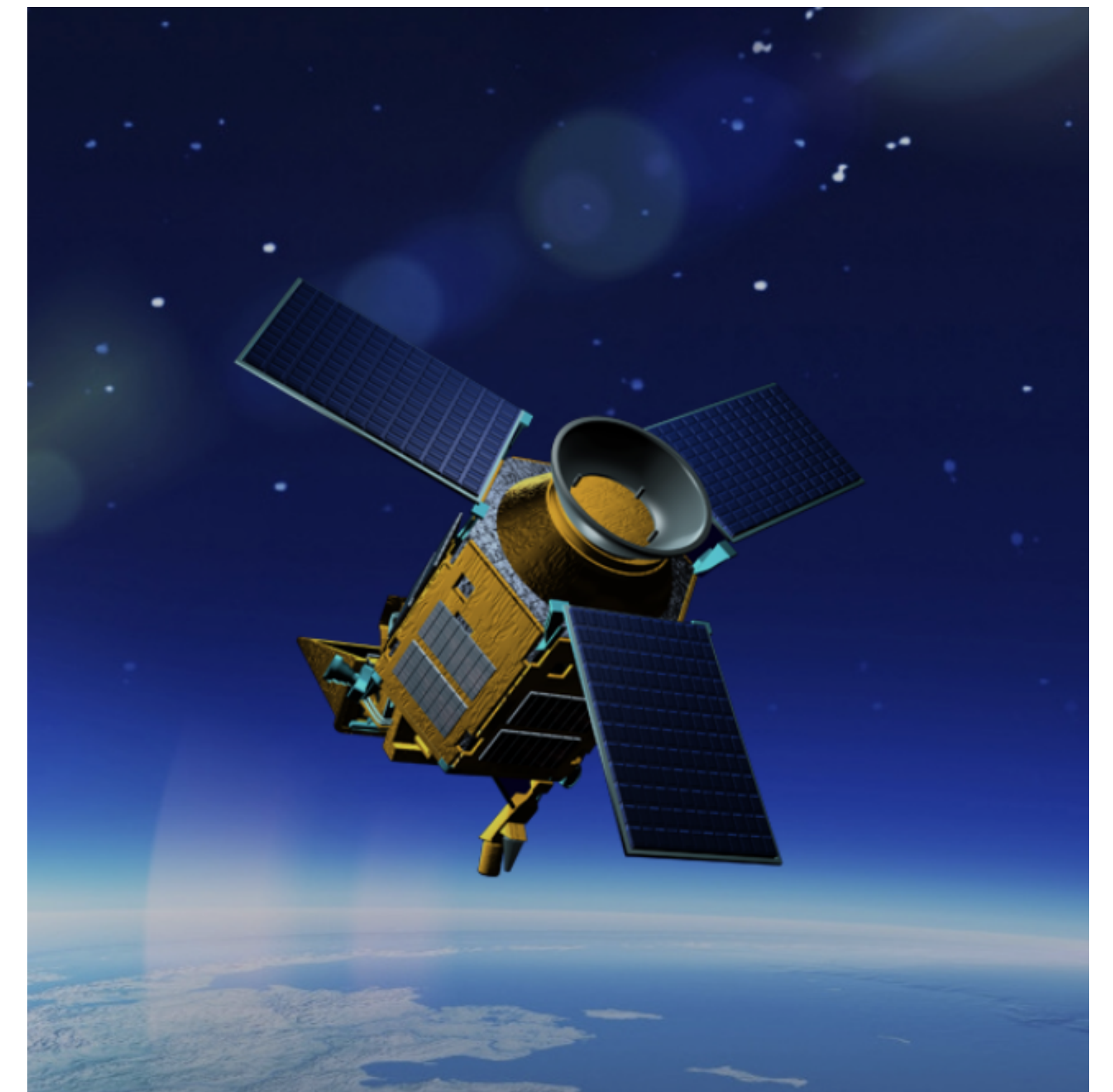


U.S. O&G Methane Emissions: Trends and Policy Impact

Ao Chen, **William Daniels**, and Scot Miller
Johns Hopkins University

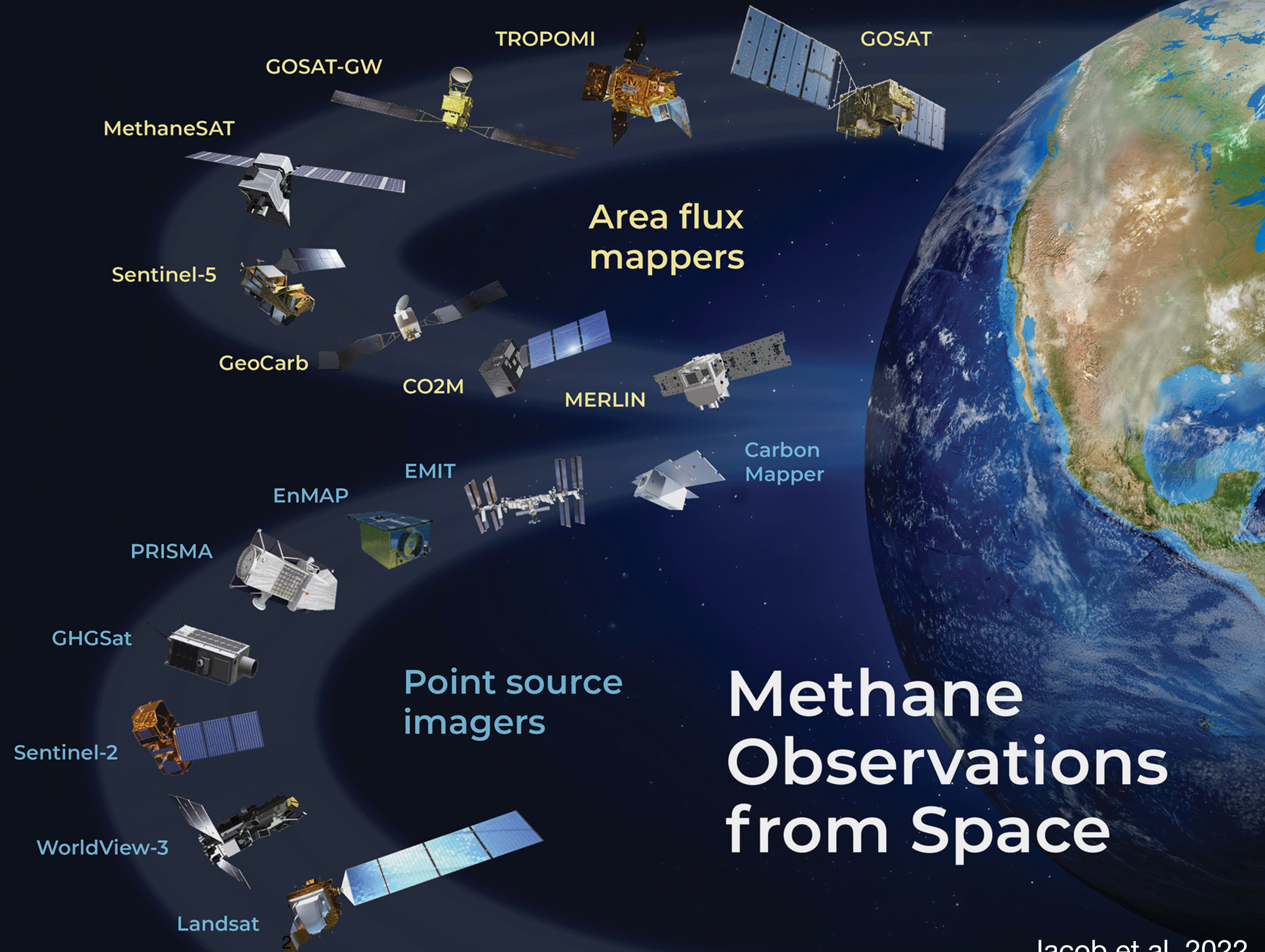
with many great collaborators from UT Austin, McGill University,
Institute of Tibetan Plateau Research, University of Rochester,
State University of New York at Albany, and Stanford!

Energy Emissions Modeling and Data Lab (EEMDL) Annual Meeting
Session on Methane Detection from Space
October 15, 2026



Current instruments for observing methane from space

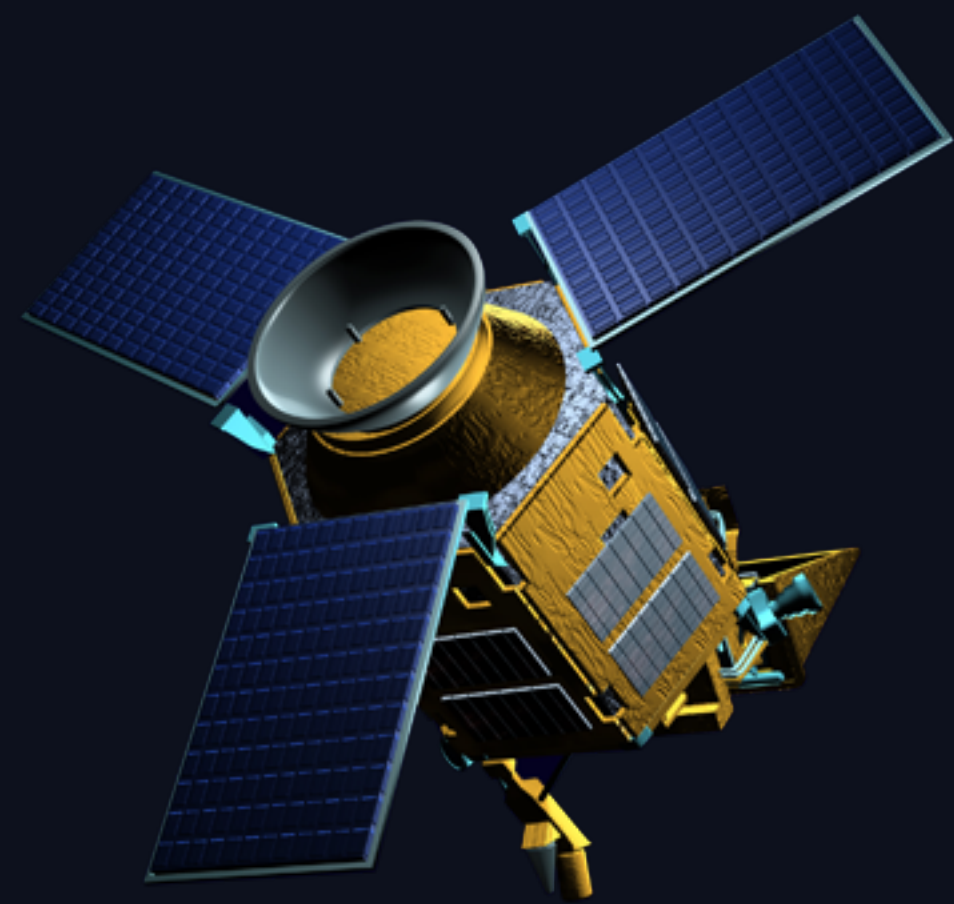
With this talk, we are
shifting gears from
point source imagers
to area flux mappers



