Does Wetland Act as a Source or a Sink of Atmospheric Mercury?

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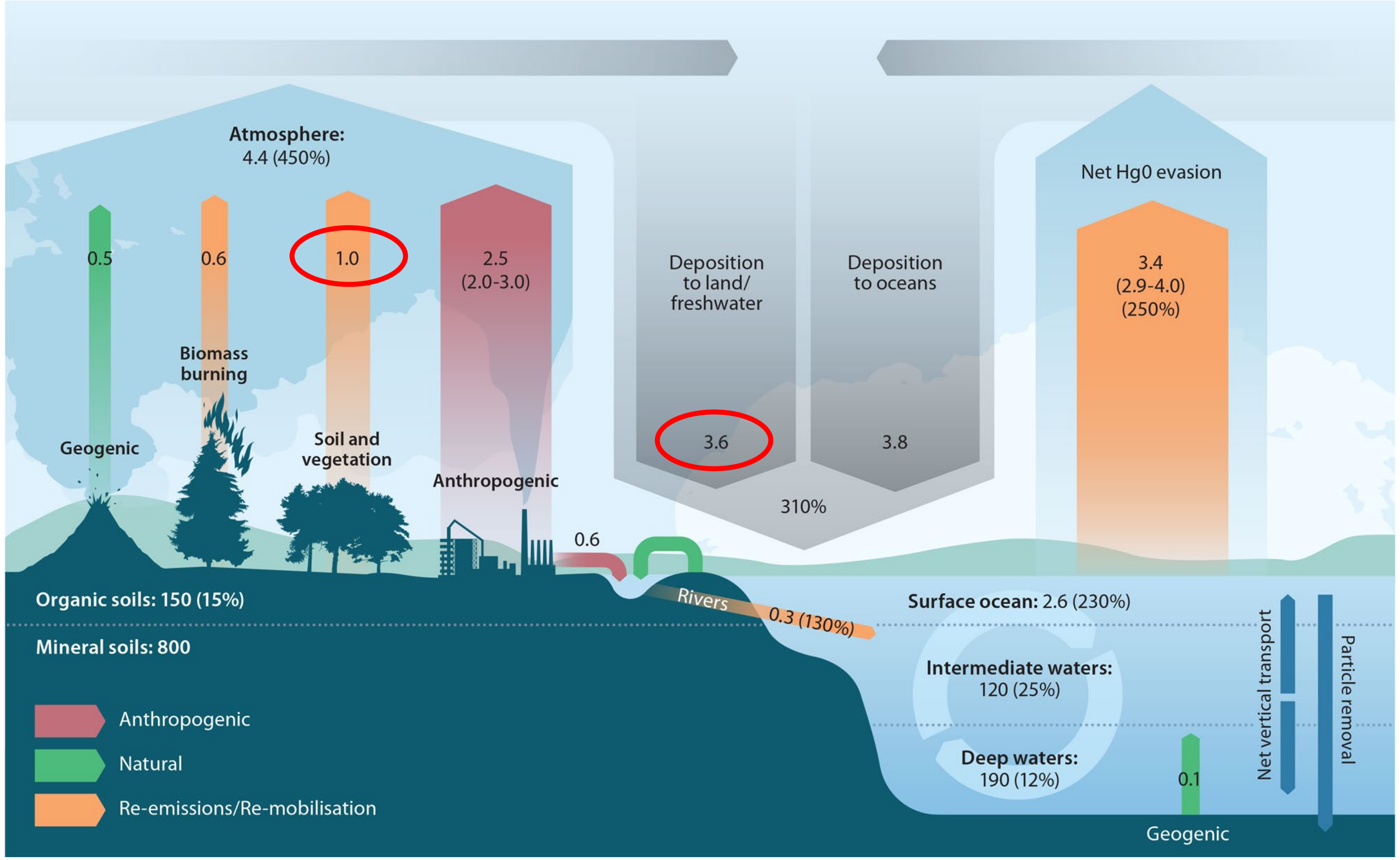
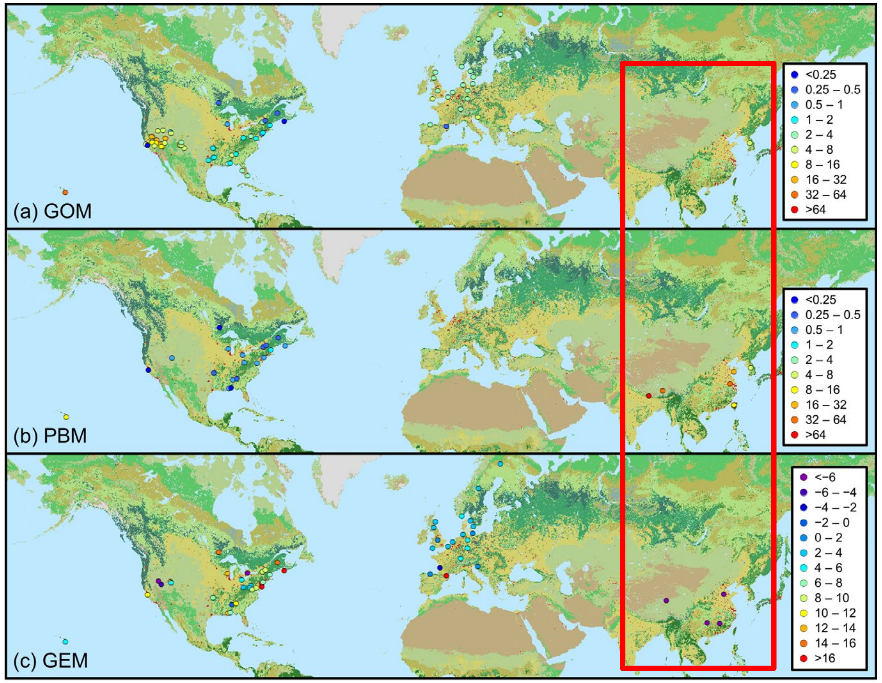
Global Hg budget and air–surface Hg exchange



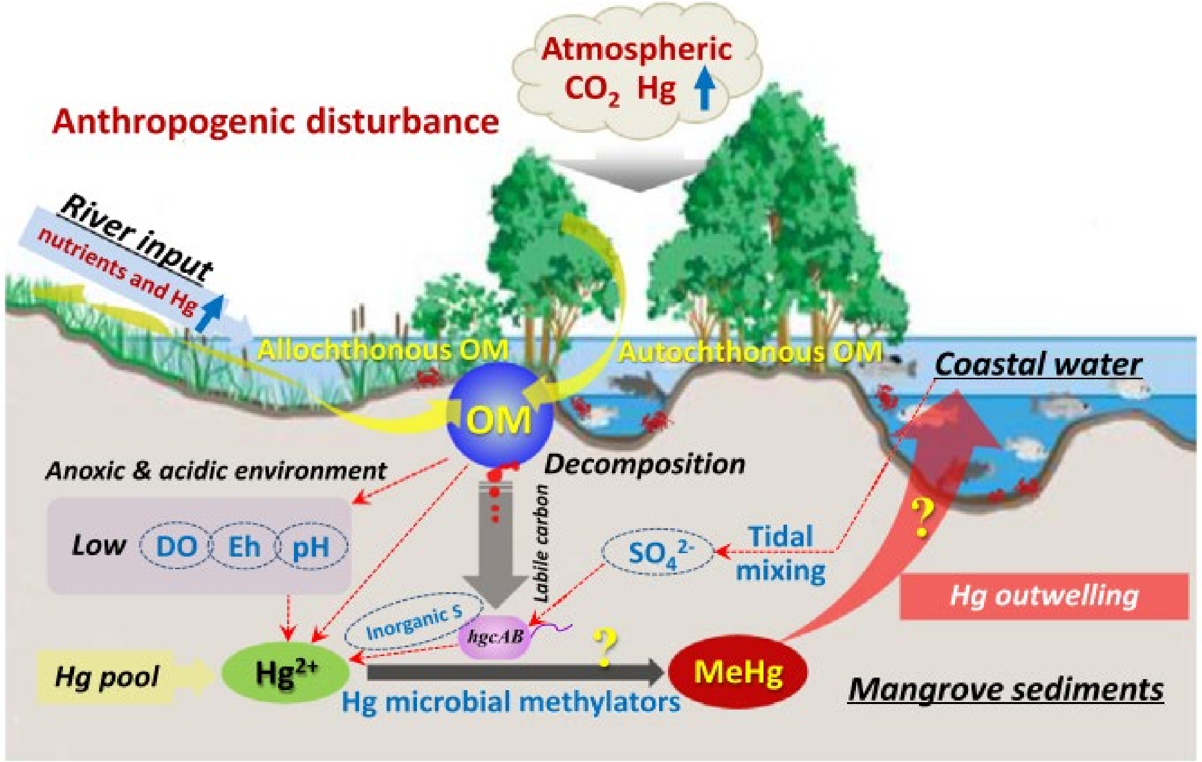


- **Air–surface exchange** is a key process in **global Hg budget**
- **Observations** of air–surface Hg exchange are **quite limited**

