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Estimating global and China's methane emissions and their trends with satellite and surface observations

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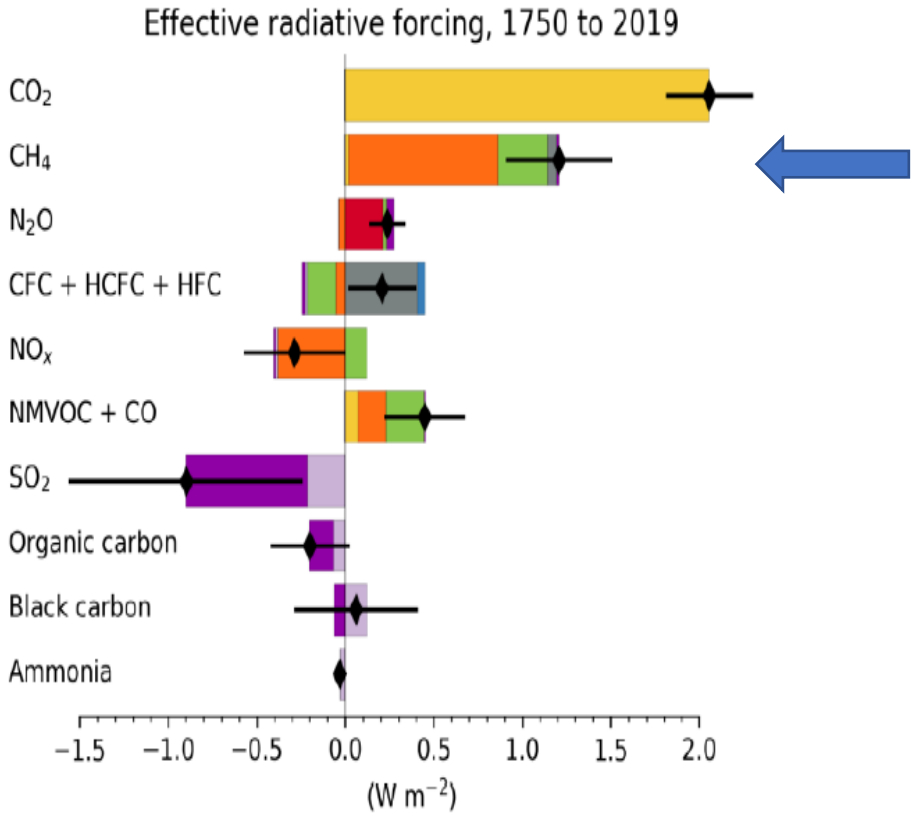
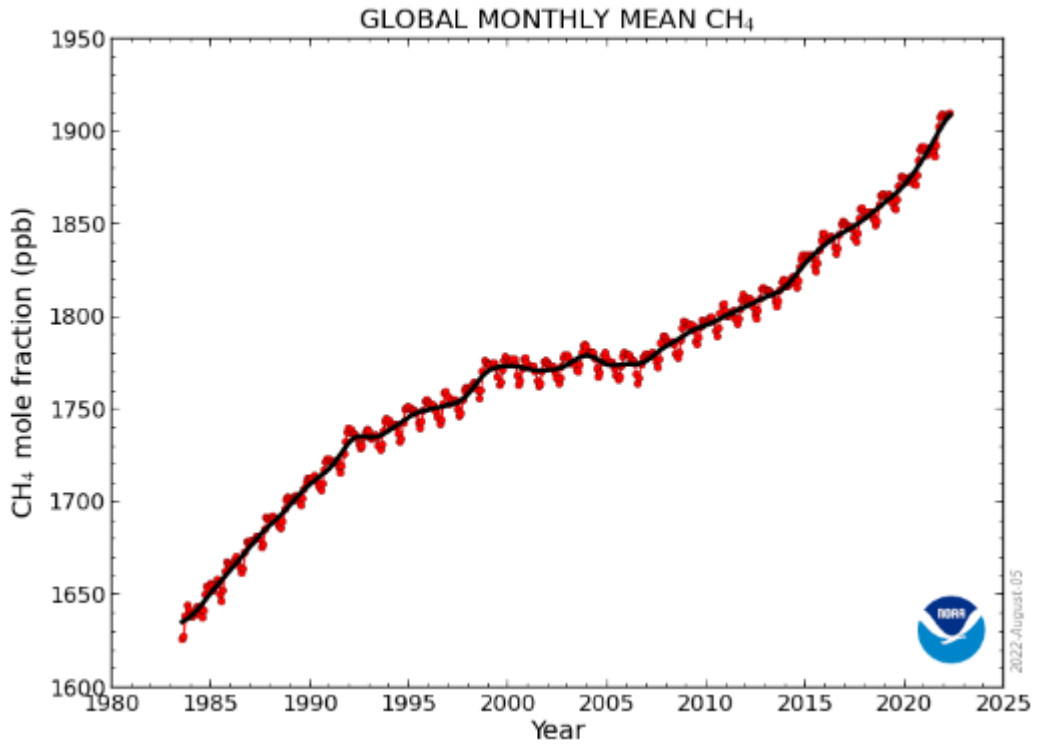
Greenhouse gas methane (CH_4)

