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A minimal quasilinear approximation of turbulent channel flow

YONGYUN HWANG, Department of Aeronautics, Imperial College London, BRUNO ECKHARDT, Fachbereich Physik, Philipps-Universitt Marburg —

Townsend's model of attached eddies for boundary layers is analysed within a quasi-linear approximation. The velocity field is decomposed into a mean profile and fluctuations. While the mean is obtained from the nonlinear equations, the fluctuations are modelled by replacing the nonlinear self-interaction terms with an eddy-viscosity-based turbulent diffusion and a stochastic forcing. The colour and amplitude of the stochastic forcing are then determined self-consistently by solving an optimisation problem which minimises the difference between the actual Reynolds shear stresses and the model. When applied to turbulent channel flow in a range of friction Reynolds number from $Re_\tau = 500$ to $Re_\tau = 20000$, the resulting turbulence intensity profile and energy spectra exhibit exactly the same qualitative behaviour as DNS data throughout the entire wall-normal location, thereby reproducing the early theoretical predictions of Townsend and Perry within a controlled approximation to the Navier-Stokes equation.

Yongyun Hwang
Department of Aeronautics, Imperial College London

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