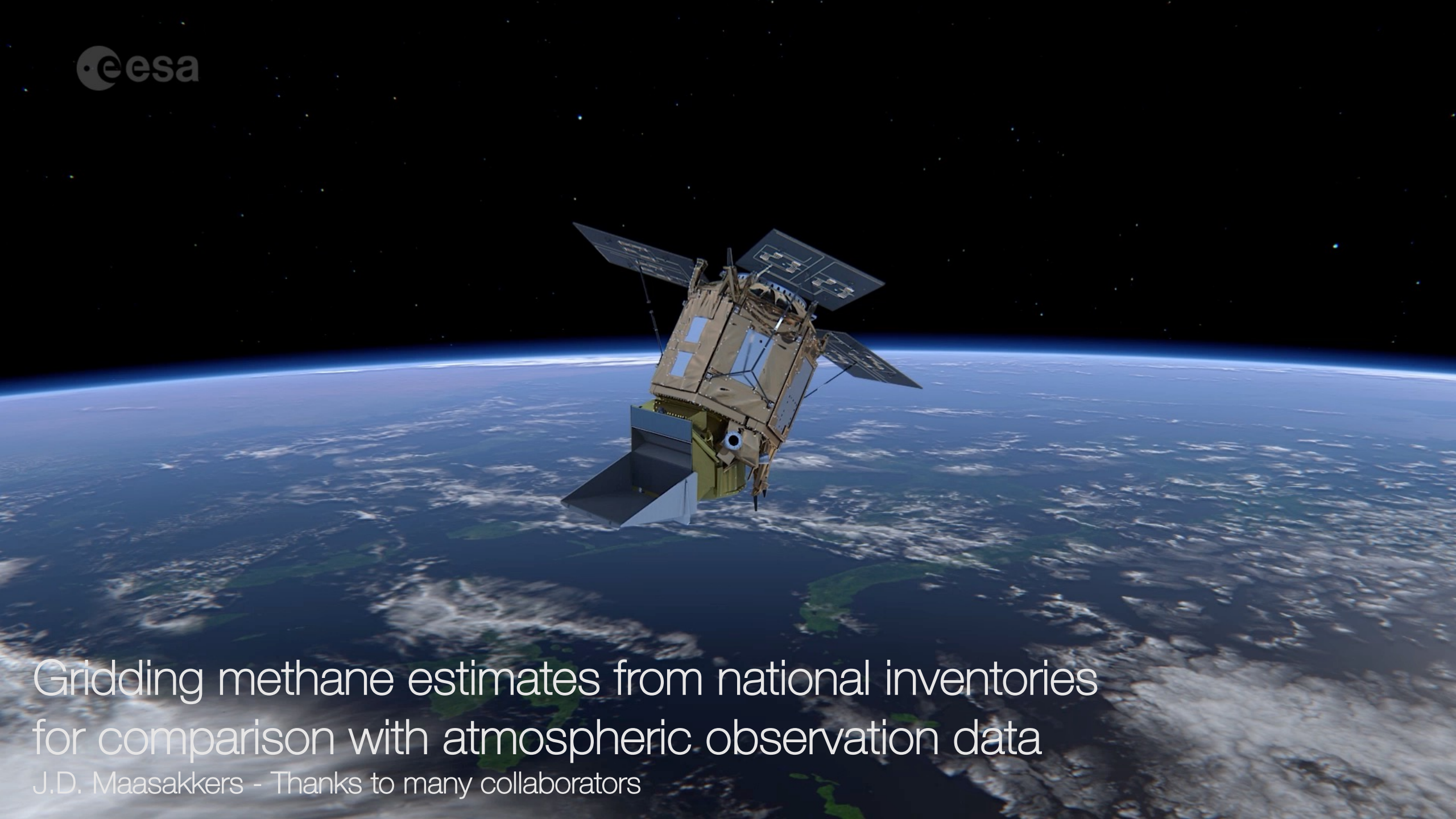
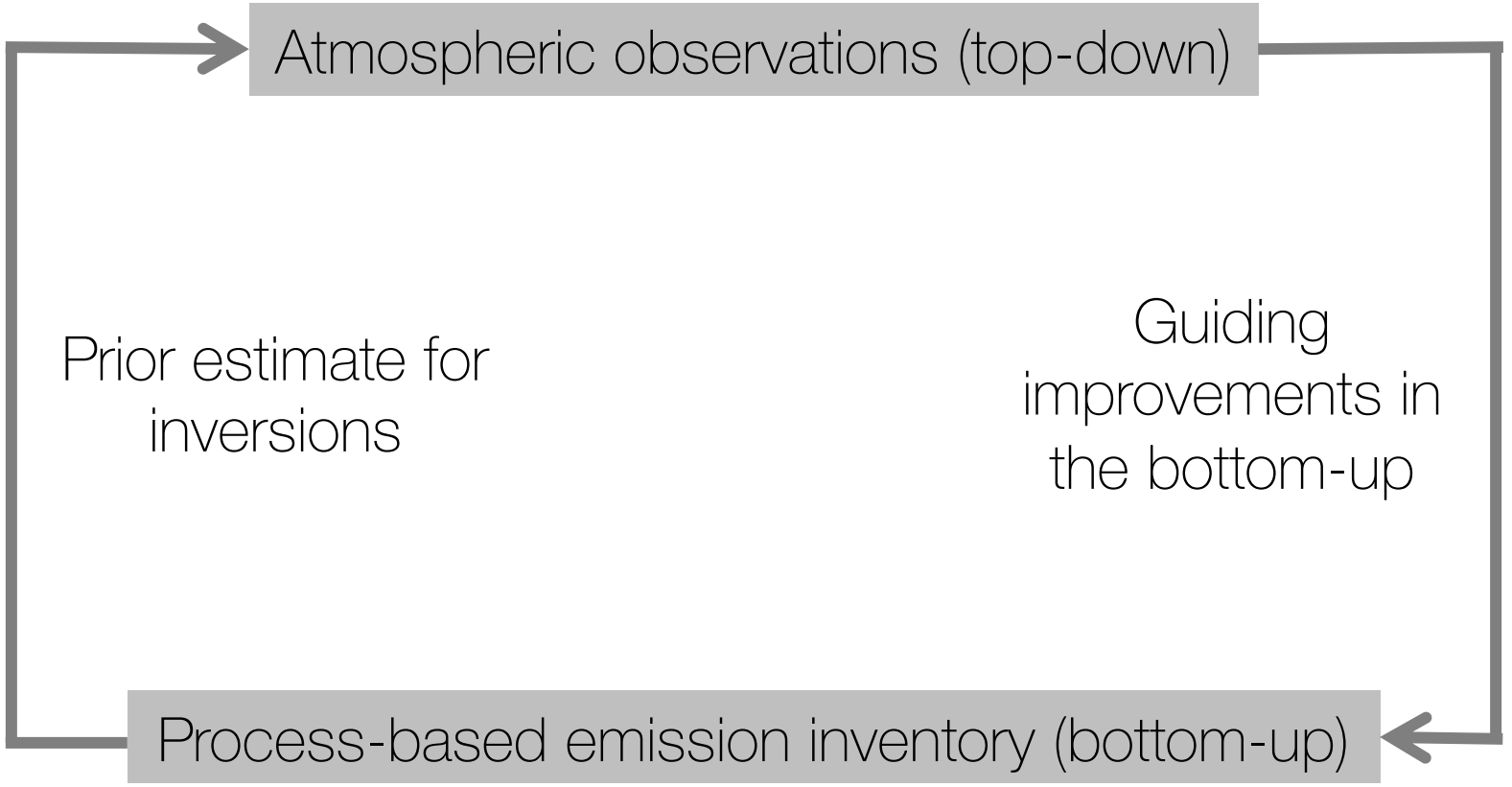


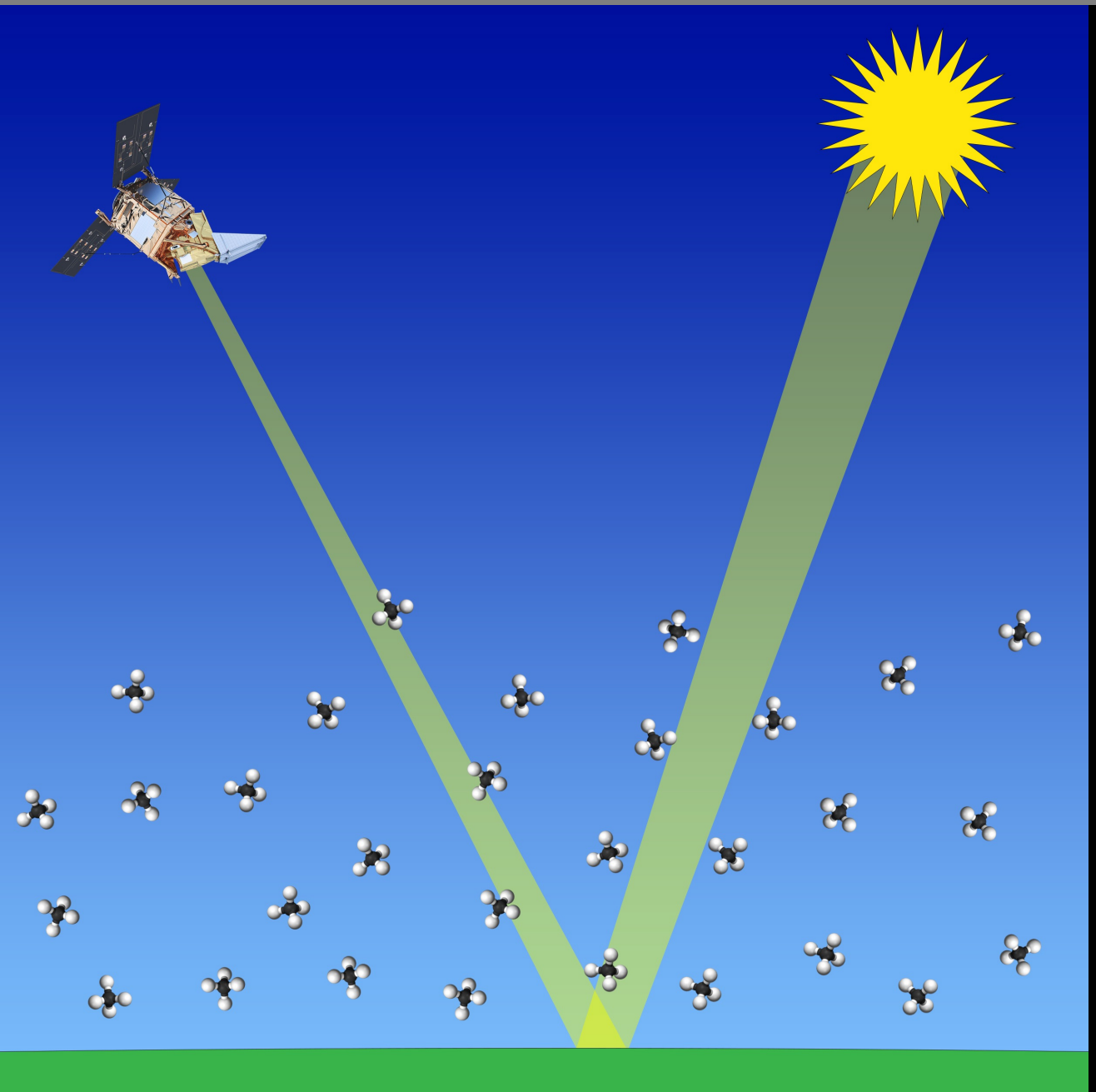
Gridding methane estimates from national inventories for comparison with atmospheric observation data

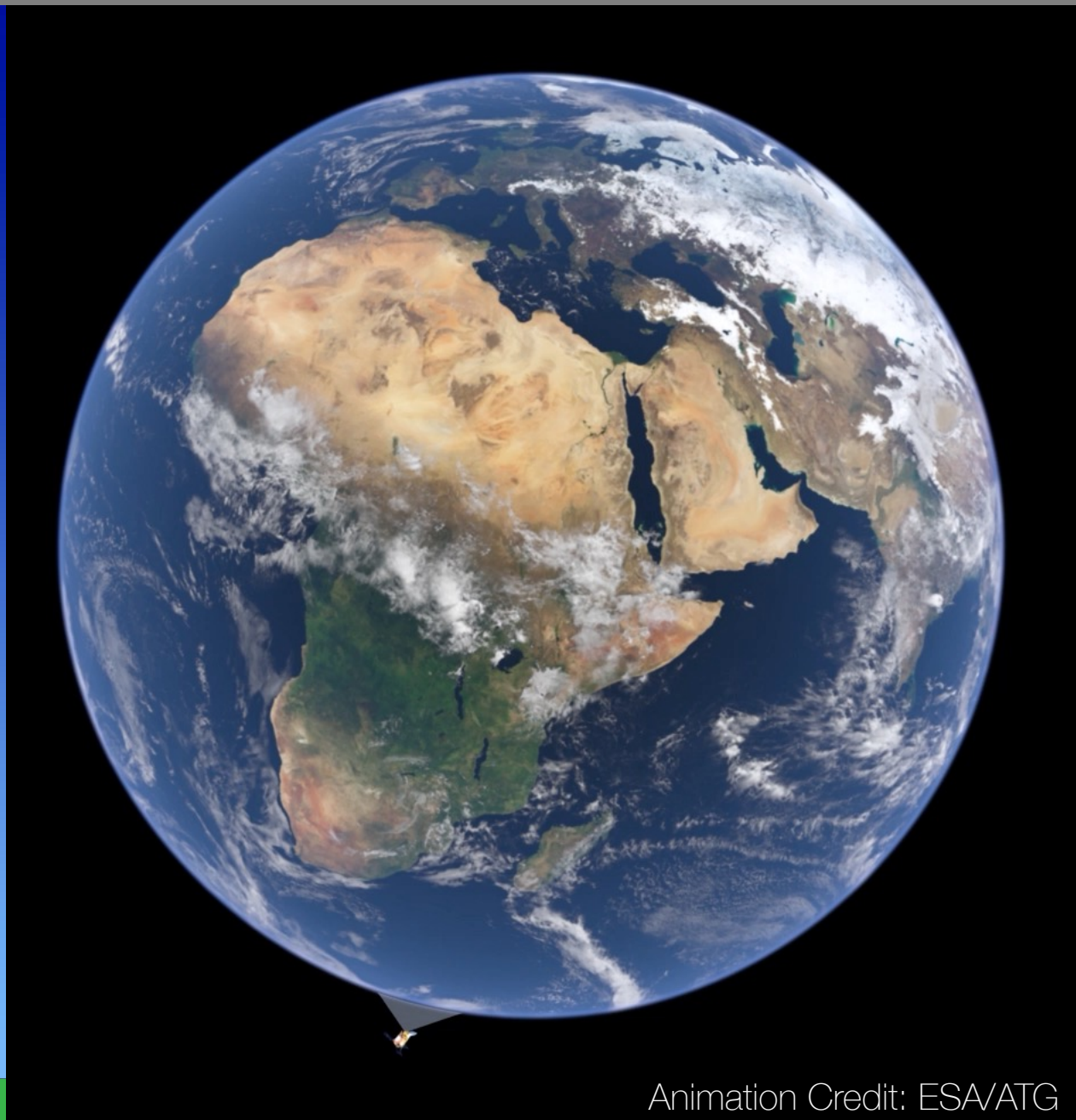
J.D. Maasakkers - Thanks to many collaborators

Using atmospheric data to improve bottom-up inventories



Seeing methane from space

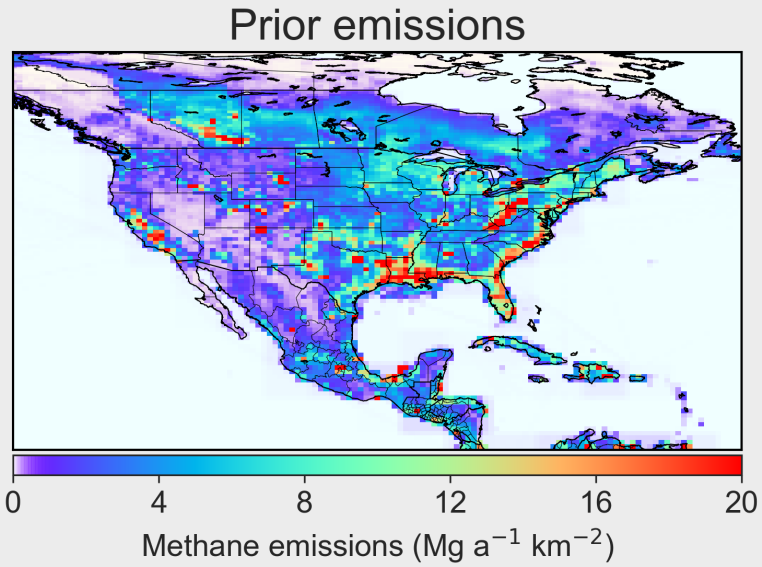




Animation Credit: ESA/ATG

Evaluating bottom-up emissions with atmospheric data

Inverse methods seek to optimize emissions by combining atmospheric methane observations with bottom-up information.



Maasakkers et al. (2021)

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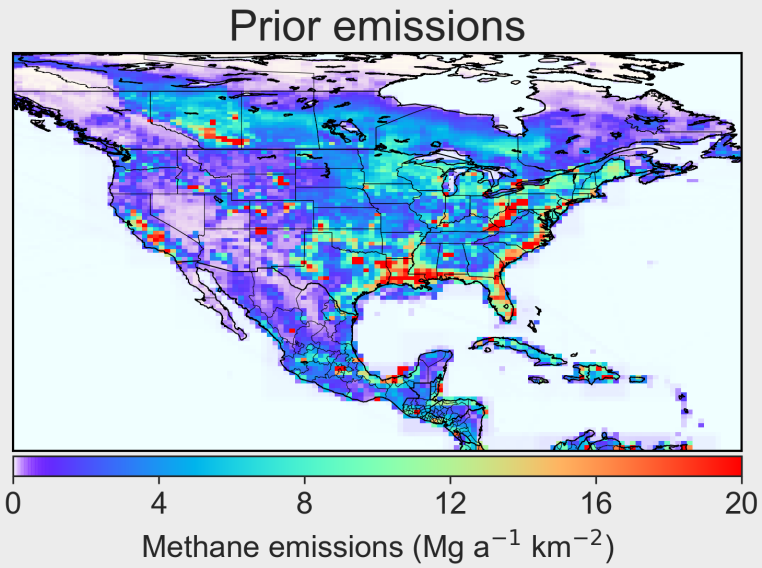

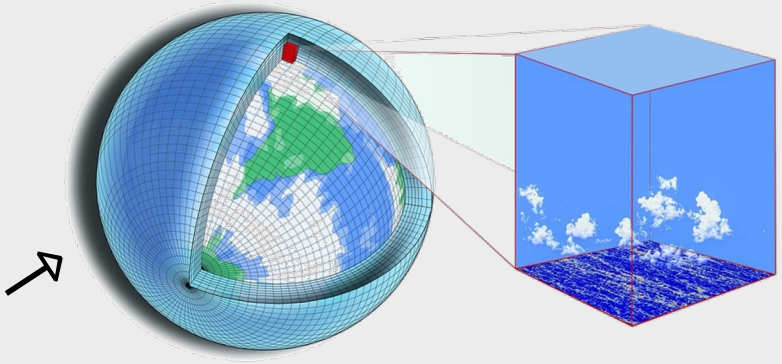

Maasakkers et al. (2021)

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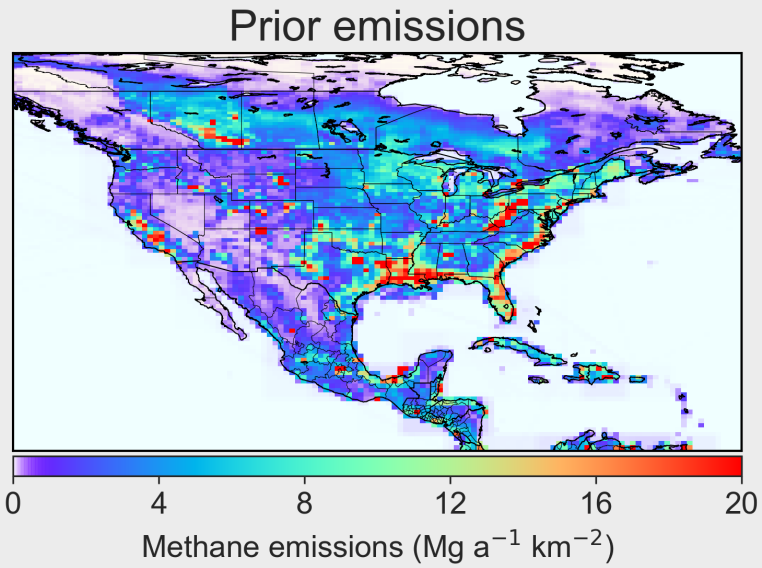

