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Field test of a portable flux-gradient system for measuring methane emission from fish ponds

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2015.08.14

Outline

- Background
- Objectives
- Methods
- Results and Discussion
  1. Zero-gradient test result
  2. Flux-gradient observation result: CH_4
  3. Flux-gradient observation result: F_c, LE
- Conclusions

Background

- CH_4 is an important greenhouse gas, and the global warming potential of CH_4 is 25 times that of CO_2 (Forster et al., 2007).

- Inland waters are thought to be important natural sources of methane (Bastviken et al., 2004) ; in recent years, the research of greenhouse gas in the inland waters mainly focused on lake, reservoir, river, etc. Pond is a part of inland waters, but documentation of emissions from this source has been limited.

- Ponds are centers of sediment accumulation characterized by organic-rich clays. The movements of animals can trigger CH_4 bubbling/ebullition in the Lagoons (Gondwe et al. 2014).

- According to national fishery economic statistical bulletin, the area of pond is 26619 km^2, which contributes about 43.77% of freshwater aquaculture (2014).

Background: method

Method	Advantage	Disadvantage
Box chambers/ Anchored funnels	1.Easy-to-operate 2. Low cost 3. Ebullition (AF)	1. Short measurement 2. Strong labor
Eddy covariance	1.Directly and fast response 2.Less interference for study site	1. Density corrections 2. Self-heating effects
Water equilibrium method	Multiple sites	Uncertainty for the *k*
Flux-gradient method	1. Simultaneously measure the flux of H_2O, CO_2 , and CH_4 ; 2. Negligibly small density corrections; 3. Resolve small CH_4 gradient and flux; 4. Continuous and noninvasive operation. (Xiao et al., 2014)	

Objective

- Test the portable flux-gradient system performance.

- Examine hypothesis: Pond is an strong source of CH_4, estimating CH_4 emission flux from fish pond.

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Site information

Location	Latitude and Longitude	Area	Water depth
Puhao Ecological Garden	32.2417° N , 118.6877° E	3720 m^2	1.5m

A : Dining kitchen (5° — 21°)

B: Fruiter (21° — 92°)

C: Underground parking

D: Fish pond

(92° — 106°) (161° — 182°)

E: Vinyl house (106° — 161°)

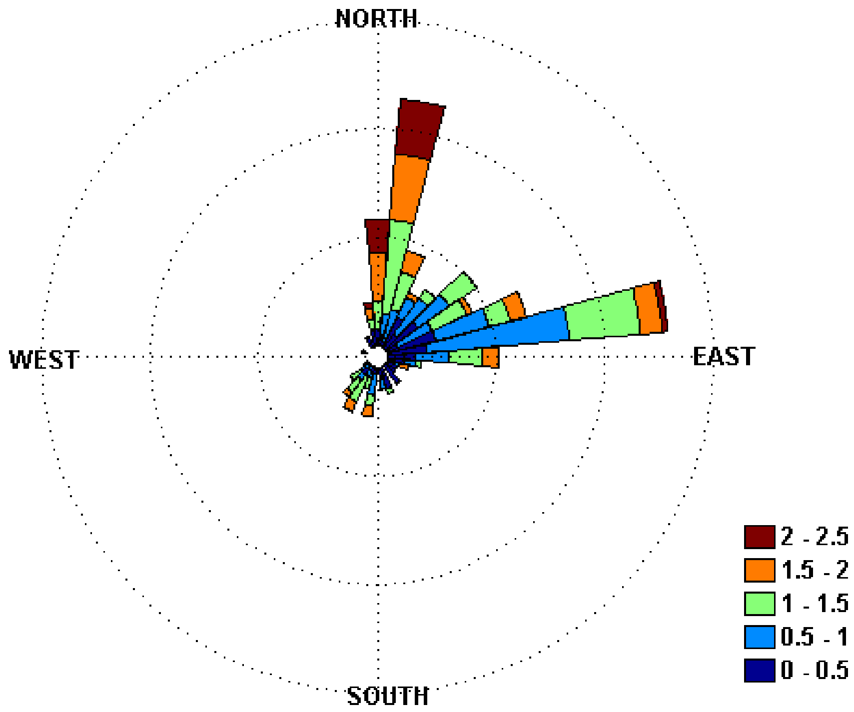
F: Chicken pen

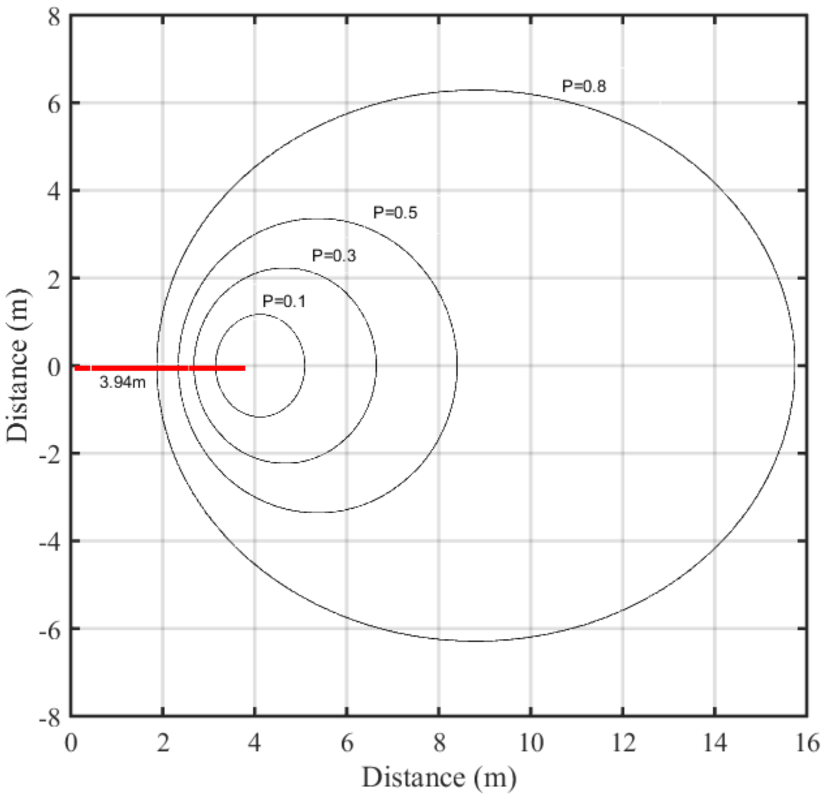
G: Lobster pond (182° — 280°)

H: Fish pond

(280° — 360°) (0° — 5°)

Wind Rose and Footprint





Footprint ----FSAM model

(Condition: wind direction: 92° — 106° , $\varepsilon < 0$)

