A 3D Map of Tidal Dissipation Over Small-Scale Abyssal Hills

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Problem

- Diapycnal mixing generated by breaking of internal tides is crucial for ocean circulation and needs to be parameterized
- Dissipation currently parameterized as

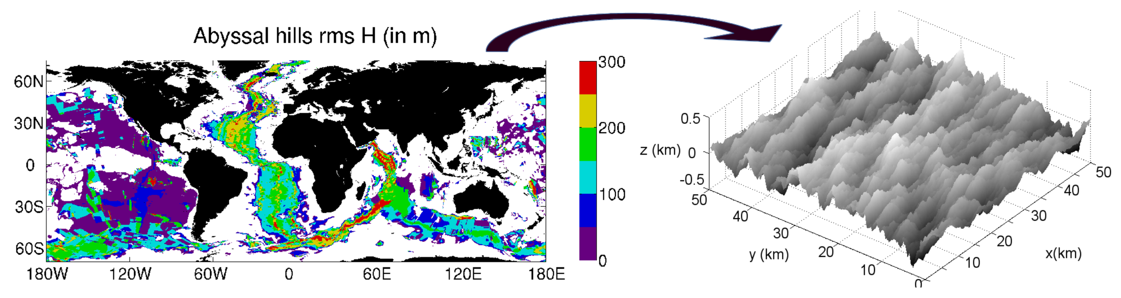
$$\epsilon(x,y,z) = q\,E_0(x,y)\,F(z)$$

  - ϵ ... tidal energy dissipation
  - E_0 ... energy conversion at seafloor
  - q ... local fraction of dissipation
  - F ... vertical structure $\int_0^H F(z)dz = 1$
- But q, F vary in space (x,y) and the ocean is sensitive to this mixing inhomogeneity
- Small-scale abyssal hills, unresolved by satellite altimetry $< O(30\text{ km})$, contribute to this inhomogeneity... but how much?

Objective: maps of $\mathbf{q(x,y)}$ and $\mathbf{F(x,y,z)}$ to quantify the impact of unresolved topography on mixing

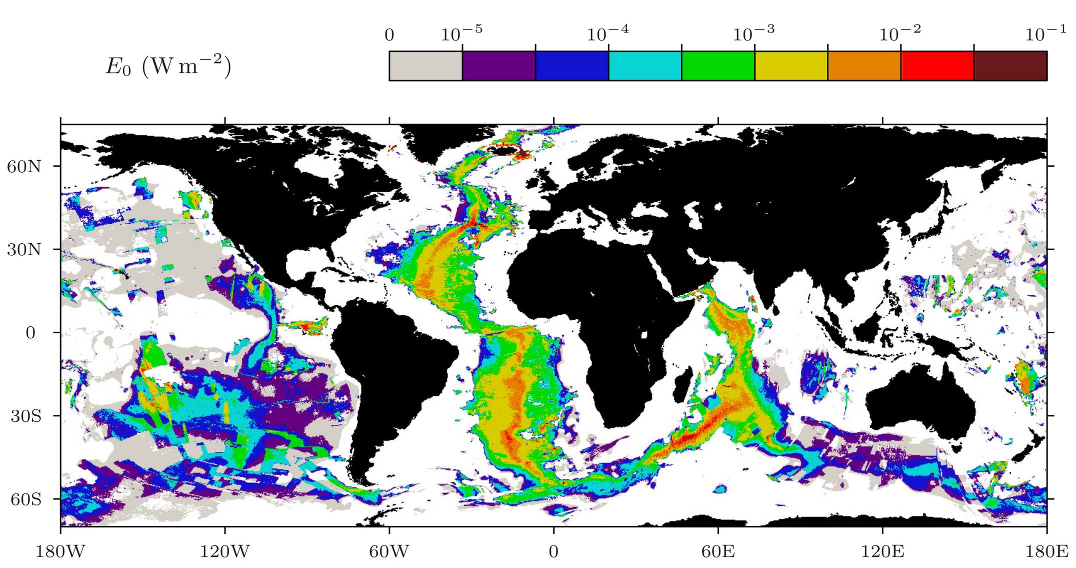
Method: Wave Saturation

- Unresolved topography described statistically by Goff-Arbic spectrum
- Random topography samples generated, constrained by $1/4° \times 1/4°$ spectrum maps



