Background & Overview:
Methane Emissions and Global Climate Change Policy

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Using Satellite Observations of Atmospheric Methane to Advance Global Climate Change Policy

Harvard Project on Climate Agreements – Enel Foundation – Government of Mexico

Sharm El Sheikh, Egypt, November 17, 2022

The Importance of Methane, and a Harvard Initiative

- **Methane has a relatively short atmospheric lifetime, but very high radiative forcing potential**
  - So, methane emissions abatement can significantly reduce concentrations, temperatures, and damages, particularly in the short to medium term

- **Project under Harvard President's Climate Change Solutions Fund**
  - "Using Satellite Observations of Atmospheric Methane to Support Effective Global Climate Change Policy" (Professor Daniel Jacob, atmospheric chemist)
  - Use satellite-based measurements of concentrations plus bottom-up information on emissions, sectors, etc.
  - Statistical estimation of geographically and temporally specific emissions
  - Disseminate emissions estimates in appropriate formats to relevant parties …

Potential Uses of Methane Emissions Estimates

- **Two Key Generic Uses of Methane Emissions Estimates**
  - Assessing compliance with goals, targets, and specific policies
  - Helping develop/design new policies, revise/improve existing policies
- **Paris Agreement**
  - Nationally Determined Contributions by 190+ UNFCCC Parties (2030)
  - Global Stocktake (2023)
- **Global Methane Pledge**
  - Non-Binding Pledge by 125 countries to Reduce Emissions by 30% by 2030
- **Other International, Multi-Party Arrangements, including Industry**
- **National Policies**
  - Potentially binding with effective “monitoring” and enforcement
  - For example, U.S. Context
- **Sub-National Policies**

Paris Agreement

- **Nationally Determined Contributions (NDCs)**
  - Emissions targets (& actions) for 2030 from 194 Parties to the Paris Agreement
  - Highly heterogeneous:
    - Hard (mass-based) emissions cap
    - Relative mass-based emissions cap (relative to BAU)
    - Rate-based emissions cap (per unit economic activity or per unit output)
    - Other, non-emissions caps, such as renewable energy penetration
    - Differences in base/target years, sectors, *GHGs, GWPs*
  - Reporting and Review of Progress relative to NDCs beginning in 2022

- **Global Stocktake** (Aggregate Only)
  - First to be completed in 2023, and every 5 years thereafter
  - Three Phases:
    - Information Collection & Preparation
    - Technical Assessment of Information
    - Political Messages Derived from Technical Assessment

Global Methane Pledge

- **Informal Agreement**
  - Announced by President Biden and EU Commission President Von der Leyen (September 2021)
  - Launched at COP26 in Glasgow (November 2021)

- **The Pledge**
  - Participants agree to take voluntary actions to contribute to collective effort to reduce global methane emissions at least 30 percent from 2020 levels by 2030
  - Currently 125 countries, representing nearly 50% of global anthropogenic methane emissions (and two thirds of global GDP)
  - Annual ministerial level meetings to review progress

The U.S. Context -- Legislation

- **Inflation Reduction Act (IRA) of 2022** – numerous “carrots” ($370 billion), & one “stick”
  - *$1.5 Billion to state/local institutions* to cut methane emissions in oil & gas sector
  - *Fee on “excess” methane emissions from oil & gas facilities* (that report >25K tons of CO_2/year and are subject to GHG emissions reporting under EPA regulations)
    - Thresholds for charge vary by source
    - “Netting” of emissions allowed for sources under common ownership
    - Fee: $900/ton (2024) → $1,200 (2025) → $1,500 (2026)
    - Exemptions for (essential) permitting delays, permanently shut & plugged wells, *and for*
    - sources in compliance with state/federal regulations (at least standards proposed by EPA in 2021)
- **Will require *calculation/estimation of methane emissions*** (and finalizing of methane rule proposed in 2021 …)

U.S. Methane Rule (Regulation)

- **Obama Rule**
  - Targeted *new* drilling sites and operations on federal lands (a "New Source Performance Standard") to update 2012 rule (transmission & storage)
  - Proposed 2015, Finalized and went into effect, August 2016
  - Rescinded by Trump administration in 2020 (also cut Obama's estimate of Social Cost of Methane Emission from $1,400/ton to $55/ton)
- **Biden Rule**
  - Proposed in November 2021, *revised Nov 2022*, to be finalized in 2023
  - Estimated to reduce methane emissions by 36 million tons 2023-2035, by:
    - Overules Trump rule to reinstate Obama rule for new sources
    - Extends federal standards to 400,000 miles of unregulated onshore pipelines
    - Requires specific control and monitoring technologies; *operators required when third party monitors find a major methane leak*
    - For existing oil & gas wells, states required to develop methane rules in line with federal regulation of new wells

For More Information

Harvard Project on Climate Agreements
www.belfercenter.org/climate

Harvard Environmental Economics Program
www.hks.harvard.edu/m-rcbg/heep

Website
www.stavins.com

Blog
http://www.robertstavinsblog.org/

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The use of bottom-up emission inventories in methane policy processes

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COP27 Sharm El-Sheikh, 17 Nov 2022

IIASA's GAINS (Greenhouse gases and Air pollutants INteraction and Synergies) model

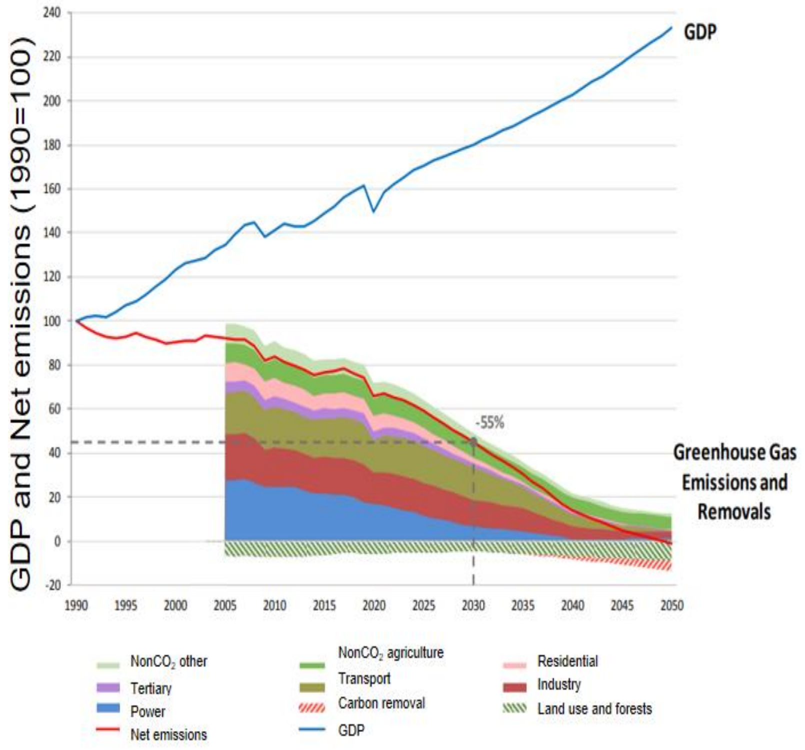
IIASA's **GAINS** model:

- Air pollutants: SO_2, NO_X, $PM_{2.5}$, NH_3, VOCs, CO, BC/OC
- Greenhouse gases: CH_4, N_2O, HFCs, PFCs, SF_6, NF_3 (CO_2)
- 182 countries/regions
- Every 5 years 1990-2050
- ~800 source sectors
- ~2000 technologies

Examples:

- Non-CO_2 GHG mitigation scenarios for EU's climate change policies (most recent: **EU's Green Deal**)
- Air pollution mitigation scenarios for EU and Europe (under UNECE's LRTAP convention)
- GAINS-China and GAINS-Asia for cost-minimizing strategies to mitigate air pollution and climate change in Asia

EU Green Deal 2020/21:

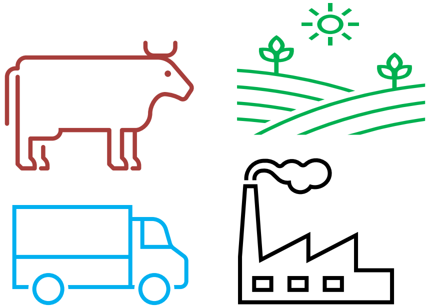


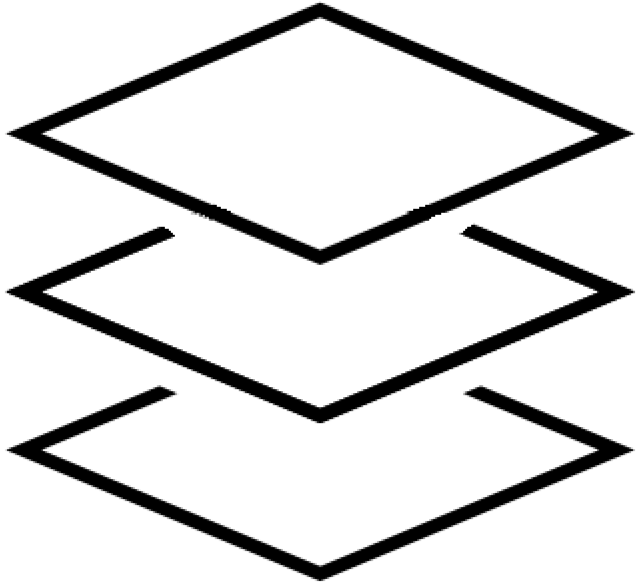
Source: European Commission, Brussels, COM(2020) 562, 17.9.2020

What are bottom-up emission models?

