Sensible heat and latent heat flux calculation based on flux-covariance method

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Calculation principle

- Flux-covariance method:

$$H = \rho c_p [\left(\frac{\sigma_T}{c_1}\right)^3 (\frac{\kappa g z}{T}) \frac{(1 - c_2 \xi)}{-\xi}]^{1/2} \quad \xi < 0$$ *(De Bruin et al., 1993)*

- Energy balance method:

$$R_n - G = H + LE$$

Sites description

Site ID	Site name	Location	Climate zone	Underlying surface type	Time
DL	Duolun	114.68°E, 37.88°N	semiarid continental climate	Grassland	Jun.-Sep., 2009
NMG	Inner Mongolia	117.45°E, 43.88°N	semiarid continental climate	Grassland	2005
GCT	Haibei (shrubland)	101.33°E, 37.48°N	plateau continental climate	Shrubland	2005
SD	Haibei (wetland)	101.33°E, 37.61°N	plateau continental climate	Wetland	2005
HA	Hai'an	120.31°E, 32.41°N	subtropical monsoon climate	Rice paddy	May-Nov., 2019
LC	Luancheng	116.26°E, 42.03°N	semi-humid and warm temperate climate	Wheat + Corn	Apr.-Sep., 2008
YC	Yucheng	116.63°E, 36.95°N	sei-humid and monsoon climate	Wheat + Corn	2005
YF	Yongfeng	118.67°E, 32.20°N	subtropical monsoon climate	Wheat + Rice paddy	2015
G21	--	93.08°W, 44.72°N	--	Soybean	2006

Part 1. Sensible heat and latent heat flux calculation on half-hourly scale

Calculation method

1. Assumed neutral stratification

$$u_{*n} = \frac{k\bar{u}}{\ln\frac{z}{z_0}} \Rightarrow H = \rho c_p \frac{\sigma_T}{c_1} u_{*n} \Rightarrow \overline{w'T'} = \frac{H}{\bar{\rho} c_p} \Rightarrow L = -\frac{u_{*n}^3}{k\frac{g}{\bar{T}}\overline{w'T'}} \Rightarrow \xi = \frac{z-d}{L}$$

2. Recalculate the sensible heat flux, u_* and stability

$$H = \rho c_p \left[\left(\frac{\sigma_T}{c_1}\right)^3 \left(\frac{\kappa g z}{T}\right) \frac{(1-c_2\xi)}{-\xi}\right]^{1/2} \Rightarrow \overline{w'T'} = \frac{H}{\bar{\rho} c_p}$$

$$u_* = \frac{k\bar{u}}{\ln\frac{z}{z_0} - \Psi(m)}$$

$$\Psi(m) = \ln\left[\left(\frac{1+x^2}{2}\right)\left(\frac{1+x}{x}\right)^2\right] - 2\tan^{-1}(x) + \frac{\pi}{2}$$

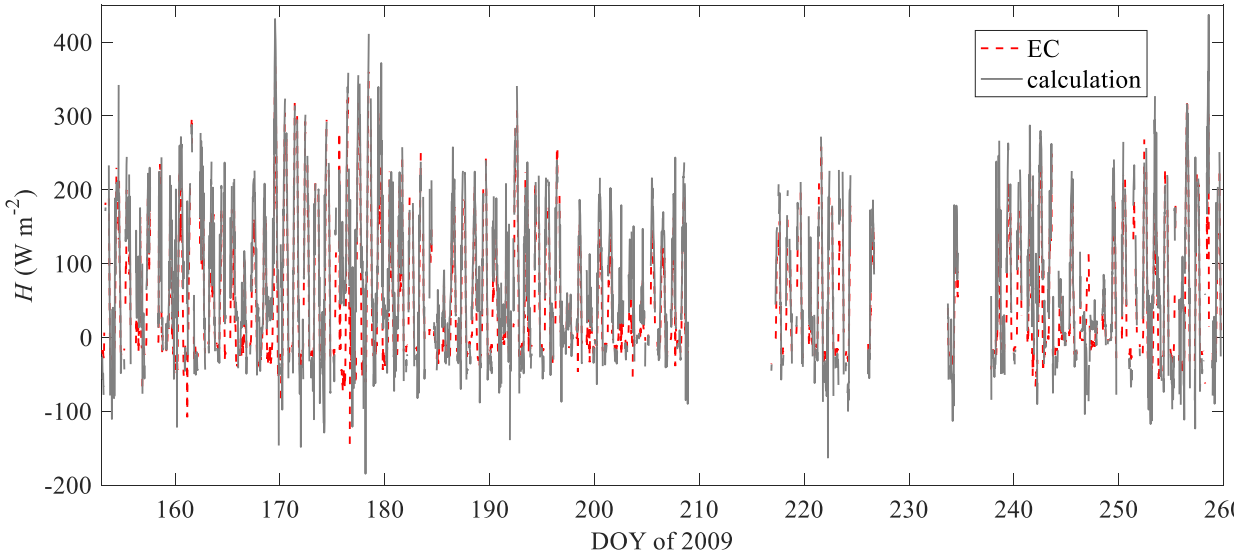
$$x = (1-16\xi)^{1/4} \quad \xi < 0$$

$$\Psi(m) = -5\xi \quad \xi > 0$$

$$L = -\frac{u_{*n}^3}{k\frac{g}{\bar{T}}\overline{w'T'}} \Rightarrow \xi = \frac{z-d}{L}$$

3. Repeat the step 2

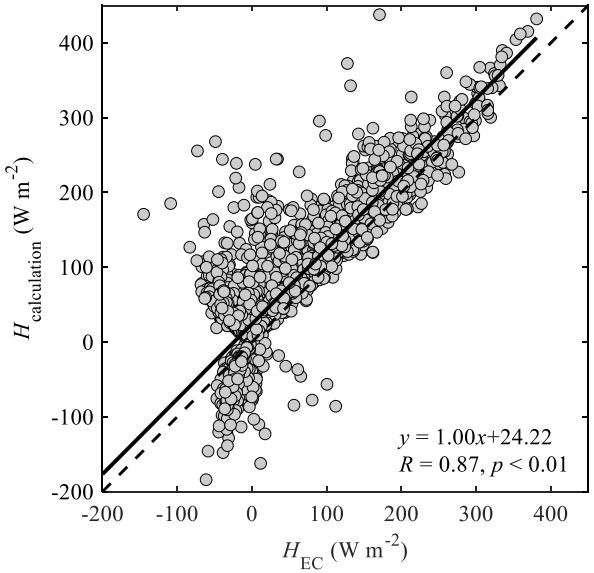
Results of DL site: H_{EC} versus $H_{calculation}$

