耶鲁大学–南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

N_2O concentration and flux in Lake Taihu

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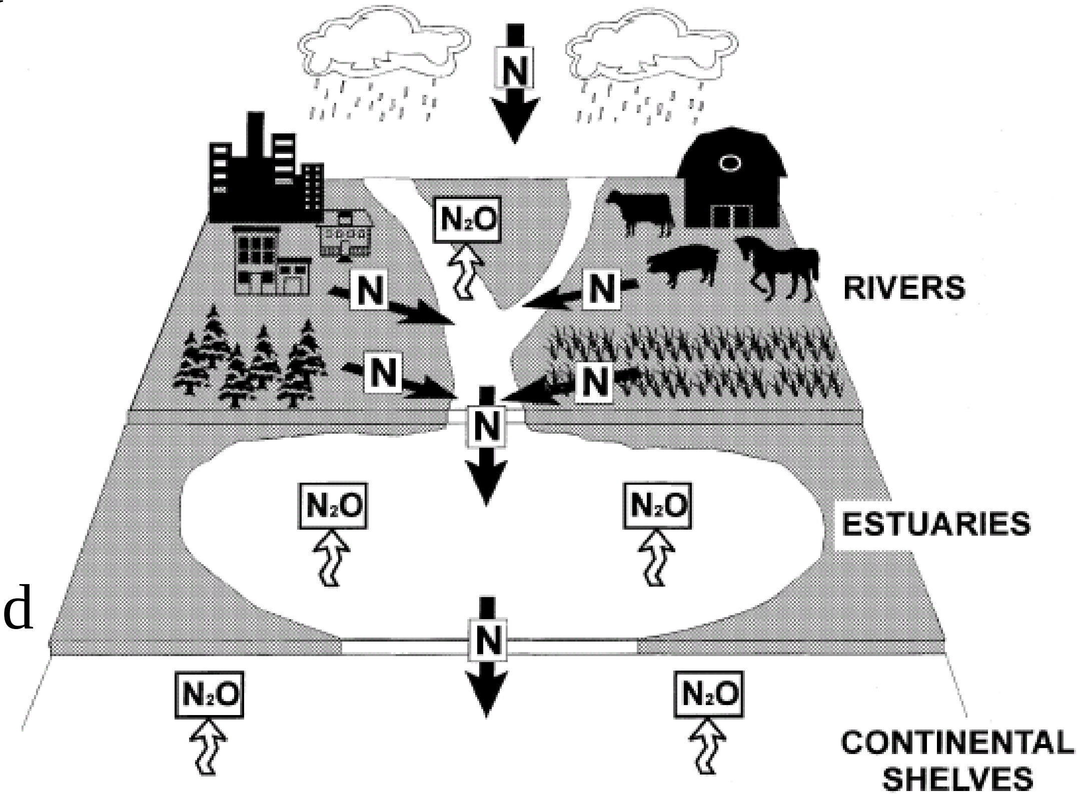
Outline

- 1. Background
- 2. Objective
- 3. Material and Method
- 4. Results and Discussion
- 5. Conclusions

1. Background

- Inland waters are potentially important source of N_2O (Beaulieu *et al*., 2011).

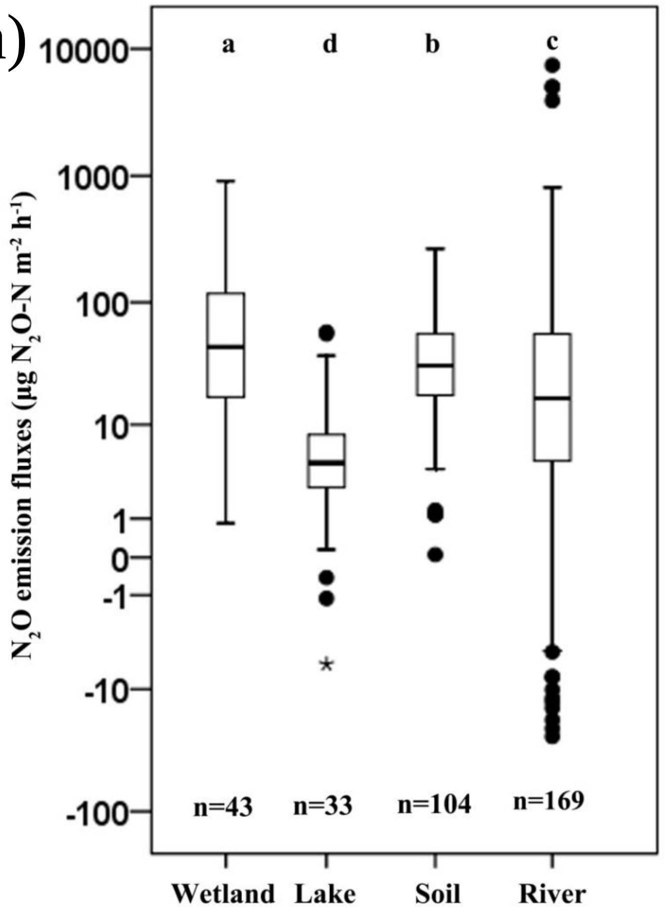
- The N_2O emission in lentic ecosystem (lake, reservoir, and pond) are often neglected due to the lower ratio of water area to water volume (Mulholland *et al*., 2008).



The N cycle in inland waters

The role of lake in N_2O emission of aquatic system

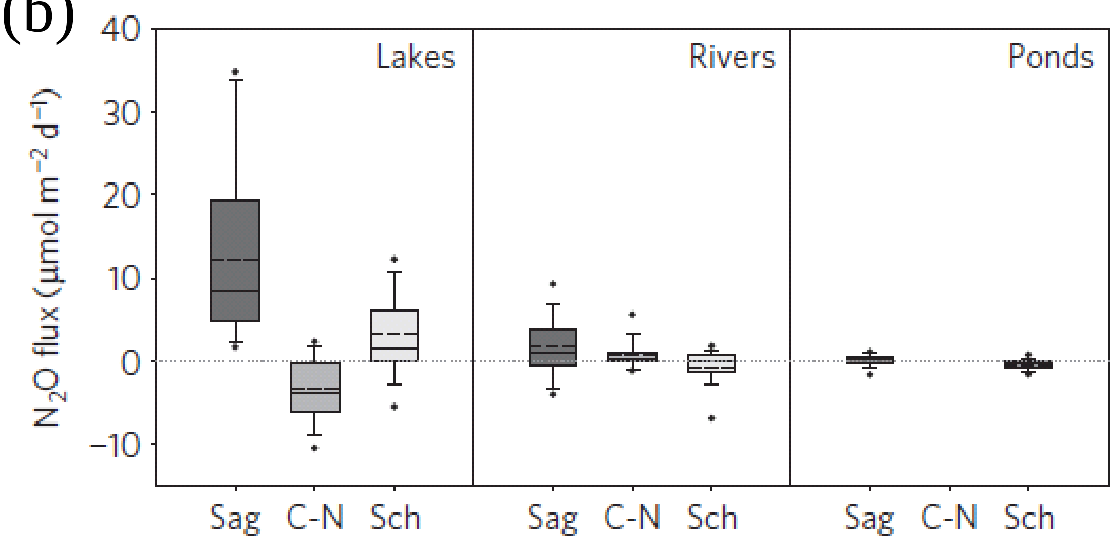
(a)



