University of Colorado at Boulder
Department of Applied Mathematics

Comprehensive Examination

November 1st, 2014
12:00pm
ECCR 257 (Newton Lab)

Presenter

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Title

Asymptotically reduced equations and numerical simulations for 3D rapidly rotating convective and stably stratified fluid layers

A single model for non-hydrostatic quasi-geostrophic motions is studied in two distinctly different physical frameworks. The first framework investigates coherent structures in the setting of rapidly rotating Rayleigh-Bénard convection while the second framework investigates motions of a rapidly stably stratified fluid layer. These flows are of physical relevance to geophysical and astrophysical systems whose dynamics are strongly influenced by rapid rotation and thermal forcing such as interiors of giant planets, rapidly rotating stars, the Earths outer liquid core, and open ocean deep convection.

In rapidly rotating convection four flow regimes with distinct characteristics have been identified via simulations of asymptotically reduced equations as a function of the a reduced Rayleigh number $\widetilde{Ra}$ and Prandtl number σ. In each regime the flow organizes, with varying intensity, into coherent vertical structures. The identified morphologies, in order of increasing $\widetilde{Ra}$, consist of the cellular regime, the convective Taylor column (CTC) regime, the plume regime, and a regime characterized by geostrophic turbulence. Presently, physical limitations on laboratory experiments and spatio-temporal resolution challenges on direct numerical simulations of the incompressible Navier-Stokes equations inhibit an exhaustive analysis of the flow morphology in the rapid rotating limit. Flow morphologies identified from simulations of an asymptotically reduced equations have been investigated from a statistical perspective. Utilization of auto- and cross-correlations of temporal and spatial signals that synthesize experimental data have been employed to (i) identify transitions in flow morphology, (ii) recover radial profiles of coherent structures, and (iii) extract transport properties of these structures. These results provide a foundation for comparison and a measure for understanding the extent to which rotationally constrained regime has been accessed by laboratory experiments and direct numerical simulations.

Motivated by recent studies on rotating and stratified flows (Pouquet *et al.* (2013)) investigations of the asymptotically reduced equations for non-hydrostatic quasi-geostrophic motions in a stably stratified setting is a subject of ongoing and future work.

References

[1] K. Julien, A.M. Rubio, I. Grooms, E. Knobloch, Statistical and physical balances in low Rossby number Rayleigh-Bénard convection, Geophysical & Astrophysical Fluid Dynamics Vol. 106, Iss. 4-5, 2012

[2] D. Nieves, A. Rubio, K. Julien, Statistical classification of flow morphology in rapidly rotating Rayleigh-Bénard convection, Physics of Fluids, 26, 086602 (2014)

[3] Pouquet, A. and Marino, R., Geophysical Turbulence and the Duality of the Energy Flow Across Scales, Phys. Rev. Lett., 111 (2013)