Recent global and Regional Methane Budgets Constrained by Atmospheric Observations

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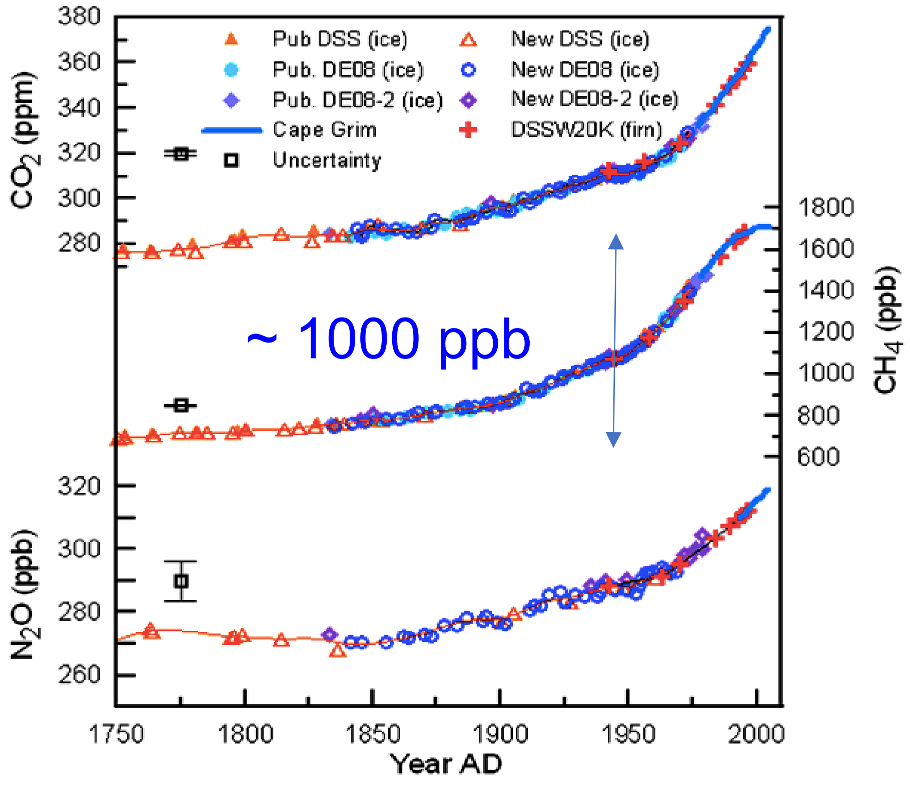
Greenhouse gas methane (CH_4)

Greenhouse gases in last 300 years



Ice core record

MacFarling Meure et al., GRL, 2006

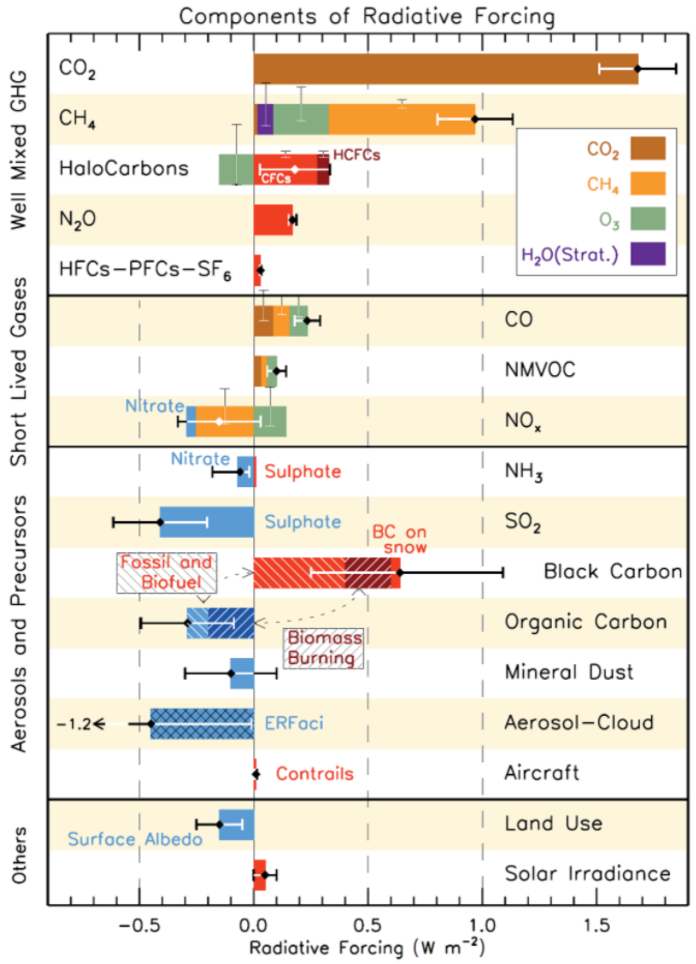
GWP (~100 years)

1

80

300

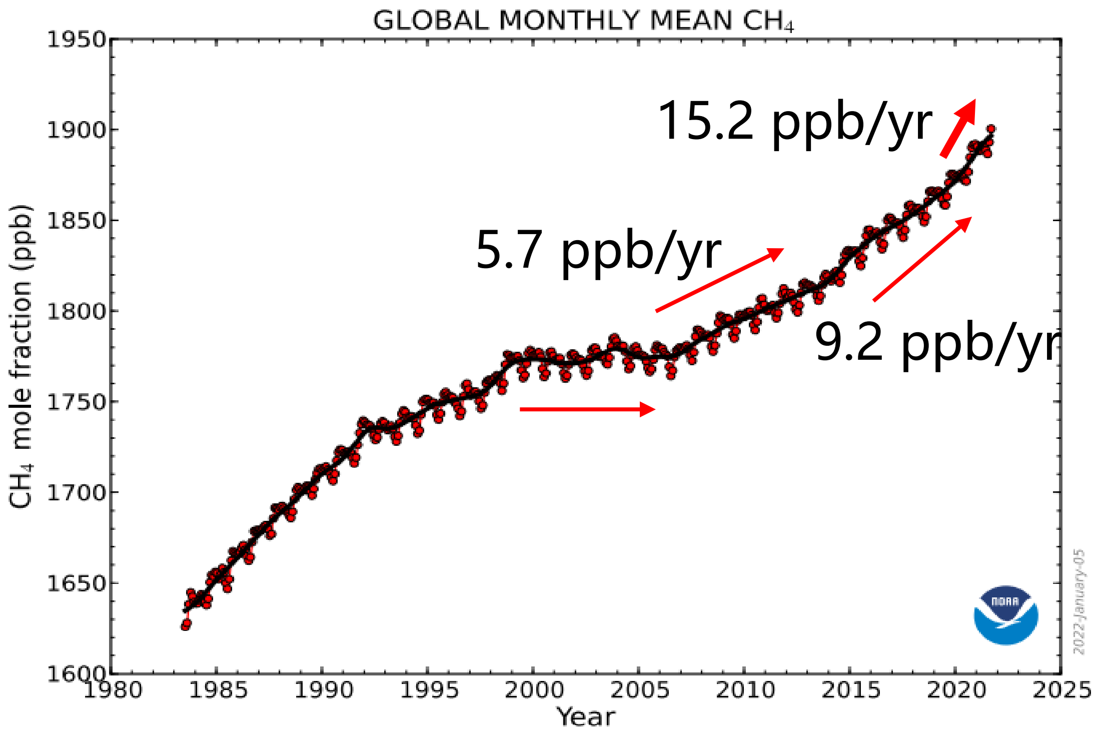
Radiative forcing

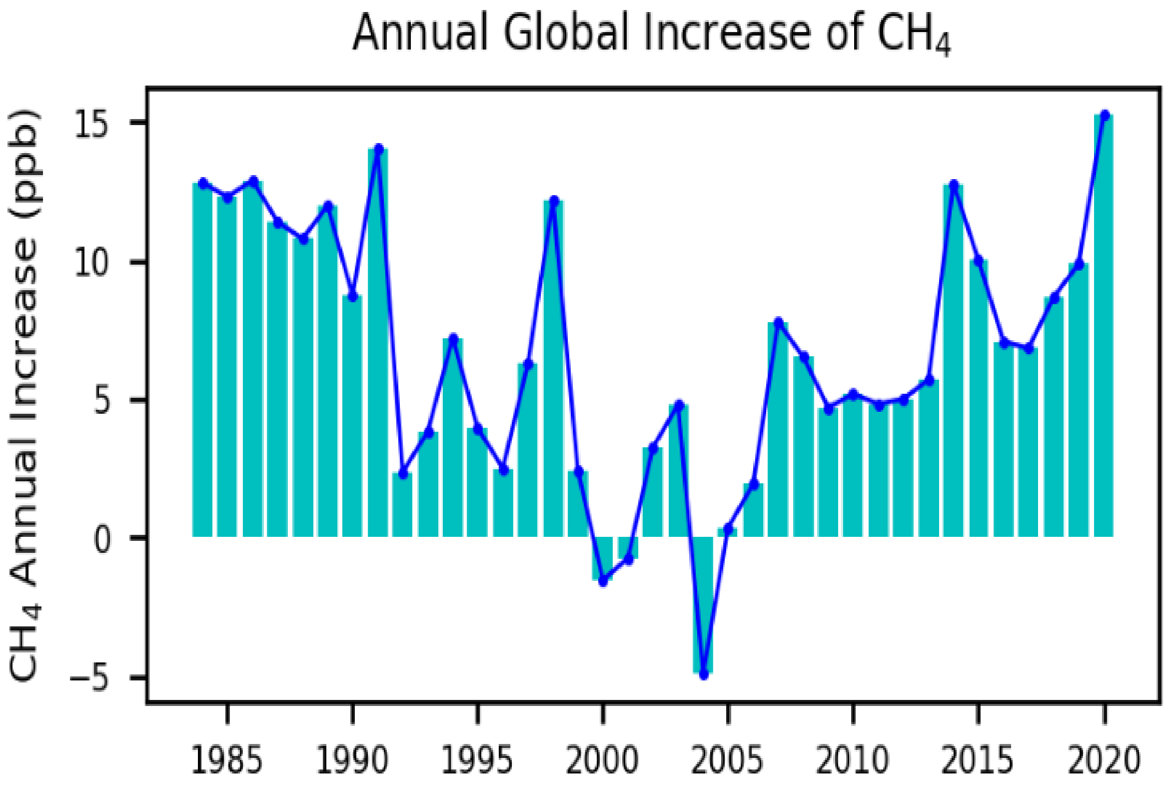


IPCC AR5

Global methane concentration

What is driving the increase of methane concentration and its variability?





