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Direct and Large Eddy Simulation of Stratified Turbulence

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The dynamics of three-dimensional turbulence under the influence of density stratification can be classified in different regimes that differ fundamentally; see Brethouwer et al. (2007) for a good review. Up to now, strongly stratified turbulent flows were mainly studied by direct numerical simulations (DNS). The available computer resources, however, limit the application of DNS to Reynolds numbers that are too small for studying the regime of real scale atmospheric problems. Large Reynolds number flows in general can be simulated efficiently by large-eddy simulation (LES). However, most subgrid-scale (SGS) models for LES are not suitable for stratified flows, as local isotropy of the SGS turbulence is assumed, and therefore require ad-hoc modifications. We propose an implicit subgrid-scale model that handles anisotropic turbulence in a straight forward way without any limiting assumptions.

We solve the non-linear Boussinesq equations for a fluid with a constant background stratification using a finite-volume solver. DNS are performed with a 4th order centered scheme. The implicit sub-grid scale model is based on the Adaptive Local Deconvolution Method (ALDM) for the incompressible Navier-Stokes equations (Hickel et al. 2006) and the ALDM for passive scalar transport (Hickel et al. 2007). The turbulence theoretical background of ALDM and the numerical details will be given in the full paper.

Two generic test cases are considered. First, we computed the temporal evolution of a 3D Taylor-Green-vortex (Brachet 1991) under the influence of stratification. We ran several fully resolved simulations with up to 768^3 cells and corresponding implicit LES with 64^3 cells. The LES show good agreement with a fully resolved DNS. The total dissipation rate is predicted correctly and also the proportions of kinetic and potential energy are well estimated. We repeated the LES and DNS at a number of different Froude and Reynolds numbers. In all cases we found good agreement between LES and DNS.

As a second test case, we computed homogeneous stratified turbulence (Brethouwer et al. 2007) at different Froude numbers. The Boussinesq equations are supplemented by a volume force that acts on the large horizontal scales only. Three-dimensional structures with finite vertical length scale develop only due to stratification. To ensure complete resolution of the smallest scales, the DNS domain contained about 900 million cells. We studied the influence of varying stratification on the averaged longitudinal kinetic energy spectra in the vertical and horizontal directions.

We will discuss the energy budget, dissipation rates, spectra of turbulence, turbulence length scales, and anisotropy of the DNS and draw conclusions with respect to SGS modeling. Our computational results support that implicit LES with ALDM can be a suitable tool for the investigation of stratified turbulence. This will enable us to compute and characterize atmospheric turbulence beyond the reach of DNS with reasonable accuracy at low computational costs.

References

[1] G. Brethouwer, P. Billant, E. Lindborg, and J.-M. Chomaz. Scaling analysis and simulation of strongly stratified turbulent flows. *J. Fluid Mech.*, 585:343–368, 2007.

[2] S. Hickel, N. A. Adams, and J. A. Domaradzki. An adaptive local deconvolution method for implicit LES. *J. Comput. Phys.*, 213:413–436, 2006.

[3] S. Hickel, N. A. Adams, and N. N. Mansour. Implicit subgrid-scale modeling for large-eddy simulation of passive scalar mixing. *Phys. Fluids*, 19:095102, 2007.

[4] M.E. Brachet. Direct simulation of three-dimensional turbulence in the Taylor–Green vortex. *Fluid Dynam. Res.*, 8(1-4):1 – 8, 1991.