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Direct numerical simulations of turbulent boundary layers beneath free-stream vortical forcing[1] JIHO YOU, TAMER ZAKI, Johns Hopkins Univ — Direct numerical simulations (DNS) are performed to study the modifications to turbulent boundary layers when they are exposed to free-stream vortical perturbations. The inflow boundary layer is computed in a precursor simulation [see e.g. Lee, Sung & Zaki, J. Fluid Mech. , 165-187 (2017)], and the free-stream disturbances are obtained from DNS of homogeneous isotropic turbulence. Additionally, a level-set approach is adopted to distinguish the free-stream and boundary-layer fluids and their contributions to the turbulence statistics. When the free stream is turbulent, the skin friction increases relative to the unforced flow. The enhanced wall friction can be attributed to an increase in turbulence kinetic energy production inside the boundary layer. Even though the free-stream perturbations are themselves void of Reynolds shear stresses, conditional statistics demonstrate that they enhance the shear stress within the boundary layer and, as a result, turbulence production and drag. In addition, the free-stream forcing alters both the spectral content and turbulence structures inside the boundary layer.

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Jiho You
Johns Hopkins Univ

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