Supplementary Material: Characterization of streak development for boundary layer transition caused by isolated and distributed roughness

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1. Supplementary Material

Here, we present some additional figures to supplement the main text. Figure S1 shows the fluctuating velocity signals acquired using the hotwire probe at $y = 1$ mm from the wall. Figure S2 shows two instances of instability developing on the steady streaks caused by the distributed roughness in spanwise PIV measurements at $x_c = 242$ mm. The supplementary video S1 shows a movie of the onset of streak instability developing near steady streaks for configuration A (distributed roughness) at $x_c = 242$ mm (colour contours and vectors are same as that of figure S2). Figures S3 and S4 respectively show other instances of lifted-up backward streak ("outer" mode) and streak interaction ("inner" mode) at $x_c = 440$ mm for configuration A (distributed roughness). Figures S5 and S6 show similar such instances for configuration B (isolated roughness) at $x_c = 738$ mm.

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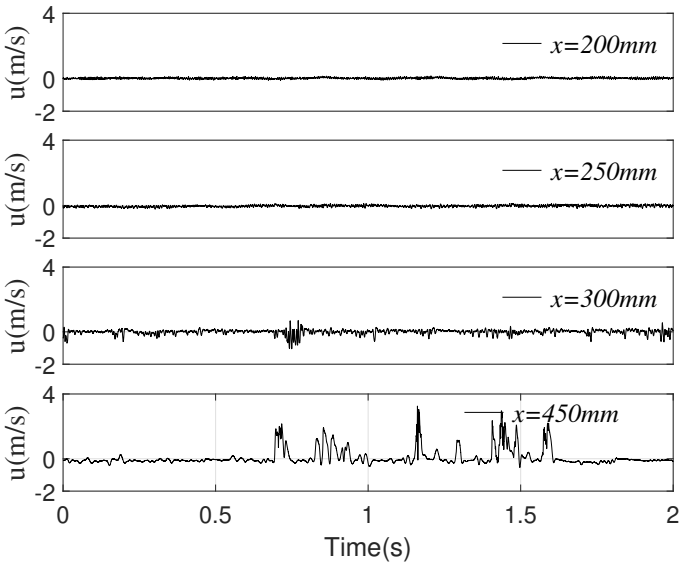

Figure S1: Fluctuating velocity signals at different streamwise locations for configuration A, acquired using hotwire anemometry.

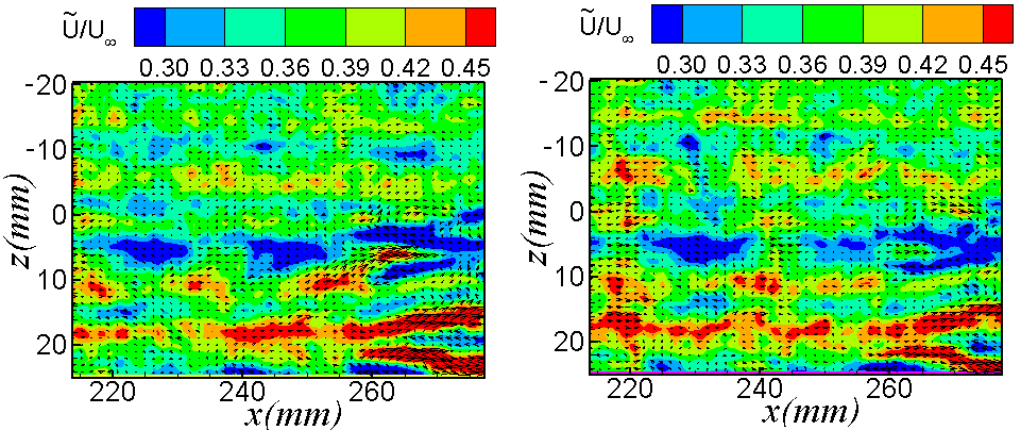

Figure S2: Instantaneous PIV frames in the x-z plane showing streak instability developing at $x_c = 242$ mm and $y/\delta^* \approx 0.64$ ($y/\delta \approx 0.24$) for configuration A. The color contours represent instantaneous streamwise velocity and the vectors represent fluctuating velocity (u,v) .

