Yale-NUIST Center on Atmospheric Environment

Comparison of CO_2 flux measured with open-path and closed-path eddy covariance system in a boreal forest

XIE Yanhong

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OUTLINE

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- Methods
- Results & discussions
- Conclusions
- Future work

1. BACKGROUND

The eddy covariance (EC) technique is widely used for measuring CO_2 exchanges between terrestrial ecosystems and the atmosphere.

In recent years, a growing body of data shows substantial differences between open-path and closed-path measurements, especially in the form of apparent and unreasonable off-season CO_2 uptake with open-path system *(Järvi et al., 2009; Wang et al., 2016)*.

There are three main explanations for the apparent negative flux: self-heating effect, insufficient compensation for spectroscopic effects and biases in CO_2 density with open-path system.

OBJECTIVES

To compare the fluxes, including sensible heat flux(*H*), latent heat flux(*LE*) and CO_2 flux(F_c) measured with open-path and closed-path system;

To investigate the bias errors of CO_2 flux measured with open-path and closed-path system in relation to *H*, solar radiation and biases in the CO_2 concentration in cold season.

2. METHODS

Site description:

Tuczno Forest District in north-western part of Poland (53.19^{o}N, 16.10^{o}E)

Eddy covariance measurements:

An open-path infrared gas analyzer (model LI-7500) and a closed-path infrared gas analyzer (model LI-7200) were on the same level and hooked up to a three-dimensional non-orthogonal sonic anemometer (model CSAT3), 38m above ground.

Time period:

2011/10/10 – 2013/7/2

Data post-processing

The raw data were processed by EddyPro software (LI-COR Inc.). Corrections made during computation included double rotation, WPL correction, spectral attenuations.

Quality control:

- ✓ All fluxes with quality flags equaled to “2”(bad data) were eliminated.
- ✓ CO_2 flux and CO_2 concentration data were eliminated during precipitation(only for open-path data).
- ✓ Threshold value control
- ✓ Five-point moving-average method
- ✓ Negative CO_2 fluxes measured at nighttime were removed.
- ✓ Nighttime CO_2 flux were removed when $u_* < 0.2$ m s^{-1}.

Theoretical consideration

$$F_{c,a} = \overline{w'\rho'_c} + \frac{\overline{\rho_c}}{\overline{T}C_p\overline{\rho_a}}\left(1 + \frac{\overline{\rho_v}M_a}{\overline{\rho_a}M_v}\right)H + \frac{\overline{\rho_c}M_a}{\overline{\rho_a}M_v}E_0$$

$$F_c = \overline{w'\rho'_c} + \frac{\overline{\rho_c}}{\overline{T}C_p\overline{\rho_a}}\left(1 + \frac{\overline{\rho_v}M_a}{\overline{\rho_a}M_v}\right)H_{real} + \frac{\overline{\rho_c}M_a}{\overline{\rho_a}M_v}E_0$$

$$H = b'H_{real} - a'$$

$$F_{c,a} = F_c + \frac{\overline{\rho_c}}{\overline{T}C_p\overline{\rho_a}}\left(1 + \frac{\overline{\rho_v}M_a}{\overline{\rho_a}M_v}\right)\left[\left(1 - \frac{1}{b'}\right)H - \frac{a'}{b'}\right]$$

$$= F_c + bH + a,$$

$F_{c,a}$: CO_2 flux after density correction; F_c: the true CO_2 flux

(Webb et al., 1980; Burba et al., 2008;Wang et al., 2017)