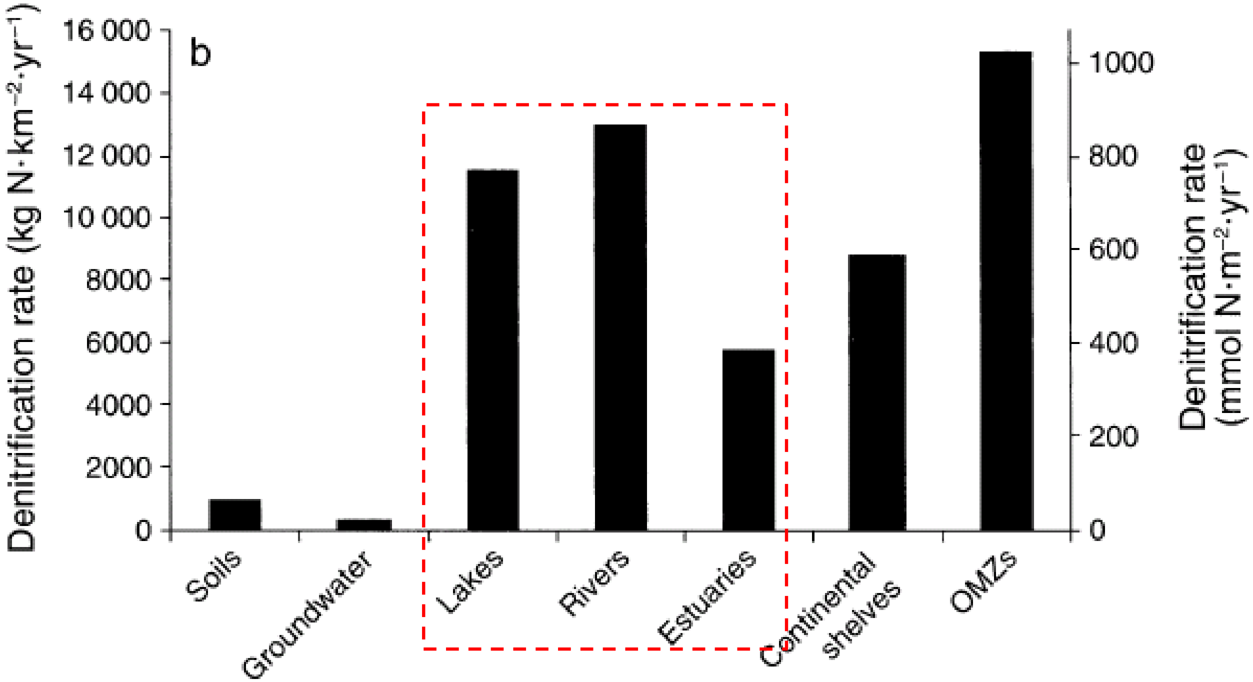
(a) A global assessment of N_2O emission fluxes for lakes, rivers, wetlands, and soil (Hu *et al.*, 2016, Global Change Biology)

(b) Regional N_2O flux fluxes for lakes, rivers and ponds (Soued *et al.*, 2015, Nature Geoscience)

(b)

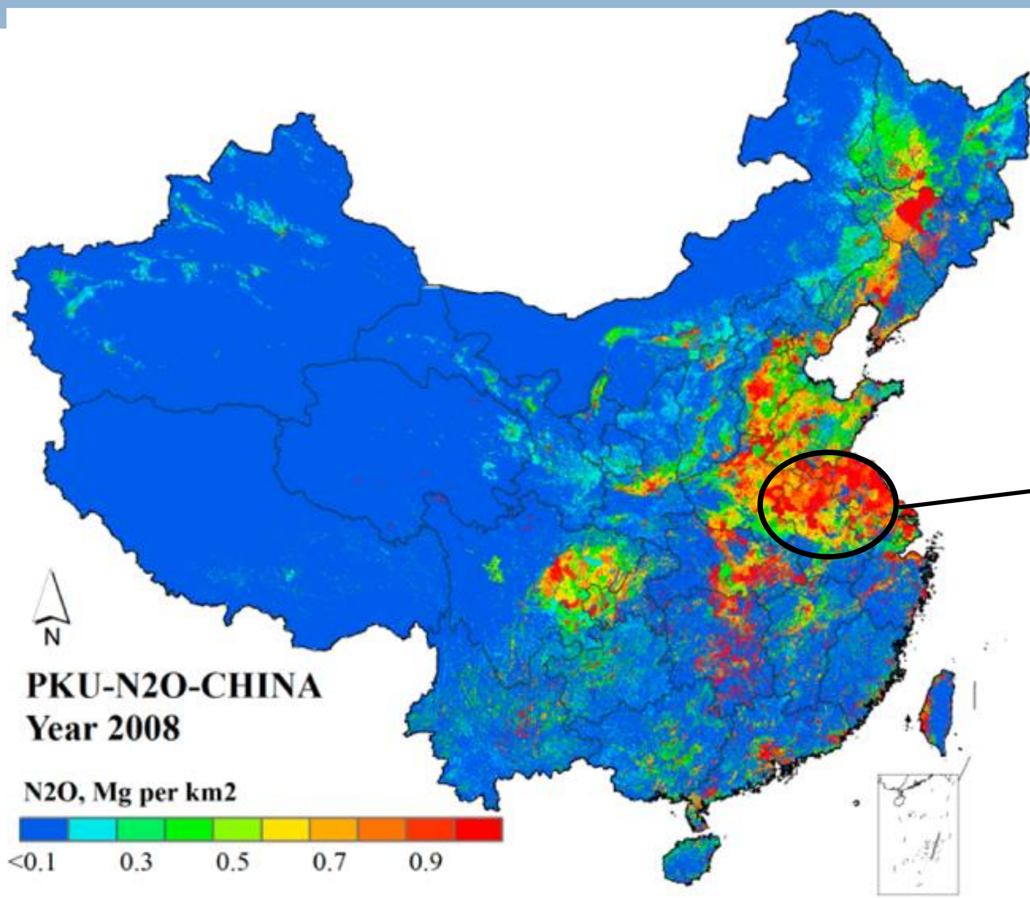


The N_2O emission from lakes show high spatial heterogeneity.



- The denitrification rate of lake was significant higher (Seitzinger *et al*., 2006. Ecol. Appl).
- The surface area of global lakes (5×10^6 km^2, Verpoorter *et al*., 2014) are significant higher that rivers (6×10^5 km^2, Raymond *et al*., 2013).
- The longer water residence time in lakes are more effective for N removal (Mulholland *et al*., 2008).

