Transfer coefficients of momentum, heat and water vapor over Lake Taihu : dependence on wind speed and atmospheric stability

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Outline

- Background
- Data and Method
- Results

  wind speed

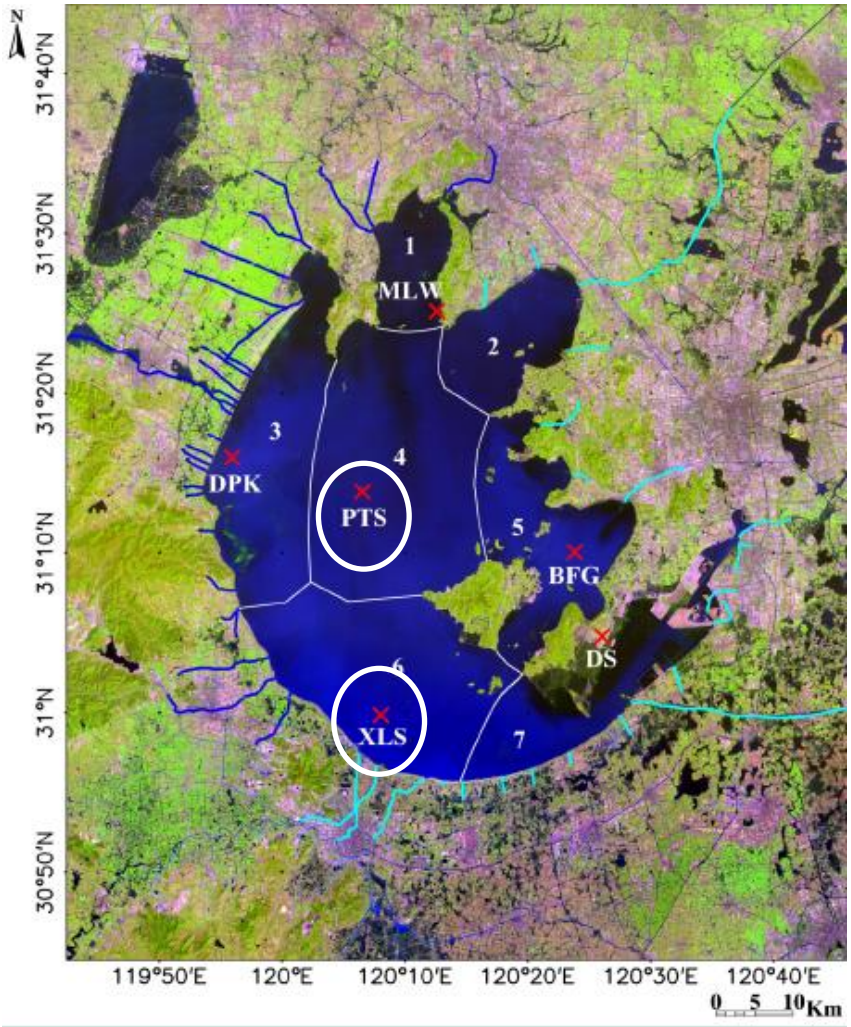
  atmosphere stability
- Conclusions

Background

- Water-air interactions(the surface energy exchanges and hydrological processes over open water surfaces) are driven by the fluxes of momentum ,heat and water vapor.

- In many numerical weather prediction and climate models, the exchange of momentum and heat between water surfaces and the lower atmosphere are parameterized using transfer relationships(Subin et al., 2012) .

Data source



PTS site:
Time: 2013.6 - 2014.12
WD: 0-225°, 315-360°

XLS site:
Time: 2012.12 - 2014.12
WD: 0-160°, 330-360°

Method

The bulk transfer coefficients

$$\tau = \rho_a C_D u^2$$

$$LE = \rho_a L_v C_E u(q_s - q_a)$$

$$H = \rho_a c_p C_H u(T_s - T_a)$$

C_D, C_E, C_H: transfer coefficients of momentum, water vapor and sensible heat.

