OceanPredict '19
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Theme 3: Numerical Modelling

Session 3: Biogeochemical and ecological applications

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Tidal vs. Atmospheric-induced mixing: case study of the effects on bloom dynamics and vertical gas exchanges using the BLING-NEMO numerical model

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The biogeochemical model, Biogeochemistry with Light Iron Nutrients and Gasses with dissolved inorganic carbon (BLING), was coupled to the general ocean circulation model, the Nucleus for European Modeling of the Ocean version 3.6 (NEMO3.6), to study the sensitivity of bloom dynamics and deep ocean gas exchange to tidal and atmospheric-induced mixing. Using climatology observations from the World Ocean Atlas 2013 version 2 (WOA13) and the Global Ocean Data Analysis Project version 2 (GLODAPv2) we measured the performance of BLING-NEMO in a degree regional configuration of the Arctic and Northern Hemisphere Atlantic (ANHA4). The simulation, integrated from 1st of January 1970 to the 31st of December 2016, captured the observed spatial and vertical gradients of nutrients, oxygen, and chlorophyll-a concentrations in the Atlantic and the Arctic Ocean. Deep ocean concentrations of nutrients and oxygen are strongly affected by the overall density of the water column and are thus influenced by ocean model drift. Atmospheric forcing (e.g. wind and precipitation fields) has an important role in defining surface water density and thus, it also strongly influences the model results. Tidal mixing has an impact on the vertical mixing of nutrients and dissolved gases throughout the Atlantic Ocean, with differences being more evident in coastal areas and shallow basins (< 500 m). We demonstrate that simplifications and assumptions within BLING (e.g., only six prognostic tracers) are not limiting our ability to understand the impact of mixing in productivity and gas exchanges.

Keywords: Models - Model assessments and verification, Models - Ecosystem/BGC modelling, Models - Coupled modelling, Models - Wave and tide modelling, Models - Ocean model boundary conditions and forcings

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Modelling Phytoplankton Dynamics in a Turbid River Plume

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River plumes can influence phytoplankton growth in complex and competing ways. Enhanced stratification and nutrient supply can promote population growth while freshwater dilution and light attenuation due to suspended sediments have the opposite effect. We investigate these phenomena in the context of the Fraser River plume and Southern Strait of Georgia using a three dimensional coupled physical-biological model (SalishSeaCast) with an observation-based turbidity-light attenuation relationship. Whereas previous models in this region have represented riverine turbidity effects through a linear relationship between light attenuation and salinity or freshwater input (Pea et al., 2016, Collins et al., 2009), our parameterization includes an additional tracer representing Fraser River turbidity. This turbidity is input according to real-time data from the Fraser River Water Quality Buoy and is removed through a constant sinking rate representative of fine sediment. We will discuss the impact of turbidity on primary productivity in the plume and surrounding region of freshwater influence. Additionally, we will discuss divergence of nearby trajectories within the plume and the implications this may have regarding scales of predictability of physical and biological properties in the plume region. Finally, we will evaluate the success of the model in reproducing available physical and biogeochemical data at varying spatial and temporal scales and address the incorporation of this model version in an ocean prediction system run operationally on a daily basis.

Keywords: Models - Ecosystem/BGC modelling, Models - Model assessments and verification, Models - Current scientific challenges of ocean modelling

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The Moana Project: Seafood sector support for ocean data collection to improve ocean prediction in New Zealand

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New Zealand derives wealth and wellbeing from the ocean, including a seafood sector worth $4.18B annually, and yet, their oceans are very poorly understood. NZ lags other developed nations that have integrated ocean observing and modelling programmes, and cannot comprehensively measure, observe or predict the state of their Exclusive Economic Zone (EEZ).Ocean circulation drives the transport of larvae, determines population connectivity and impacts fisheries recruitment and abundance, all of which are being impacted by ocean warming and changes in circulation patterns.

Embracing the Internet of Things concepts, we are developing a low-cost smart ocean sensor to be deployed throughout NZs EEZ by the seafood sector. With our industry partners; Seafood NZ, Deepwater Group, Paua (Abalone) and Rock Lobster Industry Councils, iwi (indigenous) and recreational fishing communities, we will revolutionise ocean data collection. The temperature profile data will be returned in near real time via the cell phone network (or satellite) and ingested into data assimilating ocean prediction models, leading to an open-access nationwide Ocean Analysis and Prediction System, delivered by the Meteorological Service. This disruptive technology approach is an exemplar for other marine nations with strong seafood sectors and under investment in the marine observing and modelling space. We show the benefit of partnering with end users to collect and return research quality datasets that are relevant for industry needs.

This project will provide a more complete picture of ocean temperatures, circulation and dynamics, and the relationships with fishery recruitment variability, aiding prediction. This project will underpin operational efficiencies, biosecurity protection, risk mitigation and economic growth for NZs seafood sector ensuring long-term sustainability.

