IMOS

marinematters

Integrated **Marine Observing** System

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Long-term research shows ocean acidification ramping up on the Great Barrier Reef

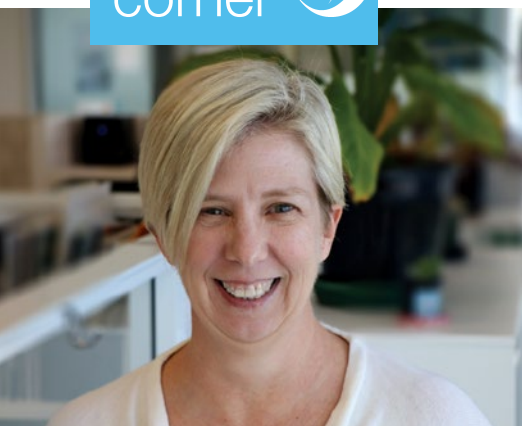
Ship of Opportunity operations during the pandemic

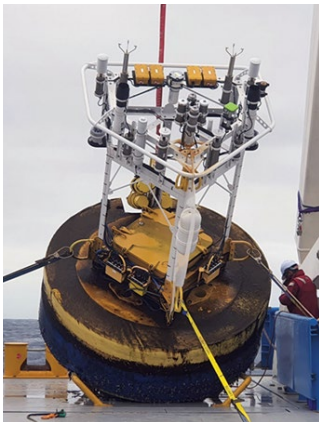
The New Technology Proving Low Cost Wave Buoy project advances to its next phase

RV *Investigator* recovers and deploys IMOS deep water moorings in the Southern Ocean after a significant delay due to the COVID-19 pandemic.

Peter Jansen, CSIRO

director's corner





Welcome to the November 2020 edition of Marine Matters

This edition of Marine Matters provides an update on progress within IMOS during 2020, despite the ongoing disruptions caused by COVID-19. There have been a number of changes in IMOS in 2020 which are worth noting. There have been some significant changes within the IMOS Office this year. We welcomed Dr Paul van Ruth as the IMOS Senior Science Officer and recently farewelled Jo Neilson as she starts her journey into retirement.

We have also had some changes in Node leadership with Dr Ana Redondo-Rodriguez (SARDI) appointed as the new Node Leader in South Australia and Dr Andrew Lenton (CSIRO), Dr Bea Pena-Molino (CSIRO), and Dr Robert Johnson (BOM) appointed as leaders of the Bluewater and Climate Node. We welcome all of them and thank them for their contributions to IMOS.

Beyond the news and updates, this issue has a strong focus on Facilities and their recent achievements. Implications of COVID-19 have created numerous issues for travel and vessel operations, but we are pleased to report that after several months' delay IMOS deep water moorings in the Southern Ocean were successfully turned around on the first RV Investigator research cruise since the pandemic began. Congratulations to the Facility and the vessel operations team for achieving this objective.

In other mooring news, a recent publication based on IMOS data from the Great Barrier Reef reveals increasing ocean acidification in the region as a result of climate change. These data reinforce the importance of sustained observing and long-time series data to understanding trends and change in our oceans.

We highlight a number of data features in this issue to keep the community up to date on changes and improvements. These include exciting new products for multi-satellite sea surface temperature, improved accuracy of seal tracking data, and an update on biogeochemical Argo data streams.

IMOS continues to support collection of additional data on waves and we are pleased to provide updates on Waverider Buoys deployed by the New Zealand Defence Force and results of the New Technology Proving low-cost wave buoy project.

These aspects and several other highlights are featured for you in this edition. We hope you enjoy it.

Dr Michelle Heupel
IMOS Director

Ocean Beach (Tas), Lea Walpole

The IMOS Annual Highlights Document 2019–20 is available now

The document showcases a selection of science highlights illustrating the many ways in which IMOS research infrastructure was used over the past year for the benefit of Australians.

The 2019-20 Annual Highlights document for Australia's Integrated Marine Observing System (IMOS) can be downloaded from the **IMOS website**. This web page has links to the **pdf of the document**, as well as more detailed information about the uses and users of IMOS data.

In our 14th year of operation IMOS and our community have weathered some significant changes. However, we have collectively continued to strive for excellence in the delivery, use and uptake of the IMOS program and this document celebrates the highlights and our achievements.

As IMOS grows and evolves we continue to move from strength to strength as our operations, data streams and outputs mature and increase in their relevance. Active monitoring of the use and users of our data outline the breadth of our community, the applicability and value of the observations we produce and reflect the strength of our partnerships. Our collaborative approach, high data quality and commitment to making our observations accessible underpin our outstanding national and international reputation.

Despite the disruptive events of the 2019-2020 year, which included extensive bushfires and the start of the global corona virus pandemic, the IMOS community rallied to continue to deliver ocean observations which are critical to numerous elements of Australian life and wellbeing. IMOS observations support weather and climate modelling and forecasting, help inform ocean conditions relative to maritime operations by industry and Defence, define dynamics related to food security and biodiversity conservation and facilitate scientific research into these areas and more.

IMOS strives for continual improvement through exploring the potential of new technologies to improve our observing capability and test new ways to deliver data for use by researchers, industry, managers, policy makers and the general public. As we enter the United Nations Decade of Ocean Science and look toward 2030, IMOS will continue to deliver ocean observations for the benefit of Australia and our regional neighbours who share our oceans.

We hope you enjoy reading the IMOS Annual Highlights document for 2019-20 and thank you for your continued interest and support. If you wish to receive any further detail about IMOS progress during the year, please do not hesitate to contact our office **imos@imos.org.au**. ■

IMOS office
STAFFING UPDATE

Jo Neilson retired from her role as the IMOS Project Manager on November 13th. Jo has led the senior management of the office since IMOS began 13 years ago and has been a key contact for the IMOS Governing Board, our operators and the wider IMOS community. We thank Jo for all of her efforts and years of service in helping IMOS grow into the program we have today. We wish Jo a very happy retirement. ■

Dr Paul van Ruth commenced in his role as the IMOS Senior Science Officer in mid-October. Paul is looking forward to working closely with the broader IMOS community to ensure we continue to deliver quality outcomes for our stakeholders and promote the sustainable management of Australia's marine resources. Paul can be contacted via **email**. ■

New ARDC co-invested projects will enhance data integration between NCRIS capabilities to support leading edge research

IMOS welcomes the investment from the Australian Research Data Commons (ARDC) Cross-NCRIS Data Assets program.

IMOS is involved in two projects successfully funded through the Cross-NCRIS Data Assets program to support leading edge research:

- Data nexus: coupling genomic and oceanographic data to enhance integration
- Ecosystem data integration to support national environmental reporting

Data nexus: coupling genomic and oceanographic data to enhance integration

Every millilitre of the vast ocean ecosystem provides a habitat for millions of microorganisms that modulate ocean health and ultimately control global climate.

However, the scales, tools and data products used to study the ocean are very different to those used to study microbes, and both research disciplines require extensive, domain specific skills that have little overlap.

IMOS will lead this project in partnership with **Bioplatforms Australia**. The project will drive the integration of large DNA sequencing datasets that describe the composition and function of Australian marine microbial assemblages, with oceanographic datasets (e.g. water temperature, salinity, nutrients, dissolved oxygen, current direction) that describe the form and dynamics of Australian ocean ecosystems.

The integration of these very different data types will accelerate our understanding of

how changing environmental conditions drive the microbial processes that sustain the planet, while enabling non-microbial researchers' direct access to key microbial insights that will enhance modelling of ecological and biogeochemical processes.

This type of data integration does not exist anywhere else in the world and will provide great advantages to the Australian research community.

