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Comparison of atmospheric turbulence characteristics and turbulent fluxes from urban and suburban sites in Nanjing

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Outline

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1. Background

At present, more than 50% of the world's population live in urban. To better manage air and environmental quality in cities, an increased understanding of the exchange of heat, mass, and momentum between the atmosphere and the urban surface is necessary.

In recent years, a number of turbulent flux measurements were performed in cities around the globe, most of them Focusing on the urban surface energy balance. However, most of the studies are restricted to single flux measurement sites to characterise the urban surface–atmosphere exchange.

Classical research progress

- Since *1988* ,Oke researched turbulent atmosphere-surface exchange in urban areas.
- Roth (*2000*) found the structure of atmospheric turbulence has shown to be rather homogeneous in urban areas.
- Grimmond(*2004*) made some flux and turbulence measurements at a densely built-up site and analysised the characteristics of heat, mass(water and carbon dioxide),and momentum flux .

- In China, a 325-m meteorological tower in Beijing is used to investigate the turbulence characteristics in urban surface layer.
- In Nanjing Peng Jiangliang made a comparison of turbulent characteristics over urban and suburban surface layer in 2006 winter.

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Motivation

The motivation of this study is to compare conditions of atmospheric stability, turbulence characteristics and turbulent fluxes of heat from two measuring sites within one city. The sites are different in terms of surface cover, surface morphology, and roughness. One site represents urban characteristics called DX site, the other site represents suburban characteristics called NUIST site. We want to estimate what extent fluxes and turbulence characteristics differ between sites. The urban estimate will apply to such as dispersion modelling of urban air pollutants.

2. Data and Sites

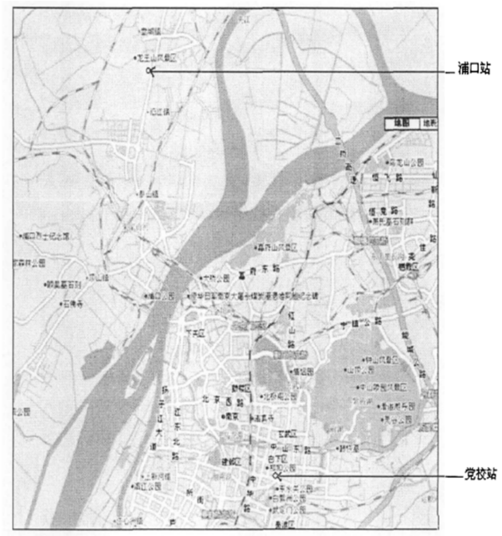
Weather condition: hot and partly cloudy, little and calm wind.

Data: July 27th to August 2nd,except July 29th ,2010

Sites：

A）9m over the roof of Dang school in Nanjing. (Urban)

B）2m over the grass of meteorological observation field in NUIST. (Suburban)



Surface characteristics	DX	NUIST
Station surroundings	Commercial district, residential housing	grass, sparse building
z(m)	39	2
z_H(m)	19.7	0
z_0 (m)	2.955	0
d(m)	13.2	0

d = 0.67 ×canopy height （EddyPro™）
z_0 = 0.15 ×canopy height

Table1. Measurement heights and surface characteristics of the two sites.

Data processing

Ultrasonic Data($10H_Z$)

Spike count/removal

Coordinate rotation

Crosswind correction

Time lag compensation

Ultrasonic virtual temperature correction

Compensation for density fluctuations(WPL)

