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Comparison of energetic spanwise modes in a boundary layer and channel

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ABSTRACT

The spanwise organization and energy contribution of motions in a $Re_\theta = 1015$ flat-plate turbulent boundary layer are investigated using PIV in the streamwise-spanwise plane. Measurements are performed at several heights: $y^+ = 21$, 46, and 92 ($y/\delta = 0.05$, 0.11, and 0.22). Dual cameras mounted side-by-side obtain a wide field of view in the spanwise direction, capturing nearly 1100 viscous units (2.55δ). Two-dimensional Fourier analysis is used to estimate the energy distribution of the streamwise component as a function of distance from the wall. The results ($Re_t = u_t\delta/\nu = 426$, based on boundary layer thickness) are compared with the channel flow data of Liu *et al*. (2000) ($Re_t = u_t h/\nu = 400$, where h is channel half-height) at a comparable wall-normal location.

Liu *et al*. showed the well-established streak spacing mode of $\lambda_z^+ = 100$ contains surprisingly little energy relative to modes in the range $\lambda_z^+ = 200$-400. A principal objective of the present work is to determine if this result is universal for wall-bounded flows. The boundary layer results show strong agreement with the channel in terms of the spanwise energy contribution of the small scales near the wall: over 75% of the energy is in scales larger than $\lambda_z^+ = 100$. The spanwise energy distribution of the smaller streamwise scales also shows excellent agreement. However, differences in the spanwise energy distribution between the boundary layer and channel flow appear in the large streamwise modes. As a result, the spanwise energy distribution at $y^+ \approx 21$ is not universal for all scales.