Methane emissions

Multiple sources

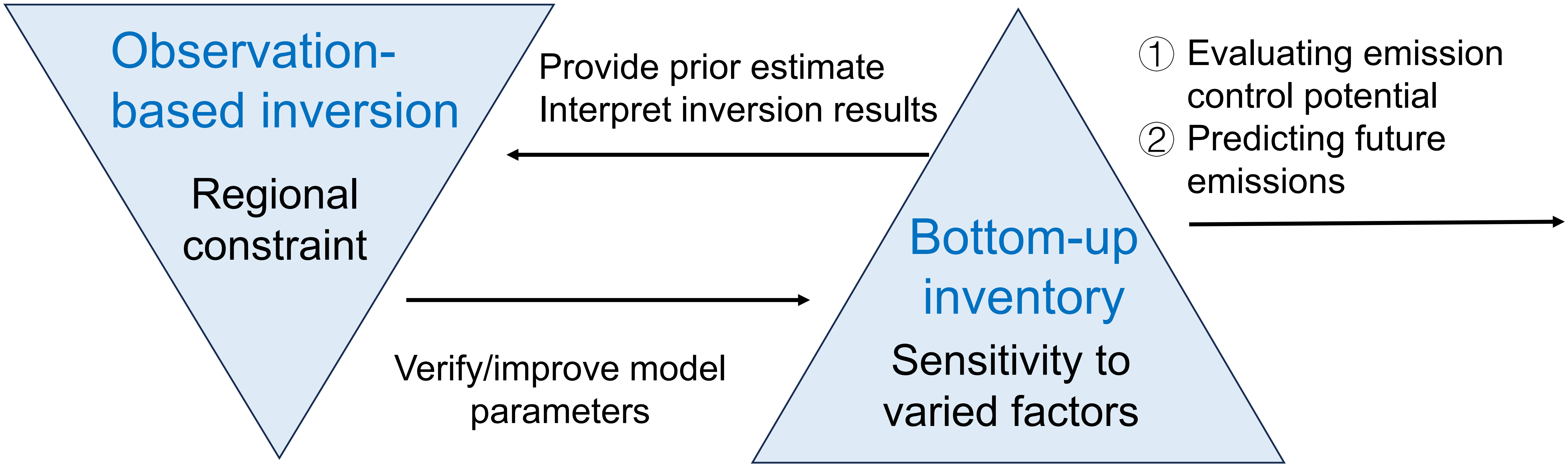
Energy transition
Food security
Waste treatment

Bottom-up estimate

Super emitters
Highly heterogeneous
Complex dependence on environment

Top-down approach using atmospheric observations

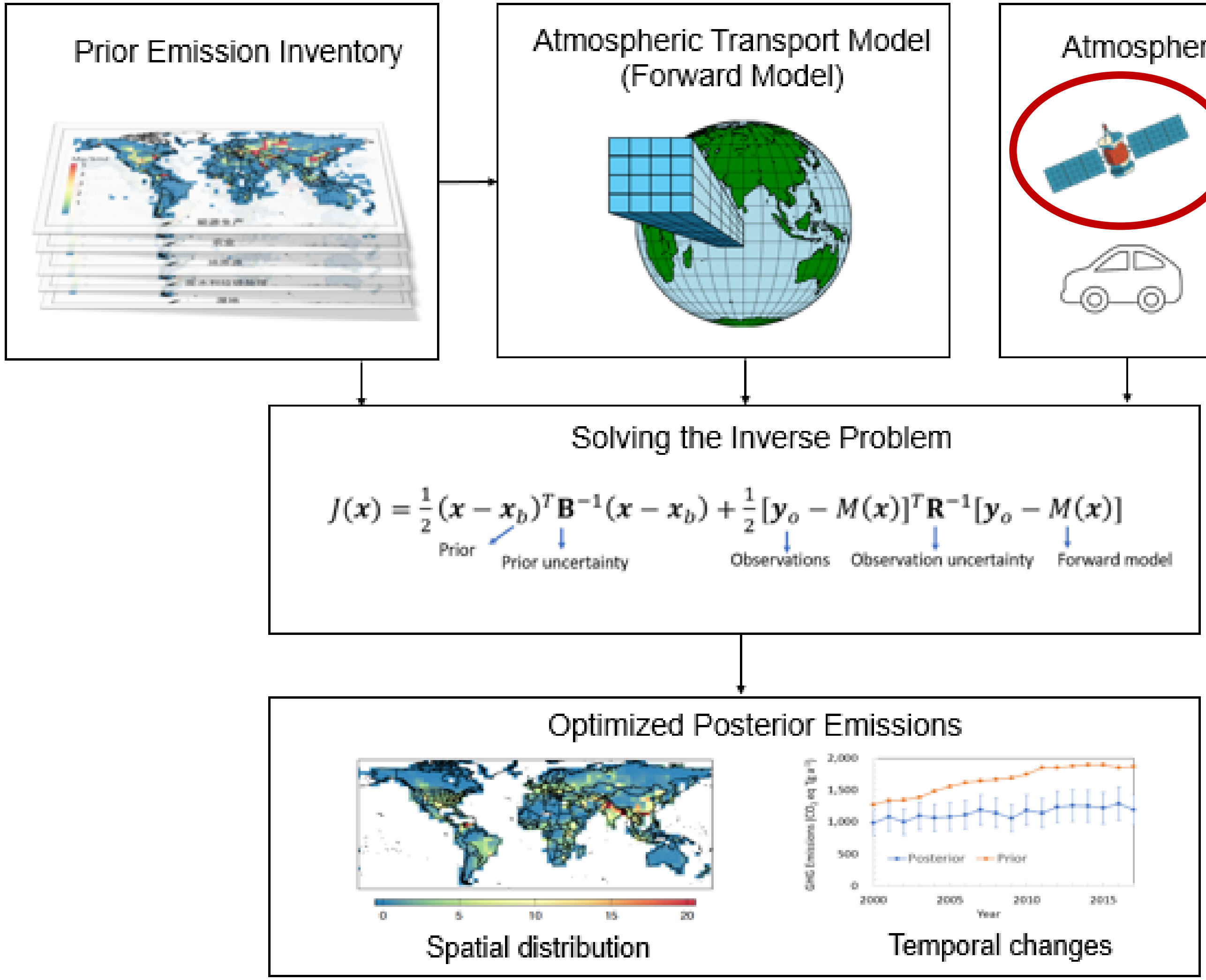
Research framework: bottom-up modeling + observation



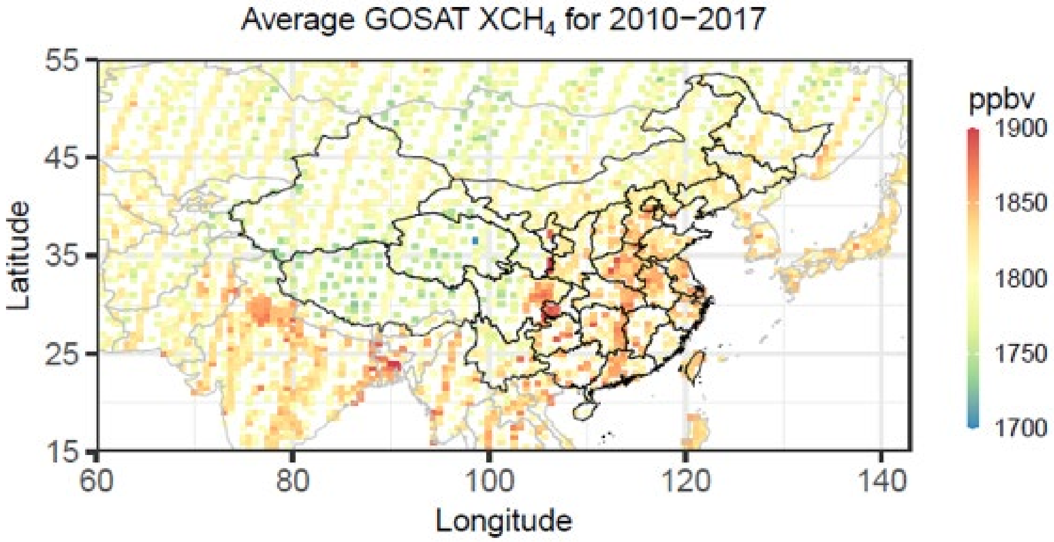
Environmental factors: T, precipitation
Human factors: water and fertilizer management

Estimating emissions from atmospheric observations

Inverse Modeling of GHG Atmospheric Observations



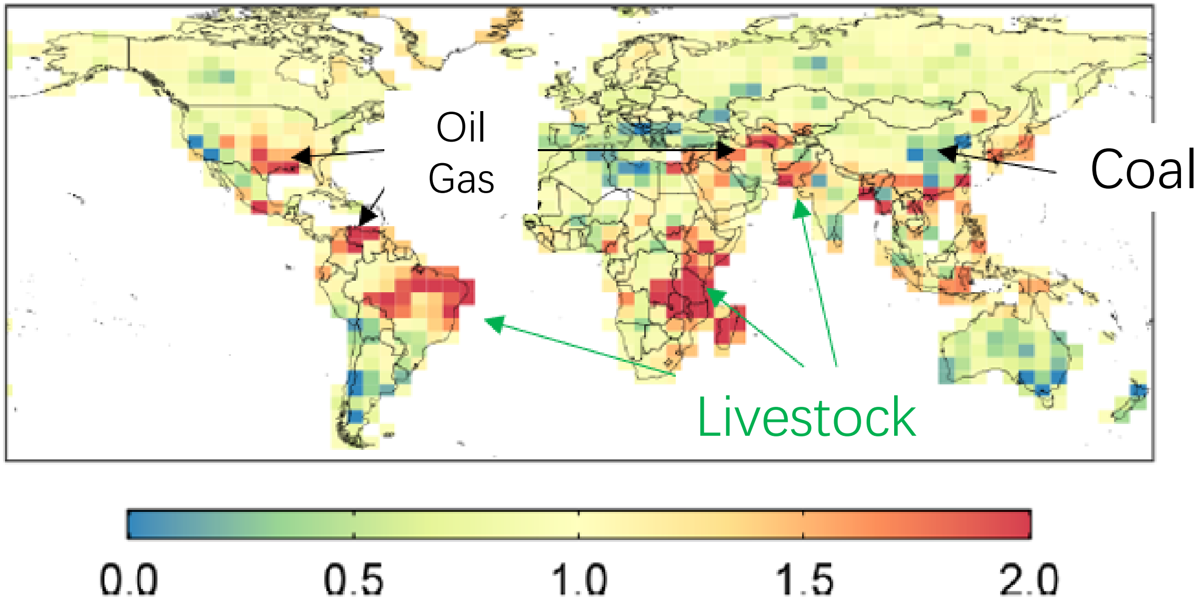
GOSAT retrieval from University of Leicester