Generation of synthetic topographies at ~ 100 m resolution

- Internal tide computed by linear theory

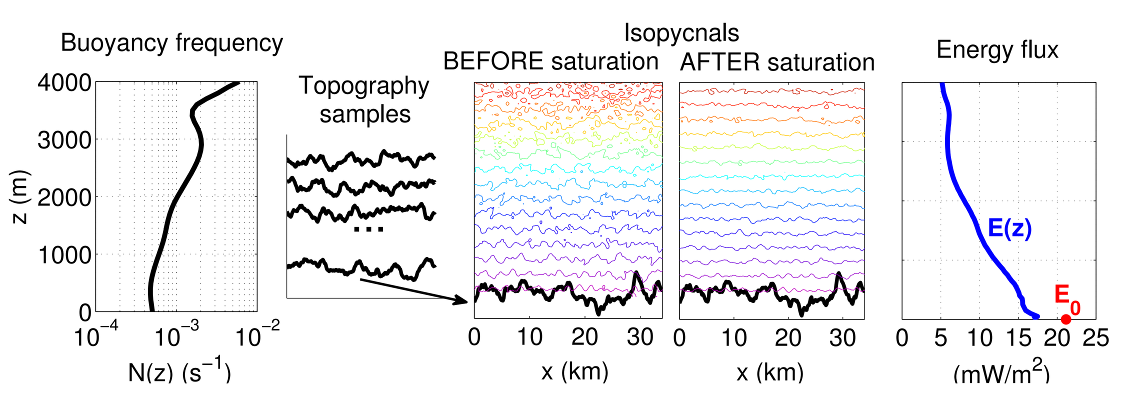


Energy flux E_0 into internal tides (total: 0.105 TW)

- Instability when isopycnals overturns:

$$\partial_z(\bar{b} + b') = N^2\left[1 - Re\{A(\mathbf{x},z)\,\mathrm{e}^{-i\omega_0 t}\}\right] < 0$$

- Saturation: force $|A(\mathbf{x},z)| \leq 1$ (nonlinear)