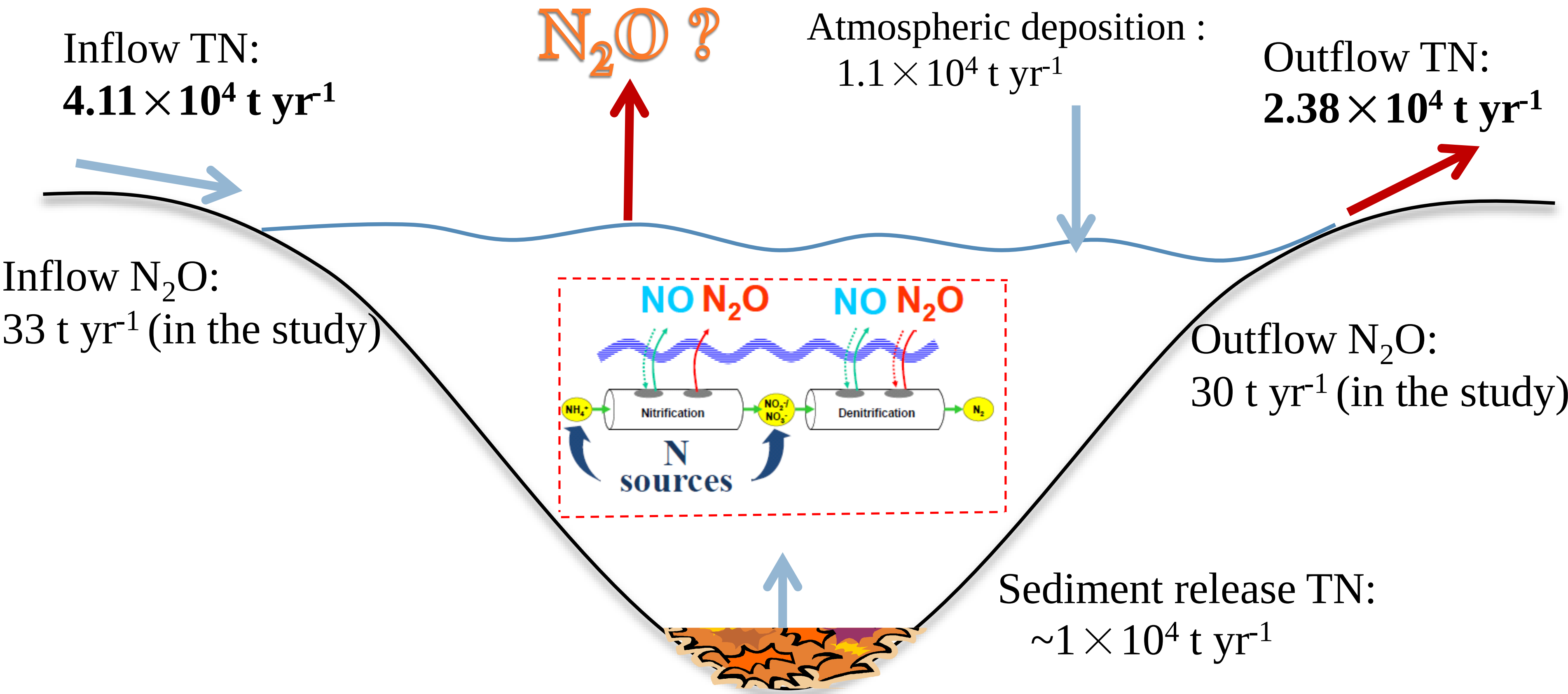
A New High-Resolution N_2O Emission Inventory for China in 2008 (Zhou *et al*., 2014, EST)



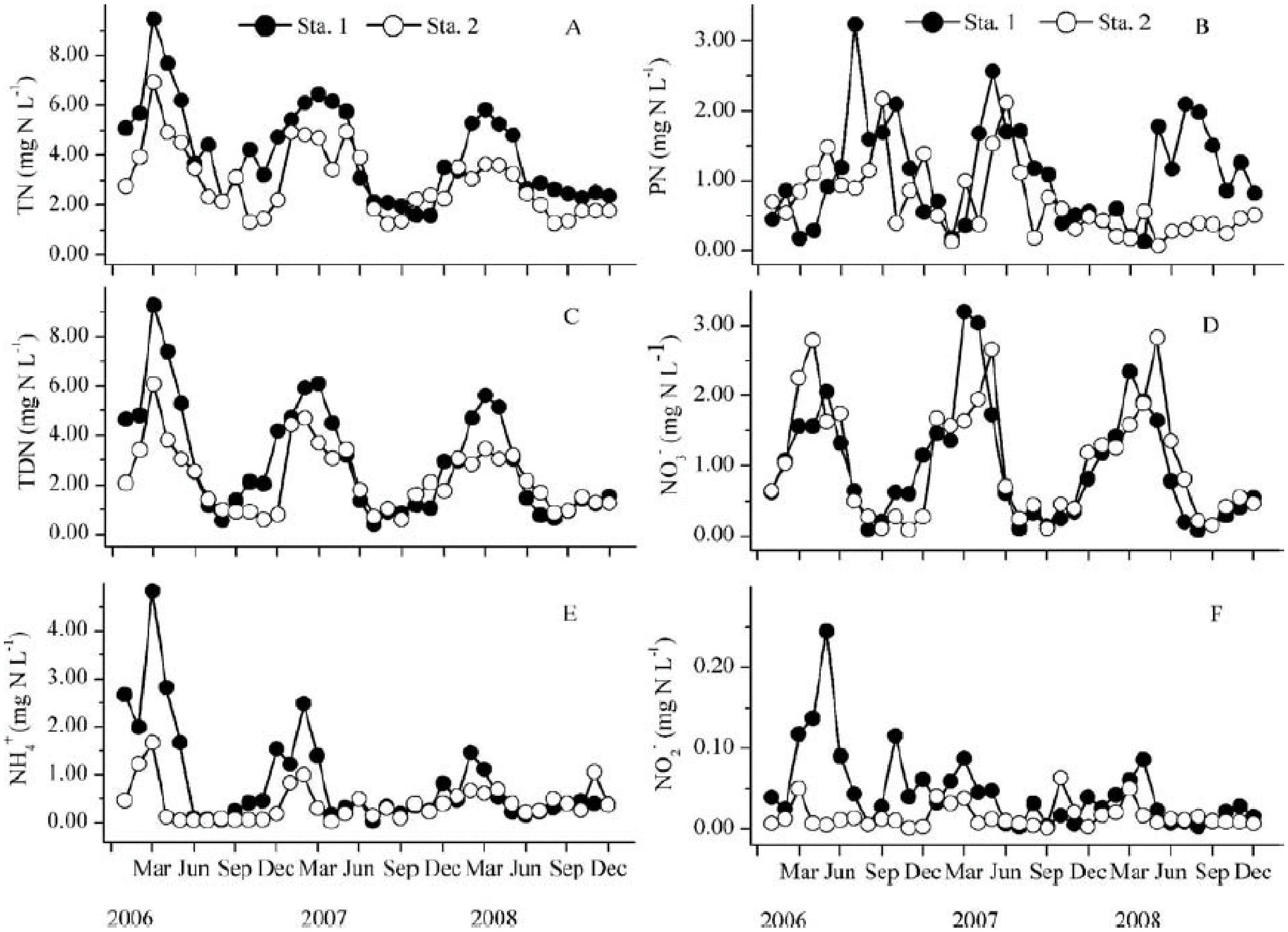
23.3% of the total Chinese lake area, with a surface area of 2.1×10^4 km^2

It was estimated that the global highest N load and N_2O emission from aquatic ecosystem appeared in eastern of China (Seitzinge *et al*.,1998)

The N budget in Lake Taihu



The effects of anthropogenic N input on water quality and algal bloom in Lake Taihu had been well documented, but its impact on the N_2O emission was not clear.