The output dataset will exploit a wealth of existing information to develop data resources and tools that are compatible with ideas and needs from the community, including human health and wellbeing; management of protected/high value ecologies, and safeguarding Australian aquaculture and fisheries.

Ecosystem data integration to support national environmental reporting

The Australian Government **Department of Agriculture, Water and the Environment** produces the State of the Environment report every five years to meet statutory reporting obligations and update all Australians and decision-makers on environmental state, pressures, trends and key issues. State of the Environment reporting relies extensively on high-quality national data.

This project will involve **Atlas of Living Australia** (ALA), Integrated Marine Observing System, and the **Terrestrial Ecosystem Research Network** (TERN) to develop new cross-facility data assets to support national environmental reporting. Integrated data products will have significant value beyond State of the Environment with use in the research sector, in related government programs.

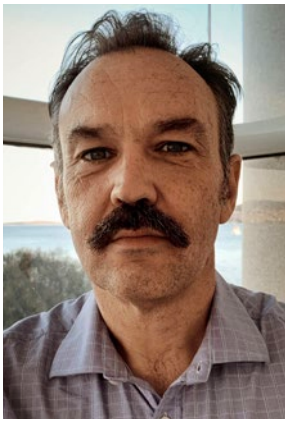
The new national and highly visible environment reference collection will have application in areas including environmental accounts and impact assessments; land, inland waters, coastal and marine management; agricultural development and biosecurity; urban planning; infrastructure design; disaster and risk assessment.

Consolidating these assets in this way will serve as a showcase for NCRIS and for the significant contributions NCRIS capabilities are making to understanding the Australian environment. High-quality environmental information is also critical for Australia to meet its reporting obligations under international conventions (e.g. United Nations Sustainable Development Goals, Aichi Biodiversity Targets, United Nations Land Degradation Neutrality). ■

Change of leadership for the IMOS Bluewater and Climate Node

Dr Beatriz Peña-Molino, Dr Andrew Lenton and Dr Robert Johnson have recently become the new leaders of our Bluewater and Climate Node.

Dr Beatriz Peña-Molino



Dr Andrew Lenton

Dr Robert Johnson

Dr Beatriz Peña-Molino is a physical oceanographer working for the Climate Science Centre at CSIRO in Hobart. Her interests span the high, mid and low latitude oceans and their role in climate. Her work has mostly focused on observations from a wide range of platforms, from in situ moorings to drifting Argo floats and remote sensing.

Through her work she's also developed strong ties to the modelling community, and like the rest of the **Bluewater and Climate node** leadership team, she would like to use her role at IMOS to further breach the gap between observations and models.

Beatriz received a PhD in Physical Oceanography from the Massachusetts Institute of Technology (MIT) - Woods Hole Oceanographic Institution (WHOI) joint program (USA) in 2010. During her PhD Beatriz explored the interaction between the Gulf Stream and the Deep Western Boundary Current in the North Atlantic. In 2011 she came to Australia and joined the former Antarctic Climate and Ecosystems Cooperative Research Centre, where her work focused on the circulation of the Southern Ocean. Since 2017 she has been employed by CSIRO, where she continues to work in the Southern Ocean, as well as in the Indo-Pacific inter-basin exchange program and contributes to Argo Australia.

Dr Andrew Lenton is an ocean carbon cycle modeler in CSIRO (Oceans and Atmosphere), based in Hobart. He has extensive experience in modelling the carbon-cycle at different temporal and spatial scales, from individual organism responses through to earth system models. He also works closely with observations using them to assess models as well as to use novel observational approaches to advance our understanding of carbon processes.

Andrew was awarded his PhD in 2006 from the University of Tasmania, and he did postdoctoral work in France at Pierre and Marie Curie University and Laboratoire des Sciences du Climat et de l'Environment, before returning to CSIRO.

Andrew's current and future research focuses on key three key impact areas:

- quantifying the past, present and future role of the ocean in the global carbon cycle,
- exploring and understanding the impact of the carbon cycle changes on both climate and marine diversity and productivity, and
- the potential role of technologies in mitigating climate change.

Andrew currently leads the Earth System Science Portfolio within CSIRO's Climate Science Centre he is also a member of many national and international working groups and projects and is an Intergovernmental Panel on Climate Change author.

Dr Robert Johnson is a biological oceanographer at the Bureau of Meteorology (BOM) with expertise in phytoplankton ecology, physiology, and productivity. His current role involves making ocean science useful through the design and implementation of ocean and remote sensing models into operations within the BOM.

Rob applies this expertise to ocean remote sensing focusing on ocean colour and sea-surface temperature satellite and airborne imagery. For the last little while his work has been focused on the use and development of tailored satellite remote sensing algorithms and models in the detection and quantification of phytoplankton in the Australian region. Rob was awarded his PhD from the University of Tasmania for having developed novel ocean colour algorithms for the Southern Ocean and Antarctica.

Our thanks to the outgoing Bluewater and Climate Node leaders, Professor Pete Strutton and Dr Steve Rintoul, who will remain involved in the science of the Bluewater and Climate Node.

If you would like to keep informed about the Bluewater and Climate Node please email **communication@imos.org.au**. ■

New Node leader for the South Australian IMOS Node

We welcome Dr Ana Redondo Rodriquez from the South Australian Research and Development Institute into the leadership team of the South Australian Node.

Dr Ana Redondo Rodriquez

Ana is a physical oceanographer at the South Australian Research and Development Institute (SARDI) with experience in fundamental and applied research. Ana studied Marine Sciences at the University of Cadiz (Spain) and completed a PhD in oceanography at the University of Queensland in 2013.

During her PhD Ana used a variety of oceanographic data, from ocean model results to remote sensing, to relate the changes in the physical environment and regional circulation of the Great Barrier Reef to conditions in the Pacific basin.

Ana joined SARDI in 2014 and became involved with the South Australian Node. As part as the Southern Australia Mooring sub-Facility team, Ana assists across all facets of the South Australian Node including data collection, QA/QC and strategic planning.

In Ana's role at SARDI, she actively uses IMOS observations from multiple facilities in combination with ocean modelling and other data sources, to deliver research outcomes to multiple stakeholders, including state government and the fisheries and aquaculture sectors. These outcomes include studies of the regional circulation and its influence on food web dynamics, marine connectivity and the productivity of ecosystems including fisheries and aquaculture.

Associate Professor Charlie Huveneers, of Flinders University, remains as the Deputy Director of the South Australian Node.

We thank the outgoing South Australian Node Leader Dr Paul van Ruth, who has taken up the position of IMOS Senior Science Officer in the IMOS office in Hobart.

If you would like to keep informed about the South Australian Node please email **communication@imos.org.au**. ■

Emma Sommerville, IMOS

South Australian coastline.

Deep Water Moorings: RV *Investigator* recovered and deployed IMOS deep water moorings in the Southern Ocean

RV *Investigator* completed a voyage in September which had been delayed by the COVID-19 pandemic.

The IMOS Deep Water Moorings were deployed into a harsh, remote location in the Southern Ocean, which is particularly vulnerable to extreme weather including very large waves, strong currents and severe storms, presenting significant technical and engineering challenges.

The **two moorings**, referred to as the Southern Ocean Flux Station (SOFS) and Sub-Antarctic Zone sediment trap (SAZ) moorings were successfully recovered and replaced by new SOFS and SAZ moorings which are scheduled to be recovered in April 2021.

IMOS is particularly pleased with the successful recovery of the SOFS mooring after an extended deployment of 16 months and two winter seasons due to the voyage delay.

Dr Elizabeth Shadwick, who leads the IMOS Southern Ocean Time Series (SOTS) Observatory sub-Facility and is a senior research scientist at CSIRO, was the Chief Scientist on this first research voyage of the RV *Investigator* since the shutdown of sea operations due to the COVID-19 pandemic.

