Forum for Operational Oceanography

FOO 2019

15-16 October

Pullman Albert Park, Melbourne

65 Queens Rd, Albert Park, Victoria

PROGRAM

Sponsors

Contents

Acknowledgements

The broader FOO community would like to thank Jan Flynn and Tim Moltmann for their service and leadership as co-chairs of the FOO Steering Committee.

Forum for Operational Oceanography

The Sponsors would like to thank Conference Designs, in particular Tara and Ben, for their amazing support in running this conference.

CONFERENCE DESIGN

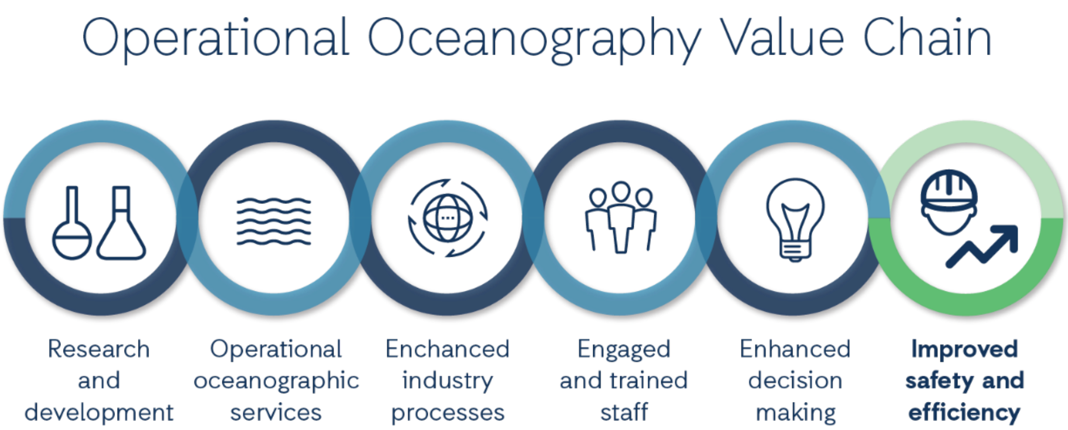
About the Australian Forum for Operational Oceanography (FOO)

The FOO is meant to be a forum for:

- discussions relating to operational oceanography, including requirements of stakeholders, industry and interested parties;
- scientific and technical discussions of common interest to practitioners working in relevant areas or drawing on products from operational oceanography service providers.

The **ultimate goal** of FOO is to **improve the safety and efficiency of marine industries** through better decision-making via operational oceanography. This requires better industry processes and trained staff. It requires better operational oceanographic services from government, and industry. It requires a solid foundation of world class research and development.

This is the **value chain for operational oceanography** in Australia.



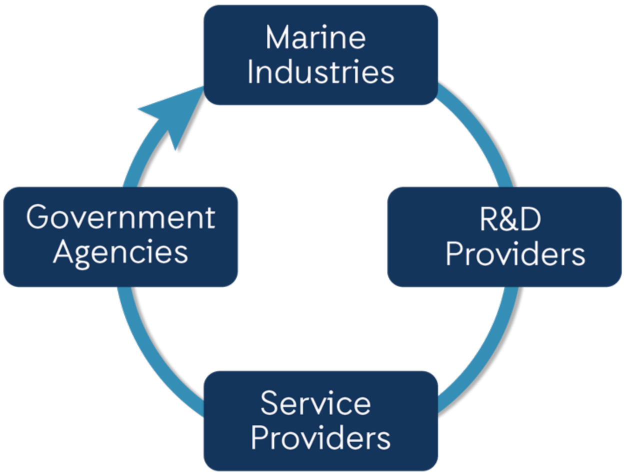
Context of the Forum

In developed countries around the world, Government agencies, R&D providers and marine industries are realising the potential advantages of creating a systematic focus on operational ocean observing, short-range prediction, and delivery of services - covering marine and coastal environments, and physical and biogeochemical properties. This has come to be described as operational oceanography.

As an island nation deriving massive social, economic and environmental benefits from its coasts and oceans, Australia has good reason to be keenly interested in these developments.

A team of scientists and managers from across industry, government and academia have therefore come together and formed a steering committee to bring an Australian Forum for Operational Oceanography (FOO) into existence. We call these the 'Pillars' of the Forum.

The Four Pillars of Operational Oceanography



Forum Objectives

The Forum represents a mechanism and opportunity for consolidating Australia's national efforts in operational oceanography for the benefit of all participating parties.

The Forum provides a mechanism for clear and coherent articulation of user needs and priorities from any sectors and jurisdictions who have an interest in operational oceanography.

The Forum facilitates awareness and utilisation of existing operational oceanography systems, focusing in particular on those developed in Australia. This has the ultimate goal of achieving greater positive impact and implements a robust feedback loop to guide further improvements to systems and services.

The Forum will keep the operational oceanography community informed of developments and best practices in the field. One aim is to strengthen links with the diverse community of intermediate service providers (metocean consultants, environmental consultants) and work towards international best practice across the sectors of marine industries.

The Forum will initiate interactions and partnerships between groups in Australia that are essential to improve both exploitation of capabilities in operational oceanography, and transitioning of systems research to operations. This includes the sharing and alignment of future plans and planned developments in operational oceanography among participants in the forum.

More information: please visit our website www.foo.org.au or contact Indi Hodgson-Johnston (Assistant Director, IMOS) on indiah.hodgsonjohnston@utas.edu.au.

FOO 2019 Program Overview

The Australian Forum for Operational Oceanography (FOO) is now in its fifth year of operation. Following successful conferences in 2015 and 2017, both held in Fremantle Western Australia, FOO 2019 moves to Melbourne in the east.

The program has two central themes, framed around opportunity and risk:

1. Opportunities for operational oceanography to drive the development of Australian marine industries
    - Next generation ocean remote sensing
    - In situ ocean observing, especially near real time
    - Ocean modelling and forecasting
    - Big ocean data
    - Marine renewable energy
2. Risks to Australian marine industries and the role of operational oceanography in helping to manage them
    - Climate risks
    - Operational uncertainties (e.g. swell, wind waves, internal waves, surface currents)

Keynote speakers for the 2019 conference have been carefully selected to stimulate thought and discussion within the FOO community on its role in helping to drive the development of Australia's blue economy:

- Opportunities theme:
    - Dr John Siddorn, UK Met Office - The UK ocean prediction community, current status and future directions
    - A/Professor Irene Penesis, University of Tasmania – The Blue Economy Cooperative Research Centre (CRC)
- Risks theme:
    - Dr Jim Stear, Chevron/International Association of Oil and Gas Producers (IOGP) - Application of oceanography and meteorology to improve design and operation of offshore and onshore structures – what next?
    - Professor David Karoly, CSIRO - A national perspective on management of climate risks to Australia's blue economy

The keynotes will be complemented by an excellent set of invited speakers, and talks selected through an open call for abstracts addressing the themes of opportunity and risk.

