An update on eddy-covariance methane flux measurement at Lake Taihu

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2016.5.6

Outline

- 1 Background
- 2 Material and method
- 3 Results
  - 3.1 CH_4 flux at submerged macrophyte habitat
  - 3.2 Relations to CO_2 flux
- 4 Discussion

The effect of global warming on lake CH_4 emission:

- Global warming significant accelerates CH_4 emission from aquatic ecosystem *(Yvon-Durocher et al., 2014).*

- The warming rate in lake (0.34 ^{o}C/10a) is significant higher , contributing significant amounts of CH_4 to the atmosphere *(O'Reilly et al.,2015).*

- Climate warming increases oxygen stratification and decrease water quality *(Zhang et al.,2016)*, facilitating CH_4 production in sediment.

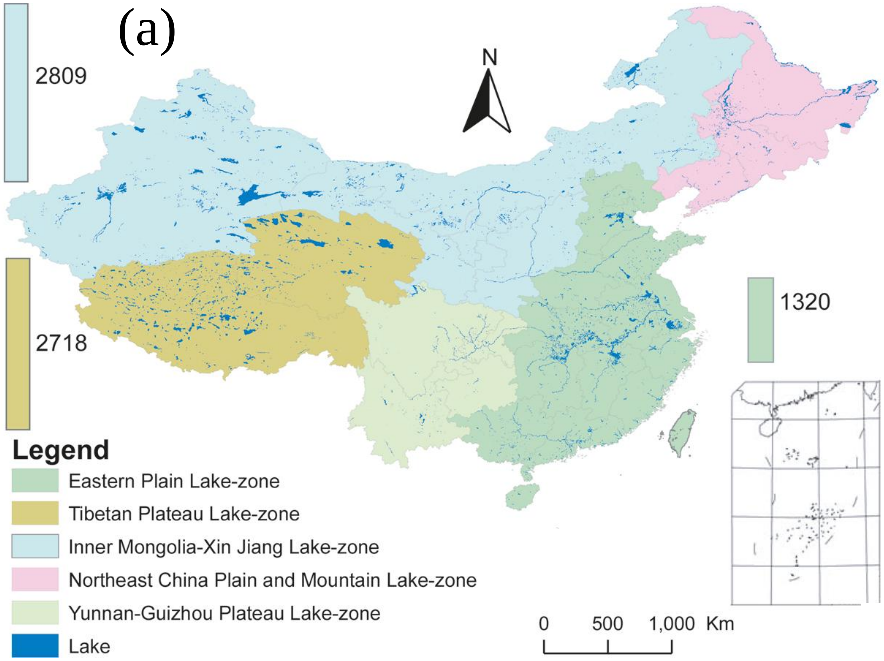
- The mineralization organic matter of in sediments, such as *submerged plants*, is strongly influenced by temperature *(Song et al., 2013).*

- Large and intermediate-sized lakes dominate the total lake surface area, and shallow lakes are very numerous *(Downing et al., 2006, Verpoorter et al., 2014).*

- Generaly, shallow lakes are dominated by phytoplankton (eutrohic) or vegetation *(Kosten et al., 2012; Beaulieu et al., 2013; Qin et al., 2014)*, which also hotspot for CH_4 emission.

- Most of lake in China is large and shallow, with a total lake surface area of 68264 km^2, occuping about 2% of the gobal lake area.

(a)



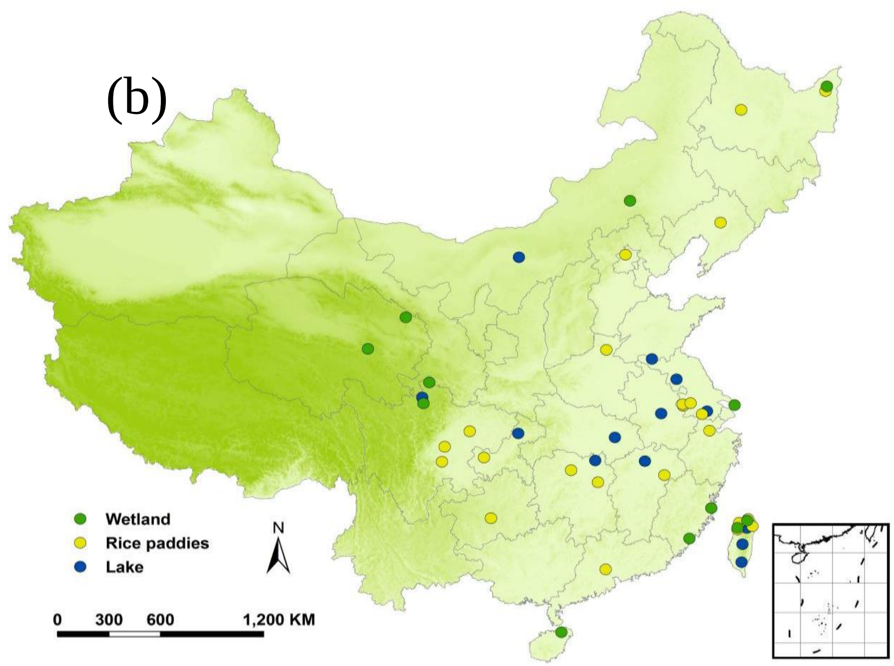
Yang et al., 2011

(a) The distribution of lake in China

(b) The study on CH_4 emission from lake, wetland, and rice paddies in China.

Numerous lakes, but limited field data

(b)



Chen et al., 2013

The lakes in China:

- *Higher nutrient enrichment*
- *Higher organic matter input*
- *Higher accumulation rates*

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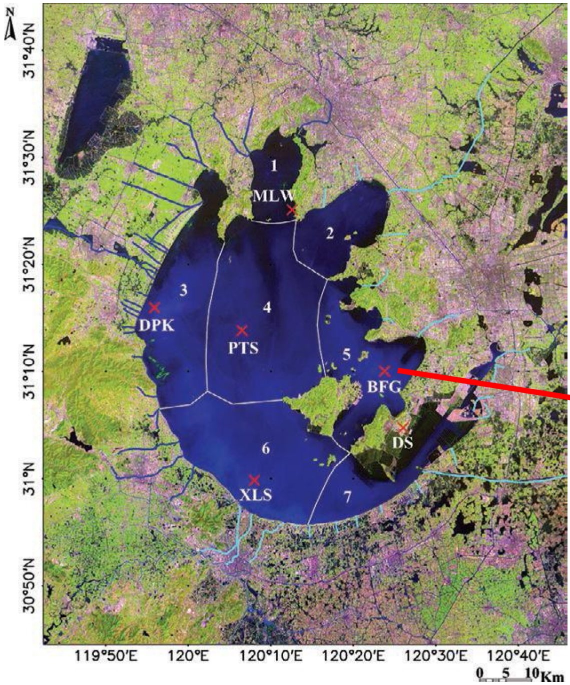

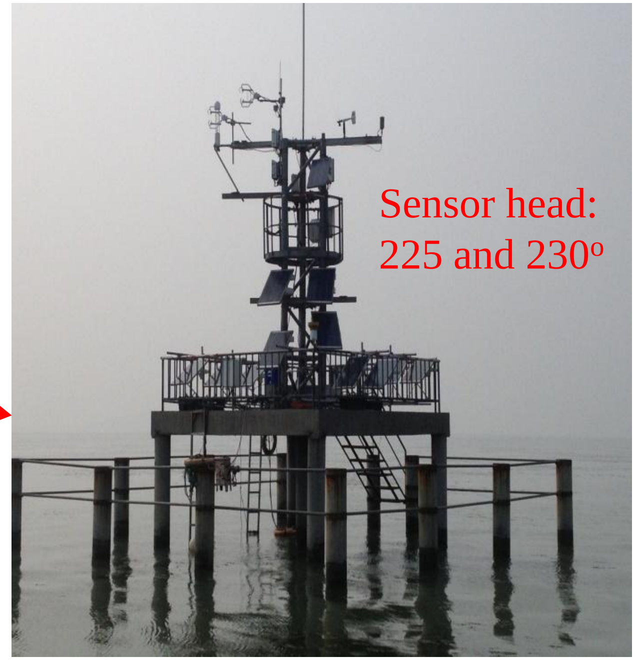

Study site (**BFG**), dominated by submerged vegetation

Instrument: three-dimensional sonic anemometer (**Model CSAT3**, Campbell Scientific Inc., Logan, UT, USA);

Open-path infrared gas analyzer (**Model EC150**, Campbell Scientific Inc.)

Open-path CH_4 gas analyzer (**Model Li-7700**, LI-COR Inc., Lincoln, NE, USA)

Lee et al., 2014

Computing CH_4 flux

$$F_m = A\left\{\overline{w'\rho'_m} + B\frac{\overline{\rho_m}}{\overline{\rho_d}}\overline{w'\rho'_v} + C(1+\mu\sigma)\frac{\overline{\rho_m}}{\overline{T}}\overline{w'T'}\right\}$$

The coefficients, *A*, *B*, and *C*, arise from the correction of the spectroscopic.

