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Low-complexity stochastic modeling of spatially evolving flows

ARMIN ZARE, WEI RAN, University of Minnesota, M. J. PHILIPP HACK, Center for Turbulence Research, Stanford University, MIHAILO JOVANOVIC, University of Minnesota — Low-complexity approximations of the Navier-Stokes (NS) equations are commonly used for analysis and control of turbulent flows. In particular, stochastically-forced linearized models have been successfully employed to capture structural and statistical features observed in experiments and direct simulations. In this work, we utilize stochastically-forced linearized NS equations and their parabolized equivalents to study the dynamics of flow fluctuations in transitional and turbulent boundary layers. We exploit the streamwise causality of the parabolized model to efficiently propagate statistics of stochastic disturbances into statistics of velocity fluctuations. Our study provides insight into interactions of slowly-varying base flow with streamwise streaks, oblique modes, and Tollmien–Schlichting waves. It also offers a systematic, computationally efficient framework for quantifying the influence of stochastic excitation sources (e.g., free-stream turbulence and surface roughness) on velocity fluctuations in weakly non-parallel flows.

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