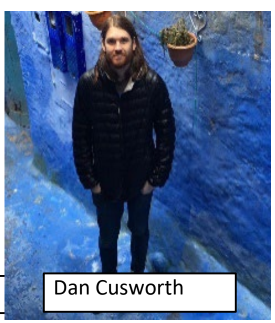
Using satellite observations to quantify methane sources and trends from the global scale down to point sources

Daniel J. Jacob, Harvard University

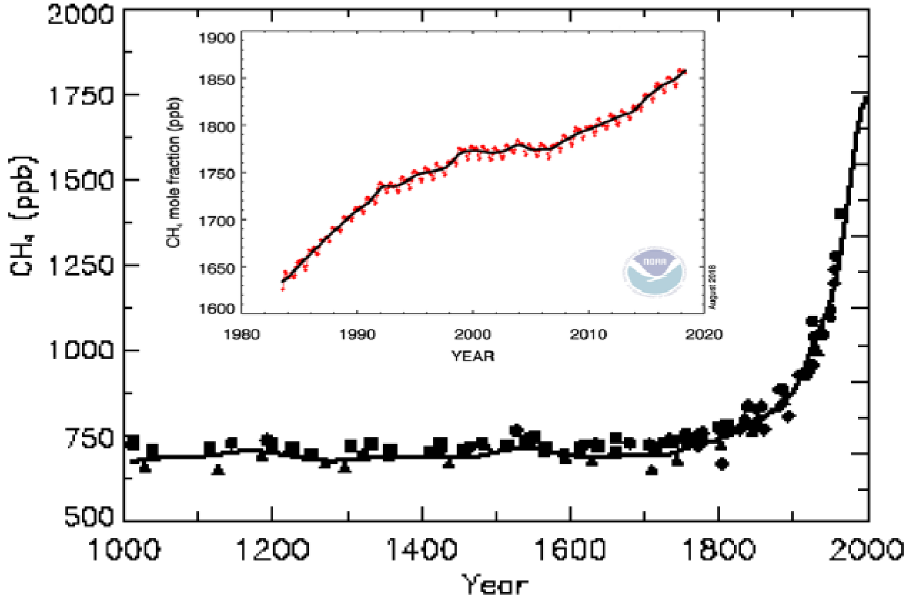


HARVARD UNIVERSITY ATMOSPHERIC CHEMISTRY MODELING GROUP

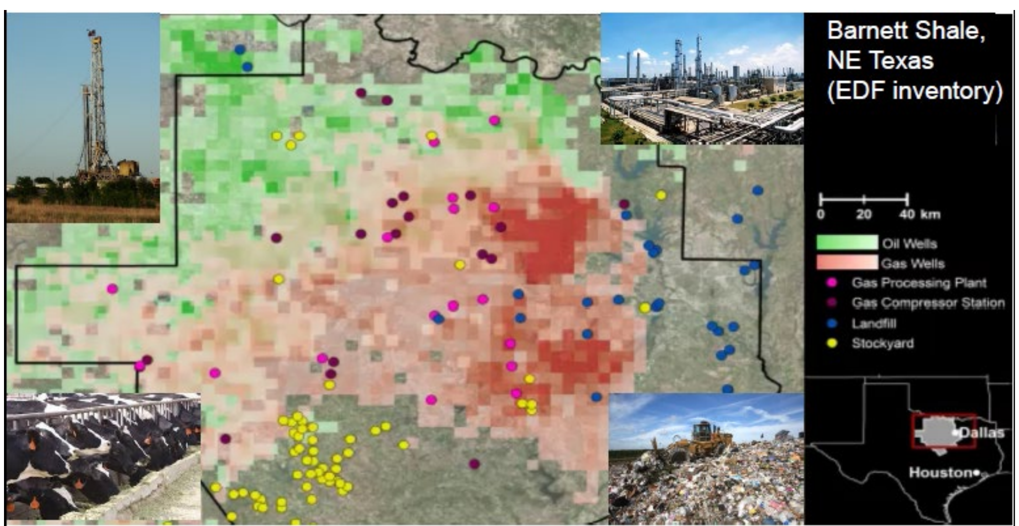
and collaborators from JPL, EDF, GHGSat

Two challenges with atmospheric methane

1. Determine the source sectors and regions responsible for methane growth



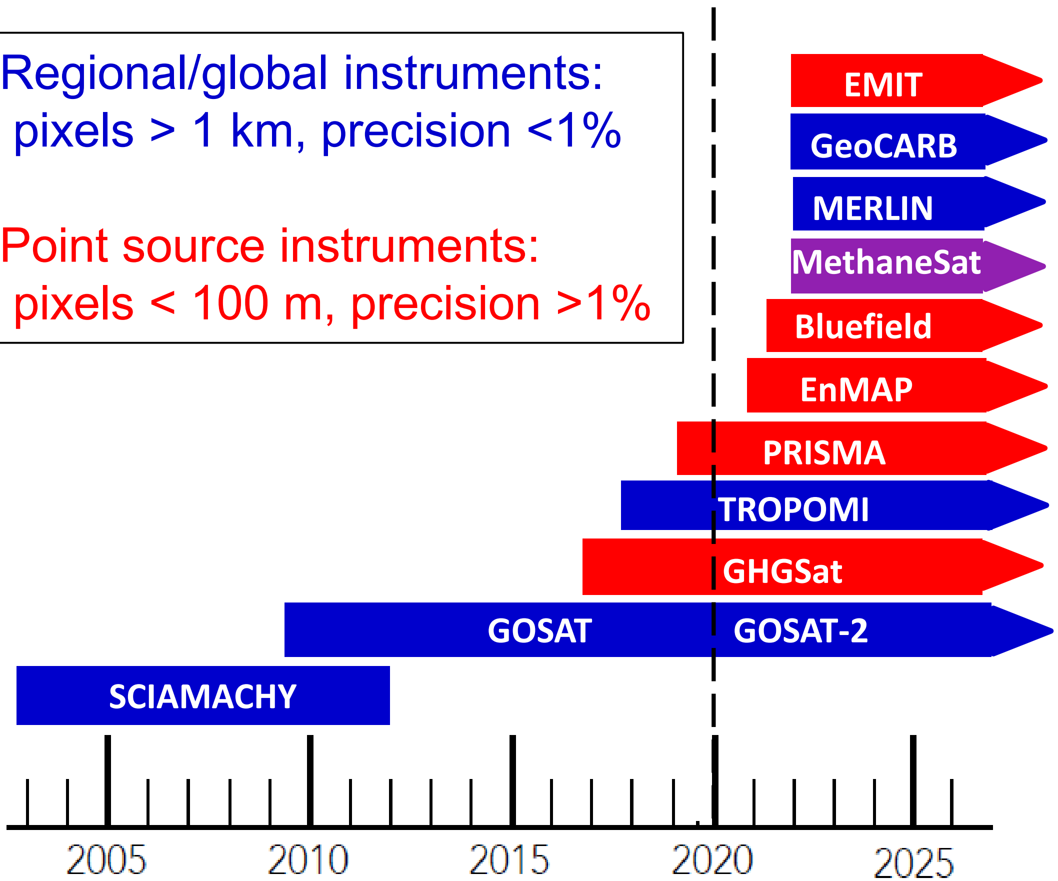
2. Quantify sources at facility level to enable action

