Unraveling the Drivers of Bubble Methane Emissions in Urban Rivers: The Roles of Organic Carbon, Temperature, and Water Depth

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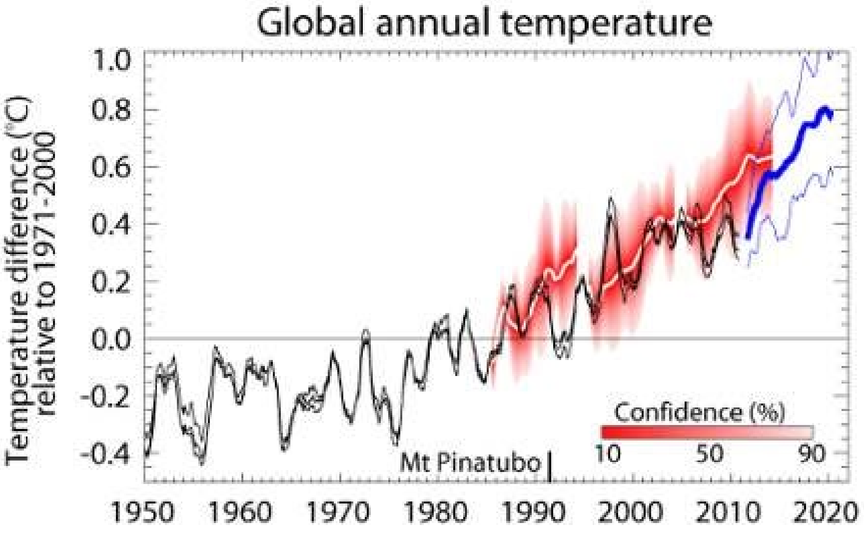
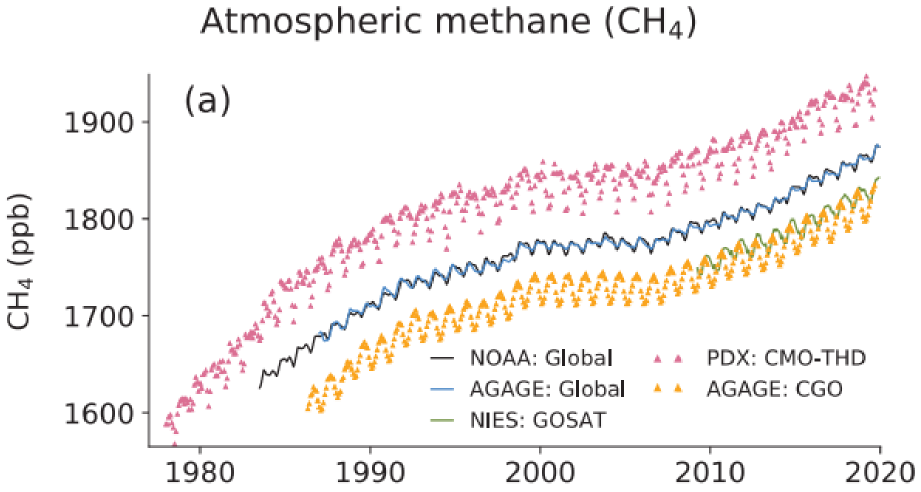
Background

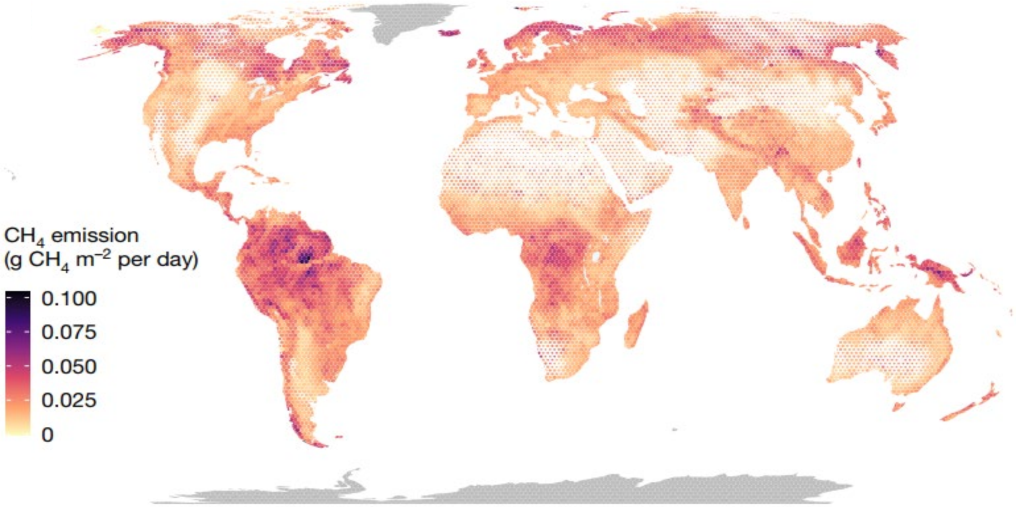
- Greenhouse gases (such as CO_2, CH_4 and N_2O) are the main factors causing global warming. Among them, the century-long warming potential of CH_4 is approximately 28 times that of CO_2, and its concentration has increased by 33.2% compared to before the Industrial Revolution.

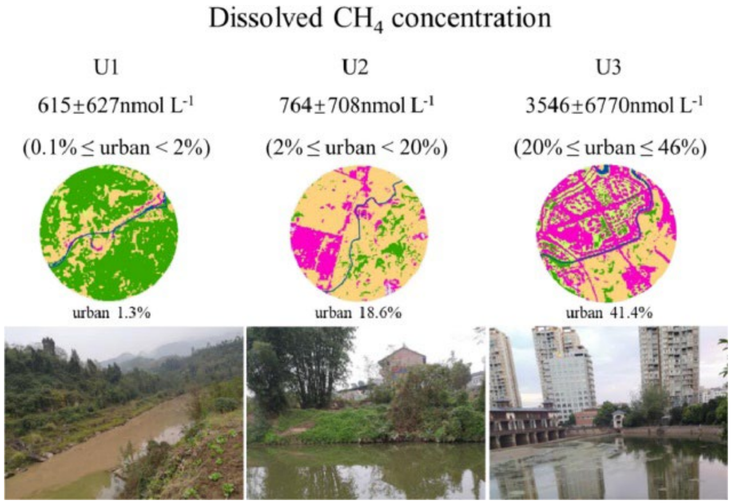




Background

- Aquatic ecosystems accounting for nearly 50% of the global CH_4 emissions.
- The total amount of CH_4 emitted by global rivers to the atmosphere is approximately 16.7-30.5 Tg CH_4 yr^{-1}.
- Urban rivers are more significant sources of CH_4 emissions due to the strong influence of human activities.