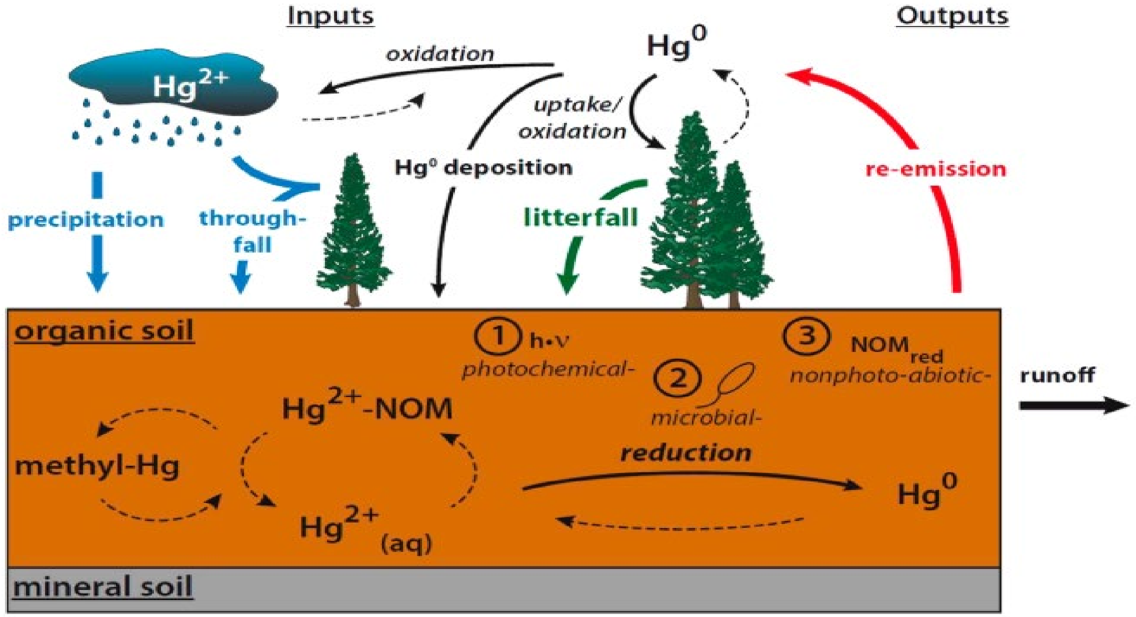
TAM
- Gaseous Elemental Mercury (**GEM** or **Hg^0**)
- Gaseous Oxidized Mercury (**GOM**) } **Hg^{II}**
- Particulate-Bound Mercury (**PBM**) } **Hg^{II}**

Obrist et al., ***Ambio***, 2018; Outridge et al., ***Environ. Sci. Technol.***, 2018; Zhang et al., ***Atmos. Chem. Phys.***, 2019

Air–soil Hg^0 exchange in wetlands



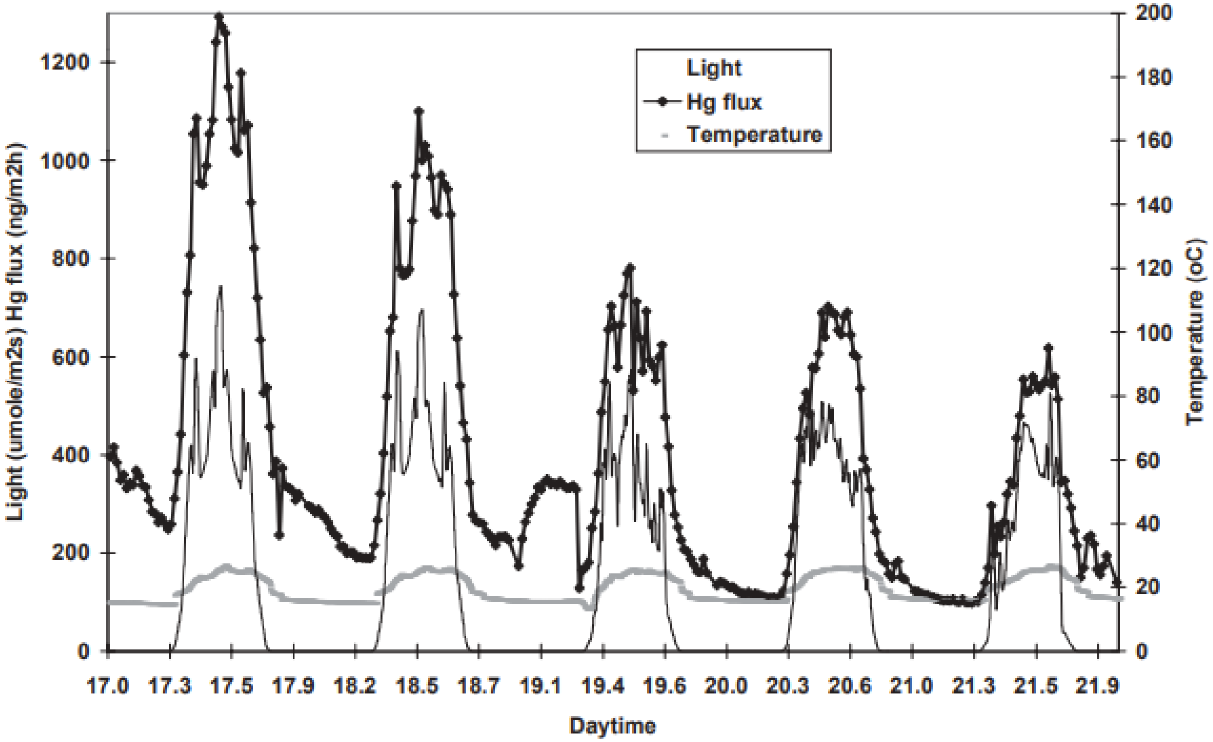
Landscapes	Hg^0 flux ($ng\,m^{-2}\,h^{-1}$)				N
	Mean	Median	Min (min)[a]	Max (max)[a]	
Background soil	2.1	1.3	−51.7 (−51.7)	33.3 (97.8)	159
Urban settings	16.4	6.2	0.2 (−318)	129.5 (437)	29
Agricultural fields	25.1	15.3	−4.1 (−1051)	183 (1071)	59
Forest foliage & canopy level	6.3	0.7	−9.6 (−4111)	37.0 (1000)	8
Grasslands	5.5	0.4	−18.7 (−989.6)	41.5 (870)	38
Wetlands	12.5	1.4	−0.3 (−375)	85 (677)	23
Freshwater	4.0	2.8	−0.3 (−18.2)	74.0 (88.9)	93
Sea water	5.9	2.5	0.1 (−2.7)	40.5 (46.0)	51
Snow	5.7	2.7	−10.8 (−2160)	40 (720)	15
Natural enriched surfaces	5618	226	−5493 (−9434)	239 200 (420 000)	329
Anthropogenically contaminated surfaces	595	184	−1.4 (−286.2)	13 700 (13 700)	58

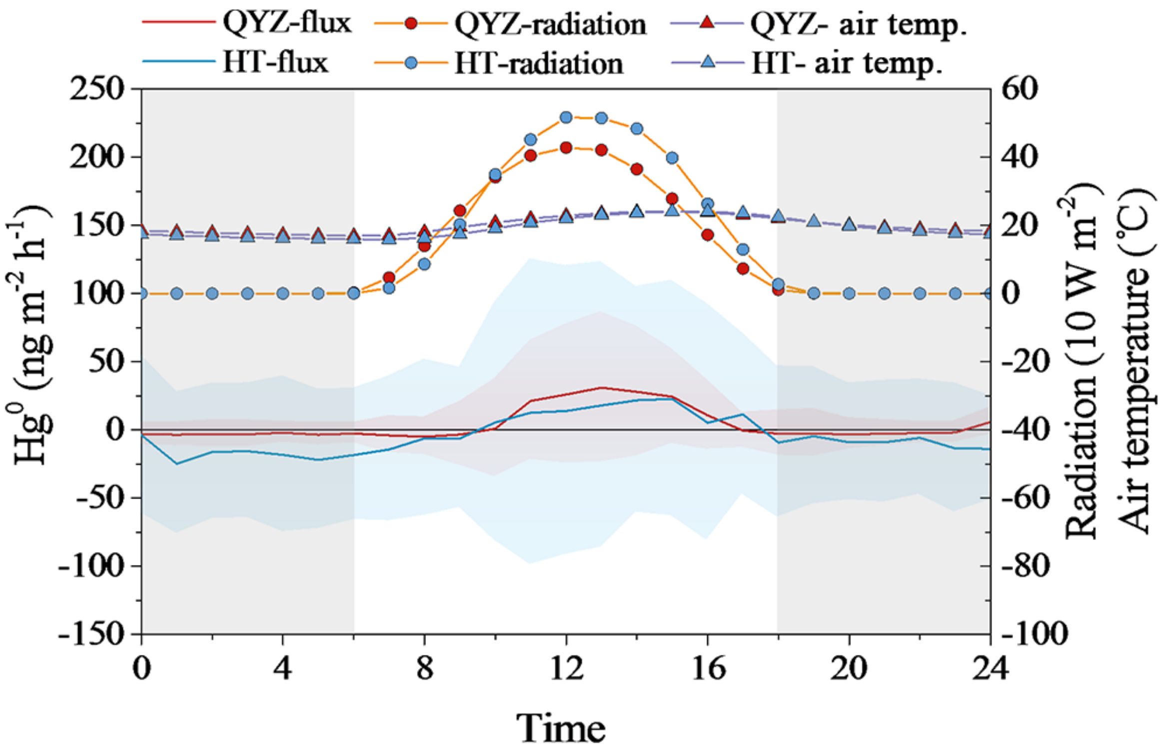


- The **dual roles of soils** as both **sources and sinks** of atmospheric Hg
- **Wetlands** are important **natural sources** for Hg^0 with **large uncertainties**