These two central themes will be bracketed by two supporting themes. On the first morning we will reflect on FOO activities since the 2017 conference, with emphasis on the Surface Waves and Surface Currents working groups. On the last afternoon we will focus on what next for the Australian Forum for Operational Oceanography.

We thank you for your ongoing engagement with FOO and look forward seeing you all in Melbourne on 15-16th October 2019.

Jan Flynn (Woodside Energy Ltd)

Tim Moltmann (Integrated Marine Observing System)

Co-Chairs of the Australian Forum for Operational Oceanography (FOO) Steering Committee

Forum for Operational Oceanography

FOO 2019 Program

DAY 1-Tuesday 15th October 2019		
8:00-9:00	Registration	
9:00-9:05	FOO 2019 Welcome and Introduction	Jan Flynn Woodside Energy Ltd
Theme 1 - The Australian Forum for Operational Oceanography		
9:05-9:15	FOO Surface Waves Working Group-current activities and future plans	Mark Hemer CSIRO
9:15-9:30	15 priorities for wind-waves research	Diana Greenslade Bureau of Meteorology
9:30-9:40	FOO Surface Currents Working Group-current activities and future plans	Craig Longmuir Australian Maritime Safety Authority (AMSA)
9:40-9:55	Overview of Forum activities since FOO 2017	Tim Moltmann Integrated Marine Observing System (IMOS)
Theme 2 - Opportunities for operational oceanography to drive the development of Australian marine industries		
9:55-10:25	**Keynote #1** **The UK ocean prediction community**	**John Siddorn** **UK Met Office**
10:25-10:45	NERA's oceanography products	Tim Duff National Energy Resources Australia (NERA)
10:45-11:15	Morning Tea	
11:15-11:35	The Wave Climate of the Southern Ocean	Qingxiang Liu University of Melbourne
11:35-11:55	The Surface Water Ocean Topography (SWOT) mission: Opportunities and challenges	Shane Keating University of New South Wales
11:55-12:15	Ocean Current: New opportunities in satellite SST	Madeleine Cahill CSIRO

12:15-12:35	Operational Oceanography in support of marine traffic	Roger Proctor Tidetech
12:35-12:55	Precise positioning for the maritime sector	Anna Riddell Geoscience Australia (GA)
12:55-13:15	New Generation of Wave Forecast Models, Made in Australia	Alexander Babinin University of Melbourne
13:15-14:15	Lunch	
14:15-14:45	Keynote #2 The Blue Economy CRC	Irene Penesis University of Tasmania
14:45-15:05	Measuring waves and winds from Autonomous Surface Vehicles (ASV)	Darren Burrowes Bluezone Group
15:05-15:25	Using machine learning to improve operational wave forecasts	Jeff Hansen University of Western Australia
15:25-15:45	Evaluation of a machine learning framework to forecast storm surge	Daryl Metters Queensland Department of Environment and Science
15:45-16:15	Afternoon Tea	
16:15-16:35	Critical Thresholds for Data Sharing on the North West Shelf of Australia	Greg Williams RPS MetOcean
16:35-16:55	The feasibility of tidal energy within Australia's future energy mix	Irene Penesis University of Tasmania
16:55-17:15	Wrap and reflection on the 'opportunities' theme	FOO Steering Committee
17:15	CLOSE DAY 1	
18:00-21:00	Conference Dinner	

DAY 2 Wednesday 16th October 2019		
8:00-8:30	Arrival Tea and Coffee	
Theme 3 - Risks to Australian marine industries and the role of operational oceanography in helping to manage them		
8:30-9:00	Keynote #3-Application of oceanography and meteorology to improve design and operation of offshore and onshore structures-what next?	Jim Stear Chevron/ International Association of Oil and Gas Producers
9:00-9:20	Design Tropical Cyclone Wind and Waves for North Western Australia	Jeff Kepert Bureau of Meteorology
9:20-9:40	Integrating physical and statistical models: a Bayesian approach to predictive uncertainty quantification of solitons	Edwards Cripps University of Western Australia
9:40-10:00	Innovative Wave Transformation Algorithm for Improved Short-term Wave Forecasting	Sean Garber Baird Australia
10:00-10:20	Using ocean models for safety and mission success in an operational environment: a Navy perspective	Joanne Haynes Department of Defence
10:20-11:00	Morning Tea	
11:00-11:20	Using predictive tools to locate containers from the YM Efficiency	Giovanna Lorenzin Australian Maritime Safety Authority (AMSA)
11:20-11:40	The development of the New Zealand Ocean Operational Forecast System	Joao Marcos Azevedo Correia de Souza MetOcean Solutions (NZ)
11:40-12:40	Bluelink ocean forecasting session • Global operations • Regional modelling • Global model advances • Orchestration framework	Edward King, CSIRO and Barbra Parker, Department of Defence Gary Brassington, Bureau of Meteorology David Griffin, Matthew Chamberlain and Uwe Rosebrock, CSIRO

12:40-13:40	Lunch	
13:40-14:10	**Keynote #4-Management of climate risks to Australia's blue economy**	**David Karoly NESP Earth Systems and Climate Change Hub**
14:10-14:30	Using seasonal forecasting to manage impacts of extreme ocean temperatures on marine industries	Clair Spillman Bureau of Meteorology
14:30-14:50	Operational products supporting the future management of the Great Barrier Reef	Richard Brinkman Australian Institute of Marine Science
14:50-15:10	Great Barrier Reef shipping-gaining insight from ocean modelling, observations and cloud-based data analytics	Daniel Machado BMT
15:10-15:30	Sea state verification	Frans Schlack Pilbara Ports Authority
15:30-16:00	Afternoon Tea	
Theme 4: So what, what next for the Australian Forum for Operational Oceanography?		
16:00-16:20	Wrap and reflection on the 'risks' theme	FOO Steering Committee
16:20-16:30	The importance of FOO to Australian marine science-perspectives from a publicly-funded research infrastructure	Tim Moltmann
16:30-16:45	What have we heard at FOO 2019? • What's the same, what's new? • What's different? • What didn't we hear?	Tim Moltmann and the FOO Steering Committee
16:45-17:00	What next? • FOO 2021, working groups, other?	FOO Steering Committee
FOO 2019 CLOSE		

Keynote Speakers

Dr John Siddorn, UK Met Office

The UK ocean prediction community, current status and future directions

John Siddorn is Head of the Ocean Forecasting Research and Development (OFRD) group at the UK Met Office. He is also co-chair of the National Partnership for Ocean Prediction (NPOP), which has much in common with Australia's Forum for Operational Oceanography (FOO).