Radiative forcing



IPCC AR6 2021

Increases in last 40 years



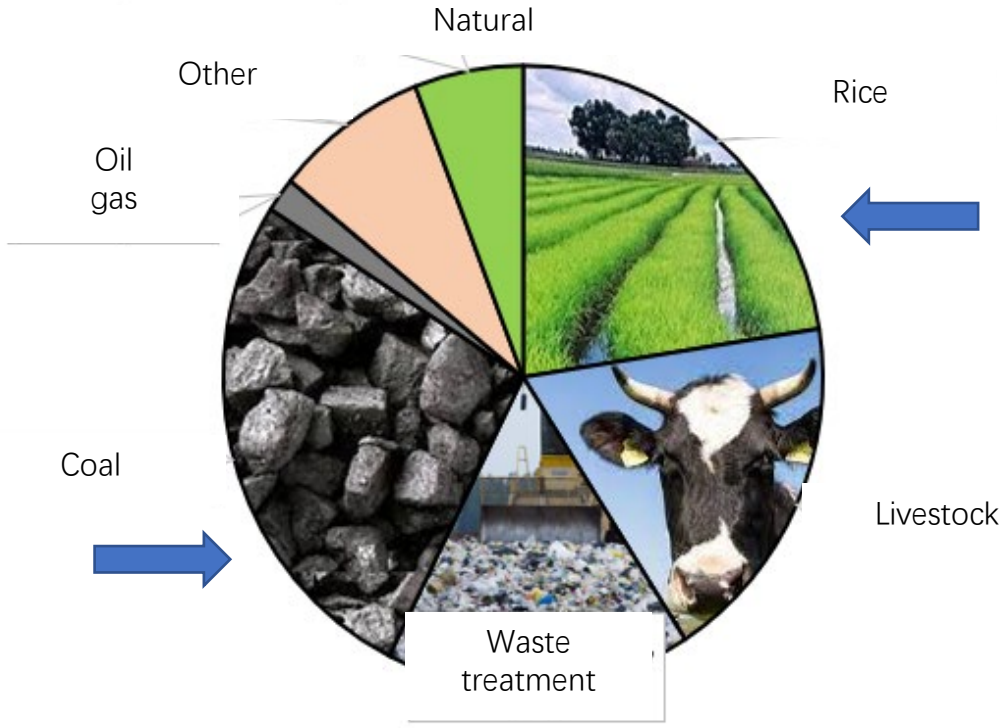
https://gml.noaa.gov/ccgg/trends_ch4/

Global and China's methane emissions

World

~ 550 Tg a^{-1}

China



~ 55 Tg a^{-1}

Based on bottom-up inventories

Critical role of atmospheric observations in quantifying methane emissions

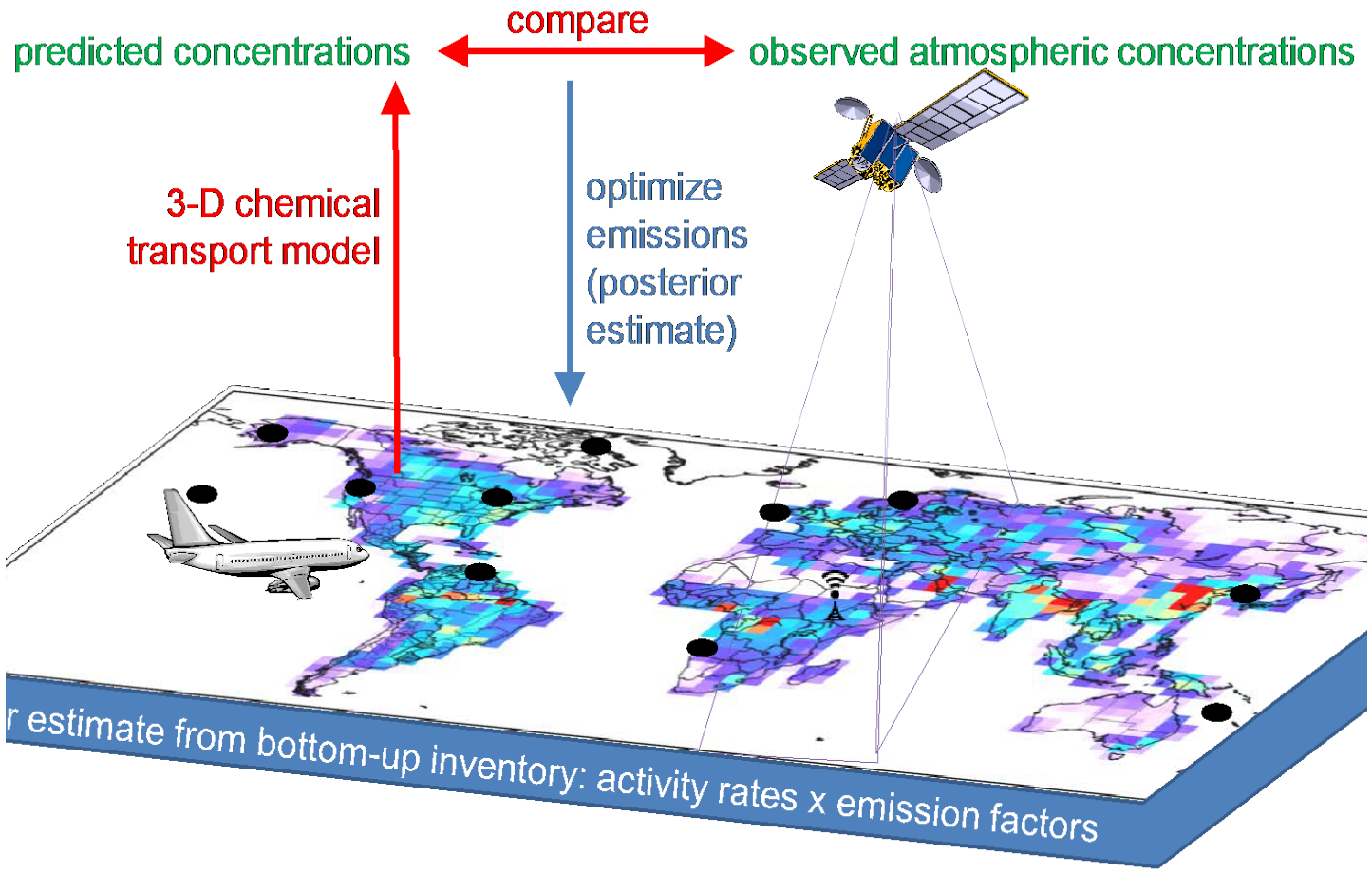
- Multiple source sectors are challenging to model from bottom up
- Fugitive emissions
- Complex dependence on environmental conditions
- Large spatial and temporal variations

Oil/Gas Field

Rice Paddies

Wetlands

Inverse analysis of satellite and surface observations



Analytical inversion

Global inversion (2010-2018)

Zhang et al., 2021

- -GEOS-Chem 4°x5°
- -GOSAT XCH_4
- -ObsPack *Lu et al., 2021*

China inversion (2010-2017)

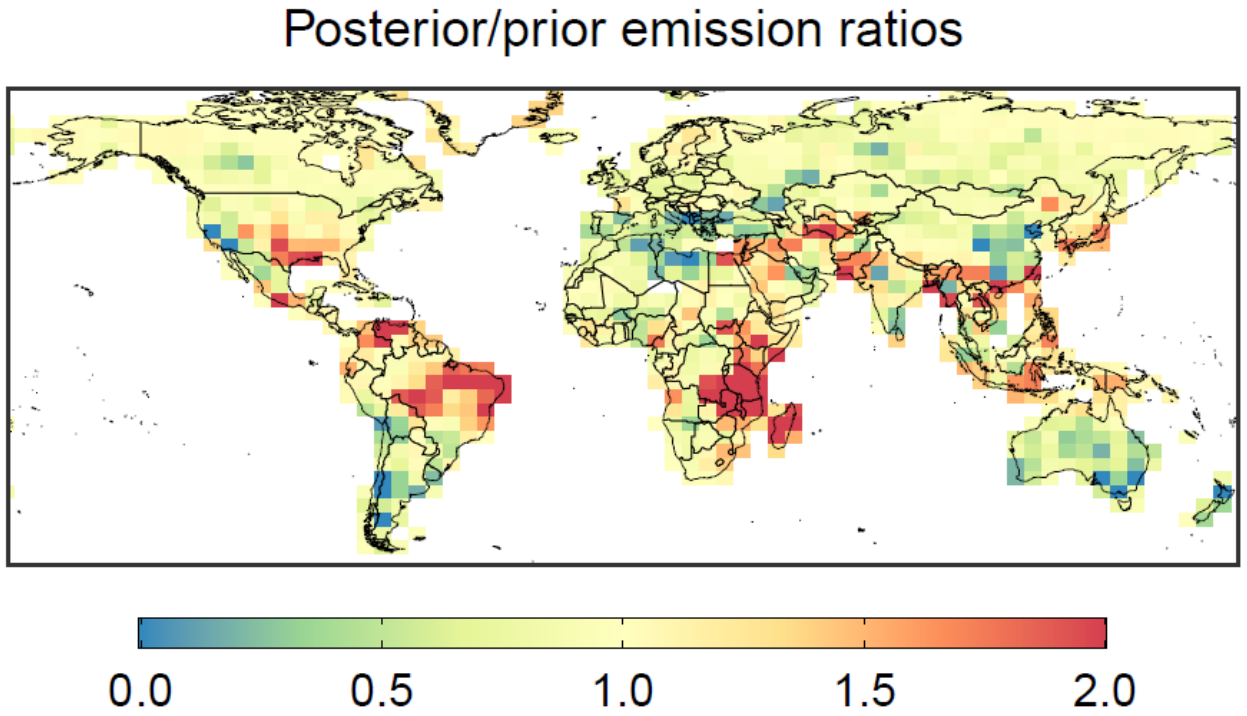
Zhang et al., in press

- -GEOS-Chem 0.5°x0.6°
- -GOSAT XCH_4
- -CMA surface network
- -TROPOMI XCH_4 (2019)

