

# Trends, seasonality, and drivers of 2019–23 methane and 2013–24 ammonia emissions inferred with an ensemble Kalman filter and satellite data

Methane 250

**Methane Action  
for People &  
Planet**

From Discovery to Solutions

2026

TIME FOR

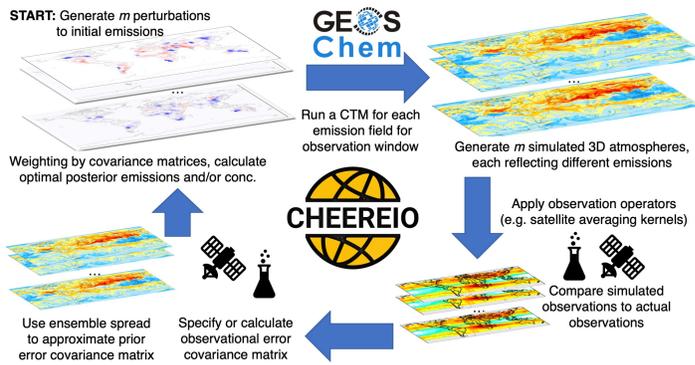
**CH<sub>4</sub>NGE**

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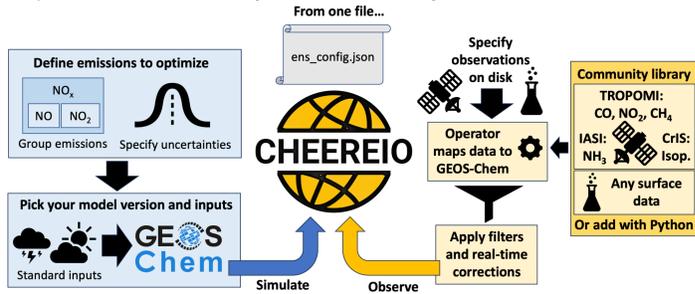
## The LETKF algorithm

The **Localized Ensemble Transform Kalman Filter (LETKF)** optimizes emissions or concentrations of chemical species using an ensemble of chemical transport model (CTM) simulations.



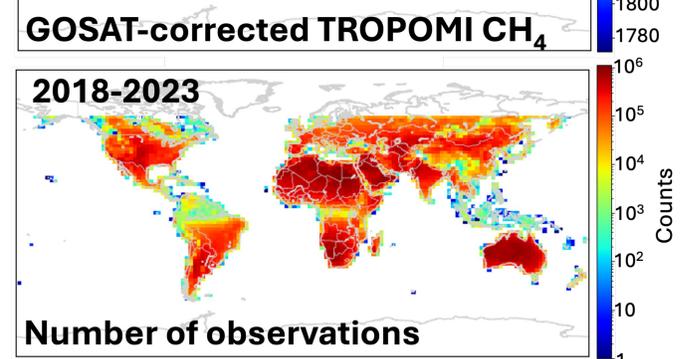
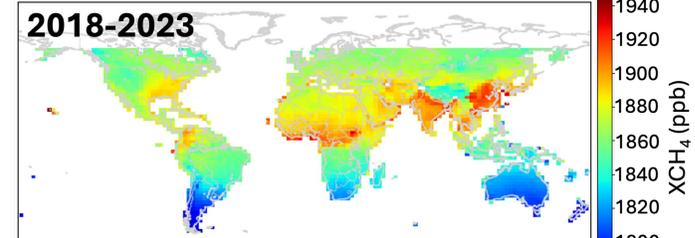
## CHEEREIO LETKF platform

CHEEREIO is a Python-based wrapper for the GEOS-Chem CTM, automating the deployment of LETKF ensembles. CHEEREIO is open-source and freely available at <https://cheere.io>

