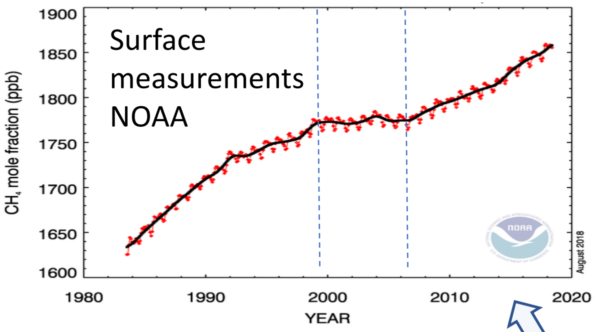
Quantifying methane emissions from the largest oil-producing basin in the United States from space

Yuzhong Zhang (Zhangyuzhong@westlake.edu.cn)

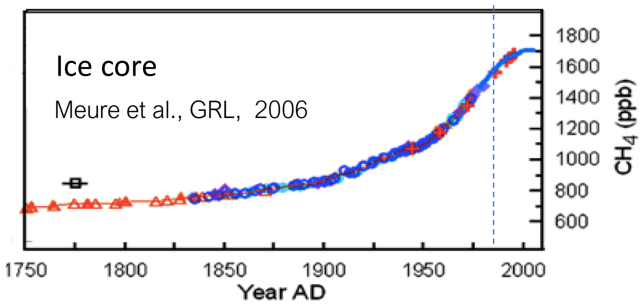
With
Ritesh Gautam, Sudhanshu Pandey, Mark Omara, Joannes D. Maasakkers, Pankaj Sadavarte, David Lyon, Hannah Nesser, Melissa P. Sulprizio,Daniel J. Varon, Ruixiong Zhang, Sander Houweling, Daniel Zavala-Araiza, Ramon A. Alvarez, Alba Lorente, Steven P. Hamburg, Ilse Aben, Daniel J. Jacob

Methane: a potent greenhouse gas

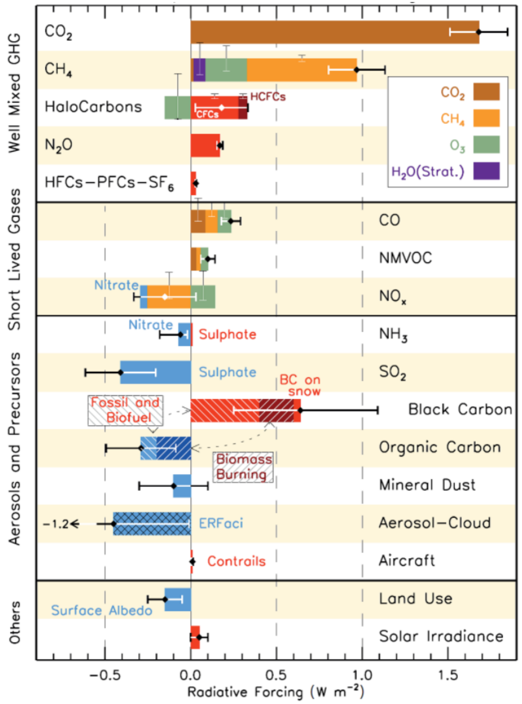
Methane concentration in last 35 years



Methane concentration in last 300 years



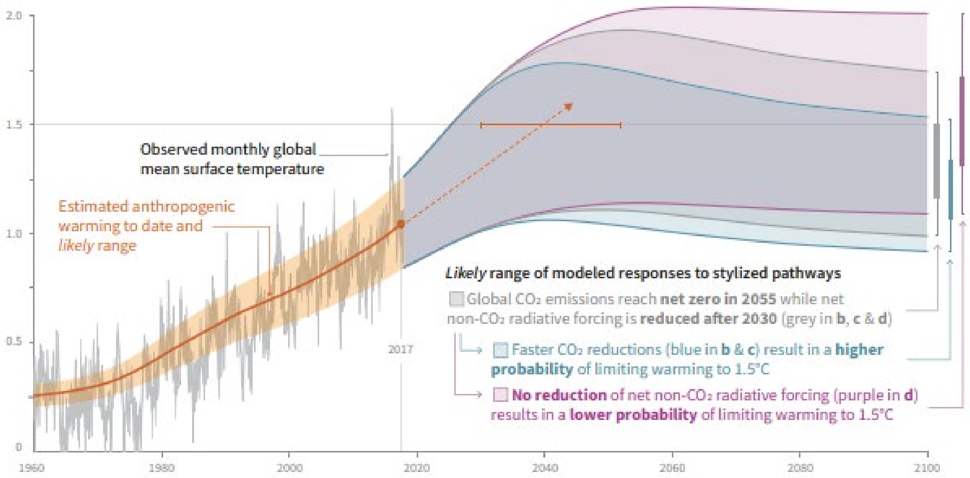
Radiative forcing



IPCC AR5

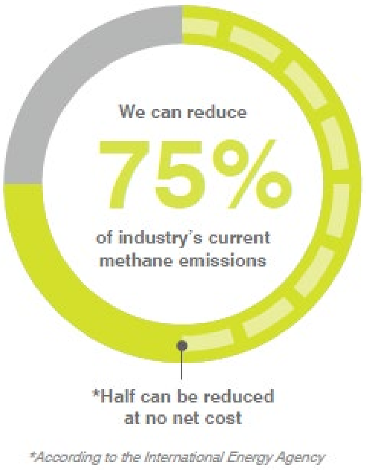
Reduce methane emissions

Necessary supplement to fast CO_2 reduction to achieve climate goals



IPCC, 2018

Economical, technological, & legal feasibility



Global Methane Initiative

OGCI OIL AND GAS CLIMATE INITIATIVE

METHANE GUIDING PRINCIPLES

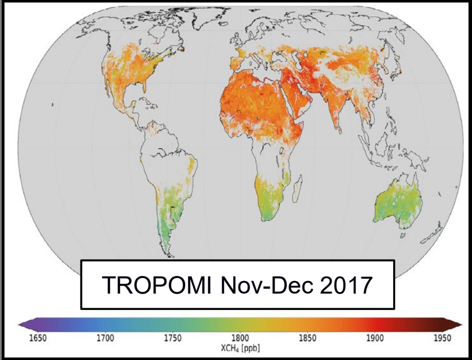
Challenging demands for monitoring

Global coverage
Emissions from every corner of the world counts

Monitor emissions
Large numbers, varied kinds, distributed over globe, highly variable