3.1 Open-path system vs closed-path system

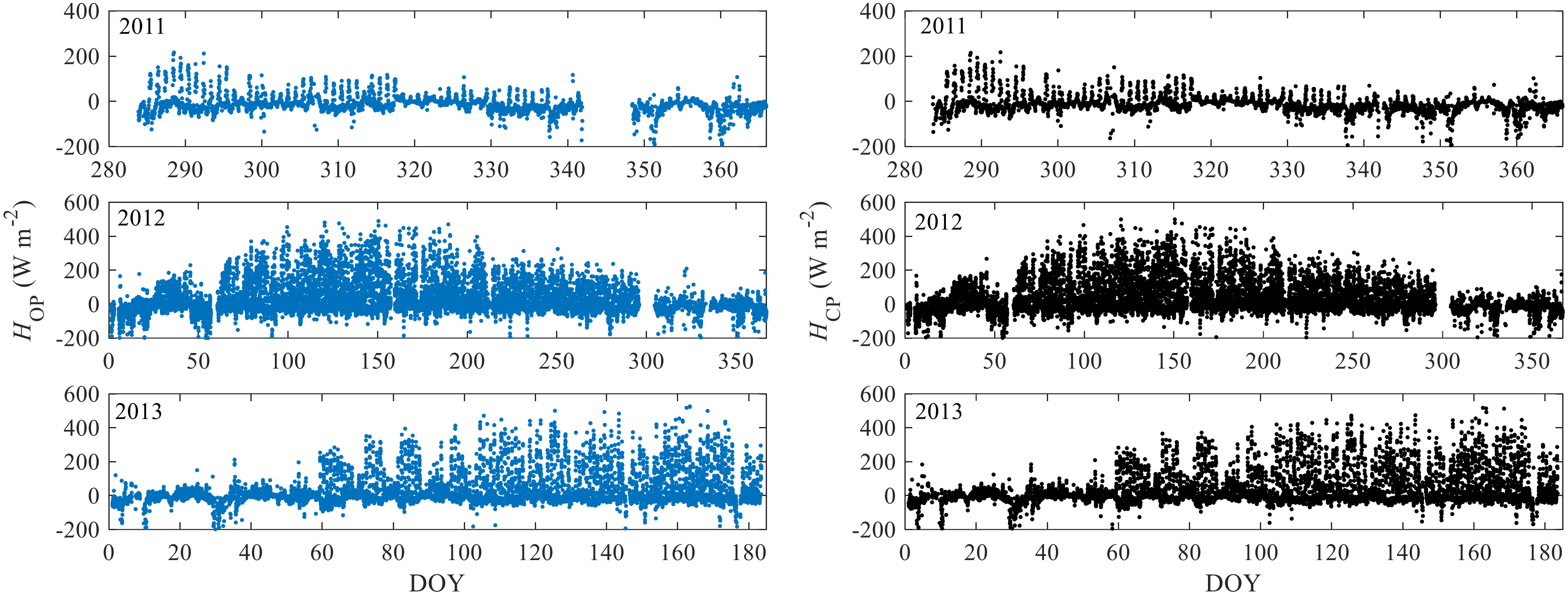


Fig.1 Time series of sensible heat flux(H)
measured with open-path and closed-path system