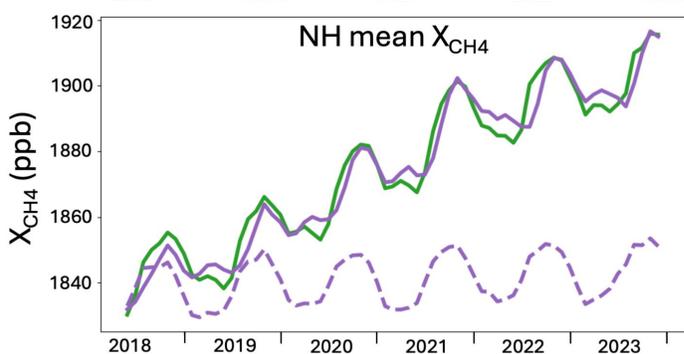
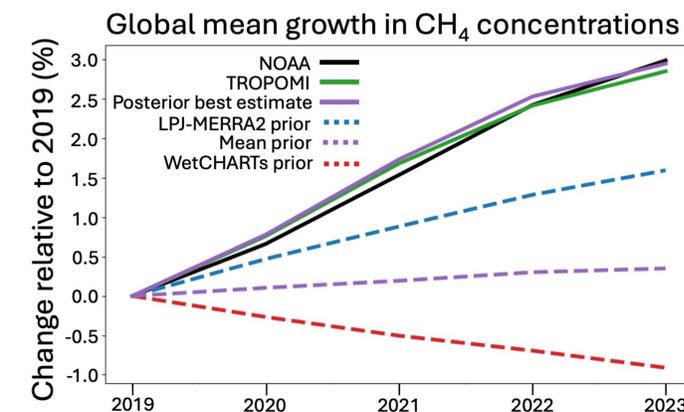


## CH<sub>4</sub> simulation: data and evaluation

We feed in TROPOMI methane columns into CHEEREIO to obtain **emissions every five days at 2°x2.5° resolution**.



Resulting emissions **solve a budget imbalance** in the prior (dotted line) simulations for two different wetland inventories

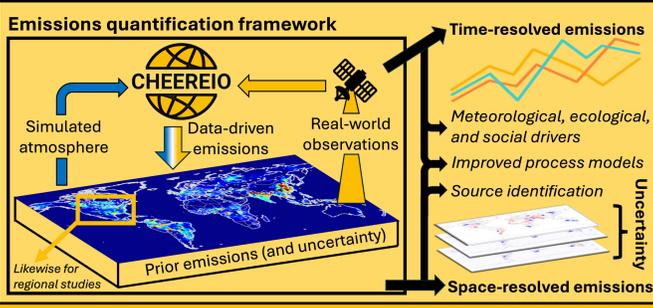


## ABSTRACT

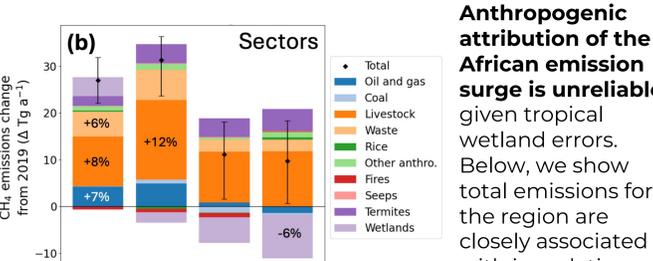
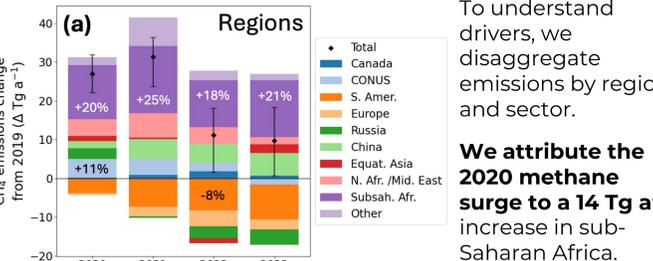
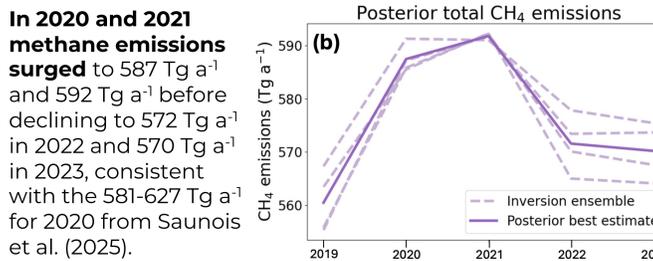
We used TROPOMI data to estimate **global methane emissions** to study rapidly increasing concentrations.