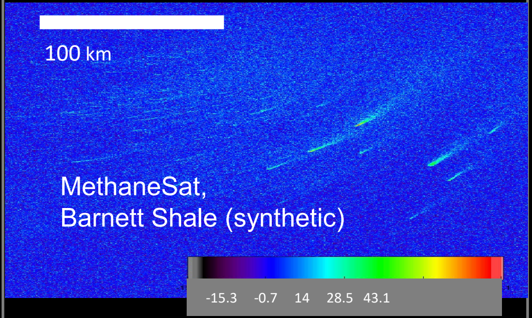
Integrate information across scales
From global budget, regional hotspots to fixing malfunctioning facility

Global/National



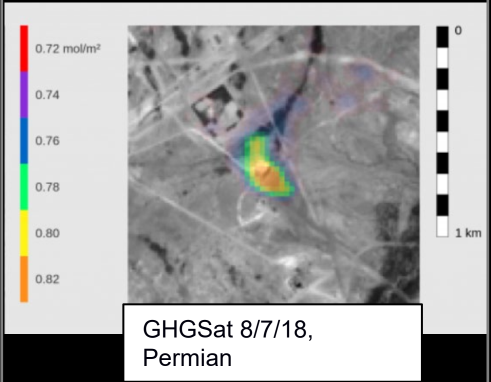
5-10 km resolution
~1000 km swath

Regional



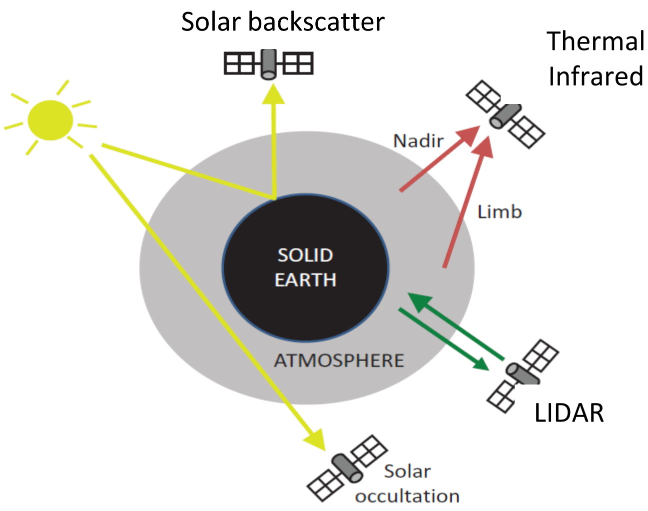
~100-1000 m resolution
~100 km swath

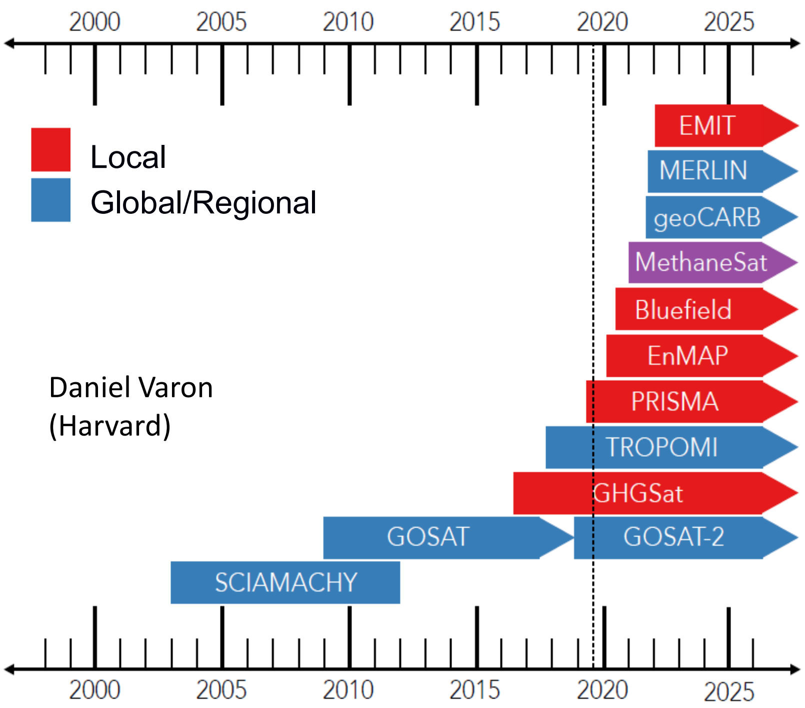
Facility Scale



~10 m resolution
~10 km swath

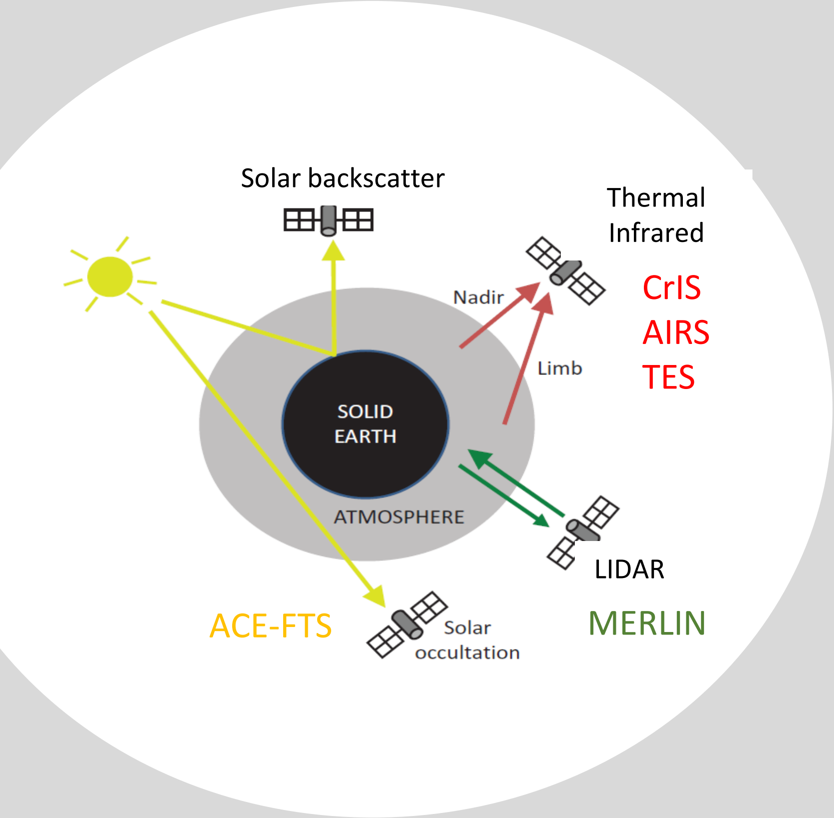
Rapidly expanding satellite capability

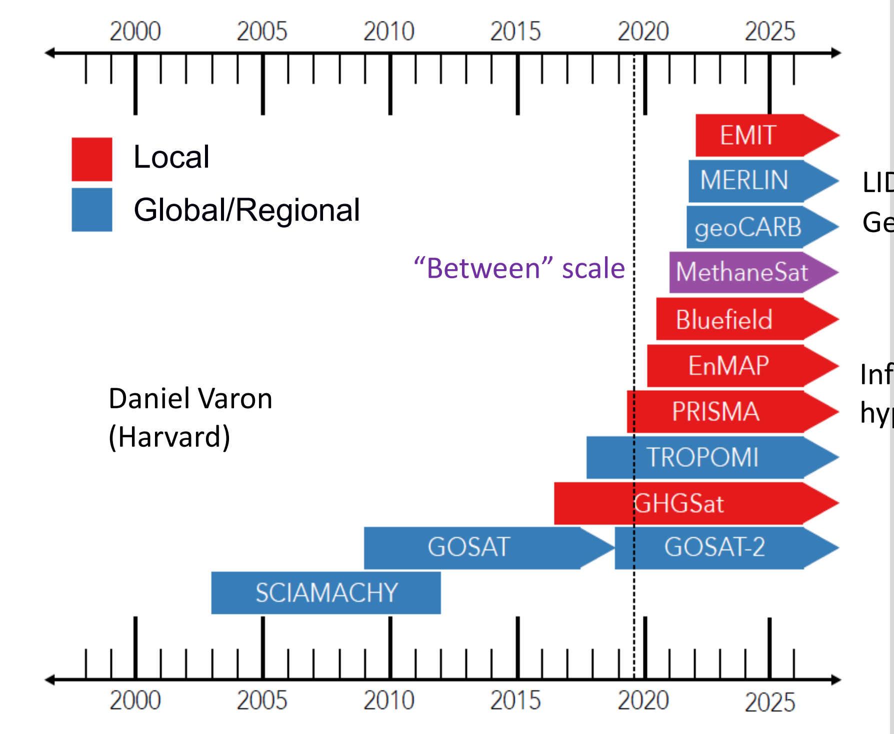




Daniel Varon
(Harvard)