The relation between roughness lengths for momentum(z_0), water vapor(z_q), sensible heat(z_T) and the transfer coefficients.

$$C_D = k^2 / [\ln(z / z_0) - \psi_M(\zeta)]^2$$

$$C_E = k^2 / \{[\ln(z / z_0) - \psi_M(\zeta)][\ln(z / z_q) - \psi_W(\zeta)]\}$$

$$C_H = k^2 / \{[\ln(z / z_0) - \psi_M(\zeta)][\ln(z / z_T) - \psi_H(\zeta)]\}$$

ζ(z/L): Atmosphere stability

ψ_M, ψ_W, ψ_H: the integral similarity functions for momentum, water and sensible heat

The transfer coefficients are adjusted to the standard reference height of 10m and for neutral stability.

$$C_{D10N} = k^2 / [\ln(z / z_0)]^2$$

$$C_{E10N} = k^2 / [\ln(z / z_0) \ln(z / z_q)]$$

$$C_{H10N} = k^2 / [\ln(z / z_0) \ln(z / z_T)]$$

Results

Data quality

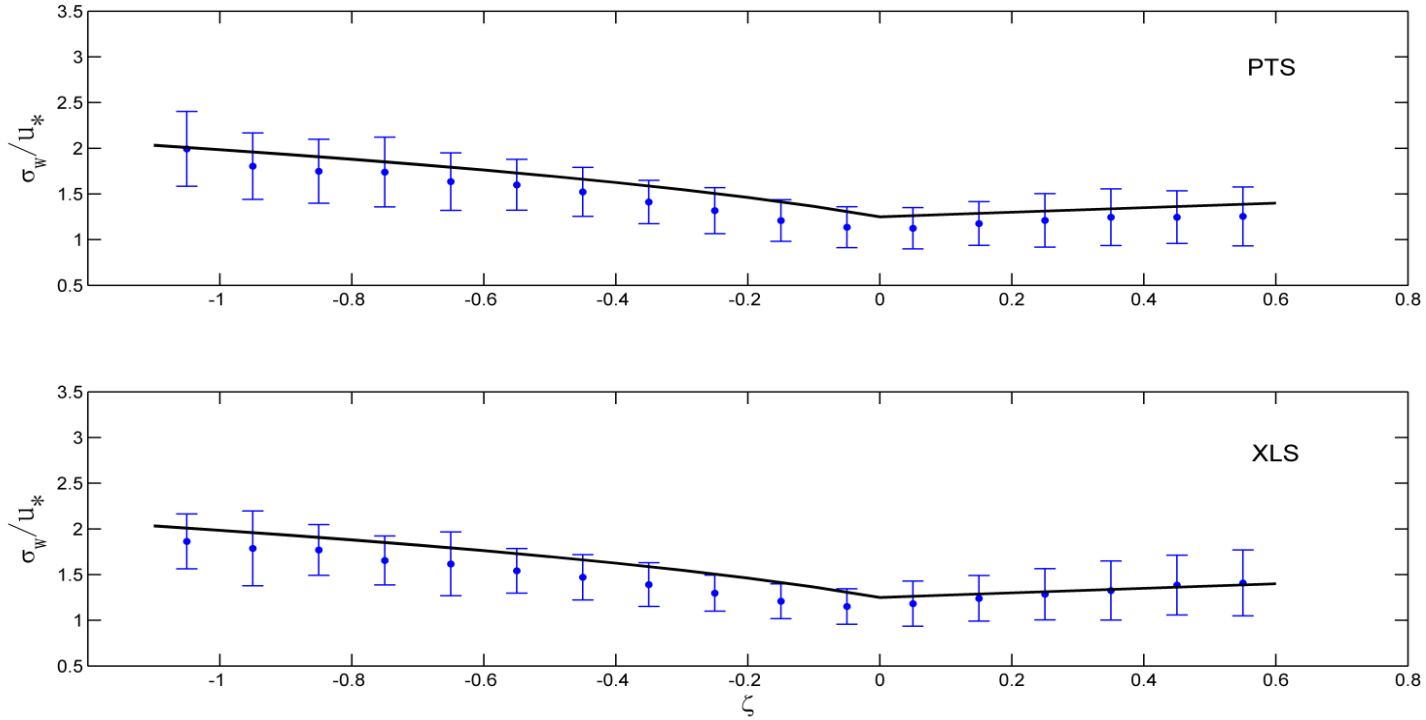


Fig1 Variation of σ_w/u_* with ζ of the measurement and the literature relationship(Garratt 1992; Kaimal and Finnigan 1994).