In his keynote, Dr Siddorn will give an overview of ocean prediction in the UK, and highlight developments in coupled short-range prediction, eddy resolving forecasting systems, and data assimilation and use of observations.

A/Professor Irene Penesis, University of Tasmania

The Blue Economy Cooperative Research Centre (CRC)

Irene Penesis is Research Director for the Blue Economy CRC.

Announced in Launceston on Tuesday, 16 April 2019 by Minister for Industry, Science and Technology Karen Andrews, the Blue Economy CRC aims to drive an evolution in marine-based industries, unlocking enormous economic, environmental and technological benefits. This $329 million research project is a 10-year collaboration between 45 national and international partners from industry, research and government, underpinned by a $70 million cash investment from the Federal Government. The Blue Economy CRC imagines a future where integrated seafood and renewable energy production systems operate offshore and where the community and industry have confidence they are safe, reliable, efficient and environmentally responsible.

The future envisioned by the Blue Economy CRC will need high quality operational oceanography if it is to be realised, and this keynote provides and exciting focal point for the "opportunities" session at FOO 2019.

Dr Jim Stear, Chevron

Application of oceanography and meteorology to improve design and operation of offshore and onshore structures – what next?

Jim Stear is a Senior Metocean Specialist at Chevron, and Chair of the International Association of Oil and Gas Producers (IOGP) Metocean Committee.

In his keynote, Dr Stear will talk about the application of oceanography and meteorology to improve design and operation of offshore and onshore structures. His talk will be in the session "Risks to Australian marine industried ans the role of operational oceanography in helping to manage them". It will focus on operational uncertainties (e.g. swell, wind waves, internal waves, surface currents).

Professor David Karoly, CSIRO

A national perspective on management of climate risks to Australia's blue economy

David Karoly is Leader of the Australian Government's National Environmental Science Program (NESP) Earth Systems and Climate Change Hub. He is an internationally recognised expert on climate change and climate variability.

The NESP Earth Systems and Climate Change Hub is committed to building world-leading climate and Earth systems science capability and using our understanding of Australia's past, present and future climate to supply useful and accessible climate information for Australia.

In this keynote, Professor Karoly will focus on the information required to manage climate risk in Australia's valuable marine industries, collectively referred to as the blue economy.

Abstracts

Theme 1: The Australian Forum for Operational Oceanography

Theme 1 will be an overview of activities since the 2017 Forum, with emphasis on the Surface Waves and Surface Currents working groups.

15 priorities for wind-waves research: An Australian perspective

Diana Greenslade[1]

[1]Bureau Of Meteorology, Melbourne, Australia

The Australian marine research, industry and stakeholder community has recently undertaken an extensive collaborative process to identify the highest national priorities for wind-waves research. This was undertaken under the auspices of the Forum for Operational Oceanography Surface Wave's Working Group. The main steps in the process were firstly, soliciting possible research questions from the community via an online survey; secondly, reviewing the questions at a face-to-face workshop; and thirdly, online ranking of the research questions by individuals. This process resulted in 15 identified priorities, covering research activities and the development of infrastructure. The top 5 priorities are 1) Enhanced and updated nearshore and coastal bathymetry; 2) Improved understanding of extreme sea-states; 3) Maintain and enhance in situ buoy network; 4) Improved data access and sharing; and 5) Ensemble and probabilistic wave modelling and forecasting. While this process has been driven by Australian needs, it is likely that the results will be relevant to other marine-focussed nations.

Theme 2: Opportunities for operational oceanography to drive the development of Australian marine industries

NERA's Oceanography Projects

Timothy Duff[1]

[1]NERA, Perth, Australia

National Energy Resources Australia (NERA) is one of six Growth Centres established by the Australian Government under the Industry Growth Centres Initiative. NERA's role is to grow collaboration and innovation to assist the energy resources sector manage cost structures and productivity, direct research to industry needs, deliver the future work skills required and promote fit-for-purpose regulation.

NERA's work program focuses on applied R&D, collaboration, innovation and regulatory reform with an aim to reduce costs, unlock resources, accelerate growth of the local supply chain and support the uptake of digital and clean technologies. While NERA's portfolio of forty industry led collaborative projects is diverse, a number of projects have a strong oceanography aspect. These projects include:

- Exmouth Integrated Artificial Reef: a unique project that will enhance marine habitat and recreational fishing opportunities by creating Australia's first integrated artificial reef, which is partially made up of re-purposed offshore structures from the oil and gas industry.
- TASER Living Lab: assessing the effectiveness of innovative coatings, materials and technologies against calcareous deposition and marine organism growth on subsea equipment.
- Cluster Program: Subsea Innovation Cluster Australia (SICA) and the Ocean Energy Cluster aim to accelerate growth and expand capabilities through collaboration.
- National Decommissioning Research Initiative: aims to improve the knowledge base underpinning decisions relating to the impact of infrastructure on the marine environment.

This presentation will provide a summary of these projects, including the key deliverables, progress to date and how the information will be shared with the wider industry.

The Wave Climate of the Southern Ocean

Ian Young[1], Qingxiang Liu[1]

[1] University of Melbourne, Melbourne, Australia

Although the Southern Ocean is often viewed as a very remote area, it plays a critical role in global climate. Waves generated in intense Southern Ocean storms propagate across the Indian, Pacific and Atlantic Oceans and define the wave climate for many areas of these oceans. In addition, the wind and wave climate of the Southern Ocean plays an important role in determining the rate of decay of Antarctic glaciers which are an important element in global sea level change. Obviously, for Australia the Southern Ocean play a critical role in many operational activities. Despite this important role, little is known about the wind and wave climate of this vast region.

