Uncertainty of hydrological processes on greenhouse gas emissions from urban rivers

Shu Chen

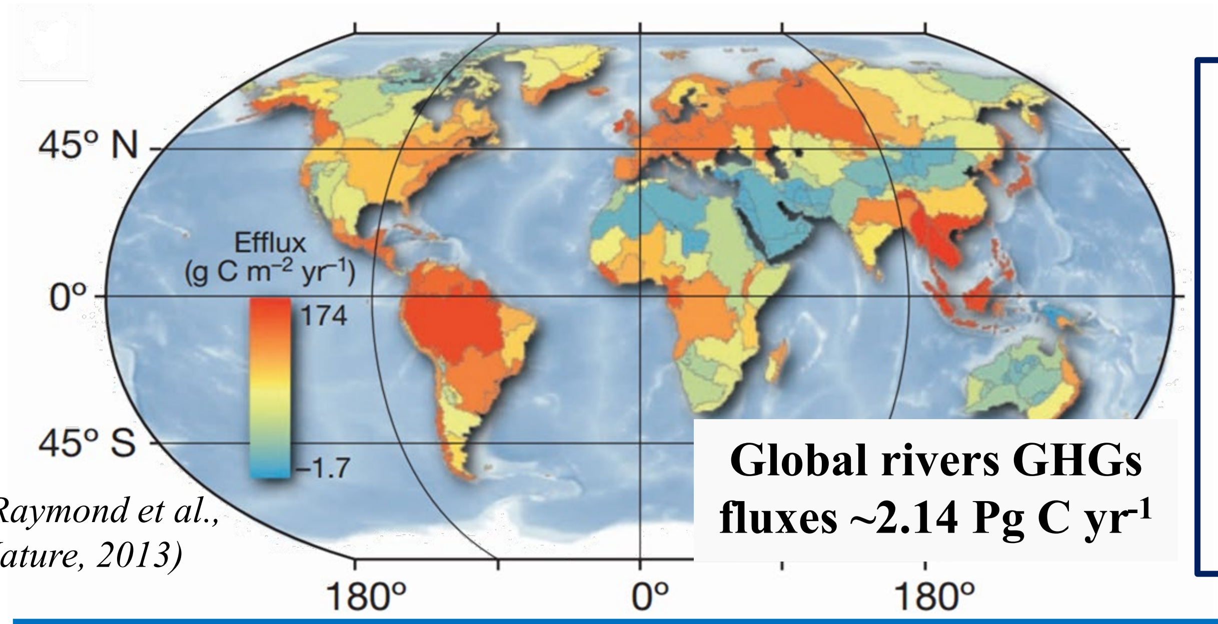
Shanghai Jiao Tong University, Shanghai, CHINA

June 5, 2025 Baton Rouge, LA, USA

Acknowledgement

National Natural Science Foundation of China (No. 42077338 and No. 42177350), Shanghai Key Lab for Urban Ecological Processes and Eco-Restoration (SHUES2021C03), and the Fundamental Research Funds for the Central Universities (40500-20104-222357)

1 Background



(Raymond et al., Nature, 2013)

- The global riverine CO_2 flux ~ 1.8 Pg C yr^{-1} (*Raymond et al., 2013)*
  CH_4 flux ~ 1.6-26.8 Tg C yr^{-1} (*Stanley et al., 2016*)
  N_2O flux ~ 0.68 Tg N yr^{-1} (*Lansdown et al., 2016*)
- Urban rivers have become more important sources of GHG emissions due to the influence of human activities
- **The uncertainty in global estimates of GHG emissions from rivers remains relatively large**

Natural and anthropogenic factors

- Tidal changes or seasonal precipitation
- Urbanization process and human activities
- Extreme weather events
- Natural disasters

Change

Hydrological processes

Water level
Water volume
Water quality
Water velocity

Affect

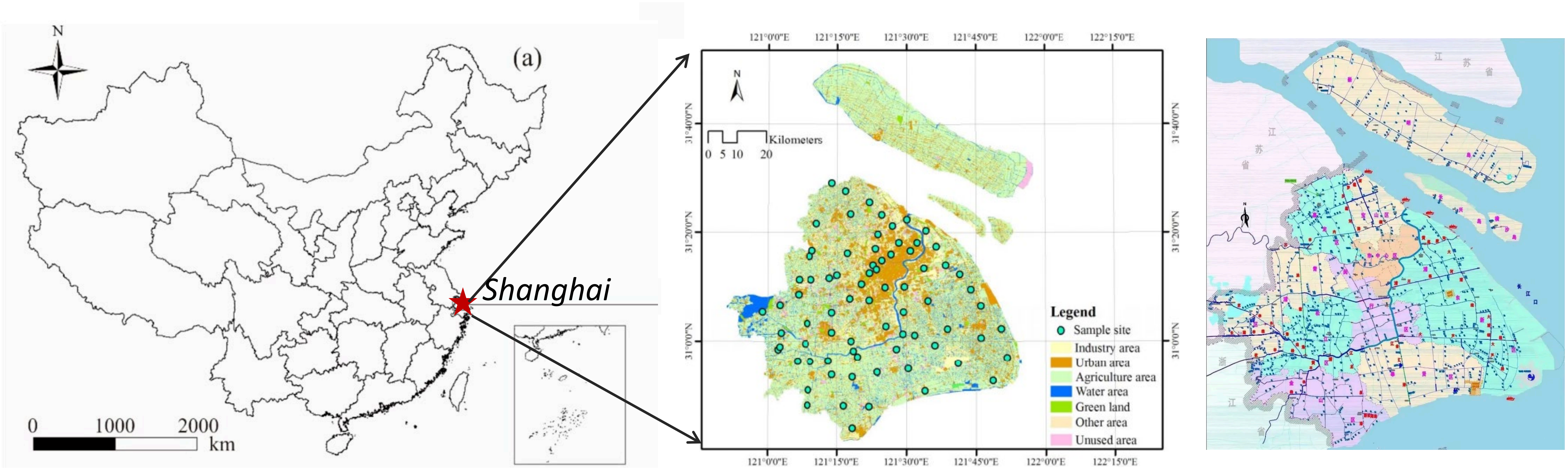
Biogeochemical processes

- Key carbon nitrogen cycle processes
- Greenhouse gases emissions

Under the background of global climate change, the complex and changeable hydrological conditions of rivers may affect the key carbon and nitrogen cycle processes and deepen the uncertainty of GHG estimations

2 Characteristics of Study Area

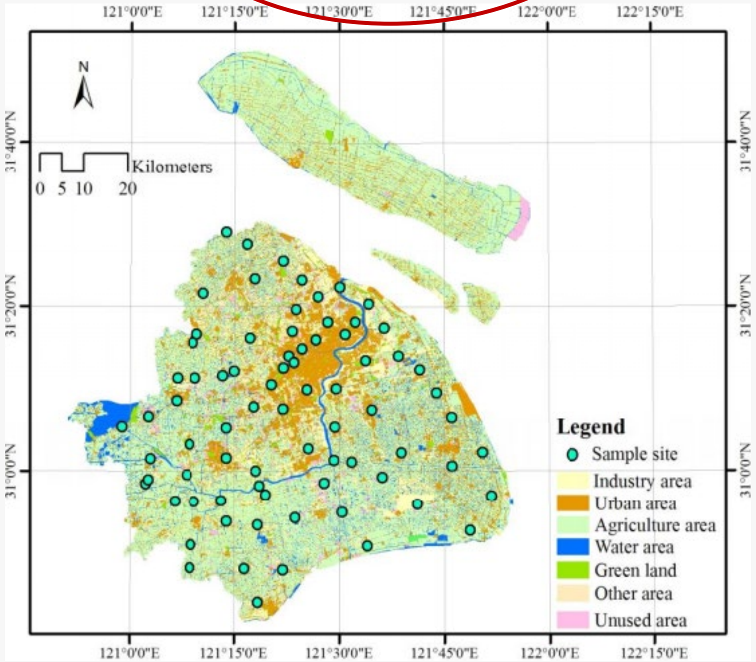
- Shanghai is situated on the east tip of the Yangtze coastal plain and is a typical megacity with a distinct division between urban and rural areas.
- The river network is extremely dense. Most rivers are influenced by diurnal tidal cycle and feature a hydrological stagnation, characterized by a sluggish and bidirectional flow velocity.
- This region has a subtropical monsoon climate, resulting about 70% of the annual precipitation occurring during the wet season (May to October).



