P6.8

TURBULENT TRANSFER EFFICIENCY OF MOMENTUM, HEAT, VAPOR, AND CO_2 MEASURED IN THE URBAN SURFACE LAYER OVER A DENSELY BUILT-UP CANOPY

Ryo Moriwaki *, Manabu Kanda and Tomoki Watanabe
Tokyo Institute of Technology, Tokyo, Japan

1. INTRODUCTION

There still exists some uncertainty as to whether Monin-Obukov similarity (hereafter M.O.S.) can be applied to the urban surface layer. In this study, a long-term field measurement is performed to investigate turbulent transfer in a densely built-up urban surface layer. The turbulent transfer efficiencies of momentum, heat, vapor, and CO_2 are examined.

2. FIELD OBSERVATION DESIGN

The “*Kugahara experiment*” has been performed continuously since May 2001 to the present. A tower was installed in a uniform low-storied residential area in *Kugahara*, Tokyo, JAPAN (35°34’N,139°41’E),see Photo 1. Plane aspect ratio is 0.48 and the green cover is less than 20%. The average building height is 7.3 m. Turbulence data, i.e. the fluctuations of 3D wind velocities, temperature, vapor, and CO_2 concentration, are sampled with 8 Hz at the heights z=21; 29 m (i.e. 3 and 4 times of building height). Vertical fluxes are estimated using the eddy correlation method. The averaging time of turbulence statistics is 1 hour.

3. DATA SELECTION

In order to ensure high data quality, the following criteria were applied. (1) The data are removed when the absolute values of flux are lower than threshold values as shown in Table 1. (2) The data in cloudy and rainy day are rejected. For example in July, the criteria for solar radiation is 24.5 MJday^{-1}m^{-2}. (3) The data from 11:00 to 13:00 are only used, because it is supposed that M.O.S. theory is valid when steady condition.

M.O.S. can be applied in the surface layer. Before discussing the turbulent transfer, the assessment for the formation of surface layer over urban canopy is conducted by calculating flux divergence. In surface layer the vertical fluxes should be constant if we ignore the storage term. Figure 1(a)-(d) show the ratios of fluxes measured at two heights and the atmospheric stability (*z’/L*). The effects of storage term are included to lower flux. The ratios are almost unity. Judging from these results we can expect the existence of surface layer in this residential area.

* Corresponding author address: Ryo Moriwaki, Tokyo Institute of Technology, Dept. of Civil Engineering, 2-12-1 O-okayama,
Meguro-ku, Tokyo 152-8552 JAPAN
e-mail: ryo@fluid.cv.titech.ac.jp

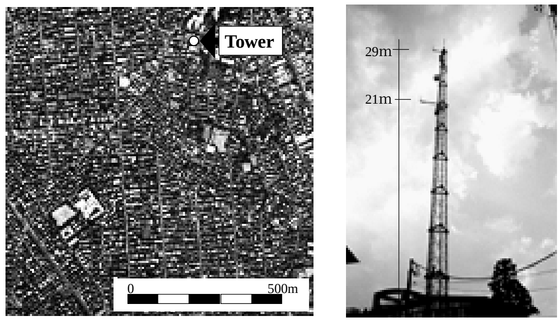

Photo 1 Aerial photo of Kugahara (left) and the tower for measurement (right).

Table 1 Lower limit flux values.

	Lower limit value
|momentum flux|	0.05 kgm^{-2}s^{-2}
|sensible heat flux|	30 Wm^{-2}
|latent heat flux|	50 Wm^{-2}
|CO_2 flux|	0.2 mgm^{-2}s^{-2}

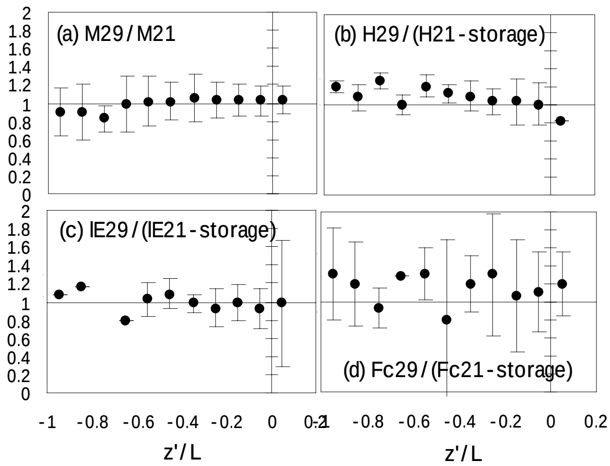

Figure 1 Ratios of fluxes measured at two heights vs. the atmospheric stability. (a)momentum, (b)heat, (c)vapor, (d) CO_2

4. TURBULENT TRANSFER EFFICIENCY

Turbulent transfer efficiency for momentum, heat, vapor, and CO_2 are investigated through analysis of the turbulent linear correlation. The ratio of transfer efficiency for heat and momentum is expressed by:

$$r_{wT} / r_{uw} = \frac{|\overline{w'T'}| / \sigma_w \sigma_T}{|\overline{u'w'}| / \sigma_u \sigma_w} \quad (1)$$

and the ratio of transfer efficiency for vapor and that for CO_2 and heat are:

$$r_{wq} / r_{wT} = \frac{|\overline{w'q'}| / \sigma_w \sigma_q}{|\overline{w'T'}| / \sigma_w \sigma_T} \quad (2)$$

$$r_{wc} / r_{wT} = \frac{|\overline{w'c'}| / \sigma_w \sigma_c}{|\overline{w'T'}| / \sigma_w \sigma_T} \quad (3)$$

where *u*, *w*: longitudinal and vertical wind velocity respectively, *T*: air temperature, *q*: specific humidity, *c*: CO_2 concentration. The prime denotes the instantaneous deviation from the time-mean value indicated by the overbar. In the following analysis, only the data measured at 29m are used.