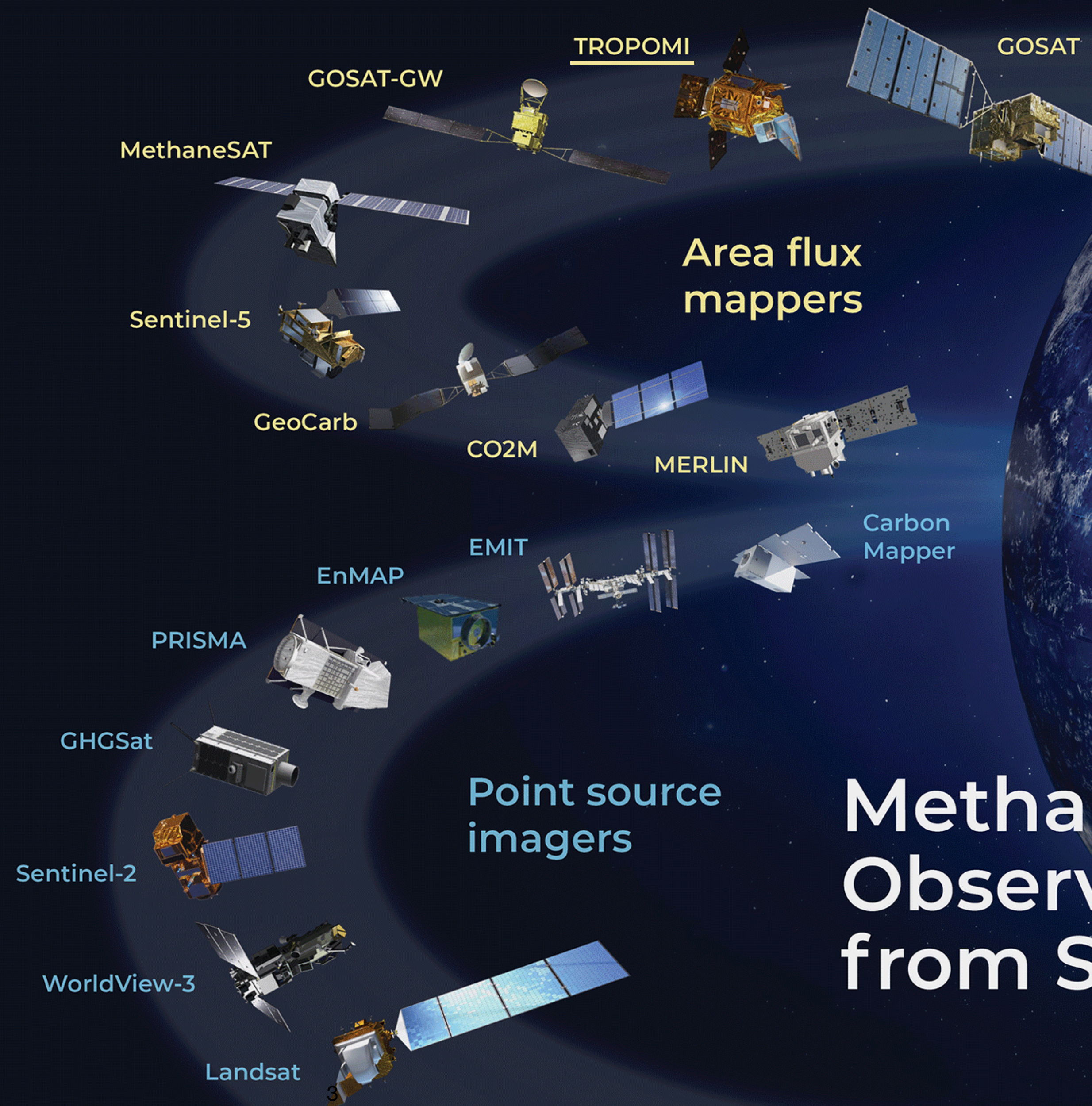
Methane Observations from Space

Current instruments for observing methane from space

With this talk, we are shifting gears from point source imagers to area flux mappers



TROPOMI
(2019 - present)



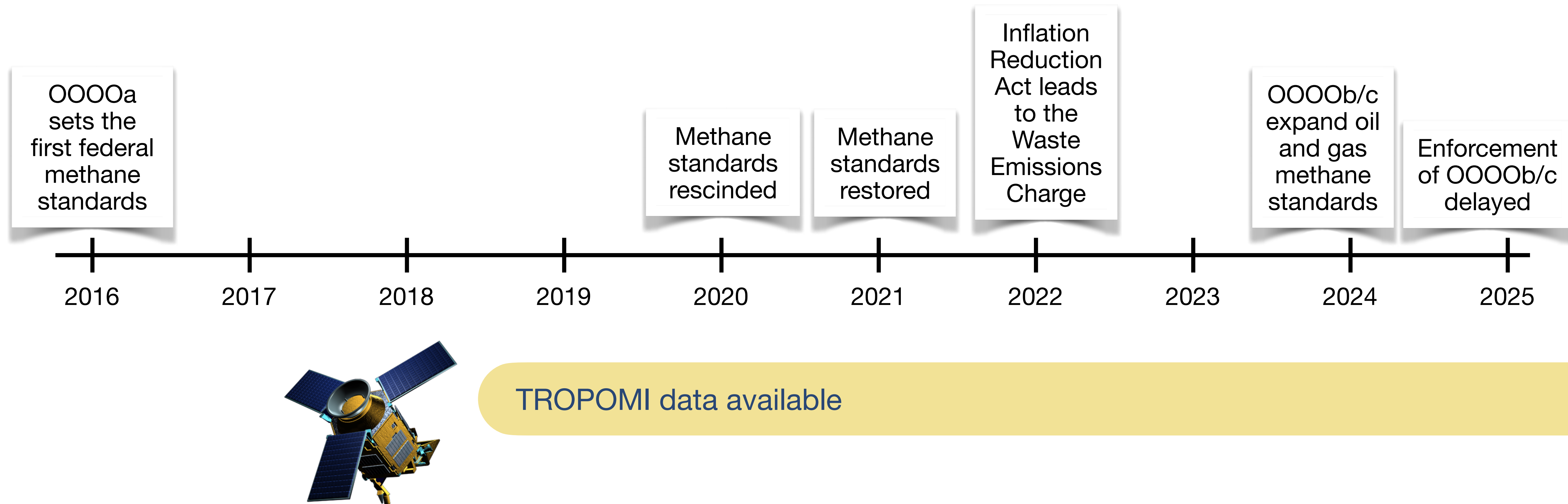
Methane
Observations
from Space

Our research questions:

1. What were O&G methane emissions from 2019 to 2024, both at the federal and state-level? What were the year-over-year trends?
2. Do the data suggest any emissions impact from federal and state-level policies?

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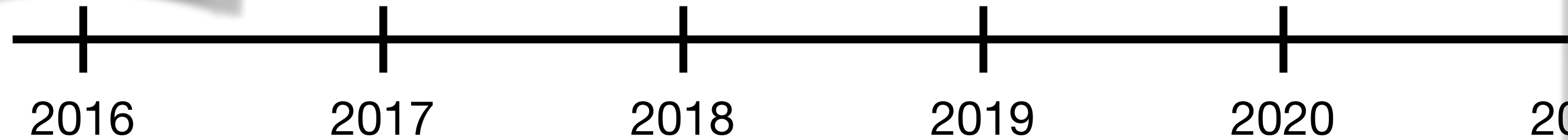
1. What were O&G methane emissions from 2019 to 2024, both at the federal and state-level? What were the year-over-year trends?
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Our research questions:

- 1. What were O&G methane emissions from 2019 to 2024, both at the federal and state-level? What were the year-over-year trends?
- 2. Do the data suggest any emissions impact from the COVID-19 pandemic?

OOOOa sets the first federal methane standards



Methane standards rescinded

Me star res

State	Target
United States	The U.S. has agreed to reduce methane emissions by 30% by 2030, compared to 2020 levels, under the Global Methane Pledge (voluntary).
California	By 2030, California aims to reduce methane by 40% compared to 2013 levels, under the SB 1383.
Colorado	Colorado aims to cut greenhouse gas emissions by 26% by 2025, 50% by 2030 and 90% by 2050 from 2005 levels under HB 19-1261.
Connecticut	Connecticut, under Public Act 18-82, targets greenhouse gas emissions reductions of 10% by 2020 (1990 baseline), and 45% by 2030 and 80% by 2050 (2001 baseline).
Delaware	Delaware plans to reduce greenhouse gas emissions, including methane, by 50% by 2030, compared to 2005 levels, under HB 99.
Hawaii	Hawaii plans to achieve net-zero emissions no later than 2045, under HB 2182.
Maine	By 2030, Maine aims to reduce greenhouse gas emissions, including methane, by 45% compared to 2005 levels, under HB 1000.
Maryland	Maryland aims to reduce greenhouse gas emissions, including methane, by 25% by 2020 and 40% by 2030, compared to 2005 levels, under Executive Order 13.
Massachusetts	By 2050, Massachusetts aims to reduce greenhouse gas emissions, including methane, by 85% compared to 1990 levels, under the Global Warming Solutions Act.
Minnesota	Minnesota aims to reduce greenhouse gas emissions, including methane, by 20% by 2025, compared to 2005 levels.
Nevada	Nevada plans to cut greenhouse gas emissions by 25% by 2025, compared to 2005 levels, and by 45% by 2050, under HB 400.
New Jersey	By 2050, New Jersey plans to reduce greenhouse gas emissions, including methane, by 80% compared to 2006 levels, under the Global Warming Solutions Act.
New Mexico	New Mexico aims to reduce greenhouse gas emissions, including methane, by 20% by 2030, compared to 2005 levels, under Executive Order 2019-003.
New York	New York plans to cut greenhouse gas emissions, including methane, by 20% by 2030, compared to 1990 levels, under the Climate Leadership and Community Protection Act.
North Carolina	North Carolina aims to cut greenhouse gas emissions, including methane, by 40% by 2030, compared to 2005 levels under Executive Order 80.
Oregon	Oregon plans to reduce greenhouse gas emissions, including methane, by 10% by 2020, compared to 1990 levels, and by 75% by 2050, under HB 3543.
Rhode Island	By 2020, Rhode Island aims to cut greenhouse gas emissions, including methane, by 10% compared to 1990 levels, and by 45% by 2035, under the Resilient Rhode Island Act of 2014.
Vermont	Vermont plans to reduce greenhouse gas emissions, including methane, by 40% by 2030, compared to 1990 levels, and by 80% by 2050, under HB 688.
Virginia	Virginia aims to achieve net-zero greenhouse gas emissions by 2045, including methane, under SB 94.
Washington	Washington plans to reduce greenhouse gas emissions, including methane, by 45% by 2030, compared to 1990 levels, and by 95% by 2050, under HB 2311.