30-minute block averages, variances and covariances

3. Result

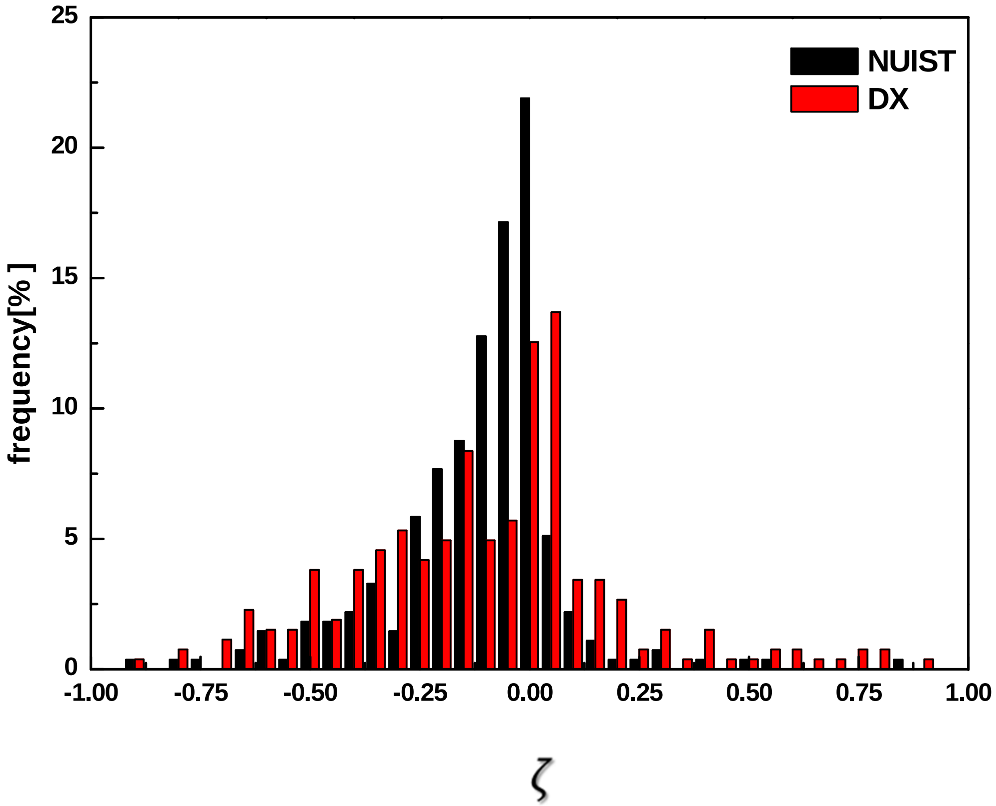


Fig1. Frequency distribution of the atmospheric stability parameter ζ binned into 0.05-ζ classes.

Only stabilities in the range from $-1<\zeta<1$ are shown in this plot. NUIST data accounts for 95% of data; DX data accounts for more than 90% of data.

