July 2024

OCEAN MODELLING AND OBSERVATIONS WORKSHOP

This is a joint workshop of the Consortium for Ocean-Sea Ice Modelling in Australia (COSIMA) and Australian Coastal and Oceans Modelling & Observations (ACOMO). It is brought to you by IMOS and ACCESS-NRI.

Program

Tuesday 2nd July

Time	Topic	Speaker	Theme
8:00	Registration		
8:50	Welcome to Country and introduction		
9:20	A decadal assessment of the eReefs platform compared with field observations in the Great Barrier Reef	Dr Jennifer Skerratt	Keynote
10:00	**Morning tea**		
10:30	The South East Australian Coastal Ocean Forecast System	Prof Moninya Roughan	Ocean Dynamics
10:45	Simulated dynamics in Circumpolar Deep Water properties in the Southern Ocean	Hangyu Meng	Ocean Dynamics
11:00	Variability of Antarctic dense water overflows observed from space	Matthis Auger	Ocean Dynamics
11:15	Implementing and evaluating a novel tidal wave drag parameterisation in MOM6	Luwei Yang	Ocean Dynamics
11:30	Does the Antarctic Slope Current control ocean heat transport towards Antarctica?	Adele Morrison	Ocean Dynamics
11:45	**Group photo**		
12:00	**Lunch**		
13:00	Tracking Australia's boundary current connections to the deep ocean	A/Prof Helen Phillips	Ocean Dynamics
13:15	Modeling ocean interior dynamics at high-resolution in the ACC meander south of Tasmania, toward the assimilation of SWOT observations	Dr Yann-Treden Tranchant	Ocean Dynamics
13:30	A machine learning approach to rapidly downscale sea surface temperature extremes on the Great Barrier Reef	Dr Chaojiao Sun	Use of Artificial Intelligence / Machine Learning in Oceanography
13:45	Assimilation of multi-platform remote sensing reflectance into a BGC model of the Great Barrier Reef	Dr Emlyn Jones	Modelling for Decision Making
14:00	**Lightning talks**		
14:30	**Afternoon tea**		
15:00	**Posters**		
17:00	**End**		
18:00	**Dinner**		

Wednesday 3rd July

Time	Topic	Speaker	Theme
9:00	Is numerical mixing in ocean models a solved problem?	A/Prof Jan David Zika	Keynote
9:40	Ocean modelling on GPUs with Oceananigans allows for ocean mesoscale-resolving climate projections	Navid Constantinou	Advances in Modelling Methods
9:55	ACCESS-OM3: progress and roadmap for Australia's next-generation global ocean - sea ice - wave model	Dr Andrew Kiss	Advances in Modelling Methods
10:10	Linking empirical data and oceanographic models to enhance marine plastic pollution management	Dr C Gabriela Mayorga Adame	Modelling for Decision Making
10:25	Implementing an automated relocatable wave-flow coupled coastal hydrodynamic forecast model	Claire Trenham	Modelling for Decision Making
10:40	**Morning Tea**		
11:10	Tidal constituents' evolution and its implication for tide prediction around Australia using ANCHORS tide gauge dataset	Dr Oceane Richet	Observational Oceanography
11:25	Seasonality of surface currents in the northwest off Australia elucidated from surface ocean drifters	Dr Prescilla Siji	Observational Oceanography
11:40	Developing a Framework for a sustained Northern Territory Fisheries Ocean Observing Network	Dr Ruth G. Patterson	Observational Oceanography
11:55	An autonomous observation oystem for RSV Nuyina to measure ocean and sea ice surface properties	Dr Ippolita Tersigni	Observational Oceanography
12:10	Oceanic teleconnections from the tropics to the Southern Ocean	Zhi Li	Observational Oceanography
12:25	**Lunch**		
13:30	A vortex-force formalisation implementation for unstructured COMPAS-SWAN coupling system—A case study along select areas of the Australian Coastline	Cagil Kirezci	Advances in Modelling Methods
13:45	National-scale assessment of coastal hazards using both deterministic and probabilistic approaches in Vanuatu	Ron Hoeke	Advances in Modelling Methods
14:00	Comparisons of CFOSAT SWIM wave measurements against wave buoys	Dr Marites Canto	Observational Oceanography
14:15	A comparison of wide-swath altimetry with an ensemble Kalman Filtering ocean forecast system	Gary Brassington	Observational Oceanography
14:30	**Lightning talks**		
15:00	**Afternoon tea**		
15:30	**Posters**		
17:00	**End**		

Thursday 4th July

Time	Topic	Speaker	Theme
9:00	The effects of ocean dynamics on the melting of ice shelves: a fine-scale numerical simulation approach	Dr Catherine Vreugdenhil	Keynote
9:40	**Breakouts**		
10:40	**Morning tea**		
11:10	Implementing sea ice thermodynamics from laboratory experiments into CICE	Kial Stewart	Ocean Interaction With Sea Ice
11:25	Impacts of Antarctic Summer Sea-Ice Extremes	Edward Doddridge	Ocean Interaction With Sea Ice
11:40	Modelling the ice edge wave-amplitude drop and its influence on the Antarctic marginal ice zone	Noah Day	Ocean Interaction With Sea Ice
11:55	Ocean surface vertical resolution controls Dense Shelf Water formation around Antarctica	Wilton Aguiar Carvalho Silva Filho	Other
12:10	Resolving Antarctic Bottom Water pathways in Australian-Antarctic Basin	Ms Polina Sholeninova	Other
12:25	**Lunch**		
13:30	Bluebottles: drifting behaviour and ocean pathways to the shore	Dr Amandine Schaeffer	Ocean Dynamics and Biology
13:45	Extremely normal; why ACCESS-OM2 missed the most remarkable Antarctic se ice loss on record	Will Hobbs	Ocean interactions with Sea Ice
14:00	Improved ocean dynamics using observational data products and models	Dr Beatriz Pena Molino	Ocean Dynamics
14:15	Towards new insights into ocean eddy structure by combining models and observations over a period of unprecedented data richness (Sept – Nov 2023)	Dr Colette Kerry	Ocean Dynamics
14:30	**Afternoon tea**		
15:00	**Breakout reporting**		
16:00	**Wrap up and awards**		
16:30	**End**		

ORAL PRESENTATION

Abstracts

KEY NOTE

A decadal assessment of the eReefs platform compared with field observations in the Great Barrier Reef

Jenny Skerratt, Anna Maggiorano, Mathieu Mongin, Fred Bennett[1], Clotilde Langlais, Severine Choukroun[2], Emlyn Jones, Mark Baird, Shawn Darr[1], Gillian McCloskey[1], Nugzar Margvelashvili, Andy Steven

CSIRO, [1]Department of Environment, Science and Innovation, [2]James Cook University

The eReefs information system integrates hydrodynamic, wave, sediment, catchment and biogeochemical (BGC) models to explore ocean circulation and marine ecosystem dynamics within the Great Barrier Reef (GBR). The land input into the GBR marine environment is a key process that drives both ocean circulation and water quality and overall reef health. The catchment model has an integrated paddock model which adds nutrient, sediments, and freshwater into GBR coastal waters. We evaluated the latest hindcast version of the eReefs marine biogeochemical model that ran over an 11-year period (2011-2022) by comparing it with in situ observations that includes over 8,000 field sample observations. Through comparison with observational data (MMP, AIMS, JCU, IMOS, Gidarjil) we assessed the eReefs model's ability to replicate key water quality parameters within the GBR. We demonstrate strengths and limitations of the model simulation and where it provides insight into model and observational improvements. The analysis emphasizes the importance and benefits of designing operating, modelling and observational research together for better understanding of marine ecosystems. We demonstrate the use of the model validation in guiding trust in modelling simulations for present and future management strategies such as Strategic Management Frameworks (SMF) and the GBR Water Quality Report Card.

KEY NOTE

Is numerical mixing in ocean models a solved problem?

Jan David Zika

University of New South Wales

Finite volume ocean models are key tools in oceanography and climate science. Confidence in their fidelity can be undermined by spurious numerical mixing of tracers such as heat and carbon, particularly across isopycnal layers. Substantial efforts have been made in recent years to remedy this issue, for example the use of high order advection schemes and modifications to model vertical coordinates. But we do not yet know if these efforts have solved the problem. Tools are needed to assess the effectiveness of these efforts, guide their implementation, and assure confidence in ocean models. Here we present a formula whose inputs are standard ocean model variables and whose output is the 3D distribution of the destruction of tracer variance by spurious numerical mixing. The formula is derived using the water mass transformation framework applied to tracer grid cells during a model's tracer advection step. We use the formula to determine rates of numerical mixing in a global configuration of the Modular Ocean Model version 6 (MOM6) and demonstrate how the formula can be used to distinguish between isopycnal and diapycnal mixing in any finite volume ocean model.

The effects of ocean dynamics on the melting of ice shelves: a fine-scale numerical simulation approach

Catherine Vreugdenhil, Bishakhdatta Gayen

University of Melbourne

Antarctic ice shelf melt rates are changing with important consequences for sea level rise. Ice shelf melting is modulated by turbulence in the ocean boundary layer, which acts to mix warmer and saltier water towards the ice base. Here, we consider numerical simulations to expand our knowledge of fine-scale ice-ocean interactions. These are high-resolution simulations of an ice face melting into the stratified ocean. The ocean dynamics show a complicated interplay between a turbulent buoyant meltwater plume, far-field stratification and double-diffusive effects. The application of these results to the real ocean system is also discussed, with implications for ice shelf melt rates.

Ocean surface vertical resolution controls Dense Shelf Water formation around Antarctica

Wilton Aguiar[1], Adele Morrison[1], Wilma Huneke[1], David Hutchinson[2], Fabio B. Dias[2], Paul Spence[3], Andy Hogg[1]

[1]Australian National University, [2]University of New South Wales, [3]University of Tasmania

The formation of deep and bottom waters in polar regions is a major control on oceanic carbon and heat uptake and is the main process that ventilates the deep and abyssal ocean. Nevertheless, ocean models often fail to accurately represent the formation of the two main dense waters that fill the deep and abyssal oceans, Antarctic Bottom Water and North Atlantic Deep Water (NADW). This study probes a model that has a good representation of dense water formation over the Antarctic continental shelf to investigate how sensitive the dense water formation is to the model configuration. In particular, we test how the thickness of the ocean top vertical layer alters the production of NADW and Antarctic Dense Shelf Water (DSW), a precursor of Antarctic Bottom Water. Several sensitivity studies were run with the ACCESS-OM2-01 and the MOM6 Pan-Antarctic ocean-sea ice models, with varying top cell thickness. We find that increasing the thickness of the top vertical layer decreases the rate of DSW production over the Antarctic continental shelf in both ACCESS-OM2 and MOM6, with a 60% decrease when the upper layer is increased from 1m to 5m thick. This result is insensitive to the choice of boundary layer mixing scheme, and occurs with both the K-profile parameterisation (KPP) and energetics based planetary boundary layer (ePBL) parameterisations. Ocean only, single column experiments show that the decrease in dense water formation is caused by a less dense surface layer in simulations with thicker surface cells. In contrast to the Antarctic region, in the North Atlantic Ocean the production of the densest NADW waters in the Labrador Sea increases as the top ocean cell thickens. We hypothesise that the differing responses between the Antarctic and North Atlantic dense water formation to vertical resolution is due to convection in the North Atlantic being driven primarily by heat fluxes, while convection at the Antarctic margins is primarily salt-driven.

Variability of Antarctic Dense Water Overflows Observed from Space

Matthis Auger

University of Tasmania

Around the Antarctic margins, dense water formed in coastal polynyas floods the bottom layer of the Antarctic continental shelf and overflows where the continental shelf break meets the shelf troughs. Being able to monitor these overflows from satellite observations would uncover the variability and the changes

in the bottom water production and export to the ocean depths. Here, we present a new method for understanding and observing dense water overflows variability using sea surface height (SSH) from satellite altimetry observation, including ice-covered regions. This method is evaluated in the Ross Sea region by cross-comparing these observations and outputs from global 0.1° ACCESS-OM-2-01 and regional 0.05° PanAntarctic model simulations of the Southern Ocean.

The simulations reasonably reproduce dense water overflows in the Ross Sea, which impact local steric height and SSH. By filtering out large-scale and long-period SSH variability, we can isolate the SSH signal related to dense water overflows. The strength of this SSH signal responds accordingly to changes in the rate of dense water export, even when subsampling the simulated SSH on the real observations. This suggests that we are able to monitor the variability of dense water export from the SSH variability at the overflow location. This approach can improve our understanding of the processes driving bottom water export from the Antarctic continental shelf to the ocean abyss and improve our ability to estimate the variability of the abyssal overturning circulation.

A comparison of wide-swath altimetry with an ensemble Kalman Filtering ocean forecast system

Gary Brassington

Bureau of Meteorology

Ocean forecast systems sequentially assimilate real-time in situ and remotely sensed observations. At present the observing system includes multiple platforms of nadir (narrow-swath) altimetry. The Bureau's ocean forecast system recently upgraded to use an Ensemble Kalman Filter method providing a more optimal use of the available observations compared with earlier methods and other international systems. Comparisons with drifting buoys against other international systems has quantified the leading forecast skill of the Bureau system. The Surface Water Ocean Topography (SWOT) mission has now successfully delivered the first products of wide-swath altimetry providing the first two-dimensional observations of sea-surface height anomalies. This independent observation is compared with the forecast system to show case the value of the observations, quantify the performance of the system and provide insights on where the largest gains in performance are likely to be found from their assimilation. Some attention will be given to the major current regions including the East Australia Current and Tasman Sea eddies with an opportunity to include independent field campaign in situ observations to extend the comparison.

Comparisons of CFOSAT SWIM Wave Measurements Against Wave Buoys

Marites Canto and Salman Khan

CSIRO

Radar systems are reliable and efficient means for obtaining measurements in remote and challenging but important oceanic environments like the Southern Ocean (SO). The surface waves investigation and monitoring (SWIM) scatterometer on-board the Chinese-France Oceanography Satellite (CFOSat) is a unique instrument dedicated to measure surface ocean waves at different incidence angles from 0° (nadir) to 10°. Meanwhile, wave buoys have been deployed that collect in situ wave measurements in the SO and other locations around Australia. In addition, an extensive wave buoy network in the northern hemisphere (i.e., NDBC) also exists. These buoys provide temporally rich observations but are limited to discrete point data across a vast spatial ocean. This study, thus, aims to compare collocated wave measurements (i.e., significant wave height, mean wave period, peak wavelength, and peak wave direction) from SWIM against wave buoys to understand how well these observations match up. Preliminary analyses showed promising results with strong correlations and small error (bias and root mean square error, RMSE) obtained for collocated wave observations in the SO and NDBC collection. These results will provide critical background information that could support efforts in developing a database of satellite-derived wave products for the SO and the Australian region.

Ocean modelling on GPUs with Oceananigans allows for ocean mesoscale-resolving climate projections

Navid Constantinou

University of Melbourne

Climate models must simulate hundreds of future scenarios for hundreds of years at coarse resolutions, along with a handful of high-resolution decadal simulations to resolve high-frequency variability and localized extreme events. I will showcase the ocean dynamical core of CliMA's new Earth Systems Model that was written from scratch. I will discuss how by taking advantage both latest hardware developments (graphical processing units or GPUs) and latest software (Julia programming language together with innovative algorithms for the barotropic solver) we achieve breakthrough performance. Specifically, we are able simulate the global ocean at 10 km horizontal resolution (~1/10 th degree) achieving 10 simulated years per day only using 64 GPUs (e.g., 16 nodes on Gadi). This immense economy of resources (about 50x less resources) compared to state-of-the-art ocean models that run on CPUs allows us to envision that routine climate projections with ocean components at the eddy-resolving 10 km resolution are within reach.

Modelling the ice edge wave-amplitude drop and its influence on the Antarctic marginal ice zone

Noah Day

University of Adelaide

The Antarctic marginal ice zone is frequently bombarded with large ocean surface waves generated by polar storms and cyclones over the open ocean. Waves create unique sea ice types (such as fractured floes and pancake ice) and keep the marginal ice zone unconsolidated. As waves propagate into the marginal ice zone, their energy dissipates through attenuation, while the diameter of floes (i.e., floe sizes) tends to increase. Recent mathematical and physical models indicate a sharp decline in wave amplitude upon encountering the edge of consolidated ice cover.