3.1 Open-path system vs closed-path system

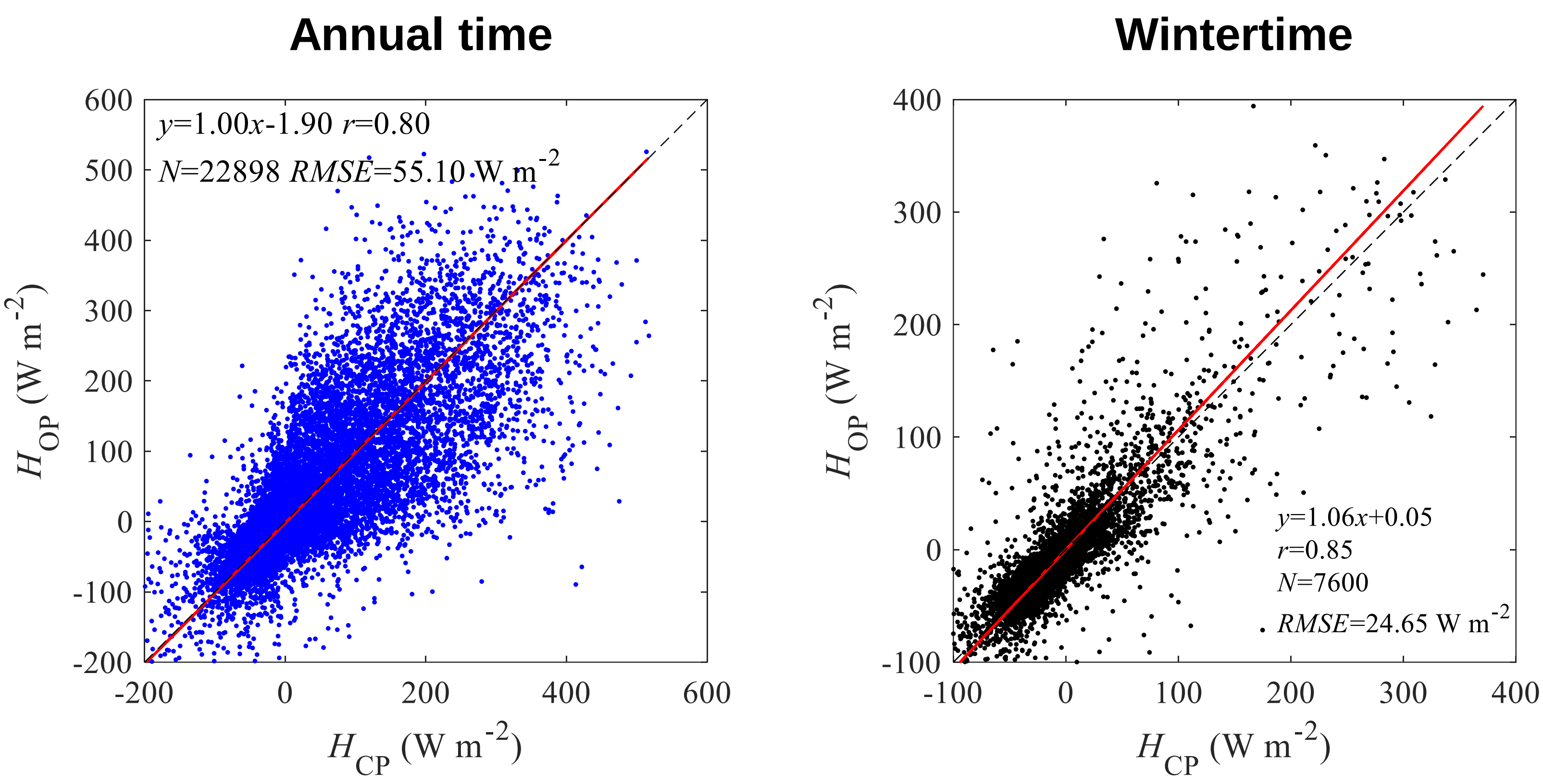


Fig.2 Comparison of *H* measured with open-path and closed-path system

3.1 Open-path system vs closed-path system

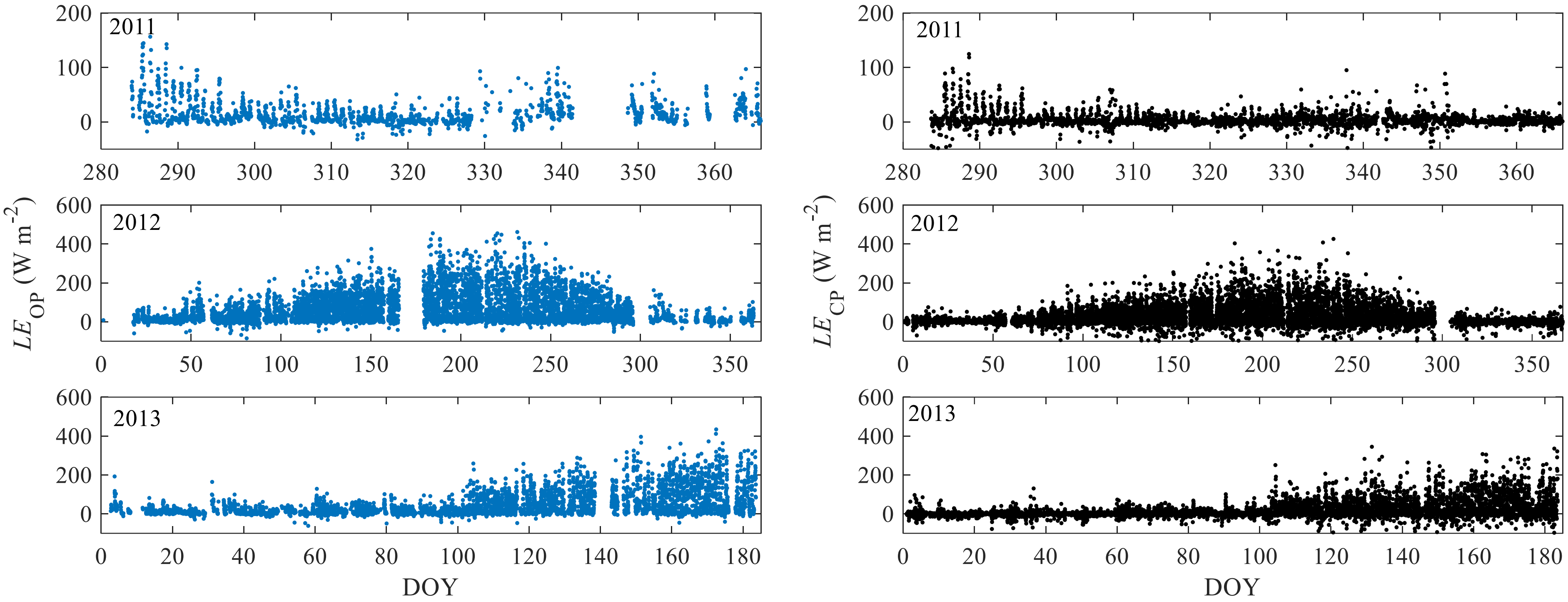


Fig.3 Time series of latent heat flux(*LE*)
measured with open-path and closed-path system

