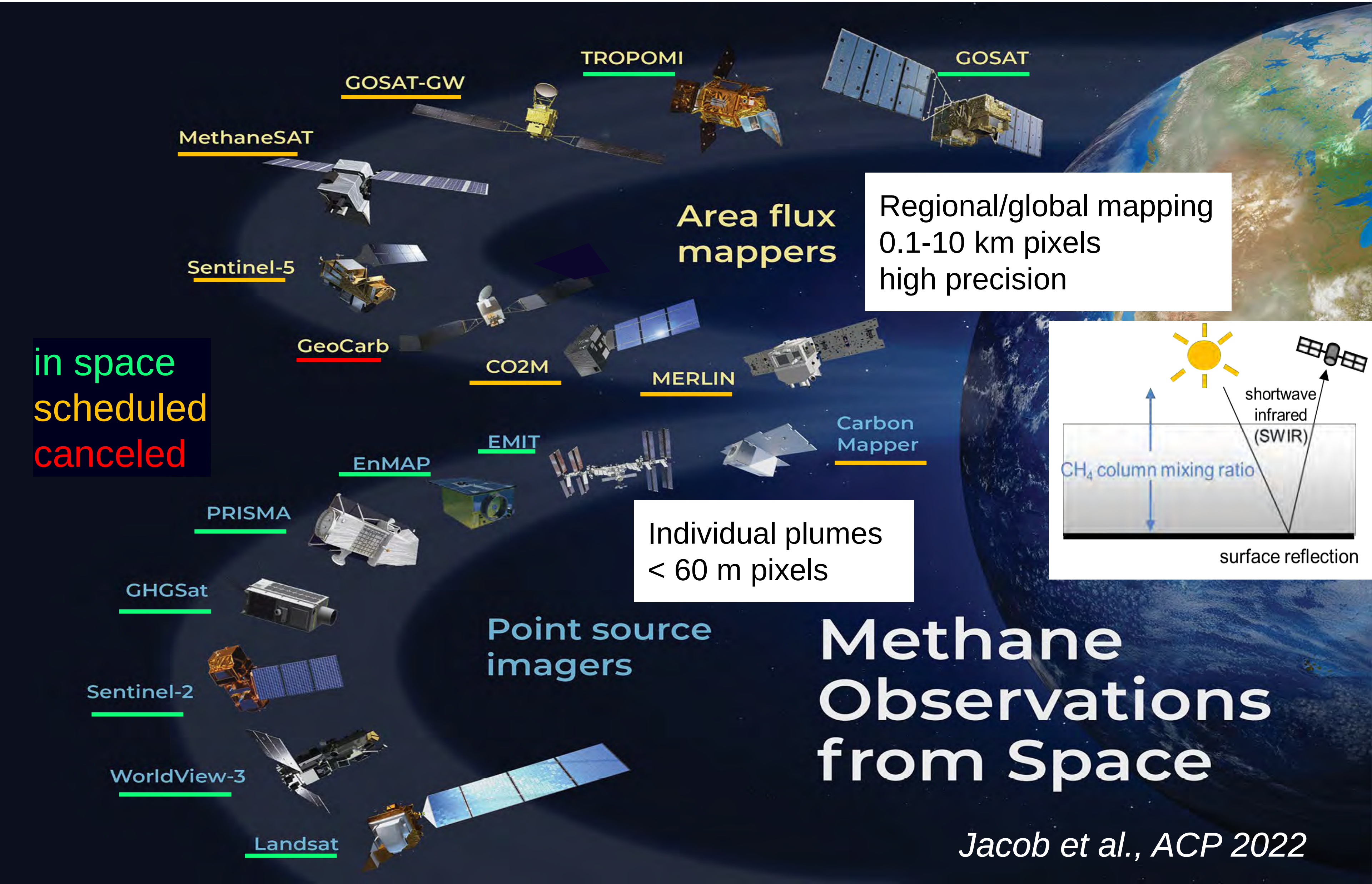
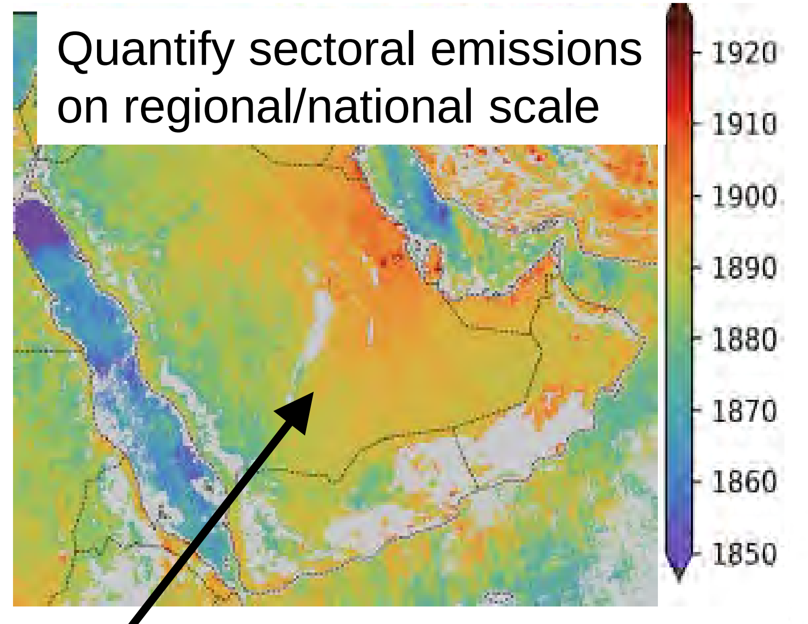
Satellite-based detection and attribution of methane emissions

