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Evidence for Bolgiano-Obukhov scaling in rotating stratified turbulence using high-resolution direct numerical simulations

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Rotating stratified flows are particularly important in the understanding of the dynamics of our planet and the Sun. Several of the key concepts needed in order to progress in predictions of the weather and in the global evolution of the climate depend crucially on a fundamental understanding of these flows. At different scales, different physical regimes become salient, and yet all scales interact. Fronts and turbulent eddies lead to enhanced dissipation and dispersion of particles and tracers, affecting the global energetic behavior of the atmosphere and climate systems. Rotating stratified turbulence thus plays a crucial role in the dynamics of the atmosphere and oceans, with nonlinear interactions–responsible for the complexity of turbulent flows–having to compete with the waves due to rotation and stratification, of respective frequencies N and f.

In this context, we report on results for rotating stratified turbulence in the absence of forcing, with large-scale isotropic initial conditions, using accurate direct numerical simulations computed on cubic grids of up to 4096ˆ3 points. The Reynolds and Froude numbers are respectively equal to Re=54000 and Fr=0.024, and N/f=4.95, a choice appropriate to model the dynamics of the southern abyssal ocean at mid latitudes. This gives a global buoyancy Reynolds number ReFrˆ2=32, a value sufficient for some isotropy to be recovered in the small scales beyond the Ozmidov scale, but still moderate enough that the intermediate scales where waves are prevalent are well resolved. We concentrate on the large-scale dynamics, for which we find a spectrum compatible with the Bolgiano-Obukhov prediction, and confirm that the Froude number based on a typical vertical length scale is of order unity, with strong gradients in the vertical. Two characteristic scales emerge from this computation, and are identified from sharp variations in the spectral distribution of either total energy or helicity. A spectral break is also observed at a scale at which the partition of energy between the kinetic and potential modes changes abruptly, and beyond which a Kolmogorov-like spectrum recovers. Large slanted layers are ubiquitous in the flow in the velocity and temperature fields, with local overturning events indicated by small gradient Richardson numbers and strong nonlinear potential vorticity. A small enhancement of energy at scales larger than the initial conditions and directly attributable to the effect of rotation is also occurring. If time permits, small-scale properties will also be described.