Global methane emissions 2010-2018

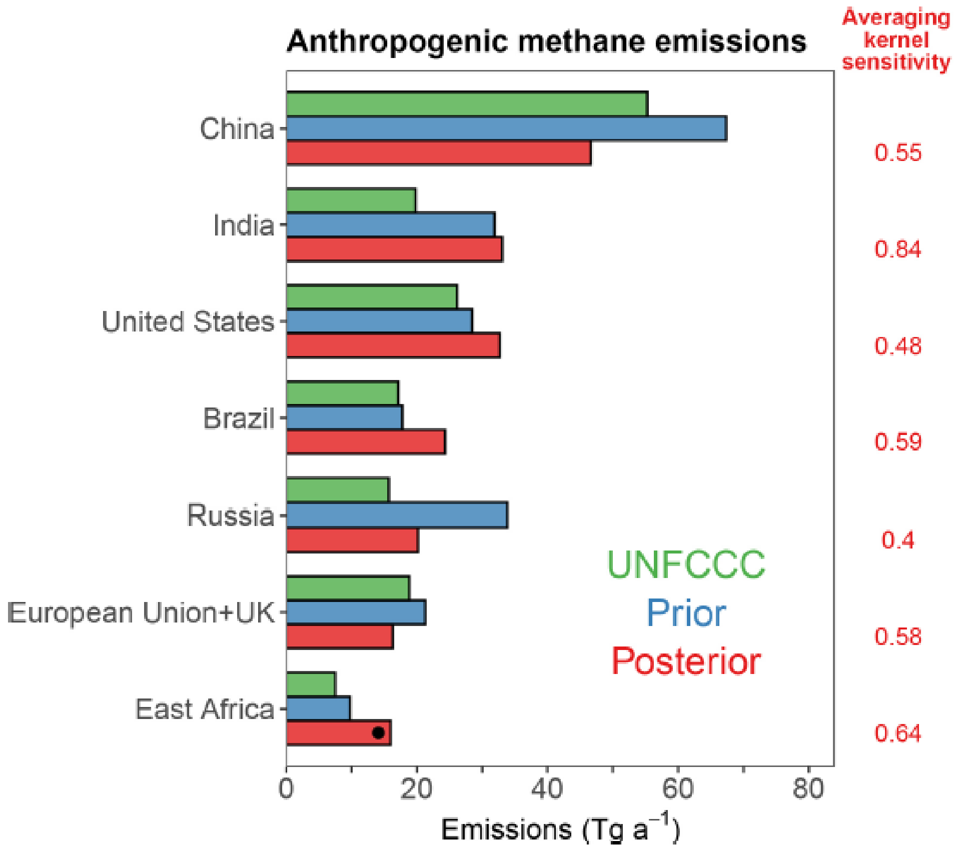
Emissions inferred from GOSAT satellite observations

Posterior / prior scaling factor



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

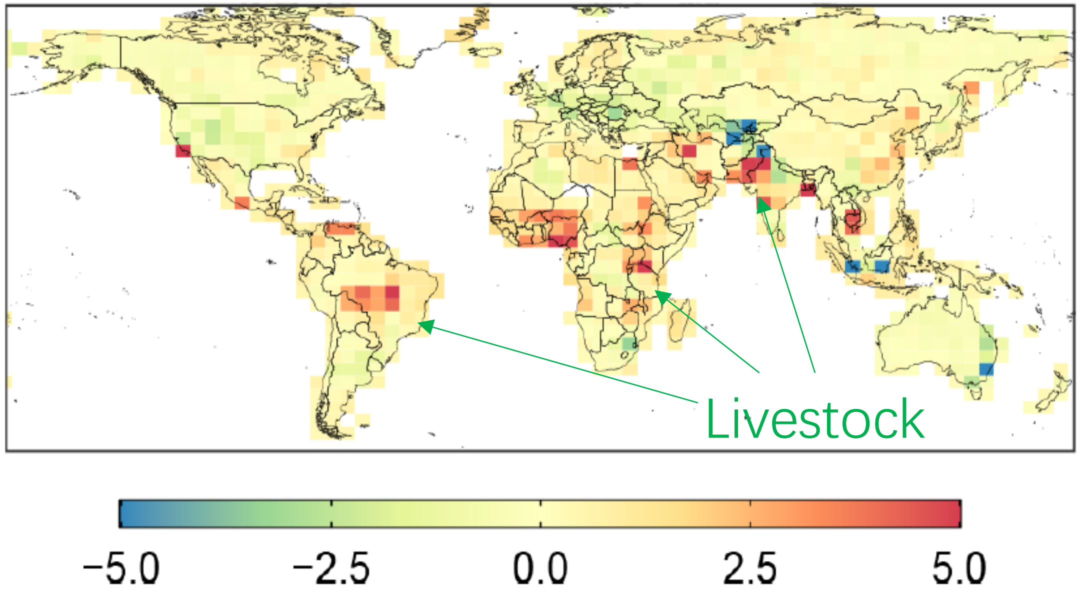
Verifying national inventory



Which sector dominates the increase in emissions?

Emissions inferred from GOSAT satellite observations

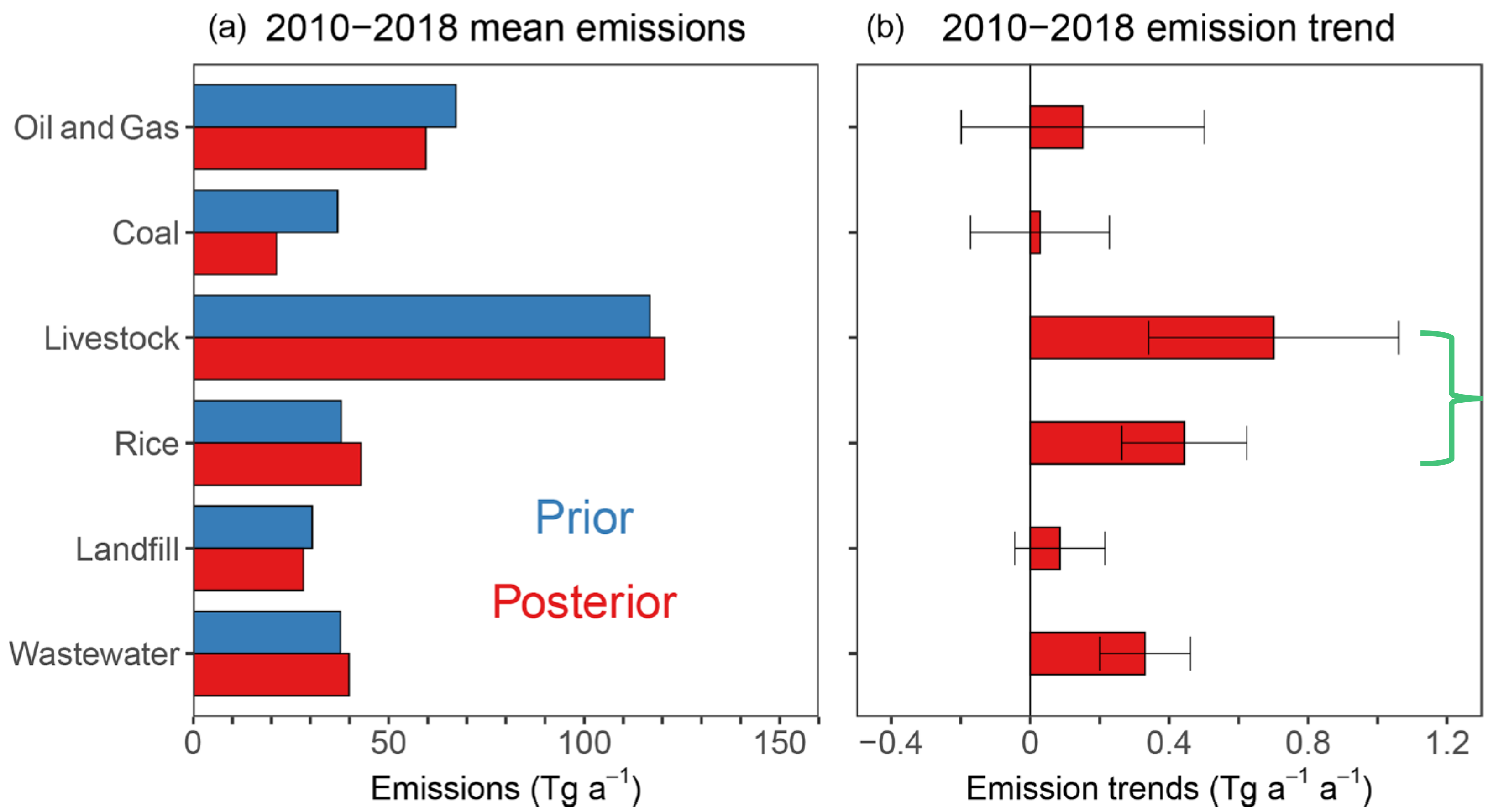
Growth rate of anthrop. emissions （%）



Countries with the fastest growing livestock population （UNFAO)

Country	Trend (million head per year)
Pakistan	1.4
Ethiopia	1.2
Tanzania	1.1
Brazil	0.9
Argentina	0.7