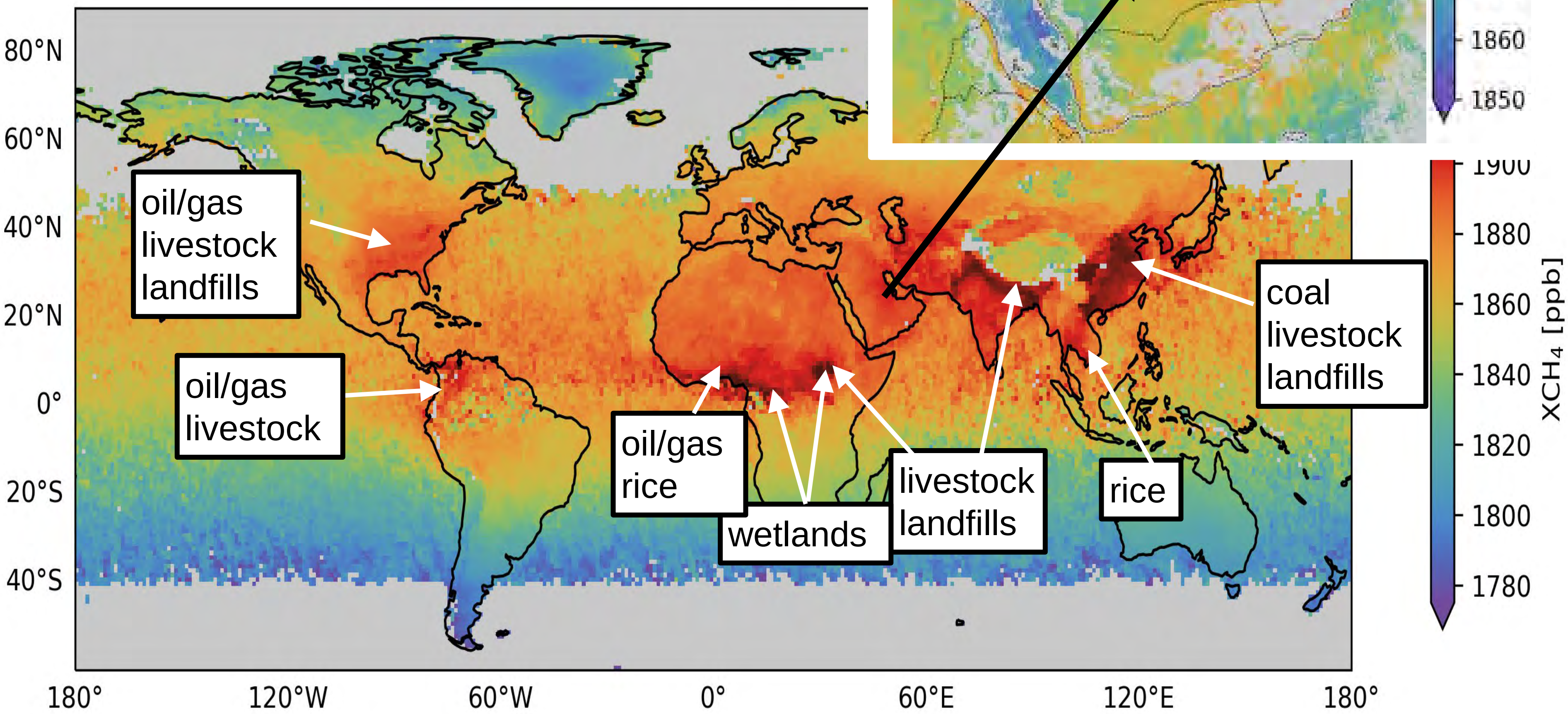
Daniel Jacob, Harvard University



TROPOMI (2018-): global daily mapping with 5.5x7 km^2 pixels, 0.6% precision



Annual mean TROPOMI observations, 2021



Balasus et al.,AMT 2023

Using satellites to improve national and regional emission inventories

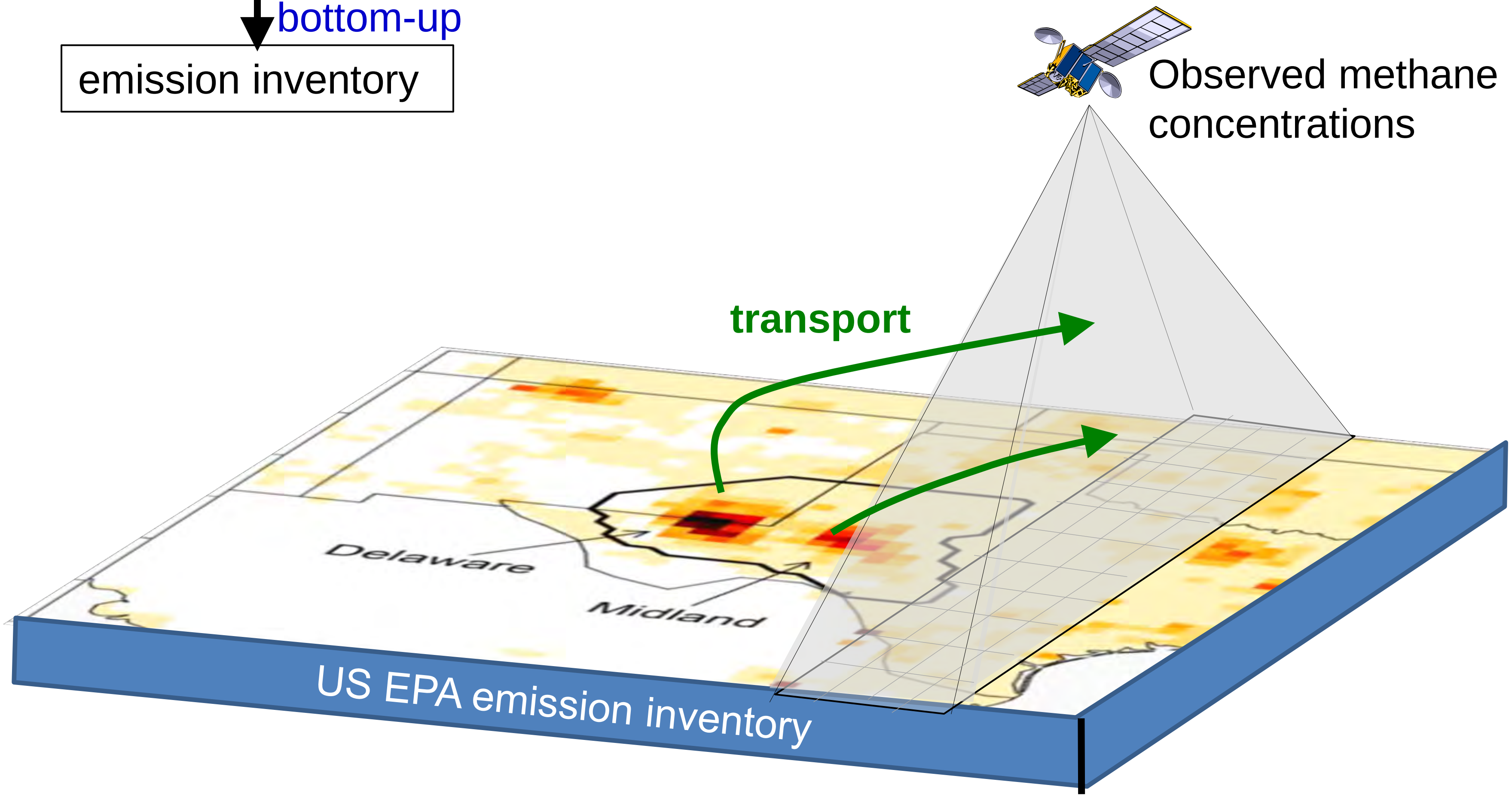