3 Key Issues

3.1
Hydrological Stagnation

3.2
Human Activities



3.4
Tidal Effects

3.3
Rainfall Effects

(1) The influence mechanism of hydrological processes in urban rivers on GHG emissions

Clarifing the influence of the hydrological process of urban rivers under the combined action of natural and human factors on GHG emissions

(2) Better estimation of GHG emissions of global rivers

Improving the accuracy of GHG flux estimation through the obtained measured data and deepen the understanding of the role of urban rivers in the carbon and nitrogen cycles of aquatic ecosystems

3.1 Hydrological Stagnation

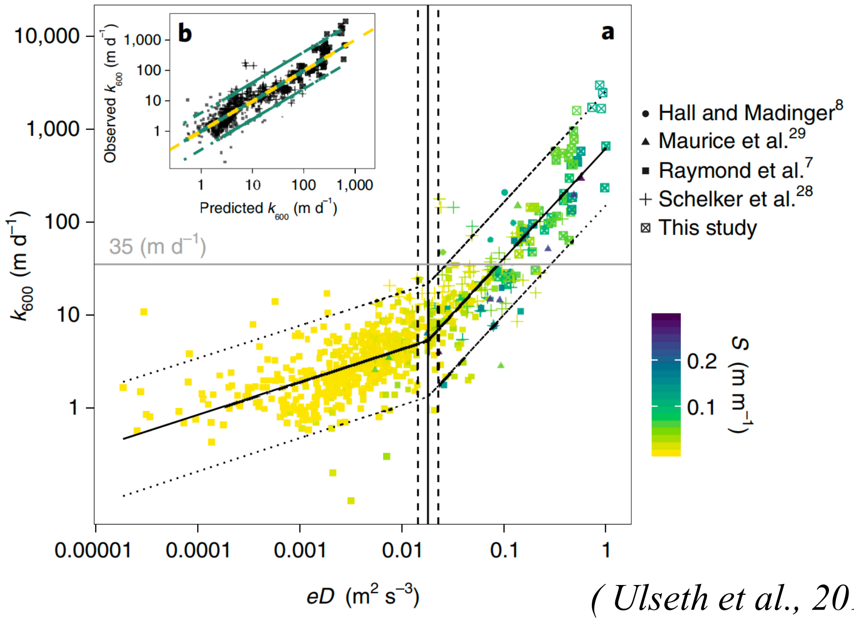
1. Research Significant
2. Methods and Materials
3. Impact on gases emissions
4. Driving Mechanisms

3.1.1 Research Significant

- **Transport of dissolved gases across the water to the air constitutes the main pathway for the CO_2 emission (>90% of the total) and is also a major pathway for CH_4 emission (~40% of total)**

$$F = k \times (C_w - C_{air}) \qquad k_{600} = k_{is} \times \left(\frac{600}{Sc_{is}}\right)^{-n}$$

NATURE GEOSCIENCE



(Ulseth et al., 2019)

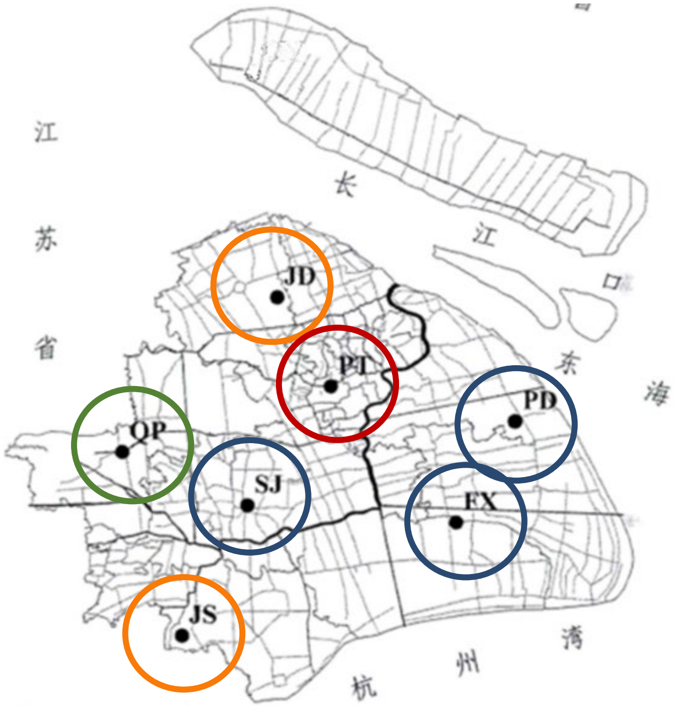
source	systems	k_{600} (m d^{-1}) CO_2/CH_4
McGinnis et al.[18]	temperate lake	0.4
Paranaíba et al.[6]	three tropical reservoirs	0.4
Prairie and del Giorgio[13]	boreal reservoir and lakes	0.43
Rantakari et al.[19]	two boreal lakes	0.56
Rosentreter et al.[20]	six mangrove estuaries	0.83
Beaulieu et al.[5]	temperate river	< 1
Guérin et al.[4]	tropical reservoir	1.16
This study	four boreal lakes	1.68
Rosentreter et al.[7]	mangrove river estuary	2.78

(Pajala et al., EST, 2023)

The k-values of hydrological stagnant water is unclear

The incompatibility between k_{600} for CO_2 and CH_4 generates questions

3.1.2 Methods and Materials

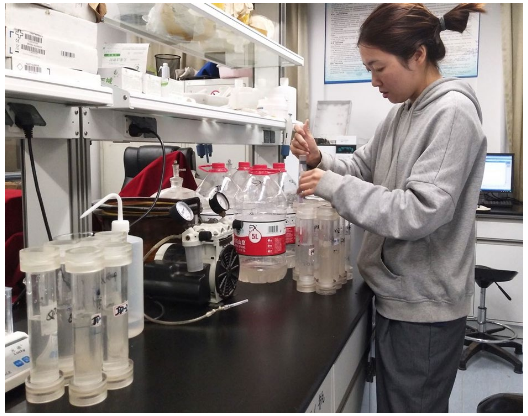


Sampling Sites

Name	Longitude	Latitude	River width (m)	Classification
QP	31.11 °N	121.05 °E	120	Rural
JD	31.37 °N	121.31 °E	20	Suburb (Agricultural)
JS	30.80 °N	121.15 °E	20	
PD	31.16 °N	121.71 °E	30	Suburb (Industrial)
SJ	31.02 °N	121.26 °E	25	
FX	30.99 °N	121.61 °E	18	
PT	31.22 °N	121.40 °E	45	Center

Sampling Dates

1. **Summer(Jul., 2020)**
2. **Autumn(Oct., 2020)**
3. **Winter (Jan,, 2021)**
4. **Spring (Apr., 2021)**



