DY 34: Fluid Physics: Turbulence and Convection

Time: Wednesday 15:30–17:15 Location: H19

DY 34.1 Wed 15:30 H19

Ejection of marine microplastics by raindrops: A computational and experimental study — •Moritz Lehmann[1], Lisa Marie Oehlschlägel[2], Fabian Häusl[1], Andreas Held[2], and Stephan Gekle[1] — [1]Biofluid Simulation and Modeling - Theorethische Physik VI, Universität Bayreuth — [2]Umweltchemie und Luftreinhaltung, Technische Universität Berlin

Raindrops impacting water surfaces such as lakes or oceans produce myriads of tiny droplets which are ejected into the atmosphere at very high speeds. Here we combine computer simulations and experimental measurements to investigate whether these droplets can serve as transport vehicles for the transition of microplastic particles with diameters of a few tens of micrometers from ocean water to the atmosphere. Using the Volume-of-Fluid lattice Boltzmann method, extended by the immersed-boundary method, we performed more than 1600 raindrop impact simulations and provide a detailed statistical analysis on the ejected droplets. Using typical sizes and velocities of real-world raindrops, we simulate straight impacts with various raindrop diameters as well as oblique impacts. We find that a 4 mm diameter raindrop impact on average ejects more than 167 droplets. We show that these droplets indeed contain microplastic concentrations similar to the ocean water within a few millimeters below the surface. To further assess the plausibility of our simulation results, we conduct a series of laboratory experiments, where we find that microplastic particles are indeed contained in the spray. Based on our results and known data, we estimate the global relevance of this transport mechanism.

DY 34.2 Wed 15:45 H19

Transition between 2D and 3D rotating incompressible convection in direct numerical simulations — •Kevin Lüdemann and Andreas Tilgner — Institute of Astrophysics and Geophysics, Göttingen, Germany

Direct numerical simulations of an incompressible fluid with a Prandtl number of 0.7 are used to investigate differences between exact 2D and 3D convection. The fluid is rotating about a direction perpendicular to the direction of gravity (centrifugal gravity) and zonal flow is suppressed by horizontal walls in a container with an aspect ratio of 0.5. The convection is controlled by a Rayleigh number ranging from 10^4 to 10^9 and rotation is characterised by the Ekman number ranging from 10^{-1} down to 10^{-5}. Due to the Taylor-Proudman theorem, the convective flow will be restrained to the plane perpendicular to the direction of rotation at high rotation rates. This behaviour will break down once convective driving and therefore kinetic energy is large enough. Thermal transport and kinetic energy density show different scalings for the 2D and 3D flow. The stability theory of a vortex with elliptical streamlines is tailored to the geometry in order to explain the transition. Ultimately, a dependence of the Reynolds number on the Rossby number is found $\mathrm{Re} \propto \mathrm{Ro}^{-2}$ for small Rossby numbers. Both are based on the RMS velocity of the vortex.

15 min. break

DY 34.3 Wed 16:15 H19

The onset of non-Gaussian velocity gradient statistics in low-Reynolds number flows — •Maurizio Carbone[1] and Michael Wilczek[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Am Faßberg 17, 37077 Göttingen, Germany — [2]Theoretical Physics I, University of Bayreuth, Universitätsstr. 30, 95447 Bayreuth, Germany

The Reynolds number prescribes the range of active scales involved in a turbulent flow. Stirring a fluid through a Gaussian forcing at vanishingly small Reynolds produces a multi-point Gaussian field, while flows at higher Reynolds exhibit non-Gaussianity, cascades, anomalous scaling and preferential alignments. Recent works (Yakhot and Donzis, Phys. Rev. Lett. 2017) showed that low-Reynolds flows exhibit features of high-Reynolds turbulence.

We address the onset of turbulent features in low-Reynolds flows by combining a perturbation theory of the full Navier-Stokes equations (Wyld, Ann. Phys. 1961) with the Lagrangian modelling of velocity gradients along fluid particle trajectories (Meneveau, Annu. Rev. Fluid Mech. 2011). We construct a stochastic model for the velocity gradient in which all the model coefficients follow directly from the Navier-Stokes equations. The associated Fokker-Planck equation for the single-time velocity gradient probability density admits analytic solutions which show the onset of non-Gaussianity: skewness, intermittency and preferential alignments arise in the gradients statistics as the Reynolds number increases. The results are in excellent agreement with direct numerical simulations of low-Reynolds flows.