3.1 Open-path system vs closed-path system

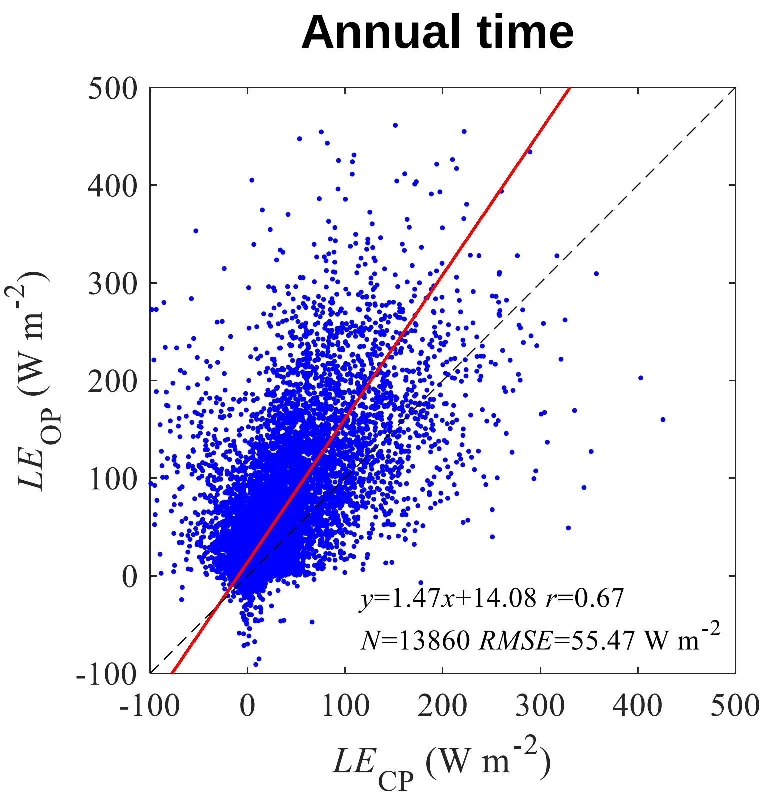


Fig.2 Comparison of *LE* measured with open-path and closed-path system

3.1 Open-path system vs closed-path system

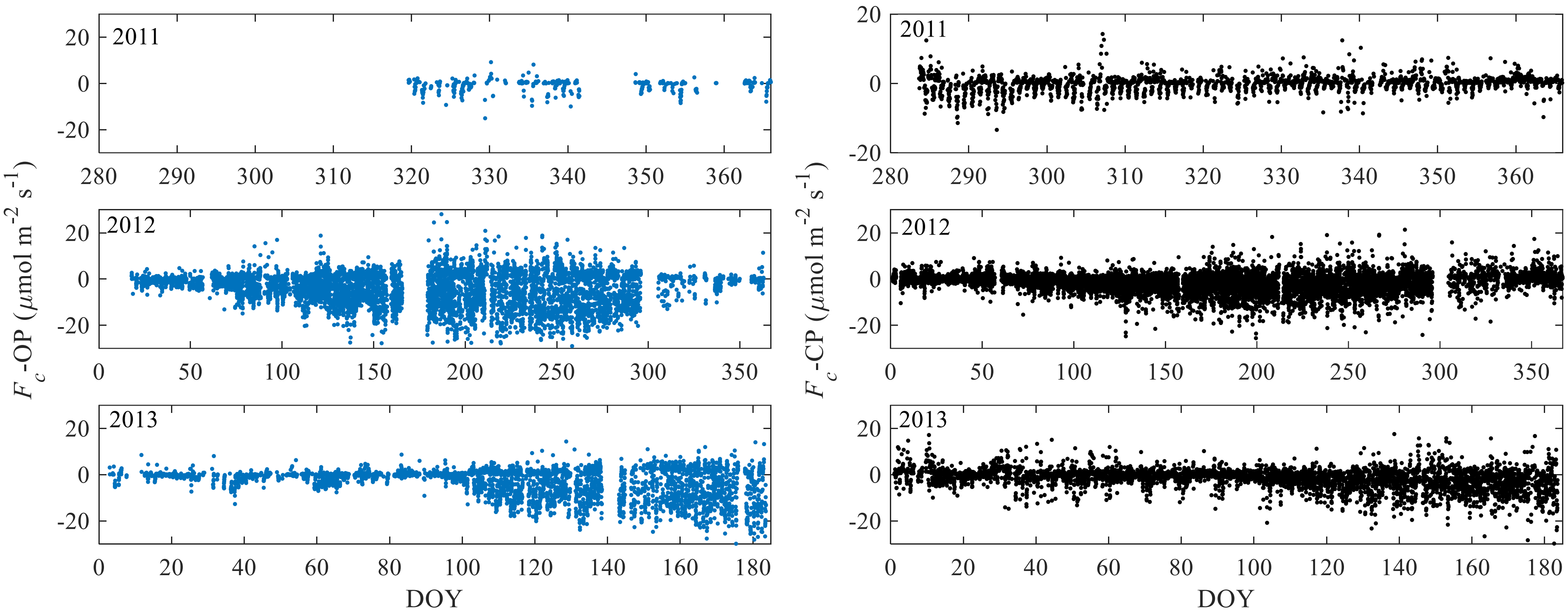


Fig.5 Time series of CO_2 flux(F_c)
measured with open-path and closed-path system