Boundary Layer Model

Floating Chamber Measurement

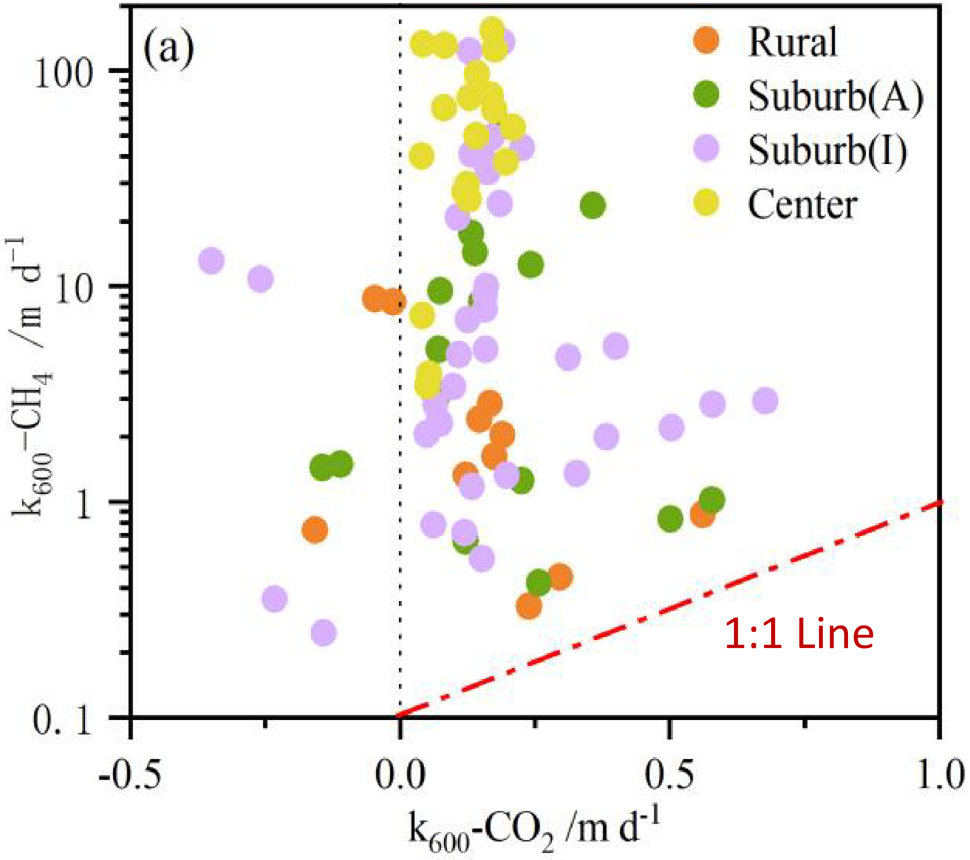
In-situ Measurement

3.1.3 Impact on gases emissions

- All sampling rivers were gas supersaturated with water to air concentration ratios (Cw/Ca) , they were overall sources of CO_2 and CH_4 to the atmosphere.
- k_{600}-values (m d^{-1})： CH_4 (0.25-153.3) much higher than CO_2 (-0.35-0.68)

Sampling Site	Rural	Suburb (Agricultural)		Suburb (Industrial)			Center
	QP	JD	JS	PD	SJ	FX	PT
Cw/Ca (CH_4)	98.57±90.06	46.59±47.02	26.03±14.58	112.13±80.40	90.22±99.40	27.01±18.98	64.44±68.83
Cw/Ca (CO_2)	5.22±2.99	5.49±1.35	7.89±2.88	5.32±2.41	10.27±4.75	5.31±1.72	9.26±1.22

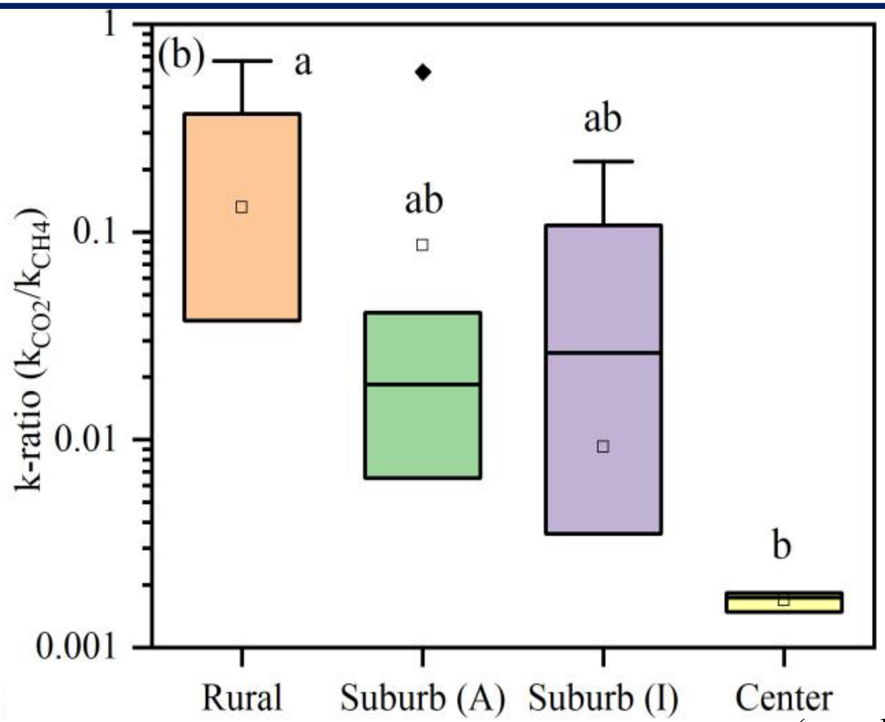
(unpublished data)



3.1.3 Impact on gases emissions

- This study showed an overall unexpectedly low mean k_{600}-ratio (k_{600}-CO_2/k_{600}-CH_4) of 0.08±0.21
- The k_{600}-ratios showed significant spatial differences, with the largest in the rural areas and the lowest in the city center.

Source	Systems	k-ratio CO_2/CH_4
Pajala et al.	four boreal lakes	1.68
McGinnis et al.	temperate lake	0.4
Paranaiba et al	three tropical reservoirs	0.4
Prairie and del Giorgio	boreal reservoir and lakes	0.43
Rantakari et al	two boreal lakes	0.56
Rosentreter et al.	six mangrove estuaries	0.83
Beaulieu et al		<1
Guerin et al	tropical reservoir	1.16
Rosentreter et al.	mangrove river estuary	2.78
This study	**urban rivers**	**0.08**