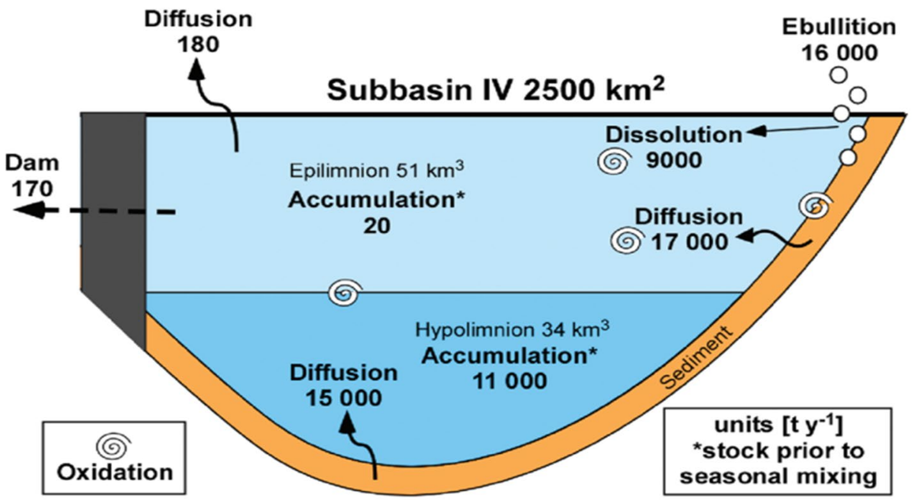


Gerard Rocher-Ros et.al,2023,Nature

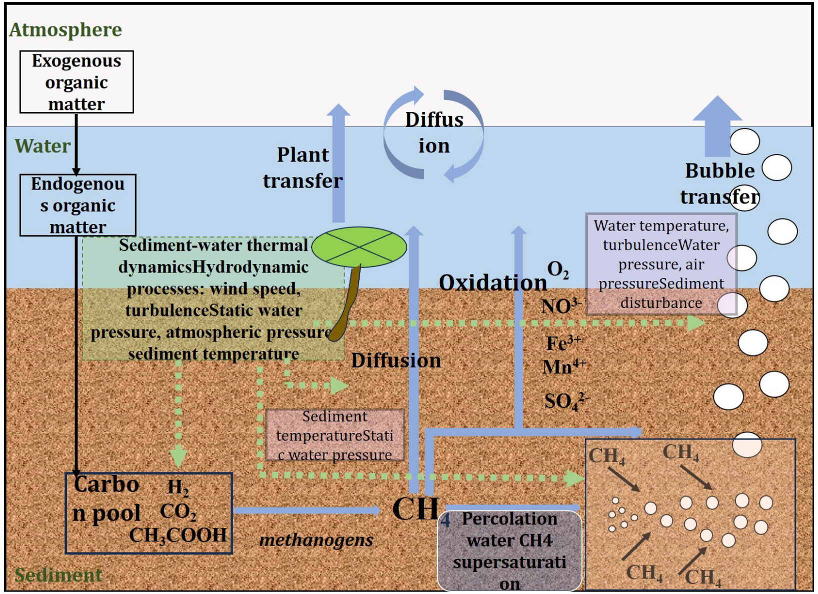
Tang et al.,2021, Water Research

Background

- Bubbles and diffusion are the main ways of gas emission.
- The production and emission of the bubble CH_4 cannot be ignored.



(Bastviken et al., Science, 2011)



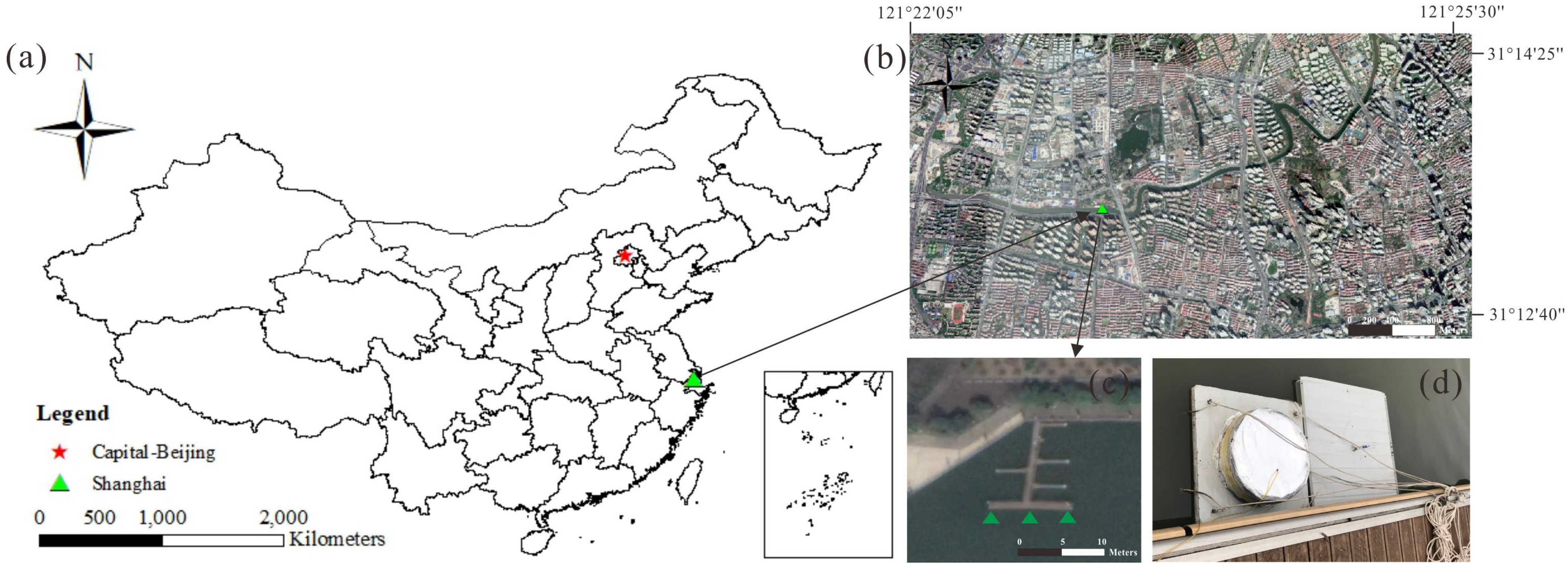
adapted from (Thauer et al.,2010, Angewandte Chemie International Edition)

