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Strongly Stratified Turbulence Wakes and Mixing Produced by Fractal Wakes

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This paper describes Shliering and Shadowgraph experiments of the wake induced mixing produced by tranversing a vertical or horizontal fractal grid through the interfase between two miscible fluids at low Atwood and Reynolds numbers. This is a configuration design to models the mixing across isopycnals in stably-stratified flows in many environmental relevant situations (either in the atmosphere or in the ocean.

The initial unstable stratification is characterized by a reduced gravity: $g' = \frac{g\Delta\rho}{\rho}$ where g is gravity, $\Delta\rho$ being the initial density step and ρ the reference density. Here the Atwood number is $A = \frac{g'}{2\ g}$. The topology of the fractal wake within the strong stratification, and the internal wave field produces both a turbulent cascade and a wave cascade, with frecuen parametric resonances, the envelope of the mixing front is found to follow a complex non steady 3rd order polinomial function with a maximum at about 4-5 Brunt-Vaisalla non-dimensional time scales: $t/N\ \delta = c1(t/N) + c2g\frac{\Delta\rho}{\rho}(t/N)^2 - -c3(t/N)^3$. Conductivity probes and Shliering and Shadowgraph visual techniques, including CIV with (Laser induced fluorescence and digitization of the light attenuation across the tank) are used in order to investigate the density gradients and the three-dimensionality of the expanding and contracting wake. Fractal analysis is also used in order to estimate the fastest and slowest growing wavelengths. The large scale structures are observed to increase in wave-length as the mixing progresses, and the processes involved in this increase in scale are also examined.Measurements of the pointwise and horizontally averaged concentrations confirm the picture obtained from past flow visualization studies. They show that the fluid passes through the mixing region with relatively small amounts of molecular mixing,and the molecular effects only dominate on longer time scales when the small scales have penetrated through the large scale structures.

The Non-stationary dynamicss and structure of stratified fluid flows around a wedge were also studied based of the fundamental equations set using numerical modeling. Due to breaking of naturally existing background diffusion flux of stratifying agent by an impermeable surface of the wedge a complex multi-level vortex system of compensatory fluid motions is formed around the obstacle. The flow is characterized by a wide range of values of internal scales that are absent in a homogeneous liquid. Numerical solution of the fundamental system with the boundary conditions is constructed using a solver such as stratifiedFoam developed within the frame of the open source computational package OpenFOAM using the finite volume method. The computations were performed in parallel using computing resources of the Scientific Research Supercomputer Complex of MSU (SRCC MSU) and the technological platform UniHUB. The evolution of the flow pattern of the wedge by stratified flow has been demonstrated. The complex structure of the fields of physical quantities and their gradients has been shown. Observed in experiment are multiple flow components, including upstream disturbances, internal waves and the downstream wake with submerged transient vortices well reproduced. Structural elements of flow differ in size and laws of variation in space and time. Rich fine flow structure visualized in vicinity and far from the obstacle. The global efficiency of the mixing process is measured and compared with previous estimates of mixing efficiency.