"We have sustained the longest time series of Southern Ocean observations operated by any nation, contributing to the global effort to understand ocean dynamics and their role in climate and responses to anthropogenic emissions," says Dr Shadwick.

The sensor records and sample collections achieved with moorings at SOTS increase our understanding of climate and carbon cycle processes in Subantarctic waters – which are now recognized as globally important in removing CO_2 from the atmosphere.

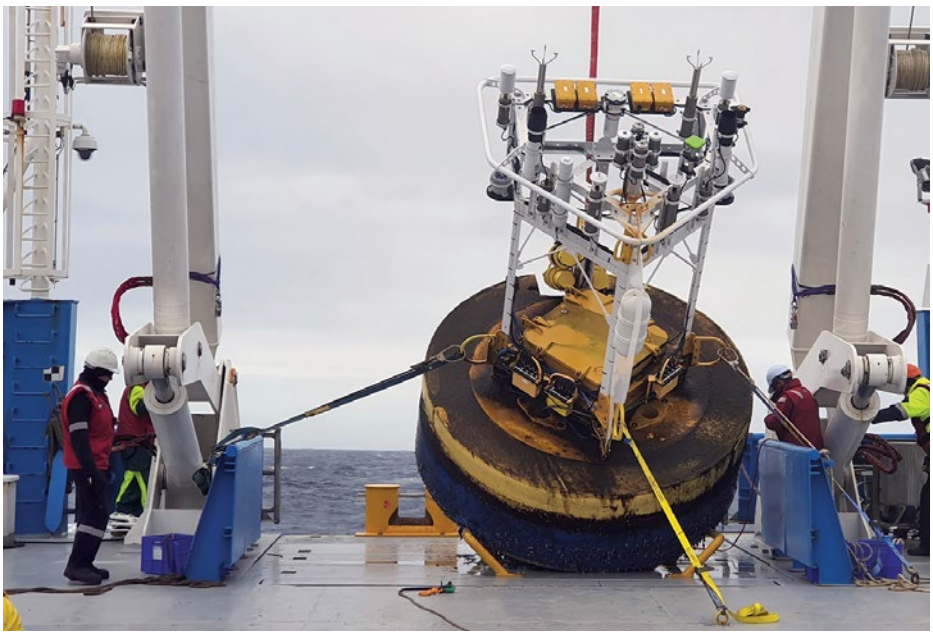
This voyage into the Southern Ocean will produce science of global significance and is made possible by the strong partnership between Australia's national Integrated Marine Observing System and the **CSIRO Marine National Facility** (MNF).

"We are grateful for the engineering expertise of the moorings group at CSIRO, the skilful deck operations undertaken by Phil De Boer, Tim Lane, Jim LaDuke and the crew of the RV *Investigator* during some difficult weather conditions. We thank the MNF staff (Rod Palmer, Anoosh Sarraf, Phil Vandenbosch, and Francis Chui) for their support with the CTD and computing and network access on board, MNF Voyage Managers Linda Gaskell and Lisa Woodward for voyage management, and finally, Master Adrian Koolhof, and 1st, 2nd and 3rd Mates (A. Roebuck, J. Hokin, and S. Edwards) for excellent ship handling during mooring operations and during transit to and from the site," says Dr Shadwick.

The moorings are operated through a partnership between IMOS, CSIRO Marine National Facility, CSIRO, Bureau of Meteorology, and the Australian Antarctic Program Partnership (AAPP). ■

Jim LaDuke, CSIRO

Mooring recovery team. Phil de Boer, Daniel Morse, Peter Taylor, Tim Lane, Roderick Langham, Elizabeth Shadwick, James Hogg, Lisa Woodward, Pete Jansen, and Linda Gaskell.



Adrian Koolhof, CSIRO

Recovery of the Southern Ocean Flux Station Mooring.

AODN: Waverider Buoys deployed by the New Zealand Defence Force are providing critical information about conditions in the remote Southern Ocean

The wave climate data from the Southern Ocean site is now available via the AODN Portal.

The New Zealand Defence Force (NZDF) routinely operates in the Southern Ocean, with their crews experiencing large waves which are often poorly forecasted.

To improve the safety of their sailors at sea the NZDF are working in partnership with the academic community to improve forecasts in the area. Moreover, the NZDF is currently engaged in a shipbuilding programme which requires a detailed understanding of the wave climate for sea keeping analysis and ice belt design.

Unlike other regions, the Southern Ocean has limited ship traffic and consequently there is a scarcity of wave observations from volunteer observing ships. The difficult conditions and remote location have resulted in limited scientific measurements of the wave climate.

The NZDF have been working to fill this knowledge gap since February 2017 by measuring waves in the Southern Ocean near Campbell Island.

The NZDF have conducted three deployments at the site (52°45.71′S, 169°02.54′E), with data from two of the three deployments available via the **AODN Portal**. The data has been added to a pre-existing data collection on the AODN Portal, forming part of the **Waverider Buoys Observations – Australia – Delayed (National Wave Archive)** collection. Once the QA/QC has been completed on data from the third deployment it will also be available via the AODN collection.

IMOS with our collaborators such as the NZDF, looks to provide observations for the operational needs, safety and efficiency of marine industries, particularly those who patrol and transit the oceans for security, by making data available on the AODN Portal.

