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Modelling Ocean Surface Waves in Polar Regions

Lucia Hosekova (1), Yevgeny Aksenov (1), Andrew Coward (1), Laurent Bertino (2), Timothy Williams (2), and George A. J. Nurser (1)

(1) National Oceanography Centre, Southampton, United Kingdom (chosak@noc.ac.uk), (2) Nansen Environmental Remote Sensing Center, Bergen, Norway
(timothy.williams@nersc.no)

In the Polar Oceans, the surface ocean waves break up sea ice cover and create the Marginal Ice Zone (MIZ), an area between the sea-ice free ocean and pack ice characterized by highly fragmented ice. This band of sea ice cover is undergoing dramatic changes due to sea ice retreat, with up to a 39% widening in the Arctic Ocean reported over the last three decades and projections predicting a continuing increase. The surface waves, sea ice and ocean interact in the MIZ through multiple complex feedbacks and processes which are not accounted for in any of the present-day climate models.
To address this issue, we present a model development which implements surface ocean wave effects in the global Ocean General Circulation Model NEMO, coupled to the CICE sea ice model. Our implementation takes into account a number of physical processes specific to the MIZ dynamics. Incoming surface waves are attenuated due to reflection and energy dissipation induced by the presence of ice cover, which is in turn fragmented in response to external stresses. This process generates a distribution of floe sizes and impacts the dynamics of sea ice by the means of combined rheology that takes into account floe collisions and allows for a more realistic representation of the MIZ.
We present results from the NEMO OGCM at 1 degree resolution with a wave-ice interaction module described above. The module introduces two new diagnostics previously unavailable in GCM's: surface wave spectra in sea ice covered areas, and floe size distribution due to wave-induced fragmentation. We discuss the impact of these processes on the ocean and sea ice state, including ocean circulation, mixing, stratification and the role of the MIZ in the ocean variability. The model predictions for the floe sizes in the summer Arctic Ocean range from 60 m in the inner MIZ to a few tens of meters near the open ocean, which agrees with estimates from the satellites. The extent of the MIZ throughout the year is also in agreement with observations.
In addition to our global implementation, the method is currently also tested in the TOPAZ framework (Towards an Operational Prediction system for the North Atlantic European Coastal Zones). We will discuss the two modeling strategies (global 35 km resolution and pan-Arctic 3 km resolution) and analyse model biases. The study contributes to the EU FP7 project 'Ships and Waves Reaching Polar Regions (SWARP)', aimed at developing techniques for sea ice and waves modelling and forecasting in the MIZ in the Arctic. The method will be implemented as part of the EU Global Monitoring and Environmental Security system GMES.