Subcritical Transition to Turbulence via Large-Scale Coherent Structures

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Abstract

Subcritical wall-bounded flows (like pipe flow, plane Couette flow or plane channel flow) undergo a transition to turbulence through the nonlinear dynamics of coexisting laminar and turbulent regions. When generated, turbulent motions at sufficiently low Reynolds number spontaneously take the form of large-scale localized structures, known as puffs in pipe flow or bands in planar flows, which coexist with laminar flow. In contrast to large Reynolds number regimes where turbulence always contaminates the flow via expanding fronts, these low-Reynolds-number structures either decay or propagate by self-replicating.

I will review some of the progress made in modelling these self-sustained nonlinear structures with reduced-order PDEs[1,2]. Localized turbulent structures are sustained by spatial energy fluxes from laminar to turbulent regions, driven by emergent large-scale mean flows, which, in planar setups, cause regular patterns to form[4,5]. I will then discuss configurations where this large-scale mean flow is absent or suppressed, focusing on a controlled numerical simulation of plane Couette flow[6]. In this setup, transition to turbulence is not mediated by permanent localized structures, but rather occurs via the propagation of fluctuating fronts at all Reynolds numbers. This simpler transition scenario, also present in curved or body-forced pipes, can be modeled by a noise-driven metastable one-variable system. I will discuss how the noise level in this model dictates whether the transition to turbulence is discontinuous or continuous.

References

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