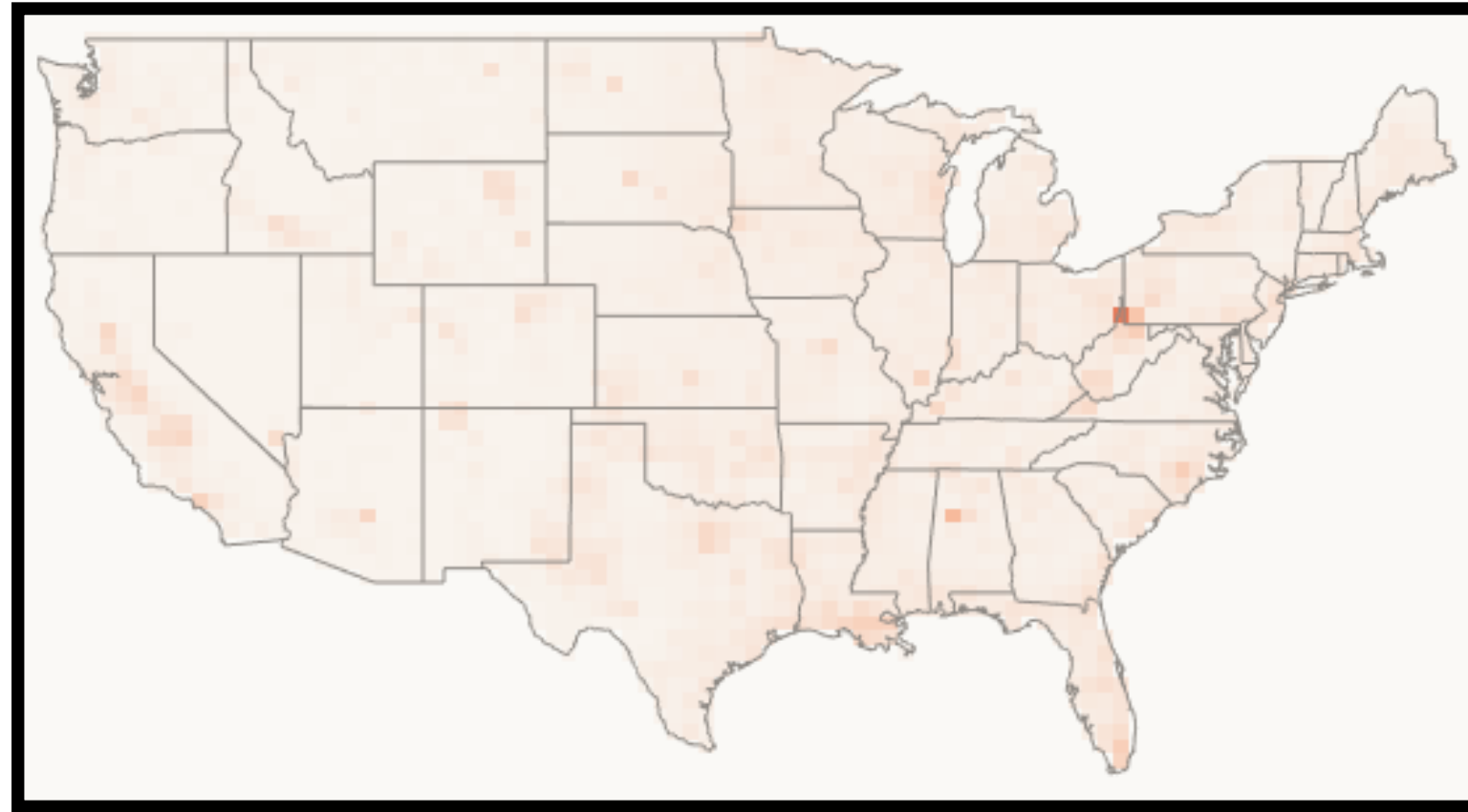
Many different state-level GHG reduction targets

TROPOMI data available

Regional inversions with a geostatistical inverse model

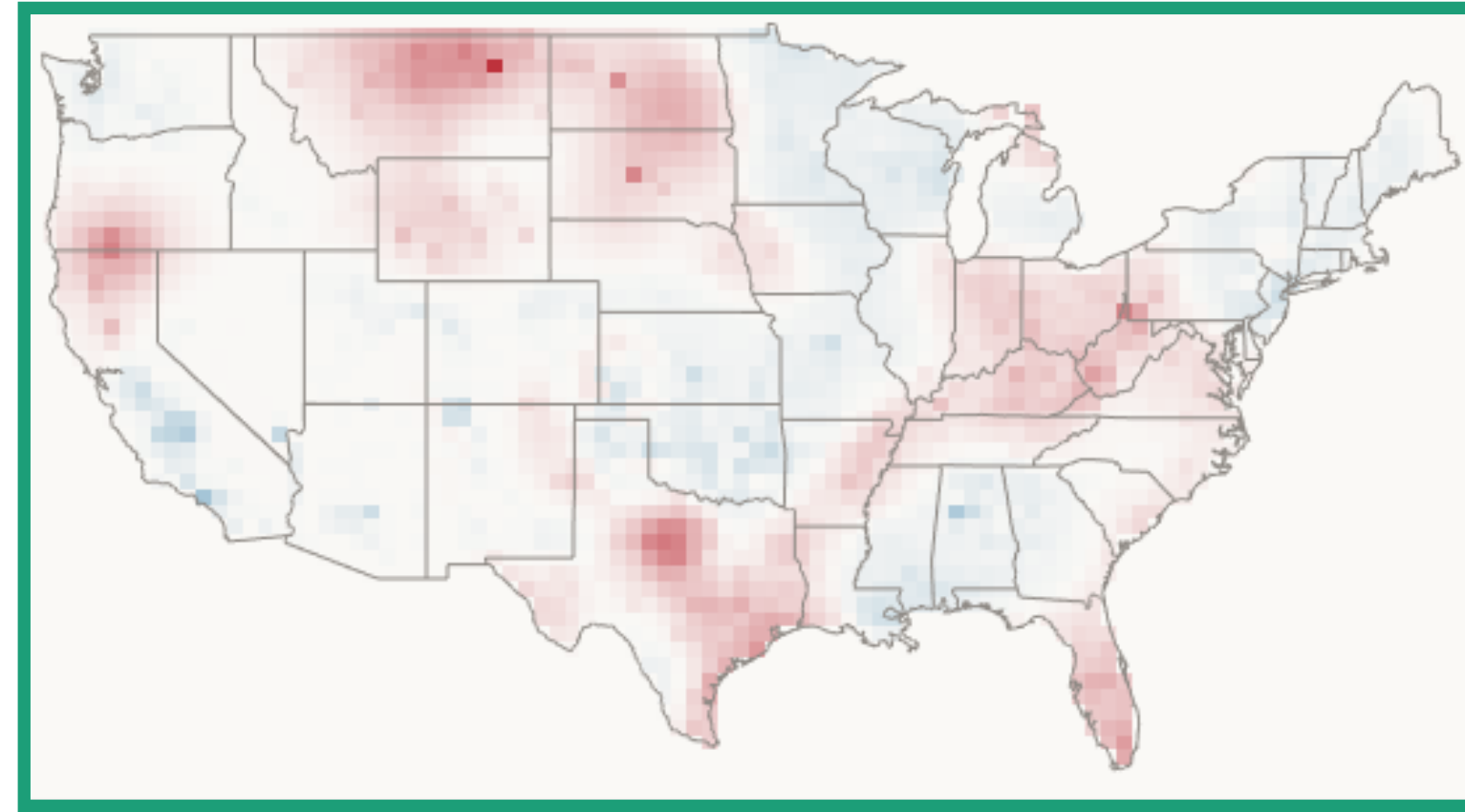
Main idea: use satellite observations to update our prior knowledge of emissions

Prior knowledge, X



EDGAR v8, GHGI, GCP, WetCHARTs

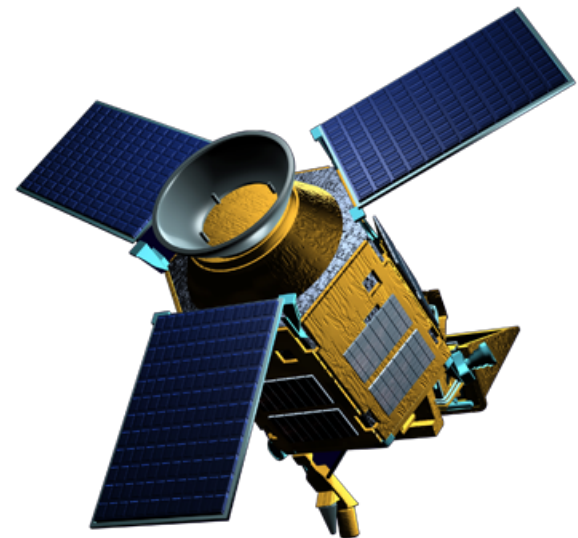
Spatially varying correction, $\zeta \sim N(0, Q)$



