ICMGP 2024
CAPE TOWN • SOUTH AFRICA • 21 - 26 JULY

ECNU

Global warming-induced vegetation changes affect atmospheric mercury cycling

Long Chen, Yu-Rong Liu, Long Guo, Xu Zeng, Qinzhen Chen, Yuzhe Shen, Xuejun Wang

East China Normal University
chenlong@geo.ecnu.edu.cn

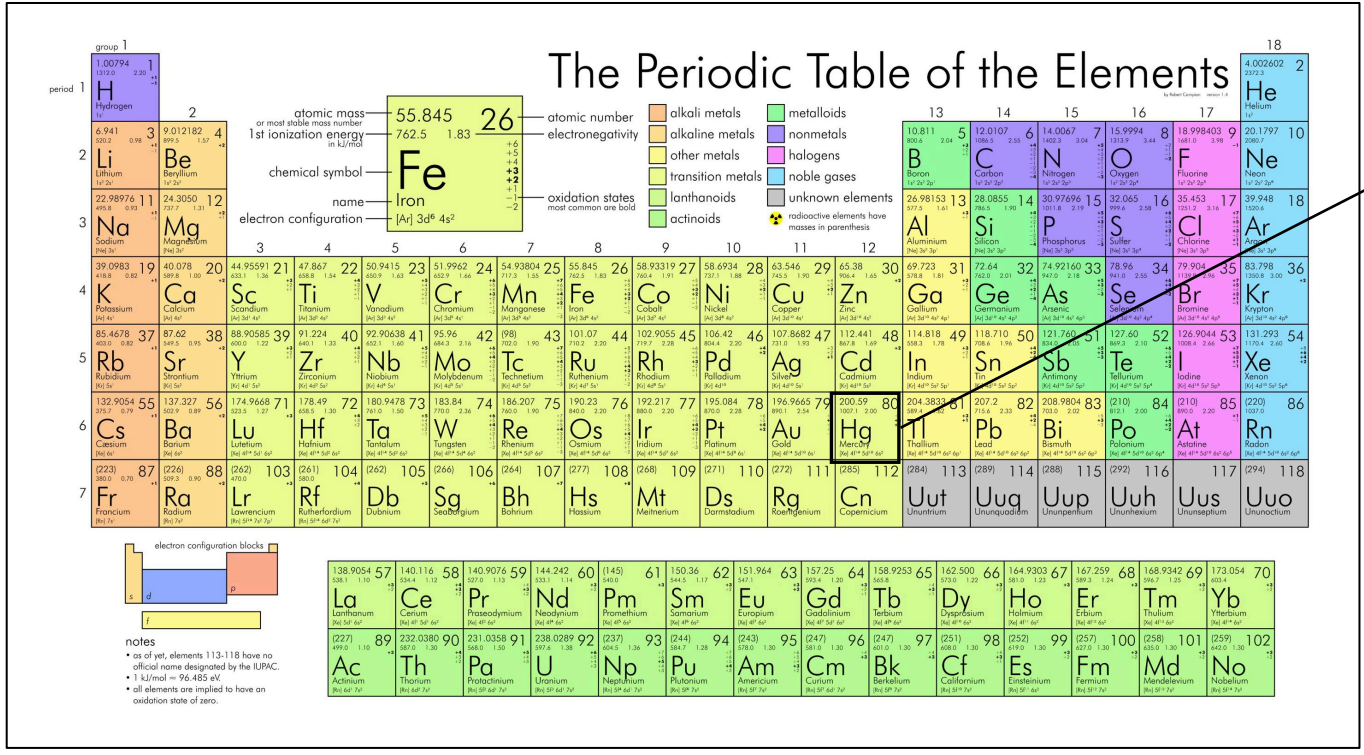
Outline

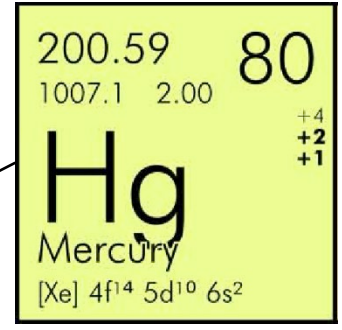
- Introduction
- Drivers of atmospheric Hg seasonality
- Impacts of vegetation Hg assimilation
- Impacts of Hg emissions from biomass burning
- Conclusions

Outline

- ☐ Introduction
- ☐ Drivers of atmospheric Hg seasonality
- ☐ Impacts of vegetation Hg assimilation
- ☐ Impacts of Hg emissions from biomass burning
- ☐ Conclusions

Hg

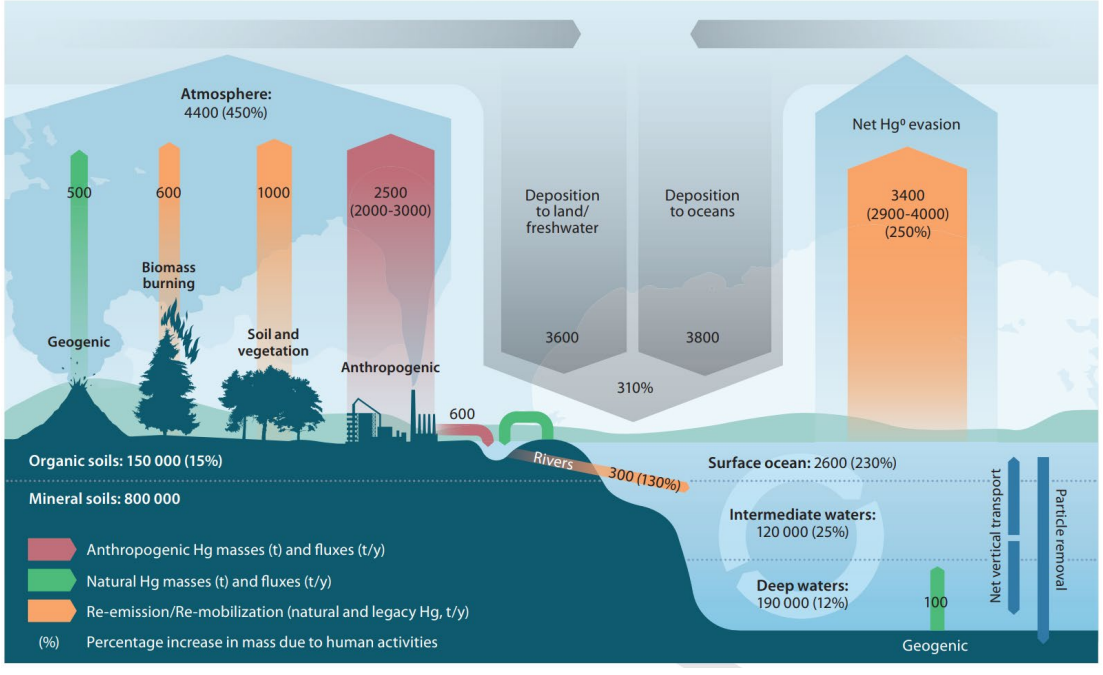




Hg^0 Hg^{2+} Hg^P

Ubiquitous on the planet!

Hg cycling and health impacts



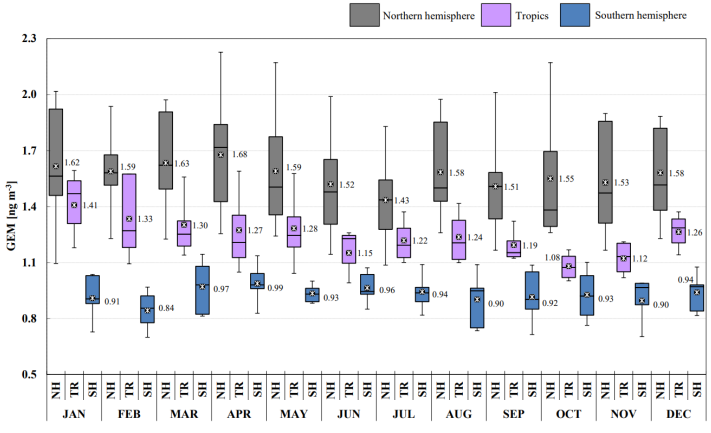
UN Environment (2019)

