INTERSCALE TRANSPORT IN WALL-BOUNDED TURBULENT FLOWS

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Couette, pipe, channel, and zero-pressure gradient (ZPG) turbulent boundary layer (TBL) flows have classically been considered as canonical wall-bounded turbulent flows since their near-wall behavior in viscous units is generally considered to be universal, i.e., invariant of the flow case and the Reynolds number. Nevertheless, the idea that large-scale motions, being dominant in regions further away from the wall, might interact with and influence small-scale fluctuations close to the wall has not been disregarded. This view was mainly motivated due to the observed failure of collapse of the Reynolds normal stresses in viscous scaling. While this top-down influence has been studied extensively over the last decade, the idea of a bottom-up influence (backward energy transfer [**1**]) is less examined. An exception is the recent experimental work by Kawata and Alfredsson [**2**] in a Couette flow at low Reynolds numbers. They investigated the interscale interactions by filtering the fluctuating part of the velocity field at different wave numbers and computing some of the terms in the scale-by-scale transport equation for the Reynolds stress component -$\langle uv \rangle$. Then, they analyzed the gain and loss of the Reynolds-stress intensity at each length-scale as a result of different physical effects: production (transfer from the mean flow), redistribution driven by the fluctuating pressure field, viscous dissipation, spatial viscous and turbulent transport as well as interscale transport.

The results from [**2**] are shown in Fig.1 (a-b). They show the interscale and spatial transport terms (tr_{-uv} and d^t_{-uv} respectively) of the transport equation of the -$\langle uv \rangle$ co-spectrum E_{-uv} at $Re = 2000$ ($Re_\tau = 108$). In a) the blue regions show a loss of -$\langle uv \rangle$ content at small values of the spanwise wavelength and a gain at larger scales is identified by the red/yellow areas. This trend is observed throughout the whole channel height, but an intense peak is located close to the wall. A redistribution of the Reynolds shear stress from the near-wall region to the channel centre is observed for both large and small scales in b), showing the scale-by-scale turbulent spatial transport of $-\langle uv \rangle$.

In the present work, the terms of the E_{-uv} transport equation are obtained from Direct Numerical Simulation (DNS) data of a Couette flow at $Re = 2000$. The spectra of tr_{-uv} and d^t_{-uv} are reported in fig. 1 c) and d), respectively. These two terms are in qualitative agreement with the experimental results (a-b). Still, discrepancies are apparent in the amplitudes, which are higher in the DNS compared to experiments, possibly due to measuring difficulties in the near-wall region. Note that the high peaks close to the wall and out of the measurement domain (white band) cause the contour colors in (c-d) to saturate since the same scale as in (a-b) is used. Based on the qualitative agreement between the experimental and numerical results conveyed here, the aim of the present work is to extend the analysis by Kawata and Alfredsson to canonical wall-bounded flows and assess its Reynolds-number dependence. Data from a TBL [**3**] covering an order of magnitude in Reynolds number will be utilized thereby helping us to address two open questions: Is the inverse interscale transport of the Reynolds shear stress a common feature of near-wall turbulence and if so, what is its Reynolds-number dependence?

References

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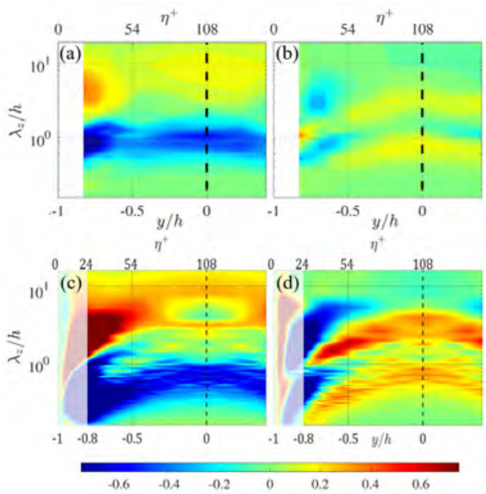

Figure 1: Space-wavelength diagrams of a) and c) scale by scale interscale transport $k_z tr_{-uv}$ and b) and d) turbulent spatial transport $k_z d^t_{-uv}$ of the premultiplied Reynolds shear stress co-spectra $k_z E_{-uv}$. The values are scaled by u^3_τ/h. DNS and experimental results are reported in the upper and lower panel, respectively. The black dashed line indicates the channel centre $y/h = 0$.