The relative importance of spectroscopic corrections would increase when observing small CH_4 fluxes *(Iwata et al., 2014; Podgrajsek et al., 2014).*

Post-processing data

Coordinate rotation - WPL correction- spectroscopic correction- quality control

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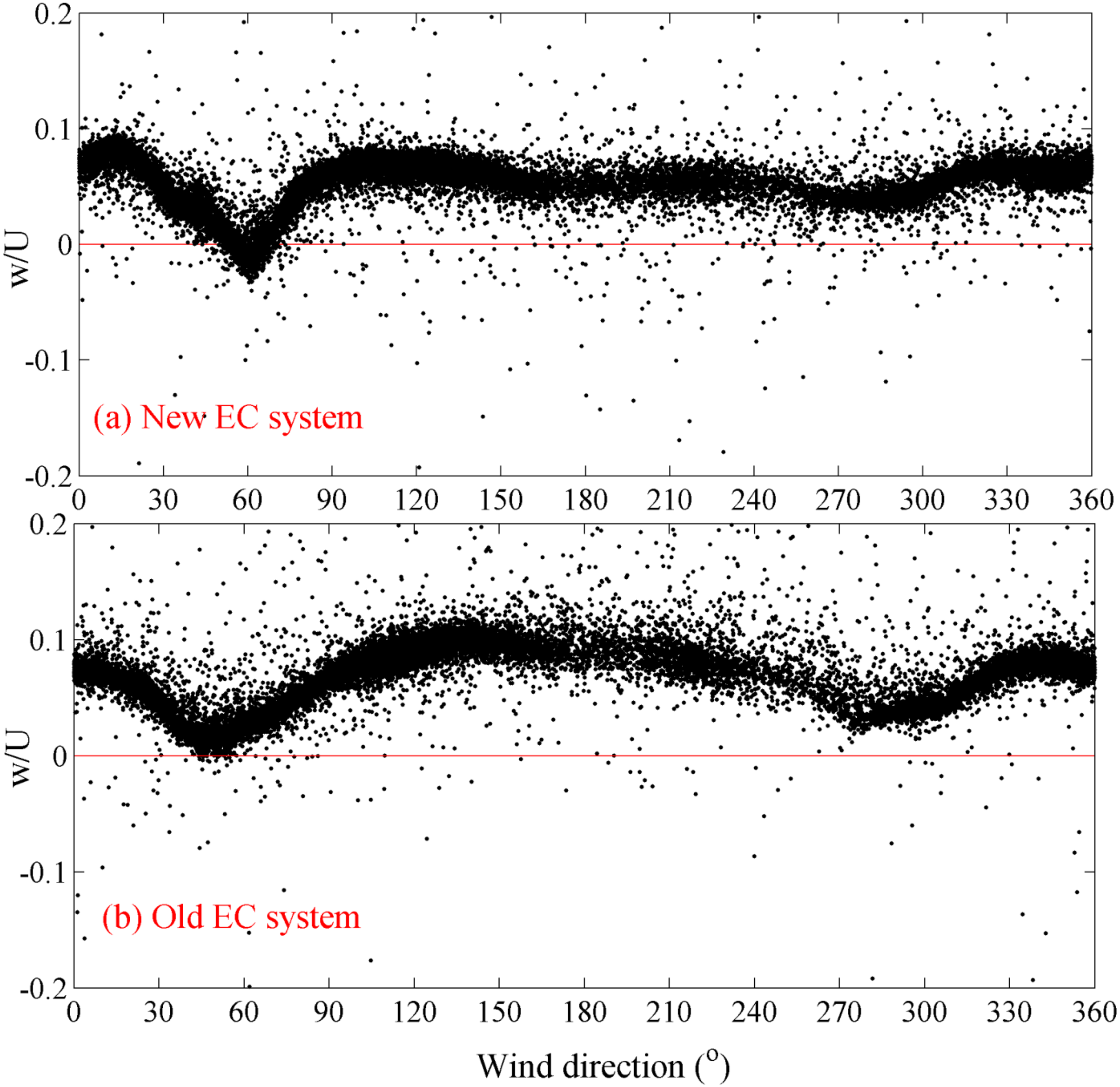

Figure.1 The tilt as a function of wind direction.

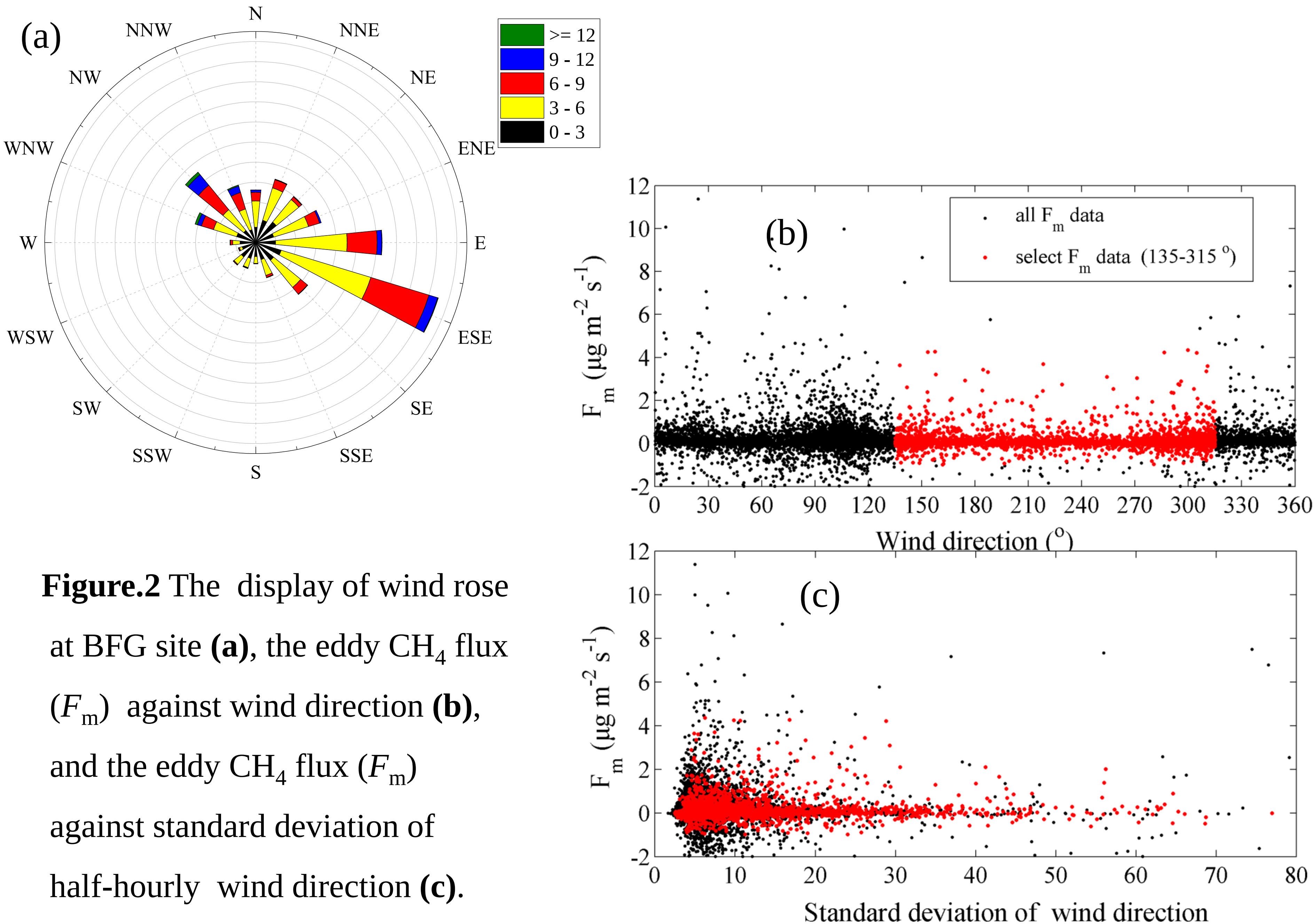

Figure.2 The display of wind rose at BFG site **(a)**, the eddy CH_4 flux (F_m) against wind direction **(b)**, and the eddy CH_4 flux (F_m) against standard deviation of half-hourly wind direction **(c)**.

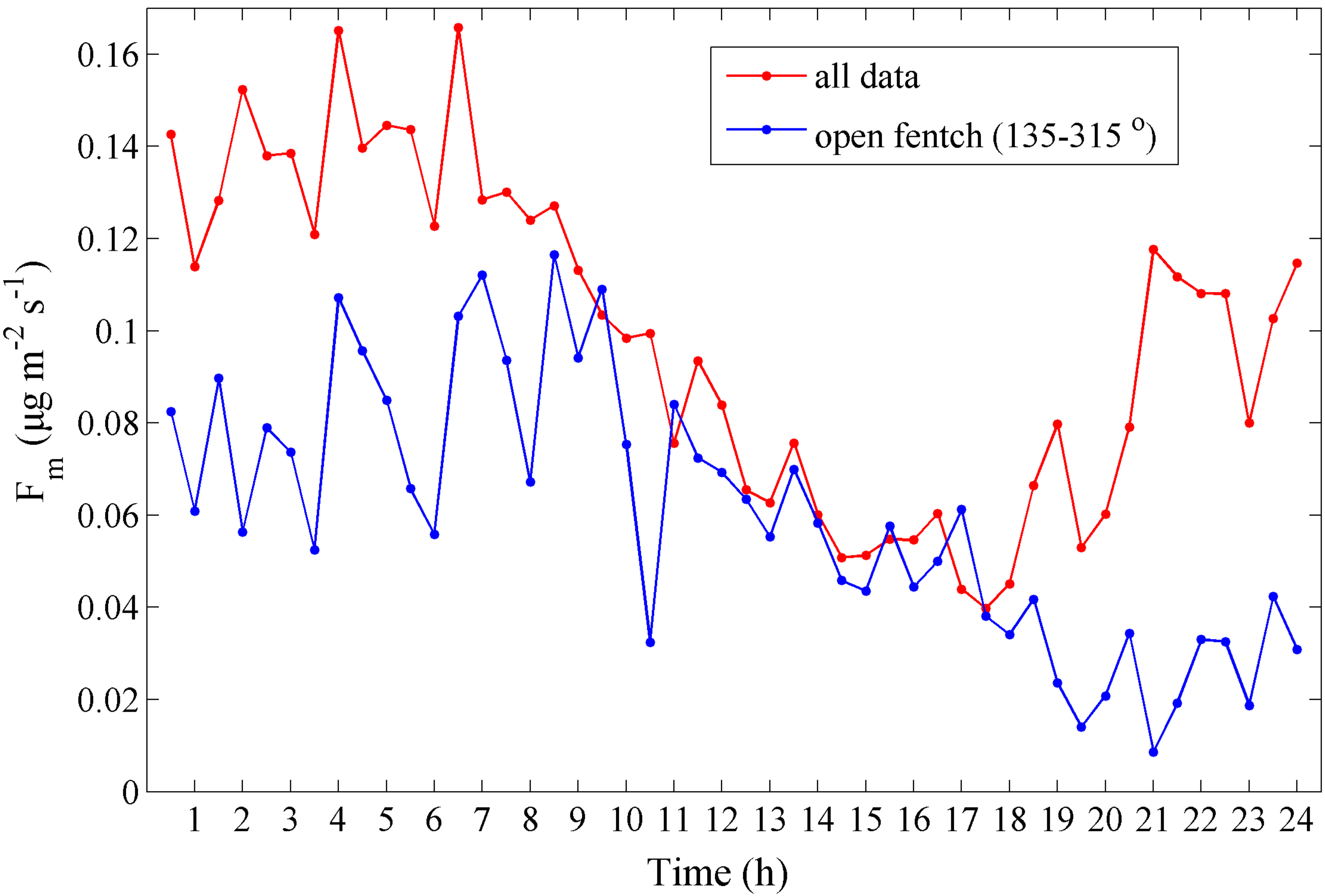

Figure.3 The diurnal cycle of measured CH_4 flux (F_m) indicated by median.