process understanding

↓

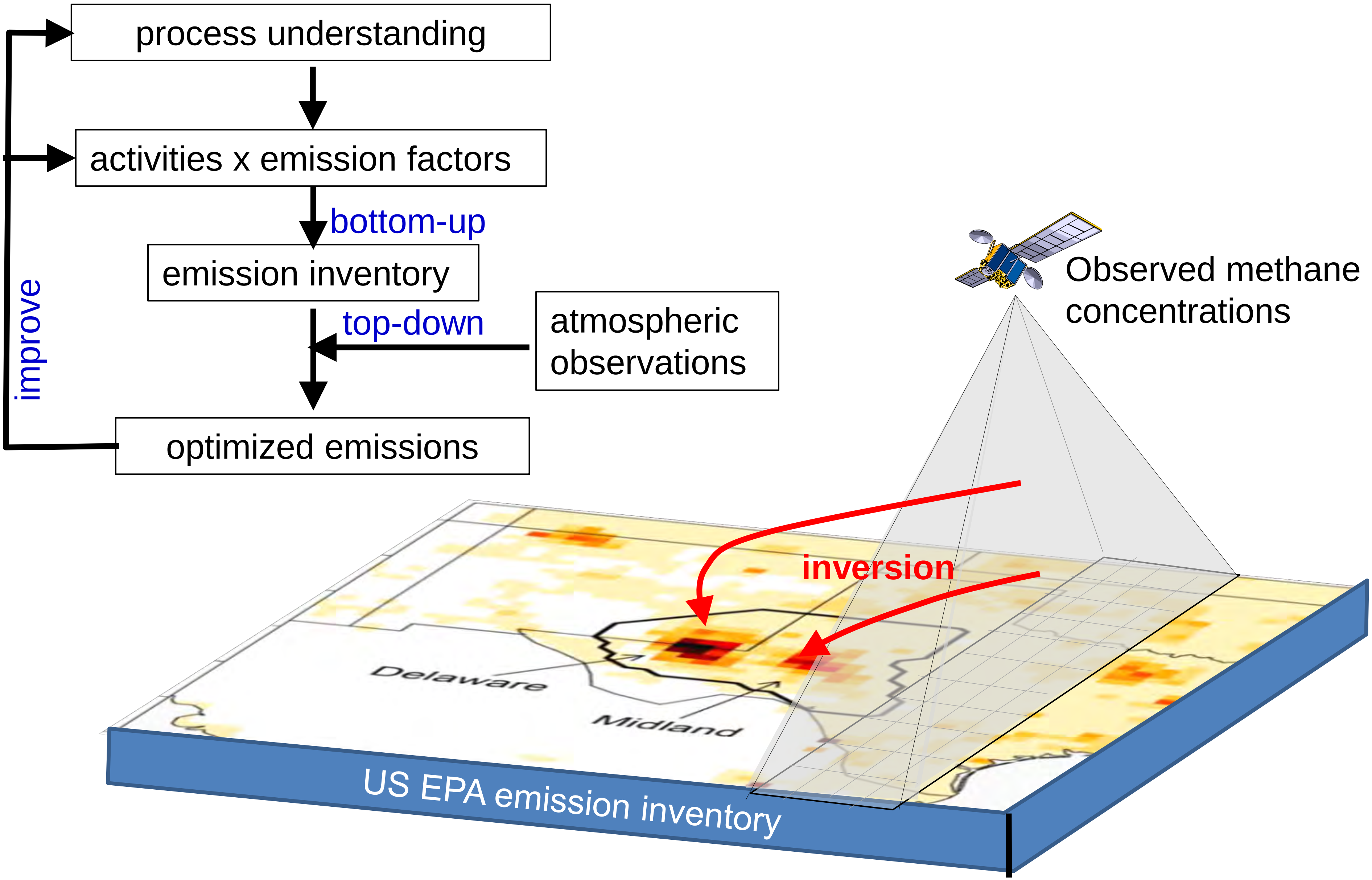
activities x emission factors

↓ bottom-up

emission inventory



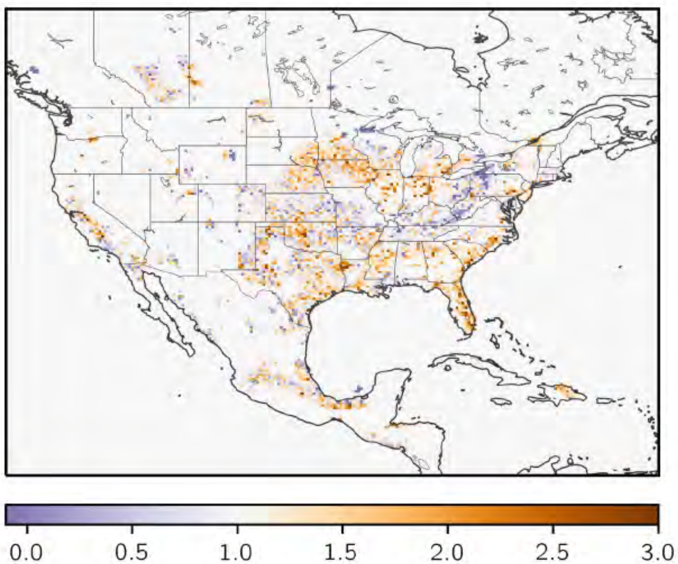
Using satellites to improve national and regional emission inventories



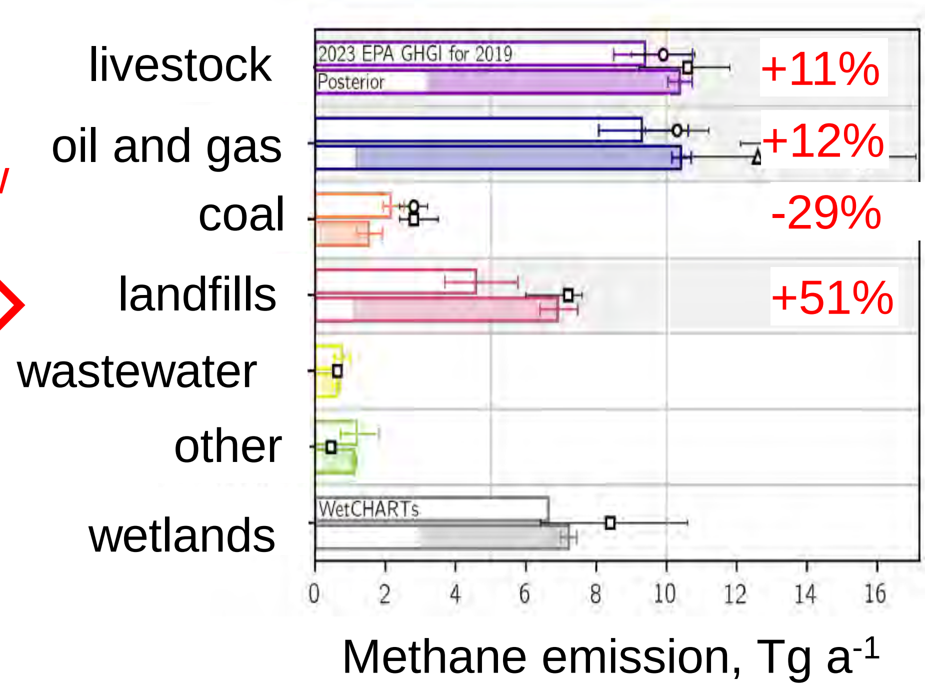
Improving US EPA inventory at 25-km resolution using TROPOMI