Jiskra et al., ***Environ. Sci. Technol.***, 2015; Zhu et al., ***Atmos. Chem. Phys.***, 2016; Lei et al., ***Sci. Total Environ.***, 2019

Impacts of meteorological factors on Hg^0 exchange flux

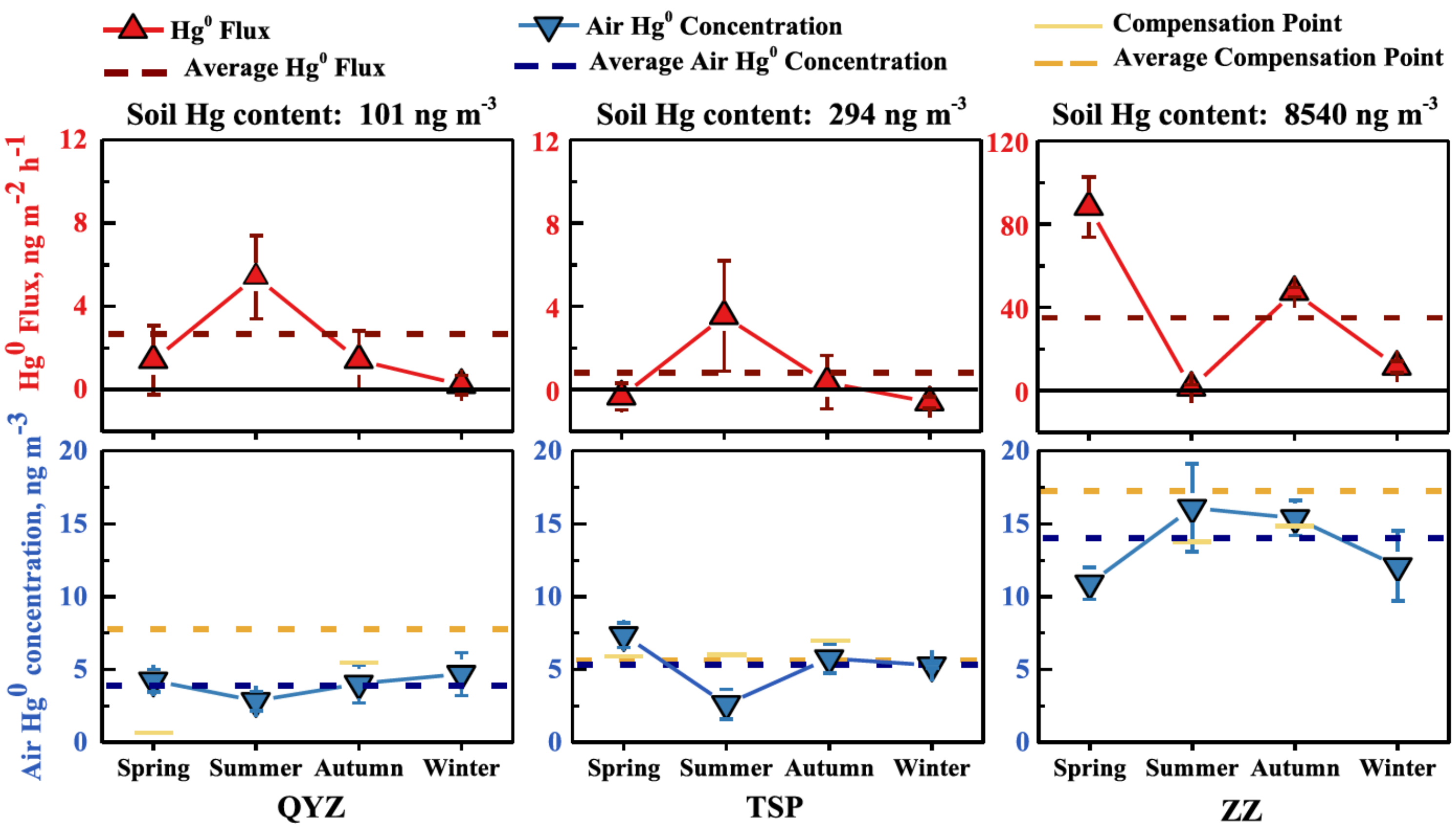


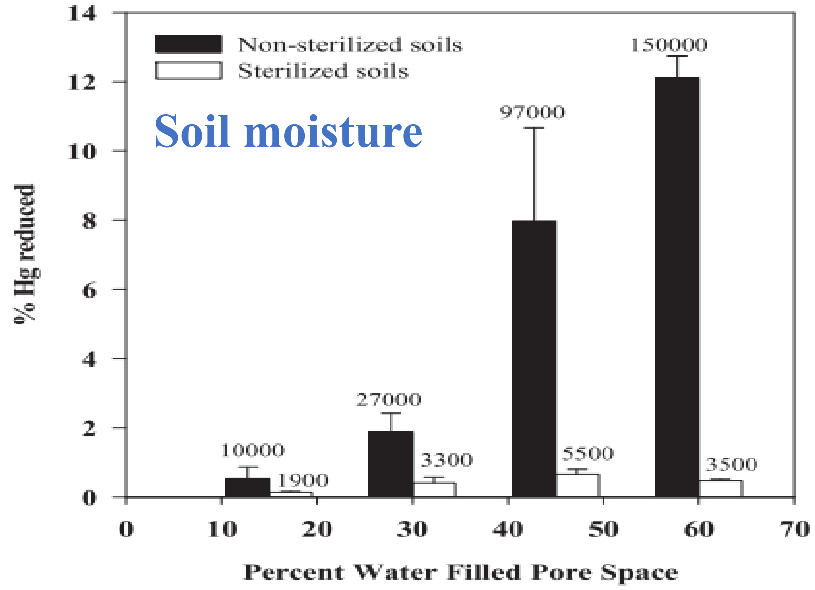


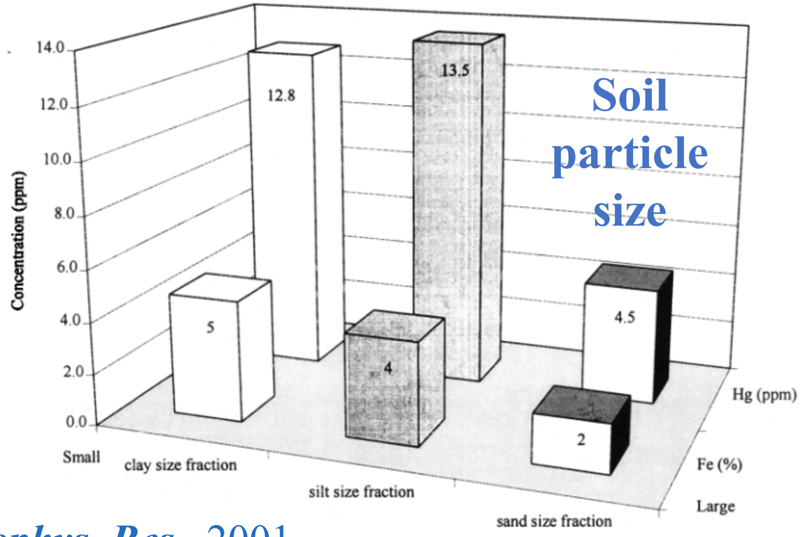
- **Solar radiation** is highly **positively correlated** with soil Hg^0 flux, which is generally regarded as **enhancing Hg^{II} reduction** and therefore facilitating Hg^0 evasion
- **Air temperature** promotes **Hg^0 desorption** from soil, contributing to Hg^0 evasion, which could be further enhanced by the **photoreduction effect** of solar radiation

Gustin et al., *Atmos. Environ.*, 2002; Yu et al., *Atmos. Chem. Phys.*, 2018

Impacts of GEM and soil characteristics on Hg^0 exchange flux







- Elevated **ambient GEM concentration** suppresses the flux by reducing the **concentration gradient** at the air–soil interface
- **Soil moisture** and **particle size** affect soil Hg^0 exchange flux

Duan et al., ***Atmos. Environ.***, 2021; Pannu et al., ***Environ. Pollut.***, 2014; Edwards et al., ***J. Geophys. Res.***, 2001

Purposes of this study

- To investigate the characteristics of air–soil Hg^0 exchange fluxes in a wetland in eastern China in different seasons
- To identify key meteorological factors and soil features for air–soil Hg^0 exchange fluxes in wetlands
- To quantify the impacts of meteorology and soil characteristics on air–soil Hg^0 exchange fluxes in wetlands