UNEP MINAMATA CONVENTION ON MERCURY

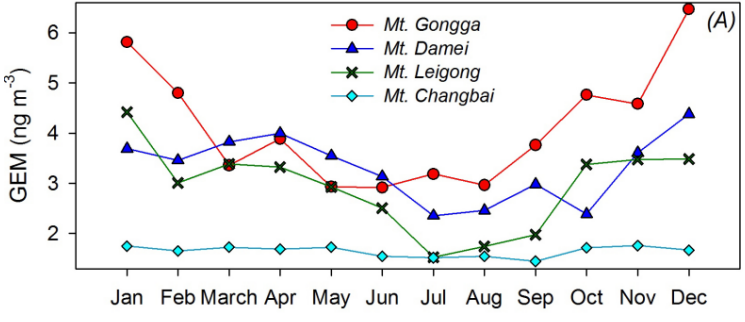
Outline

- ☐ Introduction
- ☐ **Drivers of atmospheric Hg seasonality**
- ☐ Impacts of vegetation Hg assimilation
- ☐ Impacts of Hg emissions from biomass burning
- ☐ Conclusions

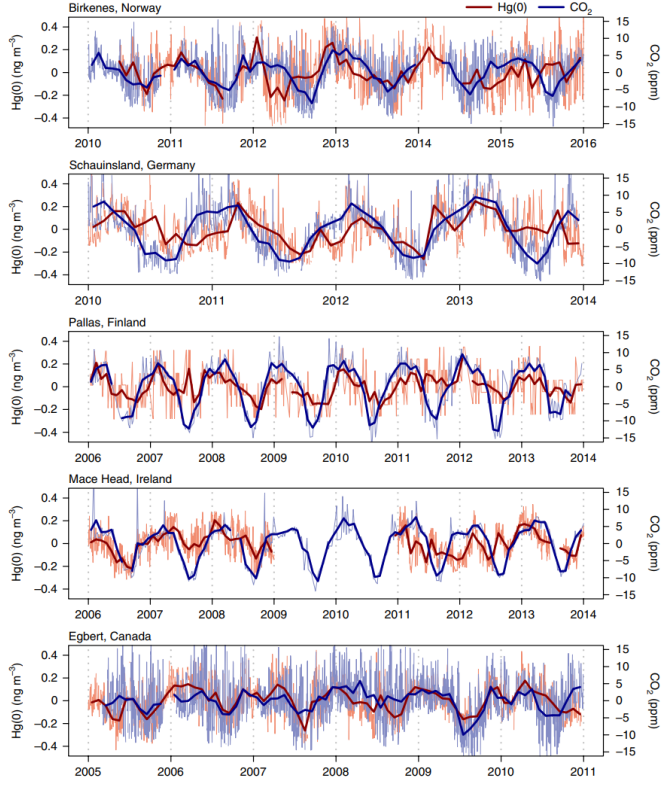
Drivers of atmospheric Hg seasonality in the NH



Sprovieri et al. (2016)



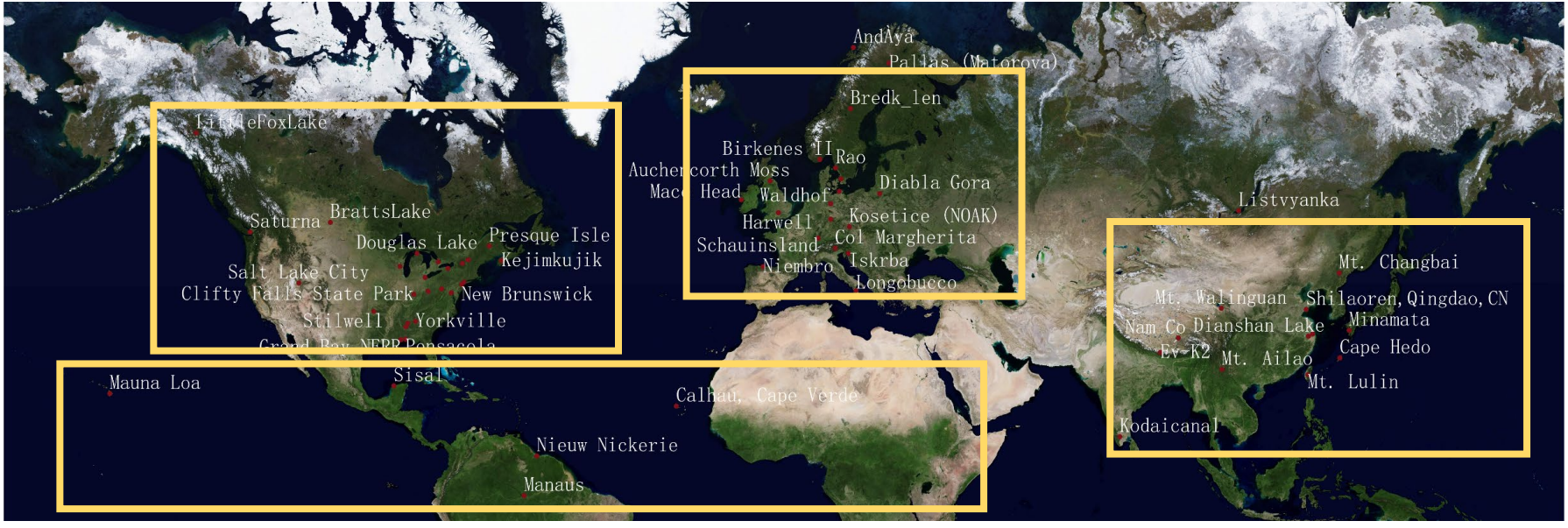
Fu et al. (2015)



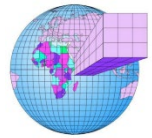
Jiskra et al. (2018)

- Vegetation assimilation
- Chemical transformations
- Anthropogenic emissions
- Monsoon climate

Drivers of atmospheric Hg seasonality in the NH



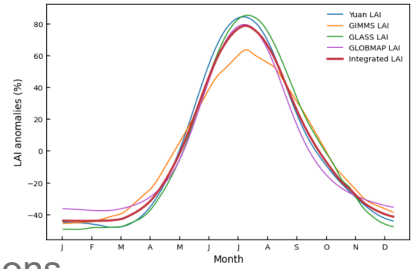
- 44 terrestrial observations during 2013-2017 from CAPMoN, AMNet, EMEP, GMOS, Literature data
- GEOS-Chem，v12.5.0 Hg modeling

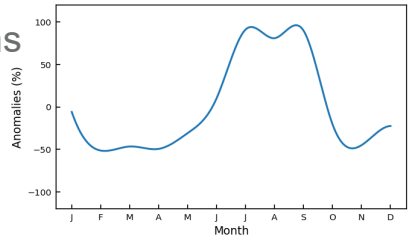


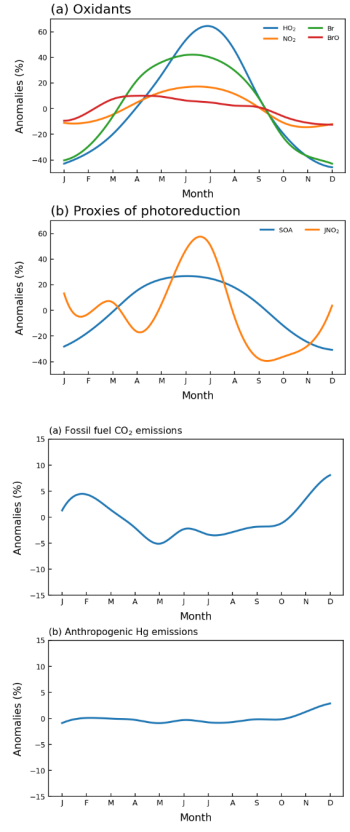
*Xu, **Chen***… et al. (2022), GRL*

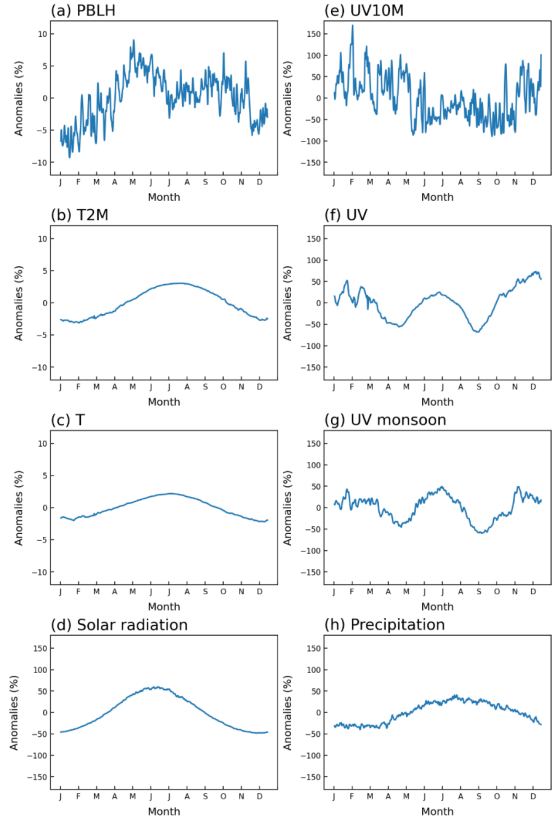
Drivers of atmospheric Hg seasonality in the NH