We attribute the 2020-22 **methane surge** to east Africa floods induced by an Indian Ocean Dipole anomaly.

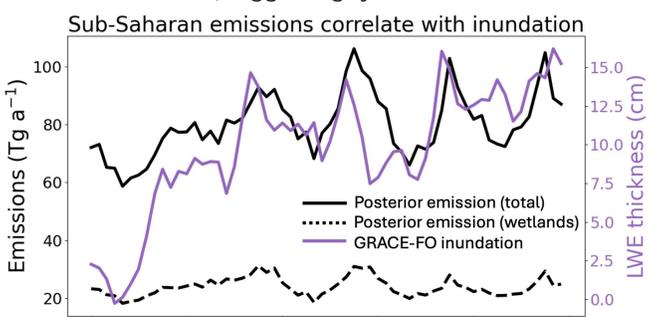
We also explore agricultural change through a complementary **2013-24 global ammonia emissions** inversion using IASI satellite data.



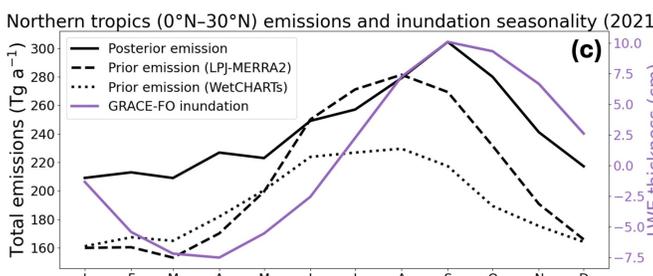
## Methane trends and seasonality



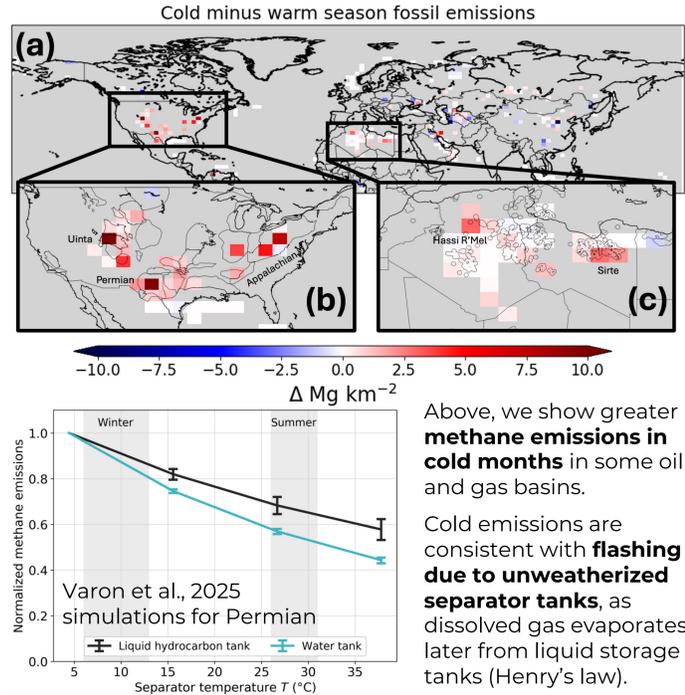
**Emissions attributed to wetlands do not reflect African inundation trends**, suggesting systematic misattribution.



Below, we show the seasonality of **northern tropical emissions follows the seasonality of mean water storage**.