The seasonal variation of (A) TN, (B) PN, (C) TDN, (D) NO_3^{-1}, (E) NH_4^+ , and (F) NO_2^{-1} at the two sampling stations in **Lake Taihu** (Xu *et al*., 2010. Limnol. Oceanogr)

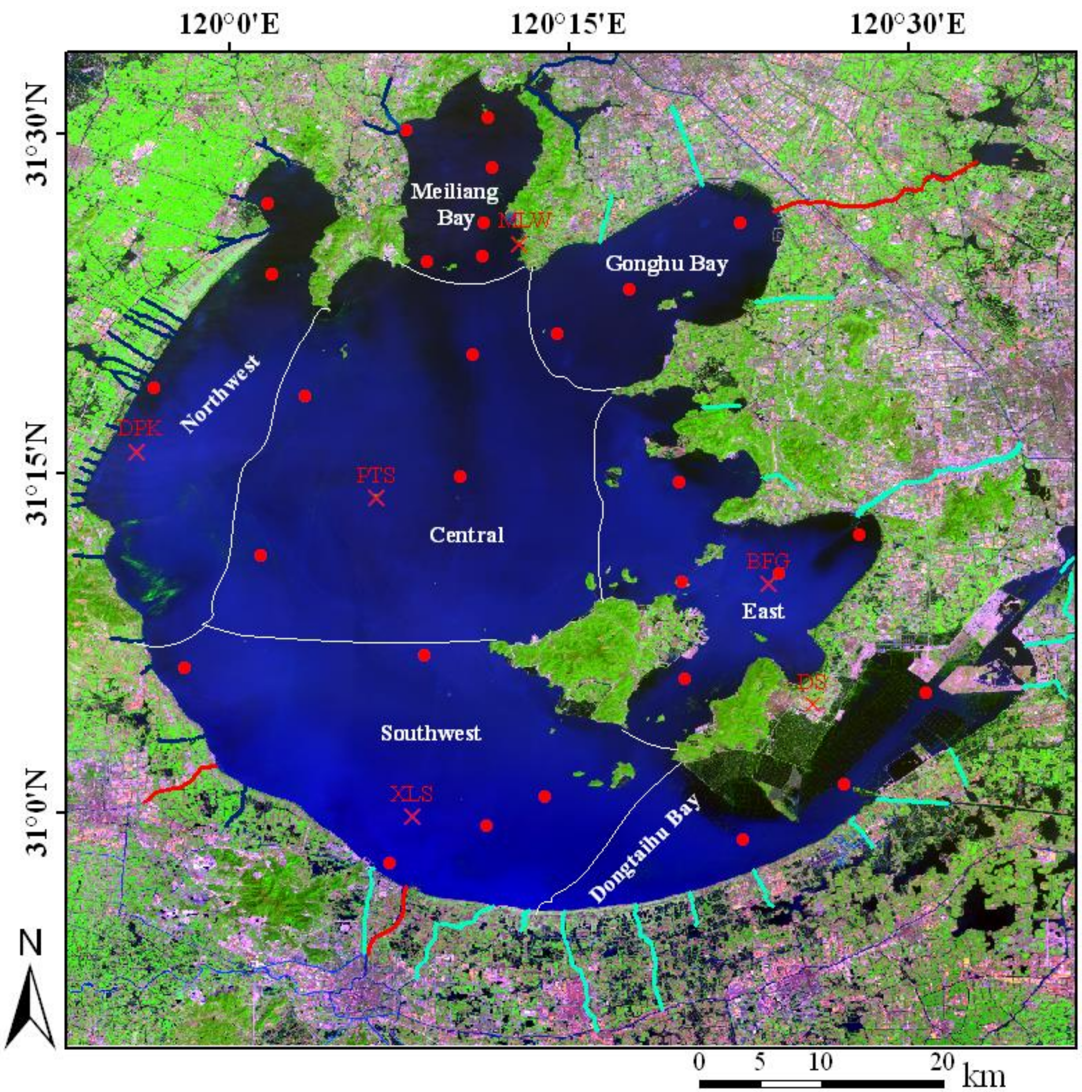
The higher denitrification rate at summer may contribute the lower N load in Lake Taihu.

2. Objective

- Characterizing temporal and spatial variability of the N_2O flux in the lake;
- Investigating the biological, chemical and physical controls of the observed variabilities;
- Determining the relative contributions of anthropogenic N load to the lake N_2O emission;
- Quantifying the roles of the lake in the N_2O emission in regional water networks;

3. Material and Method

3.1 Study site



- 29 spatial sampling sites (red dots) at the seven biological zones;
- 51 rivers (green lines, outflow rivers; blue lines, inflow rivers; red lines, rivers with reversible flow);
- Eddy flux sites (red crosses): temporal sampling site;
- The Northwest Zone is hyper-eutrophic due to pollution discharged by urban and agricultural runoffs;

3.2 Flux calculation

The N_2O flux (F_n) at the water-air interface was calculated using the transfer coefficient method based on the bulk diffusion model, as:

$$F_n = k \times (C_w - C_e)$$

C_w : N_2O concentration dissolved in the surface water (at the depth of 20-cm);

C_{eq}: N_2O concentration in water that is in equilibrium with the atmosphere at the in-situ temperature;

k : the gas transfer coefficient;

3.3 Emission factor (*EF*) calculation

EF	Equation	Remarks
EF (a)	$EF(\mathrm{a}) = \mathrm{ER}/\mathrm{L}_{\mathrm{DIN}}$	ER is the annual N_2O-N emission rate ; $\mathrm{L}_{\mathrm{DIN}}$ is annual DIN load
EF(b)	$EF(\mathrm{b}) = c(\mathrm{N_2O}) / c(\mathrm{DIN})$	c(N_2O) and c(DIN) denote dissolved N_2O-N and DIN concentrations
EF(c)	$EF(\mathrm{c}) = c(\mathrm{pN_2O}) / c(\mathrm{DIN})$	c(pN_2O) is dissolved N_2O concentration in excess of equilibrium with atmospheric N_2O concentrations