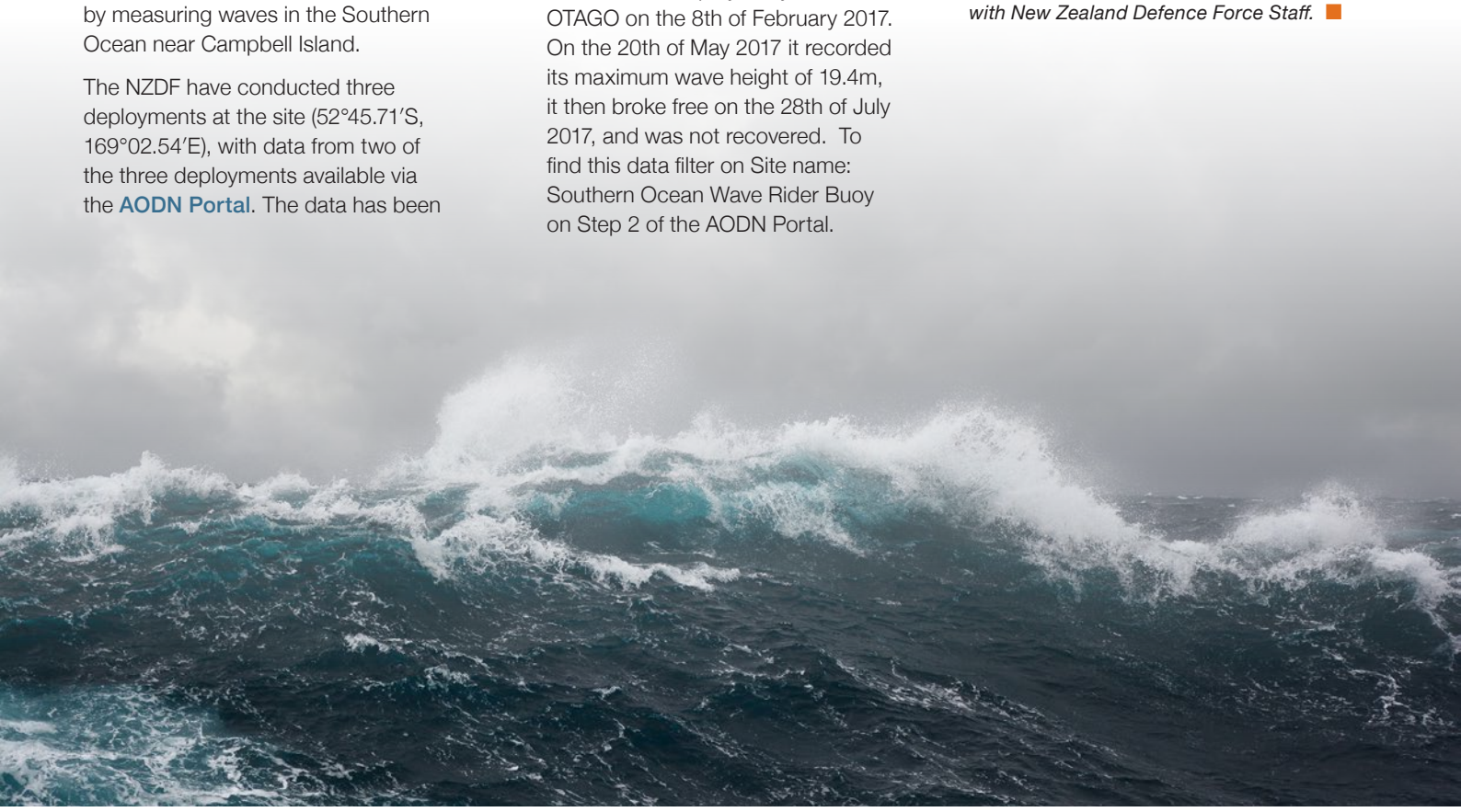
History of the deployments

The Southern Ocean is known for being quite treacherous, possibly resulting in the three deployments to date;

- The first was deployed by HMNZS OTAGO on the 8th of February 2017. On the 20th of May 2017 it recorded its maximum wave height of 19.4m, it then broke free on the 28th of July 2017, and was not recovered. To find this data filter on Site name: Southern Ocean Wave Rider Buoy on Step 2 of the AODN Portal.
- The second deployment by HMNZS WELLINGTON occurred on the 2nd of March 2018, the highest wave it recorded was 23.8 m on the 9th May 2018, then on 27th of July 2019 the battery stopped. To find this data filter on Site name: Campbell Island Wave Rider Buoy on Step 2 of the AODN Portal.
- The third deployment installed by HMNZS CANTERBURY on the 23rd November 2018, collected data onsite until it broke free on 11th June 2020, maximum wave height during operation is still to be assessed.

Feedback and questions regarding the Wave buoy data or any product available via the AODN Infrastructure, are always welcome, please send to **info@aodn.org.au**.

This news item was written in collaboration with New Zealand Defence Force Staff. ■



Satellite Remote Sensing: IMOS multi-satellite sea surface temperature (SST) composite products have been updated

The Bureau of Meteorology have reprocessed the products adding a further six years of data.

The IMOS Multi-sensor L3S composites of sea surface temperature (SST) have recently been reprocessed by the Bureau of Meteorology and are now available from the AODN Portal back to 2012 (previously only back to 1 Jan 2018). They also contain data streams from additional satellites that significantly improves the spatial coverage and accuracy of the products.

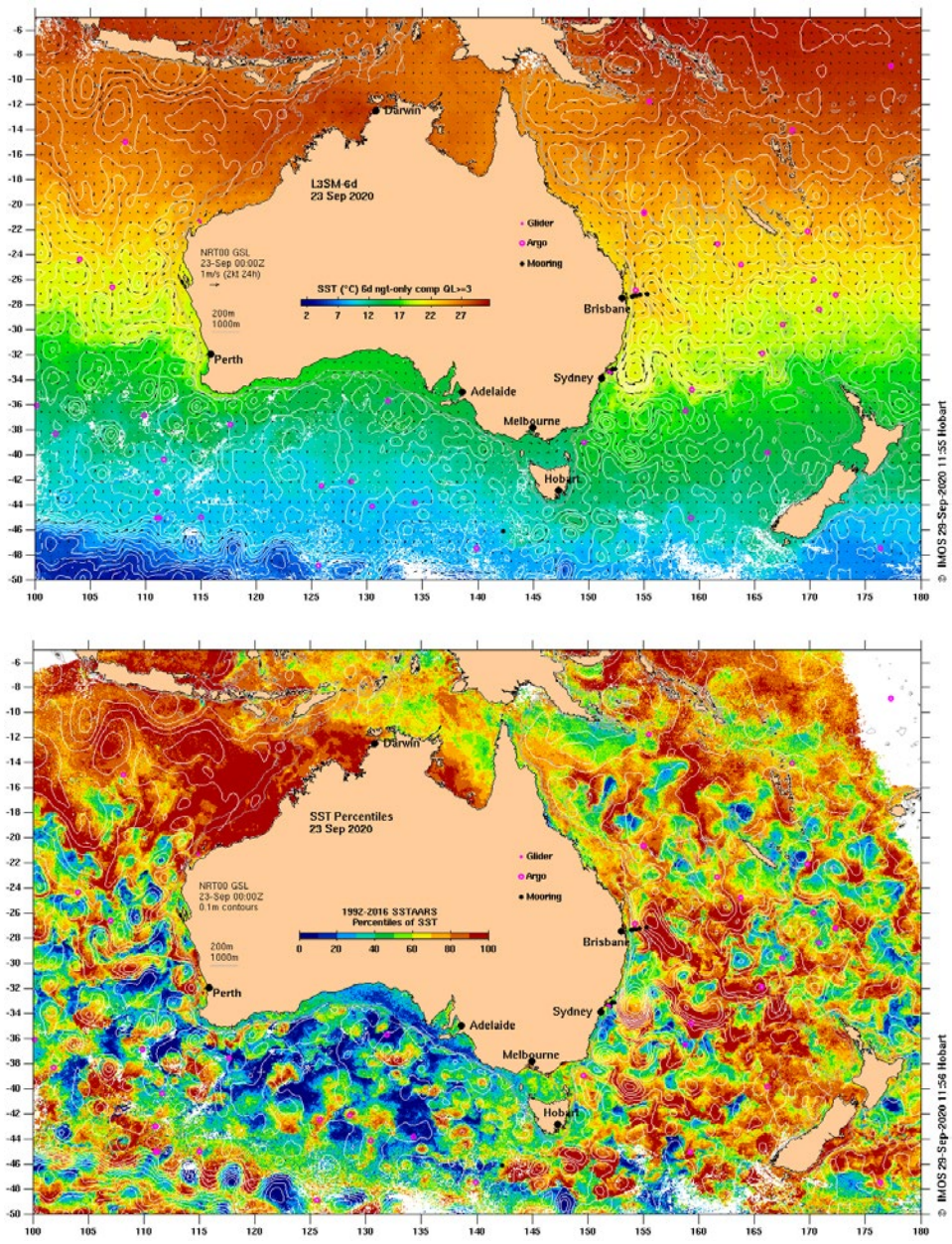
The Sea Surface Temperature (SST) Satellite Remote Sensing Sub-Facility is a collaborative effort with the Australian Bureau of Meteorology to produce high-resolution satellite sea surface temperature (SST) products over the Australian and Southern Ocean regions, designed to suit a range of operational and research applications.

The Multi-sensor L3S products are used to nowcast coral bleaching (IMOS SST products are used in **ReefTemp**) and marine heatwaves (**IMOS OceanCurrent**), and to study coastal ocean features and short-term ocean phenomena such as diurnal warming and upwelling.

Data links and further information

The new IMOS Multi-sensor L3S SST products are available from the AODN Portal (**this news item** provides the links to the individual products) and **AODN Thredds server**.