Rapidly expanding satellite capability

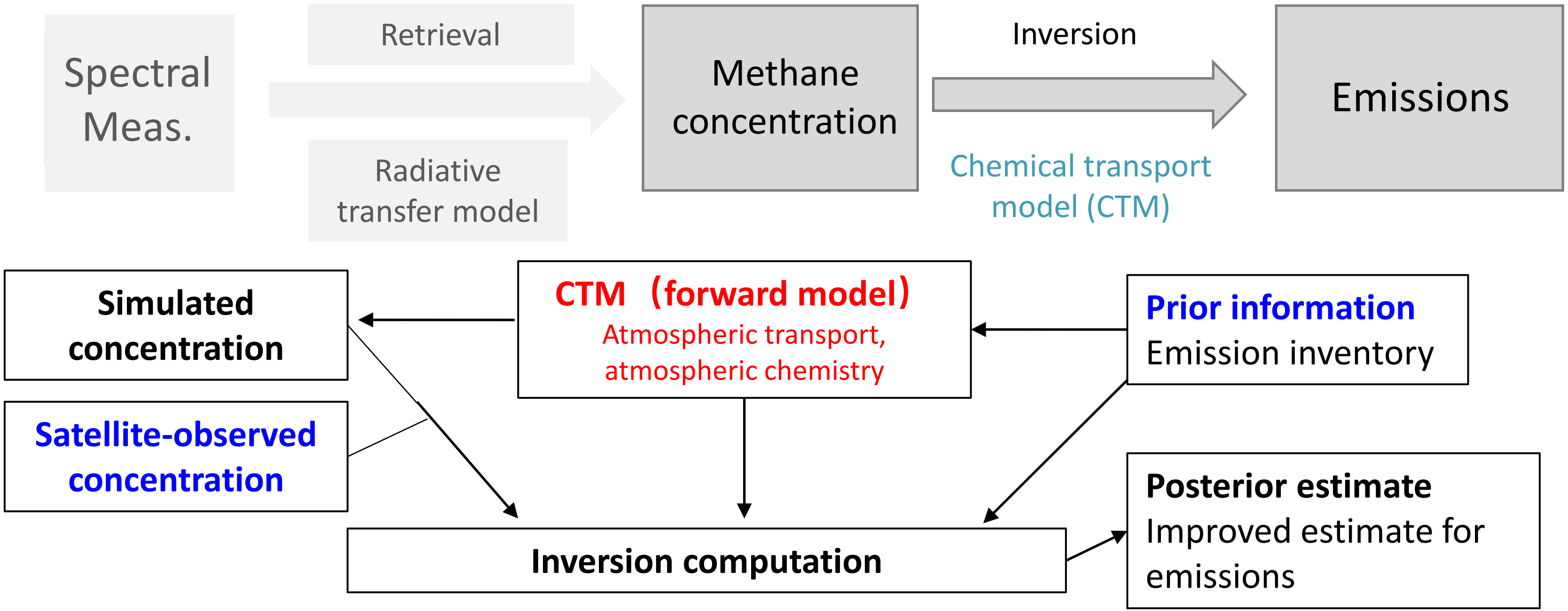




LIDAR
Geostationary

Infrared hyperspectral

Use satellite observations to quantify methane emissions



$$J(\boldsymbol{x}) = (\boldsymbol{x} - \boldsymbol{x}_a)^T \mathbf{S}_a^{-1} (\boldsymbol{x} - \boldsymbol{x}_a) + \gamma (\boldsymbol{y} - \mathbf{K}\boldsymbol{x})^T \mathbf{S}_O^{-1} (\boldsymbol{y} - \mathbf{K}\boldsymbol{x})$$

Prior

Prior uncertainty

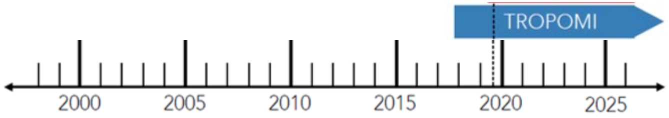
Satellite

Instrument & model uncertainty

Forward model

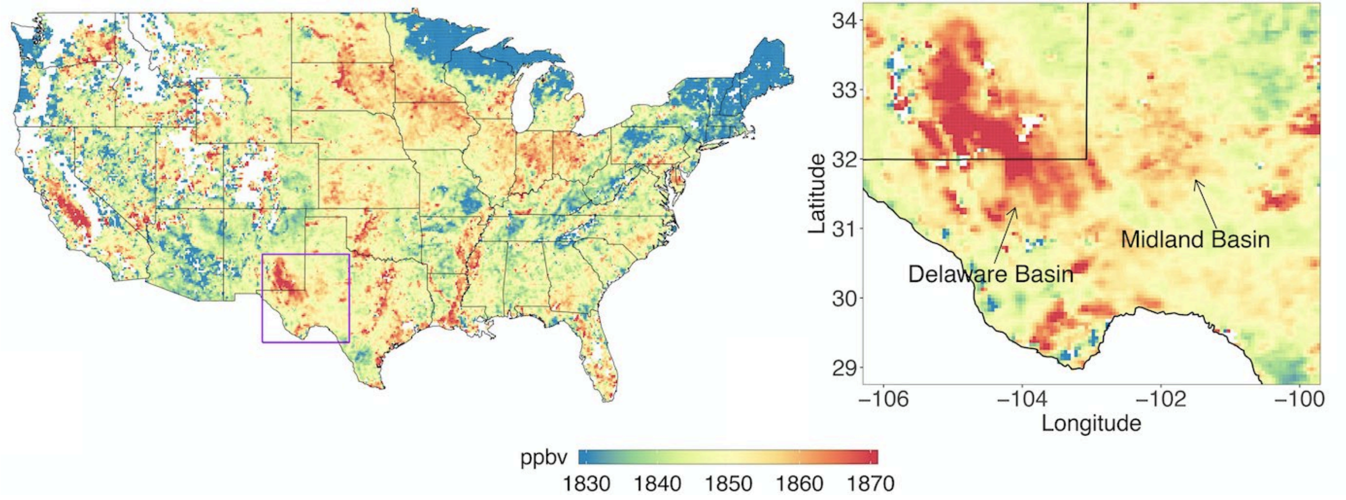
Methane emissions from the Permian Basin

Tropospheric Monitoring Instrument (TROPOMI)



Satellite: Sentinel-5 Precursor; Swath width: 2600 km;

Overpass: ~13:30 LT; Resolution: 7×7 km^2; Retrieval: “full physics” (*Hu et al., 2016*)



Zhang et al., Science Advances, 2020

Permian Basin

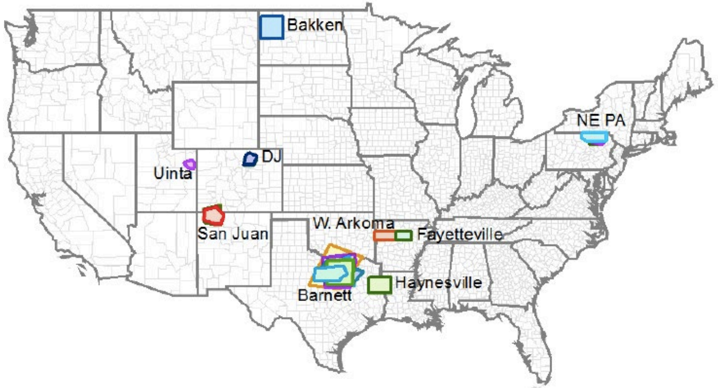
Permian Basin： the largest oil producing basin in the U.S.
a lack of “top-down” constraint for its methane emissions