This presentation will bring together a series of unique datasets to provide a comprehensive view of this wind and wave climate. These datasets include: the long duration model reanalysis dataset ERA-I, a 33-year calibrated and validated altimeter dataset and buoy data from four deployments. These buoys have been located at: Macquarie Island (540S), Campbell Island (520S), a site west of South America (550S) and the Southern Ocean Flux Buoy south of Tasmania (460S). Data from these buoy deployments spans a total of approximately 7 years and provide directional spectra in unique long fetch environments. In addition to providing valuable data for model validation, coastal and offshore engineering design and Naval Architecture, these combined datasets provide new insights into air-sea interaction under extremely long fetch conditions. The paper will also use the satellite datasets to investigate changes in wave conditions in recent decades and the role that climate variability plays in such changes. This analysis will examine: long-term trends, annual variability and multi-year oscillations.

The Surface Water Ocean Topography (SWOT) mission: Opportunities and challenges

Shane Keating[1]

[1] UNSW Sydney, Sydney, Australia

In the coming decade, new satellite missions will map Earth's surface water and sea level (ocean topography) at a resolution that has not been possible before. These observations will provide critical information that is needed to assess water resources on land, track regional sea level changes, monitor coastal processes, and observe small-scale ocean currents and eddies. The first of these satellites, the NASA/CNES Surface Water Ocean Topography (SWOT) mission, is scheduled for launch in late 2021.

In this talk, I will present an overview of the SWOT mission objectives and discuss future challenges and opportunities for operational oceanography in the region. I will also outline the goals and activities of the Australian Surface Water and Ocean Topography Working Group (www.auswot.org), a consortium of researchers and stakeholders in academia, government, and industry working to develop Australia's capability in the field of wide-swath altimetry.

OceanCurrent: New opportunities in satellite SST

Madeleine Cahill[1], Edward King[1], Roger Scott[1]

[1] CSIRO, Hobart, Australia

Himawari-8 was launched by JAXA (Japan Aerospace Exploration Agency) in 2015 and the Bureau of Meteorology has been producing the 10min full disk SST since mid-2017. With 10min sampling Himawari-8 greatly improves the chances of getting cloud-free images throughout the day but the 10min data also presents a data management issue. OceanCurrent provides images of 4hr composite SST based on the 2km Himawari-8 SST and all other AVHRR and VIIRS SST. Four-hour composites provide a high-enough time resolution SST record that allows small-scale oceanographic features to be discovered and followed, without overwhelming data volume. By including the higher resolution VIIRS and AVHRR SST we provide improved near-coastal SST. In particular, the VIIRS sensor offers the prospect of sub-1km spatial resolution which is an area of great potential and further research activity.

Operational Oceanography in support of marine traffic

Roger Proctor[1], Penny Haire[1], Henry Nichols[1], Clothilde Langlais[2]

[1]Tidetech, Hobart, Aus, [2]CSIRO CEM, Hobart, Aus

Ninety per cent of world commerce is carried by 50,000 commercial vessels traversing the planet's oceans and coastal seas. Increasingly these vessels are required to conform to navigational and environmental constraints, for example shipping lanes, piracy no-go regions and low emission zones. These constraints bring efficiency requirements to the fore-for example to conform to US and EU standards for air quality ocean-going ships carry two fuel types, a high grade fuel for use in low emission coastal zones and a lower grade fuel for ocean transits; minimising the use of high grade (and hence expensive) fuel becomes a priority. Passage transits can be made safer with advanced warnings of storm centres and wind/wave conditions; an example is the LNG carrier business which is affected by certain wave fields creating 'sloshing' in the LNG tanks. The industry is looking to science to provide reliable, accurate and appropriate information.

Providing efficient access to the necessary information to meet these requirements requires a complex computational infrastructure. Demands for forecasts of ocean currents, tides, waves and weather parameters up to 10-15 days in advance are now the standard requirements. Increasingly, as companies recognise the value of these data, the need is for hindcast data as well, so that historical voyages, for which they have data, can be used to calibrate future requirements.

This talk will give an overview of industry requirements, of the infrastructure built to acquire and deliver to their requirements, and examples of how different sector requirements are implemented.

Precise positioning for the maritime sector

Anna Riddell[1]

[1] Geoscience Australia

Geoscience Australia is delivering a national capability that will provide accurate, reliable and instant positioning across Australia and its maritime zones. To ensure that accurate positioning information can be received without the need for mobile phone or internet coverage, we're delivering an Australian Satellite-Based Augmentation System (SBAS). An SBAS will overcome current gaps in mobile and radio communications and correct positioning signals down to centimetres, greatly benefiting the maritime sector through improved positioning information available anywhere, anytime.

A recent 18 month trial of SBAS signals demonstrated significant benefits of precise positioning across commercial shipping, marine construction, offshore research, cruise, commercial port operations and general harbour management. It's expected that an operational SBAS will provide greater redundancy to automated and semi-automated port operations, enable real-time hydrographic surveying for dynamic harbour environments and congested areas and replace the costs of subscription services for offshore activities. Demonstrator project participants included Maritime Industry Australia Limited, Acoustic Imaging, Port Authority of NSW and Identic Solutions.

New Generation of Wave Forecast Models, Made in Australia

Alexander Babanin[1]

[1] University of Melbourne, Australia

This major update of the physics of the third generation models took 15 years to complete and the effort is ongoing. New source terms for wind input, whitecapping dissipation, interaction of waves with adverse winds (negative input), swell attenuation, wave-bottom interactions, wave-ice interactions have been developed and implemented in official releases of WAVEWATCH-III and SWAN models. Physics and parameterisations for the new source functions are based on field experiments and observations, which allowed us to reveal features and processes previously unknown and dynamics not accounted for. A new source functions for nonlinear wave-wave interactions, including quasi-resonant (rogue-wave) interactions, and for wave-current interactions are also under way and will be outlined. For extreme Metocean conditions, physics of the wind input and whitecapping dissipation terms exhibit additional behaviours irrelevant or inactive at moderate weather.

Measuring waves and winds from Autonomous Surface Vehicles (ASV)

Darren Burrowes[1]

[1]Chief Technology Officer, Bluezone Group

Methods for measuring waves and winds from a Wave Glider Autonomous Surface Vehicle (ASV) are described and evaluated. The wave method utilises the frequency spectra of orbital velocities measured by GPS, and the wind stress method utilises the frequency spectra of turbulent wind fluctuations measured by ultrasonic anemometer. Both methods evaluate contaminations from vehicle motion. The methods were evaluated with 68 days of data over a full range of open ocean conditions, in which wave heights varied from 1 to 8 m and wind speeds varied from 1 to 17 m/s. Reference data were collected using additional sensors onboard the vehicle. For the waves method, several additional datasets are included which use independently moored Datawell waverider buoys as reference data. Bulk wave parameters are determined within 5%

error, with biases of less than 5%. Wind stress is determined within 4% error, with 1% bias. Wave directional spectra also compare well, although the Wave Glider results have more spread at low frequencies.

