Projekt 510:
Wechselwirkung von Ozean Zirkulation und Gezeiten

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.

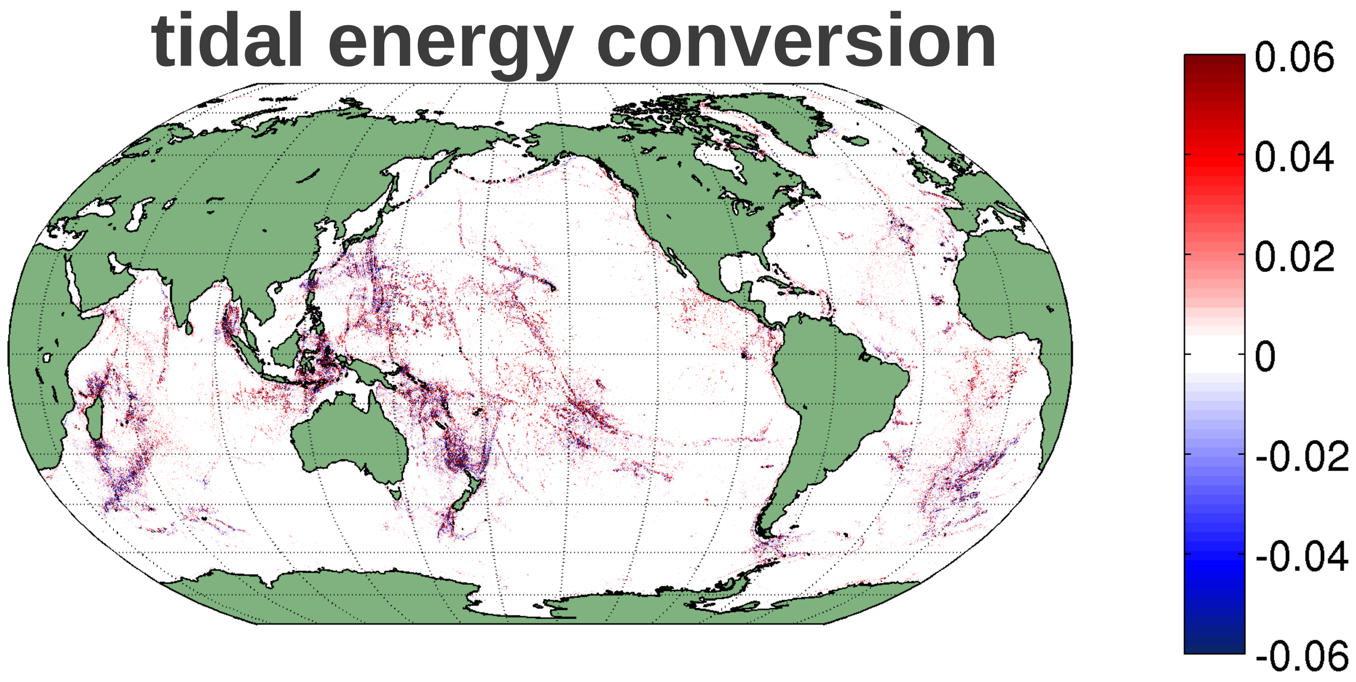
Model & Experiment

- 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

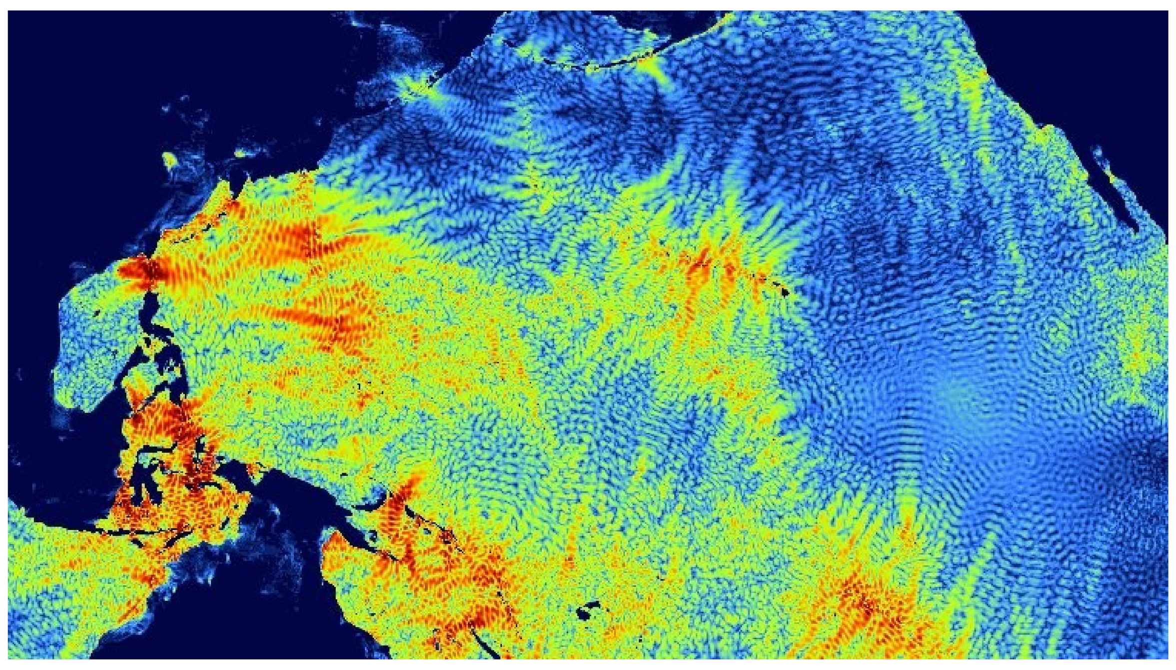
Results

Barotropic-to-baroclinic tidal energy conversion



The Figure shows the barotropic-to-baroclinic tidal energy conversion in W/m^2. We estimate that about 1.2 TW of M_2 tidal energy is converted and including the S_2, K_1, and O_1 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.