Instrument information

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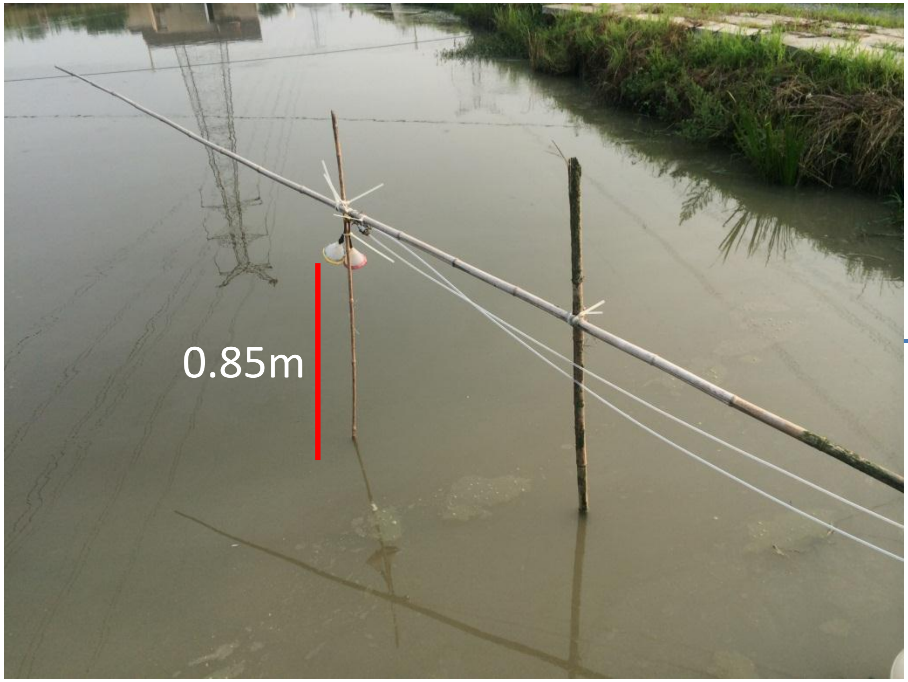
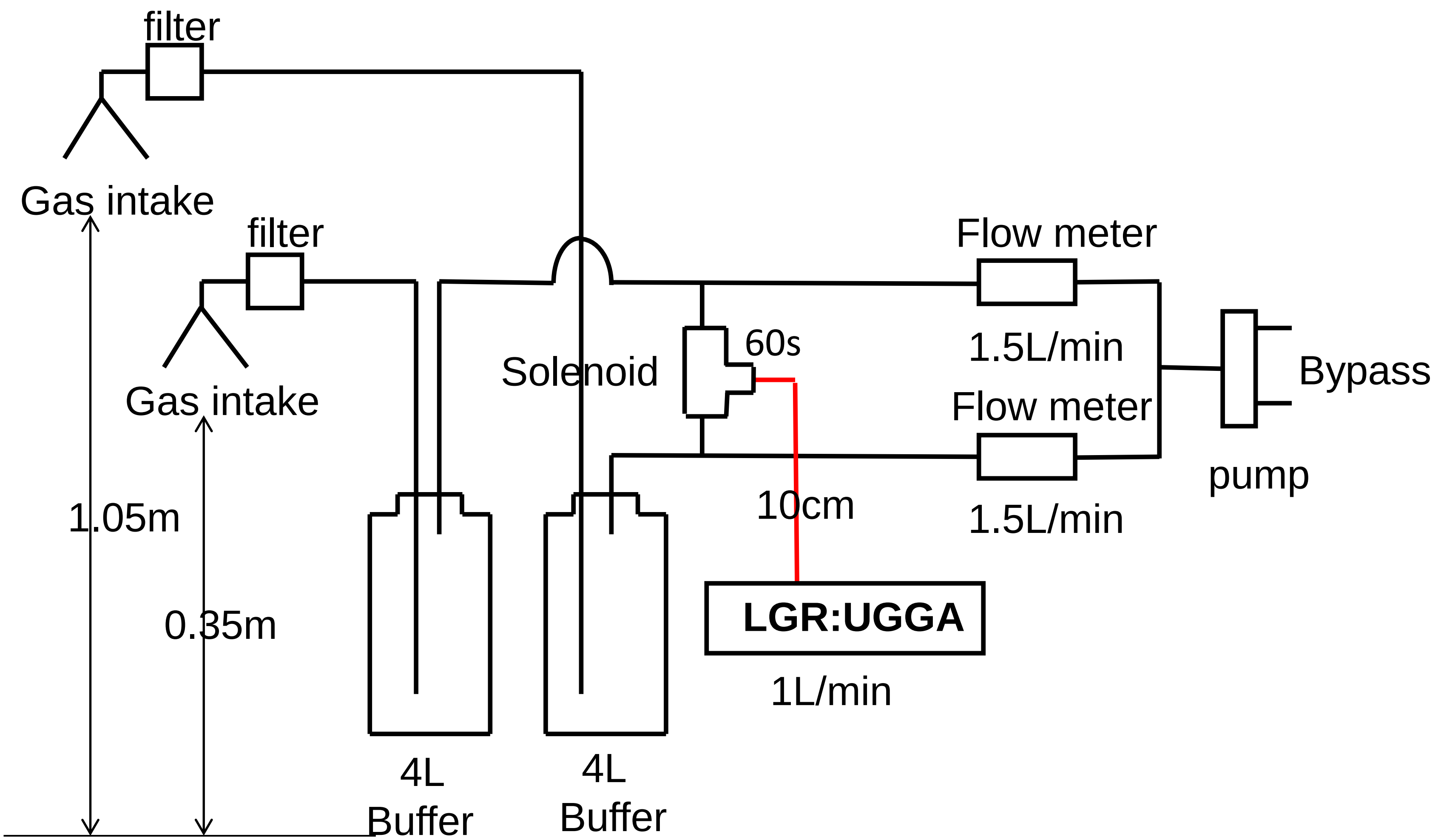
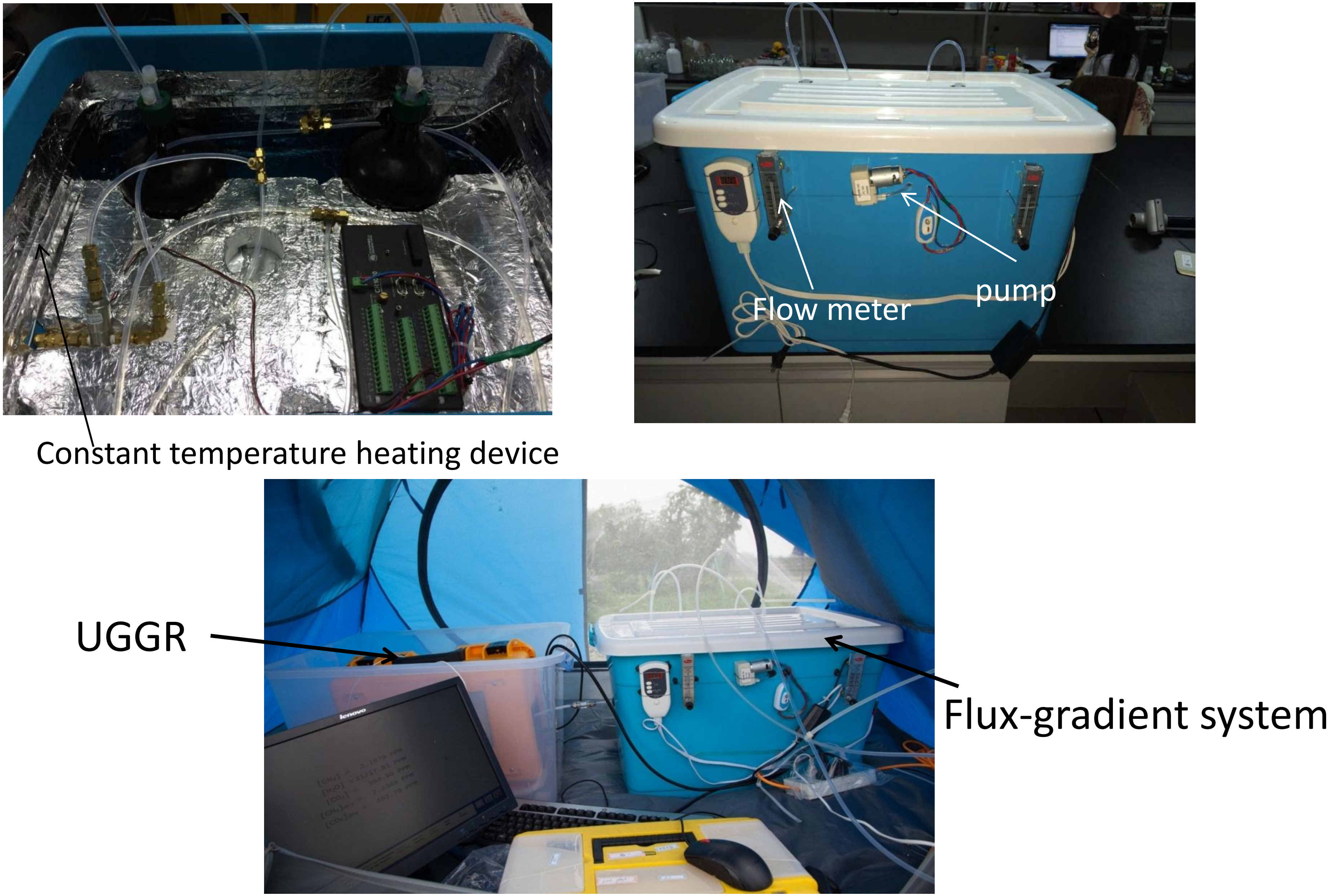


