Burgers Lecture: Zipping Wetting—and Other Surface Phenomena

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Micro-structured materials can show a superhydrophobic behavior with effective contact angles of 160^ and beyond ("Lotus effect"), while the contact angle of the smooth surface is much smaller. Such materials are used e.g. for medical applications, coatings, self-cleaning, textiles, and microfluidics. However, under certain conditions, the superhydrophobicity ("Cassie-Baxter state") spontaneously breaks down: fluid enters in between the micro-structures and spreads, resulting into a smaller contact angle ("Wenzel state"). Ultra-high-speed imaging allows us to analyze the dynamics of this breakdown. Depending on the scales of the micro-structure, the wetting fronts propagate smoothly and circularly or – more interestingly – in a stepwise manner, leading to a growing square-shaped wetted area: entering a new row perpendicular to the direction of front propagation takes milliseconds, whereas once this has happened, the row itself fills in microseconds ("zipping"). The time scale separation of this zipping-wetting originates from a divergence in the characteristic wetting time (critical slowing down) which can analytically be derived by balancing capillary and viscous effects. Numerical simulations confirm this view and are in quantitative agreement with the experiments. Our results provide design criteria for superhydrophobic surfaces.

In the second part of the talk I focus on the opposite effect, namely bubble nucleation at surfaces which is a poorly understood phenomenon. We did visualization experiments at structured hydrophobic surfaces and compared the results with model calculations, in particular focusing on bubble-bubble interactions. It is demonstrated that in the many bubble case the bubble collapse is delayed due to shielding effects. We succeed in making cavitation totally reproducible in space and time. Finally, I will address the question on whether surface nanobubbles play a role in the bubble nucleation.

Quasi-Balanced Hurricane Dynamics

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Despite the presence of intense latent heat release and vertical motion in the eyewall, hurricane vortices can be approximated, after azimuthal average, by gradient-wind and hydrostatic balance equations within an error of less than 10%, except in the boundary layer and the upper outflow layer.

In this presentation, I will show how to isolate and quantify the contributions of dry dynamical, latent heat release and frictional processes to the hurricane's quasi-balanced transverse circulations in three dimensions. The impact of the vertical shear-induced transverse circulations on the hurricane inner-core dynamics is presented. Hurricane eye dynamics will also be discussed.

Quantitative Visualization of Oscillatory and Pulsatile Flows Using Temperature

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Applications of holographic interferometry to the simultaneous visualization of oscillatory and pulsatile flow and temperature fields in complex geometries are discussed. Self-sustained oscillatory flows are considered in grooved and communicating channels as well as oscillatory heat transfer in the stack region of a thermoacoustic refrigerator model. Visualization images generated using real-time holographic interferometry combined with high-speed cinematography showing the unsteady temperature fields suggest that the temperature distributions can accurately mirror the flow structures in a class of complex unsteady flows. This allows, in addition to the measurement unsteady of temperature profiles and heat transfer, also the measurement of oscillatory amplitudes, frequencies, wavelengths, as well as the speed of the of propagation of traveling waves.

Twenty Years of Experimental and DNS Access to the Velocity Gradient Tensor: What Have We Learned About Turbulence?

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Twenty years ago there was no experimental or computational access to the velocity gradient tensor for turbulent flows. Without such access, knowledge of fundamental and defining properties of turbulence, such as vorticity, dissipation and strain rates and helicity, were inaccessible. In 1987 the results of the development and first successful use of a multi-sensor hot-wire probe for measurements of all the components of the velocity gradient tensor in a turbulent boundary layer were published by J.-L. Balint, P. Vukoslavcevic & J.M. Wallace (Advances in Turbulence, Proc. 1st Euro. Turb. Conf.). That same year the first DNS of a turbulent channel flow was successfully carried out and reported by J. Kim, P. Moin & R. Moser (J. Fluid Mech. 177). Since then several experimentalists have used multi-sensor hot- wire probes of increasing complexity in turbulent boundary layers, wakes, jets, mixing layers and grid flows. Numerous computationalists have employed DNS in a wide variety of turbulent flows at ever increasing Reynolds numbers. PIV has been developed and advanced during these two decades and has provided another means of access to these fundamental properties of turbulence. This presentation will review these remarkable developments and point out some of the most important things we have learned about turbulence as a result.