3.1 Open-path system vs closed-path system

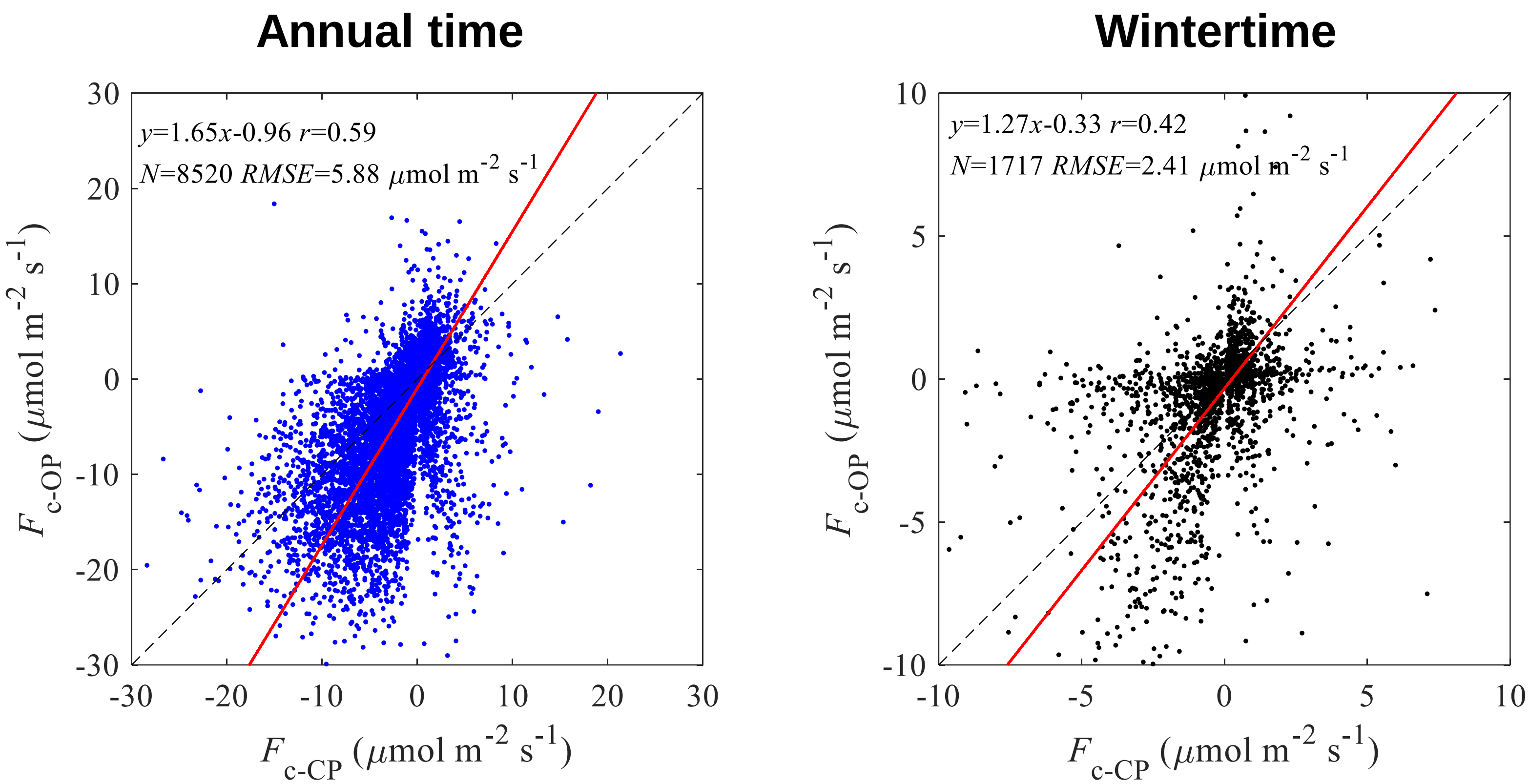


Fig.6 Comparison of F_c measured with open-path and closed-path system

3.1 Open-path system vs closed-path system

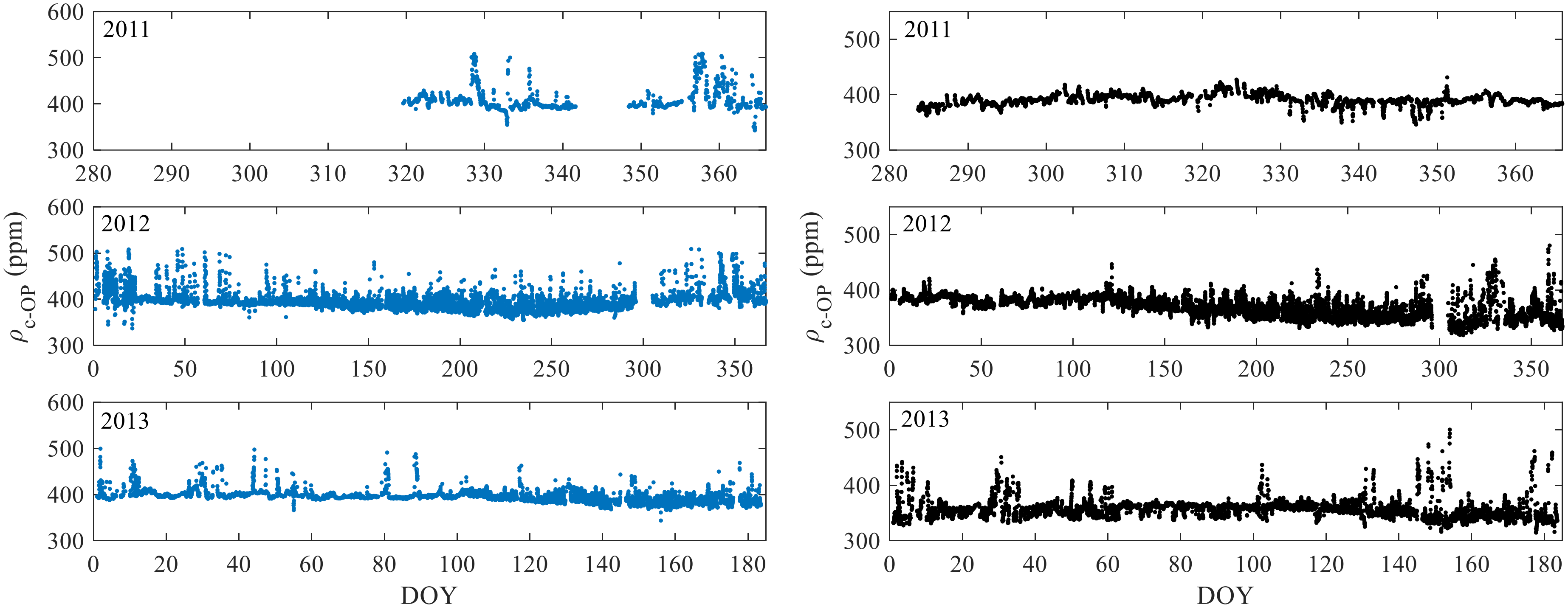
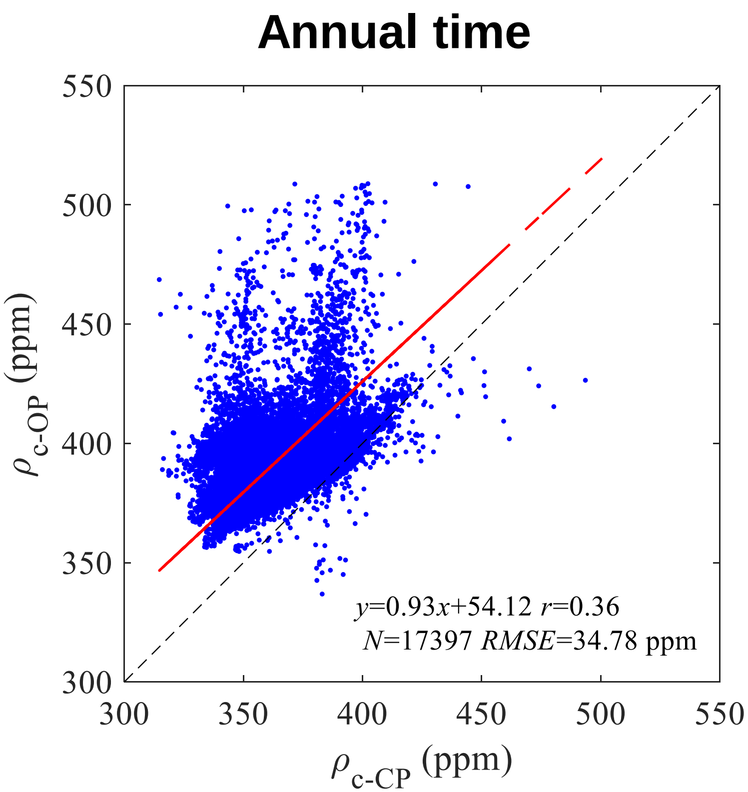