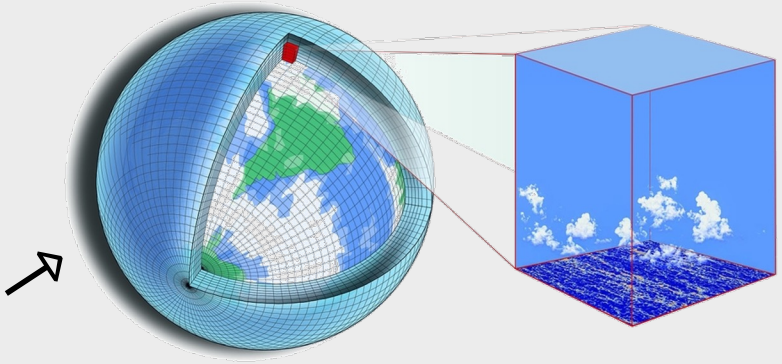

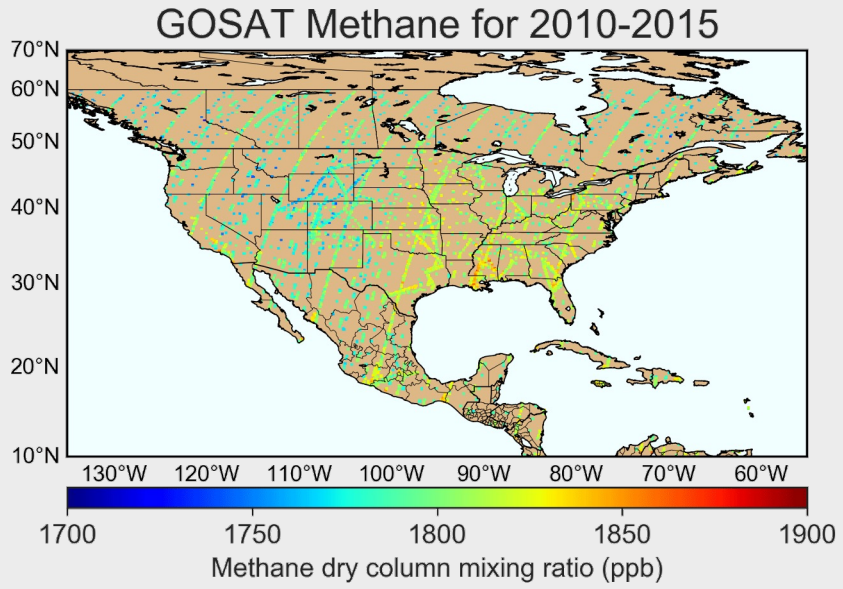

Maasakkers et al. (2021)

Evaluating bottom-up emissions with atmospheric data

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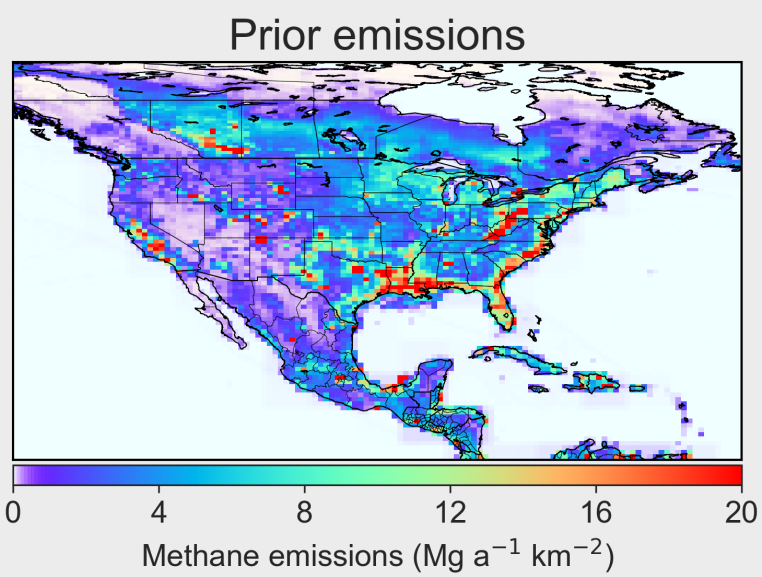
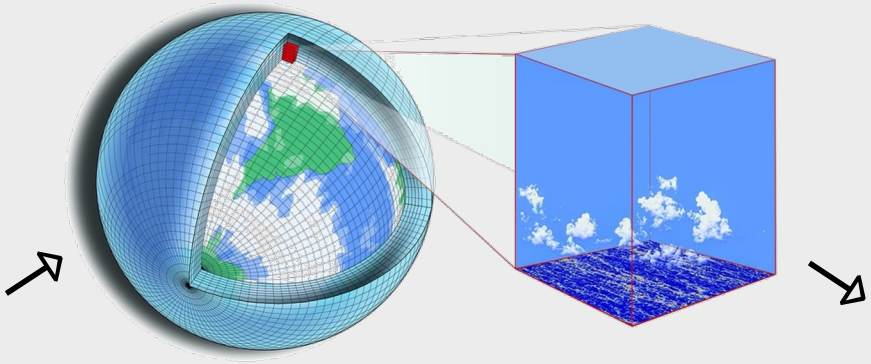
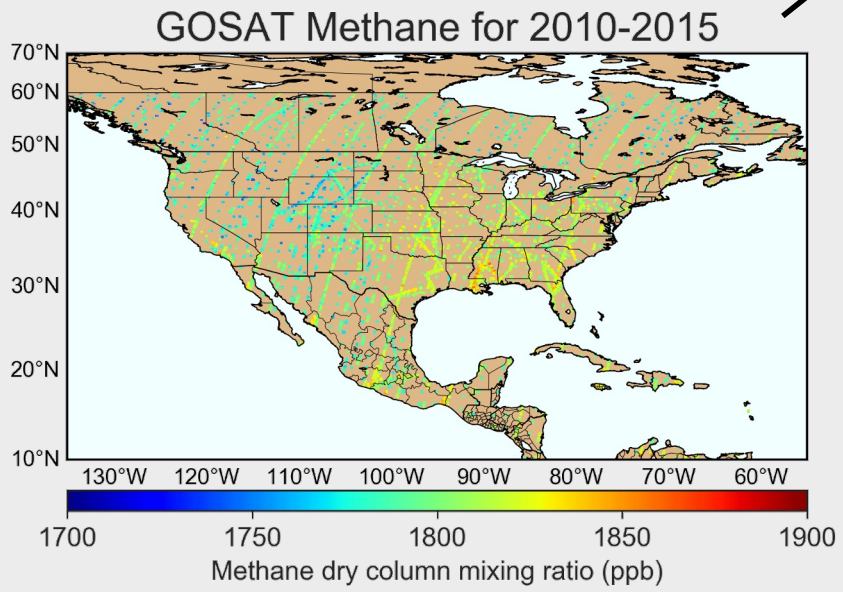
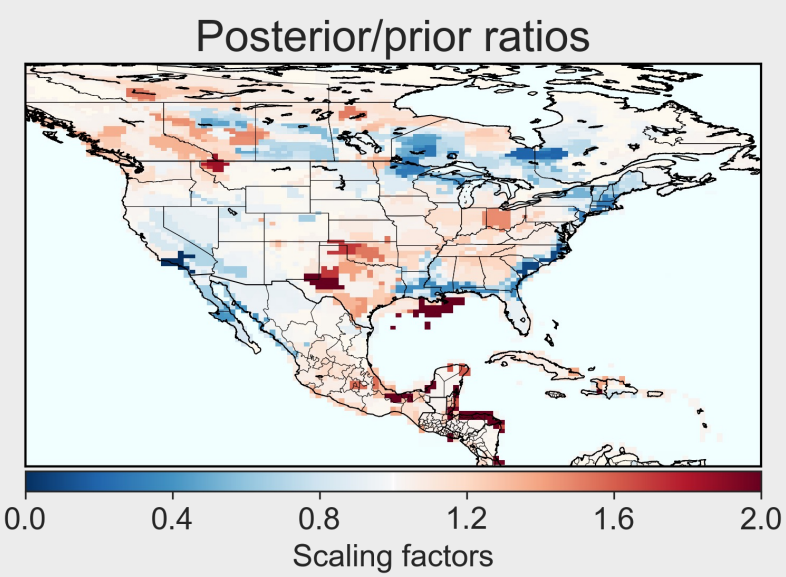








Maasakkers et al. (2021)

2020 US EPA anthropogenic methane emissions

0.7 Tg Other

0.6 Tg Rice cultivation

1.6 Tg Petroleum Systems

1.9 Tg Coal mining

9.4Tg Livestock

5.2 Tg Waste

6.6 Tg Natural gas

Available only as national/state totals

US EPA (2022)

An evaluable gridded EPA inventory for 2012

Region-specific EPA emission factors

Spatial allocation on 0.1° x 0.1° grid using national & high resolution (inventory-consistent) datasets with facility-level information from the Greenhouse Gas Reporting Program

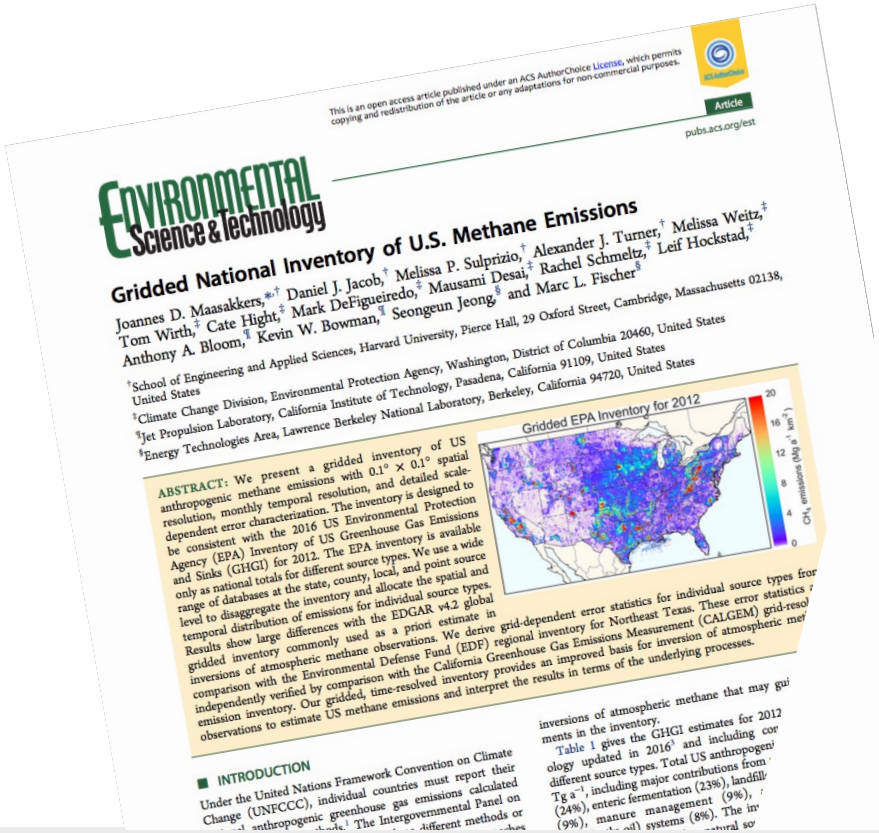
22 layers of data for emissions from different processes

Monthly time resolution

Scale-dependent error characterization

An evaluable gridded EPA inventory for 2012

Published in 2016, now finalizing 2012-2018 emissions from the 2020 inventory.



Gridded National Inventory of U.S. Methane Emissions

Joannes D. Maasakkers, Daniel J. Jacob, Melissa P. Sulprizio, Alexander J. Turner, Melissa Weitz, Tom Wirth, Cate Hight, Mark DeFigueiredo, Mausami Desai, Rachel Schmeltz, Leif Hockstad, Anthony A. Bloom, Kevin W. Bowman, Seongeun Jeong, and Marc L. Fischer

Environmental Science & Technology

Article

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ABSTRACT: We present a gridded inventory of US anthropogenic methane emissions with 0.1° × 0.1° spatial resolution, monthly temporal resolution, and detailed scale-dependent error characterization. The inventory is designed to be consistent with the 2016 US Environmental Protection Agency (EPA) Inventory of US Greenhouse Gas Emissions and Sinks (GHGI) for 2012. The EPA inventory is available only as national totals for different source types. We use a wide range of databases at the state, county, local, and point source level to disaggregate the inventory and allocate the spatial and temporal distribution of emissions for individual source types. Results show large differences with the EDGAR v4.2 global gridded inventory commonly used as a priori estimate in inversions of atmospheric methane observations. We derive grid-dependent error statistics for individual source types from comparison with the Environmental Defense Fund (EDF) regional inventory for Northeast Texas. These error statistics independently verified by comparison with the California Greenhouse Gas Emissions Measurement (CALGEM) grid-resolved emission inventory. Our gridded, time-resolved inventory provides an improved basis for inversion of atmospheric methane observations to estimate US methane emissions and interpret the results in terms of the underlying processes.

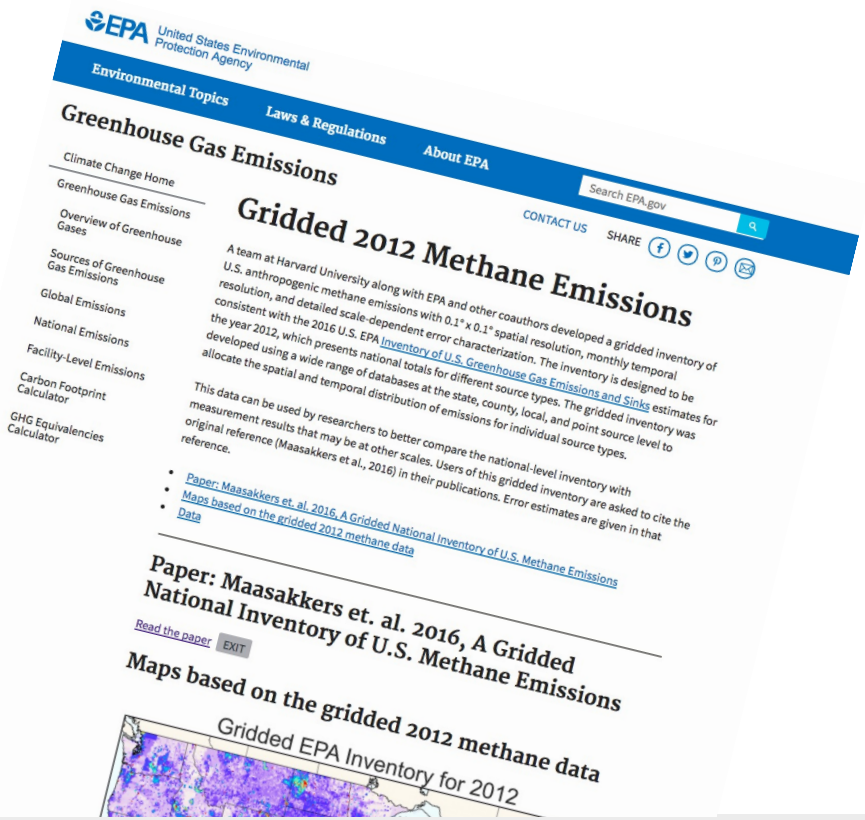
Gridded EPA Inventory for 2012

INTRODUCTION

Under the United Nations Framework Convention on Climate Change (UNFCCC), individual countries must report their anthropogenic greenhouse gas emissions calculated

inversions of atmospheric methane that may gui ments in the inventory.

Table 1 gives the GHGI estimates for 2012 ology updated in 2016[3] and including cor different source types. Total US anthropogeni Tg a^{-1}, including major contributions from (24%), enteric fermentation (23%), landfill (9%), manure management (9%), systems (8%). The in



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- Facility-Level Emissions
- Carbon Footprint Calculator
- GHG Equivalencies Calculator

Gridded 2012 Methane Emissions

A team at Harvard University along with EPA and other coauthors developed a gridded inventory of U.S. anthropogenic methane emissions with 0.1° x 0.1° spatial resolution, monthly temporal resolution, and detailed scale-dependent error characterization. The inventory is designed to be consistent with the 2016 U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks estimates for the year 2012, which presents national totals for different source types. The gridded inventory was developed using a wide range of databases at the state, county, local, and point source level to allocate the spatial and temporal distribution of emissions for individual source types.

This data can be used by researchers to better compare the national-level inventory with measurement results that may be at other scales. Users of this gridded inventory are asked to cite the original reference (Maasakkers et al., 2016) in their publications. Error estimates are given in that reference.

- Paper: Maasakkers et. al. 2016, A Gridded National Inventory of U.S. Methane Emissions
- Maps based on the gridded 2012 methane data
- Data

Paper: Maasakkers et. al. 2016, A Gridded National Inventory of U.S. Methane Emissions

Read the paper EXIT

Maps based on the gridded 2012 methane data

Gridded EPA Inventory for 2012

Maasakkers et al. (2016)

Gridding strategy – Livestock

Gridding strategy – Livestock

State-level emissions from EPA.

↓

County-level emissions: USDA 2012/2017 Census for 14 animal types.

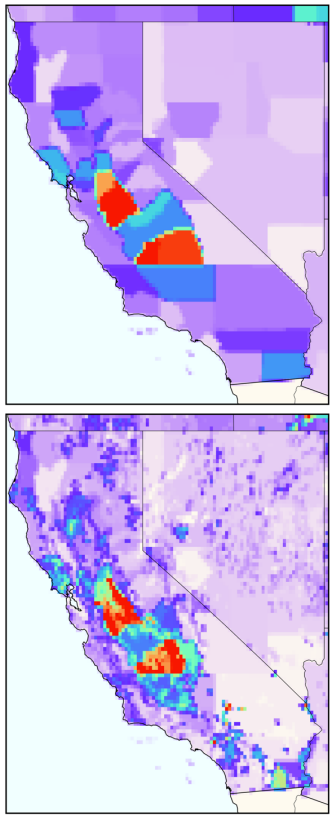
↓

0.1° x 0.1° Grid emissions: USDA livestock occurrence probability maps for 9 animal types.

↓

Seasonal cycle based on the temperature dependence of manure management emissions.

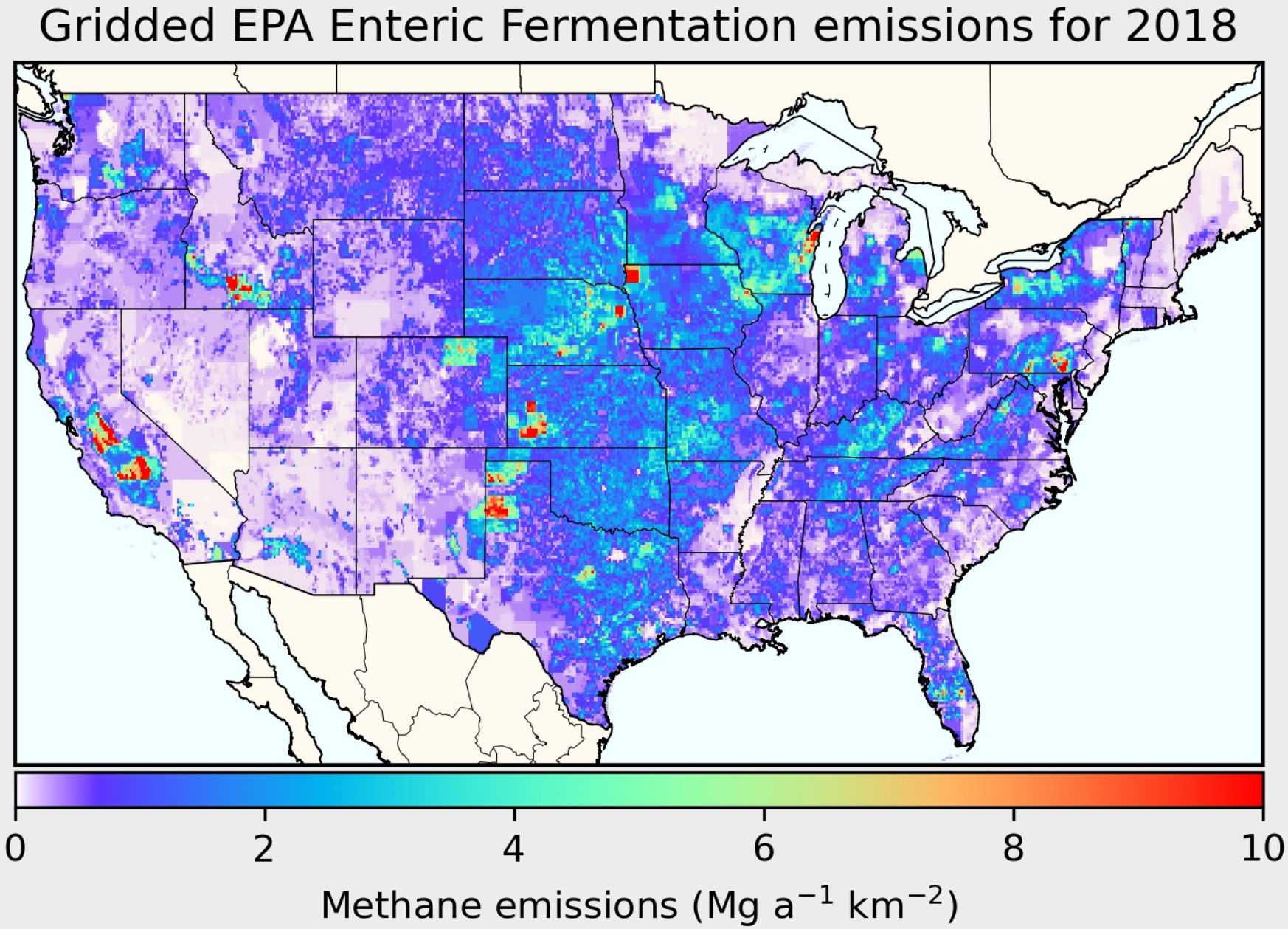
County-level methane emissions



Grid-level methane emissions

USDA (2013/2019) / Huntzinger et al. (2013)

