# The Application of Bathymetric Data in Calculations of Internal Tides and Mixing

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## Introduction

Internal waves have been implicated as the major source of mechanical energy for mixing in the ocean interior. In particular, internal waves generated by tidal forcing, the "internal tides," have been directly associated with mixing in numerous observational studies. The physical mechanisms controlling the transfer of energy from internal tides to turbulent mixing are complicated, though models based on wave-wave interactions have been formulated (Polzin, 1999). A basic metric for estimating turbulent mixing rates is provided by the energy flux of the internal tides. This quantity measures the rate at which energy is transferred from tidal currents into internal waves. All of this energy is assumed to dissipate as turbulence somewhere in the ocean.

St. Laurent and Garrett (2002) present energy flux estimates for the internal tides generated at mid-ocean ridge topography. The properties of the generated spectrum of waves are considered, and the efficiencies of various wave instability mechanisms are assessed. In general, low-mode internal waves with spatial scales of 20 to 100 km carry much of the energy flux. These low-mode waves radiate energy away from generation regions. Higher mode waves with spatial scales of 20 km or less are generated by fine-scale bathymetric roughness. These waves dissipate their energy close to the generation site, leading to enhanced levels of turbulent mixing.

A new bathymetric altimeter mission should resolve bathymetry in the spectral bandwidth between 10 and 30 km. This bandwidth captures the spatial scale of the dominant wave energy at mid-ocean ridge topography. The transition to the fractal regime of bathymetric roughness (Goff and Jordan, 1988) is also resolved. At present, calculations of internal-tide energy must be based entirely on multibeam data. In the future, internal tide calculations will be based on bathymetry measured by altimetry and a fractal model for fine-scale roughness.

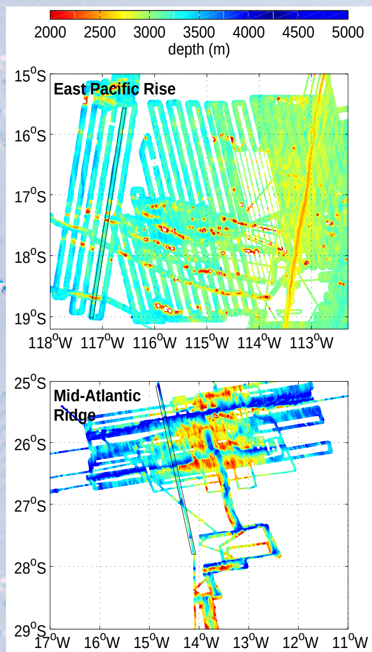


**Figure 1**: Multibeam bathymetry data from the East Pacific Rise and the Mid Atlantic Ridge. St. Laurent and Garrett (2002) employed these data in calculations for internal tide energy. These maps show some of the most comprehensively sampled bathymetry in the global ocean. Boxed regions indicate the locations of several sections used for spectral analysis.

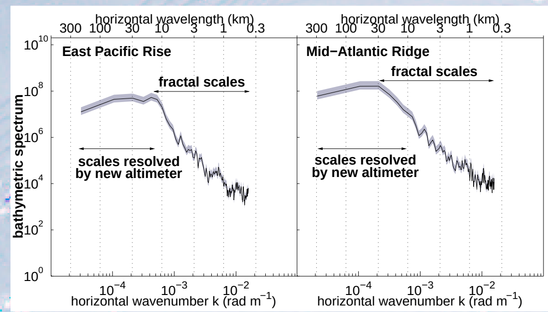


**Figure 2**: Bathymetric spectra for the East Pacific Rise and the Mid Atlantic Ridge from the sections indicated in Figure 1. Current altimetric bathymetry can only be used to examine wavelengths greater than 25 to 50 km.

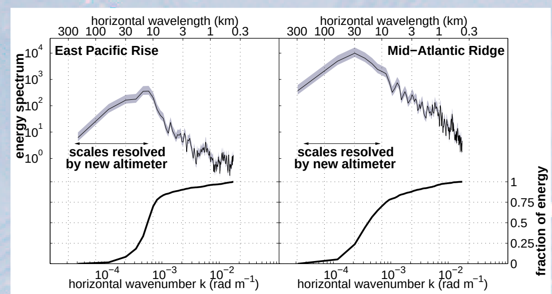


**Figure 3**: Energy flux spectra of the semidiurnal internal tide estimated from a model employing the multibeam bathymetry spectra in Figure 2. The cumulative integrals of energy flux are also shown. Currently, only 30% of the energy flux can be estimated using altimetric bathymetry. The next generation of altimeter will resolve spatial scales associated with up to 75% of the energy flux.

