Two-dimensional numerical simulations of stratified turbulence

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Ocean dynamics is composed of large horizontal vortices and propagating internal gravity waves. Its kinetic energy spectra follow the well-known *Garrett-Munk spectrum*[1], which is usually interpreted as a superposition of waves.

Two-dimensional stratified flows on a vertical cross-section differ from its analogous three-dimensional flows in its lack of vertical vorticity, supporting only wave and shear modes. Two-dimensional numerical simulations have been performed in stratified turbulence using an isotropic forcing[2,3].This type of forcing excites modes with different frequencies.

We report results from two-dimensional high-resolution numerical simulations of a fluid in the presence of a linear density stratification. The simulations have been carried out with the open-source pseudo-spectral code *fluidsim*[4]. We force the linear mode of the Navier-Stokes equations. Unlike precedent works, the forcing is applied to a localized region of the spectral space, in which forced waves have a similar frequency. We analyze the outcome dynamics in detail by looking at the anisotropic energy spectra, the energy fluxes and the spatio-temporal spectra for different levels of stratification. In the strongly stratified regime, the vertical energy spectra look like the ocean spectra while no clean wave cascade is obtained.

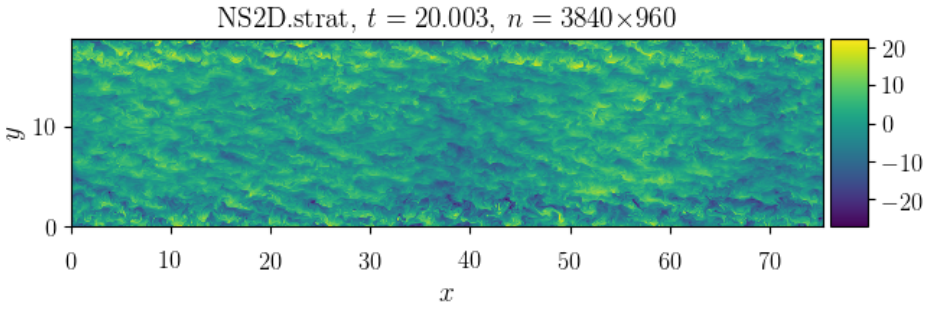

Figure 1: Instantaneous buoyancy field at $t/T_f = 20$, where T_f is the characteristic forcing time scale. The numerical domain is rectangular with a spatial resolution 3840×960.

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[1]W. Munk, *Physical Oceanography*, 264-291, 1981
[2]G. Boffetta, F. De Lillo, A. Mazzino and S. Mussachio, *Europhysics Letters*, **95**, 2011.
[3]M.K. Verma, A. Kumar and J. Sukhatme, *J. Turbulence*, **18**:219-239, 2017.
[4]https://bitbucket.org/fluiddyn/fluidsim