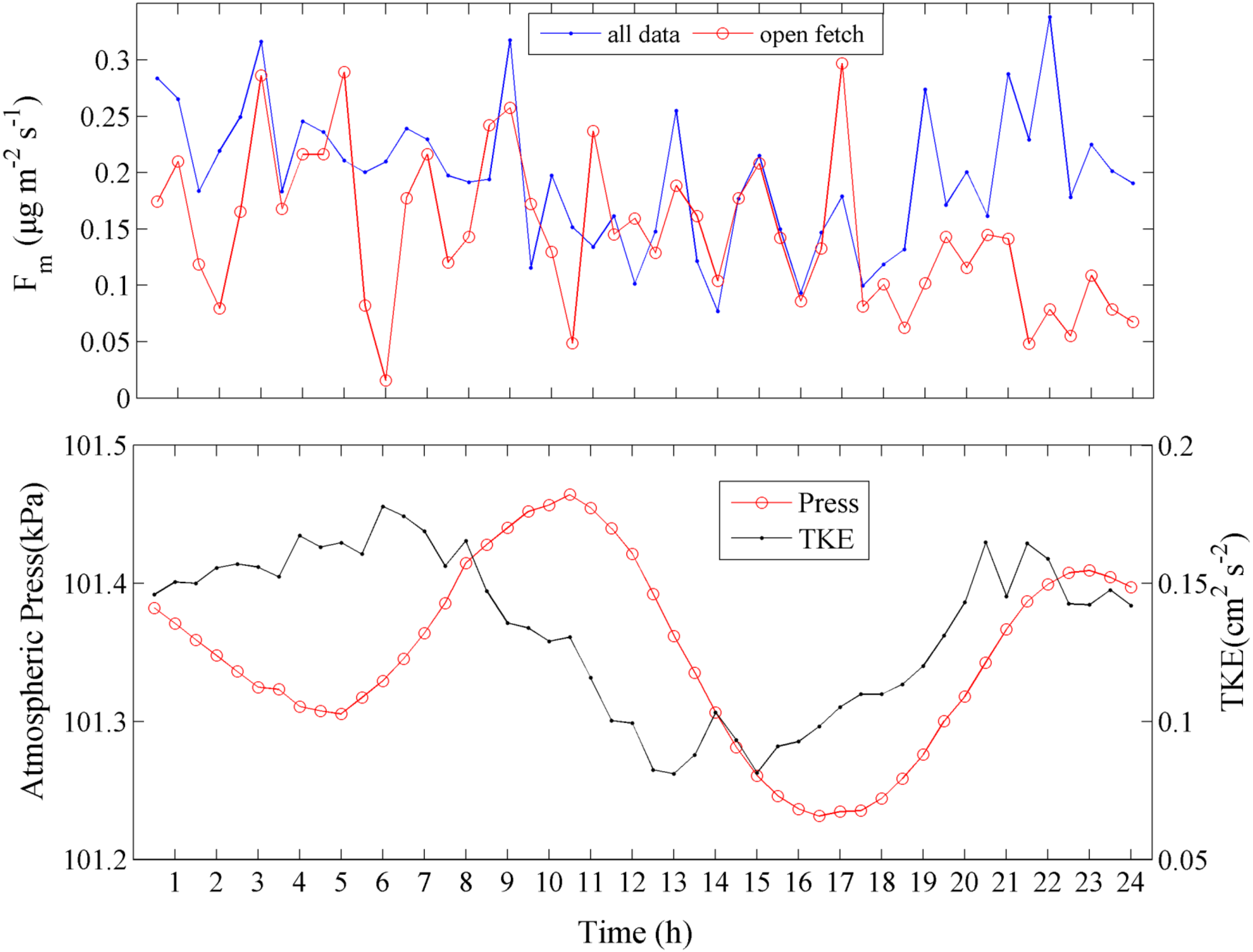

Figure.4 The diurnal pattern of measured CH_4 flux (F_m) against atmospheric press and turbulent kinetic energy (TKE, cm^2 s^{-2}) 1 m above the sediment.

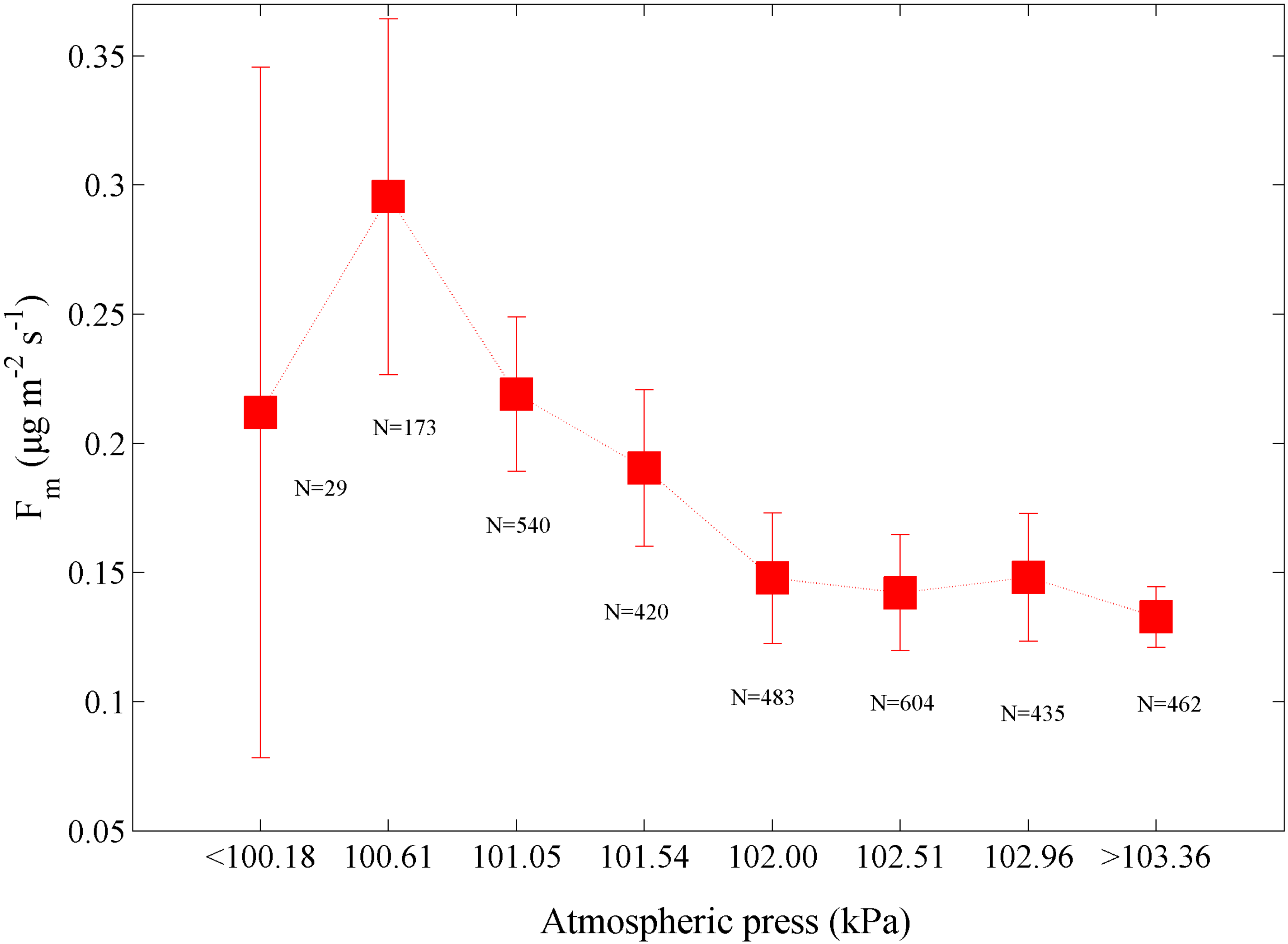

Figure.5 The bin-average atmospheric press (0.5 kPa) against CH_4 flux (F_m, mean ± SE).