REPORT

Assessment of methane emissions from the U.S. oil and gas supply chain

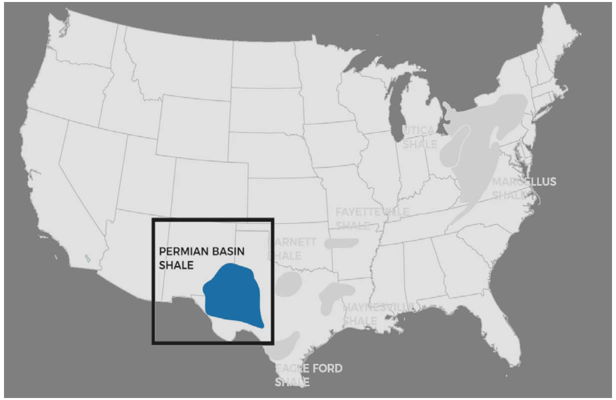
Ramón A. Alvarez[1,*], Daniel Zavala-Araiza[1], David R. Lyon[1], David T. Allen[2], Zachary R. Barkley[3], Adam R. Brandt[4], Kenneth J. Dav...
+ See all authors and affiliations

Science 13 Jul 2018:
Vol. 361, Issue 6398, pp. 186-188
DOI: 10.1126/science.aar7204

