Modern view(s) of wall turbulence: what changed in the last 50 years

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Abstract

Turbulence if often described as being the last unsolved problem of classical physics. At the same time, turbulence compellingly demands attention in many various applicative fields, and routinely challenges engineers concerned with flows bounded by solid walls (boundary layers, duct flows, etc).

In my lecture I will address the most exciting new important results and achievements of the last decades in the field of turbulence research. For example, one true moment of discontinuity has been the irruption of computers into the realm of fluid dynamics. The role of Computational Fluid Dynamics (CFD) is steadily increasing, but here I am specifically referring to the hardware and algorithmic advances that suddenly, in the '80s, made Direct Numerical Simulation (DNS) of the full Navier-Stokes equations possible. Today a new discipline is born, backing up the tremendous achievement in experimental techniques, that builds upon the ability of carrying out experiments within the computer to advance our physical understanding of turbulence. Such experiments are high-fidelity idealizations of reality, and can additionally choose not to obey the true laws of physics the laboratory experiments are bound to.

Another recent cornerstone has been the progressive discovering of the role played in the dynamics of turbulent flow by the so-called coherent structures, that populate the flow while being immersed in a cahotic background that inherits the traditional "featureless" nature of turbulence. The possibility of selectively addressing the coherent part of the flow, to either study its dynamics in a simpler setting with a lesser number of degrees of freedom, or manipulate it to achieve some practically relevant goal like reduction of turbulent drag or increase of turbulent heat transfer, is a more recent by-product of these discoveries. The very concept of coherent structure motivates the discipline of flow control.

In my talk, I will address these and other major topics, providing a wide-scope introductory description of what wall turbulence looks like to the eyes of the modern researcher that enters the field animated by the need to solve advanced practical problems. The subject of DNS will be described, highlighting the advantages of such a powerful research tool as well as potential shortcomings and pitfalls should such a tool be used without the required critical thinking. As an example, the recent advances in our knowledge concerning the physical processes that regulate the interaction between the various layers of a turbulent wall-bounded flow will be described, as they are exemplary of how experiments and numerical simulations can fruitfully interact with each other. As far as coherent structures are concerned, I will depict our current understanding of their role in sustaining the so-called near-wall viscous turbulent cycle. As an example, I will briefly illustrate flow control strategies that aim at modifying such structures and succeed at reducing turbulent friction drag and increasing turbulent heat transfer.