Our study introduces a novel approach by employing a frequency-dependent parameterisation to capture the abrupt reduction in wave amplitude as sea ice transitions from unconsolidated to consolidated states. This transition occurs at the point where the average floe size surpasses the dominant wavelength. The parameterisation is implemented in conjunction with a known attenuation rate of Antarctic sea ice to model wave propagation through the marginal ice zone. The wave propagation module is incorporated within the CICE6 sea ice model with wave forcing from a WaveWatch III hindcast to complete medium resolution (0.25-degree) experiments. When compared with a standard attenuation model variations in the marginal ice zone width are found, with deviations of up to 150 kilometres along specific longitudes, while the circumpolar-average widths remain relatively similar. Furthermore, we assess the respective contributions of atmospheric, ice, and wave conditions to the sectoral variability in the marginal ice zone width.

Impacts of Antarctic Summer Sea-Ice Extremes

Edward Doddridge

Australian Antarctic Program Partnership

Antarctic sea ice has experienced five extreme events in the last decade: three record lows, and two record highs. These extreme sea ice events have wide ranging impacts on the ocean, other cryospheric components, and the Southern Ocean ecosystem as well as far field repercussions. Extreme low summer sea ice results in an increased loss of multiyear fastice, increases in coastal exposure and changes the seasonality of the sea-ice cycle. Surface ocean warming during the summer is observed due to the ice-albedo feedback, resulting in changes to the rate of watermass transformation. We find that ice-shelf calving is correlated with sea-ice area, so that years with less sea ice show increased calving. Within the annual cycle, prolonged open water affects the seasonality of surface phytoplankton blooms. In addition, changes to the sea-ice seasonal cycle alter the input of iron from melting sea ice, subsequently modifying primary productivity. Under-ice algae are strongly affected by changes to the sea-ice coverage, and years with less ice show substantially reduced under-ice primary productivity. The impacts on higher trophic levels are complex, but include habitat loss and impacts on prey availability. The loss of coastal fast ice in the summertime causes logistical challenges for Antarctic fieldwork and resupply missions for Antarctic research stations. Changes in the sea-ice and fast-ice seasonality as well as in the physical properties of the ice have profound effects on coastal and ice-infested water operations, requiring increased observations and analysis of the ice conditions. Changing accessibility of the Southern Ocean may lead to renewed tensions around Antarctic treaty negotiations. Understanding the full impacts of recent, and future, sea ice extremes requires a broad observational network that spans the physical and ecological systems of Antarctica and the Southern Ocean.

Extremely normal; why ACCESS-OM2 missed the most remarkable Antarctic sea ice loss on record

Will Hobbs

University of Tasmania

2023 was the most remarkable year (to date) in the Antarctic sea ice record. It started with a record low minimum in February 2023, and continued onto a mid-winter sea ice extent that was 7 standard-deviations below climatology. The latter was all the more alarming since winter fluctuations tend to be quite small compared to summer. ACCESS-OM2 failed to capture any of that. In fact at all resolutions, OM2 faithfully captures the satellite Antarctic sea ice area (SIA) record up until 2017, highlighting the atmosphere's dominant role. Since 2018 though, the model has failed to represent the consistently low sea ice state, providing a serious barrier to understanding these important extreme events. In this talk, I will give an overview of how the model differs from the available ocean/sea ice observations, and comment on the observing network that is needed to reliably evaluate our model.

National-scale assessment of coastal hazards using both deterministic and probabilistic approaches in Vanuatu

Ron Hoeke[1], Vanessa Heranman[1], Bryan Hally[1], Emilio Echevarria[1], Claire Trenham[1], Sara O. van Vloten[2], Beatriz Pérez-Díaz[2], Jared Ortiz-Angulo[2], Laura Cagigal[2], Sonia Castanedo Bárcena[2], Fernando J. Méndez[2]

[1]CSIRO, [2]Universidad de Cantabria

Vanuatu experiences significant coastal inundation and erosion impacts from tropical cyclones (TCs), which are projected to increase in frequency and severity in future. Accurate assessment is challenging, however.

Ranges in local exposure to TC-induced storm tides and the rarity of their occurrence result in high statistical uncertainties when traditional deterministic approaches (those based on limited 20- to 50-year observation or simulation time periods) are used.

We address this via a national scale modelling system (using the unstructured mesh SCHISM-WWMIII model) which simulates the combined effects of tides, storm surge, waves, and background sea level (SL) variability. The system has been used to produce a 40-year deterministic hindcast as well as a "hybrid" Monte Carlo simulation approach, which uses libraries of thousands of "synthetic" TCs, allowing for probabilistic assessment of TC-related coastal hazards. Extreme value analyses of both the hindcast and the probabilistic approaches illustrates the value of both, particularly the utility of the latter to drastically reduce statistical uncertainties in TC-induced coastal hazard information.

Here, we provide an overview of this national modelling system, the coastal hazard/SL rise scenarios information it produces, and examples of how this information can be used to explore and investigate associated climate risks.

Assimilation of multi-platform remote sensing reflectance into a BGC model of the Great Barrier Reef

Emlyn M. Jones[1], Mark E. Baird[1], Mathieu Mongin[1], Roger Scott

[1]CSIRO

The waters of the global coastal ocean are sparsely observed by in-situ measurements and are optically complex, leading to difficulties in using Remote Sensing products to assess and constrain coastal biogeochemical (BGC) models. Skilful coastal BGC models are required to understand a range of phenomena such as changes in nitrogen and carbon cycles (e.g. nutrient pollution), effects of marine heatwaves (e.g. coral bleaching) and understanding the environmental response to critical incidents (e.g. oil spills). The refinement and constraint of BGC models through the assimilation of variables calculated from observed in-water inherent optical properties (IOPs), such as phytoplankton absorption, are problematic in the coastal ocean. The errors in these IOP based algorithms are greatest in shallow coastal regions, such as the Great Barrier Reef (GBR), due the additional signal from bottom reflectance and CDOM/TSS derived from river plumes. This study uses the CSIRO Environmental Modelling Suite (EMS, https://research.csiro.au/cem/software/ems/) to produce a simulated remote-sensing reflectance, that can be directly compared to an observed remote sensing reflectance. The difference between the simulated and observed remote sensing reflectance can then be used to constrain the BGC model. We demonstrate this approach using two assimilation methods (EnOI and EnKF) and assess the results against independent and withheld in-situ observations. The assimilation system reduces the forecast errors of remote sensing reflectance by up to 50%, when compared to a non-assimilating model. An assessment against withheld in-situ observations of Chl-a (HPLC pigments and Fluorescence), and nutrients shows a substantial improvement at many sites. The approach we are presenting here is a generalisable approach for the use of remote sensing data for assessing and constraining BGC models of the global coastal ocean.

Towards new insights into ocean eddy structure by combining models and observations over a period of unprecedented data richness (Sept-Nov 2023)

Colette Kerry, Shane Keating, Moninya Roughan

University of New South Wales

Mesoscale eddies are the "weather" of the global oceans with a myriad of societal and environmental impacts, yet their complex structure is poorly understood due to insufficient observations at suitable scales. A critical limitation of conventional satellite altimeters, and ocean models that rely on this data, is their

inability to resolve horizontal scales below O(50) km. The Surface Water and Ocean Topography (SWOT) mission provides the first ever synchronous 2D maps of sea-surface height, enabling the direct calculation of sea-surface height gradients and upper ocean currents at less than O(10) km resolution. O collected concurrently on board the RV Investigator provide a comprehensive 3-dimensional picture of eddy structure and eddy-eddy interactions.

Here we present new insights into eddy structure in the East Australian Current (EAC) gained by combining a state-of-the-art numerical model with ocean observations over a period of unprecedented data richness (Sept-Nov 2023). These include SWOT observations and in situ observations collected on the research cruise. We use a high-resolution (2.5-6km) numerical ocean model and 4-dimensional variational data assimilation to model EAC eddies (the South-East Australia Forecasting System). We begin by comparing our model estimates that assimilate traditional data streams: satellite derived SST and along-track SSH and (sparse) profiling floats, with the new observations in the context of surface and subsurface eddy structure. We reveal new information on eddy surface structure revealed by SWOT and how this translates below the surface. Preliminary results towards the challenge of assimilating the spatially-dense and temporally-sparse SWOT data are also presented.

A Vortex-Force formalization implementation for unstructured COMPAS-SWAN coupling system— A Case Study Along Select Areas of the Australian Coastline

Cagil Kirezci, Mike Herzfeld, Farhan Rizwi, Vanessa Hernaman, Ron Hoeke

CSIRO

We introduce a two-way coupled unstructured wave-flow model based on vortex-force formalization. This study integrates the hydrodynamic COMPAS model (Coastal Ocean Marine Prediction Across Scales, Herzfeld et al., 2020) with the SWAN wave model (Booji et al., 1999). COMPAS is a versatile unstructured 3D hydrodynamic model applicable to various scales, from estuaries to regional ocean domains. It operates on an unstructured variant of the Arakawa C-grid, with normal velocity components staggered at the edges of Voronoi cells, and fluid height and tracer variables located at each cell. The coupling is achieved by incorporating SWAN as a library object, with COMPAS linking to this library using C interoperability protocols. This results in a highly efficient numerical coupling without the need for an additional coupler.

In the present work, we have incorporated the effects of waves on currents (WEC) within an Eulerian reference frame by introducing contributions from conservative forces, specifically Stokes drift and wave-induced pressure, as well as non-conservative wave forcing, including bottom friction, whitecapping, and depth-induced wave breaking. To accurately represent the impact of WEC terms across realistic broadband spectra, the WEC terms are computed using 2D directional wave spectra, diverging from the traditional approach of relying on averaged wave parameters or a monochromatic approximation.

We have rigorously tested our model across diverse wave and hydrodynamic conditions spanning various regions along the Australian coast. Validation against observational data has shown promising results, indicating the model's efficacy. Leveraging the advantages of unstructured meshing, we were able to capture the nearshore impacts of dissipation parameters, including bottom friction and depth-induced wave breaking, particularly evident in surface elevation simulations.

ACCESS-OM3: progress and roadmap for Australia's next-generation global ocean - sea ice - wave model

Andrew E. Kiss[1], Andy McC. Hogg[1], Micael Oliveira[1], Dougie Squire[1], Ezhilsabareesh Kannadasan[1], Anton Steketee[1], Minghang Li[1], Siobhan O'Farrell[2], Pearse Buchanan[1,2]

[1]Australian National University, [2]CSIRO

I will present an overview of the development, initial results and future plans for ACCESS-OM3, a multi-resolution global coupled ocean - sea ice - wave model suite. This is being developed by COSIMA and ACCESS-NRI as a successor to ACCESS-OM2, which has been widely adopted in Australia, underpinning over 75 papers since its introduction in 2019. The new ACCESS-OM3 couples the latest MOM6 ocean, CICE6 sea ice and WaveWatch 3 surface wave models, bringing Australia's modelling capability up to date with the leading edge of international development. These upgraded model components enable representation of ice-ocean-wave interactions, landfast sea ice, a floe size distribution that evolves in response to wave breaking, circulation in cavities under ice shelves, and more flexible ocean vertical discretisation with reduced numerical diffusion and improved representation of bathymetry. The ocean and sea ice biogeochemistry are also more detailed and efficient. A suite of configurations at resolutions ranging from 1° to a planned 1/25° are being developed; the 1° and 0.25° configurations are also being coupled with UM-CABLE atmosphere and land surface components to form the ACCESS-CM3 and ACCESS-ESM3 climate and Earth system models intended for Australia's CMIP7 submission.

Oceanic teleconnections from the tropics to the Southern Ocean

Zhi Li[1], Ivana Cerovečki[2], Sjoerd Groeskamp[3] Alexander Haumann[4,5] and Matthew H. England[1]

[1]University of New South Wales, [2]University of California, [3]NIOZ Royal Netherlands Institute for Sea Research, [4]Helmholtz Centre for Polar and Marine Research, [5]Ludwig-Maximilian-University Munich

The Southern Ocean is one of the most quickly warming and freshening areas of the Earth system due to anthropogenic heat. It connects three major ocean basins via the ACC, driving the transports of heat and carbon that shape Earth's climate. In this study we use observationally based data to examine the oceanic teleconnections from the tropics to the Southern Ocean along a pathway of ITF – SEC– Agulhas Current – ACC. Our analysis reveals the propagation of ITF water and its interannual variations into the Southern Ocean along this pathway, taking approximately 2–3 years from the Indonesian exit passages to the Agulhas Retroflection region. The Agulhas water and the ACC water combined to govern the temperature-salinity pattern of downstream ACC waters in western Indian Ocean. Strong quasi-biennial variability is revealed in the western Indian Ocean mixed-layer depth (MLD) and Sub-Antarctic Mode Water (SAMW) volume and properties. These variabilities introduced in the western Indian Ocean are advected eastward and re-emerge in the eastern Indian Ocean in approximately one year, reaching the southeast Pacific in 4–5 years and further to the east of Drake Passage one year later, with a propagation speed of around 40–55 degrees longitude per year.

Linking empirical data and Oceanographic Models to Enhance Marine Plastic Pollution Management

C. Gaby Mayorga Adame, Moninya Roughan, Jordan Gacutan

University of New South Wales

Plastic pollution poses a significant threat to health of coastal ecosystems and related economic activities. Efficient and effective mitigation strategies require an understanding of plastic pollution dynamics at scales relevant to management. Observational data sets of plastic debris collected at the beach are useful, however observational studies identify the spatial and temporal disconnect between the source of pollution and the receptor as one of the main caveats of their approach. Lagrangian particle tracking coupled to ocean circulation modelling has the potential to fill in this disconnect.

Here, as a proof of concept we used a daily climatology of currents of a high-resolution coastal ocean circulation model (SEA-COFS) to backtrack particles from the coast, in order to identify potential marine sources and pathways of plastic debris. To add some realisms to the simulation the number of particles released is scaled by the density of plastic debris collected along the beaches of Southeast Australia over two decades.

Model results, juxtaposed with extensive empirical datasets, offer unprecedented insights into plastic pollution patterns within the complex coastal ecosystems of Southeast Australia. By identifying key plastic sources and their connections our results provide actionable intelligence for policymakers. This study underscores the value of regional oceanographic modelling as a tool to address plastic pollution for sustainable coastal management.

Simulated dynamics of Circumpolar Deep Water properties in the Southern Ocean

Hangyu Meng, Wilma Huneke, Wilton Aguiar, Andy Hogg, Adele Morrison, Hannah Dawson

Australian National University

Circumpolar Deep Water (CDW) is the warmest water mass in the Southern Ocean. Onshore transport of CDW contributes the most to heat transport to the Antarctic continental shelf. Observations indicate CDW has warmed, possibly explaining an increase in onshore heat transport and an acceleration of Antarctic ice shelf melting in recent decades. There are plenty of dynamical mechanisms which could affect CDW warming, e.g., changes in ocean heat content, surface wind stress, upwelling, and large scale ocean circulations. However, because of sparse observations and the complexity between these dynamics and CDW, it is unclear what processes lead to CDW warming around the Southern Ocean. In this study, we use the high resolution, coupled ocean-sea ice model ACCESS-OM2-01 to understand mechanisms on changes in CDW. Spatially variable normalities from the high anthropogenic-emissions scenario (SSP5-8.5), projected by 22 CMIP6 models are forced in ACCESS-OM2-01. Then the thermal, wind, and thermal+wind perturbation experiments are conducted individually. Between these experiments, we find a warming signal of CDW in the thermal perturbation experiment, and cooling signal in the wind forcing case offshore in the Southern Ocean. The results highlight that prolonged global warming plays a dominant role in warming of CDW, while enhanced wind field can reduce future's warming of CDW.

Does the Antarctic Slope Current control ocean heat transport towards Antarctica?

