DFD16-2016-002349

Abstract for an Invited Paper
for the DFD16 Meeting of
the American Physical Society

On turbulent mixing in stably stratified geophysical flows[1]

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The understanding and quantitative prediction of diapycnal (irreversible) mixing of density and momentum in geophysical flows remains an important ongoing challenge. This is not surprising given the complexity introduced into most geophysical flows by factors such as density stratification, complex topography and a host of physical phenomena associated with such flows. However, accurate prediction of the small-scale irreversible mixing induced by turbulent processes is critical for many applications such as the prediction of heat fluxes and global circulation in oceanic flows. From a practical standpoint, a major goal is the **inference** of turbulent heat and momentum fluxes using indirect measurements in field studies of geophysical flows. This usually involves the need to either measure directly or infer two key quantities namely: (1) the rate of dissipation of turbulent kinetic energy ϵ, and (2) the mixing efficiency R_f^*, which is a measure of the amount of turbulent kinetic energy that is irreversibly converted into background potential energy, respectively. Indirect estimates of ϵ in oceanic flows has been traditionally achieved by assuming a linear relationship between the Thorpe (vertical overturn) length scale L_T and the Ozmidov scale L_O. This approach is particularly attractive since the vertical scales of overturns can be readily obtained using a sorting algorithm from inversions in standard density profiles obtained from Conductivity-Temperature-Depth (CTD) measurements in the ocean. Hence, L_T is essentially a kinematic scale that provides a description of the turbulence at a given sampling location. On the other hand, L_O is a representative dynamic length scale of the largest eddy that is unaffected by buoyancy. A review of a number of recent studies that were conducted in our research group will be presented in this talk to highlight the lack of a linear relationship between L_T and L_O. These studies indicate that inferred estimates of ϵ may be biased high by up to an order of magnitude or more especially for large overturns in the ocean. An alternative unifying framework using a two-dimensional parameter space based on a buoyancy strength parameter (i.e. an inverse Froude number) and a shear strength parameter will be discussed to characterize the scaling correspondence of the overturning length scale with pertinent turbulent length scales. The second key quantity that is a necessary ingredient for the inference of diapycnal mixing from oceanic measurements is the flux Richardson number R_f^*. To date, however, no unifying parameterization of R_f^* exists due to both the variability inherent in geophysical flows as well as certain ambiguities that are introduced in descriptions based on ill-conditioned single parameters. A discussion on the mixing efficiency and implications for estimates of diapycnal mixing in geophysical flows will also be presented.

[1]Funded by the Office of Naval Research and the National Science Foundation