The K_1 internal tide simulated by a 1/10° OGCM

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1. Introduction

- Internal waves provide energy necessary to maintain the meridional overturning circulation (MOC).
- Internal waves at tidal frequencies (**internal tides**) are energetic and have large length scales at low modes. Until recently, the global concurrent simulation of internal tides with the eddying circulation becomes available under hydrostatic approximation. One such model is the STORMTIDE model, which provides a realistic wave environment for internal tides.
- Better understanding of internal tides is required for a better parameterization of tidal-induced mixing in climate models.
- **In this study, we focus on the K_1 internal tide, the major diurnal component, by using the STORMTIDE model. Internal tide dynamics are separated by the critical latitude at 30˚ into bottom-trapped and freely-propagating motions, both of which will be studied.**

2. Methods

- **In supercritical latitudes (bottom-trapped internal tides):**
  (1) The simulated kinetic energy (KE) has been interpolated onto a vertically uniform 100 m resolution grid, starting from the very bottom.
  (2) The bottom KE is averaged within water-depth intervals of 500 m.
- **In subcritical latitudes (freely-propagating internal tides):**
  (1) The 2D complex discrete Fourier transform is applied to baroclinic tidal velocities, in overlapping $15°/cos\varphi \times 15°$ boxes with φ being the latitude.
  (2) Wavelengths are identified based on the wavenumbers of spectral peaks in 1D wavenumber spectra.
  (3) The wavelengths are further compared with predictions of linear theory.

3. Results

3.1 Kinetic energy of the STORMTIDE model

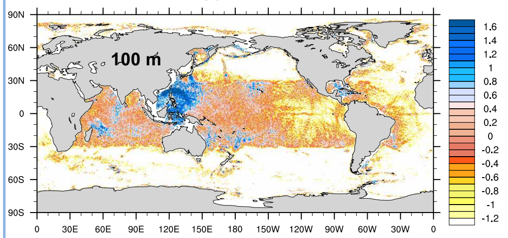


Fig. 1: Kinetic energy (cm^2/s^2) of the K_1 internal tide at 100 m from the STORMTIDE simulation, given on a logarithmic scale.

- The kinetic energy is mainly confined within 30˚N-30˚S, indicating the presence of the critical latitude φ_c at 30˚, where the tidal frequency equals the Coriolis frequency. This critical latitude is, however, not captured in a simulation with the same model, but at 0.4˚ resolution.
- Localized hotspots of the kinetic energy are observed in the vicinity of topographic features in supercritical latitude ($\varphi > \varphi_c$).

3.2 Bottom-trapped internal tides in supercritical latitude

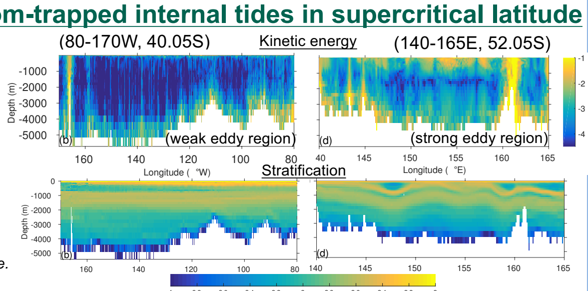


Fig. 2: Kinetic energy (cm^2/s^2) (top) of the K_1 internal tide and the corresponding stratification (bottom) poleward of the critical latitude, both given on a logarithmic scale.

- Kinetic energy is mainly concentrated at the bottom in weak eddy regions.
- High energy level shows up also in the surface layers in eddy-rich regions, which could be attributed to the oscillating structures of the local maxima of stratification.

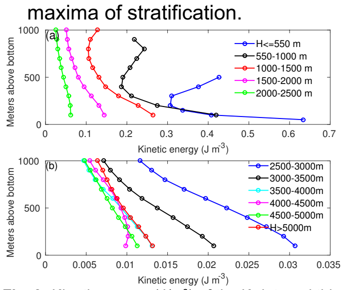


Fig. 3: Kinetic energy (J/m^3) of the K_1 internal tide above the bottom, divided into different water-depth intervals of 500 m in supercritical latitudes.

- Bottom trapping occurs over a finite vertical scale, over which the energy gradually reduces with height above the bottom.
- The kinetic energy further increases above the energy-minimum level, associated with the hotspots at surface in eddy-rich regions.
- The kinetic energy is stronger and decreases faster above the bottom in shallower than in deeper water regions.

