Analysis of turbulent bands in planar shear flows

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Turbulence in wall-bounded shear flows exhibits a remarkable phenomenon: spatially periodic patterns of alternating turbulent and laminar flow emerge spontaneously from uniform turbulence as the Reynolds number is decreased.[1] See Fig. 1(a). These patterns are ubiquitous in subcritical shear flows and explaining them has been a long-standing challenge for understanding the route to turbulence. These patterns are fascinating from a dynamical-systems viewpoint because they appear in a highly fluctuating, highly nonlinear state. Here and in an accompanying talk, we report on a model obtained by projecting the Navier-Stokes equations onto a few vertical modes, with closure coming from simple and justified assumptions for Reynolds stresses, dissipation, and turbulent viscosity.

We focus on an analysis of the flows from direct numerical simulations of a stress-free wall-bounded flow driven by a body force.[2] By time averaging, we obtain mean flows and TKE (turbulent kinetic energy) fields.[3] These are then decomposed into vertical (wall-normal) modes and the energy budgets of each mode is assessed.

Figure 1(b) shows a representative budget for the mean flow along the turbulent band projected onto the first vertical mode: $\sin(\pi y/2)$, where y is the vertical coordinate. Similar budgets are obtained for other mean flow components and for the TKE. From these budgets, as well as an analysis of the Reynolds stresses and turbulent dissipation, we construct a justified closure for the Reynolds averaged Navier-Stokes equations projected onto a minimal set of vertical modes. Here and in the accompanying talk, we will present the behavior of the resulting model system and show its implications for our understanding of the transition phenomena.

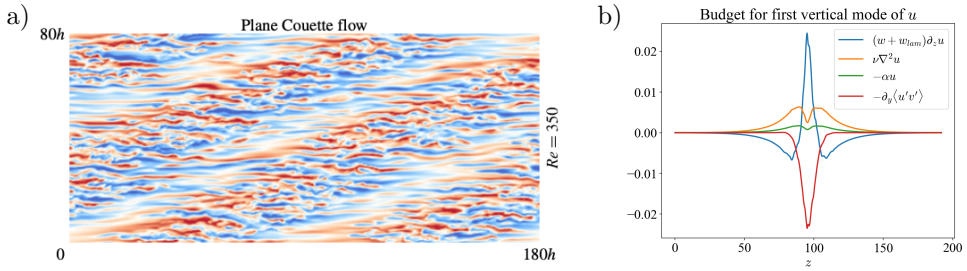

Figure 1: (a) Banded turbulence visualized by instantaneous streamwise velocity at the midplane, with contours from negative (blue) to positive (red) velocity in plane Couette flow (from Tuckerman *et al.*). (b) Along-band force budget for the first vertical mode of u.

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