Correction to 2023 US EPA inventory by inversion of TROPOMI data

Correction factor



EPA is low by 13%

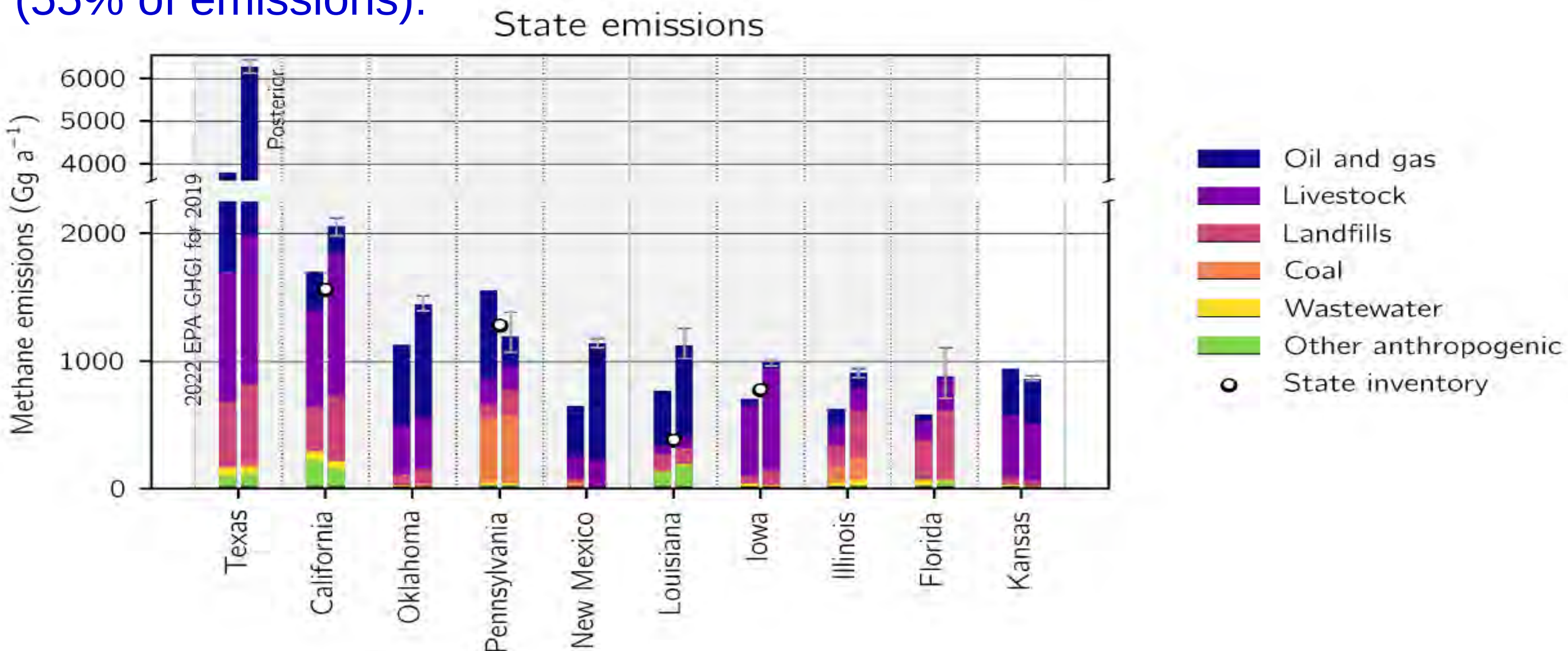


- EPA emission estimates for individual landfills have large errors:
  - Overestimated gas recovery
  - Overestimated decay rate of emission
  - Inadequate accounting of site-specific operating practices

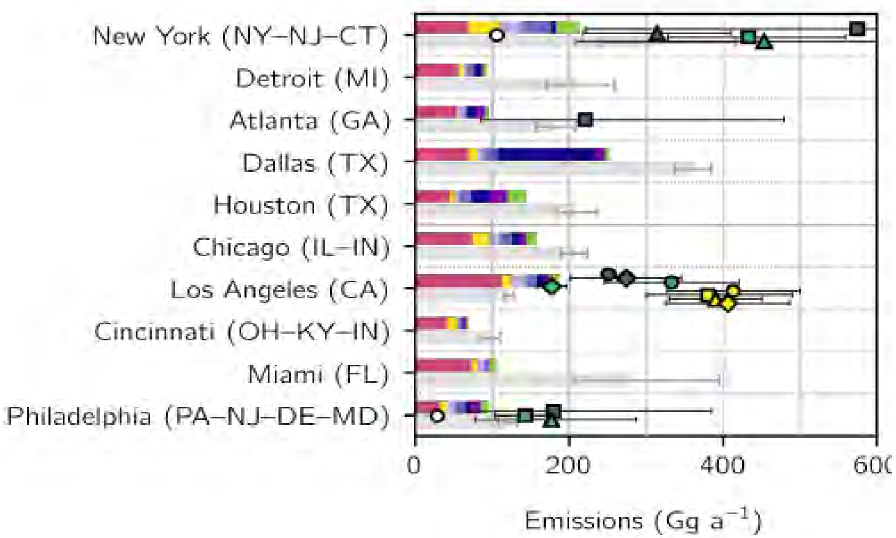
Nesser et al., ACPD 2023

Optimizing emissions for individual US states and urban areas

Top ten states (55% of emissions):



Top ten urban areas:



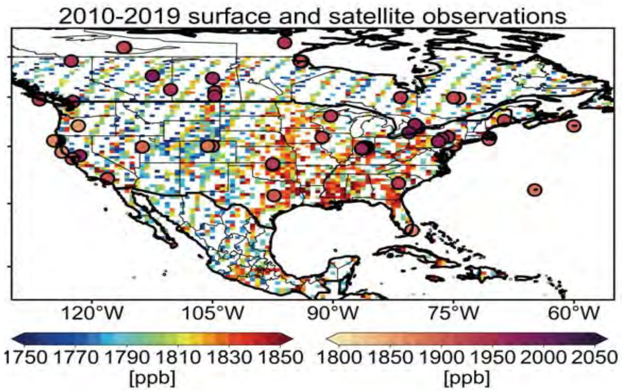
Enable subnational climate action

- states:
  - oil/gas production
  - livestock
  - landfills
- cities:
  - landfills
  - gas distribution
  - wastewater

Nesser et al., submitted to ACP

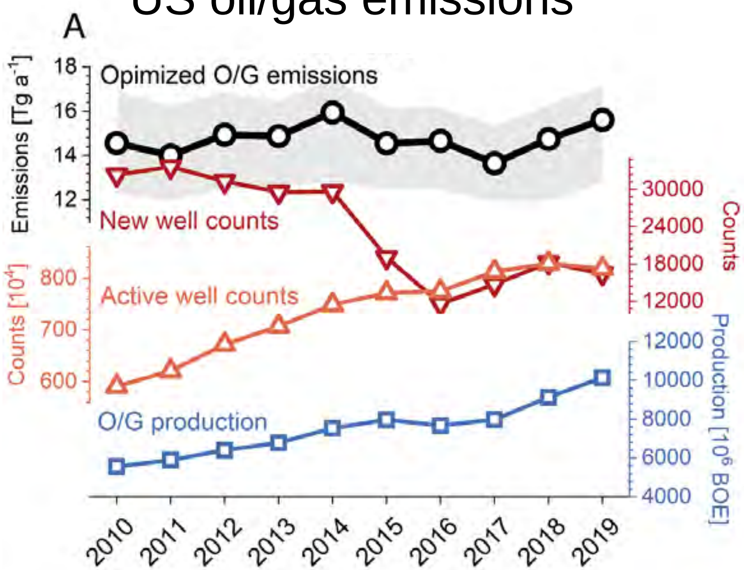
2010-2019 trends in US oil/gas emissions

from inversion of GOSAT satellite and NOAA surface data

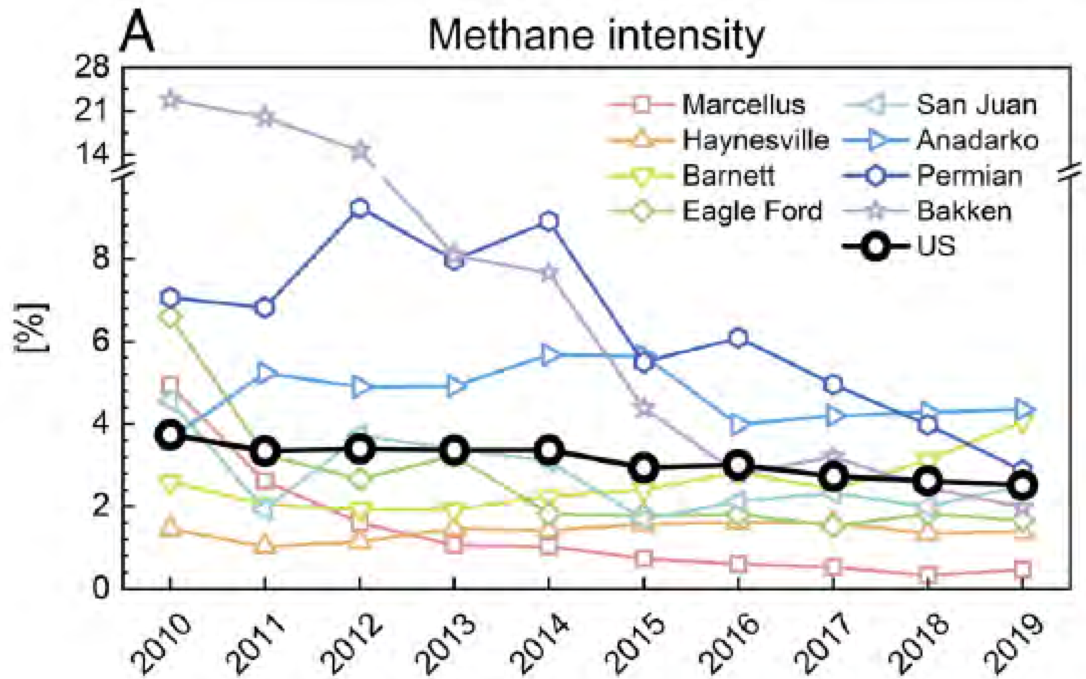


annual inversions

US oil/gas emissions



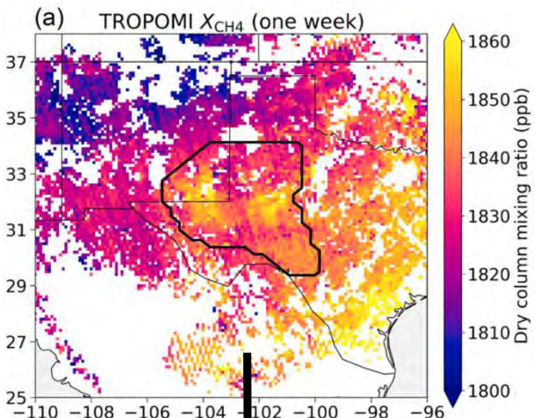
$$\text{intensity} = \frac{\text{emission from upstream oil/gas activities}}{\text{gas production (to market)}}$$