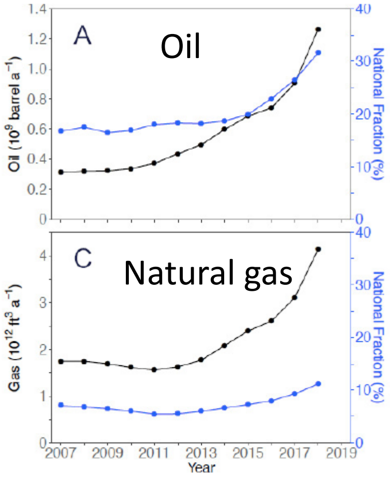


Alvarez et al., Science, 2018

Permian Basin



Oil & gas production

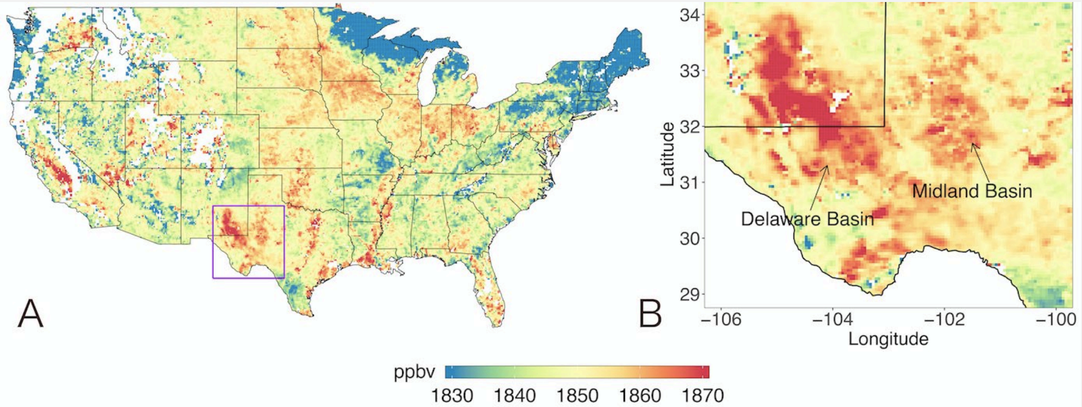


Methane emissions from the Permian Basin

Methane concentration

TROPOMI

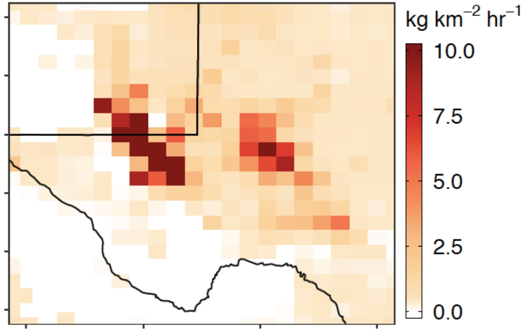
5/2018-3/2019



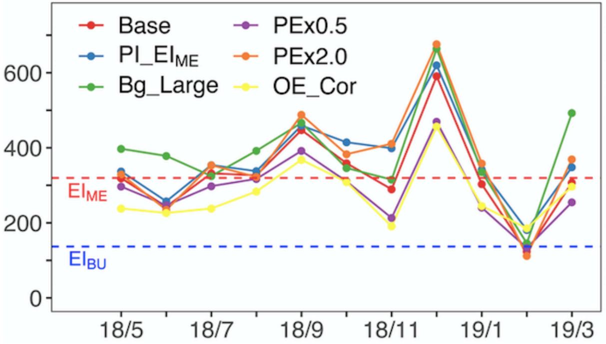
Solve inversion

Methane flux

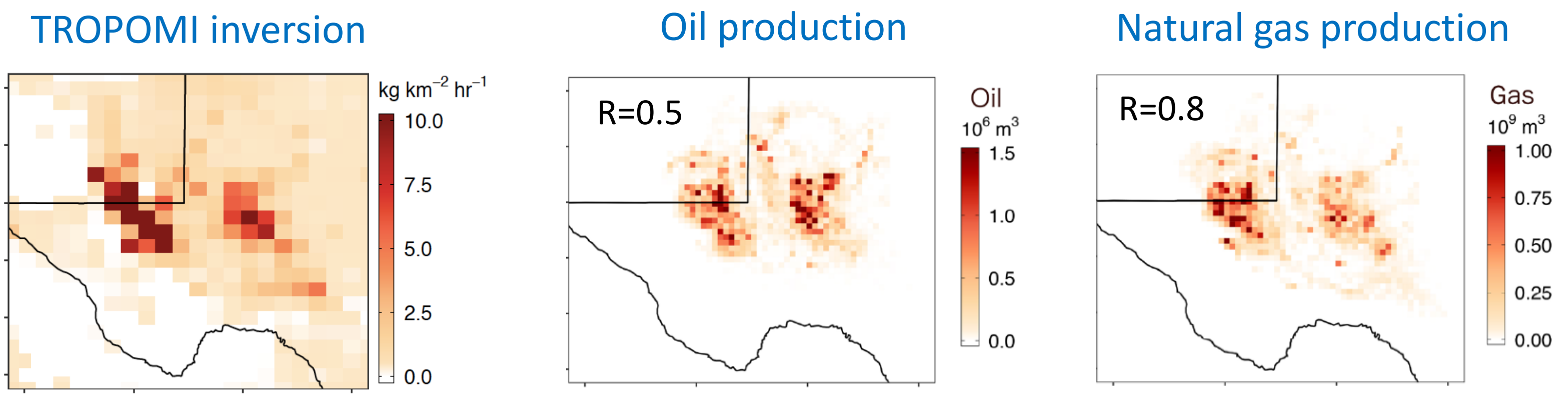
Spatial distribution

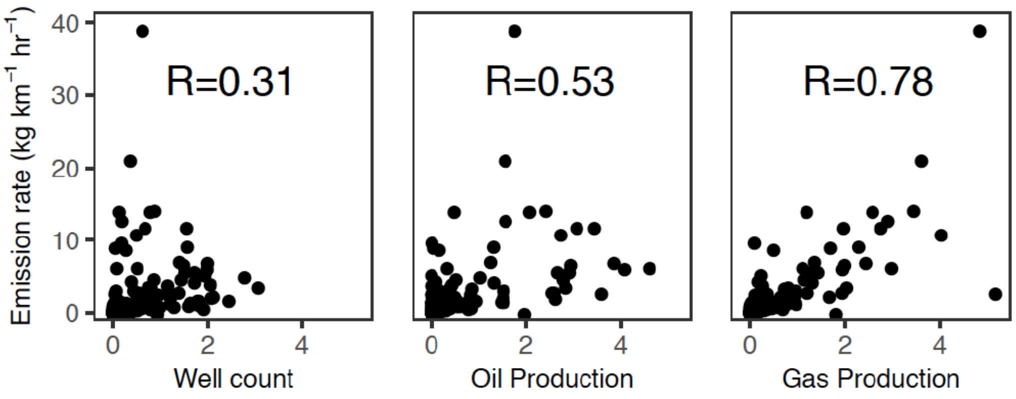


Temporal changes



Spatial distributions of methane emissions

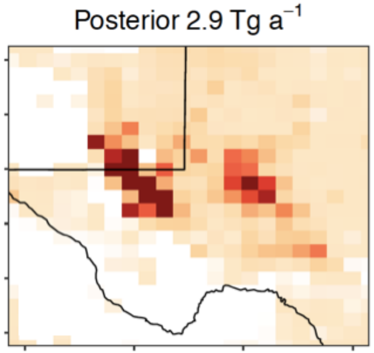




Estimate methane emissions with multiple approaches