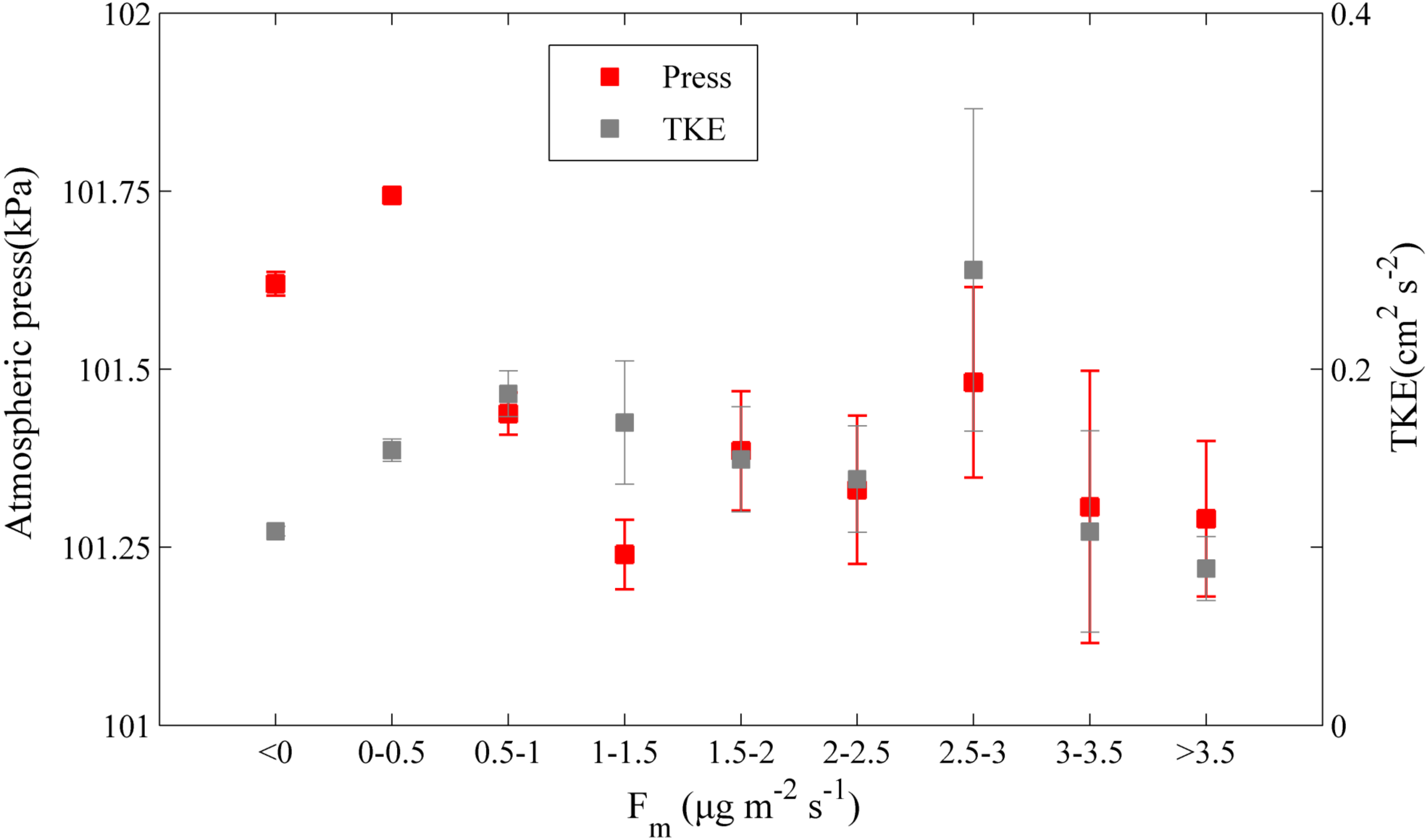

Figure.6 The bin-average CH_4 flux (F_m, 0.5 μg m^{-2} s^{-1}) against turbulent kinetic energy (TKE) and atmospheric press (mean ±SE).

Table.1 The eddy covariance CH_4 measurement at submerged macrophyte habitat

	Raw	**WPL-LE**	**WPL-H**	**Sp[(a)]**	**Total**
CH_4 ($\mu g\ m^{-2}\ s^{-1}$)	0.101	0.050	0.022	0.022	0.196

(a) Sp: spectroscopic corrections

Table.2 The CH_4 emission flux in Lake Taihu

Study site	**Method**	**CH_4 ($\mu g\ m^{-2}\ s^{-1}$)**	**Reference**
Submerged vegetation zone	Eddy covariance	0.196 (0.146 [(b)])	In the study
	Water equilibrium with correction	0.075 (day)	Our study
Eutrophic zone	Flux gradient	0.056	Xiao et al., 2014
The whole lake	Water equilibrium with correction	0.060	Our study
Littoral zone with alga and macrophyte	Static chamber	2.32	Wang et al., 2006

(b) Selected by wind direction (135 - 315 ^oC)

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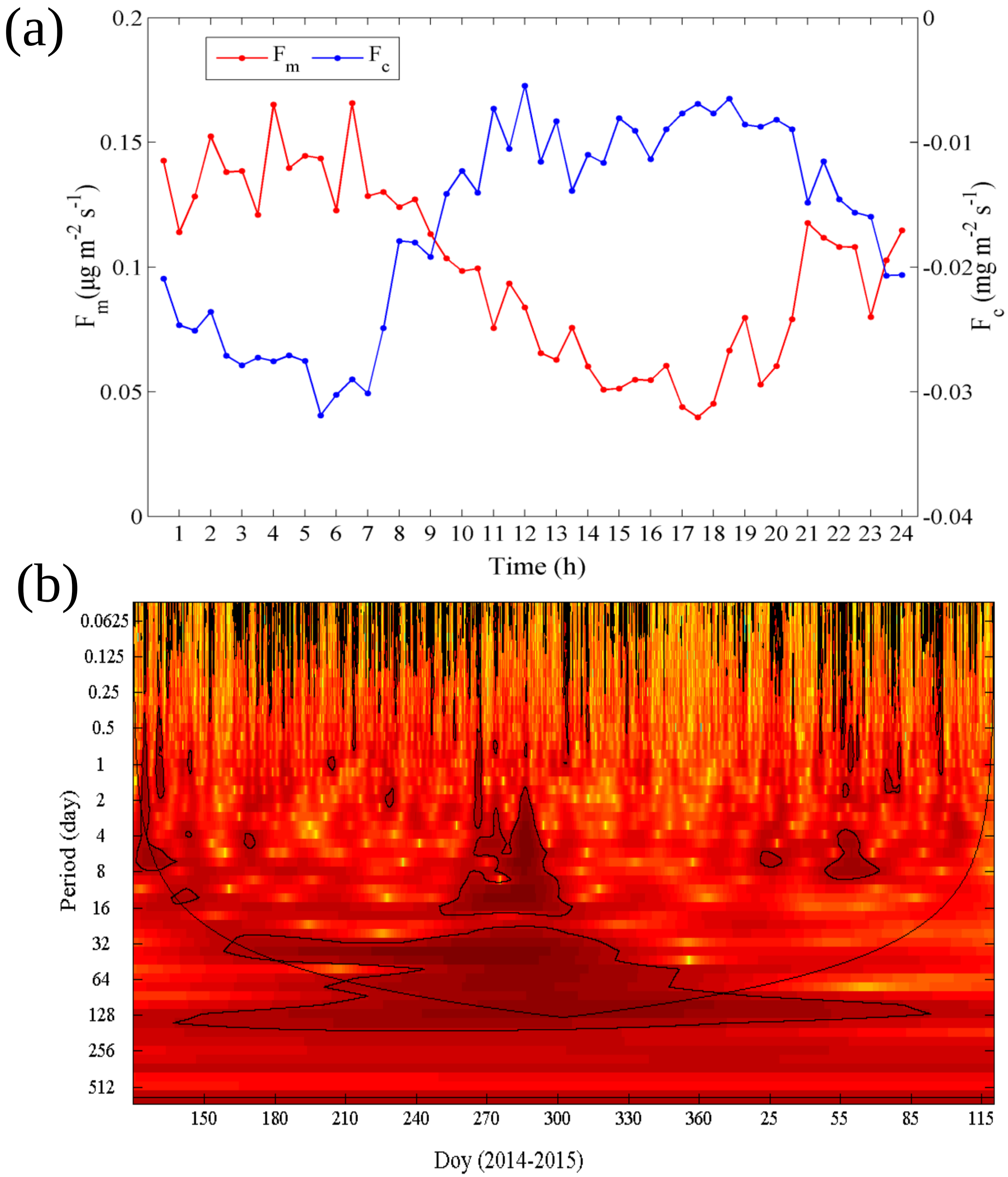

Figure.7 The diurnal pattern of CH_4 flux (F_m) against CO_2 flux (F_c) **(a)**, the wavelet power spectrum of CO_2 flux at the BFG site **(b)**.

Biological factor drive the F_m ?

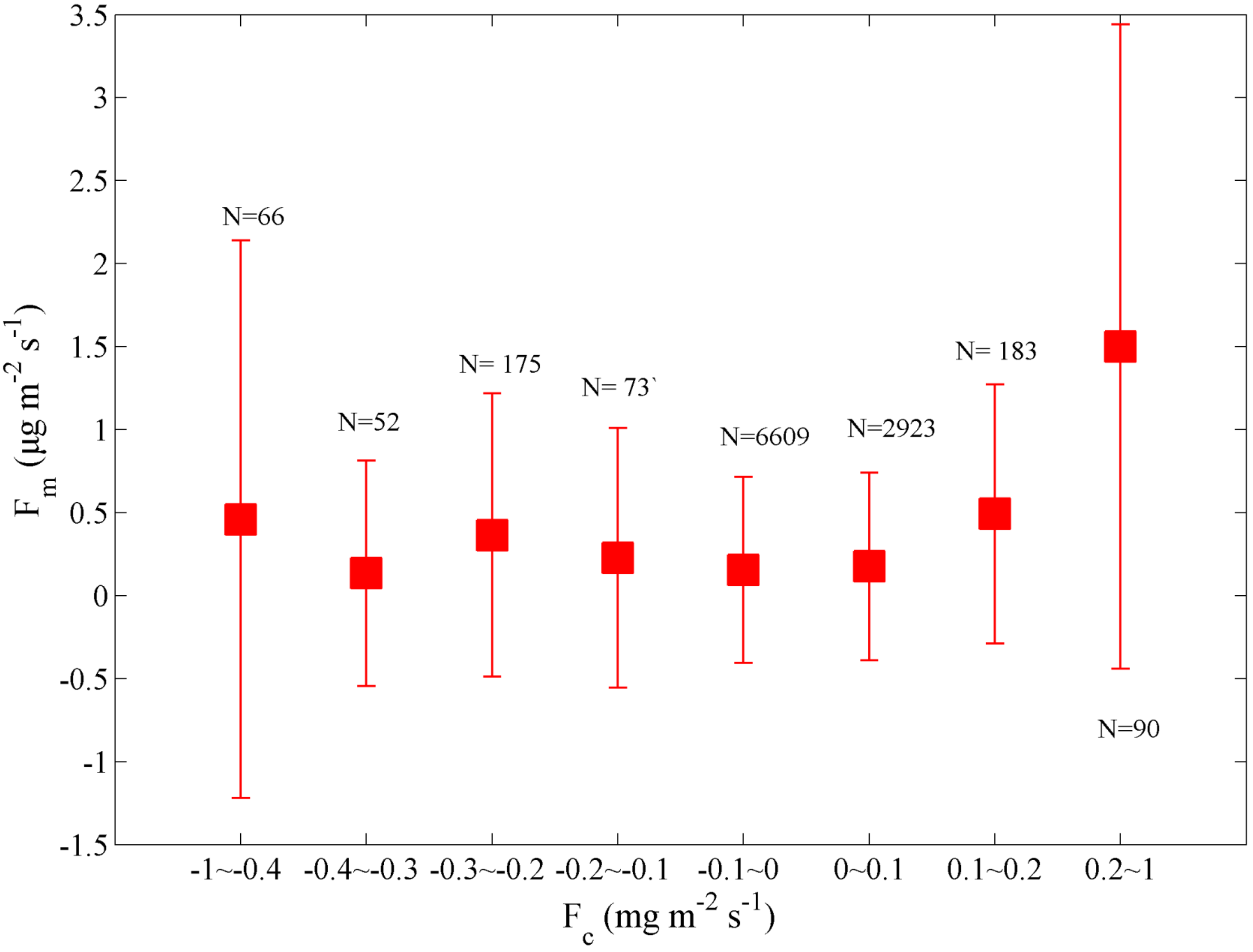

Figure.8 The bin-average CO_2 flux (F_c, 0.1 mg m^{-2} s^{-1}) against CH_4 flux (F_m, mean ± SD).