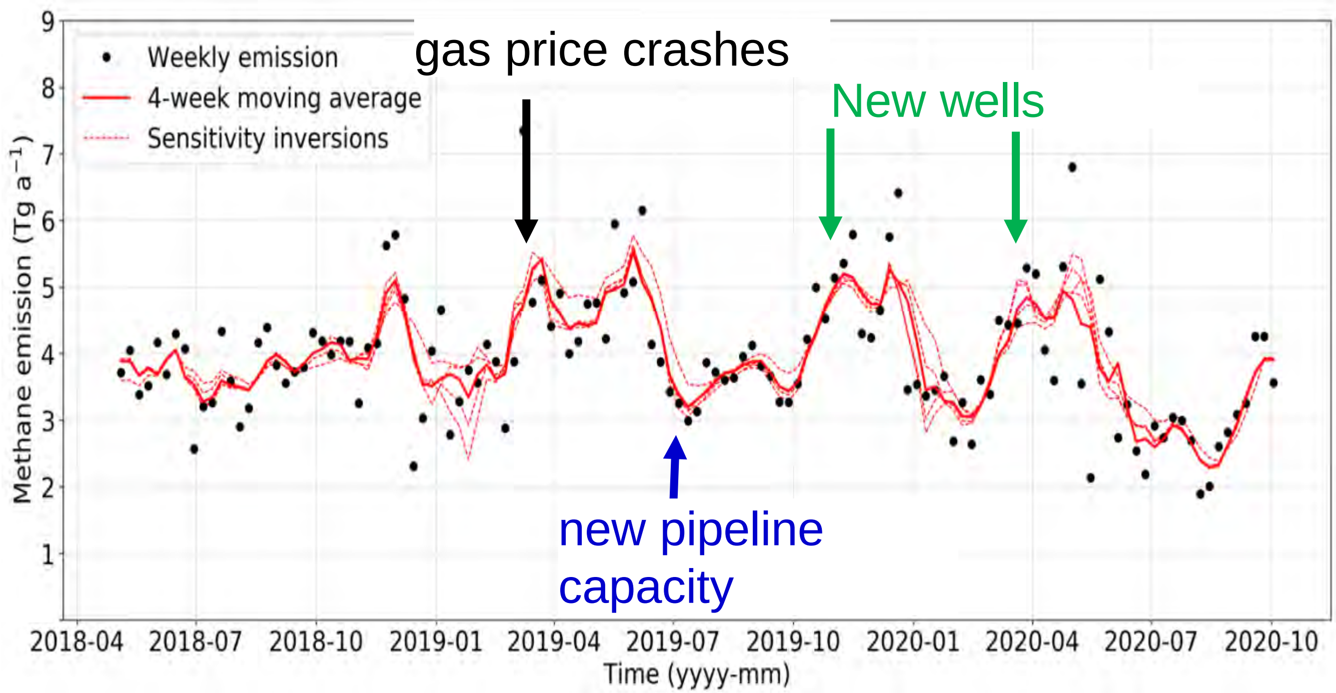
- Methane intensity over 2010-2019 has steadily decreased from 3.7% to 2.5%, spread across basins has narrowed; still much larger than industry target of 0.2%

Lu et al., PNAS 2023

Monitoring the weekly variability of emissions



Weekly inversion of TROPOMI data over Permian Basin



- No increasing trend in emissions over 30-month period (May 2018- Oct 2020) despite 50% increase in oil production and 100% increase in gas production
- Large week-to-week variability: near-real-time monitoring can enable action

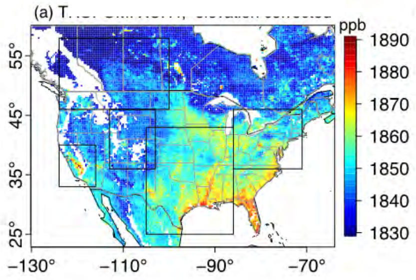
Varon et al., ACP 2023

Integrated Methane Inversion (IMI): enabling stakeholders to monitor emissions worldwide

TROPOMI

Point sources

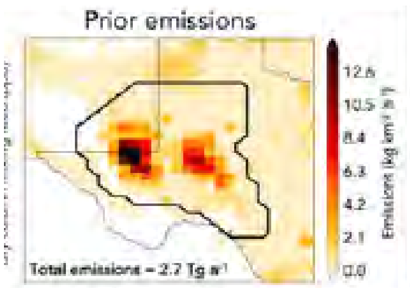
Satellite observations



https://imi.seas.harvard.edu

Varon et al., GMD 2022

User requests emissions for selected domain and period



Default or user-selected bottom-up inventory

AWS cloud

Integrated Methane Inversion (IMI)

Optimized emissions: statistics, maps, trends, validation

IMI circumvents need for:

- big data downloads
- technical expertise
- in-house computing

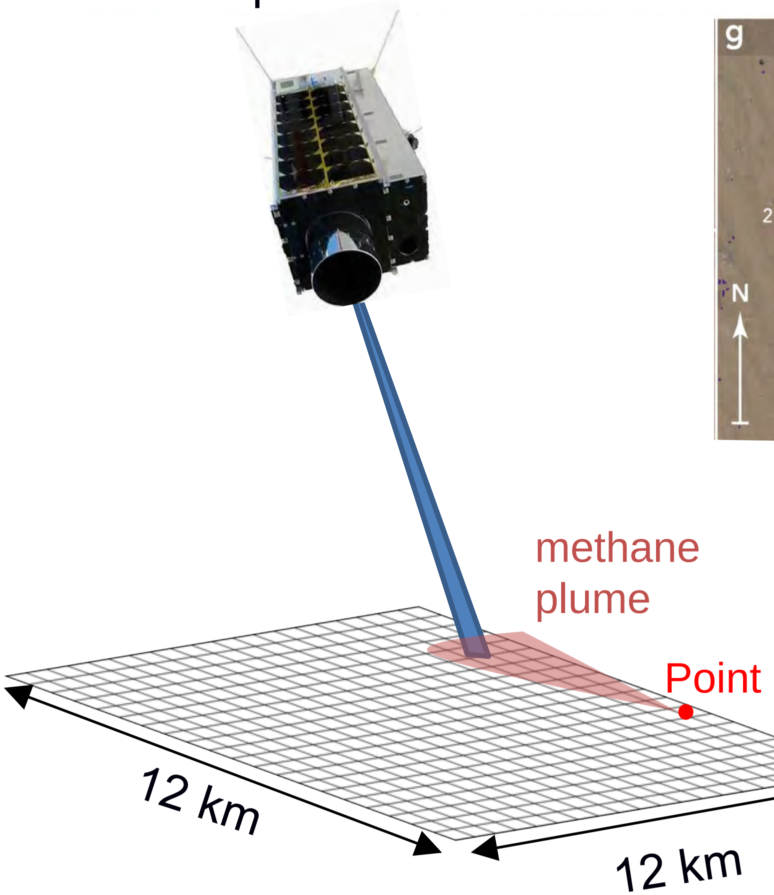
IMI provides:

- user-friendliness
- research-grade algorithm
- transparency
- continuous monitoring

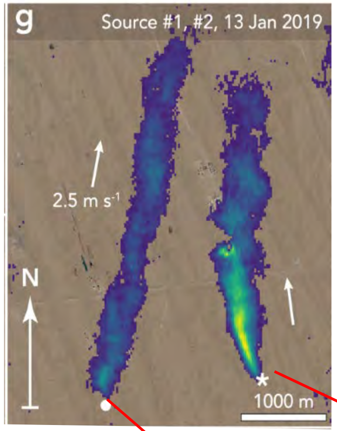
IMI User's Workshop (remote) will be held in mid-2024