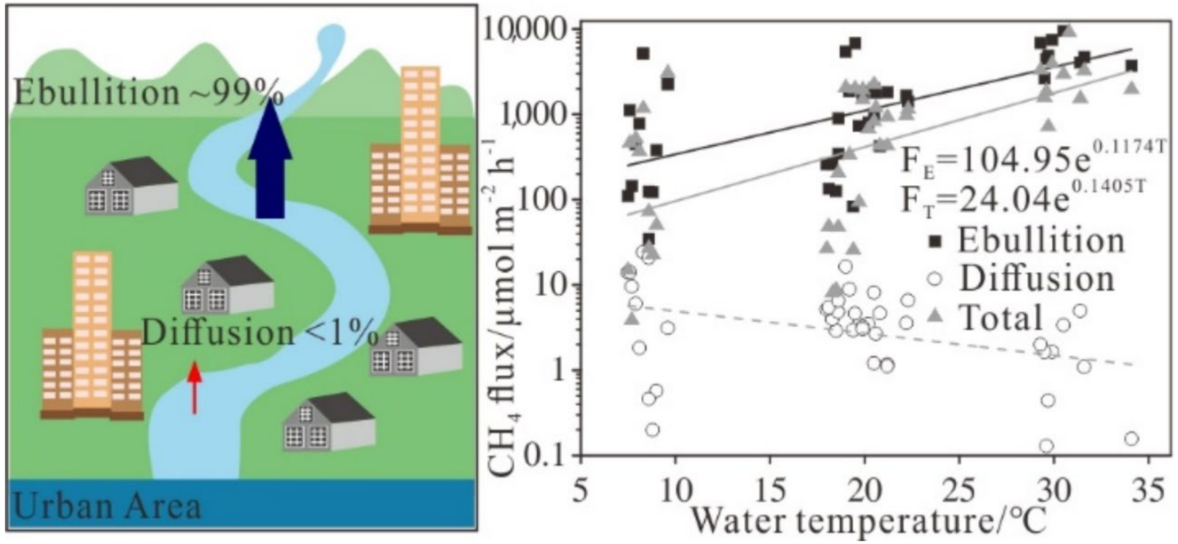
(unpublished data)

- **The mismatches between k_{600} for CO_2 and CH_4 are prone to occur in rivers and the resulting discrepancies can be substantial.**

3.1.3 Impact on gases emissions

- Microbubbles is the main cause of the high k_{600}-CH_4 in urban rivers
- The contribution of bubbles is the highest in the center and the lowest in the rural area

- The CH_4 flux contribution of bubbles can reach up to 99% at most
- Temperature sensitive



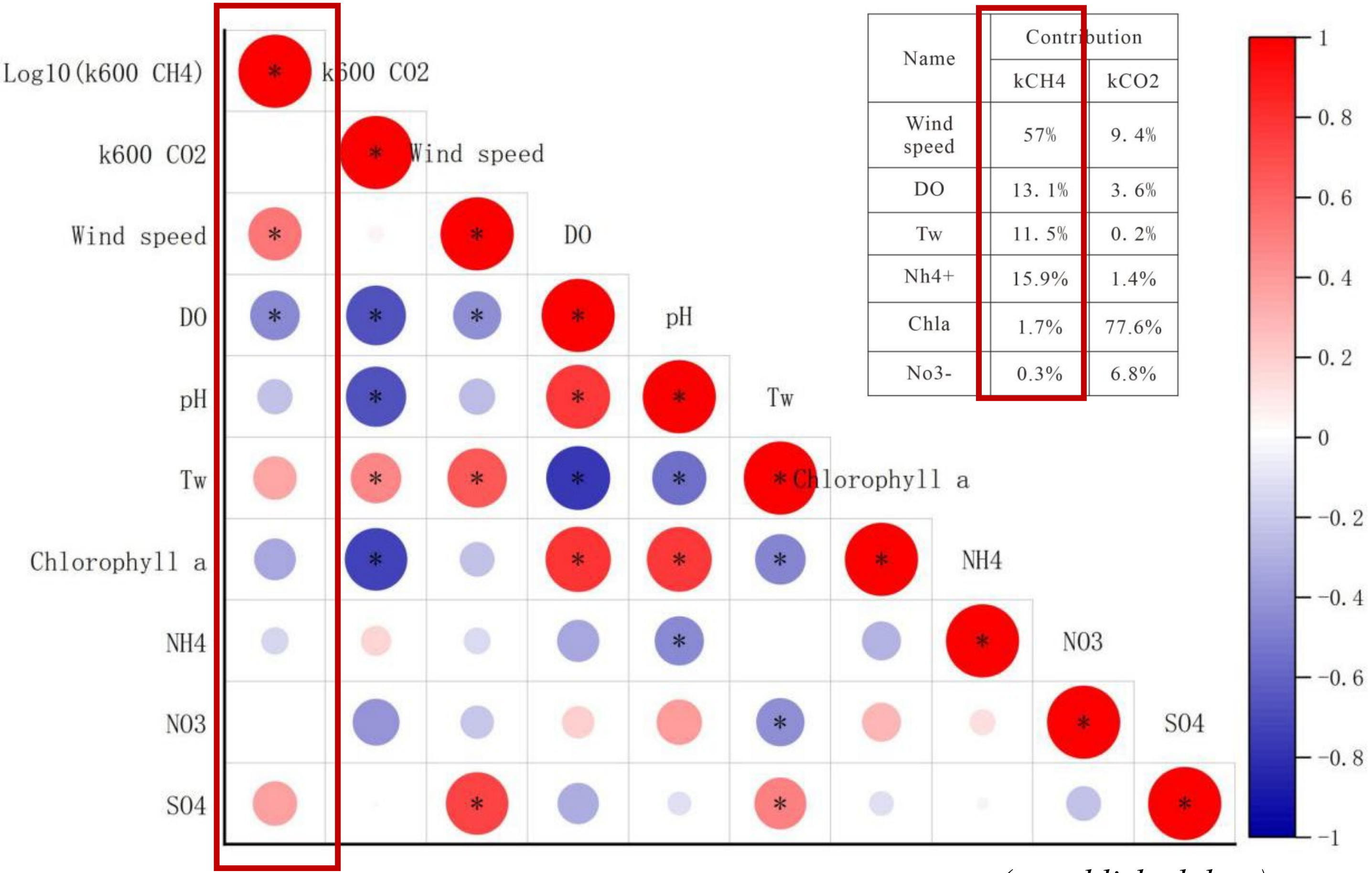
(Chen et al., EST, 2021)

Sampling Sites		The CH_4 flux contribution of bubbles / %
PD		48.35±55.85
JD		44.02±51.17
FX		73.09±34.08
QP	Rural	33.66±41.79
SJ		56.36±37.70
JS		78.09±14.56
PT	Center	86.05±26.56

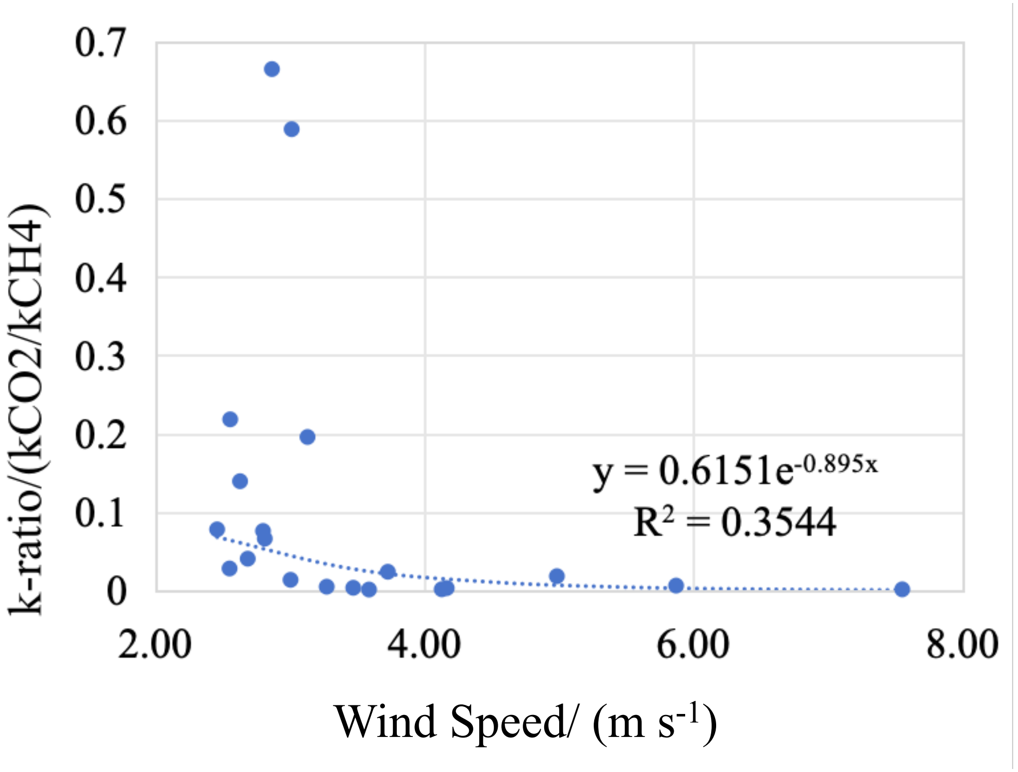
(unpublished data)

3.1.4 Driving Mechanisms

- Wind speed, dissolved oxygen (DO) and water temperature (T_w) are the main factors controlling k_{600}-CH_4
- The k-ratios were exponentially correlated with wind speed, indicating that the mismatches between k_{600} for CO_2 and CH_4 will further increase under high wind speed conditions.



