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A discussion on the paper " Large contribution to inland water CO_2 and CH_4 emissions from very small ponds"

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2016.04.22

Outline

1.Background

- 1.1 The importance of inland water
- 1.2 Why might small ponds be very important?

2.Method

- 2.1 Estimating gas flux for each water body
- 2.2 Estimating of the global size distribution of lakes and ponds
- 2.3 Upscaling to global carbon flux

3.Results and discussion

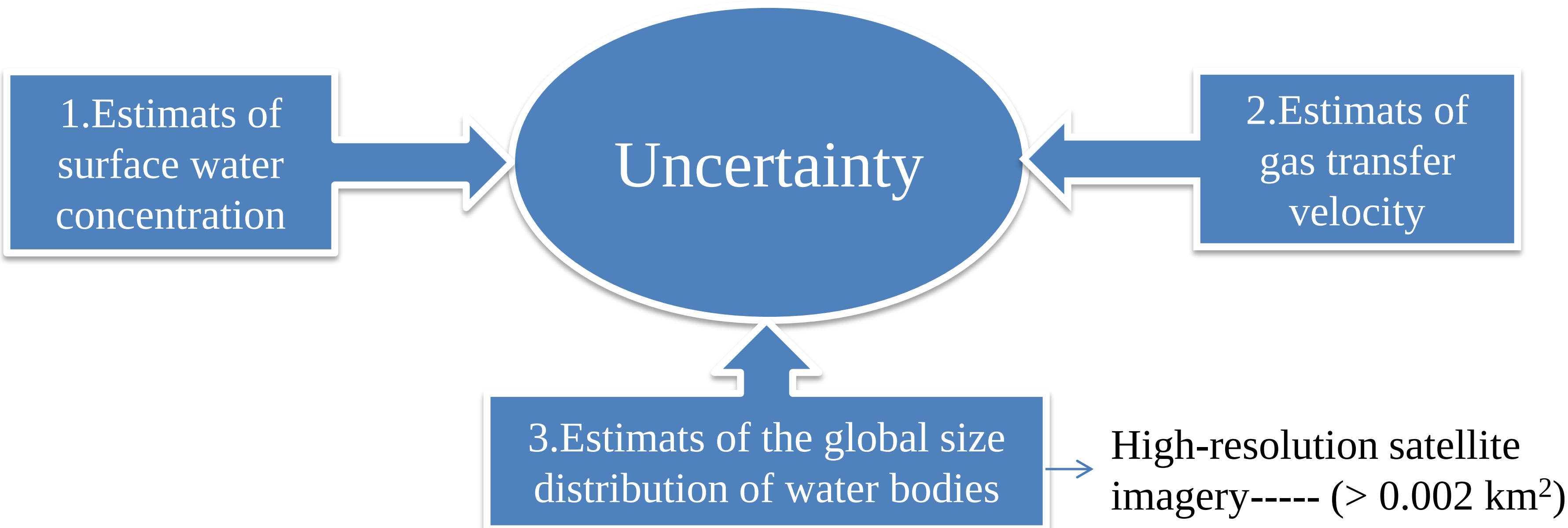
- 3.1 CO_2 and CH_4 concentration in relation to lake surface area and latitude
- 3.2 Estimated global flux of CO_2 and CH_4 for each lake size class
- 3.3 Uncertainty in estimated values

4.Our work

1. Background

1.1 The importance of inland water

- Inland waters are an important component of the global carbon cycle. Yet, accurately estimating inland water carbon budgets remains challenging.



- So far, upscaling estimates for carbon budgets **exclude very small ponds less than 0.001 km^2** in surface area because of uncertainty in their global distribution.

1.2 Why might small **ponds(< 0.001km^2)** be very important?

1. The vast majority of ponds and lakes are small:

90% of all ponds and lakes are <0.01km^2 (Downing et al.2006; Verpoorter et al. 2014), not including very small ponds (0.0001 – 0.001 km^2) which could number as high as 3.2 billion and cover 0.8 million km^2 of surface area (Downing et al. 2010).

2. Rich biodiversity, High productivity, small area, shallow depth

Regardless of their areal extent, small ponds may be important for their contributions to global aquatic elemental fluxes, biodiversity, and productivity (Verpoorter et al. 2014).

