Numerical simulation of a reduced set of equations for rapidly rotating convection on the tilted $f$-plane

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To be presented at the American Physical Society Division of Fluid Dynamics Meeting in New Jersey on 25 November 2003.

Abstract

Using DNS, we investigate the solution to a reduced system of non-linear PDEs for rapidly rotating convection: non-hydrostatic quasi-geostrophic equations (NHQGE). The NHQGE are derived asymptotically in the limit of rapid rotation from the Navier-Stokes equations under the Boussinesq approximation. Two distinct vertical scales are present: a small-scale occurring as a consequence of rotational alignment and large-scale due to convective forced motions. The resulting equations filter fast inertial waves and relax the need to resolve Ekman boundary layers, and are applicable to deep-ocean turbulent convection, which, under thermal forcing, is characterized by thermal and vortical coherent structures that span the layer depth. Using a Chebyshev-Petrov-Galerkin algorithm, we examine variation of heat transport as a function of scaled Rayleigh number and compare results from a single-mode theory. We also investigate the dynamics of the vortical structures and their effect on lateral mixing.