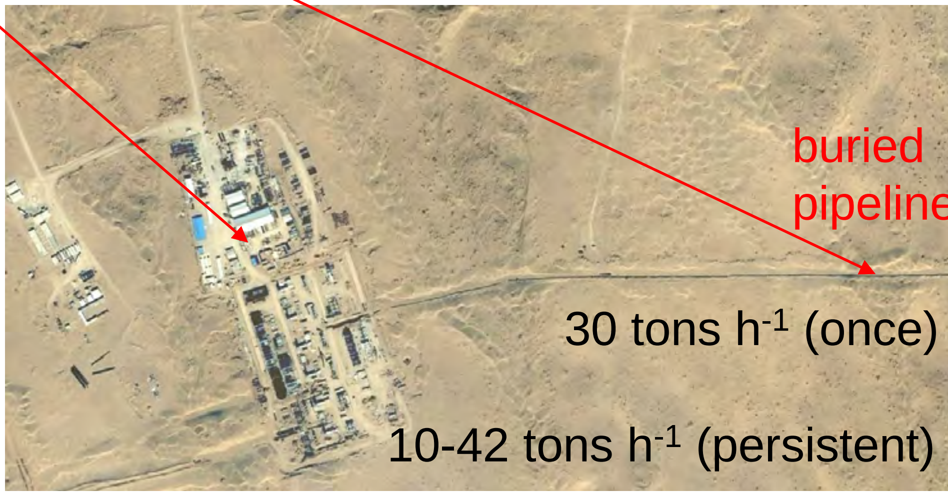
Observation of methane point sources from space

GHGSat microsatellite fleet
25x25 m^2 pixels



13 Jan 2019



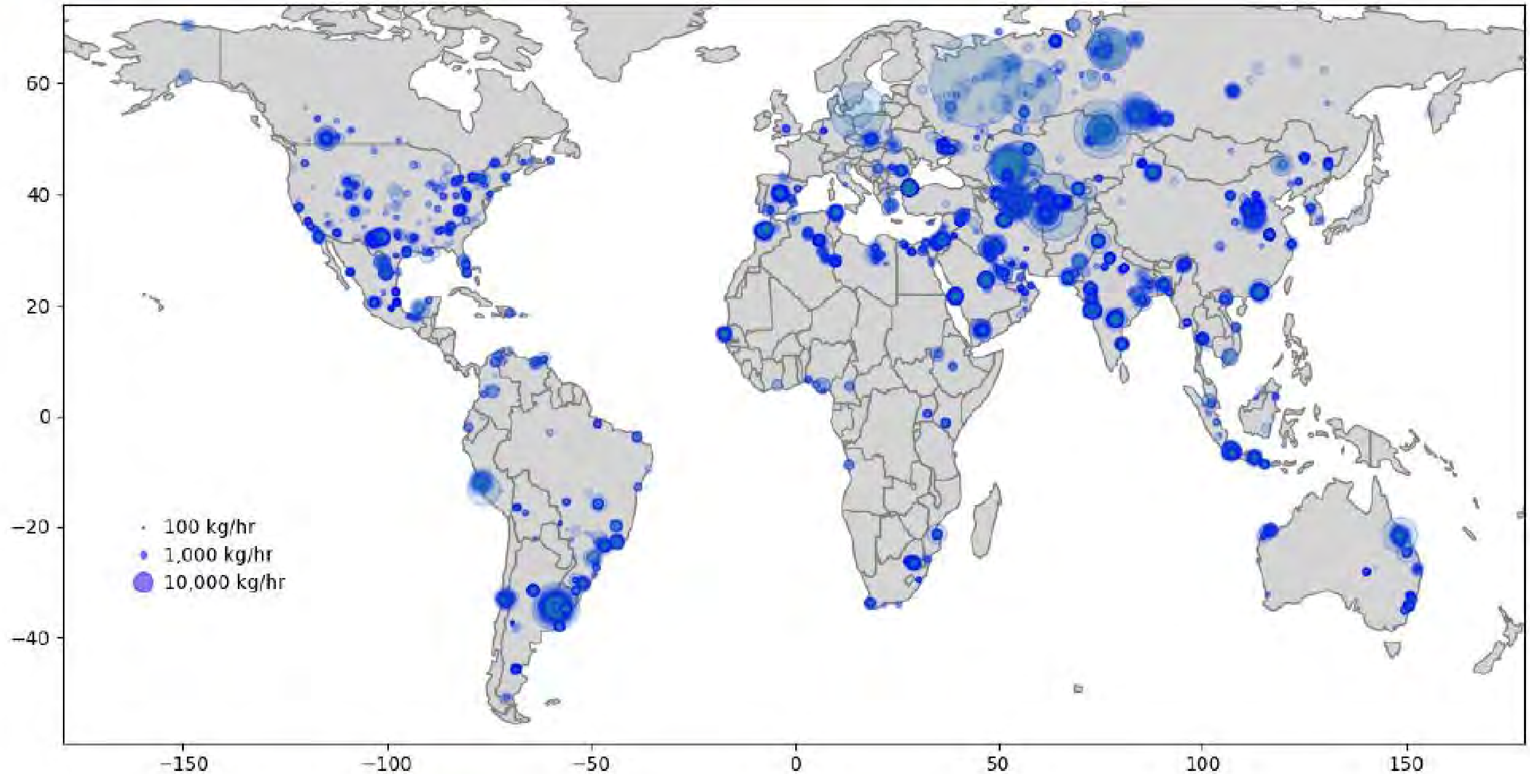


Korpezhe gas compressor station

Varon et al., GRL 2019

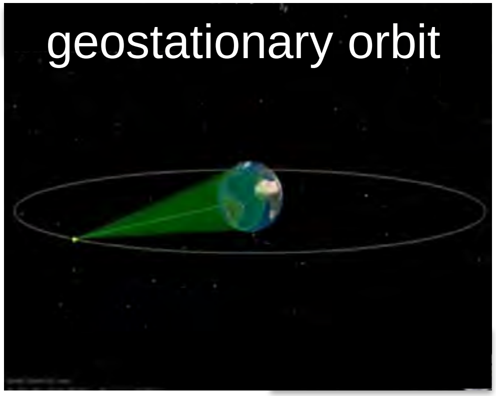
Detection of point sources as targets for climate action

