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NUMERICAL ANALYSIS OF STRATIFIED WAKE FLOWS

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ABSTRACT

The density stratification is an important topic in environmental flows and technological flows. Density changes lead to specific set of phenomena, especially internal and lee waves and anisotropic turbulence due to inhibition of vertical mixing by stratification. Internal waves effectively transport momentum but not the mass, and their breaking causes turbulent patches that may decay to form fossil turbulence or sustain and grow into vertically thin but horizontally vast regions of property transport and high refractive-index fluctuations.

Internal waves are generated by various mechanisms, for example, during the collapse of mixed regions in stratified fluids, disturbances induced by moving objects, flow past topography, including Lee waves locked on to the topography.

Nowadays, Meteorological and Ocean Circulation fine grid Models are “eddy and internal wave permitting” and a large effort needs to be devoted in the subgrid parametrization of coarse grid climatic models to improve the vertical transport budget of heat, momentum and species..

In laboratory studies of internal waves increased attention has been given to internal waves generated by stationary placed oscillating sources and moving bodies in stratified fluids [1]. The main attention was paid to study flows past bodies of perfect shapes like sphere [2], cylinder [3] of thin strip [3] which are the best theoretical (analytical or numerical) studies. Due to simplicity of geometry flow around a strip has a potential to investigate separately effects of a drag and lift forces on the body by changing the slope of the horizontally moving strip which can be placed vertically [1], horizontally [2], or be tilted under some angle to the direction of towing velocity [5].

In this investigation, uniform flow of a stratified fluid with density profile $\rho(z)$, of horizontal velocity U and buoyancy frequency $N = \sqrt{\frac{g}{\rho}\frac{d\rho}{dz}}$ past a body of characteristic

dimension D is considered (equivalent to a body moving with the same speed in opposite direction in a quiescent stratified fluid). The major dimensionless parameters governing this problem are the Froude Number $\mathrm{Fr} = \frac{U}{ND}$ the Reynolds number $\mathrm{Re} = \frac{UD}{\nu}$ and ratio of intrinsic length scales $C = \Lambda / D$ ($\Lambda = d(\ln \rho / dz)$ is stratification length scale). Ratio of dissipative coefficients defines the Schmidt number $\mathrm{Sc} = \nu / \kappa_S$ (ν is kinematic viscosity and κ_S is salt diffusivity). The set of the dimensionless parameters define conditions of numeric and small scale laboratory modeling of environmental flows.

Numeric modeling of a flow past vertical strip uniformly towing with permanent velocity in horizontal direction in a linearly stratified talk which was based on a finite differences solver adapted to the low Reynolds Navier-Stokes equation with transport equation for salinity (LES simulation [6]) has demonstrated reasonable agreement with data of Schlieren visualization, density marker and probe measurements of internal wave fields. Both parts of the wave fields including upstream transient and downstream stationary waves were resolved.

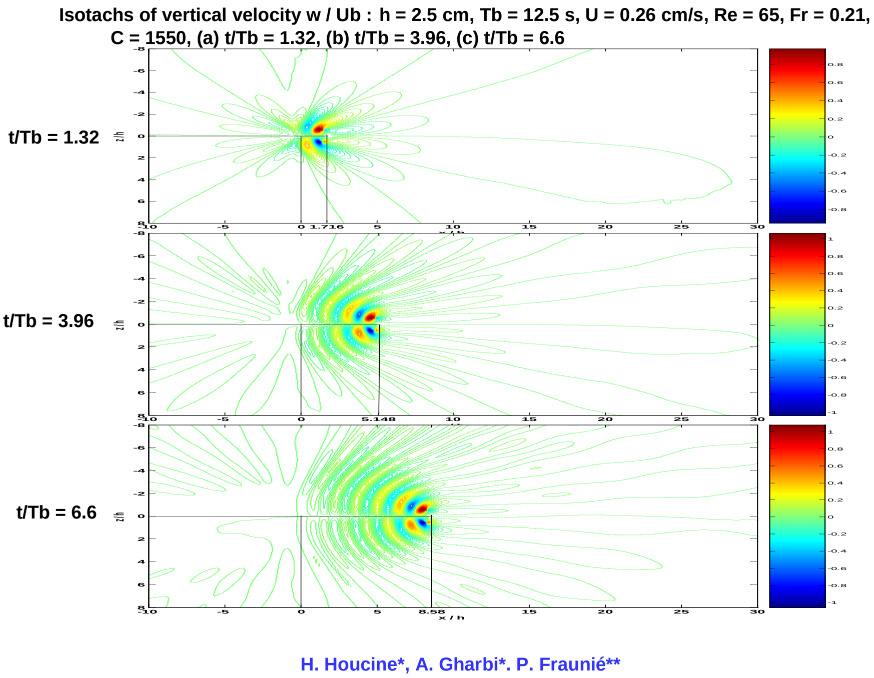

Figure. Vertical velocity contours in the proximity of the strip.

The chosen test cases allowed demonstrating the ability of selected numerical methods to represent stably stratified flows over horizontal strip [4] and hill type 2D obstacles [1, 3] with generation of internal waves.

From previous LES [6] and RANS [7] realistic simulations code, the ability of research codes to reproduce field observations is discussed.

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