These multi-sensor L3S products are non-interpolated 0.02 degree composites (equal area weighted averages) of 0.75 km to 4 km resolution SST observations from AVHRR and VIIRS infra-red sensors on various polar-orbiting satellites (AVHRR on NOAA-15/17/18/19 and MetOp-A/B, and VIIRS on Suomi-NPP and NOAA-20). ■



Recent plots from IMOS OceanCurrent demonstrate the (a) Sea Surface Temperature (SST) and (b) corresponding SST Percentiles over the Australian region for 23 September 2020, derived using the IMOS 6-day night-time 2 km Multi-sensor L3S SST data and CSIRO's SSTAARS daily 2 km SST climatology.

These illustrate the improved spatial coverage from including additional data streams from NOAA-20 and MetOp-B (in addition to Suomi-NPP and NOAA-18). The Percentile maps are useful in identifying Marine Heat Waves around the Australian and New Zealand coast. The 23 Sep 2020 map illustrates the strong marine heatwave at the time off the northwest coast of Australia.

AODN/Animal Tracking: IMOS improves the accuracy of our seal tracking location data

The IMOS Animal Tagging sub-Facility has developed a new quality control process to improve the accuracy of data transmitted by Seal Satellite Relay Data Loggers (SRDL).

IMOS Animal Tagging scientists have created two new quality control packages for the software R to use with data transmitted from seal Satellite Relay Data Loggers – **foieGras** and **imosQCdev**.

The foieGras package fits continuous-time models in state-space form, estimating most probable locations along animal trajectories from error-prone locations observed via the Argos satellite system.

The imosQCdev package applies the foieGras models automatically to the new data received every 24-hours and appends the estimated locations to Conductivity-Temperature Depth (CTD) profiles and other data collected. The data are available in **near real-time mode** on the AODN Portal, and also become available in **delayed mode** on the AODN Portal when a second level of supervised QC is completed by the end of the Austral Summer.

The IMOS Animal Tracking – Animal Tagging Sub-Facility annually deploys Satellite Relay Data Loggers (SRDL) on several species of Southern Ocean seals including Weddell and Southern Elephant seals.

The data loggers are equipped with a CTD and sometimes a fluorometer, collecting high resolution ocean observations in the deep Southern Ocean and Antarctic waters. Animal activity such as dive depths and duration, which are important for understanding marine mammal foraging ecology are measured by the data loggers.

Researchers are advancing understanding of the world's oceans and its top predators, how these species interact with their environment and predicting how they may be affected by future changes through analysis of combined oceanography and marine mammal ecology data.

Data Links and Further Information

Near real-time collection on the AODN Portal.

Delayed Mode on the AODN Portal.

Both dataset collections are available as a set of csv files, including the automated QC summary output.

The original format files for these two dataset collections can be found on the AODN data server (for **the delayed mode** and **the near real-time**).

The two new dataset collections replace the **Satellite Relay Tagging Program – Delayed mode data** collection that provides access to the data coming directly from the Sea Mammal Research Unit (SMRU, University of St. Andrews, UK).

The **Satellite Relay Tagging Program – Delayed mode data** will remain available in the AODN Portal until all historical data have been added to the new dataset collection. The IMOS Animal Tagging team will run the QC packages on the satellite locations of the historical records, supplying all records with improved satellite locations.

Thank you to Ian Jonsen of Macquarie University and Clive McMahon from the Sydney Institute of Marine Science for their contribution towards this story.

For any questions or feedback about these dataset collections or any other AODN Portal collections, please contact us at **info@aodn.org.au**. ■

Rob Harcourt, Macquarie University.

BGC Argo: Update from the IMOS Biogeochemical Argo sub-Facility

The IMOS Biogeochemical Argo team would like to update the community on progress and plans, discuss deployments, and offer our assistance to new users of the data.

In October last year, two Biogeochemical Argo floats were deployed in the EAC off Brisbane. You can look at their tracks and data via the **AODN Portal** or IMOS OceanCurrent (**Float 5905441** and **Float 5905442**)

In early 2021, we intend to deploy three floats close to Antarctica from RV Investigator. The approximate location of these floats is about halfway between Davis Station and Heard/McDonald Islands (67.5°E, 62.5°S). We are also hoping to deploy three floats in the northern EAC/Coral Sea in late 2020, but those plans have been impacted by COVID and we are still seeking options.

The current IMOS Biogeochemical Argo project, which runs through mid-2022, will enable the purchase and deployment of about another three floats. Candidate locations for deployment include the Great Australian Bight, the SE Indian Ocean and the eastern tropical Indian Ocean. We would welcome community input on the relative priority of these locations, and ideas for other deployment locations.

The IMOS Biogeochemical Argo deployments are of course part of a larger international community that includes the **SOCCOM** project to deploy up to 200 Biogeochemical Argo floats in the Southern Ocean (including the GAB).

Data from older Biogeochemical Argo deployments by CSIRO in the Indian Ocean, in collaboration with India, are also available via the IMOS data portal.

Data QC protocols for biogeochemical data are evolving, and we realise that understanding the sensors, data, QC and processing may represent a barrier to some users. For that reason, we'd like to extend an offer to potential users to draw on our experience. We are more than happy to provide code and expertise. The following web sites also provide resources for new users:

https://biogeochemical-argo.org/

https://kimbaldry.github.io/FriendlyExperts/

Biogeochemical Argo data represent a great opportunity for undergraduate and graduate teaching and student projects, and we are excited about helping new users to access the data.

Regards
Pete, Tom, Christina and Bozena

If you would like more information please contact:
Peter.Strutton@utas.edu.au
Tom.Trull@csiro.au
Christina.Schallenberg@utas.edu.au

Dr Thomas Moore, CSIRO

One of the first IMOS Biogeochemical Argo floats to be deployed.

National Mooring Network: Long-term research shows ocean acidification ramping up on the Great Barrier Reef

The collaborative research conducted between AIMS and CSIRO drew on over a decade of IMOS observations.

Ocean acidification is no longer a sombre forecast for the Great Barrier Reef but a present-day reality, a new study reveals.

The study, published in the **international Journal Scientific Reports**, shows carbon dioxide (CO_2) and ocean acidification are rapidly increasing on the Reef. Seawater CO_2 has risen 6 per cent over the past 10 years and matches the rate of CO_2 increases in the atmosphere, confirming the influence of atmospheric CO_2 on seawater CO_2 levels.

"People talk about ocean acidification in terms of 50 years' time, but for the first time our study shows how fast ocean acidification is already happening on the Reef," said **Dr Katharina Fabricius**, lead author and Senior Principal Research Scientist at the Australian Institute of Marine Science (AIMS).

The research, a collaboration between AIMS and CSIRO, drew on over a decade of **observations** collected as part of Australia's Integrated Marine Observing System (IMOS) to conclude that the Reef's rich carbonate seafloor is not buffering against ocean acidification as previously thought.

"Our research shows that acidification is rapidly changing the conditions that support the growth of coral on the Reef. It's never been more important to address ocean acidification in plans to manage the Reef", said Dr. Bronte Tilbrook, a Senior Principal Research Scientist at CSIRO who leads IMOS' observational projects for CO_2 and ocean acidification.

Ocean acidification results from seawater absorbing excess CO_2 that has been emitted into the atmosphere. The CO_2 dissolves in the seawater where it changes the chemistry. This includes decreasing the water's pH, and reducing the aragonite saturation state, which is critical for building the skeletons of reef-building coral and other marine organisms. Under reduced pH conditions, their calcium carbonate skeletons take longer to form and weaken, leaving them more susceptible to damage and erosion.

While long-term data exist for CO_2 and ocean acidification trends in open oceans, there have been very few long-term data on these trends in coastal waters around the world, including the Great Barrier Reef. Biological and physical processes like respiration create large fluctuations in CO_2 in coastal areas, making the detection of trends more difficult.