$$\sigma_w / u_* = 1.25(1-3\zeta)^{1/3} \quad \text{for } \zeta < 0$$

$$\sigma_w / u_* = 1.25(1+0.2\zeta) \quad \text{for } \zeta > 0$$

- The effective transfer coefficients

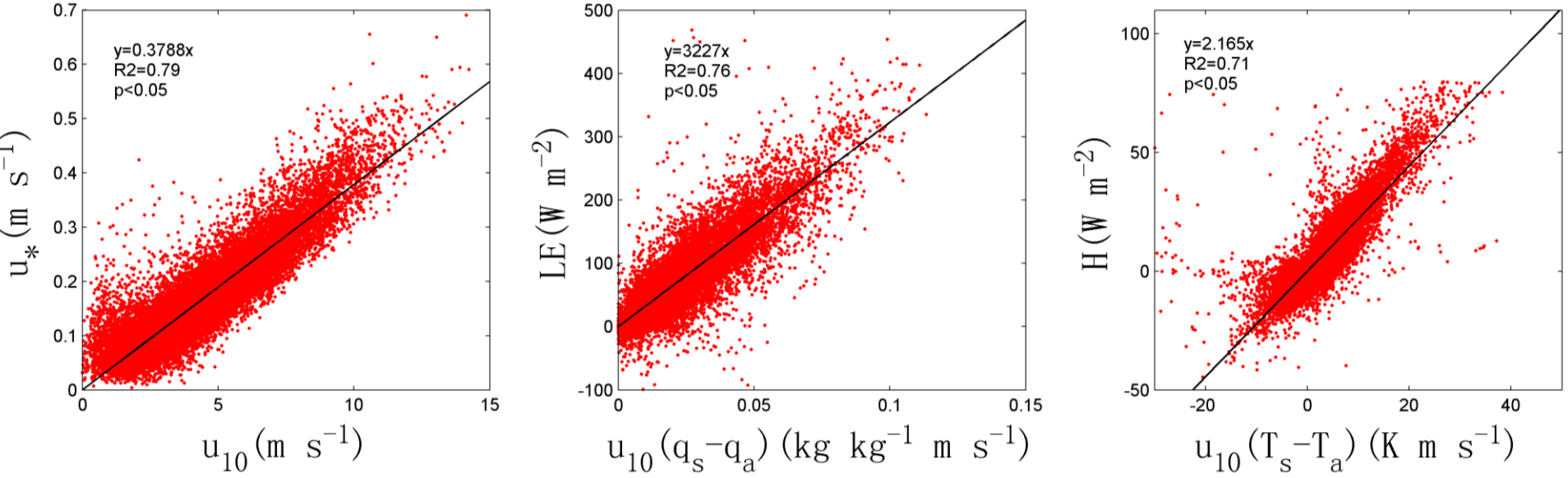


Fig2 bulk transfer relationships at PTS and XLS sites

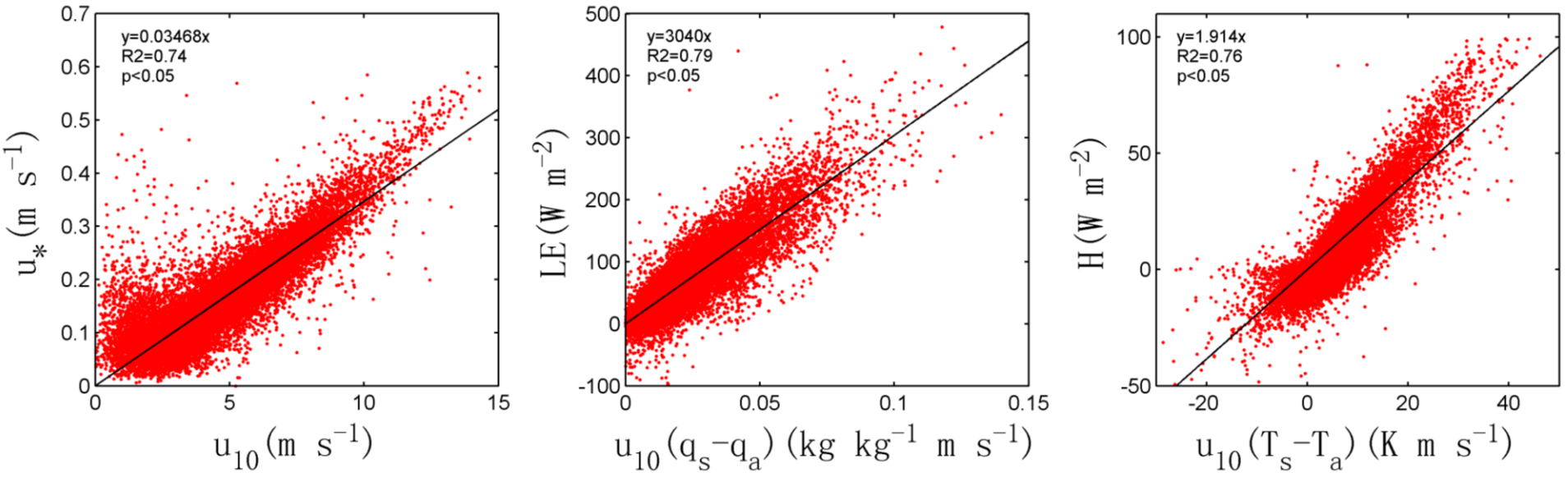


Fig3 bulk transfer relationships at XLS site

Table1 A summary of the effective transfer coefficients

Lake name		10^3C_{D10}	10^3C_{E10}	10^3C_{H10}	Reference
Lake Taihu	PTS	1.4±0.03	1.1±0.01	1.8±0.02	This study
	XLS	1.2±0.02	1.0±0.01	1.6±0.02	
	MLW	1.8±0.02	0.9±0.01	1.5±0.02	Xiao et al. (2013)
	DPK	1.9±0.03	1.0±0.01	1.2±0.02	
	BFG	1.1±0.02	1.0±0.01	1.4±0.02	
Lake Erhai		2.02	1.36	1.47	Liu et al.(2014)
Lake Tamnaren		1.4±0.34	1.0±0.40	1.3±0.35	Heikinheimo et al.(1999)
Great Slave Lake		1.1±0.06	2.0±0.19	0.4±0.05	Blanken et al.(2003)
Lake Valkea-Kotinen		5.2±1.05	1.0±0.04	1.0±0.09	Nordbo et al (2011)