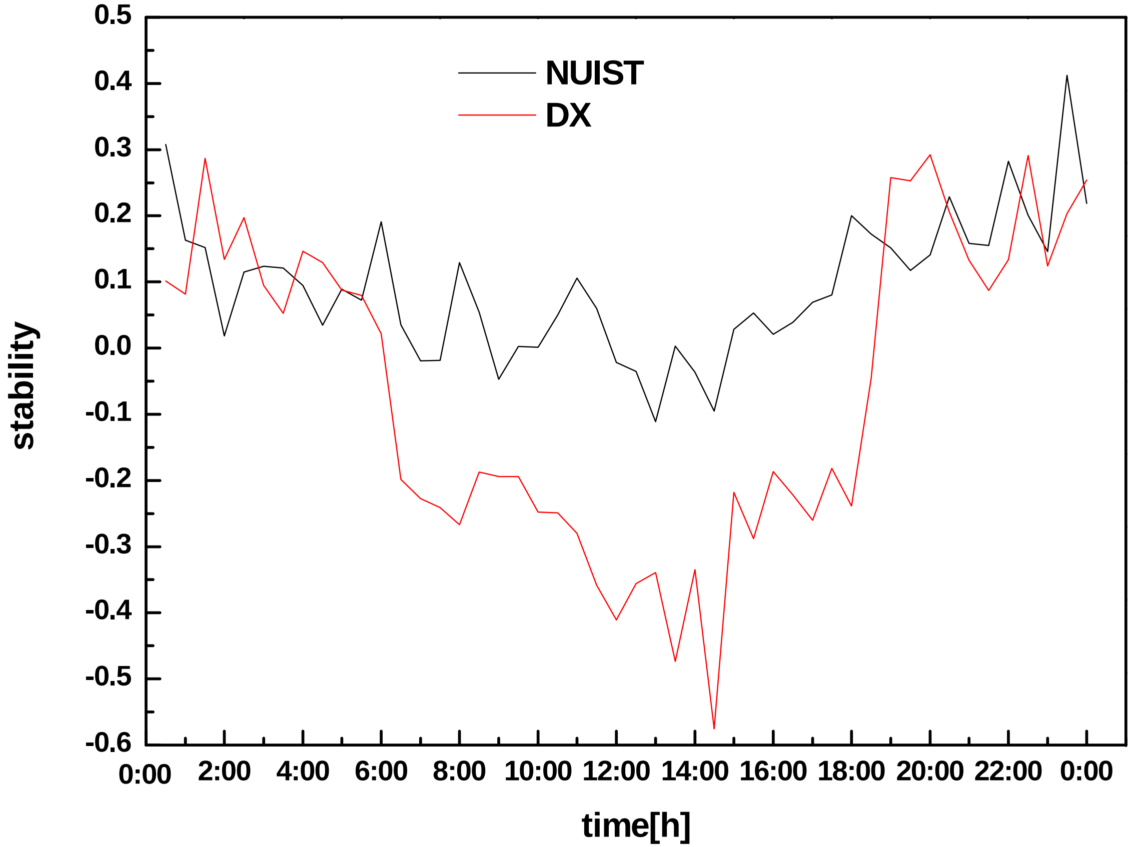


Fig2. Diurnal courses of stability parameter ζ at DX and NUIST for the entire study period.

$$\frac{\sigma_i}{u_*}=a(1-b\zeta)^{\frac{1}{3}} \Rightarrow \frac{\sigma_i}{u_*}=a(1-b\zeta)^{\frac{1}{3}}$$

		Al-Jiboori et *al.*(2000)		This Study			
		a	b	a(DX)	b(DX)	a(NUIST)	b(NUIST)
$\zeta<0$	σ_u/u_*	1.75	1.80	2.12	0.78	2.67	0.65
	σ_v/u_*	1.60	2.10	1.89	0.57	2.36	2.19
	σ_w/u_*	1.22	1.05	1.46	0.66	1.25	0.27
$\zeta>0$	σ_u/u_*	1.76	2.39	2.10	-1.96	0.84	-172.63
	σ_v/u_*	1.60	1.96	2.06	-1.85	2.32	-0.26
	σ_w/u_*	1.22	1.05	1.55	-1.83	1.96	-36.30

Table2. Contrast of constants in empirical fits according to Eq. for unstable and stable stratification.