Process-based BU emission models derive emission estimates at a very detailed source sector level for a specific geographic region and time

Emission factors are determined from several layers of information that identify region- and time- specific factors affecting emissions





Human behavioral and operational practices

Technological setups

Physical factors: e.g., climatic conditions, geological, etc

Emissions = Activity data × Emission factor

t CH_4

e.g., Joule, no. of animals, ton waste generated, etc...

t CH_4/activity unit

Future emission scenarios and mitigation strategies that are internally consistent across different stakeholders

Bottom-up emission models in policy processes: a way forward despite uncertainty in emission estimates

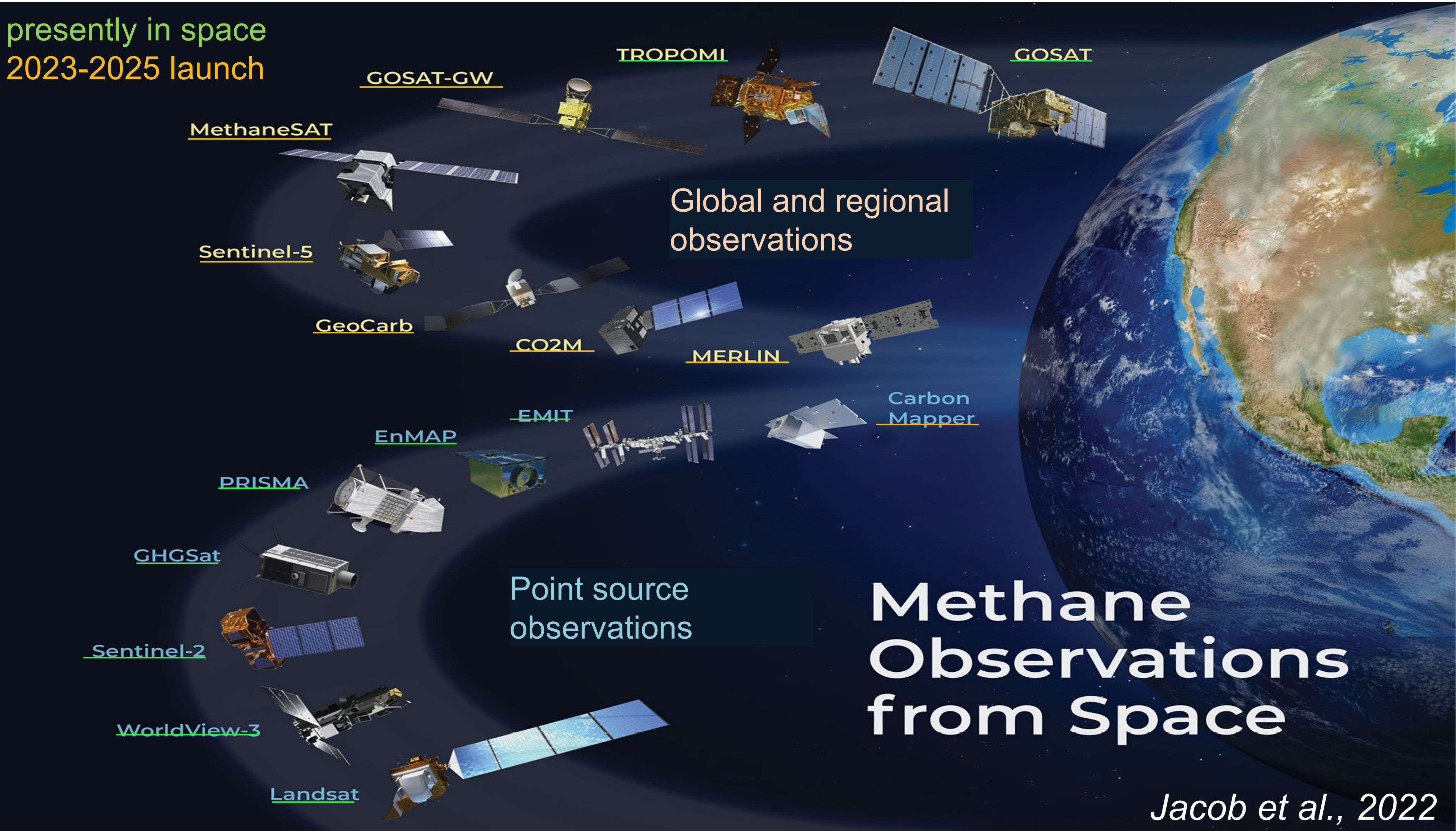
Important features of model and process:

- **Consultative** process at expert level
- **Transparent** sharing of information
- BU model is **detailed** enough in terms of sectors and technologies to reflect country-specific characteristics in an adequate manner.
- Stakeholders **trust** in objectivity and comparability of emission estimates and future mitigation potentials, despite presence of uncertainty

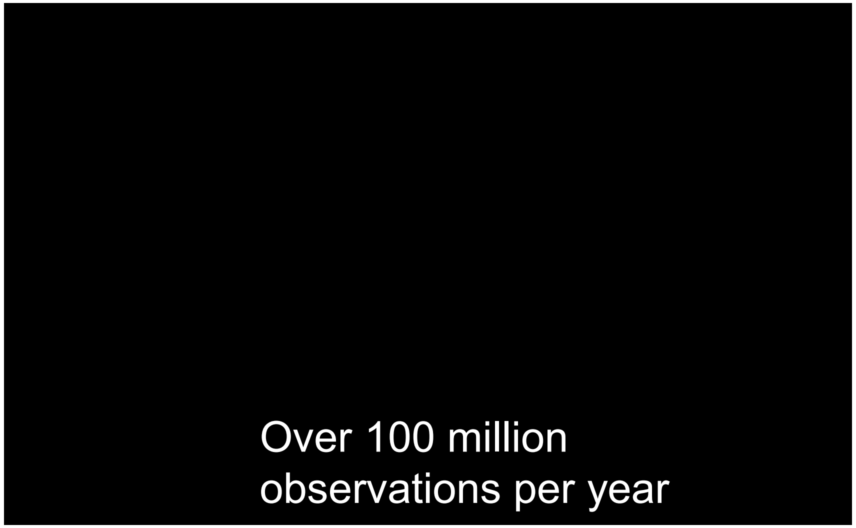
Thank you for listening!

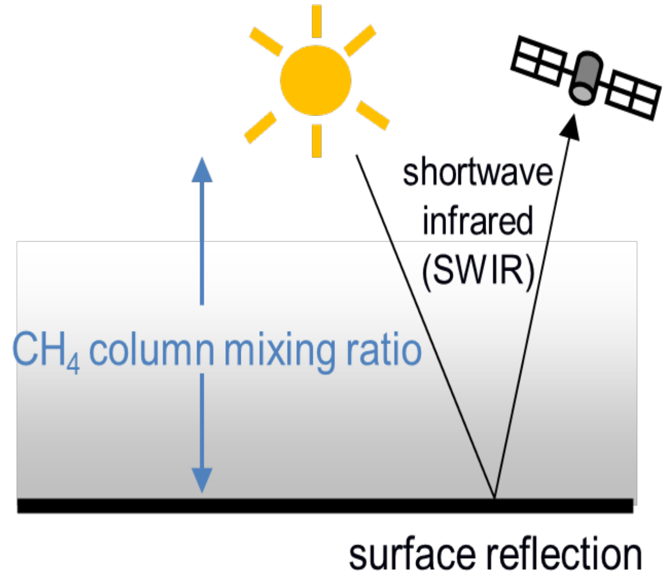
Recent advances in satellite detection of methane and advanced statistical methods for attribution of emissions

