette Sloyan in front of the orange mooring floats aboard the RV *Investigator*.

The current doesn't just control weather and seasonal forecasting. Bernadette Sloyan explains the more scientists know about the EAC the better equipped they'll be to protect the marine animals living in and around it.

"The EAC does control not just our climate, so our weather and our seasonal forecasting, but it also controls very strongly the marine biodiversity along the coast."

"We've seen many records in recent times of species being found much further south than they normally are. Some of this is controlled by the current strength, so advecting those species south. But also change in the temperature and the properties of the ocean that allow species to actually extend their range."

"However, for vulnerable species this range extension may put them at their tolerance level, say of water temperature, that's actually a cause for concern."

The new data from the retrieved moorings will be added to the IMOS data already in the Australian National Data Network (AODN) Portal. Bernadette Sloyan outlines how she will use the latest data.

"We're collecting the temperature and the salinity of the ocean, and the velocity of the ocean every hour. So now we have 18 months' worth of hourly data and we can put that together to present a movie of what the current does," says Dr Sloyan.

"The EAC rapidly moves inshore and offshore, it doesn't take a week it can do it in a day. It's a dynamic system and understanding what drives why it's moving so rapidly onshore or offshore, or then why is it stable for a long period of time, is what really interests me."

Bernadette Sloyan says long time-series observations are essential to learn how to protect the ocean.

"There are key places in the ocean and the ocean surrounding Australia that I think long term monitoring is going to be the thing we have to do. That will then enable us to work with the modelling community and sophisticated circulation models of the ocean to actually then project change in a much wider domain than just in the EAC at Brisbane."

Quotes are from the ABC Radio National Interview with Bernadette Sloyan. ■

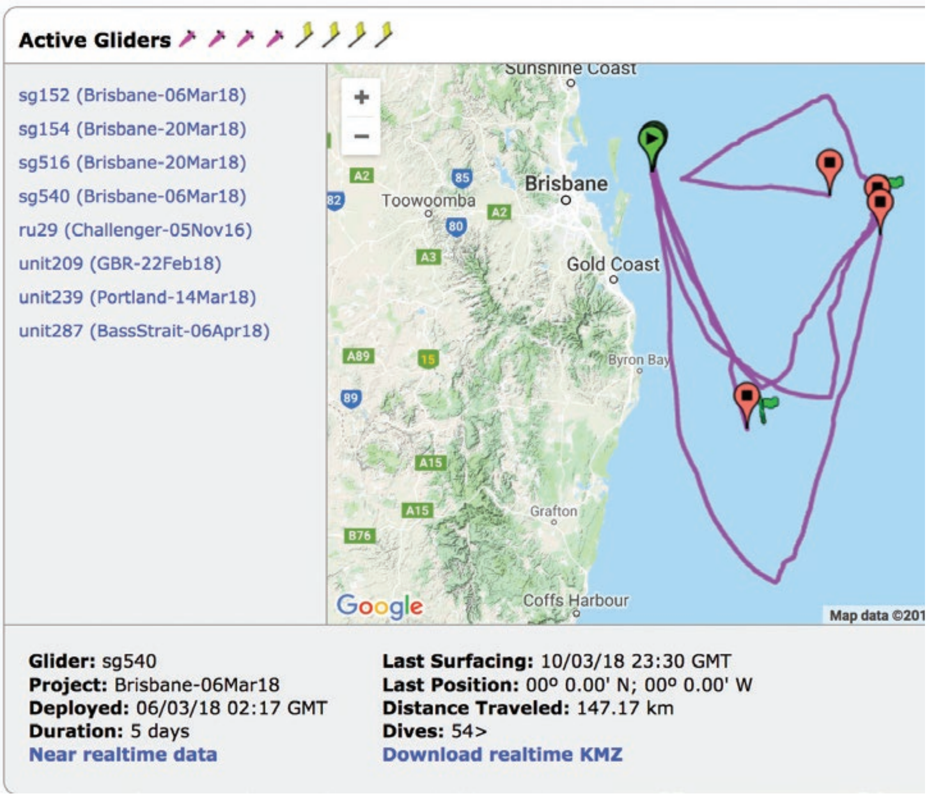
Ocean Gliders

Gliders working together to further our understanding of the complex East Australian Current