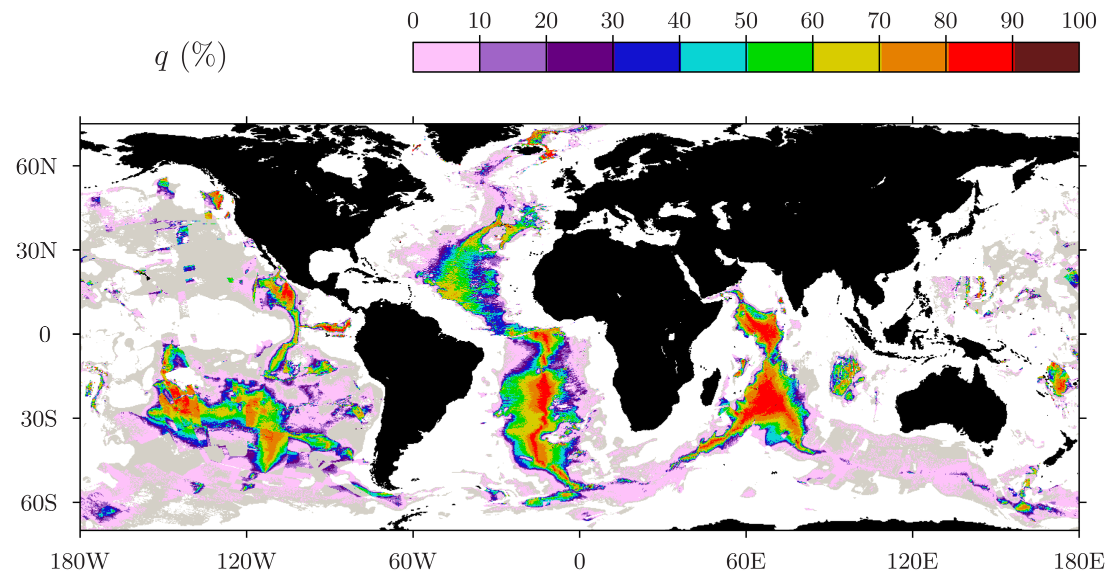


Wave propagation and energy dissipation by saturation

Results: 3D Structure of Tidal Dissipation

Horizontal: $\mathbf{q(x,y)}$

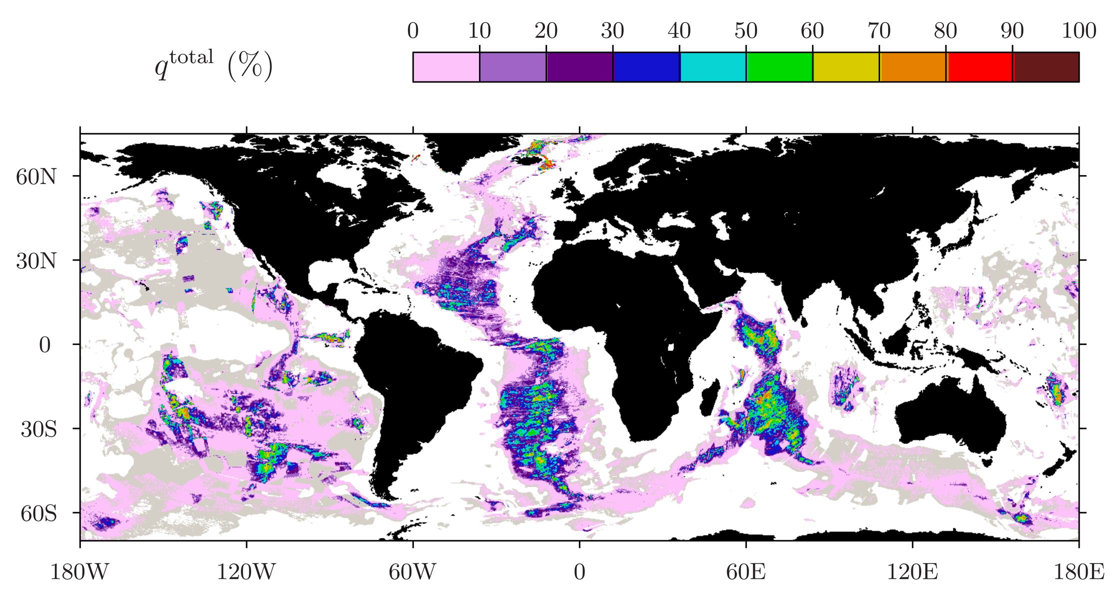
- The fraction of energy dissipated q is highly inhomogeneous in space
- Highest values $q = 60-90\%$, mostly above Southern-Hemisphere ridges



Local fraction q of energy dissipated from bottom to surface

- High local dissipation even when rescaled by large-scale, satellite-resolved energy