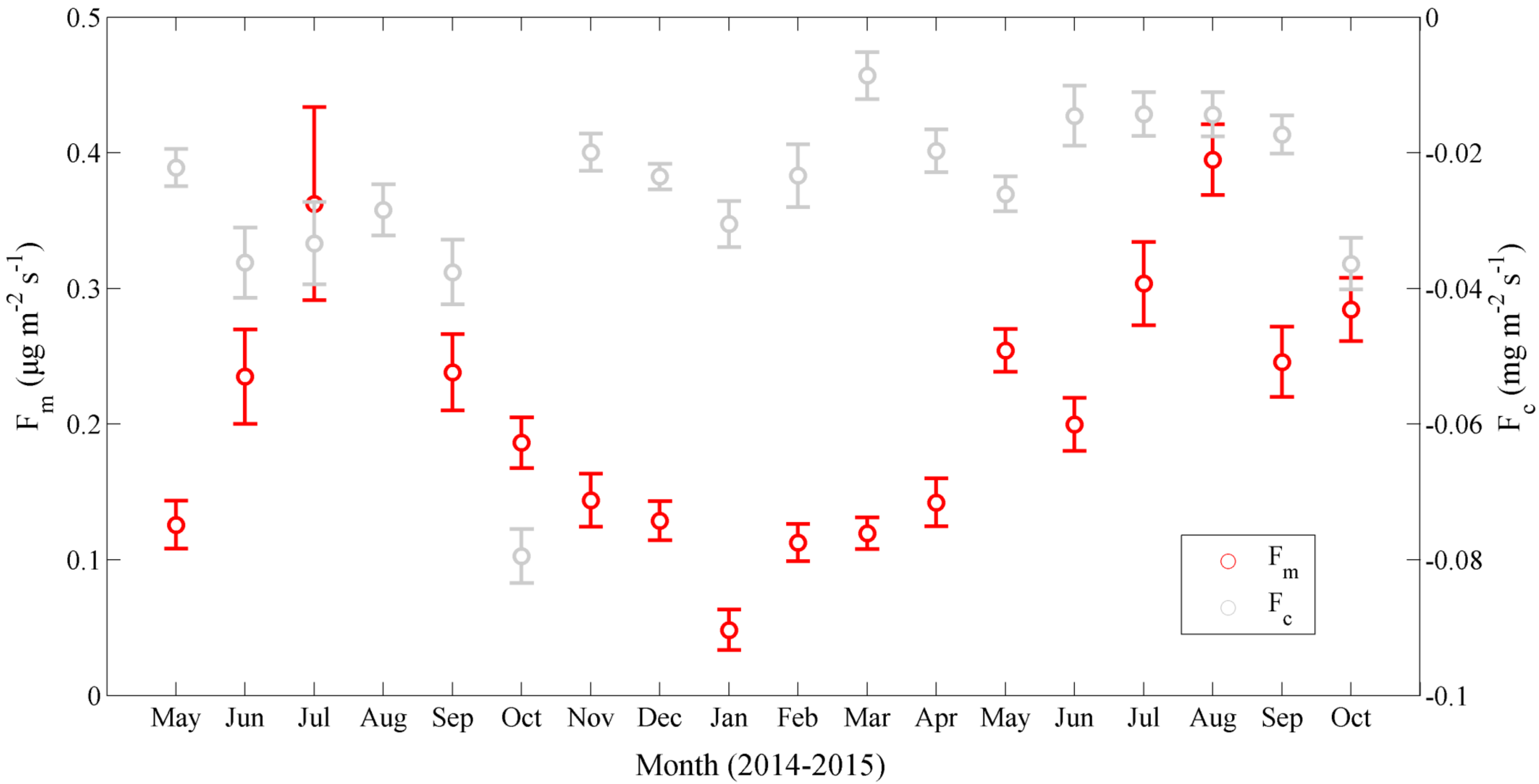

Figure.9 The mean monthly CH_4 flux (F_m, mean ± SE) and CO_2 flux (F_c, mean ± SE).

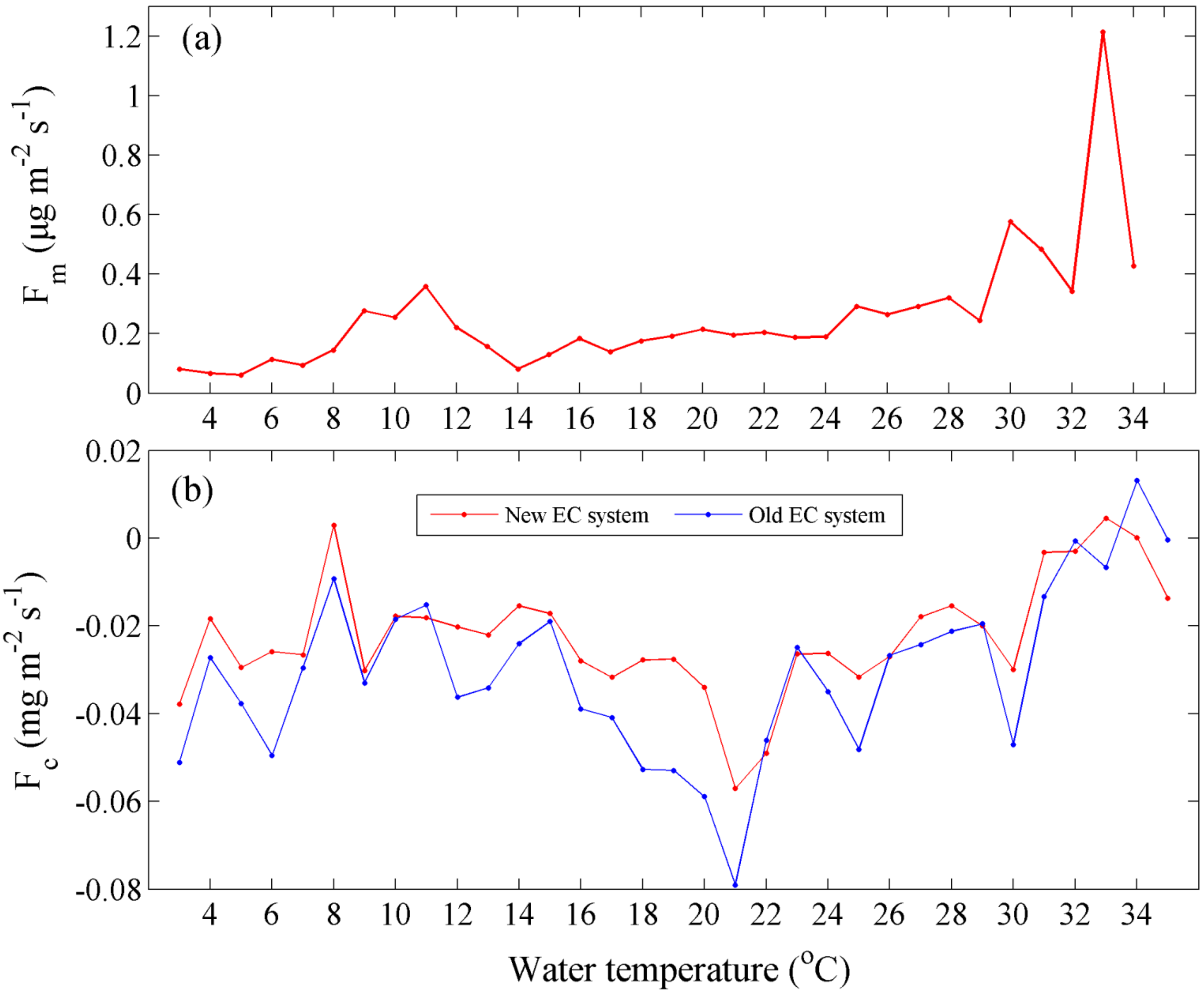

Figure.10 The bin-average water temperature (1 ^oC) against CH_4 flux (F_m) and CO_2 flux (F_c).