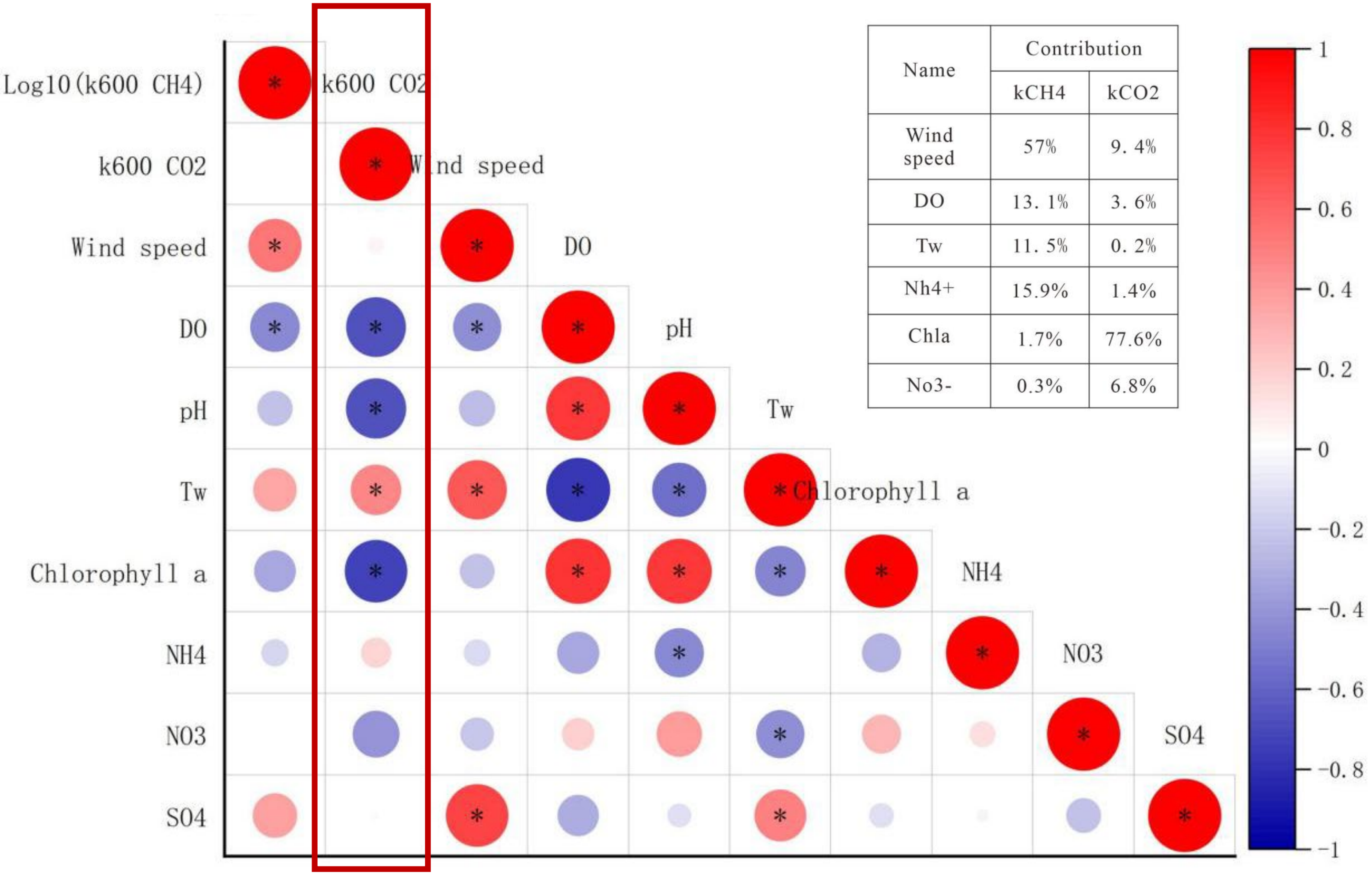
Name	Contribution	
	kCH4	kCO2
Wind speed	57%	9. 4%
DO	13. 1%	3. 6%
Tw	11. 5%	0. 2%
Nh4+	15.9%	1.4%
Chla	1.7%	77.6%
No3-	0.3%	6.8%



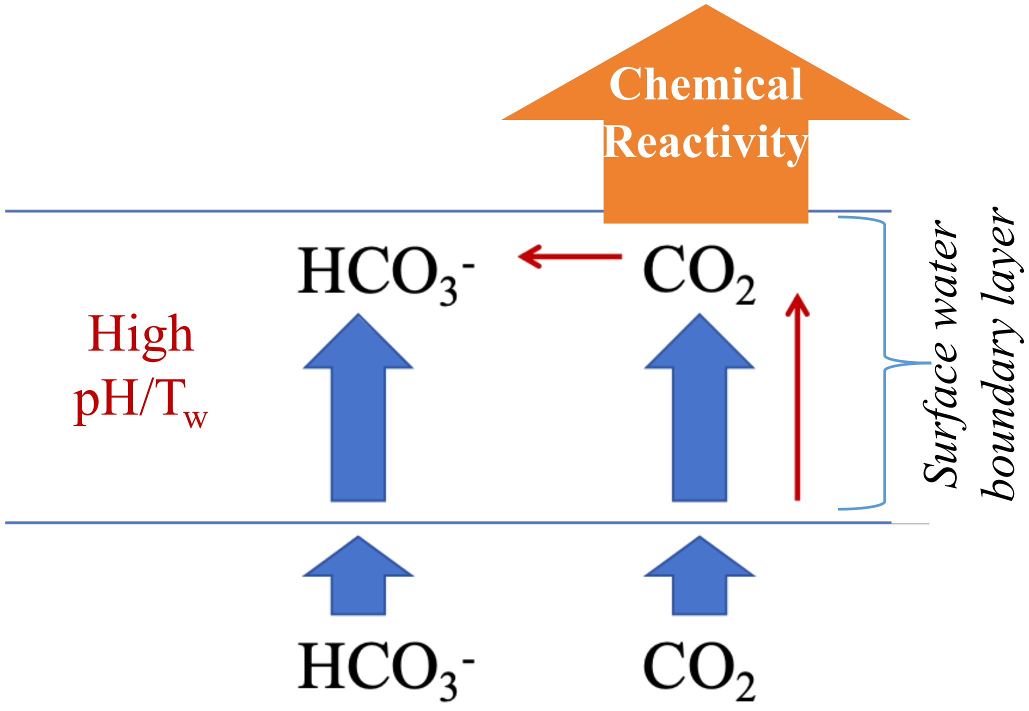
(unpublished data)

3.1.4 Driving Mechanisms

- There were significant negative correlations between k_{600}-CO_2 and water DO, pH and Chlorophyll a.
- The geochemical factors become the dominant divers of CO_2 gas exchange.



