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Evidence of very long meandering features in the logarithmic region of turbulent boundary layers. (English) Zbl 1113.76004

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Summary: A regime of very long meandering positive and negative streamwise velocity fluctuations, that we term 'superstructures', are found to exist in the log and lower wake regions of turbulent boundary layers. Measurements are made with a spanwise rake of 10 hot wires in two separate facilities (spanning more than a decade of Re_τ), and are compared with existing PIV and DNS results. In all cases, we note evidence of a large-scale stripiness in the streamwise velocity fluctuations. The length of these regions can commonly exceed 20δ (δ denotes the boundary layer thickness). Similar length scales have been previously reported for pipes and DNS channel flows. It is suggested that the true length of these features is masked from single-point statistics (such as autocorrelations and spectra) by a spanwise meandering tendency. Support for this conjecture is offered through the study of a synthetic flow composed only of sinusoidally meandering elongated low- and high-speed regions. From detailed maps of one-dimensional spectra, it is found that the contribution to the streamwise turbulence intensities associated with the superstructures appears to be increasingly significant with Reynolds number, and scales with outer length variables (δ). Importantly, the superstructure maintains a presence or footprint in the near-wall region, seeming to modulate or influence the near-wall cycle. This input of low-wavenumber outer-scaled energy into the near-wall region is consistent with the rise in near-wall streamwise intensities, when scaled with inner variables, that has been noted to occur with increasing Reynolds number. In an attempt to investigate these structures at very high Reynolds numbers, we also report on recent large-scale sonic anemometer rake measurements, made in the neutrally stable atmospheric surface layer. Preliminary results indicate that the superstructure is present in the log region of this atmospheric flow at $Re_\tau = 6.6 \times 10^5$, and has a size consistent with outer scaling.

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