Respiration *Photosynthesis*

$$F_{c} = F_{c,\, r} + F_{c,\, p}$$

$$F_{m} = F_{m,\, r} + F_{m,p}$$

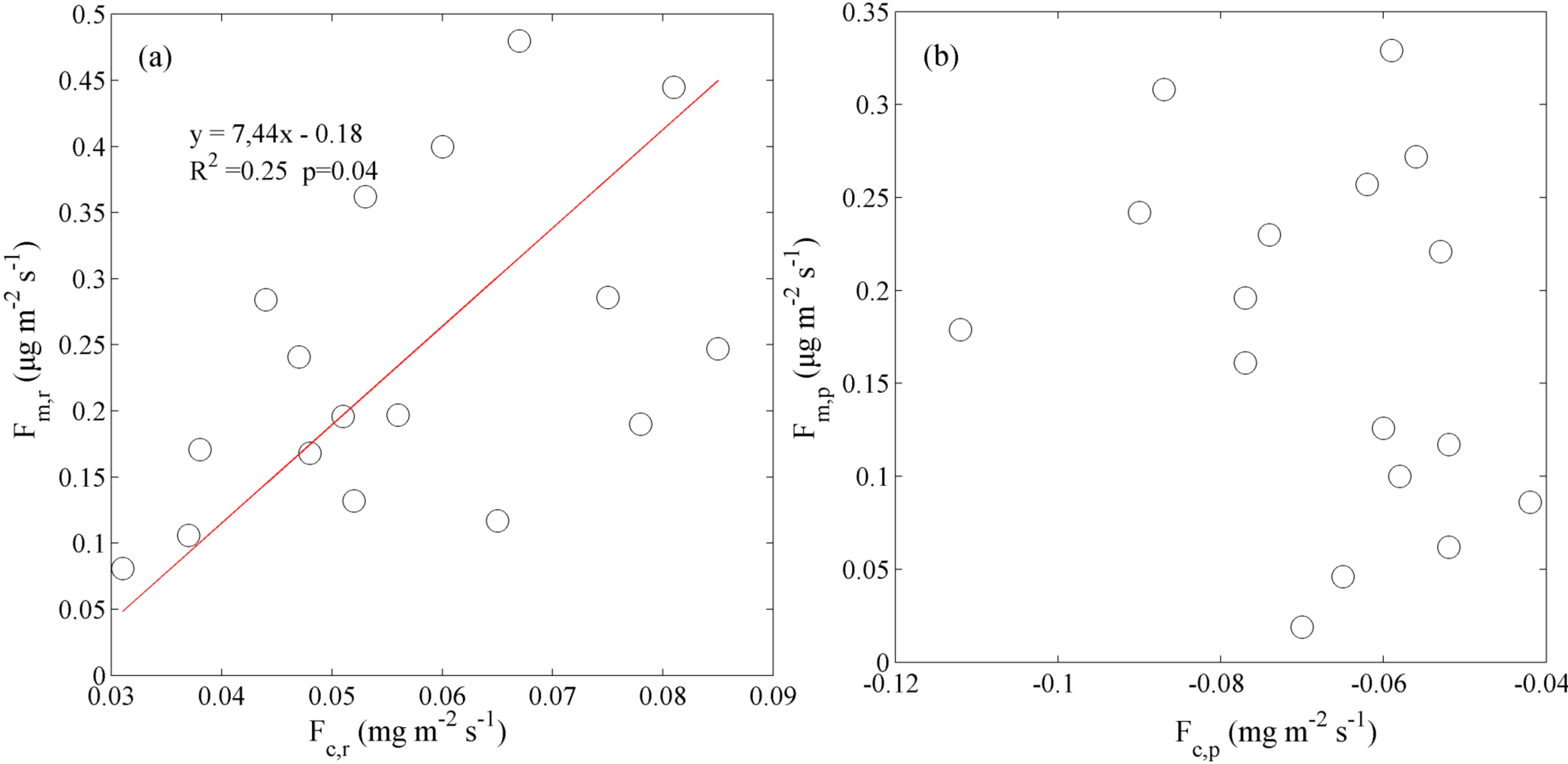

Figure.11 The effect of ecosystem respiration (a) and photosynthesis (b) on the mean monthly CH_4 flux (F_m)

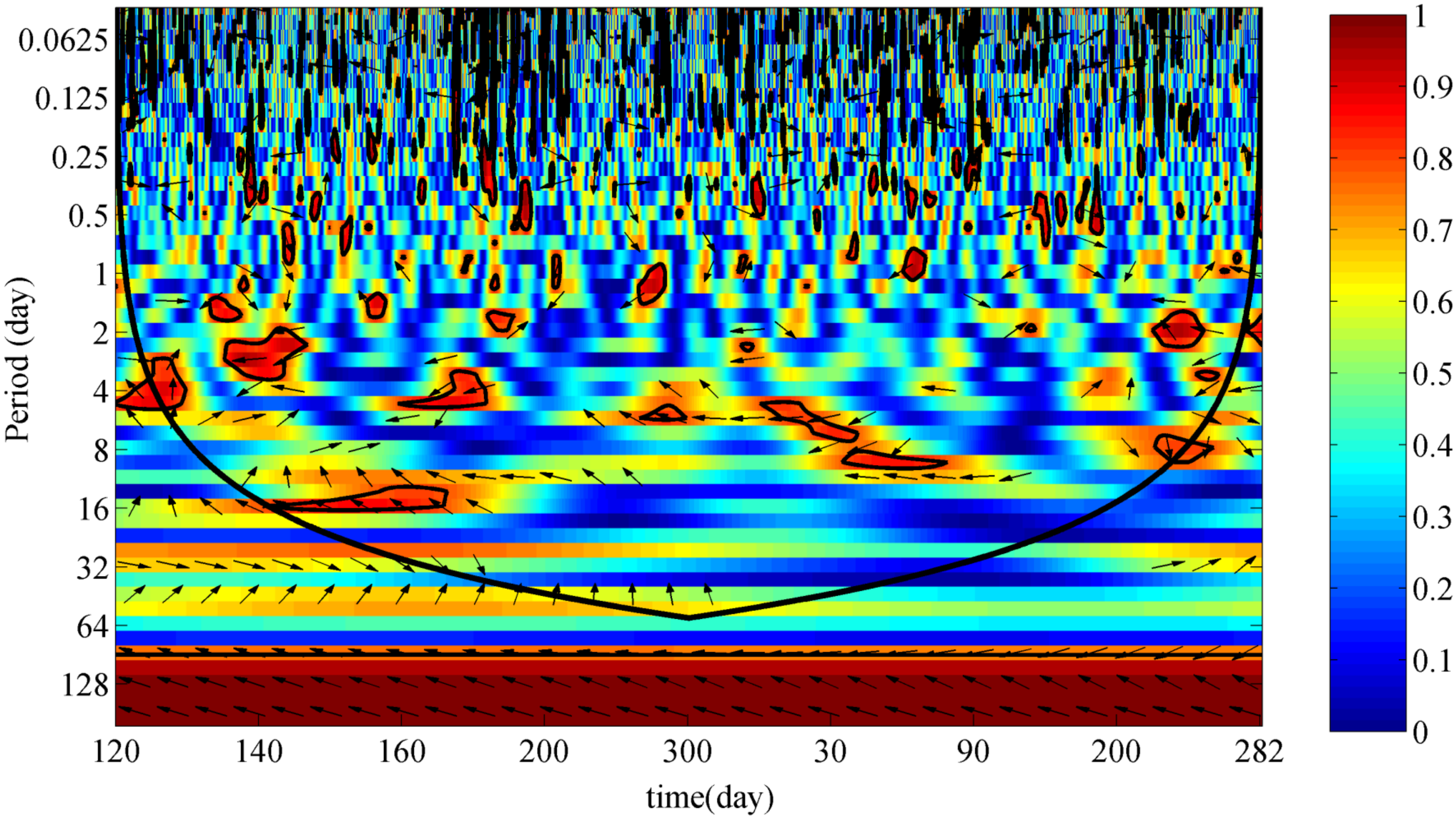

Figure.12 The wavelet coherency and phase difference between CH_4 flux and CO_2 flux. The arrows show the phase difference : in-phase pointing right, anti-phase pointing left, and the angle indicates time lag *(Grinsted and Zhang, 2011).*

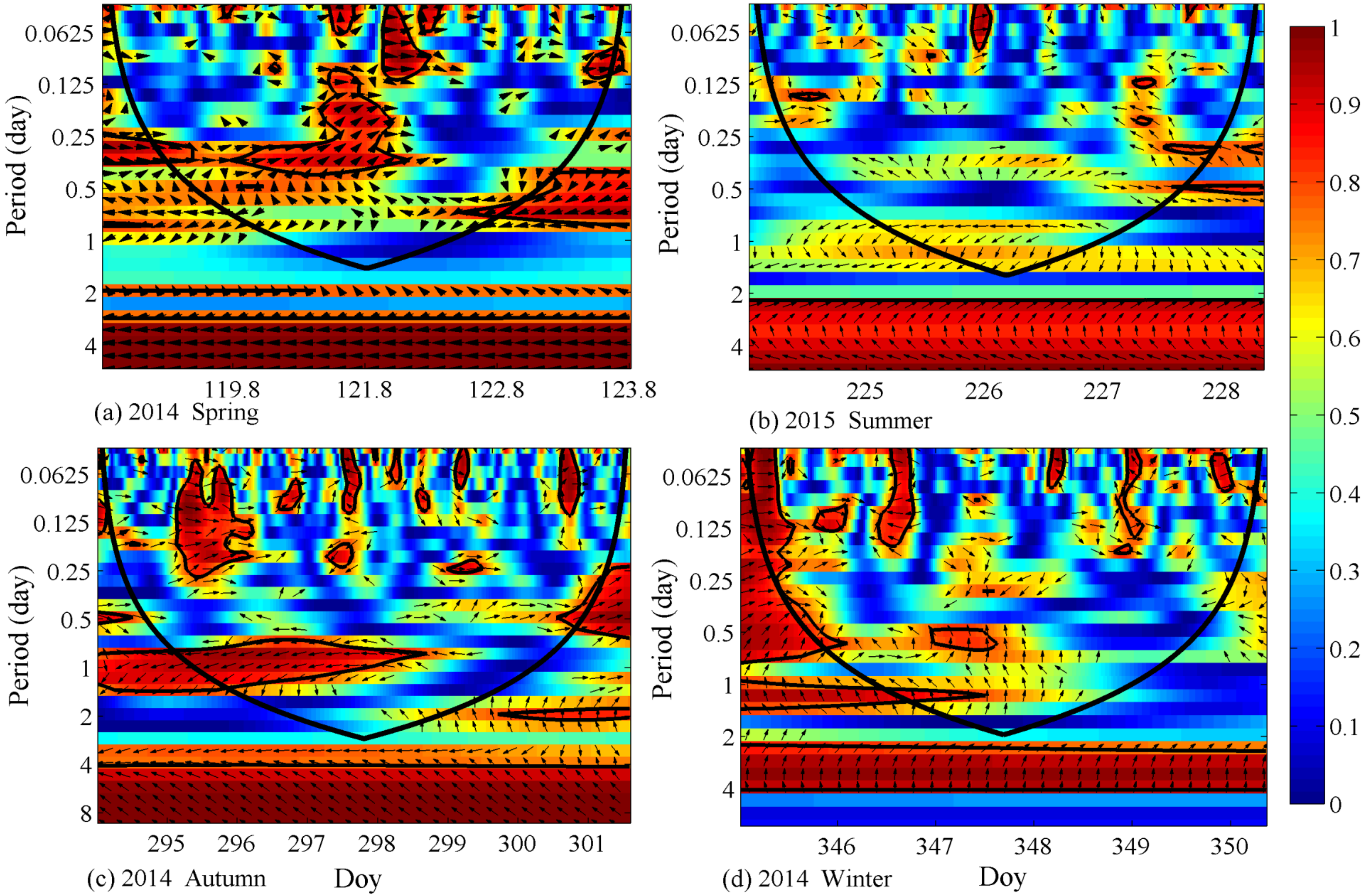

Figure.13 The wavelet coherency and phase difference between CH_4 flux and CO_2 flux at (a) spring, (b) summer, (c) autumn, and (d) winter.