Research Objectives

1. Characteristics of Bubble Events
2. Bubble Contribution to GHGs
3. Spatiotemporal Patterns of Bubble CH_4
4. Impact on Flux Estimation
5. Drivers of Emission Heterogeneity
6. Determining CH_4 Formation Pathways

Methods and materials

Sampling Time：Four seasons, Oct., 2018; Jan., Apr., and Jul., 2019



Methods and materials

Boundary Layer Model

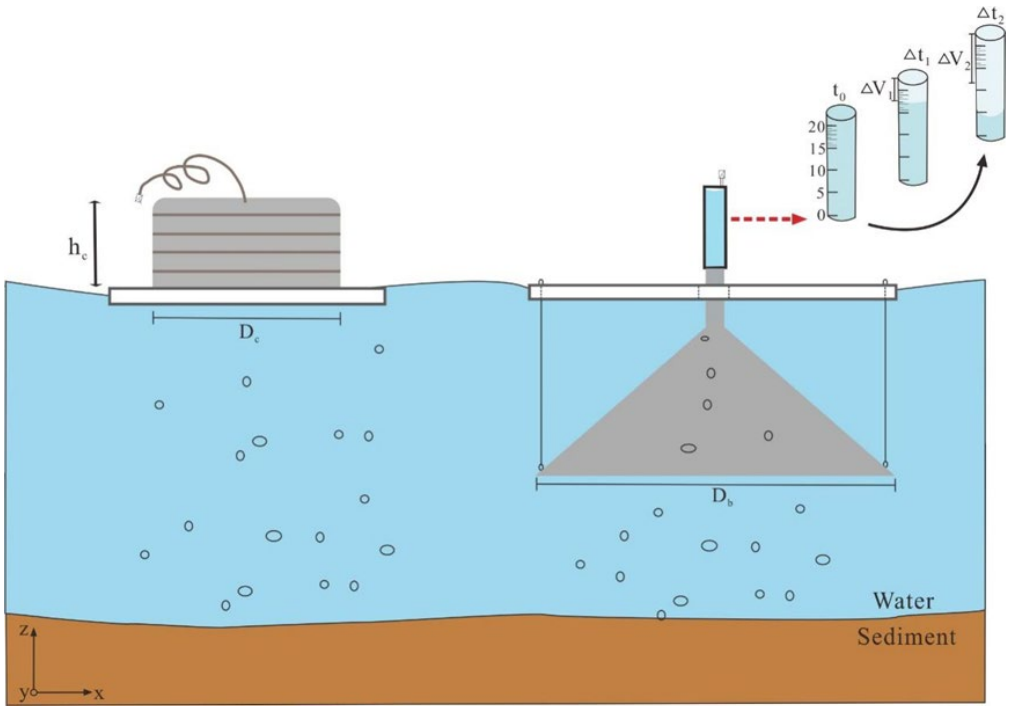