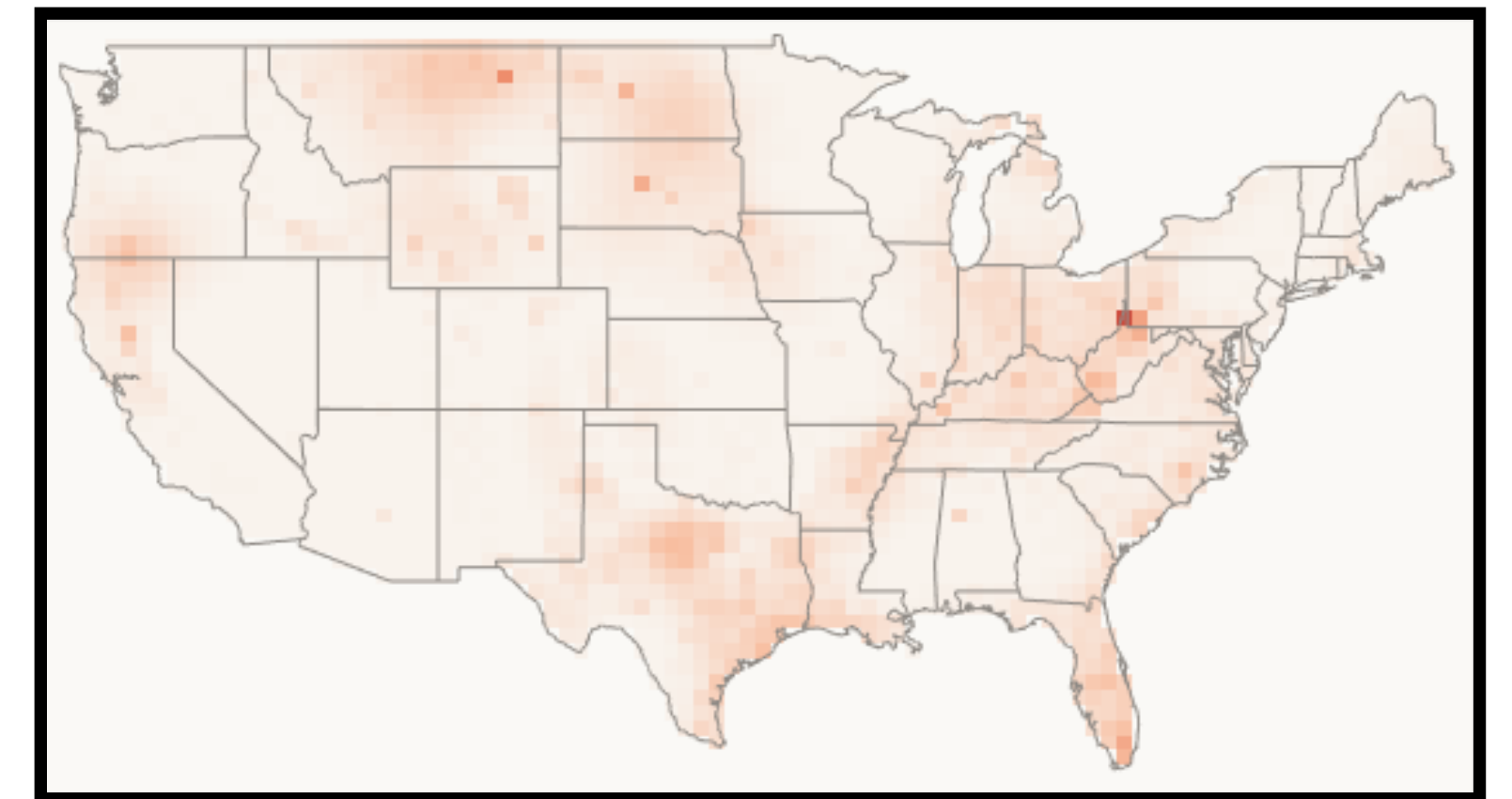
$\times \beta +$

Uniform
correction

TROPOMI data are used
to estimate β and ζ



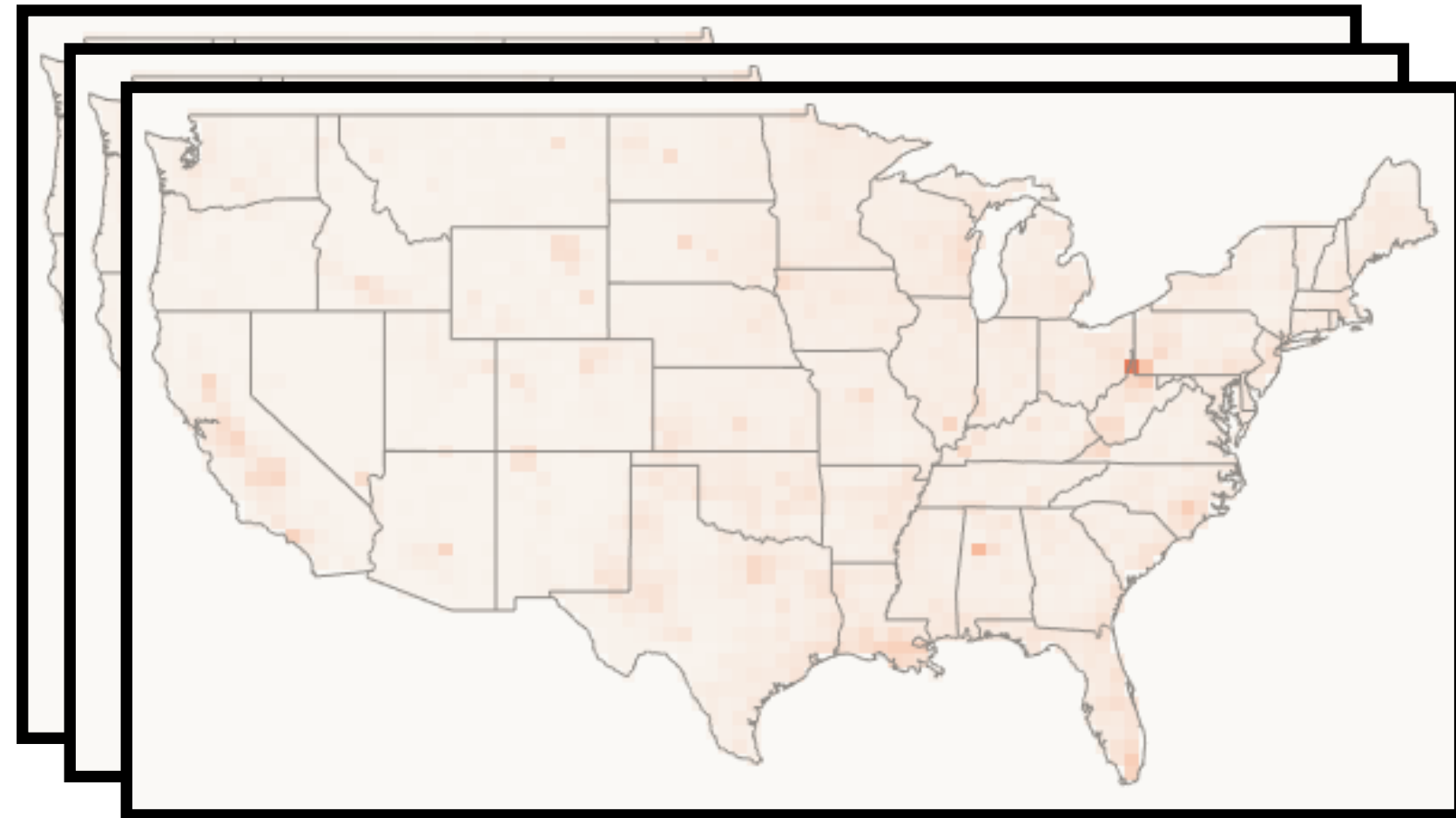
Optimized emissions estimate, s



Regional inversions with a geostatistical inverse model

Main idea: use satellite observations to update our prior knowledge of emissions

Prior knowledge, X

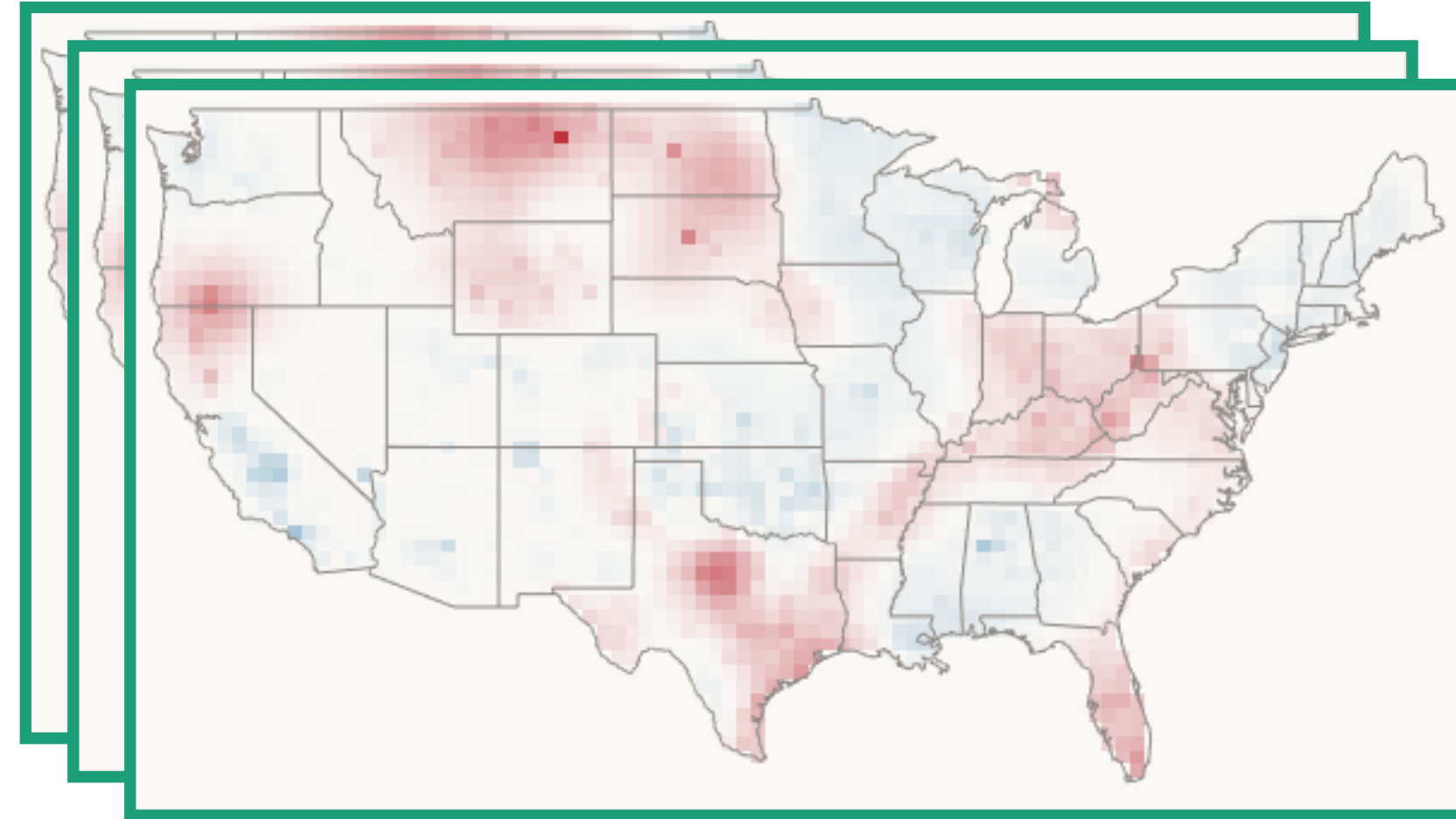


EDGAR v8, GHGI, GCP, WetCHARTs

$\times \beta +$

Uniform
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Spatially varying correction, $\zeta \sim N(0, Q)$