Sector attribution of emission trend

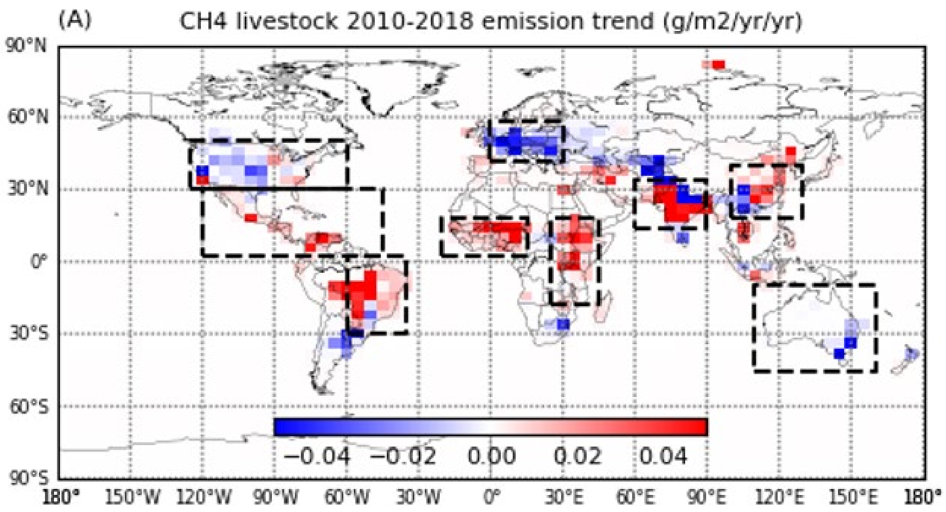


Agricultural system key driver for anthropogenic increase

Satellite analysis of multiple species

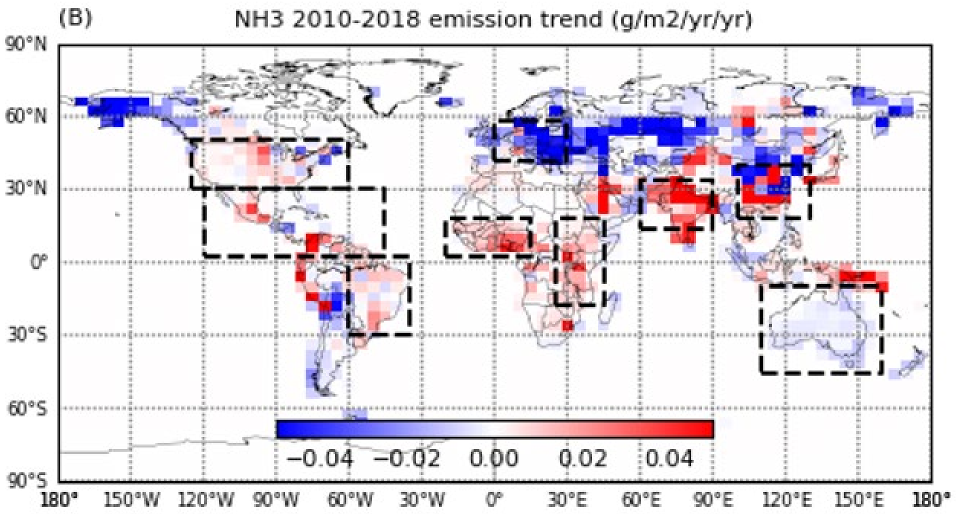
Livestock sector emits both methane and NH3

GOSAT livestock methane trend



Zhang et al., *ACP*,2021

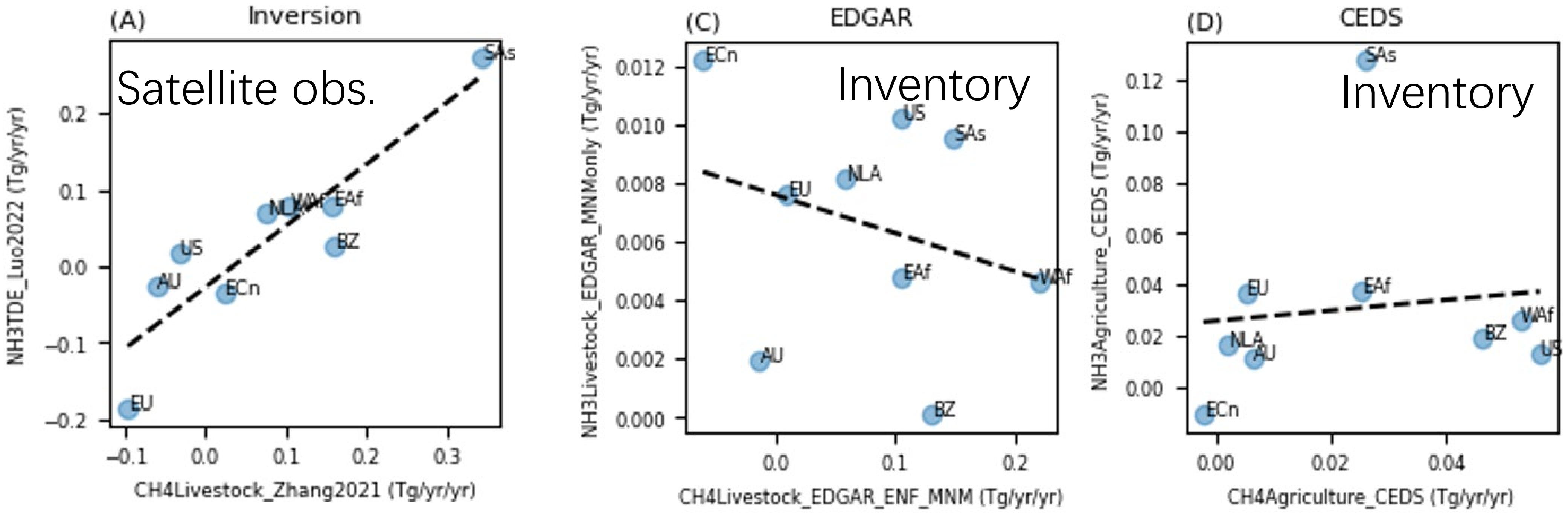
IASI NH3 emission trend



Luo et al., *ACP*,2022

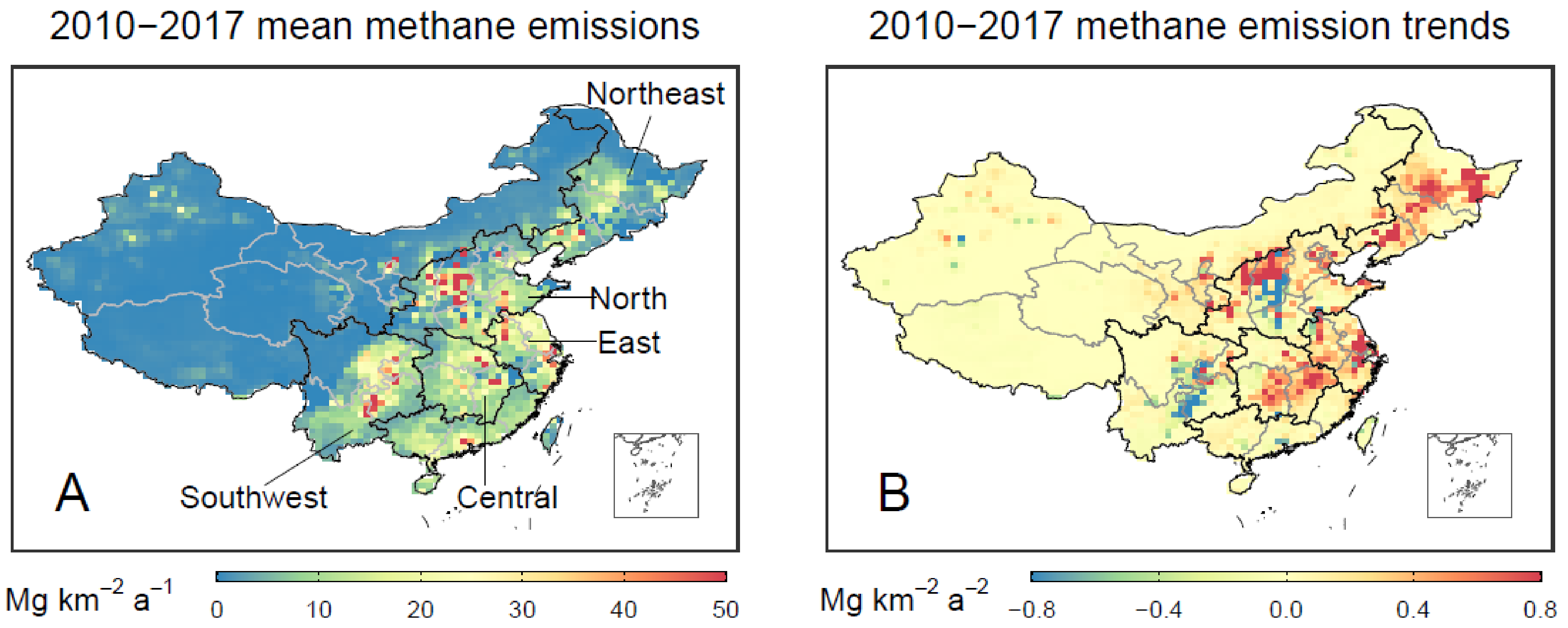
Global livestock emission trend – shown in methane and NH_3

Bottom-up inventory cannot capture the observed correlation between CH4 and NH3



Tang et al., in prep

China's methane emissions



- Data repository: Optimized monthly emission fluxes on 0.5x0.6 grid (2010-2017)