Spatially allocating livestock methane emissions



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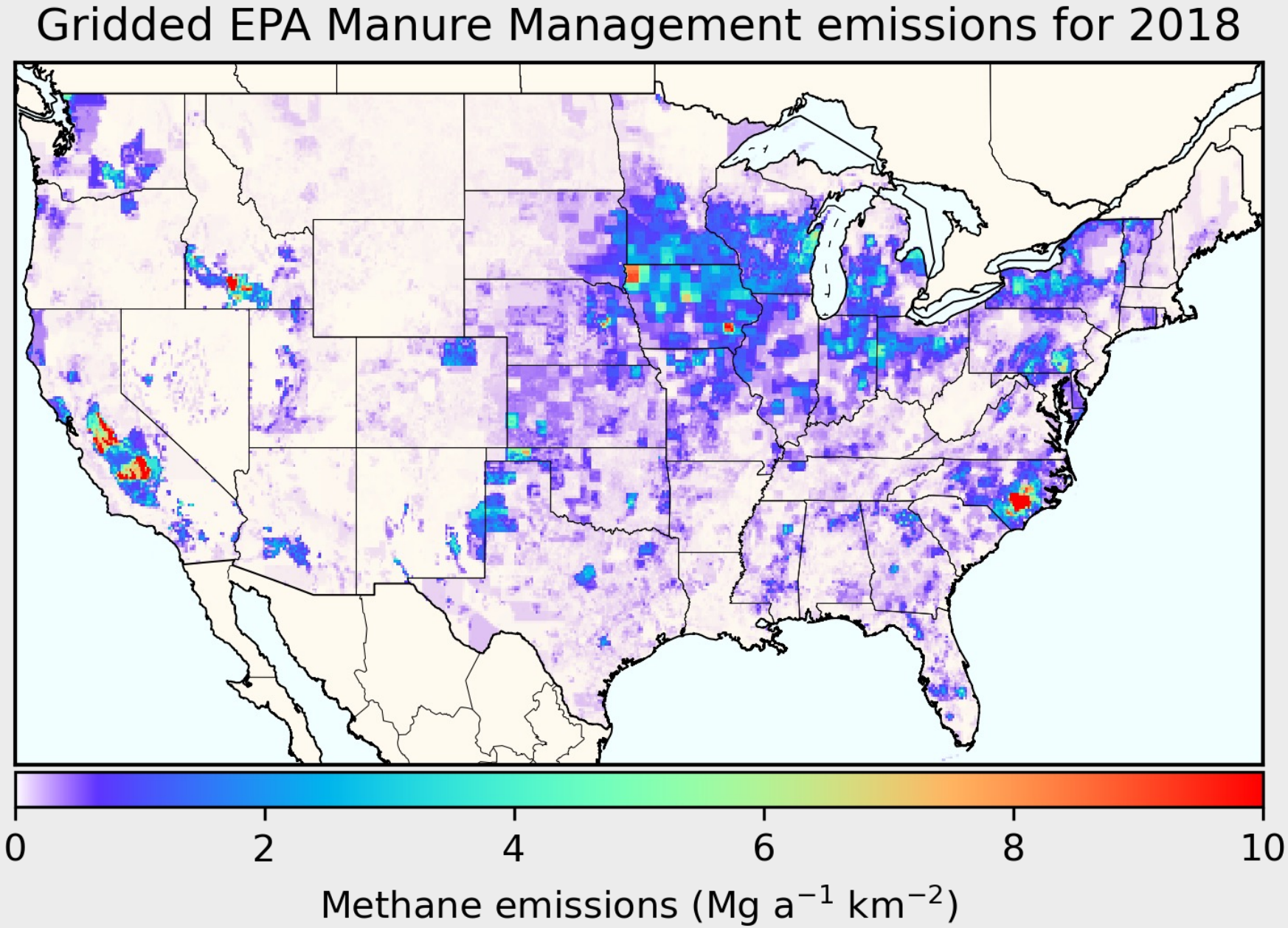
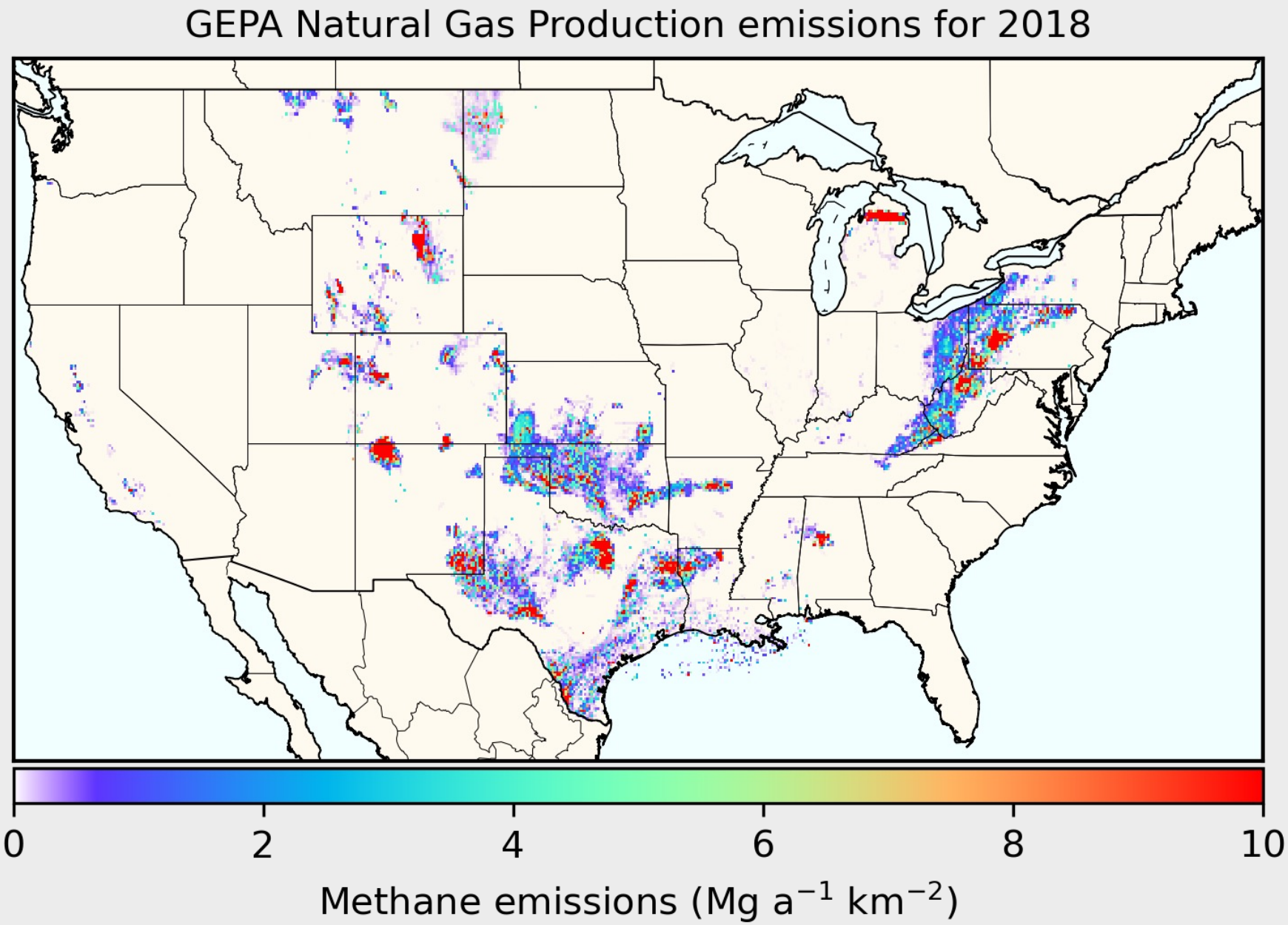
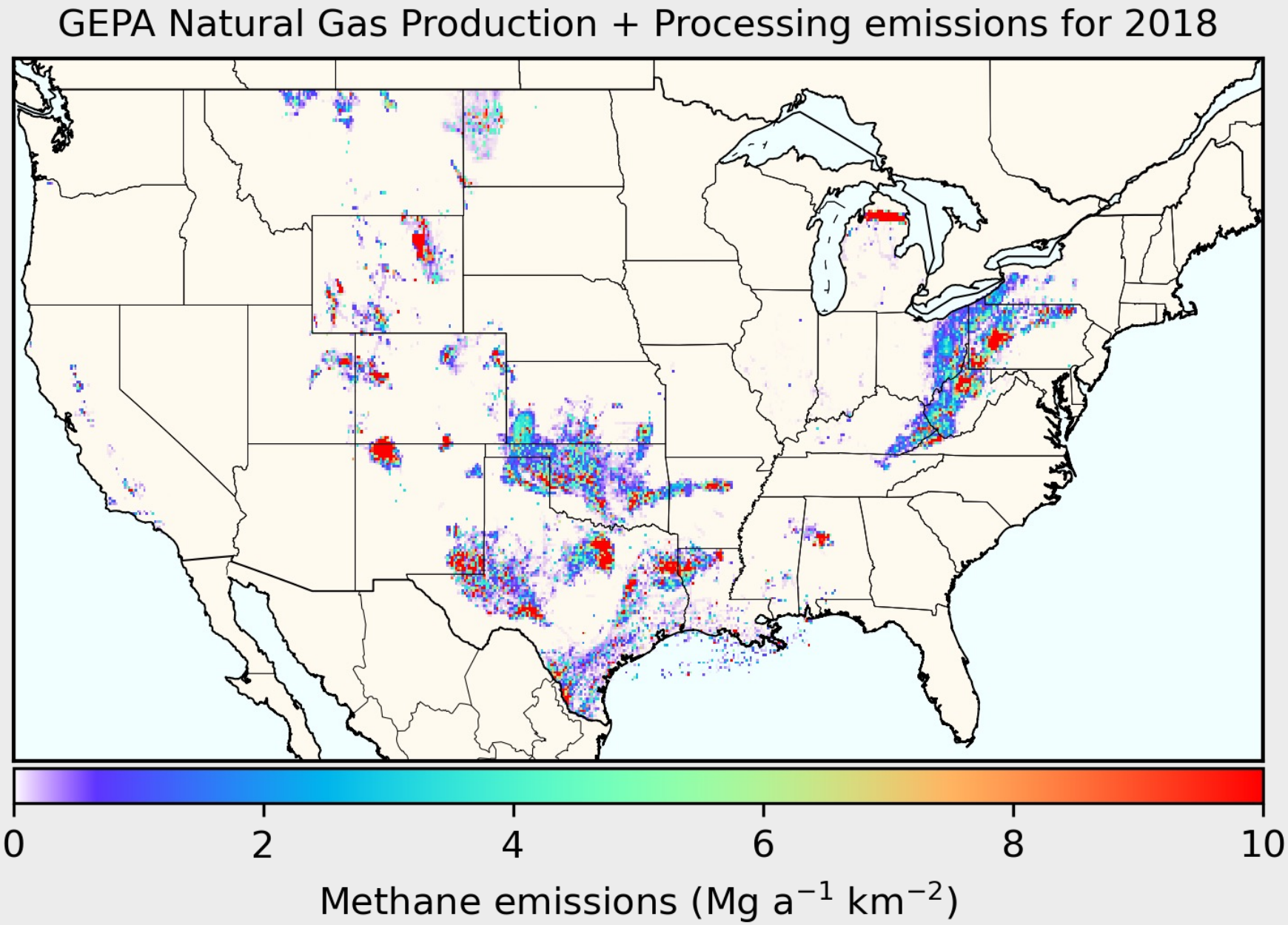


Gridding strategy – Natural Gas Systems

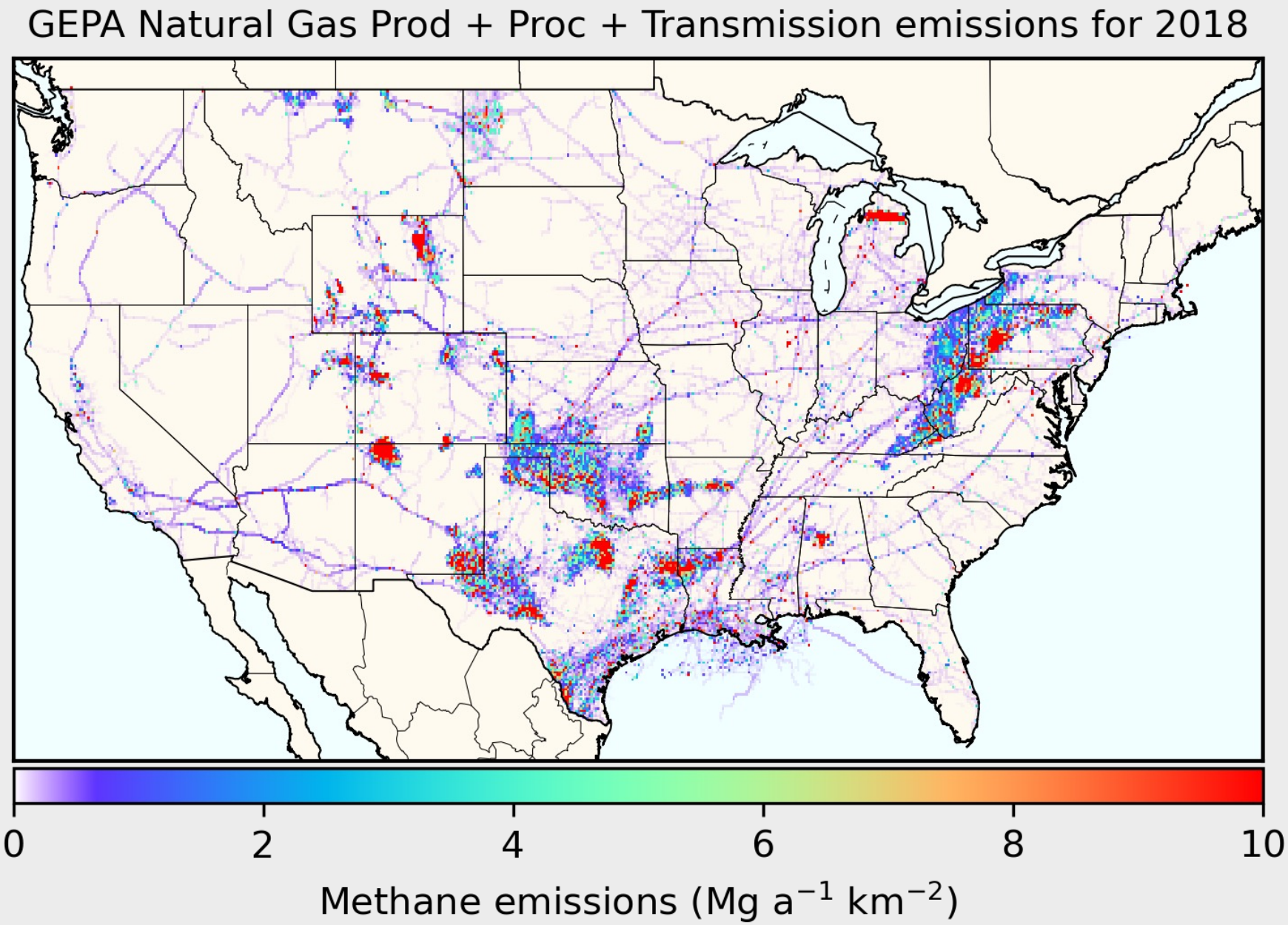
Production & Exploration: Enverus monthly well-level data



Processing: GHGRP & Enverus processing plant data



Transmission: Compressor stations, storage stations, pipelines, and many others



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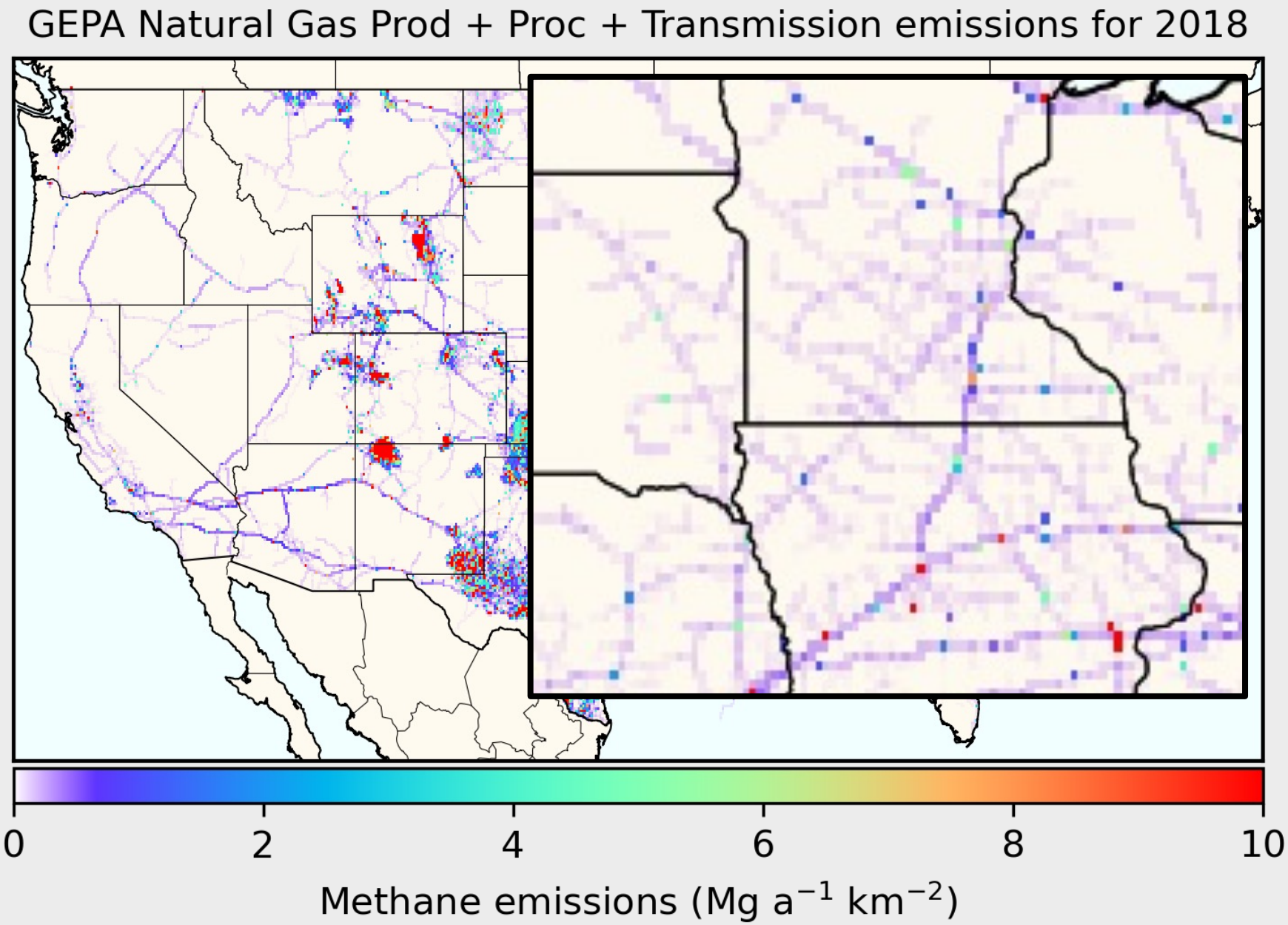