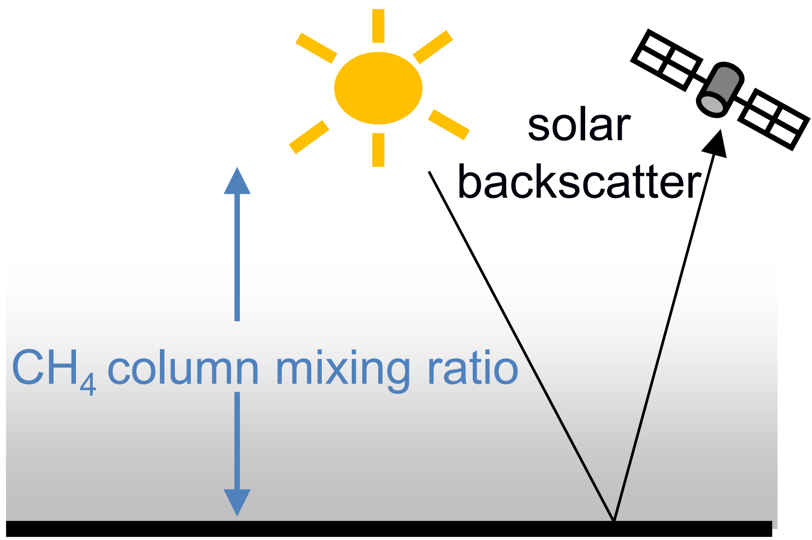


Shortwave IR satellite instruments for atmospheric methane

Regional/global instruments:
pixels > 1 km, precision <1%

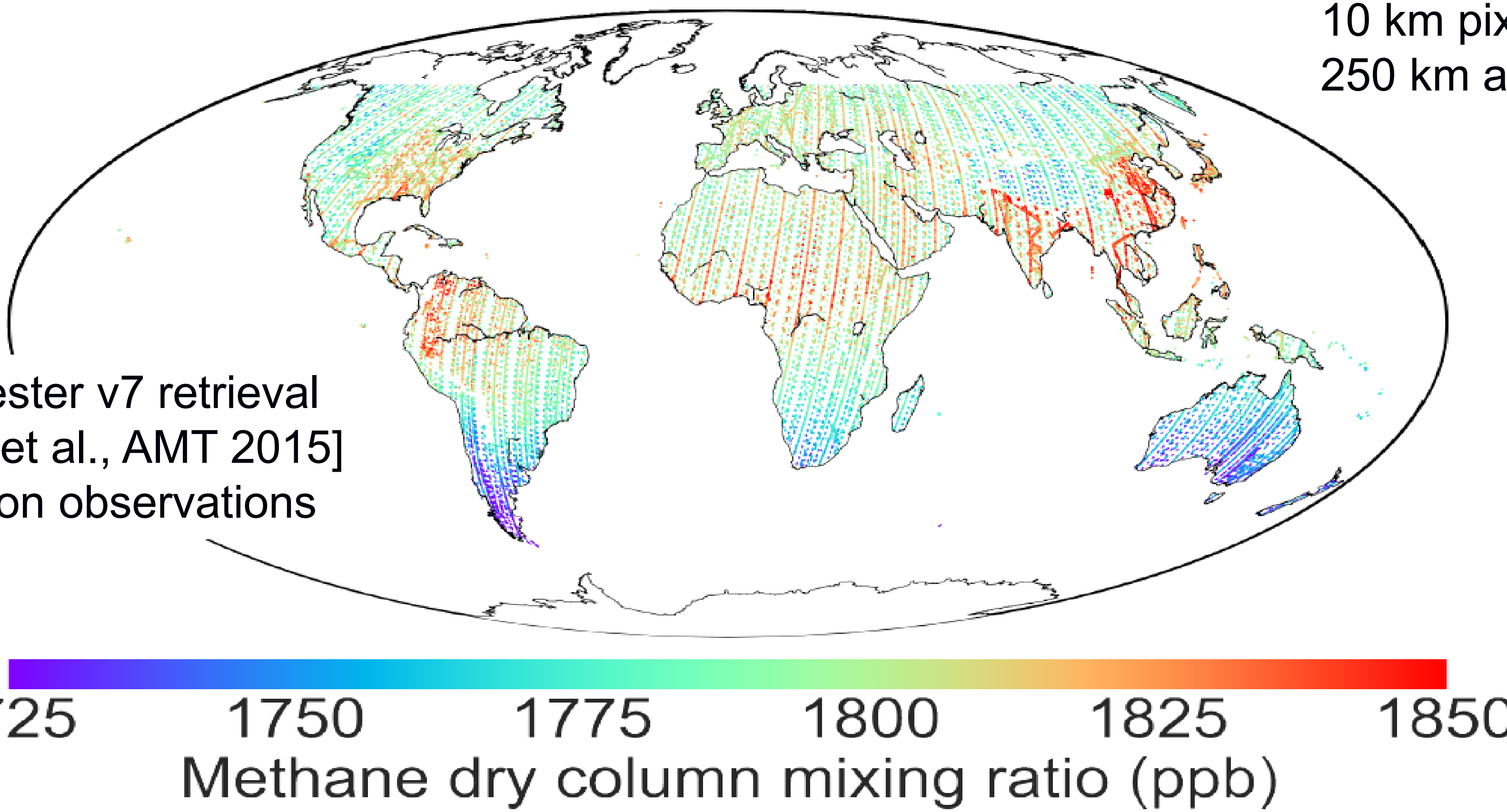
Point source instruments:
pixels < 100 m, precision >1%





