The internal gravity wave spectrum: A new frontier in global ocean modeling

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Motivation

• Breaking internal gravity waves drive most of the mixing in the subsurface ocean.

• The internal gravity wave spectrum is just starting to be resolved in global ocean models.

• Somewhat analogous to resolution of mesoscale eddies in basin- and global-scale models in 1990s and early 2000s.

• Builds on global internal tide modeling, which began with 2004 Arbic et al. and Simmons et al. papers utilizing Hallberg Isopycnal Model (HIM) run with tidal foricng only and employing a horizontally uniform stratification.

Motivation continued...

• Here we utilize simulations of the HYbrid Coordinate Ocean Model (HYCOM) with both atmospheric and tidal forcing.

• Near-inertial waves and tides are put into a model with a realistically varying background stratification.

• Nonlinear interactions fill out the frequency-wavenumber spectrum.

• Note other groups are following suit with tide+circulation models (Harper Simmons, personal communication; Dimitris Menemenlis, personal communication; Müller et al. 2012).

• Talk focuses on the development of an internal gravity wave spectrum, after briefly discussing our other results.

Implementation of tides in HYCOM

--Add astronomical tidal potential of largest semidiurnal and diurnal constituents (8 in run analyzed here, 5 in newest runs)

--Add self-attraction and loading term (scalar approximation in run analyzed here, altimeter model in newest runs)

--Apply parameterized topographic wave drag to tidal part of flow in bottom 500 meters

HYCOM vs TPXO M_2 barotropic tides (Shriver et al. 2012)

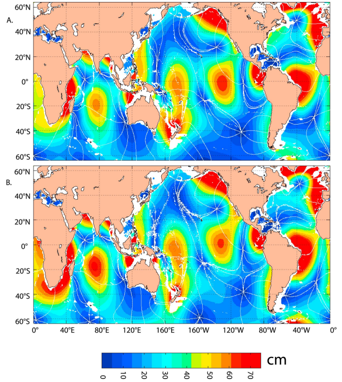


Figure 2. Amplitude (cm) of M_2 surface tidal elevation in (a) TPXO7.2 (an update to that described by *Egbert et al.* [1994]), a barotropic tide model constrained by satellite altimetry, and (b) HYCOM simulations in which the tide is unconstrained by satellite altimetry. Lines of constant phase plotted every 45° in Figures 2a and 2b are overlaid in white.

altimetry-constrained barotropic tide model [*Egbert et al.*, 1994] and the internal tides in HYCOM to results from an analysis of along-track satellite altimetry data [*Ray and Mitchum*, 1996]. Several previous comparisons of modeled and observed internal tides have utilized regional models of strong internal tide generation sites forced by specified barotropic tides at their horizontal boundaries [e.g., *Cummins et al.*, 2001; *Kang et al.*, 2000; *Merrifield et al.*, 2001].

HYCOM vs along-track altimetric estimates of surface signature of M_2 internal tides (Shriver et al. 2012)

- Computed from high-passing total M_2 signal

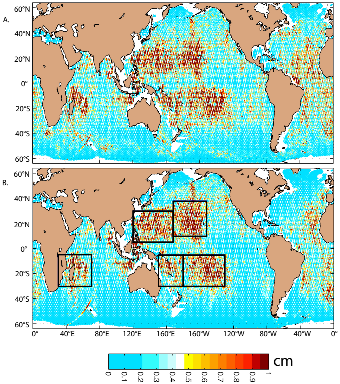
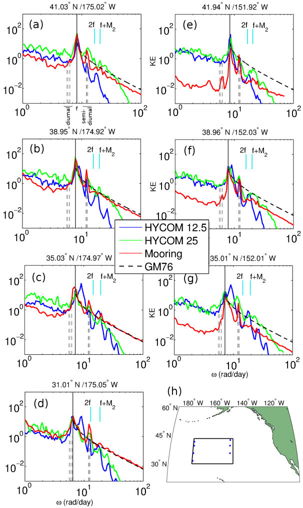


Figure 7. The M_2 internal tide amplitude from the (a) altimetric-based and (b) HYCOM tidal analyses. The five subregions denoted by black boxes in (b) are used to compute the area-averaged amplitudes in Table 2.

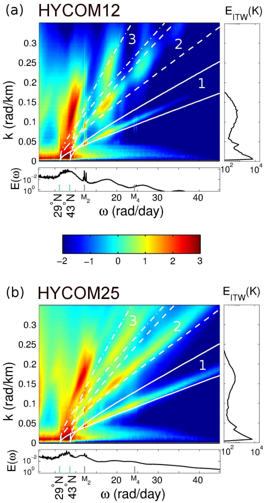
Now on to today's main topic...internal gravity wave spectrum

Internal gravity wave kinetic energy frequency spectra (Müller et al. in press GRL)

- Note logarithmic smoothing employed.

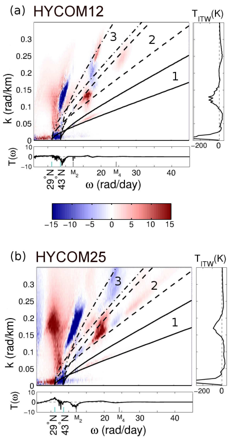


Internal gravity wave kinetic energy frequency-horizontal wavenumber spectra (Müller et al. in press GRL)



Nonlinear internal gravity wave kinetic energy frequency-horizontal wavenumber spectral transfers (Müller et al. in press GRL)

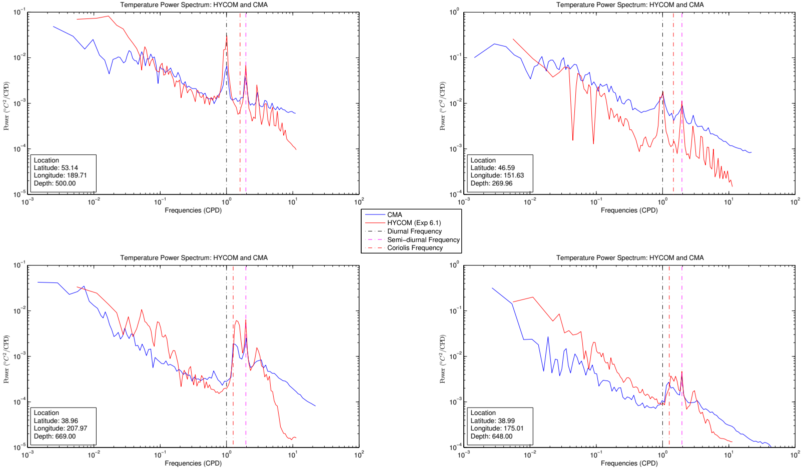
- $T(k,\omega) = Re[-\hat{\vec{u}}^* \cdot [\widehat{\vec{u} \cdot \nabla \vec{u}}]]$



Application of frequency-horizontal wavenumber spectrum to altimetry

- We will compute the frequency-horizontal wavenumber spectrum of SSH to separate low-frequency, internal tide, and non-tidal internal wave contributions.

Frequency spectra of temperature (Bassette et al. and Luecke et al. in preparation)



Summary

• Models with concurrent atmospheric and tidal forcing are beginning to develop an internal gravity wave spectrum, especially as resolution increases.

• Frequency-horizontal wavenumber spectrum of modeled internal gravity wave kinetic energy fills in along predicted linear dispersion curves, and fills out more completely with higher model resolution.

• Kinetic energy frequency spectra lie closer to observations, and nonlinear interactions are more vigorous, when model resolution is increased.

• We are now investigating internal gravity wave temperature variance.