Climate Process Team: Improving Representations of Internal-Wave Driven Mixing in Global Ocean Models

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The overall goal of this CPT is to refine, develop and implement dynamically appropriate parameterizations for diapyncal mixing due to internal-wave breaking for use in global climate models. In the ocean interior, the internal wave field is largely responsible for connecting the forcing scales of the circulation to the dissipative scale of turbulence. In particular, internal-wave-driven mixing drives the diabatic evolution of the ocean's stratification on the very time scales of central interest to the climate prediction problem. Since the initial proposal, we have found it useful to frame the problem in terms of sources and sinks for internal waves. The main sources of internal wave energy in the ocean are internal tides and wind-generated internal waves. Here we look at both sources, with separate parameterizations being developed for energy dissipated near the generations sites (the 'nearfield' problem) and energy that radiates long distances to dissipate elsewhere (the 'farfield' problem).

Some percentage of energy converted from the barotropic to baroclinic tides dissipates near the generation source. Appropriate parameterization should reflect that there are roughly two different classes of physics leading to mixing. First, some energy goes into higher-mode internal tides, which decay due to weakly nonlinear wave-wave interaction as they propagate upwards and outwards from topography. Such physics was the inspiration for the parameterization proposed by St. Laurent et al. [2002]. A new version of this, based on Polzin [2009], is being implemented and tested by post-doc Angilique Melet at GFDL, who finds moderate sensitivity in the thousand meters above the bottom. Second, in the vicinity of tall topography and/or strong currents turbulent dissipation may be driven by strongly nonlinear, hydraulically controlled events, new parameterization for which have been developed by Sonya Legg and Jody Klymak, and are slated for test implementation by GFDL this coming year.

The percentage of baroclinic energy that escapes generation sites to dissipate elsewhere varies depending on basin bathymetry. For example, in the North Pacific it's clear from altimetry that the majority of low-mode internal tide energy generated at the Hawaiian Islands and the Aleutian Ridge propagates mostly unscathed for hundreds to thousands of kilometers [Zhao et al., 2010]. Candidates for wave dissipation being investigated by the CPT include scattering off deep-sea topography [Muller and Xu, 1992; Johnston et al., 2003], reflection and wave breaking at the continental shelf break [Nash et al., 2004, 2007; Martini et al., 2011; Kelly et al., 2011], or nonlinear interactions with an ambient internal wave or mesoscale field [Polzin, 2008].

Wind-generated near-inertial internal waves are the other main component of the internal wave field being investigated for their role in mixing the ocean, with NCAR taking the leading role. Their first step was to link coupled atmosphere and ocean models every two hours, a computationally expensive effort but one required to explicitly resolve the near-inertial motions that elevate mixing in the upper ocean. Power input into the ocean is enhanced in mid-latitude storm tracks, the Southern Ocean, and the Arctic. The latter displays a strong seasonal cycle related to ice cover, which is interesting in that it may change substantially as the ice continues to melt. Enhanced upper ocean mixing results from 1) KPP triggered by newly resolved near-inertial shear, and 2) a new parameterization meant to account for high-mode near-inertial internal waves. As currently scaled, the GCM results suggest that NIWs lead to a 20-50% deeper ocean mixed layer under the storm tracks and the trade winds. Especially the tropical deepening leads to a cooler SST and a substantial shift in global precipitation, sea level pressure and the resulting surface winds. Since these changes project onto longstanding GCM biases we expect that much of the current GCM biases can be traced back to poorly represented mixed layer processes in the tropics.

References

Garrett, C., Internal tides and ocean mixing, Science, 301, 1858–1859., 2003.

Johnston, T. M. S., M. A. Merrifield, and P. E. Holloway, Internal tide scattering at the Line Islands Ridge, J. Geophys. Res., 108, 2003.

Kelly, S., J. Nash, K. Martini, M. Alford, and E. Kunze, Internal-tide generation and scattering on a continental slope, J. Phys. Oceanogr, in press, 2011.

Martini, K. I., M. H. Alford, E. Kunze, S. H. Kelly, and J. D. Nash, Observations of internal tides on the Oregon continental slope, J. Phys. Oceanogr., 41, 1772–1794, 2011.

Muller, P., and N. Xu, Scattering of oceanic internal gravity-waves off random bottom topography, J. Phys. Oceanogr., 22, 474–488, 1992.

Nash, J., M. H. Alford, E. Kunze, K. Martini, and S. Kelly, Hotspots of deep ocean mixing on the oregon continental slope, Geophys. Res. Lett., 34, doi:10.1029/2006GL028,170, 2007.

Nash, J. D., E. Kunze, J. M. Toole, and R. W. Schmitt, Internal tide reflection and turbulent mixing on the continental slope, J. Phys. Oceanogr., 34, 1117–1134, 2004.

Nikurashin, M., and R. Ferrari, Global energy conversion rate from geostrophic flows into internal lee waves in the deep ocean, Geophys. Res. Lett., 38, 10.1029/2011GL046,576, 2011.

Polzin, K. L., Mesoscale Eddy–Internal Wave Coupling. Part I: Symmetry, Wave Capture, and Results from the Mid-Ocean Dynamics Experiment, J. Phys. Oceanogr., 38, 2556–2574, 2008.

Polzin, K. L., An abyssal recipe, Ocean Modelling, 30, 298–309, 2009.

St. Laurent, L., H. Simmons, and S. Jayne, Estimating tidally driven mixing in the deep ocean, Geophys. Res. Lett., 29, doi:10.1029/2002GL015,633.e, 2002.

Zhao, Z., M. H. Alford, J. A. MacKinnon, and R. Pinkel, Long-range propagation of the semidiurnal internal tide from the Hawaiian Ridge, J. Phys. Oceanogr., 40, 713–736, 2010.