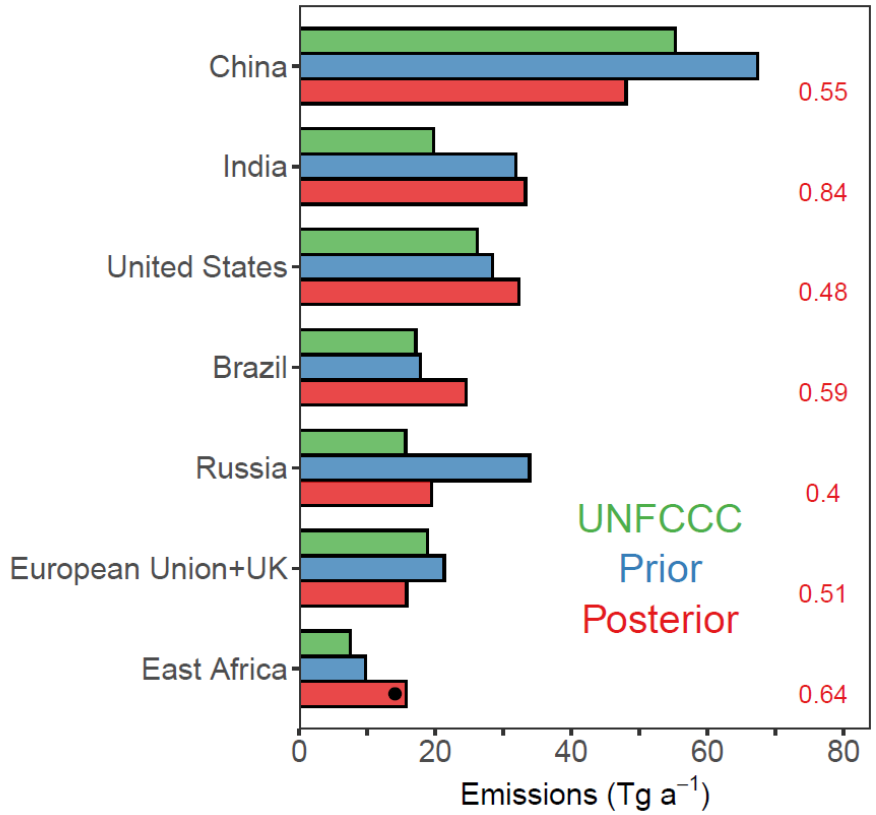
Liang et al., in review

Global methane inversion of GOSAT observations, 2010-2018

Correction factors for anthropogenic emissions



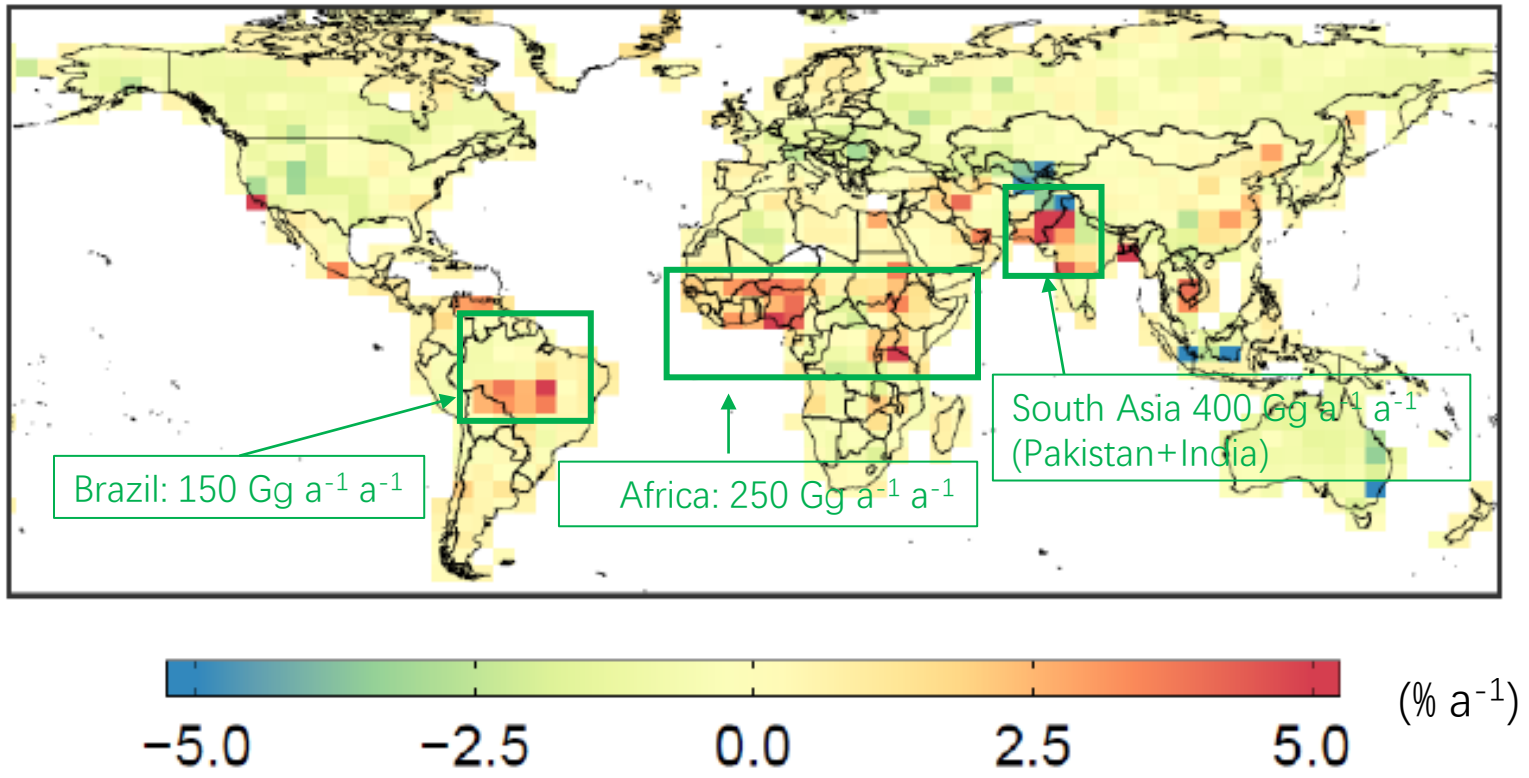
National estimates



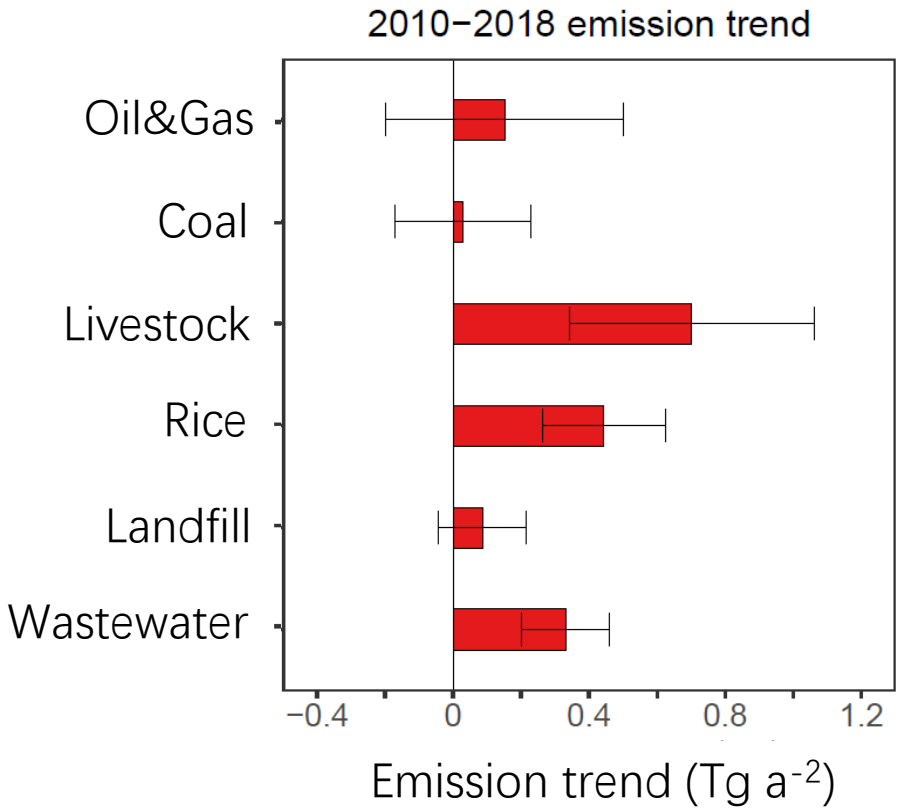
Zhang et al., Atmos. Chem. Phys., 2021

Global methane inversion, 2010-2018 emission trends

2010-2018 Anthropogenic emission trends



Attribution of anthropogenic trends