Name	Contribution	
	kCH4	kCO2
Wind speed	57%	9. 4%
DO	13. 1%	3. 6%
Tw	11. 5%	0. 2%
Nh4+	15.9%	1.4%
Chla	1.7%	77.6%
No3-	0.3%	6.8%



(unpublished data)

3.1 Conclusions

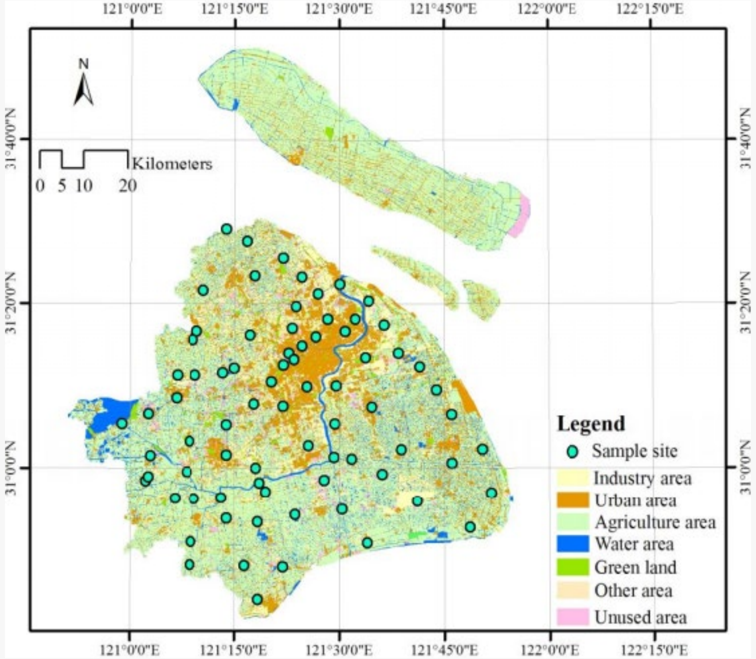
- The mismatches between k_{600} for CO_2 and CH_4 are prone to occur in urban rivers and the resulting discrepancies can be substantial. In the future, when conducting flux estimates on a global or regional scale, such differences should be taken into account.

- Bubbles increase the k_{600}-CH_4, while the chemical reaction mainly caused k_{600}-CO_2 lower. In order to eliminate this difference, errors can be reduced by adopting appropriate monitoring methods for and different gases.

3 Key Issues

3.1 Hydrological Stagnation

3.2 Human Activities



3.4 Tidal Effects

3.3 Rainfall Effects

(1) The influence mechanism of hydrological processes in urban rivers on GHG emissions

Clarifing the influence of the hydrological process of urban rivers under the combined action of natural and human factors on GHG emissions

(2) Better estimation of GHG emissions of global rivers

Improving the accuracy of GHG flux estimation through the obtained measured data and deepen the understanding of the role of urban rivers in the carbon and nitrogen cycles of aquatic ecosystems

3.2 Influence of Human Activities

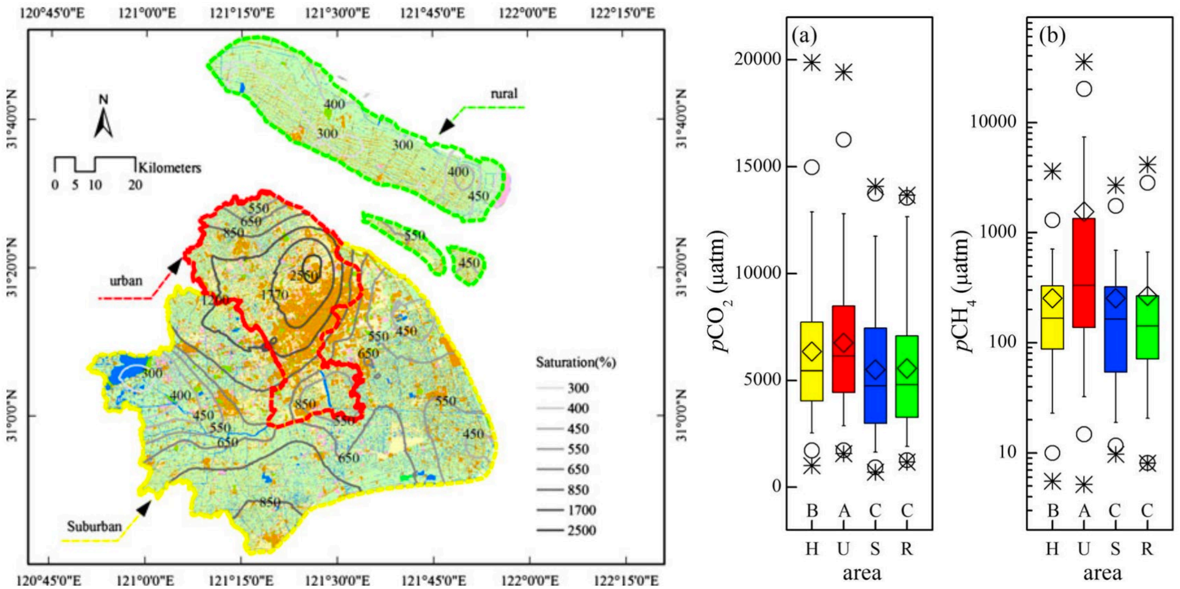
Rapid development and increased human activity

Industrial acticity

Agricultural acticity

Residential sector

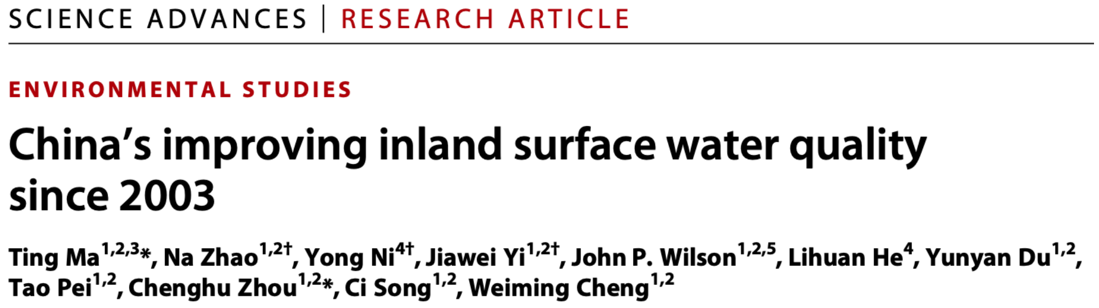
Excess organic matters and nutrients inputs from urban environments and their watersheds



(Yu et al., 2013)

(Yu et al., 2017)