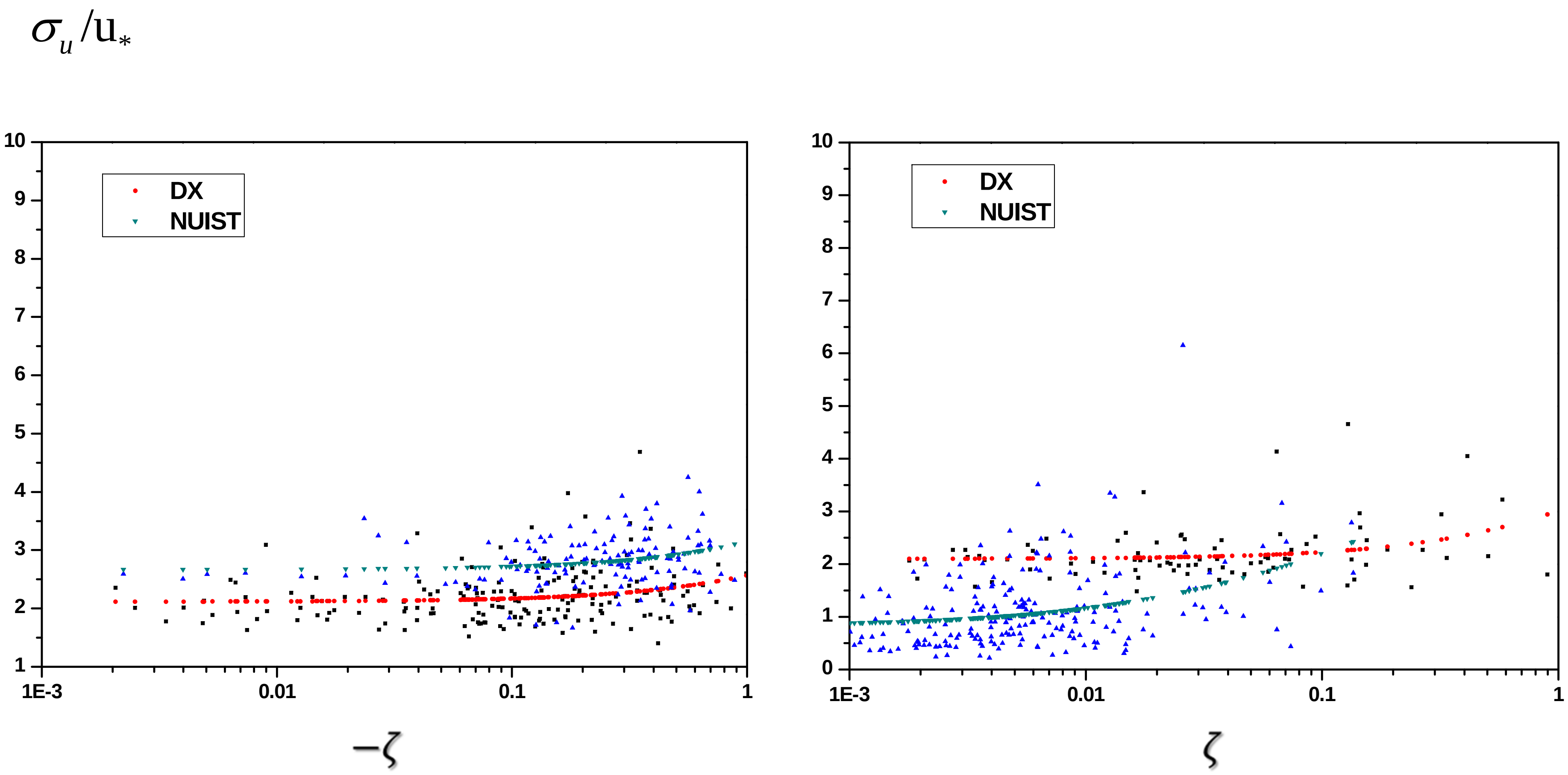


Fig3. Contrast of nonnormalized standard deviation of wind vectors between urban site and suburban site

