On the detection and characterisation of intermittent low-drag behaviour in turbulent boundary-layer flows

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Recent experimental[1][2] investigations of intrinsic low-drag states called "hibernating turbulence" revealed time intervals where the instantaneous streamwise velocity profiles approached the MDR asymptote in channel flow, even with Newtonian fluids. To date, investigations on hibernating turbulence have been limited to low-Reynolds number transitional channel flows. Here we present the detection and characterisation of this hibernating turbulence phenomenon in a turbulent boundary-layer flow.

Laser Doppler Velocity (LDV) and stereo particle image velocimetry (SPIV) were conducted in a water flume to capture the intrinsic low-drag states associated with hibernating turbulence. All experiments were conducted in Newtonian fluid flow. During the experiments the instantaneous wall-shear stress is measured with a hot-film probe whilst, simultaneously, the streamwise and wall-normal velocity is measured over several hours at various wall-normal locations with LDV to allow conditional sampling of the velocity data during states of low-drag. In a separate set of experiments, all three velocity components are captured with cross-stream SPIV to elucidate on the 3-dimensional flow structures during these intermittent low-drag states. Conditionally sampling the wall-shear stress data when the instantaneous signal drops 10% below the mean for a duration of $t^+ > 200$ reveals intervals of hibernating turbulence, see Fig. 1 (a). Conditionally sampling the U^+ data during the low-drag events causes the mean streamwise velocity profile to approach the MDR asymptote close to the wall, up to $y^+ < 50$, see Fig. 1 (b). For $y^+ > 50$, there appears to be a loss of communication with the wall at these low Reynolds numbers, with the streamwise velocity profile presenting a gradient similar to the classical log-law, but shifted upwards due to the scaling with the lower than average wall-shear stress.

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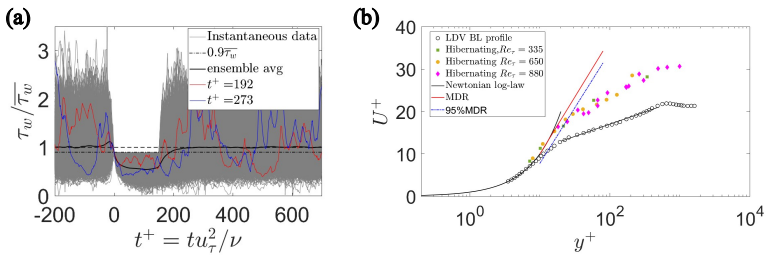

Figure 1: (a) Wall-shear stress during intervals of low dra,; (b) Black symbols: canonical turbulent boundary layer profile at $Re_\tau = 880$; color symbols: hibernating turbulence data.

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[1]Whalley, *Phys. Rev. Fluids* **2**, 034602,(2017).
[2]Whalley, *Experiments in Fluids* **60**, (2019).