$$F=k*\Delta c$$

Floating Chamber

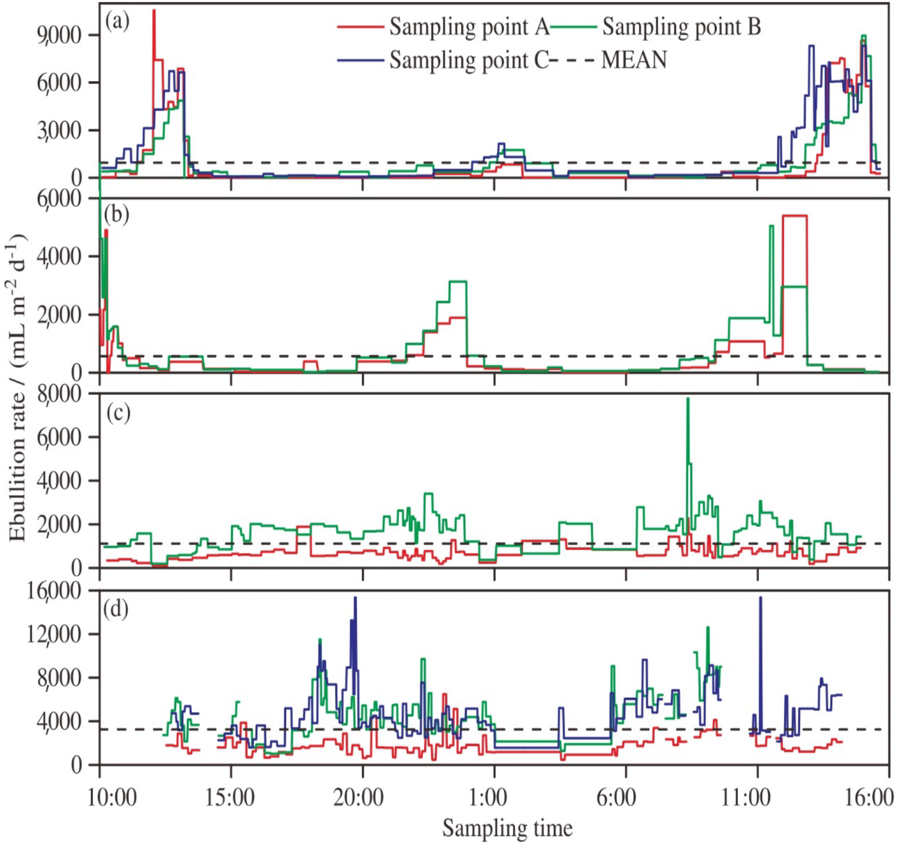
$$F=\frac{\Delta c*V}{t*S}$$

Bubble Trap

$$F=\frac{v*c}{S}$$

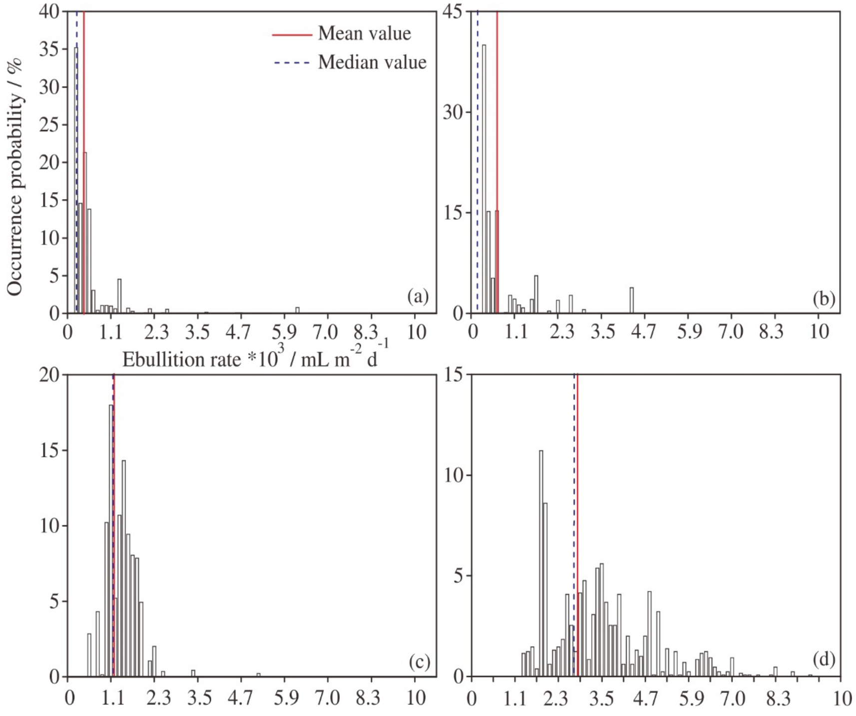


Characteristics of Bubble Events



Ebullition rates at each sampling point

- ➢ High spatiotemporal heterogeneity



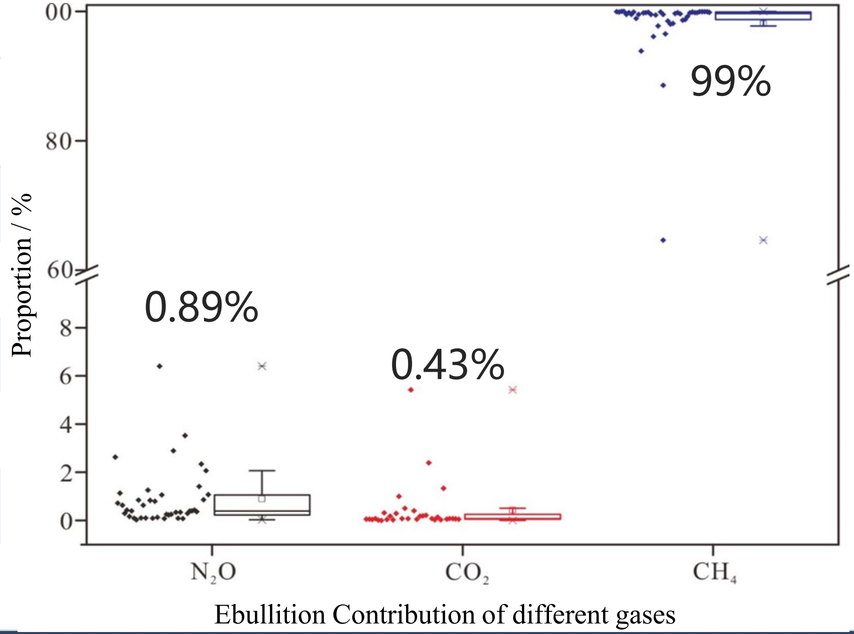
Probability distribution of ebullition rates

