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Micro- and macro-dispersive fluxes in canopy flows

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Abstract

Resolving every detail of the three-dimensional canopy morphology and its underlying topography remains untenable when modeling high Reynolds number geophysical flows. How to represent the effects of such a complex morphological variability and any concomittant topographic variability into one-dimensional bulk flow representation remains a fundamental challenge to be confronted in canopy turbulence research.

Theoretically, planar averaging to the scale of interest should be applied to the time-averaged mean momentum balance; however, such averaging gives rise to covariance or dispersive terms produced by spatial correlations of time-averaged quantities that remain ‘unclosed’ or require parameterization. When the averaging scale is commensurate with few canopy heights, these covariances can be labeled as ‘micro-dispersive’ stresses. When averaging is intended to eliminate low-wavenumber topographic variations, we refer to these covariances as ‘macro-dispersive’ terms. Two flume experiments were used to explore the magnitude and sign of both micro- and macro-dispersive fluxes relative to their conventional Reynolds stresses counterparts: a rod-canopy with variable roughness density and a dense rod canopy situated on gentle hilly terrain. When compared to the conventional momentum flux, the micro-dispersive fluxes in the lowest layers of sparse canopies can be significant (~50%). For dense canopies, the dispersive terms remain negligible when compared to the conventional momentum fluxes throughout.

For the macro-dispersive fluxes, model calculations suggest that these terms can be neglected relative to the Reynolds stresses for a deep canopy situated on a narrow hill. For the region in which topographic variations can interact with the pressure, both model calculations and flume experiments suggest that the macro-dispersive fluxes cannot be neglected, and their value can be 20% of the typical Reynolds stresses.

Key words: canopy turbulence, dispersive fluxes, double averaging, flow on hills, micro-dispersion, macro-dispersion, planar averaging.