Surface signature of internal tides



The generated internal tides have a surface expression which is O(1-5cm). 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.

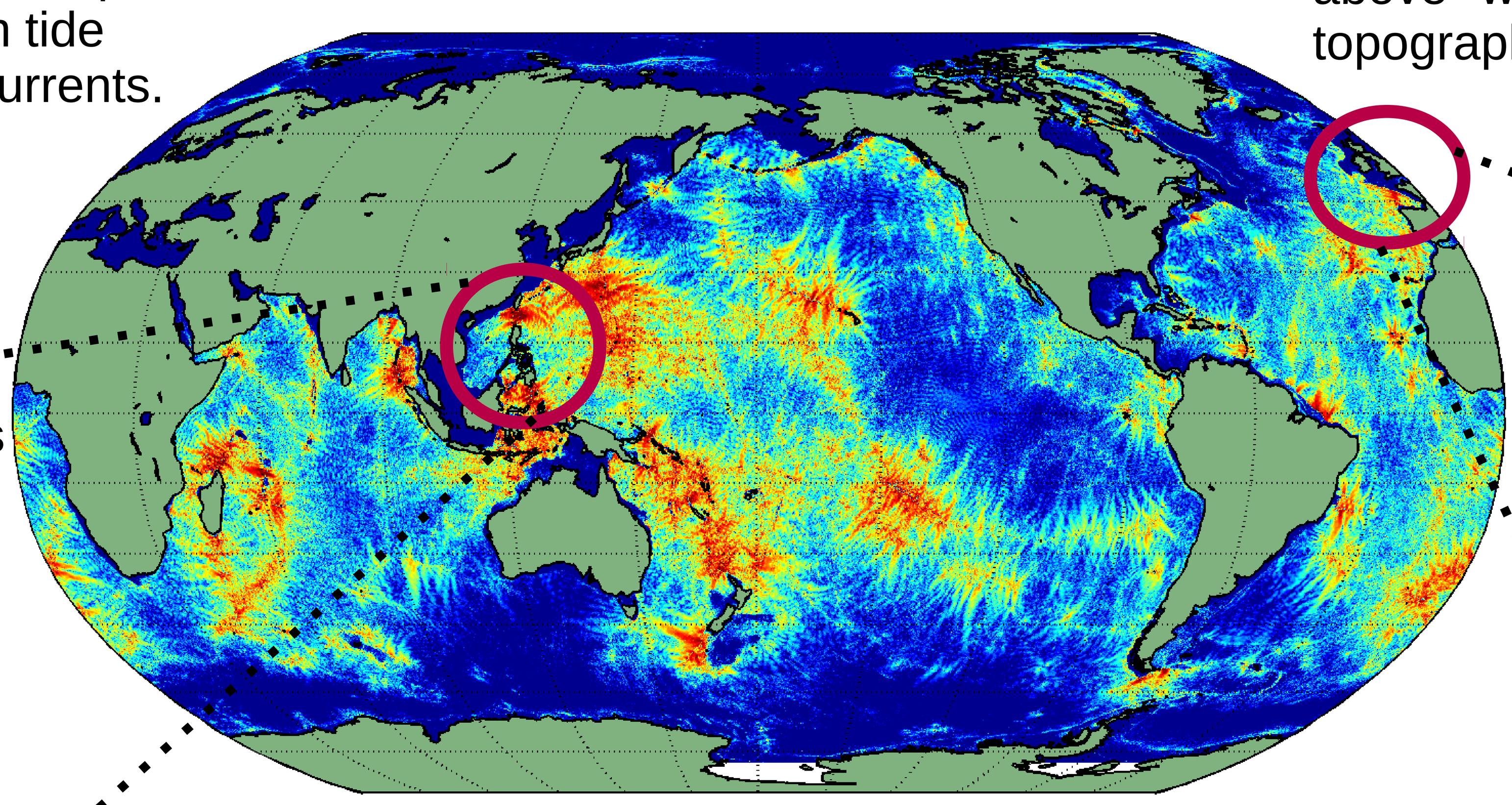


Figure: The baroclinic energy flux of the M2 tide

Seasonal internal tides

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

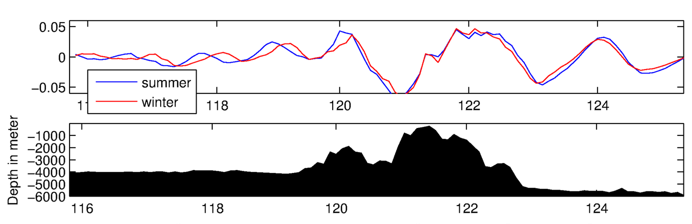


Figure: Surface expression of model simulated generation of internal tides at Luzon Strait for winter and summer.

