Charcterization of turbulent overturns in stratified turbulence

L. Gostiaux[1]*, H. van Haren[2]

[1]Laboratoire de Mécanique des Fluides et d'Acoustique (LMFA), UMR CNRS 5509,
École Centrale de Lyon - Université de Lyon
[2]Netherlands Institute for Sea Research (NIOZ), Texel, The Netherlands

Introduction

Estimating turbulent diffusivity and mixing in the deep ocean is one of the most challenging issues in modern physical oceanography. First, because such measurements require high precision instrumentation operating at large depths, and long time series to statistically compensate the intermittency of turbulence. Second, because vertical turbulent fluxes of heat and salt are driving general circulation in the oceans, hence influencing climate predictions. These processes, well below the resolution of global circulation models, need to be parametrized at sub-grid scale, although uncertainities remain on the location and source of this dissipaiton [1].

High resolution Thorpe Scale analysis

In his seminal paper, Steve Thorpe proposed a practical method to estimate overturns size from in situ density profiles [2]. By adiabatically sorting the water column, the absolute value of the vertical displacement is a measure of the vertical extent of overturns, and the rms of these displacement – called the Thorpe Scale L_T – can be related, with the local buoyancy frequency N, to turbulent dissipation. We used this method with high sampling rate thermistors designed at the NIOZ [3], which have been moored in several locations resolving the first 100 meters of the bottom boundary layer above deep ocean topographies [4, 5, 6]. Our datasets present an unprecedented resolution of mixing events in the deep oceans, where turbulent diffusivity K_z is seen to vary over time and depth by 4 orders of magnitude, with an overall time-depth mean value of $k_z \simeq 10^{-3} m^2/s$, denoting the importance of boundary mixing in the ocean.

Re-visiting Thorpe Scale

We recently considered looking more in detail to the shape of the displacement profiles obtained after adiabatically sorting unstable density profiles obtained by fast sampling CTD's [7]. When displayed as a function of z, the displacements reveal a characteristic zigzag shape. Comparing model-overturns for a solid-body-rotation and a Rankine vortex, we show that this Z shape has slopes slightly $>$1/2 in the interior and $>$1 along the sides when entrainment of the fluid occurs. On the other hand, in the case of a well mixed homogeneous layer – what is expected after a complete irreversible mixing event – the displacement values fill a parallelogram with side-edges having a slope of 1. This description is used to interpret overturn shapes in NE-Atlantic-Ocean-data from moderately deep, turbulent waters above Rockall Bank (off Ireland) and from deep, weakly stratified waters above Mount Josephine (off Portugal).

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*corresponding author: louis.gostiaux@ec-lyon.fr