Zero-gradient
(07.14 16:00 – 07.15 17:00)

Normal observation
(07.15 19:00 – 07.24 24:00)

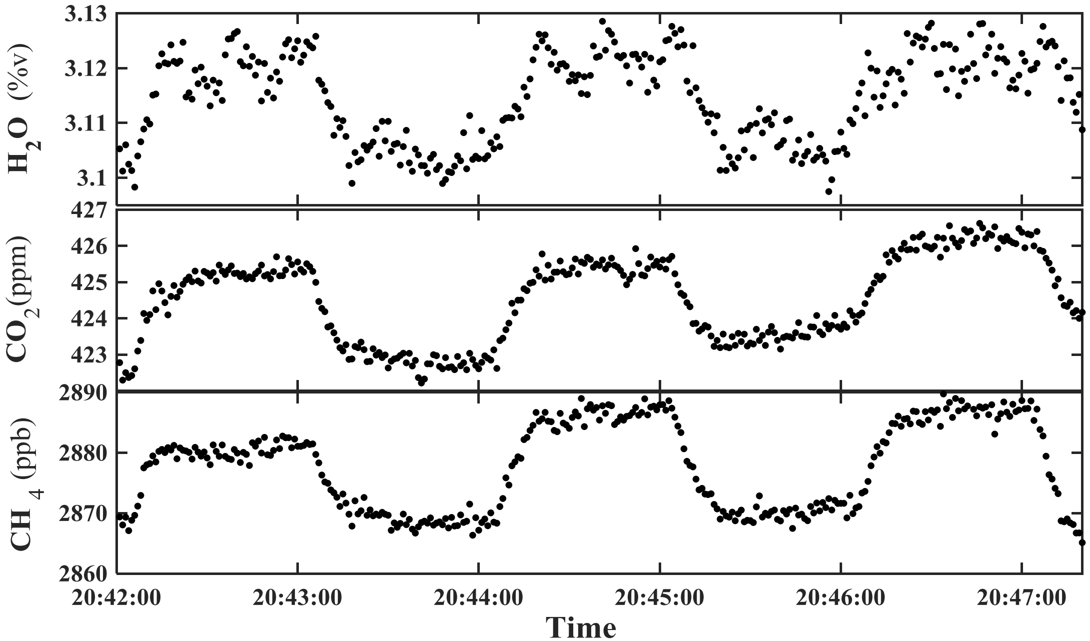
Flux-gradient system




Flow meter
pump
Constant temperature heating device
UGGR
Flux-gradient system

UGGR

- Principle: Off-Axis integrated cavity output spectroscopy.
- The instrument signal was recorded at 1 Hz.
- The 100sec precision supplied by the manufacturer for the analyzer is 0.6 ppb for CH_4, 100 ppb for CO_2, and 60 ppm for H_2O.



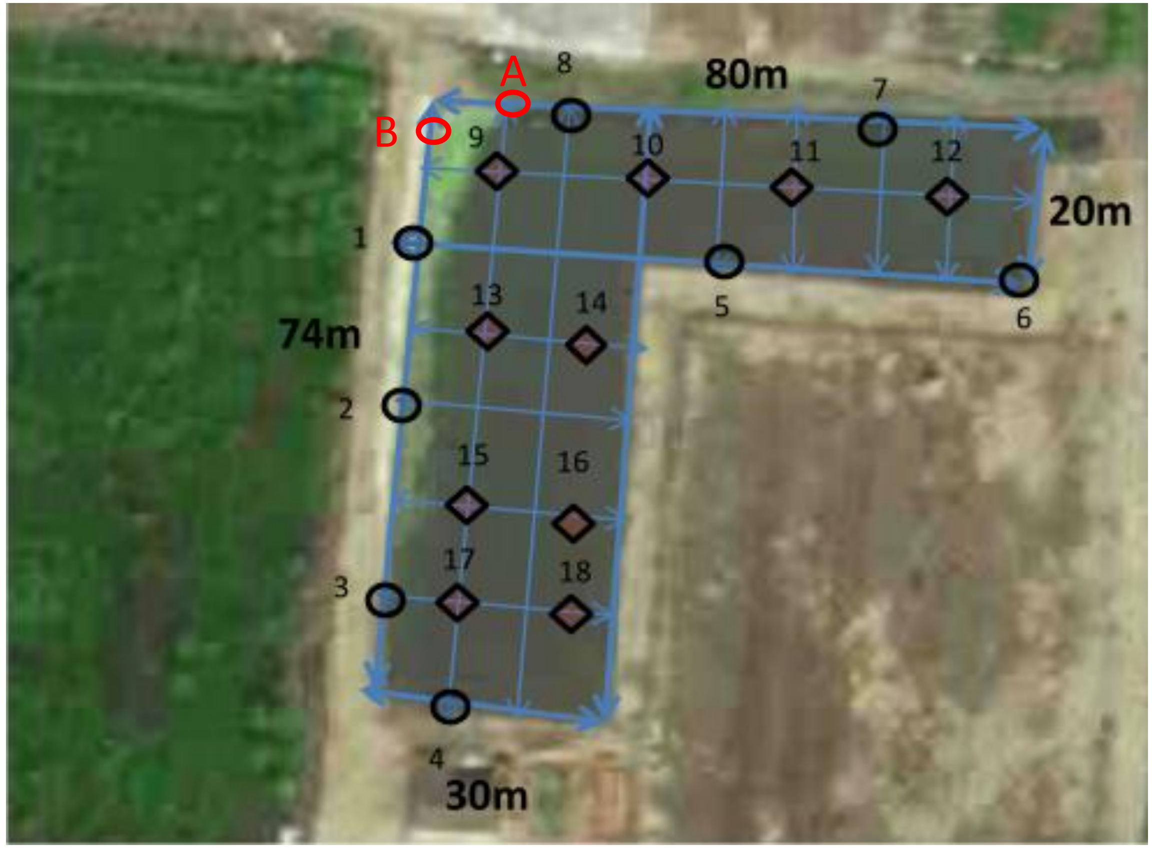
Step changes in the H_2O, CO_2, and CH_4 mixing ratio from around 20:42:00 to 20:47:00 on DOY 201, 2015.

