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Building multidisciplinary collaboration in coastal and ocean modelling and observation in Australasia

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1. The Australian Coastal Ocean Modelling and Observations workshop

Australia has the third-largest ocean territory on Earth, with 85% of Australians living within 50 km of the coast. As a result, coasts and ocean matter to Australia and are integral to the use of marine resources for sustainable economic development, i.e. Australia's blue economy. The societal, economic and cultural issues associated with the blue economy range from marine sovereignty, safety and security to food and energy security, biodiversity conservation, management and coastal populations.

Marine, climate and Antarctic science have the potential to drive the development of Australia's blue economy through the creation of new knowledge, tools, technology, and innovation. This requires observations from the past to the present, as well as numerical modelling capability that can hindcast, nowcast, and forecast the marine environment with skill.

Before the establishment of an Integrated Marine Observing System (IMOS) in 2007, Australia's vast and valuable marine estate was poorly observed. The observing programs that existed before were fragmented across institutions and mostly funded by projects of limited and uneven durations. Through IMOS, Australia now has a much more adequate marine observing system that is sustained (currently to 2023) and available for use by the whole marine, climate and Antarctic science community and its international collaborators. Key to this success has been ensuring all IMOS observations are available as quality controlled data that is discoverable and accessible via the Australian Ocean Data Network (AODN).

The IMOS observing program has always been guided by science plans developed by the national community through a series of science Nodes (Fig. 1) (Lara-Lopez et al., 2016). These Nodes cover the open ocean as well as shelf and coastal oceans in areas of high environmental, social, and economic significance e.g. the Great Barrier Reef. IMOS Node science plans were subjected to international peer-review during 2009 and 2010. A clear and consistent message from reviewers was the need for better integration between observations and modelling and greater engagement with the modelling community. At the time, however, a national coordination mechanism that could facilitate engagement of IMOS with the coastal and ocean modelling community did not exist.

In discussion with Australia's National Marine Science Committee, IMOS developed a proposal to establish a national workshop series to address this gap. A decadal vision was put forward that over time would engage communities from hydrodynamics, sediments, biogeochemistry, biology, and ecosystems, extend across systems that include open ocean, ocean-ice zone, continental shelf, coasts, and estuaries, and include developers and researchers, end-users and managers. The proposal was approved in early 2012, and the Australian Coastal Ocean

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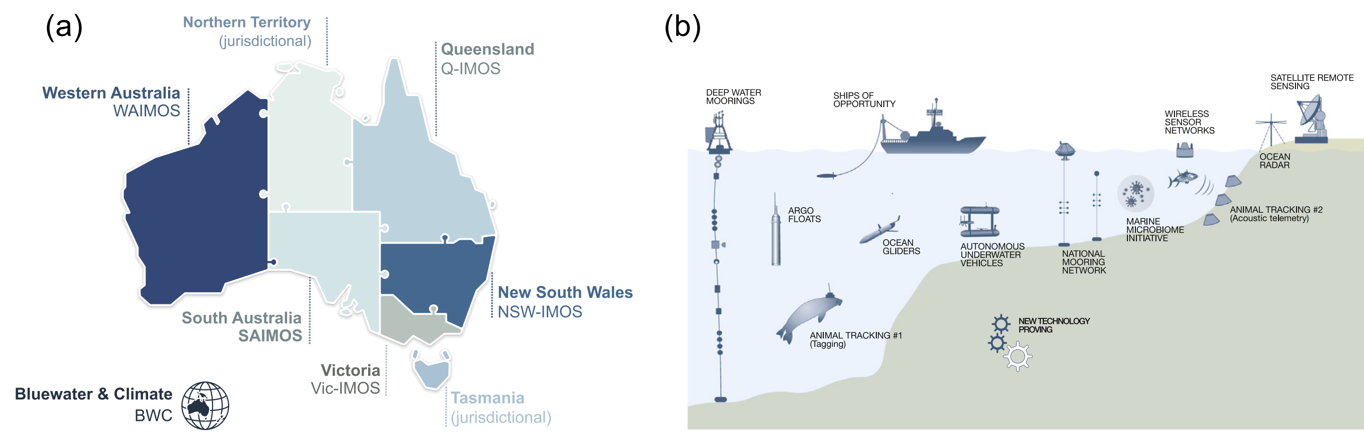

Fig. 1. (a) Schematic showing the Integrated Marine Observing System's Science Nodes, created to provide the scientific rationale for IMOS and identify the data streams required through the appropriate technology platforms. (b) IMOS observing platforms, including its data management facility, the Australian Ocean Data Network.