Shu Chen, Dongqi Wang, ES&T, 2021*

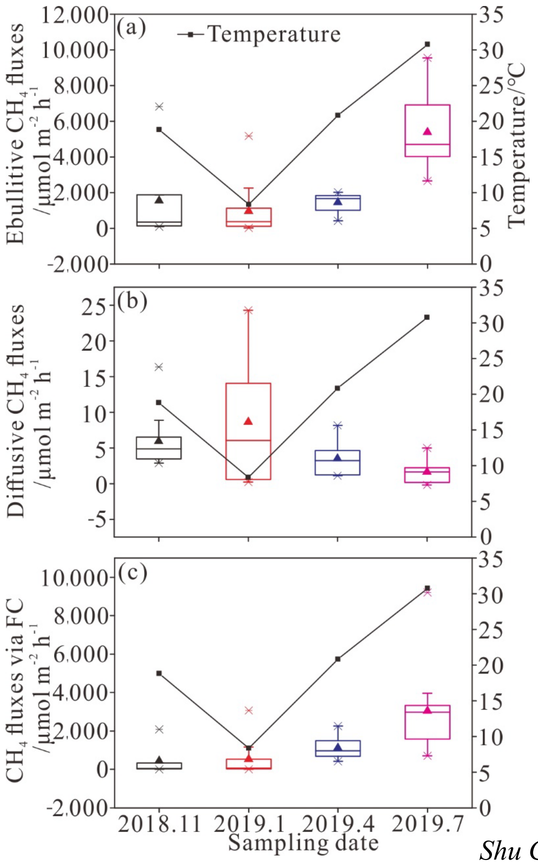
Bubble Contribution

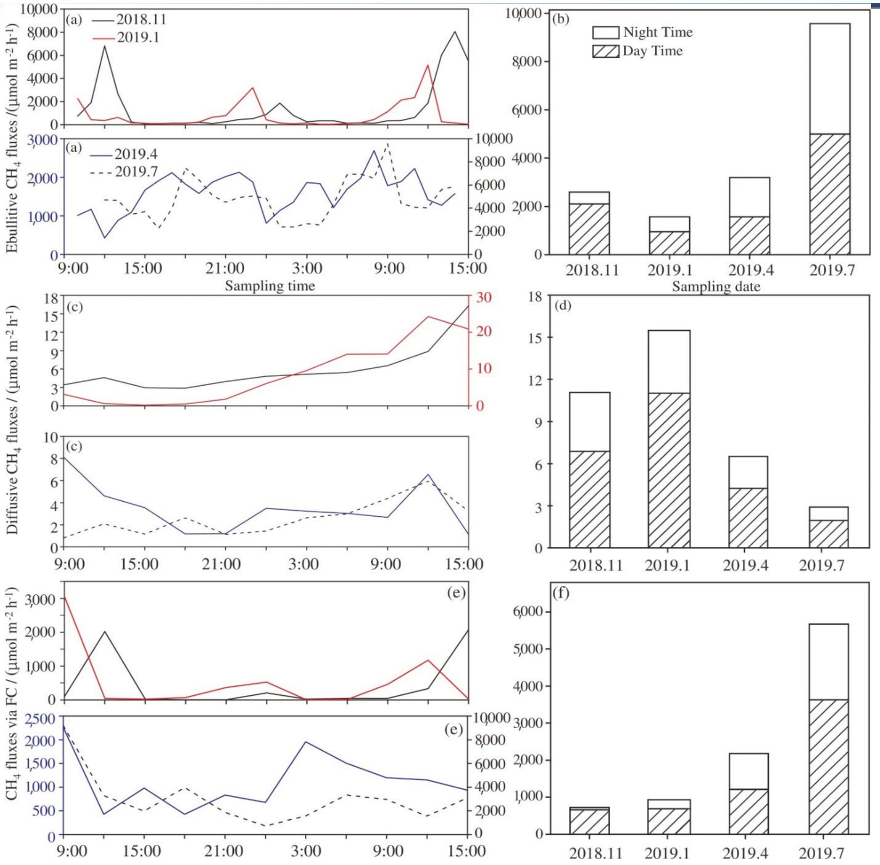
- The contribution of bubble to the fluxes of N_2O and CO_2 is negligible, but its contribution to CH_4 is very significant.

Season	N_2O (ppm)	CH_4 (% by volume)	CO_2 (% by volume)
2018.10	1.66	60.7	1.31
2019.1	0.84	65.2	0.56
2019.4	0.25	69.7	0.15
2019.7	0.38	69.7	Null
Mean	**0.78**	**66.3**	**0.67**



Spatiotemporal Patterns of bubble CH_4





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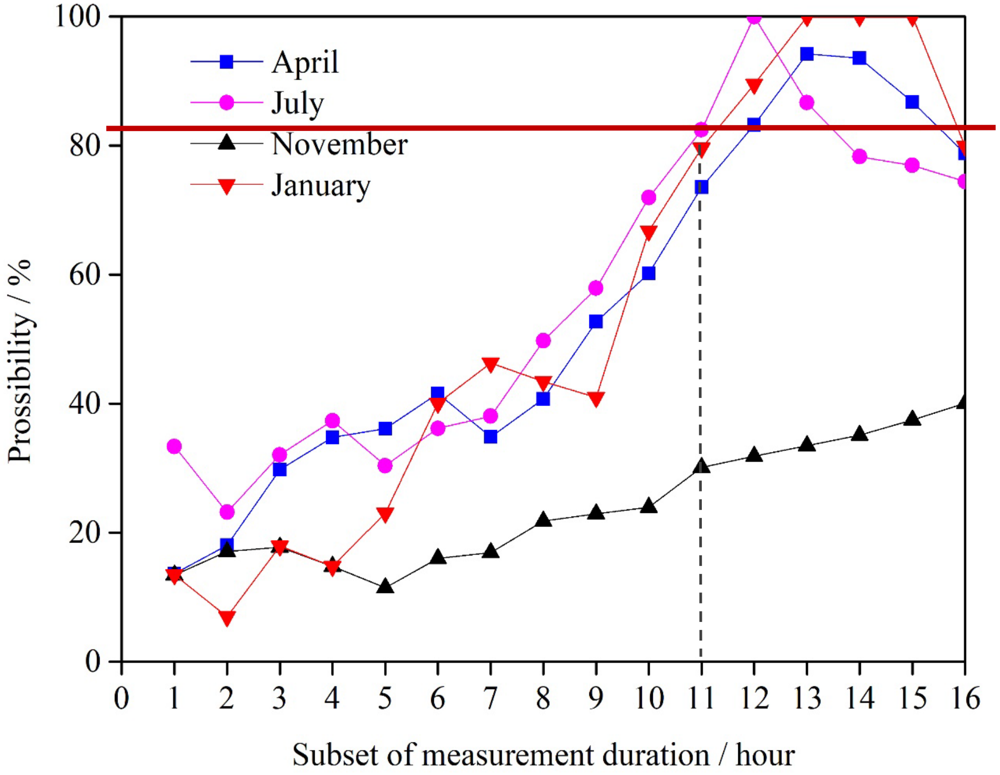
Impact on Flux Estimation