Using machine learning to improve operational wave forecasts

Jeff Hansen[1], Chen Wu[1], Phil Watson[1], Diana Greenslade[2]

[1]University Of Western Australia, Crawley, Australia, [2]Bureau of Meteorology, Melbourne, Australia

Operational wave forecasts rely on spectral wave models that due to their numerical implementation (i.e. phase-averaged) and resolution, either parametrize or do not fully resolve key physical processes that impact wave generation, propagation, and dispersion. These factors, coupled with potential errors in atmospheric forcing, can sometimes result in incorrect forecasts for wave conditions and/or the timing of their onset. Many offshore industries depend on accurate wave forecasting, and unexpected conditions may incur cost (due to halting an underway operation or a missed opportunity to complete an operation) or add safety concerns. In this presentation we outline results from an initial study to test the use of machine learning to adjust Bureau of Meteorology AUSWAVE-R wave forecasts. Two years of archived wave forecasts, each extending 72 hours, were extracted at the location of three WA Department of Transport directional wave buoys. Eighty percent of the observed and forecast wave conditions were used as a training data set for a Recurrent Neural Network algorithm which was then used to adjust the remaining 20% (randomly selected and independent from training data). This initial test resulted in the root mean square error of the forecasts being reduced by one-third for significant wave height and by nearly one-half for peak wave period and direction across all sites. Currently the technique is also being applied to the spectral data from the buoys and forecasts. These initial results indicate that machine learning can be an effective mean of improving existing operational wave forecasts with negligible additional computation.

Evaluation of a machine learning framework to forecast storm surge

Daryl Metters[1]

[1]Queensland Department Of Environment And Science, Brisbane, Australia

Machine learning is being used to achieve solutions to issues in many areas of science. Forecasting storm surge is an area of interest that has traditionally relied on parametric and numerical modelling methodologies to achieve any degree of forecasting precision. Machine learning in comparison offers computationally inexpensive means of elucidating solutions to many issues. In this study machine learning is investigated as an alternative to modelling of storm surge using numerical modelling methods only. Two methodologies were implemented using inputs of: the non-tidal residual; wind speed and direction and; atmospheric pressure. A 24-hour forecast of sea level was achieved via initially (1) forecasting wind speed and direction and atmospheric pressure using two time series

machine-learning models and (2) using BoM numerically modelled forecasts of wind speed and direction and atmospheric pressure. Six machine-learning models were then used to forecast the non-tidal residual using standard learning and testing machine-learning methods extended with the two weather forecast datasets. The 24 hour forecast of sea level and storm surge was then compared to the actual sea level and storm surge for each of the two methodologies and six machine learning models. Model performance was evaluated with correlations between actual and forecast sea level and storm surge levels. Good results were achieved with the numerical model forecast inputs giving a close fit to the sea level and a good correlation with actual storm surge. The time series generated inputs failed to achieve a significant correlation. The six machine learning models varied in their performance.

Critical Thresholds for Data Sharing on the North West Shelf of Australia

Greg Williams[1]

[1]RPS MetOcean

For over 40 years, RPS have conducted metocean measurement programmes on the North West Shelf of Australia and established a suite of state-of-the-art tools and proven wind, wave, and current model configurations for setting design and operational criteria for offshore facilities, pipelines, ports and coastal infrastructure and Defence applications.

In a domain where measurement techniques, quality assurance and control processes, and numerical weather prediction models are undergoing continuous improvement, a variety of mechanisms for repeatable verification and evaluation against specific aims, applications, and performance metrics are well defined, established, and generally formalised by expert working groups, international agencies, and industries that have been engaged in these activities for decades.

In the past, commercial measurement activities occurred in regions where data were sparse or non-existent, and numerical modelling was used to understand the larger area or long-term environmental extremes. Now, with over 1000 measurement sites, 25000 datasets, and a billion data records supporting the calibration of numerical models, it is possible to design an optimal measurement+modelling network, sufficient to replace a large portion of the existing sites supporting day to day operations - with associated savings in time, convenience, maintenance, cost sharing and collaborative data sharing by participants. A significant additional advantage would be the establishment of consistent practice across all elements of maritime design and operation.

This presentation will demonstrate the foundation and design of an optimal measurement network providing support for offshore oil & gas, ports, coastal, defence, and research activities in the North West Shelf of Australia.

The feasibility of tidal energy within Australia's future energy mix

Irene Penesis[1], Mark Hemer[2], Remo Cossu[3], Jenny Hayward[4], Jean-Roch Nader[1], Uwe Rosebrock[2], Alistair Grinham[3], Saad Sayeef[4], Peter Osman[4], Philip Marsh[1], Mike Herzfeld[2], David Griffin[2], Camille Couzi[1]

[1]Australian Maritime College, University Of Tasmania, Launceston, Australia, [2]CSIRO Oceans and Atmosphere, Hobart, Australia, [3]School of Civil Engineering, The University of Queensland, Brisbane, Australai, [4]CSIRO Energy, Newcastle, Australia

For decades, tidal energy has been identified as a potential resource to meet Australia's future low-emission energy needs. The Australian Tidal Energy (AUSTEn) project (http://www.austen.org.au), co-funded by the Australian Renewable Energy National Agency (ARENA), and led by the Australian Maritime College (University of Tasmania), in partnership with CSIRO and University of Queensland, with strong industry support (SIMEC-Atlantis Energy, MAKO Tidal Turbines Ltd) seeks to determine the technical and economic feasibility of tidal energy in Australia, based on the best understanding of resource achievable. The project also benefits from collaboration with international researchers from Acadia University, Canada, and Bangor University, UK, both of whom are at the forefront of international developments in tidal energy, and who support the project to gain international exposure.

The project consists of three interlinked components to support the emerging tidal energy sector. Component 1 will deliver a National Australian high-resolution tidal resource assessment; Component 2 comprises focused case studies at two promising locations for energy extraction-Banks Strait, eastern Bass Strait, and Clarence Strait, Northern Territory; and Component 3 will deliver a technological and economic feasibility assessment for tidal energy integration into Australia's electricity infrastructure.