Adele Morrison

Australian National University

Increased ocean heat transport towards Antarctica directly drives melting of ice shelves, leading to sea level rise and reduced dense water formation. A common dynamical assumption is that poleward heat transport across the Antarctic continental slope is controlled by the strength of the Antarctic Slope Current (ASC), which is thought to act as a barrier to heat transport. However, the relationship between poleward heat transport and the ASC has not been examined in detail. Here, using a global, eddy-rich ocean – sea ice simulation, we find that the strength of the relationship varies significantly across different ASC regimes, with local correlations between ASC speed and cross-slope heat transport ranging from $r^2 < 0.1$ to $r^2 > 0.8$. In the temporal domain, the relationship between the ASC and heat transport is strongest on seasonal and interannual timescales, with surprisingly low correlations at high frequency, eddy timescales. Our results suggest that the relationship between ASC strength and poleward heat transport may not be as simple as is often assumed. Even for regions and timescales with a strong relationship, it remains an open question whether a strong ASC is dynamically limiting the heat transport, or whether both quantities are responding concurrently to external forcing.

Developing a Framework for a sustained NT Fishing Ocean Observing Network

Ruth G Patterson[1,2], Deepak Pazhayamadom[3], Veronique Lago[4], Moninya Roughan[4]

[1]Elysium EPL, [2]Charles Darwin University, [3]Northern Territory Government, [4]University of New South Wales

For at least two decades there has been growing concern amongst the fisheries industry and marine science community that ocean variables are not well-monitored across the Northern Territory (NT) and 'Top End'. This limits our understanding of how climate change will impact the sustainable management of fisheries and enhance Indigenous commercial aquaculture business opportunities. To address this, the NT Government Fisheries division has recently invested in a national ocean temperature profiling pilot project, Fishing Ships Of Opportunity Program ('Fish SOOP'), which deployed temperature/pressure sensors onboard seven NT-based fishing vessels. This initiative increased the number of ocean temperature profiles in the region from almost zero, to over 3000 profiles (350,000 data points) during a nine-month period, demonstrating its potential as a high-impact and low-cost monitoring program. To ensure this effort is sustained and aligns with local needs and values, we aim to (1) compile potential applications for the data within and beyond the NT fisheries industry, and (2) Develop a framework that can be used as a roadmap for a long-term NT fishing ocean observing network. This network will provide data and applied management opportunities in the NT, bolstering NT representation and inclusion in national and international ocean monitoring and management efforts.

Improved ocean dynamics using observational data products and models

Beatriz Pẽna-Molino, Bernadette Sloyan, Chris Chapman

CSIRO

We will introduce several published gridded ocean observational data products that can be used with ocean models to investigate ocean dynamics across local, regional and global scale from daily to decadal time scales. The observational data products are freely available and provide observational data sets that have been produced to enable easy comparison to ocean model data. The data products we will discuss include the East Australian Current mooring and gridded data products available from the CSIRO Data Access Portal and the GO-SHIP Easy Ocean available from the GO-SHIP data portal hosted by Scripps CCHDO and the ACCESS OM2 and BRAN2020 models.

The combination of in situ observation data products and models will enable a more complete understanding of the ocean dynamics and highlight key difference that will lead to both future model developments and observational requirements.

Tracking Western Australia's boundary current connections to the deep ocean

Helen Phillips[1,2,3], Meng Han[1], Nathan Bindoff[1,2,3], Ming Feng[4], Ryo Furue[5]

[1]University of Tasmania, [2]Australian Antarctic Program Partnership, [3]Australian Centre for Excellence in Antarctic Science, [4]CSIRO, [5]JAMSTEC

The Leeuwin Current System (LCS) and South Australia Current System (SACS) are conduits for watermass transport along the Australian coastline between the tropical-subtropical Indian Ocean and the Southern Ocean. The LCS and SACS host zonal and meridional overturning circulations that funnel offshore waters toward Australia, drive downwelling from shallow, poleward (eastward) flows – the Leeuwin Current and South Australian shelf break currents – to deeper undercurrents that flow equatorward (westward) - the Leeuwin Undercurrent and Flinders Current.

The shallow currents bring fresh Indonesian Throughflow water and saltier Indian Ocean tropical and subtropical waters as far south as Tasmania. The undercurrents carry Subantarctic Mode Water and Antarctic Intermediate Water to the tropical Indian Ocean. The CARS 1/8-degree observational climatology and 1/10-degree model simulations agree on the mean and seasonal cycle of the circulation and volume transports of the LCS and SACS.

Repeat occupations of a hydrographic line along 110ºE reveal substantial physical and biogeochemical change in the shallow inflow to, and deeper outflows from, Western Australia. We suggest that Australia's weaker currents along its southern and western coastlines, of which there is no routine monitoring, may play a significant but unquantified role in the Indian Ocean overturning circulation.

Tidal constituents' evolution and its implication for tide prediction around Australia using ANCHORS tide gauge dataset

O.Richet, R. Holmes, C. Spillman, G. Smith, B. Hague, J. Chittleborough

Bureau of Meteorology

In coastal areas, astronomical tides are often the main driver of sea level variability and thus contribute to both high and low water extremes along with other processes such as storm surges and waves (setup and runup), interannual and interdecadal variability and sea level rise. Hence, harmonic tide predictions are an essential factor in the development of any robust sea level prediction. However, the accuracy and utility of a tide prediction depends on a range of subjective choices. For example, the choice of whether to perform the tidal analysis year-on-year or over a long multi-decadal baseline period changes the resulting tidal prediction by including/excluding various constituents. Tidal analyses of multi-year time series allow us to isolate closely located constituents which cannot be fully captured by the year-on-year analyses and to identify long tidal cycles. Here we perform a tidal analysis using these 2 different methods across the Australian tide gauge network to give an overview of the tidal dynamics around Australia. With the year-on-year tidal analysis we capture variations in constituent amplitude due to, for example, sedimentation/erosion, changes in mean sea-level, and sea-level rise, allowing us to track constituent change over years, in contrast with the long-term tidal analysis.

The South East Australian Coastal Ocean Forecast System (Sea-COFS)

Moninya Roughan, Colette Kerry

University of New South Wales

The East Australian Current flows along South-Eastern Australia, where 80% of the population lives impacting the weather, climate and ocean productivity. It is a dynamic and variable eddy dominated system, therefore coastal models and predictions are fundamental to inform the sustainable use of marine resources. The South East Australian Coastal Ocean Forecast System (Sea-COFS) is a new initiative to integrate high resolution operational ocean observing and modelling programmes with forecasting capabilities within the ACCESS-NRI framework. This project will combine cutting edge ocean sensing and advanced numerical modelling to provide an open access high resolution ocean forecast system the EAC to make meaningful predictions about the state of our coastal oceans along SE Australia. This programme, which has been endorsed by the UN Ocean decade for Ocean Sciences will create a new, dynamic and more integrated knowledge base – reducing uncertainty, maximising opportunity, and preparing for future ocean changes.

Bluebottles: drifting behaviour and ocean pathways to the shore

Amandine Schaeffer[1], Natacha Bourg[2], Anne Molcard[2], Daniel Lee[1], Luca Ferraro[1], Moninya Roughan[1], Christopher Luneau[3]

University of New South Wales , [2]USTV Toulon, [3]Aix-Marseille Universite

Understanding the drifting patterns of bluebottles (Physalia physalis) in the ocean is crucial for accurately predicting and mitigating the painful stings experienced by beachgoers. Bluebottles float at the ocean's surface due to their gas-filled sail, advected by currents and pushed by winds. Notably, their asymmetrical morphology results in varying drift angles relative to the wind.

We present an experimental parametrisation of the bluebottle's drift in response to wind obtained in a controlled lab, which is then used in numerical Lagrangian modelling. Based on 10 month observations of beached bluebottles, we investigate their likely pathway in the ocean before they reached Sydney.

Three quarter of virtual bluebottle particles originated from the North a month before reaching Sydney. Interestingly, left-handed particles, which drift to the right of the wind direction, were twice as more likely to have come from Queensland.

Our investigation aims to delineate the respective contributions of ocean currents and winds in guiding bluebottles towards coastal areas. In particular, we analyse the impact of the East Australian Current, local coastal winds, and offshore storms. This analysis sheds light on the intricate dynamics governing bluebottle distribution in oceanic environments, a first step towards the predictability of large swarms.

Resolving Antarctic Bottom Water pathways in Australian-Antarctic Basin

Polina Sholeninova

Australian National University, CLEX, ACEAS

Antarctic Bottom Water (AABW) is a cold, dense water mass originating around Antarctica that fills the abyssal global ocean. Recent studies have reported warming, freshening and thinning of the AABW layer globally and especially in the Australian- Antarctic Basin. AABW in the Australian-Antarctic Basin is sourced from the Ross Sea and the continental shelf ol Adélie Land. Observations near the overflows show that the export transport of Ross Sea bottom water is much larger than that of Adélie Land bottom water. However, in the abyss observations show that Adélie Land bottom water dominates over much of the Australian-Antarctic Basin. To understand this inconsistency, we examine the transport and water mass evolution along the bottom water pathways using the ACCESS-OM2-01 model. The modelled pathways and fraction of each type of bottom water generally agree with Deep Argo data and provide a more comprehensive picture compared with the scarce observations. The results show that a substantial amount of Ross Sea bottom water recirculates eastward to the Pacific sector before it reaches the Australian-Antarctic Basin. It also undergoes significant mixing along its way and becomes lighter than Adélie Land bottom water, occupying lighter density layers before the water masses mix into AABW.

Seasonality of surface currents in the northwest off Australia elucidated from surface ocean drifters.

Prescilla Siji & Charitha Pattiaratchi

University of Western Australia

Drifting objects have been utilised as a practical method for several decades to understand the nature of the ocean surface currents. With the invention of satellite tracked GPS, this approach has significantly advanced and offers a more comprehensive understanding of the spatial and temporal aspects of the ocean surface currents. In the northwest region off the coast of Australia over 150 such drifters were deployed from 2020 to 2022. This data is used in this study to examine the Lagrangian characteristics of the ocean surface currents. This extensive deployment revealed the prominent mean currents in the region, ie, the South Equatorial Current and the seasonally reversing South Java Current. Furthermore, our drifters could capture the variability in the surface currents which were not always captured in the satellite observations of ocean surface current data. These include the variability with different periods of oscillations in association with tides, inertial currents, and eddies. The drifters also revealed a region of higher mixing which is in agreement with the higher kinetic energy imagery from satellite data. Seasonality in response to changes in the wind field associated with the surface currents also will be addressed in this talk.

Implementing Sea Ice Thermodynamics from Laboratory Experiments into CICE

Kial Stewart & Callum Shakespeare

Australian National University

Sea ice exists in some of the most inaccessible, inhospitable, and extreme environments on Earth, meaning direct observations of sea ice are scarce, biased, and uncertain. This dearth of in situ sea ice observations inhibits our knowledge of the complex, finescale thermodynamic properties of sea ice and their accurate representation in numerical sea ice models. These properties – which include the temperature, salinity, brine fraction, porosity, and thermal conductivity – control how rapidly sea ice grows, to what thickness, and how rapidly it melts in the spring. Here we employ a novel laboratory apparatus to grow sea ice in controllable conditions and directly measure its thermodynamics under a wide range of atmospheric forcings. The sea ice thermodynamics model obtained from the experiments exhibit substantial differences to existing models. We implement these new sea ice thermodynamics into the CICE model in ACCESS-OM2, and investigate their impacts on the sea ice and ocean fields.

A machine learning approach to rapidly downscale sea surface temperature extremes on the Great Barrier Reef

Ajitha Cyriac & Chaojiao Sun*

*Presenting author

CSIRO

Over recent decades, Australia's iconic Great Barrier Reef (GBR) has experienced increasing mass coral bleaching events driven by climate change. Reef-scale climate projections are critical to guide the development of effective intervention strategies. We have successfully developed a machine learning (ML) model based on a super resolution deconvolutional neural network to rapidly downscale sea surface temperature (SST) on the GBR. When downscaling 80 km data to 10 km resolution, the ML model captures the spatial variability of SST and extreme thermal events significantly better than a conventional interpolation method. We have applied this model to independent datasets from both current and future

climates to demonstrate its robustness. With its ease of implementation and low computational cost, this ML model could be used to rapidly downscale multiple climate model outputs under different scenarios to provide robust local climate data on the GBR or trained to provide climate projections for other coral reefs around the world to improve environment management.

An Autonomous Observation System for RSV Nuyina to Measure Ocean and Sea Ice Surface Properties

Ippolita Tersigni, Filippo Nelli, Petra Heil, Luke Bennetts, Giulio Passerotti, Alessandro Toffoli

The University of Melbourne, The University of Adelaide

We present a novel approach to enhance observation capabilities in the remote and challenging environments of the Southern Ocean and Antarctic sea ice. By deploying a comprehensive camera system aboard the RSV Nuyina, Australia's Antarctic icebreaker, we address the limitations posed by satellite constraints and insufficient field observations. The system forms part of the Ocean-Sea Ice-re [OSIA] Underway Observatory and consists of seven strategically positioned cameras to capture data across visible, near-infrared, and infrared ranges. Specifically, four industrial cameras record grayscale images of the ocean surface, in the visual range: one sensor is dedicated to capturing sea ice conditions such as the type of ice, the sea ice concentration, and the floe size distribution; one optical zoom camera monitors the sea ice thickness observing overturning ice floes broken by the ship during icebreaking operations; and a synchronized pair of sensors to reconstruct the three-dimensional features of the wavy surface in open ocean and sea ice. In addition, there is one infrared sensor to sense the sea and sea ice surface temperatures and two multispectral cameras to extrapolate information on snow properties, melt ponds, wave overwash, and spatial signatures of primary production on sea ice. Integration of this camera system represents a significant advancement in observational capabilities, offering a comprehensive view of the surface Southern Ocean and sea ice dynamics. We demonstrate the capabilities of the system by the first ever showing processed for the first time images of the same portion of the surface through multiple wavelengths in both the open ocean and sea ice environments. Comparison with available collocated satellite information is also presented and used to discuss the advantages and disadvantages of the observational system.

Modeling ocean interior dynamics at high-resolution in the ACC meander south of Tasmania, toward the assimilation of SWOT observations

Y.-T. Tranchant, P. Sandery, C. Langlais, B. Legresy

AAPP, University of Tasmania, CSIRO

The Southern Ocean and its main component, the Antarctic Circumpolar Current (ACC), have a key role in the heat and carbon uptake and transport, with hotspots occurring where the current interacts with topographic features. In recent times, more and more studies have pointed out the key role of small-scale ocean processes in driving vertical exchanges, heat transfer and carbon uptake in the ACC.

Launched in December 2022, the new SWOT satellite (NASA/CNES) provides high-resolution Sea Surface Height (SSH) observations, offering an unprecedented view of the small-scale ocean eddies and fronts that are associated with significative vertical velocities. However, these observations are limited to the ocean surface, necessitating efforts to link the signature observed at surface to vertical dynamics.

This study presents the implementation of a regional high-resolution implementation of the SHOC circulation model and examines its performance in reproducing ocean interior dynamics within an ACC meander south of Tasmania. The model dynamics (horizontal and vertical) is assessed over a range of spatial scales

using wavenumber spectral analysis and validated against an array of in-situ datasets acquired during the RVI SWOT voyage in November/December 2023. Then, we present first conducted SWOT assimilation experiments with the aim of quantifying the impact on ocean interior dynamics and vertical fluxes within the meander.

Implementing an automated relocatable wave-flow coupled coastal hydrodynamic forecast model

Claire Trenham, Ben Leighton, Blake Seers, Paul Branson, Bryan Hally, Vanessa Hernaman, Ron Hoeke, Edward King, Cagil Kireczi, Tim Leeson, Simon Pigot, Tracey Pitman

CSIRO

The CSIRO Relocatable Ocean Atmosphere Model system includes regional ocean (SHOC), wave (SWAN), atmospheric (CCAM), and high-resolution surf-zone (XBeach) models. We have prototyped a littoral-zone wave-flow coupled model (SCHISM-WWMIII) for inclusion in the ROAM suite. SCHISM-WWMIII utilises an unstructured computational mesh and semi-implicit numerical solvers, which can achieve high accuracy at relatively low computational cost. We implemented SCHISM-WWMIII to simulate water levels, currents and waves in the Great Barrier Reef region. After tuning the model using hindcast forcing, we automated preparation of model run spaces using Python via Airflow every 12 hours to create a 24hr “nowcast” and 72hr forecast, utilising forcing from the Bureau of Meteorology for winds, water levels and waves. With automation of model run configuration and execution we produced outputs which validated well against observations. This output can be used as forcing data for high-resolution surf-zone modelling. Current limitations are a requirement for high quality bathymetry, fine-tuning of the model mesh, and physics tuning for optimal performance. We expanded the `rompy` python package to streamline model preparation. We ran this model forecast cycle in July-September 2023, and December-February 2024 to assess the model’s performance between seasons, including TC Kirrily incursion.