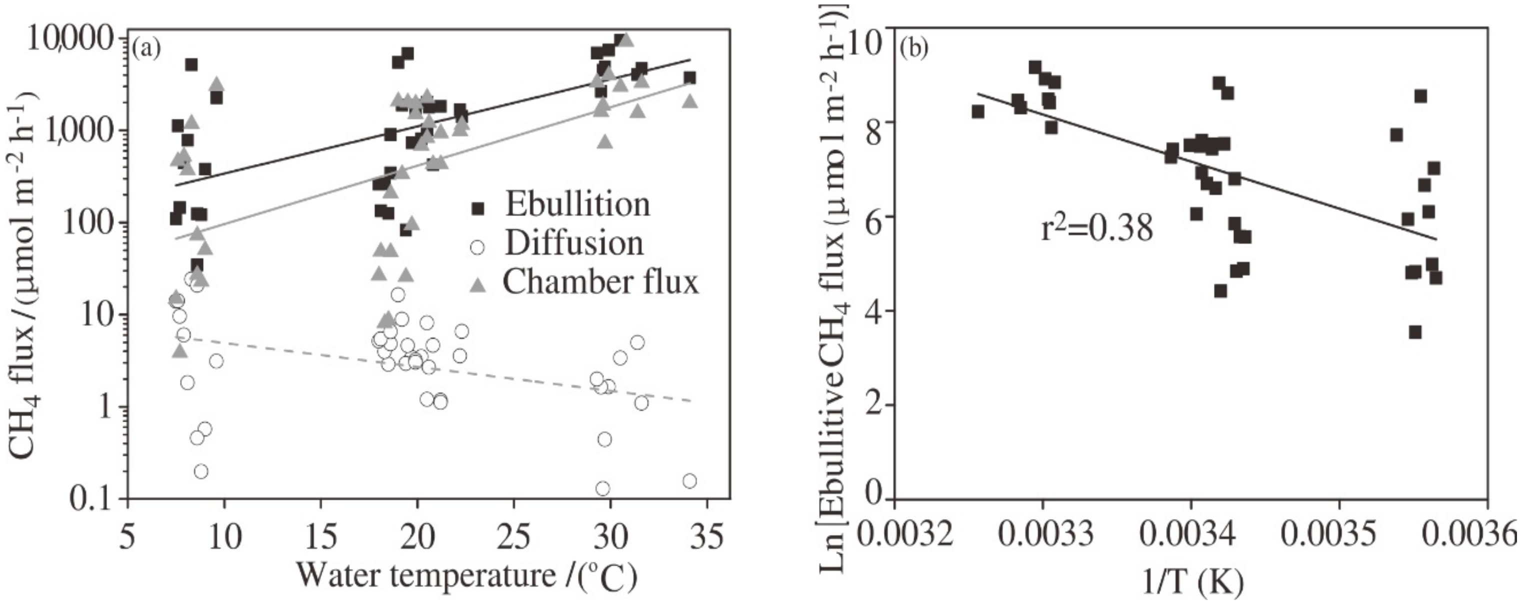


- The bubble CH_4 flux is more likely to be underestimated at low temperatures because capturing the bubble flux is more difficult given the low frequency of ebullition events.

Shu Chen, Dongqi Wang, ES&T, 2021*

Drivers of Emission Heterogeneity

- High temperature dependency of bubble emissions



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Key Conclusions

Environmental Science & Technology

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Ebullition Controls on CH_4 Emissions in an Urban, Eutrophic River: A Potential Time-Scale Bias in Determining the Aquatic CH_4 Flux

Shu Chen, Dongqi Wang,* Yan Ding, Zhongjie Yu, Lijie Liu, Yu Li, Dong Yang, Yingyuan Gao, Haowen Tian, Rui Cai, and Zhenlou Chen

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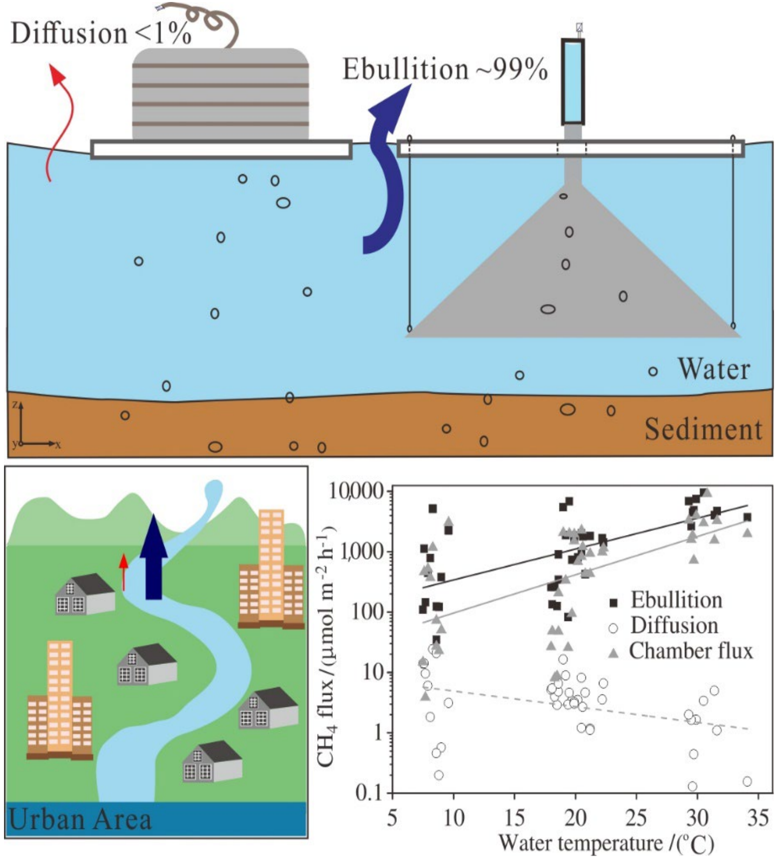
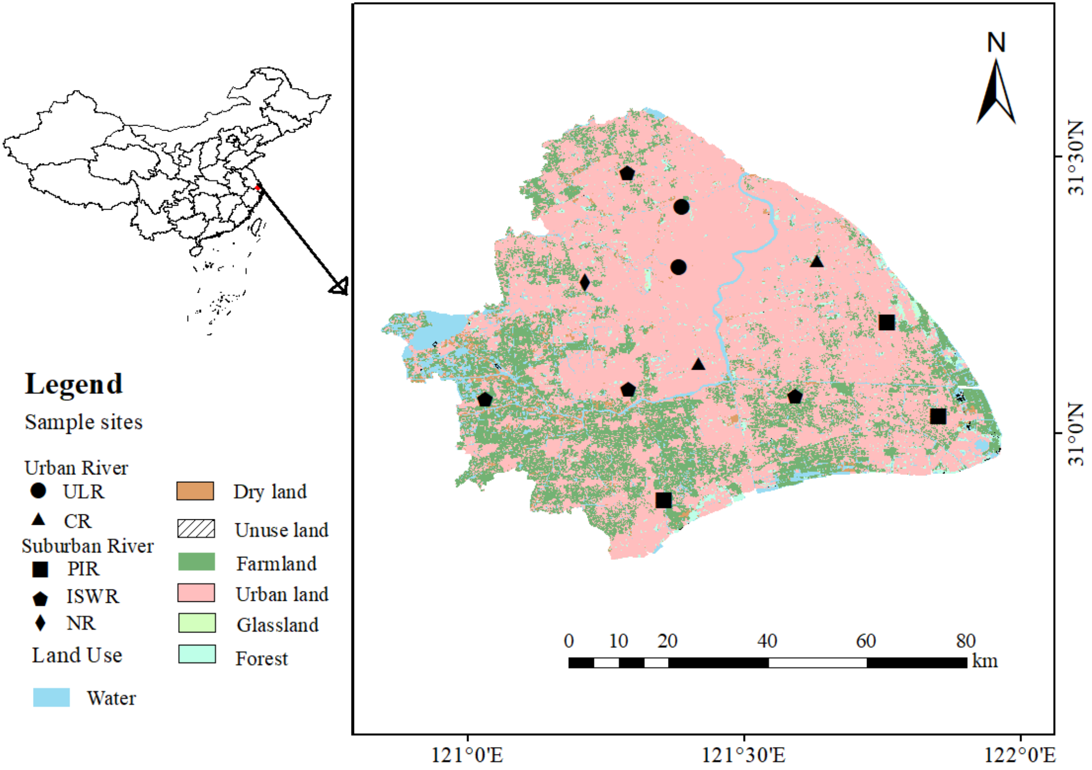
- The bubbles contributed nearly 99% of CH_4 emissions of urban rivers. The bubble CH_4 fluxes cannot be excluded when upscaling CH_4 fluxes.



