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Pressure redistribution of turbulence kinetic energy in rotating stratified flows

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The redistribution of turbulence kinetic energy among velocity components of a turbulent flow is key to determining a number of defining features such as relaxation time scales and the classification of the flow stability and anisotropy, for instance on anisotropy invariant maps such as the Lumley triangle or Barycentric map. In a geophysical context, anisotropic body forces that include density stratification and rotation, exist beyond shear generation, thus necessitating further inquiry into the aforementioned redistribution terms. Estimation of the return-to-isotropy terms requires considerable effort along with a number of assumptions when using observational or laboratory data. Also, turbulence models prevent a reliable estimation of these terms from numerical simulation as correlation between pressure and velocity is commonly part of the turbulence modelling procedure.

Here, direct numerical simulation data that explicitly resolve the pressure redistribution are used. While such data are only available at intermediate friction Reynolds number on the order of $Re = 10^3$, the quantitative effects of the Reynolds number is assessed by a series of simulations where Re is increased. Bou-Zeid et al. (2018, J Fluid Mech vol. 856: p. 61-78) proposed a simplified TKE budget model to unfold the role of buoyancy on energy redistribution in wall-bounded flows.

We introduce here a modification of this model that makes it suitable for the study of rotating stratified flows. It is shown by a priori and a posteriori tests that the modification weakens the assumptions of the simplified model with regards to the isotropy of the dissipation, but also with regards to the absence of transport terms. Interestingly, deviations from these assumption partly cancel among the two horizontal contributions when lumped together. It is also demonstrated that consideration of anisotropy in the dissipation tensor significantly improves the skill of the reduced model when comparing its results to direct numerical simulation.