Fig.7 Time series of CO_2 mixing ratio(ρ_c)
measured with open-path and closed-path system

3.1 Open-path system vs closed-path system



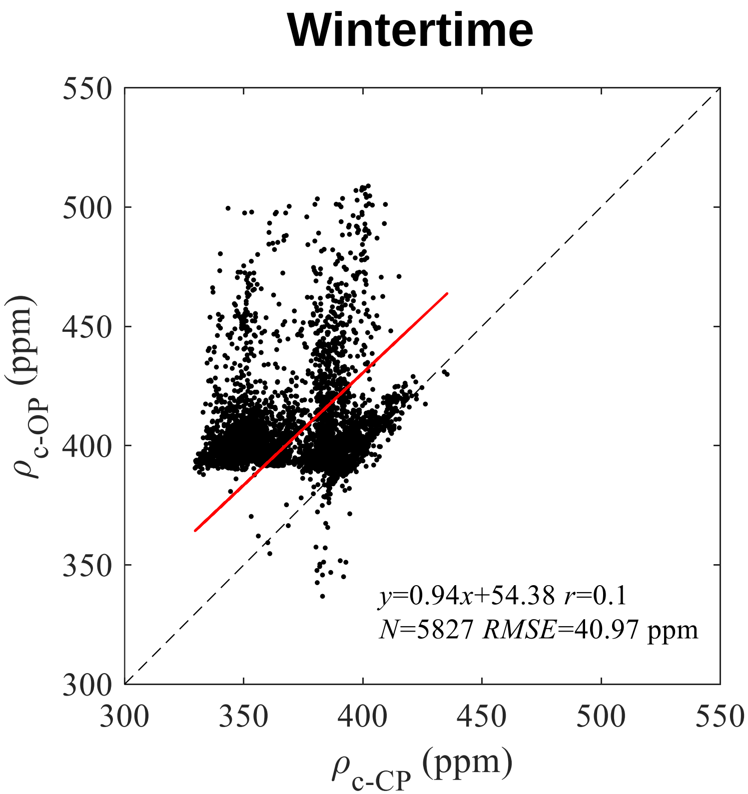
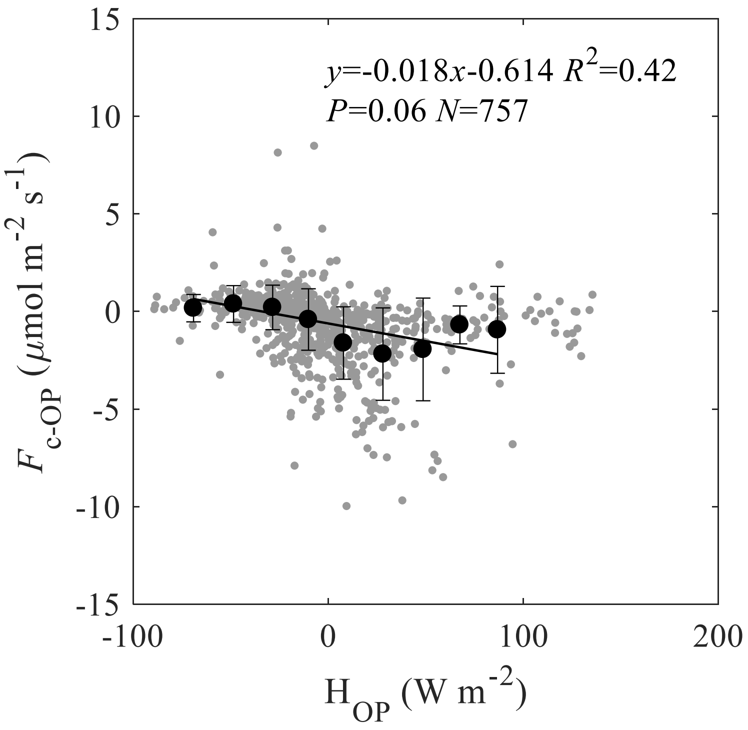


Fig.8 Comparison of ρ_c measured with open-path and closed-path system

3.2 Impact factors analysis



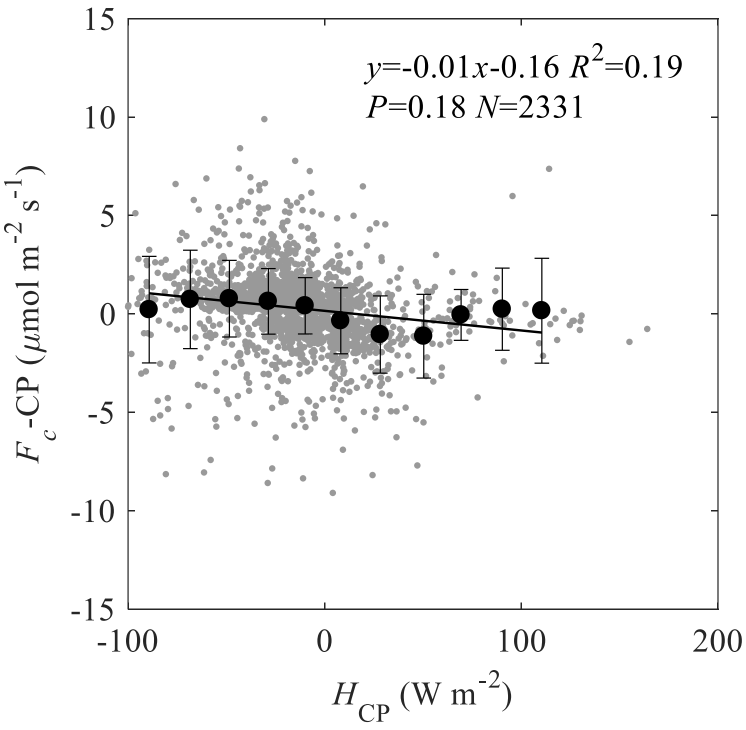


Fig. 9 Relationship between wintertime F_c and H.