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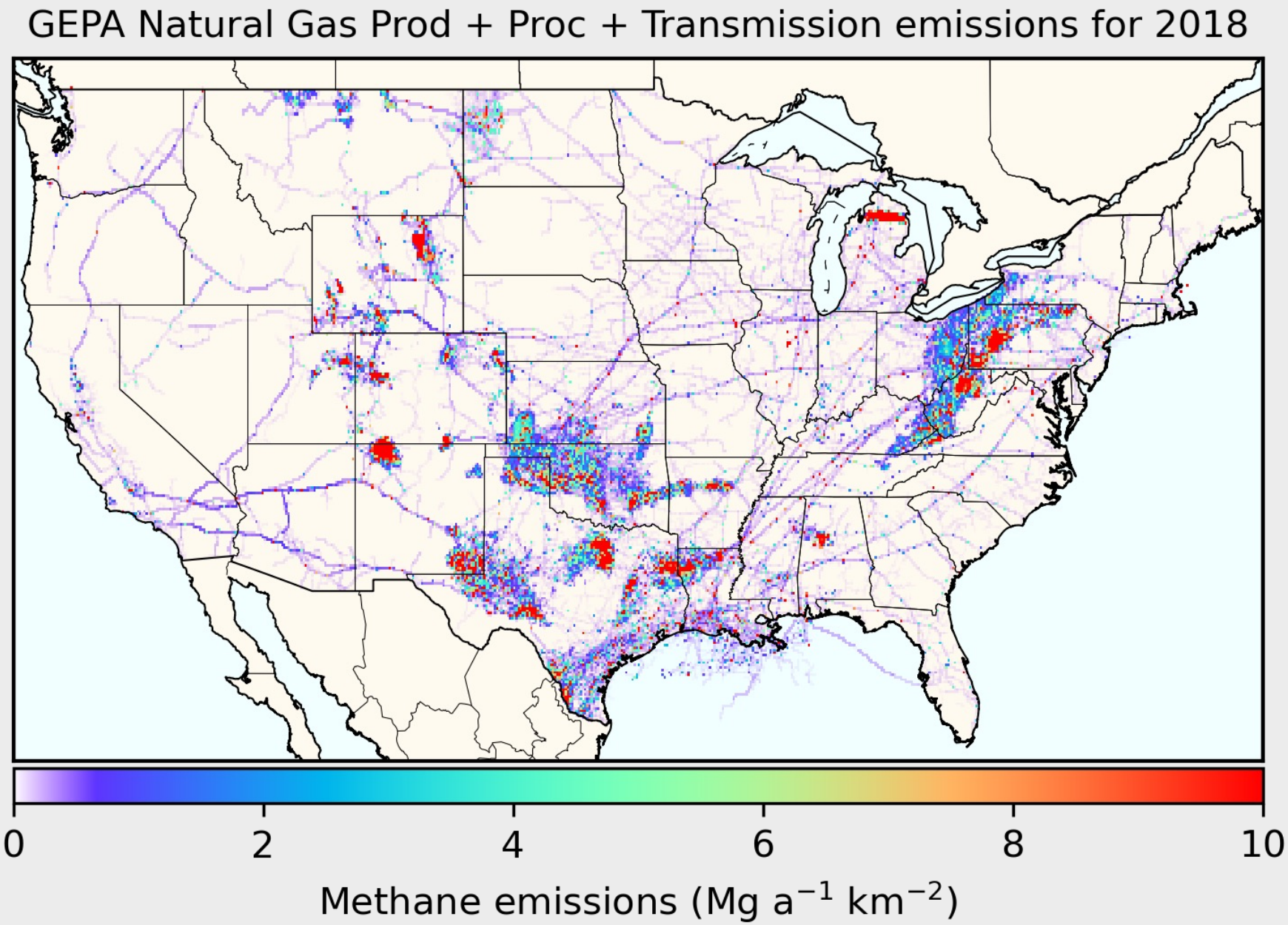
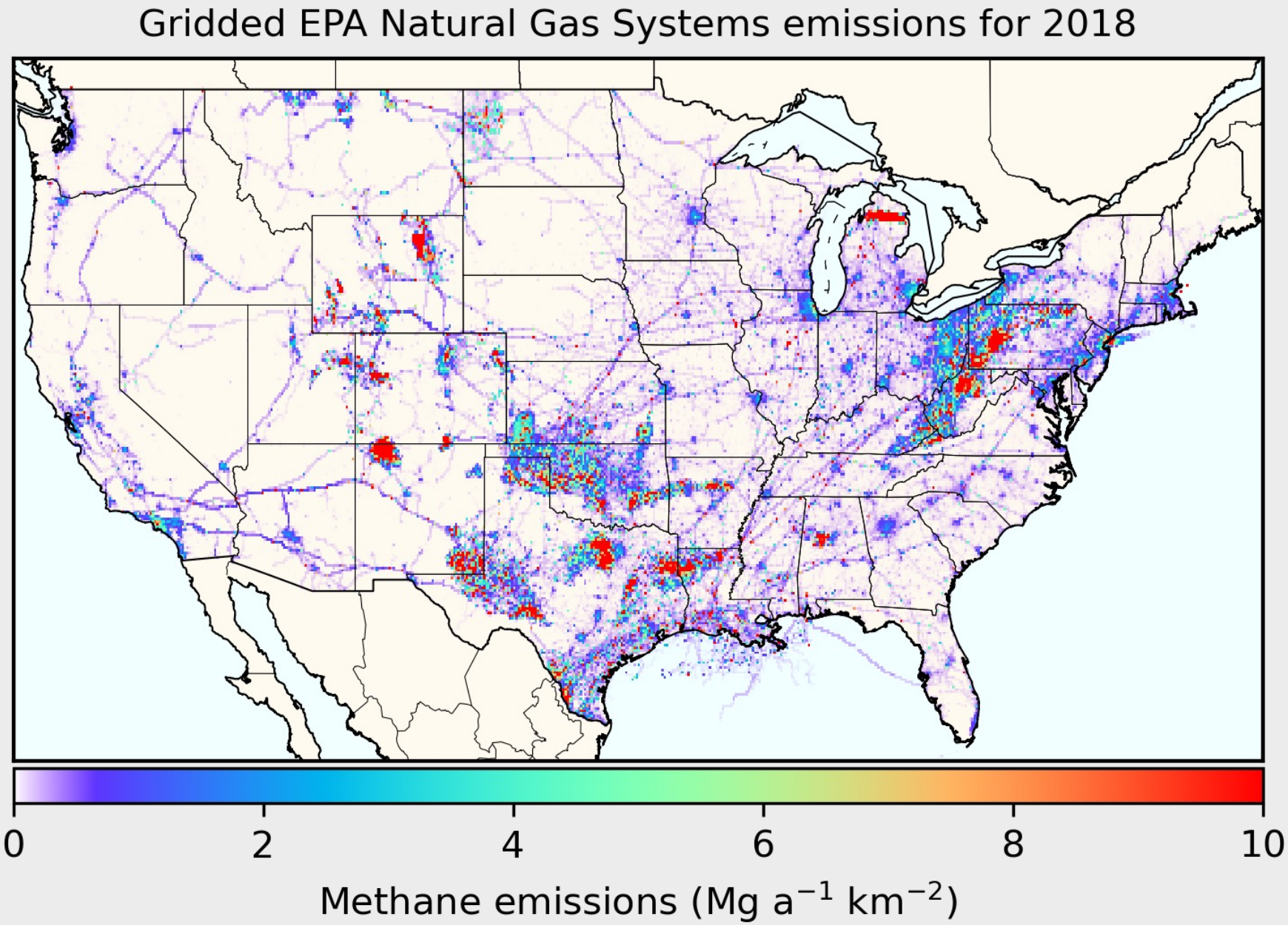
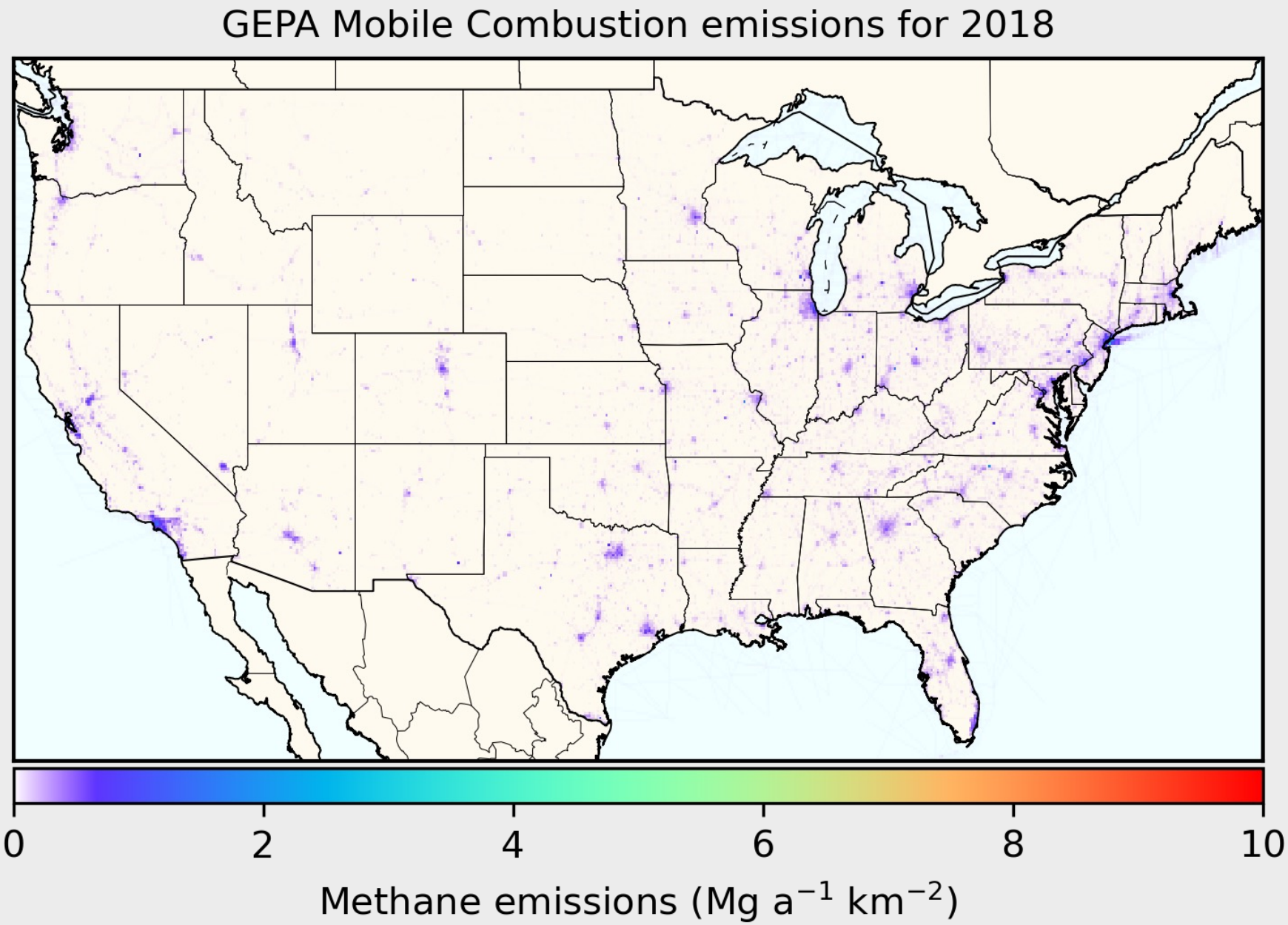


Distribution: State-level leakage data combined with the US Census



Atmospheric comparisons require completeness including small sources



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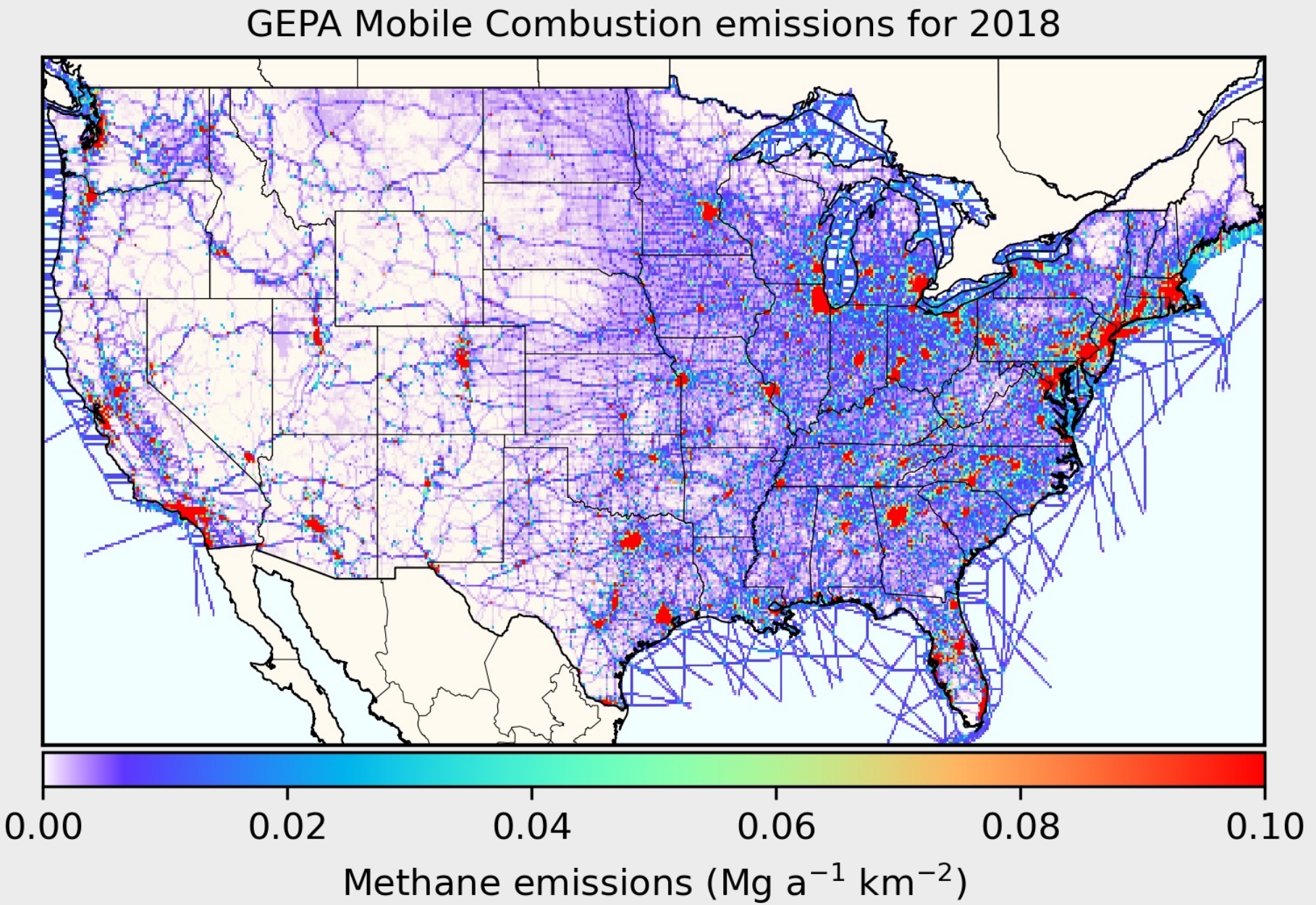
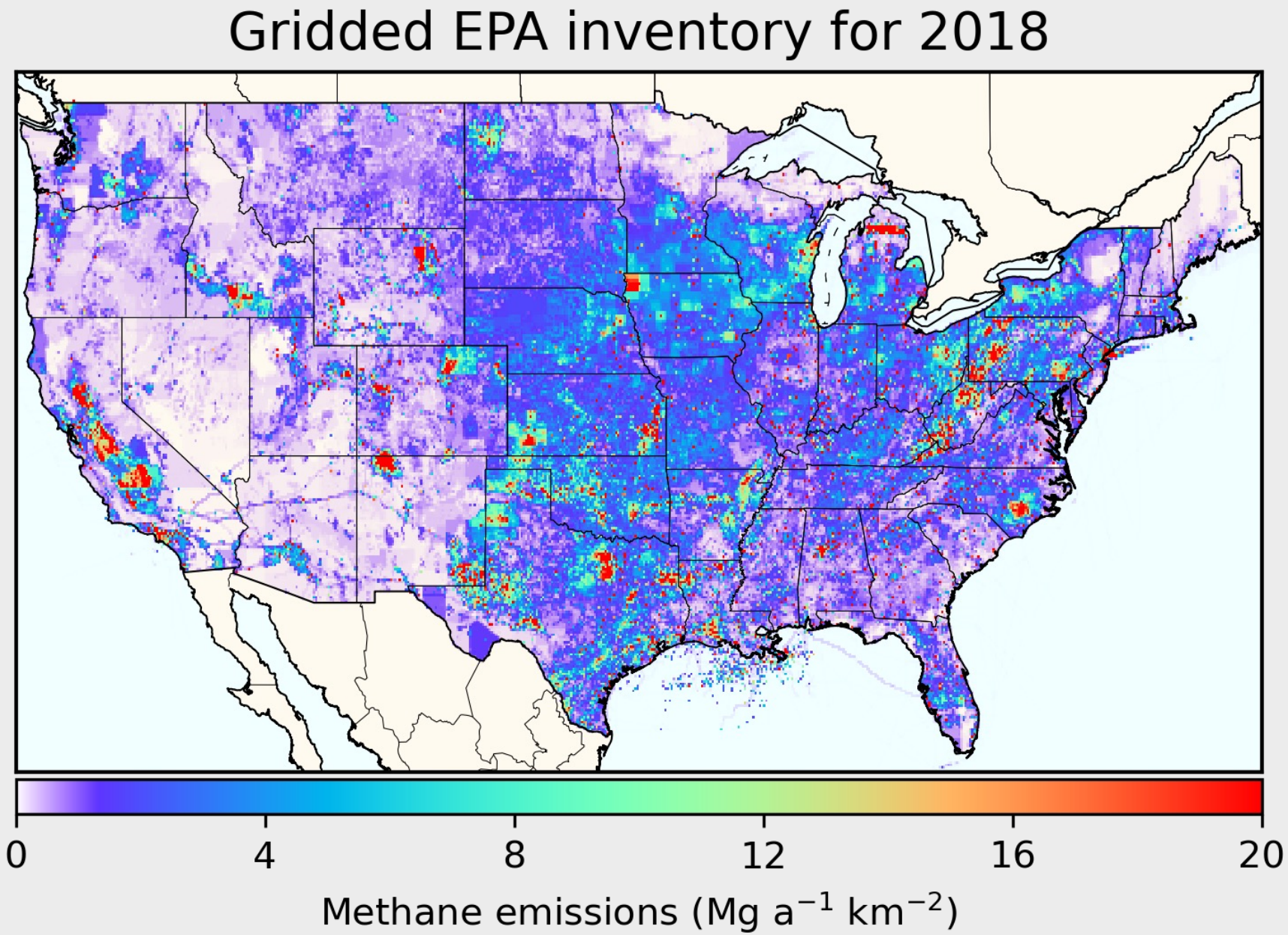


The Gridded EPA inventory for 2018 (2020 GHGI)



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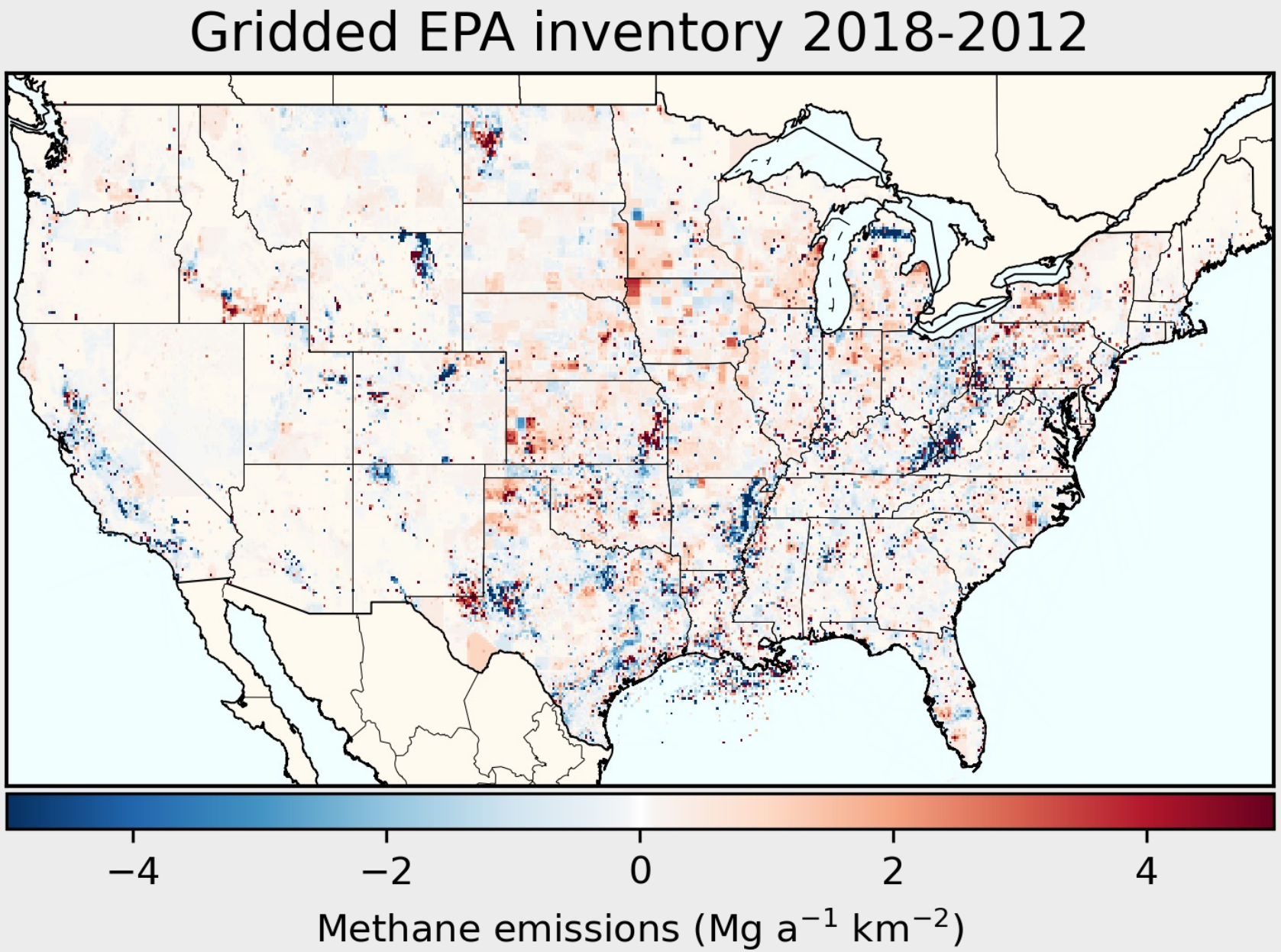