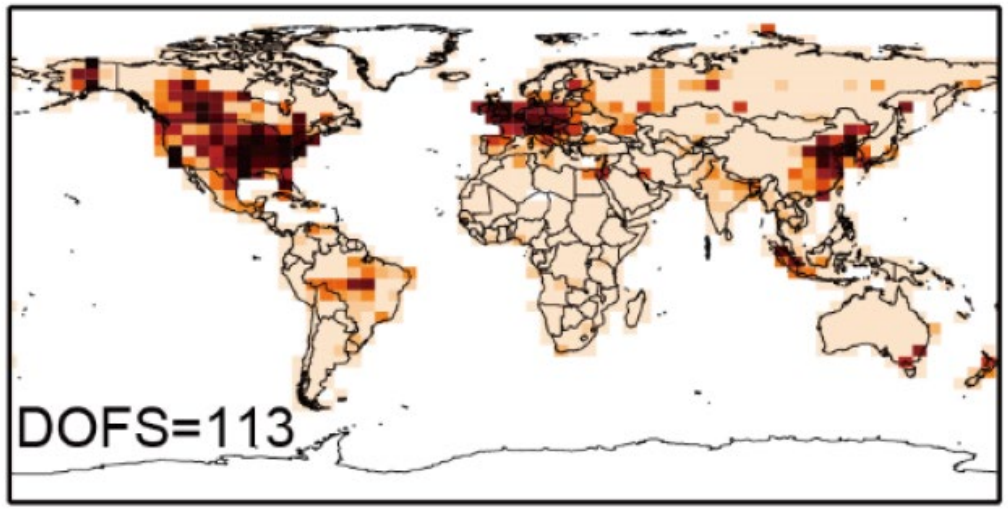


Zhang et al., Atmos. Chem. Phys., 2021

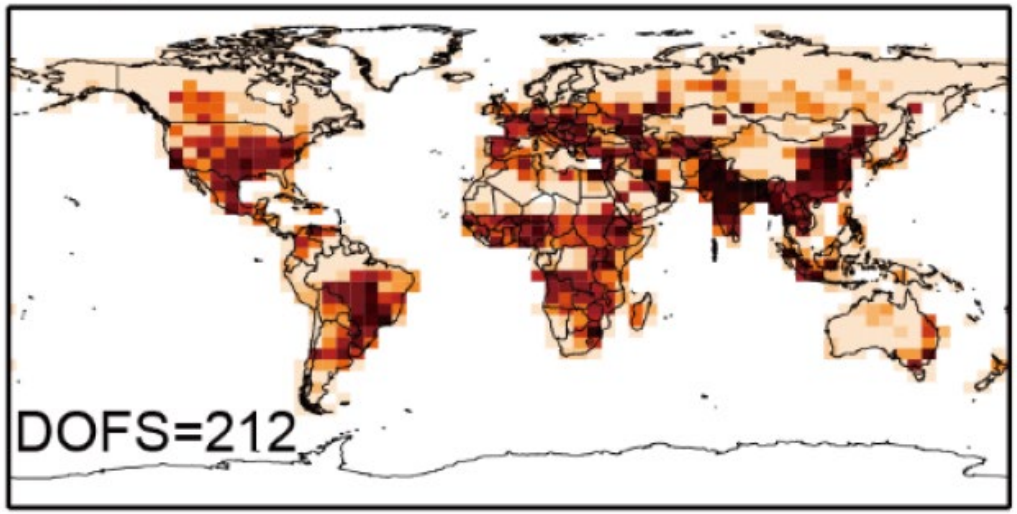
Satellite vs. ground network: Complementarity

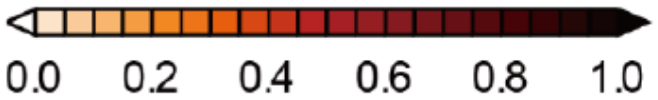
Observation constraints measured by averaging kernel sensitivity

Ground network/aircraft (ObsPack)



Satellite observations (GOSAT)





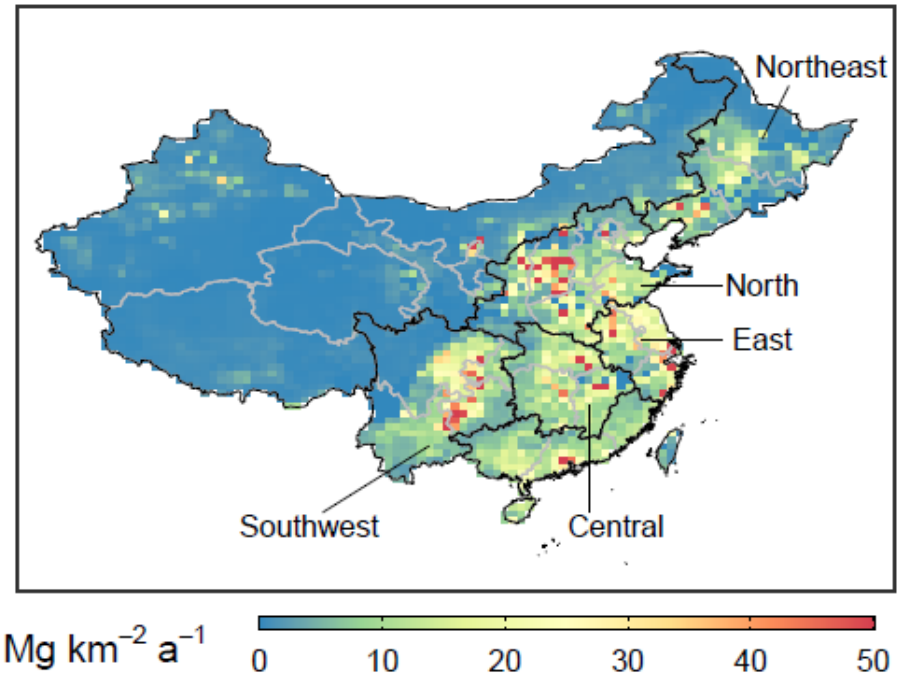
0=no information from obs.
1=fully constrained by obs.