Implementing and evaluating a novel tidal wave drag parameterisation in MOM6

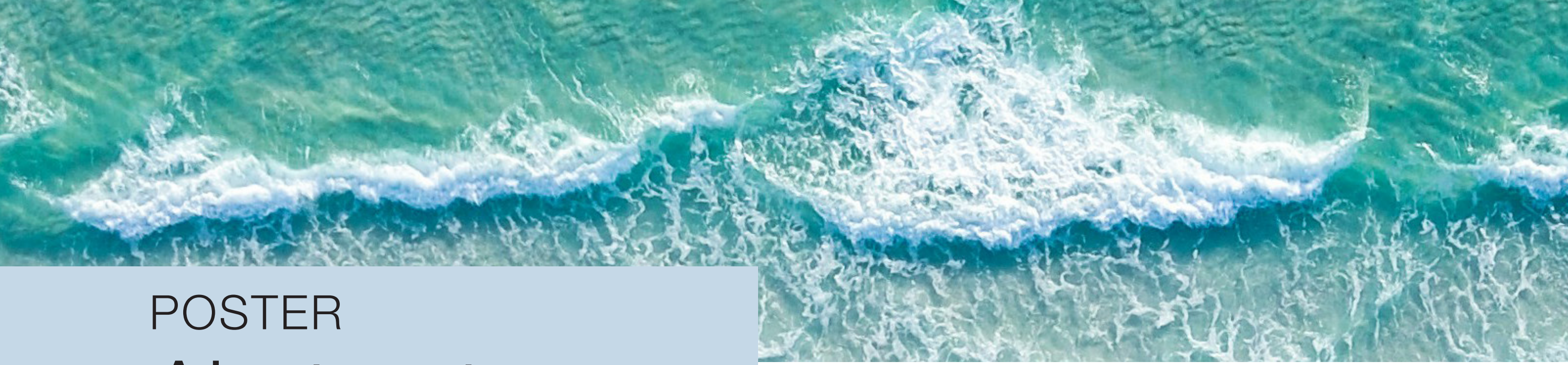
Luwei Yang[1,2], Callum Shakespeare[1,2], Adele Morrison[1,3,] Andy Hogg[1,2,4], Angus Gibson[1]

[1]RSES, Australian National University, [2]CLEX, [3]ACEAS, [4]ACCESS-NRI

Tides modify sea surface height up to a few meters near the coast. However, the tidal elevation is not accurately reproduced by ocean models. The discrepancy between observed and modelled tidal elevations (i.e. the tidal elevation error) indicates an inaccuracy in simulating tidal energy, likely resulting from an incomplete representation of tidal energy dissipation. This error is particularly large in the shelf regions, such as the northwest and northeast shelf regions of Australia and around Antarctica, where it exceeds 10 cm. Improving the representation of tidal energy dissipation in ocean models is thus crucial for reducing the tidal elevation error and for improving sea level prediction, particularly in the shelf regions.

The generation of internal tides due to tide-topography interaction accounts for 25% of tidal energy loss through anisotropic wave drag at the corresponding tidal frequencies. In regions where the tidal frequency is super-inertial (equatorward of the critical latitude), wave drag results in tidal energy dissipation. Poleward of the critical latitude, wave drag becomes sub-inertial and is out-of-phase with the tidal velocity, resulting in zero net tidal energy dissipation. However, it still modifies tidal energy over the tidal period analogous to a spring force, potentially affecting tidal elevation.

Currently, the wave drag parameterization in MOM6 is frequency-independent, isotropic, and lacks a sub-inertial component. To improve the simulation and future prediction of barotropic tides in MOM6, we implement a frequency-dependent, anisotropic wave drag parameterization that includes both super-inertial and sub-inertial components of the wave drag for a given tidal frequency. The parameterization introduces frequency-dependence, anisotropy, and sub-inertial component of wave drag one at a time. At each step, we run a 1-layer tide-only global ocean model at semidiurnal (M_2) and diurnal (K_1) frequencies, respectively, with the modified wave drag parameterization. We then compare across steps and evaluate the importance of frequency-dependence, anisotropy, and the sub-inertial component for the tidal energy dissipation and for reducing the tidal elevation error.



POSTER

Abstracts

Recent changes in the Agulhas Extension meander field

Christopher Aiken

IMAS, CLEX

Three decades of satellite altimetry reveal that the largest trends in sea surface height (SSH), far exceeding the thermal expansion signal, occur in a number of the Western Boundary Current Extensions, suggesting translation of their sharp meridional SSH gradients, and hence of the jet cores. In the Agulhas Extension (AE) – the WBCE of the southwest Indian Ocean whose jet has a marked standing wave pattern in the mean - the SSH trends take the form of a remarkable zonal wave pattern along the jet axis, where meander amplitudes are increasing upstream but decreasing further downstream. We demonstrate that this result is actually due to variations in the zonal location of the meanders, and present empirical analysis that links the upstream growth to the apparent downstream decay. We then run through the various suspects for driving the changes – wind, density, inflow.

Methods for Interpolation of Ice Thickness Distributions in Sea-Ice Models

Stewart Allen, Pavel Sakov, Gary Brassington

Bureau of Meteorology

The finite spatial resolution of Eulerian sea-ice models means each model grid cell can contain a mixture of open, ice-free water and sea ice of varying thickness and character. The usual approach is to discretise the distribution of sea-ice thicknesses into several thickness categories. The mass balance of sea ice across the thickness categories is governed by equations that describe the area and volume of ice in each category and the transfer of ice between them due to a range of processes.

Choosing an appropriate number of thickness categories and the range of sea-ice thicknesses spanned by each category is non-trivial, especially as the evolution of sea ice can occur on multi-year timescales. A standard configuration for climate studies is often assumed, but with sea-ice models increasingly being used for high-temporal and spatial simulations, a larger set of thickness categories might be required or desired.

This presentation describes two methods that allow the number of thickness categories in an existing sea-ice simulation to be changed. Both methods conserve the total mass of sea ice in each grid cell and estimate a new category-based sea-ice distribution using zero-order and first-order interpolation techniques. Once an estimate of the thickness distribution with the new set of categories is known, other quantities, such as the ice entropy, internal salinity, and overlaying snow, can be proportioned across the new thickness categories.

Both methods have application to sea-ice models at any domain size and resolution and removes the need for costly model spin-up, should a new set of thickness categories be adopted. They have been developed and applied to CICE5 within COSIMA's ACCESS-OM2 ocean and sea-ice coupled model but are readily adaptable to any sea-ice model that follows a similar category-based discretisation of the ice thickness distribution, such as the LIM, SIS and SI3 sea-ice models. However, adaptation to sea-ice models with an ice-floe size distribution, such as CICE6, present a challenge.

Impact of Coastal Ocean and Weather Dynamics on Ocean Alkalinity Enhancement

Harris Anderson

CSIRO

Ocean alkalinity enhancement (OAE) is an emerging marine carbon dioxide removal technology, which increases ocean pH and allows for the uptake of additional atmospheric CO2. As global interest in OAE increases and deadlines for emissions targets get closer, understanding the OAE capacity in Australian waters is becoming increasingly critical. Here we present results from alkalinity point-source addition scenarios in Tasmanian coastal waters using a high-resolution coupled hydrodynamic-biogeochemical model. Conservative rates of alkalinity addition are estimated based on renewable energy generation in Tasmania and the energy consumption of sodium hydroxide (NaOH) generation by electrochemical methods. We then assess the rate-dependent likelihood that coastal waters are impacted by alkalinity addition finding a suitable addition rate within the above parameters. Local wind and tide conditions are shown to strongly influence dispersal rates and the areal impact of the alkalinity plume. Model results indicate that within weeks to months, the carbon sequestration efficiency of coastal waters in Tasmania is comparable with that of global circulation model studies.

Zonal Wave-3 impact on subpolar Southern Ocean dynamics

Matthis Auger

University of Tasmania

The Zonal Wave 3 (ZW3) mode is the most prominent meridional-wind mode over the Southern Ocean, characterized by three pairs of cyclonic and anticyclonic atmospheric features. This mode is variable in both magnitude and phase, with significant implications for the direction and strength of meridional winds, with strong impact on sea ice cover.

In this study, we assess the response of the subpolar Southern Ocean to various phases of strong ZW3 patterns using the ACCESS-OM2-01 model. Our experiments are designed with ZW3-like perturbations derived from historical JRA-55 records and applied to a repeated-year atmospheric forcing. The phase of the ZW3 perturbation markedly influences sea ice concentration. We further explore how these anomalies in wind and sea ice affect the dynamics of the subpolar Southern Ocean, including the dynamics of the marginal ice zone, the access of Circumpolar Deep Water to the continental shelf, and the formation of dense water.

The response of oceanic meridional heat transport to varying surface forcing

Dhruv Bhagtani, Andrew McC Hogg, Ryan M Holmes, Navid C Constantinou

Australian National University

The ocean gains thermal energy in the tropics and loses energy by radiation at polar latitudes. Radiative equilibrium necessitates a net transport of heat from lower to higher latitudes. To achieve this balance, the large-scale ocean circulation, fuelled by a combination of winds and surface buoyancy fluxes, carries a peak of 1.5-2 PW of poleward heat. However, the relative influence of winds and surface buoyancy fluxes in maintaining the local meridional heat transport is not well understood. Moreover, both of these surface forcings and, consequently, the meridional heat transport are expected to readjust in the wake of climate change. Through a series of eddypermitting global ocean model simulations, we aspire to quantify better the relative contribution of wind stress and surface buoyancy fluxes in carrying the meridional heat transport through anomalies in the ocean circulation. We perturb the atmospheric forcing by varying wind stresses and/or surface buoyancy fluxes and attempt to decompose the meridional heat transport due to the large-scale ocean circulation into meridional overturning circulation and gyres. We find that the meridional heat transport, dominated by the strength and the near-surface temperature of the Gulf Stream, responds to varying surface forcing on different timescales.

A NEMO-based EnKF global ocean data assimilation system

Chris Bladwell, Pavel Sakov, Frank Colberg, Stewart Allen, Saima Aijaz, Gary Brassington

Bureau of Meteorology

The Bureau of Meteorology currently runs a MOM5 based operational ocean forecasting system, (OceanMAPSv4.0i). A full global ocean-sea ice system based on ACCESS-OM2-0.1 (developed by COSIMA), is currently being tested for future operationalisation. Both operational and future systems use the model agnostic, public Ensemble Kalman Filter (EnKF) data assimilation software (EnKF-C). As part of the Bureau's strategy to adopt a unified NEMO-based forecasting system across all ocean and coupled modelling applications, we have developed a next generation EnKF data assimilation system. Here we present results from a NEMO-based 2-year test ocean reanalysis which uses the Global Ocean and Sea Ice 9 model (UK Met Office) at 1/4-degree resolution, forced with the ECMWF Reanalysis Version 5.0. Initial results from this system show encouraging performance for ocean and sea ice variables compared to OceanMAPSv4.0i, OceanMAPSv4.2, and other ocean forecasting systems. It is particularly noteworthy for subsurface temperature and salinity, substantially outperforming the high-resolution EnKF reanalysis based on OceanMAPSv4.0i. Further, it is assuring to see that the estimated states of unobserved model fields such as ocean currents are overall consistent across the different EnKF systems. The work presented here may be used to assimilate ocean and sea-ice observations in future numerical weather prediction and seasonal forecasting systems, which will be developed in partnership with the UK Met Office.

Sensitivity of the poleward heat transport at the Antarctic margin to model resolution and tides

Fabio Boeira Dias

UNSW, ACEAS

Understanding oceanic heat transport towards the Antarctic margin is crucial for assessing the impacts of ocean-driven basal melting on Antarctic ice shelves. Despite the significant role of basal melting in the mass loss of the Antarctic Ice Sheet over recent decades, our understanding of these mechanisms remains limited, primarily due to observational and modelling challenges in this region. In this ongoing study, we investigate the mechanisms driving ocean heat transport across the continental slope (1500m) and the ice shelf calving front, utilizing simulations with the circum-Antarctic ocean-ice shelf model WAOM. We are currently decomposing the cross-contour heat transport into mean and eddy components to explore the effects of mesoscale eddies, tidal forcing, and model horizontal resolution in our set of WAOM experiments. This research is expected to delineate the dynamics of heat flux that contribute to ice shelf vulnerability and potential mass loss, thereby enhancing our understanding of the stability of the Antarctic Ice Sheet and its implications for global sea-level rise.

The World Ocean Model of Biogeochemistry and Trophic-dynamics (WOMBAT) versions ``lite” and ``mid”

Pearse J. Buchanan

CSIRO

We present the “lite” and “mid” versions of the World Ocean Model of Biogeochemistry and Trophic dynamics. Like its predecessor, the core of WOMBAT-lite is a classic nutrient-phytoplankton-zooplankton-detritus (NPZD) model and is computationally cheap, making it viable for large ensembles and high-resolution configurations. WOMBAT-mid considers three phytoplankton functional types (nano, micro and diazotrophs), two zooplankton functional types (micro and meso), two detrital sinking pools (slow and fast), and five nutrients (ammonium, nitrate, silicic acid, dissolved iron and phosphate), making it about three-fold larger in terms of tracers and three-fold slower to run, but apt for a greater suite of research questions. Both models feature major updates to the iron cycle, explicit chlorophyll to carbon ratios of phytoplankton, a type III disk-formulation for grazing, new optical properties of the water column, and variable sinking rates of detritus. These updates brought an expanded parameter set and necessitated an optimisation procedure. To optimise both models, we performed 512 sensitivity experiments, each with a unique parameter set sampled randomly from predefined ranges, and thereafter assessed model performance against 7 (10) key observation-based products for WOMBAT-lite (WOMBAT-mid). Global sensitivity analysis showed that the model performance was dependent on numerous parameters, once again emphasising the chronic problem of biogeochemical models being under constrained. However, the most important parameters were the phytoplankton maximum growth rates, the half-saturation coefficients for nutrient uptake, the optimal chlorophyll quotas of phytoplankton, the prey capture efficiency of grazers, the temperature sensitivity of heterotrophy, and the base sinking rate of detritus. Using a traffic light system of model evaluation, the 10 parameter sets that performed well were chosen and run forward for 100 years. The best performing of these 10 was chosen as the optimised model version for WOMBAT-lite and WOMBAT-mid and are presented here.

Australasian Coastal SAR Ocean Winds: Data, Portal, and Next Products

Marites Canto and Salman Khan

CSIRO

High-resolution coastal wind data across the Australian region is vital for understanding coastal dynamics and supporting various applications including environmental applications, climate research, recreational activities, and industry sector such as the emerging offshore wind energy. This presentation aims to highlight the newly developed database of regional high-resolution (1 km) ocean surface winds over the Australian region. This database exploits the Sentinel-1 Synthetic Aperture Radar (SAR) Level-2 acquisitions over the Australian nearshore areas complementing global scatterometer wind measurements. The database has been made available through the Australian Ocean Data Network (AODN) portal which provides an interface that facilitates data access with the ability to search and filter by date, spatial extent, percentage of map containing wind data, satellite platform, and swath as well as quick display of wind maps of interest. A regularly gridded version of this dataset has been recently developed and updated approximately every six months. Such coastal winds archive is envisaged to be of great importance to both the Australian marine science research community and industry sector as data can help to better understand coastal wind climatology alongside other regional/global model hindcast and reanalyses products, and verification of model wind fields.

The new CSIRO Ocean Data Archive (CODA) and CSIRO Atlas of Regional Seas (CARS) products: high quality ocean information for Australia.

Chris Chapman

CSIRO

We present an update on efforts to develop a high quality ocean climatology for the Australian region, building on the sucess of the original CARS product. Two related products are in production:

1) a (relatively) complete database of historical in-situ profiles that supplements global databases (eg. the World Ocean Database) with “boutique” Australian data, subject to consistent automated quality control procedures devloped by the International Quality-controlled Ocean Database (IQuOD) consortium, provided in a standard format; and

2) a gridded climatology produced with the Data-Interpolating Variational Analysis (DIVA) scheme, a state-of-the-art gridding proceedure that allow for the effects of coastlines and ocean currents to be included naturally as constraints.

