Modeling turbulent bands in planar shear flows

S.J. Benavides*, L.S. Tuckerman †, and D. Barkley*

The transition from simple laminar flow to the chaotic and multi-scale turbulent state in many wall-bounded shear flows is subcritical: laminar flow remains linearly stable to perturbations, and the transition to turbulence occurs through the local proliferation of large-scale turbulent patches throughout the domain. The phenomenon is inherently nonlinear and involves the nontrivial interaction of turbulent and laminar regions. Despite the success of models capturing the dynamics of these turbulent structures in pipe flow[1] (with a single extended dimension), the large-scale organization of turbulent structures in planar geometries (with two extended directions) remains a challenge[2].

Here, we take an important step in this direction by introducing a one-dimensional model of Plane Couette Flow (PCF) in the tilted configuration which is able to reproduce the phenomenology of banded turbulent structures. In an accompanying talk by the same authors, we show how we arrive at the new model through a series of approximations[3] and assumptions which we validate using direct numerical simulations.

In this talk, we will focus on the resulting behavior of the model and its implications for our understanding of the transition phenomena. Apart from being able to reproduce the transitional phenomena observed in PCF, the deterministic version of the model reveals a spatial instability of the uniform turbulence, ultimately leading the system to a patterned state comprising of an arranged series of nonlinear band solutions. Finally, we will discuss the extension to a fully two-dimensional model.

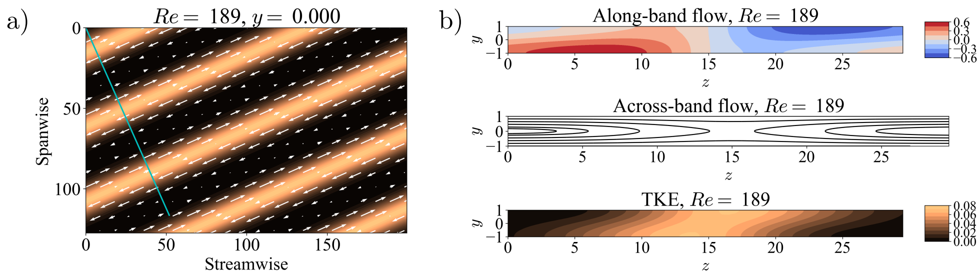

Figure 1: Spatial reconstructions of turbulence and mean flows from a multi-band solution of the one-dimensional model. (a) Streamwise-spanwise snapshot at the midplane of the turbulent kinetic energy (color) and large-scale flow (arrows). The cyan line represents the one-dimensional domain on which the solution is computed with the model. (b) Visualisations of the along-band and across-band large-scale flow and of the turbulent kinetic energy.

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*Mathematics Institute, University of Warwick, Zeeman Building, Coventry, UK

†PMMH (CNRS, ESPCI, PSL, Sorbonne Univ., Univ. Paris Cité) Paris France

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