# ON THE SPATIAL DISTRIBUTION OF DIAPYCNAL MIXING IN THE ABYSSAL OCEAN: AN EMPIRICAL STUDY

A DISSERTATION SUBMITTED TO
THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAI'I IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

OCEANOGRAPHY

DECEMBER 2009

By
Thomas Decloedt

Dissertation Committee:

Douglas S. Luther, Chairperson
Mark Merrifield
Eric Firing
Axel Timmermann
John Learned

ABSTRACT

The picture emerging from observations of turbulence in the abyssal ocean is one of weak diapycnal mixing in the interior and bottom-intensified mixing, by orders of magnitude, over rough topography. Numerical simulations indicate that the large-scale ocean circulation is sensitive to the spatial distribution of diapycnal mixing in the abyssal ocean. In addition, spatially varying mixing may largely control the structure of the abyssal stratification. Consequently, insofar as the complex processes generating abyssal turbulence cannot be directly simulated in OGCM's, mixing parameterizations with realistic spatial distributions in the abyssal ocean are desirable. While spatially varying mixing parameterizations based on internal tide dissipation have been proposed in the past decade, the external tide likely provides no more than half of the mechanical energy available for mixing in the abyssal ocean. A plethora of complex flow-topography interactions deriving their energy from various sources can be expected to contribute to the observed bottom-intensification of diapycnal mixing.

A simple empirical model for the spatial distribution of the abyssal ocean's diapycnal diffusivity $K\rho$ is introduced based on microstructure observations of turbulence. The Roughness Diffusivity Model (RDM) is dependent upon the observation that observed bottom-intensified mixing amplitudes actually stratify according to a simple metric of topographic roughness. The functional vertical dependence of the RDM is founded on a heuristic recipe developed by K. Polzin (2004, 2009) containing an inverse square law decay with height above bottom. In developing the RDM, both the scale height and maximum boundary diffusivity are assumed to be functions of topographic roughness. The empirical functions were determined from iterated nonlinear regressions on the microstructure data. Armed with these functions, the mean vertical

diffusivity profiles at the locations of the microstructure data can be reproduced to within a factor of two at all heights above bottom. This is a superior comparison with the microstructure data than achieved by Kρ models that use an exponential decay with constant scale height in the vertical.

Basin-averaged diffusivities predicted by the RDM increase from $\sim 3 \times 10^{-5}$ $m^2/s$ at 1 km depth to $\sim 1.5 \times 10^{-4}$ $m^2/s$ at 4 km and are shown to be consistent with inverse model results by Lumpkin and Speer (2007) and Ganachaud (2003), supporting the contention that strong localized mixing plays a major role in maintaining the observed abyssal stratification against deep and bottom water formation. Ocean volumes containing known passages of deep flow (e.g., Romanche Fracture Zone, Samoan Passage) are regions where the RDM underestimates diffusivities compared to inverse model results, suggesting that these passages require a separate parameterization. The power required to sustain the stratification in the abyssal ocean (defined as 40S-48N, 1-4 km depth) is shown to be sensitive to the spatial distribution of Kρ. The power consumption in this domain, given the parameterized bottom-intensified and horizontally heterogeneous diffusivity structure in the RDM, is estimated as approximately 0.37 TW, considerably less than the canonical value of ~2 TW estimated under the assumption of a uniform diffusivity of $\sim 10^{-4}$ $m^2/s$ in the abyssal ocean.