J2.4 FLOW SIMULATION OF TURBULENT AND MEAN ADVECTIVE VELOCITY AND SCALAR FIELDS ACROSS A CANOPY EDGE

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1. Introduction

Although the quantification of the advection inside canopies is difficult to achieve from field experiments (Aubinet et al., 2003), numerical experiments for scalar fields across a canopy edge can be useful in studying scalar advection. Understanding of air flow across a leading edge is important to simulate transport or diffusion of passive scalar within and above a plant canopy. The wind field within a plant canopy is directly influenced by the plant density and structure from which the aerodynamic drag is determined.

2. Methods

A 2-dimensional 3rd-order turbulence closure model has been used to investigate air flow and scalar fields in a neutral condition across a canopy edge. The model is based on the one-dimensional model of Meyers and Paw U (1986, 1987). An explicit finite-difference method was used to solve 13 and 6 governing equations for air flow and scalar, respectively, in a steady state with the prescribed initial and boundary conditions. The 2-dimensional domain has 501x71 grid points with a grid size of 1 meter. Three different plant densities of canopy (Leaf Area Index=0.2, 0.8, and 3) are tested to investigate density effects on the turbulence. The canopy structure has a triangular shape with a maximum at z=0.6*h*.

3. Results

Flow disturbance caused by the edge is complex in the transition region. The streamwise extent of the transition region is dependent on atmospheric conditions and canopy structure, and varies for different turbulence statistics. Edge effects on turbulence are manifested by rapid variations of wind velocities, pressure, Reynolds stress, and standard deviations of velocity components.

As the air flow approaches the canopy's leading edge, the streamwise wind velocity decreases and the pressure and vertical velocity increases. Above the edge, vertical flow is greatest and its vertical convergence is closely related to the speed up of stream wise flow (Fig. 1). The convergence of streamwise flow below half the canopy height at the edge creates downward motion and a sub-canopy jet in the trunk space immediately downwind of the edge. Tangential stress, standard deviation, and 3rd-order moments begin to change from the edge, but wind velocity and pressure significantly change far upwind, throughout the entire domain, vertically. Above the edge, the mean wind flow and pressure respond to the roughness change very quickly whereas the turbulence mimics that upwind of the edge, over an open field.

Downwind of the edge inside the canopy, the streamwise velocity drops greatly due to the drag of the plant elements. Large gradients of pressure and streamwise velocity are responsible for the enhancement of standard deviation (or TKE) and reduction of Reynolds stress (Fig. 2) in the transition region before they adjust, to approach the equilibrium state farther downwind. Above the canopy, the flow adjusts to the increased surface drag resulting in a decrease of wind velocity and an increase of turbulence magnitude.

The low density canopy requires a longer fetch because the wind speed is stronger than that of higher density canopy. Increased plant density intensifies the edge effect on air flow and turbulence that are generally responsible for the exchange of scalars between ecosystems and atmosphere above.

The variations of scalar concentration and streamwise/vertical eddy fluxes across a canopy edge are greatly dependent on wind speed and momentum flux (or Reynolds stress). The canopy in the atmospheric conditions of low wind speed and weak stress, which appears in a highly dense canopy, has high scalar concentrations in the lee of the edge. The vertical eddy flux within the canopy is proportional to stress and inversely proportional to wind speed. Along the downwind distance the wind speed effects decrease, but the shear stress keeps influencing on the scalar flux. However, far downwind where the turbulent field is close to the equilibrium state, vertical flux is independent on the stress inside the canopy. There are negative vertical fluxes or downward fluxes in the trunk space just downwind of the edge where most of the emitted scalar is advected downwind by sub-canopy jet flow (Fig. 3). The canopy with a low wind

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speed and strong stress requires shorter fetch to reach to equilibrium state for scalar.

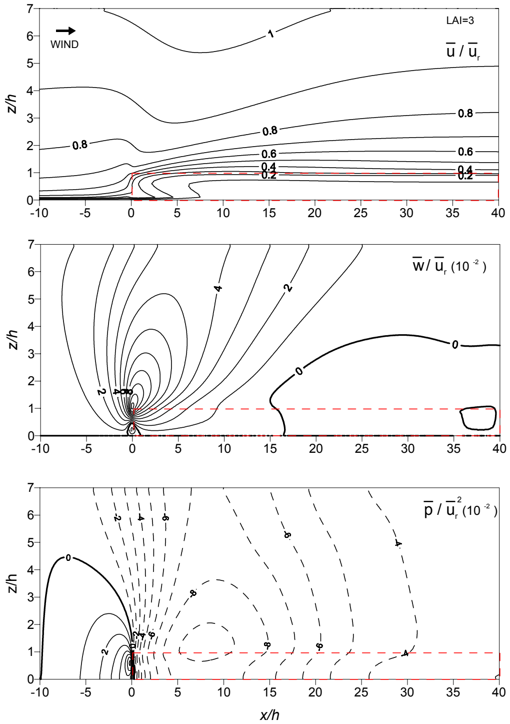

Figure 1. Contours for mean wind velocities in streamwise (top) and vertical (middle) directions, and for pressure (bottom) for canopies of LAI=3 normalized by wind speed at the top upwind boundary ($\bar{u}_r$ = 4 ms^{-1}). Wind blows from left to right. Canopy height *h* is 10 m. A dotted line encloses the canopy.

The internal boundary layer heights for scalar fluxes are lower than the IBL heights for Reynolds stress and TKE.

Most of source is removed from the canopy by horizontal advection in the vicinity of the edge but by vertical eddy flux farther downwind. Vertical advection and divergence of streamwise eddy flux are negative overall but the magnitude is much smaller than horizontal advection. Near the edge the horizontal advection is greater than the source strength because divergence of the horizontal flux and vertical advection supply the scalar inside the canopy. The edge effect is reflected by the sharp change of advective and eddy fluxes near the edge. A denser canopy enhances the edge effects generally.

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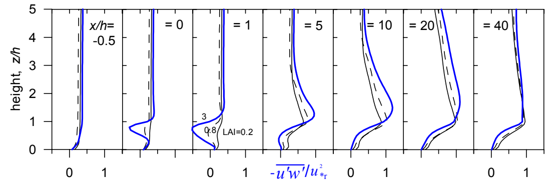

Figure 2. Profiles of Reynolds stress for LAI=0.2 (solid lines), 0.8 (dot lines), and 3 (thick lines) at 7 selected locations normalized by friction velocity which resulted from one-dimensional model in homogeneous canopy environment for the corresponding leaf area index.

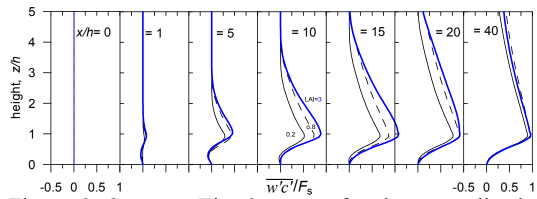

Figure 3. Same as Fig. 2 except for the normalized vertical scalar flux where F_s is the integrated source strength.

References

Aubinet, M., B. Heinesch, and M. Yernaux, 2003: Horizontal and vertical CO_2 advection in a sloping forest. *Bound.-Layer Meteor*., 108, 397-417.

Meyers, T. P., and K. T. Paw U, 1986: Testing of a higher-order closure model for airflow within and above plant canopies. *Agric. For. Meteorol.*, 37, 297-311.

Meyers, T. P., and K. T. Paw U, 1987: Modeling the plant canopy micrometeorology with higher-order closure principles. *Agric. For. Meteorol.*, 41, 143-163.