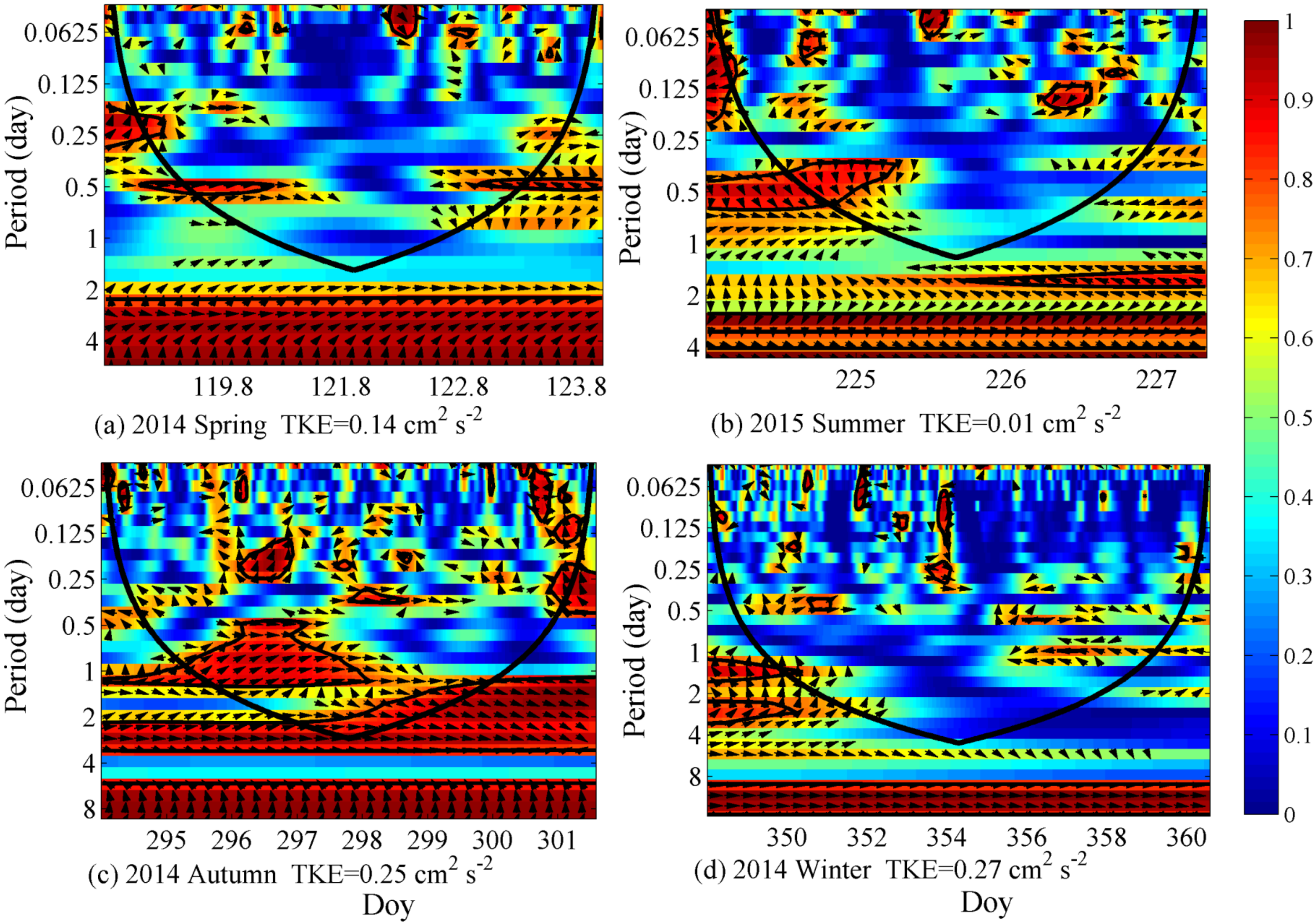

Figure.14 The wavelet coherency and phase difference between CH_4 flux and TKE at (a) spring, (b) summer, (c) autumn, and (d) winter.

Table.3 Mean time lag within days with significant correlation between F_m and F_c

	Time period (d)	Phase difference	Time lag (h)
Spring	<1	In-phase	-2.10 ±1.79
Summer	<1	In-phase	0.50±1.56
	2	Anti-phase	-2.45
Autumn	<1	In-phase	-0.16±2.44
	1	Anti-phase	6.70±7.52
Winter	<1	In-phase	-2.17±5.8
	1	In-phase	-6.35±0.85

Table.4 Mean time lag within days with significant correlation between F_m and TKE

	Time period (d)	Phase difference	Time lag (h)
Spring	0.5	In-phase	-0.37 ±0.15
Summer	0.5	In-phase	4.60±1.22
Autumn	0.5-1	In-phase	-1.47±1.86
Winter	0.5	In-phase	-1.57±0.74

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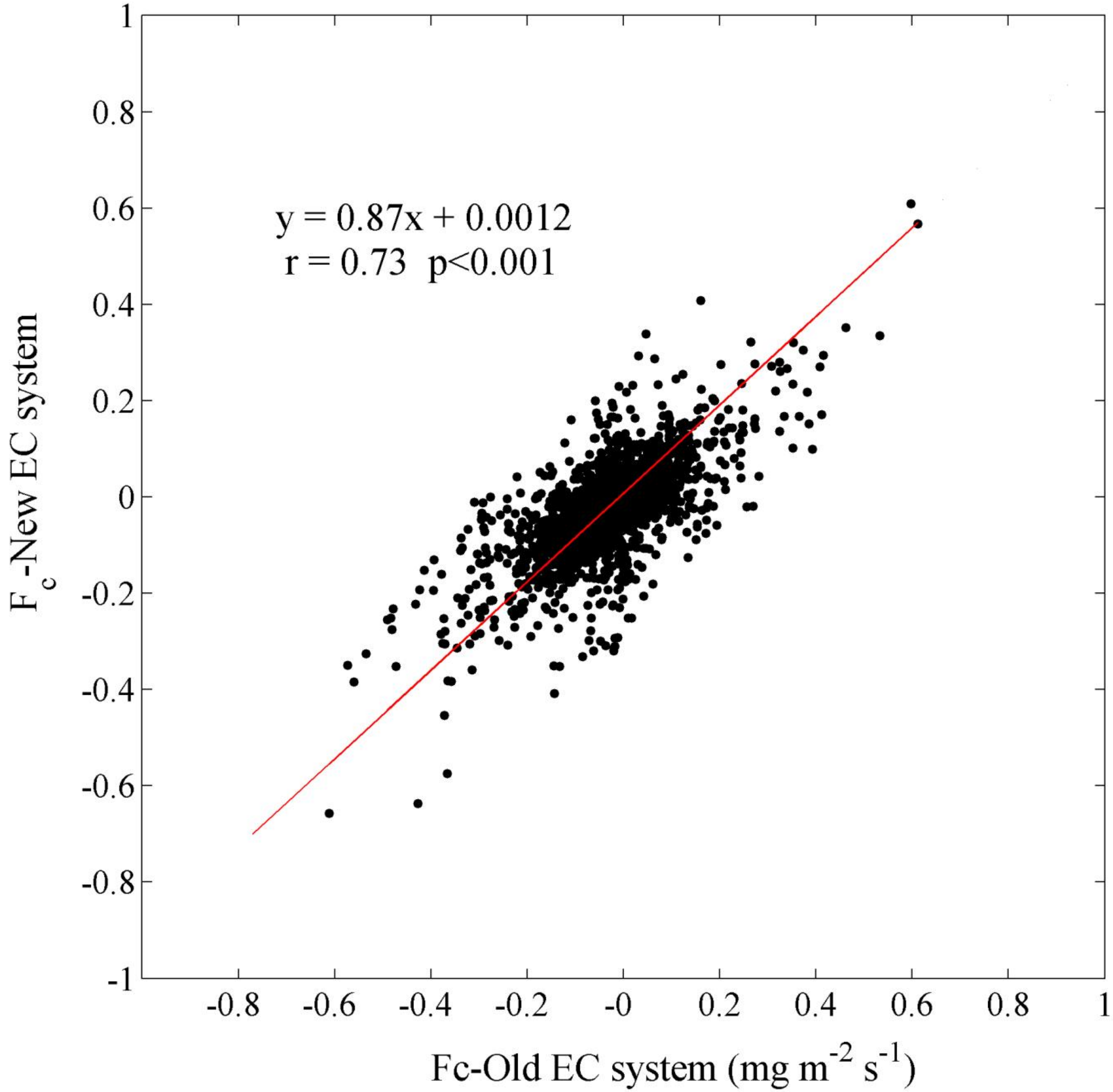


Figure.15 The difference between CO_2 flux (F_c) measured by two new EC systems.