The relationship between transfer coefficients and wind speed

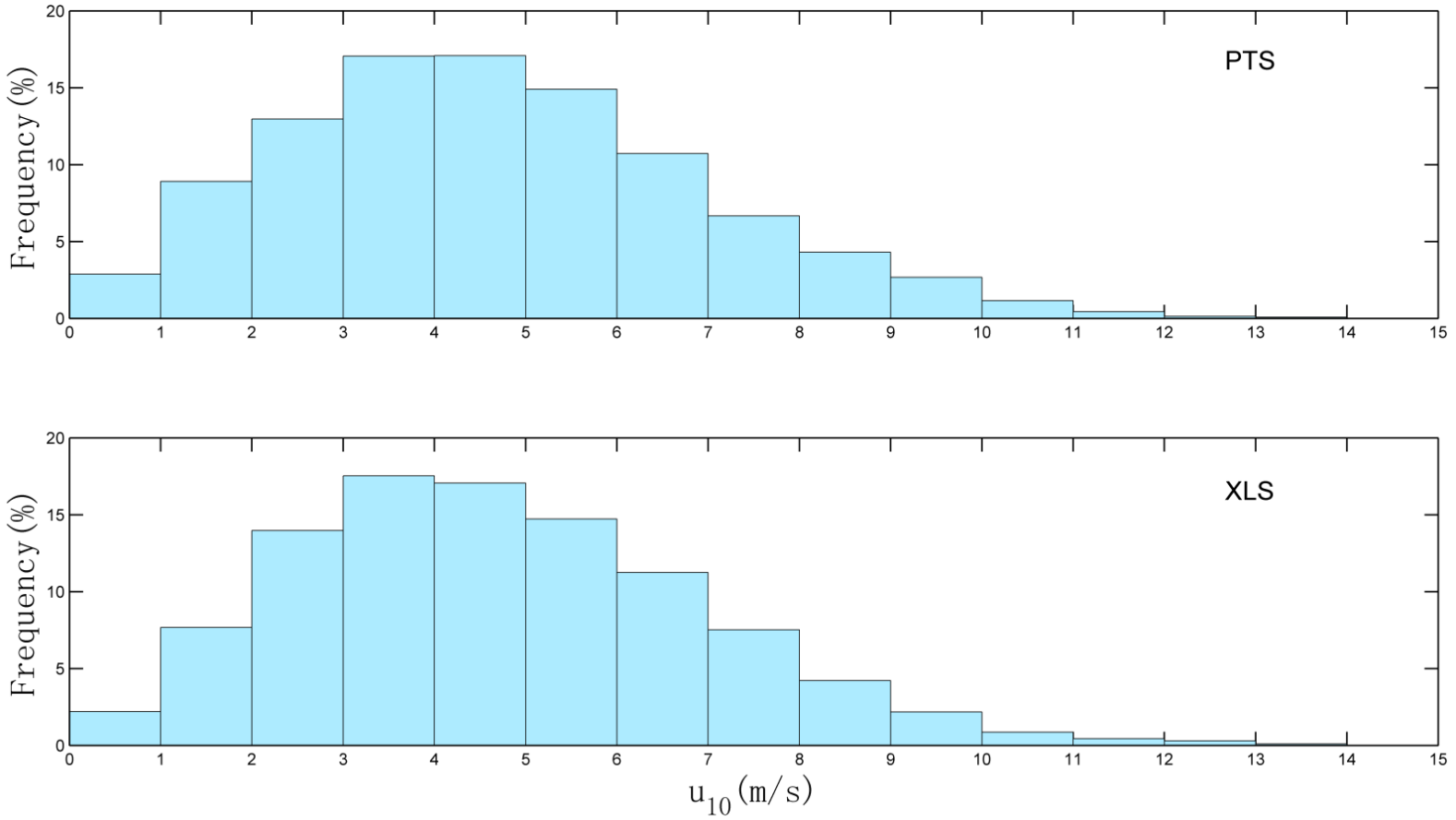


Fig4 wind speed histograms at PTS and XLS

The percentage of strong winds (u_{10} >4 m s^{-1}) was 58.2% and 58.6% at the PTS and XLS sites, respectively.