Water Quality Improvement



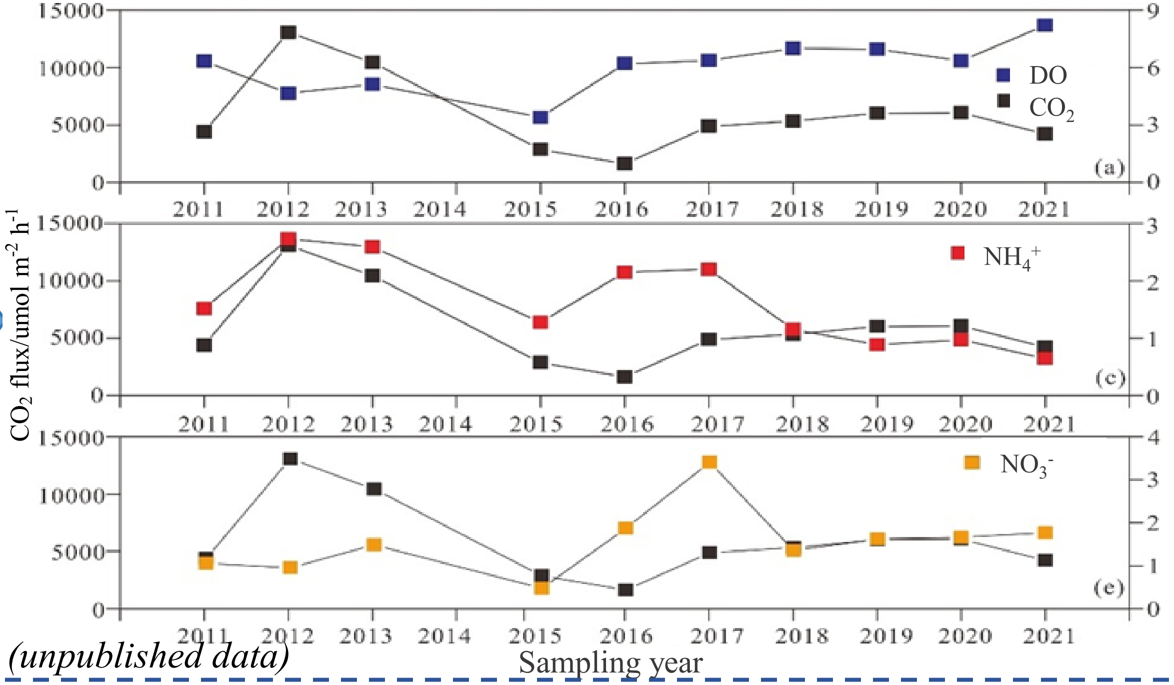
SCIENCE ADVANCES | RESEARCH ARTICLE

ENVIRONMENTAL STUDIES

China's improving inland surface water quality since 2003

Ting Ma[1,2,3]*, Na Zhao[1,2†], Yong Ni[4†], Jiawei Yi[1,2†], John P. Wilson[1,2,5], Lihuan He[4], Yunyan Du[1,2], Tao Pei[1,2], Chenghu Zhou[1,2]*, Ci Song[1,2], Weiming Cheng[1,2]

The water nutrients load decreases and the dissolved oxygen concentration increases

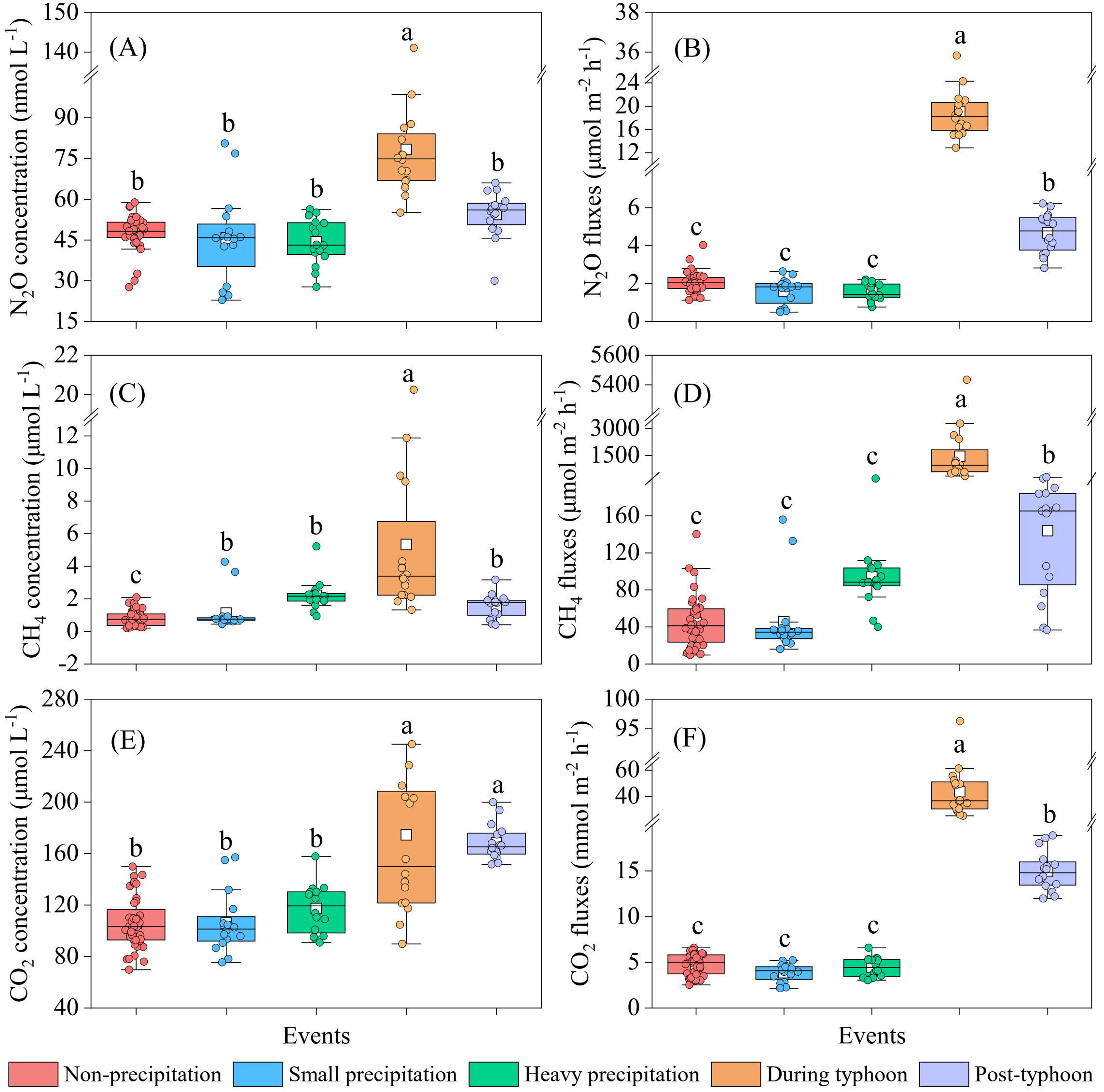


(unpublished data)