The study has filled this important knowledge gap by analysing 10 years of CO_2, pH and aragonite saturation state data (2009–2019). These data were collected as part of Australia's IMOS network at two long-term monitoring stations, located 650 kilometres apart at contrasting locations.

The researchers found the minimum CO_2 concentrations measured today were likely to already have passed the highest CO_2 levels expected 60 years ago, even after accounting for the effects of temperature, nutrients, salinity, and daily and seasonal changes.

"We know now that oceans are taking up about 23% of the excess CO_2 from the air. They actually provide a service to humanity by slowing climate change. But the price to pay is that the seawater's carbon chemistry is changing, and we didn't know it was happening in dynamic coastal waters at such fast rates," Dr Fabricius said.

In another research first, AIMS and CSIRO scientists have used data from 1384 Reef sites to show coastal acidification's negative impacts on three important indicators of Reef health:

- the numbers of both baby coral and coralline algae are plummeting as CO_2 increases across the Reef, and
- undesirable seaweed is thriving at high CO_2 locations.

The study, published earlier this year in the **journal Global Change Biology**, found these baby coral and coralline algae also decreased and seaweed increased as fine suspended sediment increased across the Reef — with the greatest sediment concentration and organism changes observed closer to the shore. The researchers highlighted effective water quality management as an achievable solution to reduce coastal acidification's impact on the Reef.

This new item was originally published as a **media release by AIMS**. ■

AIMS

The IMOS Yongala National Reference Station on the central Great Barrier Reef with the AIMS research vessel *Cape Ferguson.*

Expendable BathyThermograph (XBT):
Ship of Opportunity operations during the pandemic.

In a time where much of the oceanographic observing community is unable to collect data in the usual way, the IMOS XBT Ship of Opportunity program has continued and adapted, where necessary, to maintain our observations as best we can.

The Bureau of Meteorology operates three XBT lines (IX01, PX02 and PX11/IX22) in frequently repeated mode, with observations undertaken every 4 hours. Each transect is repeated on a weekly or monthly basis.

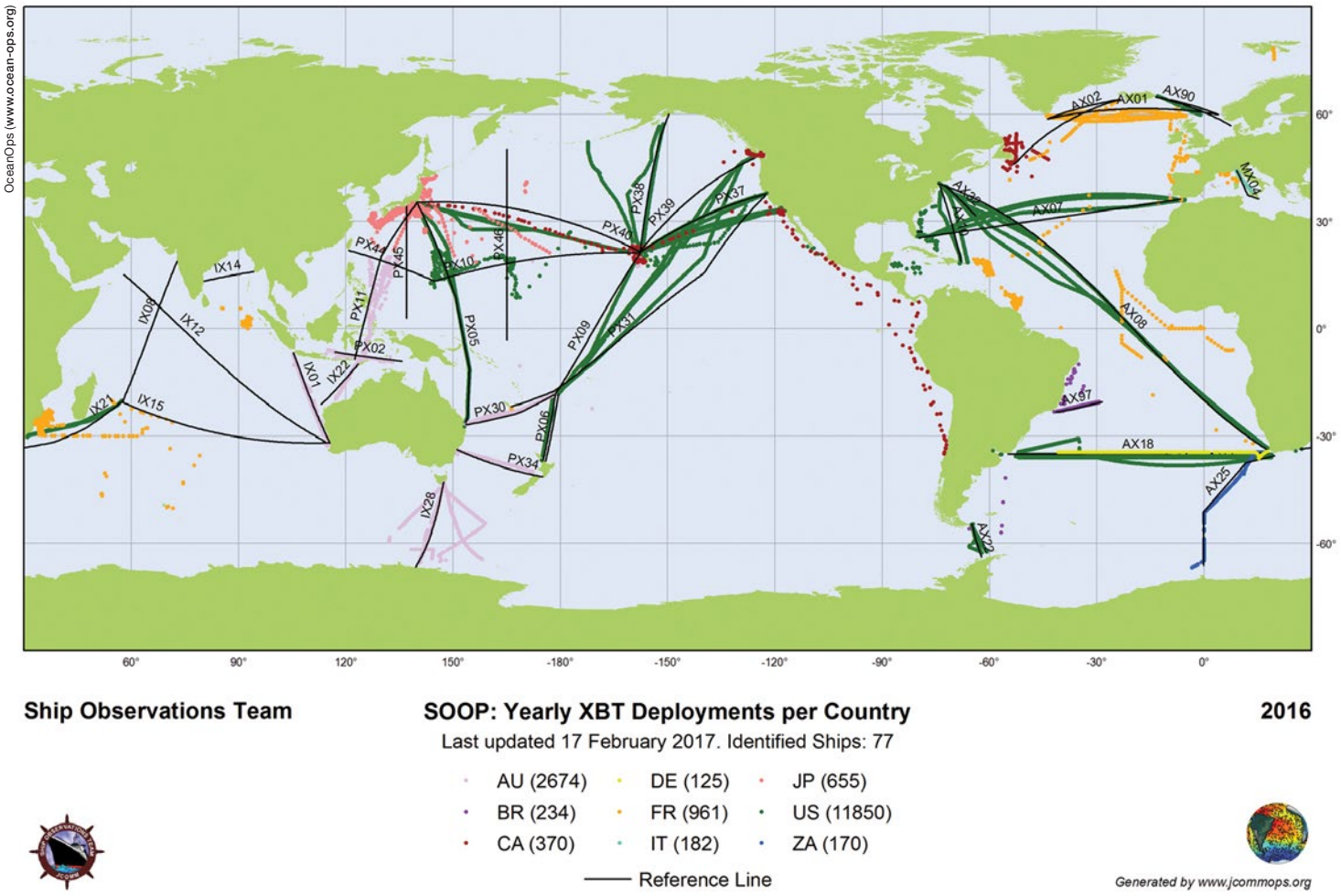
These observations are collected by ships' crew and have therefore been able to continue their normal operations. They are the only organisation in the global XBT program that have been able to continue operations uninterrupted through 2020.

Under normal conditions, the CSIRO operates three XBT lines (PX30, PX32 and IX28) in high density, low frequency mode, with an observation undertaken every 1-2 hours. Each line or transect is occupied four times per year.

This demanding sampling regime requires a ship rider to join the SOOP vessel and collect the data while on board. Travel restrictions and COVID-19 health and safety requirements on board, means that ship riders are currently unable to join our volunteer vessels to collect XBT observations.

To continue the collection of data along the PX32 and PX30 lines, we have enlisted the help of the ships' crew to undertake sampling at a reduced frequency (every 4 hours). The crews of *Hansa Freyburg*, *Seatrade Orange* and *Seatrade Red* have volunteered to collect XBT data during their transits. After a brief pause on sampling in May-June while arrangements were made and equipment modified, XBT observations recommenced from September 2020.

The IX28 line (Hobart to Dumont D'Urville, Antarctica) is completed from the *l'Astrolabe* during the Austral summer months (October to March). This season's planning has been complicated



Map of global XBT lines from 2016, showing Australia's contribution in pink.
Note PX32 line is slightly North of the PX34 line and is not shown on the map.

by quarantine requirements for visits to Antarctica, plus federal and state government quarantine requirements for international travellers. Fortunately, we have found a path forward and for *l'Astrolabe's* first rotation in November, Pat McMahon (CSIRO) will be on board to collect our usual high density XBT observations. We now expect that the program will operate as normal for IX28 for this summer season.

In addition, the RV *Investigator* was able to sample part of the IX28 line (from 50S to Hobart) during September 2020.

