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Canopy roughness coherence: The 'chimney' effect

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The three dimensional variability in canopy morphology often necessitates a planar averaging operation to the scale of interest. Because of the multiply-connected spaces within the canopy, such spatial averaging gives rise to covariance or dispersive terms produced from the spatial correlations of time-averaged quantities that remain 'unclosed' or require further parameterization. To date, parameterizations of these dispersive terms remain illusive, in part because of the limited experiments dedicated to quantifying them. As a first step towards their parameterization, it is necessary to estimate their magnitude, their sign, possible correlations with conventional Reynolds stresses, and any spatial coherency that may be exploited in phenomenological models. Flume experiments for various canopy densities were used to explore these aspects for a cylindric canopy where the rod density was varied but the single rod attributes were identical. Quadrant analysis was used to explore the spatial coherency of these dispersive stresses at various heights and for a wide range of canopy densities. When compared to the conventional momentum flux, we found that these dispersive stresses in the lowest layers of sparse canopies can be significant ($>$30%). For dense canopies, the dispersive stresses remain negligible when compared to the conventional momentum stresses throughout ($<$10%). An analysis on the constitutive components of the dispersive stresses revealed that the positions contributing most to the dispersive terms were localized in the immediate vicinity downstream of the rods (termed here as hotspots). In the deeper canopy layers, their contribution is negative, but in the upper layers, their contribution is positive. The genesis of the sign shift originates from the interplay between the behaviour of the pressure immediately behind the rods and the reduced continuity equation. The fact that remains positive downstream from the rods over a significant portion of the canopy depth (i.e. bottom 75%) has important im-

plications on a number of applications. For example, long-term measurements of net ecosystem CO2 exchange (NEE) are now routinely employed to estimate ecosystem carbon budgets using eddy covariance (EC) methods, yet the large error in the measurement of ecosystem respiration (RE) remains an unresolved problem that must be confronted. The ’chimney’ effect, or the vertical advective flow of CO2 immediately adjacent tree stems may provide some clues as to why EC methods might underestimate respiration. Whether such ’chimney’ effect persists in real canopies or not remains to be explored - as branches and foliage may intercept and disperse the rising.