ENGINEERING SCIENCES & APPLIED MATH--FEATURED SPEAKER

Advanced Models of Thermal Convection: A Window into Coherent Structures and Geophysical Turbulence

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Turbulent thermal convection is ubiquitous in the universe and is inherently intricate in itself. But for a wide range of geophysical and astrophysical phenomena it is the interplay of convection with other forces that determines the efficiency of the heat and momentum transport, as well as the shape and appearance of the coherent flow structures. The canonical model that captures the essential underlying physics is Rayleigh-B´enard convection, where a fluid is heated from below and cooled from above. Through the introduction of increasingly sophisticated aspects to this system, a window is opened into geophysical turbulence and the formation and evolution of coherent structures in realistic settings such as stellar and planetary interiors, atmospheres, and oceans. Here, I will focus on two specific examples. First, I will present results from direct numerical simulations of turbulent thermal convection in liquid metals subject to the simultaneous action of Coriolis and Lorentz forces, giving insight into planetary core and stellar convection zone dynamics. By analyzing the generated flows with advanced techniques such as the dynamic mode decomposition (DMD) I am able to extract and identify the coherent structures that govern these complex magnetohydrodynamical (MHD) systems. Second, I will discuss the effect of centrifugal buoyancy on rotating turbulent convection. In most studies, rotation has only been considered in terms of the Coriolis force, whereas the centrifugal force has been neglected. I have recently developed novel theoretical arguments for characterizing rotating convective turbulence including the full inertial term, i.e., both Coriolis and centrifugal forces. In Coriolis-centrifugal convection, storm-like flow structures can develop, ranging from eyes and secondary eyewalls found in hurricanes and typhoons, to concentrated helical upflows characteristic for tornadoes. Hence, these studies reveal that centrifugal buoyancy is, in fact, highly relevant for the understanding of geophysical vortices, and, thus, far more important than previously thought.