Mean GOSAT methane observations, 2010-2016

10 km pixels
250 km apart



U. Leicester v7 retrieval
[Parker et al., AMT 2015]
1.4 million observations

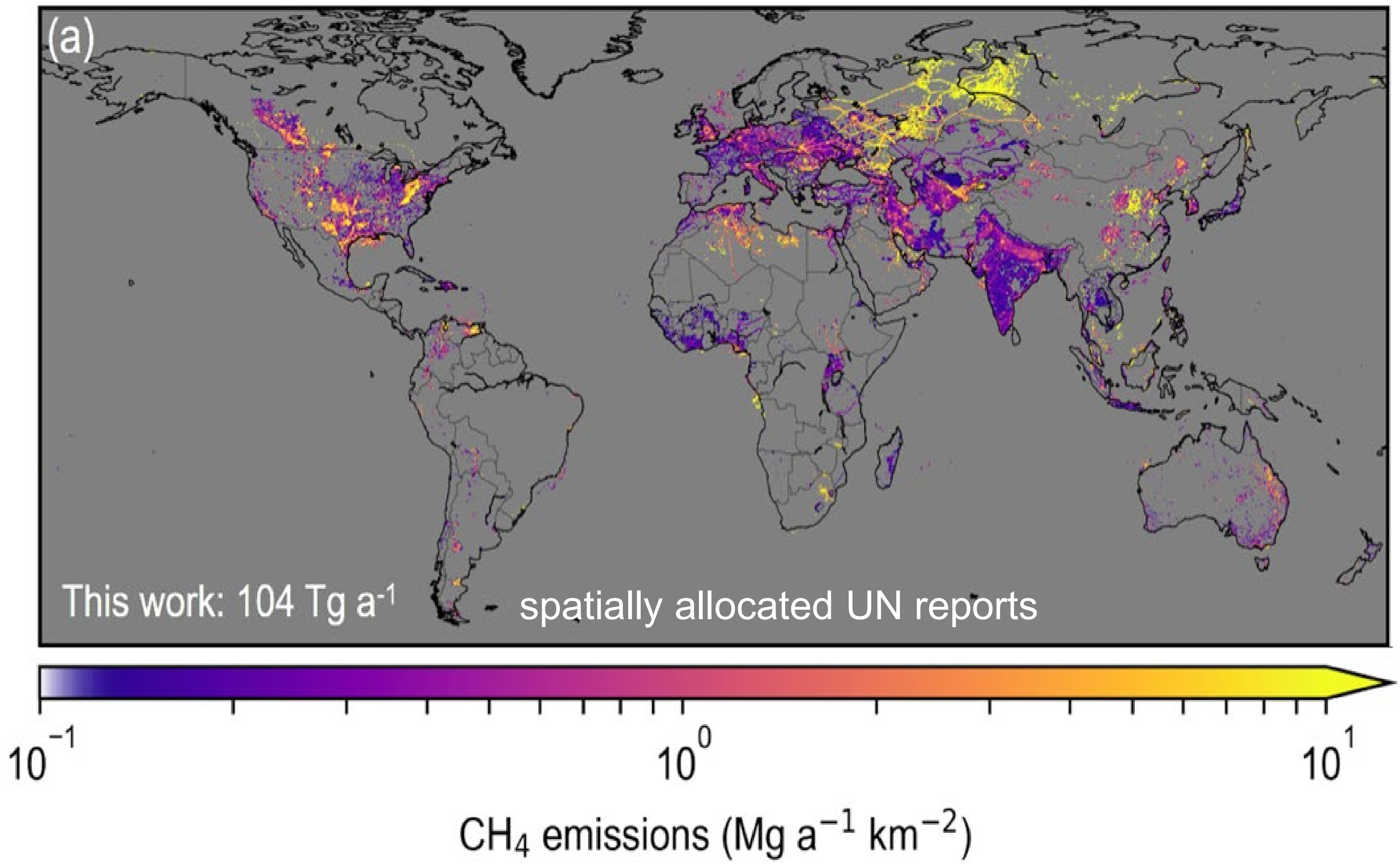
Invert GOSAT methane data with GEOS-Chem chemical transport model to optimize:

- mean 2010-2016 non-wetland methane emissions and trends on 4^ox5^o grid
- monthly wetland emissions in 14 regions
- annual hemispheric OH concentration

Analytical inversion with Gaussian errors → posterior errors as part of solution

Prior estimate of methane emissions from fuels (oil, gas, coal)