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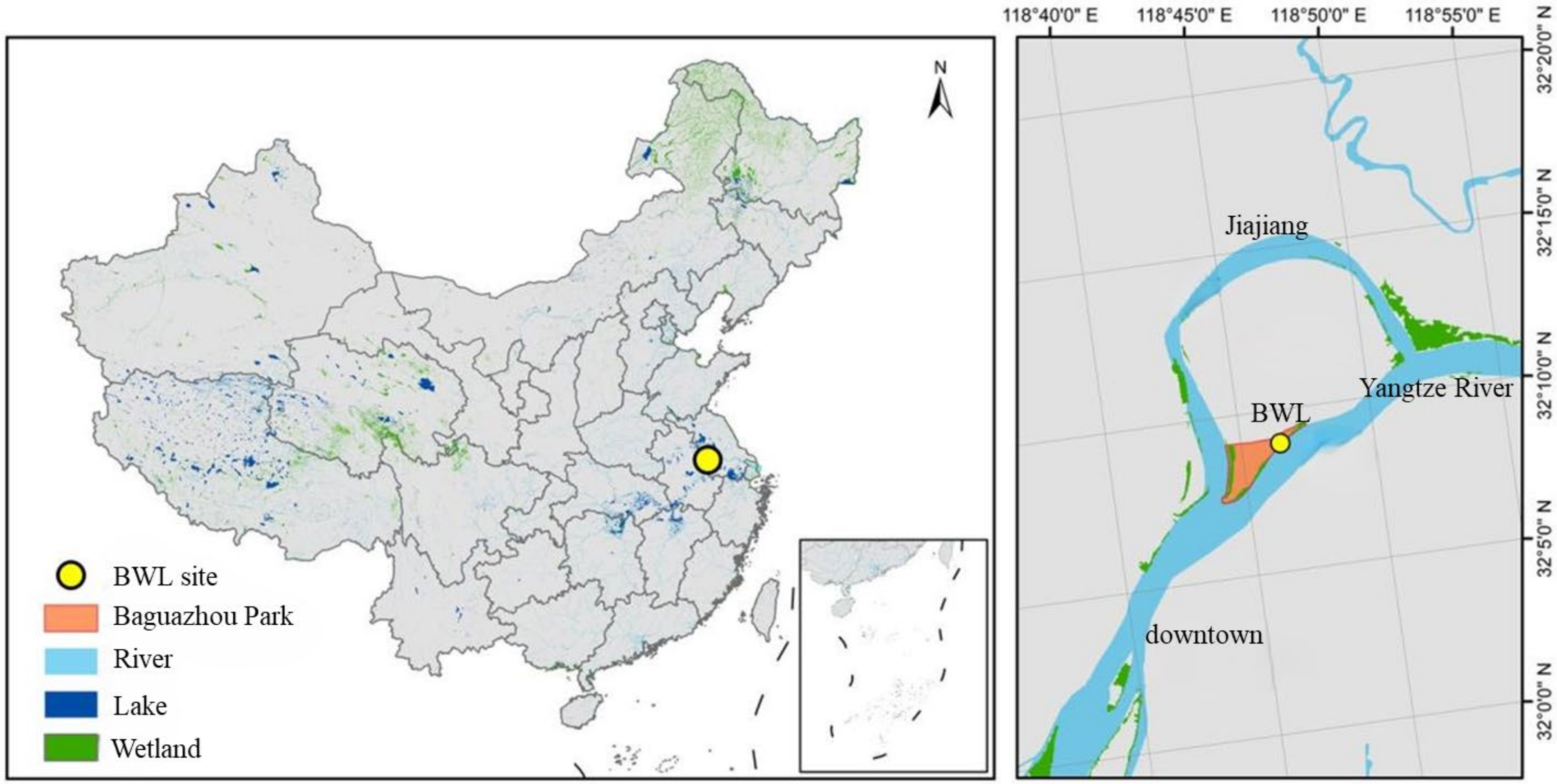
Description of the BWL monitoring site in eastern China



Monitoring Campaigns

No.	Season	Period	Duration
1	Autumn	2022-09/10	17 d
2	Spring	2023-04/05	24 d
3	Summer	2023-07	21 d

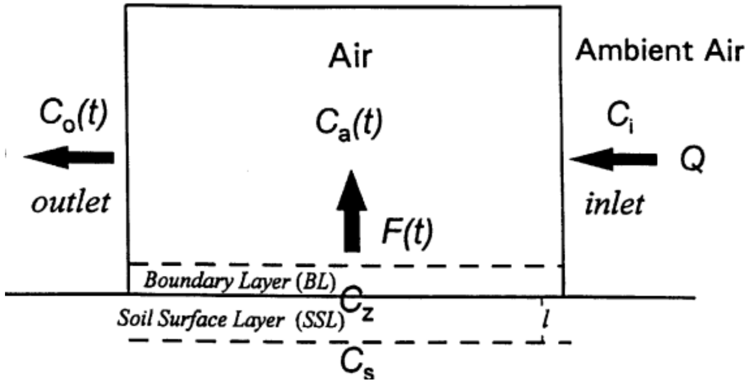
Location:

32.16°N, 118.79°E, 8 m asl

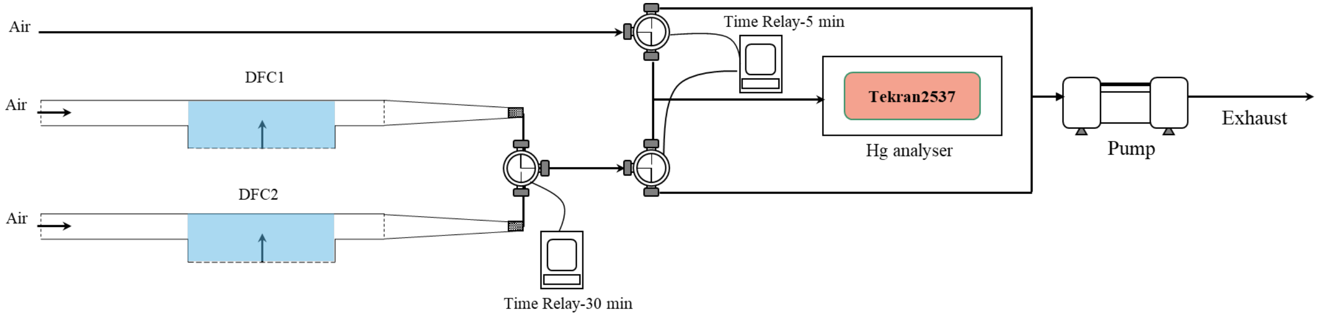
- **Site description**

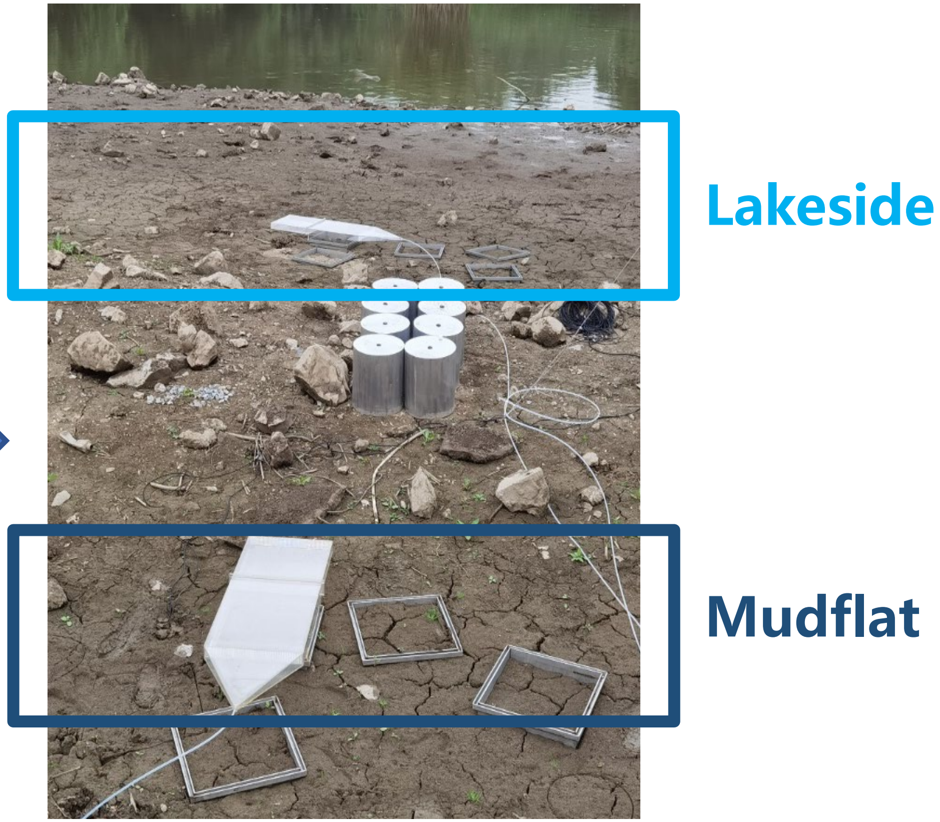
Baguazhou Wetland (BWL) site is located in Nanjing, a megacity in eastern China, one river away from the densely populated downtown Nanjing, with a subtropical monsoon climate. The BWL site is located at the southern Baguazhou Island, which is a well-maintained inland wetland environment.