Daniel J. Jacob, Harvard University

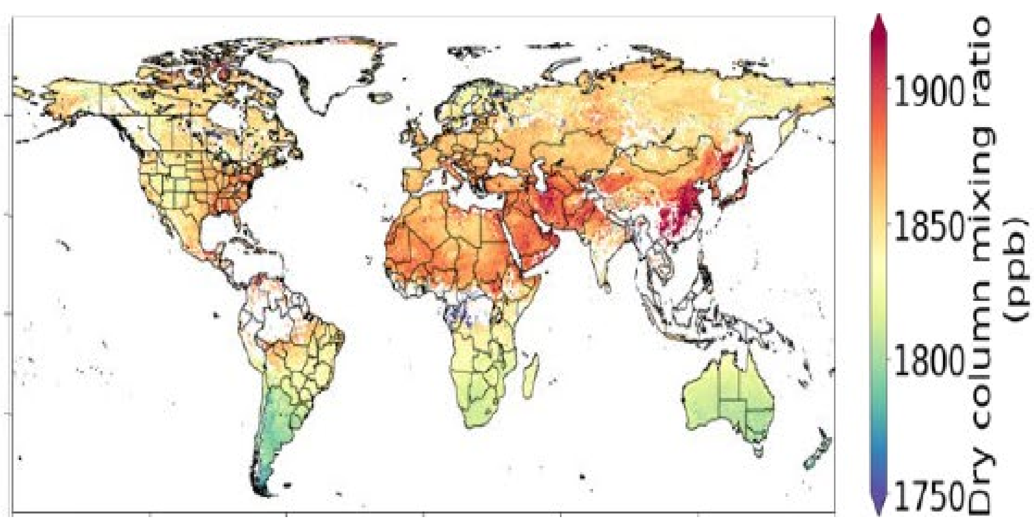


TROPOMI (2018 -): global daily atmospheric methane in 5.5x7 km^2 pixels



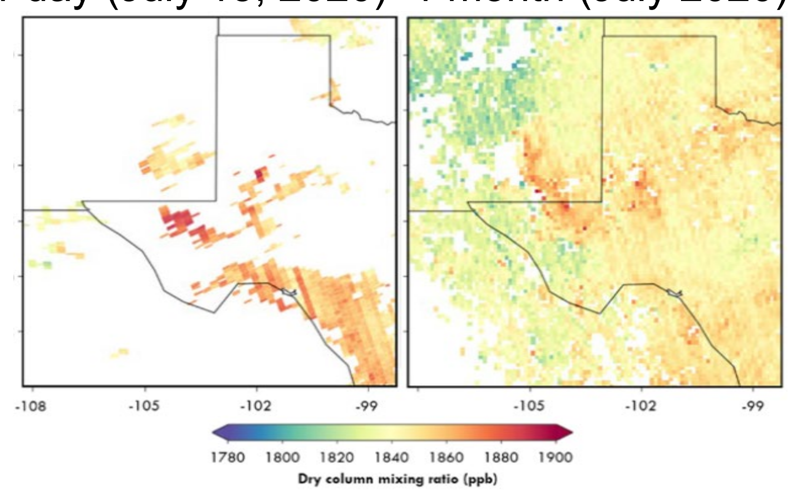


Global methane distribution, JJA 2020



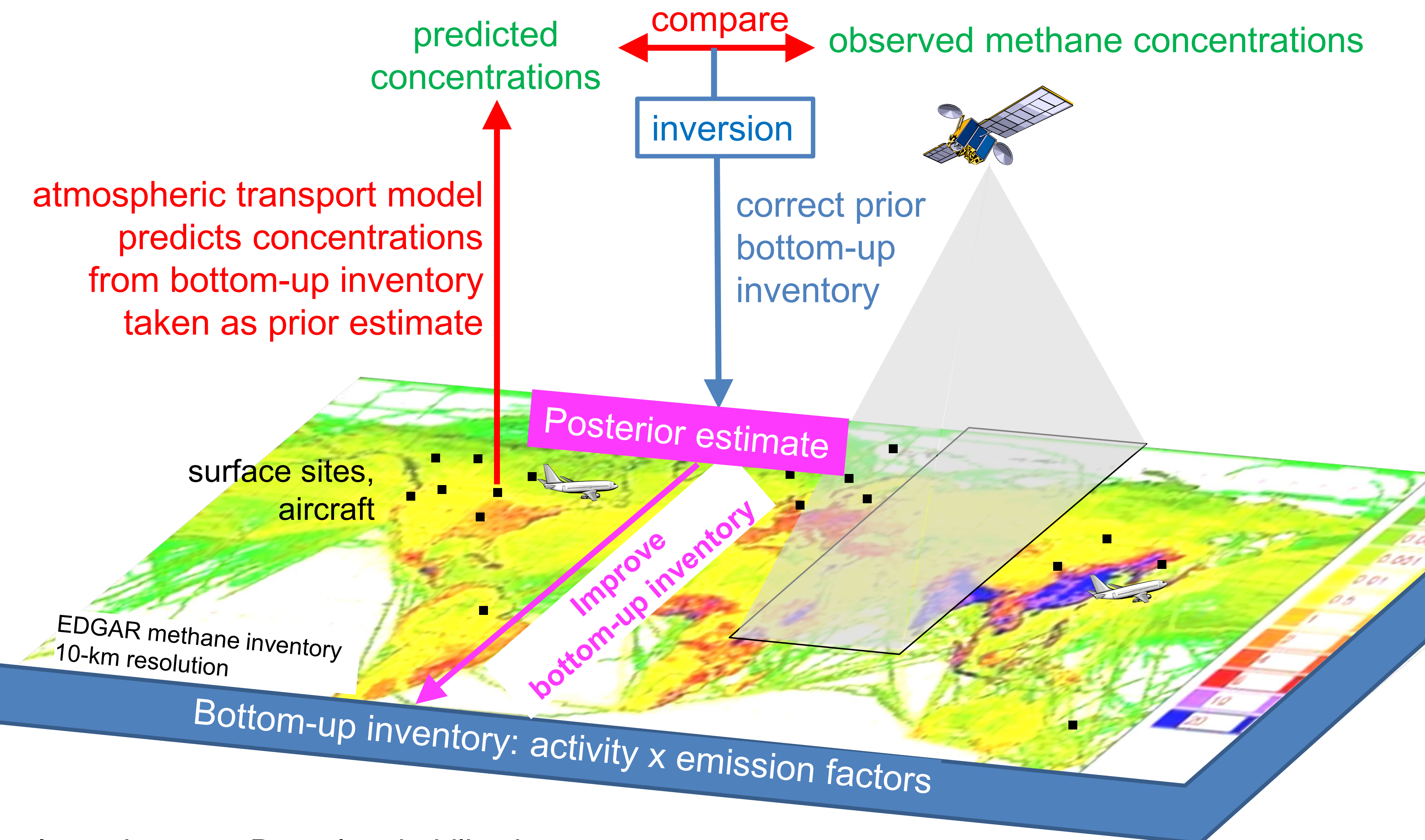
Permian basin (largest US oil field)

1 day (July 15, 2020) 1 month (July 2020)



Jacob et al., 2022

Using satellite observations to evaluate and improve emission inventories



Inversion uses Bayes' probability theorem:

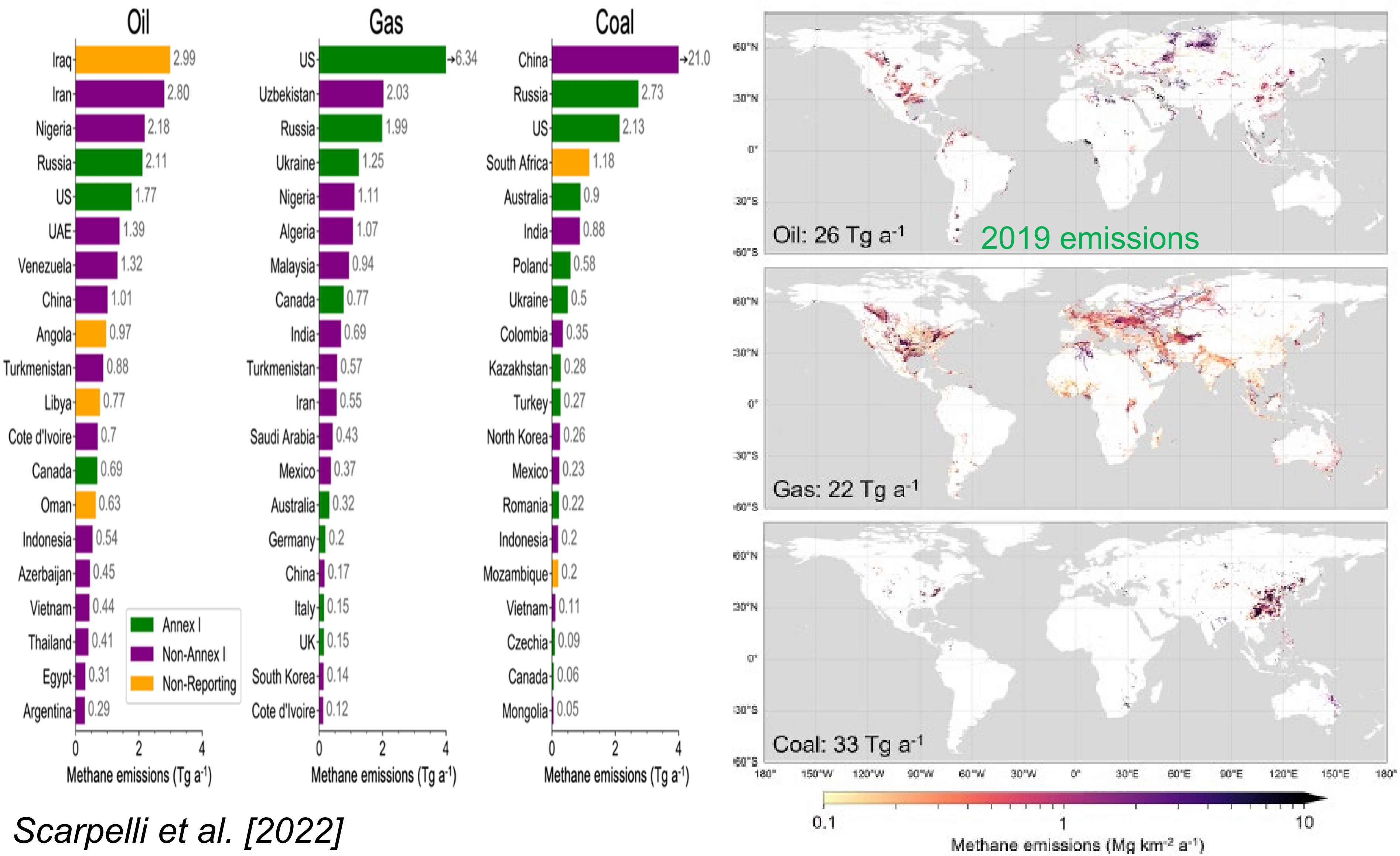
p (true emissions | observations) ~ p (bottom-up emissions) x p (observations | true emissions)

posterior

errors

Using UNFCCC-reported national inventories for inversions of satellite data requires mapping of these inventories to high spatial resolution

