Theoretical and Observational Studies of the Distribution of Diapycnal Diffusivity in the World's Deep Oceans

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Global mapping of diapycnal diffusivity in the deep ocean is essential to improve the ability of global ocean circulation models to predict future climate change. This study summarizes the theoretical and observational work on the global mapping of diapycnal diffusivity of the author's research group during the past 10 years.

First, we have carried out numerical experiments to see how the energy supplied from the semidiurnal internal tide and atmospheric disturbances cascades through the deep ocean internal wave spectrum down to dissipation scales. We found that this energy transfer process is dominated by the latitude-dependent, internal wave-wave interaction termed *parametric subharmonic instability* which transfers energy from low-vertical wavenumber internal waves with twice the local near-inertial frequency to high-vertical wavenumber internal waves with the local near-inertial frequency; as the high-vertical wavenumber, near-inertial current shear increases, the surrounding small-scale internal waves especially those with high horizontal wavenumbers are efficiently Doppler shifted such that their vertical wavenumbers rapidly increase and enhanced turbulent dissipation takes place. Next, we have carried out separate numerical experiments to examine the global distribution of energy available for diapycnal diffusivity in the deep ocean from the semidiurnal internal tides and atmospheric disturbances. In sharp contrast to the previous theoretical predictions, we found that wind-induced internal wave energy is mostly dissipated within the upper 150 m without penetrating down into the deep ocean so that the major energy source for diapycnal diffusivity in the deep ocean is the semidiurnal internal tides. This implies that enhanced fine-scale near-inertial current shear causing strong diapycnal diffusivity will not be found at latitudes farther than about 30˚ from the equator where the diurnal tidal frequency is less than the local inertial frequency so that a resonant triad of internal waves for *parametric subharmonic instability* cannot be formed.

We have validated this theoretical prediction through detailed expendable current profiler (XCP) surveys carried out throughout the world's oceans. Furthermore, based on the results of the XCP surveys, an empirical relationship has been found between the diapycnal diffusivity inferred using fine-scale parameterization and the local energy density of the semidiurnal internal tide; by incorporating the numerically predicted energy density of the semidiurnal internal tide at each longitude and latitude into the resulting empirical formula, we have obtained a global map which shows that diapycnal diffusivity is significantly enhanced around prominent topographic features in the latitude range from 20˚ to 30˚ (mixing hotspots). Finally, the validity of the resulting global map of diapycnal diffusivity has been confirmed through direct turbulence measurements carried out by deploying microstructure profilers down to depths of ~5000 m at key locations in the North Pacific.