3. The level of supersaturation: CO_2 :19-fold, CH_4: 504-fold

Research surveys: Six ponds (forested ponds in Connecticut, USA) : For CO_2 and CH_4 gases, this level of supersaturation in the pond is among the highest reported for lentic freshwaters. (Holgerson et al. 2015)

Objectives

Estimating the CO_2 and CH_4 emission flux and ratio from small ponds

Research process:

Data acquisition

↓

Estimate diffusive gas flux

↓

Estimate of the global size distribution of lakes and ponds

↓

Upscale to the global carbon efflux

2. Method

2.1 Estimating gas flux for each water body

$$F = k(C_{\mathrm{w}} - C_{\mathrm{eq}})$$

- F : Flux of CO_2 or CH_4 (mmol m^{-2} d^{-1})
- k : Gas transfer coefficient (m d^{-1})
- C_w : CO_2 or CH_4 concentration dissolved in the surface water, μmol l^{-1}

----literature research :427 lakes and ponds globally (2.5 m^2 – 674 km^2)

- C_{eq} : CO_2 or CH_4 concentration in water that is in equilibration with the atmosphere, μmol l^{-1}

---- Mauna Loa Observation sites

2.1 Estimating gas flux for each water body-----Gas exchange velocity

Size class	<0.001	0.001 – 0.01	0.01 – 0.1	0.1 - 1	1 - 10	10 - 100	>100
k_{600}	0.36	0.48	0.57	0.80	0.85	1.09	1.15

A. >0.01km² : *Courtesy of Raymond, 2013* ; the calculate method as follows:

1. $$k_{600} = 2.07 + 0.215\, U_{10}^{1.7}$$ ----- (Cole and Caroco,1998)

k_{600}: the gas transfer coefficient adjusted to Schmidt number 600, U_{10} : the wind speed at 10m height

2. $$k = \eta(\varepsilon v)^{1/4} Sc^{-n}$$ ------ (Read et al. 2012)

η: the constant of proportionality, v: the kinematic viscosity of water, Sc: the Schmidt number of the gas
n: the coefficient representing surface conditions.

B. 0.001 – 0.01 km² : *Courtesy of Read, 2012*

C. <0.001 km²: the average k_{600} from four study ponds using a propane trace gas
------(Author's study)

2.2 Estimate of the global size distribution of lakes and ponds

Size class	**<0.001**	**0.001 – 0.01**	**0.01 – 0.1**	**0.1 - 1**	**1 - 10**	**10 - 100**	**>100**
Surface area (km^2)	147763 861578	406575.9	675233.8	984650.6	782073.8	597789.3	2024015.8

A. > 0.002 km^2 : Using the high-resolution satellite images to identify.(Verpoorter et al. 2014)

B. 0.001 – 0.002 km^2: The author assumed that lakes between 0.001 and 0.002 km^2 comprised 10% of lakes in the entire size class, which equaled 9988889 lakes.

C. < 0.001 km^2:

Using **the Monte Carlo analysis** by using a lower and an upper bound estimate.

For the lower bound: **using the log-log linear regression**:-----547268724 lakes

number for lakes(ln)=-0.71 × size class +8.74, R^2 = 0.996

For the upper bound: **using the Pareto distribution:------**3.19×10^9 lakes

2.3 Upscale to global carbon flux

Table 1 | Characteristics of surface area, gas exchange rates, and gas concentrations and fluxes for each lake size class

