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Model-based analysis of turbulent drag reduction in channel flow over corrugated surfaces WEI RAN, University of Southern California, ARMIN ZARE, The University of Texas at Dallas, MIHAILO JOVANOVIC, University of Southern California — We develop a model-based approach to quantify the effect of spatially periodic surface corrugation on skin-friction drag in turbulent channel flow. The effect of surface corrugation is modeled as a volume penalization on the Navier-Stokes equations and the dynamics of velocity fluctuations around the resulting base velocity profile are studied using the eddy-viscosity enhanced linearized equations. We utilize the second-order statistics of velocity fluctuations resulting from the stochastically forced linearized model to compute a correction to the turbulent viscosity of flow over the corrugated surface. This correction in turn influences the turbulent mean velocity and modifies skin-friction drag. For triangular surface corrugation, our simulation-free approach reliably predicts drag-reducing trends observed in high-fidelity simulations and experiments. We investigate the effect of height and spacing of triangular riblets on these drag-reducing trends and demonstrate similar trends for the turbulent kinetic energy of velocity fluctuations. Finally, we examine the flow structures that are extracted from a modal decomposition of the velocity covariance matrix and uncover the influence of periodic surface corrugation on the energetic near-wall cycle.

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