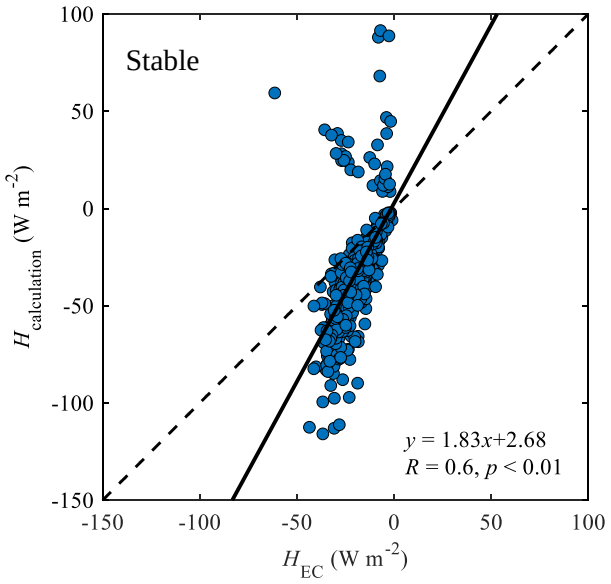


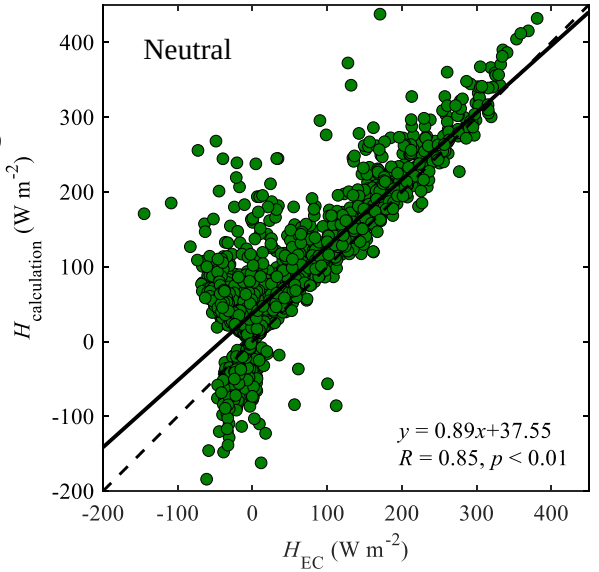
Stable condition, $\xi > 0.04$

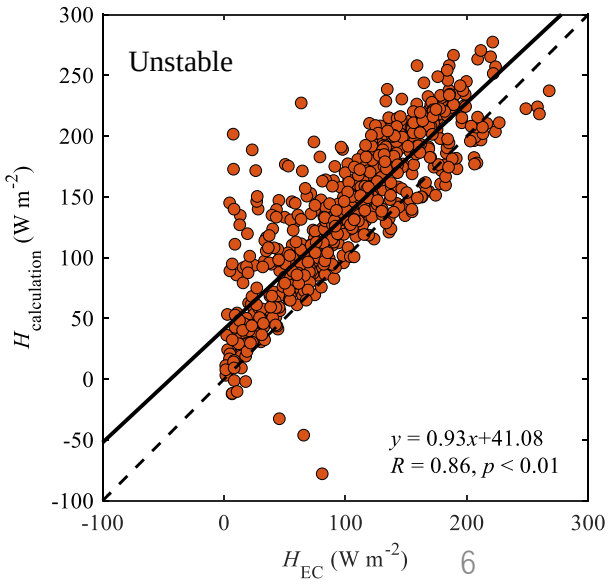
Neutral condition, $-0.04 < \xi < 0.04$

Unstable condition, $\xi < -0.04$

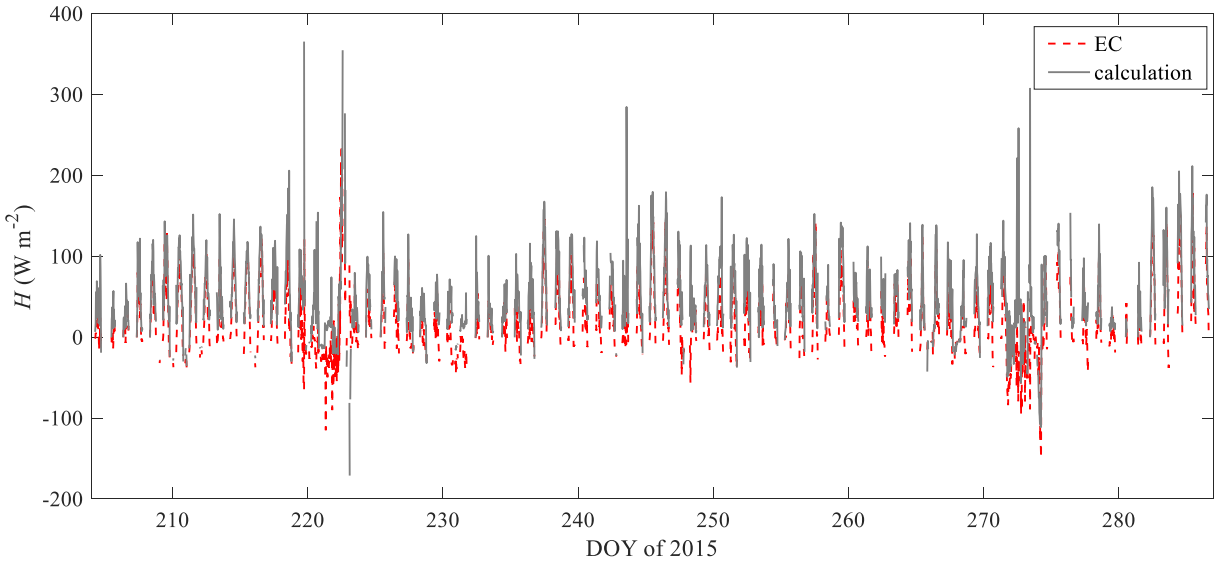


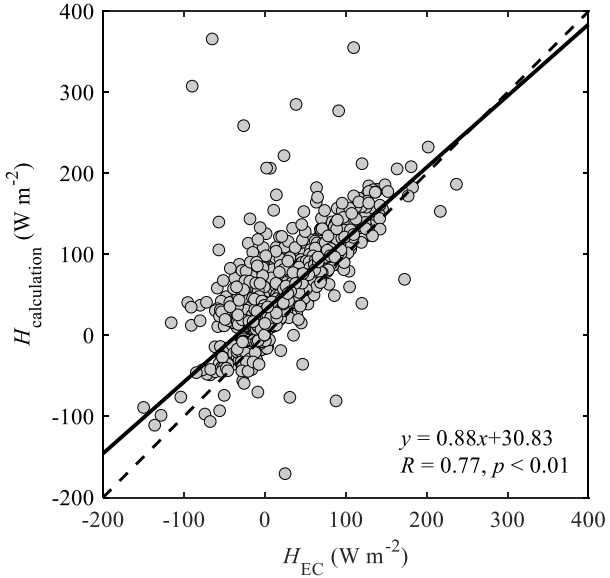


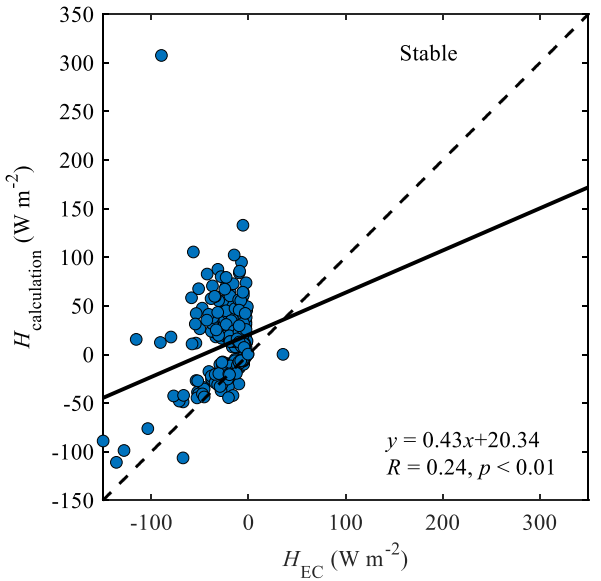


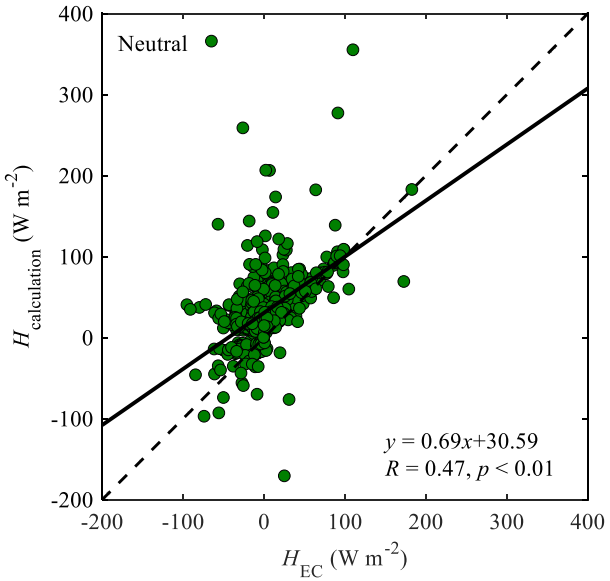


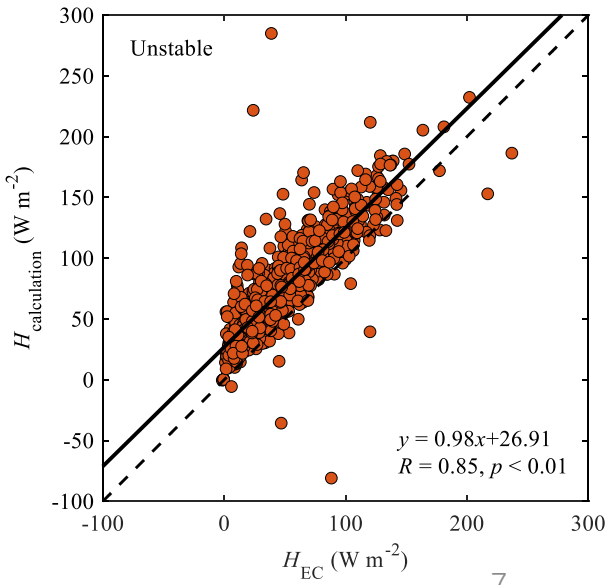
Results of YF site - - period of rice paddy growing season