Size class (km^2)	Surface area (km^2)	k_{600}	CO_2			CH_4			Ratio CO_2:CH_4				
			n	Conc. (μmol l^{-1})	Flux (mmol C m^{-2} d^{-1})	*n*	Conc. (μmol l^{-1})	Flux (mmol C m^{-2} d^{-1})	*n*	Conc.	Conc. (CO_{2eq})	Flux	Flux (CO_{2eq})
<0.001	147,763 861,578	0.36	50	133.99 (16.69)	35.18 (5.21)	50	7.57 (1.64)	2.28 (0.51)	50	92.22 (33.21)	10.12 (3.64)	15.46	1.70
0.001–0.01	406,575.9	0.48	22	70.29 (14.8)	21.21 (5.88)	20	1.70 (0.49)	0.65 (0.16)	14	157.42 (48.99)	17.28 (5.38)	32.49	3.57
0.01–0.1	675,233.8	0.57	111	68.79 (4.4)	21.57 (1.85)	86	0.68 (0.09)	0.28 (0.05)	60	399.14 (49.66)	43.81 (5.45)	77.13	8.46
0.1–1	984,650.6	0.80	110	58.05 (4.1)	23.87 (3.03)	86	0.36 (0.07)	0.16 (0.04)	63	483.46 (50.96)	53.06 (5.59)	151.68	16.65
1–10	782,073.8	0.85	45	57.83 (3.3)	22.42 (1.88)	43	0.24 (0.08)	0.12 (0.06)	33	968.53 (124.73)	106.30 (13.69)	192.50	21.13
10–100	597,789.3	1.09	10	47.27 (5.7)	20.90 (4.08)	18	0.20 (0.06)	0.10 (0.05)	10	1,361.34 (233.10)	149.41 (25.58)	204.21	22.41
>100	2,024,015.8	1.15	1	32.63	11.49	6	0.13 (0.04)	0.06 (0.04)	0	–	–	–	–

Attention: Concentration ratios are calculated for each lake; flux ratios are averages for the size class. Numbers in parentheses represent standard error.