Lu et al., Atmos. Chem. Phys., 2021

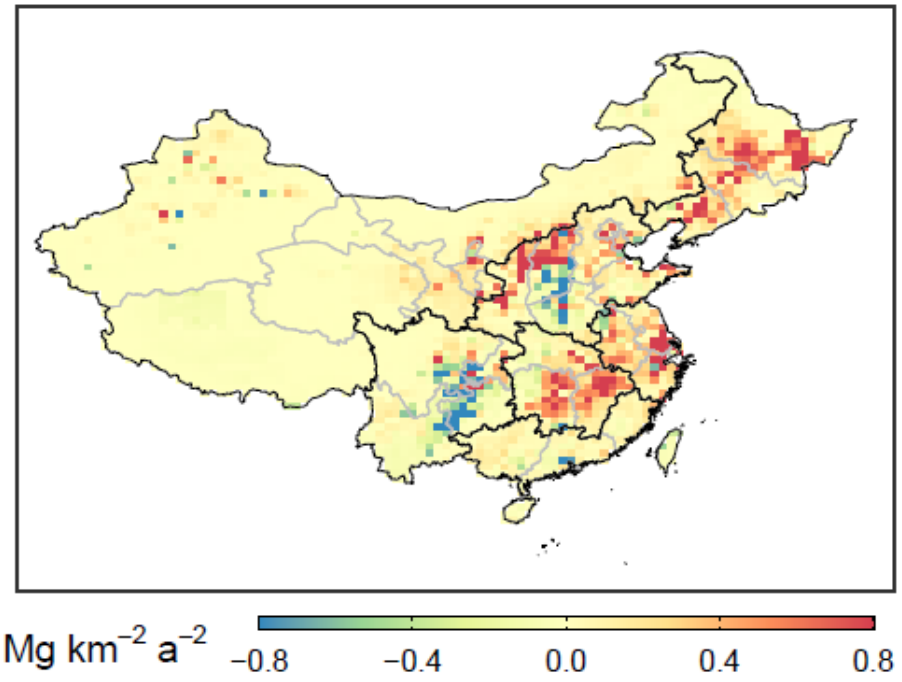
Joint inversion of satellite and surface observations for China