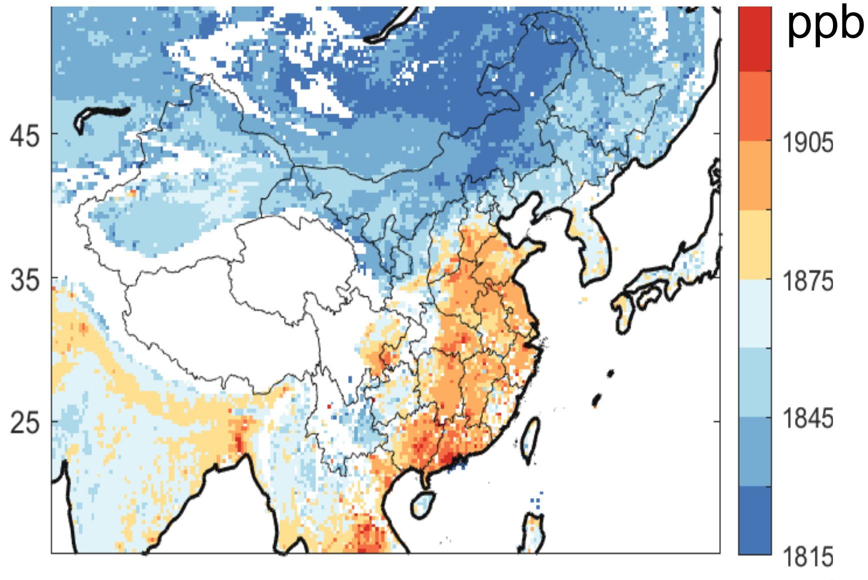
Example: Global Fuel Emission Inventory (GFEIv2) at 10x10 km^2 resolution



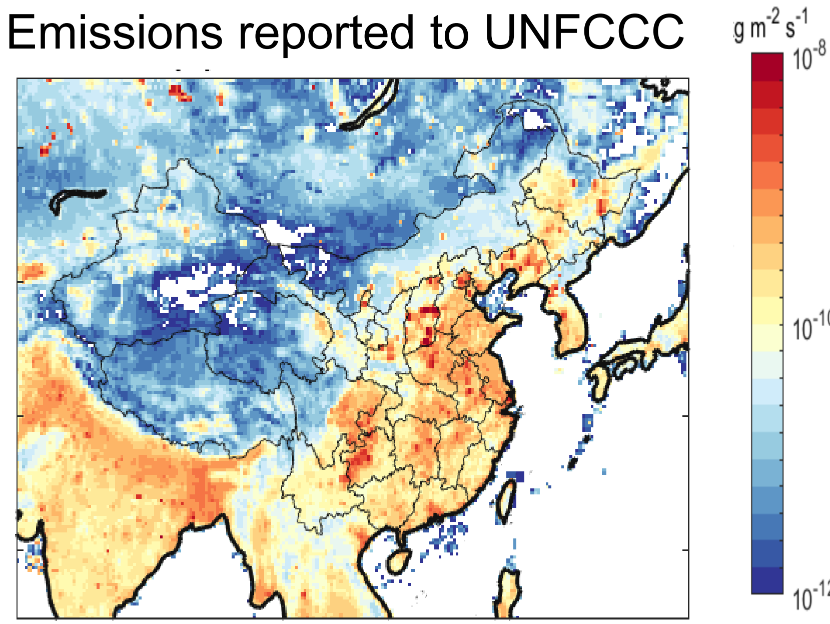
Scarpelli et al. [2022]

Application to improve UNFCCC-reported emissions from China

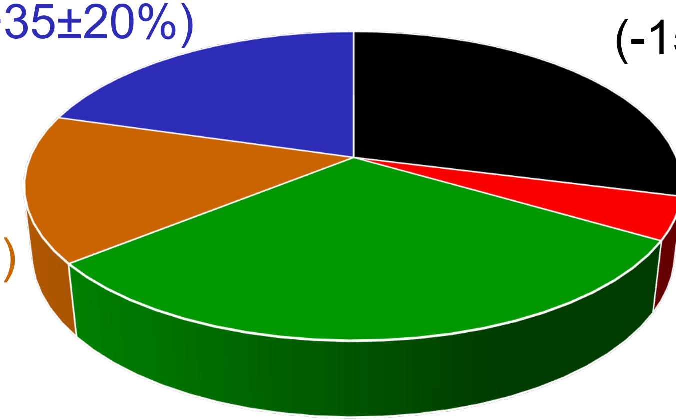
TROPOMI methane observations (2019)



Emissions reported to UNFCCC



Improved emission estimates, Tg a^{-1}
(% correction to UNFCCC estimates)

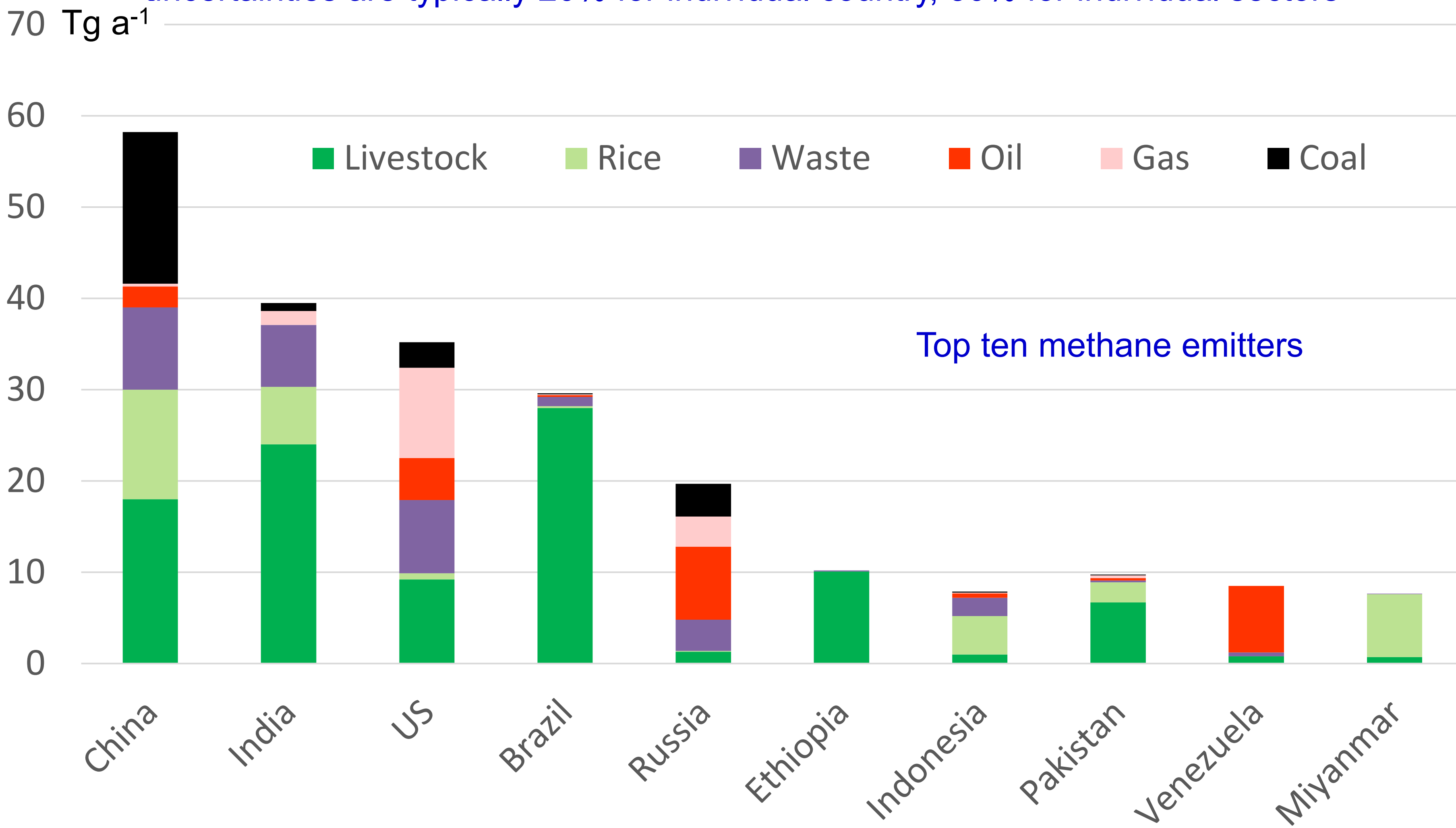


- Coal-to-gas transition may drive large increase in methane emissions

Chen et al. [2022]