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3. Results and Discussion

3.1 CO_2 and CH_4 concentration in relation to lake surface area and latitude

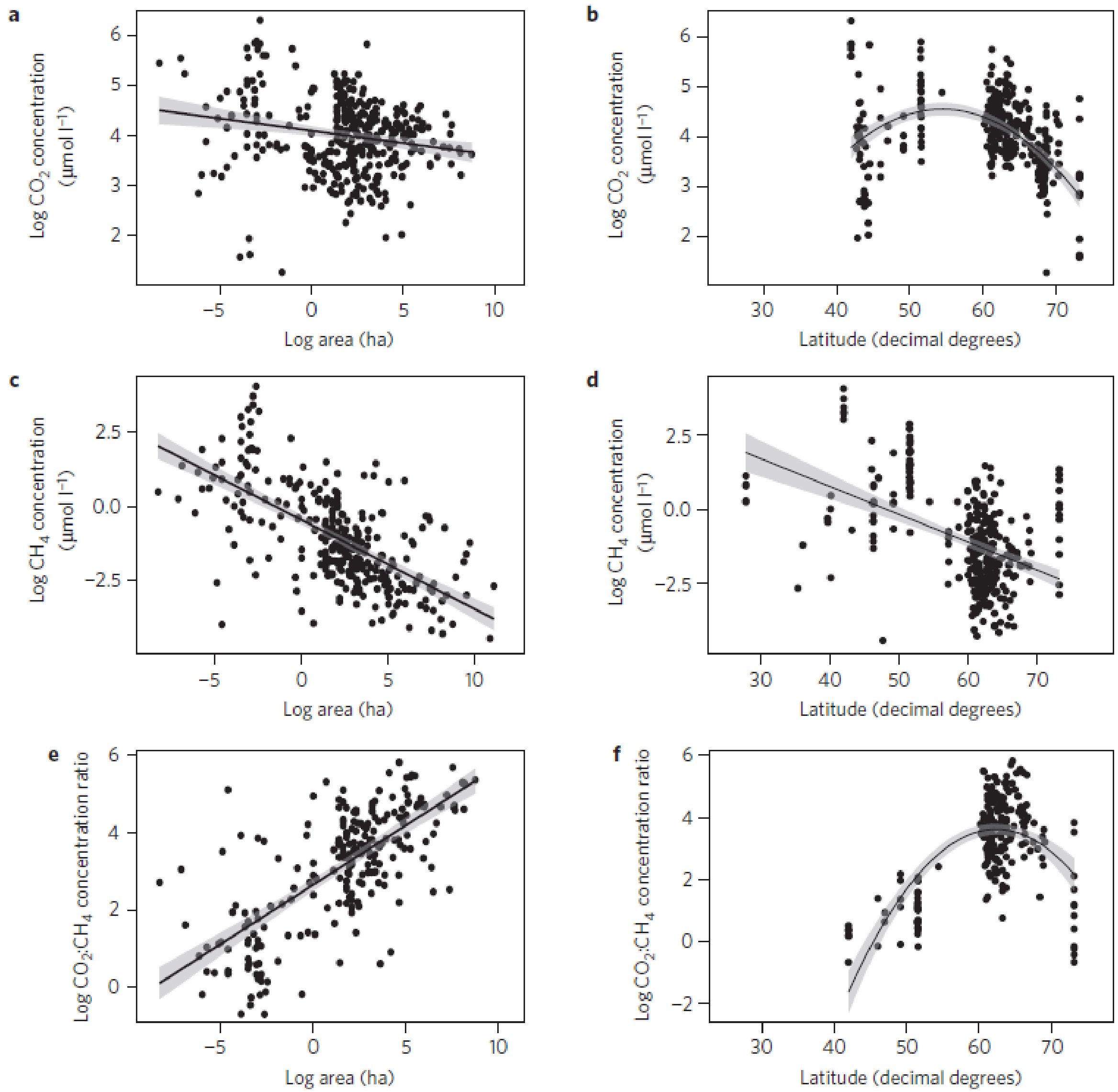


Table 2 Relationship between gas concentrations, lake or pond surface area and latitude.

Equation	Intercept	Area (ln)	Latitude	$Latitude_a^2$	Area (ln) x $Latitude_a$	*F*	*p*	R^2
$\ln(CO_2) \sim \ln(area) \times latitude_a + latitude_a^2$	4.44 (0.06)	−0.061 (0.011)	−0.055 (0.005)	−0.0042 (0.0005)	0.008 (0.0014)	49.1 (4, 343 DF)	<0.001	0.36
$\ln(CH_4) \sim \ln(area) + latitude$	4.25 (0.440)	−0.278 (0.017)	−0.080 (0.007)	-	-	213.2 (2, 306 DF)	<0.001	0.58
Ratio ($\ln CO_2/\ln CH_4$) ~ $\ln(area) \times latitude_a + latitude_a^2$	5.20 (0.090)	0.190 (0.022)	0.063 (0.012)	−0.0081 (0.0011)	0.0077 (0.0034)	109.2 (4, 225 DF)	<0.001	0.65

$Latitude_a$: values are centred around the mean.

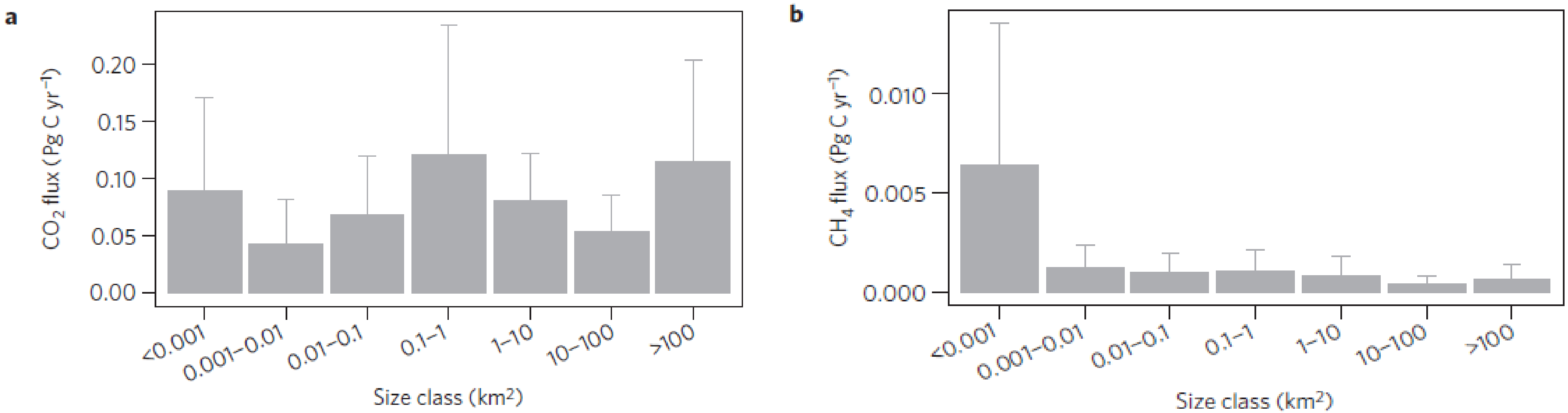
Relationship:

1. $\ln CO_2$ = -0.061 $\ln(Area)$ - 0.055 $Latitude$-0.0042 $Latitude_a^2$+0.008 $\ln(Area) \times Latitude_a$+4.44

2. $\ln CH_4$=-0.278 $\ln(Area)$ -0.080 $Latitude$+ 4.25

3. Ratio($\ln CO_2/\ln CH_4$)= 0.190$\ln(Area)$ + 0.063$Latitude$-0.0081$Latitude_a^2$+0.0077 $\ln(Area) \times Latitude_a$+5.20

3.2 Estimated global flux of CO_2 and CH_4 for each lake size class



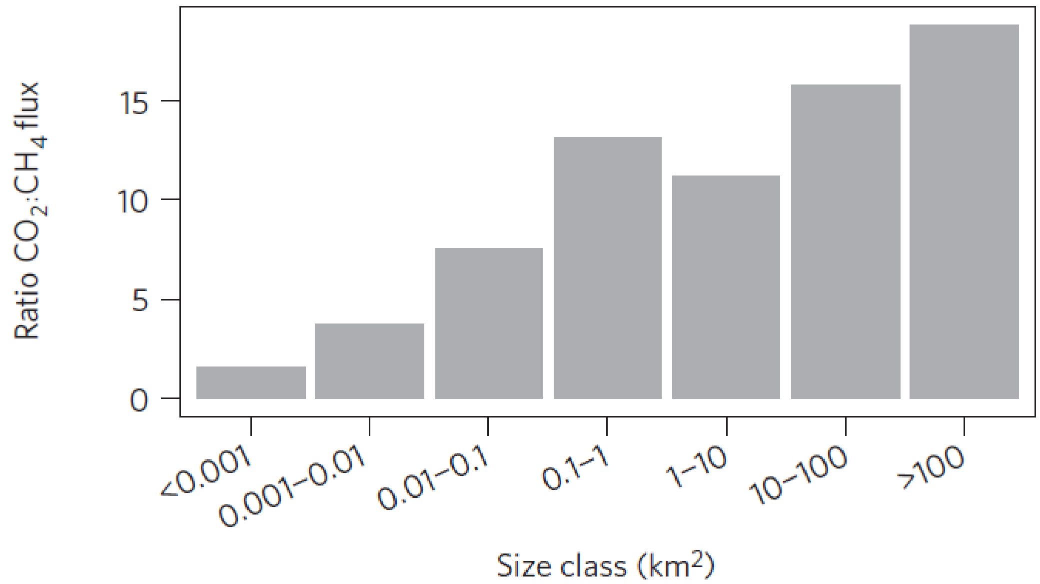
Size Class (km^2)	CO_2 flux (Pg C yr^{-1})	CO_2 CV	CH_4 flux (Pg C yr^{-1})	CH_4 CV
<0.001	0.0890	92.0%	0.00643	111.1%
0.001- 0.01	0.0425	94.2%	0.00125	87.3%
0.01 – 0.1	0.0689	74.7%	0.00101	95.6%
0.1 – 1	0.0121	93.6%	0.00102	107.8%
1 – 10	0.0802	53.2%	0.00079	124.4%
10 – 100	0.0537	60.2%	0.00037	108.6%
> 100	0.1152	77.3%	0.00067	105.0%
TOTAL	**0.571**		**0.012**	
25 – 75th quantiles	**0.439 – 0.683**		**0.006 – 0.015**	

Small ponds (Area:8.6%)

15.1%

40.6%

3.2 Estimated global flux of CO_2 and CH_4 for each lake size class



1. Global CO_2 flux is only **1.5 times higher** than global CH_4 flux **in very small ponds**.

2. Global CO_2 flux is only **19 times higher** than global CH_4 flux **in very largest lakes**.

Only focused on diffusive CH_4 flux;
Not considered the CH_4 ebullition;

3.3 Uncertainty in estimated values

Ebullition Analysis

→ **Low sample size** (47 water bodies)
small range (0.002, 1.449 km^2)

The relationship **between ebullition to surface area** was weak
(linear regression, R^2=0.19, p= 0.02)
No significant relationship **between the ratio of diffusion and ebullition and lake surface area**
(linear regression, R^2=0.002, p= 0.56)

Uncertainty in k_{600} Values

1. Much uncertainty remains regarding k_{600} estimates from **convection and wind speed**.
2. Used the **k_{600} was daily average**, we may **underestimate gas flux**.
3. using **eddy covariance techniques** typically calculate **large k_{600} estimates** than those predicted **from gas concentration and wind speed**.

