DY 2: Fluid Physics 1 - organized by Stephan Weiss and Michael Wilczek (Göttingen)

Time: Monday 9:00–10:00 Location: DYa

DY 2.1 Mon 9:00 DYa

Transition to the ultimate regime in a stochastic model for radiatively driven turbulent convection — •Marten Klein[1], Heiko Schmidt[1], and Alan R. Kerstein[2] — [1]Lehrstuhl Numerische Strömungs- und Gasdynamik, Brandenburgische Technische Universität Cottbus-Senftenberg, Germany — [2]Consultant, Danville, California, USA

Heat transfer in thermal convection is investigated using the stochastic one-dimensional-turbulence model (ODT). A Boussinesq fluid of Prandtl number 1 is confined between two horizontal adiabatic no-slip walls (located at $z = 0$ and H) and exposed to constant gravity that points in vertical $(-z)$ direction. A flow is driven by radiative heating from below yielding the local heating rate $Q(z) = (P/\ell)\,\exp(-z/\ell)$, where P is the prescribed heat flux and ℓ the absorption length. ODT resolves all relevant scales of the flow, including molecular-diffusive scales, along a vertical one-dimensional domain, whereas stochastically sampled eddy events represent the effects of turbulent advection. ODT results reproduce and extrapolate available reference experiments direct numerical simulations of Lepot *et al.* (*Proc. Natl. Acad. Sci. USA*, **115**, 2018, pp. 8937–8941) and Bouillaut *et al.* (*J. Fluid Mech.*, **861**, 2019, R5) in particular capturing the turbulent transition from the classical to the 'ultimate' regime. For these regimes, the exponent values in $Nu \sim Ra^p$ scaling are found to be $p \approx 0.3$ and $p \approx 0.55$, respectively, in agreement with measured values. Joint probabilities of eddy size and location indicate that the regime transition is accompanied by a relative increase of bulk turbulence.

DY 2.2 Mon 9:20 DYa

Reservoir Computing of Dry and Moist Turbulent Rayleigh-Bénard Convection — •Florian Heyder, Sandeep Pandey, and Jörg Schumacher — TU Ilmenau, Ilmenau, Germany

Reservoir Computing (RC) is one efficient implementation of a recurrent neural network that can describe the evolution of a dynamical system by supervised machine learning without solving the underlying nonlinear partial differential equations. We apply such a neural network to approximate the large-scale evolution and the resulting low-order turbulence statistics of two-dimensional dry and moist Rayleigh-Bénard convection. We acquire training and test data by long-term direct numerical simulations (DNS). They are postprocessed by a Proper Orthogonal Decomposition (POD) with the snapshot method. The training data comprise time series of the first 150 POD modes, which are associated with the largest total energy amplitudes and thus the large-scale structure of the flows. Feeding the data to the Reservoir Computing model and optimizing the reservoir parameters results in predictions for the evolution of the dry and moist convection flows. The prediction capabilities of our model are comprehensively tested by a comparison with DNS and test data, the latter of which are reconstructed from the most energetic POD modes. Vertical profiles of mean thermodynamic fields and their mean vertical transport show good agreement. We find that RC is capable to model the large-scale structure and low-order statistics of dry and moist turbulent convection. This shows potential for subgrid-scale turbulence parameterization in large-scale atmospheric circulation models.

DY 2.3 Mon 9:40 DYa

Generation of zonal flows in convective systems by travelling thermal waves — •Philipp Reiter[1], Rodion Stepanov[2], and Olga Shishkina[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Götttingen, DE — [2]Institute of Continuous Media Mechanics, Russian Academy of Science, Perm, RU

In this work we study the effects of travelling thermal waves which are applied at the fluid layer, specifically on the formation of global mean horizontal (zonal) flow. Earlier studies suggest that the periodic heating of the Earth's, due to Earth's rotation, could cause zonal winds in the atmosphere. Additionally, the 4-day retrograde rotation in the Venus' atmosphere might be driven by such a periodic thermal forcing. In this work we revisited an existing theoretical model and validated it by means of direct numerical simulations (DNS). Furthermore, we expanded the analysis above the limits of the theory and studied travelling thermal waves in strongly convective flows.

Our results can be summarized as follows. The 2D simulations show excellent agreement with the theoretical model for low Rayleigh numbers (Ra). For larger Ra, the theory overestimates the magnitude of the zonal flows. However, the asymptotic scalings are still valid. The 3D system shows very similar characteristics than the 2D flows, therefore we provide further evidence for the relevance of this problem to natural systems. Finally, we show that the direction of the induced mean zonal flows can change. While it is always directed opposite to the travelling wave (retrograde) for low Ra flows, as the Ra increases the zonal flow is often found in a prograde state.