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Adjustment of roughness sublayer in turbulent flows over two-dimensional idealised roughness elements

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The atmospheric boundary layer (ABL) immediately above the urban canopy is the roughness sublayer (RSL). In this layer, flows and turbulence are strongly affected by the roughness elements beneath, e.g. building obstacles. The wind flows over urban areas could be represented by conventional logarithmic law of the wall (log-law) in the neutrally stratified ABL. However, in the RSL region, the vertical wind profile deviates from that predicted from log-law and the effect could be extended from ground level up to several canopy heights. As a result, the Monin-Obukhov similarity theory (MOST) fails and an additional length scale is required to describe the flows.

The key aim of this study is to introduce a simple wind profile model which accounts for the effect of the RSL in neutral stratification using wind tunnel experiments. Profile measurements of wind speeds and turbulence quantities over various two-dimensional (2D) idealised roughness elements are carried out in an open-circuit wind tunnel with test section of size 560 mm (width) $\times$ 560 mm (height) $\times$ 6 m (length). The separation between the roughness elements is varied systematically so that ten different types of surface forms are adopted. The velocity measurements are obtained by hot-wire anemometry using X-probe design (for *UW*- measurements) with a constant temperature anemometer. For each configuration, eight vertical profiles are collected over the canopy, including solid boundaries and cavities of the roughness elements.

Firstly, we compute the measurement results using conventional MOST to determine different roughness parameters. Afterwards, we derive the RSL height from the Reynolds stress profiles. Since the profiles taken from different locations of the canopy are eventually converged with increasing height, we use this “congregated height” to define the RSL height. Next, we introduce an alternative function, i.e. power-law function, instead of MOST, to describe the velocity profile in attempt to account for the RSL effect. Lastly, the RSL effect on turbulent behaviours over different roughness configurations is quantified.