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Observation of Turbulent Diffusion within a Forest Canopy

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1.Introduction

A lot of concerns are poured into the clarification of the turbulent diffusion of various materials in the atmosphere, the ocean , the river and the bottom of a lake as environmental problems in recent years. The flow in the inside and outside of the vegetation layer has also attracted attention. The disturbance of the flow in the inside and outside of the forest is an important factor that controls the dispersion of the pollen and the concentration distribution of transpiration and CO2 in the forest. Therefore, the flow within a forest canopy exerts a full influence on diffusion of the pollutant and the forest ecosystem. However, the report concerning the flow in a forest is few though the measurements in corn and the wheat field were reported. Then we measured the velocity of the wind and fluctuations with a ultrasonic anemometer in the forest that has comparatively complex geographical features, and the turbulent flow structure and the eddy diffusion coefficient in the forest were examined in this research.

2. Measuring device and method

The data was taken in the hill surrounding the Kanazawa University campus. The observation tower of 20m in height is set up at above sea level of 138m , and the ultrasonic anemometers were operated there. Vegetations around the observation tower are Quercus variabilis Blume and Quercus serrata Murray belonging to the deciduous tree, and leaves are completely lost in winter. Fig.1 shows the experimental apparatus in the forest. The ultrasonic anemometer can be measured three elements(u,v,w) , the velocity of the wind resolution is 0.01m/s, and the sampling rate 50Hz. (KAIJO company , SAT550). Two ultrasonic anemometers were operated at above-ground heights of 17.7,16,14.2,12.6,10.7,9.1,7.2,5.7,4.0,2.0m. The eddy diffusion coefficient K is computed from Eq.(1). Eq.(2) shows the mixing length.

$$K = \sigma_w l(z) \approx U_* l(z) \quad (1) \qquad\qquad l(z) = U_* /(du/dz) \quad (2)$$

where K is the eddy diffusion coefficient, $l(z)$ the mixing length ,σ_w the standard deviation of vertical wind fluctuations, and U_* the friction velocity. To measure the temperature distribution , ten T type thermo-couples (CHINO company , JT6)were also operated there.

3.Result and consideration

Fig.2 shows the distribution of the eddy diffusion coefficient at different heights. For the eddy diffusion coefficient, a big change is seen for different seasons. Though the value of eddy diffusion coefficient in summer is 1m^2/s,but in winter where the leaves completely have fallen it is 2~2.5m^2/s, in a word, it is thought that the existence of the leaves is greatly related to determine the value. The leaves have grown in abundance from spring to summer, the results infer that tree leaves reduce eddy scales by behaving as elastic obstacles. In winter ,on the other hand, it seems that turbulence in an atmosphere invades in the forest because there is nothing that attenuates the turbulence of the atmosphere, bigger eddy diffusion coefficients were observed consequently. Moreover, the wind velocity dependency of eddy diffusion coefficient is shown in Fig.3. When the density of the leaves is high, even if the wind velocity increases, the change is not so obvious in the value of the eddy diffusion coefficient. As time series data, when you see the fluctuating pattern of u',w' and T' at z=16m

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on September 6 (2005), a similar feature appears repeatedly every about 100 seconds, and an example of complete period is shown in Fig.4. In quadrant analysis, $u'w'$ is divided into four categories, with quadrant 2 ($u'<0,w'>0$) identified as ejection , quadrant 4 ($u'>0,w'<0$) identified as sweep. The temperature rose when ejection was seen, and sweep was generated when the temperature decrease was seen. Moreover, the time series of u' and w' at height of z=20m and 16m are shown in Fig.5 and Fig.6. The delay of about five seconds is seen, and the lower position at 16m always dictates the change earlier. As a results, it is guessed that eddy inclines at the upstream side. For the size of the eddy, the vertical cross-section of temperature fluctuation and velocity fluctuation on November 28 (2005) is shown in Fig.7. Positive temperature deviations are represented by solid lines, and negative deviations by dashed lines. It falls in temperature from 340 to 400s on the vicinity of z=14m by sweep. The results infer that cooler air parcel sweeping downward through the warmer canopy. Horizontal peak scale λ_m is computed from Eq.(3) at this time, it resulted in λ_m=17m. When the temperature change is compared with the scale of the eddy, it is understood that the center of the eddy is the vicinity of the vegetation boundary. It is thought that the velocity of the wind distribution in the vicinity of the vegetation boundary becomes unstable, and the eddy occurs.

$$\lambda_m = U/(n_m)_w \quad (3)$$

where λ_m is a horizontal peak scale, U the horizontal mean wind, and n_m the frequency at maximum of power spectrum.