Modelling and Observations (ACOMO) workshop series came into being.

The first workshop, held in October 2012, aimed to bring together the national observing and modelling communities to share information on current activities, compare, contrast, and explore opportunities for enhanced collaboration. The first workshop was mainly focused on ocean and coastal hydrodynamics. There was unanimous support from the community to continue the workshop series and to broaden its scope gradually in line with the decadal vision. As a result, ACOMO workshops have been held on a biennial basis and have focused on a range of issues. The 2014 workshop devoted sessions to biogeochemistry, shelf reanalysis, and coastal impacts i.e. sea level, waves, and storm surges. The 2016 workshop included sessions on biogeochemistry and ecosystems, polar dynamics and processes, nearshore and coastal processes, boundary currents, and end-user applications.

Interest in ACOMO workshops has been sustained and grown, from 75 attendees in 2012 to 100 by 2016 because these fulfil a community need that is not addressed by any other national workshop. The workshops have fostered enhanced coordination and collaboration both within and between the Australian coastal and ocean modelling and observing communities. Recommendations and actions emerging from ACOMO workshops have influenced investment decisions within IMOS and other research funding programs.

Creation of an Australian Forum for Operational Oceanography (FOO) in 2015 has promoted further synergies with ACOMO, generating useful cross-pollination between operational and research communities. FOO conferences occur every other year (e.g. 2015, 2017, 2019) to maximise the potential for synergistic development. For example, there as been increasing interest in ACOMO by the end-user community, which now accounts for > 10% of attendees.

The ACOMO 2018 workshop explored the theme of integration – across geography, scales, and disciplines, given its history and maturity. The 2018 workshop was again considered a success by the community, giving rise to the first ACOMO special issue on '*Integrated Approaches in Ocean Modelling and Observations*'.

2. Highlights of research — ACOMO 2018 "Integrated Approaches in Ocean Modelling and Observations"

The contributions in this special issue highlight some of the research presented at the ACOMO 2018 workshop. The studies exemplify the workshop's progress, from a single discipline focus in 2012 to integration in 2018, where the disciplinary boundaries that characterised the previous workshops were blurred to highlight the advances and gaps in integration within and between ocean modelling and observations. Thus, contributions included in this special issue are heterogeneous in their content and approaches. As such, they provide useful examples of how different disciplines, methodologies and scales are integrated to address questions of relevance for management, decision-making and process understanding.

Bracco et al. (2019) bring together the fields of molecular biology and physical oceanography to study connectivity between deepwater coral communities along the continental slope in the Gulf of Mexico. A combination of models and observations are used to investigate the physical processes that enable, or hinder, the connectivity between the different coral communities through the dispersal of their larvae. Bracco et al. (2019) show how fine-scale circulation (~1 km) in the deep ocean can act as a barrier for larval dispersal to deepwater coral communities inhabiting different depths, and therefore affect the community structure of deepwater corals. It is through integrating disciplines and methods that Bracco et al. (2019) provide important information for decision-makers to manage risks to deepwater corals in a region impacted by multiple stressors due to human activities, thereby enhancing conservation efforts.

Bainbridge's (2019) study on shallow-water corals in the Great Barrier Reef integrates available data to produce a risk index that decision-makers can use in real-time. Stressors such as temperature-driven coral bleaching, fishing impacts, and cyclones, among others, affect shallow-water coral reef systems (Bainbridge, 2019; De'ath et al., 2012; GBRMPA, 2014). By combining real-time observations from the IMOS wireless sensor network and Bayesian probabilistic models, Bainbridge (2019) provides an index of current and future risk of coral bleaching. This bleaching model summarises the relationship between the various threshold values and integrates that information into a single index for use in risk management and decision-making.

