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Asymptotic Strategies for Modeling Geophysical and Astrophysical Convective Flows

Keith Julien

Professor and Chair Department of Applied Mathematics, University of Colorado, Boulder, CO

ABSTRACT:

Fluid turbulence under the influence of rotation and buoyancy is ubiquitous in the universe. It is the primary driving mechanism for atmospheric and oceanic dynamics, magnetic field generation in planets and stars, and is thought to be a necessary ingredient for the formation of planets. A defining characteristic of fluid turbulence is a broad-band kinetic energy spectrum; a range of scales are present within the flow that range from domain-size down to the scale where fluid motions are converted irreversibly to heat by the action of viscosity. This property represents the single biggest road-block for employing direct numerical simulations (DNS) of the full governing equations to study geophysical and astrophysical turbulence at realistic parameters (e.g. the Reynolds number); current computational constraints limit DNS to parameter values that are very distant from those that characterize natural systems. Reduction of the governing equations is therefore necessary, both as a means to reduce the computational cost of numerical simulations, but also as a means of gaining an improved understanding of the physics through a simplified equation set. Often times, mathematically rigorous reduced equations can be derived by employing multiple scale asymptotics. Aided with computationally fast numerical algorithms, these new models can interrogate physical processes at realistic flow regimes and fluid properties that remain out of reach to DNS and laboratory experiments. In this talk, I will discuss this strategy for rotationally constrained turbulent flows and its application to the canonical problem of Rayleigh-Benard thermal convection. A specific focus will be on the classification of flow regimes and the existence and details of the inverse energy cascade resulting in large scale vortices.

BIOGRAPHY:

Dr. Keith Julien is a professor of Applied Mathematics at the University of Colorado at Boulder (CU). Prior to joining CU, Dr. Julien received is PhD from the University of Cambridge's Department of Applied Mathematics and Theoretical Physics. This was followed by postdoctoral fellowship at the University of Colorado and an advanced Postdoctoral Fellowship at the National Center for Atmospheric Research. Dr. Julien's primary area of research is focussed in the mathematical geo- and astro-physical sciences. Specifically, the modeling of dynamical processes and instabilities occurring in geophysical and astrophysical flows. Particular emphasis is placed on the identification of reduced PDE models that accurately describe coherent structures, the transport and organization of large-scale flows, mean flow generation, and wave propagation. Complimentary to these interest is the development of fast numerical algorithms for the purpose of numerical simulations on state of the art high performance computing architectures.