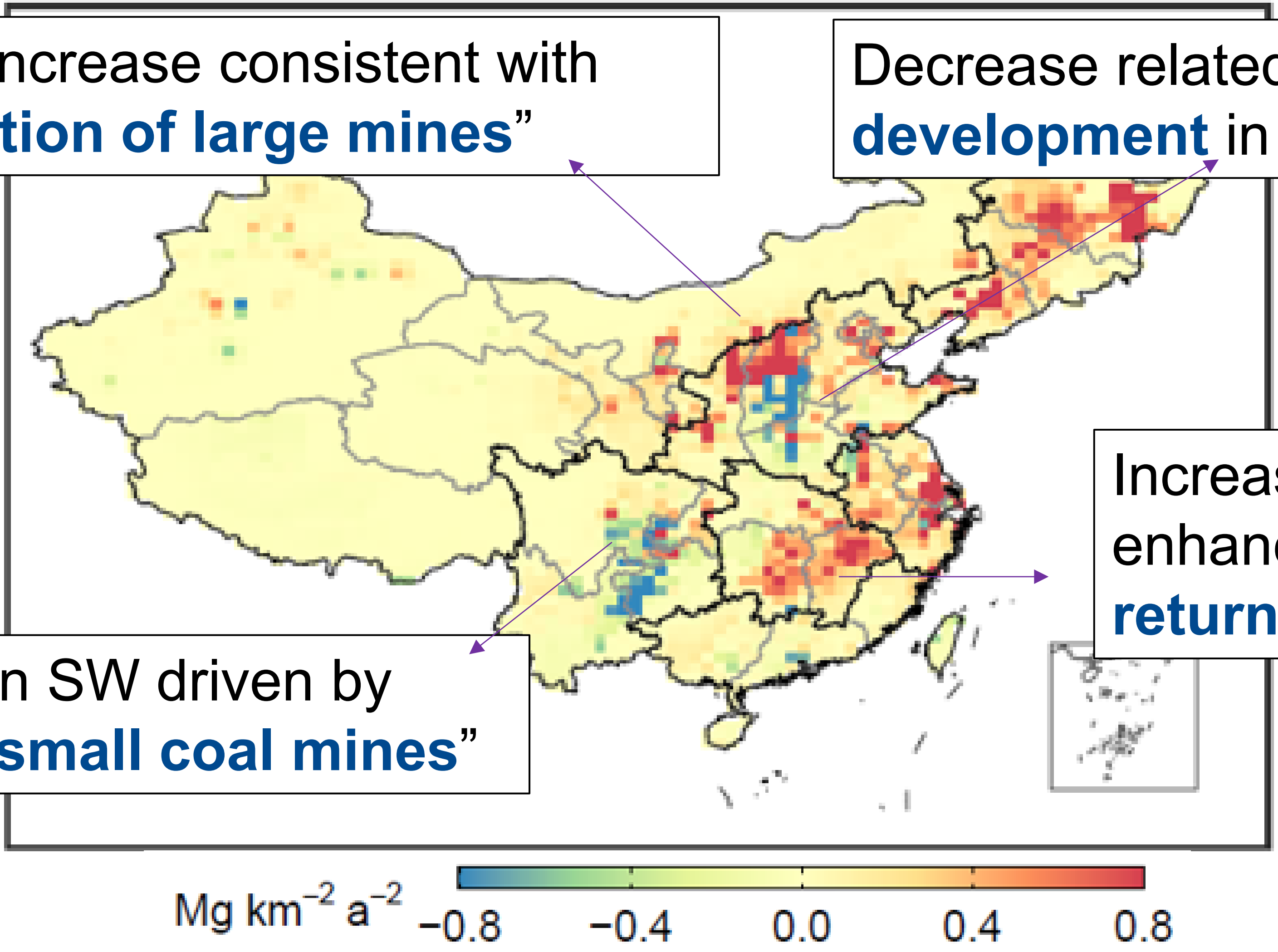
https://doi.org/10.57760/sciencedb.02269 Zhang et al., PNAS, 2022

Observed regional emission trends linked to energy, agricultural, environmental policy

2010-2017 methane trend

Sustained increase consistent with "**consolidation of large mines**"

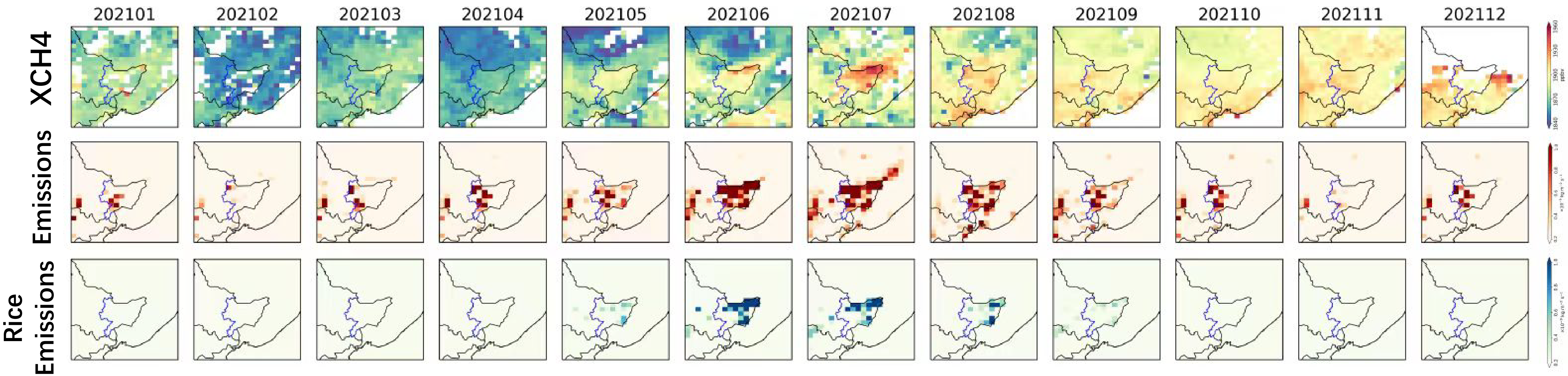
Decrease related to **coalbed methane development** in Qinshui Basin

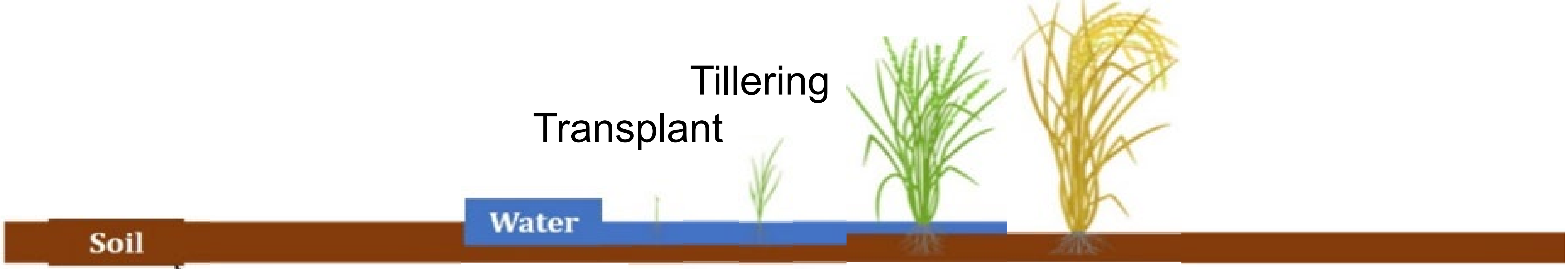


Increase explainable by enhanced **crop residue return**

Decrease in SW driven by "**close off small coal mines**"

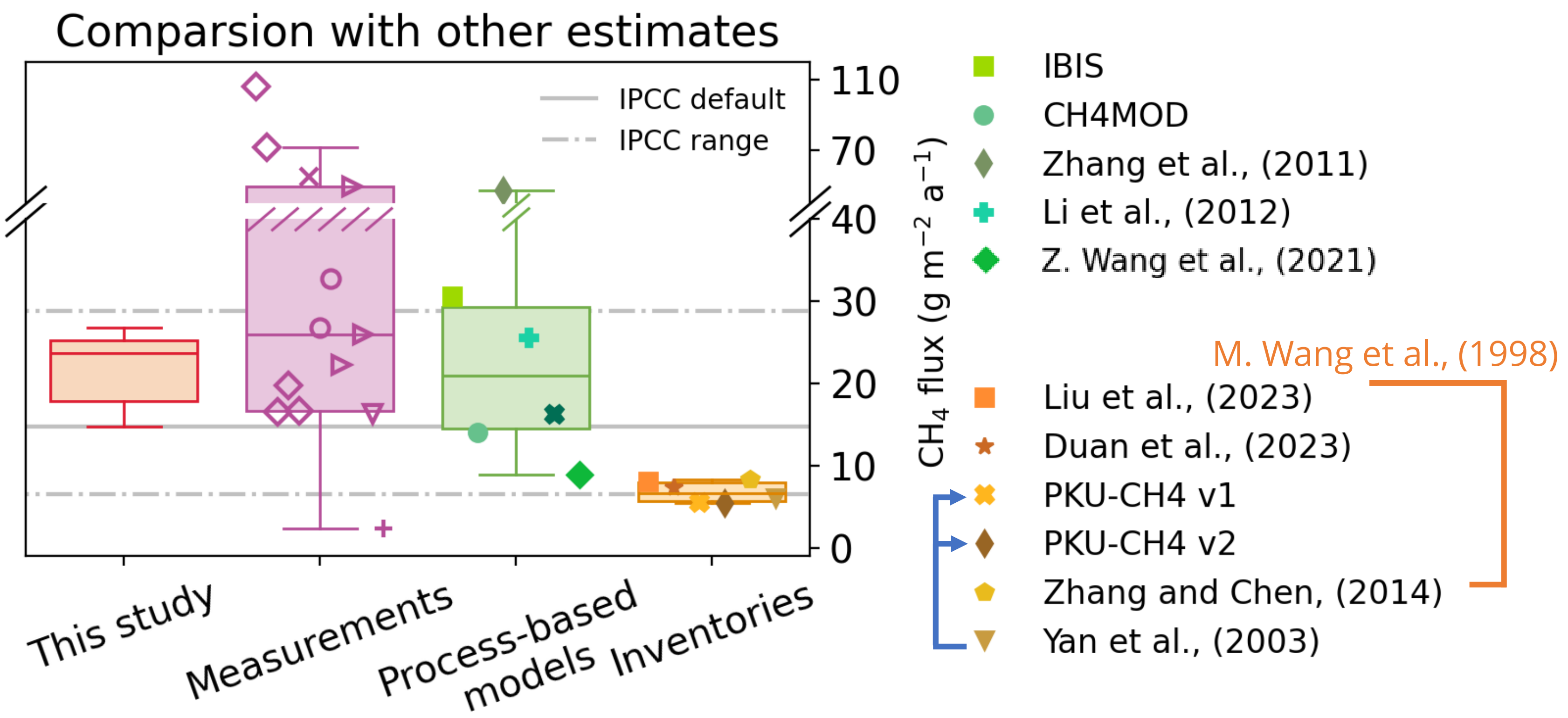
In-depth understanding of key methane sources