Flux-gradient calculation method

$$F = -c\rho_{\mathrm{a}} K \frac{r_2 - r_1}{z_2 - z_1}$$

- F : flux of CO_2 (mg m^{-2} s^{-1}), CH_4 (μg m^{-2} s^{-1}), or H_2O (g m^{-2} s^{-1})
- c : unit conversion constant (44/29 for CO_2, 16/29 for CH_4, and 18/29 for H_2O)
- K : eddy diffusivity (m^2 s^{-1})
- ρ_{a} : air density (kg m^{-3})
- r : the half-hourly mean dry air mixing ratios → UGGA

Water equilibrium method



Sample Frequency : 3h
GC: Agilent 7890B

The sample site of fish pond
(Circle: Edge of pond; Rhombus: in the pond; 2015.07.21 11:30)
GC: Agilent 6890N

Water equilibrium calculation method

$$F = k(C_w - C_{eq}) \quad \begin{cases} k / k_{600} = (S_c / 600)^{-n} \\ k_{600} = 2.07 + 0.215\, U_{10}^{1.7} \\ U_{10} / U = ln(10 / z_0) \; / \; ln(1.5 / z_0) \end{cases}$$

- F : flux of GHGx (mol m^{-2} d^{-1}, or mmol m^{-2} d^{-1})
- k : gas transfer coefficent (m d^{-1})
- C_W : measured GHGx concentration, mol m^{-3} ⟶ GC
- C_{eq} : GHGx concentration in equilibration with the atmosphere.

Ancillary Measurements

u_*, θ_v, H_c

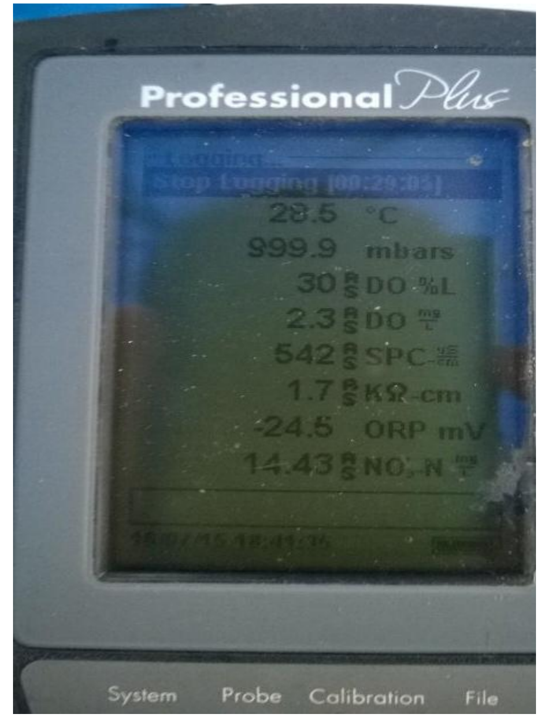
LE, F_c

Eddy covariance
Orientation: 180°

Wind direction
Wind speed

Meteorological observation
Orientation: 0°

Ancillary Measurements



Water thermometer: water temperature (20cm)
YSI: water temperature (20cm), dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance (SC).

