The turbulence characteristics of the atmospheric surface layer on a rice paddy and an urban flux tower

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Abstract

In this study, we measured urban surface radiation at a rice paddy (120°41'E, 24°01'N, Fig 1), at different land type sites and turbulent heat fluxes on a tower standing on the roof of a 7-floor building (24°12' N, 120°67' E, Fig 2) by using Eddy covariance system (ECS) in Taichung, Taiwan. The results show that the aerodynamic roughness estimated from EC data is determined to be 0.02-0.03 m and the Bowen Ratio was about 0.16 during the daytime on a rice paddy. The urban experimental results show that the average urban albedo is determined to be 0.2 estimated within the radius of 1.4 km from the tower site. Furthermore, corrections, including coordinate system rotation, Webb, urban albedo, advected term, and long-wave radiational cooling term correction, are incorporated. As a result, the energy closure gap between turbulent heat flux and available surface heat flux on the urban tower is reduced to 4%-5% after using 2-D and 3-D coordinate rotation correction, and the gap is around 6% on a rice paddy.

While measuring the turbulent heat fluxes at different height, it is found that the turbulent heat flux (the sum of the latent heat flux and sensible heat flux) at 33 m agl (above ground level) was 21% lower than the available surface heat flux. In contrast, at 50 m agl the turbulent heat flux was only 4% lower than the available flux. The main reason to this difference is due to that observation at 50 m agl was within the atmospheric surface layer, while the observation at 33 m agl was not.

Introduction

In the past, these characteristics have been difficult to measure. They are usually derived from the measurements of wind speed, temperature and humidity at many levels within the atmospheric surface layer (ASL) (e.g., Brutsaert and Kustas 1987; Sugita and Brutsaert 1990; Brutsaert and Parlange 1992; Parlange and Brutsaert 1993; Sugita et al. 1997). Recently, due to the advance of the EC technique, they can now be measured continuously at a single level, at a much lower price. The use of EC flux towers to monitor these fluxes and trace gases between the land surface and the atmosphere has proliferated, such as Euroflux (Valentini et al., 2000), AmeriFlux (Baldocchi et al., 2001), through global networks such as Fluxnet (Baldocchi et al.,2001).

According to a formulation for the first law of thermodynamics, the energy flux should obey the energy balance principle; however, it is found that the surface energy budget is not balanced at many flux tower sites (Aubinet et al., 2000; Baldocchi et al., 2001; Wilson et al., 2002a; 2002b). In this study, we measured the urban surface radiation different land type sites and used the ECS to understand the turbulent heat flux in the different land types and tried to find out the possible methods to correct the energy closure gaps.

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a) b)

Figure 1. a) Photograph taken facing north, from 80 m south of the study site (star) in Wufeng, Taichung County, Taiwan on 1 May 2005; b) Satellite image of the studied area, where the star denotes the instrument site. The radius of the outer circle is 1000 m and that of the inner circle is 150 m.

a) b) c)

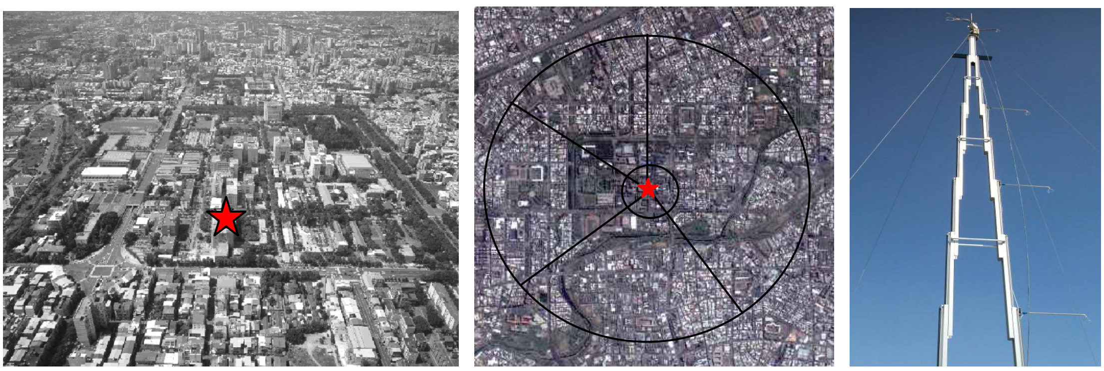

Figure 2. a) the oblique photographs taken from the east of the study site to the west; b) the satellite image of the study site (star), the radius of yellow circle is 1.4 km; c) the flux tower image after raising and the height of the top is 50 m agl.

Table 1. Energy balance ratio (EBR) and the regression coefficients from the ordinary least squared (OLS) relationship between the hourly sums of the turbulence heat fluxes (LE + H) against the available heat flux (V) on a rice paddy.

Step	Variable	EBR		OLS	
		full day	daytime	slope	r
I	Raw LE, H	0.755	0.855	0.721	0.903
II	I+Coordinate rotation	0.786	0.904	0.794	0.95
III	II+Webb et al. (1980) correction	0.803	0.921	0.836	0.90
IV	III+C correction	0.791	0.930	0.845	0.901
V	III+A correction	0.798	0.922	0.838	0.899
VI	III+F correction	0.801	0.931	0.848	0.895
VII	III+C+A+F correction (final)	0.810	0.941	0.861	0.90

Table 2. Energy balance ratio (EBR) and the regression coefficients from the ordinary least squared (OLS) relationship between the hourly sums of the turbulence heat fluxes (LE + H) against the available heat flux (V) on a flux tower.

Step	Variable	EBR	OLS	
		full day	slope	r
I	LE+H / Rn-G	0.719	0.43	0.842
II	LE+H (2D & Webb) / Rn-G-C-S	0.832	0.53	0.869
III	LE+H (3D & Webb) / Rn-G-C-S	0.818	0.51	0.855
IV	III+ albedo correction	0.942	0.63	0.874
V	IV+ albedo correction	0.927	0.61	0.861
VI	V+ ($A+\Delta R_{ln}$) correction	0.959	0.63	0.874
VII	VI+($A+\Delta R_{ln}$) correction	0.943	0.61	0.860