- Drivers:
  - ✓ Vegetation activity
  - ✓ Redox fields
  - ✓ Biomass burning emissions
  - ✓ Anthropogenic emissions
  - ✓ Meteorological factors (PBLH, T2M, T, Solar radiation, UV10M, UV, Precipitation)



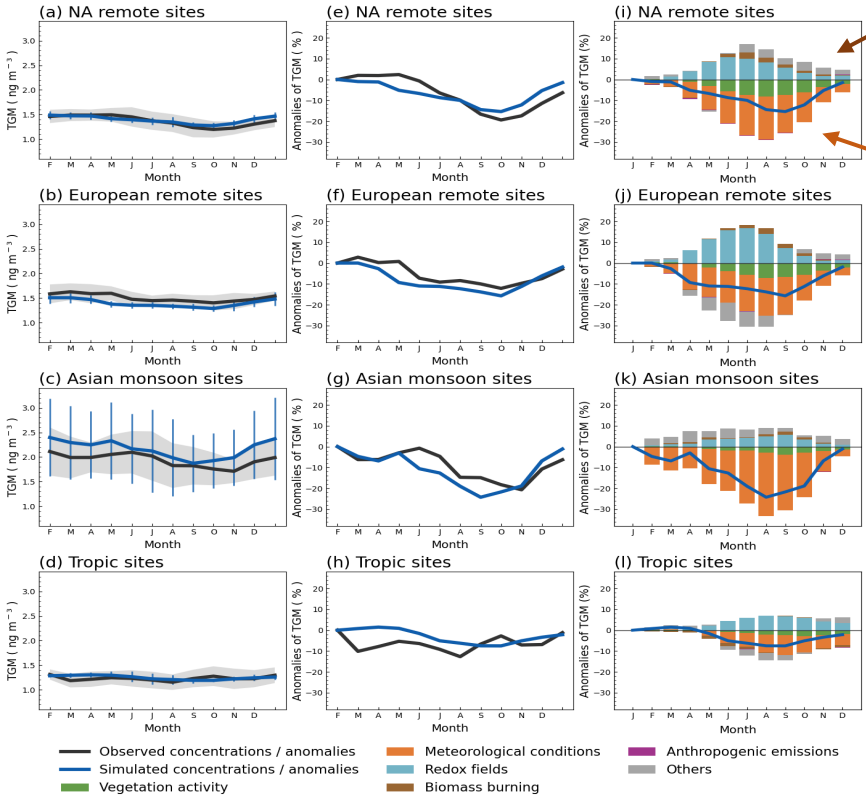






*Xu, **Chen***… et al. (2022), GRL*

Drivers of atmospheric Hg seasonality in the NH



Biomass burning

Vegetation assimilation

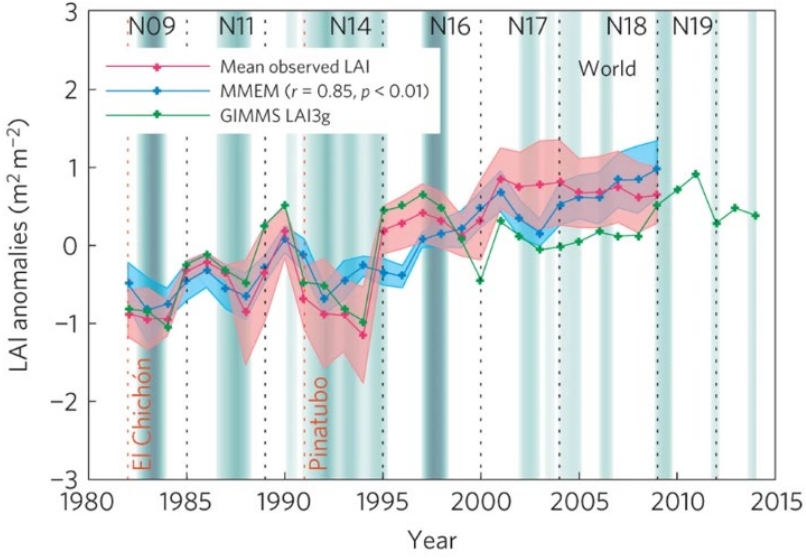
Meteorological conditions

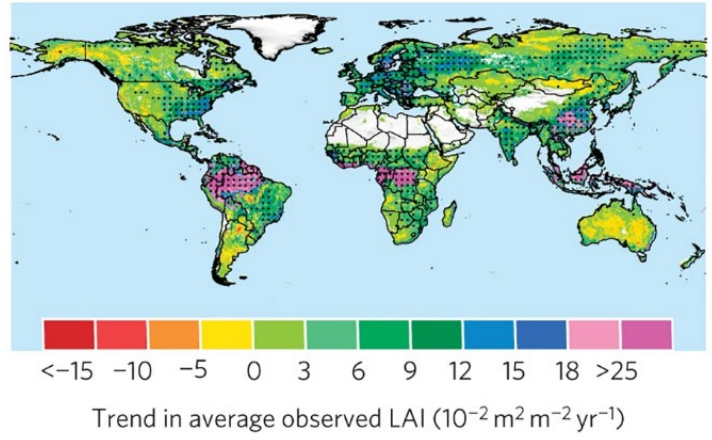
- Atmospheric Hg seasonality across diverse temperate regions mainly driven by meteorological conditions, **vegetation assimilation**, redox fields, and **biomass burning**.
- Vegetation assimilation mainly matters during **vegetation growth seasons** (warm months), and biomass burning mainly matters during **vegetation recession seasons.**

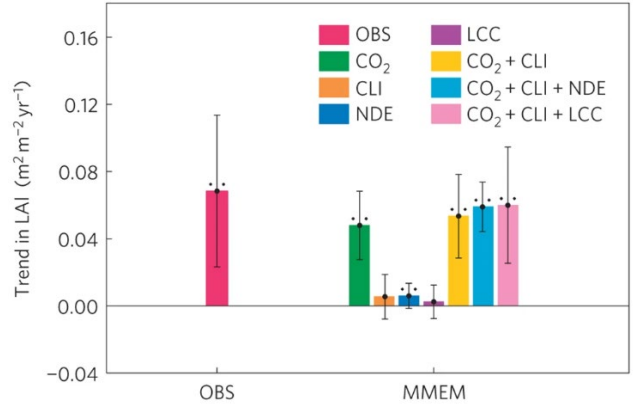
Short-term interannual variations of meteorological factors are fluctuant.

*Xu, **Chen***… et al. (2022), GRL*

Trend in vegetation activity







- Greening of the Earth and the dominant driver is **CO_2 fertilization**
- Trend in vegetation activity is closely related to vegetation Hg assimilation and biomass burning emissions

Firstly, we need more accurate estimates of these two fluxes!