The outcomes of this project will provide considerable benefit to the emerging tidal energy industry, the strategic-level decision makers of the Australian energy sector, and the management of Australian marine resources by helping them to understand the resource, risks and opportunities available.

Theme 3: Risks to Australian marine industries and the role of operational oceanography in helping to manage them

Design Tropical Cyclone Wind and Waves for North Western Australia

Jeff Kepert[1], Stefan Zieger[1], Saima Aijaz[1], Diana Greenslade[1] and Aaron Wassing[1]

[1]Bureau of Meteorology, Melbourne

Experience has shown that the observational record of tropical cyclones is too short to directly estimate long return-period risk for offshore or coastal areas. Accordingly, such risk is usually estimated through the analysis of synthetic datasets.

A new synthetic Tropical Cyclone dataset representing 100,000 years for the Australian region has been developed. The key parameters are cyclone position, movement, maximum wind speed and radii of maximum winds and gale-force winds. The tracks were trained on Best Track data since 1979, but the intensity and structure parameters on post-2003 Best Track data due to inhomogeneities in the historical record earlier than this.

Gradient-level wind fields were based on the parametric wind profile of Willoughby et al (2006). These winds are adjusted for the effects of friction using the dynamical boundary-layer model of Kepert and Wang (2001). A statistical adjustment of the winds is also available, which was trained on output of the dynamical boundary-layer model.

These winds were merged into environmental fields from the ERA-I reanalysis in order to drive the wave simulations. It was desired to merge storms into synoptic situations that were consistent with the presence and track of a tropical cyclone. Accordingly, analogues to the synthetic storms were identified in the observed dataset, then the dates of the analogue were used to determine the merging fields. The reanalysis fields had the existing vortex removed to facilitate the merging.

Wave simulations were undertaken with WAVEWATCHIII® on a 5 km grid with two dedicated 1 km grids around shallow reef areas. Boundary conditions were derived to align in time with the merged fields.

The wind and wave modelling procedures were validated for about 15 historical Tropical Cyclones that occurred in the north-west Australian region.

The dynamical boundary-layer and wave models are computationally expensive, so were used only for storms that were estimated to have high impact at locations of interest by simpler models.

This presentation will give a broad overview of the methods and results and show some verifications. Challenges will also be discussed.

Integrating physical and statistical models: a Bayesian approach to predictive uncertainty quantification of solitons

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In shelf seas of 50 to 500 m depth solitons (non-linear internal waves), generated by tidal forcing over topography, are the main driver of extreme currents, induce some of the largest stresses on offshore infrastructure, drive sediment resuspension, and influence dynamic positioning systems during operations. This work demonstrates how recent advances in Bayesian statistical methods and computing integrates with physical models to predict solitons, provide industrial tools for decision making under uncertainty and refine our scientific understanding of associated ocean dynamic processes. Using data collected on the North West Shelf, we estimate a Bayesian hierarchical model of density stratification and initial amplitude inputs and propagate the results through the Kortweg-de Vries (KdV) equation soliton forecast model. Posterior distributions summarise the predictive uncertainty of maximum soliton amplitudes, density stratification characteristics, isopycnal heights and various ocean dynamic processes. Code is implemented in the probabilistic programming language Stan to estimate the Bayesian model and prototype frontend software has been developed. The work is multidisciplinary and is a collaboration between The Industrial Transformation Hub for Offshore Floating Facilities, University of Western Australia, and The Programme for Data Centric Engineering, Alan Turing Institute-Lloyd's Register Foundation, London.

Innovative Wave Transformation Algorithm for Improved Short-term Wave Forecasting

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This paper presents recent developments and validation of a wave transformation algorithm capable of accurately and efficiently computing shelf scale spectral wave propagation of swell conditions. The computational efficiency of the wave transformation approach makes it applicable for both the development of high-resolution long term hindcasts over large spatial scales and use in operational nearshore wave forecasting.

When coupled with real-time measurements of waves, a transformation algorithm is able to achieve improved accuracy and resolution of short-range wave forecasts compared with global and regional numerical wave forecasts.

An implementation of the wave transformation algorithm that derived relationships between wave energy at a nearshore location and spectral wave buoy measurements located over 300km away will be presented. The implementation includes the following unique features compared to other wave transfer applications:

- Use of a spectral transfer method based on the propagation of hypothetical narrow-banded spectral distributions, centred on each frequency-direction bin of the spectral space.
- Consideration of the influence of hydrodynamics, in terms of both water level and tidal currents, on wave energy transformation.
- The inclusion of frequency dependent propagation time in the transformation algorithm.

With directional wave spectra as input, the algorithm then computes the nearshore directional wave spectra and associated parameters. Comparisons between measured and forecast/hindcast wave conditions derived from spectral transfer and third-generation spectral wave models are presented to demonstrate the value of the transformation algorithm, particularly for short term swell forecasts.

Using ocean models for safety and mission success in an operational environment: a Navy perspective

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Understanding and exploiting the environment above, at, and below the ocean surface is key to ensuring the best possible employment of Defence capability in order to protect Australia's national interests. In the Navy context, ocean models play a key role in ensuring the safety of our assets and personnel at sea, as well as equipping the war-fighter with sufficient information to gain tactical advantage in an operationally uncertain environment. This brief will focus on the role of operational oceanography in the provision of forecasting products to the Under Sea Warfare (USW) community in order to ensure safety at sea and achieve mission success. The ocean forecasting tools and models in use by the Navy have been developed as part of the Bluelink Ocean Forecasting Project (a RAN/BoM/CSIRO collaboration) and include: the global scale Ocean Forecasting Australia Model (OFAM), and the regional scale Relocatable Ocean Atmosphere Model (ROAM) and Australian Defence Environmental Prediction Tool (ADEPT). Although they are unlikely to be operating in a contested space, marine industries face a number of similar operational challenges to the Navy due to uncertainties in the ocean environment. Opportunities may exist for better collaboration between marine industries, Defence and the other Bluelink partners. These could include the collection and sharing of ocean observations for model verification and re-analysis purposes, and the identification and analysis of oceanic events which are often difficult to forecast (for example, internal waves) in order to ensure the ongoing usefulness and reliability of operational ocean models well into the future.