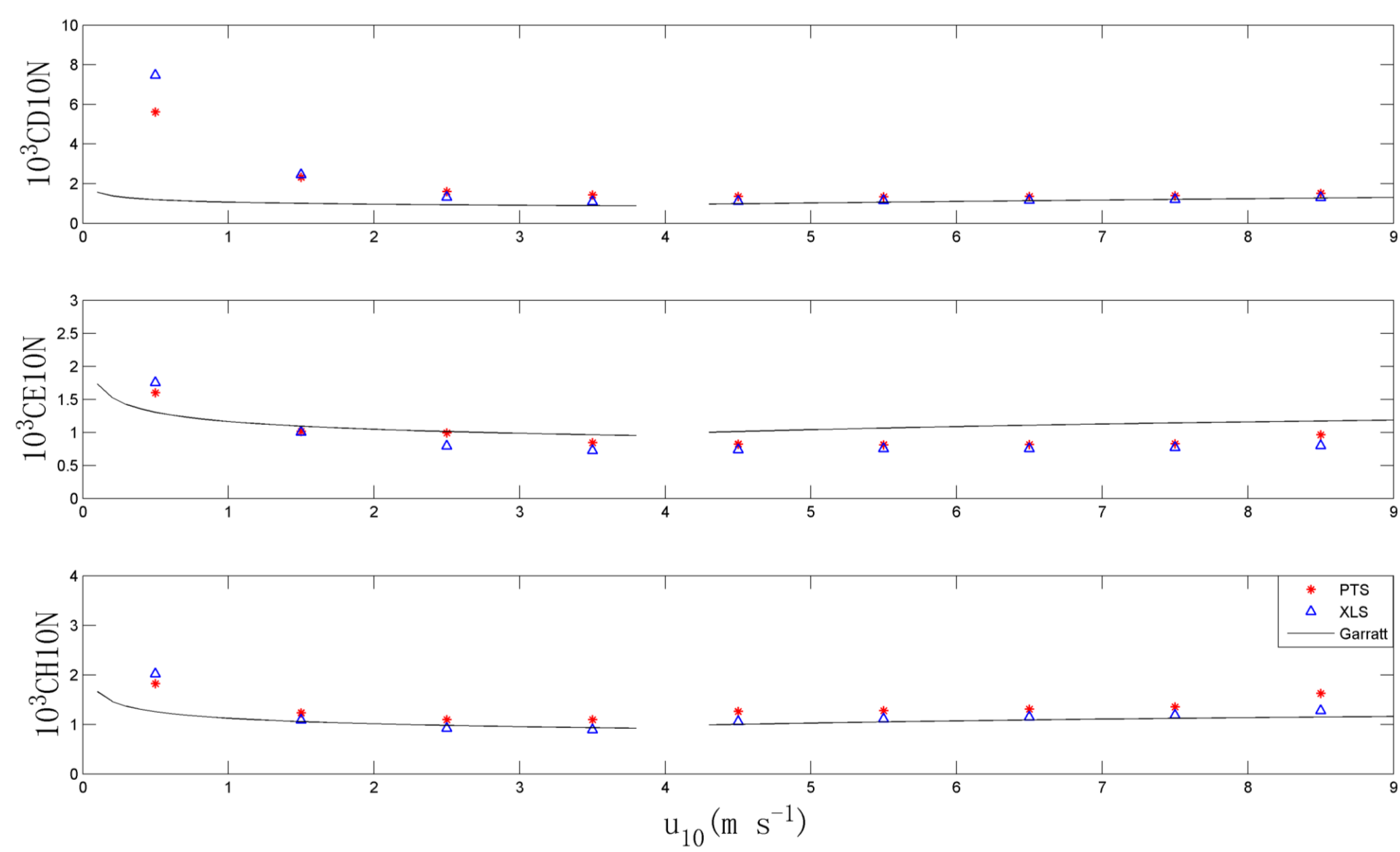


Fig5 Neutral transfer coefficients at 10-m height for the PTS, XLS sites.

