INTERNAL TIDE GENERATION OVER DEEP-OCEAN TOPOGRAPHY

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Abstract

Simulations of internal tide generation are examined to describe the spatial distribution of energy transfer from barotropic to baroclinic tides over two cases of mid-ocean ridge topography: a section of the Mid-Atlantic Ridge in the Brazil Basin, and the southern Hawaiian Ridge including the main Hawaiian Islands. The internal tide generation, also referred to as the barotropic to baroclinic tidal conversion, is estimated for the $M_2$ tidal constituent using a primitive equation model and an analytic formulation.

For the Mid-Atlantic Ridge, model runs are made with different horizontal smoothing (1.5, 6, and 15 km) applied to a 192 km x 183 km section of multibeam bathymetry to characterize the influence of topographic resolution on the model conversion rates. In all model simulations, barotropic to baroclinic conversion is highest over near- and super-critical slopes on the flanks of abyssal hills and discordant zones. From these generation sites, internal tides propagate upward and downward as tidal beams. The most energetic internal tide mode generated is mode 2, consistent with the dominant length scales of the topographic slope spectrum (50 km). The topographic smoothing significantly affects the model conversion amplitudes, with the domain-averaged conversion rate from the 1.5-km run (15.1 $mWm^{-2}$) 4% and 19% higher than the 6-km (14.5 $mWm^{-2}$) and 15-km runs (12.2 $mWm^{-2}$). Analytical models for internal tide generation at subcritical topography predict conversion rates with modal dependence and spatial patterns qualitatively similar to the Princeton Ocean Model (POM), and also show a decrease in conversion with smoother topography. The POM conversion rates are approximately 20% higher than the analytical estimates for all model grids, which is attributed in part to spatial variations in the barotropic flow and near-bottom stratification over generation sites, which are incorporated in the model but not in the analytical estimates.

The conversion of barotropic to baroclinic $M_2$ tidal energy is examined over the southern Hawaiian Ridge using the same numerical and analytical models as in the Brazil Basin study. For the southern Hawaiian Ridge, it is estimated that 2.6 GW of the $M_2$ barotropic energy is transferred into baroclinic energy over the domain, a value two times lower than predicted by a primitive equation model (5.3 GW). The underestimation of the analytical model compared to the numerical model arises from the assumption in the
former that the bottom stratification and the barotropic tidal currents are constant over the topography, which is not the case in the latter. Different approaches are tested to parameterize the spatial variability of the bottom stratification and the barotropic tidal currents in the analytical model. Including the variable bottom stratification and barotropic current amplitude and phase gives geographic distribution of the main conversion regions agreeing best with the numerical model. Using the conversion-weighted bottom stratification and the variable vertical velocity gives a domain-integrated energy conversion (7.8 GW) closest to the numerical model.

Moored hydrographic and current measurements are used to study the time variability of $M_2$ internal tide generation at the Kaena Ridge, between the islands of Oahu and Kauai. The conversion from the barotropic to baroclinic tide at the ridge crest varies by a factor of two over the nearly 6 months deployment (0.55-1.1 W m$^{-2}$). The time-variability of out-going energy flux measured just off the ridge undergoes a similar modulation as the ridge conversion. 50% of the energy conversion goes into the first two baroclinic modes with two-thirds of this amount accounted for by mode 2. The time variation of energy conversion is associated with changes in the amplitude and phase of the perturbation pressure. In particular, the phase change of mode 2 perturbation pressure resembles the modulation in total energy conversion. The passage of two eddies near the Kaena Ridge results in across-ridge currents. The advection of the mode 2 internal tide over the ridge by the eddy currents may account for the portion of the energy conversion variations associated with perturbation pressure phase changes. In addition, the background stratification may contribute to the changes in mode 2 phase speed, and hence the phase of the mode 2 perturbation pressure, during portions of the record.