High-resolution modelling of ocean circulation and tides

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Introduction

Ocean tides have a strong impact on the accuracy of geodetic products (e.g. from satellite altimetry and gravimetry) and play an important role for our understanding of ocean dynamic since they provide a substantial amount of energy for deep ocean mixing which is important for the maintenance of global circulation. The high-resolution simulation with an eddy and internal tide resolving ocean circulation and tide model gives us a unique tool to explore the impact of transient signals, such as changes in stratification, ocean currents, and sea-ice cover on surface tides. Further, the derived global patterns of internal tide generation can now be used for improved parameterizations of internal tide mixing.

Results

Barotropic-to-baroclinic tidal energy conversion

The Figure shows the barotropic-to-baroclinic tidal energy conversion in Wm⁻². We estimate that about 1.2 TW of M2 tidal energy is converted and including the S2, K1, and O1 tides the net conversion rate is 1.9 TW. About 50% of the tidal energy is converted in regions shallower than 2000 m. These rates are consistent with previous studies and represent the first estimates obtained from an tide model with realistic stratification and ocean currents.

Summary

We use a high resolution eddy and internal tide resolving ocean circulation and tide model with a stationary seasonal cycle of mixed-layer-depths. The accuracy of the barotropic tide is comparable with recent tide models which are based on a realistic stratification and ocean currents. The global patterns of internal tide generation (barotropic-to-baroclinic tidal energy conversion) are derived for the four largest tidal constituents and reflect the seasonality of internal tide beams generated in Luzon Strait. Globally this phenomenon can be seen at many topographical features.

Model & Experiment

- Global high-resolution ocean circulation model MPI-OM TP6M developed within the framework of the consortium project STORM
  + with explicit consideration of full luni-solar tidal forcing
- horizontal resolution ~0.1° (5 – 10 km)
- vertical resolution 40 z-layers
- 10 year experiment with monthly restoring to climatological data with an advanced restoring scheme (Cherniawsky and Holloway, 1991), in order to simulate an accurate seasonal cycle of mixed-layer depths
- harmonic analysis of the last two years of the experiment

Seasonal internal tides

The seasonal varying stratification modifies the generation of internal tides as seen for the example in the Luzon Strait, which separates the South China Sea and Pacific Ocean.

Seasonal barotropic tides

Seasonal variability of the barotropic tide is found in coastal shelf areas and in the Arctic. In the Arctic the friction between sea-ice and surface tidal current leads to a strong seasonal cycle in seasonally ice-covered regions, e.g. Hudson Bay. We estimate that 34 GW is dissipated by this process during Northern Hemisphere winters. On the other hand, a barotropic stratification effect [Müller 2012] introduces a seasonal cycle in the M2 tide in seasonally stratified coastal seas, e.g. in the North Sea.

Surface signature of internal tides

The generated internal tides have a surface expression which is Q1(1-5m). The hot spots of internal tide generation are consistent with the surface internal tide expression observed from satellite altimetry. In the Figure above we see strong internal tide generation at topographic features in the North Pacific.