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Transitional and turbulent flat-plate boundary layers with heat transfer XIAOHUA WU, Royal Military College of Canada, PARVIZ MOIN, Center for Turbulence Research, Stanford University — We report on our direct numerical simulation of two incompressible, nominally zero-pressure-gradient flat-plate boundary layers from momentum thickness Reynolds number 80 to 1950. Heat transfer between the constant-temperature solid surface and the free-stream is also simulated with molecular Prandtl numberPr = 1. Throughout the entire flat-plate, the ratio of Stanton number and skin-friction St/C_fdeviates from the exact Reynolds analogy value of 0.5 by less than 1.5%. Turbulent Prandtl number Pr_t peaks at the wall. Preponderance of hairpin vortices is observed in both the transitional and turbulent regions of the boundary layers. In particular, the internal structure of merged turbulent spots is hairpin forest; the internal structure of infant turbulent spots is hairpin packet. Numerous hairpin vortices are readily detected in both the near-wall and outer regions of the boundary layers up to momentum thickness Reynolds number 1950. This suggests that the hairpin vortices in the turbulent region are not simply the aged hairpin forests convected from the upstream transitional region. Temperature iso-surfaces in the companion thermal boundary layers are found to be a useful tracer in identifying hairpin vortex structures.

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