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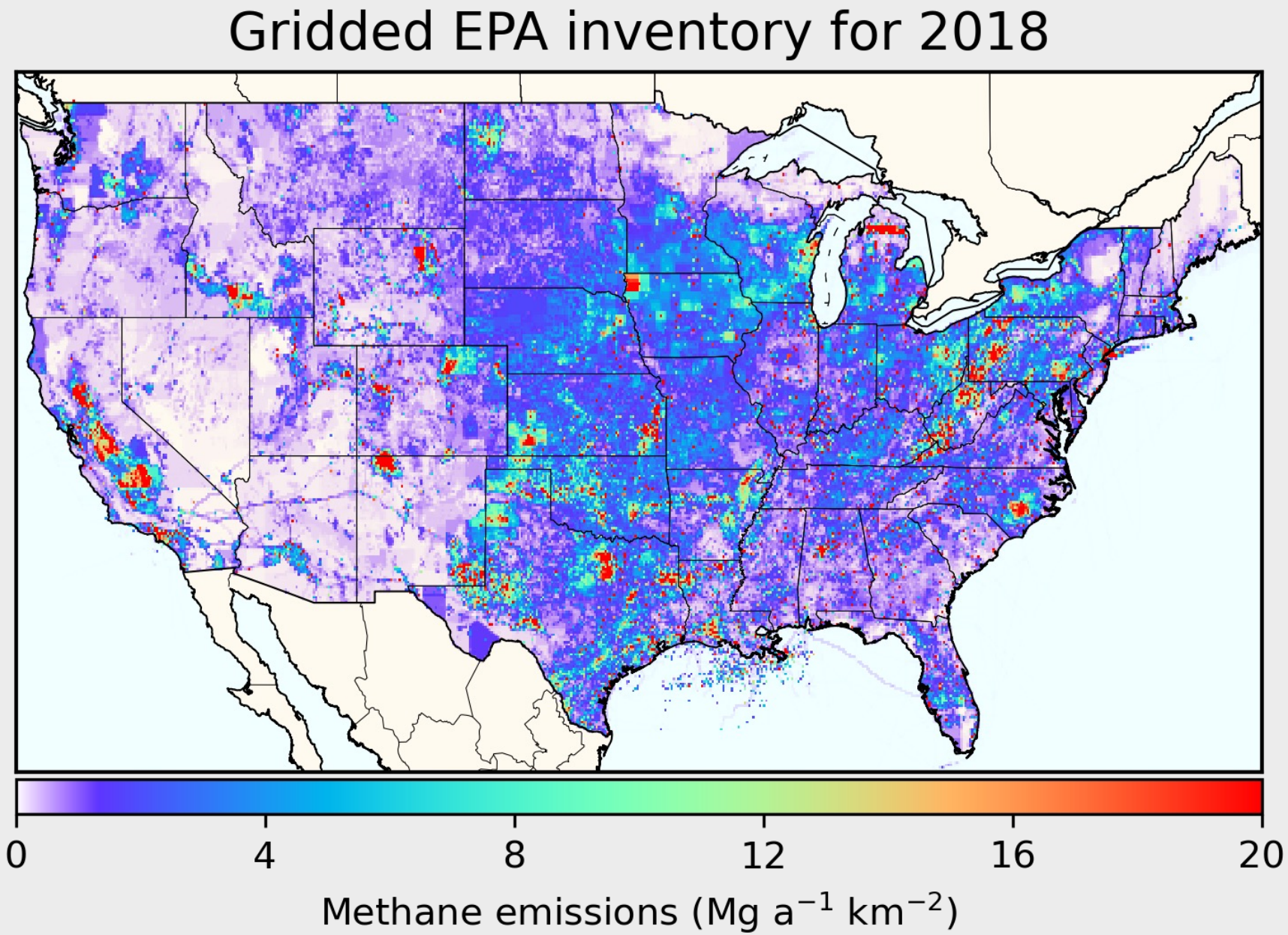
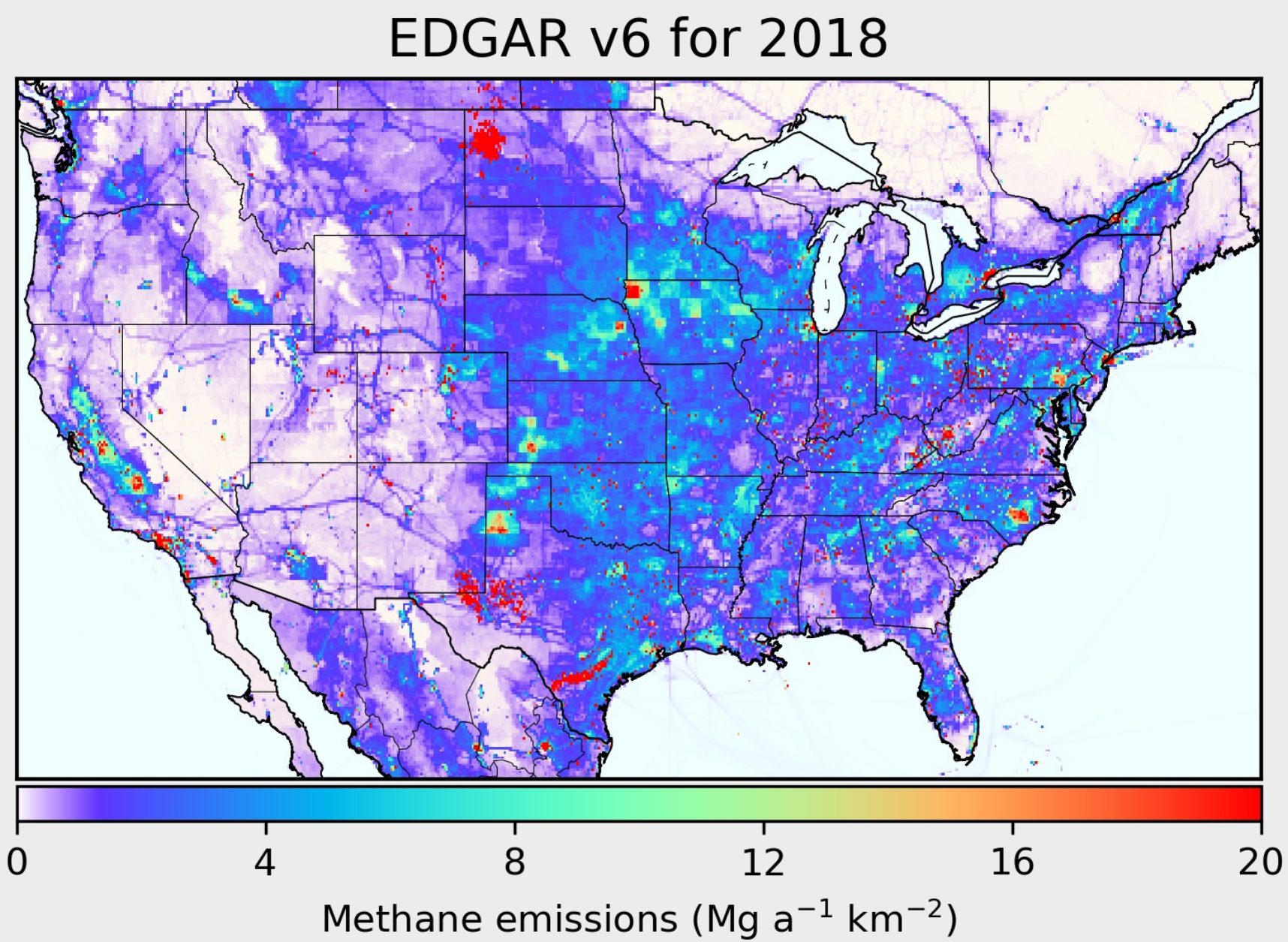
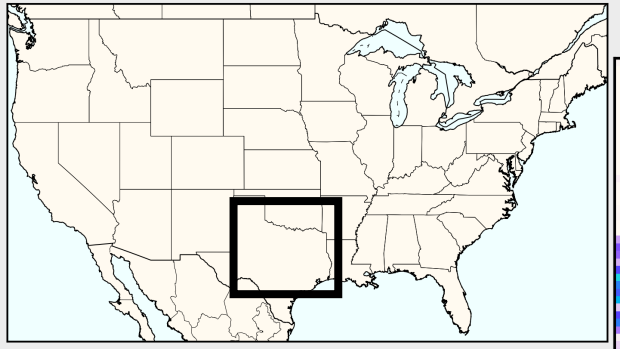


EDGAR v6 is a global inventory using consistent methodology across the world



Spatial differences will impact inversion results and source sector interpretation



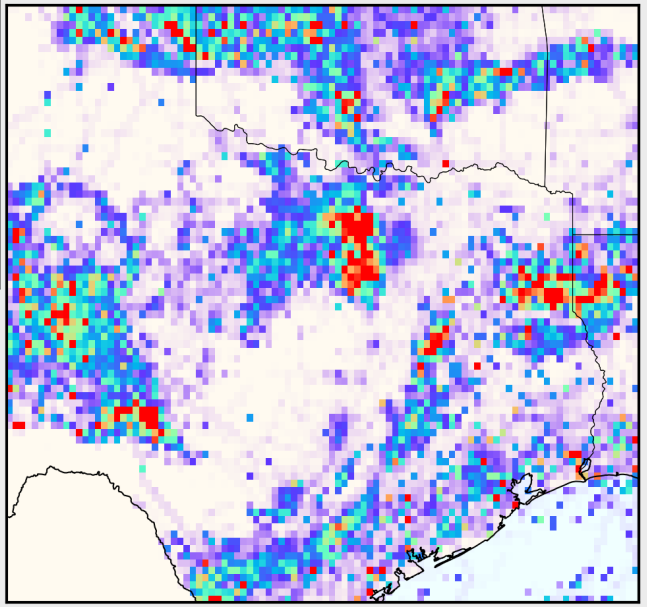
Oil/Gas

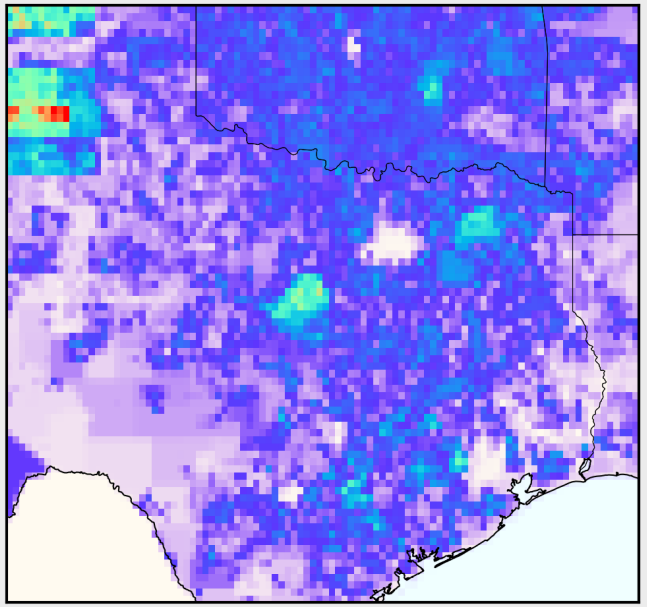
Livestock

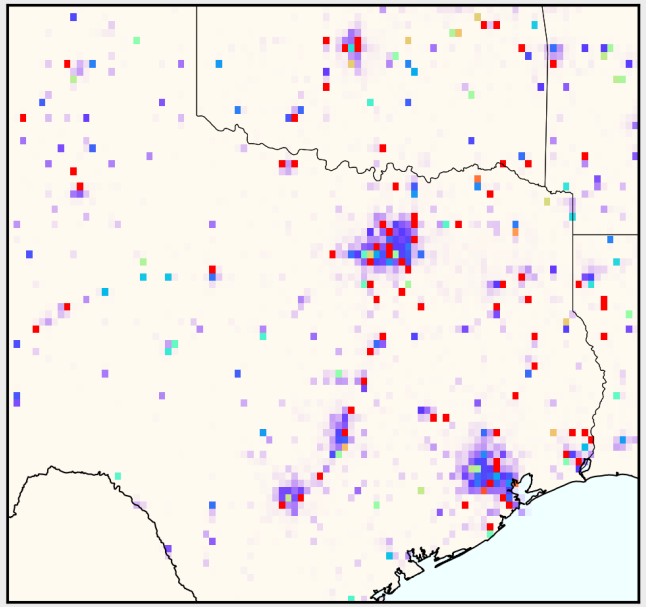
Waste

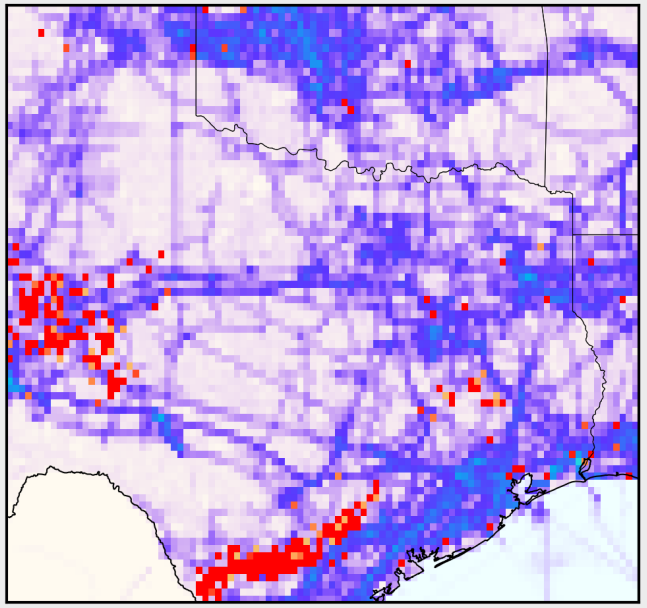
Gridded EPA

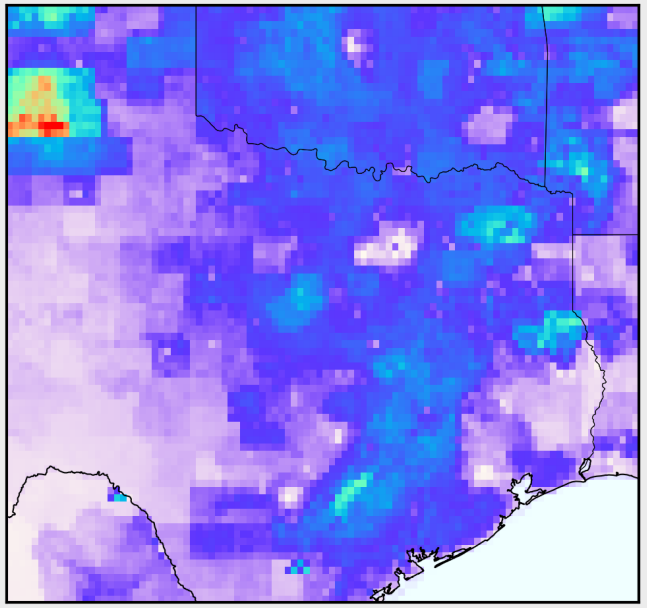
EDGAR v6

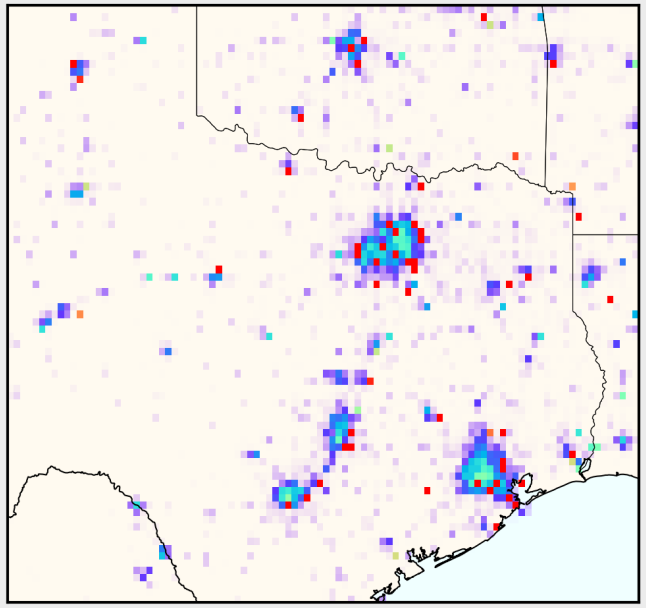






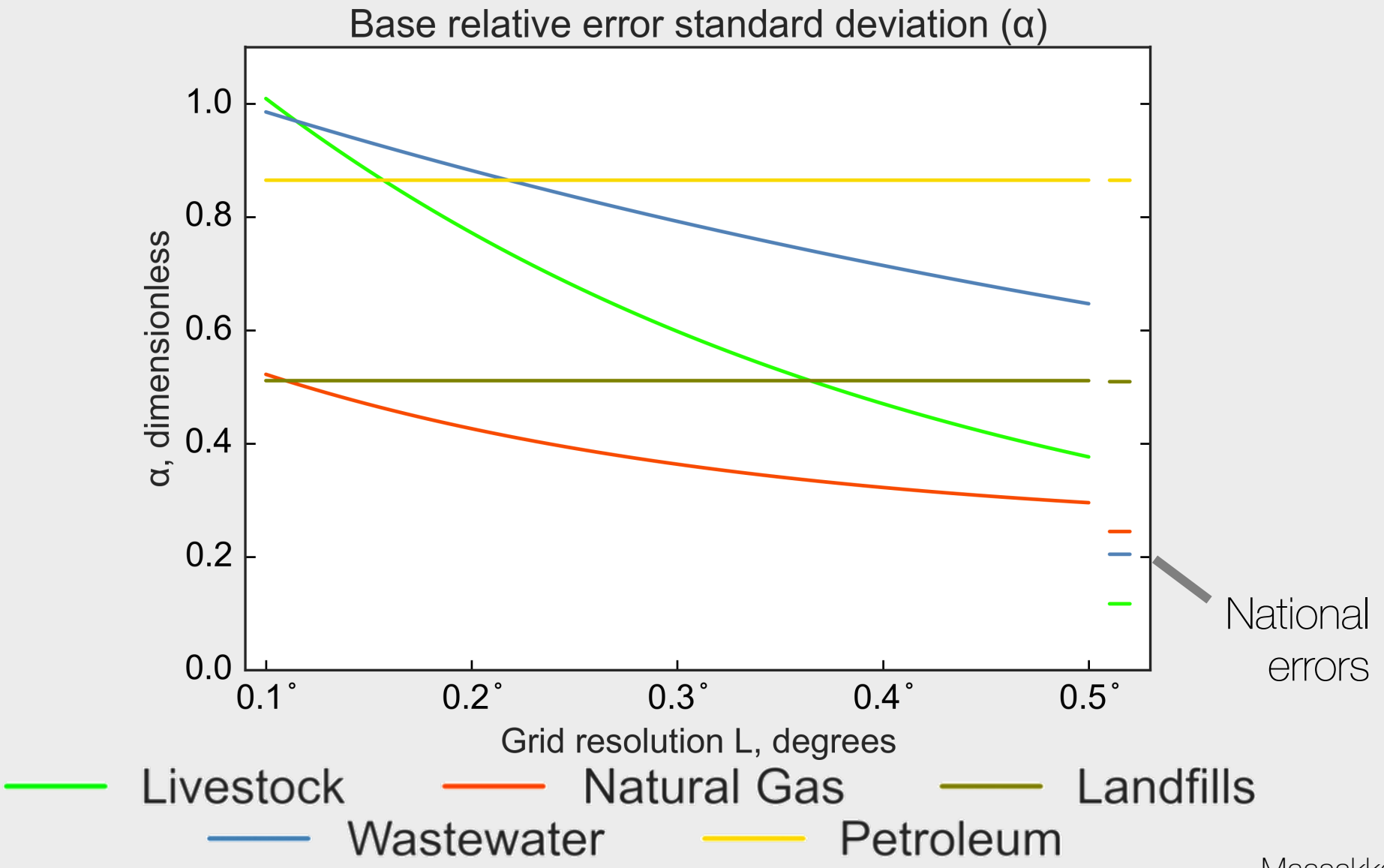






Quantifying errors in gridded emissions is a challenge

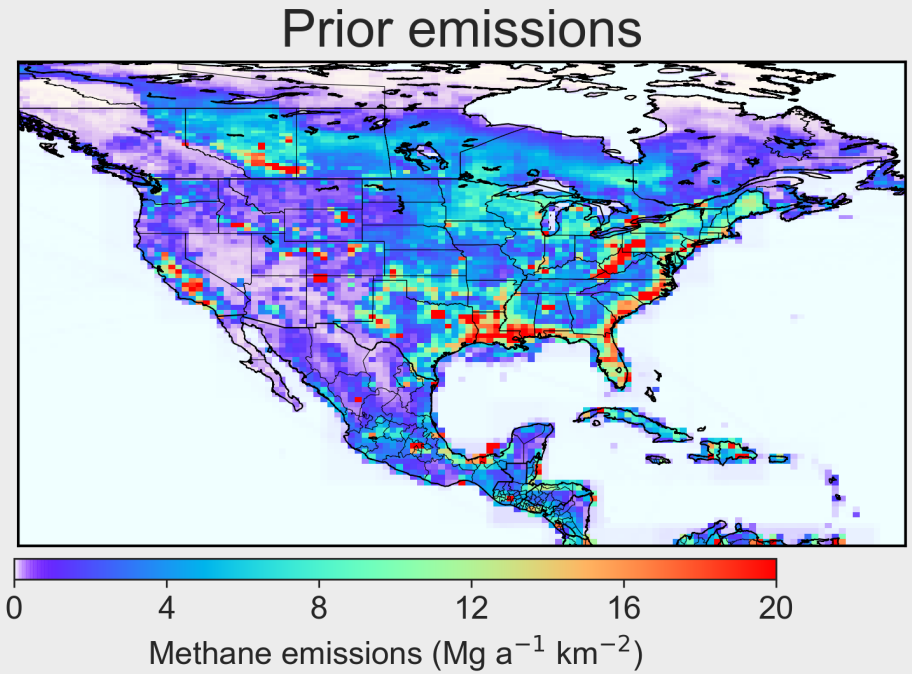
The resolution-dependency depends on the source type.



Maasakkers et al. (2016)

Evaluating the gridded EPA inventory using atmospheric observations

The 2012 emission maps have been used by many studies, including ones using satellite data.



