Investigations of the origin of turbulent superstructures in a flat-plate boundary layer with pressure gradient

This contribution is devoted to the numerical study of turbulence in flat-plate boundary layers without and with streamwise pressure gradients using long integration domains in streamwise flow direction. To avoid a possible bias of the development of turbulent superstructures turbulence shall be generated via laminar-turbulent transition within the integration domain, following the successful approach of Schlatter et al. (2009). This has the distinctive advantage that the amount of artificial disturbances which do not comply with the full Navier-Stokes equations is kept to a minimum. The simulations are intended to reach as large as possible Reynolds numbers beyond $Re\Theta = 5000$, where Θ is the momentum thickness.

Under the influence of an adverse streamwise pressure gradient the maximum of turbulence production moves away from the wall similar to the increase of the Reynolds number. Therefore, the pressure gradient shall be used to "speed-up" the flow development in streamwise direction such that formation of large-scale superstructures can be observed easier. Different mechanisms in close-to-the-wall and far-from-the-wall areas can be separated from each other by a suitable choice of pressure gradient, studied separately and conjointly. Appropriate means for the detection and tracking of turbulent superstructures shall be inspected and tested. Thus, detected structures can then be compared with eigenfunctions of linear stability theory and results of linearized Navier-Stokes equations for $Re\Theta$=const which are obtained for the Reynolds-averaged local flow or filtered flow fields. This comparison is intended to investigate whether turbulent superstructures can be explained, modeled and predicted by local instability. The hypothesis, according to which turbulent superstructures might be generated further upstream and then convected downstream by the flow, shall be evaluated using data from feature tracking.

The present direct numerical simulations complement experimental investigations within the priority programme 1881 „Turbulent Superstructures". They yield additional data and understanding for examination of hypotheses, despite their limitations to smaller Reynolds numbers than in most experiments. This allows additional insight into the flow and theoretical studies of existing as well as new hypotheses that may appear in the course of the priority programme.