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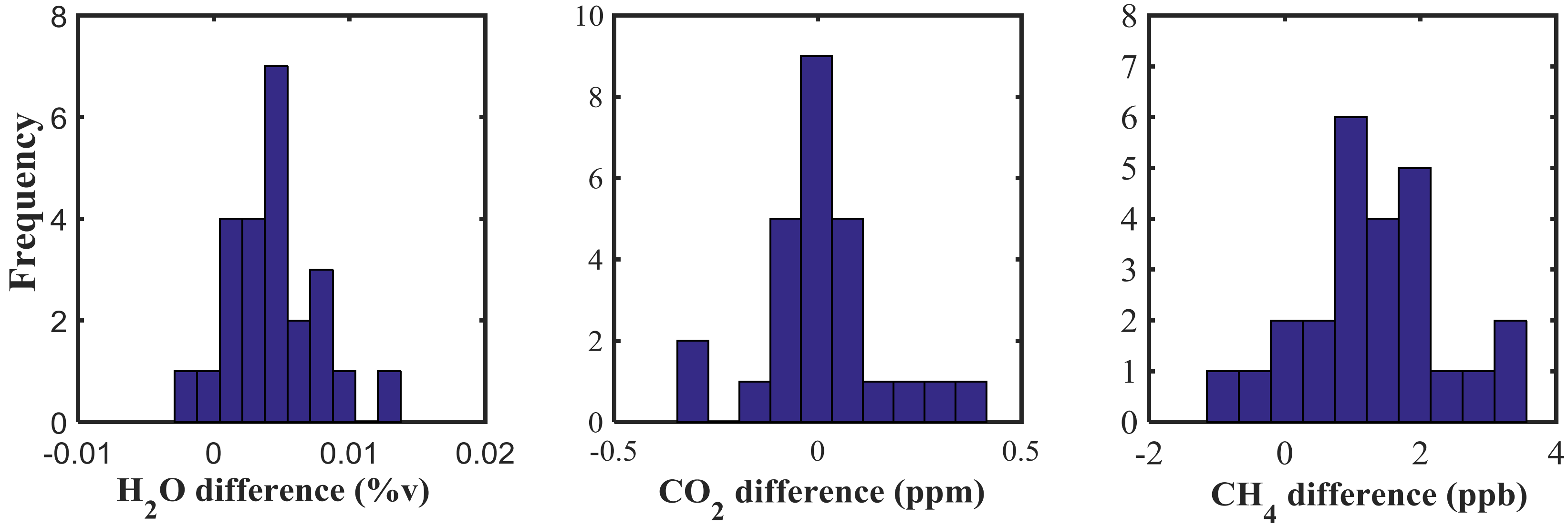
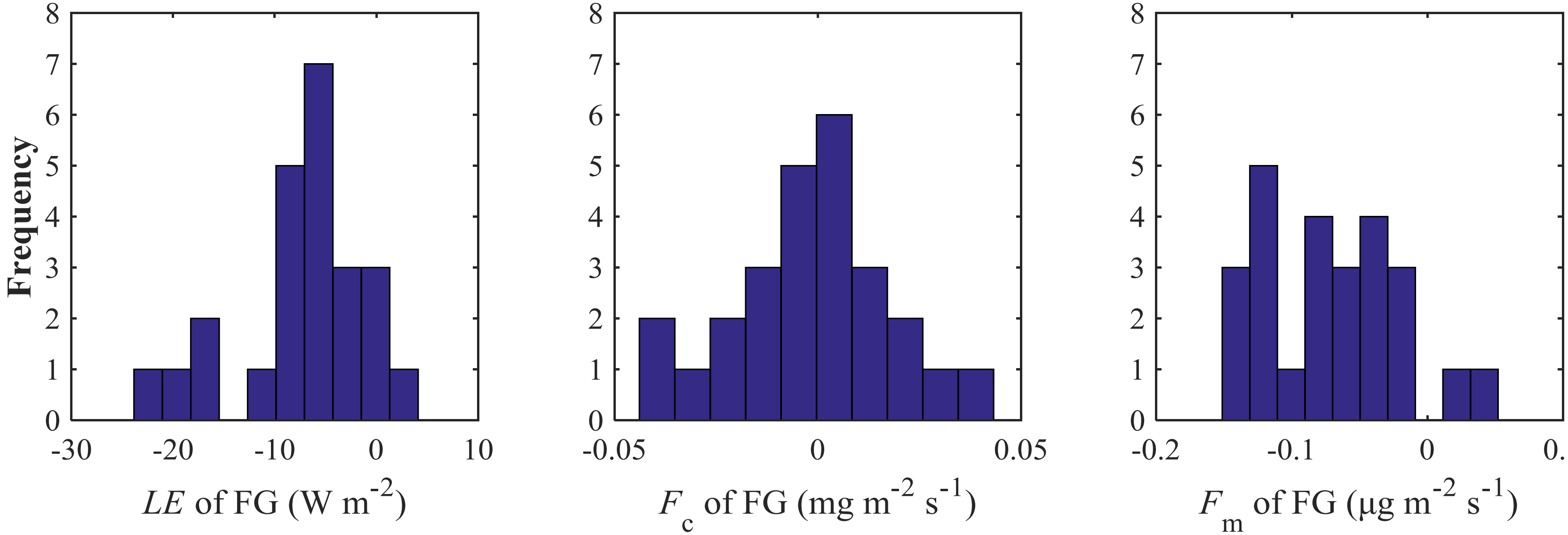
1.1 Frequency distribution of H_2O, CO_2, and CH_4



	Mixing ratio difference		
	H_2O (%v)	CO_2 (ppm)	CH_4 (ppb)
Mean value	4.3×10^{-3}	-0.009	1.30
Standard deviation	0.0034	0.138	1.10

Mean mixing ratio	2.72	423.17	2317
Relative percentage	0.15%	0.002%	0.05%

1.2 Frequency distribution of *LE*, F_c, and F_m

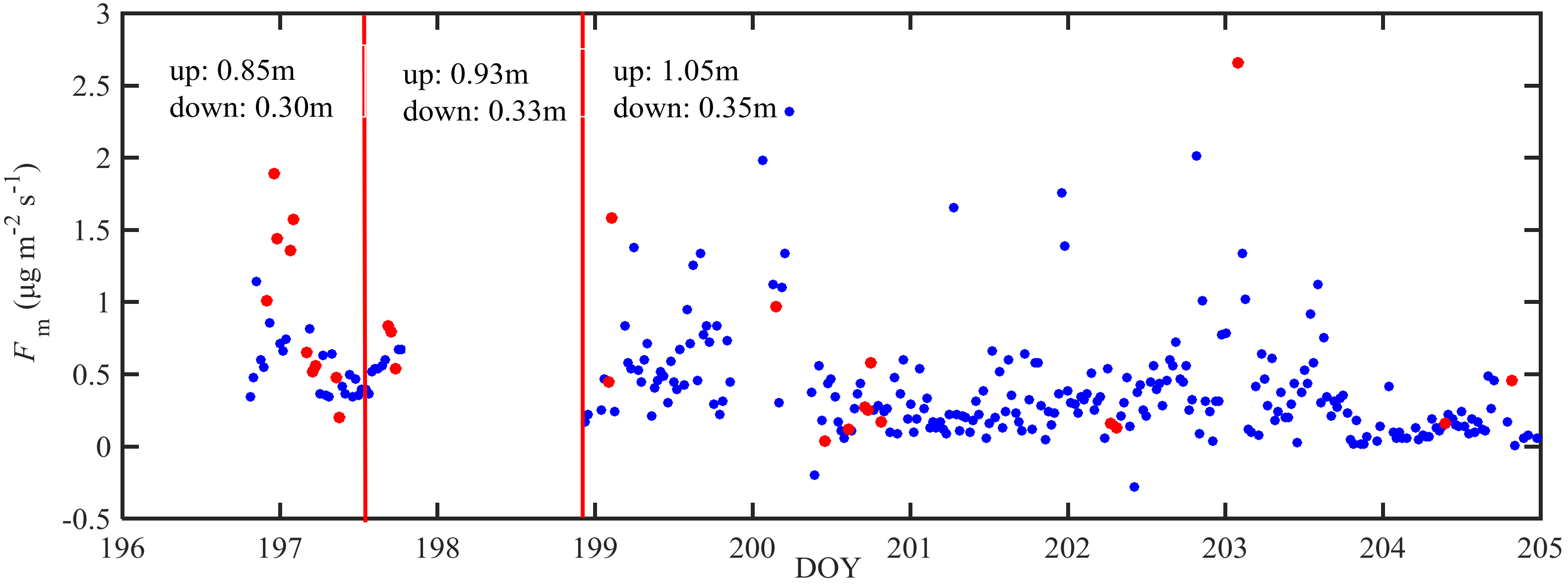


	Flux			K ($m^2\ s^{-1}$)
	LE ($W\ m^{-2}$)	F_c ($mg\ m^{-2}\ s^{-1}$)	F_m ($\mu g\ m^{-2}\ s^{-1}$)	
Mean value	-7.2	0.002	-0.07	0.05
SD	6.5	0.019	0.07	0.01