The dynamic flux chamber (DFC) monitoring method



$$F = \frac{Q(C_{out} - C_{in})}{A}$$





The "lakeside" plot was located close to the river and are over- or nearly saturated with soil water; and the "mudflat" plot was situated in the adjacent area of higher topography with lower soil water content.

Zhang et al., ***Atmos. Environ.***, 2002; Yu et al., ***Sci. Total Environ.***, 2019

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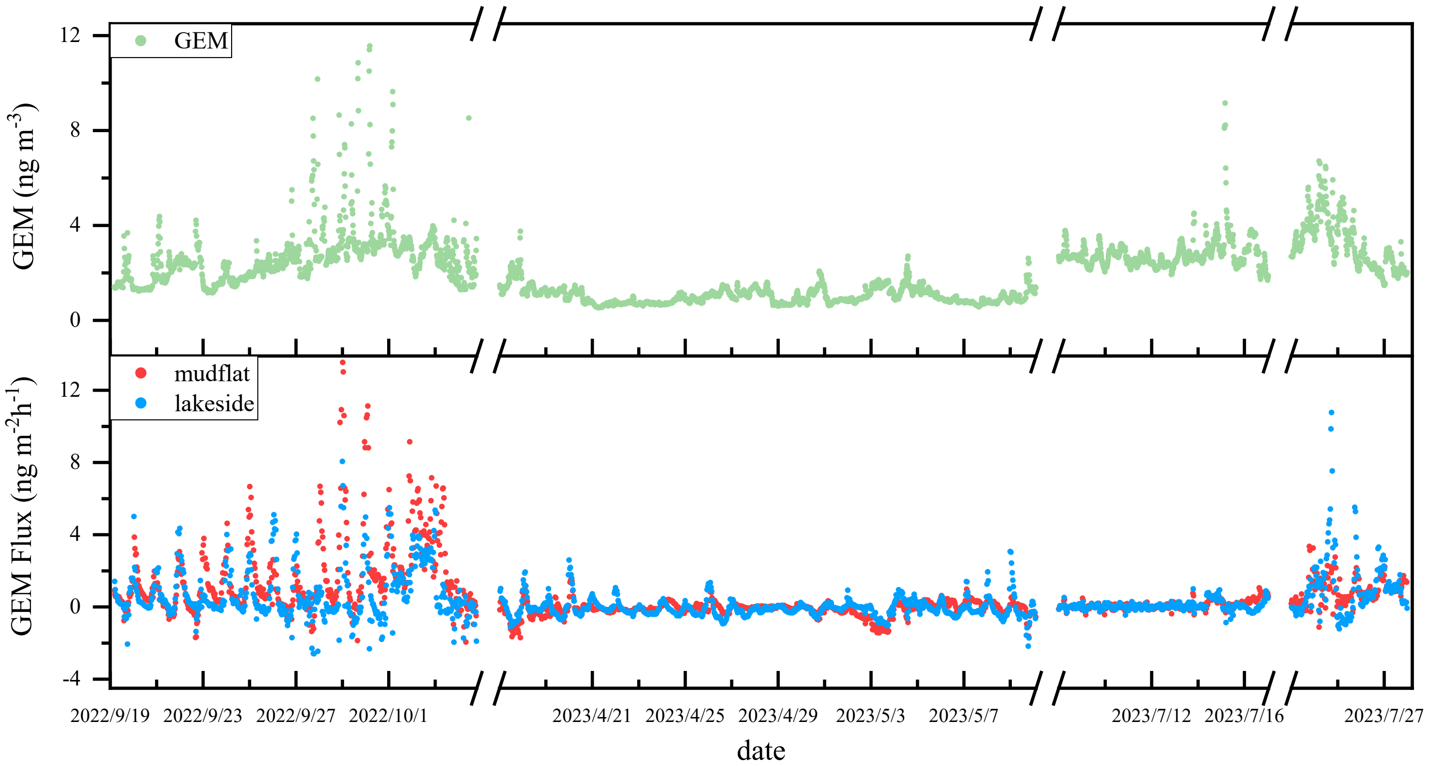
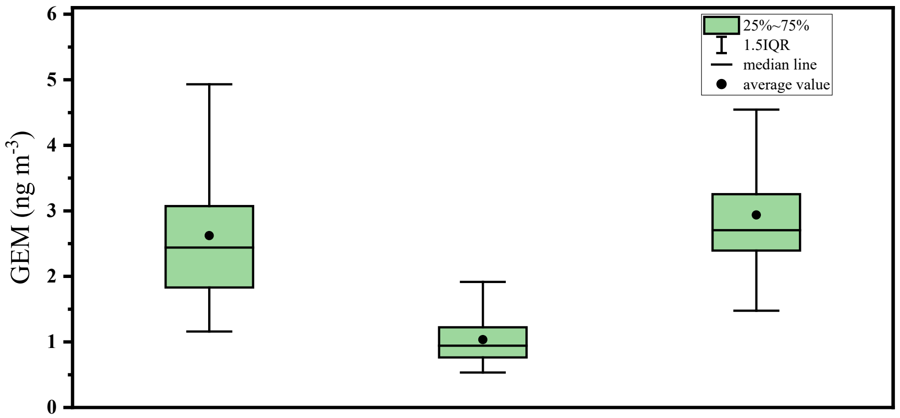
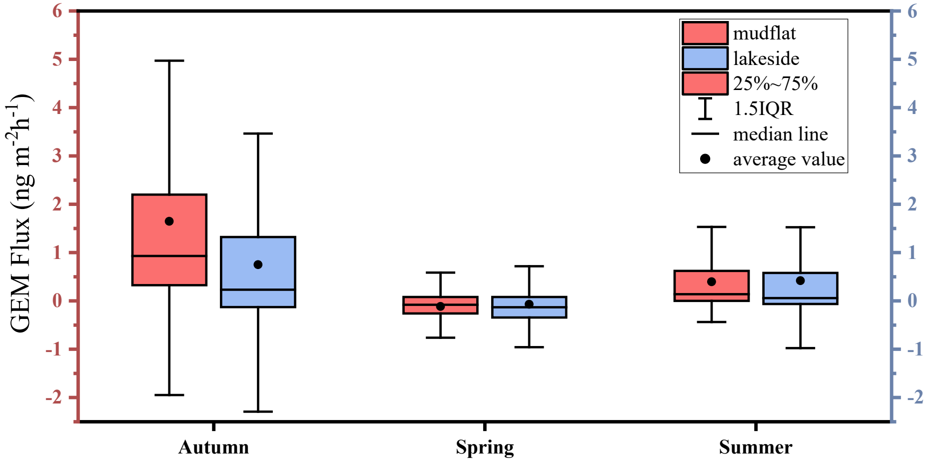
Seasonal variation of GEM concentration and exchange flux