Uncertainty in Global Size Distribution of Very Small Ponds(< 0.001 km^2)

The upper bound: Parote distribution

It can **accurately estimate** the number of lakes **in some flat regions** in Earth, but **overestimates** the number of lakes **in mountainous regions.**

Conclusion

Notably:

Ponds from the smallest size class(<0.001km^2) have a disproportionately large contribution to carbon flux relative to their size. It play a critical role in geochemical cycling and represent an important contribution to natural carbon cycling in inland waters.

(surface area:8.6%；CO_2 emission:15.1%; CH_4 emission:40.6%)

On-going work:

Clearly, more research on **the global distribution of small ponds** is needed for upscaling, which will require capitalizing on new technologists to map small ponds.

Our work

Title:

Measuring Methane Emission from Fish Ponds with Micrometeorological and Water Equilibrium Methods

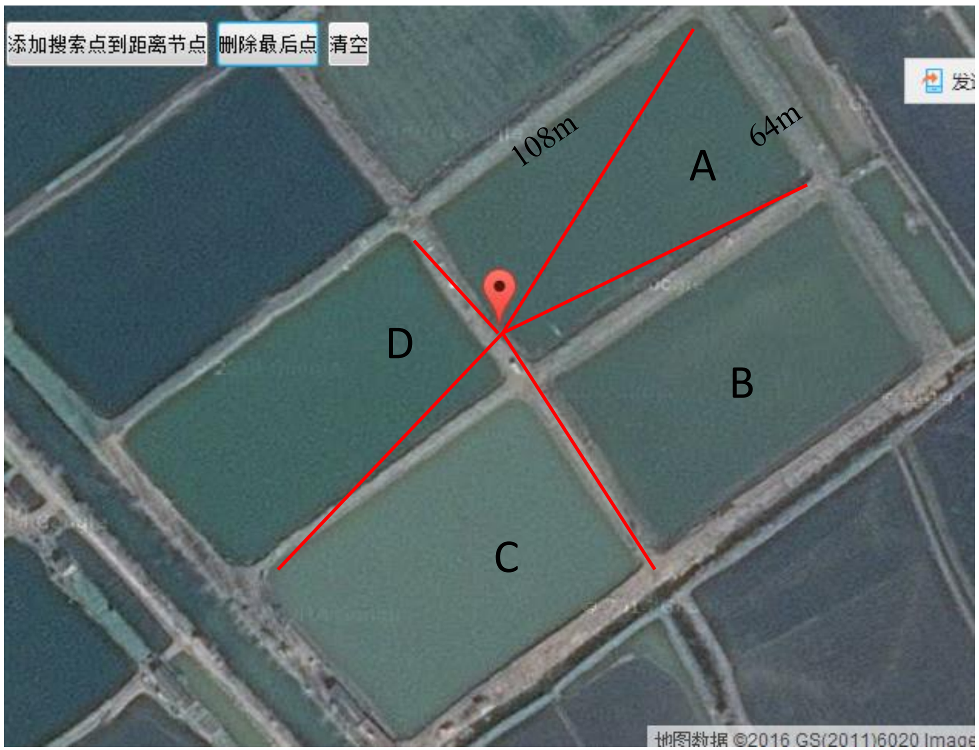
Objectives:

(1) Quantify the CH_4 emission from small ponds (Diffusive flux + Ebullition flux)

(2) Identify critical environmental factors that regulate the emission intensity.