3.2 Impact factors analysis

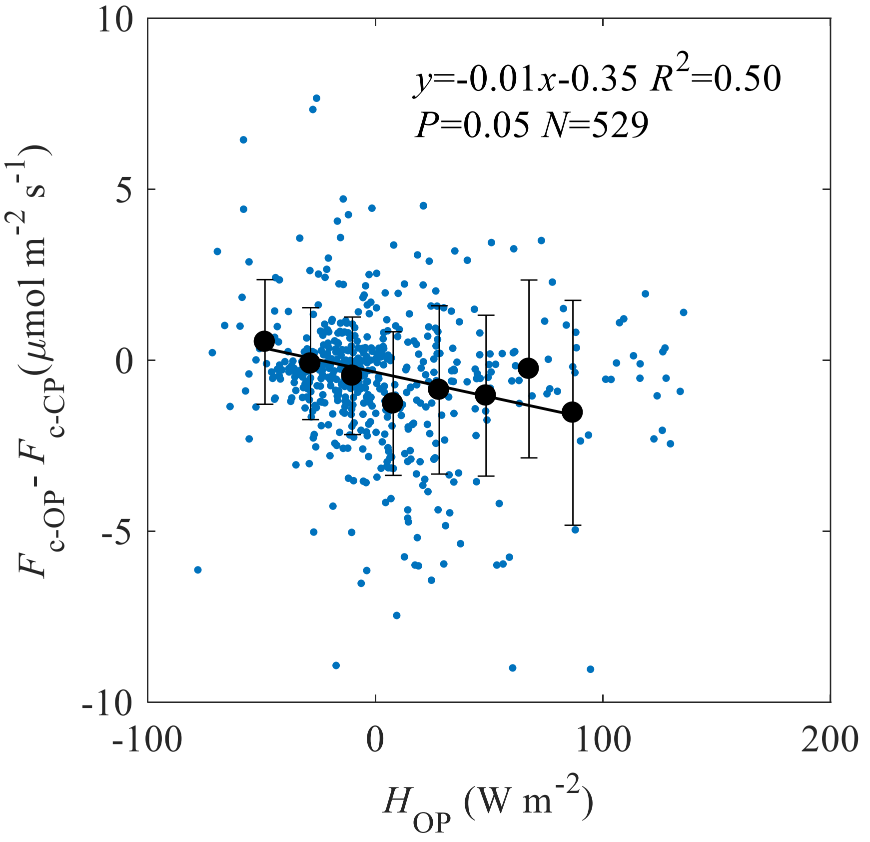


Fig. 10 Relationship between wintertime ΔF_c and H.

3.2 Impact factors analysis

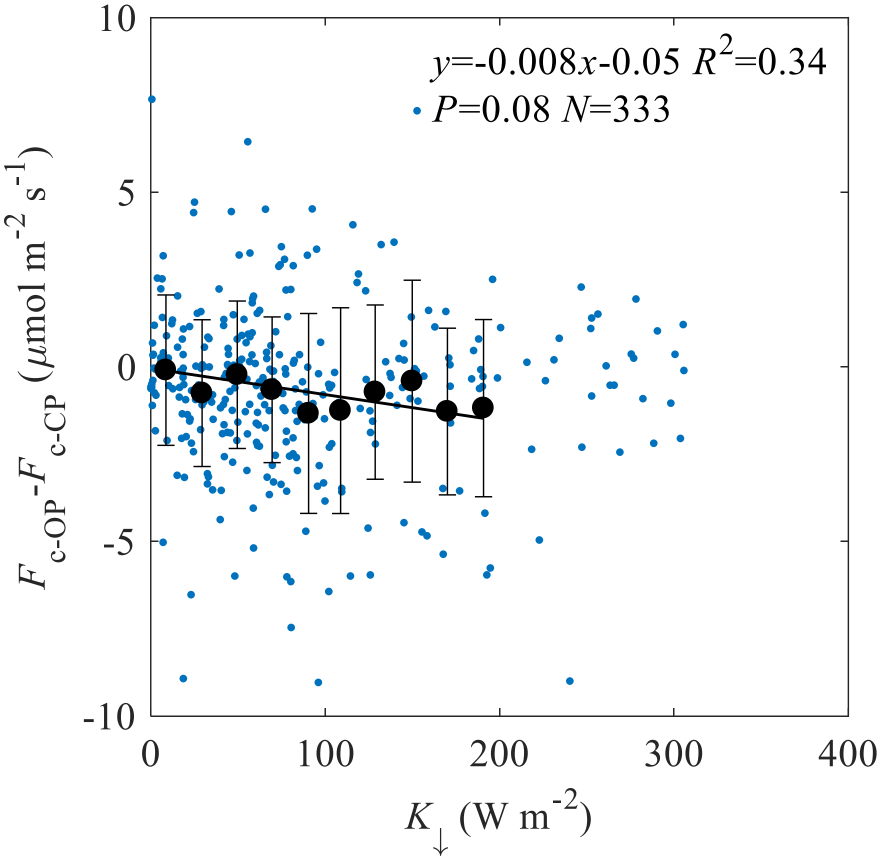


Fig. 11 Relationship between wintertime ΔF_c and incoming shortwave radiation($K_\downarrow$) .