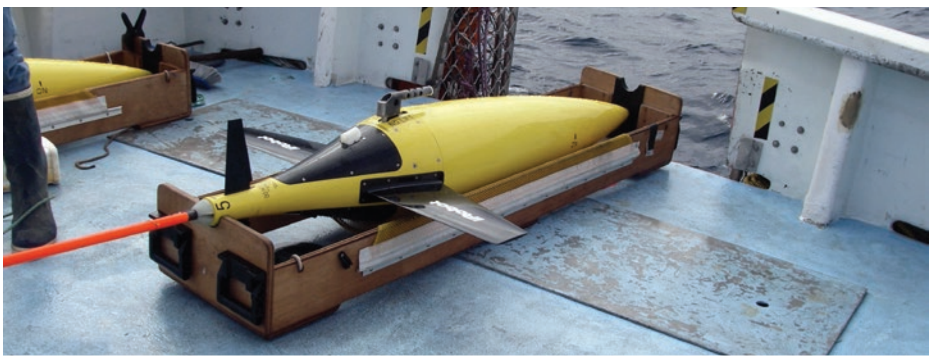
IMOS deployed four ocean gliders concurrently in the same region for the first time, alongside our deep water mooring array.

The East Australian Current (EAC) is the complex and highly energetic western boundary current of the South Pacific Ocean. The EAC is the dominant mechanism for the redistribution of heat and freshwater between the ocean and atmosphere in the Australian region; it is a vital component of the eastern Australian coastal ecosystem. The monitoring of the EAC is central to our understanding of how climate variability is communicated through the global ocean.

The IMOS Ocean Glider Facility (operated by The University of Western Australia) has recently deployed four Sea gliders north of the EAC deep water mooring line. The ocean gliders were deployed in early March and stayed in the water for approximately two and half months.



The location of the four moorings around the EAC mooring array.



Paul Thomson, UWA

After their deployment the ocean gliders were navigated southwards until they intersected with the mooring array. Upon reaching the mooring line they then began their planned deployment of a continuous transect between the on-shore and off-shore extremities of the mooring array. The ocean gliders are undertaking full depth (0-1000m) profiles approximately every 12 hours and are being actively piloted to achieve best success of keeping them on the designated transect.

The EAC ocean glider deployments will provide high resolution profiles, from 0-1000m, coincident with the EAC deep water mooring array. They will be used to understand the spatial structure of the EAC along the mooring line and help with the development of an efficient and cost effective observing system to monitor the EAC.

The data will also provide significant insights into the interactions between the EAC, the Pacific basin and the local shelf ocean circulation.

The monitoring of the EAC with the ocean gliders will more specifically:

- provide improved understanding of relationship of EAC to the South Pacific gyre;
- determine the impact of the EAC variability on the shelf circulation and coastal marine ecosystem;
- enable investigation of the relative influence of local and large-scale remotely driven variability on coastal dynamics and;
- build a long time-series of the EAC for assessment of the simulation of the EAC system in climate and ocean models including BlueLINK, ACCESS and eReef and other high resolution coastal models; and
- add to the international global ocean observing system for boundary current monitoring (e.g. Gulf Stream, Agulhas Current and Kuroshio Current). ■

Autonomous underwater vehicles

The AUV Sirius returns to South Australia

WRITTEN BY GRETCHEN GRAMMER (SARDI)

After 10 years, the autonomous underwater vehicle (AUV) Sirius has returned to South Australia to expand the IMOS integrated benthic monitoring program into the region.

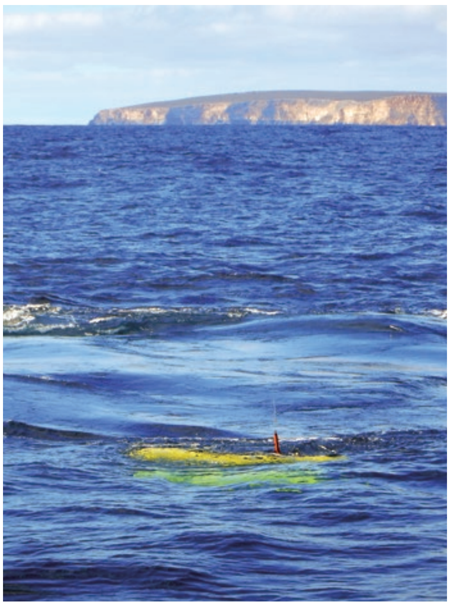
In May, a team of scientists led by Dr Gretchen Grammer of the South Australian Research and Development Institute (SARDI) successfully completed a voyage with the Sirius in the coastal waters around the Sir Joseph Banks in Spencer Gulf and in shelf waters off western Kangaroo Island.

