Revelations about parameterizing lee waves in ocean models
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Abstract
Internal lee waves are generated when geostrophic flow impinges upon rough topography. Lee wave formation, radiation, and breaking are thought to contribute substantially to the ocean momentum, wind, and energy budgets. Due to the relevant horizontal length scales of lee waves are generally smaller than the grid spacing of most state-of-the-art, high-resolution ocean general circulation models, the effects of lee waves must be parameterized in ocean models. However, ocean models are currently lacking such a parameterization. Here, the impacts of rotating a momentum term associated with lee wave generation and wave breaking into a high-resolution ocean simulation are investigated. Overall, the unsuitability of directly observing the global energy generation and dissipation rates, it is inferred that the main productivity of lee wave dissipation occurs within the upper ocean and the atmosphere. Lee wave dissipation to environmental parameters is a nonlinearity and a comparison of their predictions with microstructure observations is performed in two regions of the Southern Ocean where geostrophic flow extends over ridges.

Methods
- Enhanced resolution
- Improved models
- Lee wave breaking
- Wave energy conversion

Results
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Conclusions
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Figure 1: The kinetic energies (units in m² s⁻²) and into 500 meter depth bins) are averaged over the horizontal face of the current meter database (averaged over the entire length of the time series). Shown along with the output of the various model simulations (averaged over the final year of the model simulations). Also shown are (a) the ratios of the average kinetic energies of the low-pass filtered observations to the output of the various model simulations and (b) the number of current meter observations (as a function of depth). The inclusion of wave drag, the kinetic energy is reduced in the abyssal and in a three-dimensional global integral, but slightly increased near the surface. The vertical structure of the kinetic energy is better agreement with the observations when wave drag is included.

Figure 2: Shown is the ratio of the effective velocity, V_{eff}/V (turbulent dissipation rate)/V (turbulent dissipation rate) (horizontal momentum stresses). The velocity averaged over the 500 meters, V, from the final year of the 1/12° HYCOM simulation with wave drag. In blue regions, our assumption that the momentum flux occurs only in the bottom 500 meters results in too much wave drag for this figure suggests that one way to improve the wave drag parameterization is to allow the vertical deposition of lee wave momentum flux to be quasihomogeneous.

Figure 3: Shown are the horizontally averaged profiles of the energy dissipation rates inferred from the microstructure observations and the GES scheme for the western (panel a) and eastern (panel b) EMIES and SOFIA station locations as a function of height above the deepest microstructure measurement (bottom) for different assumed levels of dissipation. The vertical profile of dissipation predicted by the GES scheme tends to closely match the observed dissipation profile in the abyss, but not close to the surface. Further, this depends upon the assumed level of dissipation. The lack of agreement closer to the surface is due part to simplifications made by the GES scheme that are inappropriate for the oceanic context.

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We use HYCOM with:
- 32 hybrid layers
- 1/12° (1/32°) resolution
- Air-sea fluxes - monthly mean ECMWF Re-Analysis (ERA-40, Källberg et al., 2004)
- WAVE - monthly mean ERA-40 supplemented with 6-hourly 2005 field data of the Navy Operational Global Atmospheric Prediction System (NOGAPS, Richardson et al., 2003)
- Vertical viscosity: -0.024 (Taylor, 1991; Lin et al., 2009)
- Wave drag: -0.024 (Taylor, 1991; Lin et al., 2009)

Full closure predictions are in reasonable agreement with observations in bottom 500 meters.