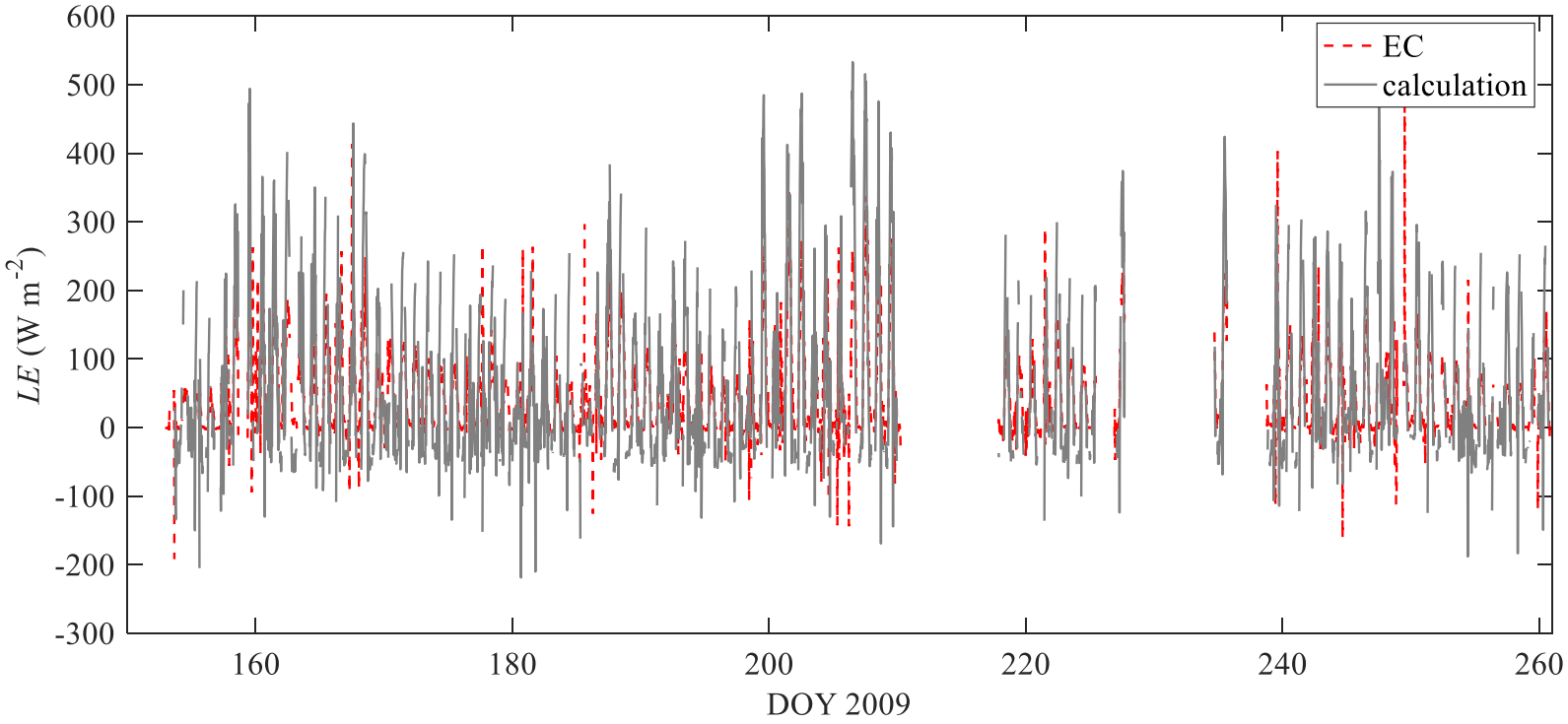


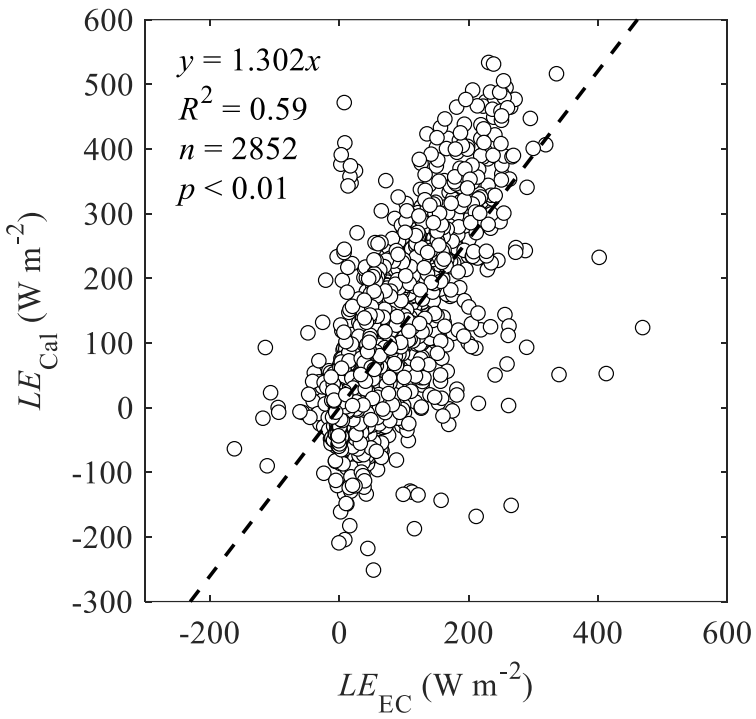




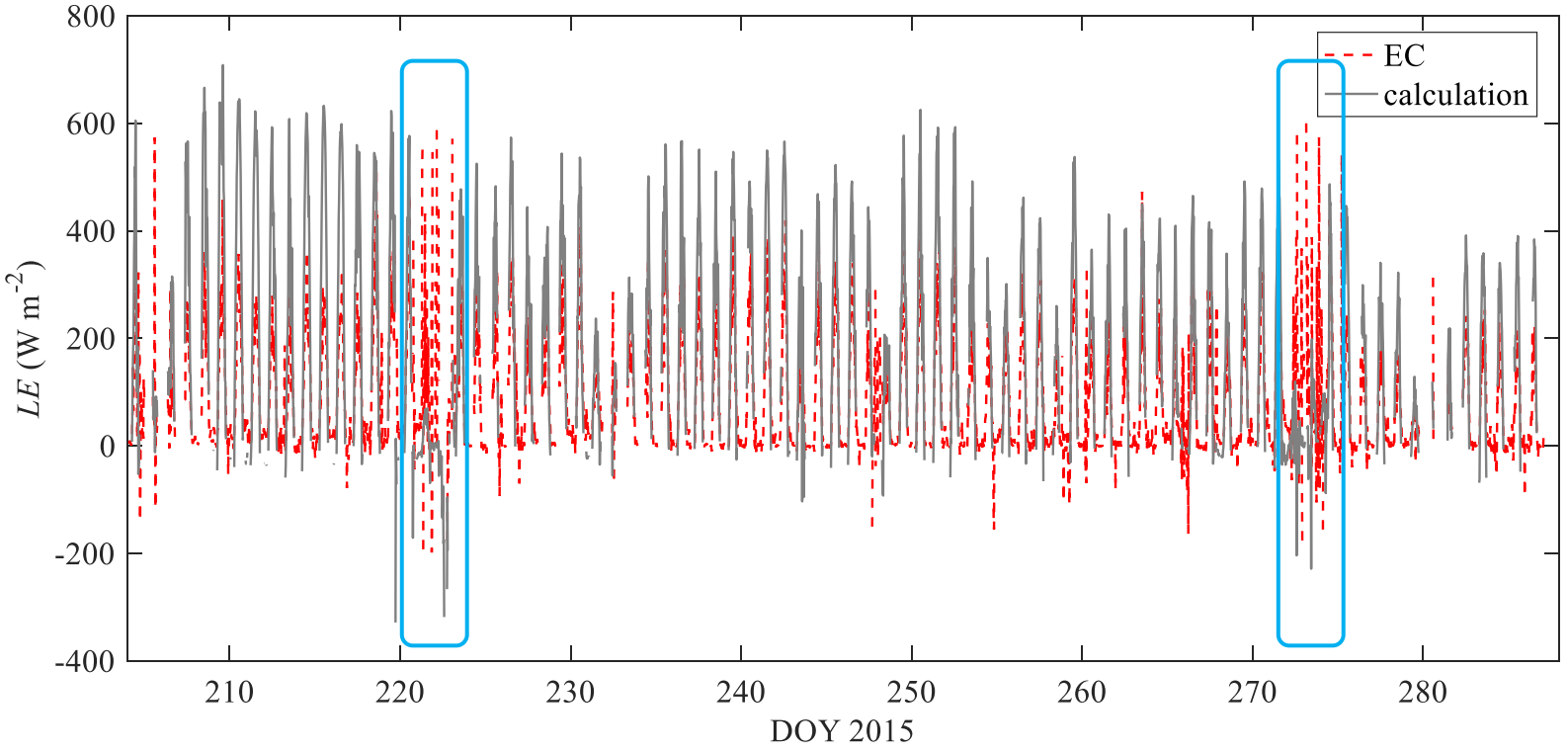


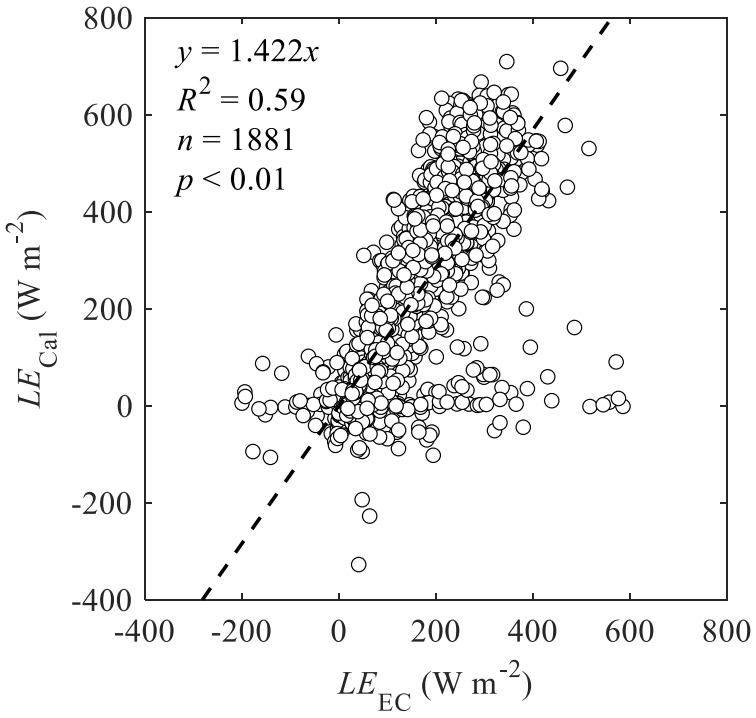
LE_{EC} versus LE_{cal}: DL site





LE_{EC} versus LE_{cal}: YF site





Part 2. Sensible heat and latent heat flux calculation on daily scale

Calculation method

- Regression of H and $\sigma_T * u_*$ (daytime: $R_n > 0$, nighttime: $R_n < 0$)

- Estimate the 24h mean H:

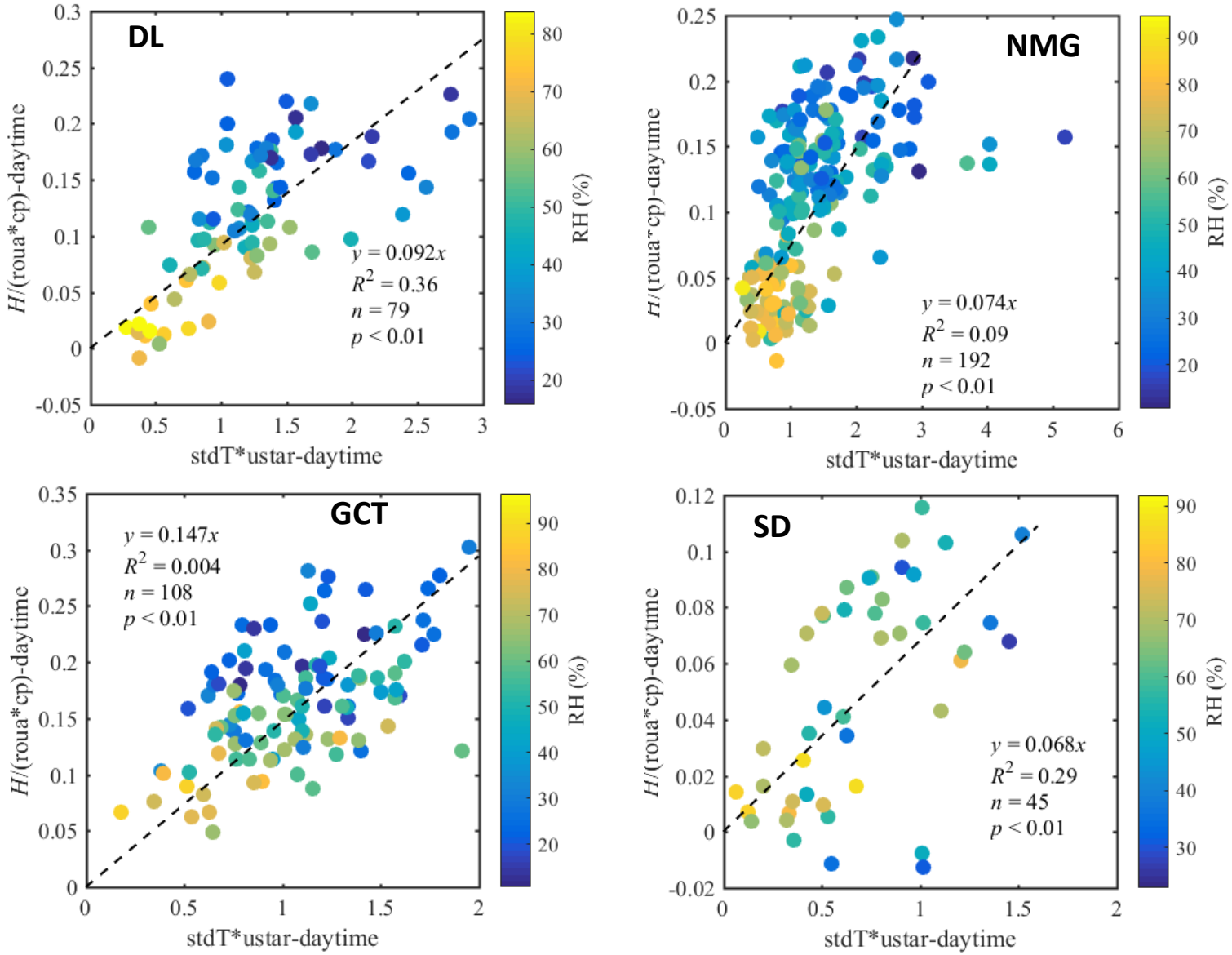
$$H\_24 = f * H\_d + (1-f) * H\_n$$

where f is daylength fraction, H_d is daytime mean H calculated from the regression, and H_n is nighttime mean H.