$$\mathrm{DIN} = \mathrm{NH_4^+} + \mathrm{NO_3^-} + \mathrm{NO_2^-}$$

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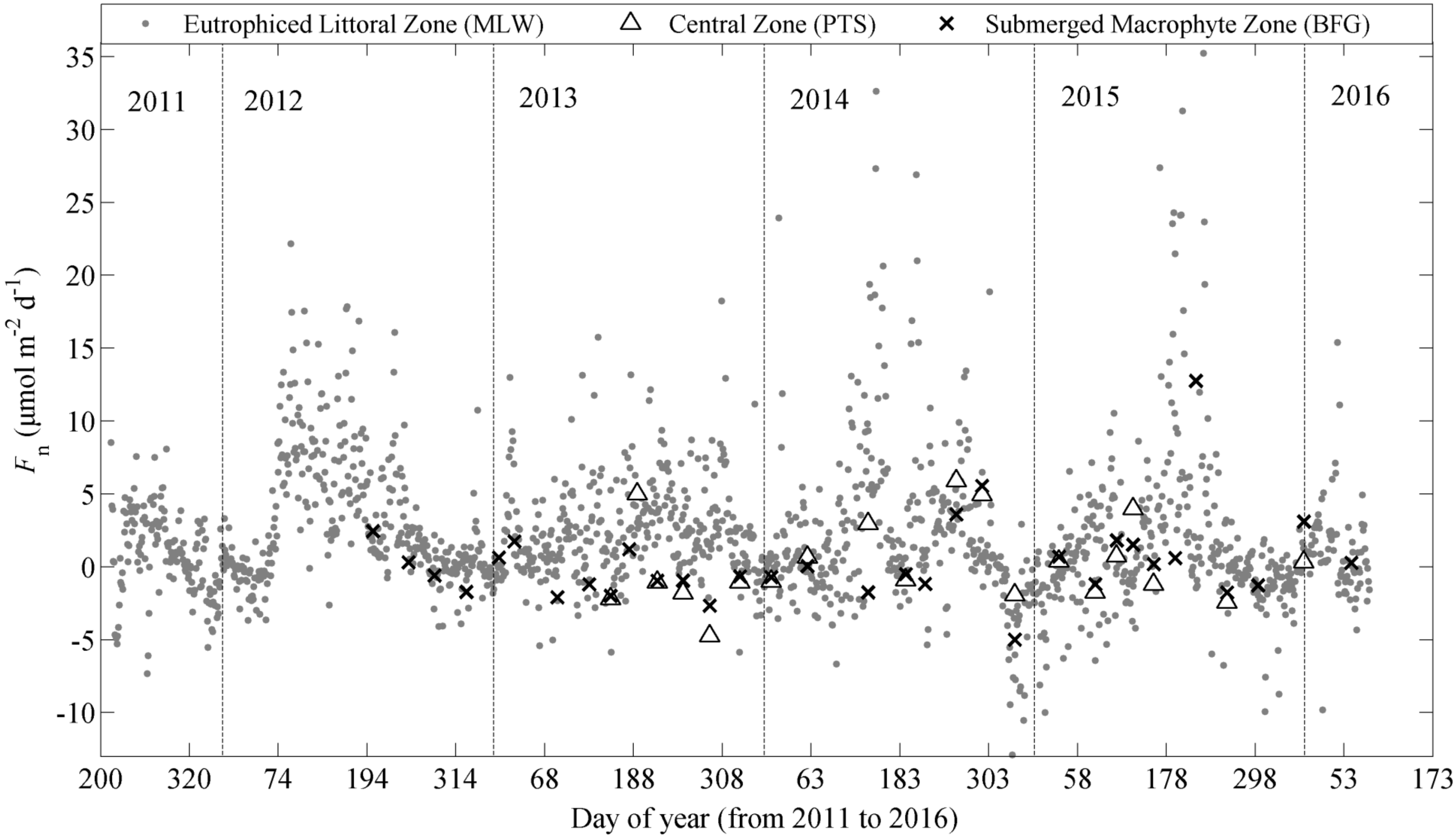
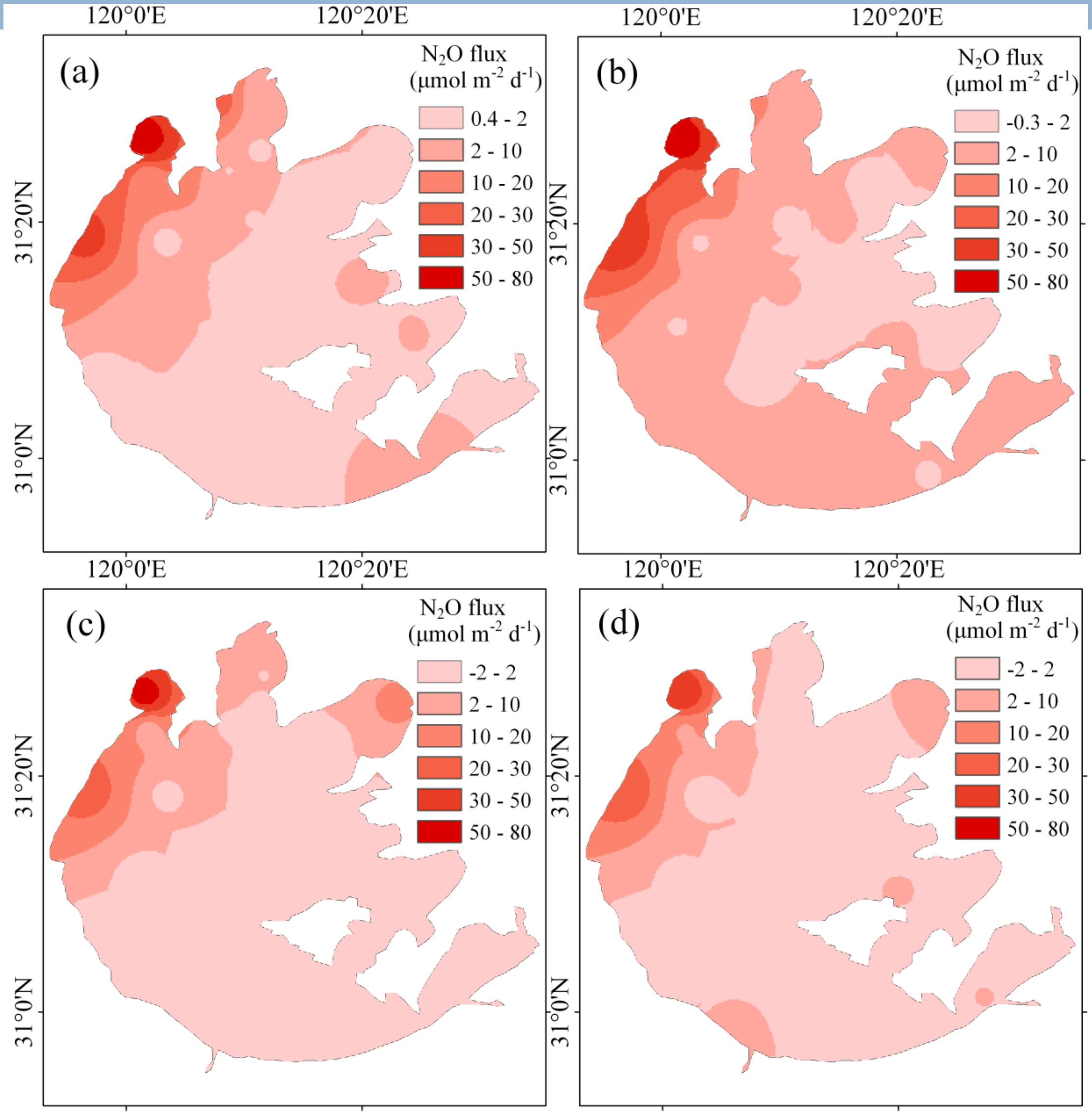
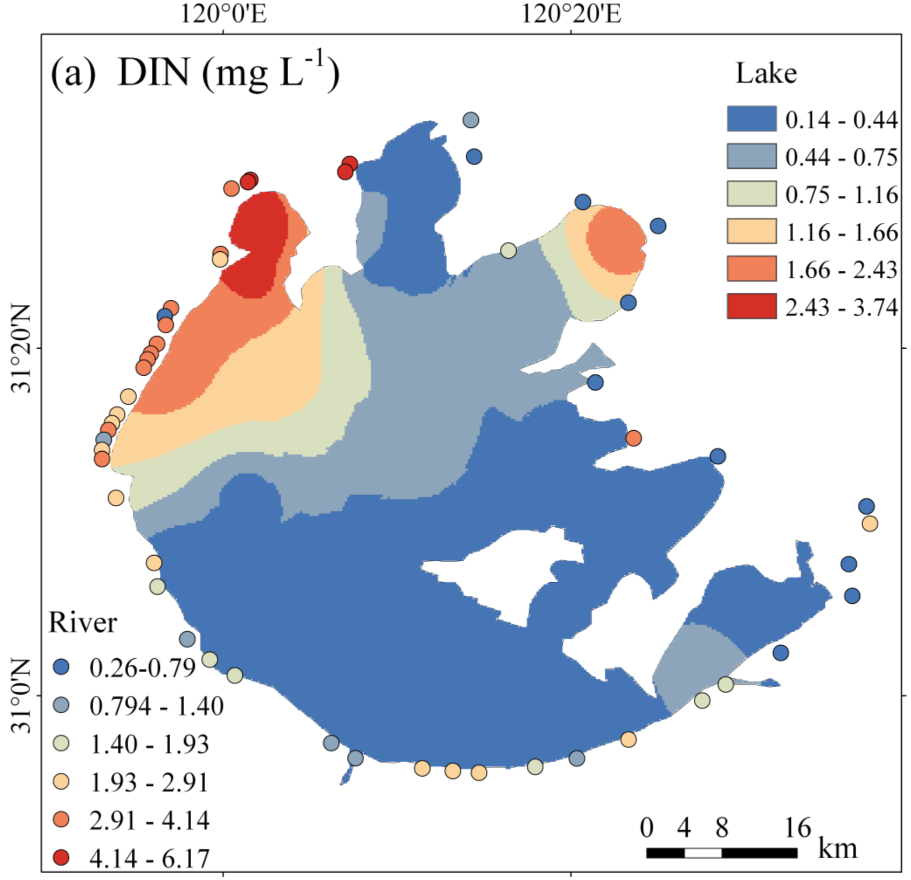
The temporal variation of N_2O flux from 2011 to 2016