Using predictive tools to locate containers from the YM Efficiency

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[1]Australian Maritime Safety Authority

AMSA commonly uses a variety of predictive modelling and mapping tools to support emergency response operations during a maritime event. These are essential to ensure resources are effectively utilised and specifically target areas that could be impacted during the event. Most often, these are used to model oil spill trajectories, drifting vessels, or persons lost at sea. However, it was recently also used to assist in locating missing containers from the container ship YM Efficiency.

On 1 June 2018, the vessel encountered bad weather approximately 30 kilometres southeast of Newcastle, and consequently lost 81 containers overboard, with an additional 30 moved or damaged on board. AMSA undertook coordination of the underwater search for the missing containers, and to address the complex issue, the question it asked was: where are they and where do we start looking?

AMSA used object drift modelling to help identify the approximate trajectories of where the containers would have floated to, if still buoyant. This modelling was then used as the basis with which to determine the search areas for the underwater side-scan and Remote Operated Underwater Vehicle (ROUV) surveys. Over the course of several months, the surveys undertaken at the predicted search areas successfully located and confirmed several containers. The locations of where some were found washed ashore also agreed with the initial predictions, making all these results reinforce the reliability and accuracy of the initial modelling.

This presentation will go through how these predictive tools effectively assisted in guiding the search for the lost containers from the YM Efficiency.

The development of the New Zealand Ocean Operational Forecast System

Joao Marcos Azevedo Correia de Souza[1]

[1]MetOcean New Zealand

New Zealand's maritime domain is one of the largest on the planet. The seafood sector alone brings $4.18B to NZ annually. MetService is the responsible institution for providing a reliable forecast system of the ocean estate to respond to such demand. To accomplish this, a complex system including different ocean models and information endpoint delivery mechanisms was developed. The system is designed for fast operationalization of state-of-the-art techniques and portability between different platforms. A mix of "Regional Ocean Modeling System" (ROMS) and "Semi-implicit Cross-scale Hydroscience Integrated System Model" (SCHISM) domains are used to evaluate and predict ocean circulation and state properties, while "Wave Watch III" (WW3) and "Simulating Waves Nearshore" (SWAN) are used for simulating surface gravity waves. An architecture based on docker images and controlled by an "in house" built python based scheduler ensures a stable and robust system. Following international best practices, new developments to include wave-circulation coupling and data assimilation are underway. These are undertaken in the framework of publicly funded research projects. A general description of the operational system with its unique architecture is presented. The development of new features is discussed, with a special focus on the assimilation of ocean observations into the national circulation model. The steps taken in the design and implementation of this national operational model are discussed. This effort is part of the Moana Project-a national research project that includes the participation of the main oceanographic institutes in New Zealand.

Bluelink ocean forecasting session

Edward King[1], Commander Barbra Parker[4], David Griffin[1], Madeleine Cahill[1], Emlyn Jones[1], Ron Hoeke[2], Stephanie Contardo[3], Paul Branson[3], Tracey Pitman[1], Matthew Chamberlain[1], Peter Oke[1], Uwe Rosebrock[1], Simon Pigot[1], Gary Carroll[1], Gary Brassington[5], Pavel Savov[5], Prasanth Divakaran[5], Xinmei Huang[5], Aihong Zhong[5], Mirko Velic[5], Justin Freeman[5], Russell Fiedler[1], Andy Hogg[6], Andrew Kiss[6]

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Bluelink is an ocean forecasting partnership between the Bureau of Meteorology, CSIRO, Department of Defence, and other collaborating partners. Its goal is to "Develop and maintain world-leading global, regional, and littoral ocean forecast systems to support Defence applications and maintain a national ocean forecasting capability for Australia.".

The new Bluelink Strategic Plan to 2025 will be introduced at the start of the session. This will be followed by talks on key components of Bluelink most relevant to Australian operational oceanography i.e. global ocean forecasting (OceanMAPS), the relocatable model (ROAM), littoral forecasting, data assimilation, and downscaling.

The Bluelink global forecasting capability supports a category one operational system at the Bureau of Meteorology that delivers services for a range of national applications. Sustaining an internationally competitive performance from this capability into the future will require national and international collaboration to tackle the next generation developments. The current forecast system, the Ocean Model, Analysis and Prediction System (OceanMAPS) version 3.1 has been developed through successive Bluelink projects. A next generation global ocean forecast system (OceanMAPS version 4) is under development with a target for operationalization in 2020. A gap in the national operational ocean forecast service resides in finely resolved regional and coastal modelling. Some progress has been made for the majority of the Australian coastline with state-based modelling systems. Recent projects have examined the feasibility of downscaling the global system to finer scales (e.g. 1/50° resolution). With the OceanMAPS global capability maturing into an internationally competitive system, and the downscaled forecast systems achieving genuine performance gains, opportunities arise for the uptake of these products by a broader range of stakeholder applications as well as their adoption by downstream service providers and the Australian research community.

The Relocatable Ocean-Atmosphere Model is the component of Bluelink that sits between the global models and the littoral models, in terms of spatial and temporal scales. 'Relocatable' means that instead of being set up and optimised for some fixed geographic domain, ROAM can be set up wherever the user wants. In this talk, we focus on the important question of how accurate and/or realistic the simulations are, by comparing them to a wide range of IMOS observations, including various quantities recorded by gliders, moored ADCPs, Argo floats and HF radars. A particular focus is ROAM's ability to simulate the depth of the mixed-layer, because of this quantity's importance to 1) sound propagation in the ocean, and 2) the vertical mixing of heat, nutrients and phytoplankton near the surface of the ocean.

Shortcomings in littoral forecasts are being addressed so as to improve their accuracy and usefulness. Here, we present an overview of past and ongoing efforts, which fall primarily into three categories: the development of value-added forecast products; improvement of numerical prediction models and their interconnectivity; and development and ingestion of emerging data sources. In particular the recent expansion of high-resolution, (relatively) cost-effective coastal remote-sensing technologies holds significant promise to improve and inform all three categories.

Bluelink Reanalyses (BRAN) continue to developed and run for the ocean around Australia and the world at 0.1 degree resolution, assimilating observations such as sea surface temperature, sea level anomalies and Argo profiles of temperature and salinity. Data assimilation (DA) at multiple spatial scales is being explored as a way to improve the efficiency of the system to correct large features (diameters of several hundred km) in the deep ocean. High-resolution (0.1 degree) ocean background states are averaged onto a coarse 1-degree grid, reducing the mesoscale variability in the state. The initial DA cycle uses a coarse ensemble that has larger spatial correlation patterns. The second DA cycle is at high-resolution, based on BRAN_2015. Increments from both the low and high-resolution DA cycles are used to update the ocean state. Initial results show this approach reduces innovation errors in analysis and forecasts, especially in the deep ocean.