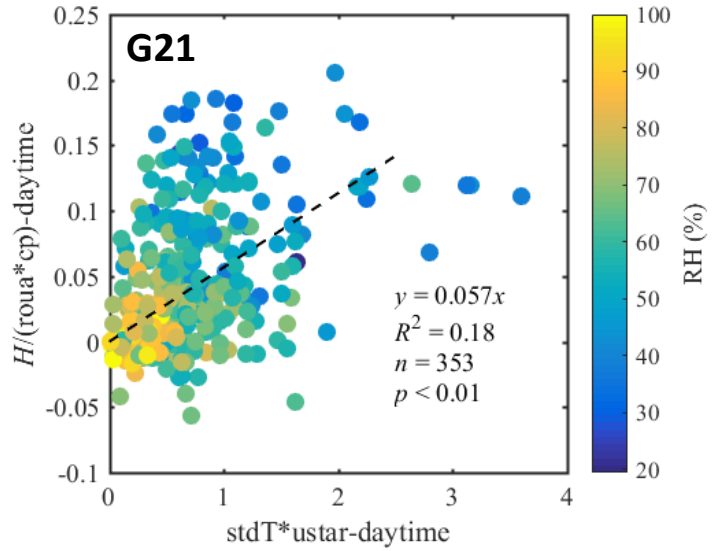
- Estimate the 24h mean LE:

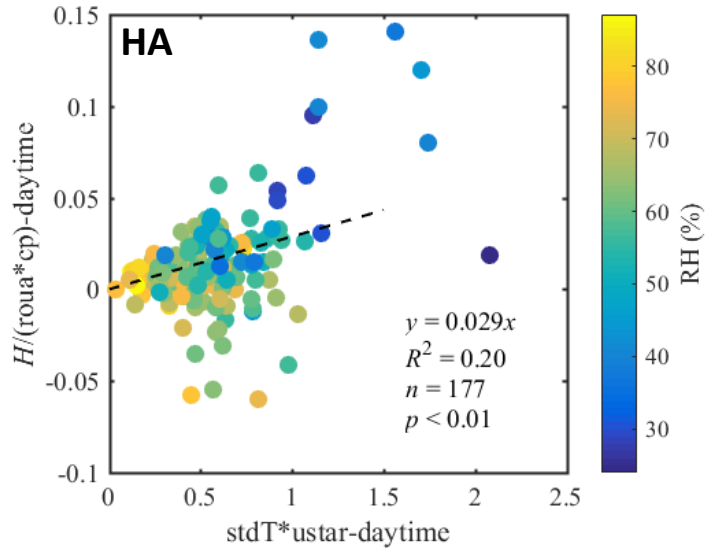
$$LE\_cal = R_n\_24 - H\_24$$

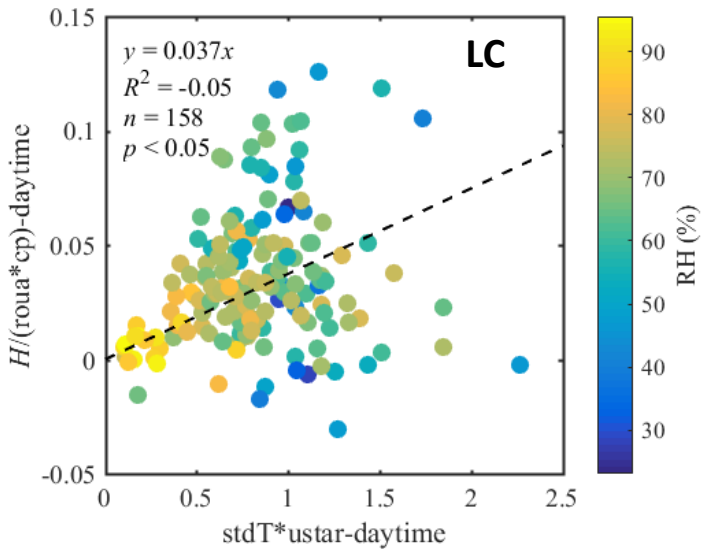
Regression of daytime $H/(\rho_a * c_p)$ versus $\sigma_T * u_*$

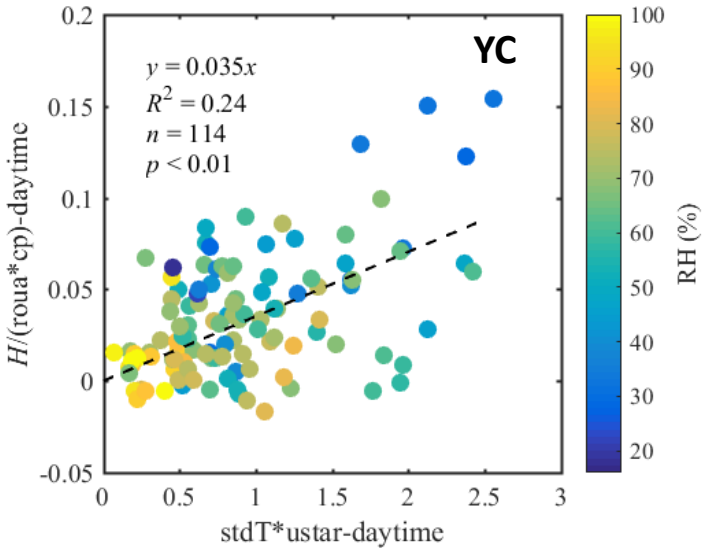


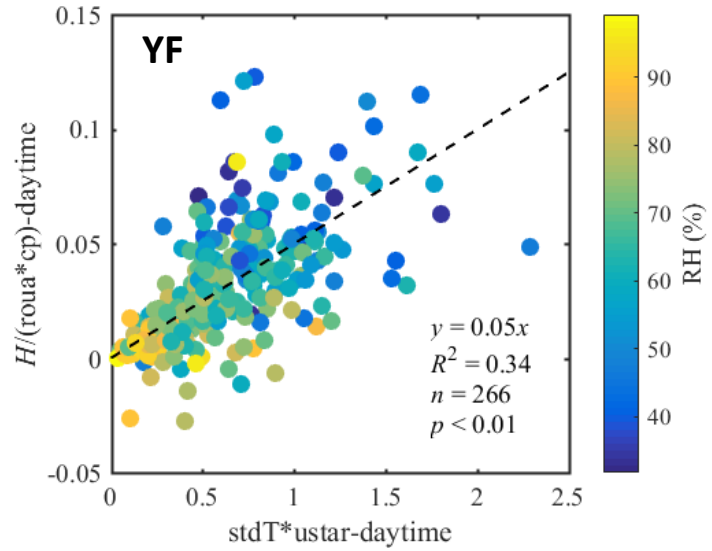
Regression of daytime $H/(\rho_a * c_p)$ versus $\sigma_T * u_*$