GOSAT CO_2 proxy retrievals + 13 surface sites in China and surrounding regions

2010–2017 mean methane emissions



2010–2017 methane emission trends

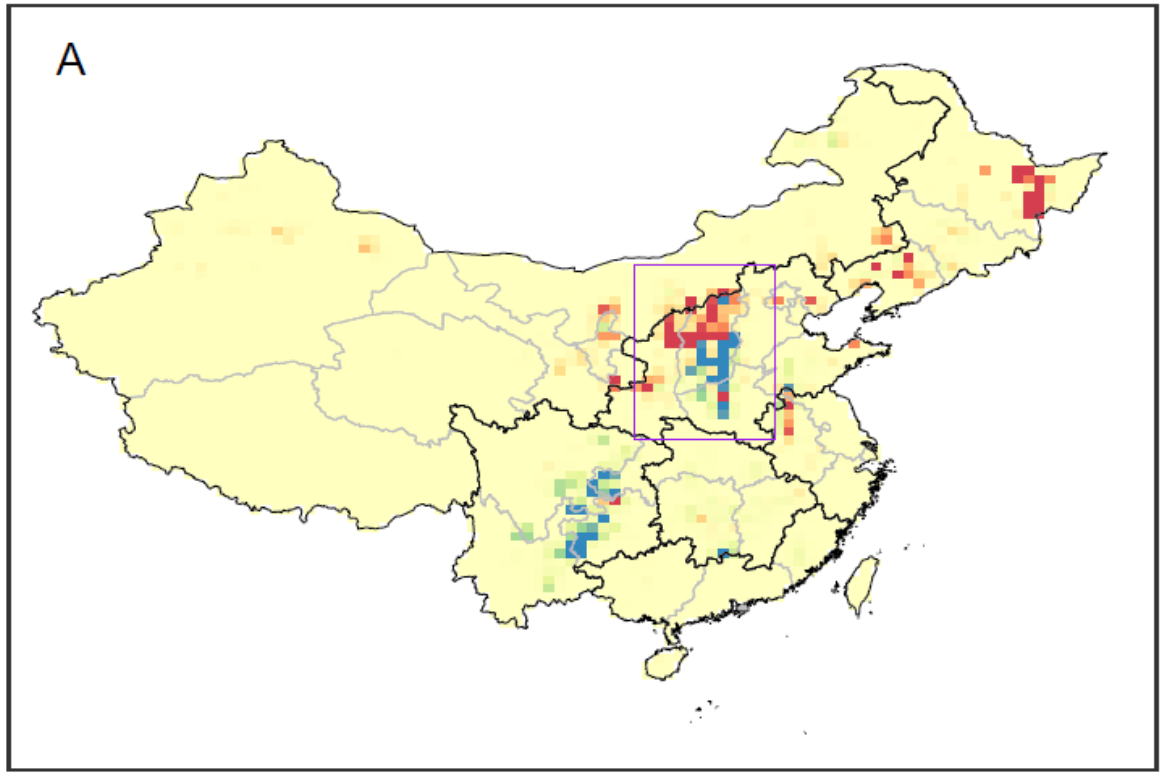


National sum 55 Tg a^{-1} 0.7 (0.45-0.85) Tg a^{-2}

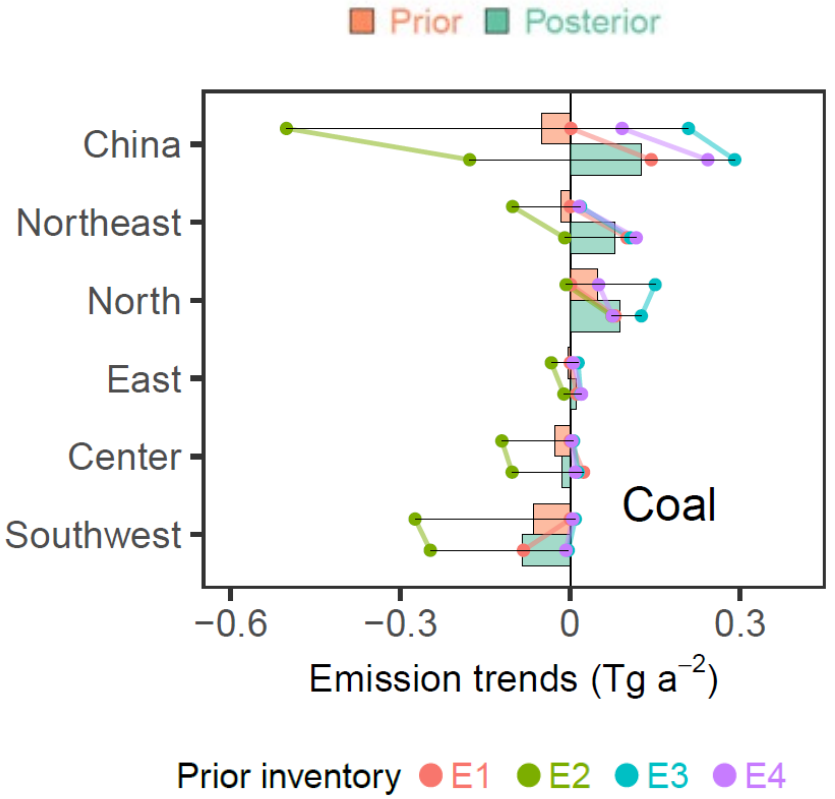
Zhang et al., PNAS, in press

Spatially contrasting trends in coal emissions, 2010-2017

Emission trends attributed to coal mining

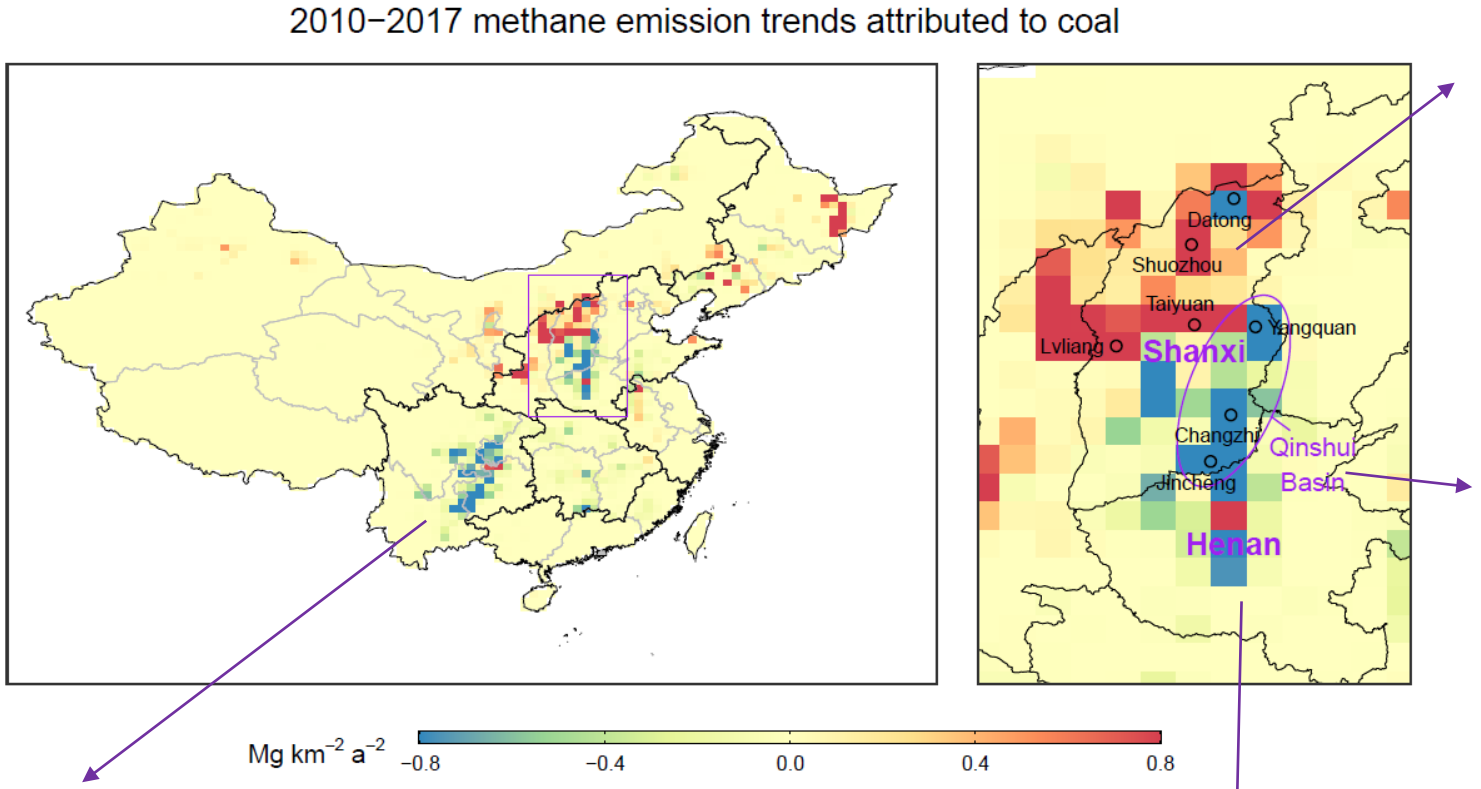


Uncertain & regionally divergent trends from coal



Zhang et al., PNAS, in press

Spatially contrasting trends in coal emissions, 2010-2017



Production in Shanxi and Shaanxi overall keeps flat with a slight increase, contributing a positive emission trend in northern Shanxi.

Expansion of **coalbed methane production** in Qinshui Basin (沁水盆地:阳泉, 晋城; Largest CBM production basin in China, >60%) in southeastern Shanxi contributes to the negative emission trend.

Decrease in Southwest China is consistent with close-off of small coal

Negative trend in Henan is consistent with rapidly decreasing coal production (-9.4% a^{-1})

Zhang et al., PNAS, in press

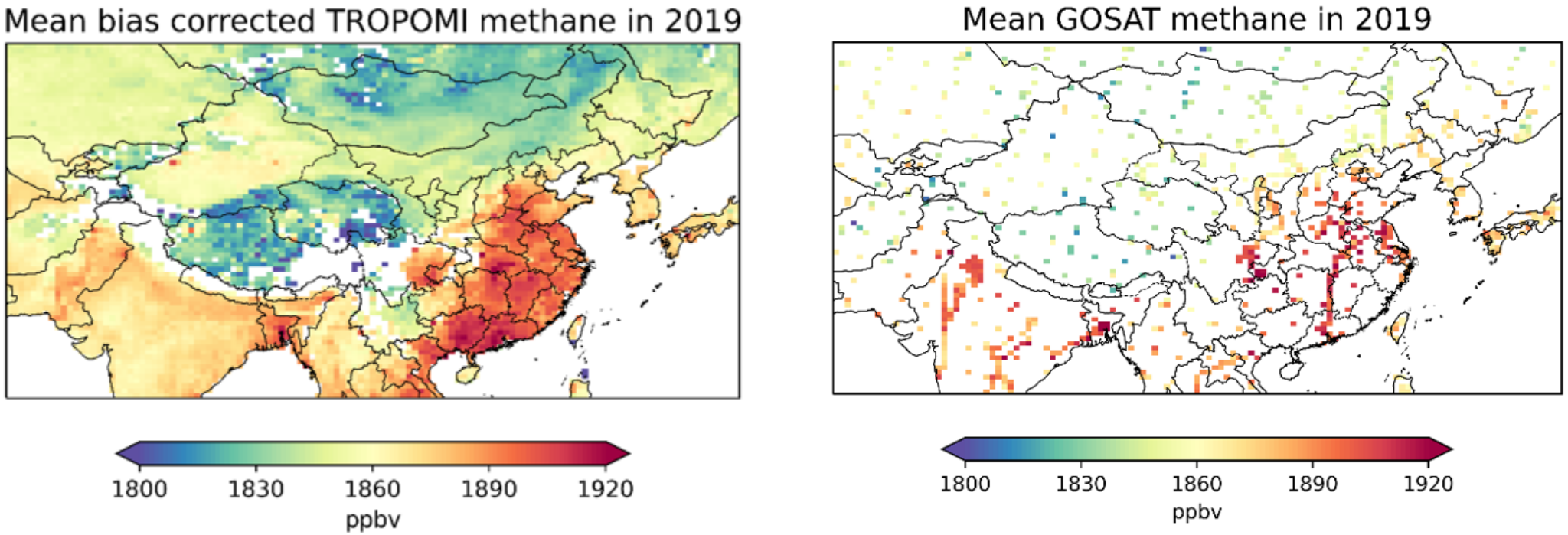
Compare inversion of GOSAT and TROPOMI observation