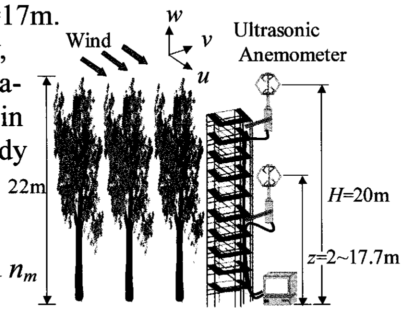

Fig.1 Experimental apparatus in the forest

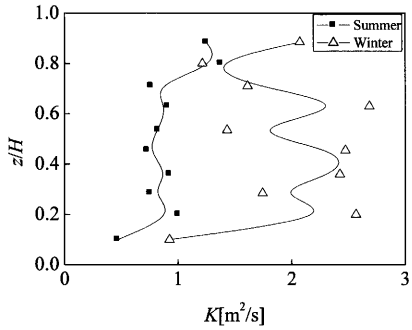

Fig.2 Eddy diffusion coefficient at different heights

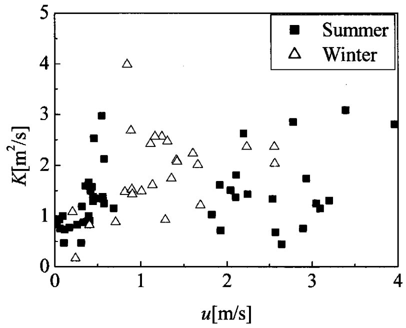

Fig.3 Wind velocity dependency of eddy diffusion coefficient

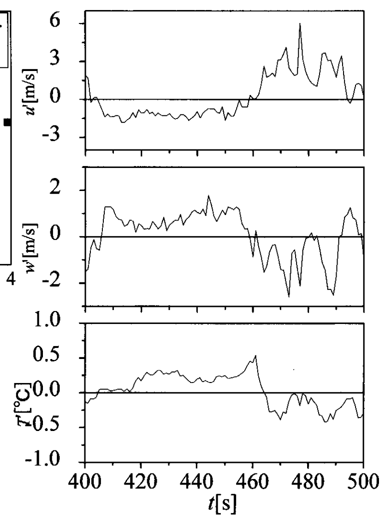

Fig.4 Time series of u', w', and T' at z=16m (September 6,2005)

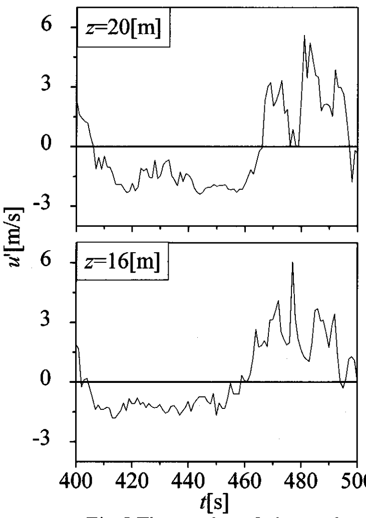

Fig.5 Time series of u' at each of two heights

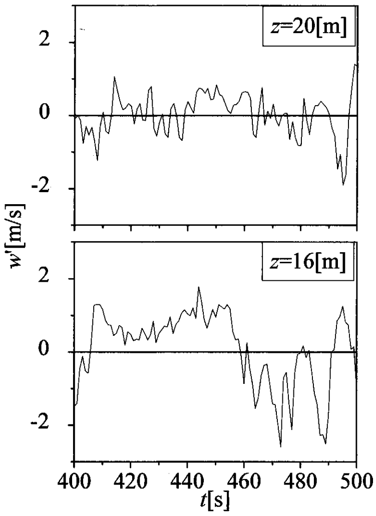

Fig.6 Time series of w' at each of two heights

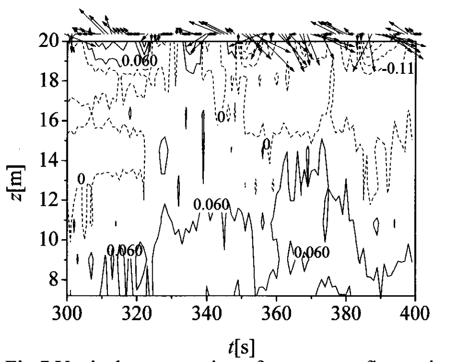

Fig.7 Vertical cross-section of temperatur fluctuation and velocity fluctuation.The maximum arrow length represents a wind magnitude of 2.3m/s