σ_v / u_*

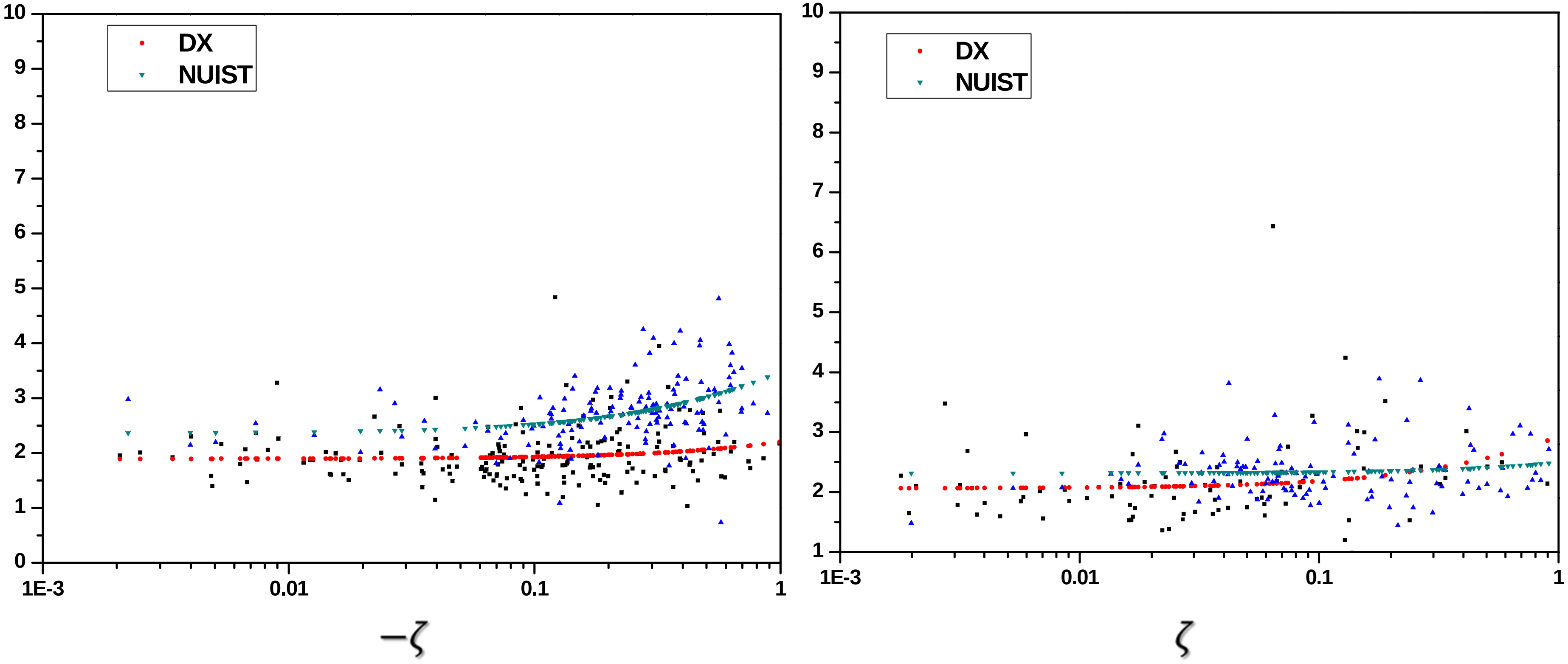


Fig4. Contrast of nonnormalized standard deviation of wind vectors between urban site and suburban site