3.3 Kinetic energy of freely propagating internal tides

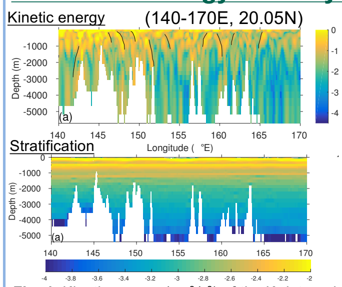


Fig. 4: Kinetic energy (cm^2/s^2) of the K_1 internal tide and the corresponding stratification in subcritical latitude, given on a logarithmic scale.

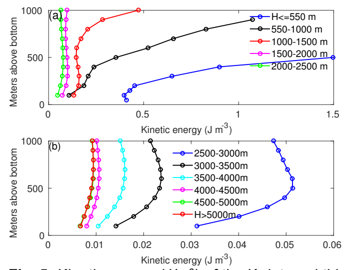


Fig. 5: Kinetic energy (J/m^3) of the K_1 internal tide above the bottom, divided into different water-depth intervals of 500 m in subcritical latitudes.

- The kinetic energy is concentrated in the surface, with beams observed and manually drawn for demonstration.

3.4 Wavelengths of the low modes

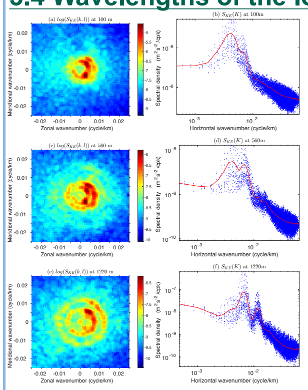


Fig. 6: Left: Wavenumber spectra $S_{KE}(k,l)$ (m^2s^{-2}/cpk) of the kinetic energy of the K_1 internal tide in the $15°/cos\varphi \times 15°$ box centered at (135E,7.55N), which are converted into 1D spectra $S_{KE}(K)$ (right) by using $K = \sqrt{k^2 + l^2}$.

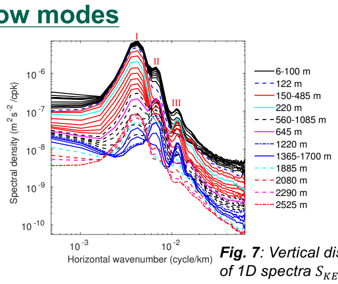


Fig. 7: Vertical distributions of 1D spectra $S_{KE}(K)$.

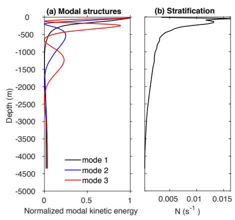
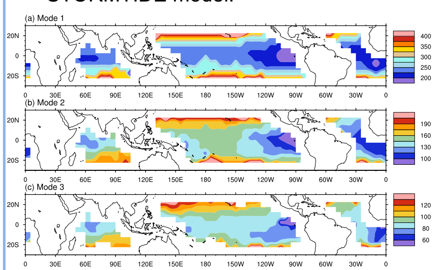


Fig. 8: Modal structures (left) derived from linear wave theory with given stratification (right).

- Three modes of the K_1 internal tides are captured in the 1/10˚ STORMTIDE model.



- There is a zonal asymmetry and a poleward increase of wavelengths for all three modes, determined by stratification and Coriolis frequency, respectively.
- The simulated wavelengths, to a first approximation, can be well approximated by predictions of linear theory.

Fig. 9: Simulated wavelengths (km) of the mode 1 to 3 K_1 internal tides.

4. Conclusions

- The 1/10˚ STORMTIDE model is able to well simulate the K_1 internal tides, correctly representing the critical latitude at 30˚ and capturing three to four modes of freely-propagating internal tides. These free waves are, to a first approximation, linear internal waves.
- In the STORMTIDE model with 40 unevenly spaced vertical layers, the bottom-trapping process is able to be identified from the gradual energy decrease with height above the bottom, which occurs over a finite vertical scale that is smaller in shallow than in deep water regions.

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References:

Li, Z., J.-S. von Storch, M. Müller, 2017: The K_1 internal tide simulated by a 1/10° OGCM, *Ocean Modelling*, **113**, 145-156

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