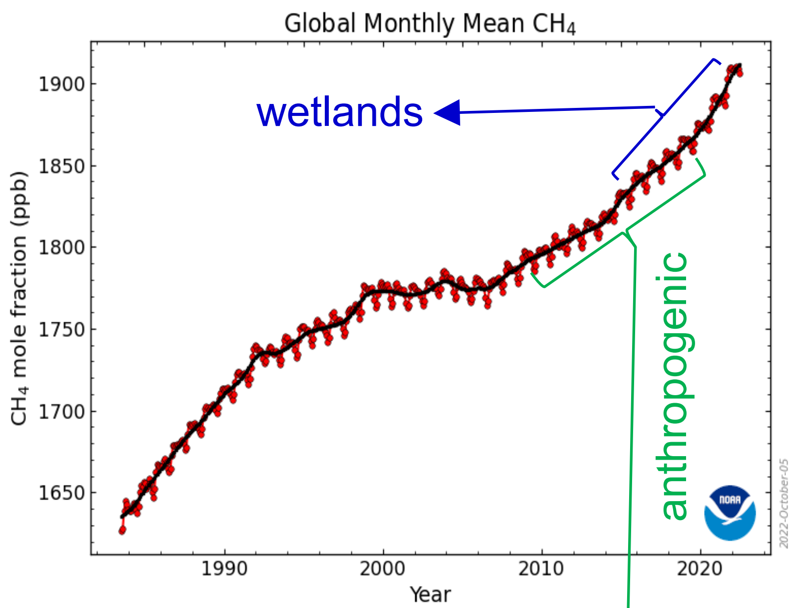
Posterior emission estimates can be generated for all countries

uncertainties are typically 20% for individual country, 30% for individual sectors



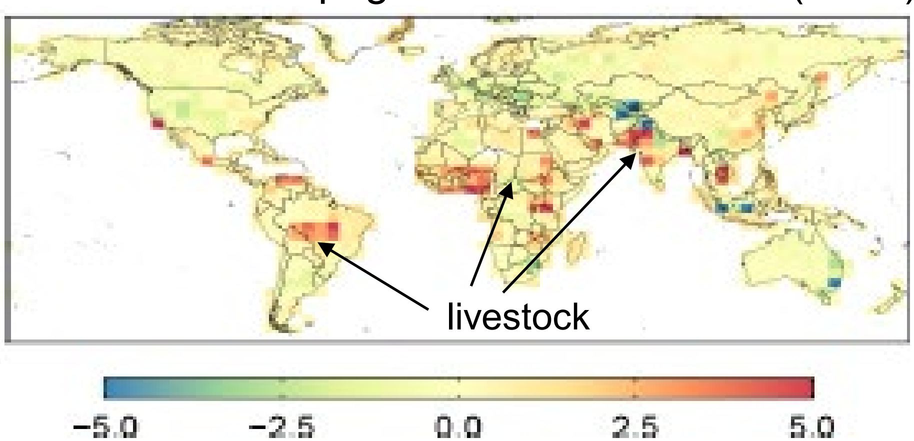
Chen et al. [2022]; Lu et al. [2022]; Worden et al. [2022]

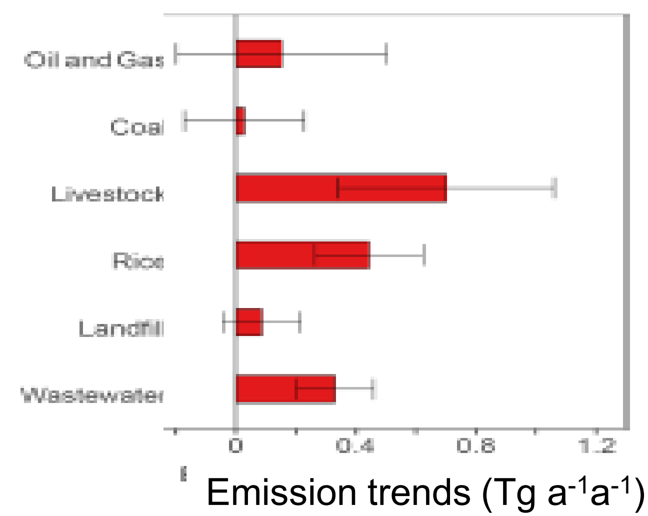
Attribution of decadal methane increase using GOSAT (2010-)



- 2010-2019 increase driven by tropical livestock
- Tropical wetlands have accelerated increase since 2015 – response to climate change?

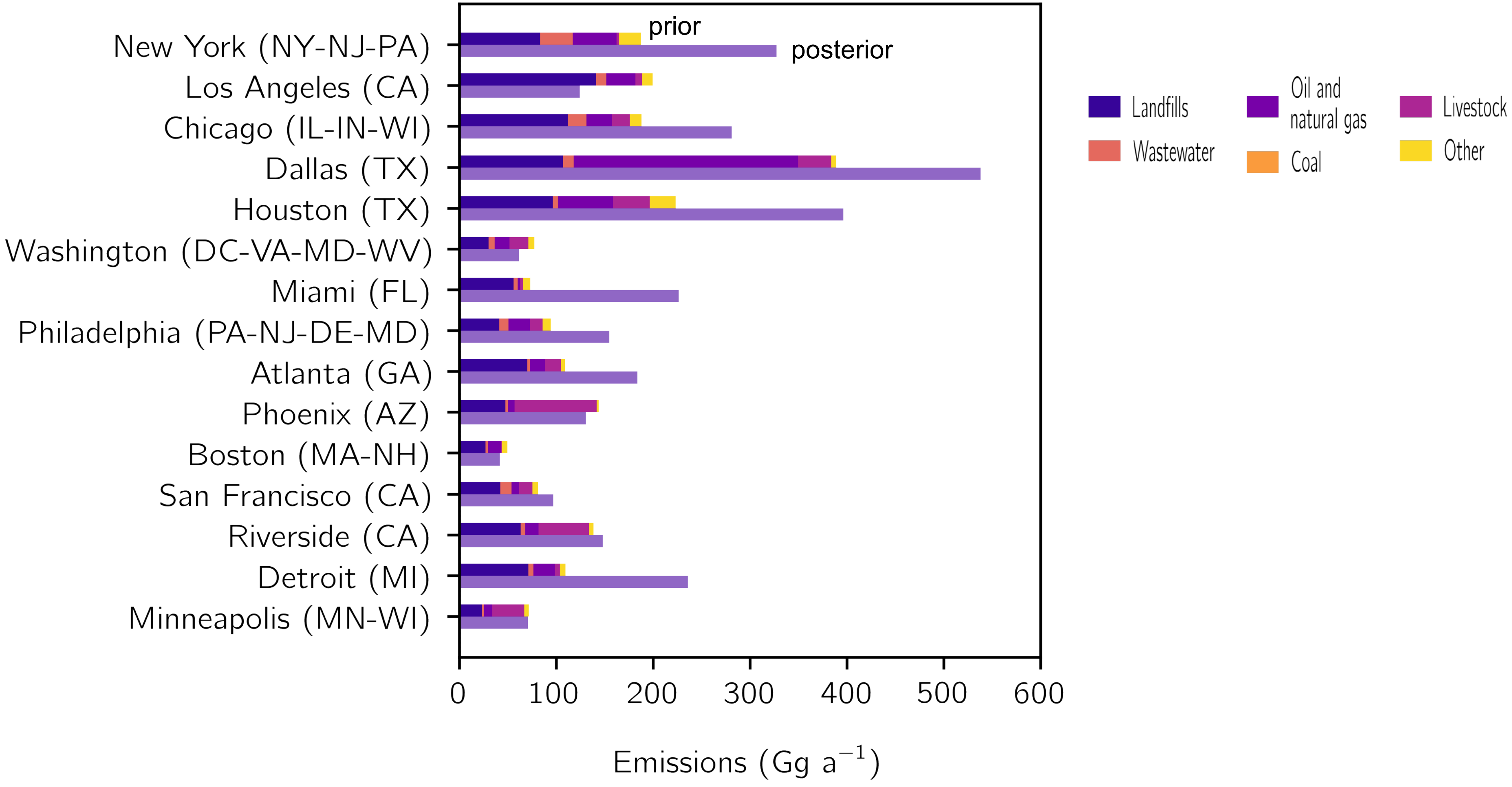
2010-2019 anthropogenic emission trends (% a^{-1})





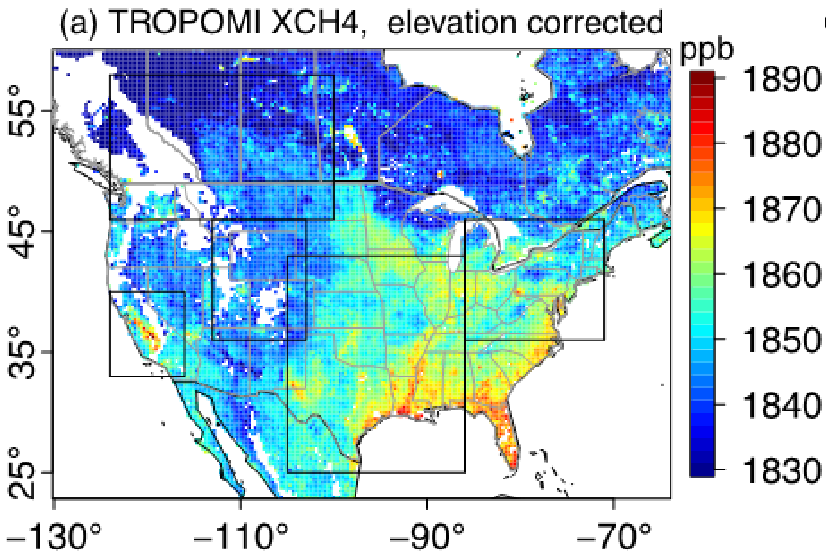
Zhang et al. [2021]; Qu et al. [2022]