Based on TROPOMI data

Atmospheric inverse modeling
0.25x0.3125 GEOS-Chem nested
Yuzhong Zhang (Westlake)



Mass balance method
Sudhanshu Pandey (SRON)
→ 3.2±2.0 Tg a^{-1}

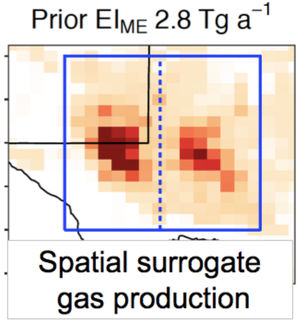
Schneising et al., ACP, 2020

Based on surface measurements

Site-level measurement extrapolation
71 site-level measurements

Mark Omara (EDF)

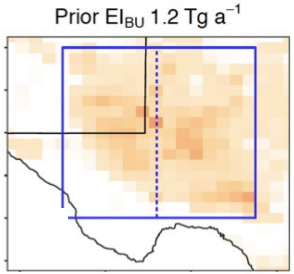
Robertson et al., EST, 2020



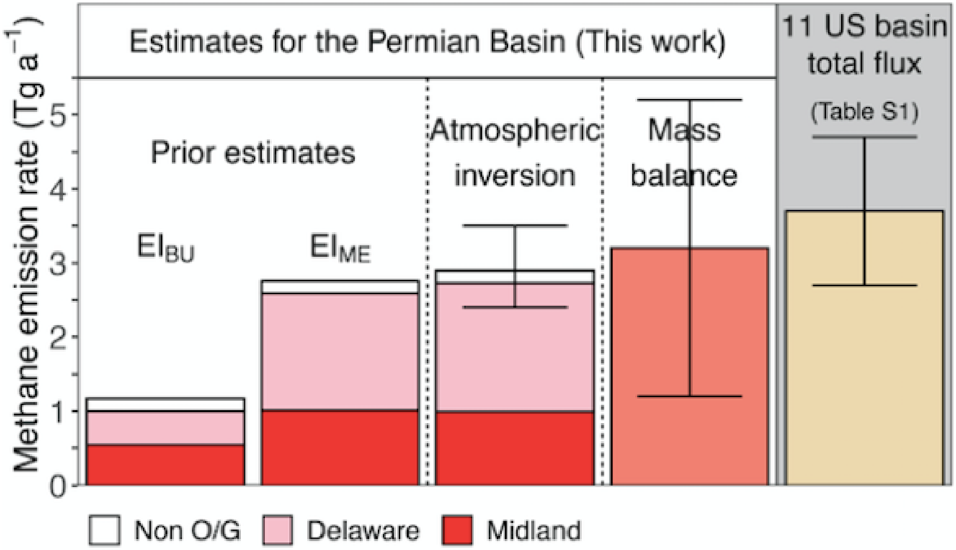
Based on bottom-up information

Bottom-up emission inventory
Extrapolation of EPA gridded inventory to 2018 DI info for O&G

Bram Maasakkers (SRON)