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σ_w/u_*

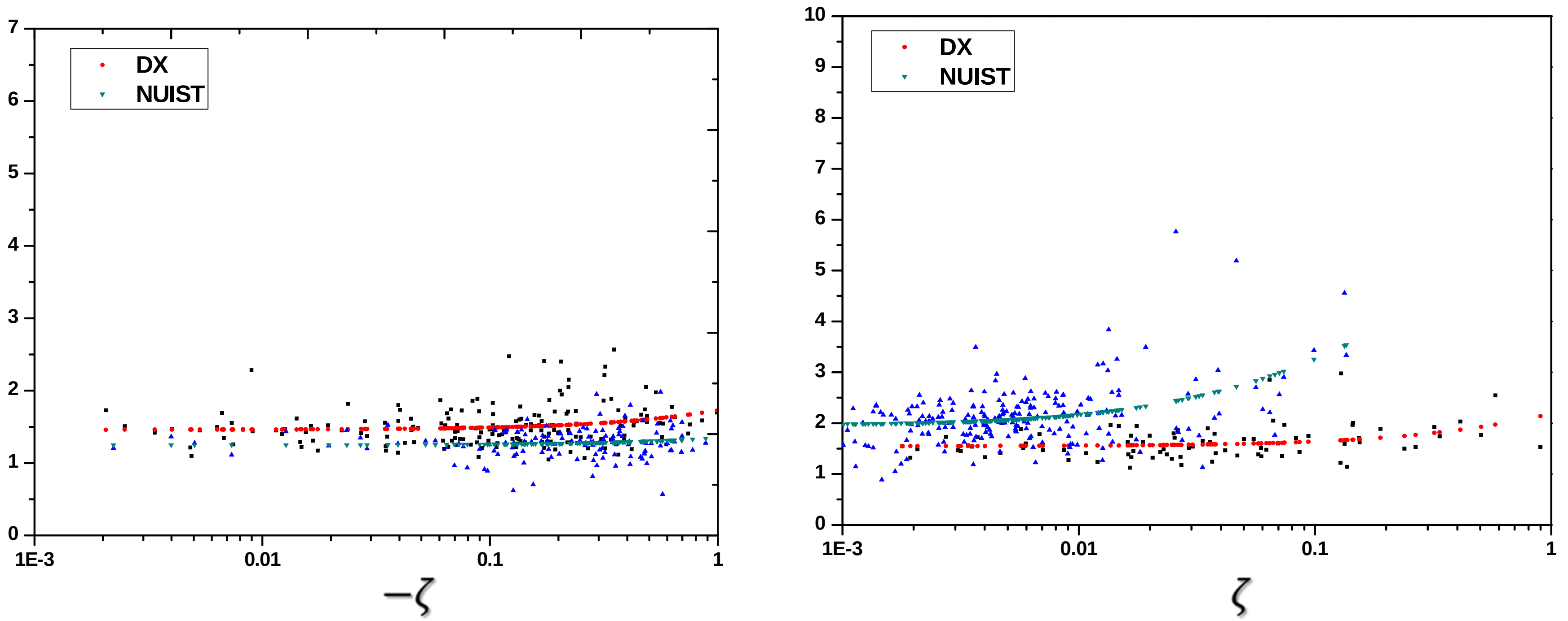


Fig5. Contrast of normalized standard deviation of wind vectors between urban site and suburban site