Study Site

Location	Latitude and Longitude	Area	Water Depth
Guandu Fish Pond A	31.97^{o} N , 118.25^{o} E	6912 m^2	0 m



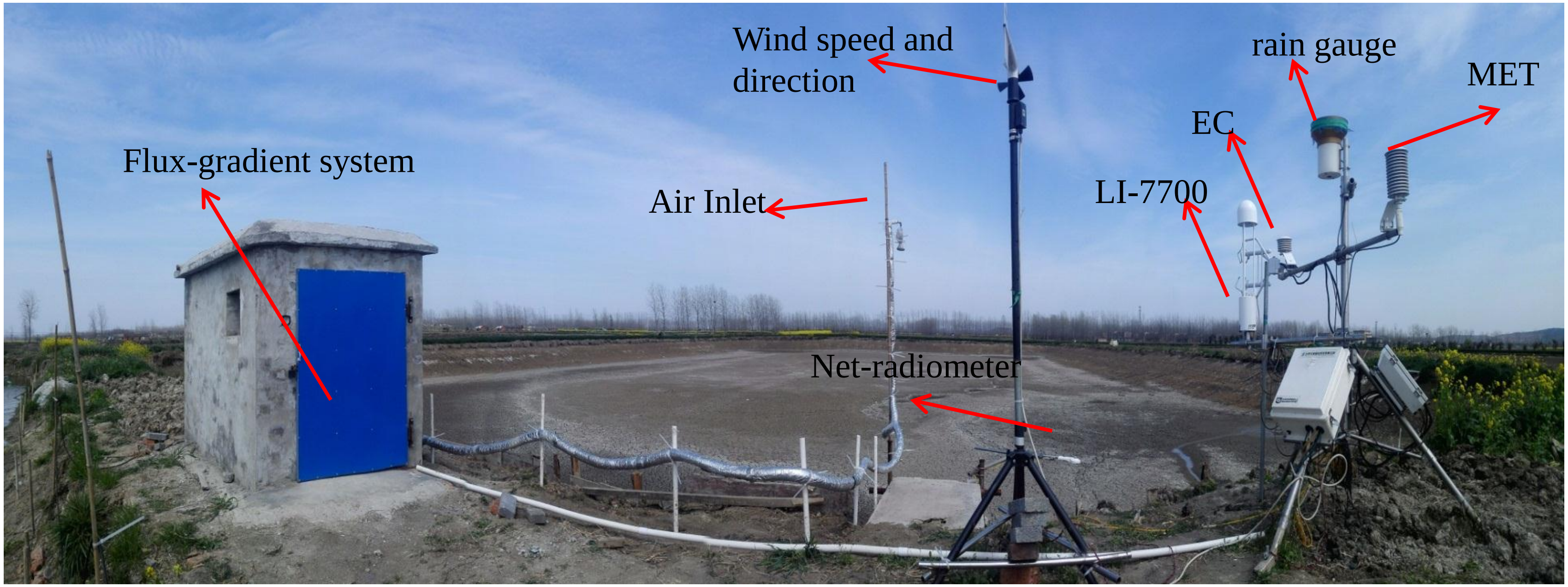
Fish Pond A: (35^{o} , 67^{o})

Fish Pond B: (68^{o} , 140^{o})

Fish Pond C: (141^{o} , 216^{o})

Fish Pond D: (217^{o} , 312^{o})

Instrument information



Flux-gradient system (UGGA)

Eddy covariance system (EC150, LI-7700)