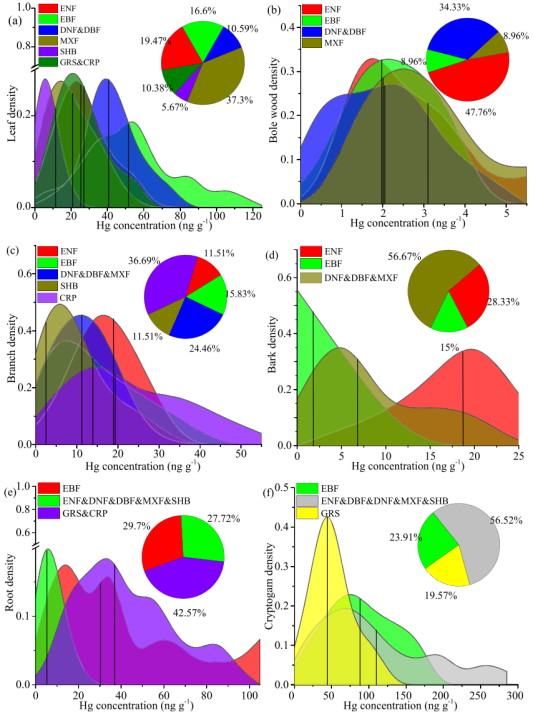
Zhu et al. (2016); Chen et al. (2019); Piao et al. (2019)

Outline

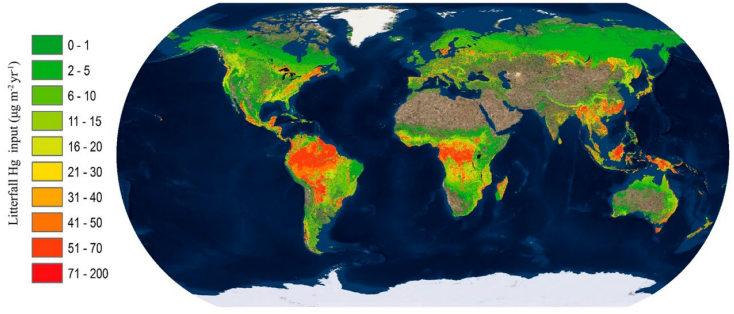
- ☐ Introduction
- ☐ Drivers of atmospheric Hg seasonality
- ☐ **Impacts of vegetation Hg assimilation**
- ☐ Impacts of Hg emissions from biomass burning
- ☐ Conclusions

Using machine learning to predict vegetation Hg assimilation

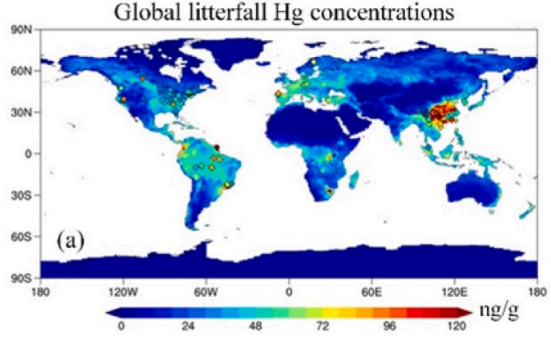
- Large uncertainties still exist: **1200~3200** Mg yr^{-1}



Zhou et al. (2021)



Wang et al. (2016)

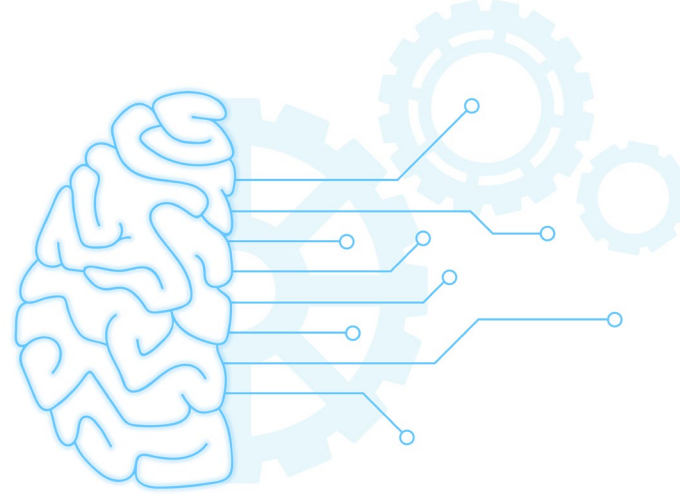


Yuan et al. (2023)

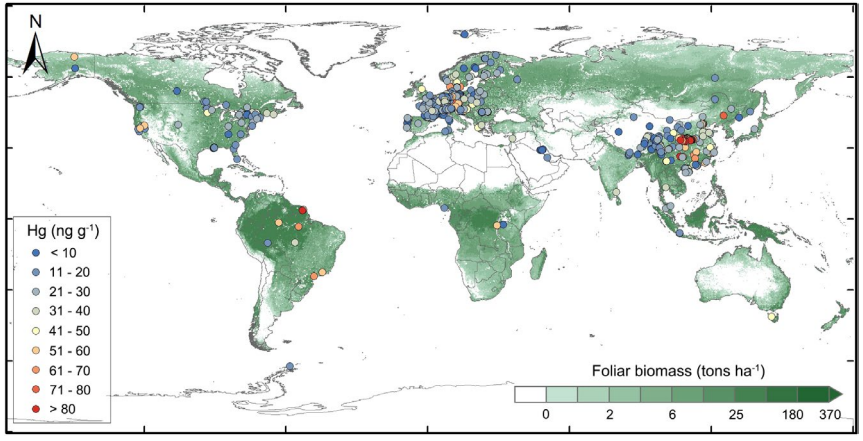
Using machine learning to predict vegetation Hg assimilation

Four candidate machine learning algorithms:

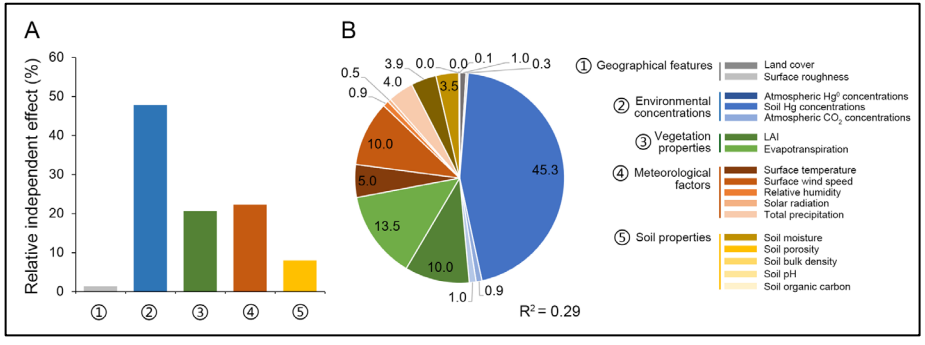
- Support vector machine
- K-nearest neighbor
- Gradient boosting decision tree
- Random forest



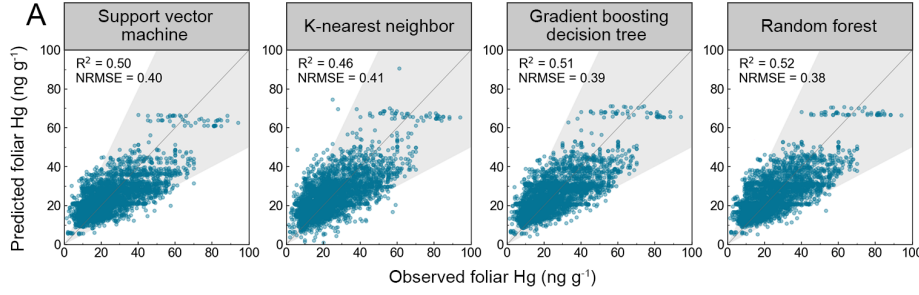
Global Hg in foliage predicted by machine learning

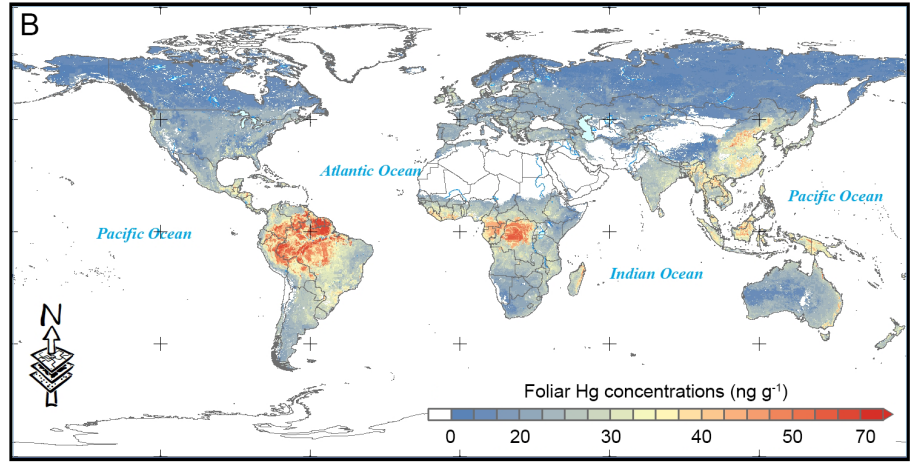


3652 individual data points retrieved from literature



20 potential predictors (HPA)

