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Very-large-scale-motion measurements in pipe flow with extended POD

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Very-large-scale motions (VLSMs) have been shown to carry more than half of the kinetic energy and Reynolds shear stresses in a fully developed turbulent pipe flow [1]. The experimental observation of VLSMs with current experimental techniques is quite challenging for both hot-wire anemometry (HWA) and Particle Image Velocimetry (PIV). HWA relies on Taylor's frozen turbulence hypothesis and provides only pointwise measurements. Large-scale measurements, on the other hand, are extremely challenging for PIV. In this work VLSMs in pipe flows at high Reynolds numbers are visualized using a POD-based dynamic estimation method. Synchronized non-time-resolved PIV and time-resolved, multi-point HWA measurements are integrated for the dynamic estimation of turbulent structures in the CICLoPE facility [2]. A modal decomposition of the turbulent structures is then carried out. The combination of PIV and HWA in the CICLoPE facility gives the unique opportunity to study the behaviour of these turbulent structures at high Reynolds number combining at the same time high spatial resolution, owing to the large size of the facility, and temporal resolution, obtained via the dynamic estimation. The dynamically-estimated fields are used to propagate the time-resolved sequence in space (using, e.g., the frozen-turbulence hypothesis, as in Figure 1) to reconstruct the streamwise organization of the VLSMs and to carry out a statistical analysis on their topology.

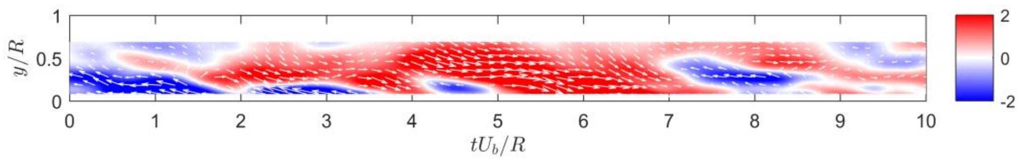

Figure 1: Velocity fluctuation field reconstructed via dynamic estimation of the PIV data using the HW signals, and application of the Taylor's hypothesis. The contour represents the streamwise velocity fluctuations u^+. Frequencies above 200 Hz have been removed in this figure for clarity.

References

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