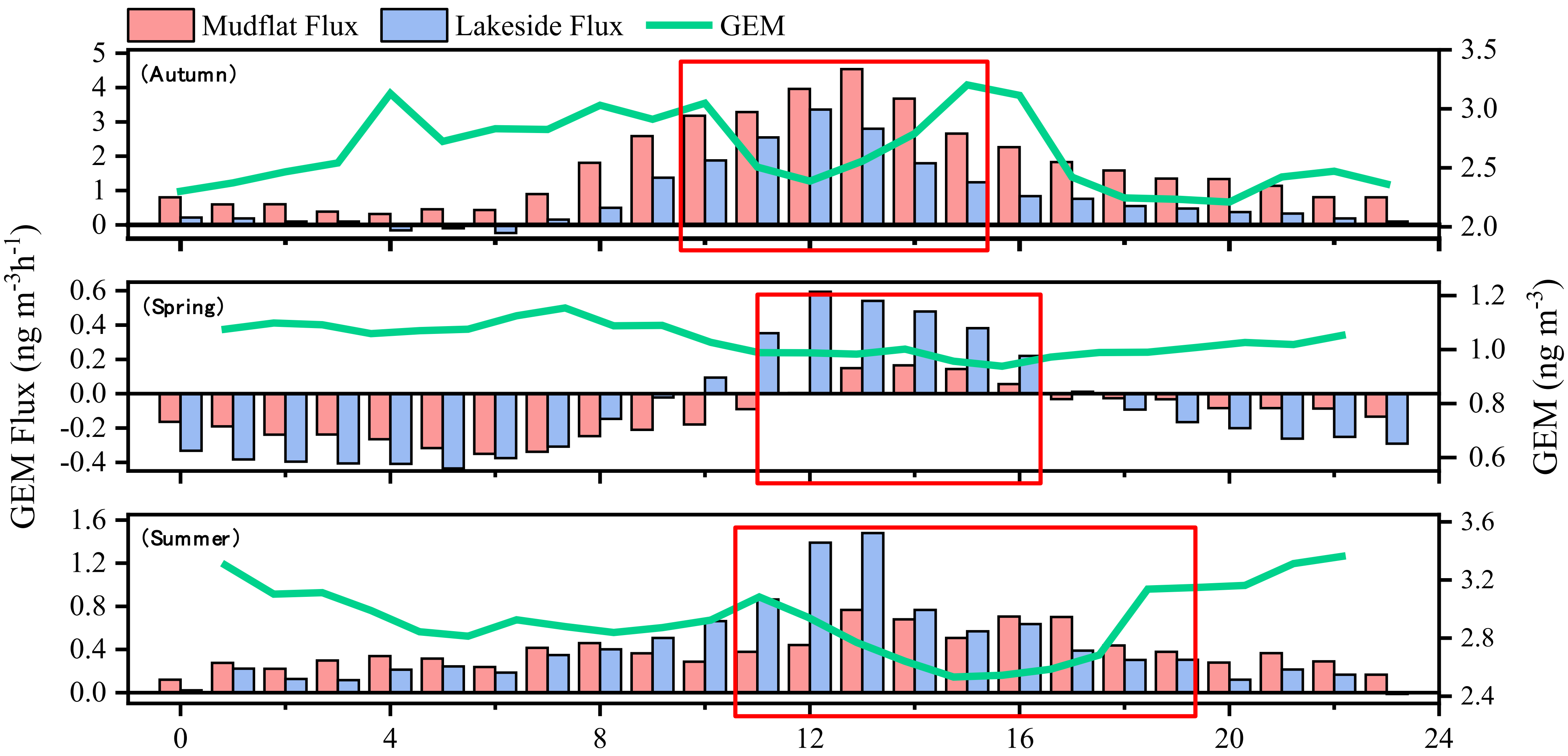




No.	Season	GEM (ng m^{-3})	Mudflat Flux (ng m^{-2} h^{-1})	Lakeside Flux (ng m^{-2} h^{-1})
1	Autumn	2.63	1.72	0.81
2	Spring	1.04	−0.17	−0.08
3	Summer	2.94	0.39	0.42

The wetland exhibited as a source of Hg^0 in summer and autumn, while as a sink of Hg^0 in spring

Diel variation of GEM concentration and exchange flux



During the peaking time of Hg exchange flux in the afternoon, especially for the mudflat plot, GEM exhibits a depletion pattern, which is probably related to solar radiation

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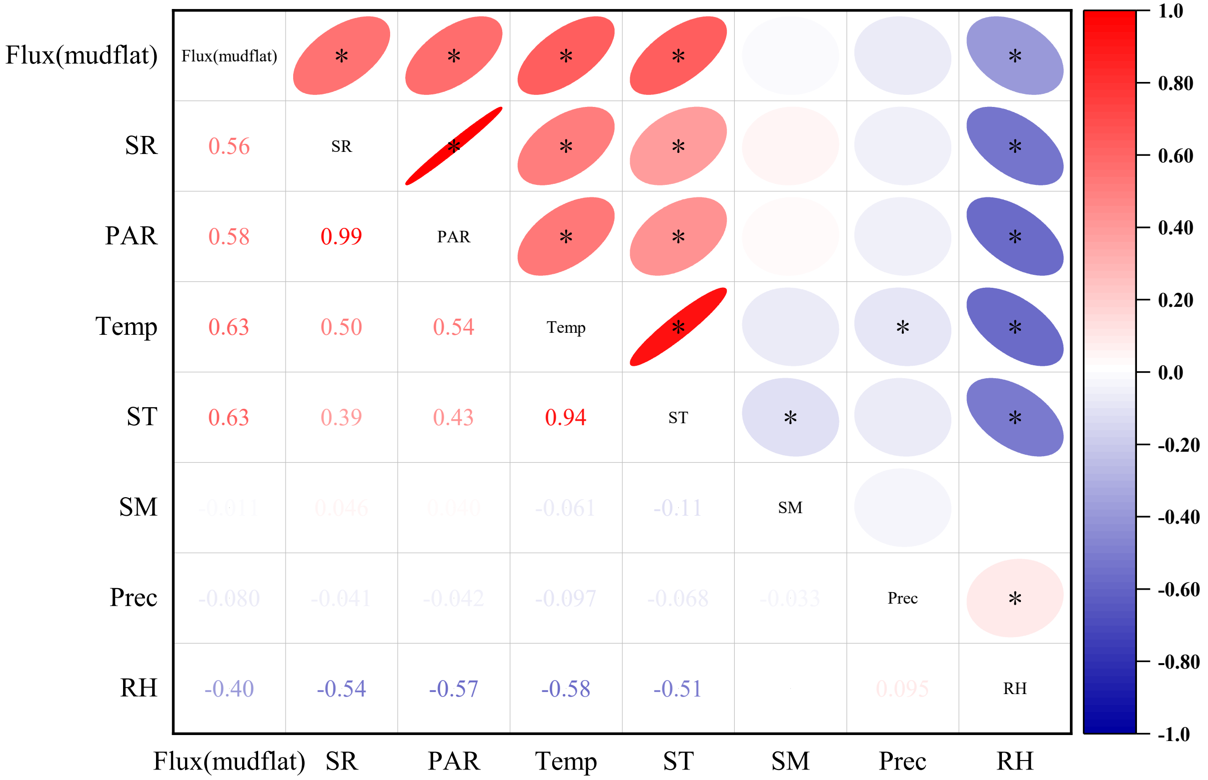
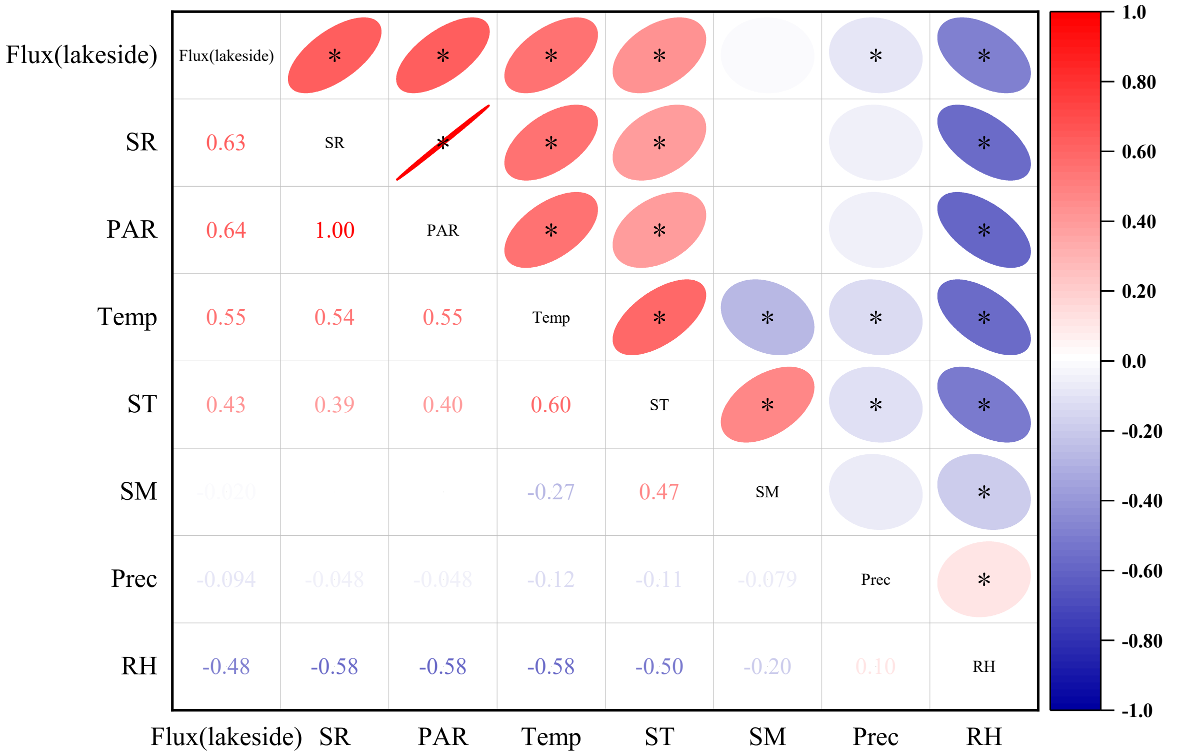
Impacts of meteorological and soil factors on Hg exchange flux