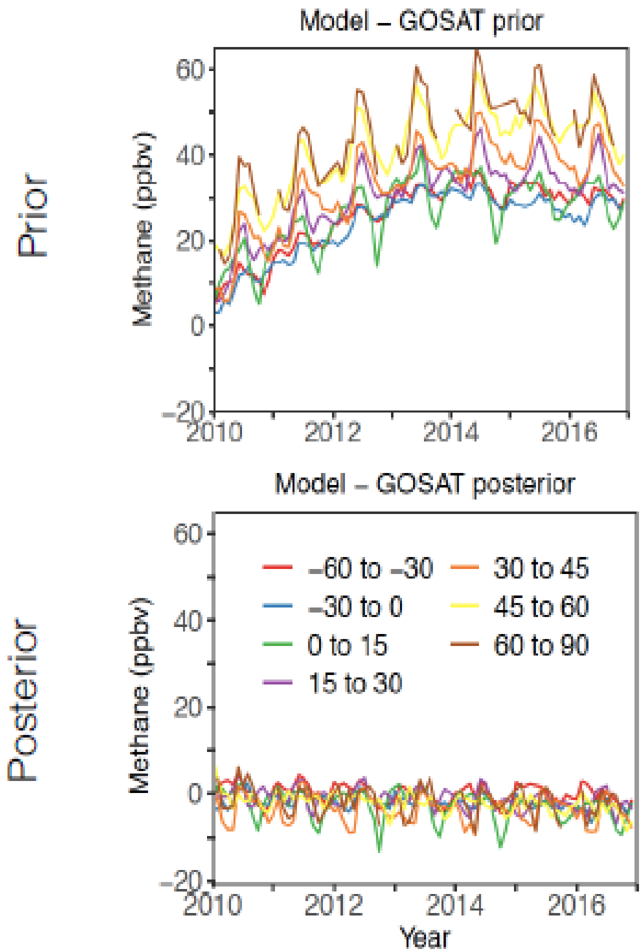
Widely used EDGAR inventory …is inconsistent with UN reports from individual countries



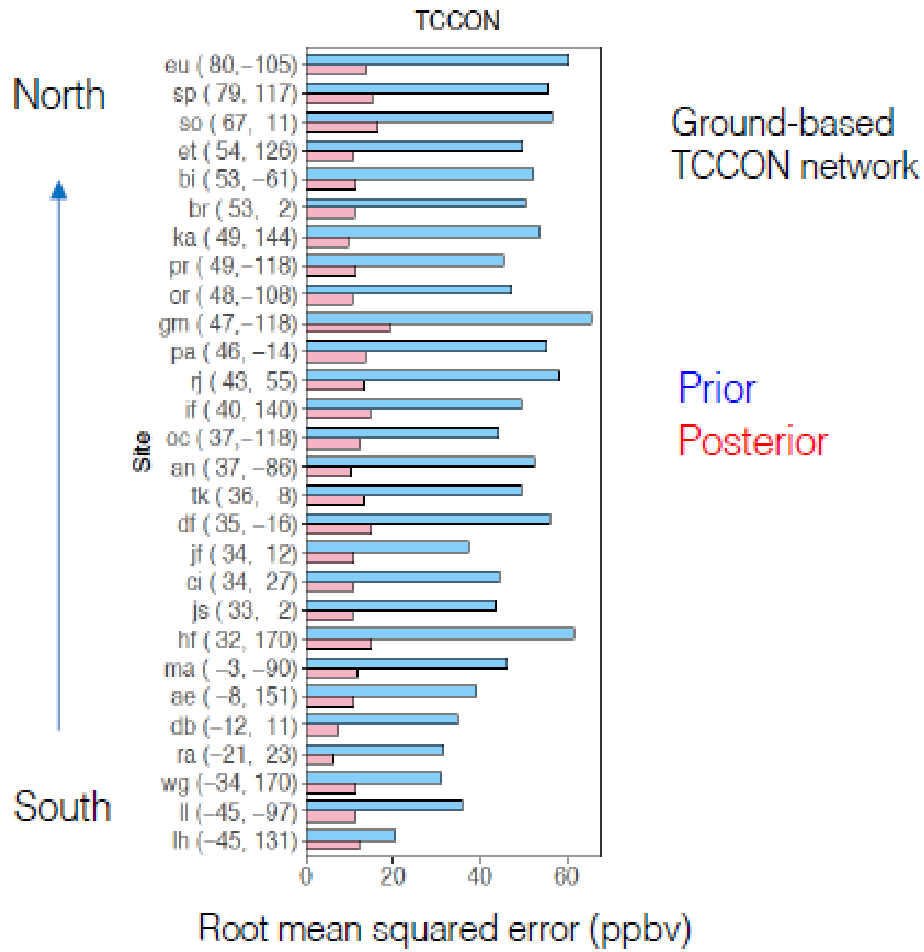
Scarpelli et al. [ESSDD 2020]