Liang et al., ES&T, in press

Reduction of uncertainty in regional rice methane emissions

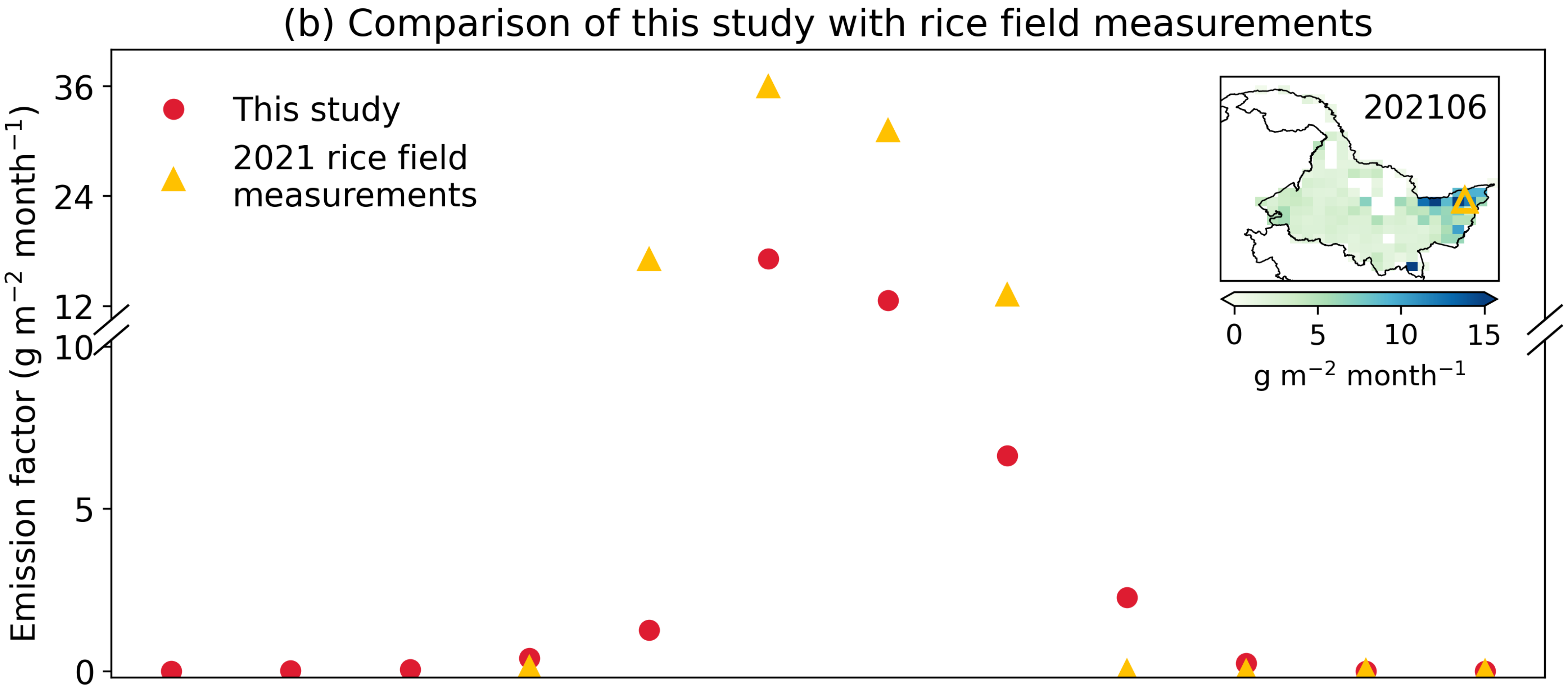


Annual averaged emission factor: 23.0 (14.7 – 26.9) g m^{-2} a^{-1}: Compatible with IPCC default, measurements and process models with **reduced uncertainty**

Emission factors used in global/national inventories based on sparse and outdated data (Yan et al, 2003; M. Wang et al., 1998)

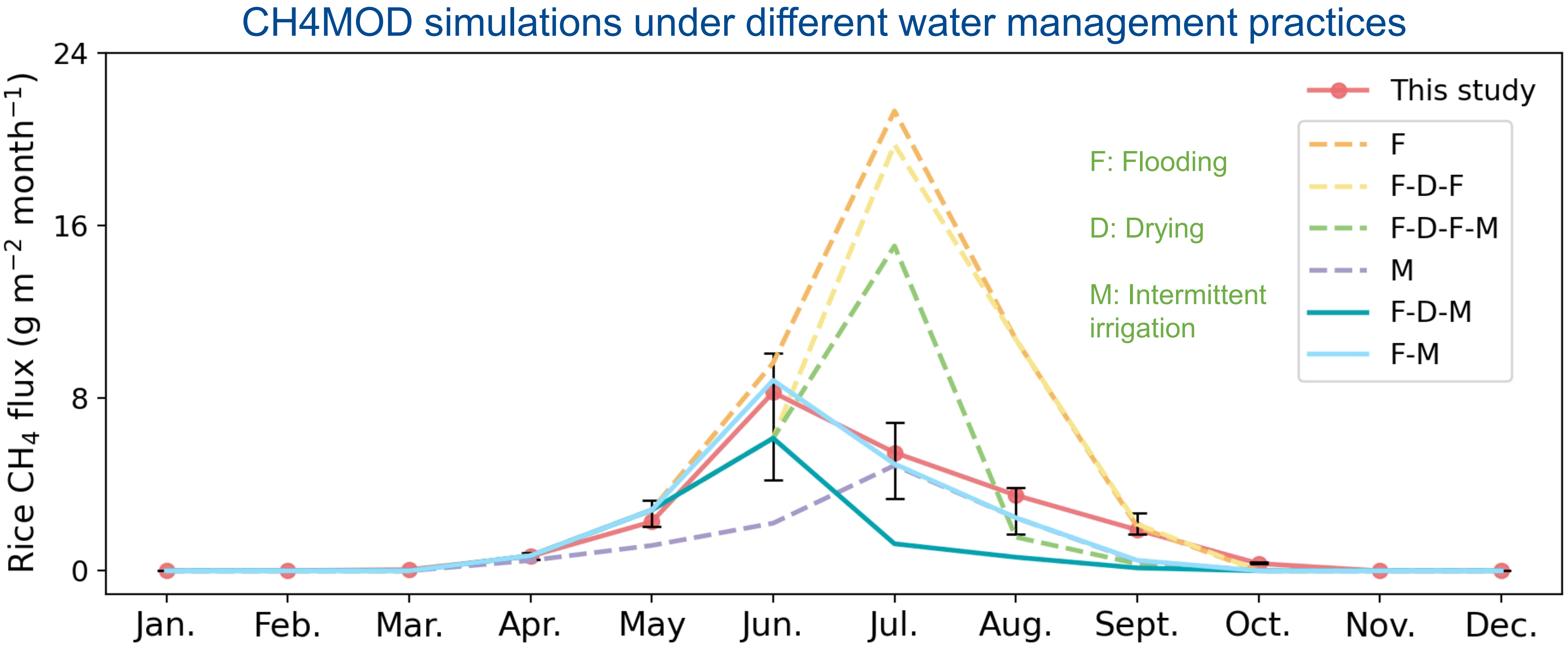
Verification of key parameters for process-based modeling

Infer regional water management mode based on seasonality



Wenping Yuan (PKU), Shihua Li (SYU)

Water management controls emission magnitude and seasonality



Liang et al., ES&T, in press

In collaboration with Qiwen Hu (SYU), Tingting Li (CAS)

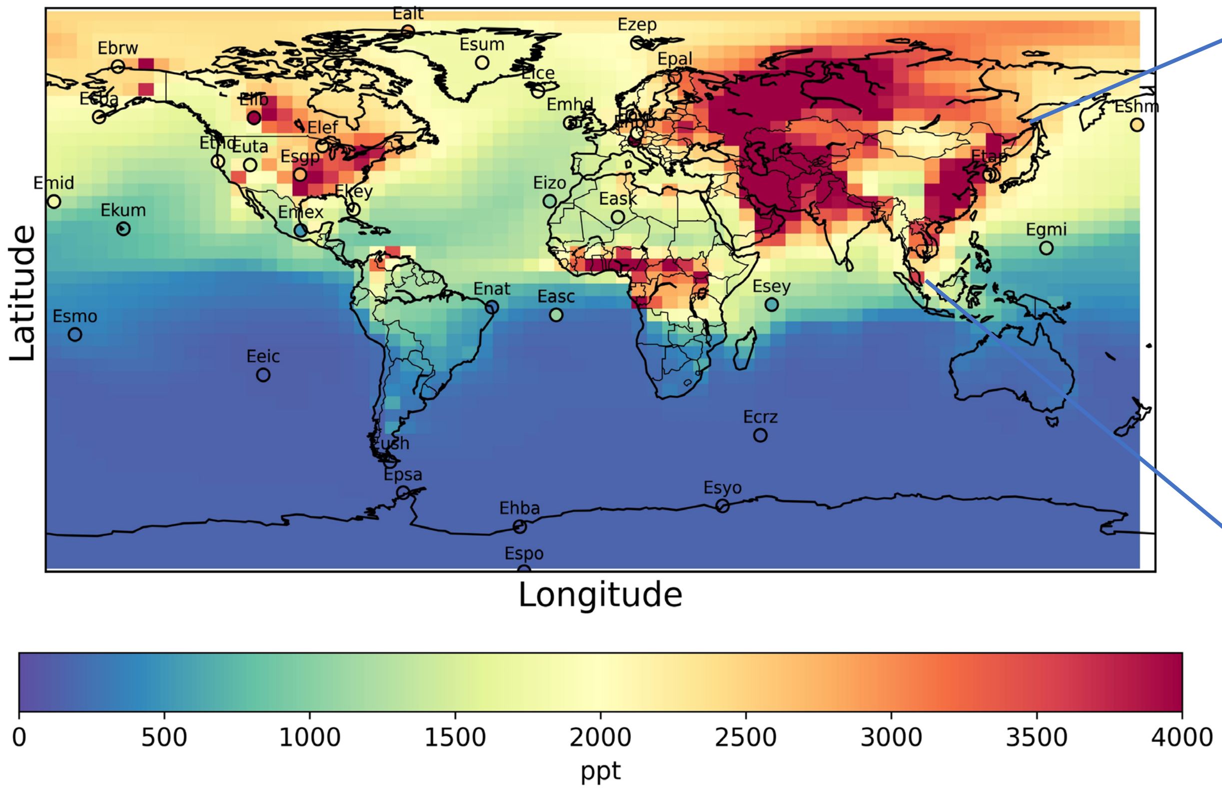
How to distinguish contributions of different urban sources?