3.2 Impact factors analysis

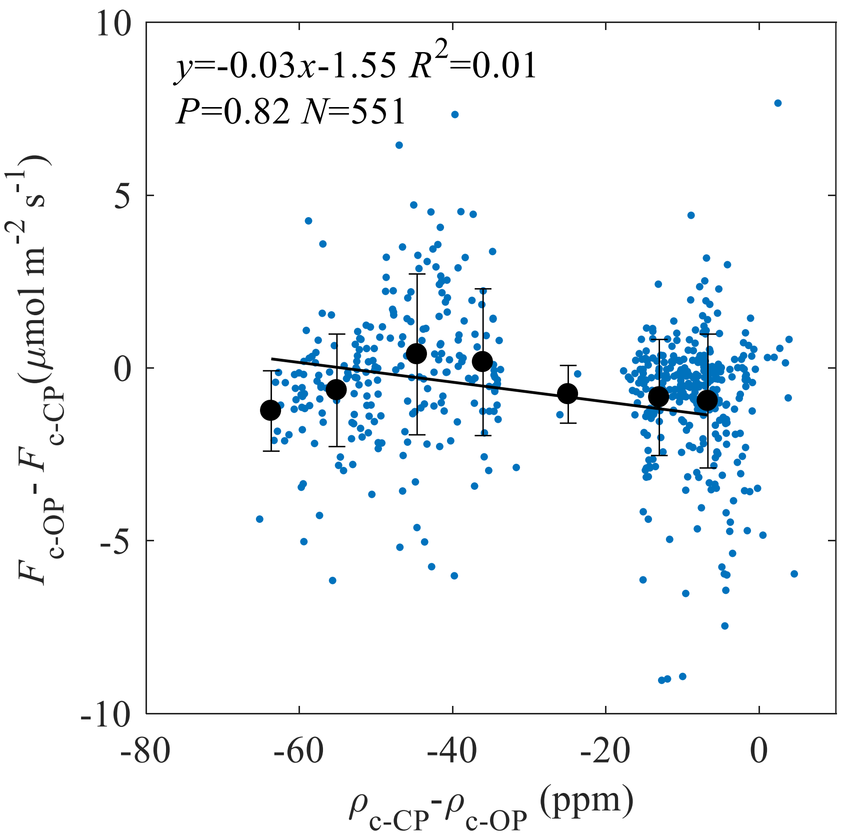


Fig. 12 Relationship between wintertime ΔF_c and biases in CO_2 concentration.

3. RESULTS & DISCUSSIONS

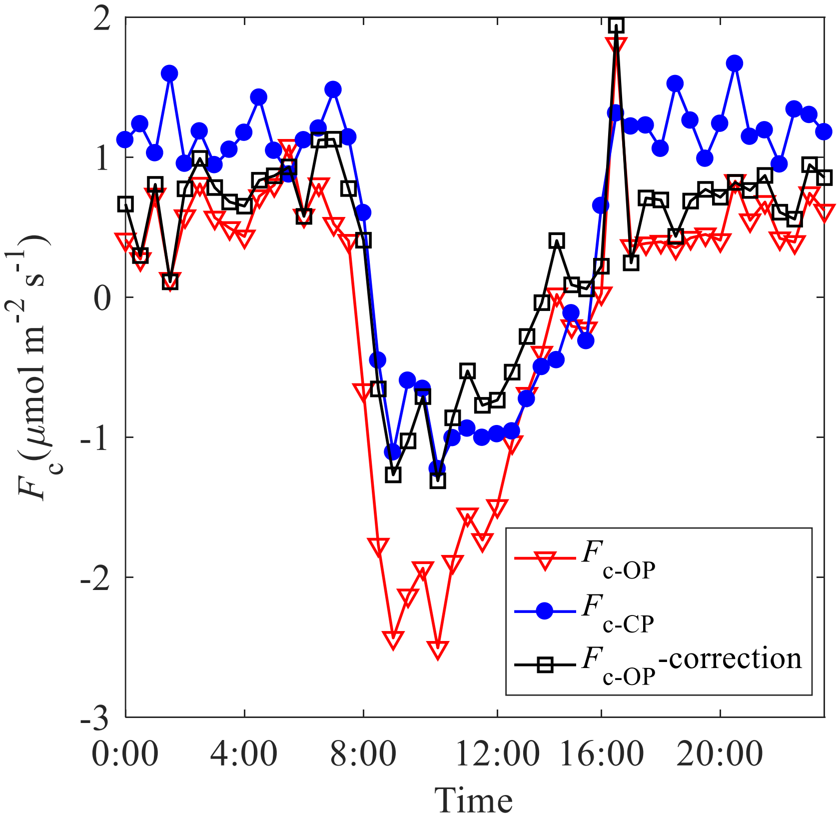


Fig.13 Diurnal composition of F_c.

$$F_c = F_{c,a} - bH - a$$

$F_{c\text{-OP}}$-correction$=F_{c\text{-OP}}-(-0.018)*H-(-0.614)$

$F_{c\text{-OP}}$: -0.05 μmol m^{-2} s^{-1}

$F_{c\text{-CP}}$: 0.57 μmol m^{-2} s^{-1}

$F_{c\text{-OP}}$-correction: 0.33 μmol m^{-2} s^{-1}

4. CONCLUSIONS

Fluxes measured with open-path system were greater than that measured with closed-path system according to the slope of fitted lines, but it is the reverse for CO_2 concentration measurement.

Self-heating effect is the main cause for the bias errors of F_c between open-path and closed-path system. When using the regression parameter values that were from the fitted line of H and F_c measured with open-path system, the corrected F_c is more close to the F_c measured with closed-path system.

5. FUTURE WORK

To investigate whether similar bias errors of F_c between open-path and closed-path system exist in the warm season.

Thank you