A system for automatically configuring and executing a model to predict the past, present, or future state of the ocean developed under Bluelink. This Bluelink Modelling Framework (BMF) makes it feasible to configure and execute high-resolution regional models anywhere in the world at a moment's notice. It runs on small scale desktop or laptop and HPC environments alike, deploys execution and services into the 'cloud' and has a distributed service-driven architecture. Ongoing development is increasing support for more use cases and a wider range of end-user and client needs. This includes an increasing number of domains and model choices, such as relocatable atmospheric downscaling and wave modelling.

Using seasonal forecasting to manage impacts of extreme ocean temperatures on marine industries

Claire Spillman[1], Grant Smith[1], Alistair Hobday[2], Jason Hartog[2], Catherine de Burgh-Day[1], Paige Eveson[2]

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Anomalously warm ocean temperatures have implications for many marine systems and industries, including mass coral bleaching and mortality, reduced aquaculture yields and altered wild fish migration patterns. Seasonal forecasts from dynamical ocean-atmosphere models of marine heatwaves and their drivers can be very useful tools for managers and business owners, allowing for proactive management responses. The Australian Bureau of Meteorology's seasonal forecast model ACCESS-S1 currently produces operational real-time global forecasts of sea surface temperatures, with tailored outlooks produced for coral reef, aquaculture and wild fisheries management in Australian and New Zealand waters. Thermal stress forecast products have been developed, incorporating both the magnitude and duration of heat stress events, with widespread management applications. Advance warning of marine heat events can enable managers and industries to plan ahead and effectively manage resources to reduce impacts of such events. Additionally, ACCESS-S1 seasonal forecasts have also been used to inform planning of monitoring programs and event-responsive instrument deployments such as the IMOS glider program. Seasonal forecasts are a valuable tool to improve both the understanding and the management of these events, as well as the complex interactions that lead to them, particularly in a changing climate.

Operational products supporting the future management of the Great Barrier Reef

Richard Brinkman[1], Claire Spillman[2], Roger Beeden[3], Jessica Benthuysen[1], Craig Steinberg[1], Neal Cantin[1], Grant Smith[2], William Skirving[4]

[1] Australian Institute of Marine Science [2] Bureau of Meteorology, [3] Great Barrier Reef Marine Park Authority, [4] NOAA

Mass coral bleaching occurred on the Great Barrier Reef (GBR) in 2016 and 2017 as part of a continuous global bleaching event that started in late 2014 and impacted coral reefs worldwide. Mass bleaching occurs during extended periods of elevated ocean temperature. It has the potential to result in significant and widespread loss of coral, and compromise the ecological, cultural, social and economic benefits and services provided by healthy coral reefs. The length and severity of the 2016-2017 event resulted in significant coral mortality over a large proportion of the GBR.

Monitoring of sea surface temperature (SST) via remote sensing has historically provided a synoptic view of anomalous ocean heating and underpinned operational products for monitoring and predicting bleaching. Advances in the resolution and accuracy of dynamical seasonal forecasts from coupled oceanographic and atmospheric models, increased in situ observations and the application of highly resolved regional & local

ocean models are improving our ability to forecast anomalous environmental conditions and move beyond surface-focused products to integrate vertically resolved subsurface observations and model outputs.

Reef managers have a range of management responses that can be implemented at different space and time scales to help manage local impacts and improve resilience to global pressures. The selection and application of tactical and strategic response actions requires access to validated long-term, seasonal and short-term forecasts of environmental condition. This presentation will outline the current state and future direction of operational products to predict coral bleaching, and support management of the GBR and reefs worldwide.

Great Barrier Reef shipping - Gaining insight from ocean modelling, observations and cloud-based data analytics

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The Great Barrier Reef (GBR) is Australia's most iconic Marine Park, the world's most extensive coral reef ecosystem, of outstanding biodiversity, conservation and scientific value, recognised by UNESCO World Heritage listing. The GBR underpins economic activities, largely around tourism, with estimated annual contribution of more than $6billion to the Australian economy and supporting over 60,000 jobs. Inland, export resource industries (coal, gas and minerals) have developed substantially and are predicted to continue doing so, with increasing port facilities and shipping demands. Threats to the GBR comprise global and regional issues like climate change and coastal development, port expansion with associated dredging of shipping lanes and berth pockets for more and larger vessels. Individual vessels calling port in the GBR are predicted to enlarge from 4,000 in 2012 to 10,000 by 2032. Traffic intensifies not only from commodity exports but also cruise-ships, recreational boats, yachts and navy vessels; in hand with traffic go underlaying risks for shipping incidents. Operational oceanography has a key role for managing these risks by informing incident prevention, response preparedness and delivery. To support this, we developed a modelling framework for three-dimensional hydrodynamic and particle tracking modelling in the GBR, using the flexible mesh TUFLOWFV model with meteorological and global ocean circulation model forcing, including baroclinic and ocean turbulence coupling. We have integrated this modelling framework and publicly available in-situ metocean observation data-streams into the cloud-based analytic platform BMT Deep, providing an interactive marine data portal for analysis, from which operational insight can be gained.

"Sea State Verification System" - a Tool (under development) applying real time Oceanography to Marine Operations from Tender to Construction

Frans Schlack[1]

[1]Pilbara Ports Authority

The Pilbara Ports Authority (PPA) recently completed the last phase of its Channel Risk & Optimisation Project (CROP) utilising a Dredging Spread consisting of a large Cutter Suction Dredge and two Split Hopper Barges in a near 'Open Ocean' environment. The Project experienced long bouts of 'Inclement Sea State' in which the Dredging Spread could not operate which in turn led to significant 'Stand By' costs. Despite the Dredging Contractor specifying the sea state parameters its equipment could operate up to in the Contract, most of the time those parameters were not reached whilst the Dredging Spread genuinely could not operate to avoid significant damage. This situation led to the development of the prototype of the Sea State Verification System to determine in which sea state conditions Marine Equipment can work up to. Once fully developed, it is expected this System can be applied at the tender stage to ensure both Proponent and Contractor will have a system against which 'Stand By' claims can be evaluated and contractually managed.

Theme 4: So what, what next for the Australian Forum for Operational Oceanography?

This theme will involve group discussion on 'what's next' for the Forum. We encourage you to bring your ideas to the session, and look forward to your contributions.