Inversion corrects prior bias, also independently with TCCON

Error against training data: GOSAT

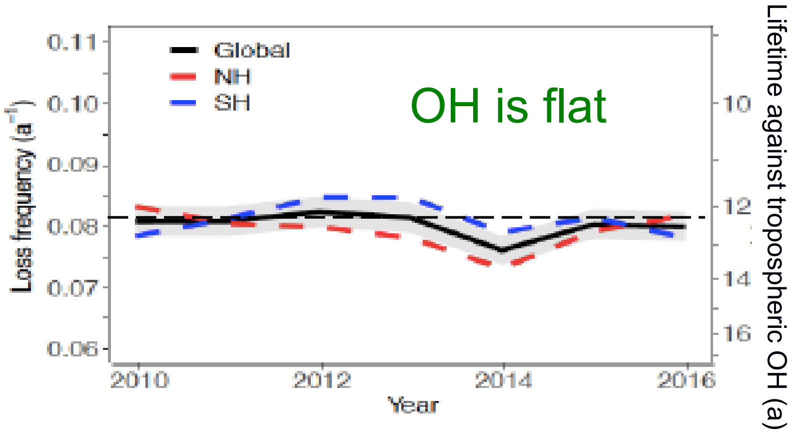


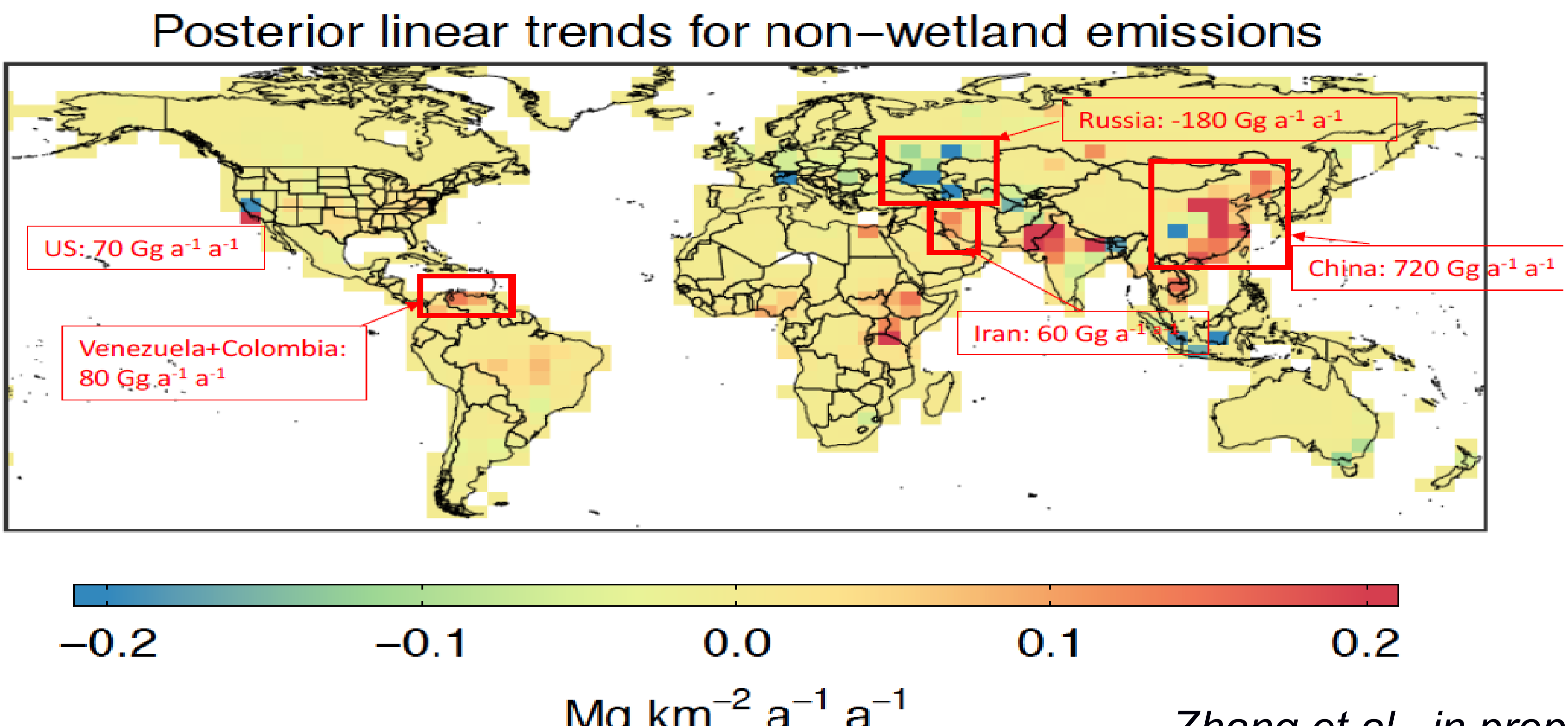
Error against Independent observation



Zhang et al., in prep.

2010-2016 methane trend is driven by anthropogenic emissions including major contributions from livestock, coal (China), and oil/gas