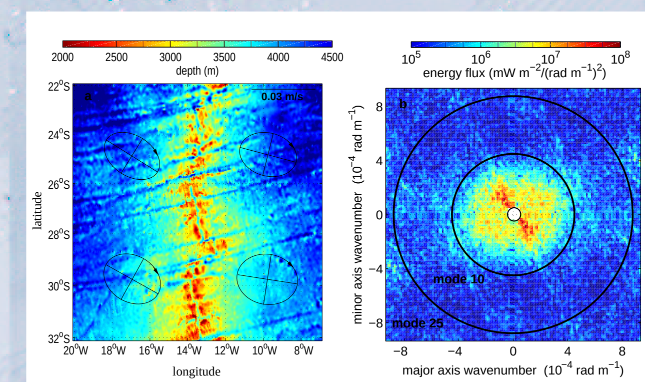


**Figure 4**: (a) Map showing the Smith and Sandwell (1997, version 8.2) bathymetric data for the Mid-Atlantic Ridge region used in calculations of internal tide energy flux. The multibeam data shown in Figure 1 were combined with altimetric measurements to produce this bathymetric map. Ellipses of the semidiurnal tidal currents are also shown.

(b) The spatially averaged spectrum of energy flux for the internal tides calculated using the bathymetry data shown in panel a. The wavenumber axes were taken along the semimajor and semiminor axes of the tidal ellipse reference frame. Circles correspond to baroclinic modes 1, 10, and 25. This two-dimensional analysis gives both magnitude and direction information for the internal tide energy flux. The analysis requires highly constrained bathymetric data, presently available in only a few regions. Future altimetric bathymetry will be adequate for analyzing modes 1 to 10. A fractal model of fine-scale bathymetry could then be used to estimate the energy flux of higher modes.

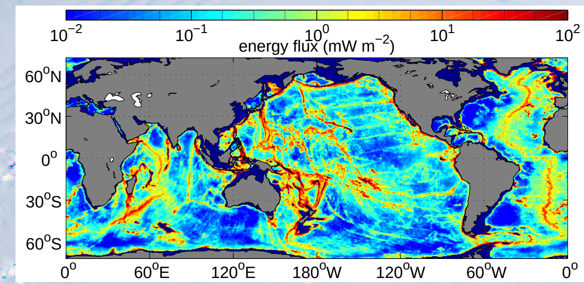


**Figure 5**: Estimates of internal tide energy flux from the parameterization of Jayne and St. Laurent (2001). The parameterization utilizes estimates of bathymetric roughness from the Smith and Sandwell (1997) data. An internal-tide drag term, proportional to the roughness, is included as a dissipative term in a forward model of the Laplace Tidal Equations. The work done by this drag gives the internal tide energy flux. An improved estimate of the global distribution of internal tide energy requires measurements from a higher resolution altimeter.

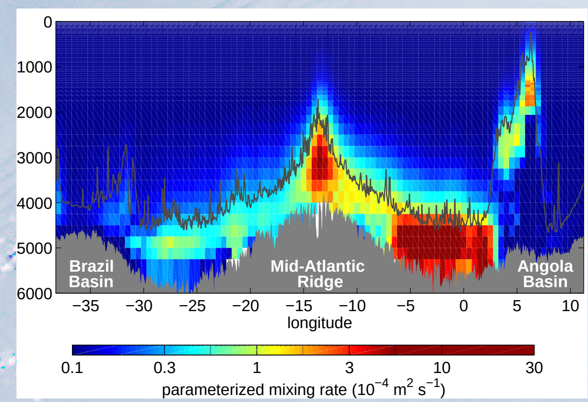


**Figure 6**: A section showing parameterized estimates of turbulence diffusivity across the Brazil and Angola Basins of the south Atlantic Ocean (St. Laurent et al., 2002). In these estimates, turbulent energy levels are inferred from the estimates of internal tide energy shown in Figure 5. Bathymetry from Smith and Sandwell (1997) are also shown. The section shows the average diffusivity from the latitude band 24°S to 28°S. The envelope of the deepest and shallowest bathymetry is also shown. These estimates provide the basis for vertical diffusivities used in numerical simulations of the ocean.

## References

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