DY 34.4 Wed 16:30 H19

Temporal large-scale intermittency and its impact on flow statistics — •Lukas Bentkamp[1,2] and Michael Wilczek[1,2] — [1]Theoretical Physics I, University of Bayreuth, Universitätsstr. 30, 95447 Bayreuth — [2]Max Planck Institute for Dynamics and Self-Organization, Am Faßberg 17, 37077 Göttingen

Turbulent flows in three dimensions are characterized by the transport of energy from large to small scales, the so-called energy cascade. Since the small scales are the result of the nonlinear dynamics across the scales of the energy cascade, they are often thought of as universal and independent of the large scales. However, as famously remarked by Landau in 1959, sufficiently slow variations of the large scales should nonetheless be expected to impact small-scale statistics. Such variations, often termed large-scale intermittency, are almost inevitable in experiments and even in simulations, while differing from flow to flow.

Here we evaluate the impact of temporal large-scale fluctuations on velocity, velocity gradient, and acceleration statistics by introducing controlled variations of the energy injection rate into direct numerical simulations of turbulence. We find that slow variations can have a strong impact on flow statistics, amplifying the tails of the measured distributions. We also show that the stronger tails can be accounted for by superposing an ensemble of stationary flows such that the temporal variations of an appropriate flow measure such as the energy dissipation rate are matched. Overall, our work demonstrates that in order to ensure comparability of statistical results in turbulence, large-scale intermittency needs to be taken into account.

DY 34.5 Wed 16:45 H19

Towards an effective description of turbulent superstructures in simple shear flows — •Fabián Álvarez-Garrido and Michael Wilczek — Theoretical Physics I, University of Bayreuth, Bayreuth

Turbulent flows driven by large-scale forces such as convection, shear, or rotation may display large-scale coherent flows, namely turbulent superstructures, coexisting with fully developed turbulence on the small scales. A complete description of these flows involves innumerable degrees of freedom, yet turbulent superstructures seem to evolve according to a comparably lower-dimensional set of equations. In addition, despite the ubiquity of turbulent superstructures, their interplay with the smaller scales is not yet fully understood. We study a simple shear-driven flow, the three-dimensional Kolmogorov flow. The large scales in this flow feature the formation of large-scale vortex pairs. Moreover, the system exhibits permanent dynamics between states having a different number of vortex pairs. Employing amplitude equations, we characterize the dynamics of the large scales close to the onset of the vortex pairs. We show that the dynamics close to the onset correspond to the one of a two-dimensional flow. Furthermore, we show that far from the onset, the derived model captures the structure of the large-scale vortices. Based on data from direct numerical simulations, we introduce new stochastic terms to these amplitude equations to model the contribution of the small scales to the dynamics of the large ones. These modified amplitude equations can qualitatively reproduce the dynamics of these large-scale vortex pairs and shed light on the role of small-scale turbulence in the formation of turbulent superstructures.

DY 34.6 Wed 17:00 H19

3D simulation of convection patterns in dry salt lakes — •Lucas Goehring[1], Matthew Threadgold[2], Cédric Beaume[2], and Steve Tobias[2] — [1]Nottingham Trent University, Nottingham, UK — [2]University of Leeds, Leeds, UK

Salt deserts are some of the most extreme and beautiful landscapes in the world–flat silver-white crystalline plains covered with bizarre and seemingly unnatural shapes. The most prominent feature of these fantastic landscapes is a characteristic tiling of polygons, formed by ridges in the salt-encrusted surface, and always a few meters across. Recently, a dynamical model has been proposed to explain their formation as the surface expression of buoyancy-driven convection happening in the wet salty soil beneath the desert surface. Here, we present a 3D numerical model of the salt lake problem, where a fluid-saturated porous medium is subject to a constant surface evaporation, mimicking the conditions of a desert with an underground aquifer near the surface. We look in turn at the initial instabilities expected in this system, and how they will evolve in time into a dynamical steady state. In this we focus on identifying the patterns that develop in the model, and exploring how the surface flux of salinity depends on the driving parameters.