We will present an update on this work, indentify the impact of additional ocean observations on gridded parameters, and discuss ways to provide data, feedback and user input.

Cyclone driven freshwater plumes in Hawke Bay, Aotearoa New Zealand

Charine Collins & Helen Macdonald

National Institute of Water and Atmospheric Research

Cyclone Gabrielle hit New Zealand’s east coast on 14 February 2023 causing widespread damage to the coastal zone of Hawke’s Bay. Numerous rivers drain into Hawke Bay, delivering large volumes of sediment and freshwater. The unprecedented rainfall associated with the cyclone dramatically increased the amount of freshwater and sediment delivered to Hawke Bay. Extensive and pervasive coastal plumes of turbid water were observed in the days and weeks following the cyclone. A high-resolution hydrodynamic model with passive tracers representing the volume of riverine freshwater was implemented to investigate the influence of Cyclone Gabrielle on Hawke’s Bay and to compare it against average conditions. A multi-year hind-cast showed that the region of freshwater influence (ROFI) in Hawke Bay is highly variable and mainly driven by river discharge. Self-Organizing Map (SOM) analysis revealed 4 distinct patterns associated with river discharge with the least (most) frequent pattern associated with high (low) discharge. The ROFI generated in Hawke Bay in the wake of Cyclone Gabrielle was double the average ROFI size and extended northward well beyond Hawke Bay. The Cyclone Gabrielle ROFI in Hawke Bay closely resembled the least frequent SOM pattern indicating that this was an extreme event with broad ranging consequences.

Trichodesmium in Australia – knowledge gained from merging observations, experiments and modelling

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Trichodesmium is a key contributor to marine ecosystems as a major nitrogen fixer, converting atmospheric nitrogen into forms usable by other organisms, thus playing a crucial role in nutrient cycling. Additionally, Trichodesmium forms large surface blooms, providing a food source for various marine organisms and supporting marine food webs. Its ability to fix nitrogen also makes it significant for carbon sequestration and climate regulation. We present characterisation, species abundance and distribution of Trichodesmium in Australian waters, particularly focusing on the Great Barrier Reef (GBR) and Australia's IMOS National Reference stations (NRS). We have used microscopy and eDNA observation data, molecular analysis of novel Australian strains and identified spatial distribution and concentrations in Australian waters and representation in models in the GBR. We aim to enhance understanding of Trichodesmium's role in Australian marine waters with this combination of field observations, laboratory experiments, statistical and ecosystem modelling. We hope to provide valuable insights into Australian Trichodesmium strains and its role in Australian waters, hypothesising that nitrogen fixers could benefit under climate change in oligotrophic conditions such as the Great Barrier Reef.

Future changes to Antarctic margin circulation and hydrography under mid- and high-range emissions scenarios

Hannah Dawson

University of Tasmania

The Antarctic margins play a crucial role in our global climate system, yet possible end-of-21st century changes to ocean circulation and temperature under different climate scenarios remain poorly constrained. Here we force a 0.1 degree global ocean-sea ice model with spatially variable anomalies derived from 22 CMIP6 models to investigate the impact of mid- (SSP2-4.5) and high-range (SSP5-8.5) emissions on Antarctic margin circulation at the end of this century. We run these simulations with and without future freshwater contributions from the Antarctic Ice Sheet to assess changes in the presence and absence of meltwater. In the experiments without anomalous meltwater, the Antarctic continental shelf warms and freshens, becoming increasingly stratified with reduced sea ice extent across all months. Reduced sea ice growth leads to freshening over the continental shelf which drives an acceleration of the upper ocean Antarctic Slope Current (ASC), even in the absence of future meltwater contributions. The formation and export of Dense Shelf Waters (DSW) also decreases. Incorporating future projections of meltwater significantly amplifies these responses, with a complete shutdown of DSW formation and export under both mid- and high-range scenarios. However, even under a mid-range emissions scenario without additional meltwater forcing, substantial changes in Antarctic continental shelf circulation and hydrography are anticipated by the end of this century, including a 35% reduction in DSW formation. Our results further suggest that the temperature response around the Antarctic margins is sensitive to the magnitude of future freshwater forcing, highlighting a need for better constraints on projections of meltwater contributions from the Antarctic Ice Sheet under different climate scenarios.

Optimising Coastal Wave Observations in Australia: A Gap Analysis Using the National SCHISM-WWMIII Hindcast

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Australia has recently seen a substantial increase in coastal wave buoy deployments and improvements in coastal coverage due to the proliferation of low-cost wave buoy technology. More organisations are now able to collect wave buoy information for their specific needs because of the smaller size, easier deployment, maintenance, and data collection. This has resulted in a national initiative led by IMOS and CoastalRI development to leverage low-cost technology for further sustaining long-term coastal wave data collection in Australia. To maximize the impact of this investment, there is a need to identify existing gaps in coastal wave information around Australia. There are several factors considered during site selection such

as ease of deployment, maintenance, and recovery, avoiding shipping lanes and fishing spots, efficiency, and cost-effectiveness, operational and user needs, etc. These gaps will inform future enhancements to the observational network, and ensure a scientific data-driven basis is also available to inform stakeholders and regional operators in planning deployment sites.

The analysis builds upon the seminal work of Greenslade et al. (2018; 2021), which followed a structured method to inform on gaps in the design of Australia's in situ wave observing network. The method identified gaps in the observing network, defined as those with a low correlation of wave parameters with any of the existing buoy locations, based on data from the Centre for Australian Weather and Climate Research (CAWCR) waves hindcast (Smith et al., 2021). We aim to update this analysis leveraging the capabilities of the newly upgraded national waves hindcast. The updated SCHISM-WWMIII model (Semi-implicit Cross-scale Hydroscience Integrated System Model, Wind Wave Model III), implemented on an unstructured grid with increased resolution near the coast and in shallow waters (down to 250m), offers a novel approach to assessing the dynamics of nearshore waves, crucial for coastal management, planning, and research.

The analysis involves calculating correlations between monthly and hourly statistics (mean, 95th percentile of wave height, mean period, and direction) at modelled data points versus existing buoy locations across the Australian coastal network. It is expected that key gaps will be identified as areas showing low correlation with the current buoy network. Importantly, the upgraded SCHISM-WWMIII model, with its refined resolution, will reveal significant observational gaps in shallow water zones, which were previously underrepresented by the CAWCR hindcast.

Ultimately, this information will help the buoy operators and planners in optimising siting such that operational, user, and research needs are met as well as regional and national gaps in wave information are reduced as much as practically possible.

Uncovering involute spatiotemporal dynamics of surface currents in the Browse Basin

William Edge

The University of Western Australia

The Browse Basin is a region of ocean north of Broome from which many in-situ observations have historically been collected due to its interesting dynamics (large barotropic and baroclinic internal tides) and natural resources (oil and gas). The aims of my research are (1) to better understand the regions dynamics, and (2) to develop a spectral spatiotemporal statistical model that can assimilate observations from many sources and make rapid predictions at unobserved points in space and/or time with quantified uncertainty. We are attempting to characterise the non-separable spatial and temporal dynamics of surface currents in a statistical sense using a uniquely "dense" amalgamated research and industry dataset. We also have a 1-year model output from an unstructured hydrostatic numerical model that can be used for comparison and potentially as a priori model fitting. Results for aim 1 show spatial differences in the eddy field, good agreement between the modelled spatial internal tide characteristics and the in-situ observations, and low frequency variation in both eddies and internal tides.

How does resolving mesoscale features in the Southern Ocean impact biogeochemistry?

Elizabeth Ellison

Australian National University

Eddies are crucial in setting both the physical and biogeochemical conditions in the ocean, and play a key role in the circulation of the Southern Ocean, a region with especially high eddy activity. While lower-resolution models parameterize eddy effects, higher-resolution models can resolve these features. In this study, we explore the impact of model resolution on the biogeochemistry of the Southern Ocean, focusing on the role of eddies. By comparing models at resolutions of 1 degree and 0.1 degree, we reveal significant changes in the distribution of nutrients and the magnitude of carbon fluxes and phytoplankton productivity in the Southern Ocean. There is not clear improvement in the fit of model outputs to available biogeochemical observations with an enhanced resolution eddy resolving model. We demonstrate that changes in the distribution of key biogeochemical tracers with altered model resolution can be classified into two scales: those that occur due to alterations in large-scale circulation patterns and those changes which occur locally due to resolving mesoscale features. Here we will quantify the relative strength of these two effects and discuss the implications for optimising future biogeochemical modelling.

The Biological Ocean Observer: An online portal for the visualisation of IMOS data

Jason D. Everett, Claire H. Davies, Anthony J. Richardson

The University of Queensland

Access to online marine data streams has never been easier, however the number of files and range of formatting creates complexities around data download, integration and visualisation. Not everyone has the necessary skills to make use of the data resources available. Here we demonstrate a solution to simplify these processes for all users: the Biological Ocean Observer (BOO). BOO is an online Shiny application that Integrates, Analyses and Visualises IMOS data so that everyone can better understand, query and interpret it. BOO increases our ability to deliver impact by expanding the analysis and visualisation of biological data to a broad audience and accelerating the generation of scientific insights. BOO uses internationally recognised programming frameworks (R and Shiny), and all code are freely available, facilitating further development and collaboration with the community. The Shiny application is underpinned by an R-package (planktonr) that allows power-users to replicate the data and visualisations they access from BOO, but also to modify the analysis and visualisation for their use case. This tool is designed to be used by a wide range of national stakeholders including science researchers, natural resource managers, policy makers, educators and the general public – including you!

Filling shelf mooring data gaps using Self-Organizing Maps

Ming Feng, Toan Bui, Chris Chapman

CSIRO

Self-Organizing Map (SOM) is an unsupervised machine-learning technique used for dimension reductions of high-dimensional data while preserving topological properties in the data. In this study, we adapted the recent progress of the SOM technique that takes into account local correlations in the data to fill mooring data gaps of a shelf mooring array ranging from 50 to 500m depth off the southwest coast of Australia, resulting in a 13-year daily mooring time series of temperatures and ocean currents from the array. Validation against withheld data suggests root-mean-square errors of gap-filled data to be 0.3°C for temperatures, and 0.1 and 0.05m s-1 for the meridional (alongshore) and zonal (cross-shore) components of velocities, respectively, allowing better detection of temporary variability on the shelf.

We used gap-filled data to study the seasonal variability of ocean temperature and ocean currents on the shelf, influenced by the Leeuwin Current and wind-driven Capes Current. The thermocline depth at the 200m mooring varies with the strength of the Leeuwin Current, being shallowest in September when the current is the weakest. The northward Capes Current in the shallow water (50m mooring) in summer is associated with an onshore flow component in the bottom Ekman layer that compensates the offshore surface Ekman flow and contributes to the coastal upwelling.

Spatiotemporal connections in the Ross Sea: A synthesis from the New Zealand Antarctic Science Platform Ocean Mechanics project

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Here we describe the contributions of the Aotearoa New Zealand Antarctic Science Platform (ASP) Project Two: Ocean Mechanics ("The Oceans Project") towards improved understanding of the Ross Sea ice-ocean-atmosphere system. Our project primarily addresses questions related to the past and current physical mechanisms in the Ross Sea. Of particular concern are the irreversible changes Antarctica is projected to experience in the next century in terms of heat, salt, and oxygen content and fluxes. Our research enables enhanced modelling of its future response to a warming Earth system, as well as provide baselines for other aspects of the Ross Sea system including future sea level rise, ocean and icescapes, ecosystems and biodiversity in flora and fauna, and the warming ocean and atmosphere system. The project activity included a number of voyage contributions, profiling float deployments, modelling and analysis of available sediment cores. We summarise the research highlights of the Oceans Project, and associated work, over 2019-2025 and discuss our contribution towards a "community" Ross Sea observatory, identification of sentinel sites and ocean metrics, and evolution of future regional research priorities.

Can a high-resolution earth system models improve the accuracy of past fish biomass estimates in the Southern Ocean?

Denisse Fierro-Arcos[1,2], Julia Blanchard[1], Stuart Corney[1,3], Hakase Hayashida[1,4], Petra Heil[3,5], Andrew Kiss[1,2,6], Amelie Meyer[1,2]

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The effects of climate change have been reported in ecosystems all over the planet, but areas like the Southern Ocean that are warming at a rate four times faster than the global average are especially at risk. Ecosystems in the Southern Ocean are uniquely adapted to high seasonal fluctuations in the environment conditions. As the ocean continues to warm and sea ice continues to decrease, it is expected that the distribution and abundance of marine organisms will be affected via direct effects linked to their physiology, and indirectly through disruption of inter-species interactions. These effects could be compounded by an increase in human activities (e.g., fishing, tourism) as sea ice loss opens up previously inaccessible areas. Marine ecosystem models (MEM) forced by earth system models (ESM) can provide estimates of biological and ecosystem change under a changing climate. However, the choice of ESM has an impact on the accuracy of MEM predictions. We forced a MEM with a high-resolution ESM capable of reproducing the observed seasonal cycle and broad baseline climatological conditions of the Southern Ocean (ACCESS-OM2-01) and evaluated the past biomass estimates against observations. We expect this will improve the accuracy of predictions, thus reducing a source of uncertainty in MEMs.

Sea Surface Temperature products and their applications from Himawari-8/9 geostationary satellites

Pallavi Govekar[1], Christopher Griffin[1], Owen Embury[2], Katherine Meletiou[1] and Helen Beggs[1]

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Advances in satellite technology have made it possible to monitor sea surface temperatures (SST) at resolutions crucial for research, climate modelling, and understanding coastal processes. The Bureau of Meteorology produces numerous high-resolution satellite-derived SST data products as a contribution to the Integrated Marine Observing System (IMOS). A full-disk of Himawari-8/9 geostationary SST data is generated every 10 minutes using the Bayesian cloud clearing and Optimal Estimation (OE) retrieval based on the ESA CCI SST version 3 processor.

The 10-minute temporal resolution of the newly developed Himawari-8/9 SST data enables a daily composite with enhanced spatial coverage, effectively filling in SST gaps caused by transient clouds. Skin SST retrievals from infra-red radiometers on Himawari-8/9 and polar-orbiting satellites are composited over multiple swaths/scenes and gridded on a 0.02° rectangular grid over the Australian domain and are used to develop thermal stress and Marine Heatwave (MHW) monitoring tools. The new tools are compared with the Bureau's existing operational ReefTemp Next Generation system which has provided heat stress monitoring metrics for the Great Barrier Reef region since 2012. Further, MHW monitoring metrics such as MHW duration and intensity are developed. We will demonstrate examples of new metrics along with case studies.

Long-term estimation of water surface nitrate from Landsat-8 timeseries imagery at the Fitzroy Estuary and Keppel Bay regions with artificial neural networks

Yiqing Guo, Nagur Cherukuru, Eric Lehmann, Kesav Unnithan, Gemma Kerrisk

CSIRO

Observational evidence from recent studies reveals that the quality of water in the Great Barrier Reef (GBR) has declined due to excess river discharge of terrestrial nitrate derived from adjacent catchments, highlighting the need to monitor the end-of-catchment nitrate discharge. While remote sensing-based approaches have shown promise in monitoring nitrate in open ocean and inland waterbodies, it is challenging to extend their applications to the tidal-affected estuarine water. This study aimed to advance our understanding of nitrate load at the spatiotemporally dynamic Fitzroy Estuary and Keppel Bay regions, using long-term Landsat-8 OLI observations. A deep learning model was trained and validated with biophysical modelling and in-situ timeseries nitrate measurements. The model was then applied to Landsat-8 images for generating timeseries maps of water surface nitrate concentration. Our results revealed the spatiotemporal patterns of nitrate load at the Fitzroy Estuary and Keppel Bay regions, providing support to the estimate of terrestrial pollutants from the Fitzroy catchment to the GBR region.