More than 2 times the bottom-up estimate

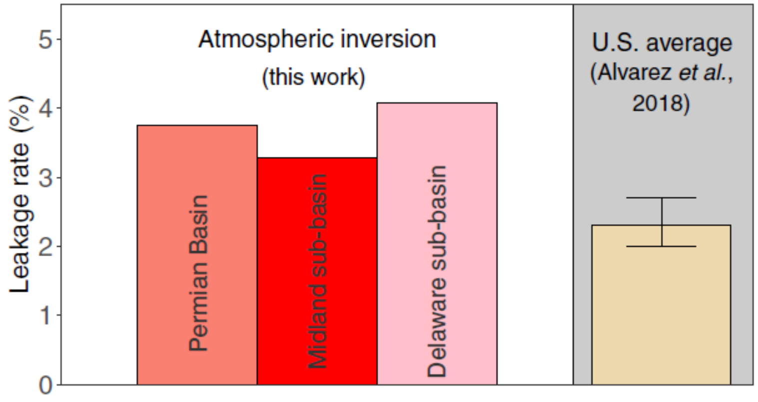


>2 times the bottom-up estimate

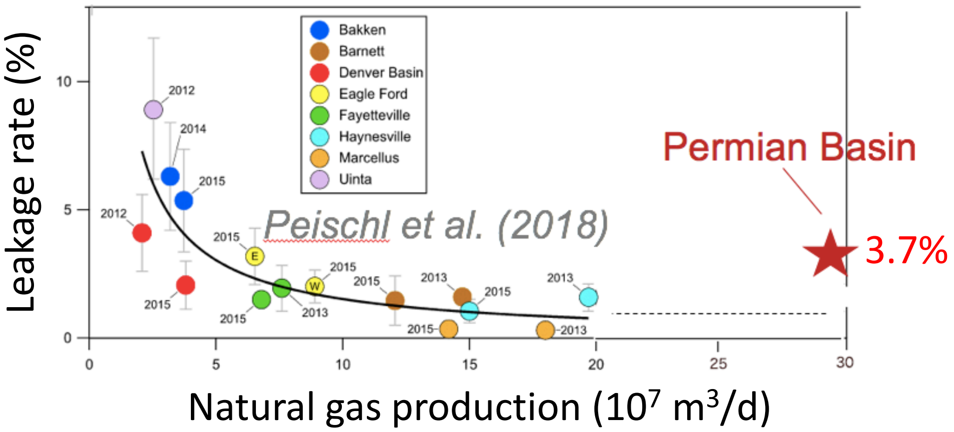
4x higher than Eagle Ford -- the largest flux reported in literature

High leakage rate

Leakage rate
with respect to gas production



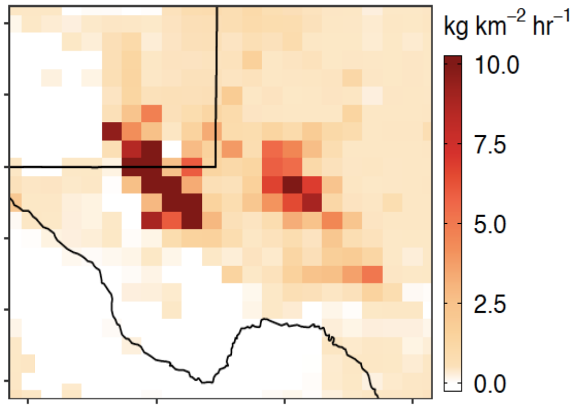
Leakage rate vs gas production



High gas production & high leakage rate indicates low efficiency in gas utilization