The scientists used the Sirius to explore and record imagery of seafloor habitats from eight different locations. The team included Professor Stefan Williams and George Wakeham from the Australian Centre for Field Robotics (ACFR) at the University of Sydney and the IMOS AUV Facility, Paul Malthouse (SARDI, SAIMOS), Dr Paul van Ruth (SARDI, SAIMOS) and the crew of the RV *Ngerin*. The South Australian Department for Environment and Water (DEW) was a funding partner for the voyage.

The sites around the Sir Joseph Banks were first surveyed with the Sirius in 2008. Four of those sites were re-surveyed during the current trip and new ground was explored in the deep water off Kangaroo Island (80-115 m). The new sites were located in the protection and general use zones of the State and Commonwealth Marine Parks in close proximity to the IMOS Kangaroo Island National Reference Station.

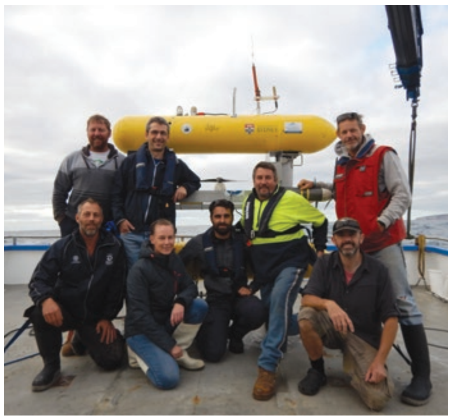
Before making the 10 hour steam from the Sir Joseph Banks to the Kangaroo Island sites, the new eSA-Marine nowcast/forecast system (**http://pir.sa.gov.au/research/esa_marine**) was used to check sea conditions and bottom currents on the shelf to make sure it would be possible to deploy the Sirius. The eSA-Marine predictions were spot on and all missions were a resounding success.

eSA-Marine was developed through a collaboration between SARDI, the Bureau of Meteorology and the University of Adelaide, with extensive use of IMOS data for calibration and validation. Another voyage with the Sirius is scheduled for May 2019, and Dr Grammer and the ACFR team are also planning to be part of an expedition to Pearson Island led by DEW in November 2018 to establish benthic monitoring sites in State and Commonwealth Marine Parks in the region. ■



G. Grammer, SARDI Aquatic Sciences

The AUV Sirius beginning a mission in the waters off western Kangaroo Island.



G. Grammer, SARDI Aquatic Sciences

Return of the AUV Sirius to South Australia. Voyage team members: Standing left to right: Darren Nohlmans (master, RV *Ngerin*), Prof. Stefan Williams (ACFR), Paul Malthouse (SARDI); kneeling left to right: Jason Nichols (crew, RV *Ngerin*), Dr Gretchen Grammer (SARDI), George Wakeham (ACFR), Chris Small (crew, RV *Ngerin*), Andrew Sellick (crew, RV *Ngerin*).

Satellite Remote Sensing – Surface Waves Sub-Facility

New surface waves product on the way

WRITTEN BY SALMAN KHAN (CSIRO)

The IMOS Surface Waves Sub-Facility will gather high quality ocean surface wave data from current and next-generation satellite missions and make it readily available to the Australian marine and climate science community through IMOS's Australian Ocean Data Network (AODN) Portal. The planned project will enhance existing IMOS facilities to deliver national satellite remotely sensed (SRS) wave products to support ongoing and emerging research and operations in Australia.

Globally, Satellite Remote Sensing (SRS) of oceans using altimeters (Jason-2, Jason-3, Sentinel-3, Cryosat-2, SARAL, HY-2), and Synthetic Aperture Radars (SAR) sensors (Sentinel-1A/B, and CNSA GF-3) are providing wave characteristics such as significant wave height, period as well as directional swell spectra. In this regard, the three-year European GlobWave program previously provided calibrated and validated SRS wave data streams for improved uptake of satellite-derived wave data by the scientific, operational and commercial user community.

With the recent launch of satellite missions measuring ocean waves such as the European Space Agency's Sentinels, China National Space Administration Gaofen (High Resolution)-3, and prospective future missions such as Surface Waves Investigation and Monitoring - Chinese-French Oceanography Satellite, there is an emerging need for continued collection, quality control, and distribution of ocean surface wave data to user groups in Australia and also globally.

