Theme 3: Numerical Modelling

Session 5: Small Scales

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Improving NEMO's iceberg module

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Icebergs constitute a major part of ice sheets mass discharge, delivering freshwater to the ocean at a slower pace than direct coastal runoff. They are also linked to phytoplankton blooms since their meltwater contain a number of terrigenous nutrients. Added to those environmental roles, icebergs pose a threat to shipping and offshore resources extraction activities. Since monitoring every individual iceberg is an operational impossibility, numerical models are useful tools to explore their common trajectories and impacts on the ocean. NEMO v3.6 has introduced an iceberg module that was originally built by Bigg et al (1996,1997) and further improved by Martin and Adcroft (2010) and Marsh et al. (2015). In this original version, icebergs are driven and deteriorated by surface ocean fields. Since then, Merino et al. (2016) has tested a new scheme (not yet included in NEMO) where ocean fields are vertically-integrated between surface and iceberg keel before being used in the dynamic-thermodynamic equations for icebergs. Since their simulation focused on Antarctic icebergs, we have applied their new scheme to Greenland and compared iceberg trajectories with the ones obtained with the original surface-only scheme. We found that icebergs that are driven by the vertically-integrated ocean velocities concentrate along the shelf break (following the geostrophic component of currents) while in the original version they drift close to the coastline. We are now further modifying NEMOs iceberg module in order to lock icebergs that get caught in a concentrated and strong sea ice pack. Future plans also include modifying how the meltwater enters the ocean. Although icebergs drifting within weak flows have their meltwater injected close to the surface (which is what the original module does), the ones embedded in stronger flows have their meltwater plume entering at depth (FitzMaurice et al., 2017). The challenge will be to find an appropriate way to reduce subsurface salinity without creating strong instabilities.

Keywords: Models - Numerical methods, Models - Ocean processes and parameterisation, Models - Ocean model boundary conditions and forcings, ,

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Inclusion of realistic tidal motions in submesoscale-permitting simulations of the North Atlantic with NEMO – eNATL60

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Basin to global submesoscale-permitting simulations of the ocean circulation down to the kilometric grid scale has become technically achievable thanks to the continuous increase in the capabilities of supercomputers. Data from this type of simulations, provided they realistically represent oceanic motions at fine scale, can be used for preparing satellite observation missions and for guiding the design of the next generation operational systems. Yet, due to the computational costs of these simulations, it remains highly challenging to perform sensitivity experiments/analysis. Moreover, the relative scarcity of observational data available at scales ~10 km makes it also challenging to assess how realistic these simulations are.
Besides, the ability of these submesoscale permitting models to realistically simulate tides and internal tides remains to be addressed. In particular, there is a need to document the impact of including tidal forcing in these models, and to understand more precisely how tidal motions affect both large and fine scale oceanic flow properties.

Here, we report on the first multiyear-long sensitivity twin experiment performed with a basin-scale model at kilometric resolution for assessing the impact of the explicit representation of tides: a simulation is performed with tidal motion and the other without. This twin experiment has been designed in preparation for the upcoming SWOT satellite altimetry mission. Our model, eNATL60, is a basin-scale configuration of NEMO (Nucleus for European Modeling of the Ocean) that spans the North Atlantic from about 6N up to the polar circle, and fully includes the Gulf of Mexico, the Mediterranean Sea, and the Black Sea. The horizontal grid resolution is about 1/60 while the vertical dimension is discretized along 300 levels, for a complete computational domain of 10 billion points.

Our assessment of the simulated surface dynamics in eNATL60 against high resolution observation products (high resolution altimetry, ship-born thermosalinographs, mooring data) shows the skill of the model in capturing oceanic flow properties (including tidal motions) at scale down to the model effective resolution (~10 km). The response of the kinetic energy cascade towards fine scale, as well as the properties of sea surface height and temperature, to the tidal forcing is assessed by means of spectral analysis.

Keywords: Models - Current scientific challenges of ocean modelling, Models - Ocean processes and parameterisation, Models - Model assessments and verification, Models - Ocean model configurations, Models - Wave and tide modelling

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The Predictability of Internal Tides in Forward and Data-Assimilative Global HYCOM simulations

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In this presentation, we discuss the predictability of internal tides in realistically forced global Hybrid Coordinate Ocean Model (HYCOM) forward and data-assimilative (DA) simulations. The predictability of the internal tide is governed by a linear wave-drag parameterization, the model resolution, and the time-variability of the background flows, among other things.
In 3D HYCOM simulations, the resolution affects the number of baroclinic wave modes that can be resolved. To obtain accurate surface tides, a linear wave drag parameterizatonis applied in HYCOM to account for the unresolved energy transfer from the surface tide to the high vertical internal tide modes. We show that the drag strength needs to be reduced when the models horizontal resolution is increased from 8 to 4 km in order to maintain accurate surface tides. In HYCOM, the wave drag operates on both the surface and internal tides. We demonstrate that the internal tides become more energetic than observations in the higher resolution simulations.

As internal tides propagate through the global ocean they interact with the time-varying mesoscale background flows, high-frequency motions, and topography. In forward models, the mesoscale background field is random in time and space, limiting the internal tide predictability. The application of DA to better forecast the mesoscale background fields may potentially lead to a better prediction of the internal tides and other high frequency motions. We show that in current HYCOM simulations, the application of NCODA-3DVAR causes shocks in the positioning of mesoscale fields. These shocks result in high-frequency internal gravity waves, which appear as noise in the tidal bands in regions with strong mesoscale activity. Hence, internal tides appear too energetic as compared to forward simulations.