1.3 Comparison with results of other papers

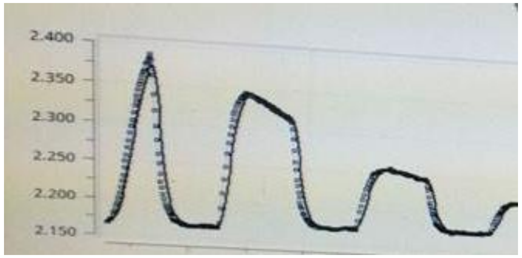
Location	Method	CH_4	Reference
MLW	Flux-gradient (picarro G1301)	0.2 ppb 0.016 μg m^{-2} s^{-1}	(Xiao et al. 2014)
Peatland surfaces	Closed-chamber Bowen-ratio methods	0.026 μg m^{-2} s^{-1} 0.6 – 7.08 μg m^{-2} s^{-1}	(Chan et al. 1998)
Rice paddy field	TDLAS (TGA 100)	0.2 ppb	(Simpson et al. 1995)
Boreal beaver pond	Gas chromatography (Shimadzu Mini II)	4 ppb	(Roulet et al. 1997)
Dairy farm	EC system (QCL spectrometer)	0.67μg m^{-2} s^{-1}	(Kroon et al. 2010)
Water surfaces	Automatic CH_4 chamber	0.053μg m^{-2} s^{-1}	(Duc et al. 2012)
Fish pond	Flux-gradient (UGGR 915)	1.3ppb 0.07μg m^{-2} s^{-1}	This study

2.1 Temporal variation of CH_4 emission

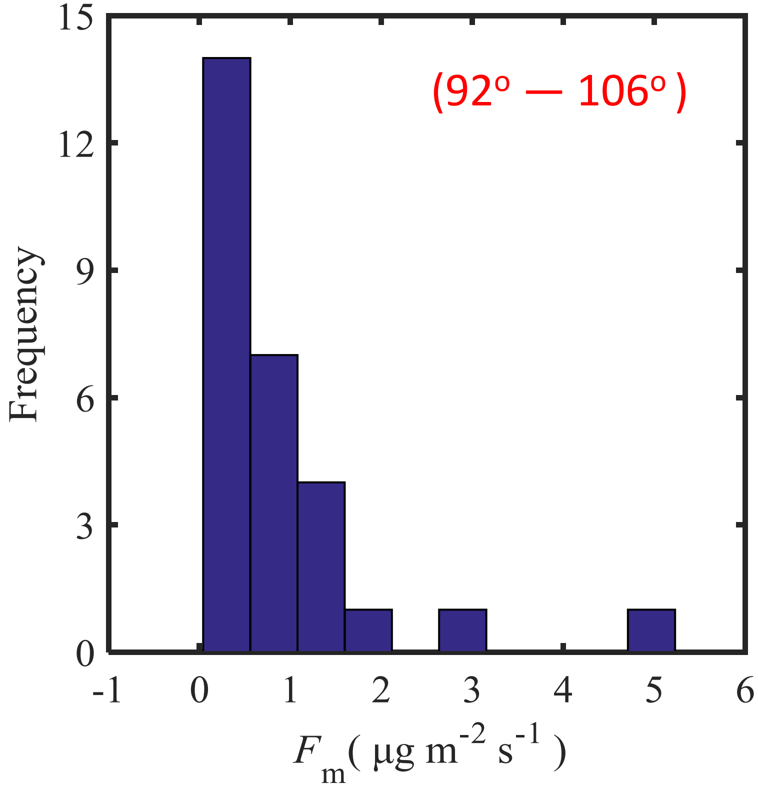


Red point: open fetch; Blue point: limited fetch

2015/07/18 03:30 /199.1458
CH_4 flux: 5.23 μg m^{-2} s^{-1}



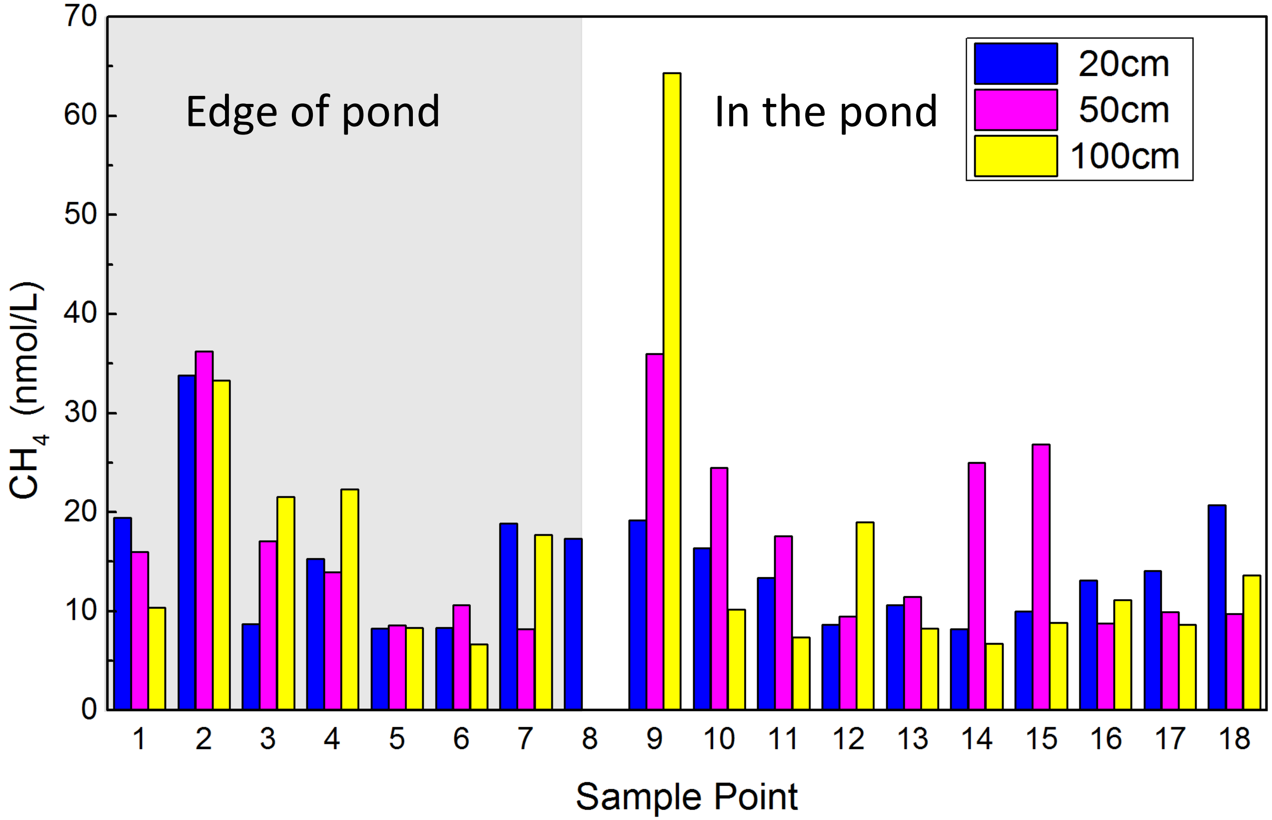
2.2 Frequency distribution of F_m



93% of CH_4 half-hourly fluxes were higher in the magnitude than the measurement precision (0.07μg m^{-2} s^{-1}).