Using TROPOMI to quantify emissions from individual cities

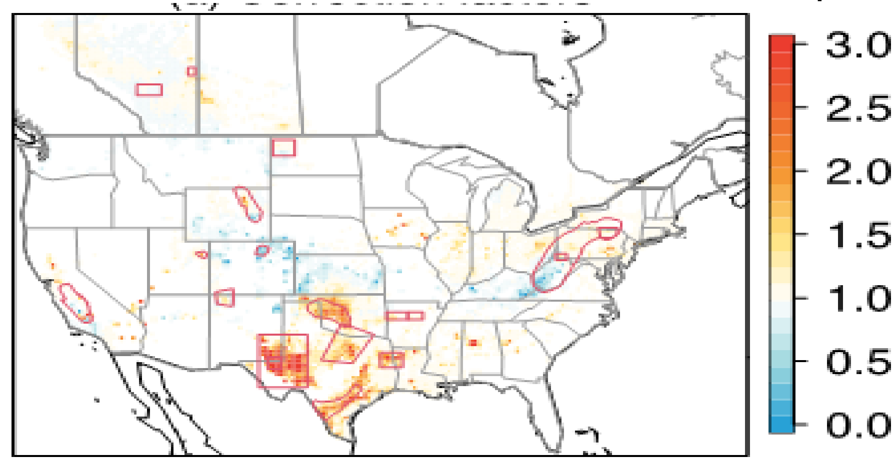


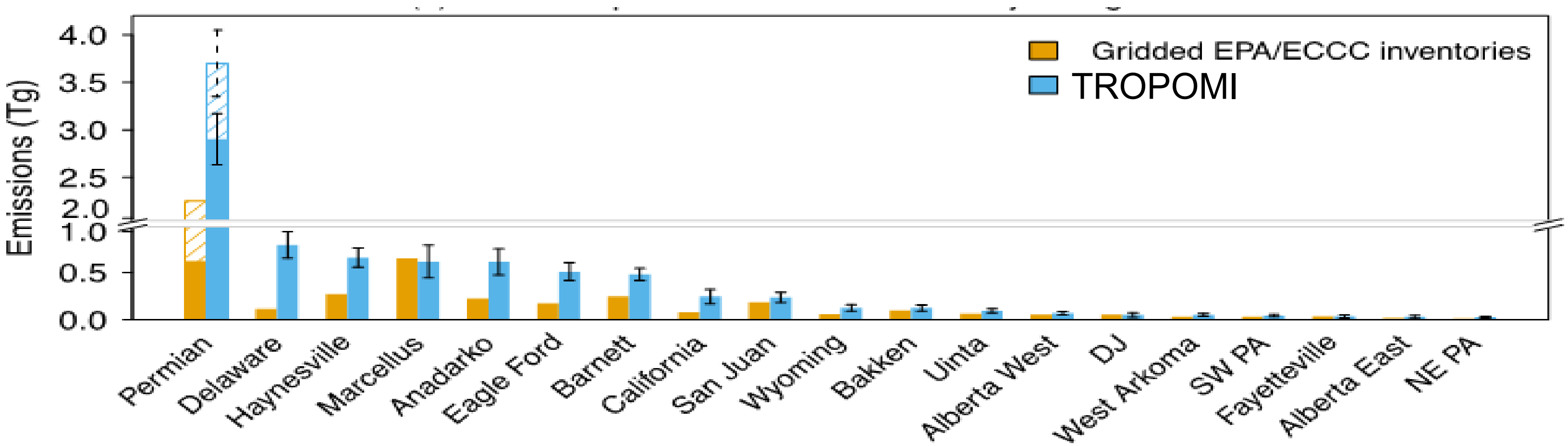
Nesser et al., in prep.

Using TROPOMI to quantify emissions from oil/gas basins



Correction factors to EPA/ECCC emission reports



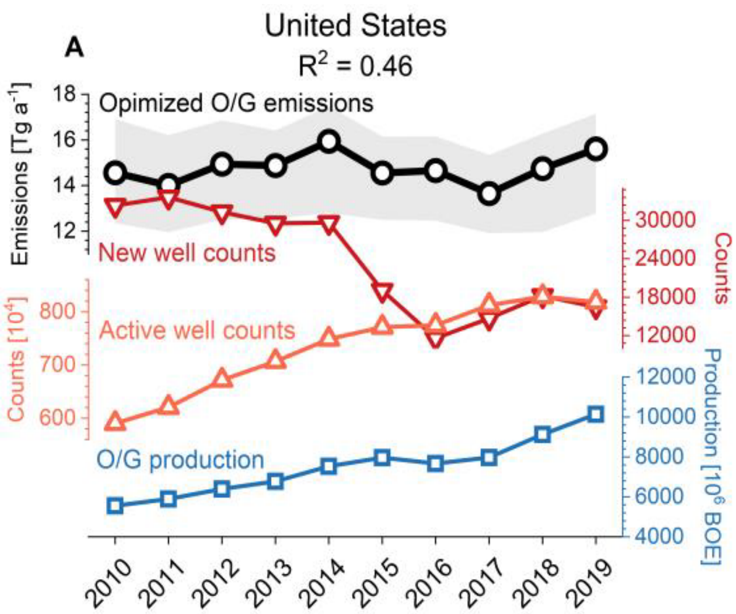


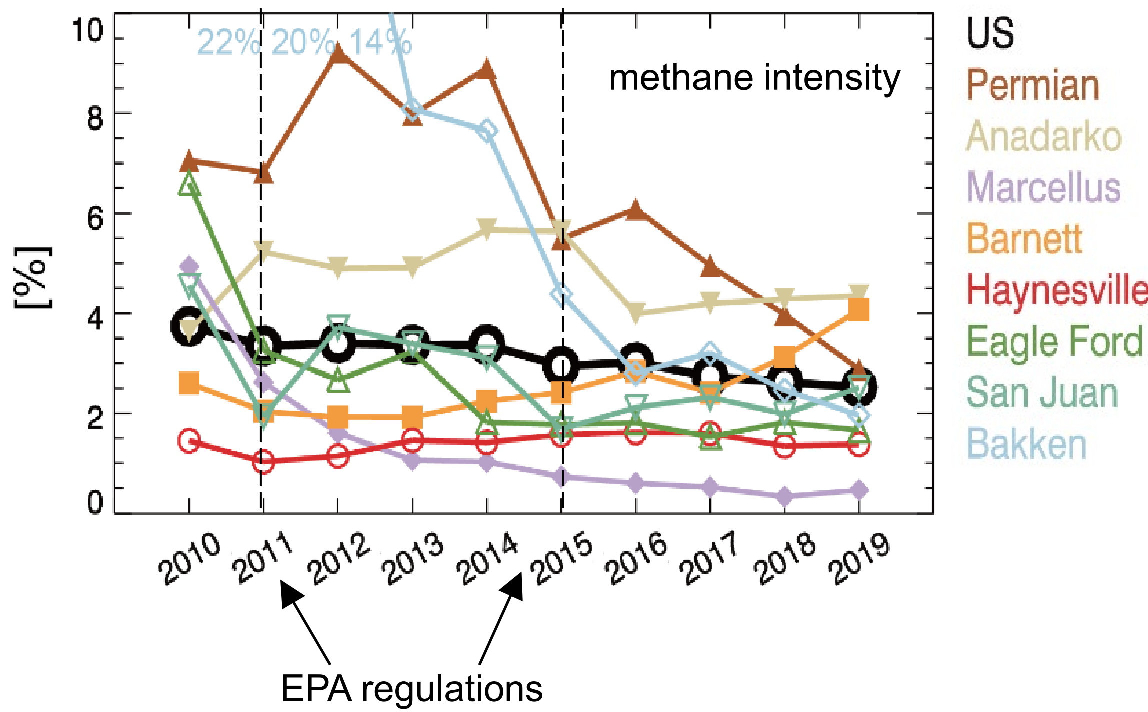
- Oil/gas emissions in US EPA inventory are too low by a factor of 2
- The Permian is responsible for half of this underestimate