The relationship between transfer coefficients and stability

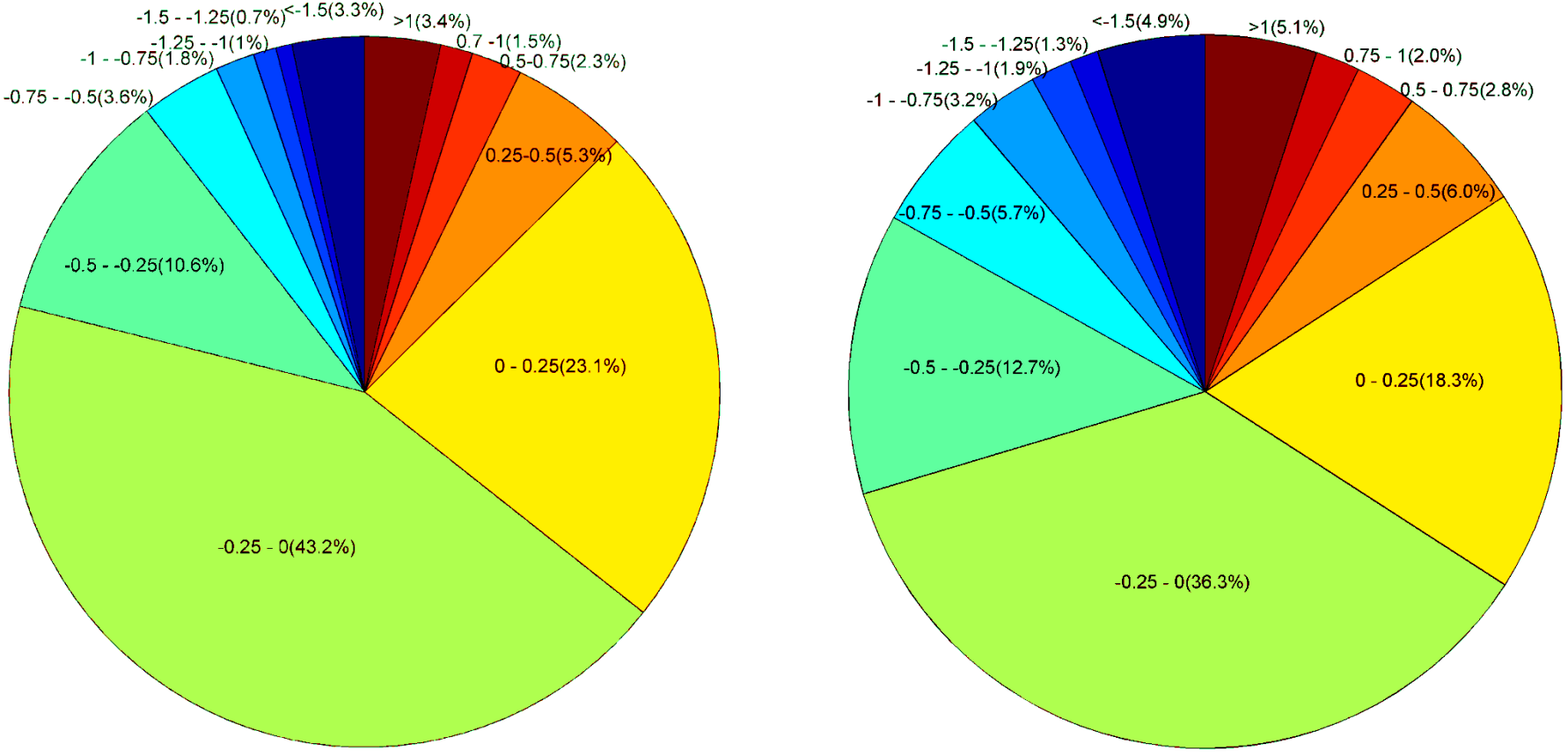


Fig5 The distribution pie of atmospheric stability ζ at PTS and XLS sites

79.4% and 76.9% of the atmosphere condition for PTS and XLS sites respectively are under the neutral condition($|\zeta|<0.1$) or unstable condition ($|\zeta|<-0.1$).

