Inferring High-Resolution Global Methane Emissions and OH Concentrations using Blended TROPOMI+GOSAT Observations from 2019 to Present

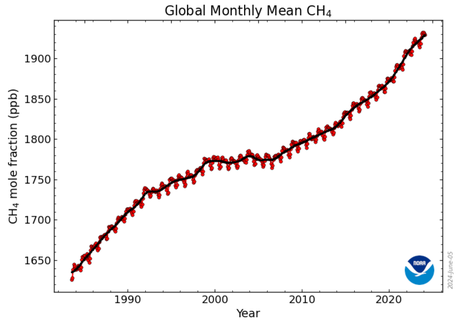
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Introduction

Methane is the second most important anthropogenic greenhouse gas in the atmosphere after carbon dioxide, and is **responsible more for near-term climate change**. Targeting methane is therefore a promising strategy to mitigate climate change over the next few years. **Atmospheric methane concentrations have been increasing globally over the past decade and surged in 2020 and 2021**, but the cause of this rising trend is still uncertain.

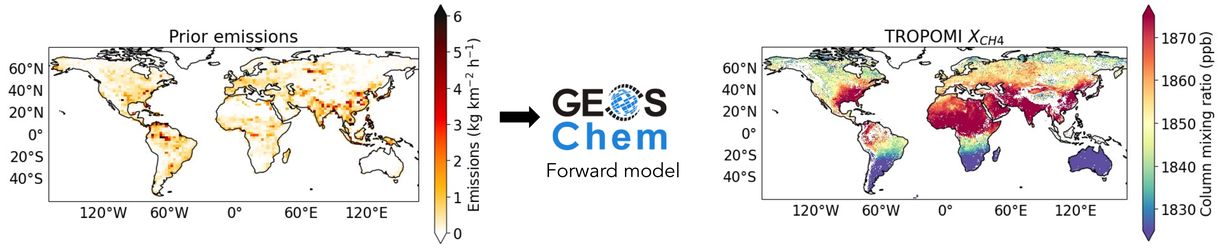
The dominant natural source of methane emissions is wetlands, while anthropogenic sources include livestock, oil/gas facilities, landfills, coal mining, rice cultivation, and wastewater treatment. The main sink of methane in the atmosphere is oxidation by the hydroxyl radical (OH). Methane emissions are reported as flux estimates in bottom-up inventories. Space-borne observations of atmospheric methane are retrieved by satellites (GOSAT, TROPOMI). These concentrations can be related to emissions via inverse modeling.



The Integrated Methane Inversion (IMI 2.0) is an open-access computing tool for performing analytical methane inversions (Estrada et al., 2024). **This work uses the IMI to infer annual global methane emissions and OH at high spatial resolution (2°x2.5°) for 2019 to 2023.**

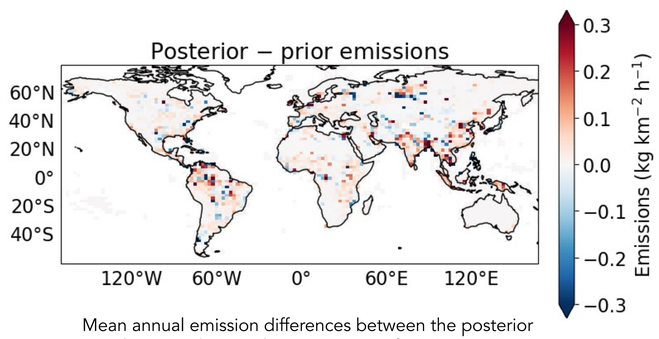
Methods

- GEOS-Chem (v14.4) simulates methane concentrations based on prior estimates from compiled emission inventories and archived 3-D OH fields (Wecht et al., 2014)
- Satellite observations are provided by the Blended TROPOMI+GOSAT product (Balasus et al., 2023)

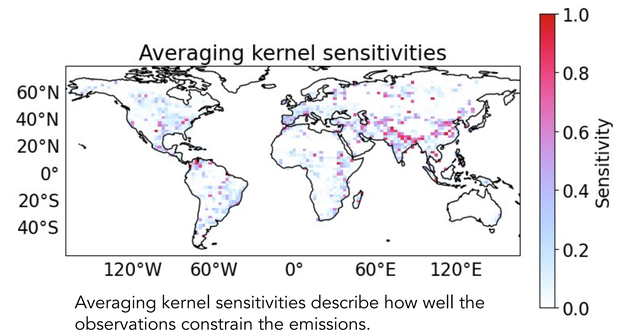


- Bayesian analytical inversion using the IMI finds the most likely posterior emissions and OH given the satellite observations

Results



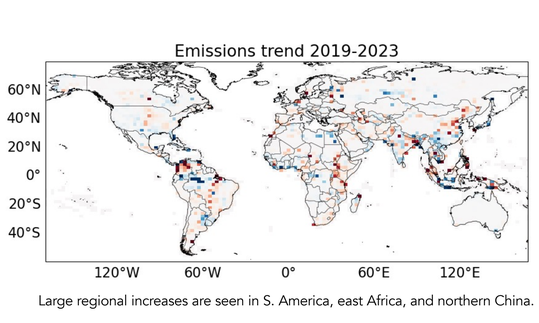
Mean annual emission differences between the posterior solution and original inventory prior for 2019-2023.