The CSIRO and the Bureau of Meteorology kindly thank the following companies, vessels and crew for their contributions through this pandemic and for their continuing support into the future:

IX01: *Swan River Bridge* (K Line)

PX02: *OOCL Houston, OOCL Texas* and *OOCL Panama* (OOCL)

PX11, IX22: *Northwest Sanderling* and *Northwest Sandpiper* (Shell)

PX32: *Hansa Freyburg* (ANL)

PX30: *Seatrade Orange* and *Seatrade Red* (Seatrade)

IX28: *l'Astrolabe* (French Navy, LEGOS & IPEV) and RV *Investigator* (Voyage in2019_v09) ■

Mitch Gimm, Master, Northwest Sandpiper, Shell.

Crew from *Northwest Sandpiper* (Shell) prepare to deploy an XBT.

Pat McMahon, CSIRO

XBT deployment tube extending from the bridge on the *l'Astrolabe*.

Capt. C.P. Licardo, Master, Swan River Bridge, K Line

XBT system set up on *Swan River Bridge* (K Line)

Dr Chris Chapman, CSIRO

View from the *Seatrade Orange* (Seatrade)

The New Technology Proving Low cost Wave Buoy project advances to its next phase

WRITTEN BY RYAN LOWE, DANIEL IERODIACONOU, JEFF HANSEN, AND IAN YOUNG

The start of November 2020 represents a one-year milestone for the two-year IMOS New Technology Proving Low Cost Wave Buoy Technology sub-Facility, representing a collaborative effort among researchers at the University of Western Australia, Deakin University, University of Melbourne, Australian Institute of Marine Science (AIMS) and CSIRO.

The project focuses on assessing the performance of a new generation of small, low-cost wave buoys that could help to efficiently expand wave observations around Australia. The trials conducted at several sites around Australia have focused on collecting sustained observations from Sofar Ocean Spotter buoys, which are both much cheaper and smaller (hence less costly to deploy) than conventional wave buoys. To benchmark wave buoy performance, the project has established several test sites around Australia where Spotter buoys are deployed directly adjacent to conventional wave buoys.

The ability of these new buoys to measure wave motions with comparable accuracy to conventional buoys has been established in the project during the first year (Figure 1). A major focus now has been on validating their ability to deliver long-term data with 6-monthly servicing across a number of different marine environments throughout Australia with different wave climates, tidal flows and biofouling regimes.

Over the past year, measurements have concentrated on test sites maintained off Western Australia (WA - maintained by the University of Western Australia) and Victoria (Vic -maintained by Deakin University and University of Melbourne), with initial data being streamed to the community in near real-time at the **https://wawaves.org/** and **https://vicwaves.com.au/** sites.

The Spotter buoys have been serviced at 3-6 monthly intervals, with minimal disruptions from the COVID-19 pandemic due to the ability to deploy and retrieve the small Spotter buoys from small coastal vessels (Figure 2). Due to the much smaller size of these new buoys (~5 kg versus >100 kg for conventional buoys), the project has also been focusing on trialling new mooring designs that are tailored to maximise performance.

For example, in the Bonney upwelling zone in southwest Victoria, three mooring designs are being trialled with performance compared to a conventional wave buoy. The deployments are co-located in proximity to the IMOS Bonney oceanographic mooring and Portland acoustic curtain.

Paul Tinkler, Deakin University

Figure 2: Port Fairy wave buoy servicing (see www.vicwaves.com.au). Research vessel MV *Yolla.*

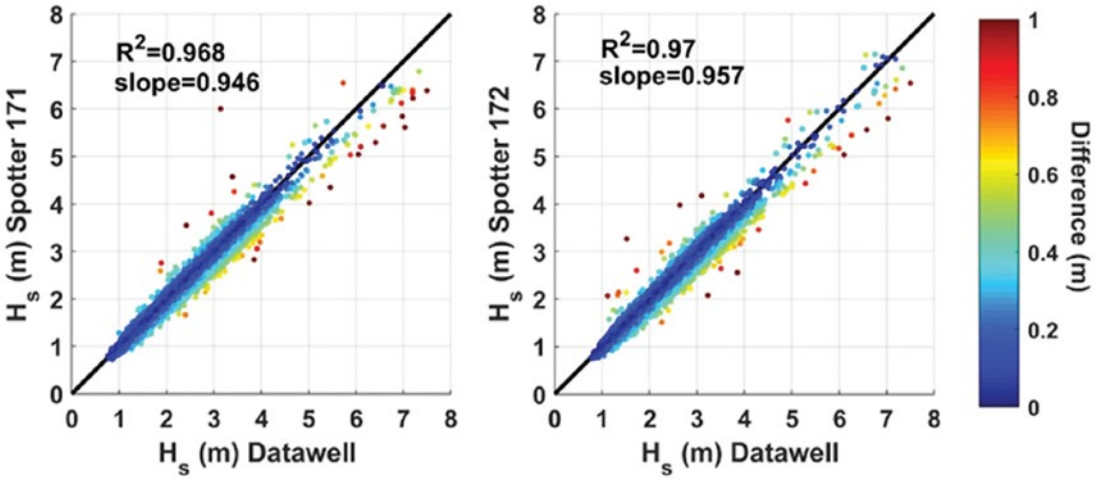


Figure 1: Comparison of significant wave heights for two Spotter wave buoys deployed off Albany, WA adjacent to a Datawell Directional Waverider buoy.

Using the large volume of data collected over the past year, the project has also been helping to develop new QA/QC procedures for wave buoy data delivery within IMOS, working closely with the AODN.

The QA/QC procedures have been developed with the larger national wave observation community, coordinated with the FOO Surface Waves Working Group and the AODN. Over the past year, the near real-time data from the Vic and WA project sites has been attracting significant stakeholder and public interest (for example, 25K web visits to the **https://vicwaves.com.au/** website alone in 2020).

With the wide range of stakeholders interested in real-time coastal observations, as additional Spotter buoys are being deployed at new sites around Australia, further stakeholder engagement and data uptake is expected to further grow. This New Technology Proving sub-Facility is doing the groundwork to trial and operationalise this new technology to enable standardisation across deployments and integration across Australia's broader wave buoy network.

In addition to the moored buoys, the New Technology Proving sub-Facility has included the deployment of drifting Spotter Buoys (Figure 3). A drifting buoy was deployed in Perth Canyon in November 2019. After deployment, the buoy travelled to the south and spent the winter of 2020 about 500 km SW of Cape Leeuwin before deciding to come home. In September, the buoy drifted north and was remarkably able to be recovered 100 m off the beach just south of Perth. The buoy, which recorded significant wave heights over 9 m, was in very good condition and contained 11 months of raw displacement data (which is not transmitted due to the file sizes).

A second drifting buoy was deployed from the RV Falkor in January of 2020 in Bremer Canyon along WA's south coast. The buoy has since drifted more than 2000 km, initially to the west and then north and now sits 350 km offshore of Exmouth in WA's northwest (see the current location at **https://wawaves.org/**). The buoy continues to report quality near real-time spectral wave data hourly.