The planned project – a collaboration between CSIRO (Dr Mark Hemer) and the University of Melbourne (Prof. Ian Young) – will build Australia's capability in SRS wave data-streams and deliver global validated, processed SRS wave data streams, with focussed effort in the Australian region. ■

Postgraduate Student | **Hugo Bastos de Oliveira**

PROJECT TITLE:

Upwelling dynamics in Southern Australia – Numerical modelling and observations

Institute for Marine and Antarctic Studies at the University of Tasmania, South Australian Research and Development Institute (SARDI), CSIRO

Hugo's PhD studied the Eastern Great Australian Bight summertime upwelling circulation. He used a numerical model and analysed several types of direct and indirect observations, which included IMOS observations from the South Australian Moorings, Ocean Gliders and Ocean Radar. It focused on the strongest upwelling region of Australia: the Bonney Coast.

The model was used to examine how variations in shelf topography and Coastal Trapped Waves influence upwelling, and a particular influence of shallow valleys and submerged banks was found. This features strongly steer the bottom flow, with upwelling found within the valleys and downwelling atop the banks. A vorticity formalism was used to explain the main circulation features, as well as the role of alongshore pressure gradients in increasing the onshore flow. The remotely forcing from the west Coastal Trapped Waves was also found important in driving significant bottom flow and pre-conditioning the upwelling.

The observations analysis is a comprehensive description of the current observational effort in the region. A strong influence of El-Niño over the whole Eastern Great Australian Bight is confirmed in several independent estimates, as well as a new influence from the Southern Annular Mode in upwelling through wind-stress. The unprecedented glider missions in the region clearly helped in defining the 2016 summer as one of the most extreme seasons on record. Finally, these in-situ measurements also support the model results and influence of alongshore topographic features.