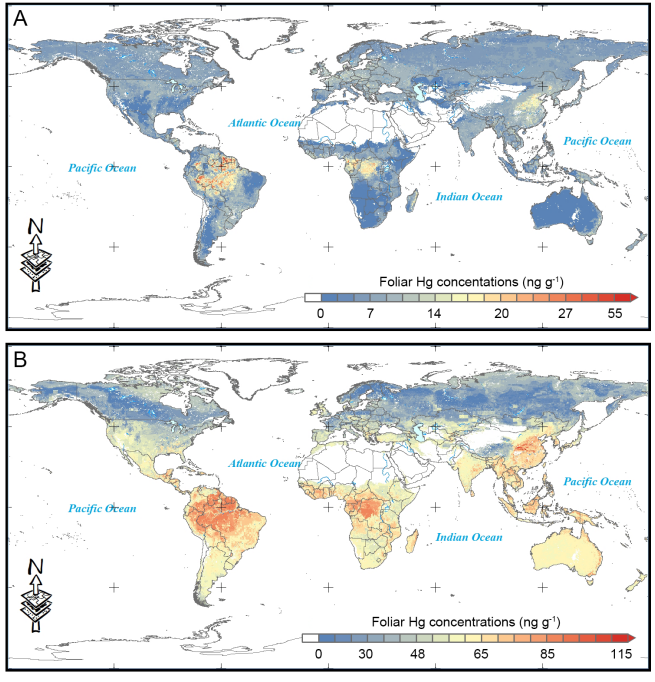




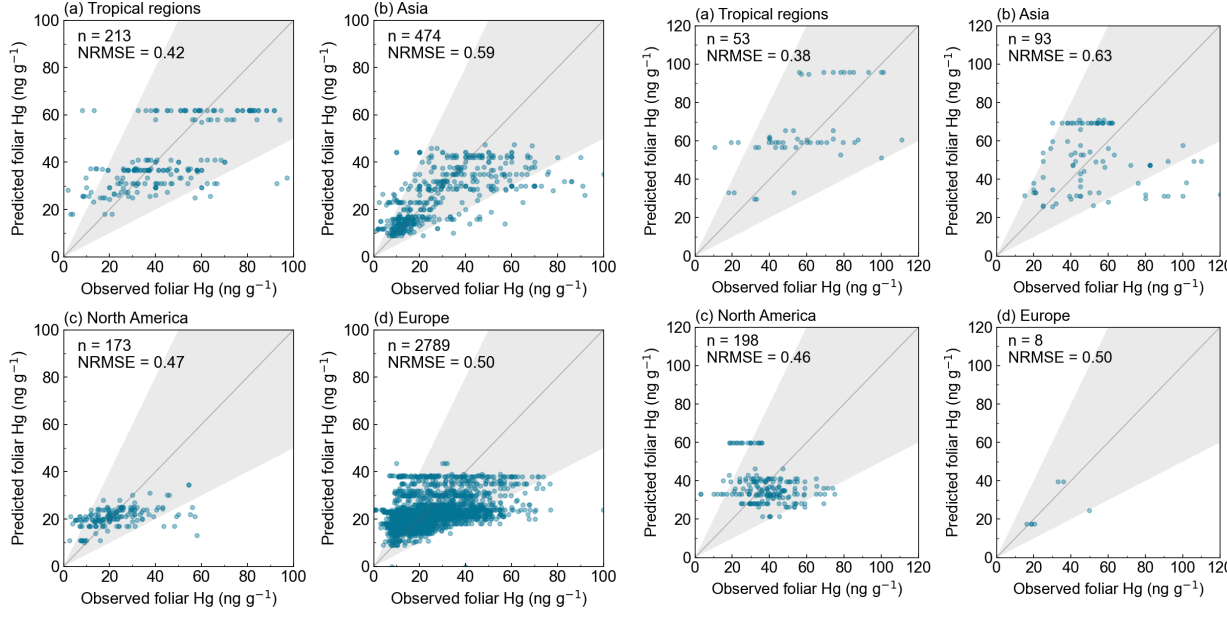
Chen et al. (2024), ES&T

Global Hg in foliage predicted by machine learning

Model uncertainty



Model evaluation

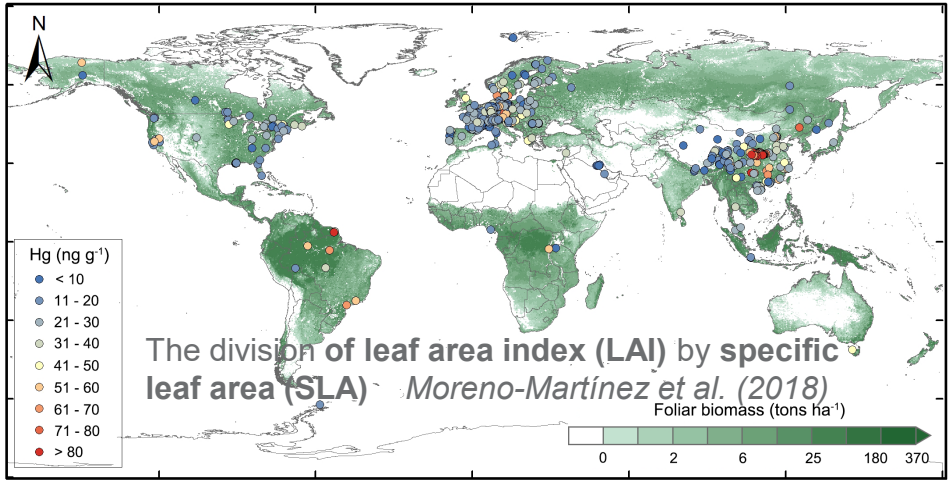


Foliar Hg concentrations

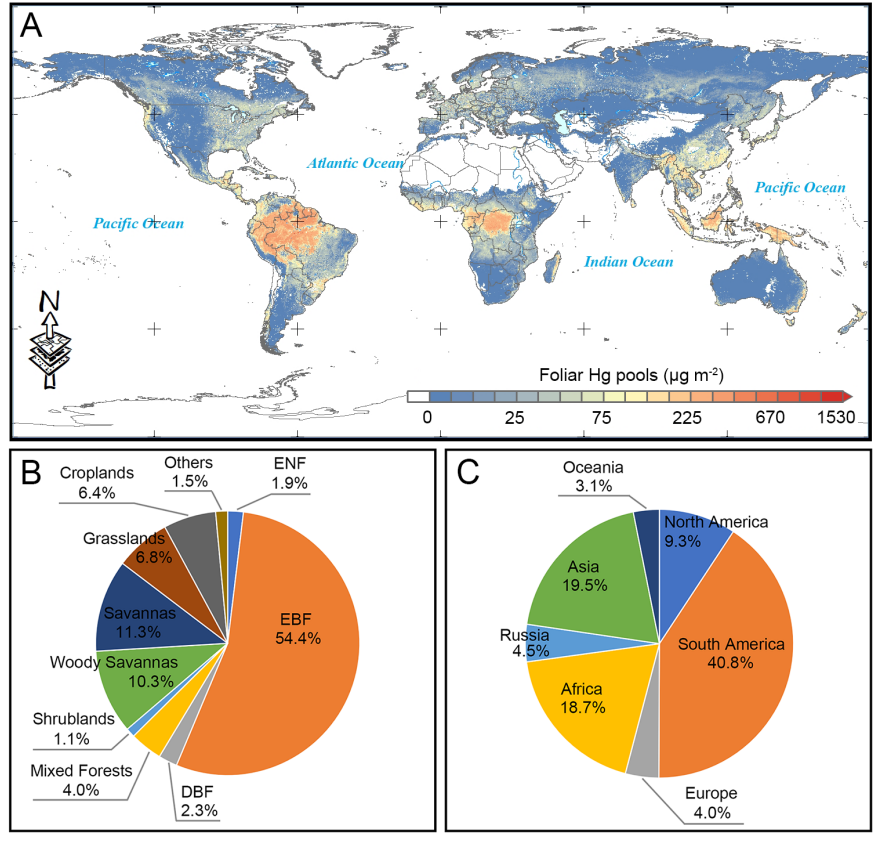
Litterfall Hg concentrations

Global Hg in foliage predicted by machine learning

Foliar biomass



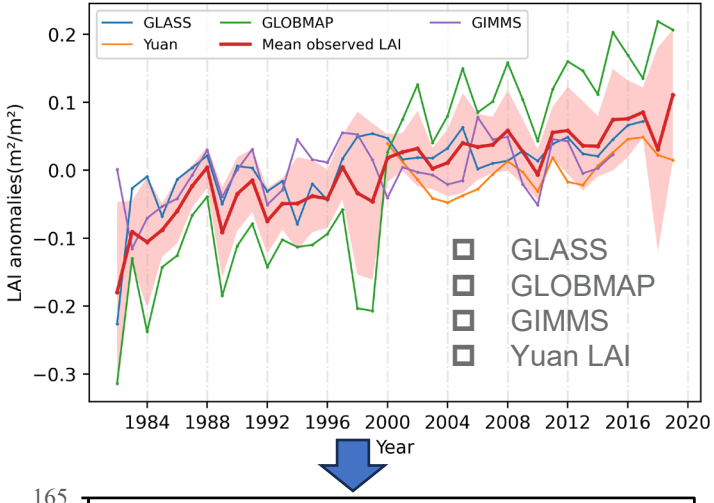
Foliar Hg pools

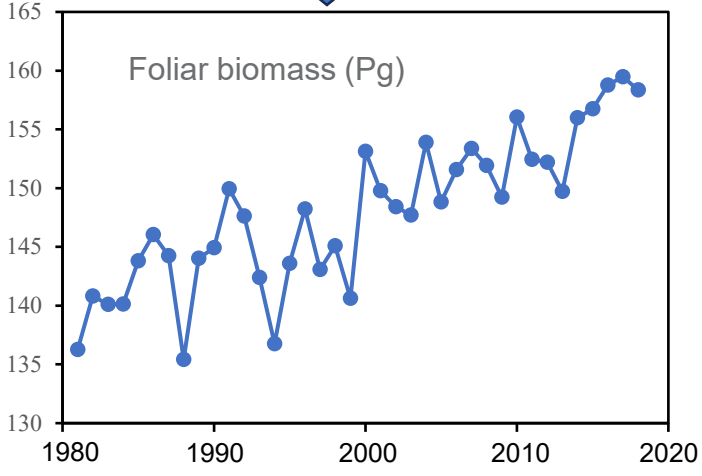


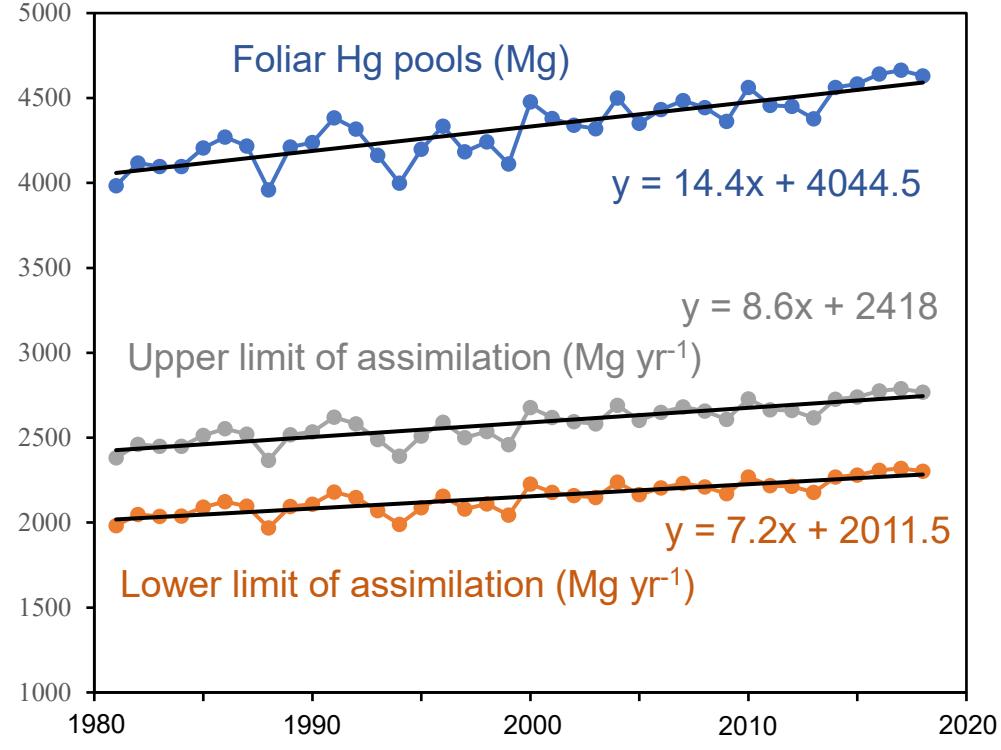
- Global total in pools:
  4561.3 Mg (1455.2−9062.8 Mg)
- Global total in annual assimilation:
  2268.5−2727.0 Mg yr^{-1}

***Chen** et al. (2024), ES&T*

Impacts of the increasing vegetation activity







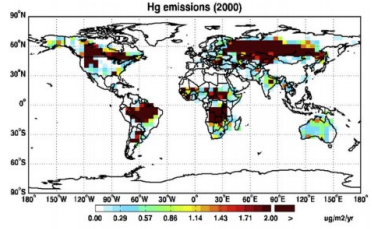
Foliar Hg assimilation: increased by **7~9 Mg yr^{-1}**

Outline

- ☐ Introduction
- ☐ Drivers of atmospheric Hg seasonality