	F_m (μg m^{-2} s^{-1})	K (m^2 s^{-1})
Mean value	0.91	0.05
SD	1.05	0.02

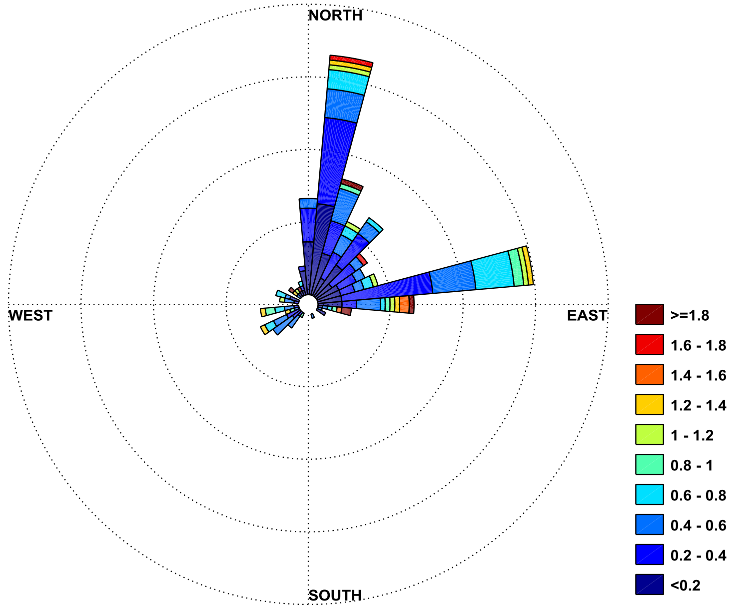
2.3 Comparison with water equilibrium results



1. Comparison with flux-gradient calculation result, the water equilibrium calculation result (0.002μg m^{-2} s^{-1}) was 445 times lower (This study).

2.Boundary model estimates were 5–30 times lower leading to a strong underestimation of methane fluxes from aquatic systems (J. Schubert et al. 2012).

2.4 Comparison with other zones near the ponds



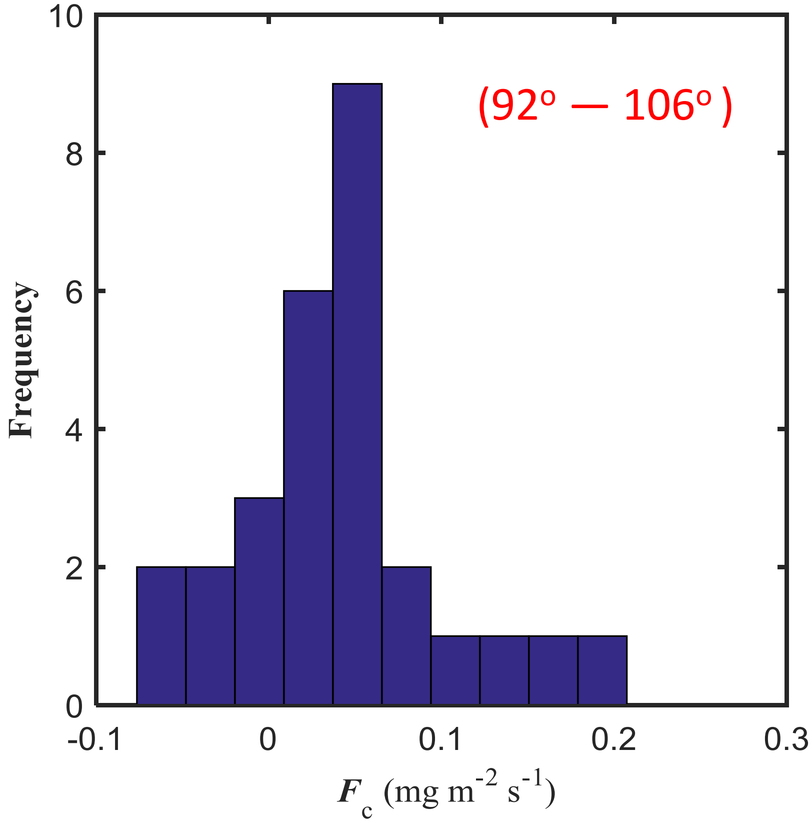
Wind rose diagrams of CH_4 flux from different zones near the ponds

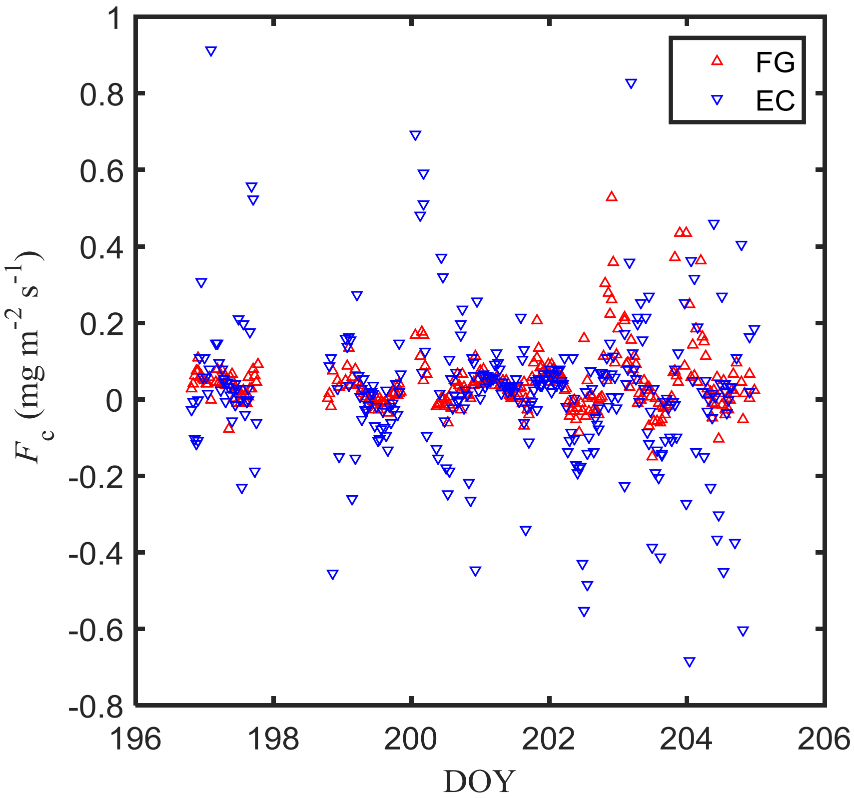
Surface	Range ($\mu g\ m^{-2}\ s^{-1}$)	Mean value ($\mu g\ m^{-2}\ s^{-1}$)
Dining kitchen	(0.01, 1.44)	0.27
Fruiter (park, WC)	(0.01, 2.33)	0.38
Fish pond	(0.04, 5.23)	0.91
Vinyl house	(0.17, 0.46)	0.32
Lobster pond	(0.20, 1.38)	0.60
Fish pond	(-0.20, 2.32)	0.47