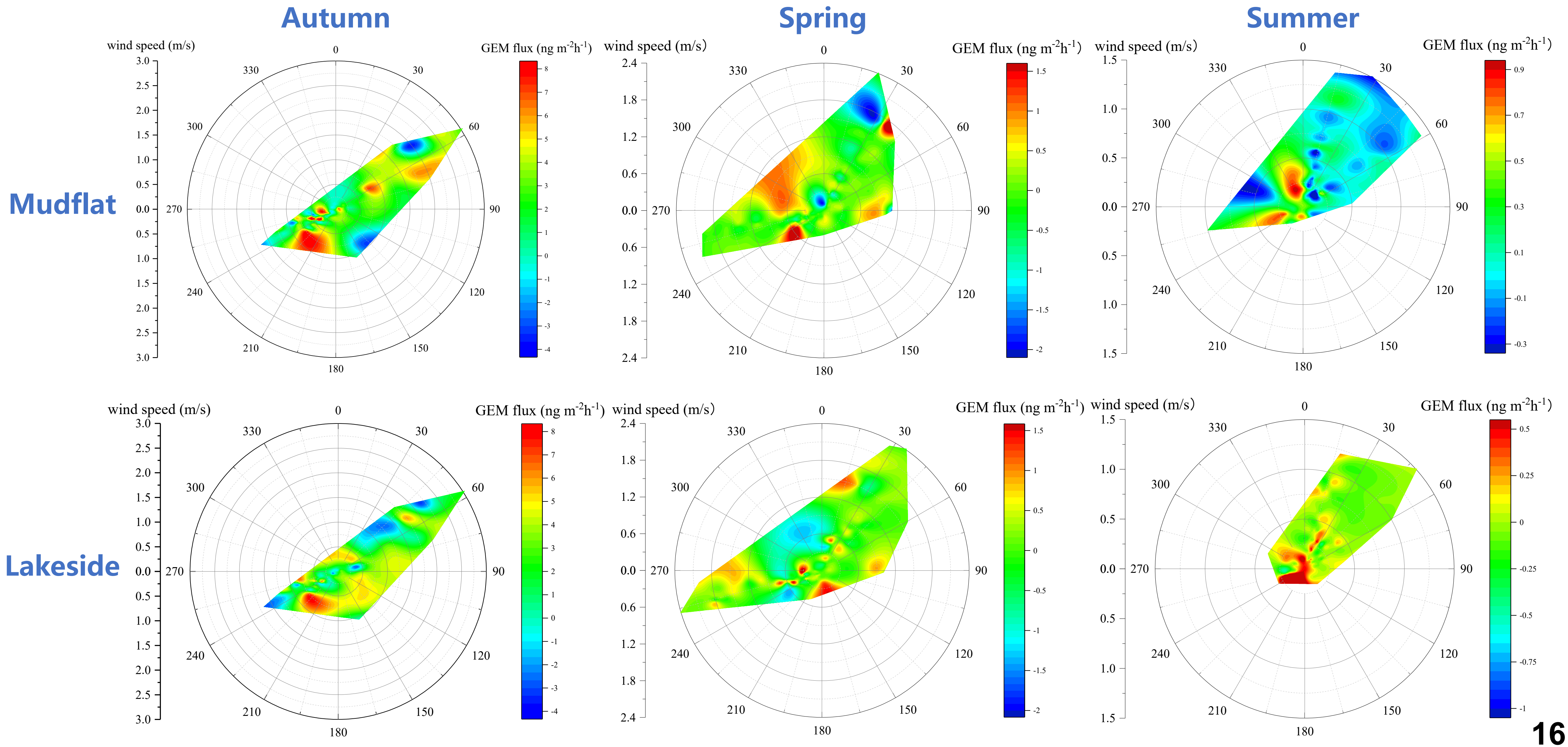




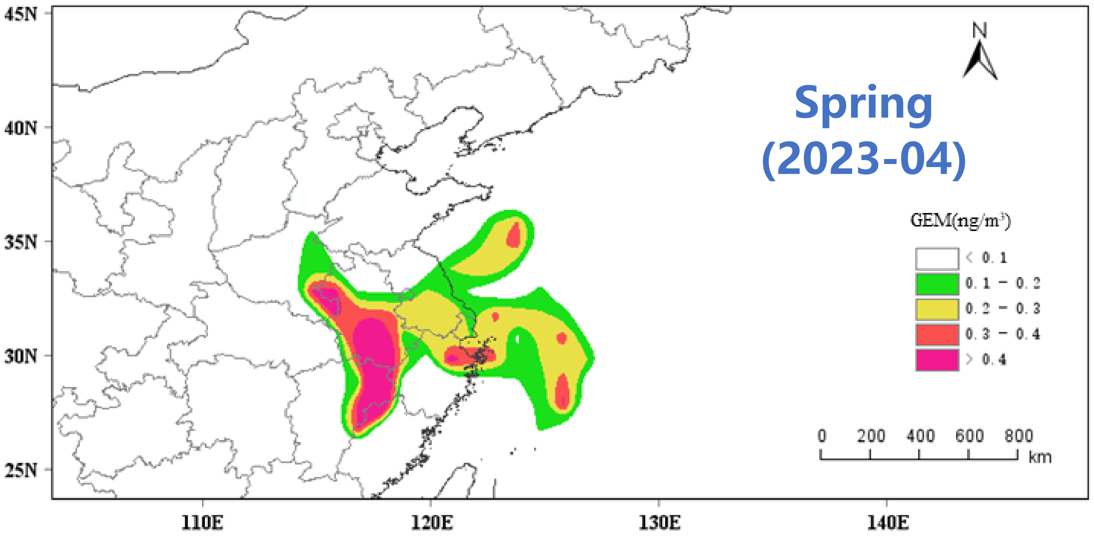
- **SR: solar radiation**
- **ST: soil temperature**
- **Temp: air temperature**
- **RH: relative humidity**
- **PAR: photosynthetically active radiation**
- **SM: soil moisture**
- **Prec: precipitation**

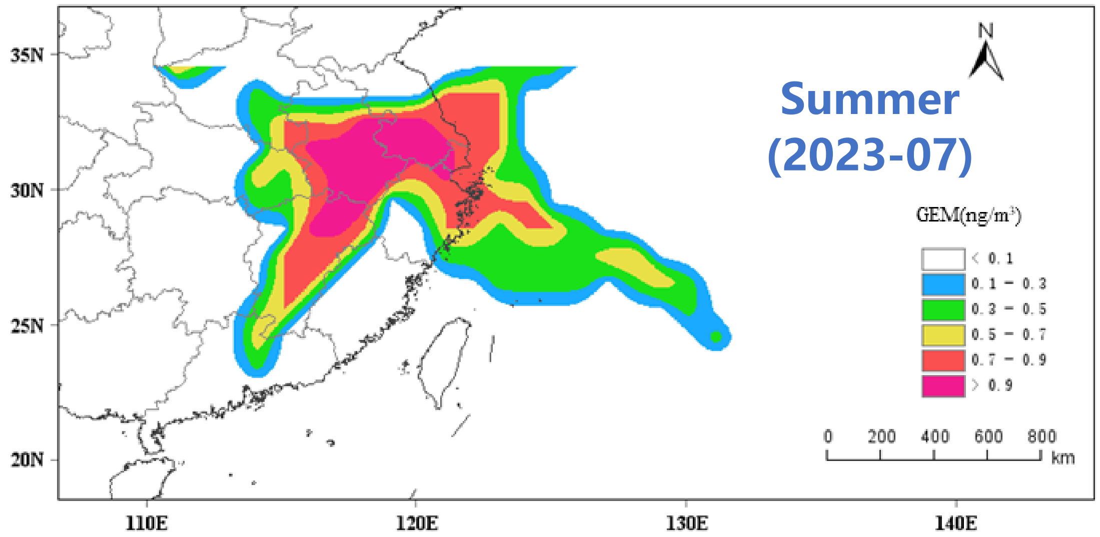
Meteorological factors have larger impacts on wetland Hg exchange flux than soil factors

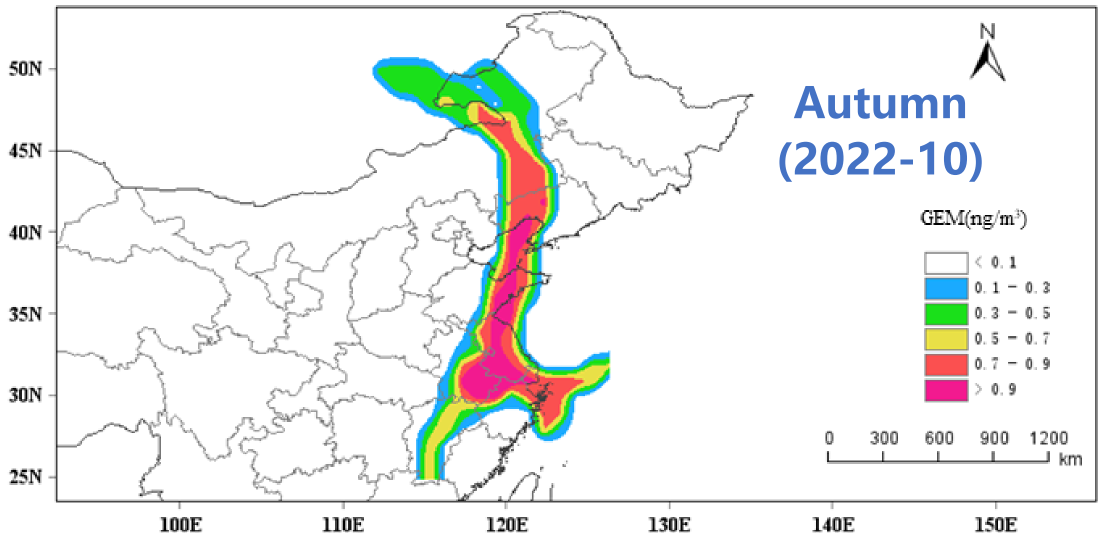
Impacts of wind speed and direction on Hg exchange flux



Source regions of GEM pollution in different seasons







- The summer GEM pollution is probably related to the coal combustion and industrial activities in the area to the southwest of the BWL site
- The autumn GEM pollution is linked to the air mass transport from northern China, especially Shandong and Liaoning provinces