- ☐ Impacts of vegetation Hg assimilation
- ☐ **Impacts of Hg emissions from biomass burning**
- ☐ Conclusions

Large uncertainties in emission estimates from global wildfires

References	Periods	Regions	Hg emissions
Friedli et al. (2009)	1997-2006	Globe	680 Mg
Kumar et al. (2017)	2000-2050	Globe	612 Mg
Shi et al. (2018)	2001-2017	Tropics	497 Mg
Huang et al. (2011)	2000-2007	China	27 Mg
Chen et al. (2013)	2000-2010	China	6 Mg
Xu et al. (2023)	2000-2019	China	172.6 kg
Cinnirella et al. (2006)	1990-2003	Mediterranean, Russia	2.2, 13 Mg



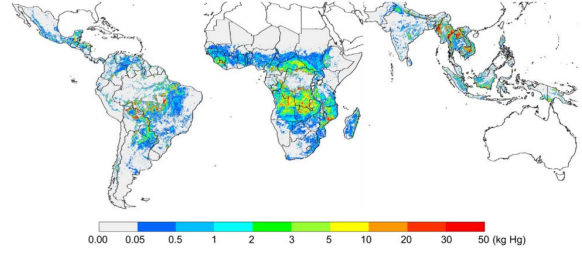


Fig. 1. Multi-year averaged total mercury emissions (0.1° × 0.1°) from biomass burning in tropical continents during 2001–2017.

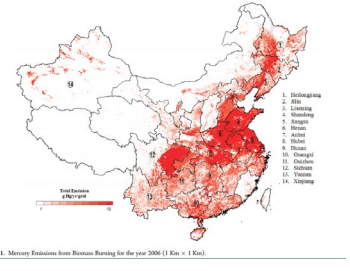
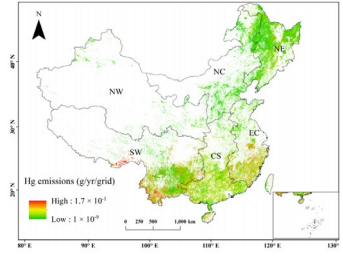


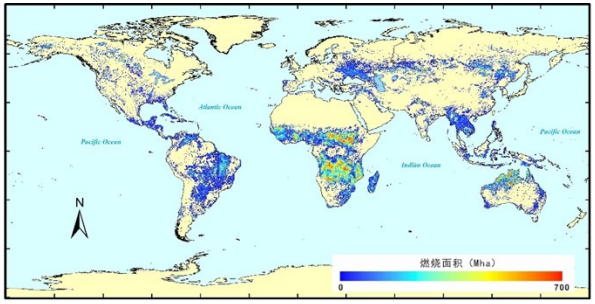
Figure 1. Mercury Emissions from Biomass Burning for the year 2006 (1 Km × 1 Km).