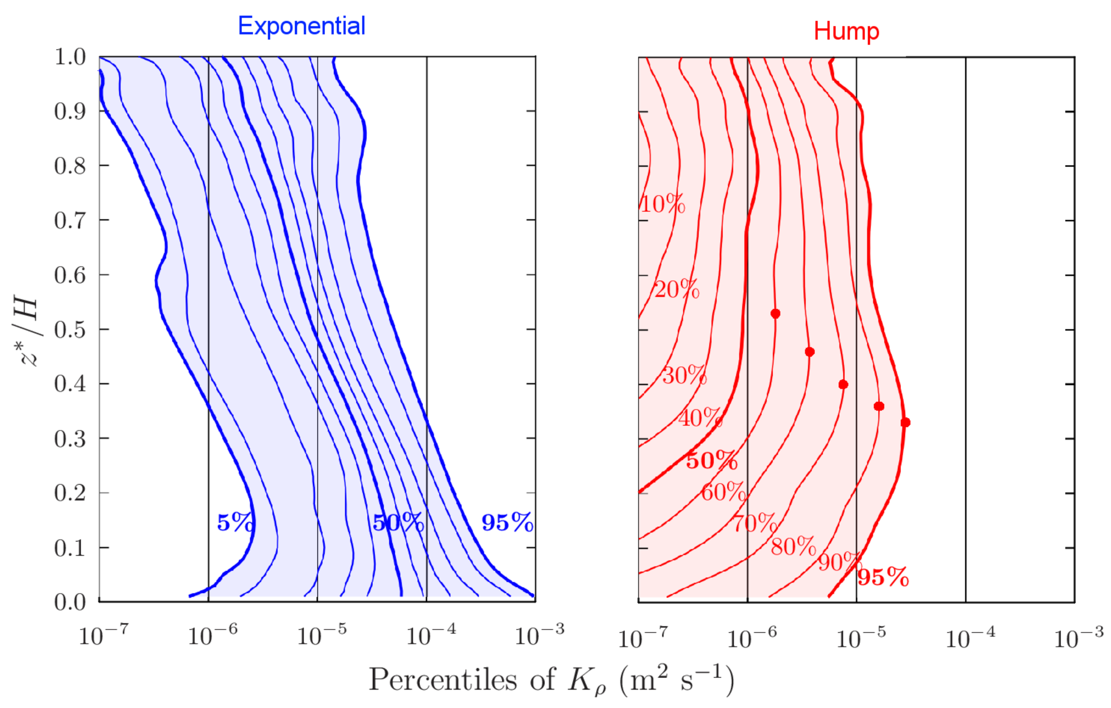
$$q^{\text{total}} = \frac{q E_0}{E_0 + E_0^{\text{large scale}}}$$



Rough estimate of the local fraction of total energy dissipated

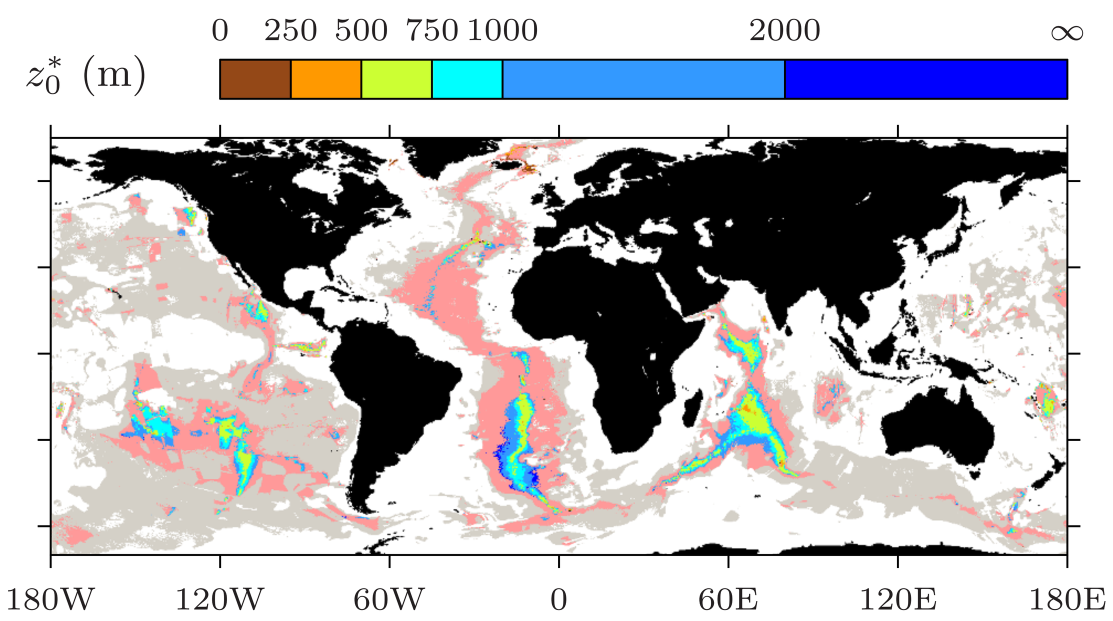
Vertical: $\mathbf{F(x,y,z)}$

- Best collapse for diapycnal diffusivity $K_\rho(z^*) \propto F/N^2$ with WKB-scaled height $z^* \propto \int_0^z \sqrt{N^2(z') - \omega^2}\,dz'$:
  - exponential decay (~ 70% of energy)
  - hump: interior mixing (~ 30%)



