

Effect of the vegetation density on the turbulence properties in a canopy flow

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Keywords: laser Doppler velocimetry, canopy flow, mixing layer analogy, canopy structure

1. Introduction

The flow through a natural canopy and near its surface is relatively well documented for dense and homogenous canopies, such as forests or crop fields. In particular, low-order velocity moments, spectra, or spatial lengths are similar to those of a mixing layer [1]. However, when the canopy becomes sparser (typically an orchard) or less homogeneous, this analogy can not be applied anymore. The flow behavior is then close to a perturbed turbulent boundary layer. Although a large litterature deals with the former canopy flows, the latter are not so well understood. Particularly, the transition from the mixing layer analogous flow to the turbulent boundary layer (and vice-versa) is not well-defined. It likely depends on the density and the porosity of the canopy.

2. Experimental device

An experimental study was developed to characterize this transition. An artificial tree canopy is disposed on the floor of a wind tunnel test section. The canopy spatial organization can be varied using different spacings Δ between the trees. Only one arrangement, aligned tree array, is studied. Canopy elements are conifer-like trees. Because of the variable spacing, the canopy roughness λ is variable too. A first series of velocity measurements performed in the hydraulic flume HERODE restricted the study to spacings larger than one canopy height h [2]. Indeed, for smaller spacings, the flow behavior trends were similar to those for dense canopy flows. The roughness density is approximated from the tree conical form and is equal to 0.2, 0.09 and 0.05 respectively for spacing $\Delta = h, 1.5h$ and $2h$. Because of very high turbulence intensity and fluid recirculation in canopy flows, particularly in the interaction regions of the tree wakes, the laser Doppler anemometry is very well-suited to measure velocity in canopy flows. Consequently, velocity measurements are achieved with one- and two-component laser Doppler anemometry at a distance of $25h$ from the canopy upside edge, for various locations within the canopy. Two laser heads are used. One, equipped with a beam expander and a relatively small focal lens, provides a very small measurement volume and thus good resolution measurements but prevents from access in the deep canopy. The other, without beam expansion and a larger focal lens, allows two-component measurements inside the vegetation to the detriment of the resolution. In spite of this disadvantage, comparisons of the different velocity profiles (mean, root-mean square) justify the use of the second system.

3. Results and discussion

Longitudinal velocity u statistical moments up to the third order and the cross-moment between u and the vertical component w are calculated. The different vertical profiles are plotted for the three spacings and compared to literature results obtained in natural and artificial canopies. Some features are deduced from the measurements such as the shear length scale and the mixing length.

A typical inflectional point of the mean velocity profile at the height $z = h$ is the first characteristic of the mixing layer analogy. This point appears more or less clearly, depending on the measurement position in the canopy, directly in a tree wake interaction region or not, and on the tree spacing.

The skewness, defined as the third order moment divided by the cubic root-mean square velocity is the most sensitive turbulent parameter for the validation of the mixing layer analogy. Indeed, canopy flows are characterized by a positive skewness factor whereas it is negative, except close to the wall, for a zero-pressure gradient turbulent boundary layer. Positive values are characteristic of brief and strong incursions of high-velocity air when associated to a negative vertical velocity skewness as analysed by Raupach et al. [1]. The skewness is negative for the two widest spacings and tends towards zero when the spacing decreases, becoming finally slightly positive for the densest canopy. This trend confirms the limiting case the spacing $\Delta/h = 1$ is for the mixing layer analogy validity.

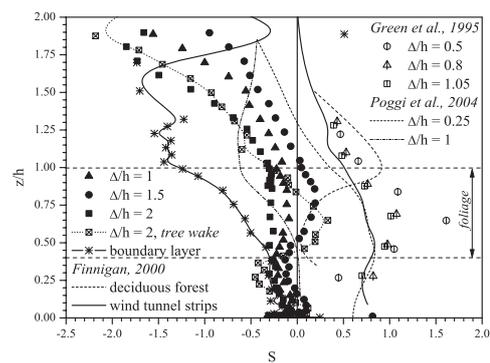


Fig.1 Longitudinal velocity skewness profiles for three spacings Δ/h , comparison with literature data

4. References

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