While significant progress has been made in the internal tide predictability, work is underway to implement better internal-tide damping and reduce tidal-band noise due to DA.

Keywords: Models - Wave and tide modelling, Applications - Navy applications, DA - Variational data assimilation, Models - Ocean processes and parameterisation,

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Seamless and cross-scale modelling of the ocean: from regional to shelf-coastal and urban scale

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The present work shows the development and implementation of 3D-thermo-hydrodynamic fully-baroclinic modelling systems, based on the unstructured-grid finite-element SHYFEM model (Umgiesser et al., 2004; Ferrarin et al., 2018) and solving with appropriate and variable resolution different oceanographic scales.

The first implementation is UMEDBS (Unstructured-grid MEDiterranean and Black Sea), covering the entire Southern European Seas (Mediterranean and Black Sea) with a unique continuum grid, and focused both on the regional and shelf-coastal scale. The model domain extends in a large Atlantic box (similar to the one described in Oddo et al., 2009) with a lateral open boundary nested into high-resolution global ocean model (GOFS16, Global Ocean Forecast System, Iovino et al., 2016). The horizontal resolution is optimized on the local bathymetry, coastline and expected solutions (relevant dynamics and coastal scale features), and ranges from 4-5 km in open-ocean to 1km-500m in overall shelf-coastal seas to 50-60m in narrow straits (Dardanelles and Bosphorus). The model has been run in hindcast and free-active mode and compared with satellite observations and in-situ coastal observations showing good agreement. The impact of straits (Gibraltar, Sicily, Otranto, Dardanelles, Bosphorus, Kerch) on the dynamics and exchanges of interconnected basins (e.g. Black Sea, Marmara Sea end Eastern Mediterranean Sea) have been investigated. Furthermore, model inter-comparison has been performed with GOFS16 and MFS (Mediterranean Forecast System products of CMEMS European Service, http://marine.copernicus.eu/) analysis.

The further implementation here presented is a test-bed of CMEMS downscaling in non-EU area. A modelling system has been designed to provide high- and hyper- resolution forecasts for the Georgia (U.S.A.) coasts, with specific focus and grid refinement in riverine and port area of Savannah city. The horizontal resolution ranges from 1-2km in open ocean to 10m in the urban area of interest. The modelling system is laterally forced in terms of (i) 3D thermo-hydro dynamics by CMEMS GLO-MFC - Global Monitoring and Forecasting Center - and (ii) tides by OTPS Oregon State University Tidal Prediction Software. The model has been compared with temperature and sea level fields at Savannah in-situ mooring station. Preliminary results suggest exploiting wetting-and-drying code capabilities to include marshes in modeling system.

Keywords: Models - Ocean model configurations, Models - Downscaling, Models - Current scientific challenges of ocean modelling, Evolution - Future perspective and new frontiers in Operational Oceanography,

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Dynamical Wave-Ice Modeling for the MIZ

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With the increasing resolution of operational forecasting models, the marginal ice zone, the area where waves and ice interact, can now be better represented . However, the proper mechanics of wave propagation and attenuation in ice, along with their feedback on the ice, remain unknown. Observations have shown that wave energy loss typically increases with frequency. This energy is transferred to the ice, breaking it into smaller floes and weakening it, as well as exerting a stress on the ice similar to winds and currents. This double effect can lead to rapid movements of sea ice in the presence of waves which are difficult to reproduce in current forecast models. A one-dimensional, fully integrated wave and ice model has been developed to test different parameterizations of wave-ice interactions. Model simulations using a variety of wind, wave and ice conditions at different scales are used to identify gaps in our representation of the impact of waves in the dynamics of sea ice.

Keywords: Models - Coupled modelling, Models - Model assessments and verification, Models - Wave and tide modelling

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Developing new high resolution coastal ice-ocean prediction systems for the northwest Atlantic and Gulf of St. Lawrence to support the Ocean Protection Plan

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In order to provide Canada with short-term ice-ocean predictions and oil spill fate and behavior forecasts for the Ocean Protection Plan, the Government of Canada CONCEPTS initiative (Canadian Operational Network of Coupled Environmental Prediction Systems) is developing new coastal ice-ocean prediction systems. Two configurations are being tested, a northwest Atlantic 1/36 degree (~2 km) resolution domain (NWA36) and a Gulf of St. Lawrence 500 m resolution domain (GSL500). The first domain covers the Gulf Stream region and the Canadian east coast including mainly the Grand Banks, the Scotian Shelf and the Gulf of St. Lawrence. The second domain covering the Gulf of St. Lawrence is bounded by Cabot and Belle-Isle straits. NWA36 and GSL500 use the NEMO-CICE ice-ocean model, both simulating explicit tides with a variable volume representation of the water column, storm surge forcing including the inverse barometer effect. Vertical mixing uses a general length scale scheme. The St. Lawrence River is represented using a one-dimensional hydrological model. The multi-category ice dynamics includes a landfast ice parameterization based on basal stress. In a first evaluation, we present free runs of both configurations focusing on results in the Gulf of St. Lawrence: tidal propagation, general circulation patterns, ice volume and concentration, water masses evolution, estuarine circulation and hydraulics, and freshwater and volume transports. It is envisaged that these configurations will eventually supersede the operational Gulf of St. Lawrence system, currently at 5 km resolution.

Keywords: Models - Ocean model configurations, Models - Model assessments and verification, Models - Ocean processes and parameterisation, Models - Ocean model boundary conditions and forcings, Models - Current scientific challenges of ocean modelling

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