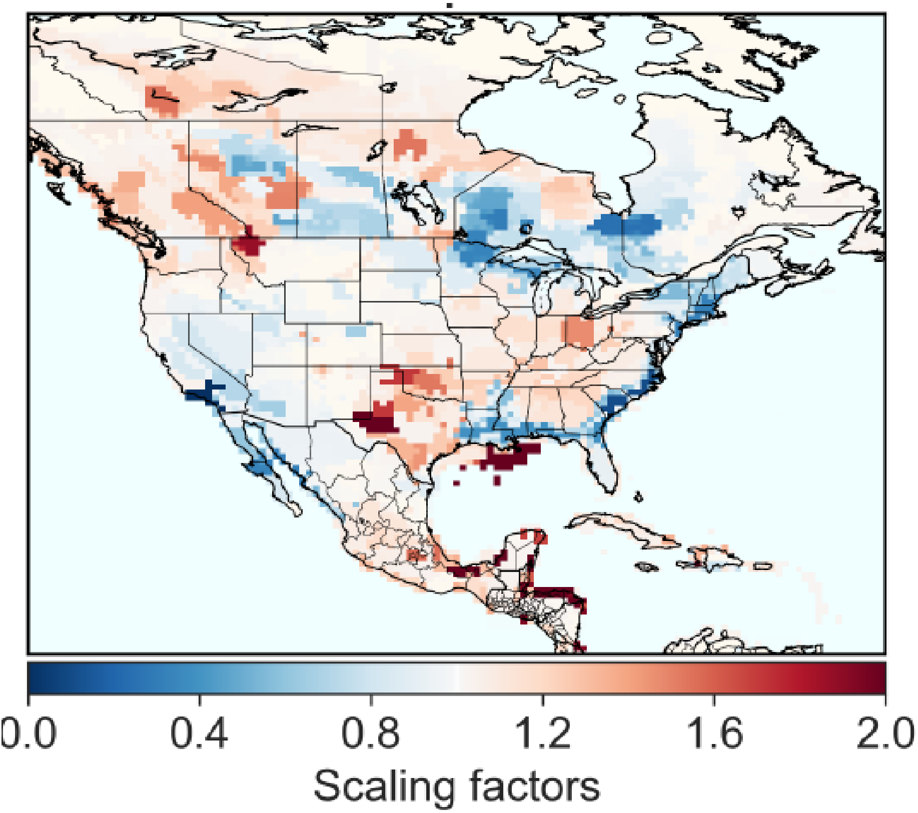




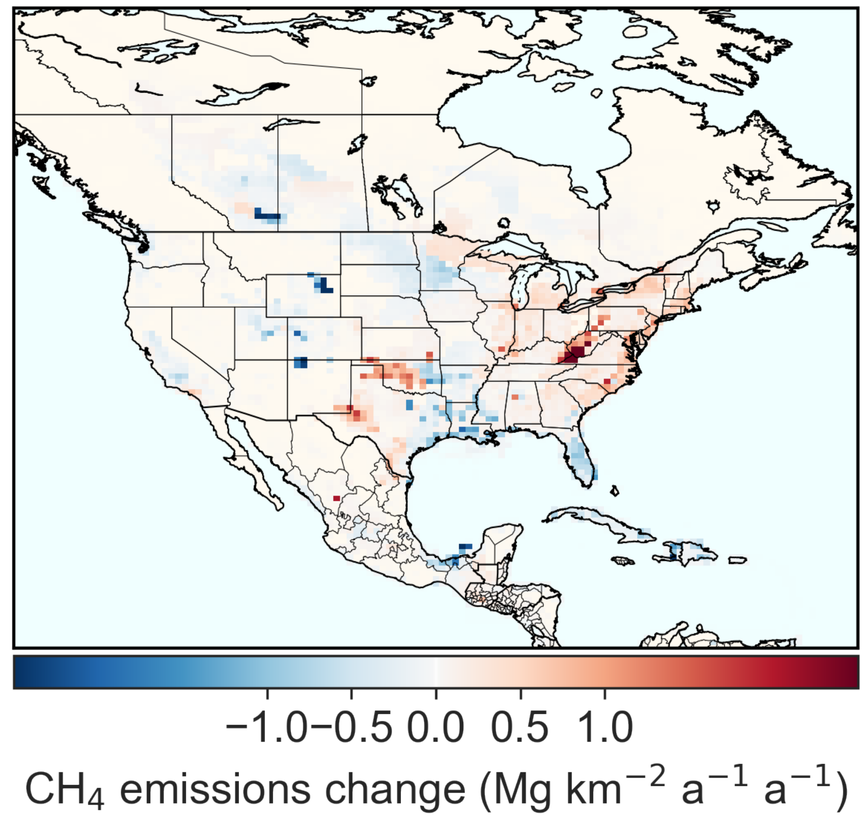
Zhang et al., in prep.

High-resolution inversion of 2010-2015 GOSAT data over North America

Correction to prior mean 2010-2015 emissions:
EPA (anthropogenic), WetCHARTS (wetlands)



2010-2015 emission trends

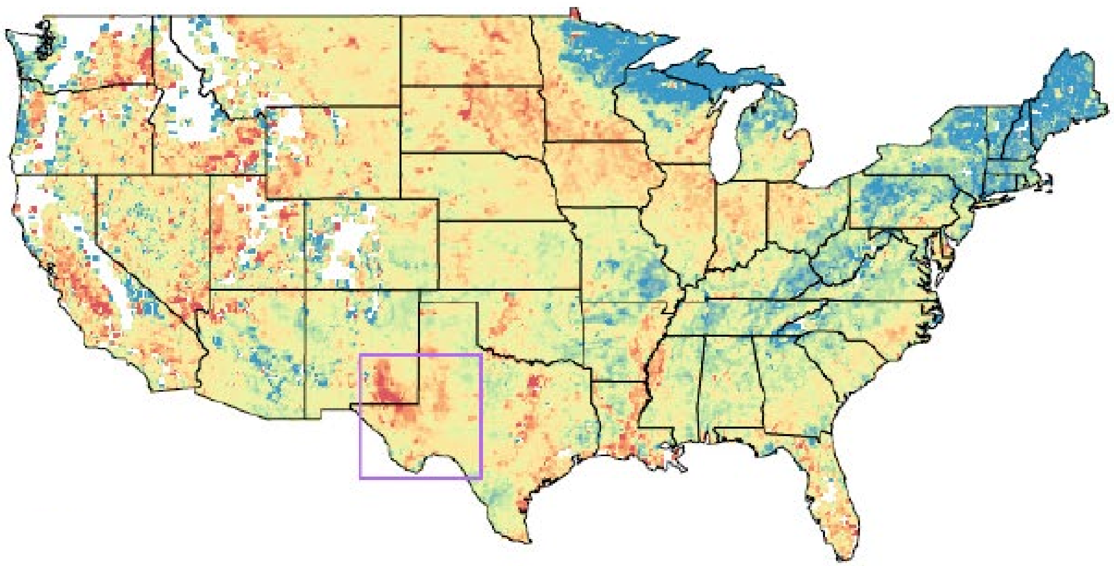


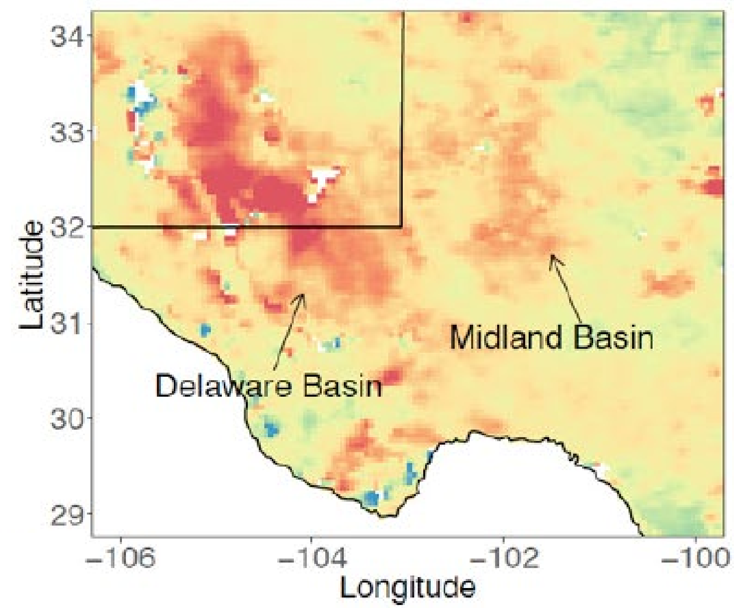
- EPA sectoral emissions are correct ±10% except for oil production which is too low
- Coastal wetland emissions are low

- Increasing emissions in Permian (oil), Midwest (fracking)
- Decreasing emissions from Four Corners

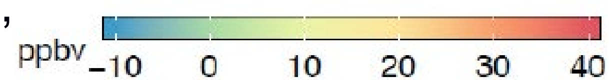
Maasakkers et al., in prep.