	CH_4 source	C_2H_6 source
Fossil fuel exploitation	√	√ (Usually away from cities)
Natural gas end use	√	√
Rice cultivation	√	
Landfills	√	
Wastewater	√	
Biomass burning	√	√ (less in cities)
Livestock	√	

Joint CH_4-C_2H_6-$^{13}CH_4$ simulation

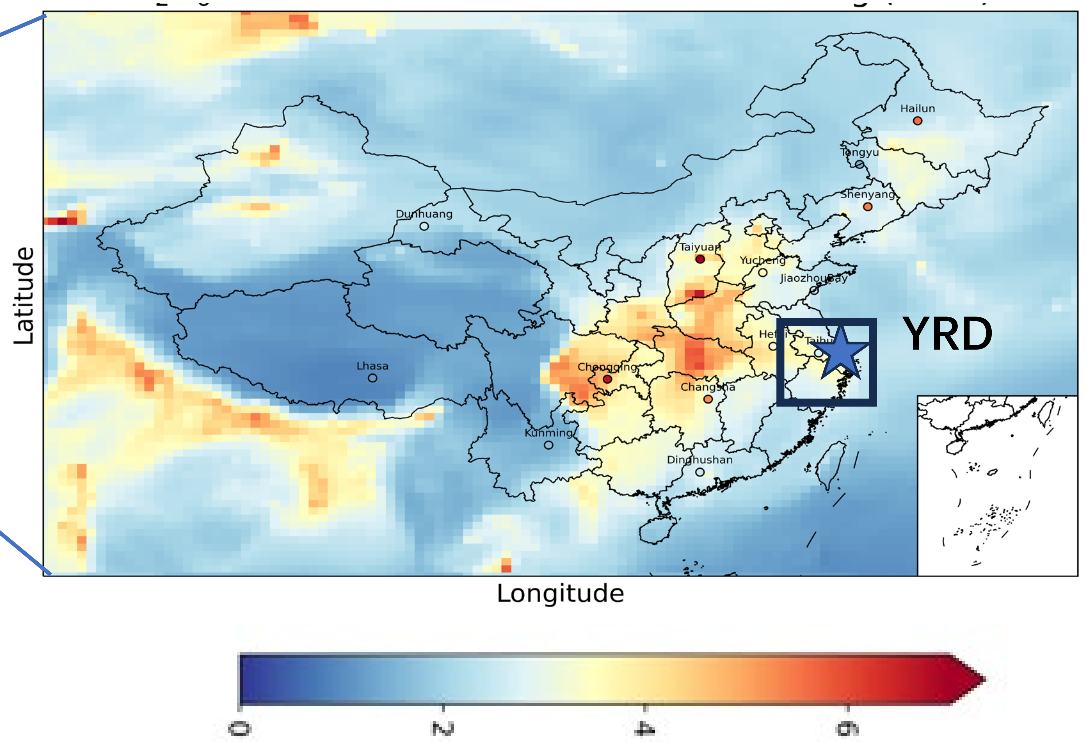
Hypothesis: Increase in methane emissions over YRD driven by natural gas consumption

Global 4x5 simulation (201201)



MB: 0.12 ppb RMSE: 1.17 ppb

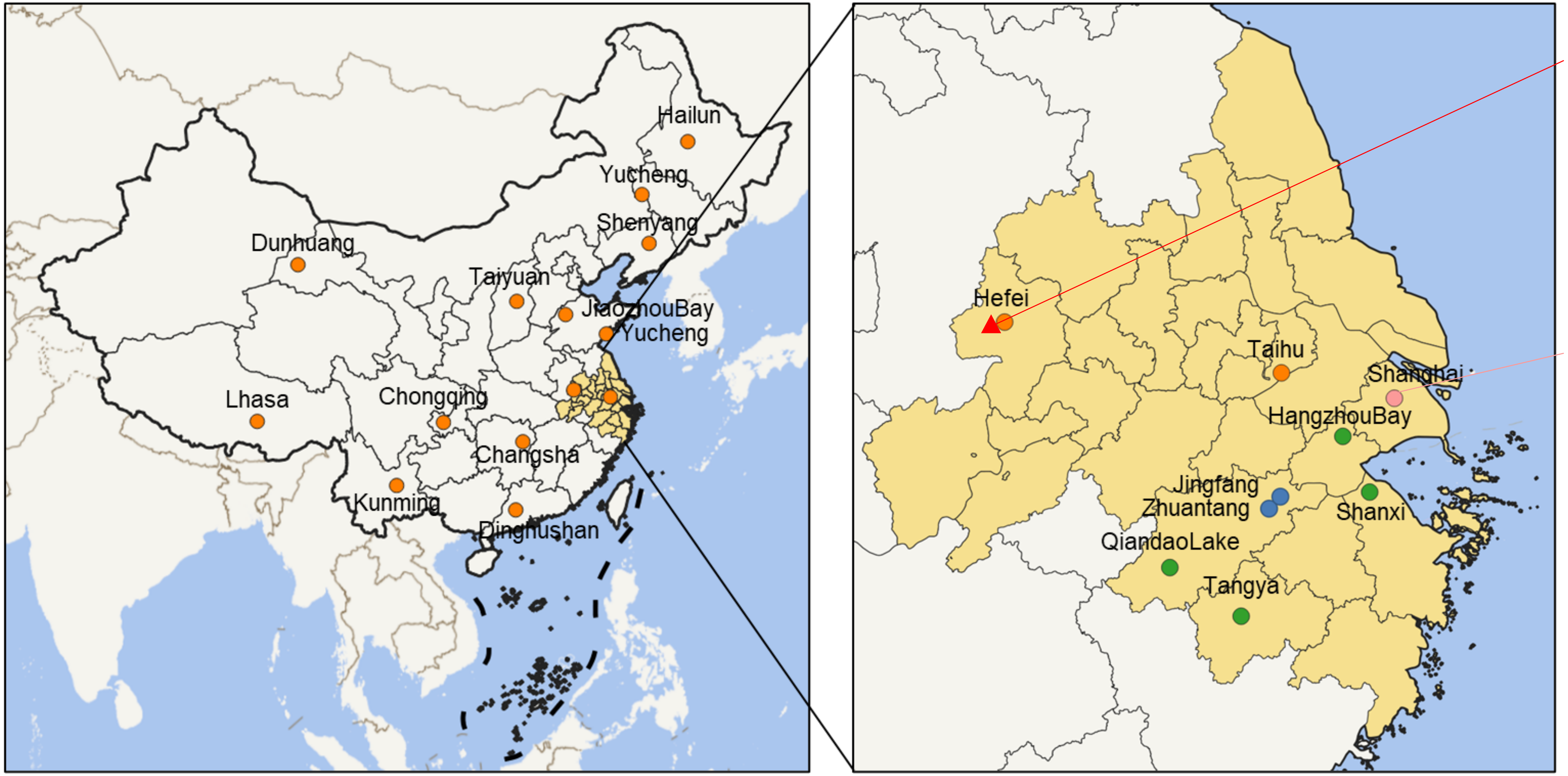
Nested 0.5x0.625 simulation (2012 heating season)



MB: 0.59 ppb RMSE: 1.15 ppb

In collaboration with Yanli Zhang

Atmospheric ethane observations



2015-2022
中科大
(remote sensing)