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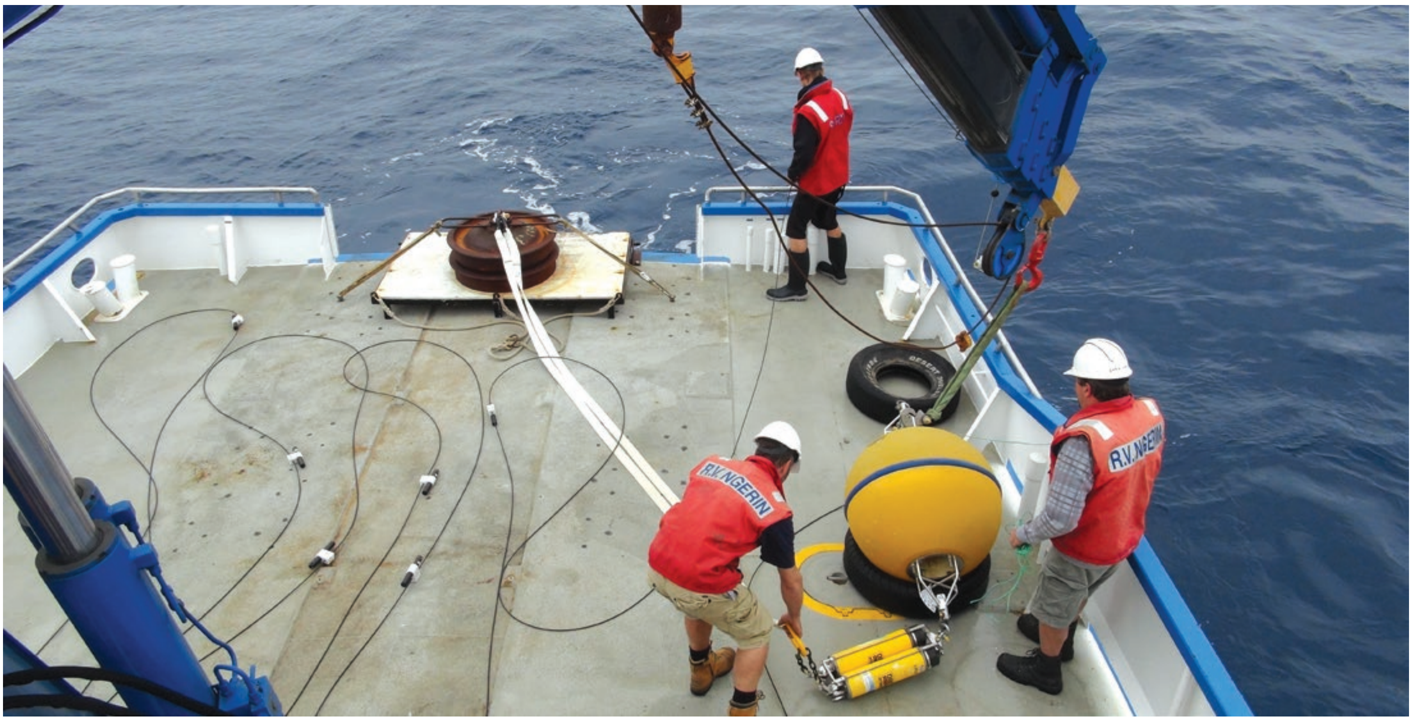
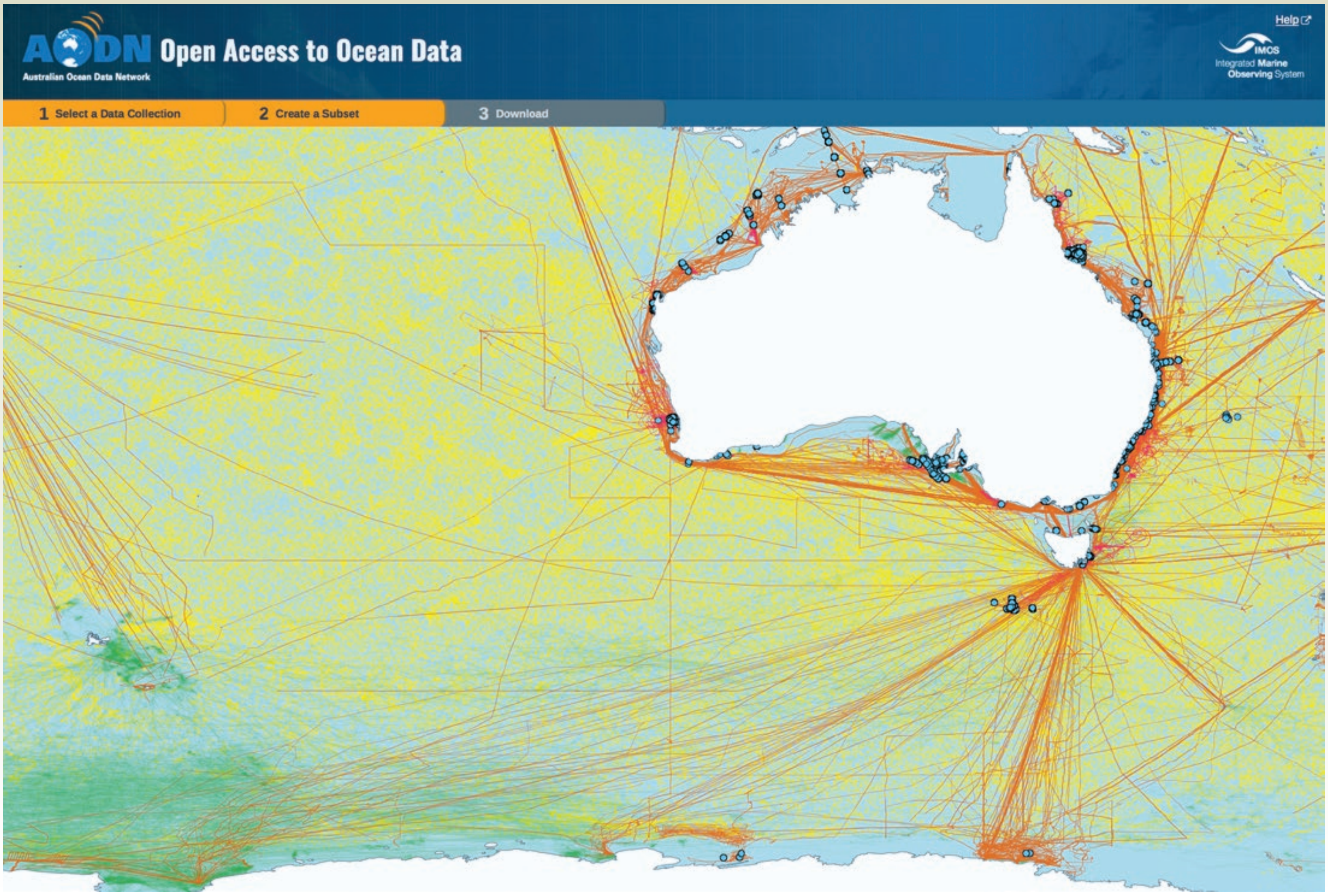


SARDI



The **AODN Portal** provides access to all available Australian marine and climate science data and provides the primary access to IMOS data including access to the IMOS metadata.

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IMOS

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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