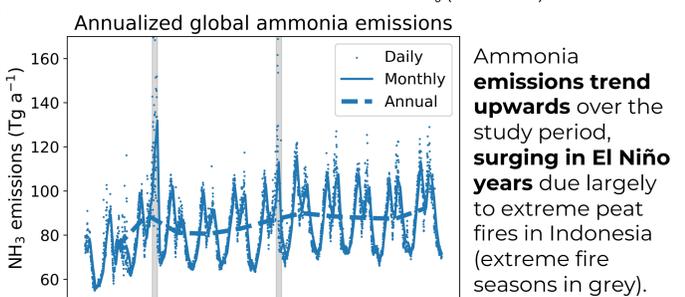
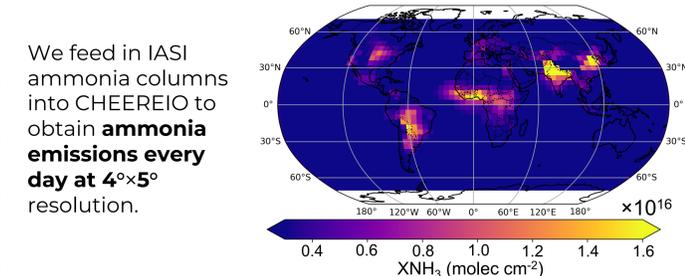


## Unexpected winter fossil emissions

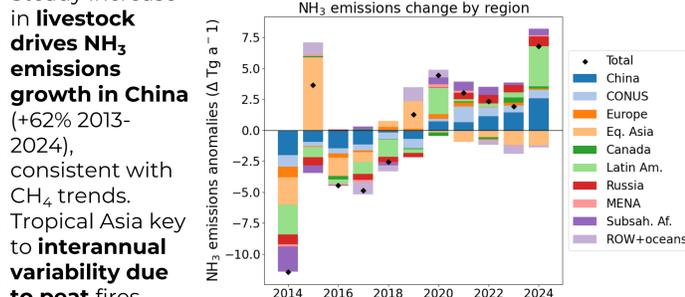


Above, we show greater **methane emissions in cold months** in some oil and gas basins. Cold emissions are consistent with **flashing due to unweathered separator tanks**, as dissolved gas evaporates later from liquid storage tanks (Henry's law).

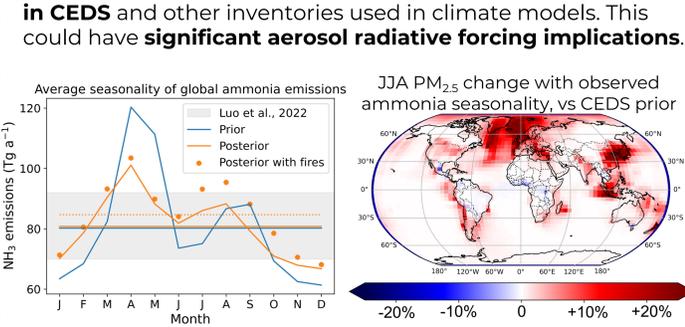
## Ammonia emissions trends



We find emissions have a **more subdued seasonal cycle than in CEDS** and other inventories used in climate models. This could have **significant aerosol radiative forcing implications**.



Steady increase in **livestock drives NH3 emissions growth in China** (+62% 2013-2024), consistent with CH<sub>4</sub> trends. Tropical Asia key to **interannual variability due to peat fires**.



## Acknowledgements and links

The methane work was funded by the NASA Carbon Monitoring System (grant no. 80NSSC21K1057) and an NSF Graduate Research Fellowship Program (GRFP) grant. CHEEREIO's current development and application to reactive nitrogen species, including ammonia, is currently supported by the NSF under Award No. 2516898. Opinions, findings, and conclusions do not necessarily reflect funding body views.

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For more on CHEEREIO, plus applications to **methane in China, CO from Canadian wildfires**, and more, visit: <https://cheere.io>

Scan for 2023 CHEEREIO model paper

Scan for 2025 methane trends paper