Shen et al., 2022

Using GOSAT (2010-) to monitor trends in US oil/gas emissions

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



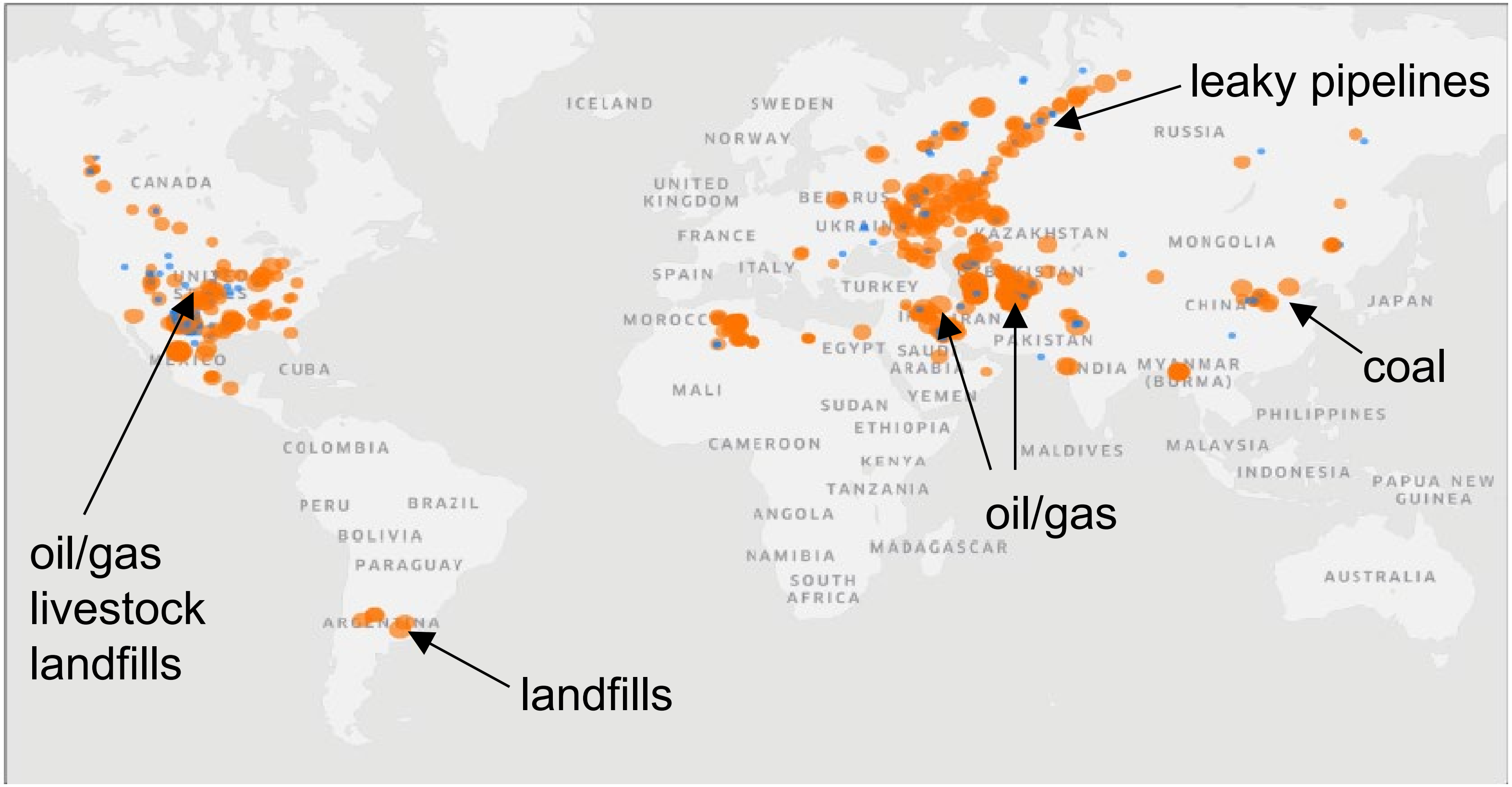


- Methane emissions respond to drilling of new wells, EPA regulations more than to production
- Current methane intensity of 2.5% is ten-fold higher than industry (OGCI) 2025 target of 0.2%
- Meeting OGCI target would decrease total US anthropogenic methane emissions by 40%.

Lu et al., 2022

TROPOMI observations of ‘ultra-emitters’

Sources emitting > 25 tons h^{-1} over 5.5x7 km^2 TROPOMI pixels



Shutting down very large point sources can be effective for climate action…
but we need better localization than TROPOMI can provide

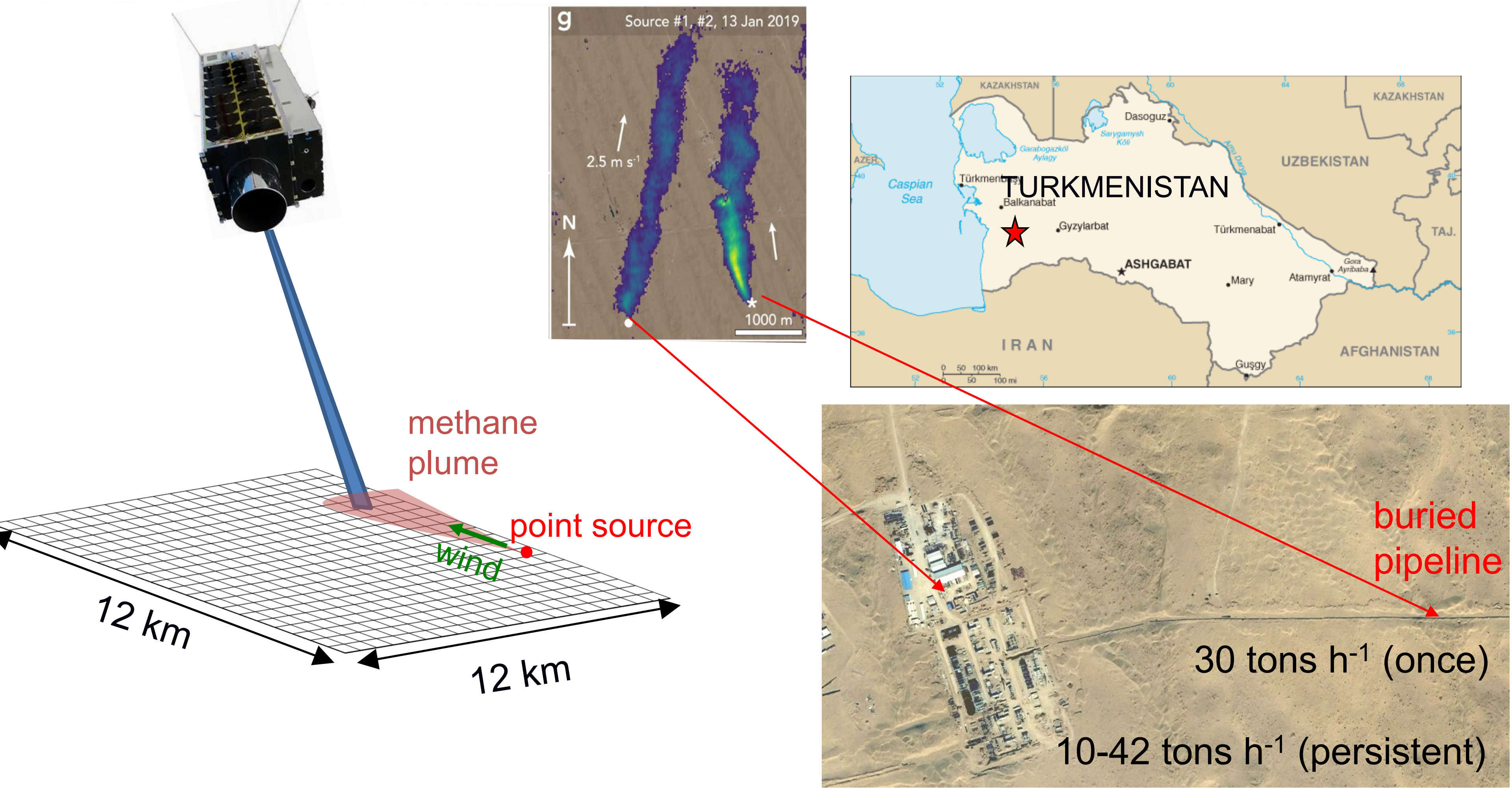
Lauvaux et al., 2022

GHGSat observation of methane point sources from space

GHGSat microsatellite fleet

25x25 m^2 pixels

13 Jan 2019



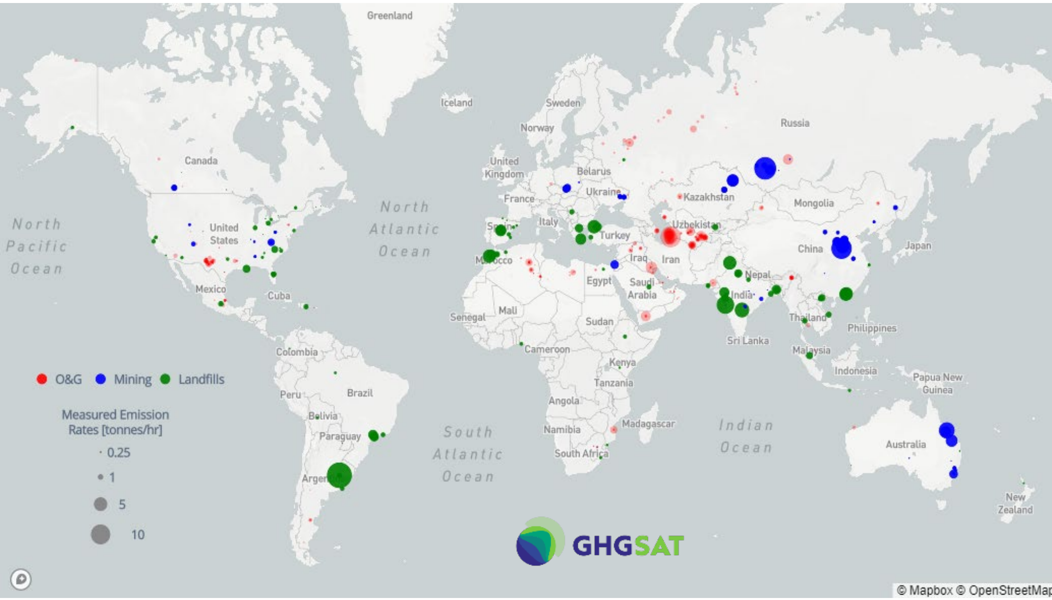
Korpezhe gas compressor station

- Detect large point sources (> 300 kg h^{-1}, ± 30% uncertainty) from single plume observations