Ruosi Liang

➡ Lack of validation & evaluation for satellite data over China

Do TROPOMI and GOSAT provide consistent inversion results?

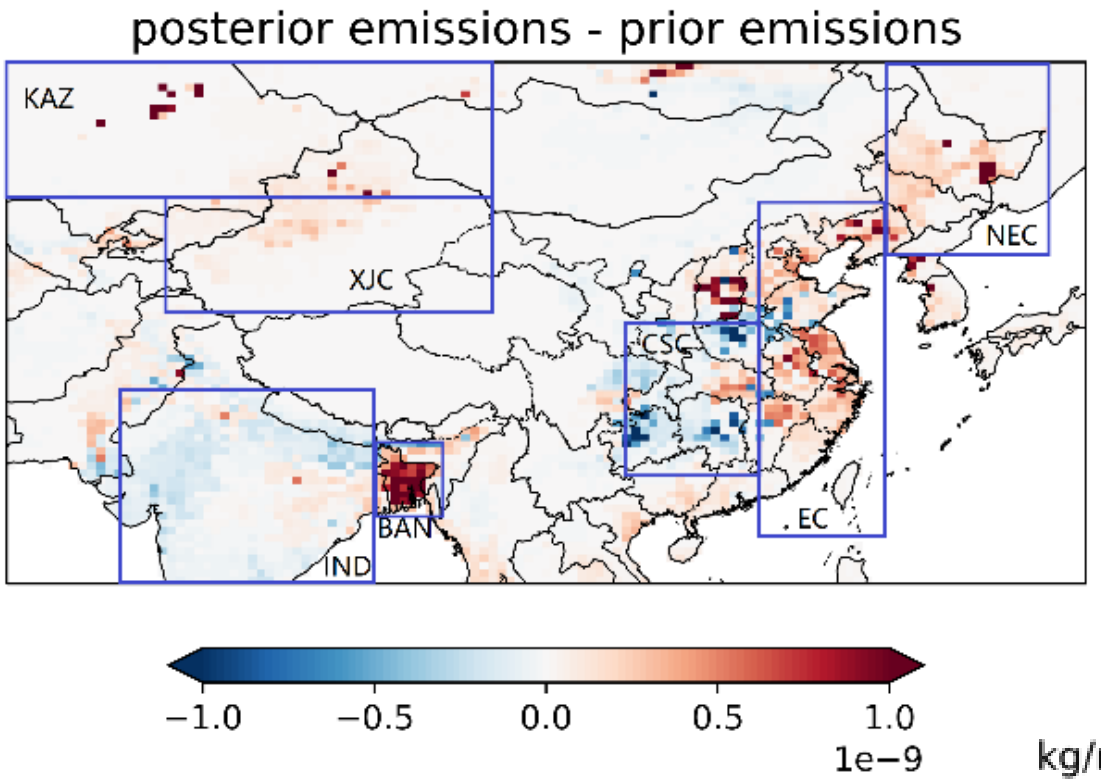
Full-physics retrieval CO_2-proxy retrieval