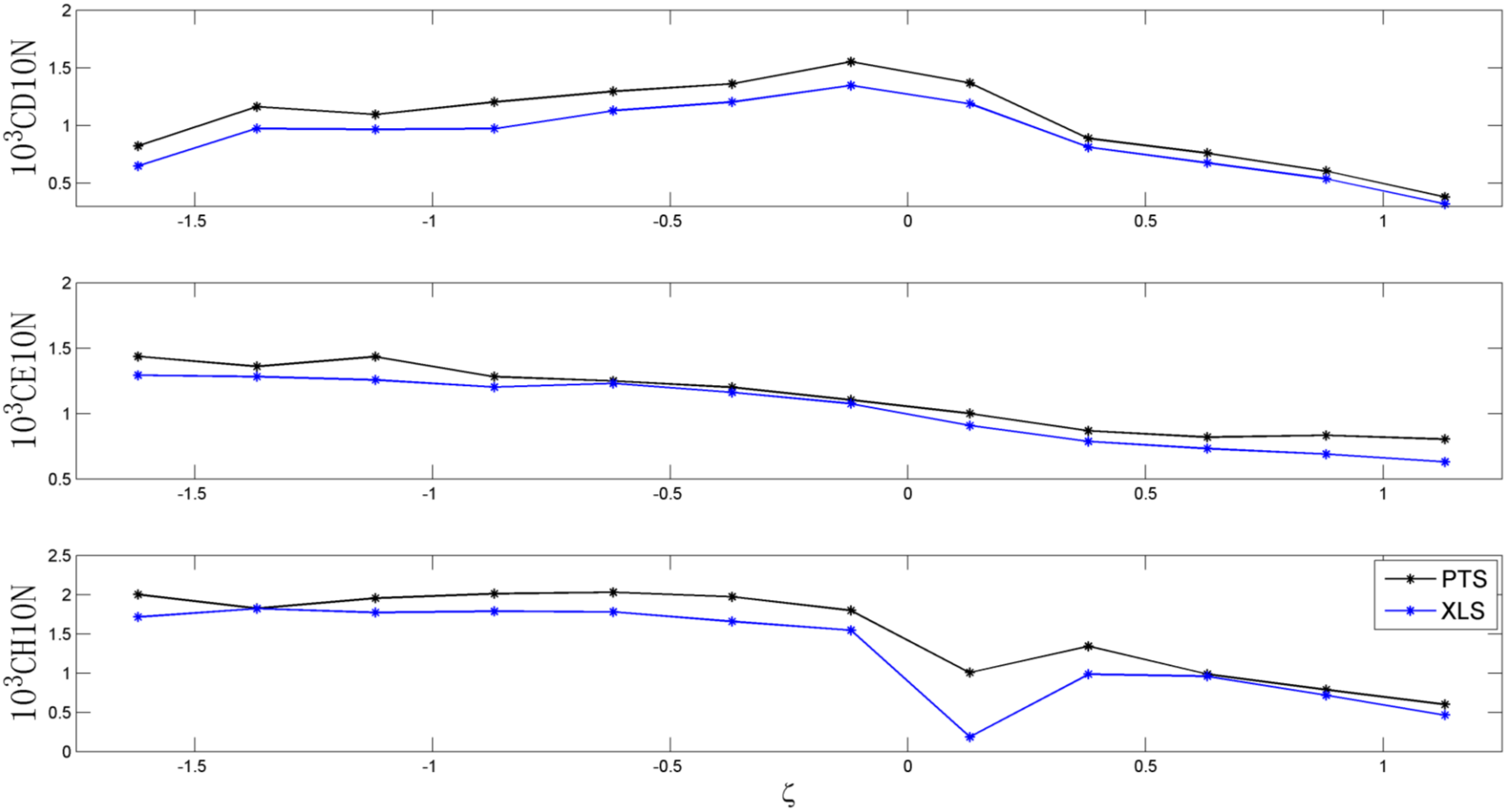


Fig6 The effective transfer coefficients at10-m height versus atmospheric stability for PTS and XLS sites

The relationship between transfer coefficients (with stability correction) and neutral transfer coefficients (without stability correction).

$$C_D / C_{DN} = [1 - \psi_M(\zeta) / \ln(z/z_0)]^{-2}$$

$$C_E / C_{EN} = [1 - \psi_M(\zeta) / \ln(z/z_0)]^{-1} [1 - \psi_E(\zeta) / \ln(z/z_q)]^{-1}$$

$$C_H / C_{HN} = [1 - \psi_M(\zeta) / \ln(z/z_0)]^{-1} [1 - \psi_H(\zeta) / \ln(z/z_T)]^{-1}$$

Table2 The results of fluxes using the transfer coefficients at the reference height without and with stability correction

Site ID	Flux	Without stability correction	With stability correction
		RMSE	RMSE
PTS	u_*/(m s^{-1})	0.043	0.041
	LE/(W m^2)	30.67	30.13
	H/(W m^2)	8.07	7.94
XLS	u_*/(m s^{-1})	0.044	0.042
	LE/(W m^2)	27.86	25.8
	H/(W m^2)	8.12	7.88

Conclusion

- In the weak wind regime (0-4 m s^{-1}), the transfer coefficients for momentum, water vapor and sensible heat decreased quickly with increasing wind speed, while reaching an asymptotic.

- The transfer coefficients is sensitive to stability correction over short time-scales while not over long time-scales.

On-going work

- Further studying of the spatial variation of transfer coefficients of momentum, sensible and water vapor and its main factors.

- The relationship between wave height and momentum transfer coefficients at DPK site.

Thank you