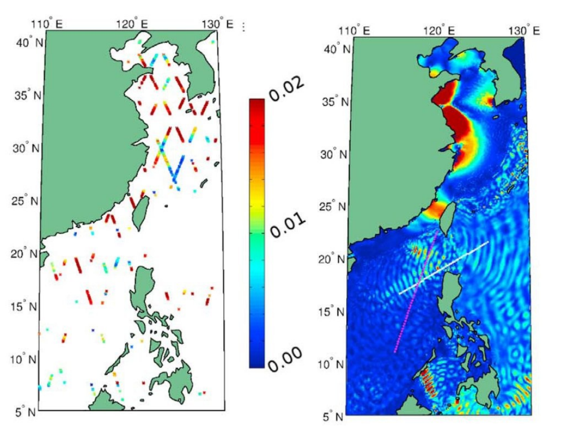


Figure: The amplitude of the seasonal cycle (in m) obtained from 19 years of satellite altimeter data (left) and 2 years of model simulation (right).

Two years of the model simulation and 19 years of satellite altimeter along track data have been harmonically analysed with respect to the annual satellites of M_2. Model results are consistent with observations and reflect the seasonality of internal tide beams generated in Luzon Strait. Globally this phenomenon can be seen at many topographical features.

Seasonal barotropic tides

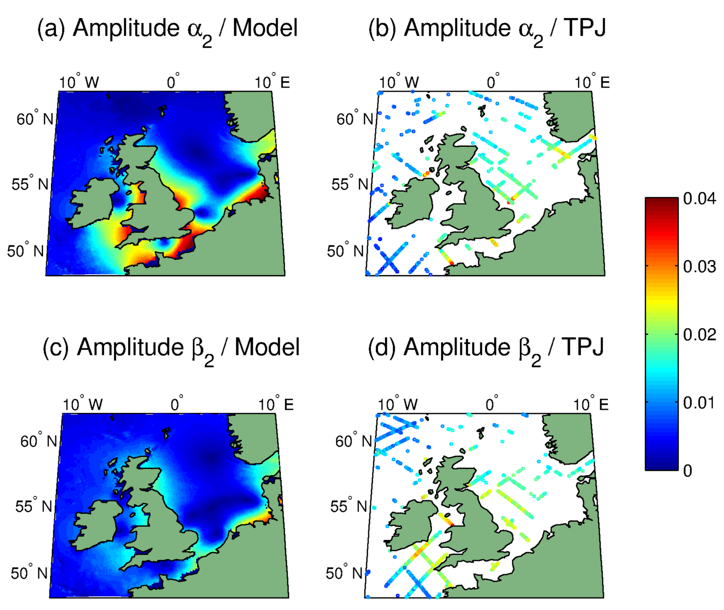


Figure: The North Sea annual satellites of M2 tidal constituent obtained from the model simulation (a and c) and from 19 years of satellite altimetry (b and d).

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 M_2 tide in seasonally stratified coastal seas, e.g. in the North Sea.

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 not constrained by satellite data and the simulated internal tide field compares reasonable well with a global map derived from satellite altimetry.
The global patterns of internal tide generation (barotropic-to-baroclinic tidal energy conversion) are derived for the four largest tidal constituents and are consistent with theoretical estimates and alternative model approaches. We estimate that about 1.9 TW of tidal energy is converted into baroclinic tidal motions [*Müller 2013*].
The model is able to predict regions where seasonal, or more generally non-stationary variations of tides can be expected. As an example, the seasonality of the internal tides in the South China Sea generated in Luzon Strait agrees with satellite altimeter data [*Ray and Zaron , 2011*]. The model results show the effect of seasonally varying stratification, controlled by seasonal solar radiation and wind forced circulation, on the propagation of the internal tide [*Müller et al. 2012*].
Further, the seasonal barotropic tide is explored and we identifiy to main processes causing seasonal tidal variation of 5-10%. First, the seasonal changes in stratification on the continental shelf affect the vertical profile of eddy viscosity and, in turn, the vertical current profile. Second, the frictional effect between sea-ice and the surface ocean layer leads to seasonally varying tidal transport [*Müller 2012, Müller et al. 2013*].
These results emphasize the use of global high-resolution ocean circulation and tide models to further understand the complex interplay between the barotropic tide and the generation and propagation of the internal tide versus low frequency changes in the ocean stratification and circulation.

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