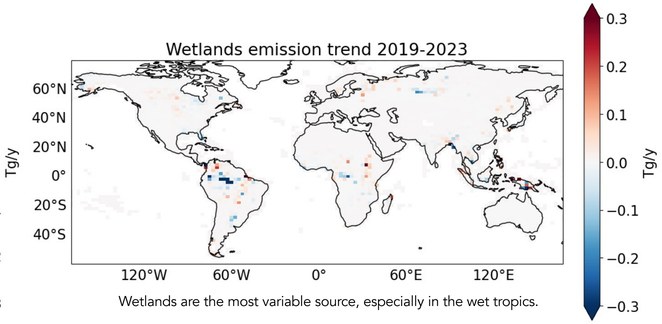
Averaging kernel sensitivities describe how well the observations constrain the emissions.

- Highest in high-emitting anthropogenic source regions with dense satellite coverage

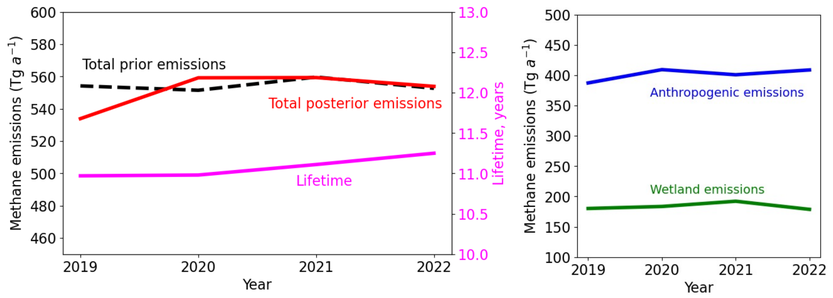
Results



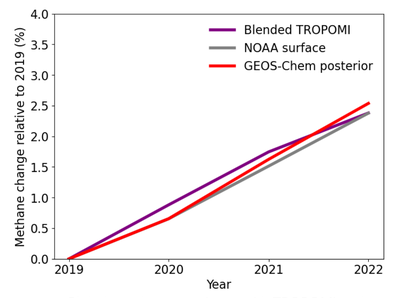
Large regional increases are seen in S. America, east Africa, and northern China.



Wetlands are the most variable source, especially in the wet tropics.

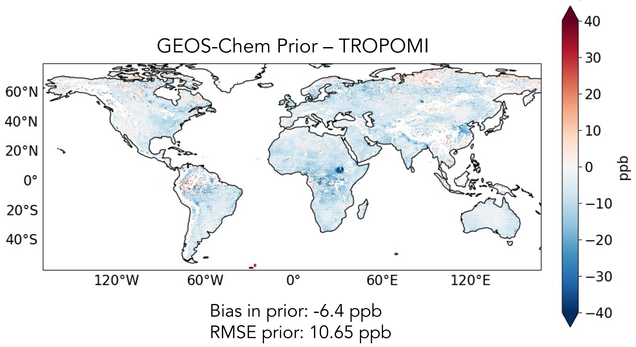


Timeseries of posterior emissions and methane lifetime across inversion period.

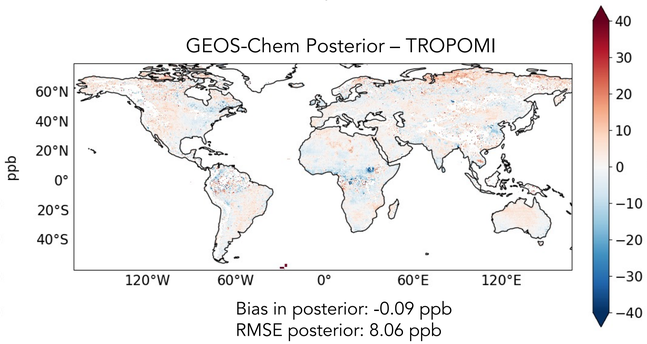


Global trends are consistent with TROPOMI and independent NOAA surface sites.

Model-observation bias improves after inversion (2020 example):



Bias in prior: -6.4 ppb
RMSE prior: 10.65 ppb



Bias in posterior: -0.09 ppb
RMSE posterior: 8.06 ppb

Takeaways

- Largest sectoral emission variability in tropical wetlands
- Major regional emission increases in Colombia, Bengal, Uganda, and northern China
- Methane lifetime to OH has slightly increased since 2019
- Increasing methane concentration trend is consistent with independent observations

Next Step

- Run ensemble of inversions with varying parameters to calculate uncertainties

References

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2. Estrada, L. A., Varon, D. J., Sulprizio, M., Nesser, H., Chen, Z., Balasus, N., Hancock, S. E., He, M., East, J. D., Mooring, T. A., Oort Alonso, A., Maasakkers, J. D., Aben, I., Baray, S., Bowman, K. W., Worden, J. R., Cardoso-Saldaña, F. J., Reidy, E., and Jacob, D. J. (2024). Integrated Methane Inversion (IMI) 2.0: an improved research and stakeholder tool for monitoring total methane emissions with high resolution worldwide using TROPOMI satellite observations. *EGUsphere* [preprint].
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IMI website