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Boundary layers in favourable pressure gradients

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Turbulent boundary layers subjected to freestream acceleration due to a favorable pressure gradient (FPG) are common in many engineering applications. For strong acceleration the flow tends to revert to a laminar state; whether it re-laminarizes fully depends on the strength of the acceleration, and on the distance over which the acceleration is maintained. As the pressure gradient is removed, the flow may then return to a turbulent state; the re-transitioning process is strongly affected by the state of the turbulence at the end of the acceleration region. In this talk we present results of simulations of turbulent flow in flat-plate boundary layers subjected to strong acceleration, exceeding the critical Reynolds number for extended distance. Two Reynolds numbers are considered: a low one is studied by direct simulations, a higher one by large-eddy simulations. As the acceleration increases, the logarithmic layer is initially preserved, albeit with a higher value of the von Kàrmàn constant; in the region of high acceleration, however, the velocity profile becomes laminar-like; in the high-Re case, a new logarithmic layer is established shortly after the end of the acceleration, while in the low-Re case re-transition occurs much later. Good agreement of the high-Re LES with the experimental data is observed. The region of maximum acceleration is characterized by significant reorganization of the wall layer, with streaks that remain stable for very long distances. Frozen turbulence advected from upstream is still present, but it does not adjust to the freestream acceleration (i.e., the freestream velocity increases, but the turbulent kinetic energy maintains its upstream value); the residual turbulent fluctuations are large enough that, once the acceleration ends, a bypass-like transition process is triggered.