Collapse of $O(10^5)$ profiles into two families

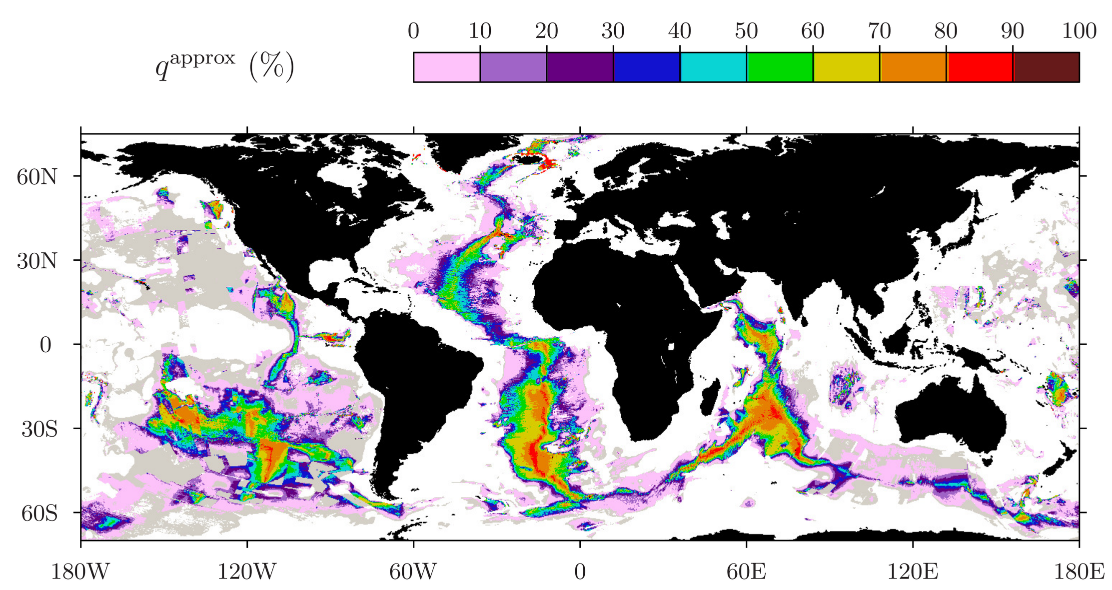
- Exponential decay scale $K_\rho \propto e^{-z^*/z_0^*}$ is also inhomogeneous in space (x,y)



Diffusivity decay scale z_0^* (pink regions have hump profile)

Application: Parameterizations of Tidal Mixing

- $q(x,y)$ and $K_\rho(x,y,z)$ can be empirically predicted based only on linear wave rms amplitude at the bottom $A^{\text{rms}}(x,y,0)$:
  - $q^{\text{approx}} = 87\left[1 - e^{-4(A^{\text{rms}}-0.1)}\right]\,\%$
  - K_ρ exponential decay for $A^{\text{rms}} > 0.4$, hump otherwise
  - $z_0^{*\,\text{approx}} = \frac{440}{\sqrt{A^{\text{rms}}} - 0.3}$ m



q^{approx} computed with A^{rms}, in good agreement with q

Key Points

- **Dissipation of internal tides above unresolved abyssal hills $< \mathbf{O(30km)}$ is inhomogeneous**
- **Interplay of waves and ocean stratification can create high interior mixing (hump profiles)**
- **3D dissipation can be approximated only using topography spectrum and forcing at seafloor**

More Details

A. Lefauve, C. Muller, A. Melet. (2015), A three-dimensional map of tidal dissipation over abyssal hills, *J. Geophys. Res. Oceans*, **120**, doi:10.1002/2014JC010598.

Acknowledgments

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