Simulating the relationship between basal melting of the Amery ice shelf and dense shelf water production in Cape Darnley, East Antarctica

David E. Gwyther[1], Sienna Blanckensee[1], Ben Galton-Fenzi[2,3,4] Helen Bostock[1]

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Global thermohaline circulation transports heat and salt, and ventilates the deep ocean, with the return limb of this important modulator of climate, being driven by dense water formation at the poles. Several recent studies have indicated the potential for imminently crossing a tipping point in the stability of this global current. It has been suggested that the observed reduction in Antarctic Bottom Water formation or changes in its properties may be impacting this global circulation. As a result, understanding why and how bottom water and its precursor, Dense Shelf Water (DSW), are formed is therefore important for quantifying the current state of thermohaline circulation and thus make projections of change. Cape Darnley, East Antarctica, has only recently been confirmed as a source of Antarctic Bottom Water, yet contributes as third highest amount of bottom water. Here we present results from a regional model of the Amery Ice Shelf and Prydz Bay, designed to explore interactions impacting DSW formation at Cape Darnley. We show the relative contribution of sea ice formation at Cape Darnley polynya, ocean heat transport into Prydz Bay, modulation in basal melting beneath the Amery Ice Shelf, and how all of these factors impact DSW present on the continental shelf of Prydz Bay.

Monitoring Coastal Waters Adjacent to the EAC using High-resolution Ocean Time Series collected since 2006 (NSW-IMOS)

Michael Hemming, Moninya Roughan, Tim Austin, Stuart Milburn, Clive Holden, Zac Anderson

University of New South Wales

Since 2006, the New South Wales (NSW) node of the Integrated Marine Observing System has overseen 10 mooring sites along the coastline adjacent to the rapidly warming East Australia Current. These mooring sites have included sensors measuring important climate variables, such as temperature, velocity, salinity, dissolved oxygen, and fluorescence. Here we summarise this vast high-resolution data set and explore the state and variability of coastal waters adjacent to an important western boundary current. Recently, the NSW-IMOS moorings team have developed an automated python-based reporting system that collates deployment information (including QC history), and creates and incorporates a range of plots. This reporting system produces a PDF document after each mooring deployment that can be archived with the raw data for later reference. We will highlight the reports' features and describe how the code works, which is fully open source and adaptable to other IMOS nodes.

An early warning system for Australian coastal sea level extremes

R. Holmes, O. Richet, B. Hague, G. Smith and C. Spillman

Bureau of Meteorology

Coastal sea level extremes have widespread impacts on coastal systems, ranging from infrastructure damage, economic damages, and human impacts due to coastal flooding to the exposure of coral reef systems during low water extremes. Sea level extremes are driven by a range of atmospheric and oceanic processes such as astronomical tides, storm surges, coastally trapped waves and subseasonal to seasonal ocean variability associated with climate drivers such as the El Niño-Southern Oscillation. Some of these

processes are potentially predictable ahead of time, such as the tides (predictable years in advance) and climate drivers (predictable weeks to months in advance), suggesting that it may be possible to provide early warning of the risk of upcoming sea level extremes. Here, we discuss ongoing work within the Australian Climate Service (ACS) to develop such an early warning system for coastal hazards by combining harmonic tide predictions with sea level forecasts from the Bureau of Meteorology's dynamical subseasonal to seasonal forecast model, ACCESS-S2. We discuss the design of this sea level prediction system and evaluate its skill across the Australian tide gauge network. Early results are promising, indicating potential for providing valuable information to support decision making by coastal managers on seasonal timescales. Future plans include coastal downscaling using statistical methods to improve skill, and the development of seamless predictions spanning weather through to seasonal time scales.

A comparison of ERA5-IAF-forced NEMO and ACCESS-OM2 ¼-degree global ocean models: biases, strengths, and weaknesses.

Ryan Holmes & Chris Bladwell

Australian Bureau of Meteorology

The Bureau of Meteorology uses a NEMO-based configuration for operational seasonal forecasting (ACCESS-S2) and has a strategic plan to develop NEMO-based ocean forecasting and coupled numerical weather prediction systems. The climate research community in Australia, led by ACCESS-NRI and COSIMA, are instead developing and using global MOM5 (e.g. ACCESS-OM2) and MOM6 (ACCESS-OM3) configurations. Here, we take advantage of the existence of global ¼-degree configurations of ACCESS-OM2-025 (MOM5-CICE5) and NEMO(-SI3) GOSI9 ORCA025, both forced with interannually varying forcing from the ECMWF Reanalysis Version 5.0 (ERA5), to compare the characteristics and performance of the two modelling systems. Initial results suggest that the two models exhibit significant differences in interior water mass drift associated with differing representations of vertical tracer transport and treatment of surface volume flux imbalances. The NEMO system exhibits stronger eddy-driven sub-monthly sea level variability, with implications for western boundary currents. The representation of sea ice also differs, with the winter maximum in sea ice extent occurring roughly one month earlier in ACCESS-OM2 than in NEMO. Understanding the biases, strengths, and weaknesses of the two models can help both communities identify problems and potential for improvement.

Linking the recent decrease in Weddell Sea dense shelf water formation to shifts in the Interdecadal Pacific Oscillation

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Antarctic Bottom Water (AABW) is formed in select few locations around the Antarctic margin. It fills out the bottom 40% of the world's ocean and is critical in circulating heat, carbon and nutrients throughout all the basins. Recent observations suggest that almost half of AABW is formed in the western Weddell Sea and that since 1992, its formation has decreased by 40%. Anthropogenic warming, through the addition of freshwater from melting glaciers and ice shelves, and natural climate variability must have led to this drastic decrease. The Interdecadal Pacific Oscillation (IPO), known to exhibit teleconnections to the Weddell Sea, is likely responsible for some of this decrease. However, to what extent recent shifts in the IPO influence AABW formation is yet unknown because limited observations include the impact of all natural climate drivers and not just the IPO. Here, we use the 1/10° global ocean-sea ice model ACCESS-OM2 to simulate the isolated impact of the IPO on Weddell Sea dense shelf and bottom water formation. We find that southward wind anomalies associated with a negative IPO phase push sea ice towards the coastline, prevent polynyas from opening up and reduce the formation of dense waters. In the Ross Sea, we see more dense shelf water formation during negative IPO phases compared to positive phases, especially for the highest density ranges. This indicates that observed Weddell Sea AABW decline might have been compensated by increased production in the Ross. These findings have implications for interpreting decadal-scale dense shelf and AABW production and its impacts on the global ocean circulation under a rapidly warming climate.

Enhancing ACCESS-OM3 with Integrated Wave-Ice Interactions

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The integration of wave-ice interactions into climate models is crucial for understanding the intricate interplay between ocean waves and sea ice, especially in polar regions where these interactions significantly influence ocean mixing, sea-ice fracturing, and changes in ocean dynamics. This work focuses on enhancing ACCESS-OM3's capability to simulate the complex feedback mechanisms between ocean waves and sea-ice by coupling the ocean (MOM6) and sea-ice (CICE6) models with the wave model (WW3) and considering wave-induced processes such as ice breakup, and changes in floe size distribution.

The methodology involves utilizing a NUOPC coupler to integrate the ocean, sea-ice and wave models and using parameterizations for floe-size dependent scattering. This parameterization estimates ice breakup due to wave action and updates the maximum floe size diameter accordingly. The coupling between CICE6 and WW3 allows for dynamic adjustments of the floe size distribution based on the WW3 surface elevation spectrum, while WW3 incorporates floe-size-dependent scattering using CICE6's distribution. Initial global 1-degree experiments highlight the significant impact of wave attenuation models on wave damping and energy penetration into sea ice, thereby influencing floe size distribution dynamics. Future work will delve into investigating wave penetration into sea ice to enhance the realism of floe size distribution.

Australia's deepest observations

Jessica Kolbusz

University of Western Australia

This presentation will outline the initial findings from two deep-sea observatories, within the Perth Canyon Marine Reserve and Gascoyne Marine Reserve off Western Australia, supported by Parks Australia. This project aimed to substantially expand on Australia's deep-sea understanding and extend oceanographic research capabilities in the deep-sea. These observatories are equipped with sensors measuring salinity, temperature, pressure, oxygen, and POM with expansion plans to include ADCPs and an eDNA Robotic Cartridge Sampling Instrument.

This initiative not only fills a significant gap in our understanding of Australia's deep-sea ecosystems, which comprise a substantial portion of the nation's marine territory but also sets new standards for deep-sea research worldwide. The data collected are pivotal for validating and improving oceanographic models, understanding carbon biogeochemistry, and supporting a wide array of marine research, including blue carbon studies and marine ecosystem modelling.

By providing a comprehensive environmental dataset from one of the least explored regions on Earth, the observatories are poised to make substantial contributions to global climate change research, marine conservation, and policy-making, aligning with the objectives of the IMOS Strategy 2030.

Fishing for Near Real Time Ocean Temperature Data

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Knowledge of the 3-D structure and variability of ocean temperature is critical for understanding ocean circulation, heat uptake and marine extremes, as well as the abundance and distribution of marine life. While satellite technology offers near-global coverage of surface ocean temperatures, sub-surface observations are still the biggest gap in the ocean temperature record. Using commercial fishing gear as a research data platform has been increasing in popularity internationally as an innovative approach to bridge that gap in the observational record. FishSOOP is Australia's pilot Fishing vessel contribution to International Fishing Vessel Observation Network recently endorsed as a GOOS emerging network and a UN Ocean decade action. Operating since May 2023 we have instrumented >30 vessels around Australia to collect temperature data with every fishing set. We are collecting more than 1000 temperature profiles per month, or more than 1.3 profiles per hour on average. Data has been collected across the breadth of Australian shelf seas, including extremely remote northern waters where there was previously almost no data. Data are returned in near real time, QC'd automatically, and returned to the fishers. Comparison with the SEA-COFS ocean forecast models shows the potential for improving forecasts of upper ocean heat content and bottom temperatures by filling the gaps in observational data coverage, and data has provided near real time insights into the spatial and temporal evolution of marine heatwaves. FishSOOP already provides a step-change in the amount of open access temperature data available at low cost. Near real time delivery of data to the GTS is the next step, and will provide critical information to marine industries, highlighting the benefit of research-industry collaboration to fill in gaps in observations.

Developing a consistent view of future climate projections in the global coastal ocean

Clothilde Langlais[3] Jason Holt[1], Jo Hopkins[1], Anna Katavouta[1], Giorgia Verri[2], Paul Myers[4], Alfonso Senatore[5], *Mathieu Mongin[3]

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Thanks to global earth system models, we have an increasingly better understanding of the impacts of climate change on the global ocean. But global climate models are not designed for the coastal ocean. They lack the necessary scale and process representation to provide coastal communities and the blue economy with reliable information about climate change risks and impacts to allow planning and adaption on local scales. Regional downscaling aims to close this gap. But current approaches are highly fragmented and projections are often highly uncertain. The Project FLAME (https://projects.noc.ac.uk/flame/) , an endorsed UN Decade, is part of the CoastPredict (coastpredict.org) programme, and aims to generate innovative, high-resolution, downscaled decadal to centennial projections of future coastal ocean climates and to explore climate change impacts on coastal ecosystems, hazards, services and resources at the local-regional scales necessary for informed decision making. Here we provide a synthesis of the activities undertook by the FLAME community.

Challenges and Progress in the 0.25° Degree Configuration of ACCESS-OM3: A Preliminary Review

Minghang Li

ACCESS-NRI

ACCESS-OM3 is poised to become the leading global coupled Ocean-Sea Ice model in Australia, yet its development and optimisation present ongoing challenges and opportunities for improvement. In this poster presentation, we undertake an examination of the hurdles encountered during the evolution of OM3 to its 0.25° configuration, the strategies employed to overcome them, and the ongoing inquiries that shape its continued refinement. It is important to note that model parameters are still in the exploration and testing phase.

Key areas of ongoing investigation include uncertain model parameterisation choices, optimisation and load balance. By shedding light on these challenges and opportunities, we invite engagement and collaboration with prospective future users who wish to contribute to the model configuration. Through collective efforts, we aim to propel ACCESS-OM3 towards greater efficacy and applicability in Ocean-Sea Ice research. Our findings not only contribute to advancing ACCESS-OM3 but also provide a platform for collaborative discourse and exploration of future research directions.

Deep learning forecasting of surface marine heatwaves in the global ocean

Zeya Li[1], Ming Feng[1], John Taylor[2], Foivos Diakogiannis[1], Fabio Boschetti[1]

[1]CSIRO, [2]The Australian National University

Marine heatwaves (MHWs), periods of extremely high sea surface temperatures (SSTs), have been widely recognized for their significant impacts on marine ecosystems. Rapid and accurate SST and MHW forecasts extending days to weeks ahead are therefore important for forewarning the arrival of MHWs. Recent deep learning-based forecasting methods are renowned for their high computational efficiency and lower requirements for input variables. While several studies have used deep learning models to explore regional and global SST forecast skills over approximately a week, a comprehensive assessment of forecast skills of MHWs in the global ocean as a whole at longer lead times is still lacking. Here, we develop an SST-TUNet model to assess global daily SST and MHW forecast skills with lead times of up to 30 days. Employing a hierarchical transformer-based framework and the U-Net model, SST-TUNet is designed to capture both local and global information with efficient self-attention mechanism while forecasting SST anomalies. The model achieves stronger forecast performance in many regions of the ocean at multiple lead times compared to the persistence model. Further analyses for MHW forecasts also demonstrate that the model can provide skilful forecasts of MHWs from days to weeks in advance in different regions.

Accuracy and Consistency of Current Satellite-Derived Antarctic Sea-Ice Freeboard

Xinlong Liu[1], Rachel Tilling[2,3], Stuart Corney[1], and Petra Heil[4,1]

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Satellite radar estimates of sea-ice thickness may be derived from radar freeboard or ice freeboard. Radar freeboard is based on the reflection of radar signals from the top of the sea ice or an icy layer within the overlying snow. Ice freeboard is derived from radar freeboard corrected for delays in propagation through snow. Studies in the Arctic have allowed in-depth comparisons of these two parameters, but there are no such studies for the Southern Ocean. Greater precipitation in the Southern Ocean, along with flooding and refreezing, is known to create multiple ice layers within snow. These layers (which are rare in the Arctic) make the relationship between radar and ice freeboard more complex. We compare twenty years of satellite-based radar and ice freeboards retrieved from three distinct products. These satellite-derived freeboards are evaluated against independent in situ upward-looking sonar observations in the Weddell Sea. In the Southern Ocean, we observe that different satellite-derived radar and ice freeboards display consistent patterns in their spatial and seasonal distributions, though the magnitude of freeboard varies between product and freeboard type. Freeboards are highest in the western Weddell Sea, Ross Sea, coastal East Antarctic, and Amundsen-Bellingshausen seas, consistent with previous observations.

Changes and trends of the Campbell Plateau Meander over the past 27 years

Xinlong Liu[1], Amelie Meyer[1], and Christopher C. Chapman[2]

[1]University of Tasmania, [2]CSIRO

Standing meanders are a unique feature of the Antarctic Circumpolar Current (ACC) in the Southern Ocean and are key in exchanges between the surface and deep ocean. They also have significant implications for primary production and biogeochemical processes. Here, we investigate the long-term characteristics and trends of the Campbell Plateau meander located south of New Zealand in the Southern Ocean. Using satellite altimetry data between 1993 and 2020, we use a local gradient maxima method to identify the meander's position and estimate its width, geostrophic current speed, and related trends. We observe that the meander's position has been nearly fixed for the past 27 years, apart from a section downstream of the Plateau moving northward by approximately 0.4° latitude per decade. The meander has become flatter upstream of the Plateau, and steeper downstream of the Plateau. In general, the meander has widened by 2km per decade and accelerated by 0.01m s^{-1} per decade, especially downstream of the Plateau. These findings are consistent with existing studies on Southern Ocean meanders. Changes in the ACC downstream jet stability and the nearby South Pacific Gyre may contribute to these observed trends.

