In-situ analysis of backflow events in the turbulent boundary layer of a wing and their relation with flow separation

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Turbulent boundary layers (TBLs) under strong adverse-pressure gradients (APGs), such as those present on a wing's suction side experience strong flow deceleration, which, at high angles of attack (very strong APGs), can lead to mean-flow separation. However, well before mean-flow separation takes place, regions of instantaneously negative streamwise velocity (backflow events) are already present. In fact, such events occur in a variety of flows, even in those in which an APG is not present[1]. Nevertheless, APGs increase the frequency and size of such events, and in turn, these can coalesce into large coherent separated structures, as shown in Fig. 1.

In the present work, well-resolved (quasi-DNS) large-eddy simulations of the flow around a NACA4412 wing profile are carried out using the spectral-element-method code Nek5000. Multiple angles of attack (5, 8, 11 and 14°) at a chord-based Reynolds number of 400,000 are considered. In order to achieve the higher angles of attack in which both attached TBLs and detached flow regions are present, adaptive mesh refinement is used in order to generate appropriate computational grids[2]. Due to the high sampling frequency required to track backflow events, and the time needed to achieve properly-converged results, storing full velocity fields for the analysis of backflow events is not feasible. Therefore, all tracking is performed in-situ[3] and in-transit (*i.e.* the tracking operation is performed on a different set of CPUs every certain number of time-steps, while the main simulation continues running), eliminating both the input/output (I/O) and the memory storage bottlenecks.

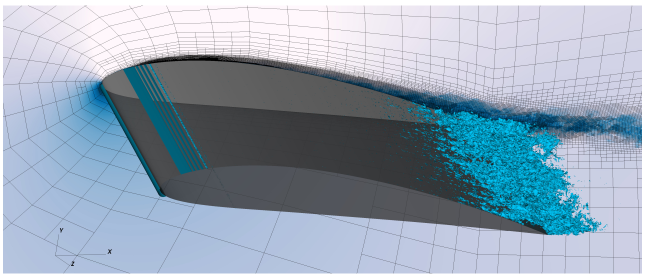

Figure 1: Instantaneous visualization of contours of negative streamwise velocity, with the spectral elements in the background for the wing at an angle of attack of 11°.

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