Permian Basin emissions inferred from inversion of TROPOMI data





TROPOMI methane anomalies,
May 2018- May 2019

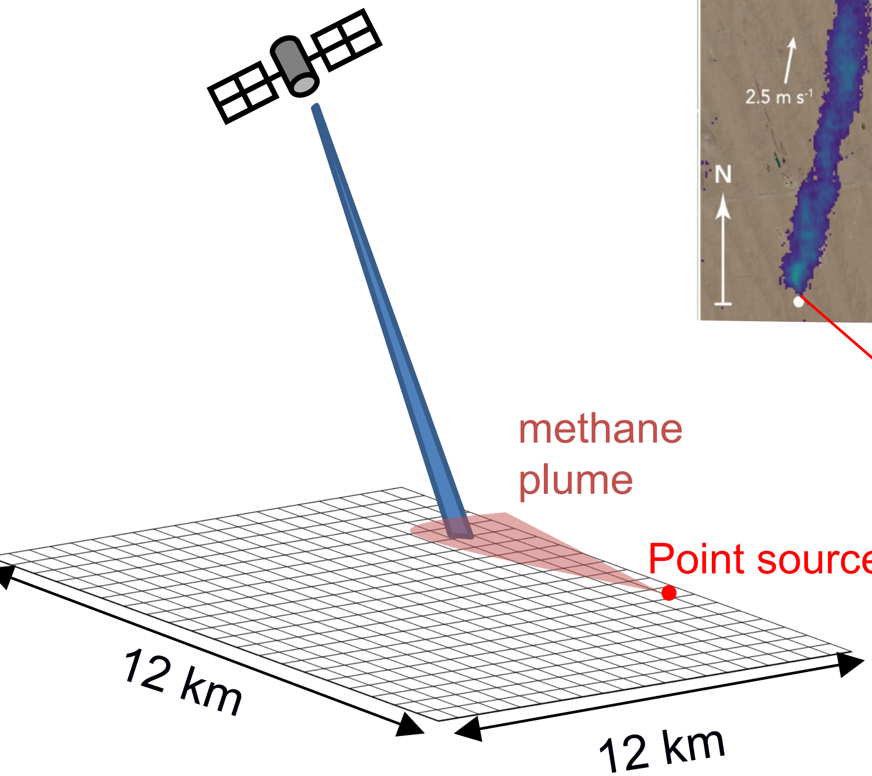


Emission from Permian Basin is 2.7 ± 0.5 Tg a^{-1}, 3.7% of gas production;
EPA GHGI gives only 1.2 Tg a^{-1}

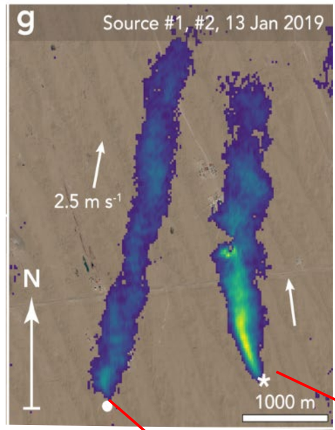
Zhang et al., submitted to SA

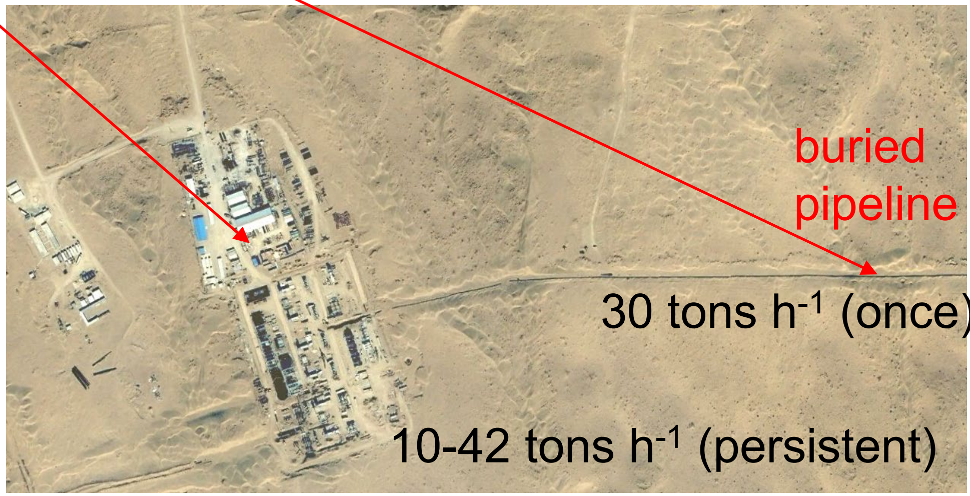
GHGSat-D discovery/quantification of methane point sources from space