Looking forward to the final year of the project, a particular focus will be expanding test sites in the northern part of Australia off WA and the Northern Territory (NT). A new test site was recently deployed off Ningaloo Reef, WA, with field support provided by the Minderoo Exmouth Research Laboratory, which will compare Spotter data against a conventional wave buoy maintained by the WA Department of Transport. In late November, the team will establish its final test site off NT, by comparing performance of a Spotter buoy adjacent to a conventional wave buoy that will be deployed by AIMS as part of the IMOS Wave Buoys sub-Facility of the National Mooring Network Facility. ■

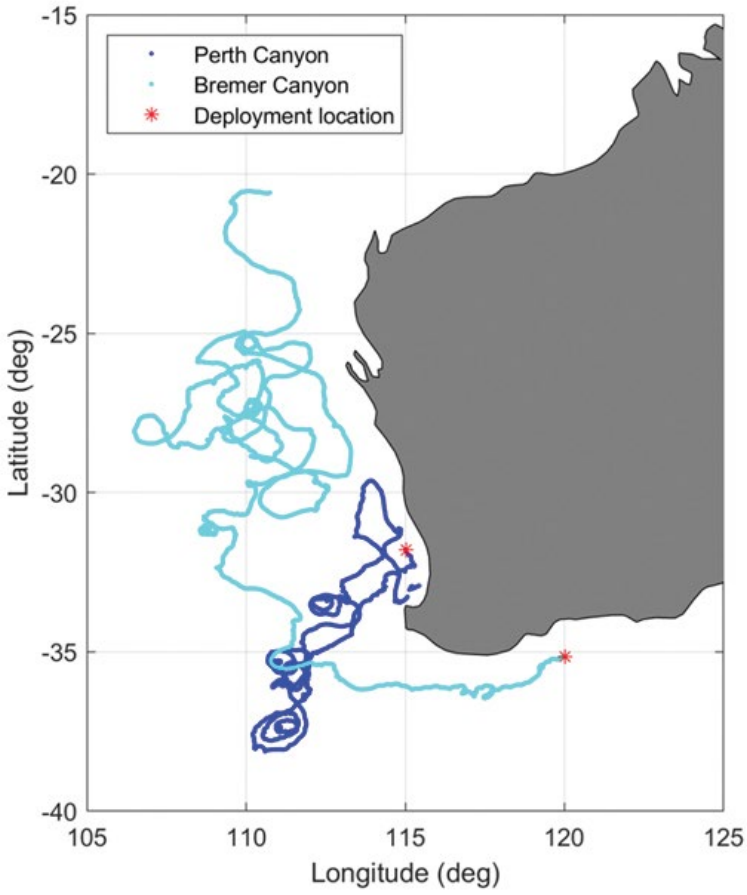


Figure 3: Drifter tracks for two Spotter buoys delivering near real-time wave data, released off Bremer Canyon and Perth Canyon.

Sharani Kodithuwakku
The University of Western Australia

Project title:
Dynamics of Mesoscale eddies around Western Australia.

IMOS DATA STREAM USED: Ocean gliders, Ocean radar, Ocean moorings and SRS.

Mesoscale eddies are ubiquitous features in the ocean with closed circular currents that are typically 50-300 km in diameter and are considered to be the weather of the ocean. They play an important role in physical and biogeochemical processes in the ocean being effective transporters of heat, salt, nutrients, and other biochemical materials in the ocean. They are highly energetic rotary features and lasts for many weeks and travel many hundreds of kilometers.

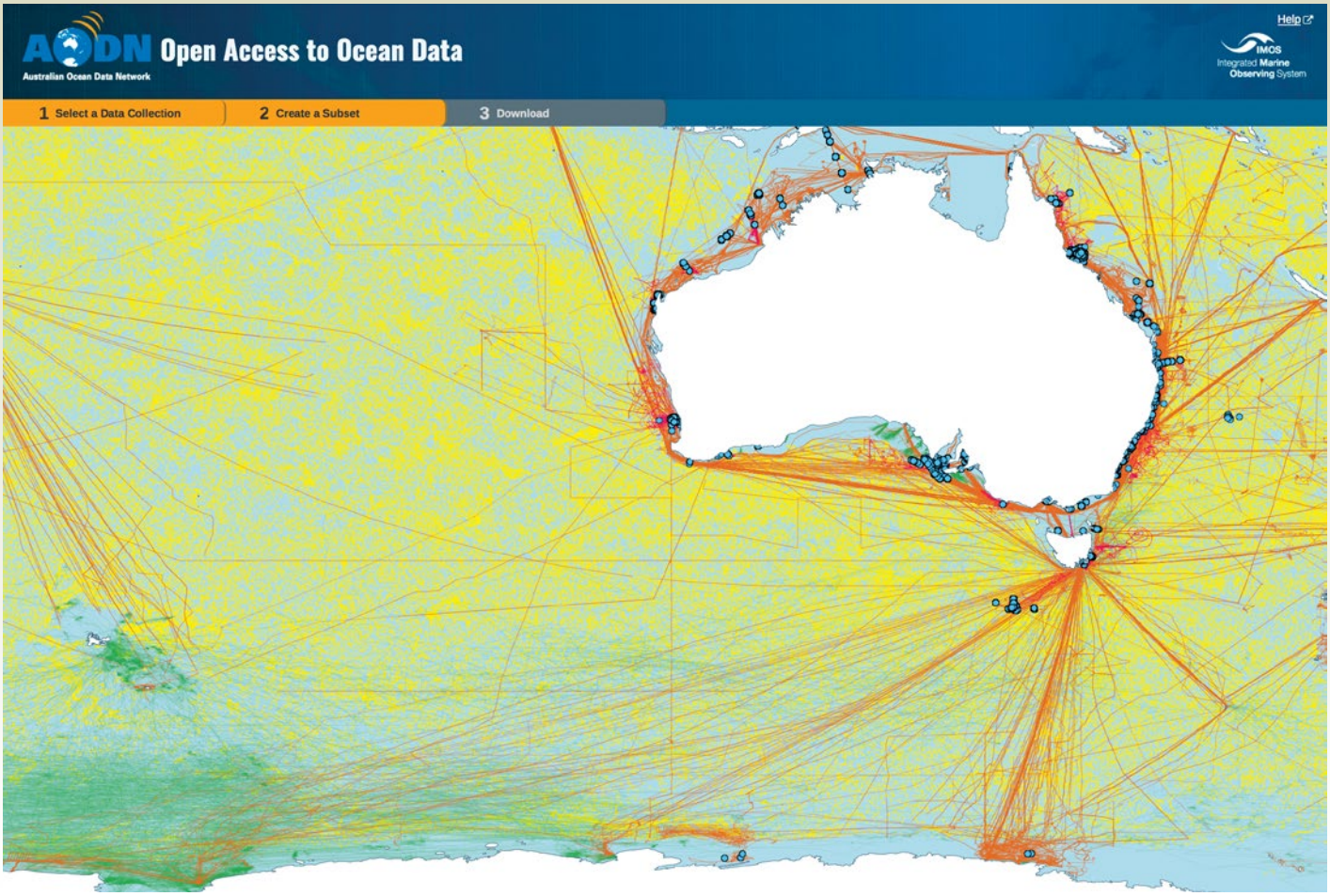
The West Australian ocean circulation is dominated by the Leeuwin Current (LC), a strong, narrow poleward flowing current with both seasonal and inter-annual variability. It is considered anomalous as it flows poleward, in contrast to other ocean basins, where the currents flow equatorward. These unique oceanographic characteristics of LC System together with changes in coastline orientation results in the most energetic eddy field associated with eastern boundary current systems globally.

Previous studies in the region have examined the eddy dynamics mainly using satellite imagery, shipborne measurements and, numerical modelling. However, these studies have been limited by low spatial and temporal resolution of ocean observations and subsequently there is a limitation in understanding of the three-dimensional structure and generation of mesoscale eddies.

Sharani's study will use a variety of oceanographic remote and in-situ observations collected through IMOS using a variety of platforms that include High Frequency Radar, ocean gliders, oceanographic moorings and satellite remote sensing along West Australian coast.

This will be the first study of its type to use such a rich array of oceanic measurements. The study consists of three major aims: (1) define the climatology of mesoscale eddies in Western Australia; (2) examine the internal three-dimensional structure of mesoscale eddies in the Perth submarine canyon; and, (3) to determine the role of topography on the generation of mesoscale eddies. ■

Paul Lethaby, UWA



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

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

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