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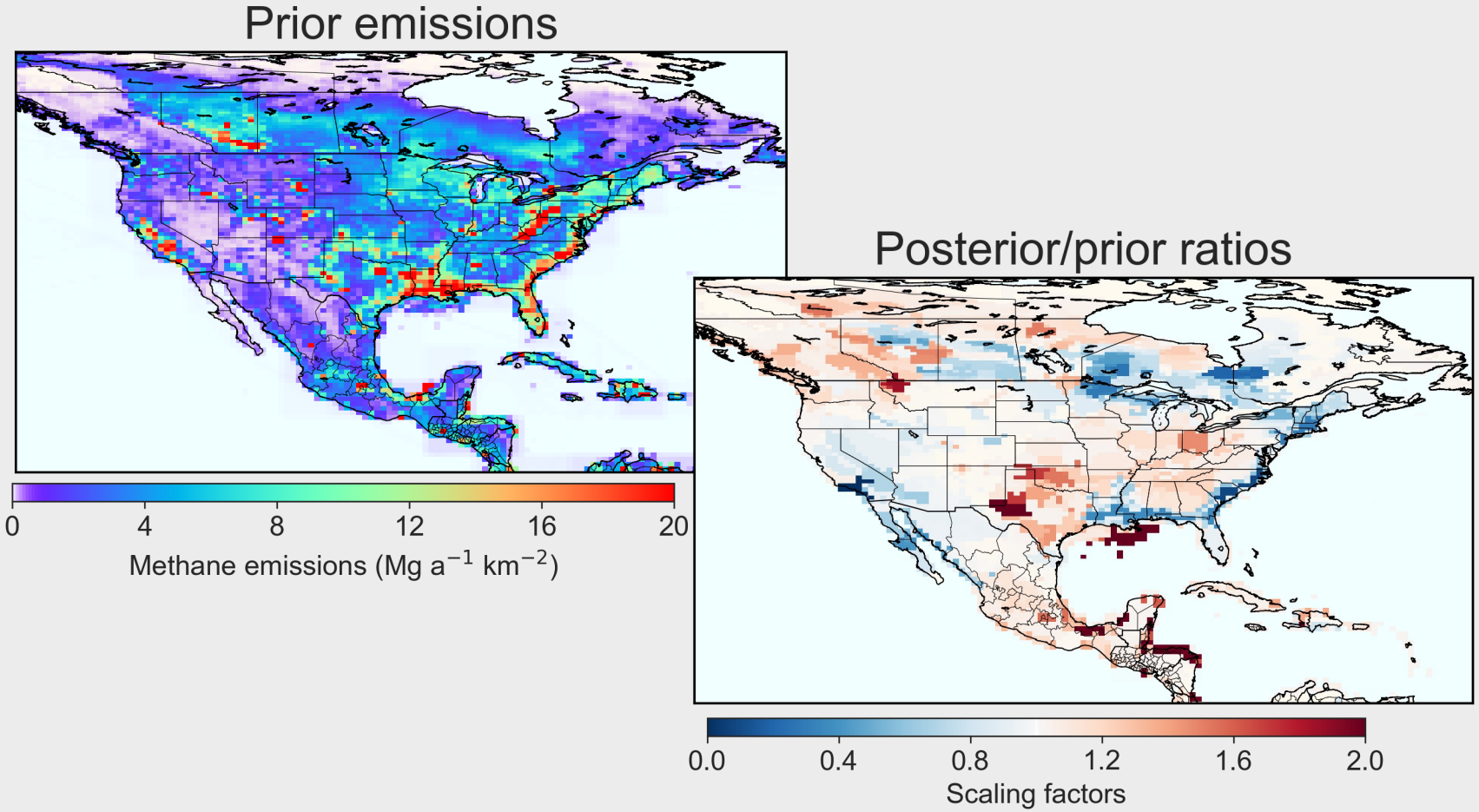

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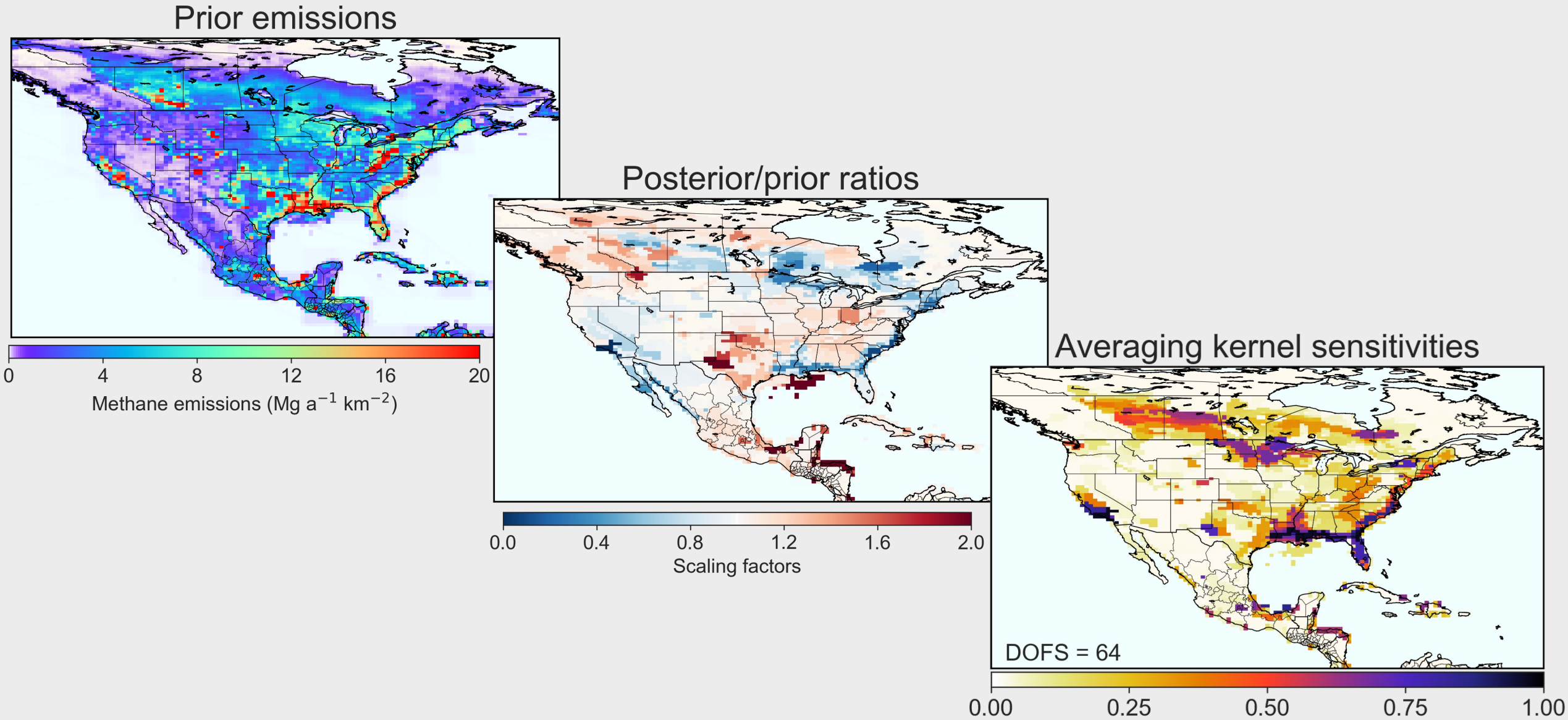
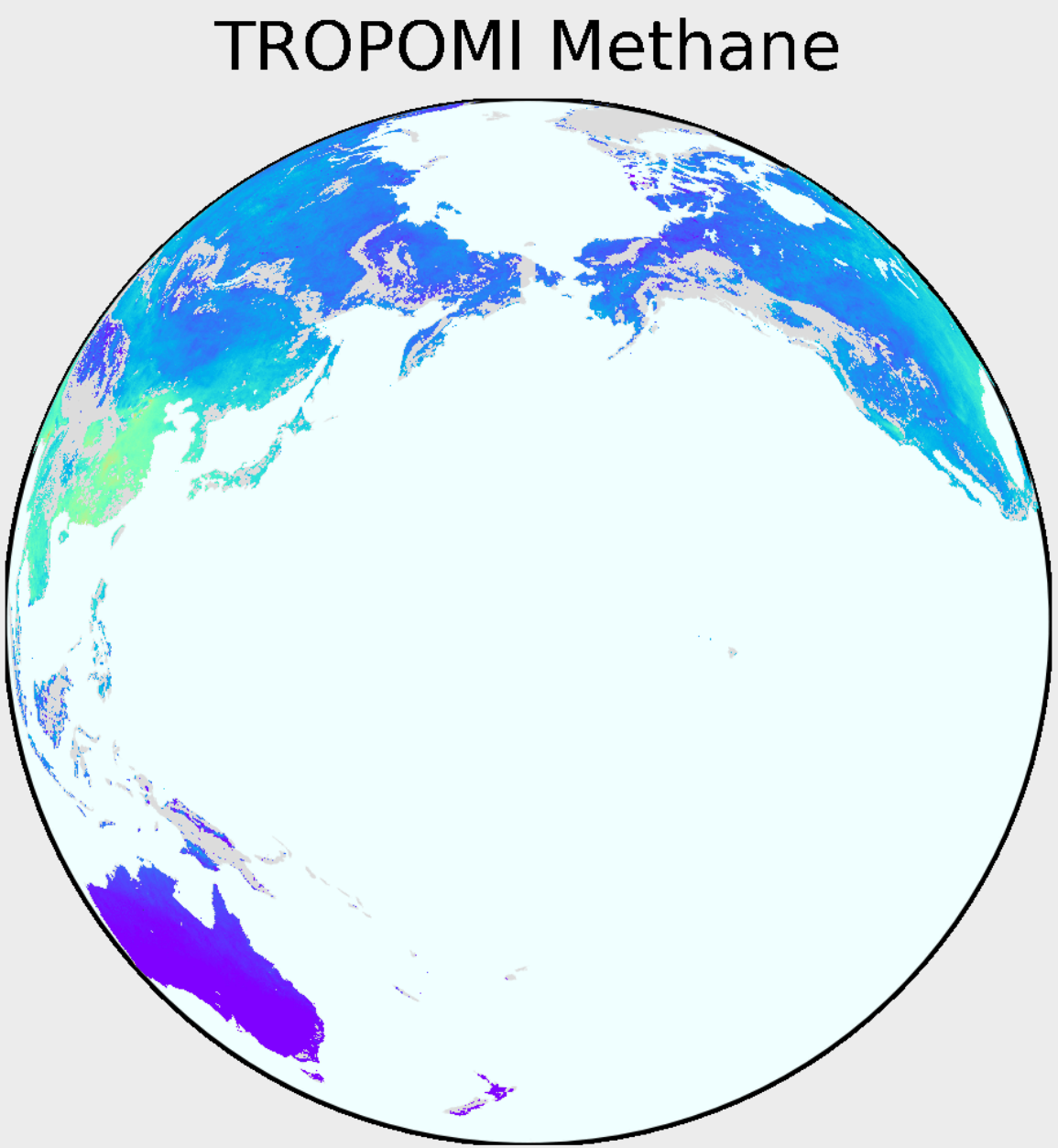


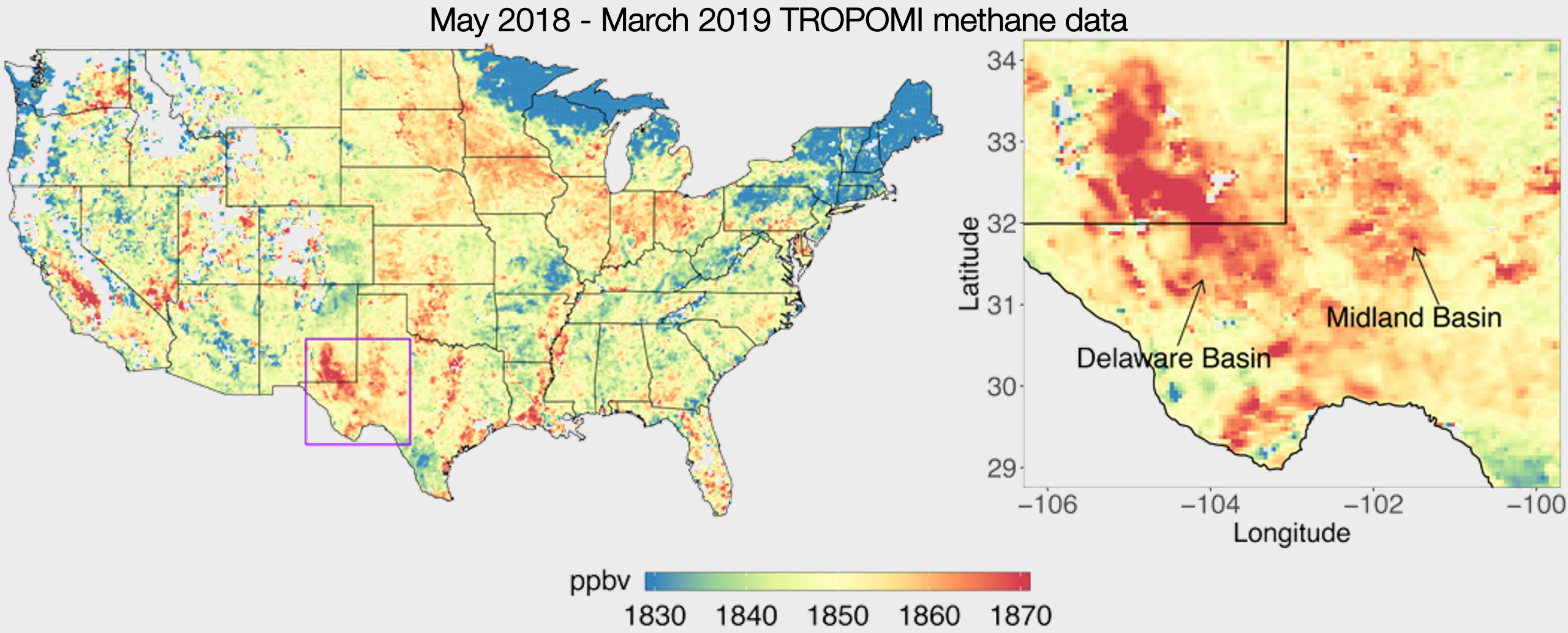
Maasakkers et al. (2021)

TROPOMI has been a game-changer for methane as well as other species



With TROPOMI we can get much more detailed information from space

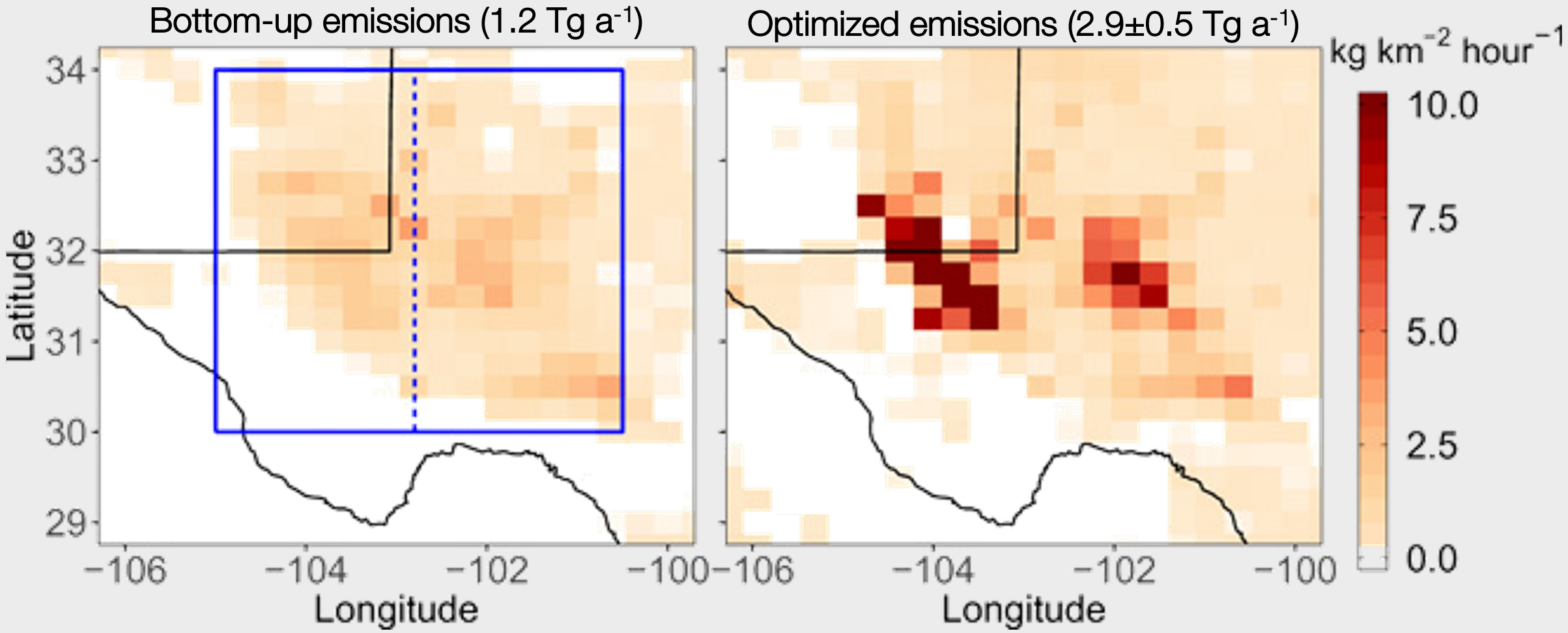
We can now monitor emissions over the Permian Basin in Texas and New Mexico.



Zhang et al. (2020)

With TROPOMI we can get much more detailed information from space

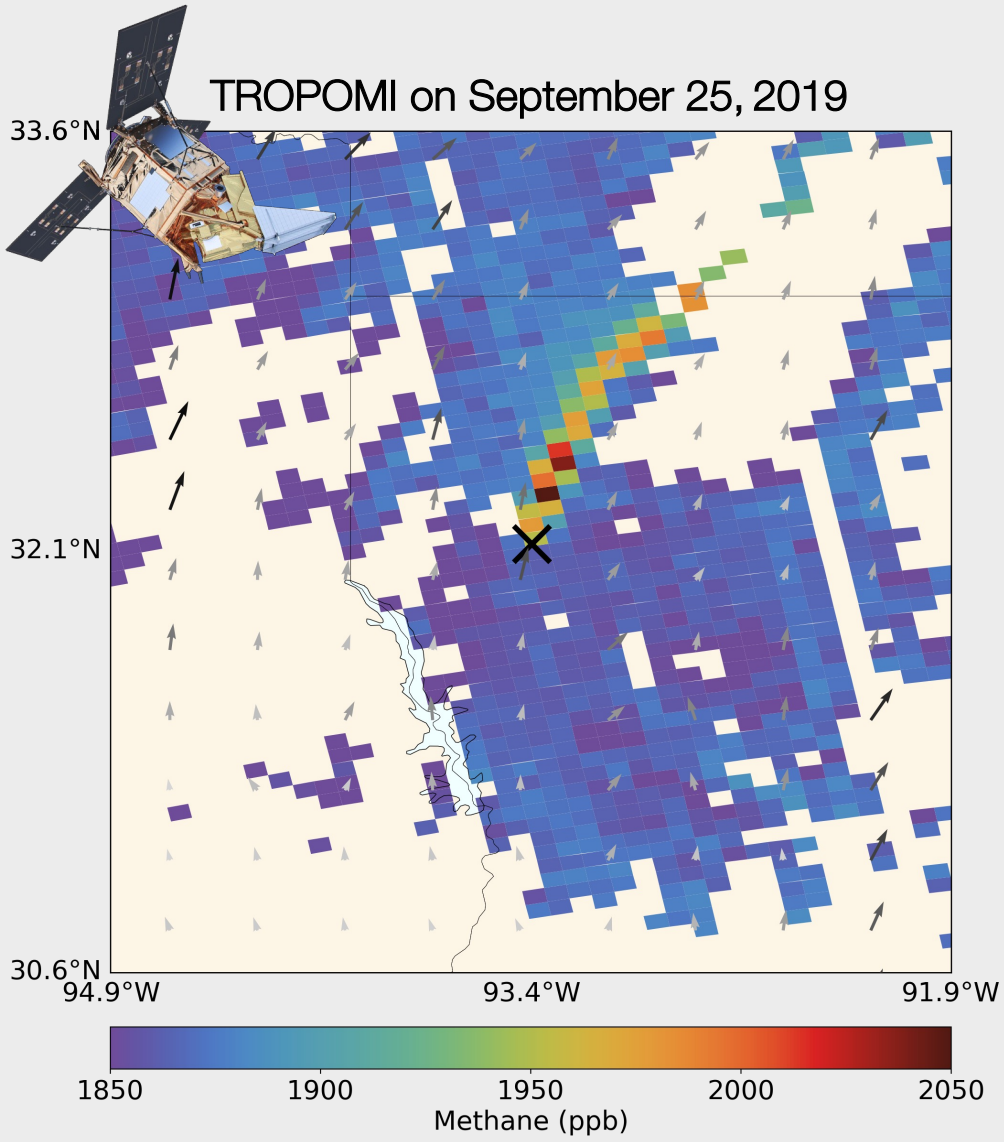
The inversion shows higher emissions over the Permian production region in the US.



Other studies have now looked at numerous regions and for example compared with information on point sources detected by aircraft.