June 1, 2024

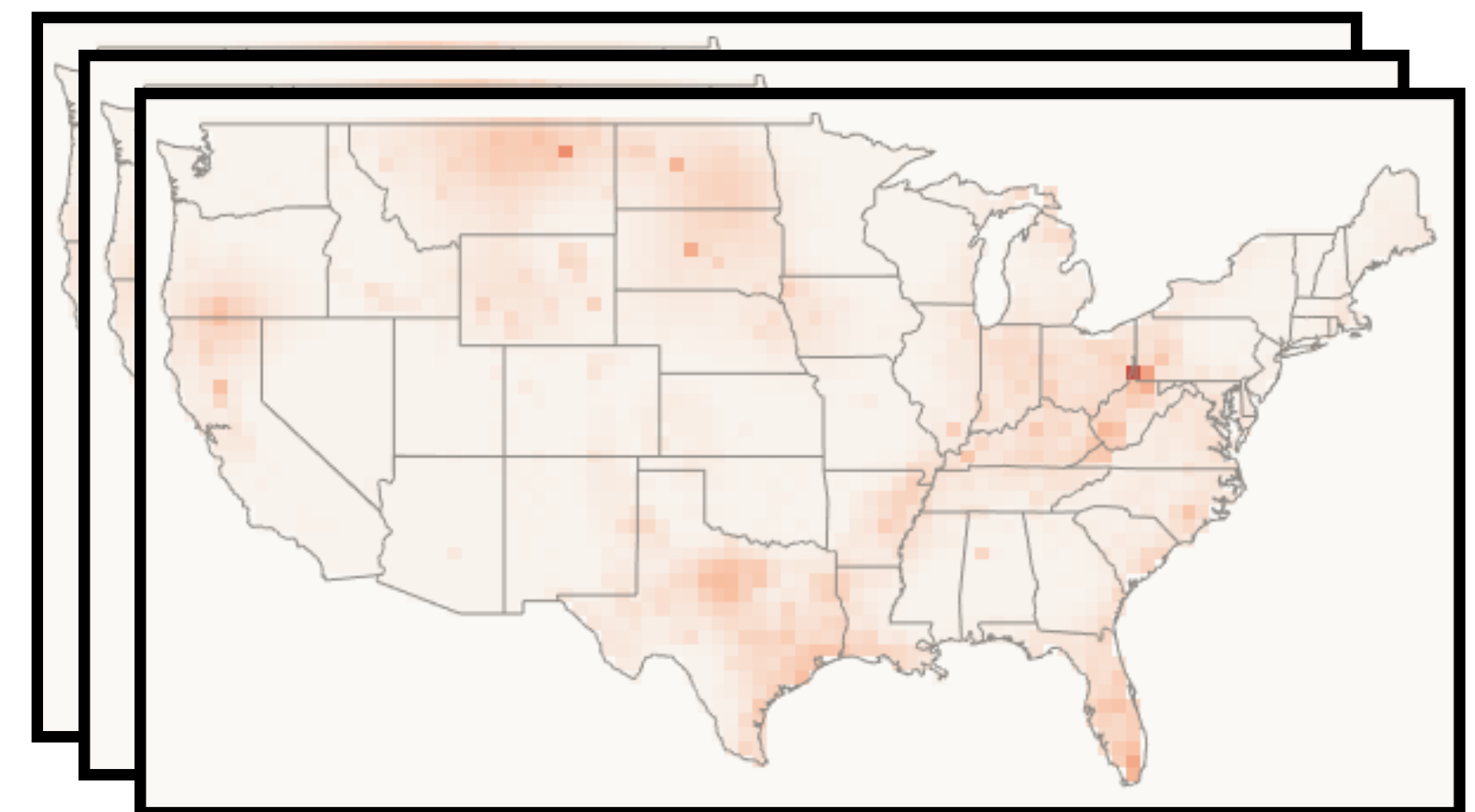
June 2, 2024

June 3, 2024

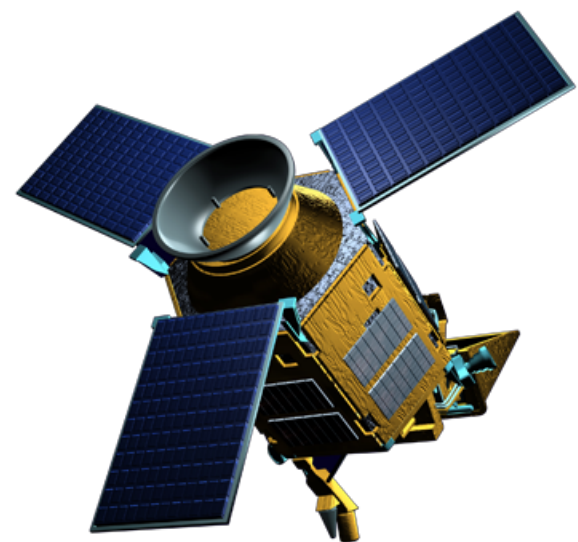
⋮

This is done for
daily fluxes!

Optimized emissions estimate, s



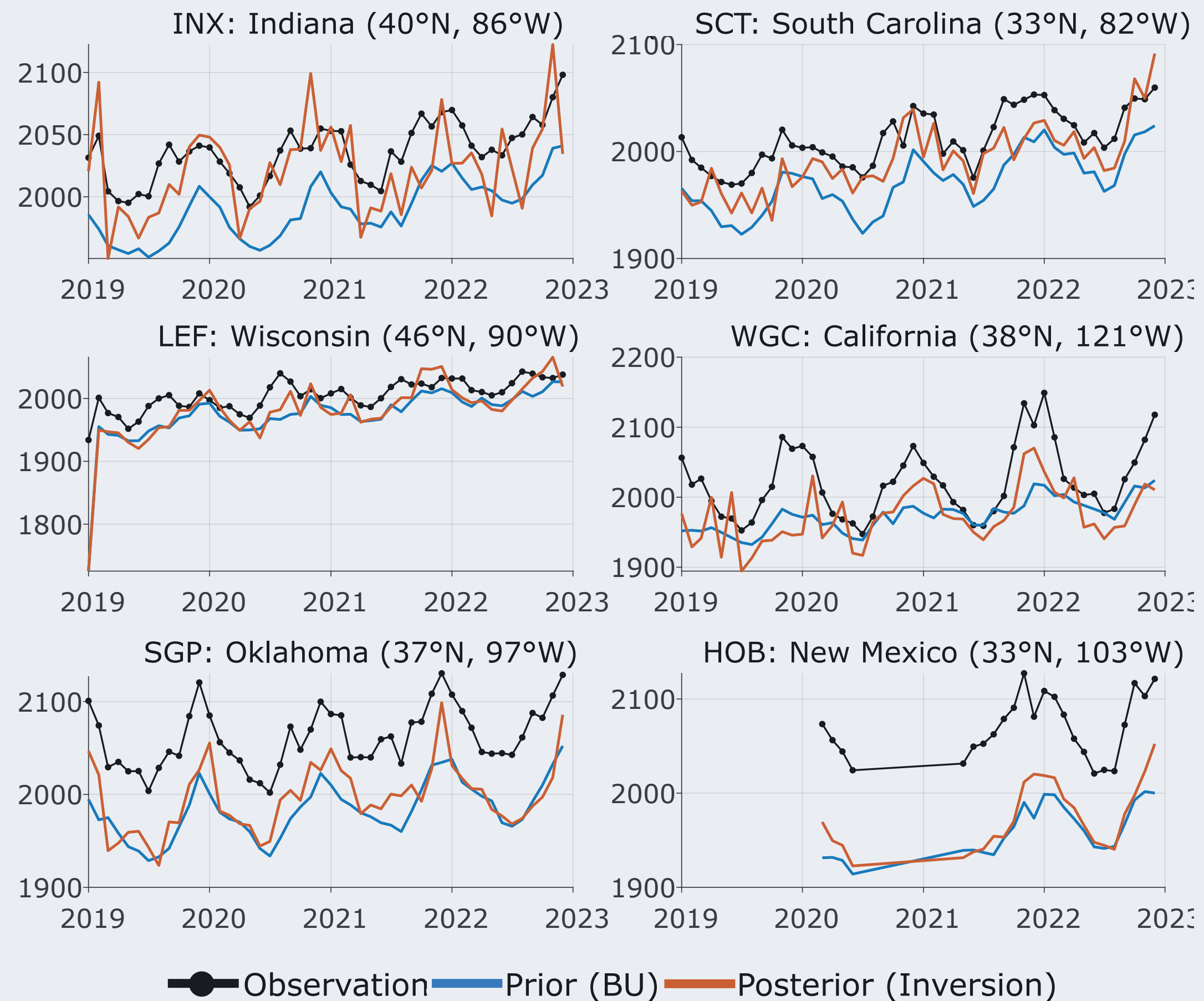
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Regional inversions with a geostatistical inverse model