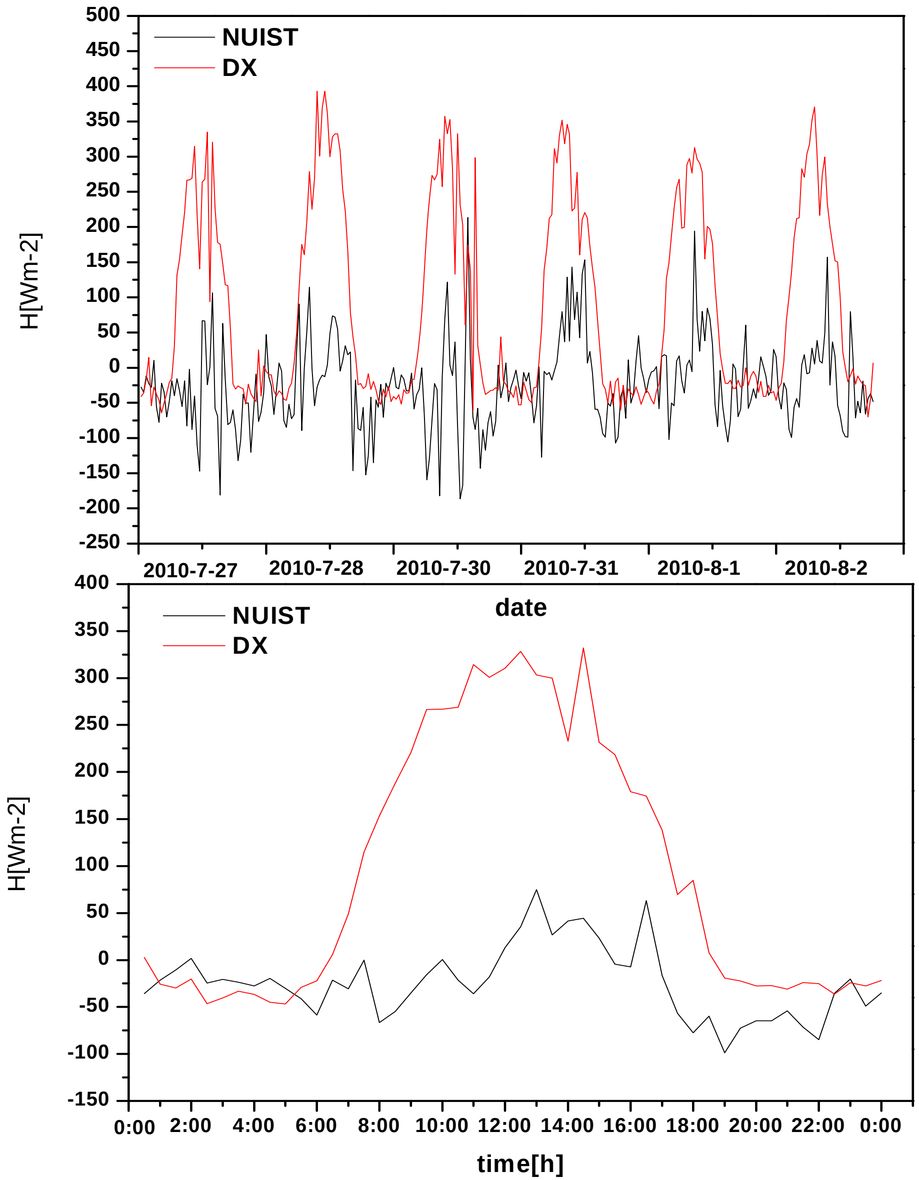
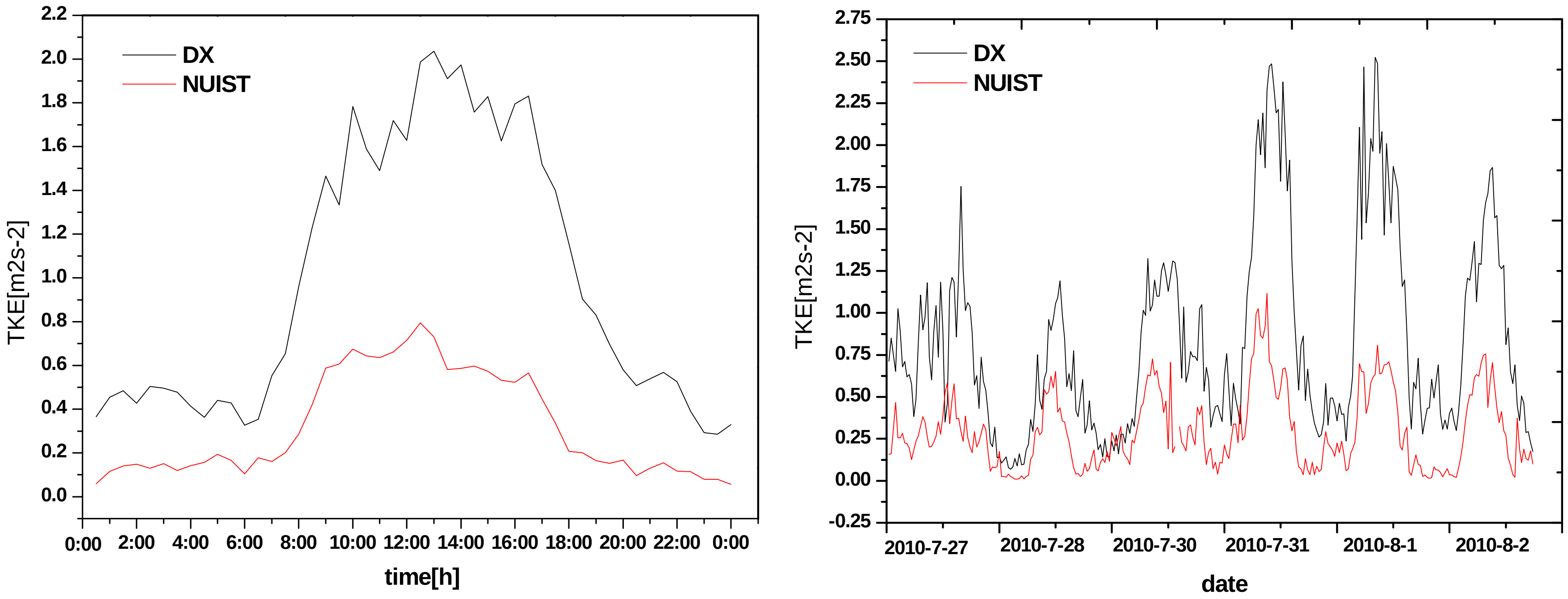