Varon et al., 2019

We now have global observation capability for point sources

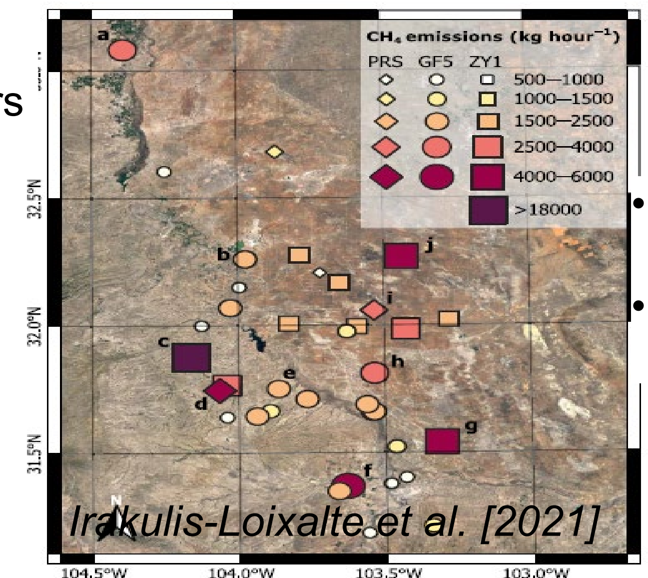
GHGSat constellation



Sentinel-2 land surface imagers

Ehret et al. [2022]

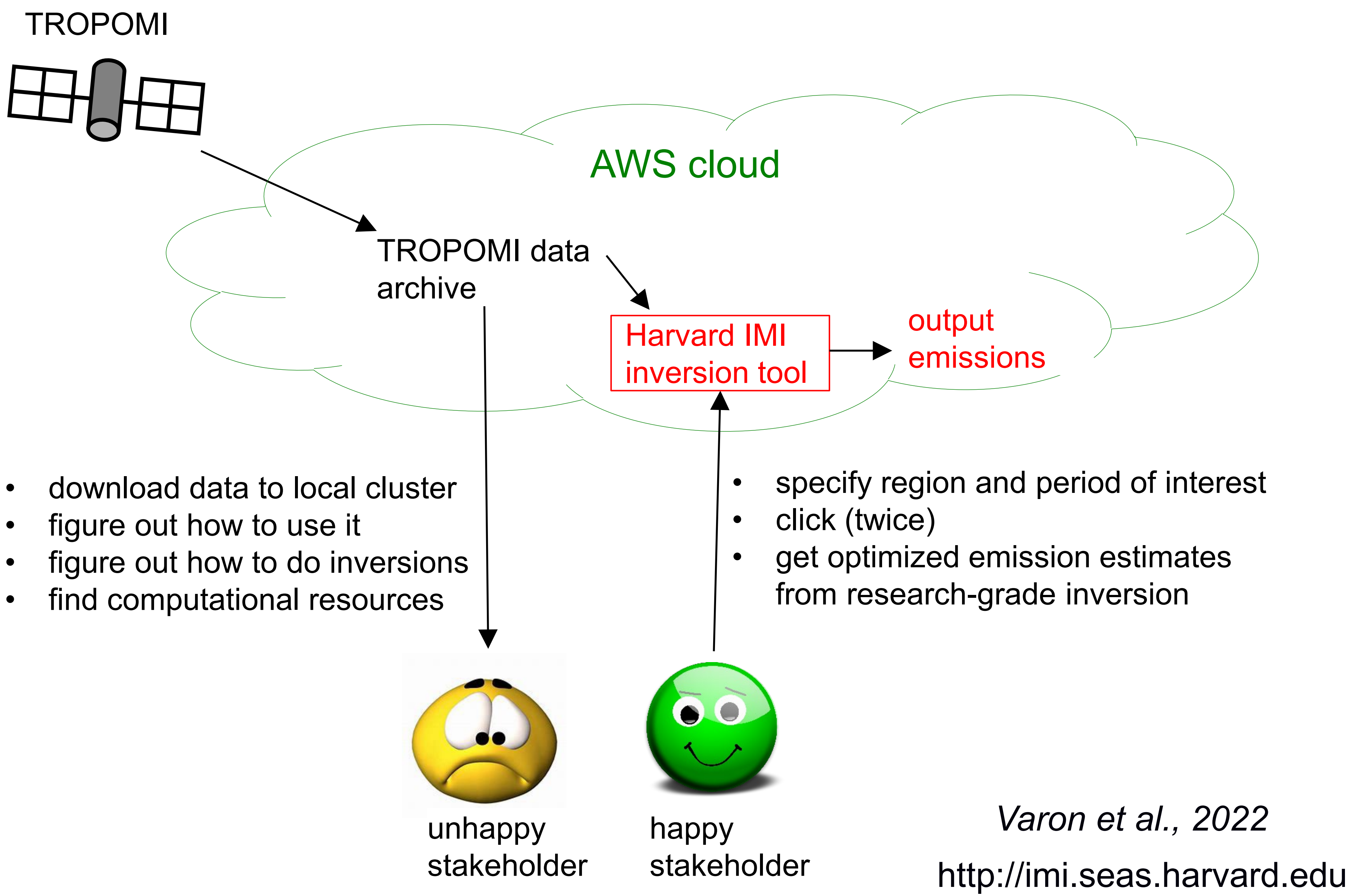
Permian Basin with multiple imagers



Irakulis-Loixalte et al. [2021]

- Large point sources (>1 ton h^{-1}) are readily seen from space
- Frequent revisit times enable quantification and prompt climate action

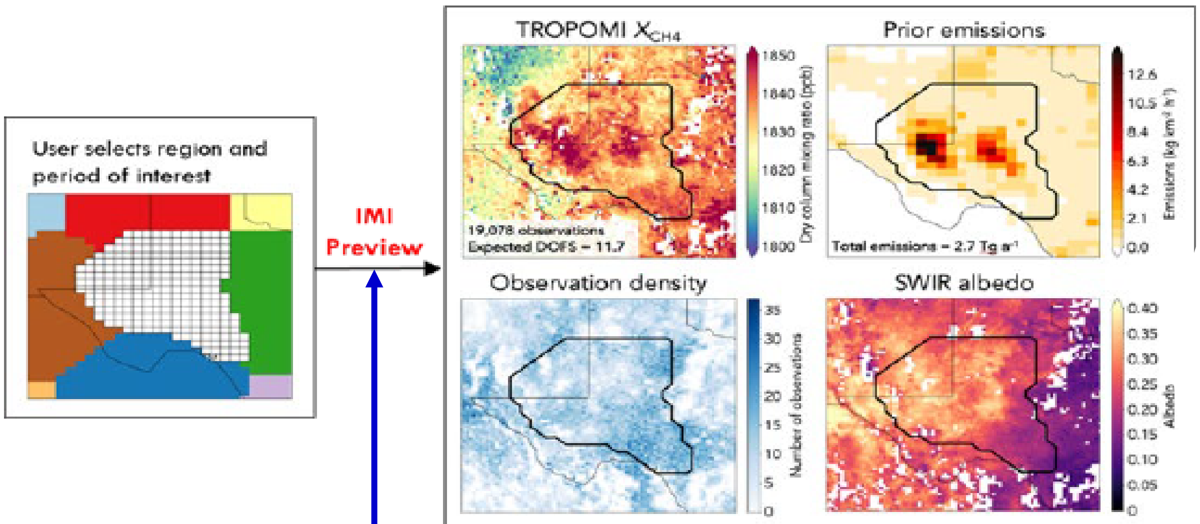
Integrated Methane Inversion (IMI) open-access cloud-based facility for stakeholders to do their own inversions of TROPOMI methane data



Example application of Integrated Methane Inversion (IMI) on AWS

1-month inversion for Permian basin

IMI preview allows user to check quality of satellite data: no significant cost incurred so far



1st click

2nd click

Jacob et al. [2022]

Take-aways

- Satellites observations of atmospheric methane are a powerful tool to evaluate national emission inventories and their trends in support of the Paris Agreement and the Global Methane Pledge

- Facility-scale observations of methane plumes from space can quantify emissions from large point sources and enable prompt climate action

- A number of new satellite instruments will enhance our capability in coming years:
    - Sentinel-5, CO2M, GeoCarb for national inventories
    - GOSAT-GW, Methane SAT for cities, oil/gas fields, livestock operations
    - Carbon Mapper for point sources