Main idea: use satellite observations to update our prior knowledge of emissions

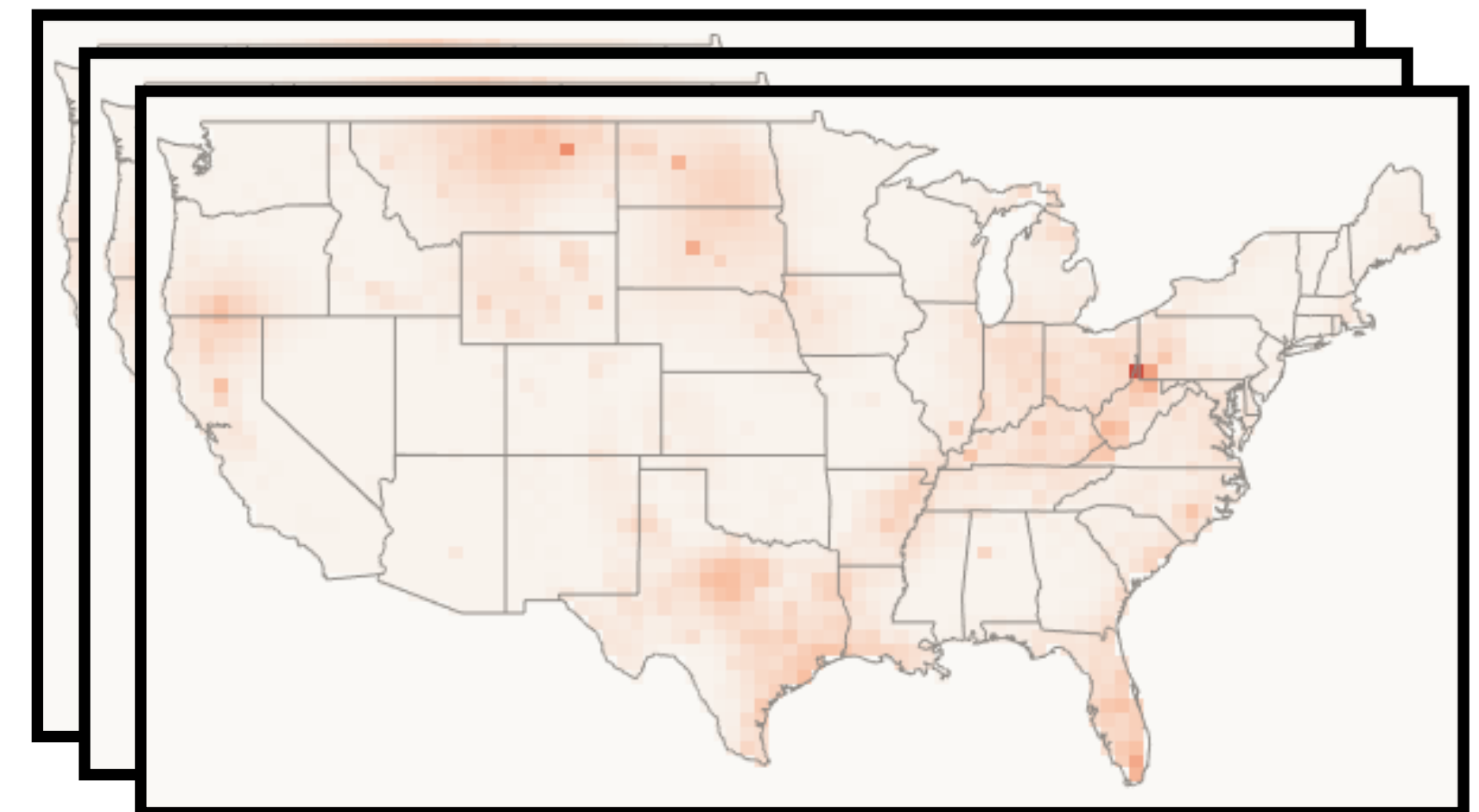
Validation: compare $h(s)$ to towers



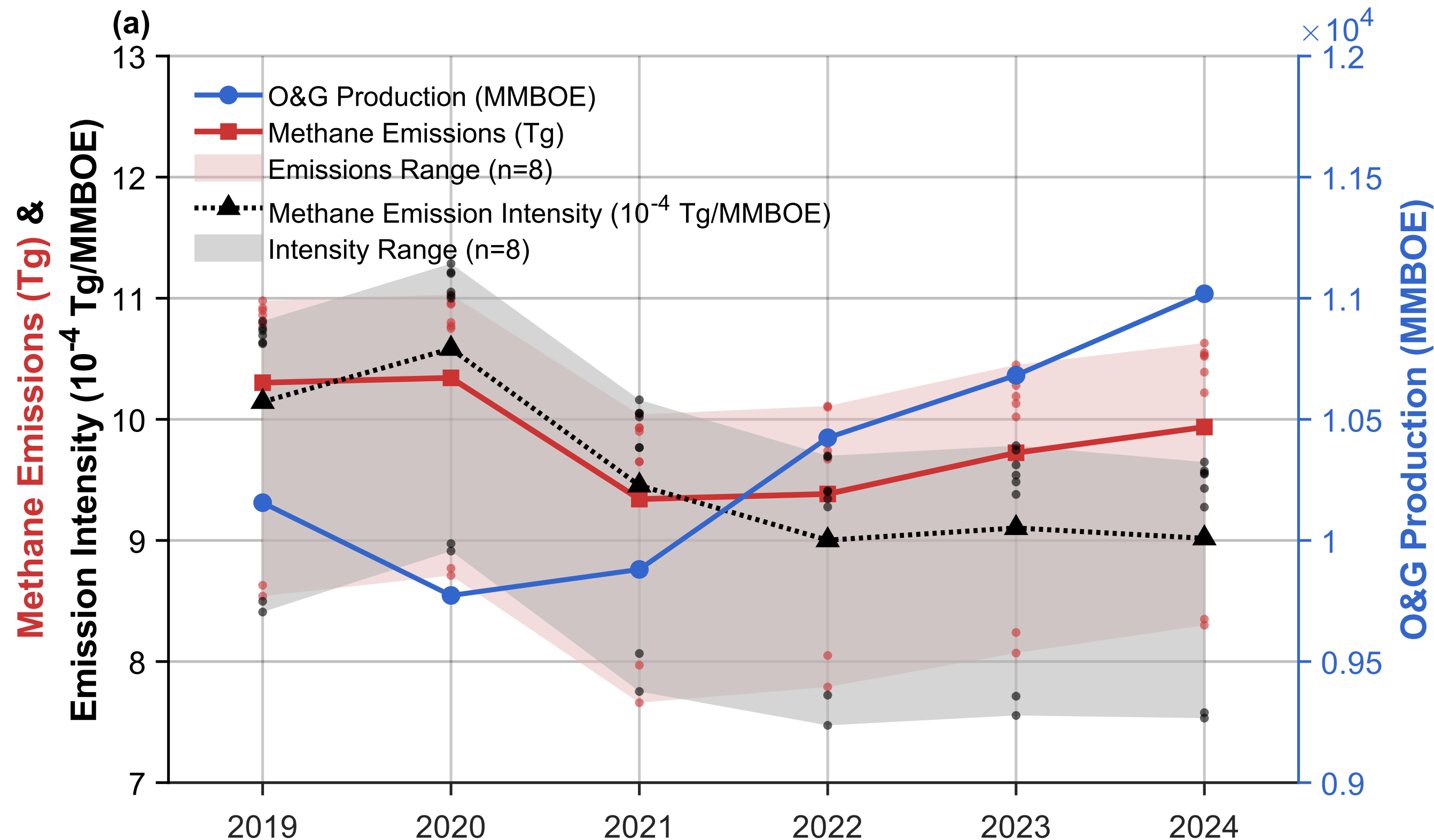
$h(s)$ = simulated concentrations at tower locations resulting from optimized emissions, s

GEOS
Chem

Optimized emissions estimate, s



Year-over-year trends: O&G emissions and emissions intensity



CONUS trends from 2019 to 2024:

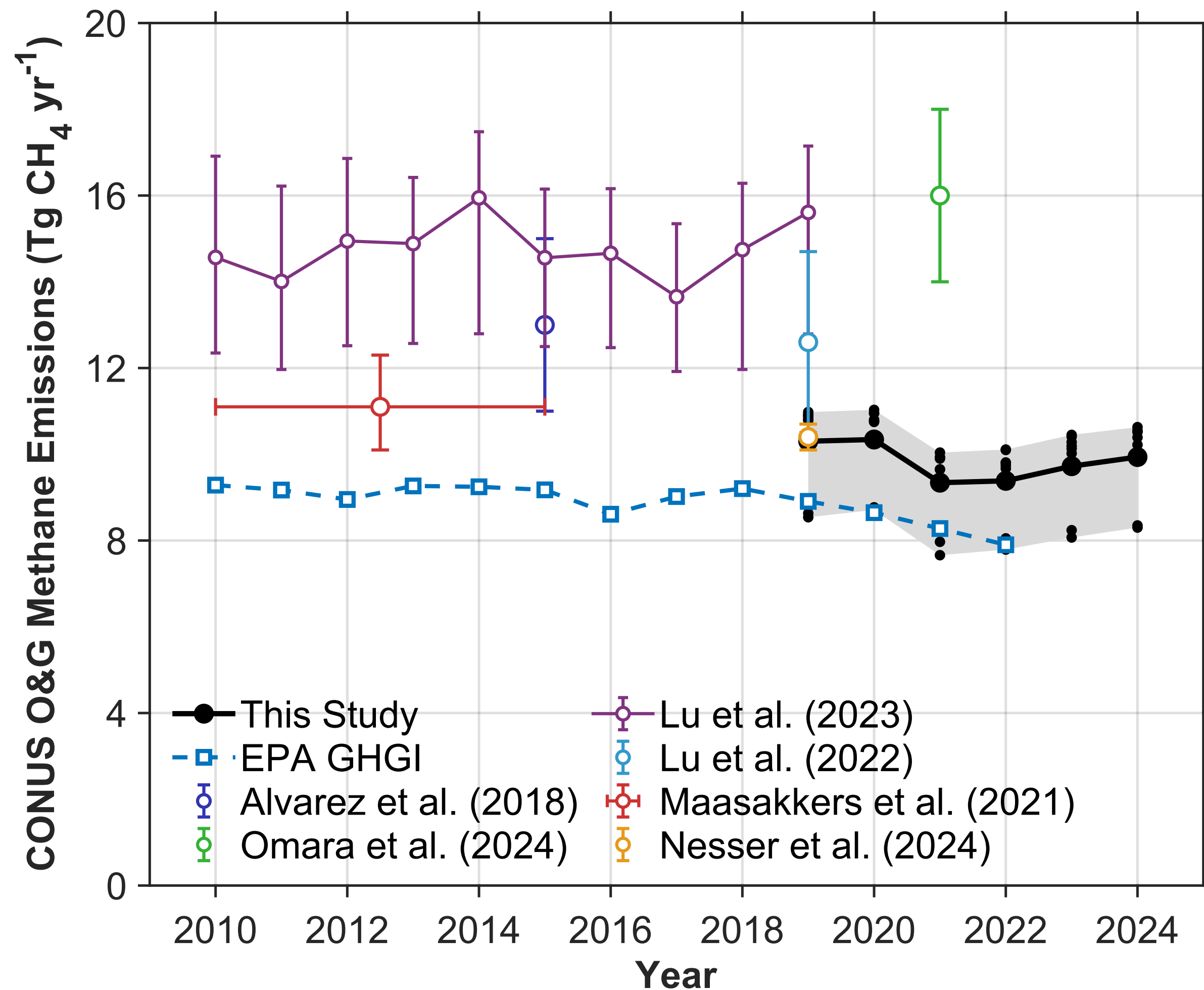
- **3.5 [1.6, 6.2]% decline** in O&G methane emissions
- **11.1 [9.3, 13.6]% decline** in energy normalized emissions intensity
- **8.5% increase** in energy production