MET system

Instrument information---- Flux Gradient

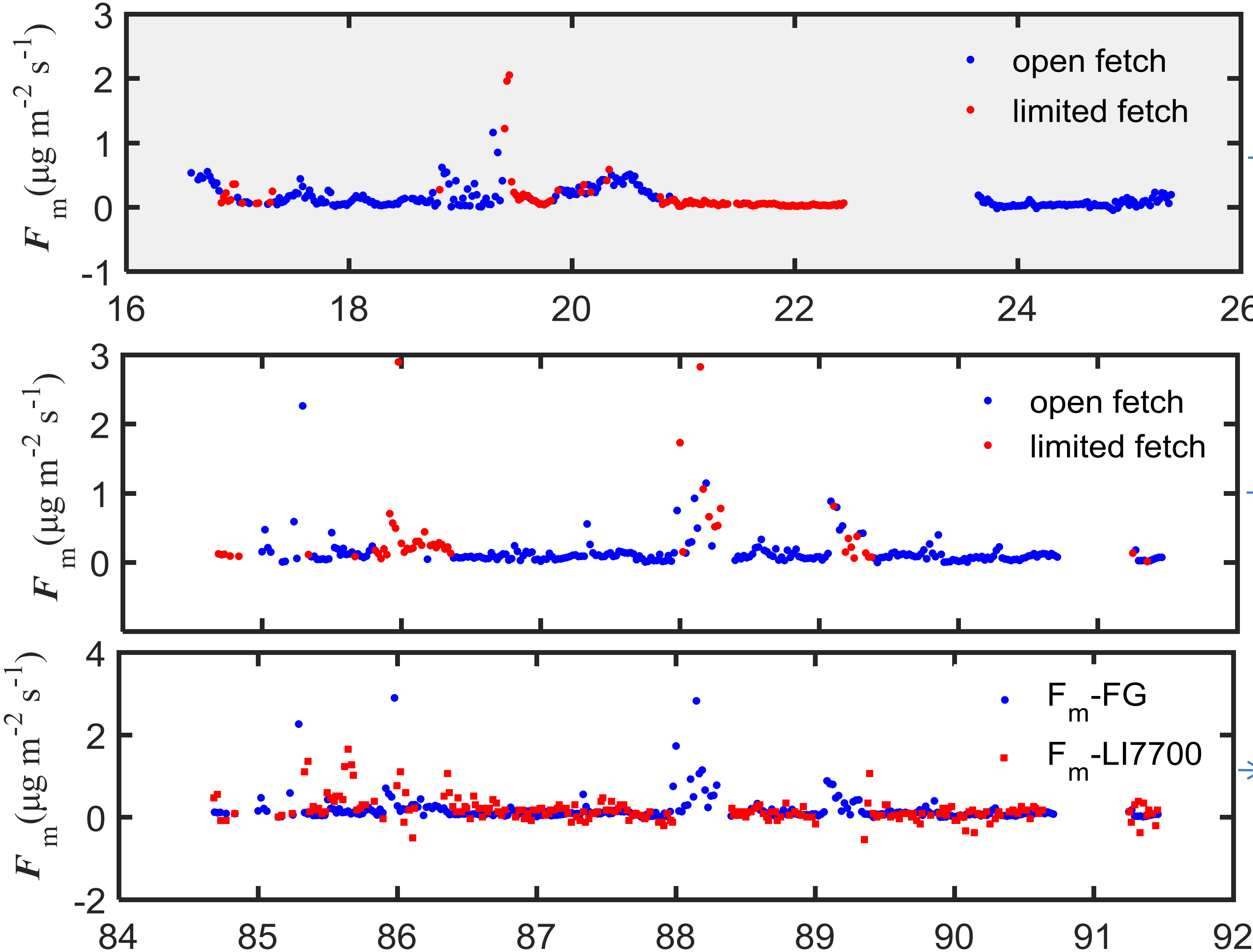
Instrument information-----Eddy covariance

Eddy covariance

Orientation: 42°

The horizontal distance between EC150 and LI-7700 is 35 cm.

Preliminary results (CH_4 Flux)



Winter experiment (Flux-gradient)

Spring experiment (Flux-gradient)

Spring experiment (Flux-gradient Eddy covariance)

All data

Table 3 The mean and standard deviation of CH_4 flux from all wind direction

	F_m-win ($\mu g\ m^{-2}\ s^{-1}$)	F_m-spr ($\mu g\ m^{-2}\ s^{-1}$)	F_m-LI7700 ($\mu g\ m^{-2}\ s^{-1}$)
Mean value	0.15	0.19	0.17
SD	0.21	0.33	0.29

Limited fetch: (35^o,67^o)

Table 4 The mean and standard deviation of CH_4 flux from limited direction (35^o,67^o)

	F_m-win ($\mu g\ m^{-2}\ s^{-1}$)	F_m-spr ($\mu g\ m^{-2}\ s^{-1}$)	F_m-LI7700 ($\mu g\ m^{-2}\ s^{-1}$)
Mean value	0.14	0.40	0.36
SD	0.29	0.58	0.50

***F*$_m$-win**: CH_4 flux observed results in winter using FG method ;
***F*$_m$-spr**: CH_4 flux observed results in spring using FG method ;
***F*$_m$-LI7700**:CH_4 flux observed results in spring using EC method ;

On-going Work

1. Continuing the spring experiment using box-chamber method and water equilibrium method in May.

2. Due to the dry fish pond, the water parameters were not measured in the winter experiment. We will measure water parameters in the spring experiment to investigate the relation between CH_4 flux and environmental factors. .

Thank you