SPATIOTEMPORAL MEASUREMENT OF SUPERSTRUCTURES IN A TURBULENT BOUNDARY LAYER FLOW

Schanz Daniel[1], Novara Matteo[1], Geisler Reinhard[1], Agocs Janos[1],
Eich Felix[2], Bross Matthew[2], Kähler Christian J.[2], Schröder Andreas[1]

[1] *German Aerospace Center (DLR), Inst. of Aerodynamics and Flow Technology, Göttingen, Germany*
[2] *Institute of Fluid Mechnics and Aerodynamics, Bundeswehr University Munich, Neubiberg, Germany*

The understanding of the formation and the dynamics of very-large scale coherent structures within turbulent flows and their influence on the wall shear stress is an ongoing research topic. [1] showed that eddies with streamwise lengths of 10–20 δ are present in the logarithmic region of wall-bounded flows. [2] found streamwise energetic modes with wavelengths up to 14 pipe radii within fully developed turbulent pipe flow. Since then, numerous experimental investigations detected and described partial views and features of these *very large scale motions* (VLSMs) or *superstructures* within turbulent flows; however a full spatiotemporal experimental investigation was still pending.

We report on an experimental undertaking to detect superstructures in their full volumetric extent within a turbulent boundary layer and describe their temporal development while propagating from a region of zero pressure gradient (ZPG) into an adverse pressure gradient (APG). The flow was characterized by Lagrangian Particle Tracking (LPT) of Helium-filled soap bubbles (HFSBs) using the DLR implementation of the Shake-The-Box (STB) algorithm [3].

A model was installed at the side wall of the 1.8 × 1.8 m^2 cross section of the Atmospheric Wind Tunnel in Munich (AWM). The flow follows a flat plate of length 4.0 m at nearly ZPG condition and enters over two deflections into an APG region of a subsequent flat plate with 18° inclination angle and 763 mm length. A system of twelve high-speed cameras was installed outside of the tunnel. Three overlapping volumetric subsystems covered a continuous volume from the middle of the ZPG plate to the APG region (~290 cm stream-wise, 80 cm span-wise and 25 cm wall-normal). Illumination consisted of 10 high-power LED arrays, installed on the wind tunnel roof. Seeding of the flow was realized by 250 HFSB-nozzles.

Time-series of 1380 images were recorded at a rate of 1 kHz for several free-stream velocities (U_{fs} = 7, 14, 21 m/s). For the U_{fs} = 7 m/s-case up to 630.000 bubbles could be tracked instantaneously with a 2-pass STB evaluation (Fig. 1a). When displaying a wall-parallel slice of the particle field (Fig. 1c), elongated structures of low and high relative velocity can be seen, reaching from the ZPG into the FPG and APG domains. The volumetric identification of these VLSMs and the analysis of their development in space and time will be the main topic of the following investigations.

The discrete velocity and acceleration values are used for data-assimilation (‘FlowFit’) [4], reconstructing the velocity and pressure field as a continuous function (Fig. 1b). Due to the dense particle tracking and further increase in resolution by FlowFit, medium-scale vortical structures are well resolved in space and time. These results can be used e.g. for analyzing the interaction of superstructures with smaller scales.

The presentation will include in-depth data-analysis, e.g. structure detection and tracking and fluid transport across structure interfaces.

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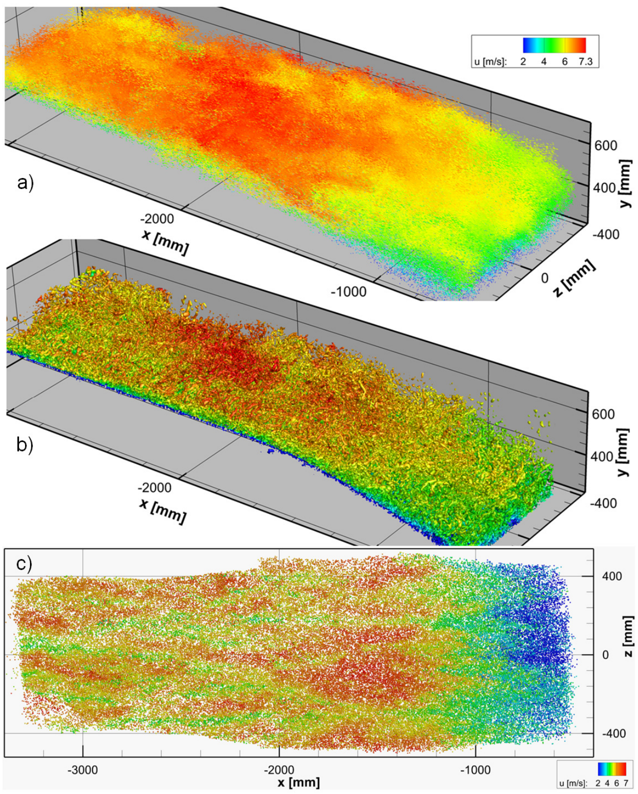

Figure 1. a) Snapshot at U_{fs} = 7 m/s with 630.000 particles; b) FlowFit interpolation of (a); Isosurface of Q = 1000/s; c) wall-parallel slice at y~0.4δ, showing traces of VLSMs

References

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