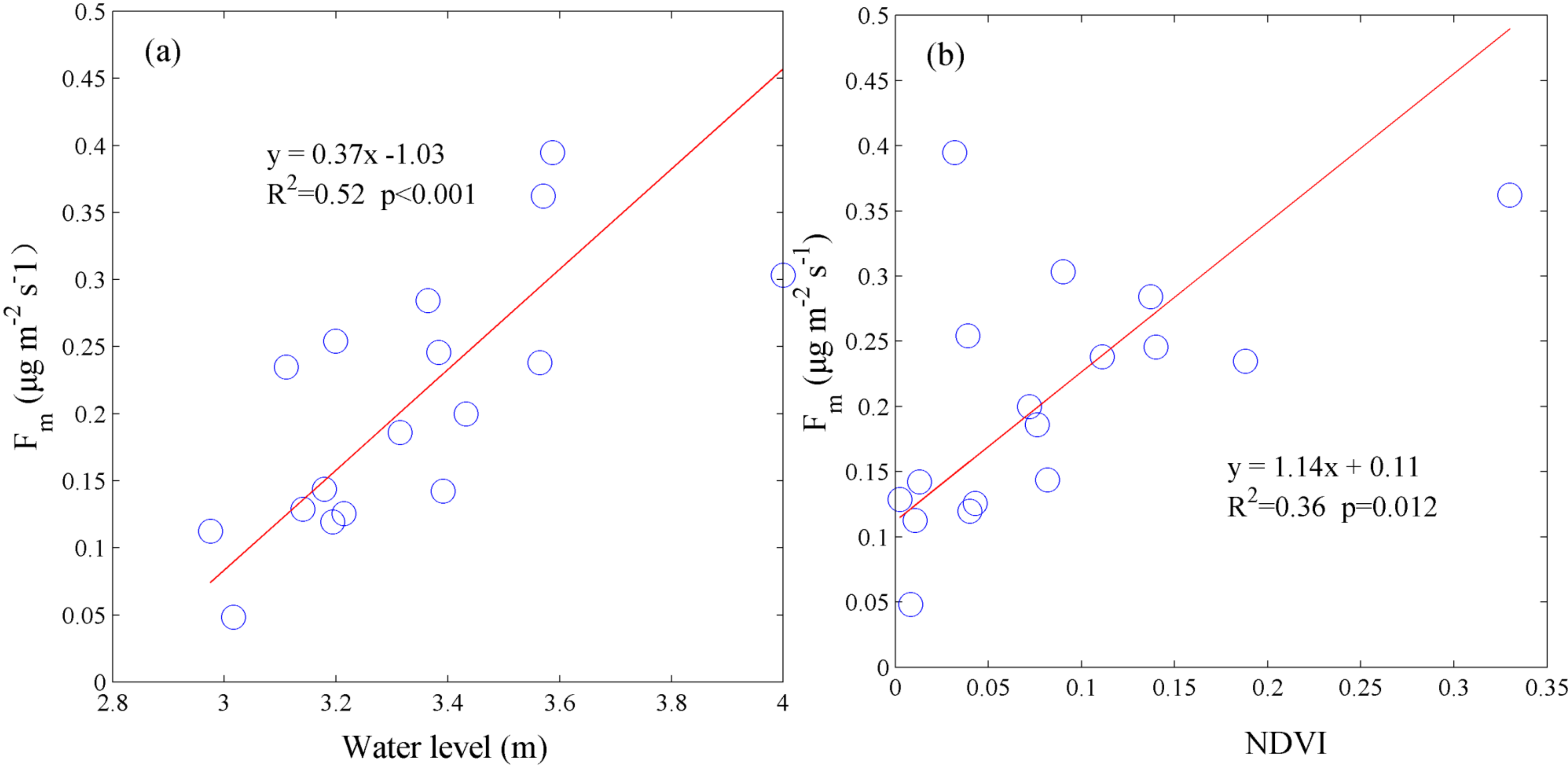
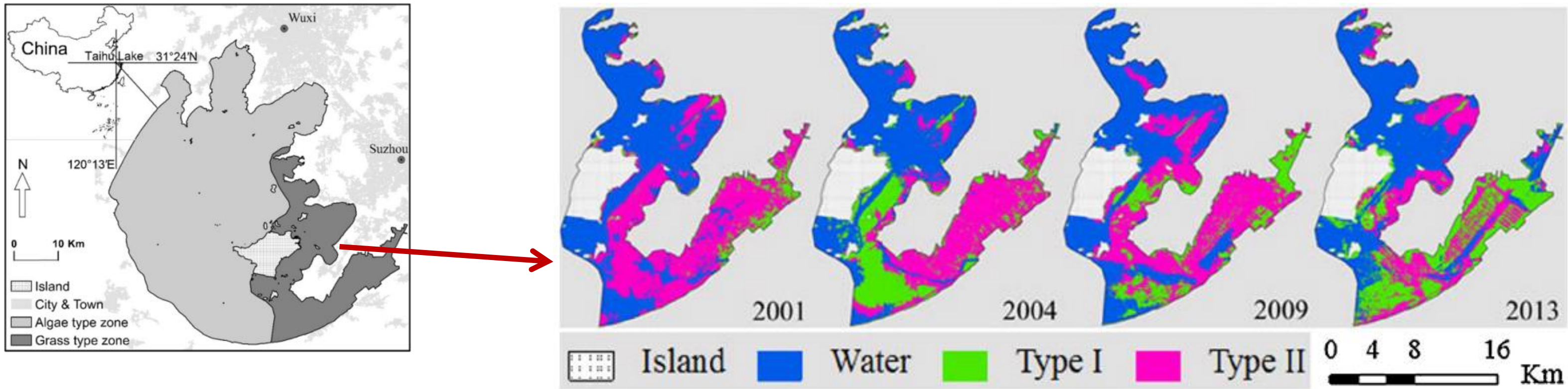


Figure.16 The correlation between mean monthly CH_4 flux (F_m) against water level(a), and NDVI (b).

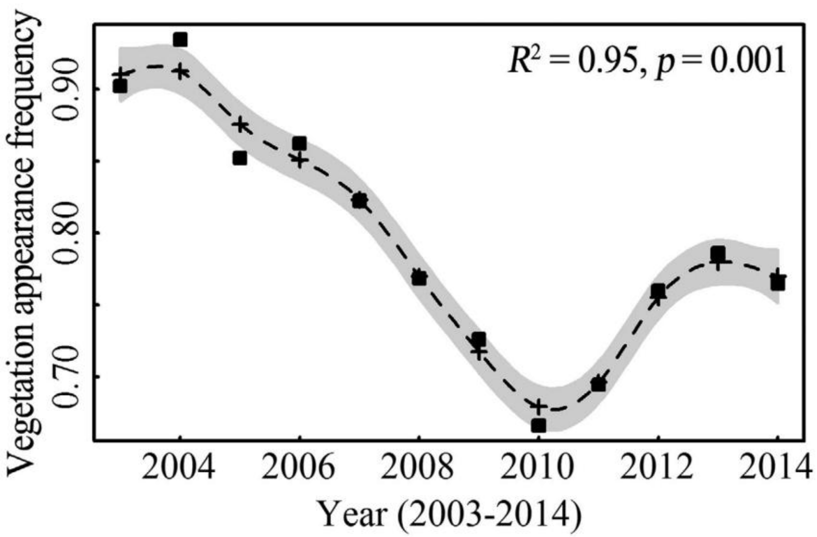
Long-term trends of environment factors in of aquatic vegetation habitat of Lake Taihu

(a)

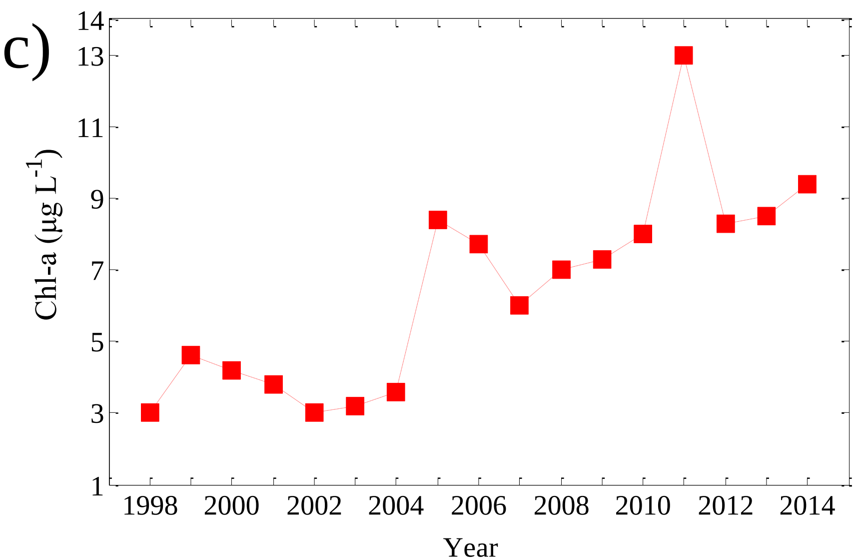


Type I: *emergent, floating-leaved and floating vegetation*, Type II: *submerged vegetation*

(b)

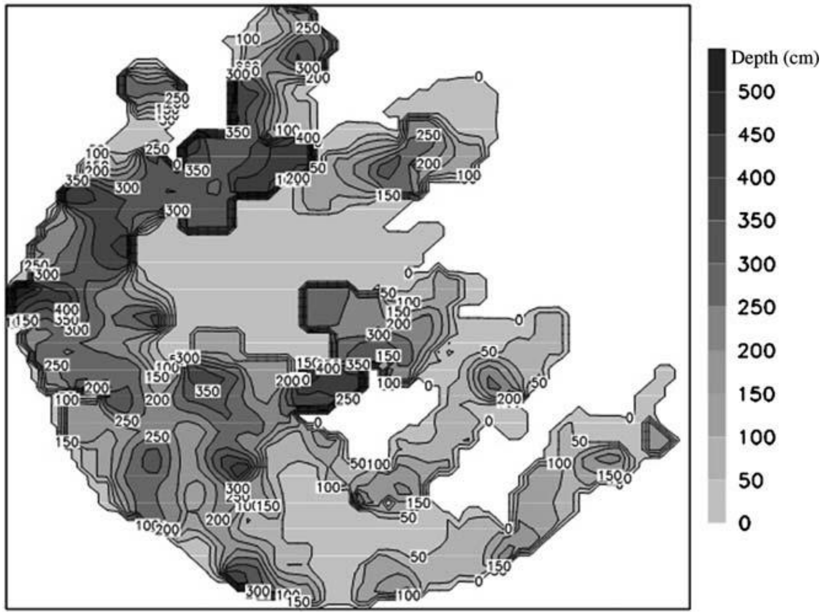


(c)



(a) interannual changes of aquatic vegetation *(Luo et al., 2016)*, (b) vegetation appearance frequency *(Zhang et al., 2016)*, and (c) long-term trends of Chl-a concentration *(Zhang et al., 2016)*.

The effect of ecological dredging on CH_4 emission



Distribution of lacustrine sediment in Lake Taihu *(Qin et al., 2007)*

The dissolved organic carbon (DOC) loss rates in Lake Taihu :1.7 $\times 10^4$ t year^{-1} *(Zhou et al., 2015).*

Dongtaihu Bay:

Surface area: 131 km^2

CH_4 emission flux: 0.192 μg m^{-2} s^{-1} (Our study).

Ecological dredging : 165 m^3 year^{-1} *(Zhu et al., 2012).*

CH_4 concentration in sediment:

19.6 mg L^{-1} *(Zhu et al., 2012)*

The CH_4 loss in Dongtaihu:

	Emission from lake	Ecological dredging
CH_4 loss (t year^{-1})	82	323

The effect of aquatic vegetation on CH_4 emission

- Supply the organic matter and labile carbon for CH_4 produce
- Vegetation-mediated transport

- Restrict CH_4 bubble and turbulent kinetic energy
- Transport oxygen to the rhizosphere and facilitate CH_4 oxidation

✓ Extreme zero CH_4 emission in wetland with high oxygen and plant roots densities *(Fritz et al., 2011).*

✓ Plant with high root: shoot biomass is associated with low CH4 emission *(Bouchard et al., 2007).*

Conclusion

- The CH_4 flux is mainly controlled by water temperature.

- Turbulent kinetic energy of water and atmospheric press dominate the diurnal cycle of CH_4 flux.

- The correlation between CH_4 flux and CO_2 flux is significant, and ecosystem respiration could influence directly CH_4 emission.

- Is shallow lake with large area associated with low CH_4 emission ?

Thank you