GHGSAT EMISSIONS: JUNE '22 – SEPT '23

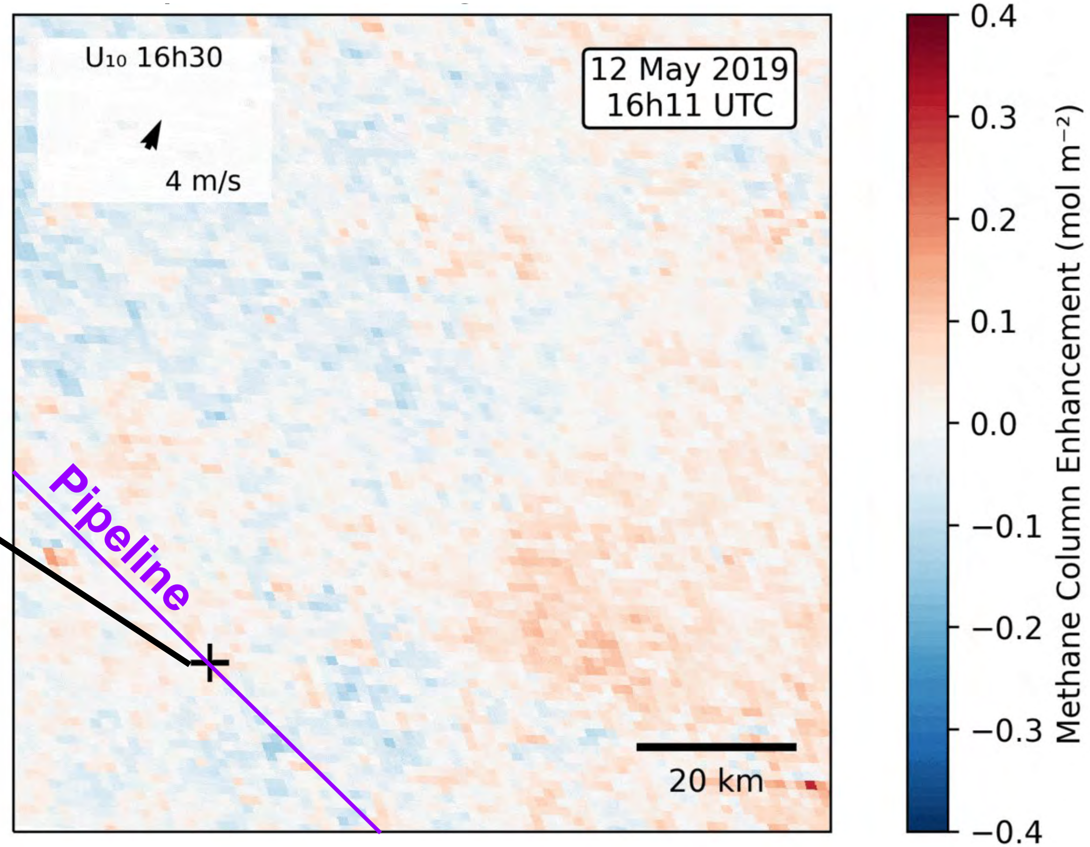


- Observed **> 15,000** plumes in 16 months

Geostationary observation of methane plumes from NOAA GOES weather satellite: transient nature of point sources



EELL pipeline from Chihuaha to Durango supplying Permian gas to Mexico

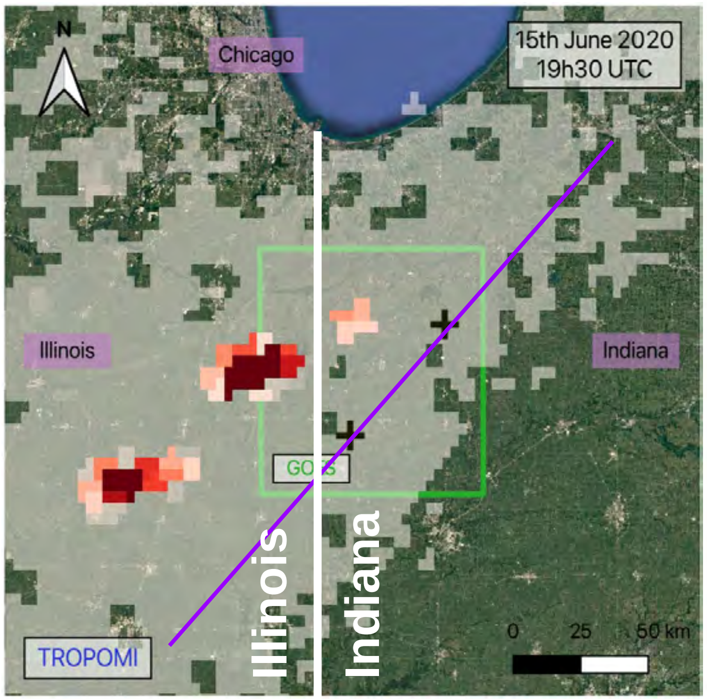


Q = 300 tons h^{-1}, 3-h duration

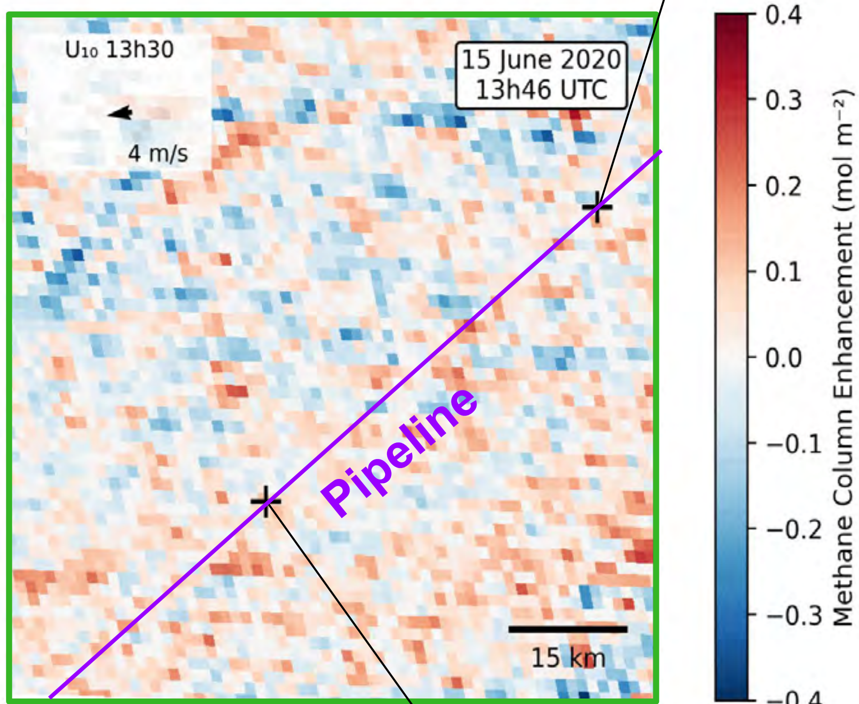
Watine-Guiu, Varon, et al., PNAS 2023

Simultaneous releases from an Indiana gas pipeline

- Releases are very brief (puffs) and synchronized, suggesting an automated venting operation
- TROPOMI observes the plumes 5 hours later and 50 km downwind



TROPOMI (1:30 pm)



GOES

Watine-Guiu, Varon, et al., PNAS 2023