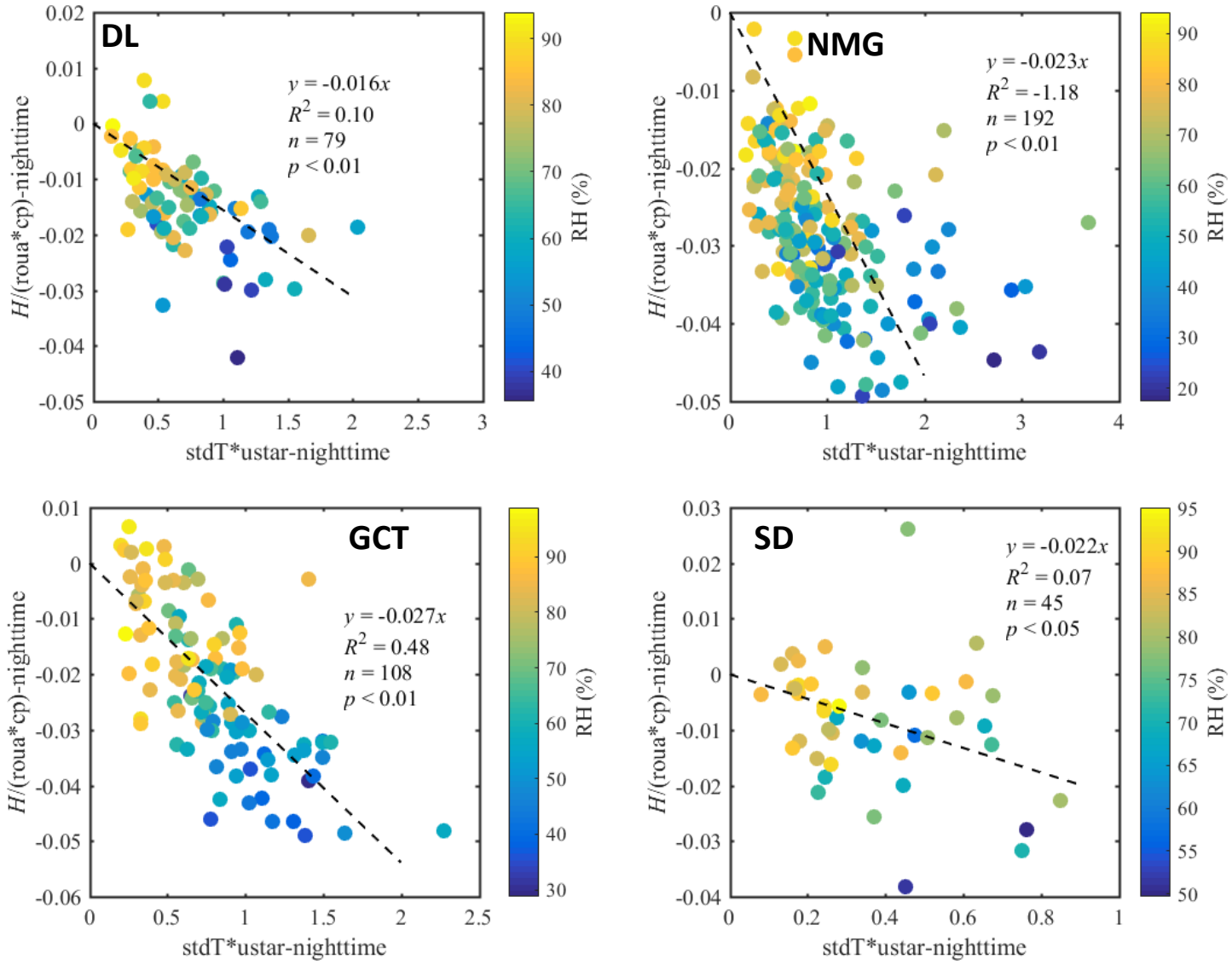




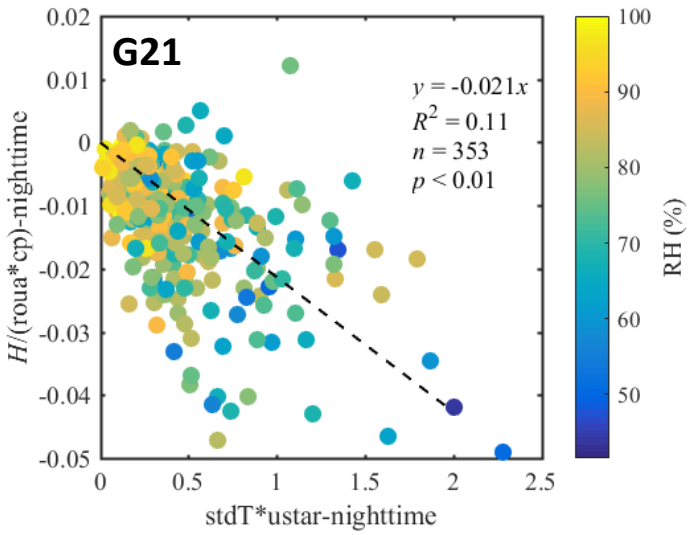


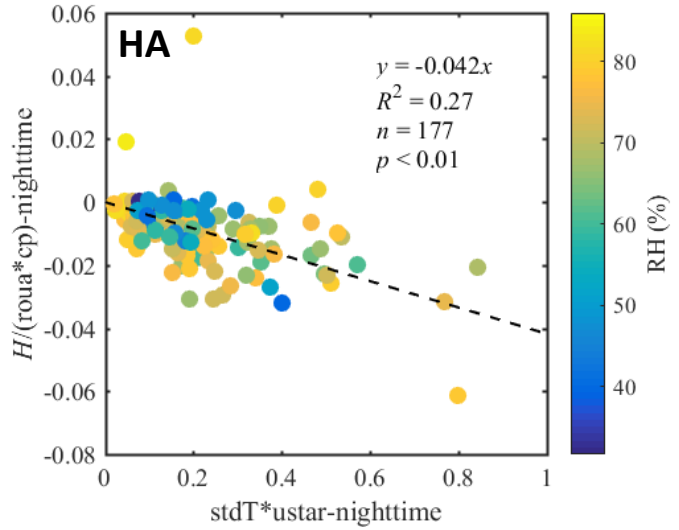


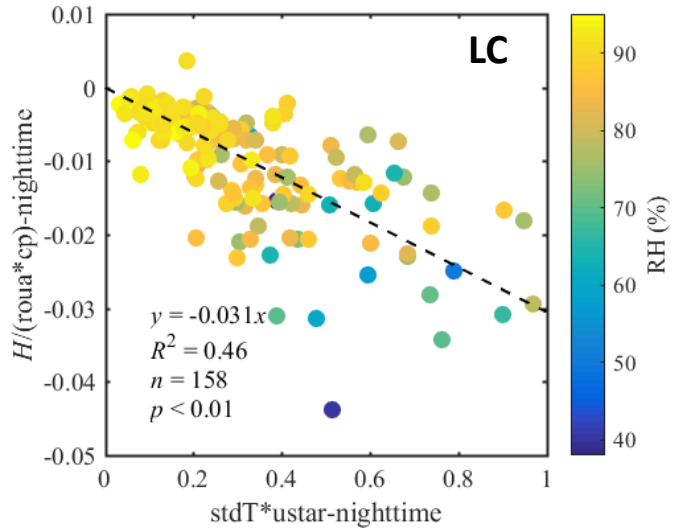
Regression of nighttime $H/(\rho_a * c_p)$ versus $\sigma_T * u_*$

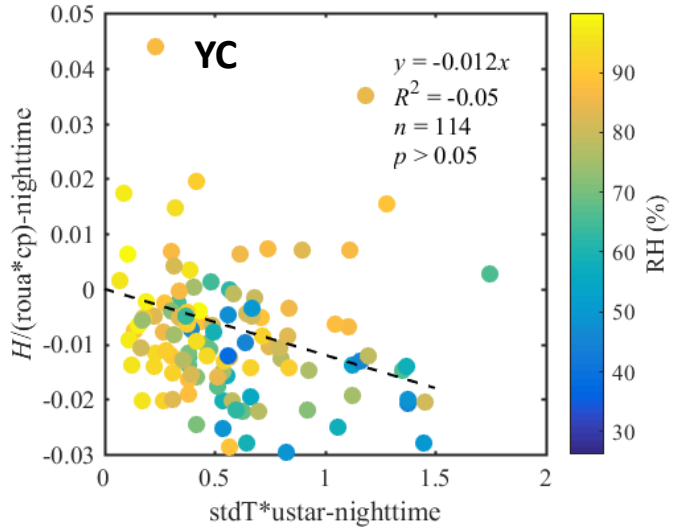


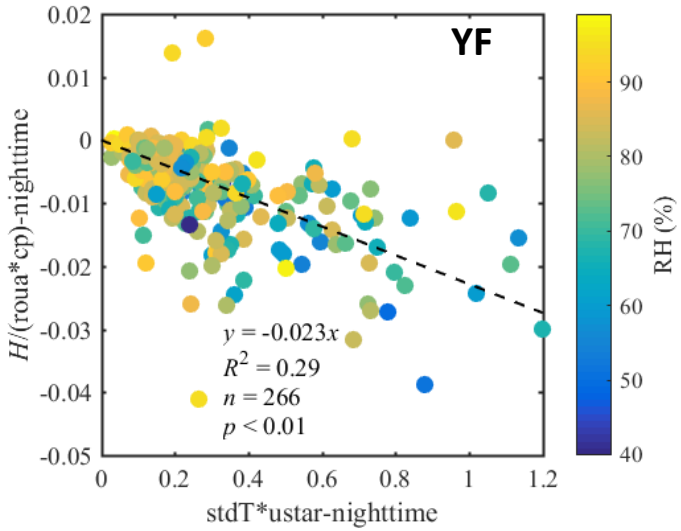
Regression of nighttime $H/(\rho_a * c_p)$ versus $\sigma_T * u_*$





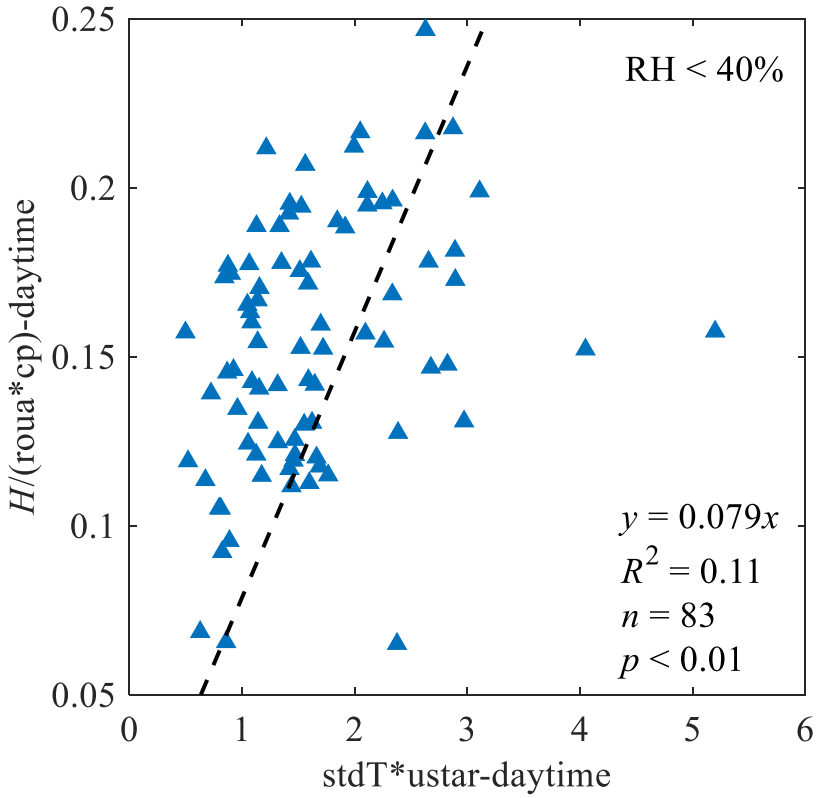


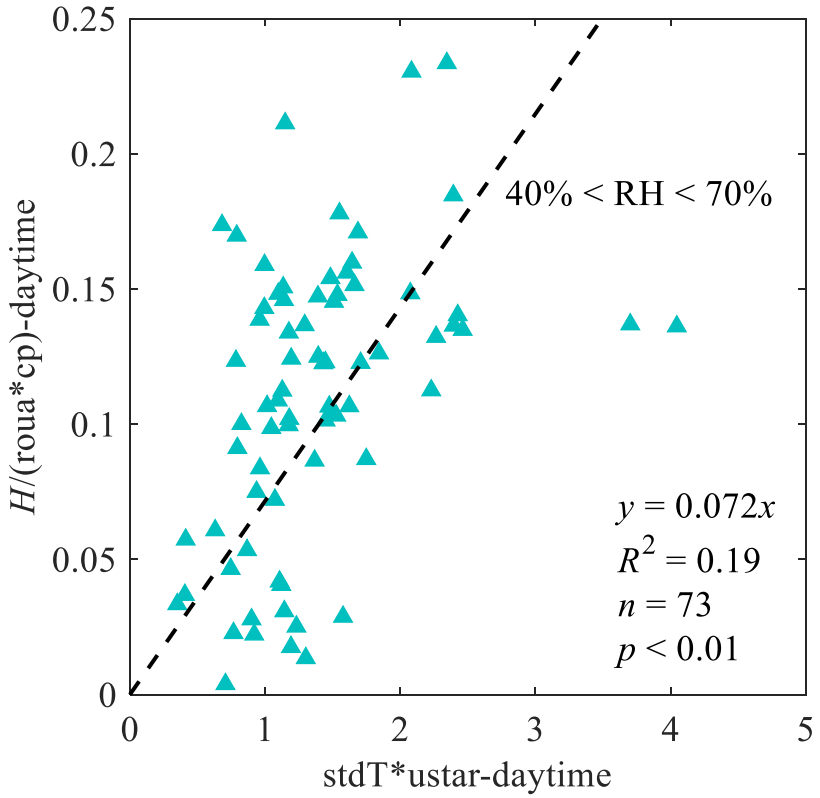


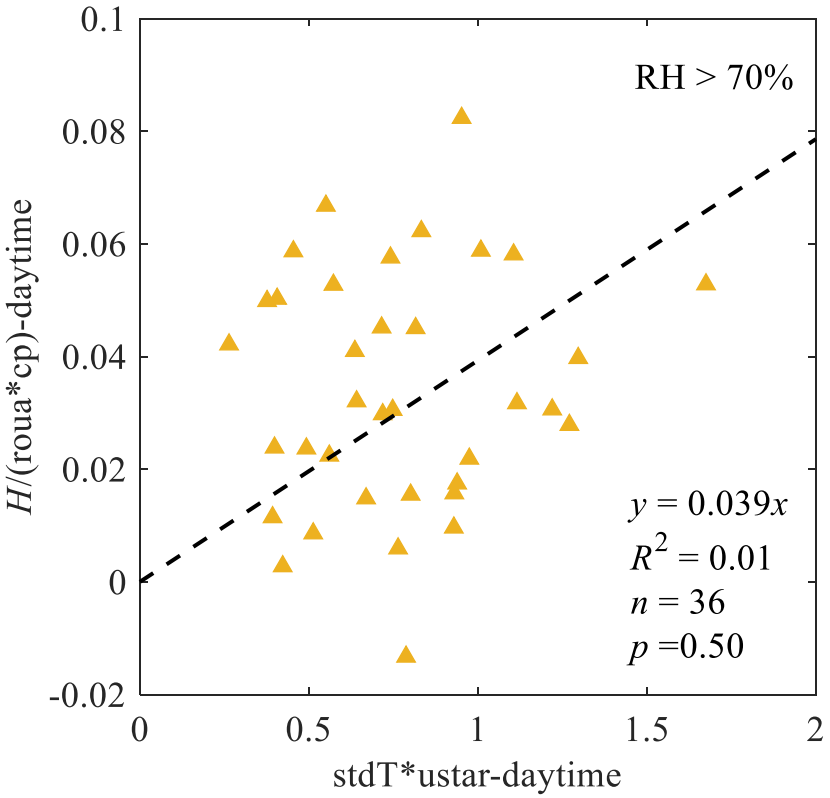


The effect of RH on the regression

NMG site:

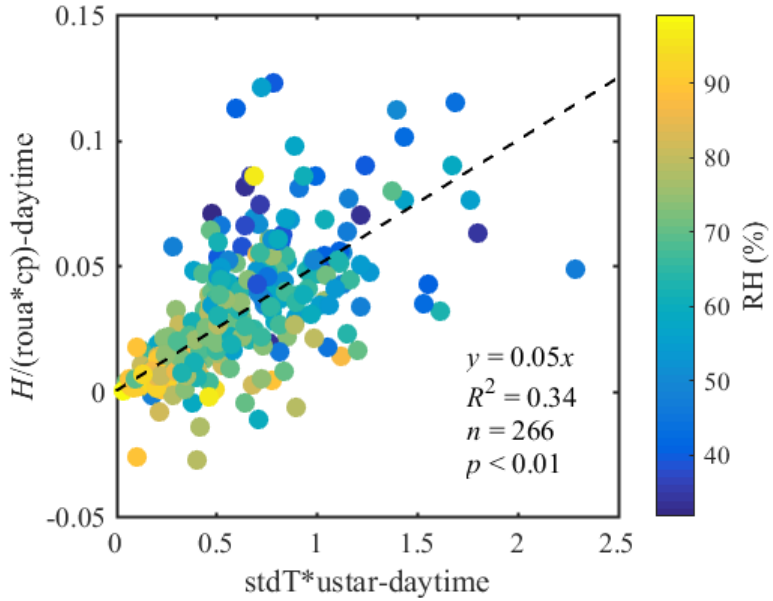


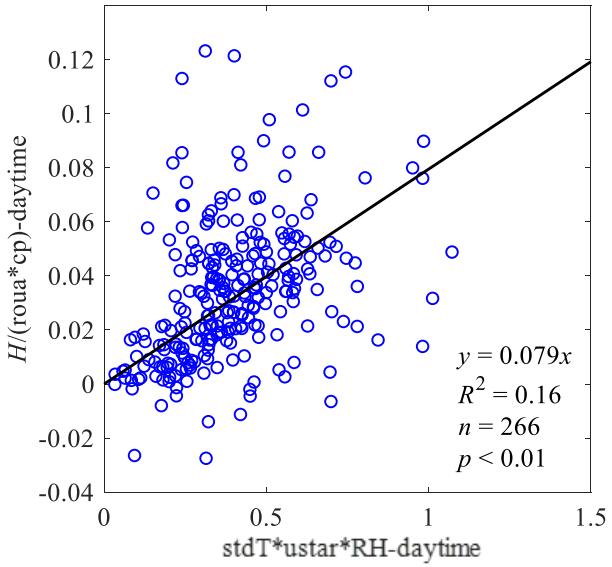


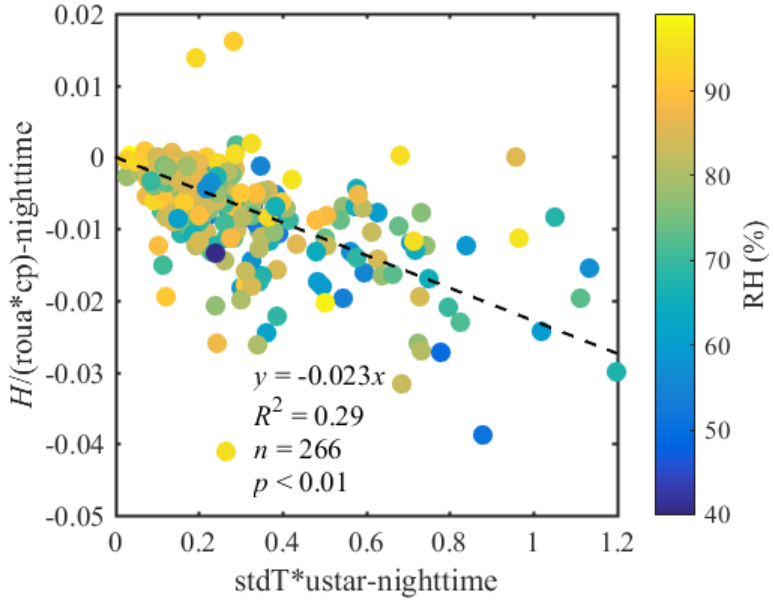


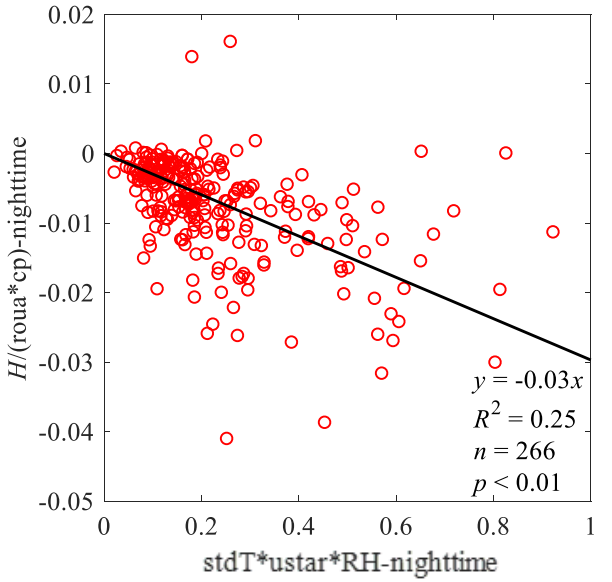
The effect of RH on the regression

YF site:

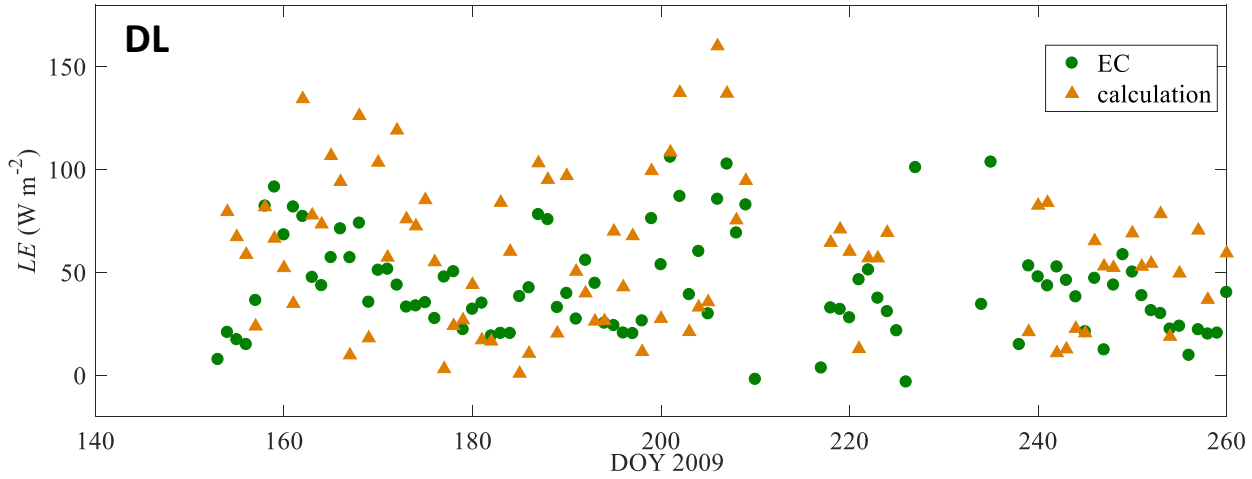


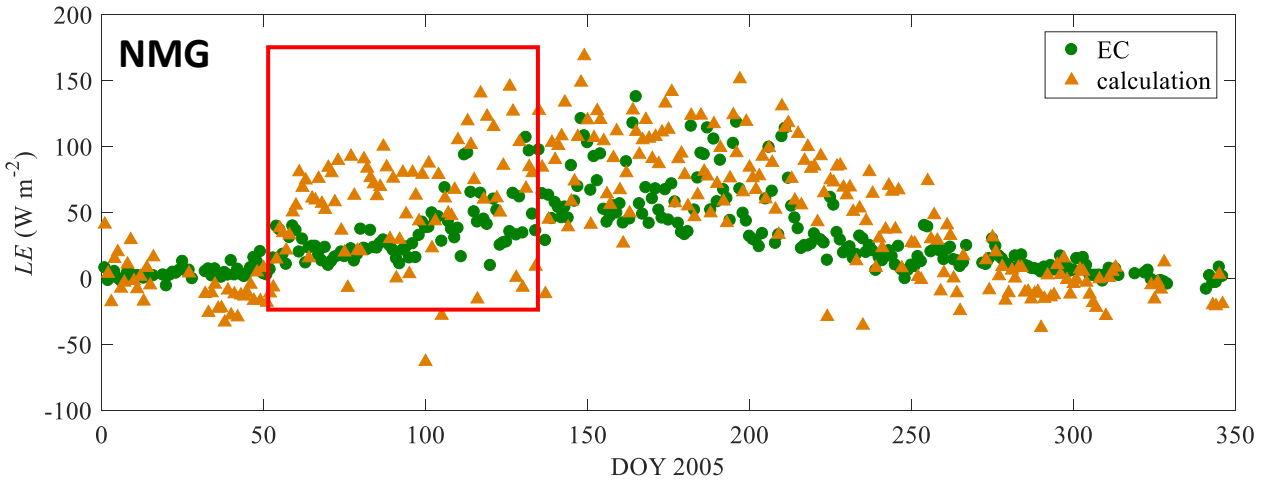


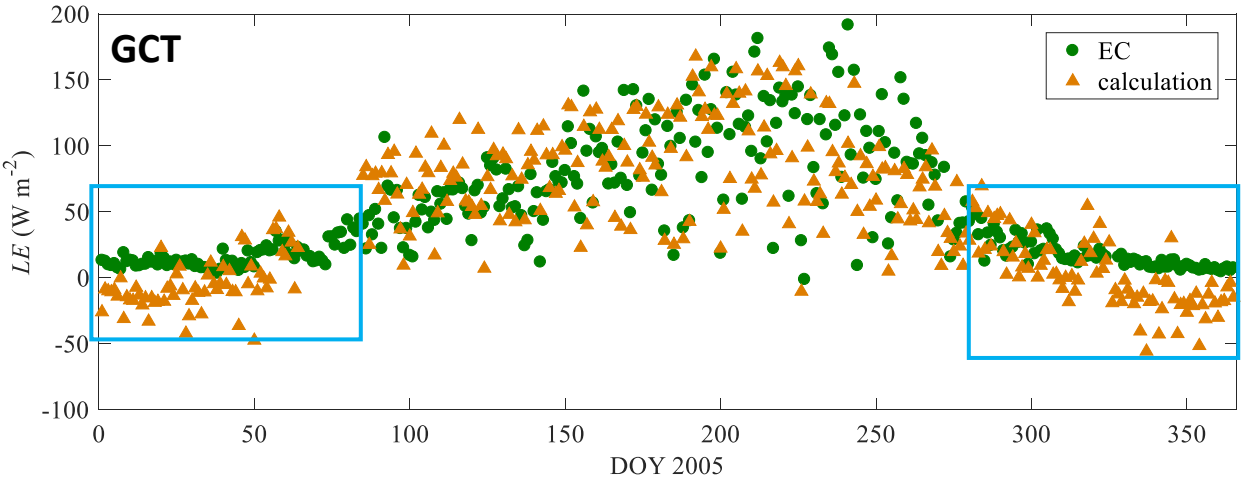


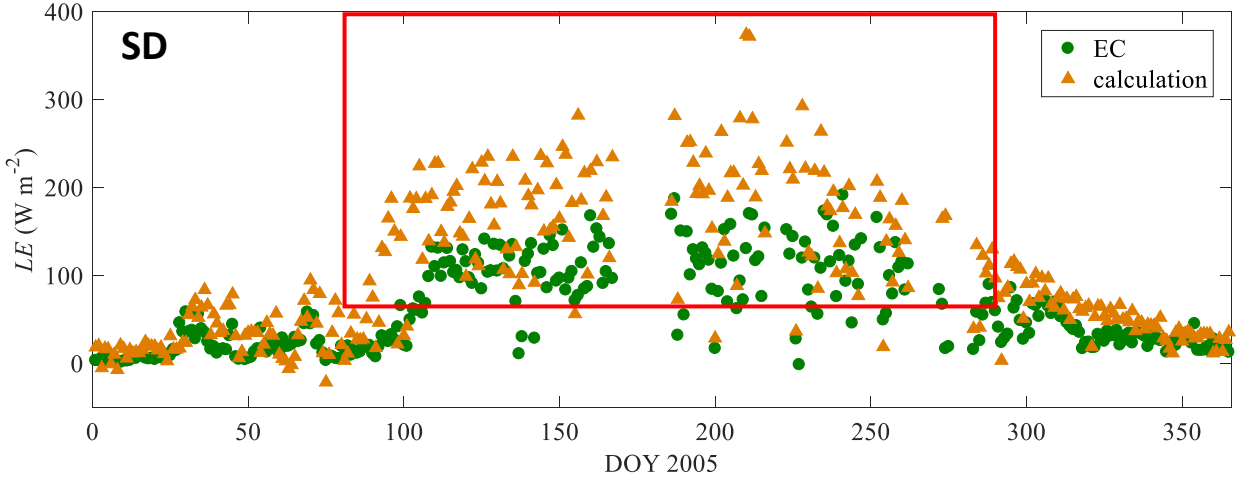


Time series of *LE*

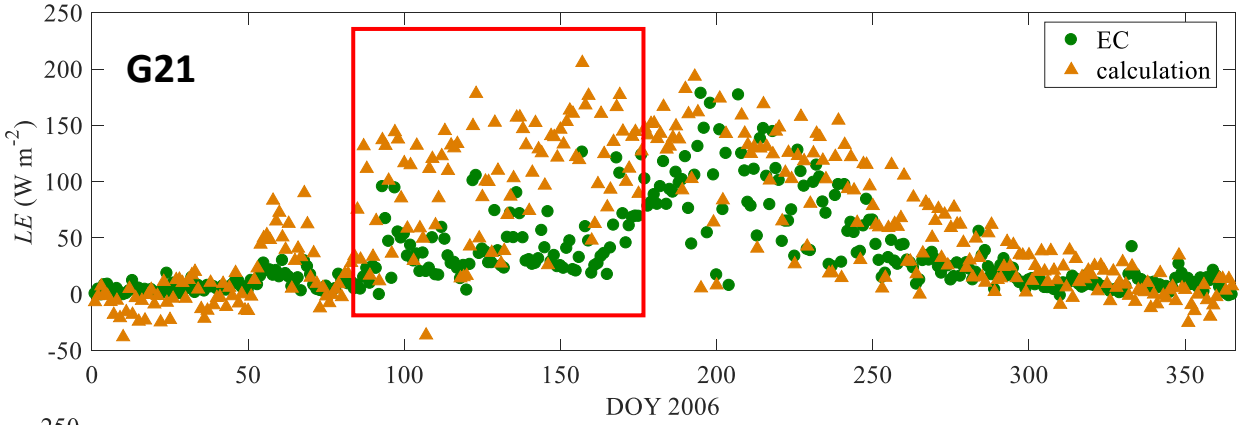


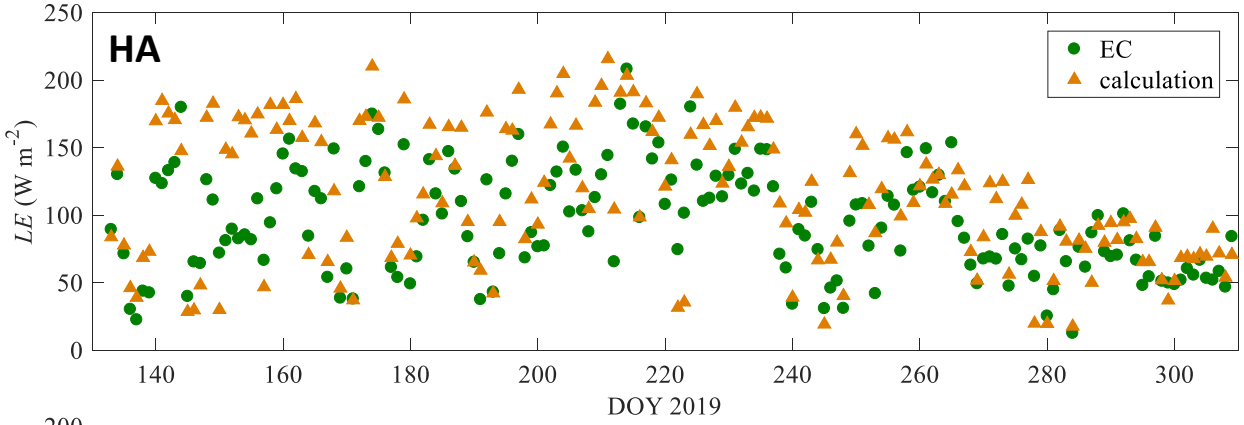


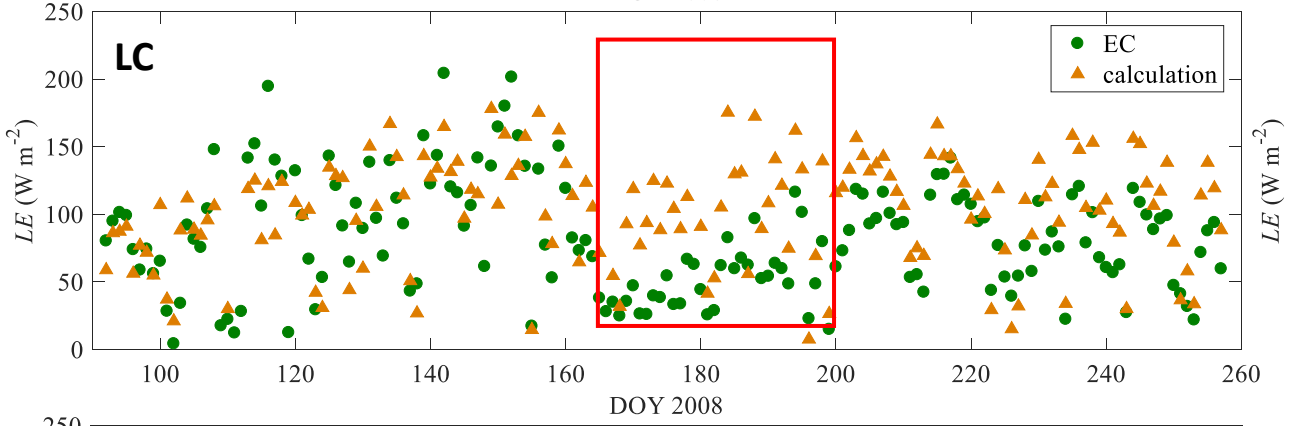


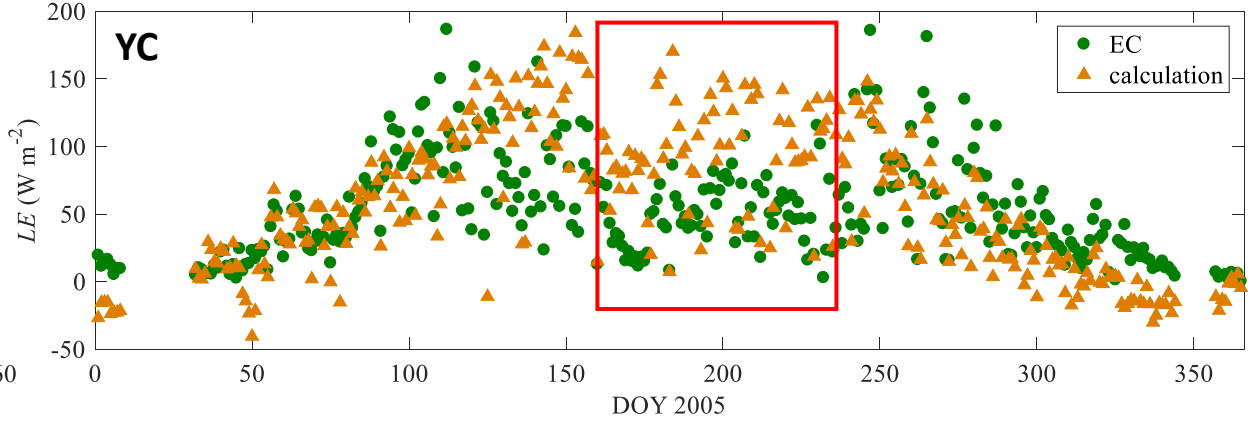


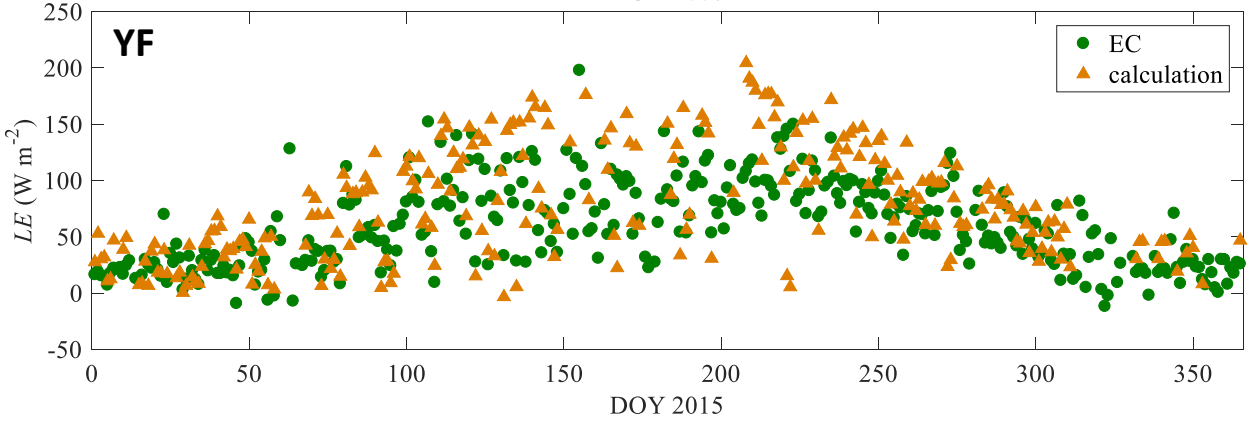
Time series of *LE*



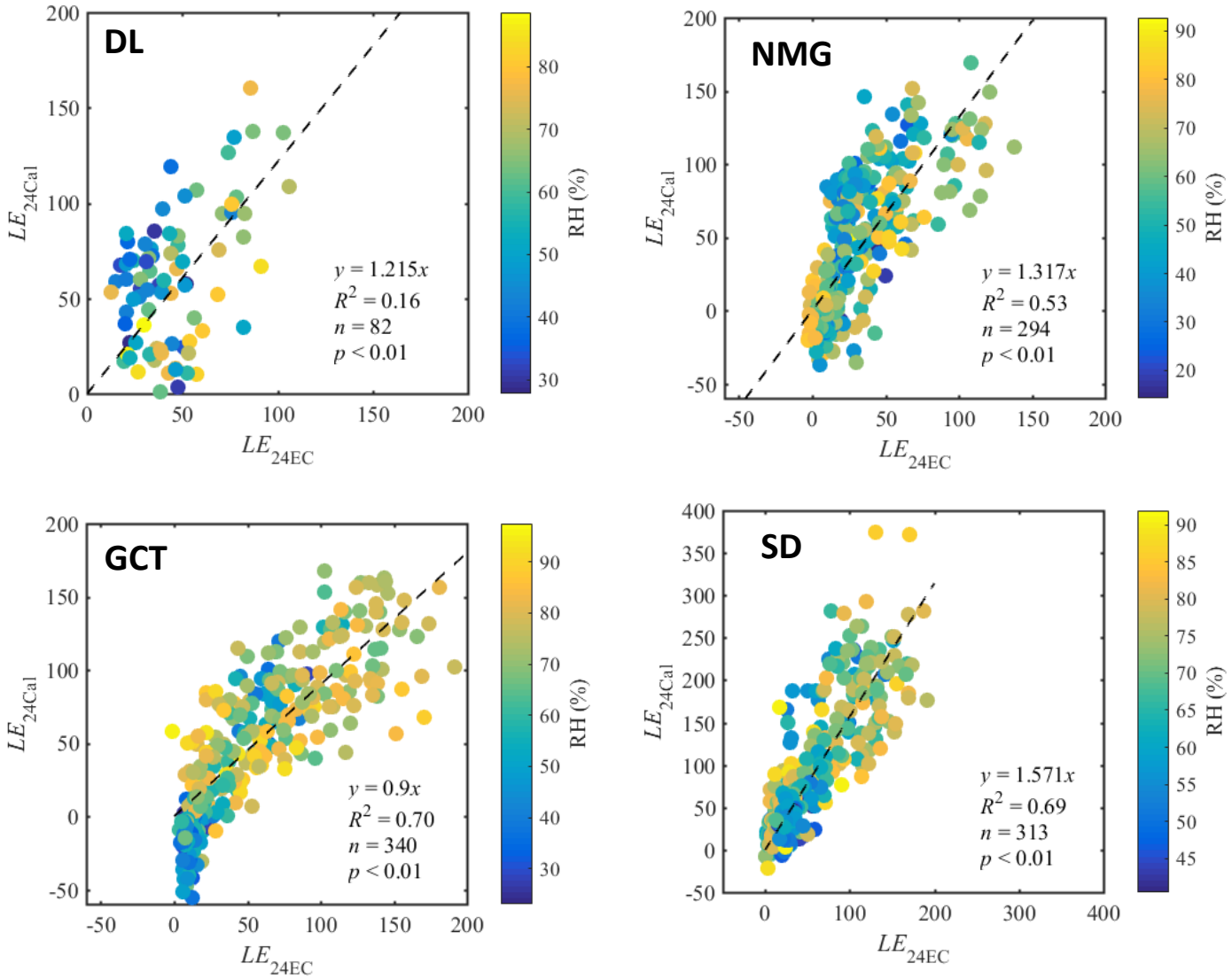








LE_{EC} versus LE_{cal}