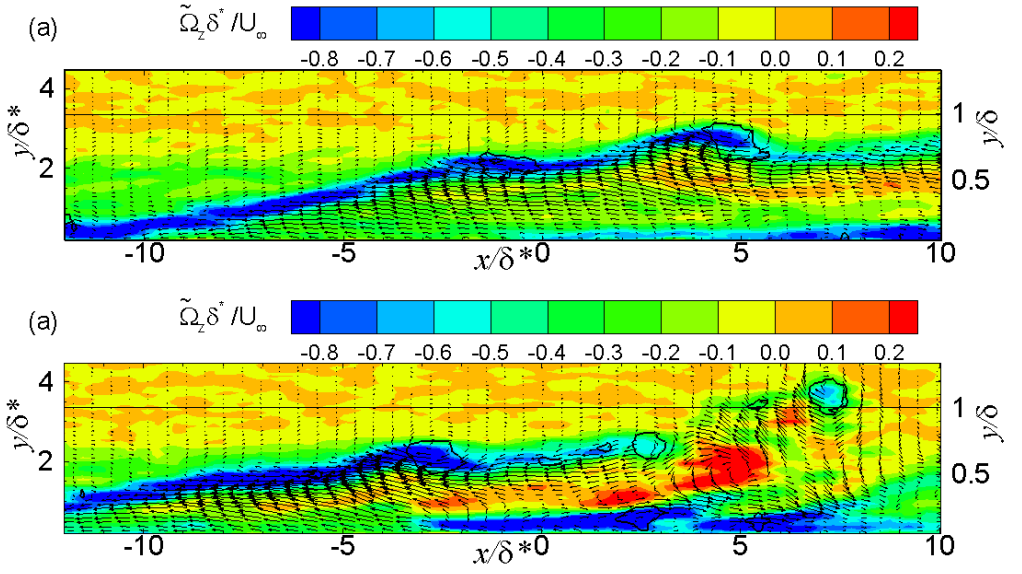

Figure S3: Instantaneous PIV frames in the x-y plane showing lifted-up backward streaks undergoing instability in configuration A at x_c=440 mm. The color contours represent normalized instantaneous spanwise vorticity and the vectors represent fluctuating velocity (u,v). The line contours indicate locations of the vortices obtained using the λ criterion (see the main text).

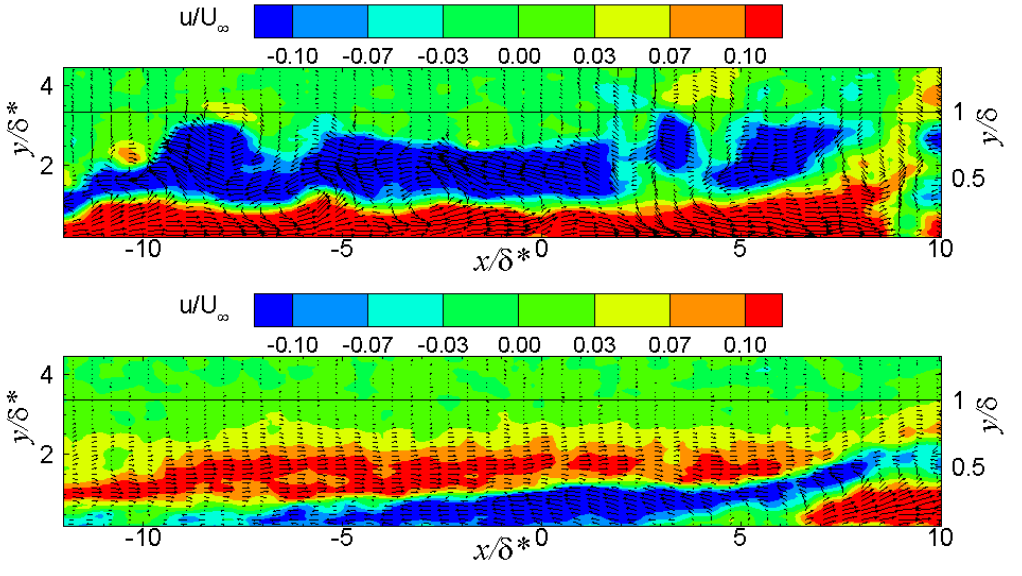

Figure S4: Instantaneous PIV frames in the x-y plane showing streak interaction in configuration A at x_c = 440 mm. The color contours show streamwise (u) fluctuating velocity and the vectors represent fluctuating velocity (u,v).