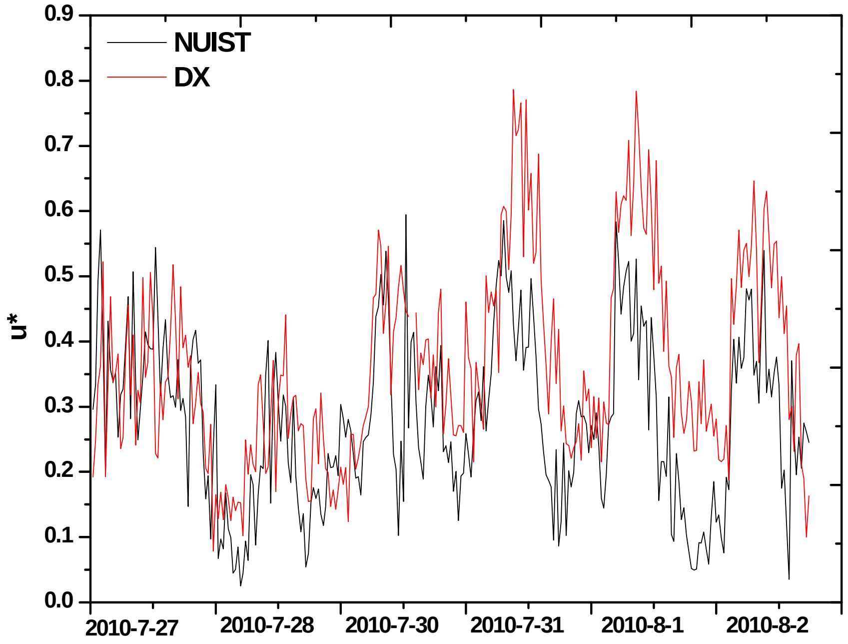
Fig6. Average diurnal courses of sensible heat fluxes at both sides for the 6-day measurement period.

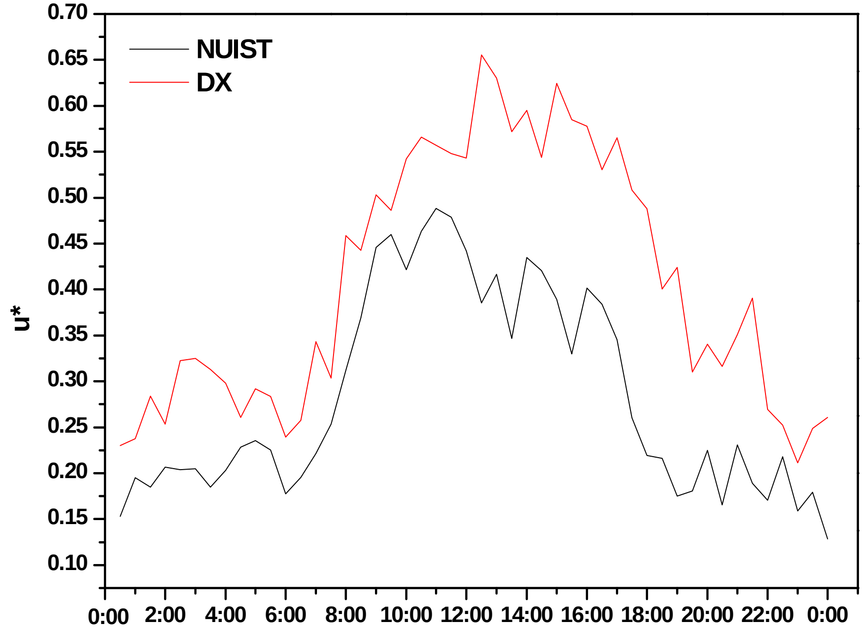
Positive values of H represents upward directed heat fluxes, and negative signs indicate downward directed fluxes.



$$TKE=\frac{1}{2}\left(\overline{u'^2}+\overline{v'^2}+\overline{w'^2}\right)$$

Fig7. Average diurnal courses of TKE at both sides for the 6-day measurement period.





$$u_* = \left[\left(\overline{u'w'} \right)^2 + \left(\overline{v'w'} \right)^2 \right]^{1/4}$$

Fig8. Average diurnal courses of u star at both sides for the 6-day measurement period.

4. Discussion

1.Similar to observations at other urban sites ,the maximum of the frequency distribution of stability at both sides lies within the neutral range.

2.The average diurnal course of ζ indicates stronger instability at DX site during daytime.

3.Generally,the urban heat island effect with release of stored heat from the urban fabric is believed to be responsible for unstable or neutral atmospheric stratification even during night time.

4.Turbulence characteristics or normalized standard deviations of velocity shows a general increase with increasing instability and varies in magnitude between the two sites.

5.The empirical constants a, b, and c are different from other empirical fits.

5. Ongoing Work

- 1. Ready to Research more flux characteristics and turbulent spectra characteristics deeply.
- 2. Read more papers about urban turbulence.

Thank You