9.1 CHARACTERISTICS OF TURBULENT EXCHANGE IN AND ABOVE AN OLD-GROWTH FOREST

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1. INTRODUCTION

Turbulence in and above plant canopies has been traditionally considered a strong function of canopy type, density, height and stability. Turbulence data were taken at the tallest and oldest forest canopy in the AmeriFlux network.

The Wind River site, located within the T.T. Munger Research Natural Area in the Gifford Pinchot National Forest (which extends northwards beyond Mt. St. Helens) has an 85m tall Liebherr 550HC tower construction crane, allowing researchers to access the entire vertical canopy of the forest. The forest is dominated by Douglas fir and western hemlock (tallest tree height of approximately 67 m).

Measurements (at 10 Hz) of the turbulent velocities, and associated measurements of the high-frequency components of the air temperature, CO_2, H_2O, were obtained from instruments mounted at 70 m on the crane tower, and 3 m near the tower. Two Solent Gill HS 3-axis ultrasonic anemometers were used.. LiCor 6262 Infrared Gas Analyzers (IRGA's) were used to measure H_2O and CO_2 concentrations at 10 Hz, allowing gas exchange (eddy-covariance) estimates at 3 m and 70 m. In addition a LiCor 7500 and a NOAA Meyers-Auble open path Infrared Gas Analyzers were used.

Measurements of mean variables are made at 2, 10, 20, 40, 60, and 70 m on the crane tower. These stations measure temperature, relative humidity, wind speed and direction (from 2 D Handar (now Vaisala) sonic anemometers, and incoming PAR (photosynthetically active radiation). At the 2 m station there are additional measurements of incoming short wave and net radiation, rain precipitation, air temperature at 1, 0.5, and 0 m, soil temperature profile down to 20 cm, soil moisture, and soil heat flux. Additionally, incoming and outgoing components of short wave and long wave radiation are measured at 85 m on top of the crane mast.

Profiles of traditional turbulent statistics are discussed. Turbulent spectra and the cospectra are presented. Although not presented here in the extended abstract, we hope to present at the meeting other analyses, including identification of coherent structures and gravity waves temperature, carbon dioxide concentrations, and humidity. The scaling of these structures with mean wind shear will be compared to results from other plant canopies. Canopy penetration of the structures as a function of stability will also be compared to data from other plant canopies.

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2. RESULTS

Statistics above and below the canopy were markedly different in magnitude, and timing. Below are figures taken from data gathered on August 27, 1999. The data represent correlations, which are essential components of the covariance-fluxes. From physical reasoning, near the source/sink and within source/sink volumes, eddy fluxes should be composed of high correlations, irrespective of the variance magnitudes.

At 70 m, the correlation coefficient is high during the day and evening, indicating a strong sink of momentum of the canopy crow under higher wind speed, but during the night the correlation coefficient drops markedly (Fig. 1) . The 3 m data show higher magnitudes at night, when a nocturnal pattern appears to increase the near-surface flow, but the maximum magnitude is considerably less than that of 70 m.

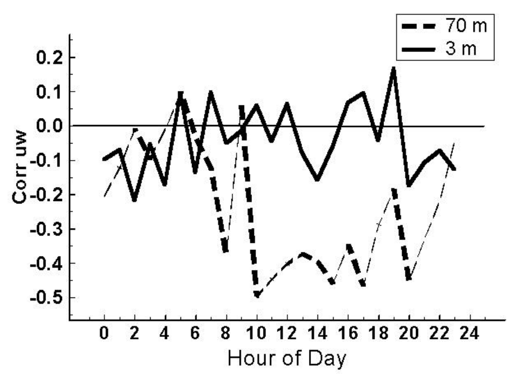

Figure 1. Correlation coefficients of the Reynolds stress as a function of time of day, above the canopy and close to the soil surface.

A disparity in the diurnal pattern can also be found in the other correlation coefficients. The 3 m sensible heat flux correlation coefficient (Fig. 2) is high at night and positive (indicating a source of heat from the soil) and negative during the day (a sink of heat to the soil). The 70 m correlation coefficient is a mirror image, being negative at night (radiative cooling) and positive during the day (radiative heating, and insufficient latent energy cooling). Both heights have maximum magnitudes between 0.5 and 0.6.

The evaporative flux correlation coefficient shows a higher maximum magnitude for 70 m (0.4-0.5) than for 3 m (0.3-0.4), indicating the stronger source of the canopy coupled with organized flow in this region (Fig. 3). Analogous to that for sensible heat, this coefficient is high at 70 m in the day, and low at night, while it is low at 3 m in the day and high at night.

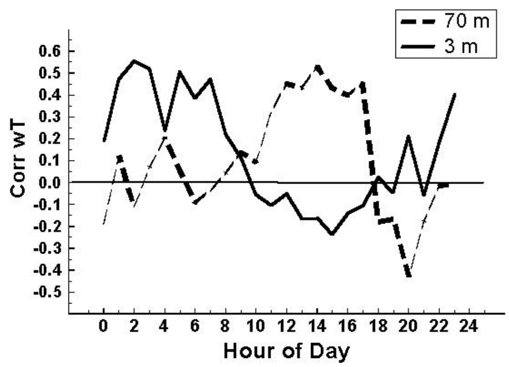

Figure 2. Correlation coefficients of the sensible heat as a function of time of day, above the canopy and close to the soil surface.

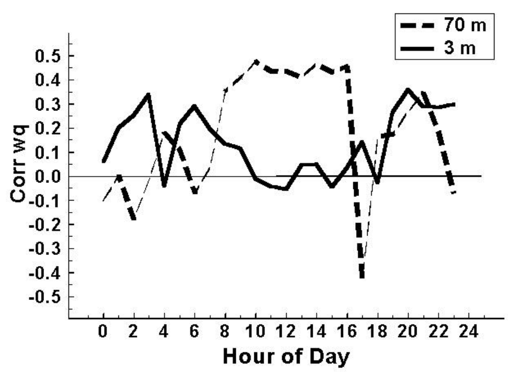

Figure 3. Correlation coefficients of the water vapor flux as a function of time of day, above the canopy and close to the soil surface.

Ramp patterns in scalars were apparent, and had longer periods (70 s) than those reported in Paw U et al. (1992). However, because of the maximum plant area index was much lower than the canopy height (estimates range from 20-30 m), the mean shear scaling from this canopy cannot be calculated using the canopy height. If the canopy height is used, for example, the mean shear is 0.04 s^{-1}, and with a the theoretical Strouhal number of 0.1 (Paw U et al., 1992), would correspond to a period of 240 s. However, if a height of 20 m is used, then the mean shear is 0.135 s^{-1} and the period would be predicted to be 74 s.

3. SUMMARY AND DISCUSSION

Turbulent statistics for flows over this tall, old-growth forest show marked difference above and below the canopy. The correlation coefficients tend to be stronger above the canopy, indicated more organized flow, and the peak values occur at different times of the day than below the canopy. Coherent structure ramp patterns cannot be scaled with mean shear determined by the canopy height, because much of the plant area is located at less than half the canopy height.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

Paw U, K.T., Y. Brunet, S. Collineau, R.H. Shaw, T. Maitani, J. Qiu and L. Hipps, 1992. On coherent structures in turbulence within and above agricultural plant canopies. *Agric. For. Meteorol.* 61:55-68.