Ocean heat supply towards the Denman/Shackleton ice shelf system

Yuhang Liu

University of Tasmania

The Denman region is home to the Shackleton Ice Shelf and Denman Glacier; the latter is the second largest contributor to the ice mass loss in East Antarctica. Understanding of the basal melting of the Denman/Shackleton ice shelf is therefore important for predicting the future behaviour of the East Antarctic ice sheet and global sea level rise. However, our understanding is hampered by the scarce observations in this region and the omission of ice shelves in most of the global ocean models. Here, we use a high-resolution (roughly 1.4 km) regional ocean-sea ice model, which includes thermodynamic ice shelves and tides, to investigate the basal melting of the Denman/Shackleton ice shelf. Our results show that the ice draft, distribution of the ice shelf area with depth, modulates the ice shelf melting and its response to the oceanographic processes. The ice shelf melting in this region is characterised by two distinct melting modes, 'near-surface' (within the top 200m) and 'deep' (below 400m depth) basal melting. The near-surface basal melting accounts for up to 60% of the meltwater discharge in this region. This melting is induced by a warm surface water carried along the coast towards the ice shelf by the strongly seasonal Antarctic Coastal Current (AACC). In turn, the deep basal melting accounts for less than 10% and is accomplished by the intrusions of the Circumpolar Deep Water (CDW) from the Southern Ocean onto the continental shelf. Using passive tracers, we identify

three major pathways of the CDW onto the continental shelf, each associated with a deep through over the shelf. The eastern pathway, in Vincennes Bay, is the dominant contributor to the total cross-shelf CDW transport in the study region, accounting for 55% of the total cross-shelf tracer exchange. However, most of the tracer, 82%, reaching the ice shelf intrudes onto the continental shelf along the trough in front of the Denman Glacier, which accounts for only 18% of the total cross-shelf tracer transport. Our results highlight the importance of the AACC and the Antarctic Surface Water (AASW) for the basal melting of the Denman/Shackleton ice shelf system.

Carbon fluxes in the Aotearoa New Zealand Region

Helen Macdonald, Charine Collins and Graham Rickard

The National Institute of Water and Atmospheric Research

Oceans are a large sink of anthropogenic carbon dioxide and proposed marine carbon dioxide removal initiatives aim to enhance this natural sequestration of carbon. However, the natural oceanic carbon fluxes are not well understood in the Aotearoa New Zealand region at the fine-scale resolution that these carbon dioxide removal processes operate in. To understand the natural carbon sinks we present coupled physical biogeochemical models of the Aotearoa New Zealand region. These models can recreate climatological means in physical and biological variables and improve on CMIP models for the region; making them a good tool to study regional biogeochemical processes. These models can be used to study primary productivity and the effect on carbon fluxes. We study primary productivity to understand how background primary productivity acts to remove atmospheric carbon dioxide. Primary productivity is large around the Aotearoa New Zealand region along the sub-tropical front, resulting in a localised increase of oceanic uptake of atmospheric carbon. However, air sea flux is only part of the story for oceanic sequestration. To achieve long-term reduction in atmospheric carbon dioxide it needs to be removed from the system. We use the model to understand export efficiencies around Aotearoa New Zealand and discuss what this means for marine carbon dioxide removal in the region.

Impact of absorption and scattering of phytoplankton, CDOM and suspended sediments on ocean heat and circulation in the Great Barrier Reef region.

Anna Maggiorano, Mark Baird, Clothilde Langlais, Mathieu Mongin, Jennifer Skerratt

CSIRO

Solar radiation propagating through the water column is scattered and absorbed by optically active constituents in the ocean, in particular phytoplankton, coloured-dissolved organic matter (CDOM) and suspended inorganic particulate matter (SPIM). These wavelength-dependent processes affect the vertical distribution of heating in the water column and its stratification and are especially important where a large gradient in water clarity is present.

The Great Barrier Reef (GBR) region is characterised by highly seasonal variable freshwater input from several rivers, which can lead to large sediment and nutrient discharge near the coast, strongly affecting the water optical properties. In this study, we use a coupled hydrodynamical-optical-biogeochemical ocean model (eReefs 4 km configuration) to investigate the feedback between heat absorption by optically active components and the ocean dynamics in the GBR region. The optical model calculates heat absorption based on the absorption and scattering of 4 phytoplankton types, CDOM and 6 sediment fractions, and as a function of solar zenith angle.

Here, we compare different simulations: one with a spatially and temporally variable heat absorption coefficient influenced by water quality, two with a fixed heat absorption coefficient, and one that only considers absorption by sea water. Our results show that heat absorption due to phytoplankton, sediment and CDOM is stronger on the continental shelf. The presence of absorbing constituents in the water column drives a temperature increase at the surface and a decrease below the mixed layer with stronger stratification and greater heat losses to the atmosphere. The change in ocean heat content due to optically active constituents is most significant inshore, while offshore the increase of heat fluxes losses to the atmosphere resulting in a decrease in the ocean heat content of the top 500 m. Considering the spatial variability of heat absorption due to phytoplankton, CDOM and suspended sediment concentrations can improve modelling the vertical distribution of heat compared to a spatially constant heat absorption coefficient. This study highlights the importance of considering water clarity and its spatial variability as an important process that drives hydrodynamic conditions.

Ice shelf ocean interaction in the Ross Sea - how much will it change?

Alena Malyarenko[1,2] , Alex Gossart[2] , Nkhil Hale[2], Yoshihiro Nakayama[3],

[1]University of Canterbury, [2]University of Wellington, [3]Hokkaido University

We have developed the first fully coupled regional model Polar-SKRIPSv2 for the Ross Sea. We use the Polar-SKRIPSv2 as published in Gossart et al. (In Prep). This coupled model uses the MITgcm model of the ocean, and the Polar version of the Weather and the Weather Research and Forecasting Model (PWRF). Our model is unique in conserving energy and can operate at the regional scale, making it the best tool to study mesoscale processes in the Ross Sea and make predictions on how variability of local wind jets above the continental shelf can impact the salinity and temperature of the ocean, and thus global thermohaline circulation.

In this presentation, we will show a case study for the present day (forced by reanalysis) and future simulations (forced by ACCESS-ESM1.5). We focus on the sea ice production, heat and mass fluxes in the polynyas, and show how those change in the future simulations. We also show the changes in the cavity conditions.

Numerical modelling of materials transport across land, ocean, and atmosphere

Margvelashvili N., Skerratt J., Wild-Allen K., Phillips L., Mongin M., Jones E.

CSIRO

This talk presents the development of a relatively simple numerical model to simulate the transport of particulate and dissolved matter across ocean, land, and atmosphere (GlobuSed). The idea is to have an effective and flexible system (compared to the existing global earth systems models) for a quick evaluation of hypothesis and scenarios. The model reads ocean currents and wind speed from existing and readily available global models (ERA-5 and Mercator EU Copernicus). Binary search trees are employed to interpolate velocities from the original grids to the meshless grid underpinning the GlobuSed transport model. Geostrophic currents are augmented with the approximate evaluation of tidal currents and wind-driven velocities. Reduced water mass balance and river routing schemes are employed to simulate transport through soils and river networks. Evaluation of the model highlights areas requiring further refinement (e.g. calibration of the water-balance equations, improving river-routing scheme, reducing uncertainty of the model in macrotidal environments etc.). We illustrate this pilot model by sharing preliminary insights into contaminants distribution in river streams and the coastal ocean.

Dispersion Characteristics in the East Australian Current System

Luke Matisons, Moninya Roughan, Amandine Schaeffer

University of New South Wales

Dispersion is a fundamental physical mechanism that shapes marine ecosystems through transporting and mixing heat, salt, and nutrients, as well as affecting the distribution and connectivity of organisms. To best apply and model dispersion, an understanding of its underlying advective and turbulent components is required. However, in many circumstances, turbulent dispersion may be parameterized incorrectly, or lack a sufficient empirical consensus. Using data collected as part of NOAA's surface velocity drifter program, we conduct an in-depth analysis of turbulent dispersion characteristics in the EAC system and elucidate the presence of any spatial heterogeneity or anisotropy in diffusivity parameters. Over the entire EAC region, we show that absolute and relative dispersion metrics closely align with theoretical quasi-geostrophic regimes. Turbulent dispersion tends to be roughly isotropic throughout the EAC system but is more meridionally skewed in the northern, jet dominated region, than in the south. Our results highlight the possible need for better model parameterizations and applications that can account for anisotropic or spatially inhomogeneous turbulent dispersion characteristics. This study contributes to our understanding of the regional oceanography of Australia and helps build upon observation-based modelling frameworks.

Two Generations of CMIP-Derived Wind Wave Extremes Future Projections

Alberto Meucci[1,2], Claire Trenham[2], Mark Hemer[2], Ian R. Young[1]

[1]The University of Melbourne, [2]CSIRO

The University of Melbourne/CSIRO CMIP6-forced wind-wave climate model ensemble has recently been finalized and made accessible to researchers and practitioners worldwide (Meucci et al.; 2024). This ensemble comprises nearly 1000 years of simulated global 3-hourly wind wave climate data at a spatial resolution of 0.5 degrees. The current CMIP6-derived wind wave climate ensemble represents a significant evolution from the initial CMIP5-derived wind wave climate ensemble produced at CSIRO (Hemer and Trenham; 2016). It enhances aspects such as physics, spatial resolution, and temporal resolution in both the spectral wave model and the Global Climate Models (GCMs) surface wind speed input. As such, it constitutes an optimal dataset to analyse the evolution of wind wave climate extremes and their future projected changes. A pioneering study by Meucci et al. (2020) first looked into global wind wave extreme future projections using CSIRO's first-generation CMIP5-derived wind wave climate ensemble (Hemer and Trenham; 2016). The study performed the first global evaluation of the 100-year significant wave height return period changes by the end of the 21st century. The present study marks an evolution both in terms of datasets and statistical methodologies. Future projected 100-year significant wave height return periods, derived from the latest CMIP6 wind wave ensemble, are determined using two state-of-the-art Extreme Value Analysis (EVA) statistical methods: a non-stationary EVA applied to two 140-year continuous wind wave climate datasets, and an ensemble pooling technique utilizing simulations from the entire 8-model ensemble across 30-year time slices. Preliminary findings reveal consistency in the projected changes of the 100-year 10-meter surface wind speed while depicting a varied scenario for the 100-year significant wave height return periods. These results will be discussed and compared to previous studies to understand the causes behind that, together with an evaluation of the level of uncertainty in the results. The study will extend with an evaluation of the added value of spatial resolution increase in representing surface wind speed and significant wave height extremes. Ultimately these results will play a crucial to improve our understanding of the ocean wind wave extremes' contribution to future projected extreme sea levels and coastal erosion/accretion patterns.

Are our workflows "analysis ready"? Thoughts on data science practices for huge CMIP & COSIMA archives

Thomas Moore & Chris Chapman

CSIRO

Helping to solve pressing societal questions in climate science and oceanography relies on leveraging model output that is at increasingly high-resolution and often has greater numbers of ensembles per experiment. This not only requires more storage and computational capacity but also large overheads in time. This time cost is placed on individual data users as they grapple with turning many thousands of discrete netcdf files into new ideas, science discovery, peer-reviewed publications, and expert advice for stakeholders. "Analysis Ready Datasets" (ARD) can help.

We'll discuss some experiences, example use cases, and proposals for how the Australian ocean and climate science community might tackle our big data problems more thoughtfully. Working smarter and helping to lift restraints on the flow of data exploration for individual researchers.

Comparing Antarctic Margin Eddy Activity Across Horizontal Model Resolutions

Ellie Ong

University of New South Wales

Eddies around the Antarctic margin are crucial in facilitating cross-slope exchanges of warm water poleward, directly leading to ice shelf melt and accelerating sea level rise. However, a circumpolar comparison of eddies around the Antarctic margin across the highest model resolutions has not been conducted before. Using the ACCESS-OM2-01 (0.1 degree resolution) and PanAntarctic 1/20th degree ocean-sea ice models, we compare the representation of eddies around the Antarctic continental margin and their link to local current features and drivers. Current strength and eddy kinetic energy both exhibit a large seasonal cycle that is strongly tied to atmospheric forcing and sea ice. While we find some interannual variability, particularly in the 1/20th degree simulation, it is smaller in magnitude than the seasonal cycle. We have found a stronger coastal current represented in the lower resolution ACCESS model than in the 1/20th degree model, particularly in East Antarctica, and link this strengthened coastal current to changes in eddy kinetic energy. This work aims to clarify the effect of model resolution on how key processes are represented around the Antarctic continental margin.

The AMOC slow-down inferred from a process-based decomposition of South Atlantic salinity

Gabriel M. Pontes[1,2] & Laurie Menviel[1,2]

[1]University of New South Wales, [2]Centre of Excellence for Antarctic Science

The Atlantic Meridional Overturning Circulation (AMOC) is the main driver of the Atlantic Ocean northward heat transport today, setting global climate patterns. Theoretical and paleoclimate studies suggest that the AMOC strength is highly sensitive to heat and salt budgets in the subpolar North Atlantic (SPNA). As such, whether global warming has affected AMOC strength over the past century is still under debate. Observational studies suggest a consistent weakening since the mid-20th century, while climate and ocean models systematically simulate a stable AMOC. Here, by assessing the oceanic inter-hemispheric teleconnection across the Atlantic Ocean triggered by meltwater input using Earth System and ocean eddy-permitting models, we present a novel process-based decomposition of the South Atlantic salinity trend. Applying this decomposition to observations indicates that the AMOC has been weakening since the 1960s.

Interannual Variability of basal melt rates in the eastern Amundsen Sea

Ole Rieke[1,2], Paul Spence[1,2,4], Beatriz Peña-Molino[2,3], Maxim Nikurashin[1,2,4], Laura Herraiz-Borreguero[2,3], and Matthis Auger[1,4]

[1]University of Tasmania, [2]Australian Antarctic Program Partnership, [3]CSIRO, [4]Australian Centre for Excellence in Antarctic Sciences

Mass loss of the Antarctic ice sheet is largest in the Amundsen Sea, West Antarctica where unrestricted access of relatively warm Circumpolar Deep Water to the continental shelf and the ice shelf cavities drives large melt rates at depth. Previous studies have linked atmospheric forcing with the inflow of Circumpolar Deep Water, changes in thermocline depth and ultimately basal melt rates. In this study we find very high correlation (>0.8) between satellite-observed basal melt rates in the Amundsen Sea (1992-2017) and temperature variability from a global ocean-sea ice model, ACCESS-OM2. Temperature variability is dominated by a local vertical displacement of the thermocline due to changes in local zonal surface stress. A weakening of the prevailing easterlies lifts warm Circumpolar Deep Water from depth, resulting in warming at the ice shelves and higher melt rates. This mechanism is modulated by wind-related changes in the inflow of Circumpolar Deep Water on the continental shelf that is then advected towards the ice shelves. The dominant contribution of atmospheric forcing over temperature variability indicates a limited role of internal ocean variability and provides the potential for predictability of future melt rates.

COMPAS: A coastal unstructured model using Voronoi meshes, C-grid staggering and inline mesh generation

Farhan Rizwi

CSIRO

There is a growing trend towards unstructured mesh modelling for coastal zones. These meshes are generally coastline following with a resolution function, typically, of distance from coast and/or bathymetry weighted. The variable resolution allows for very fine-scale structure at the areas of interest and expanding out to coarse resolution allowing for a single direct nesting in larger scale global models. However, generating high quality meshes is a non-trivial task, often requiring several iterations to balance the desired resolution and run-time ratios.

In this poster, I will introduce our unstructured mesh hydrodynamic model COMPAS (Coastal Ocean Marine Prediction Across Scales), within EMS (Environmental Modelling Suite), which operates on the dual (voronoi) of the triangulation, outline its inline mesh generation using JIGSAW and relocatable capabilities. This allows users to deploy models very quickly with only a minimal set of inputs, the package handles the automated bootstrapping of the full parameter file.

COMPAS also includes a mass-conserving transport model, allowing for greatly reduced simulation times when coupled with ecological ad sediment processes, and particle tracking.

Antarctic Bottom Water formation and export is sensitive to horizontal model resolution

Christina Schmidt

University of New South Wales

A high horizontal resolution of 1/16° to 1/50° is required to simulate mesoscale processes on the Antarctic shelf important for the formation of AABW. During the downslope flow of AABW into the abyss, numerical mixing and coarse bathymetry can substantially alter the properties and pathways of AABW resulting in too weak northward flow of AABW even if formation rates on the shelf were sufficient. We developed a new regional, PanAntarctic Southern Ocean model, using MOM6 under a hierarchy of configurations with resolution increasing from 1/10° (~4 km resolution at 68°S), to 1/20° (~2 km) to 1/40° (~1 km). The AABW transport across the 1000 m isobath increases by 27% in the 1/20° model compared to the 1/10° simulation, but there is no significant transport increase in the 1/40° case relative to 1/20° resolution. The higher AABW export in 1/20° is due to formation of denser waters on the shelf and less diapycnal mixing during the downslope flow compared to 1/10°. This has effects downstream with newly ventilated AABW occupying the abyss in the Australian Antarctic Basin in the 1/20° case, but in the 1/10° it is only found in deep layers between 2000 and 3500 m, at odds with observations.