3.3 Influence of Rainfall Effects

The CO_2-eq emissions：

Typhoon > Heavy rain > non-rain > light rain



Journal of Hydrology 625 (2023) 130166

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

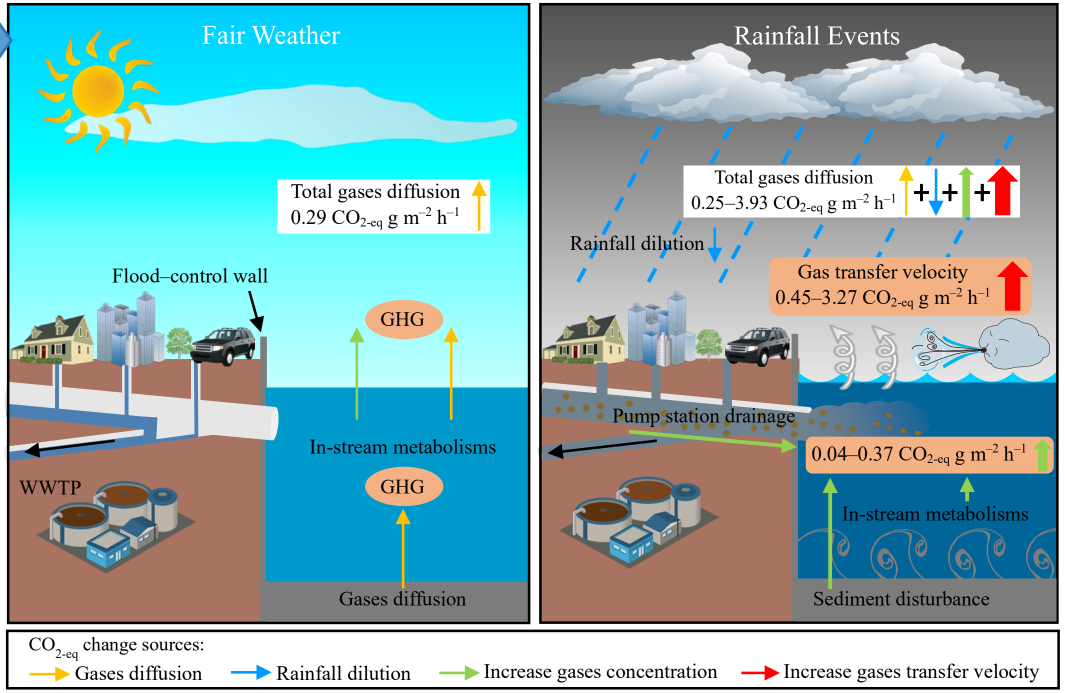
ELSEVIER

Research papers

Emission of greenhouse gas from urban polluted river during different rainfall events: Typhoon and storm will promote stronger evasions

Guanghui Zhao [a], Dongqi Wang [a,b,*], Taihu Sun [a], Yan Ding [a], Shu Chen [a,c,d], Yizhe Li [a], Hechen Sun [a], Chenyang Wu [a], Zhongjie Yu [e], Zhenlou Chen [a,*]

[a] School of Geographical Sciences, Key Laboratory of Geographic Information Science (Ministry of Education), East China Normal University, Shanghai 200241, China
[b] Shanghai Key Lab for Urban Ecological Processes and Eco-Restoration, Shanghai 200241, China
[c] College of Smart Energy, Shanghai Jiao Tong University, Shanghai 200240, China
[d] Research Institute of Carbon Neutrality, Shanghai Jiao Tong University, Shanghai 200240, China
[e] Department of Natural Resources and Environmental Sciences, University of Illinois Urbana-Champaign, Urbana 61801, IL, USA



3.4 Influence of Tidal Effects

- The dry-wet cycle caused by tidal fluctuation may lead the drawdown zone to a potential hotspot of GHG.
- Neglecting drawdown zones might have resulted in the underestimation of GHG emissions from deltaic urban rivers.

(Pinto et al., 2020)

Journal of Hydrology 657 (2025) 133058

Contents lists available at ScienceDirect

Journal of Hydrology

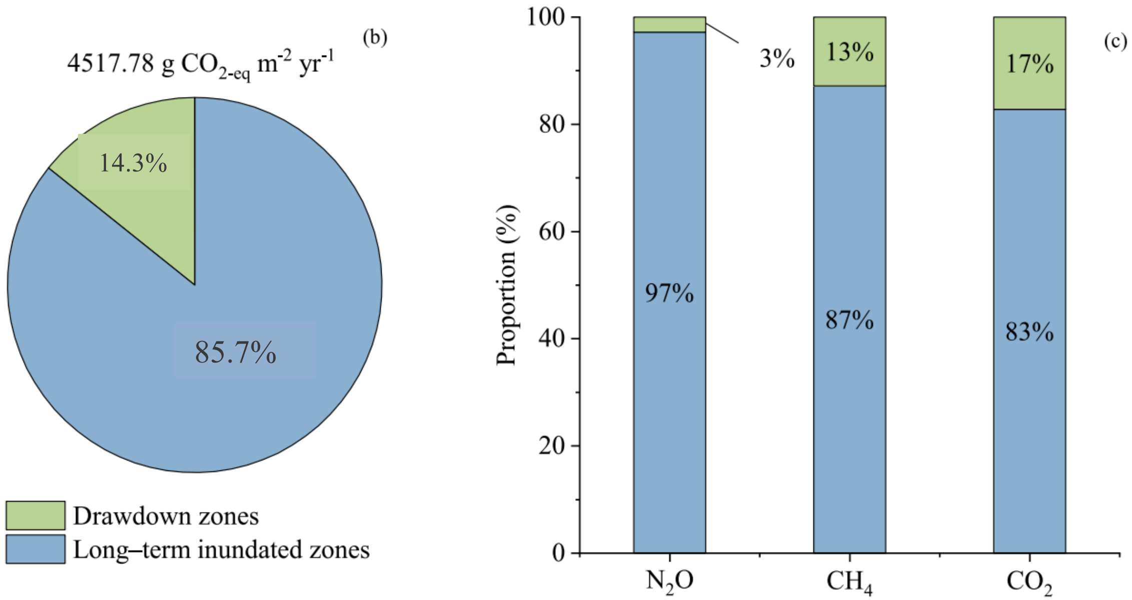
journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Uncertainty of hydrological processes on greenhouse gas emissions from urban river driven by natural and anthropogenic factors

Yizhe Li [a], Dongqi Wang [a,b,*], Chenyang Wu [a], Guanghui Zhao [a], Hechen Sun [a], Xin Xu [a], Yufang Li [a], Shengnan Wu [a], Fanyan Yang [a], Zhenlou Chen [a,*]

[a] School of Geographical Sciences, Key Laboratory of Geographic Information Science (Ministry of Education), East China Normal University, Shanghai 200241, China
[b] Shanghai Key Lab for Urban Ecological Processes and Eco-Restoration, Shanghai 200241, China



References

- Yizhe Li, Dongqi Wang*, Chenyang Wu, Guanghui Zhao, Hechen Sun, Xin Xu,Yufang Li, Shengnan Wu, Fanyan Yang, Zhenlou Chen. (2025) Uncertainty of hydrological processes on greenhouse gas emissions from urban river driven by natural and anthropogenic factors. Journal of Hydrology, 657133058.
- Zhao, G., Wang, D*., Sun, T., Ding Y., Chen S., et al. (2023) Emission of greenhouse gas from urban polluted river during different rainfall events: typhoon and storm will promote stronger evasions. Journal of Hydrology. 625, 130166.
- Shu Chen, Dongqi Wang*, Yan Ding, Zhongjie Yu, Lijie Liu, Yu Li, Dong Yang, Yingyuan Gao, Haowen Tian, Rui Cai, Zhenlou Chen. (2021). Ebullition Controls on CH4 Emissions in an Urban, Eutrophic River: A Potential Time-Scale Bias in Determining the Aquatic CH4 Flux. Environmental Science & Technology.
- Yu, Z., D. Wang*, Y. Li, H. Deng, B. Hu, M. Ye, X. Zhou, L. Da, Z. Chen, and S. Xu (2017), Carbon dioxide and methane dynamics in a human-dominated low_x0002_land coastal river network (Shanghai, China), J. Geophys. Res. Biogeosci., 122, 1738–1758.
- Zhongjie Yu, Huanguang Deng, Dongqi Wang, Mingwu Ye, Yongjie Tan, Yangjie Li, Zhenlou Chen and Shiyuan Xu . (2013) Nitrous oxide emissions in the Shanghai river network: implications for the effects of urban sewage and IPCC methodology. Global Change Biology, 19, 2999–3010.

THANK YOU !

Questions?