4.1 *Correlation coefficients and z'/L*

Plots of the ratios r_{wT}/r_{uw}, r_{wq}/r_{wT}, and r_{wc}/r_{wT} versus *z'/L* are shown in Figure 2. The ratio for heat/momentum has a good agreement with full line proposed by Kanda et al.(2000) based on the measurement over an urban canopy. But it is smaller than broken line proposed by De Bruin and Wyngaard based on the Kansas experiment. This behavior is expected over an urban surface where form drag due to bluff-body effects of buildings increases the transfer efficiency of momentum compared to scalar transfers (Roth and Oke, 1995). The ratios for vapor/heat and CO_2/heat are shown in Figure 2(b)(c) respectively. M.O.S. theory predicts that relative transfer efficiencies are unity and have no dependency on stability. But plots show that the transfer efficiencies of vapor and CO_2 are smaller than heat. This tendency is more significant in unstable condition.

4.2 Wavelet analysis for correlation coefficient

In order to discuss this result, wavelet analysis for transfer efficiency of scalars is conducted from 13:00 to 14:00 on July 11 as an example. The analyzing wavelet is Mexican hat wavelet, a second derivative of a Gaussian. The wavelet coefficients (contours) are shown in Figure 3. Dark colors represent positive, light colors negative. The real and dotted circles in bold line correspond to the thermal structure and organized structure. These structures transfer heat efficiently. Vapor and CO_2 are also transferred as well as heat by some structures. But they are not or adversely transferred by other structures. Followings are considered as this reason. (1) Heat is active scalar and produces the thermal structures by itself. Hence, the heat is transferred most efficiently. Vapor and CO_2 are transferred passively and the efficiency is less than heat. (2) The absorption/source of vapor and CO_2 is inhomogeneous. As a result, the heterogeneity of vapor and CO_2 concentration distribution causes their transfer efficiency lower (Roth and Oke, 1995).

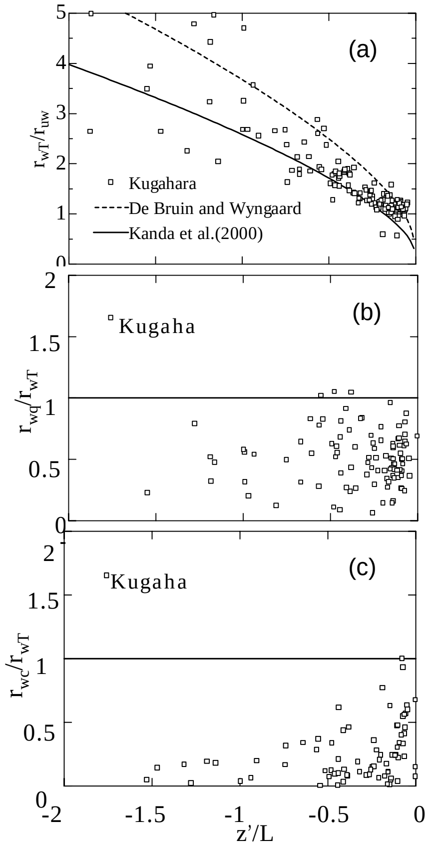

Figure 2 Correlation coefficient ratio and *z'/L*

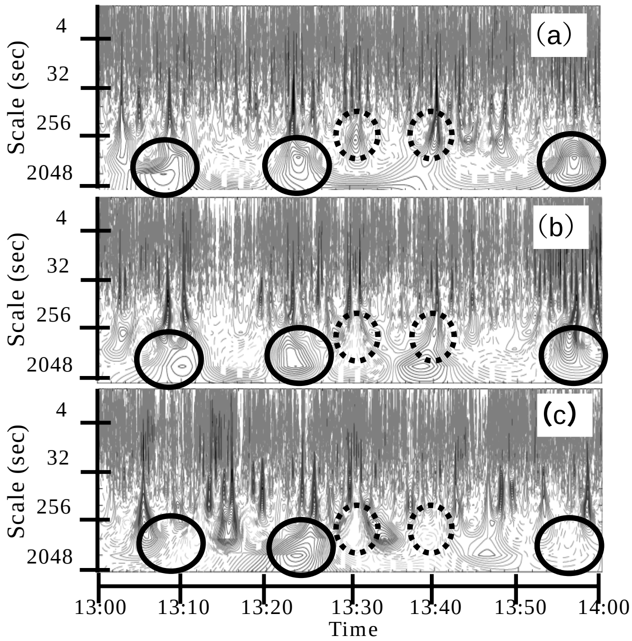

Figure 3 Wavelet analysis of correlation coefficent (a)heat, $w'T'/\sigma_w\sigma_T$, (b)vapor, $w'q'/\sigma_w\sigma_q$, (c)CO_2, $w'c'/\sigma_w\sigma_c$

REFERENCES

Roth,M. and T.R.Oke,1995:Relative efficiencies of turbulent transfer of heat, mass, and momentum over a patchy urban surface,J.Atmos.Sci.,52,1863-1874.

Kanda,M.,R.Moriwaki, J.Suzuki, M.Roth,and T.R.Oke, 2000:Study on similarity functions of turbulent statistics in urban boundary layers, Tenki, 47, 493-501.