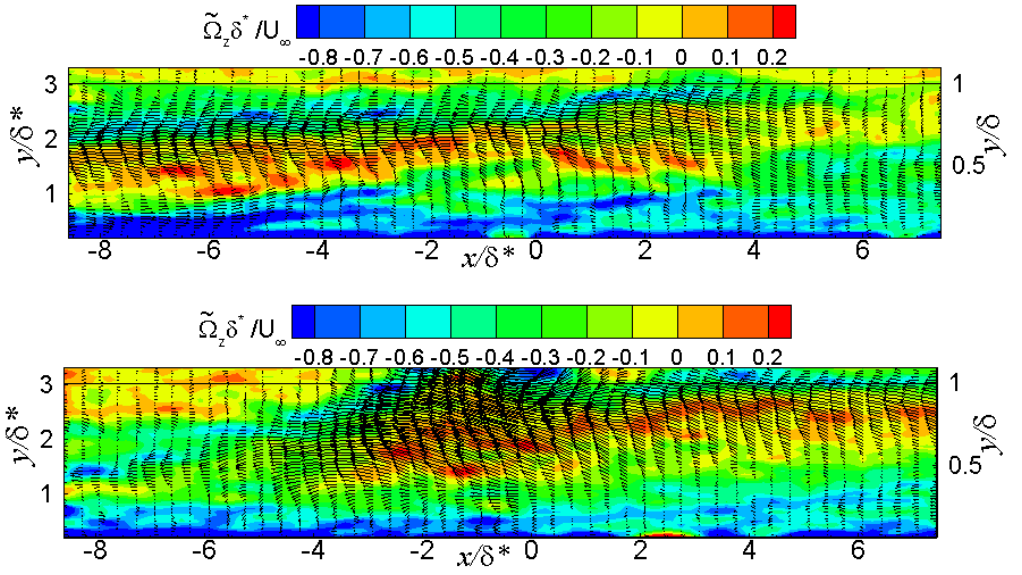

Figure S5: Instantaneous PIV frames in the x-y plane showing lifted-up backward streak in configuration B at $x_c = 738$ mm. The color contours represent normalized spanwise vorticity and the vectors represent fluctuating velocity (u,v).

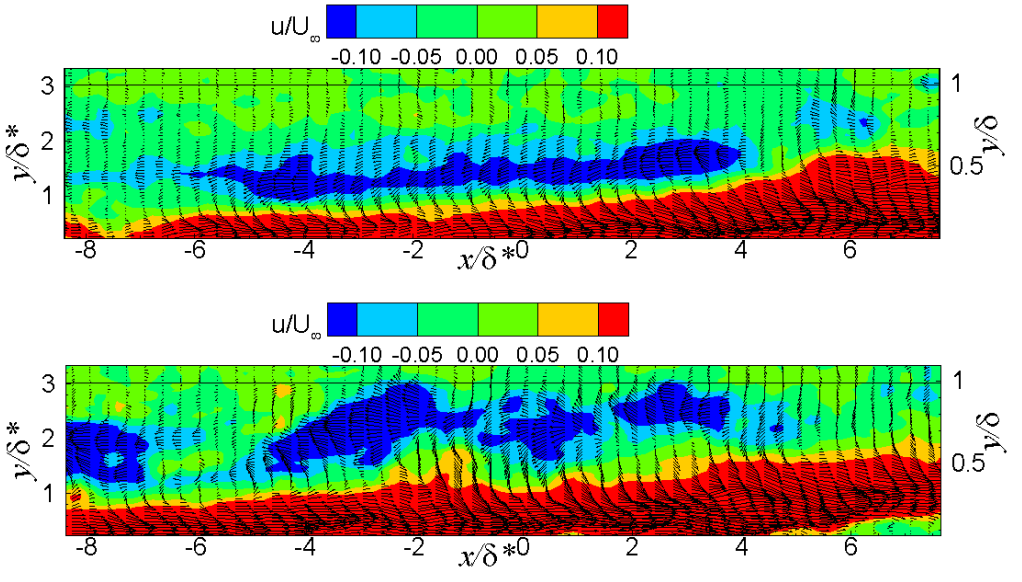

Figure S6: Instantaneous PIV frames in the x-y plane showing streak interaction in configuration B at $x_c = 738$ mm. The color contours show streamwise (u) fluctuating velocity and the vectors represent fluctuating velocity (u,v).