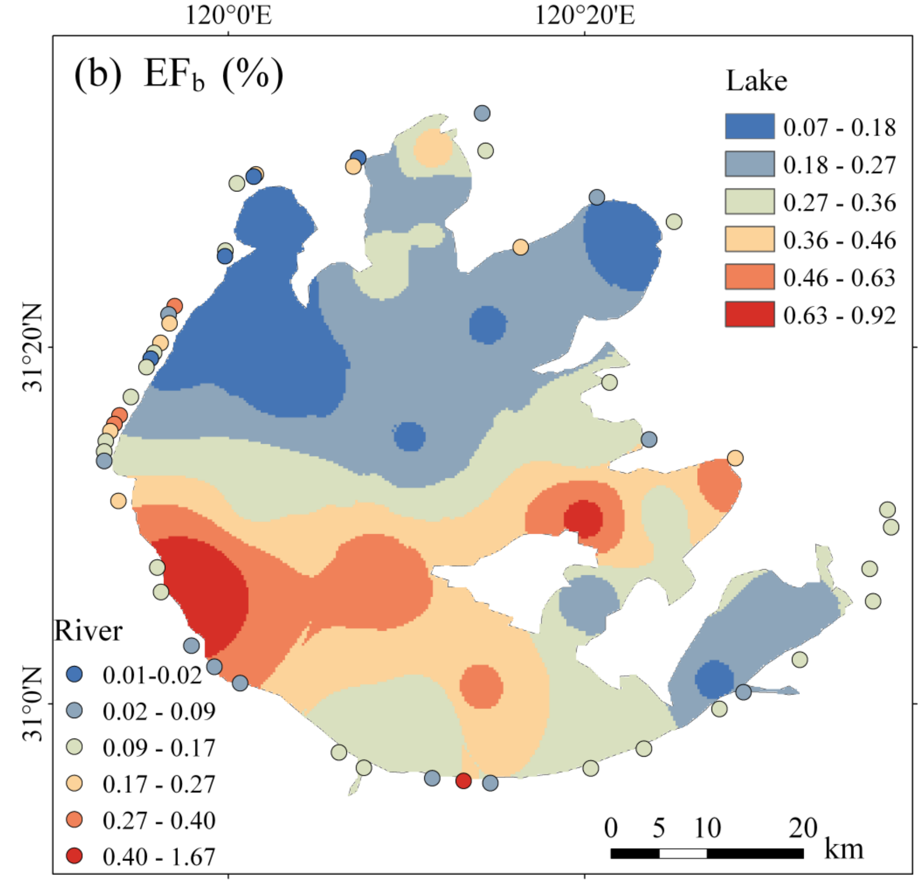


The spatial pattern of N_2O flux (F_n) at (a) spring, (b) summer, (c) autumn, and (d) winter from 2012 to 2015



The spatial pattern of DIN (a) and EF_b (b) in Lake Taihu and river during autumn