Here we define emissions intensity as:

$$\text{Intensity} = \frac{\text{O\&G methane emissions}}{\text{Combined energy equivalent of produced oil and gas}}$$

Perhaps unsurprisingly, we see no large drop in emissions after onset of federal emissions policy

Year-over-year trends: O&G emissions and emissions intensity



Declining intensity in both our satellite inversion and the GHGI:

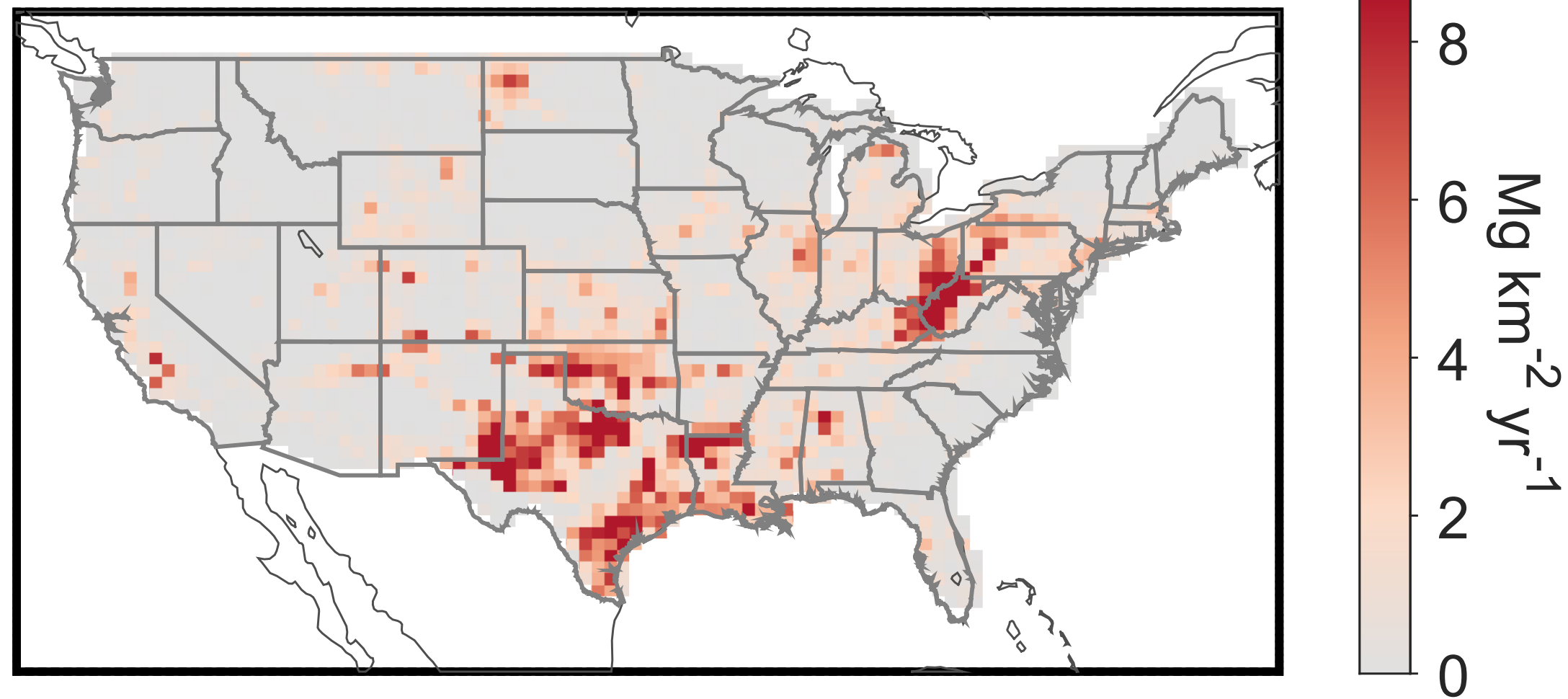
- **Our inversion: 11.2 [9.1, 13.0]% decline** from 2019 to 2022
- **GHGI: 6.7% decline** from 2019 to 2022

However, GHGI continues to underestimate emission magnitude relative to inversions

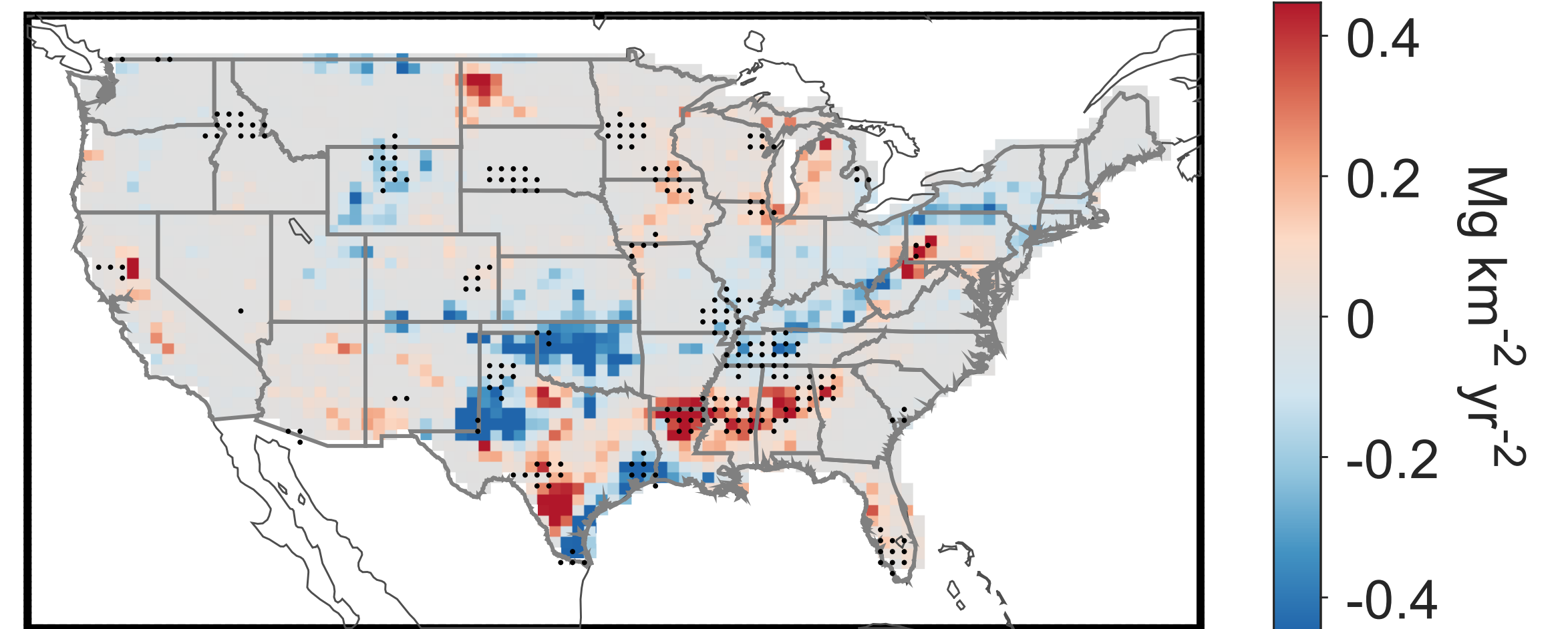
- Our emissions estimate is **17% higher** than the GHGI, averaged over 2019-2022
- Emissions estimates from other studies are **33% to 100% higher** than GHGI

Average methane emissions over 2019 - 2024

(a) Average Methane Emissions (2019-2024)



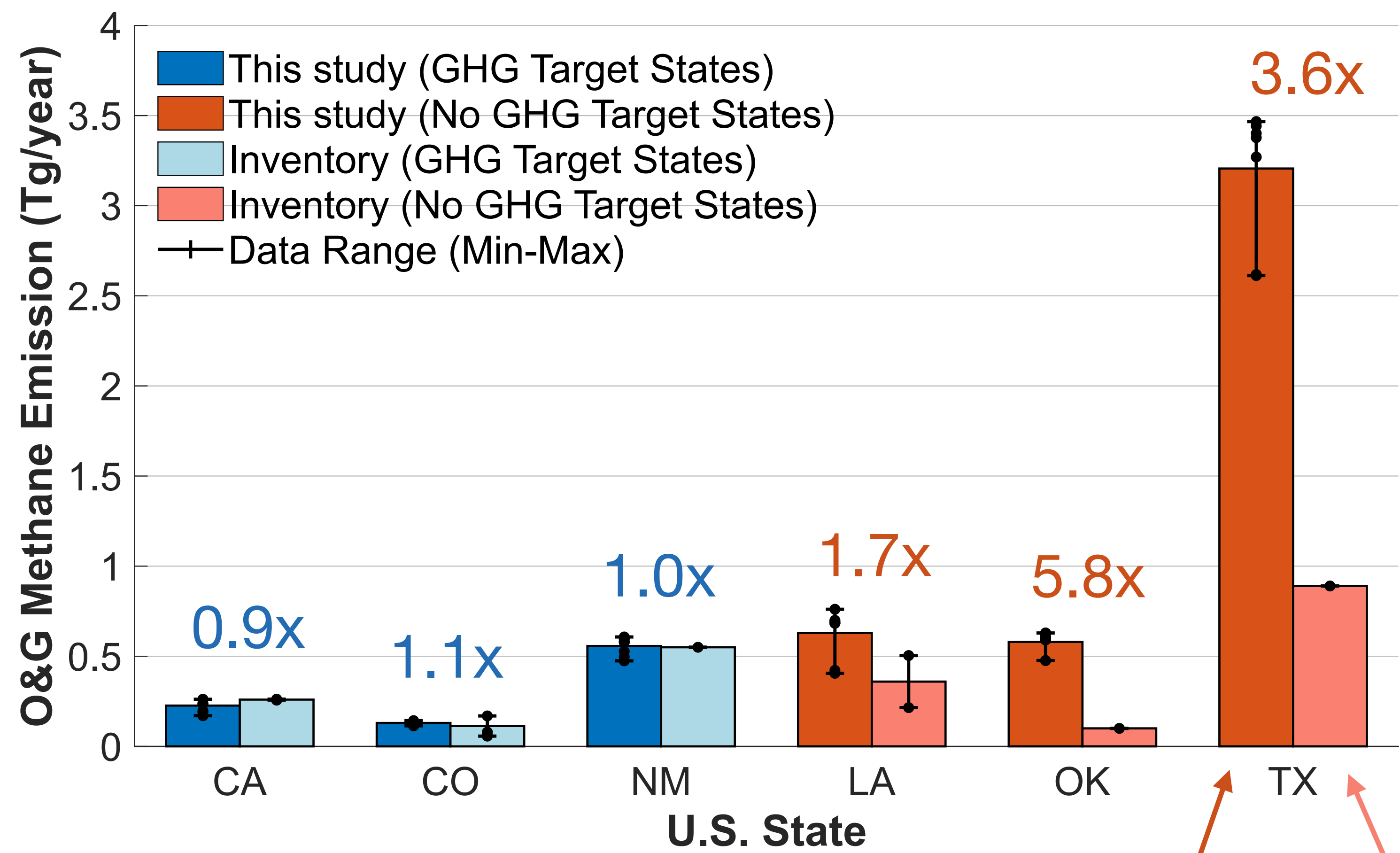
(b) Methane Emission Trends (2019-2024)



We see regional differences in emissions magnitude and trends.

