Transition to turbulence without large-scale flow

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Transitional wall-bounded turbulent shear flows contain coexisting laminar and turbulent regions organized into oblique regular patterns[1] with large-scale flow along the turbulent-laminar interfaces[2]. In order to investigate the role of the large-scale flow, we suppress it by numerically filtering out the large-scale spanwise velocity. Although transition to turbulence takes place at nearly the same Reynolds numbers in the filtered flow, we find that turbulence does not take the form of regular oblique laminar and turbulent bands, but rather of disordered turbulent zones of broadly-distributed sizes. The resulting transition scenario is governed by nucleation or retraction of small-scale vortices at the turbulent-laminar front and by their local decay inside the turbulent phase.

Pomeau[3] was the first to suggest that transition to turbulence falls into the universality class of directed percolation. Previous numerical[4] and experimental[5] investigations of wall-bounded shear flows have confirmed this, with the naturally occurring large-scale oblique bands playing the role of the elementary objects whose rate of propagation and decay govern transition. We show that the filtered system also falls into the directed percolation universality class, but with the small-scale vortices as the elementary objects, as was originally proposed by Pomeau.

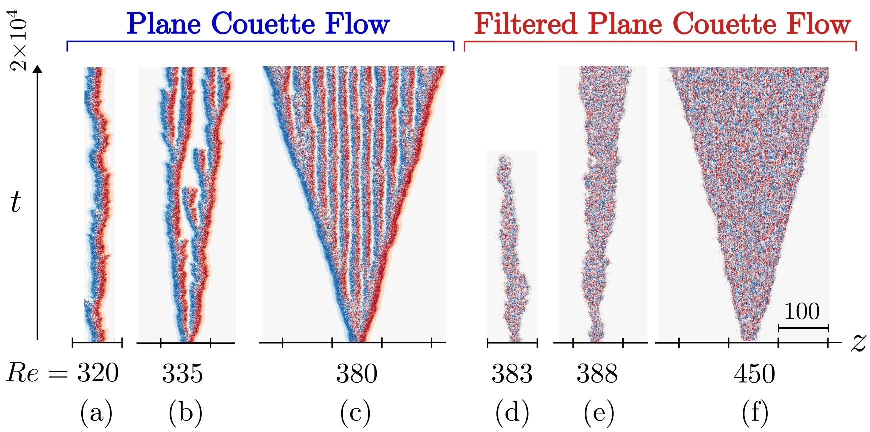

Figure 1: Evolution from a turbulent spot in plane Couette flow (a, b, c) and filtered plane Couette flow (d, e, f).

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