Refer to: Zhang et al., ***Atmos. Environ.***, 2021

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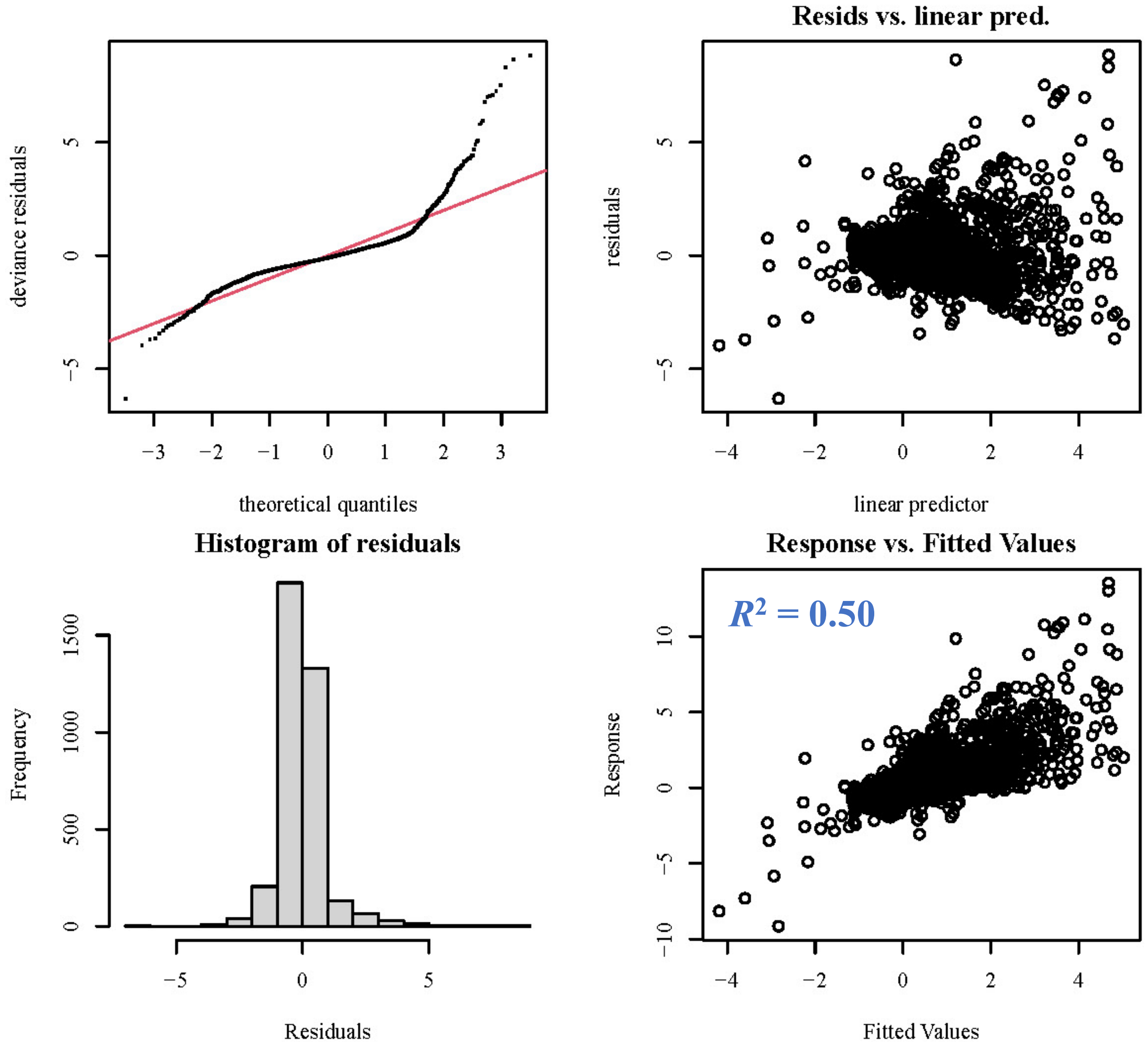
A generalized additive model for Hg exchange flux quantification

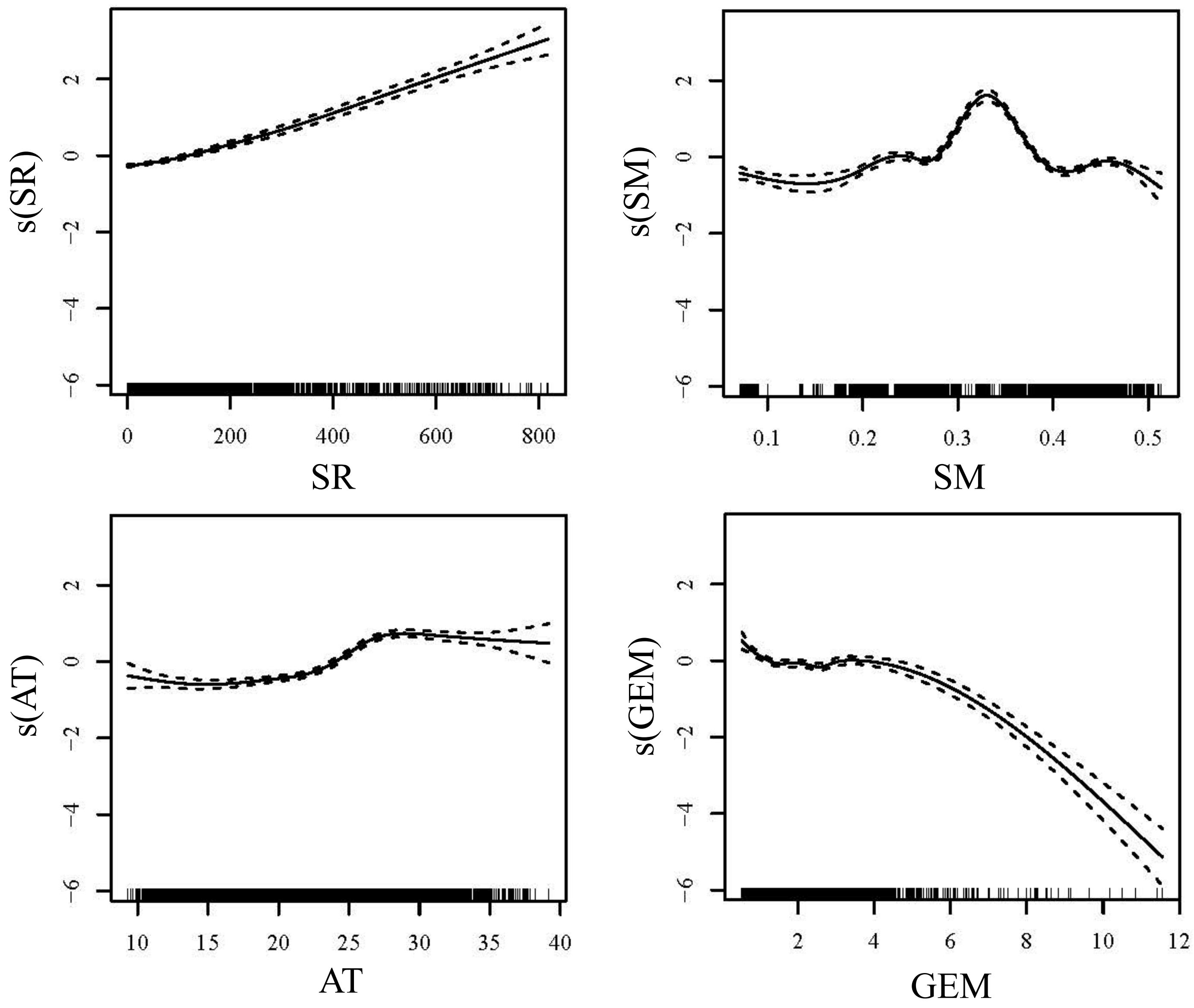
Generalized Additive Model (GAM)

$$g(\mu) = a_0 + s_1(x_1) + s_2(x_2) + \cdots + s_k(x_k)$$

Variable	*F* value	Share	*p* value
SR	174.499	47.3%	< 2e-16 ***
SM	68.640	18.6%	< 2e-16 ***
AT	52.263	14.2%	< 2e-16 ***
Conc	38.017	10.3%	< 2e-16 ***
RH	22.245	6.0%	< 2e-16 ***
WD	6.939	1.9%	1.31e-06 ***
WS	6.510	1.8%	5.67e-06 ***



Influencing patterns of key factors on Hg exchange flux



- Solar radiation is highly positively correlated with Hg^0 exchange flux, which is probably due to soil Hg^{II} photoreduction
- Soil moisture is the second largest contributor to flux variation, which has a positive impact at low level and a negative one at high level
- Air temperature is positively linked to Hg^0 exchange flux, which is due to Hg^0 desorption, while the effect is offset at high temperature level
- The impact of Hg^0 concentration is negative, due to the compensation effect

Special Session on Friday:
Advances in Statistical/Machine Learning and Process-Based Models

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Take-home messages

- In eastern China, inland wetland acts as a source of Hg^0 in summer and autumn, while as a sink of Hg^0 in spring.
- Solar radiation is the key factor for the air–soil Hg^0 exchange flux in wetland, probably due to the soil Hg^{II} photoreduction.
- Soil moisture and air temperature (at low levels) also have positive effects on the flux, while GEM concentration has a negative one.

Thank you very much for your attention

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