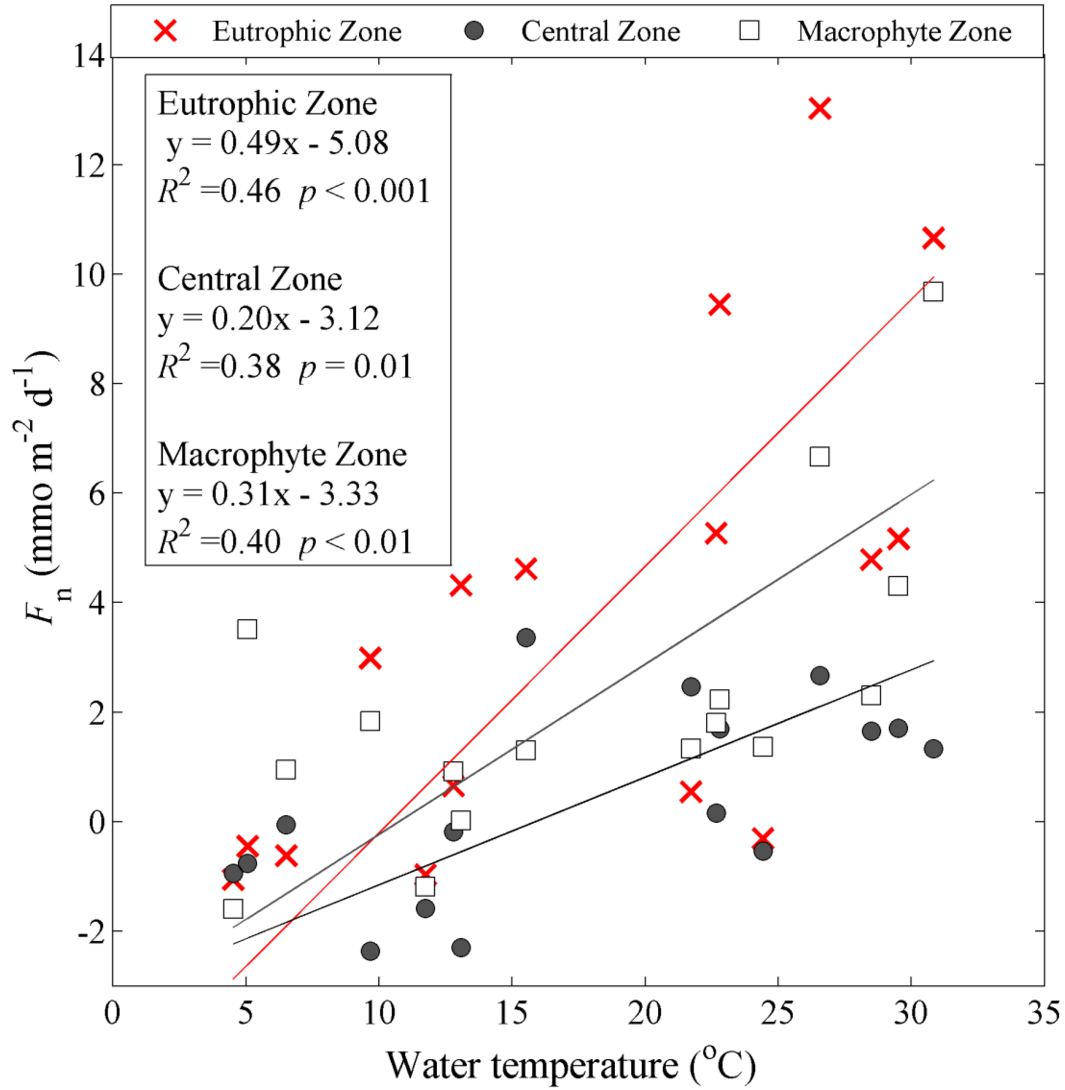




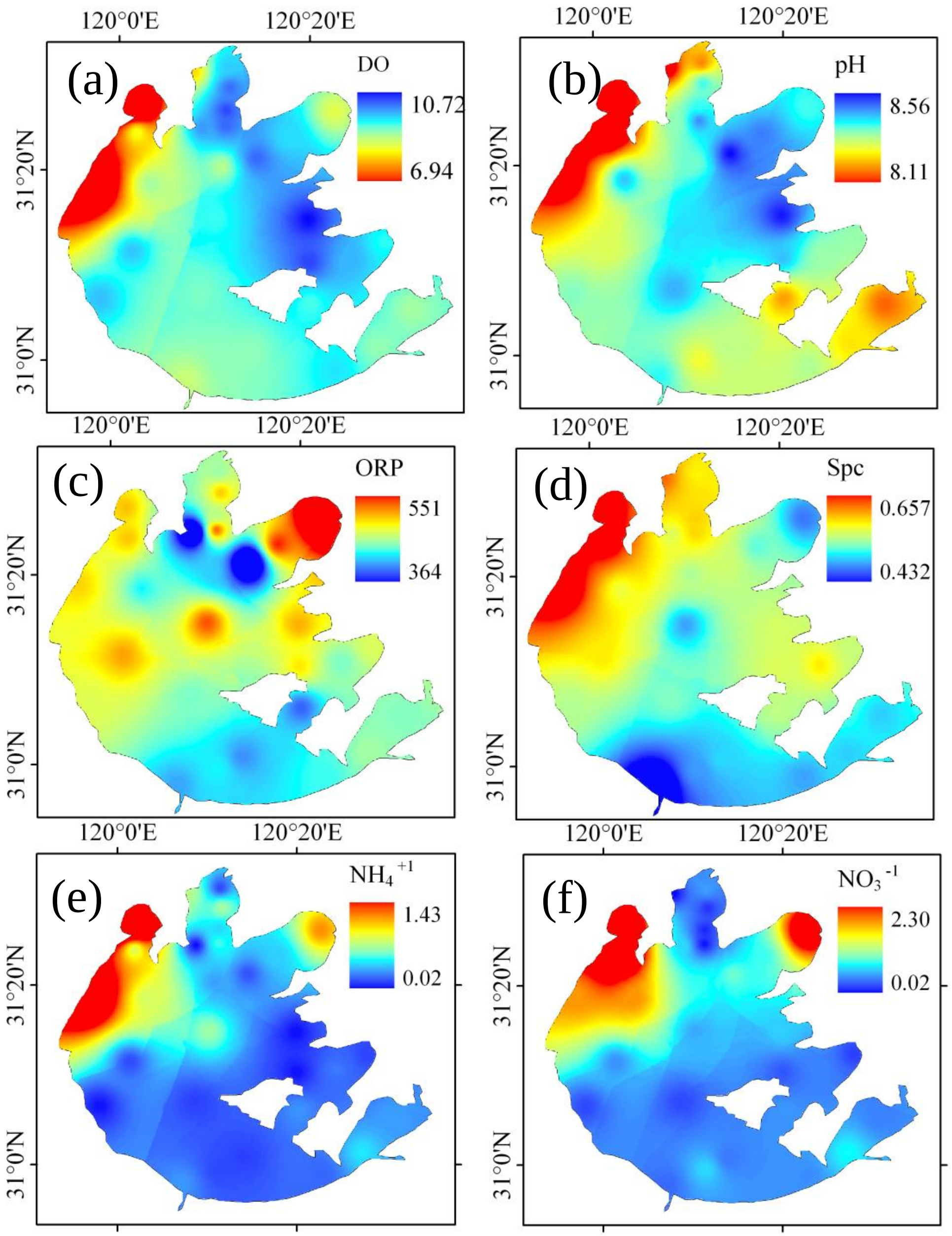
In Lake Taihu: EF_a = 0.69%; EF_b = 0.27%

In river: EF_{b}_Inflow = 0.15%; EF_{b}_Outflow = 0.12%

Control factor of N_2O flux (F_n) temporal variation



Spatial variation of environmental factors



(a) DO: dissolved oxygen concentration (mg L^{-1});

(b) pH;

(c) ORP: oxidation reduction potential (mv);

(d) Spc: specific conduce (ms cm^{-1});

(e) NH_4^+ concentration (mg L^{-1})

(f) NO_3^- concentration (mg L^{-1})

Control factors of N_2O flux (F_n) spatial variation

Spatial correlation of the mean N_2O flux against mean water quality indices

	DO	Chl	Spc	ORP	pH	NTU	NH_4^+ (c)	NO_3^- (c)
F_n (a)	-0.93**	0.20	0.57**	0.18	-0.68**	-0.19	0.95**	0.64**
F_n (b)	-0.55**	0.26	0.01	0.17	-0.54**	-0.11	0.63**	0.30

*, ** Correlation is significant at the 0.05, and 0.01 level, respectively.

(a) data acquired at all the spatial sampling sites; (b) excluding sites in the Northwest Zone