Paikea: A Python package for validating numerical models

Blake Seers

CSIRO

How do we know if our model data is accurate? To quantify the answer to this question we typically need to compare the model data to another trusted dataset to be used as a reference, for example in-situ observations. This process of validation can be complicated by the various possible model grids, along with the wide range of formats and dimensions of the reference datasets, among other considerations. This presentation introduces Paikea, covers how it works, and how we have used it to validate various numerical models at scale.

Seasonal variability in heat transport in the East Australia Current (EAC) System using a high-resolution multi-decadal regional ocean model

Fernando Sobral, Moninya Roughan, Neil Malan, Junde Li

University of New South Wales

The East Australian Current (EAC) plays a crucial role in controlling regional heat budget transporting warm waters from the tropics poleward along the east coast of Australia. The way heat converges or diverges influences changes in ocean sub-surface temperature. While cross-shelf transport is typically orders of magnitude less than alongshore transport, its ability to cross high-gradient zones makes it important for exchanging properties between shelf-offshore. Presently, there is limited knowledge about the seasonality of heat transport (HT) in the EAC System, particularly regarding shelf-offshore exchange. Using a multi-decadal high-resolution model, we investigate mean and seasonal HT in the EAC System. Our research reveals a strong seasonal cycle in key variables (such as mean and eddy kinetic energy, upper ocean heat content, and heat transport), peaking in summer and reducing in winter. At the separation zone, the dominance of jet-driven heat transport transitions to eddy-driven transport, altering the dynamics from efficient poleward heat transport to recirculation of heat. Our results underscore the need for multi-decadal, spatially resolved ocean models to accurately quantify variability and improve understanding of regional oceanic processes.

Inferring missing salinity observations in the Antarctic margins

Taimoor Sohail

University of New South Wales

The delivery of heat and freshwater on and off the Antarctic shelf region is a key controller of ice melt. However, observations of ocean temperature and salinity remain scarce in the Antarctic margins. In addition, there are half as many reliable salinity observations in the region as there are in-situ temperature observations. To improve our understanding of ocean freshwater fluxes around Antarctica, we must infill these missing salinity observations. In this work, we infill missing salinity observations around Antarctica using a combination of machine learning and water mass methods. Given a known temperature observation at a pressure level, we produce a constrained prediction of the corresponding salinity. This infilled salinity dataset enables better predictions of salt and heat fluxes around Antarctica, thus enhancing our understanding of this critically data-constrained region.

In search of Antarctic Bottom Water: a message from the CTD team on Multidisciplinary Investigations of the Southern Ocean voyage.

Paul Spence

University of Tasmania, AAPP, ACEAS, W21C

The MISO voyage departed Hobart on January 1, 2024 and sailed south to the edge of the Antarctic ice, travelling 9260 kilometres, before returning to Fremantle in early March. The voyage path from Hobart to Fremantle on CSIRO research vessel (RV) Investigator has basically two parts: firstly, the southern track along the Antarctic margin below 60°S; and secondly, we sail up longitude 115°E across the entire ocean basin all the way from Antarctica to Western Australia, along GO-SHIP I09S.

This poster presents early results from the CTD (Conductivity-Temperature-Depth) team on the MISO voyage. More than 100 full depth casts were done on the voyage. Early results suggest a continued warming and contraction of AABW, a weakening of the salinity rebound in the Ross Sea, and shelf waters in the Mertz regions are relatively more oxygen-rich than the previous records.

Biogeochemistry in ACCESS-OM3

Dougie Squire

ACCESS-NRI

ACCESS-NRI and COSIMA are actively developing the ACCESS-OM3 global ocean/sea-ice model. Relative to its predecessor ACCESS-OM2, ACCESS-OM3 includes updated ocean and sea-ice components—to MOM6 and CICE6—and new coupling infrastructure built on NUOPC. These updates have necessitated a rewrite of WOMBAT, the ocean biogeochemistry model available in ACCESS-OM2. In ACCESS-OM3 WOMBAT is implemented and integrated with MOM6 using the GFDL “generic tracers” framework, which has a number of benefits over the previous implementation. Here we describe these benefits, the technical implementation and the impact to users interested in ocean biogeochemistry in ACCESS-OM3.

CICE6 adds Wave-Ice Interaction, Fast-Ice and Metamorphic Snow

Anton Steketee

ACCESS-NRI

CICE is the sea-ice component to the ACCESS Ocean, Climate and Ecosystem Models. This poster focuses on the latest updates made available through by the CICE-Consortium. Ongoing work to update ACCESS to use CICE6 allows research into waves, fast-ice and metamorphic snow. Wave spectra, from the Wave-Watch III, will be used within CICE to improve our representation of the Marginal Ice Zone, and how this is affected by wave breakup. CICE6 also adds the capability to model land fast ice, which is critical as a habitat for marine mammals and birds and impacts ocean physics and biogeochemistry. An advanced snow scheme has been added, which might allow better understanding of how the snowpack impacts Antarctic Sea Ice. These new capabilities in CICE6 will bring improved research capabilities in Sea Ice modelling.

Enhanced glacial melt rates driven by internal waves

James Sweetman

The Australian National University

Accurate parameterisations of ice ablation rates are essential for modelling the impacts of climate change and sea level rise. Recent interest has focused on the interaction between ice and internal wavefields as a mechanism to enhance ablation rates. In this study, we present preliminary novel laboratory data on the ablation rates of vertical slabs of ice subjected to internal wave forcing in conditions typical of ocean salinities and temperatures. Our experimental set-up includes a 1.1m deep, 1.5m long, 0.2m wide double-glazed Plexiglas tank, pure ice grown in situ by a heat exchanger, two high-resolution cameras, and a traversable conductivity-temperature probe, all in a temperature-controlled environment. We implement edge-detection and synthetic-schlieren techniques for our analysis to measure the ablation rate and wavefield energy, respectively. Our initial results indicate that stratified environments with internal wavefields significantly enhance the depth-averaged ablation rate compared to control environments. These experiments provide insights into the relatively unknown and complicated interactions between ice and internal wavefields.

The impact of meanders and eddies on air-sea interaction and subduction in an eddying Southern Ocean

Felipe Vilela-Silva, Nathan L. Bindoff, Helen E. Phillips, Stephen R. Rintoul, Max Nikurashin

University of Tasmania,

The Antarctic Circumpolar Current (ACC) is forced at the ocean surface by heat, freshwater fluxes, and westerly winds. Observations and models show that the ACC's volume transport has not increased despite a 20% increase in wind stress over the past decades. Standing meanders along the ACC host regions of elevated eddy variability, meridional heat transport, and vertical exchange. In this study, we diagnose air-sea interaction and subsurface dynamics in a standing meander south of Australia and water subduction in an eddying Southern Ocean. We use the 1/10° ACCESS-OM2 ocean-sea ice model forced by the JRA55 atmospheric reanalysis. We track the ACC fronts in the model based on the transport of the whole water column and meridional density gradients. The thermodynamic and dynamical properties are compared to the position and flexing of the ACC's Polar Front meander. The standing meander induces trough-to-crest variations in surface heat flux, mixed layer depth, wind stress curl, vertical velocity, and subduction. At the crests, the ocean loses heat, and the mixed layer is deeper. The opposite occurs at the troughs. Wind stress curl, vertical velocity and subduction change sign on entering and exiting crests and troughs. The difference in composites of a relaxed and flexed Polar Front meander highlights the link between vertical velocity and meander curvature. Moreover, we also estimate the eddy-induced and Eulerian subduction in the Southern Ocean following the definition per se without any parameterization or spatial filter. The results show that ACC meanders impact air-sea fluxes of heat and momentum and that eddies and meanders enhance the SAMW and AAIW subduction at key locations around the Southern Ocean linked to regions of steep topography. These discussions are relevant for exploring the Southern Ocean Overturning Cell, Global Overturning Circulation, and dissipation of momentum input from the atmosphere to the ocean along ACC meanders.

Nearshore wave prediction using Graph Neural Network at Darwin Harbour, Australia

Xiao Hua Wang[1], Nazeat Ameen Iqra[1], Jun Li[2], Gang Yang[1]

[1]UNSW, [2]University of Technology Sydney

Darwin Harbour (DH), Australia, is a flood-dominated estuary where the wave substantially influences sediment resuspension and transportation, especially in the outer harbour. Hence, the prediction of waves is crucial for coastal activities and management in DH. This paper presents a graph neural network (GNN) model to forecast wave characteristics in the nearshore zone of DH. The model was assigned for next-frame prediction of wave parameters such as significant wave height, peak period, wavelength, velocity, and wave period. This implies that the model had been configured to project future features by assessing parameters at a specific domain and timeframes. The GNN framework is intended to identify graph dependence via message passing between the nodes. Input of the model is the wave findings from 62-days simulation of the SWAN model. The study was carried out among 7194 nodes, and each node was linked to 5 neighbour nodes to forecast dependencies accurately. The data has been split into 80% and 20% for training and testing purposes. Furthermore, the significance of the number of hours as an input on anticipated outcomes was investigated. The results reveal that GNN model can replicate wave variables from physics-based model with mean-squared errors less than 0.14% and coefficients of r-squared more than 71%. Moreover, it demonstrates that increasing the number of hours for input and time steps for forecasting reduces the model's performance. As such, the proposed GNN model can be useful for wave prediction and can be integrated with traditional coastal modelling to examine coastal phenomena.

Interannual variability of primary production by algae in Antarctic sea ice during the satellite era

Pat Wongpan[1], Klaus Meiners[2,1,3], Hakase Hayashida[4,5], Andrew Kiss[6,7], Alex Hayward[8,9,10], Matt Pinkerton[10], Anton Steketee[2,1,11], Pete Strutton[5,3,12], and Delphine Lannuzel[1,3,5]

[1]Australian Antarctic Program Partnership, [2]Australian Antarctic Division, [3]Australian Centre for Excellence in Antarctic Science, [4]Japan Agency for Marine-Earth Science and Technology, [5]Institute for Marine and Antarctic Studies, [6]Australian National University, [7]Australian Research Council Centre of Excellence for Climate Extremes, [8]National Centre for Climate Research, [9]University Of Otago, [10]National Institute of Water and Atmospheric Research, [11]ACCESS-NRI, [12]Australian Research Council Centre of Excellence for Climate Extremes

Observations of primary production by algae in Antarctic sea ice are discontinuous, sparse, and under-described. To assess the impact of Antarctic sea ice extremes on algal primary production, our study uses a high temporal and spatial resolution (daily and 0.1°) ice-ocean-biogeochemistry model, the Australian

Community Climate and Earth System Simulator - Ocean Model version 2 (ACCESS-OM2-01). The biogeochemical component is composed of the Whole Ocean Model of Biogeochemistry and Trophic-dynamics (WOMBAT) and CICE 5.1 for ocean and sea-ice biogeochemistry, respectively. The model is forced with JRA55-do which is a surface-atmospheric dataset for driving ocean-sea-ice models based on Japanese 55-year atmospheric reanalysis (JRA-55). We evaluated the model results (1979–2023) with a satellite-based light penetration index during 1988–2016. There is a significantly positive correlation between simulated and satellite-derived primary productions. The model captures the impacts of the recent increase of Antarctic sea ice variability on the changes of sea ice algal primary production.

How do model configurations affect the evaluation of air-sea equilibration time in CDRs?

Yinghuan Xie[1], Paul Spence[1,2,3], Stuart Corney[1,3], and Lennart T. Bach[1]

[1]University of Tasmania, [2]University of New South Wales, [3]Australian Antarctic Partnership Program

In this study, we evaluate the impact of model configurations on the estimation of air-sea equilibration time within Carbon Dioxide Removal strategies (CDRs) using the ACCESS-OM2-BGC model. Specifically, we analysed the response of the model to an identical initial Dissolved Inorganic Carbon (DIC) perturbation across three different resolutions: 1, 0.25, and 0.1 degrees. Experiments are conducted at various global locations to simulate the diverse surface ocean connectivity and assess its influence on the outcomes. By comparing the results across different model configurations and locations, we aim to identify how spatial resolution and regional oceanographic characteristics influence the model's ability to simulate air-sea gas exchange processes effectively. We also compare our results to other research to provide a cross-model comparison. Our research provides important insights into the configurational dependencies of modelling for CDR evaluation, thereby helping to better design and implement CDR strategies in varying marine environments.

Monthly Climatology of the Southern Ocean under Sea Ice

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The advent of under-ice profiling float and biologging techniques has enabled year-round observation of the Southern Ocean and its Antarctic margin. These under-ice data are often overlooked in widely used oceanographic datasets, despite their importance in understanding the seasonality and its role in sea ice changes, bottom water formation, and glacial melt. We develop a four-dimensional climatology of the Southern Ocean (south of 40°S and above 2,000m) using Data Interpolating Variational Analysis, which excels in multi-dimensional interpolation and consistent handling of topography and advection. The climatology captures thermohaline variability under sea ice, previously hard to obtain, and outperforms other products in data fidelity with smaller root-mean-square errors and biases. Our dataset will be instrumental for investigating seasonality and for improving ocean models. This work further highlights the quantitative significance of under-ice data in reproducing ocean conditions, advocating for their increased use to achieve a better Southern Ocean observing system.

A Slowdown of Subsurface Freshening in the Southwest Pacific Since 1990

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The Southwest Pacific, as the western boundary of the South Pacific Subtropical Gyres, is one of key regions exhibiting notable subsurface freshening trends in the past decades. Using observation-based reanalysis dataset, however, we demonstrate that the subsurface freshening in the Southwest Pacific Ocean has slowed down in the most recent three decades (1990-2020), occurring at a rate less than one-fourth of that observed during the earlier three decades (1960-1990). To understand the drivers of this subsurface salinity variability, we conducted flux-form model experiments based on a global ocean sea ice model by changing one type of surface flux at a time while repeating climatology of others, to clearly distinguish their individual effects. The results show that this multidecadal variability is predominantly induced by surface wind stress (~113%), through deepening isopycnal and anomalous Ekman transport. While the contribution from the surface heat flux (~32%) is comparable but counteract that from the surface freshwater flux (~--45%). Further EOF analysis suggests that the Interdecadal Pacific Oscillation likely contributes to this multidecadal variability. The distinct contribution of individual surface forcing and the experiment design conducted here provide an essential reference for identifying the impact of climate variability on ocean interior hydrography.

A Machine Learning Parametrisation for the Internal Gravity wave Spectrum

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Understanding internal waves is pivotal as they play a critical role in ocean dynamics, influencing processes such as mixing and energy transport from large to small scale. The phase of internal waves can rapidly be altered during propagation, leading to broad spectral peaks. We introduce a stochastic model designed to parametrise the spectral properties of coastal internal waves, using Lorentzian function to characterise the broad internal tide peaks and a Matern function for the energy continuum. Utilising long-term mooring temperature data from the Australian Northwest Shelf (NWS) and Timor Sea, we validate the efficacy of our model. By optimising the model parameters using debiased Whittle likelihood in the frequency domain, our approach reproduces the spectrum of the internal wave incoherent peaks, as well as the continuum of energy down to the buoyancy frequency. The fitted parameters allow comparison of internal wave properties between depths and sites. The time-scale parameter for the internal tide peak characterises the extent of the phase shift; this timescale was largest at the Timor Sea 400 m mooring for the diurnal peak and Kimberley 200m mooring for semidiurnal peak. The depth variation for the energy continuum amplitude and the amplitude of the semidiurnal peak follow an internal wave mode-1-like structure, particularly at the deeper mooring sites. The largest amplitudes were present within the surface mixed layer and thermocline. The slope parameter of the continuum varied seasonally, with a more rapid decay of internal wave energy in the summer compared to winter. The parametric model can be used to construct more realistic internal tide boundary conditions, thereby enabling more skilful predictions of internal waves in coastal regions.