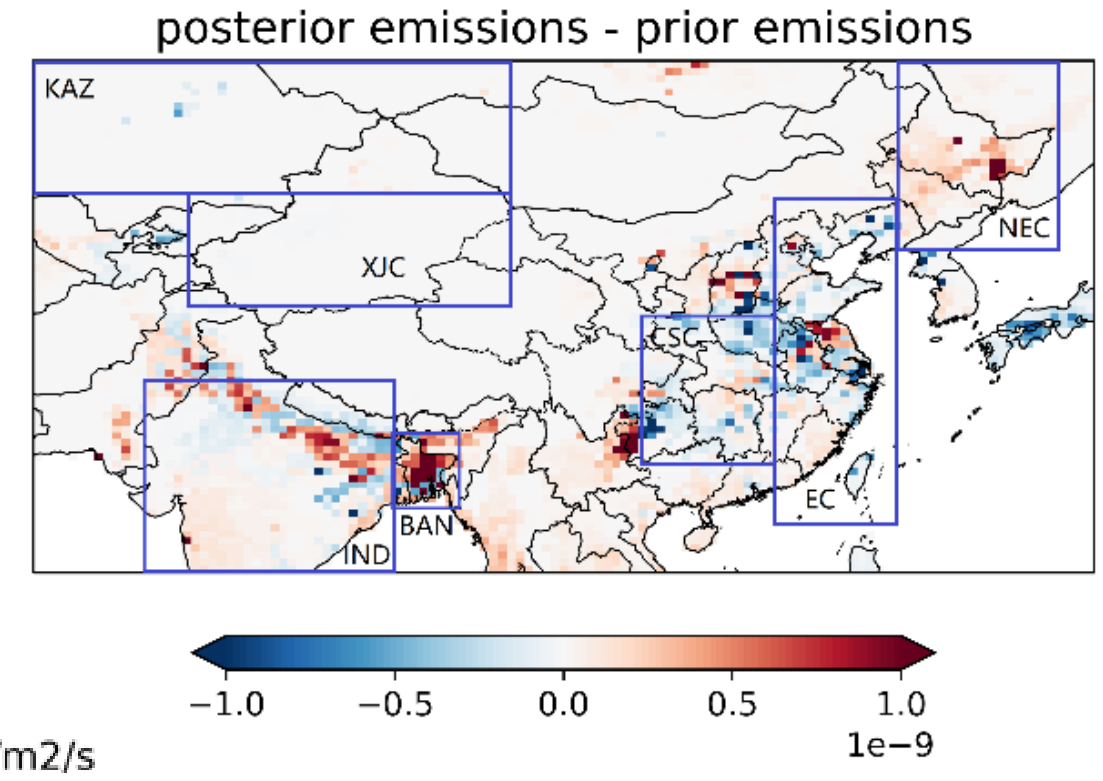
Liang et al., ACP, in review

Compare inversion of GOSAT and TROPOMI observation

TROPOMI Inversion



GOSAT Inversion



kg/m2/s

Consistent: NEC, CSC, BAN

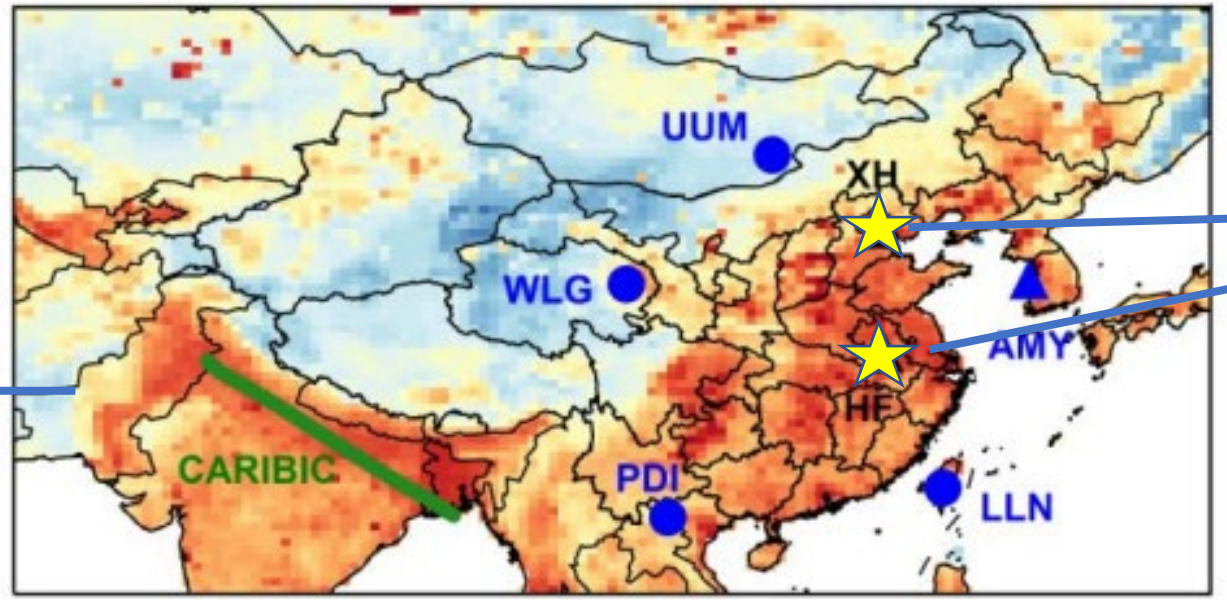
Inconsistent: KAZ, XJC, IND, EC

Liang et al., ACP, in review

Compare inversion of GOSAT and TROPOMI observation

Independent observations for evaluation

CARIBIC
Commercial aircraft data in the troposphere



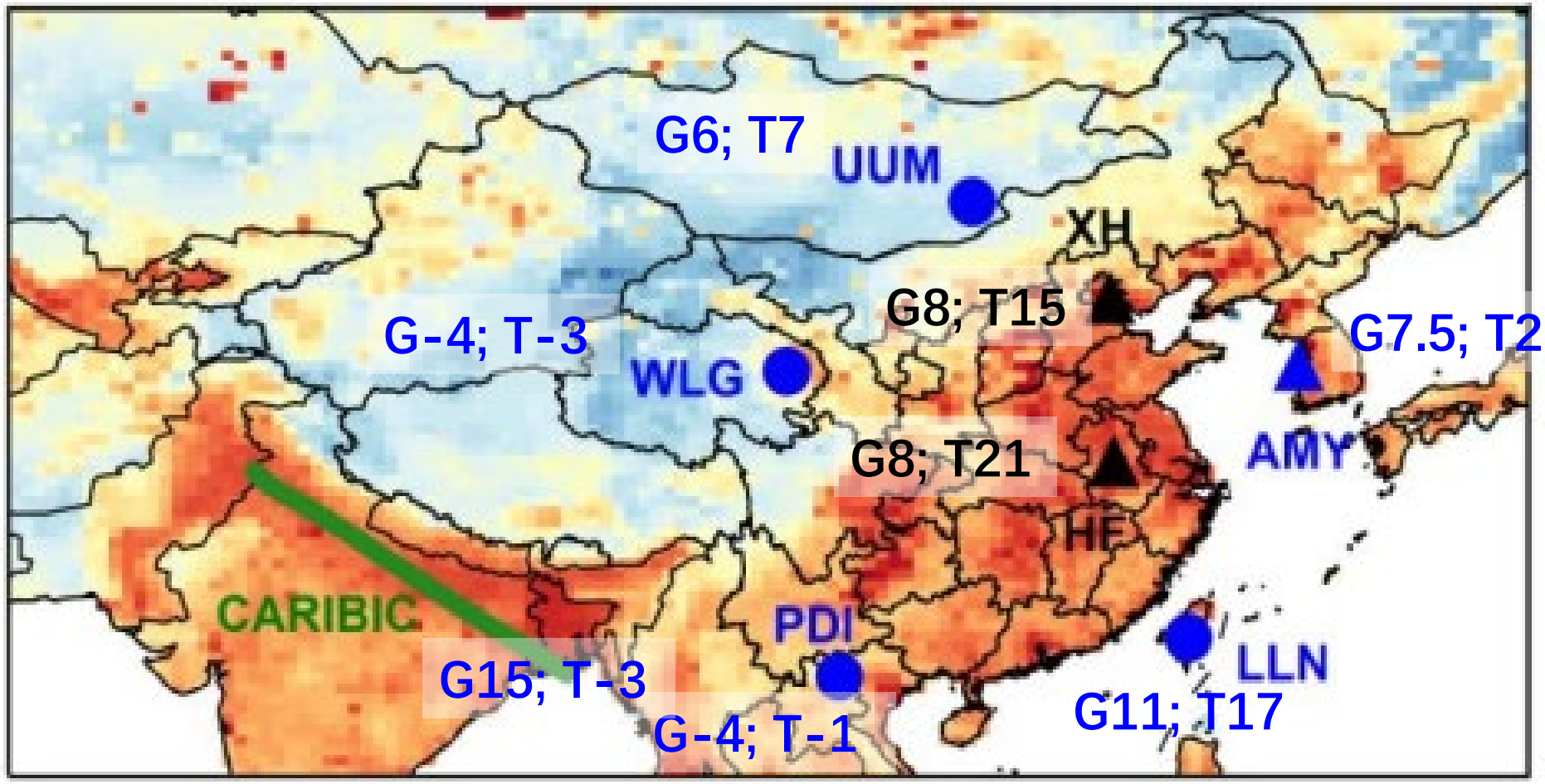
TCCON
Total column measurements (Beijing, Hefei)

Posterior simulations serve as an intercomparison platform for comparison to observations

Liang et al., ACP, in review

Compare inversion of GOSAT and TROPOMI observation

Biases against independent observations (posterior simulation – observation, ppbv)



Independent observations support the GOSAT inversion than TROPOMI in East China

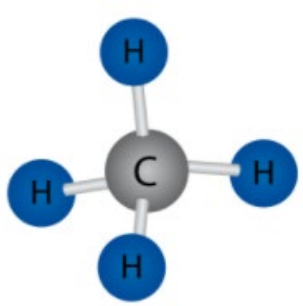
Liang et al., ACP, in review

Data archival

Global inversion: https://doi.org/10.57760/sciencedb.02328

China inversion: https://doi.org/10.57760/sciencedb.02269

Summary



- Global and national methane emissions and trends can be constrained by inversion of atmospheric observations
- Satellite and surface observations are supplementary to provide observational constraints
- Increases in livestock emissions in South Asia, Africa, and South America are inferred from the global analysis
- Trends in coal emission in China shows spatially contrasting patterns, consistent with changes in production at the provincial level
- TROPOMI and GOSAT inversions inconsistent over eastern China (retrieval difference)