Any relationship to regional emissions targets or policies?

State-level O&G emissions estimates vs. inventories



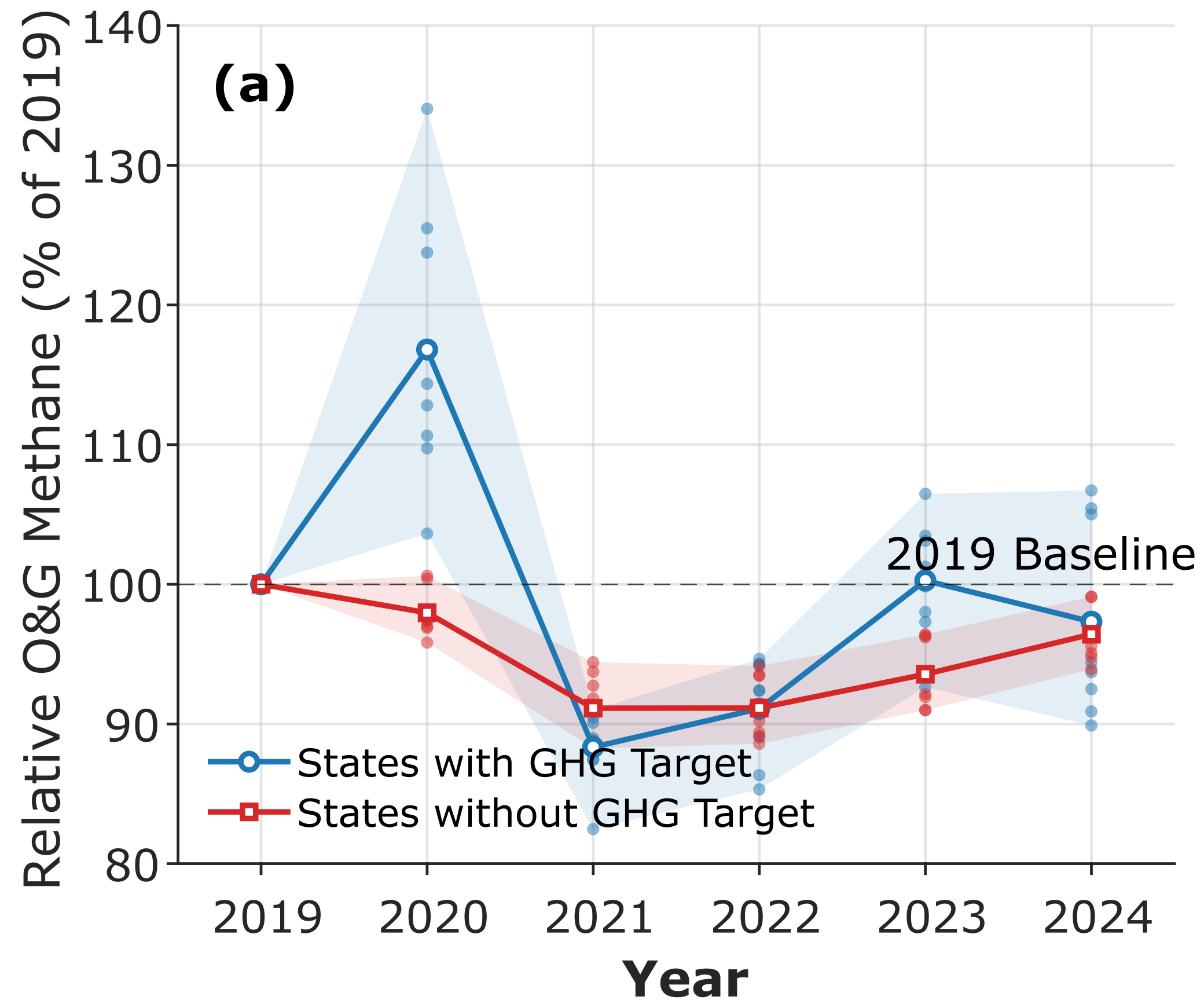
Presence of a GHG emission reduction target correlates with bottom-up vs. top-down agreement

Two possible explanations:

- 1. More state-sponsored emissions measurements in CA and CO
- 2. CA and CO both use custom emission factors for some sources that differ from EPA's factors

ratio = (our inversion estimate) ÷ (state-level, bottom-up inventory)

Presence of state-level GHG targets has not yet translated into clear emission reductions

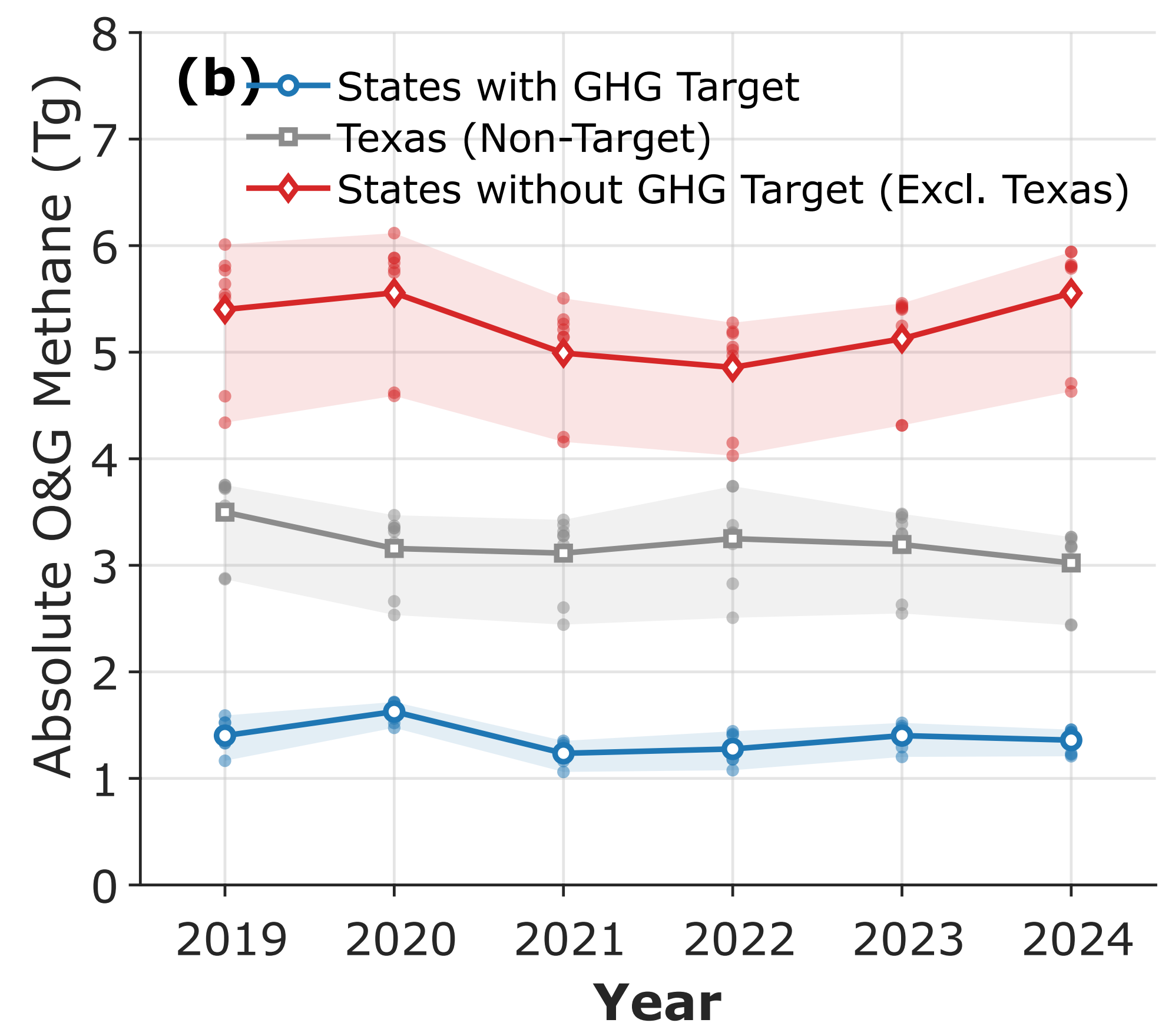


Relative emission reduction is similar between target states and non-target states:

- **1.0 to 2.6% decline** in states with GHG reduction target
- **0.6 to 1.5% decline** in states without GHG reduction target

Texas drove reduction in non-target states, with a **14 [13, 15]% decline** in O&G methane emissions from 2019 to 2024

Presence of state-level GHG targets has not yet translated into clear emission reductions



Texas drove reduction in non-target states, with a **14 [13, 15]% decline** in O&G methane emissions from 2019 to 2024

Decreasing trend in Texas is likely a result of new pipeline capacity in the Permian basin that came online between 2019 and 2024

Conclusions

Questions? Ideas?
wdanie16@jh.edu

- **3.5% decline** in O&G methane emissions and **11.2% decline** in emissions intensity from 2019 to 2024.
- Our estimate for CONUS is 17% higher than GHGI.
- Presence of GHG reduction target a strong predictor for state-level bottom-up vs. top-down alignment.
- However, presence of GHG reduction target has not yet translated to clear emission reductions.

Paper



Chen et al. (2026).
Communications Earth & Environment