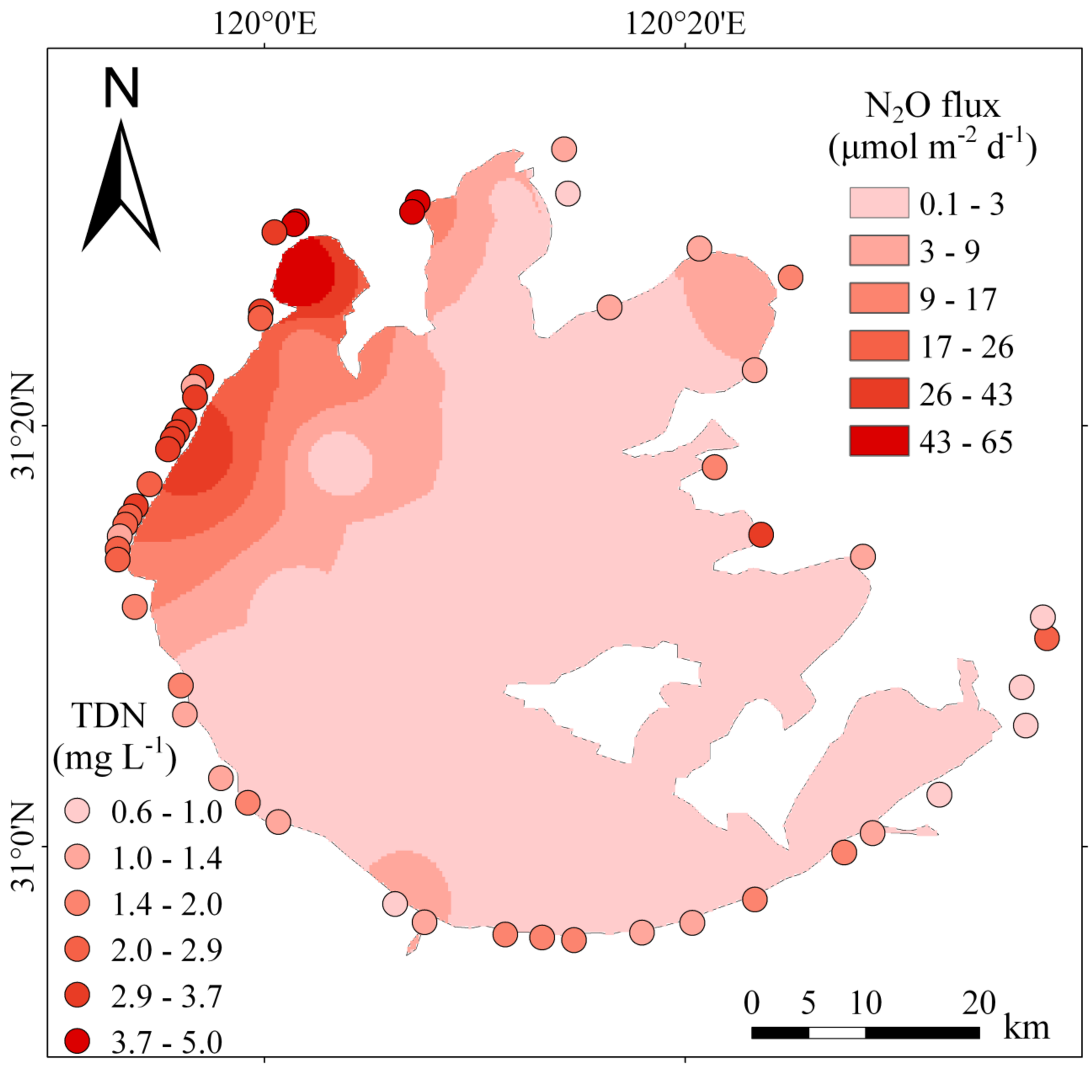
(c) data acquired at November 2015;

DO: dissolved oxygen concentration (mg L^{-1}); Chl: chlorophyll a concentration (μg L^{-1}); Spc: specific conduce (μs cm^{-1}); ORP: oxidation reduction potential (mv); NTU: turbidity

$$F_n = 38.48\,(NH_4^+) - 0.05\,(ORP) - 16.26(pH) + 156$$

$$(R^2 = 0.92 \quad p < 0.001)$$

The effect of N input on the N_2O flux in Lake Taihu (TDN: total dissolved nitrogen)



Anthropogenic N inputs controlled 70% of N_2O emission in Lake Taihu

Zones	Surface area (km^2)	DIN ($mg\ L^{-1}$)	Mean N_2O flux ($\mu mol\ m^{-2}\ d^{-1}$)	Weight
Meiliang Bay	100	0.31	3.63	3.18%
Northwest Zone	215.6	**2.88**	37.12	70.15%
Central Zone	316.4	0.48	0.39	1.08%
Gonghu Bay	131	1.13	2.53	2.90%
East Zone	443.2	0.28	1.03	4.01%
Dongtaihu Bay	394.1	0.43	2.21	7.63%
Southwest Zone	737.5	0.26	1.71	11.05%
Whole lake	2338	0.72	7.36	

$$DIN = NH_4^+ + NO_3^- + NO_2^-$$

Lakes contributed 17% of N_2O emission from aquatic networks in Taihu basin

		Lake	River
Period		2012.2 ~ 2015.11	2013.5 ~ 2016.2
N_2O flux ($\mu mol\ m^{-2}\ d^{-1}$)	Range	-7.13 ~ 152.76 [a]	-13.14~572.80 [a]
	Mean	7.36	51.92
Area (km^2)		3231	2320
N_2O yield ($t\ yr^{-1}$)		380	1912

(a) Given the large variability in observed fluxes, we proposed the reported values in the study represented all lake and river N_2O emission in Taihu basin.

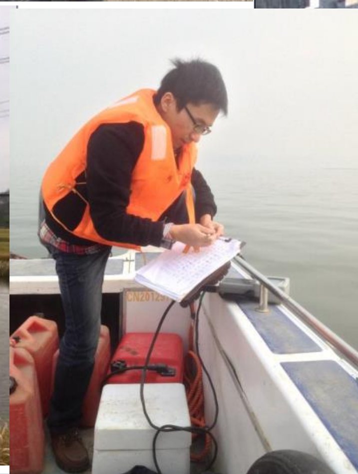
5. Conclusions

- The N_2O emission flux in Lake Taihu ranged from -7.13 to 152.76 μmol m^{-2} d^{-1} showing large temporal and spatial variation;
- Anthropogenic N inputs controlled 70% of N_2O emission in the lake ;
- Lakes contributed 17% of N_2O emission from aquatic networks in Taihu basin;

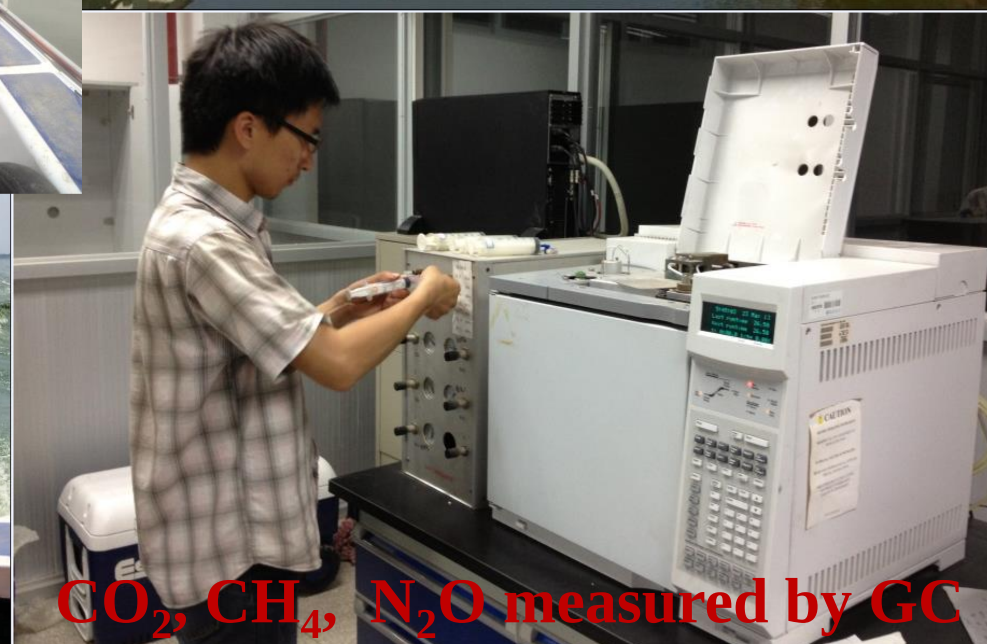

Water sampling


River in Taiu Basin


Paddy field




Algae blooming
115


CO_2, CH_4, N_2O measured by GC