Fabry-Perot on microsatellite
50x50 m^2 pixels
Precision 13%



13 Jan 2019





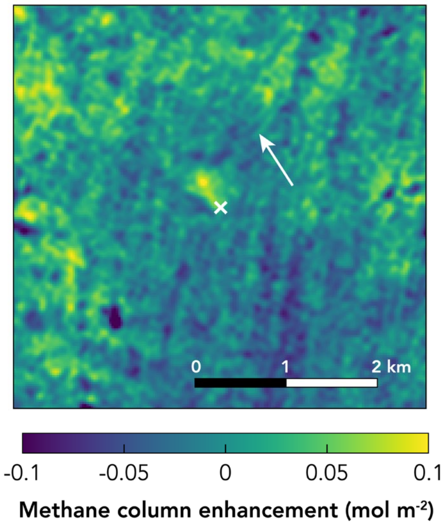
Korpezhe gas compressor station

GHGSat-C1 and C2 to be launched in 2020 have target precision of 2%

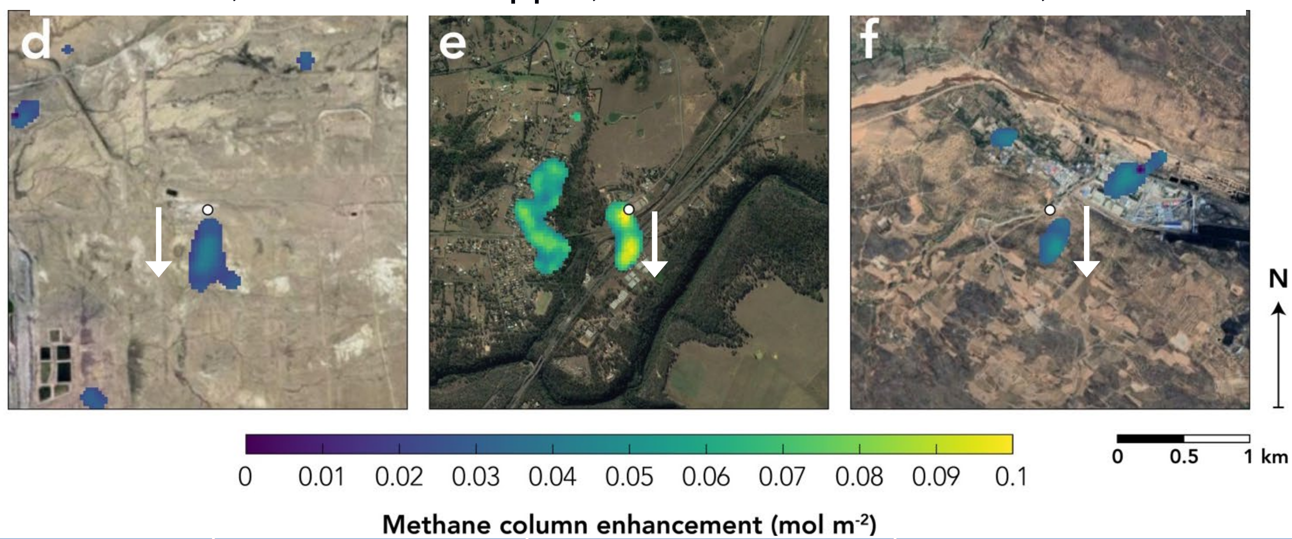
Varon et al., GRL 2019

Using GHGSat-D to quantify mean emissions from coal mine vents

L2 retrieval data,
San Juan mine vent
1 Nov 2017



Mean wind-rotated and masked plumes
from 13-24 overpasses over 2016-2018



Source estimates, tons h^{-1}	San Juan	Appin	Bulianta
Integrated mass enhancement method	1.8 ± 1.0	3.8 ± 1.9	2.1 ± 1.0
Cross-sectional flux method	1.6 ± 0.9	3.2 ± 1.5	1.9 ± 0.9
Previous estimates	0.4-2.8	1.1-12.6	0.17

- Retrieve mean sources down to ~1 ton h^{-1} with 50% uncertainty
- GHGSat C1 and C2 could push capability down to 0.1 ton h^{-1}

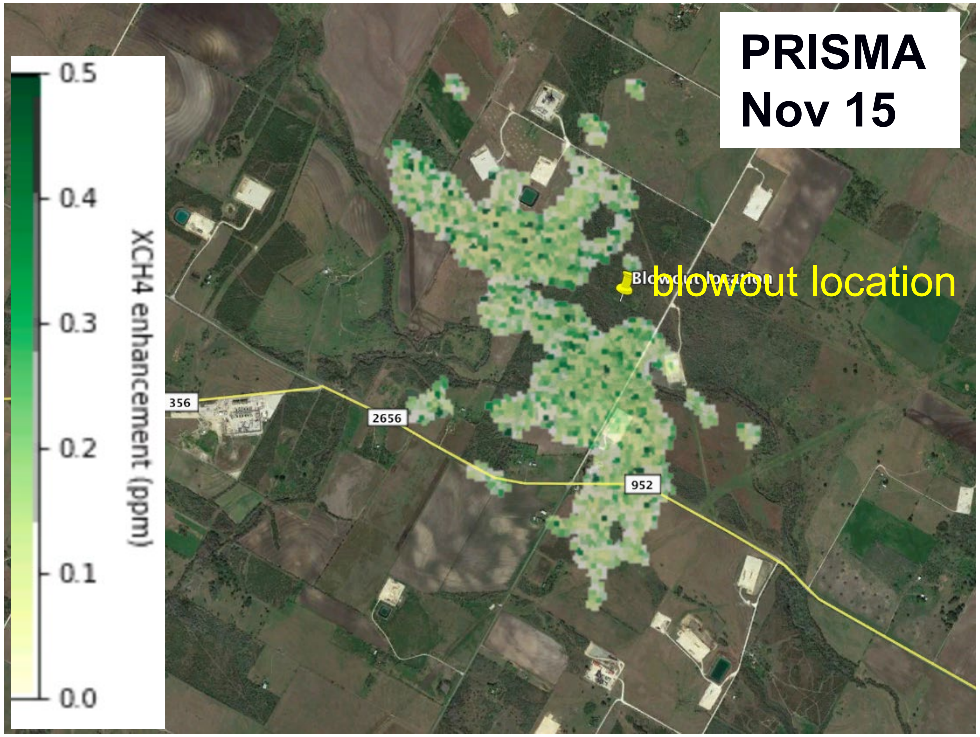
Varon et al., in prep.

Potential of land-imaging spectrometers for methane point sources

PRISMA: 30x30 m^2 pixels, 10 nm spectral resolution in SWIR, launched in January 2019

should be able to detect sources of 0.1-1 tons h^{-1} if surface is ~ homogeneous

Gas well blowout at Eagle Ford, Texas, Nov 1-23, 2019



Source rate
13.7 ± 2.6 tons h^{-1}

Expect improved capability in future from EnMAP, SBG, EMIT instruments…

Cusworth et al., AMT 2019, in prep.

Conclusions

- 2010-2016 methane trend attributed by GOSAT to anthropogenic emissions including livestock, Chinese coal, and oil/gas

- EPA national methane inventory for the US is consistent with GOSAT data except for underestimate from oil production

- Emissions from rapidly growing Permian Basin are estimated at 2.7 Tg a^{-1} by TROPOMI for 2018-2019, largest in US and larger than EPA estimate (1.2 Tg a^{-1})

- Demonstration GHGSat-D instrument can quantify point sources > 1 ton h^{-1}; expect better precision from future GHGSat instruments

- Next generation of land imaging spectrometers has considerable potential for global observations of methane point sources