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Direct simulation of flat-plate boundary layer with mild free-stream turbulence XIAOHUA WU, Royal Military College of Canada, PARVIZ MOIN, Center for Turbulence Research, Stanford University — Spatially evolving direct numerical simulation of the flat-plate boundary layer has been performed. The momentum thickness Reynolds number develops from 80 to 3000 with a free-stream turbulence intensity decaying from 3 percent to 0.8 percent. Predicted skin-friction is in agreement with the Blasius solution prior to breakdown, follows the well-known T3A bypass transition data during transition, and agrees with the Erm and Joubert Melbourne wind-tunnel data after the completion of transition. We introduce the concept of bypass transition in the narrow sense. Streaks, although present, do not appear to be dynamically important during the present bypass transition as they occur downstream of infant turbulent spots. For the turbulent boundary layer, viscous scaling collapses the rate of dissipation profiles in the logarithmic region at different Reynolds numbers. The ratio of Taylor microscale and the Kolmogorov length scale is nearly constant over a large portion of the outer layer. The ratio of large-eddy characteristic length and the boundary layer thickness scales very well with Reynolds number. The turbulent boundary layer is also statistically analyzed using frequency spectra, conditional-sampling, and two-point correlations. Near momentum thickness Reynolds number of 2900, three layers of coherent vortices are observed: the upper and lower layers are distinct hairpin forests of large and small sizes respectively; the middle layer consists of mostly fragmented hairpin elements.

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