Zhang et al. (2020) / Shen et al. (2022) / Worden et al. (2022) / Cusworth et al. (preprint)

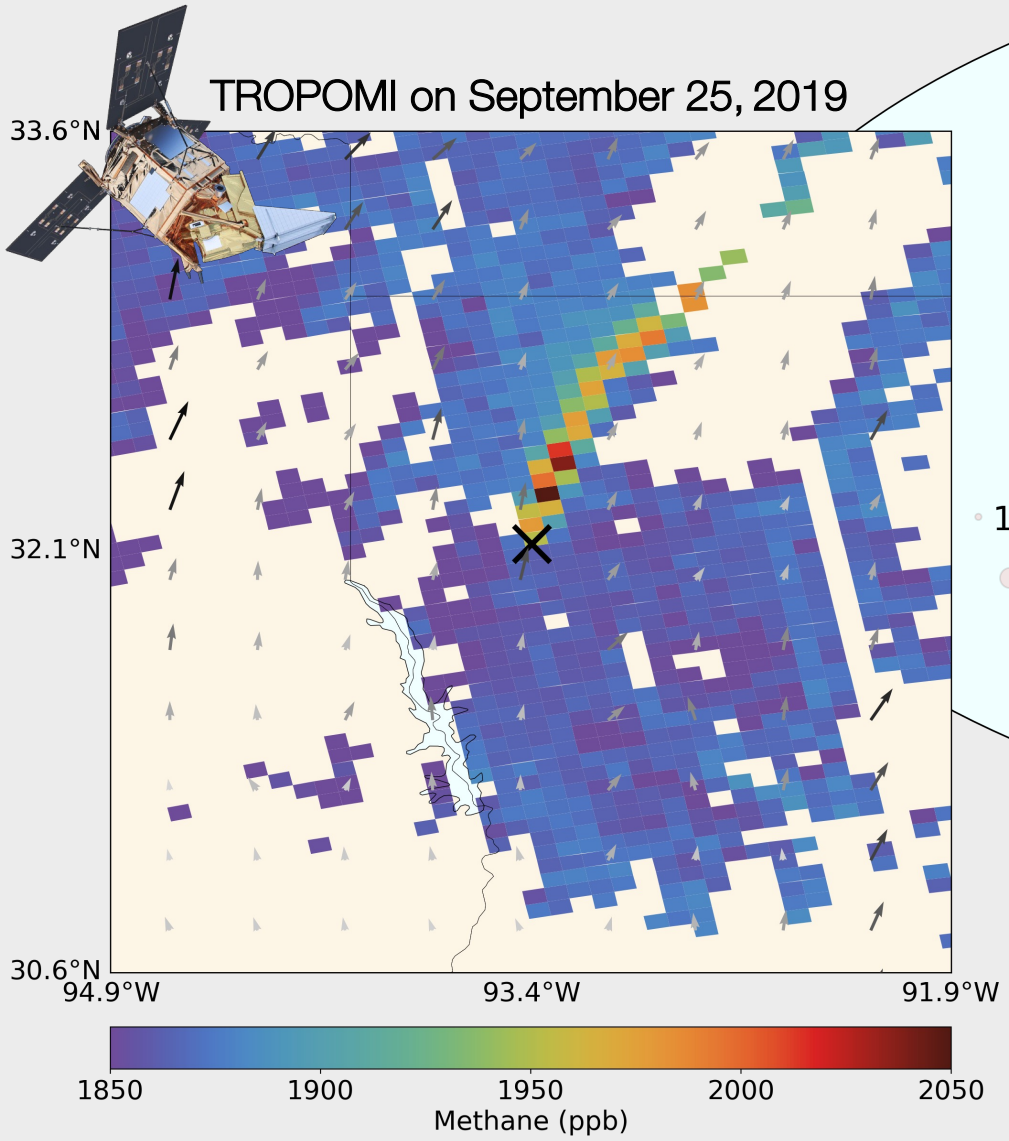
Three blowouts are now included in the EPA GHG as Anomalous Events

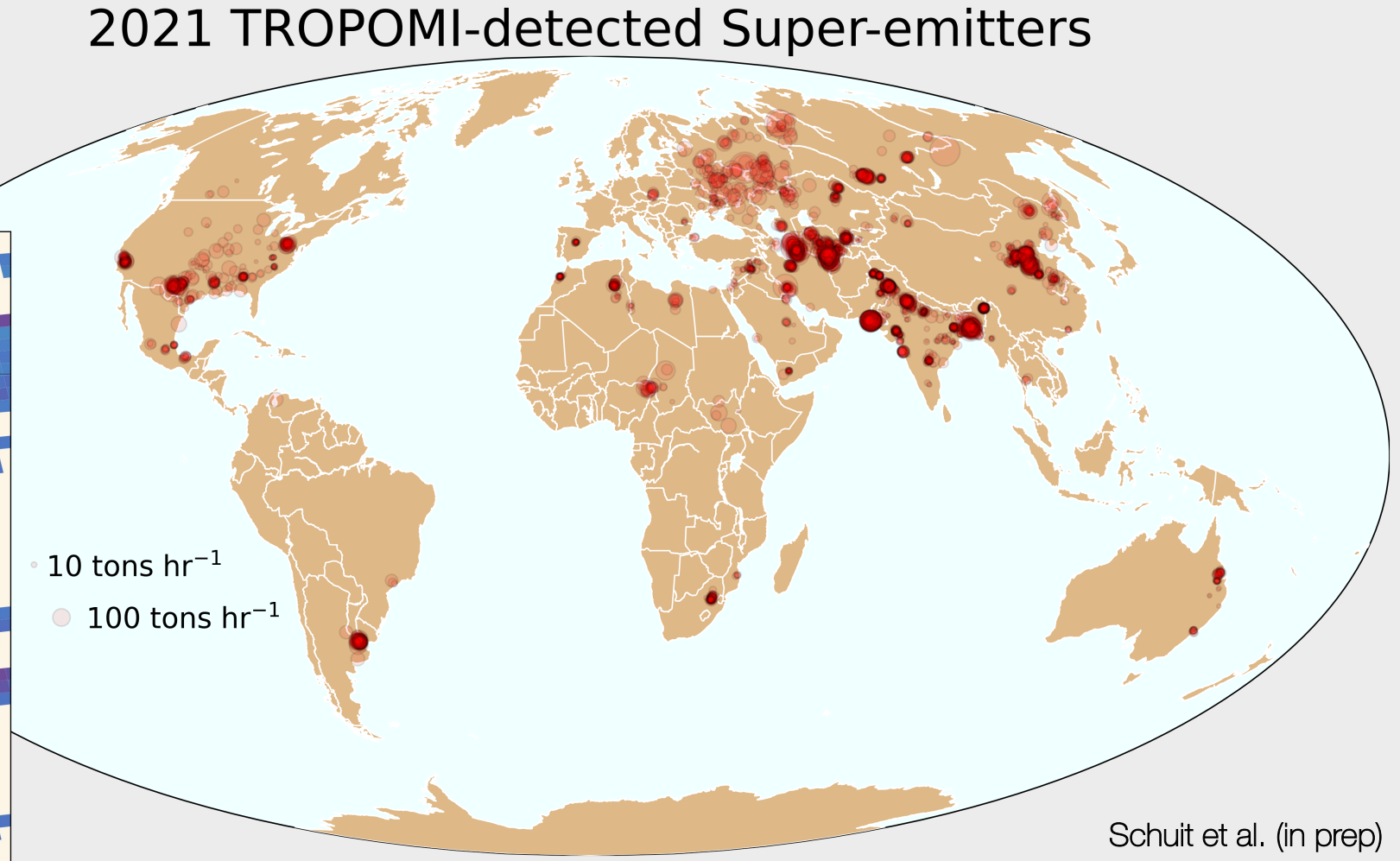


Three blowouts quantified using satellites are now included in the US inventory as Anomalous Events

Pandey et al. (2019) / Cusworth et al. (2021) / Maasakkers et al. (2022)

Three blowouts are now included in the EPA GHG as Anomalous Events





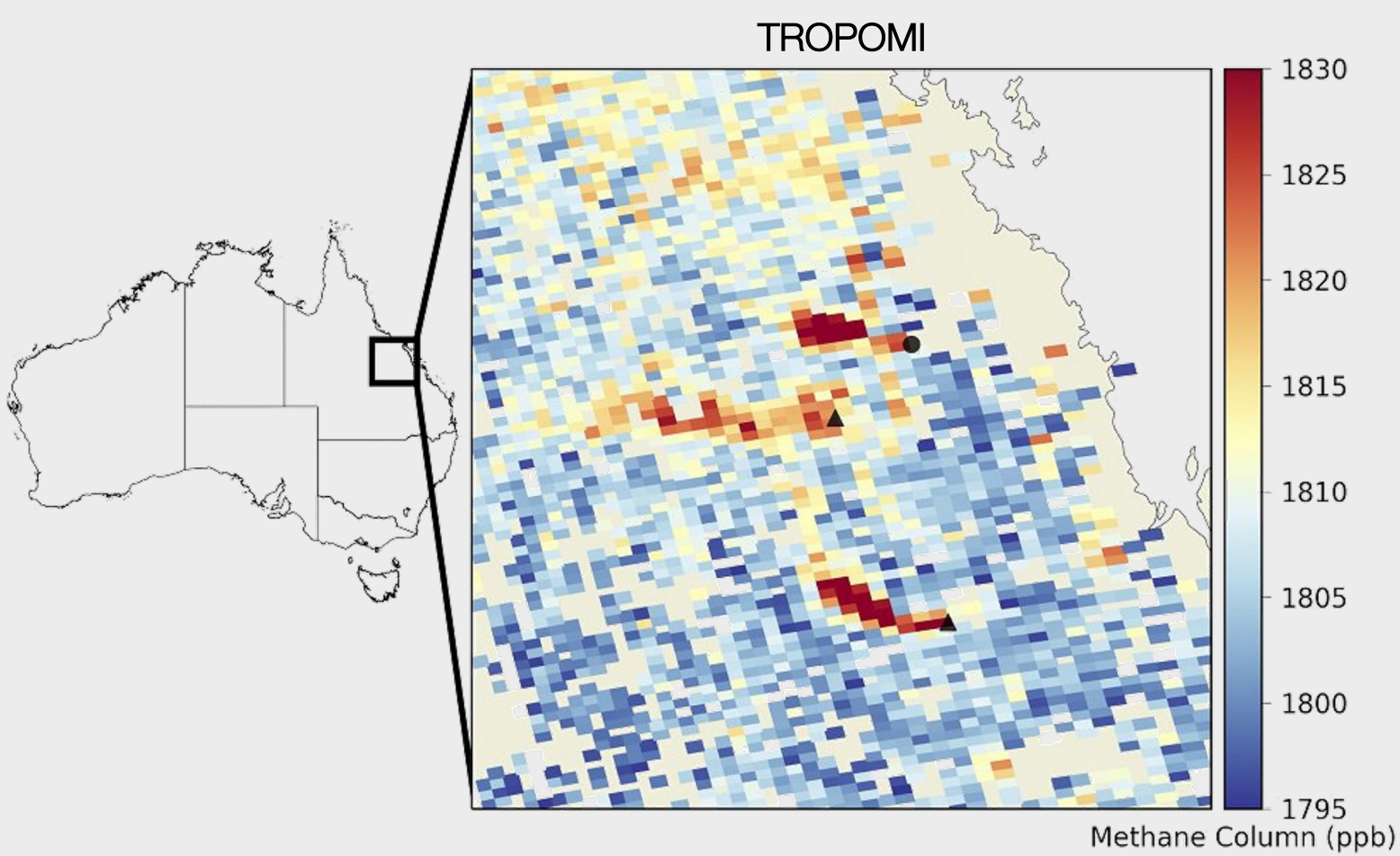
Schuit et al. (in prep)

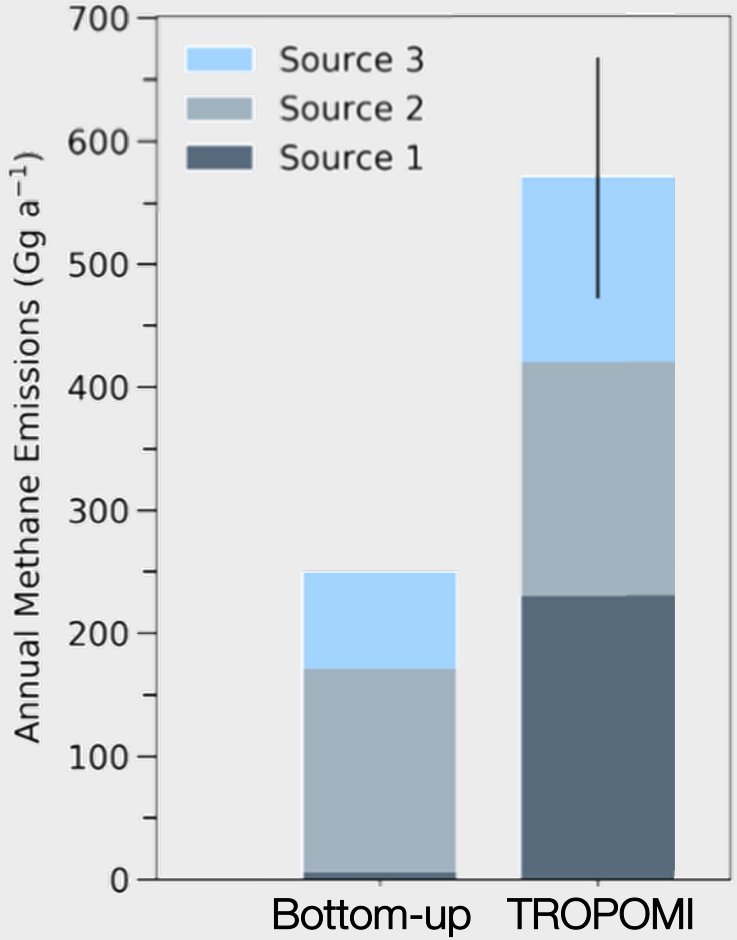
Three blowouts quantified using satellites are now included in the US inventory as Anomalous Events

Pandey et al. (2019) / Cusworth et al. (2021) / Maasakkers et al. (2022)

Not just events, we detected persistent emissions in Australia

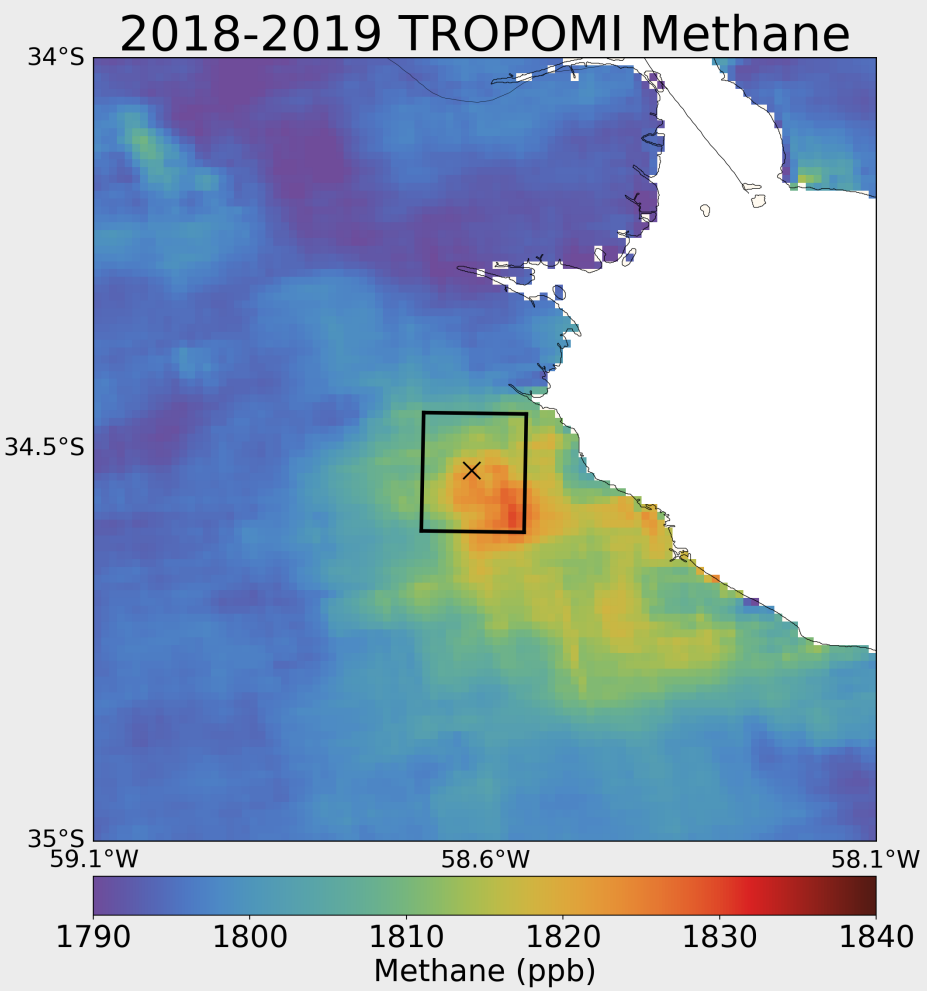
After gridding national coal mining emissions, TROPOMI points at an underestimate for two our of three studied clusters of coal mines.



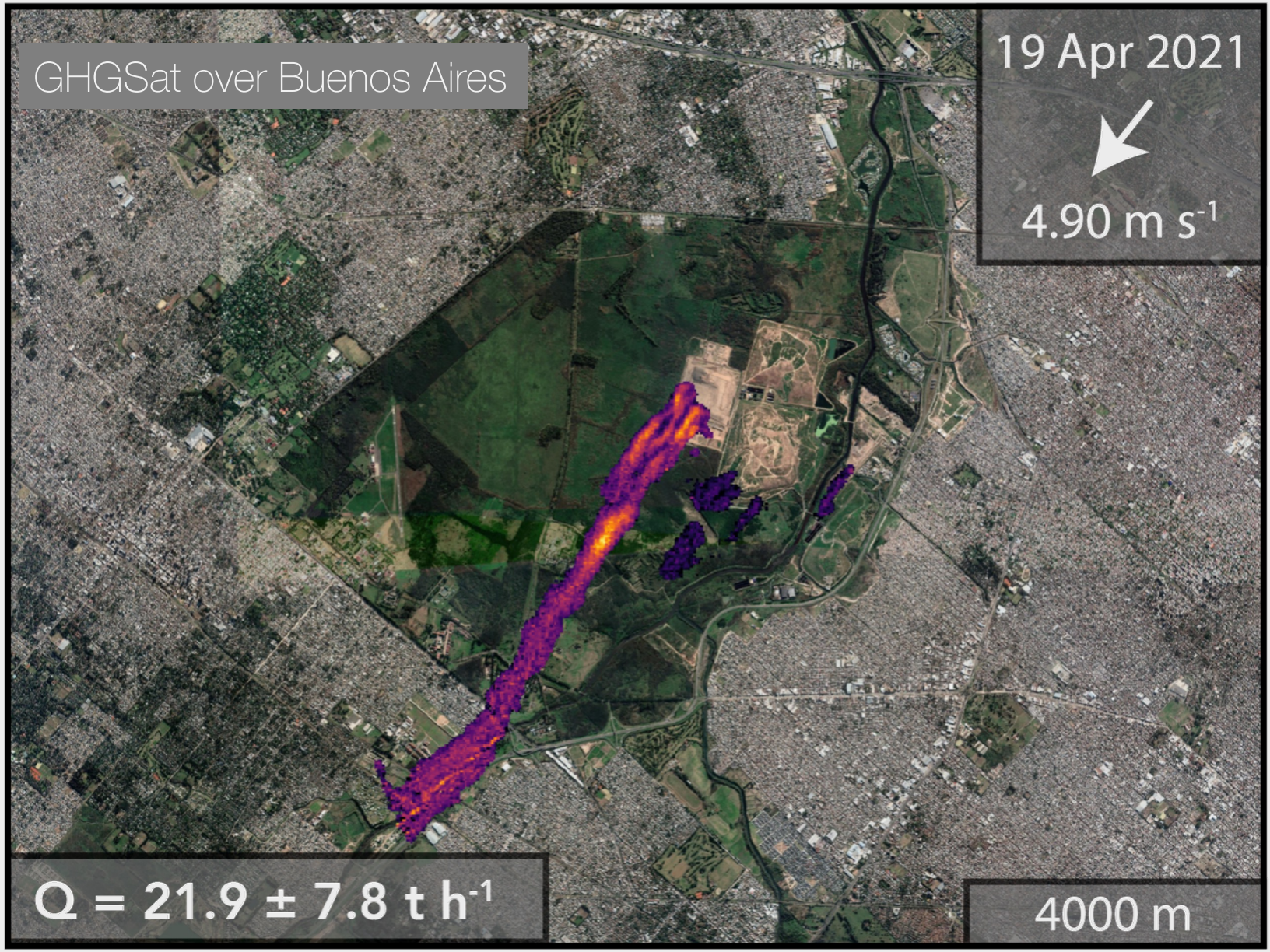


Sadavarte et al. (2021)

Not just events, we detected persistent emissions from Buenos Aires (Argentina)



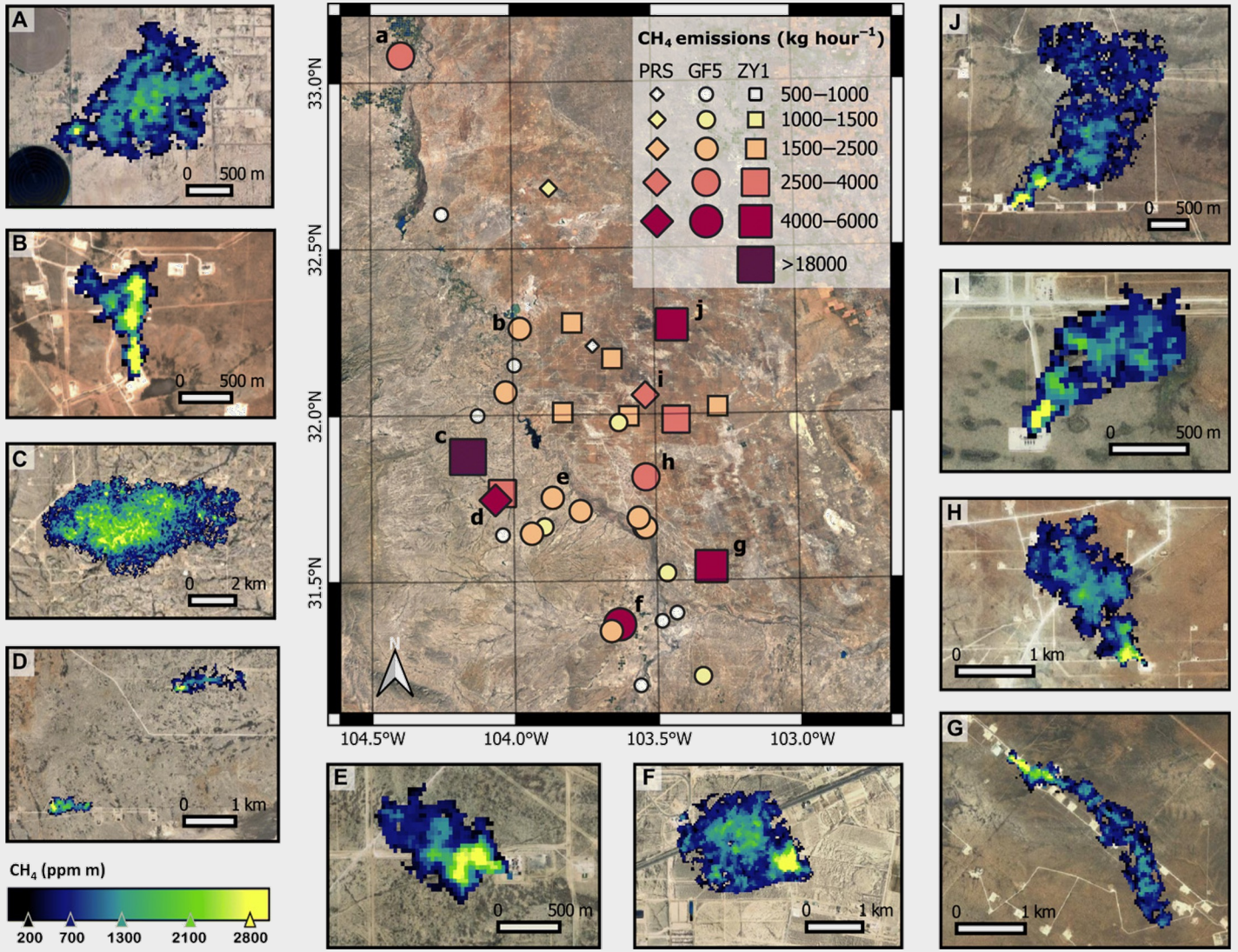
The landfill is not included as a point source in EDGAR.