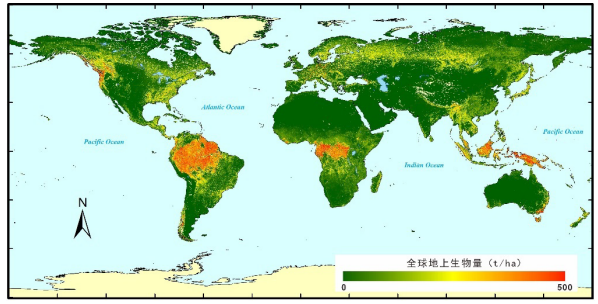
Emission-factor model → Mass-balanced model

$$\text{Emission} = BA \times F \times CF \times EF$$

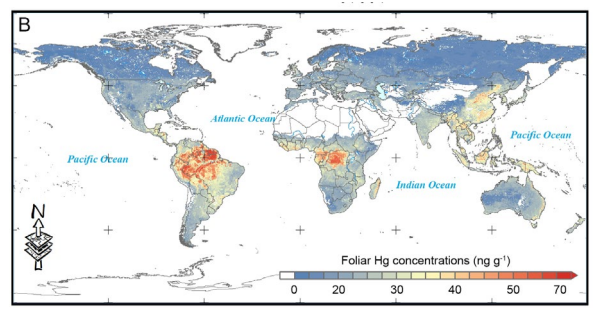
$$\text{Emission} = BA \times F \times CF \times MC \times (1 - \text{Ash})$$



MODIS MCD64A1 burning area



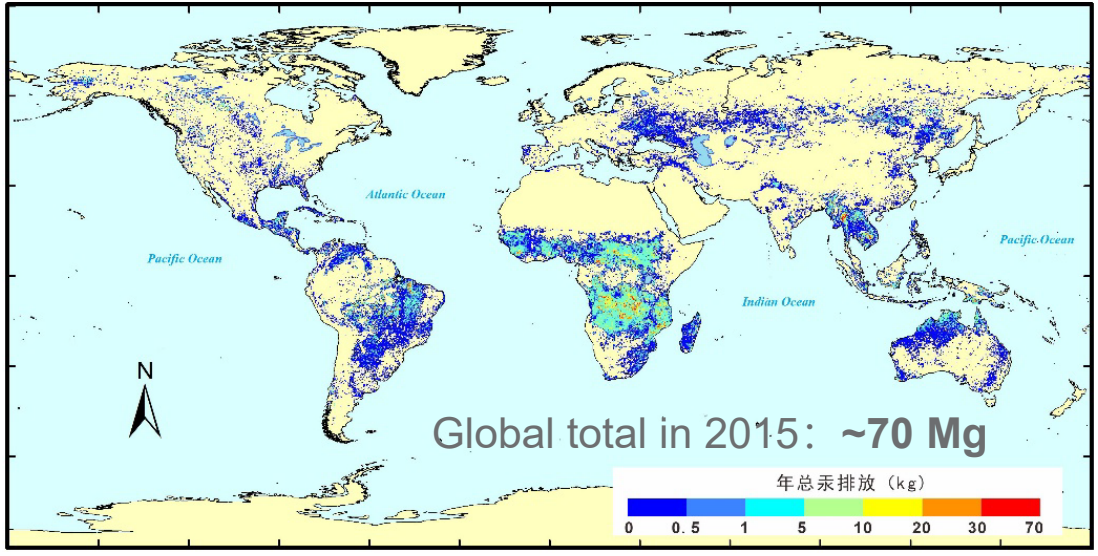
Aboveground biomass（*Spawn et al., 2015*）

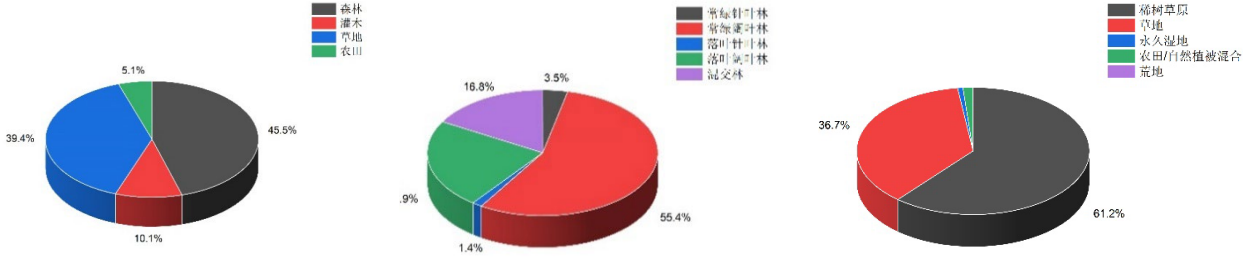


Foliar Hg concentrations

*Shen, **Chen***… et al., In prep.*

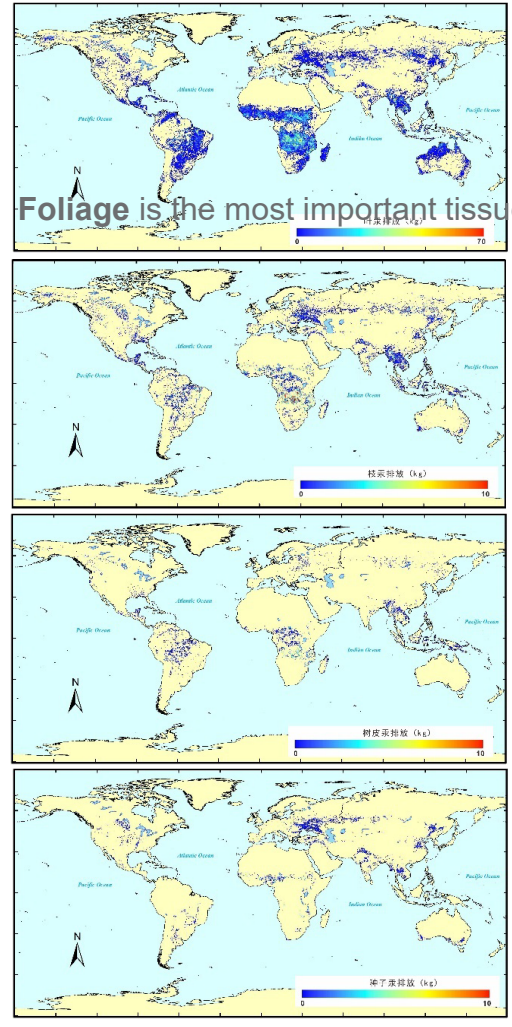
New estimate of Hg emissions from global wildfires





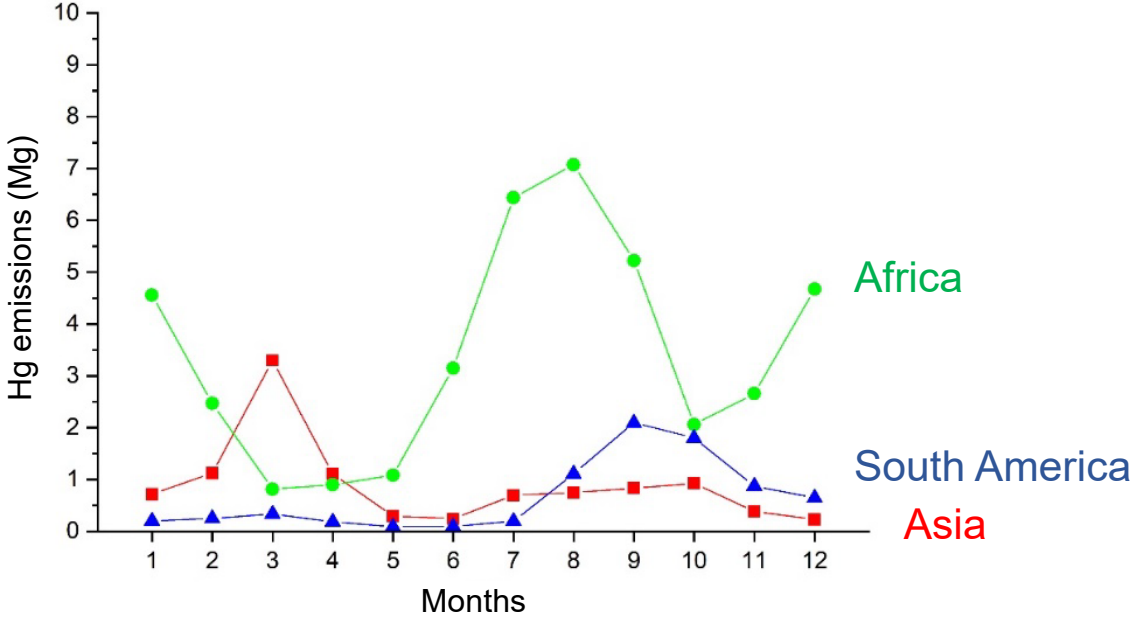
Evergreen broadleaf forest (25.2%) and **Savanna** (24.1%) contribute the most emissions