Wider Study Area



According to the types of river functions:

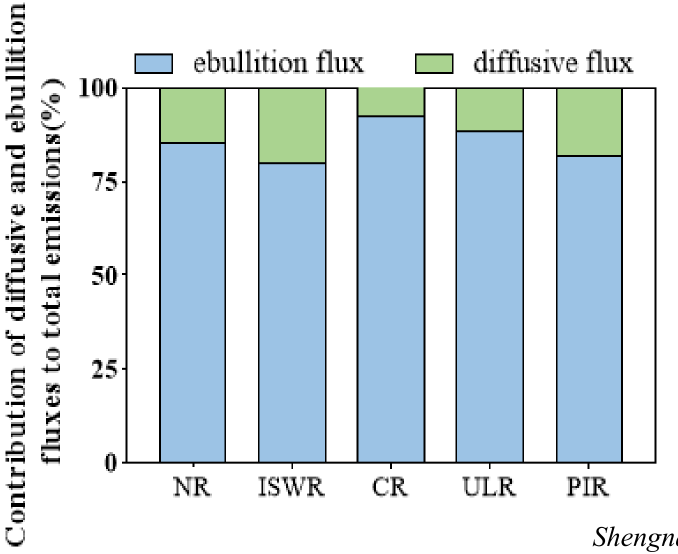
1. Urban Landscape Rivers(ULR),
2. Navigation Rivers(NR),
3. Composite Rivers(CR),
4. Pollution Input Rivers(PIR)
5. Irrigation Water Supply Rivers(IWSR)

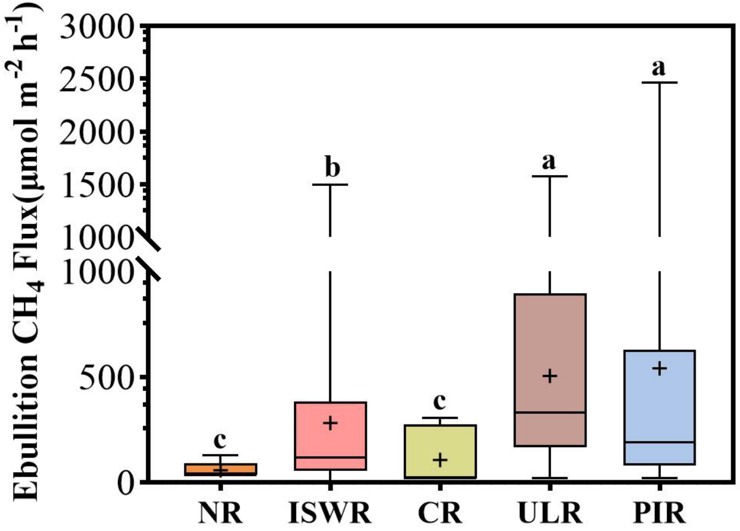
Sample collection and analysis:

- In May, August, November, January, 2023, and May, July, 2024
- Water sample/Sediment: Physical and chemical indicators of water bodies/SOC
- $\delta^{13}CH_4$/$\delta^{13}CO_2$: CH_4/CO_2 stable isotope analyzer

Bubble Contribution to different rivers

- The bubble emission is the main pathway for CH_4 flux, contributing 83% (54%-99%) to the total CH_4 flux.
- The spatial variation of bubble CH_4 fluxes in the river is significant, and the CH_4 bubble fluxes are the highest in rivers in the city center and those with severe pollution.