Keywords: Applications - Fisheries, DA - Data assimilation applications, Observations - Integration of local/coastal measurements in the global observing system, Systems - Ocean Prediction Systems types (forecasting, analysis, scales, assessment, regions, ecosystem, ice, wave, etc.),

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Model-data assessment of Scotian Shelf carbon dynamics: A spatially varied and biologically active system

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The broad Scotian Shelf off the coast of eastern Canada is located at the dynamic junction of the subpolar and subtropical gyres. Biological processes on this shelf are characterized by strong seasonality, including a large spring bloom in late March. The dynamic circulation and biological activity are reflected in spatially and temporally heterogeneous inorganic carbon and pCO2 distributions. Observations from a moored buoy provide a multi-year time series of surface pCO2 measurements, and show a rapid and large drawdown of pCO2 during the spring bloom on the inner Scotian Shelf. Repeated high-resolution spatial observations from a cross-shelf transect show that surface pCO2 also changes dramatically across the shelf. The transect observations indicate higher pCO2 in a thin band directly adjacent to shore (leading to net outgassing) and lower pCO2 values across the rest of the shelf. In this study, we use our model of the northwest North Atlantic combined with the aforementioned observations from the moored buoy and highly resolved transects to elucidate biological and physical processes underlying the observed carbon dynamics on the Scotian Shelf. We specifically aim to address how the regional circulation is impacting the Scotian Shelf pCO2 distributions and what is driving the inshore outgassing.

Keywords: Models - Model assessments and verification, Models - Ecosystem/BGC modelling, Observations - Observation impacts, Observations - In-situ ocean observing systems,

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Tradeoffs between satellite surface and Argo profile observations when optimizing a biogeochemical model for the Gulf of Mexico

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Biogeochemical ocean models are useful tools but contain uncertainties arising from simplifications, inaccurate parameterization of processes and poorly known model parameters. Parameter optimization is a standard method for addressing the latter but typically cannot constrain all biogeochemical parameters because of insufficient observations. Here we assess the tradeoffs between satellite surface observations and Argo profiles, and the benefits from combining both observation types, for optimizing biogeochemical parameters in a model of the Gulf of Mexico. A suite of optimization experiments was carried out using different combinations of satellite chlorophyll and profile measurements of chlorophyll and phytoplankton biomass, and particulate organic carbon (POC) from autonomous floats. As parameter optimization in 3D models is computationally expensive, we optimize the parameters in the 1D model version, and then perform the 3D simulations using these parameters. We show first that the use of 1D optimized parameters can improve the skill of the 3D model. However, parameters that are only optimized with respect to surface chlorophyll cannot reproduce subsurface distributions. Adding profiles of chlorophyll in the parameter optimization yields significant reductions of misfits for surface and subsurface chlorophyll but does not capture subsurface phytoplankton and POC distributions well because the parameter for the maximum ratio of chlorophyll to phytoplankton carbon is not well constrained in that case. Using all available observations led to significant improvements of both observed (chlorophyll, phytoplankton, and POC) and unobserved variables, e.g. primary production. Our results highlight the significant benefits of Biogeochemical Argo measurements for biogeochemical parameter optimization and model calibration.

Keywords: Models - Ecosystem/BGC modelling, Models - Model assessments and verification, , ,

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A model assessment of the effects of Beaufort Gyre circulation changes on nutrient pathways and transport times in the Arctic Ocean

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The hydrography and biogeochemistry of the Arctic Ocean, which links the North Pacific and North Atlantic, are strongly influenced by water masses from both adjacent oceans. The cold and relatively fresh Pacific Water is nutrient-rich although depleted in nitrate relative to phosphate, while the warm and saline Atlantic Water is characterized by lower but more balanced nutrient concentrations. Here, we investigate how subsurface circulation, transit times and nutrient transport of Pacific and Atlantic Waters change under different regimes of the surface circulation in the Beaufort Gyre. The analysis provides insight in the potential impacts of changes in circulation and nutrient supply on the biogeochemistry of the Arctic. For this purpose, we employ a regional model based on NEMO (Nucleus for European Modelling of the Ocean) that reaches from the North Pacific through the Arctic to the North Atlantic Ocean. Passive dye and age tracers are implemented to track Pacific and Atlantic Waters and to quantify the transit times from their source regions to the different parts of the Arctic Basin. A simulation for the years 1958-2015 is analyzed with focus on two different periods: pre-1996, when the Beaufort Gyre alternated between cyclonic and anti-cyclonic circulation regimes on a quasi-decadal cycle, and post-1996, when a strong anti-cyclonic circulation persisted. Previous studies suggest that these changes in surface circulation impact the subsurface circulation in the Artic Basin but did not address the consequences for nutrient transport. We analyze two distinct layers formed by Pacific Water: the warm and fresh Pacific Summer Water at ~50-100 m depth and the colder Pacific Winter Water at ~100-150 m depth. We further investigate how the changes in surface circulation affect the intensity and direction of circulation in the upper Atlantic Water layer at ~200-300 depth, formed by warm and saline water entering through Fram Strait, and how these changes affect the transit times of Atlantic Water in the Arctic Ocean. These results provide first insights into potential changes in nutrient availability in the Arctic Ocean under different circulation regimes.

Keywords: Models - Numerical methods, Applications - Climate change research, , ,

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