DY 28: Fluid Physics and Turbulence

Time: Tuesday 14:00–15:15 Location: ZEU/0118

Invited Talk DY 28.1 Tue 14:00 ZEU/0118

Geometry of turbulent mixing in thermal convection — •Jörg Schumacher — Institut für Thermo- und Fluiddynamik, TU Ilmenau, Germany

Thermal convection flows, which are driven by buoyancy forces, are ubiquitous in nature and technology ranging from atmospheric dynamics to heat transfer in blankets of nuclear fusion devices. They are mostly connected to further physical processes, such as phase changes, radiation or magnetic fields, but the paradigm to all these turbulent flows is the plane Rayleigh-Bénard convection layer that is uniformly heated from below and cooled from above. In my talk, I will review some recent numerical investigations, both in the Eulerian and Lagrangian frames of reference, which shed new light on geometric aspects of these flows. This comprises the organization of thermal plumes in hierarchical and self-affine near-wall networks, the large-scale organization of the flow structures, and the organization of tracer particle tracks to extreme swirling events. Consequences for the turbulent transport of heat and momentum across the convection layer and their necessary modeling will be discussed.

DY 28.2 Tue 14:30 ZEU/0118

Compression, simulation, and synthesis of turbulent flows — •Stefano Pisoni[1,2], Raghavendra Peddinti[2], Siddhartha Morales[2], Egor Tiunov[2], and Leandro Aolita[2] — [1]TUHH, Hamburg, Germany — [2]TII Abu, Dhabi, UAE

Numerical simulations of turbulent fluids are paramount to real-life applications. However, they are also computationally challenging due to the intrinsically non-linear dynamics, which requires a very high spatial resolution to accurately describe them. A promising idea is to represent flows on a discrete mesh using tensor trains (TTs), where the values of the velocity field are encoded as a product of matrices (also known as Matrix Product States). This representation features an exponential compression of the number of parameters, under the assumption of low inter-scale correlations. However, it is yet not clear how the achieved compression of TTs is affected by the complexity of the flows. In fact, no TT fluid solver has been extensively validated in a fully developed turbulent regime yet. We fill this gap by analyzing TTs as an Ansatz to compress, simulate, and generate 3D snapshots with turbulent-like features. We first investigate the effect of TT compression on key turbulence statistical signatures. Second, we present a TT solver to time evolve a 3D fluid fields according to the incompressible Navier-Stokes equations. Third, we develop a memory-efficient TT algorithm to generate artificial snapshots displaying turbulent-like features. In all three cases we observe that the memory-efficient TT representation captures the relevant features of turbulent flows, offering a powerful quantum-inspired toolkit for their computational treatment.

DY 28.3 Tue 14:45 ZEU/0118

Physics-based reduced order modeling of complex chemical reactors — •Lisanne Gossel[1], Leon L. Berkel[2], Maira Gauges[2], Paul Brand[1], Mathis Fricke[1], Christian Hasse[2], Alessandro Stagni[3], Hendrik Nicolai[2], Dieter Bothe[1], and Tiziano Faravelli[3] — [1]Mathematical Modeling and Analysis, Technical University of Darmstadt, Darmstadt, Germany — [2]Simulation of Reactive Thermo-Fluid Systems, Technical University of Darmstadt, Darmstadt, Germany — [3]CRECK Modeling Group, Politecnico di Milano, Milan, Italy

Understanding and predicting observables in complex reacting flows is crucial for many applications related to the clean energy transition. We are interested in describing chemical reactors with detailed, often multiphase chemistry including thousands of reactions. While detailed understanding of the fluid physics can be gained by highly-resolved numerical models of the reactors, i.e., different types of Computational Fluid Dynamics (CFD) simulations, these usually rely on strongly simplified chemistry models to retain computational tractability. On the other hand, we use a physics-based reduced order method that allows to complement CFD by detailed chemistry computations. This is achieved by describing the reactor by a network of modeling components representing certain states of the reactor. The talk will focus on recent achievements in the development of algorithms for creating these network models based on prior CFD results. We discuss the roles of model consistency and defining proper trade-offs between model accuracy and complexity.

DY 28.4 Tue 15:00 ZEU/0118

Numerical investigation of surface wind veer in a transitional Atmospheric Boundary Layer — •Maharun Nesa Shampa, Heiko Schmidt, and Marten Klein — Brandenburgische Technische Universität Cottbus-Senftenberg, Cottbus, Germany

The Atmospheric Boundary Layer (ABL) is defined as the lower part of the atmosphere that dynamically couples the free atmosphere and Earth's surface. Transitional features and strong variability in boundary layer thickness due to surface heating and cooling pose a challenge for modeling atmospheric dynamics, placing a burden on flow profile and surface-flux parameterizations. This study addresses the mentioned challenge by investigating an idealized ABL, the so-called Ekman Boundary Layer (EBL) using a stochastic One-dimensional Turbulence (ODT) model as standalone tool. The EBL is characterized by absence of stratification such that a statistically stationary force balance between the pressure-gradient, Coriolis and drag forces is reached asymptotically for a prescribed synoptic pressure gradient. A single non-dimensional parameter, the Reynolds number, characterizes the flow regime and reflects the range of the turbulent scales participating in the flow. It is demonstrated that ODT is capable of capturing surface properties (like friction velocity, wind-turning angle) compatible with reference data and appropriate parameterization for transitional Reynolds numbers. In addition, the model offers additional insight into the boundary layer structure and statistical flow properties, which are likewise discussed. By constraining the stochastic sampling of turbulent length scales, an outlook to cut-off mechanisms is given.