Thorpe's scale, Ozmidov's scale and isotopy restored at small scales in freely decaying stratified turbulence.

Alexandre Delache[*1], Louis Gostiaux[2], Fabien Godeferd[2], and Claude Cambon[2]

[1]Laboratoire de Mecanique des Fluides et d'Acoustique site de Saint Etienne (LMFA site de Saint Etienne) – CNRS : UMR5509, Université Jean Monnet - Saint-Etienne – École Centrale de Lyon 36, avenue Guy de Collongue 69134 Écully cedex France, France
[2]Laboratoire de Mecanique des Fluides et d'Acoustique (LMFA) – CNRS : UMR5509, Université Claude Bernard - Lyon I (UCBL), Ecole Centrale de Lyon, Institut National des Sciences Appliquées [INSA] - Lyon – 36 Av Guy de Collongue 69134 ECULLY CEDEX, France

Abstract

Stably stratified homogeneous turbulence (SST) is known to exhibit quasi-horizontal structures organized in vertically sheared layers. These structures are a mix between internal wave and turbulence. Different lengthscales are used to characterise the overturning of buoyancy. The most commonly used in oceanography are Thorpe's scale L_T which is a measure of large-scale vertical overturns and Ozmidov's scale $L_o = (epsilon / N^3)^{1/2}$ (where N is the Brunt-Väisälä frequency and epsilon is the dissipation). Structures larger than L_o are strongly influenced by stratification whereas structures smaller than L_o recover three-dimensional isotropy. L_o and L_T are related by Dillon's relation $L_o \sim 0.8 L_T$ which is observed in the ocean and was also recently checked in Direct Numerical Simulations (DNS). Moreover, the lengthscales L_o and L_T are widely used to analyse data from numerical simulations or from experiments. This shows that a refined description is important for an accurate characterization of turbulent mixing in stratified flows that include large-scale anisotropy and overturnings.

We propose here a parametric study of the scale-by-scale anisotropy using dedicated spectra, as an extension of the lengthscales characterization of SST. In order to analyze further small-scale isotropisation, we present results from high resolution DNS (2048^3 grid points) of freely decaying turbulence at four different stratification rates. They confirm that the Ozmidov scale is a separating scale between anisotropic and isotropic ranges: for moderate stratification, the large scales are preferentially horizontally oriented but the smaller scales recover a classical isotropic behaviour. When stratification is increased, smaller and smaller scales also gradually adopt a quasi horizontal motion. We analyze this anisotropy scale by scale by considering the angle-dependent energy spectrum of velocity and density. Moreover, we separate poloidal and toroidal contributions of velocity to the kinetic energy spectrum, which are respectively linked to waves and vortex motion (similar to the geostrophic/ageostrophic decomposition).

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[*]Speaker