*Shen, **Chen***… et al., In prep.*



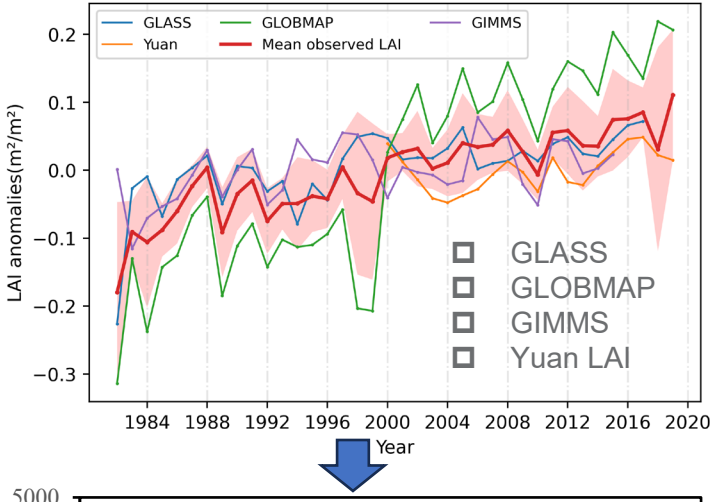
Foliage is the most important tissue

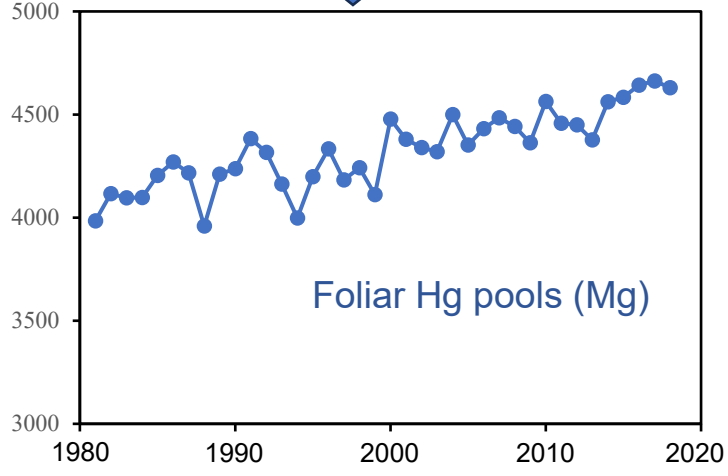
Seasonality of Hg emissions from global wildfires

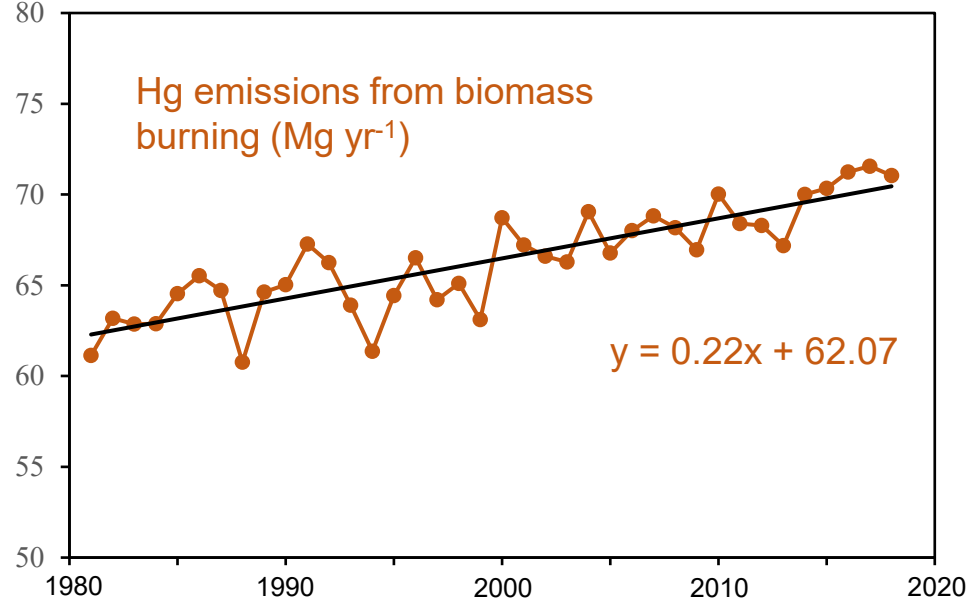


Higher emissions during vegetation recession seasons

Impacts of the increasing vegetation activity



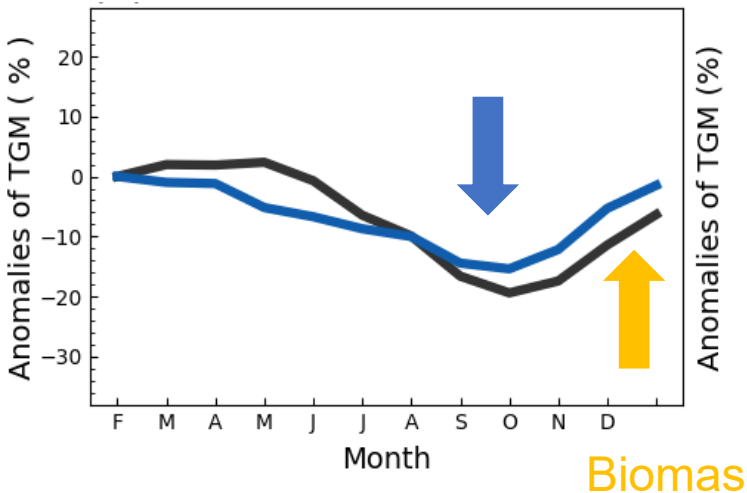




Hg emissions from biomass burning: increased by **0.22 Mg yr^{-1}**

Potential impacts of increasing vegetation assimilation and biomass burning emissions

Vegetation assimilation



Biomass burning

May the increasing vegetation assimilation and biomass burning emissions in the context of global warming **intensify** atmospheric Hg seasonality?

Next step…

Outline

- ☐ Introduction
- ☐ Drivers of atmospheric Hg seasonality
- ☐ Impacts of vegetation Hg assimilation
- ☐ Impacts of Hg emissions from biomass burning
- ☐ **Conclusions**

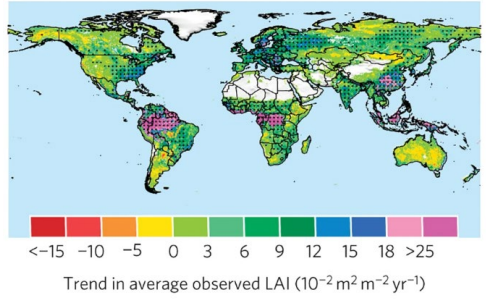
Conclusions

- **Vegetation assimilation** and **biomass burning** made important contributions to atmospheric Hg seasonality across diverse temperate regions
- Global total in foliar Hg pools reaches **4561.3 Mg**, and annual foliar assimilation ranges from **2268.5** to **2727.0 Mg yr^{-1}.** Increasing foliar biomass during the last 40 years potentially contributes to the increase of **7~9 Mg yr^{-1}** for foliar Hg assimilation.
- Hg emissions from global wildfires in 2015 are estimated to be **~70 Mg**. Increasing foliar Hg pools potentially contributes to the increase of **0.22 Mg yr^{-1}** for the emissions.
- Different periods of these impacts, derived from vegetation greening, may potentially **intensify** atmospheric Hg seasonality, which needs more studies.

Conclusions

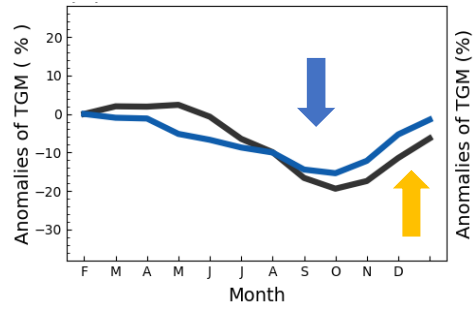
Global warming

CO_2 fertilization



Vegetation greening

Vegetation assimilation



Biomass burning

Got a ball and on the way!

Impacts of climate change on Hg

THANKS!

- Chen, L.; Zhou, J.; Guo, L.*; Bian, X.; Xu, Z.; Chen, Q.; Wen, S.-H.; Wang, K.; Liu, Y.-R.* Global distribution of mercury in foliage predicted by machine learning. *Environmental Science & Technology* 2024, https://doi.org/10.1021/acs.est.4c00636
- Xu, Z.; Chen, L.*; Zhang, Y.; Han, G.; Chen, Q.; Chu, Z.; Zhang Y.; Li C.; Yang Y.; Wang X. Meteorological drivers of atmospheric mercury seasonality in the temperate Northern Hemisphere. *Geophysical Research Letters* 2022, 49, e2022GL100120.