Similarly, Huang et al. (2019) developed a water quality decision system for use by managers. They integrate hydrodynamic and biogeochemical numerical models, high-frequency observations, and machine learning to guide management of the water quality in the Swan Canning Estuary in Western Australia. This urban estuary has experienced fish kills and blooms from harmful algae triggered by human activities. Their integrated modelling system aimed to meet the needs of managers at different time scales from daily (harmful algal blooms), to seasonal (hypoxia), and decadal (climate change). Their modelling system assimilates the observations for hindcast, forecast and different scenario modes to meet these managerial demands. Their work provides a multidisciplinary example that integrates different time scales, observations, modelling, and disciplines, and one which was developed with end-user requirements in mind.

Kerry et al. (2019) study focused on the East Australia Current (EAC). They used an integrative approach to assess the ability of an ocean forecast system to predict small scale features including cyclonic eddies (frontal eddies) in the EAC. The forecasting system consists of a fine-scale resolution (1 km) model nested within a coarser resolution model (3–6 km), with high-resolution observations assimilated into the parent model. Simulations show that the fine-resolution model improves the representation of fine-scale eddies, but does not improve predictive capacity. Small scale circulation plays an important role in distributing biota, trophic web dynamics, connectivity, and the vertical transfer of physical and biogeochemical tracers (Bracco et al., 2019). Kerry et al.'s (2019) study, therefore, provides important insights into the challenges of modelling and predicting small scale circulation features. Indeed, predictions at these scales require observations that match the modelling requirements.

Schaeffer et al. (2019) present a study of the energy resource available in the EAC, a boundary current system that has the potential to be a source of renewable energy in the future. Schaeffer et al. (2019) integrated high resolution in situ and satellite observations with a data assimilating hydrodynamic model (as described in Kerry et al., 2019) of the EAC. Their study provides a first step in assessing the amount of renewable energy that could be extracted from this boundary current. The study can also be used to inform the development of new technologies with the capacity to harness this potential resource.

At a larger spatial scale, Oke et al. (2019) re-mapped historical (1970s) temperature data from the Tasman Sea, and together with an ocean reanalysis (Bluelink ReANalysis), assessed an earlier conclusion of a persistent front in this region (Denham and Crook, 1976). Oke et al. (2019) used the 25-year reanalysis to test a range of scenarios and compared the reanalysis with the re-mapped observations. This analysis provides insights into how modern-day reanalysis products and contemporary data can be integrated with historical observations to re-assess previous descriptions of hydrographic and circulation conditions. A result of the analysis by Oke et al. (2019) is the new definitions of the southern and eastern extension of the EAC, as opposed to a persistent Tasman Front.

At an oceanic scale, Brasier et al. (2019) used the Southern Ocean as a case study to illustrate the necessary elements for developing an integrated marine ecosystem assessment. Their framework audits the observations, synthesis and system models available to undertake a Marine Ecosystem Assessment for the Southern Ocean. They identified a circumpolar krill-based assessment as the “low hanging fruit” for an ecosystem assessment of the Southern Ocean. Their framework provides an avenue to collate information in an adaptive manner, and meet the requirements of the different international bodies responsible for the management of Southern Ocean ecosystems. It also provides a template that can be used for other marine ecosystems assessments.

The importance of sustained ocean observations goes beyond meeting the knowledge needs about our oceans, they support evidence-based decision making by delivering information over multiple time and space scales on ocean change, climate variability and ecosystem responses. Together with the use of models, they are a potent tool critical for decision-makers and for operational services to mitigate risks through improved early warning systems and improved knowledge. ACOMO provides a forum where both the ocean observing and modelling communities coalesce and collaborate to develop Australia's capability in ocean modelling and observing, and the work presented here are a testament of ACOMO's role in fostering these collaborations.

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