2012-2013
广州地化所

2011-2019
上海环科院

2016-2020
浙江监测站/浙大

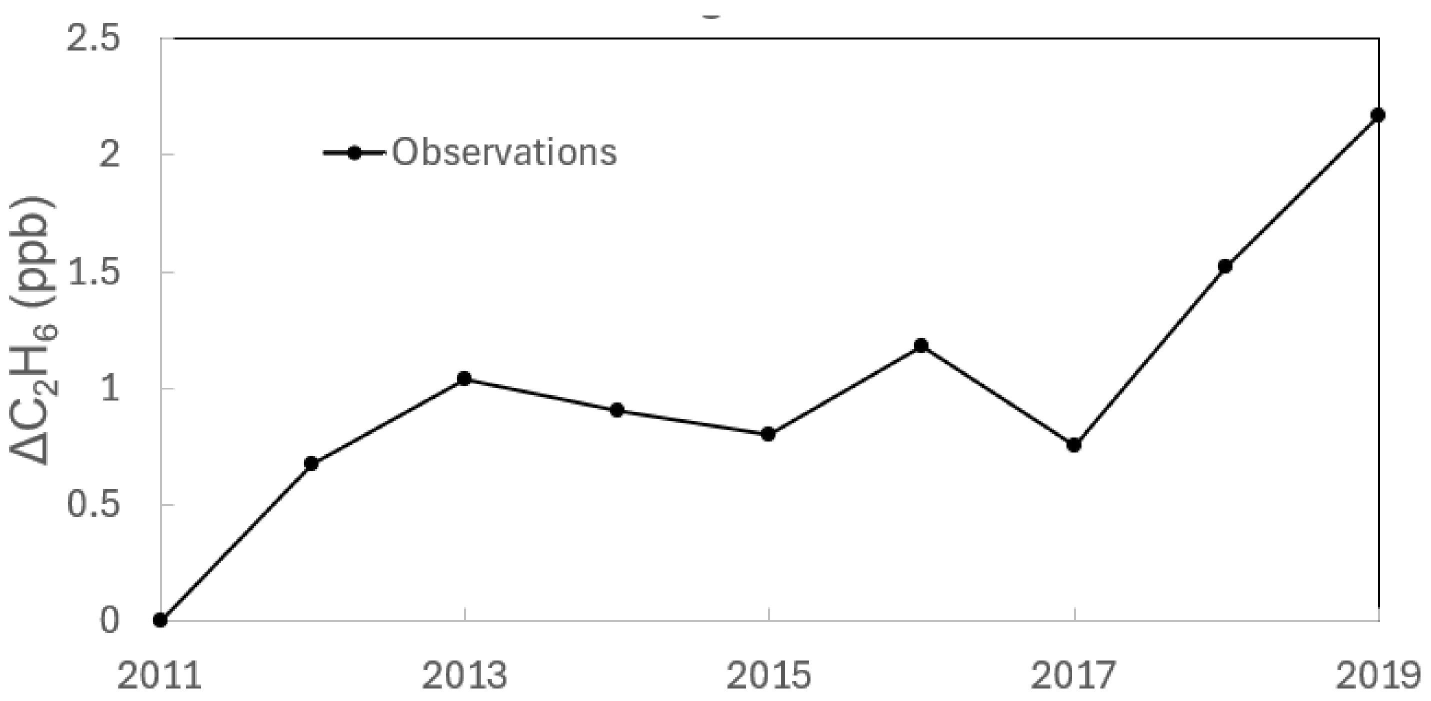
2022
杭州监测站

Increase in urban C_2H_6 concentrations

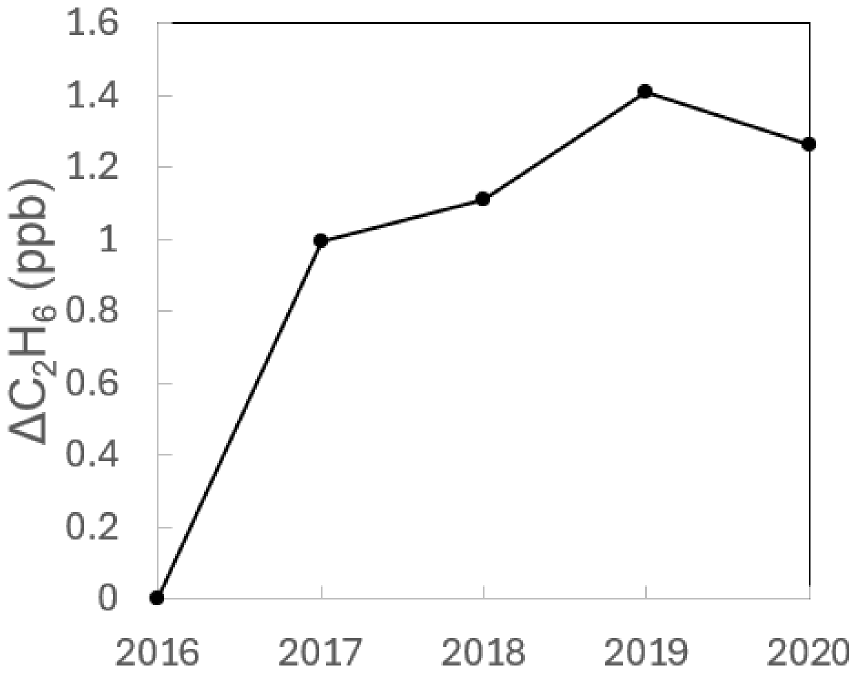
Preliminary

In collaboration with Cheng Huang (Shanghai), Zhenning Xu (Hangzhou)

Shanghai (cold season average)



Hangzhou (cold season average)



The trend is best matched with **4% leakage rate** from NG consumption

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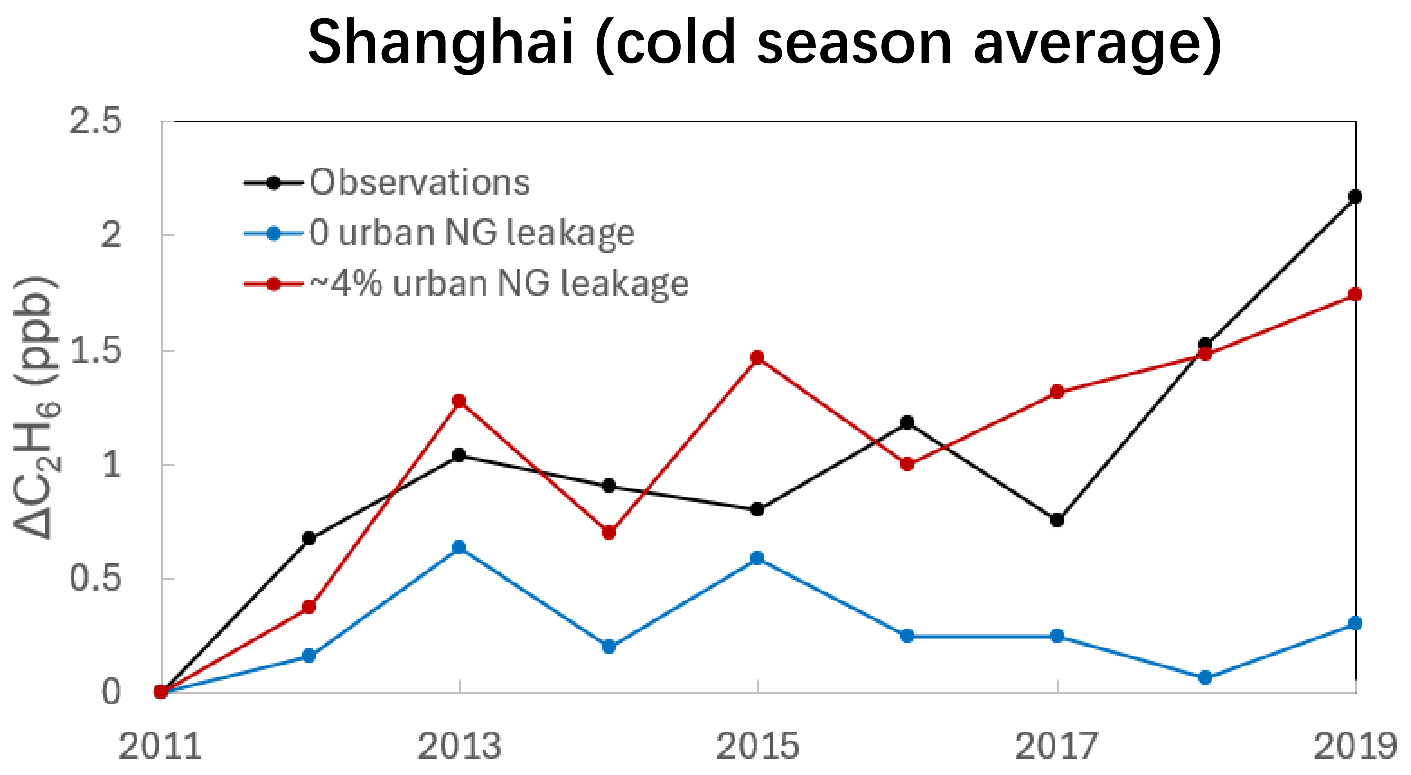

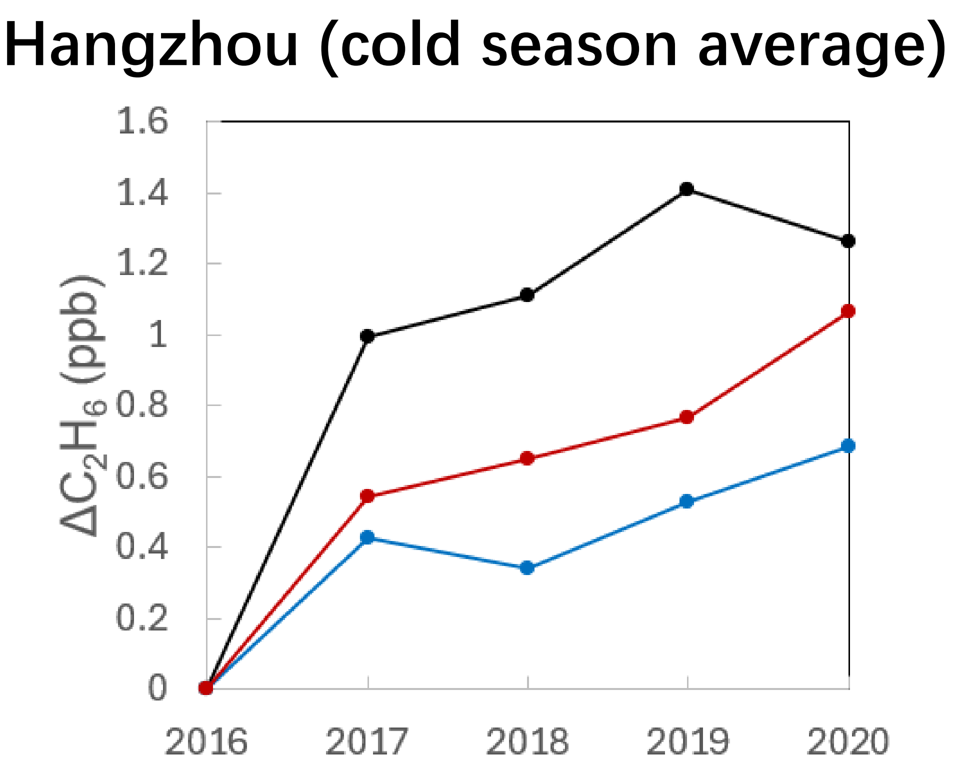

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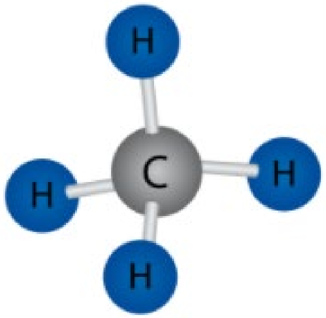

Summary

- Satellite methane observations are useful for quantifying global and regional methane emissions.
- Combining methane with other species, such as NH_3 (livestock) and ethane (natural gas) are helpful for source attribution.
- Combining observation-based inversion with process-based modeling provides insight into key factors controlling methane emissions