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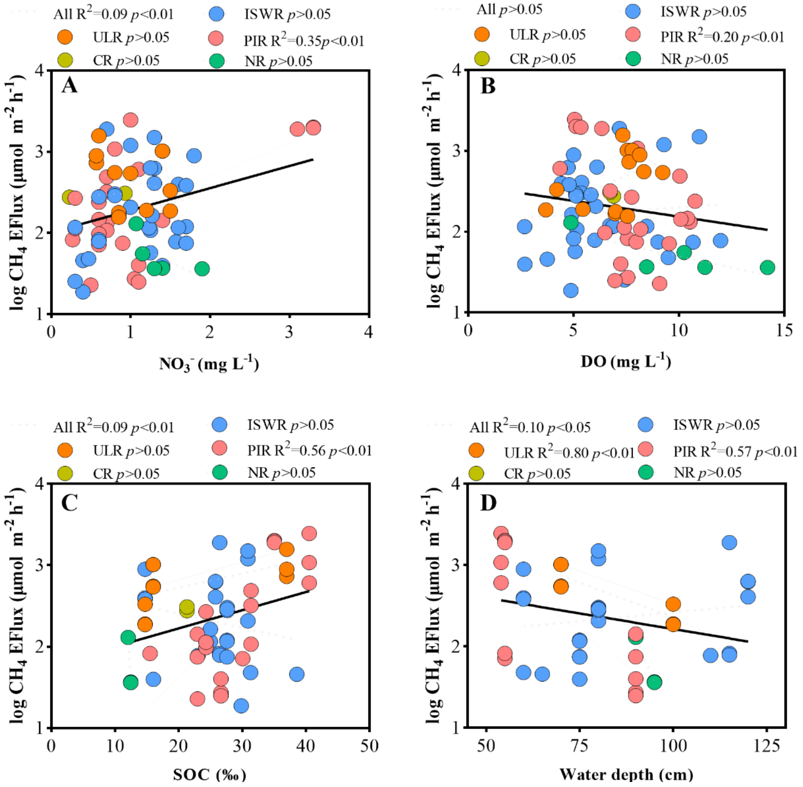
Drivers of Emission Heterogeneity



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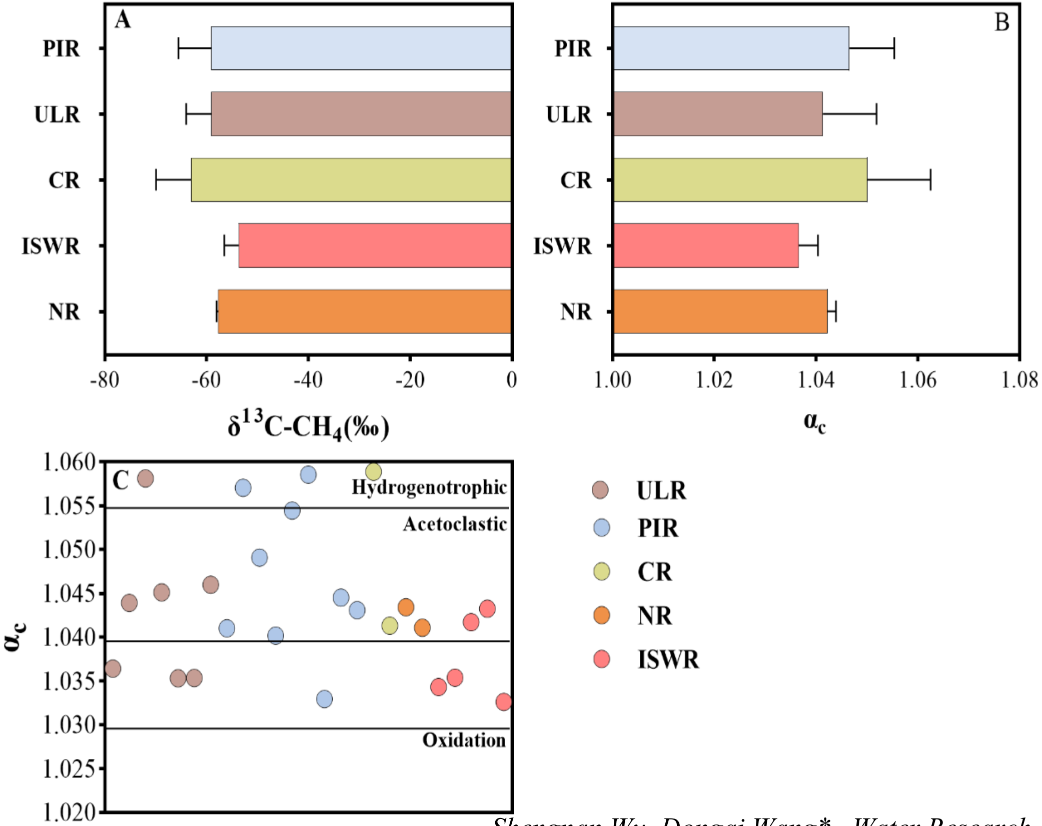
- The river bubble CH_4 flux is significantly positively correlated with water body **NO_3^-, temperature and sediment SOC**; and significantly negatively correlated with **water depth**.
- It indicates that **the input of pollution load caused by human activities, the increase in anthropogenic organic carbon content, and the shallower water depth** jointly enhance the bubble CH_4 flux in urban rivers.

Determining CH_4 Formation Pathways



- The $\delta^{13}C\text{-}CH_4$ values of all the sampling points range from **-68.09‰ to -48.23‰,** indicating that in most of the samples, the CH_4 in the bubbles is likely to be produced through the **microbial methanogenesis pathway**.
- Most of sampling sites exhibited **dominant Acetoclastic methanogenesis** (αC = 1.04–1.055), A small part showed CO_2-reducing methanogenesis (αC = 1.055–1.09)

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Key Conclusions

- The bubble CH_4 flux in Shanghai River Network accounts for 83% of the total CH_4 emissions, and it has significant spatial heterogeneity
- The input of pollution load brought about by human activities, the increase in anthropogenic organic carbon content and the shallower water depth jointly enhance the bubble CH_4 flux in urban rivers.
- The bubble CH_4 emissions have a relatively high temperature sensitivity. Eutrophication and higher sediment organic carbon may have triggered this high-temperature sensitivity.
- In the river network of Shanghai, the bubble CH_4 mainly proceeds through the fermentation of Acetoclastic methanogenesis.

THANK YOU

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QUESTIONS?