Andreas Acrivos Dissertation Award Talk: Modeling drag forces and velocity fluctuations in wall-bounded flows at high Reynolds numbers
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The sizes of fluid motions in wall-bounded flows scale approximately as their distances from the wall. At high Reynolds numbers, resolving near-wall, small-scale, yet momentum-transferring eddies are computationally intensive, and to alleviate the strict near-wall grid resolution requirement, a wall model is usually used. The wall model of interest here is the integral wall model. This model parameterizes the near-wall sub-grid velocity profile as being comprised of a linear inner-layer and a logarithmic meso-layer with one additional term that accounts for the effects of flow acceleration, pressure gradients etc. We use the integral wall model for wall-modeled large-eddy simulations (WMLES) of turbulent boundary layers over rough walls. The effects of rough-wall topology on drag forces are investigated. A rough-wall model is then developed based on considerations of such effects, which are now known as mutual sheltering among roughness elements. Last, we discuss briefly a new interpretation of the Townsend attached eddy hypothesis—the hierarchical random additive process model (HRAP). The analogy between the energy cascade and the momentum cascade is mathematically formal as HRAP follows the multi-fractal formulism, which was extensively used for the energy cascade.