2.5 Comparison with results of other papers

Location		Method	Flux (μg m^{-2} s^{-1})	Reference
MLW (2012.05 ~ 2014.01)		Flux-gradient	0.056	(Xiao et al. 2014)
BFG (2014.5~ 2014.8)		EC (Model Li-7700)	0.367	Xiao report
Taihu		Water equilibrium	0.017	Zhang report
Min jiang	Shrimp pond	Floating chamber	0.28	(Yang et al. 2012)
	Culturing pond		1.59	
Pond (Linköping University)		AFC	0.14	(Duc et al. 2012)
Fish pond (Puhao)		Flux-gradient	0.91	This study
		Water equilibrium	0.002	
Lagoons (Delta)		Static chamber	4.69	(Gondwe et al. 2014)
Nihe reservoir (summer)		Floating chamber	3.74	(Yu et al. 2012)
Ditches		Floating chamber	9.36	(Schrier et al. 2011)

3.1 Flux-gradient test result : F_c





1. 90% of CO_2 half-hourly fluxes were higher in the magnitude than the measurement precision (0.019mg m^{-2} s^{-1}).

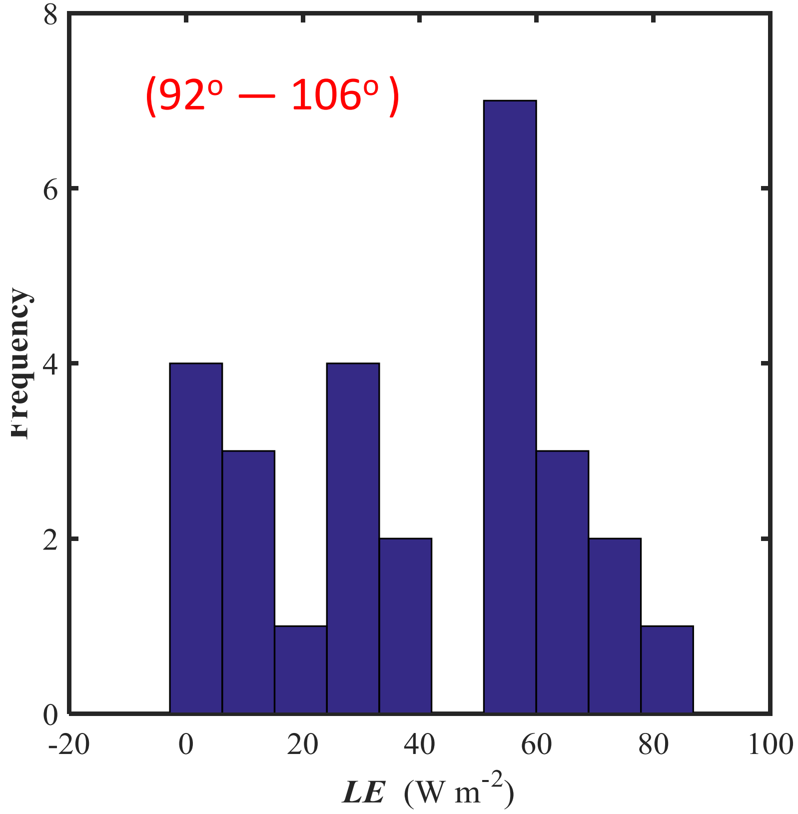
2. Comparison with flux-gradient result (0.042), the water equilibrium result (0.009 mg m^{-2} s^{-1}) was 5 times lower (This study).

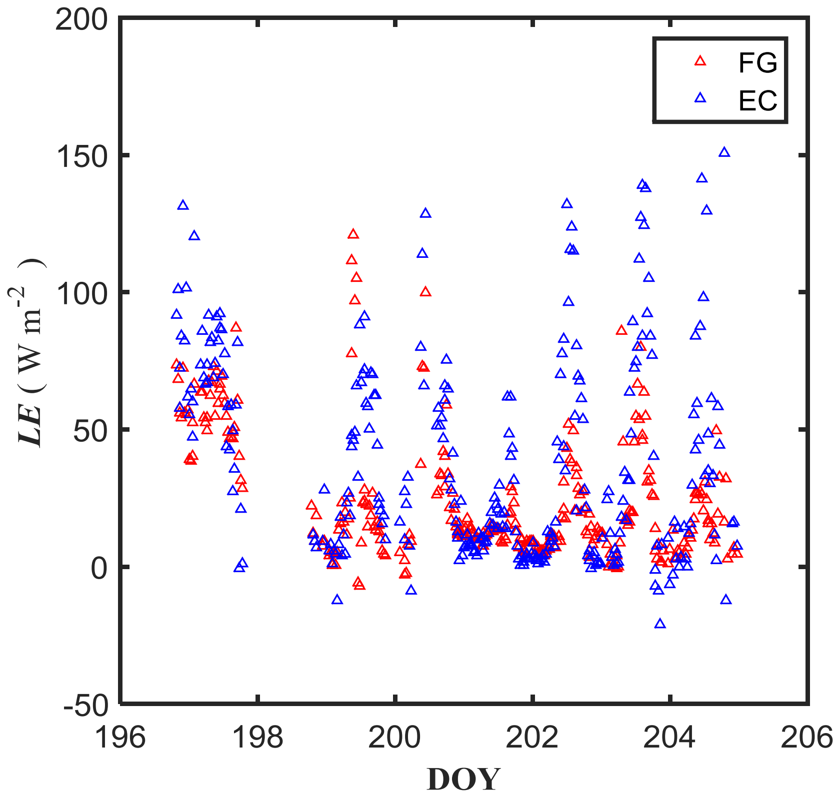
$$y = 0.40(\pm 0.05)x + 0.03(\pm 0.001)$$

(R^2=0.02, $p < 0.05$)

where y is the FG flux; x is EC flux

3.2 Flux-gradient test result: *LE*





80% of H_2O half-hourly fluxes were higher in the magnitude than the measurement precision (6.5W m^{-2}).

$y = 0.63(\pm 0.05)x + 0.81(\pm 2.12)$

(R^2=0.42, $p < 0.001$)

where y is the FG flux; x is EC flux

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- Results of zero-gradient test show that the flux measurement precision of 6.5 W m^{-2} for water vapor, 0.019 for CO_2 mg m^{-2} s^{-1}, and 0.07 for CH_4 μg m^{-2} s^{-1}.

- During the flux-gradient measurement period, 80%, 90%, and 93% of H_2O, CO_2, and CH_4 half-hourly fluxes were higher in the magnitude than the measurement precision. According to the zero-gradient test results, the flux-gradient system had adequate precision for the fish pond measurement.

- The mean CH_4 flux from fish pond is 0.91 μg m^{-2} s^{-1}.

Future work

1. Comparison *LE* and F_c between EC and FG by using MBR method.

2. Find the reason about the times between flux-gradient results and water equilibrium results.

3. Analyzing the relationship between CH_4 flux and water quality parameter.

4. Summary of experiments.

Thank you