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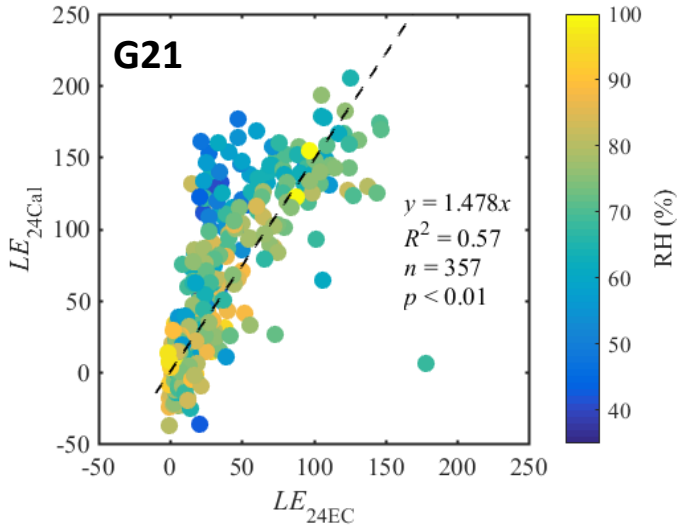

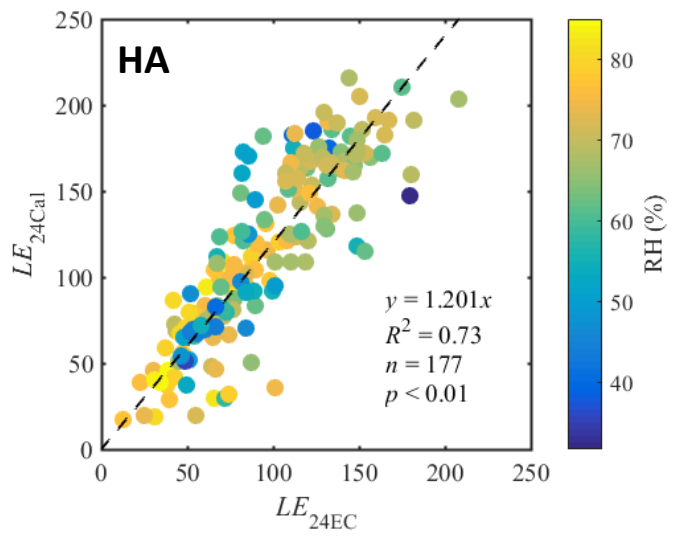

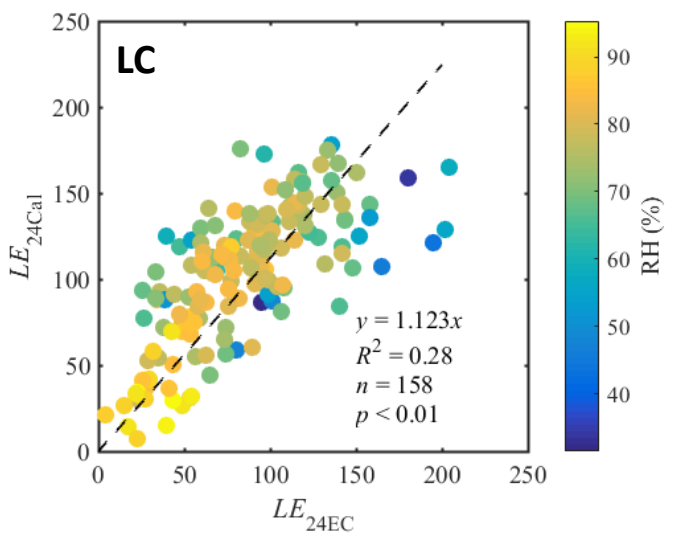

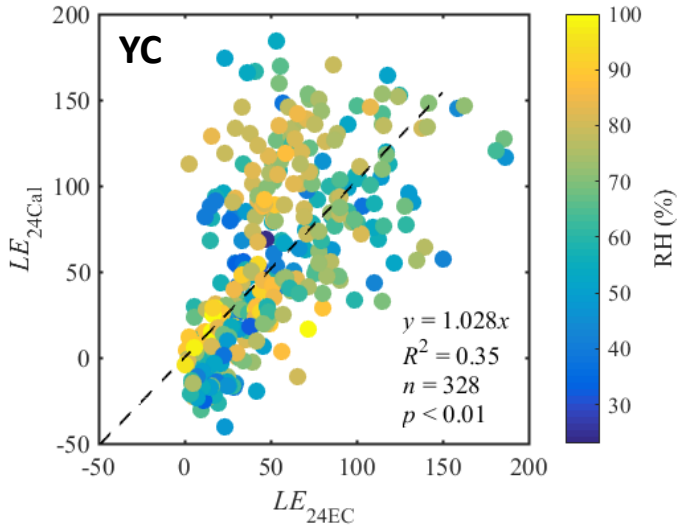

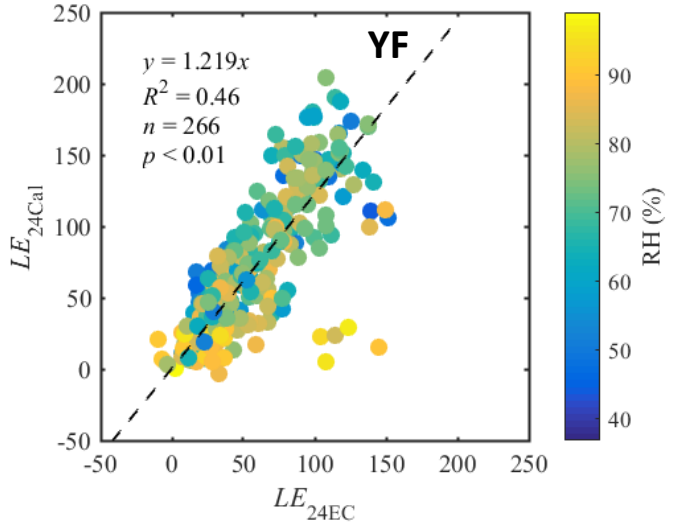

Summary

- Regression of $H/(\rho_a * c_p)$ versus $\sigma_T * u_*$ in nighttime was better than that in daytime.
- The improvement of results was not obvious when we took RH into consideration.
- Overall, the calculated *LE* were 27% higher than the observations.