TURBULENT WALL-BOUNDED FLOWS OVER RIGID- AND FLEXIBLE-ROUGH BEDS

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Introduction and background
Vegetation in both fresh and sea waters is not only ubiquitous in natural habitats but also instrumental for a variety of reasons. It provides the foundation for many food chains [4], contributes to the thriving of fish and corals [6], plays a role in reducing coastal erosion [1] and drastically improves the water quality by producing oxygen [3]. Furthermore, many engineering applications rely upon and would benefit from a better understanding of the flow physics characterising these problems. Despite the numerous reviews [2, 5, 6] that have attempted to capture different aspects of canopy flows over flexible vegetation, a satisfactory understanding of this topic is still elusive. For this reason, a simple controlled experiment aimed at comparing wall-bounded flows over rigid and flexible roughness was designed and carried out.

Experimental facility and details
Three different surfaces are considered in this work: a smooth wall and two rough-wall cases. The first rough surface is characterised by rigid roughness (i.e. conventional rough wall), while in the second case the flow develops over flexible roughness elements (i.e. aquatic vegetation). Experiments were designed to compare the statistical properties of flexible-rough beds as opposed to their rigid counterpart when the roughness height under wind loading, $h_{eff}$, is matched. The tests were carried out in the Donald Campbell wind tunnel at Imperial College London (freestream turbulence $T_u < 0.5\%U_{\infty}$). The tunnel working section measures $2.98 \text{ m}$ in length, with a $1.37 \text{ m} \times 1.12 \text{ m}$ cross section. The conditions were set to represent a nominally zero-pressure gradient at a freestream velocity of $12 \text{ m}\text{s}^{-1}$. Boundary layer velocity profiles (containing approximately 50 wall-normal nodes) were acquired at several different locations, as shown in figure 1(a), by traversing a miniature hot-wire sensor (Dantec 55P15). The sampling frequency of the Dantec Mini CTA is fixed at $20 \text{ kHz}$, while the low-pass filter is set to $10 \text{ kHz}$.

Preliminary results
Figure 1(b)&(c) compares the mean streamwise velocity profiles across cases. The data in figure 1(b) shows how the effect of the roughness (both rigid and flexible) is to induce a well-known downward shift of the log-law region of the velocity profiles. It is also shown in figure 1(c) that, despite the different bed morphologies, the two rough walls conform to outer-layer similarity when the data is presented in defect form. However, differences between the rough cases become apparent by looking at the skin friction generated by the two surfaces and by the means of frequency-domain analysis. The full paper will expand on both these aspects.

Figure 1. (a) Sketch of the experimental setup where the symbols ● indicate the measurement locations. Mean velocity profiles in (b) inner scales and (c) defect form. The dashed line in (b) indicates a smooth wall log-law with $\kappa = 0.41$ and $B=5$.

References