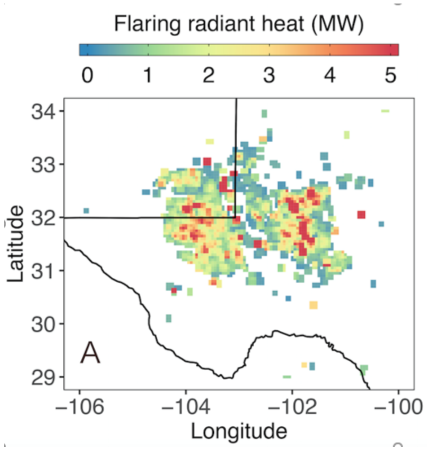
Intensive gas flaring over the Permian

TROPOMI inversion

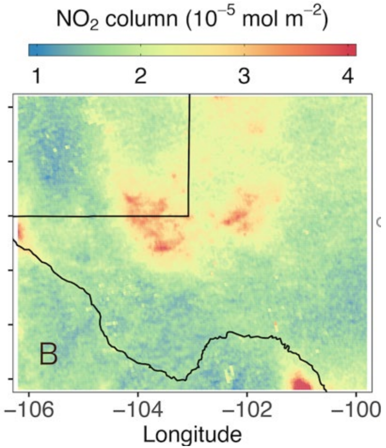


2.9 Tg a^{-1}

VIIRS Infrared radiation



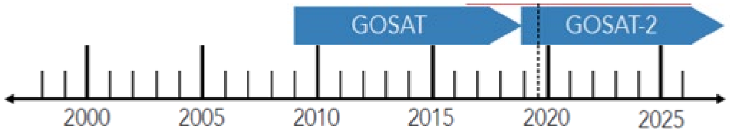
TROPOMI NO_2



Burning of 5.2 – 8.7 10^9 m^3 a^{-1} natural gas
→ ~ 3 Tg a^{-1}

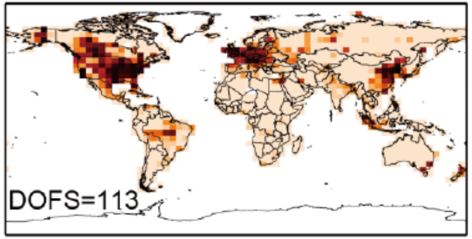
Global emission and trend

GOSAT （2010-2018）



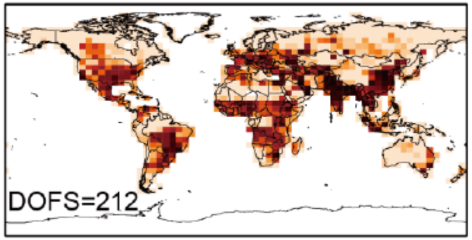
Averaging kernel sensitivities

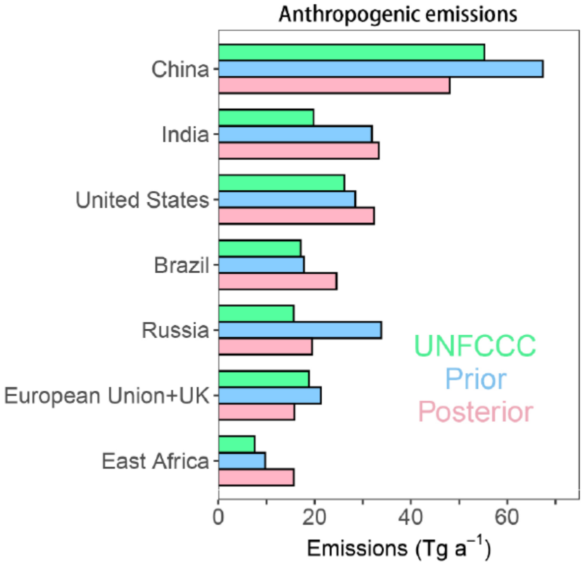
Surface



(c)

Satellite

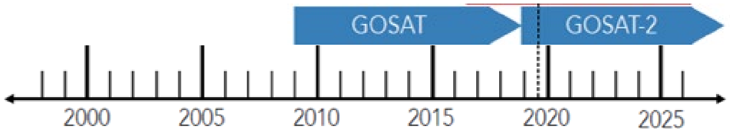


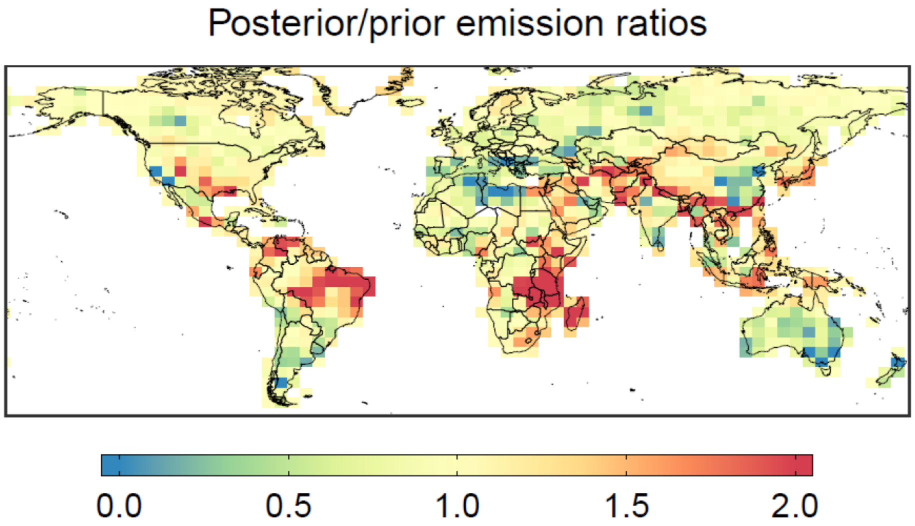


Zhang et al., ACPD, 2020; Lu et al., ACPD, 2020; Maasakkers et al., ACP, 2019

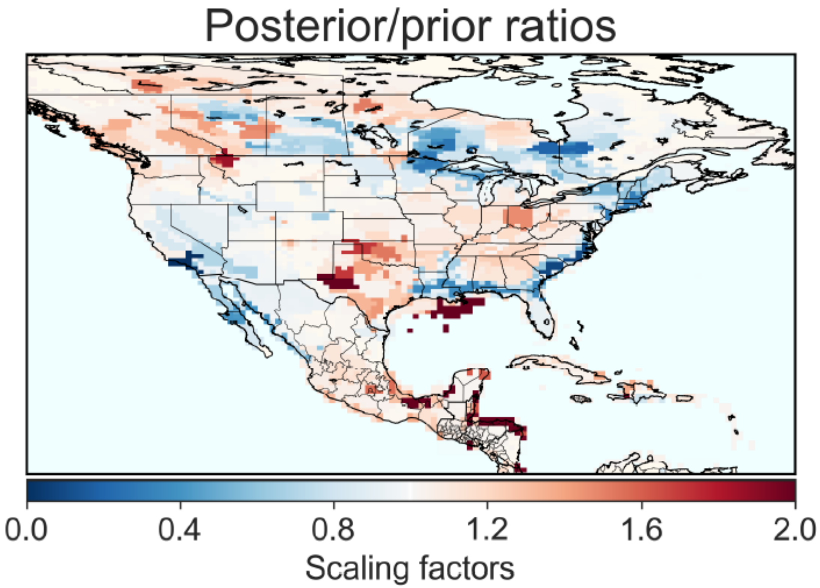
Global emission and trend

GOSAT （2010-2018）





Zhang et al., ACPD, 2020



Maasakkers et al., ACPD, 2020

Summary

Yuzhong Zhang
(zhangyuzhong@westlake.edu.cn)

- Demonstrate the capability of satellite observations to constrain regional methane emissions, through a case study at the Permian Basin
- Inverse analysis infers an annual emissions of 2.7 Tg a^{-1} from the Permian Basin, more than 2 times the bottom-up estimate
- Low rate in gas capture/utilization contributes to high leakage rate
- Globally, satellite observations supplement surface observations for understanding global methane budget and its changes.