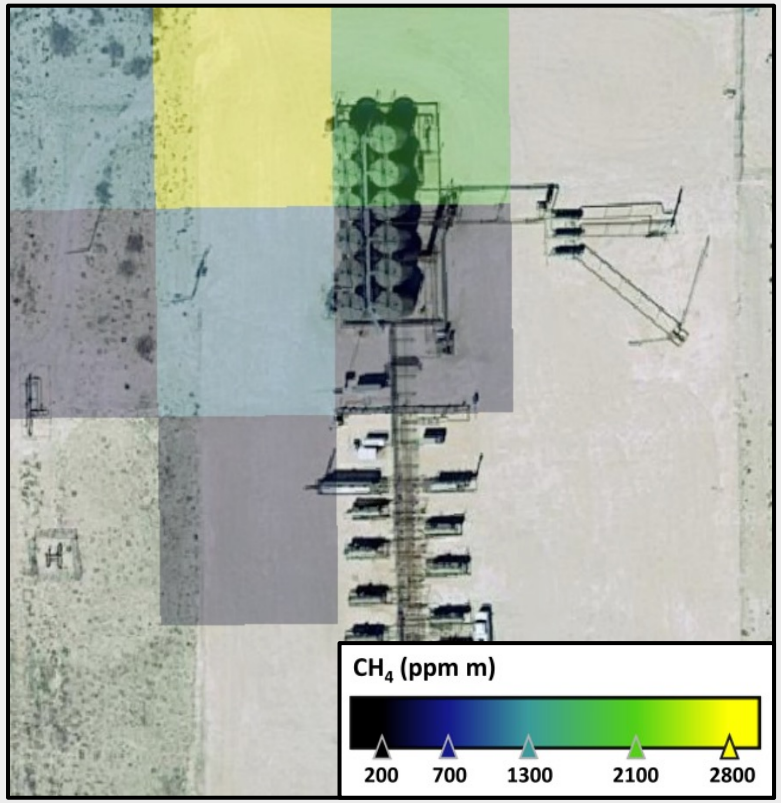
Maasakkers et al. (2022). Wind data: GEOS-FP (GMAO, 2021)

Point source mappers can explain part of the emissions seen in inversions

We found 37 plumes over 4 days in the Permian. On one day, 19 plumes accounted for ~30-50% of total emissions from the studied area.



Source identification example: tank battery



Irakulis-Loitxate et al. (2021)

Global perspective

Satellite data are global but require regional interpretation.

Scarpelli et al. (2020/2022) / Cusworth et al. (2021)

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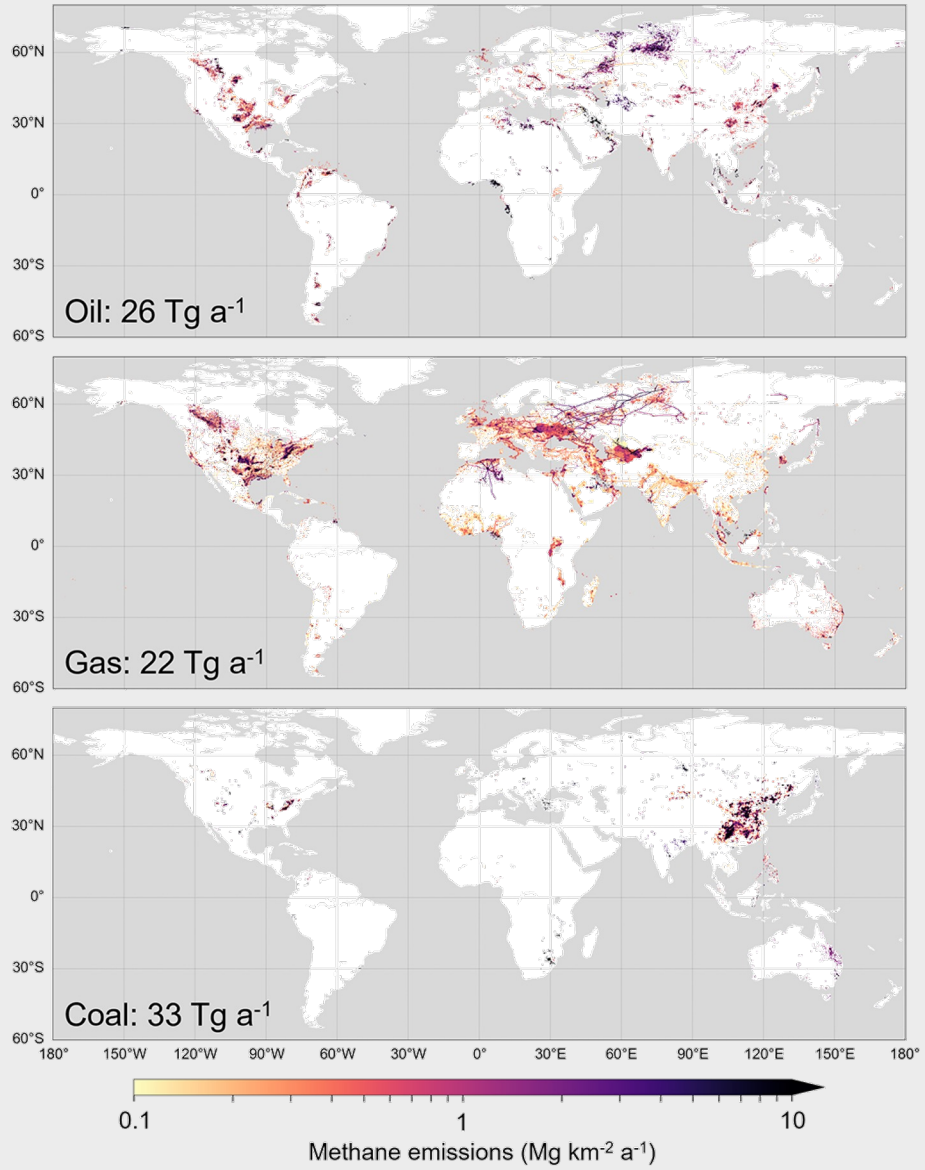
Global UNFCCC-consistent gridded inventories are helpful
In absence of national gridded inventories.
Spatial data is a challenge.

GFEI emissions for 2019



Scarpelli et al. (2020/2022) / Cusworth et al. (2021)

Global perspective

Satellite data are global but require regional interpretation.

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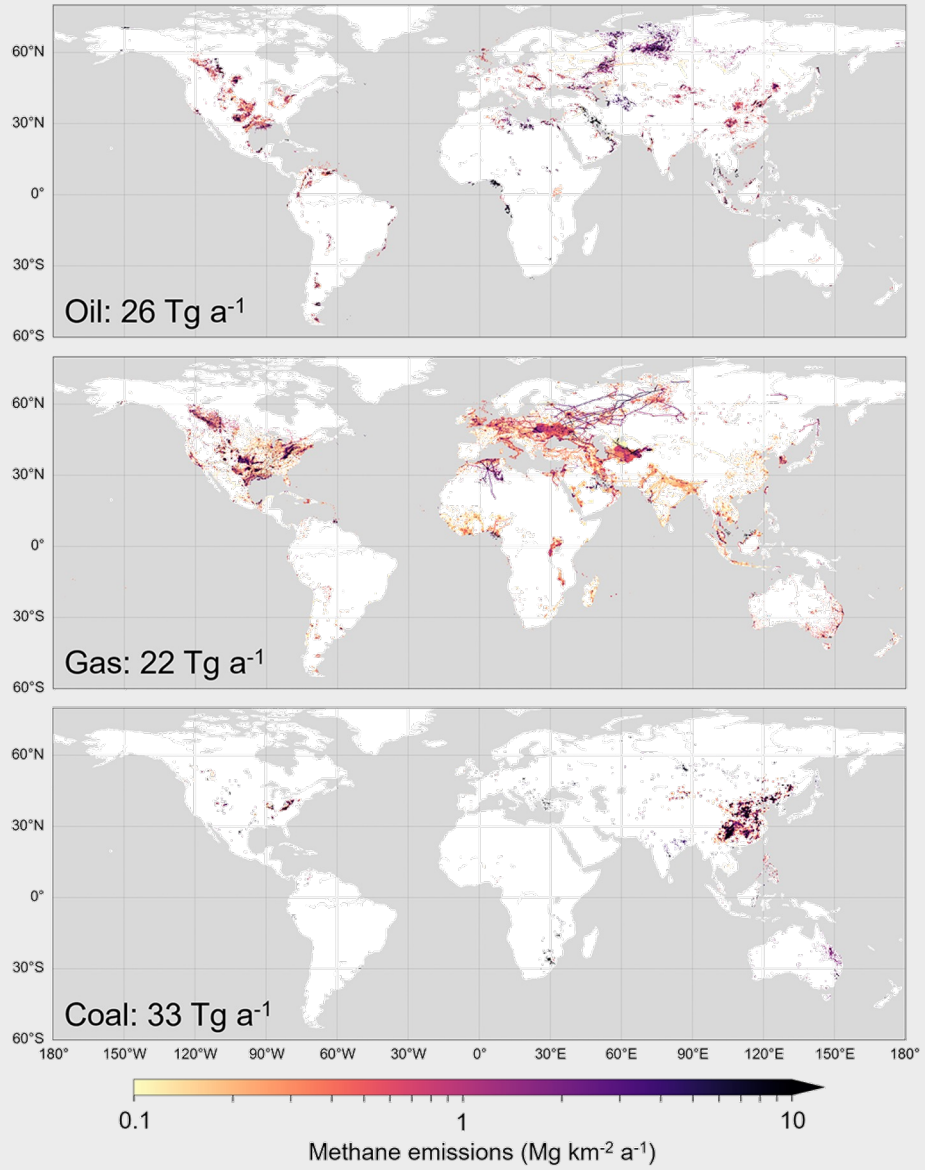
Analytical inversions allow full error characterization,
interpretation of the information gained, and
flexible prior attribution and swapping.

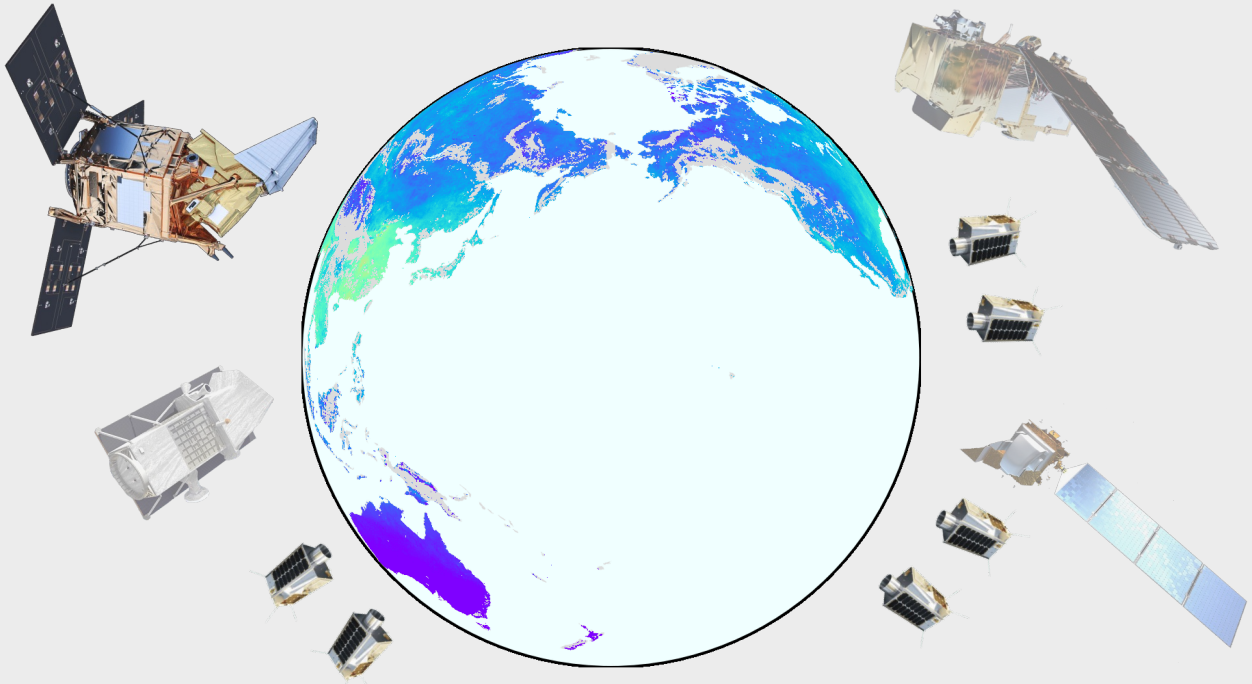
GFEI emissions for 2019



Scarpelli et al. (2020/2022) / Cusworth et al. (2021)

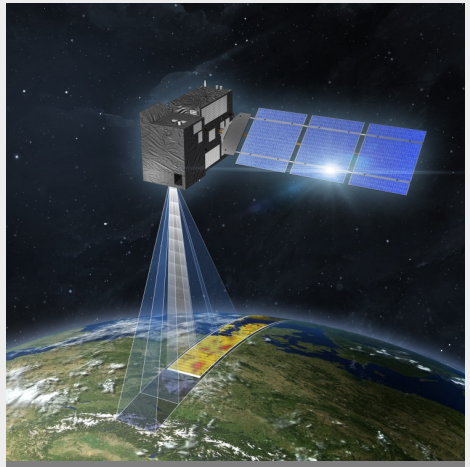
Seeing methane from space: future opportunities but we can do a lot already

Sentinel-5

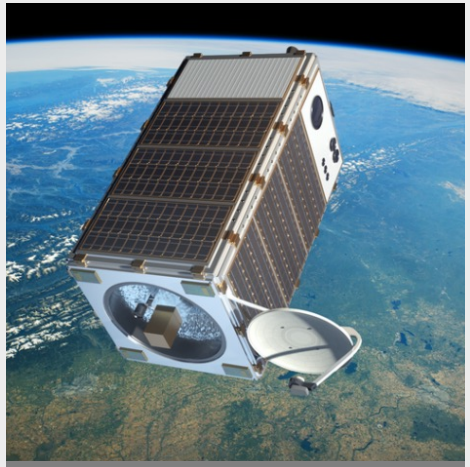


More GHGSat

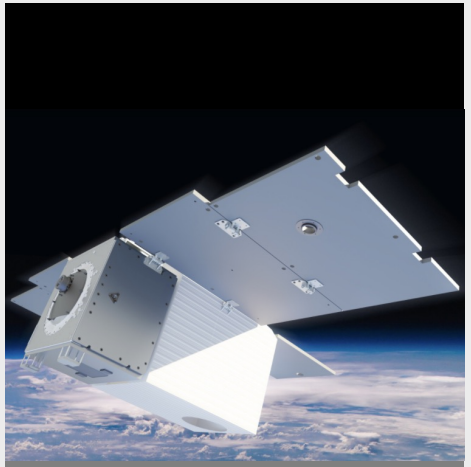
GOSAT-GW



CO2M

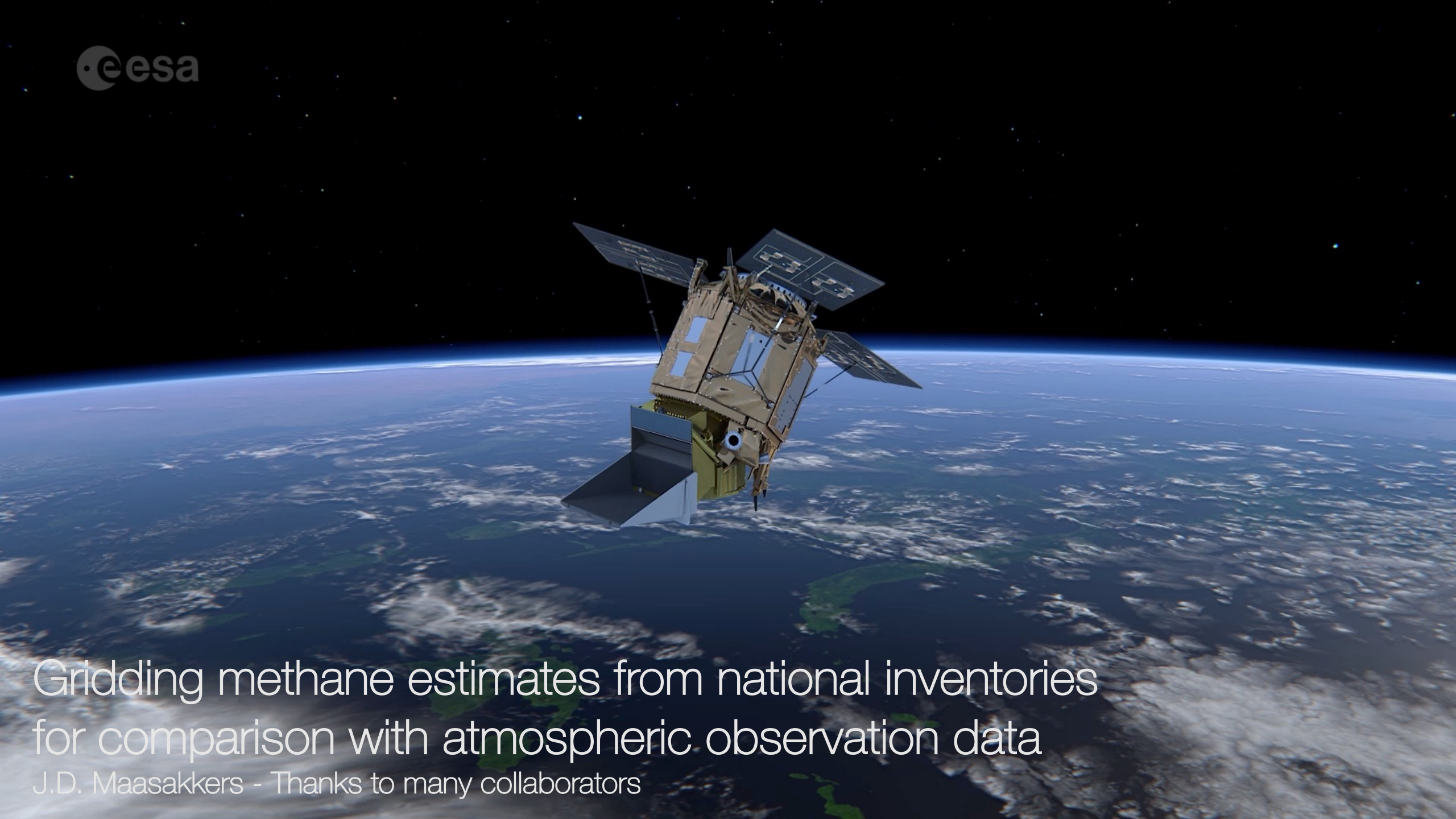


MethaneSAT



Carbon Mapper

Many others



Gridding methane estimates from national inventories for comparison with atmospheric observation data

J.D. Maasakkers - Thanks to many collaborators