Use of GHG observations by satellites for estimating surface emissions

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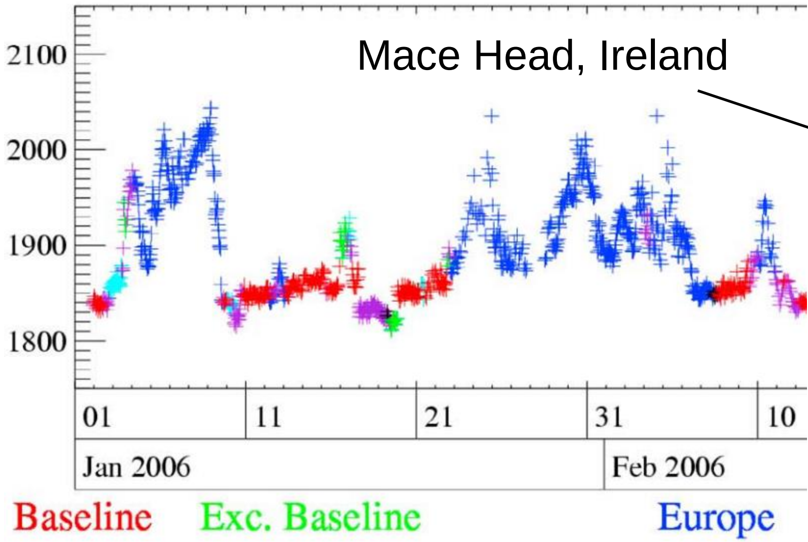
Contents of the talk

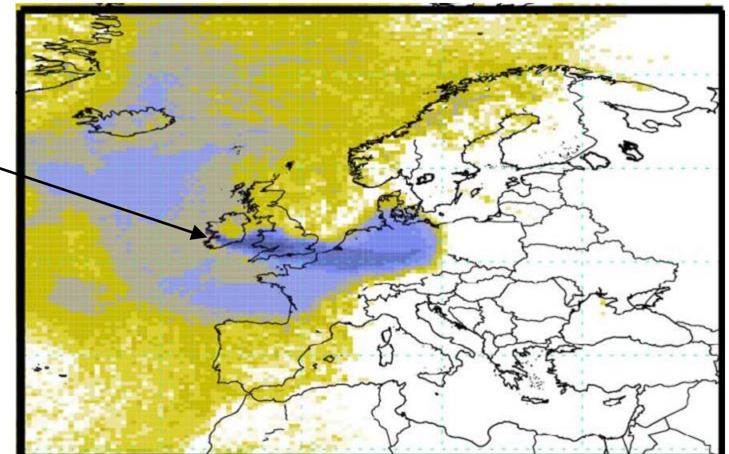
- Three countries (UK, Switzerland, Australia) are supporting national inventory reporting with independent emission estimates based on atmospheric observations made at 3-4 continuous observation sites.
- Scientific studies of the methane emission trends for India and other countries started using atmospheric observation data from GOSAT satellite to compensate for limited coverage with surface observations
- Use of GHG satellite data for estimating emissions at country and regional scale is expanding actively in last 5 years due to availability of new observational data, from GOSAT and OCO-2 satellites.
- Most widely used approaches are (1) inverse modeling and (2) comparison of the observed concentration anomalies to model estimated enhancements around large point sources
- Examples using satellite data are highlighted in “Guidebook on use of satellite GHG observations …” published in Japan.

Use of atmospheric observations in UK (2017 National Inventory Report)

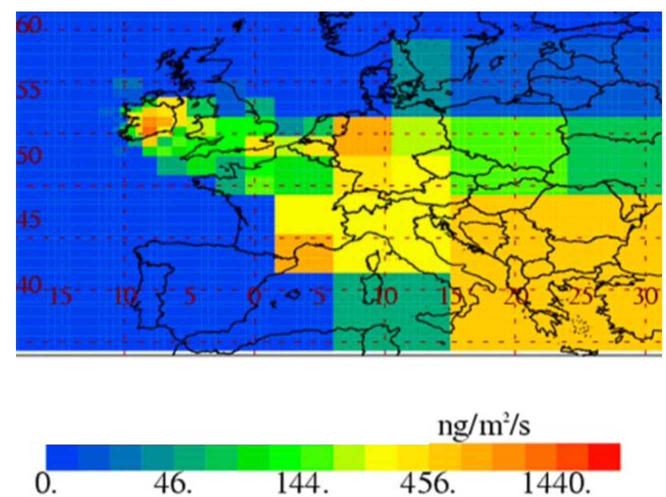
Observations: CH_4 concentrations



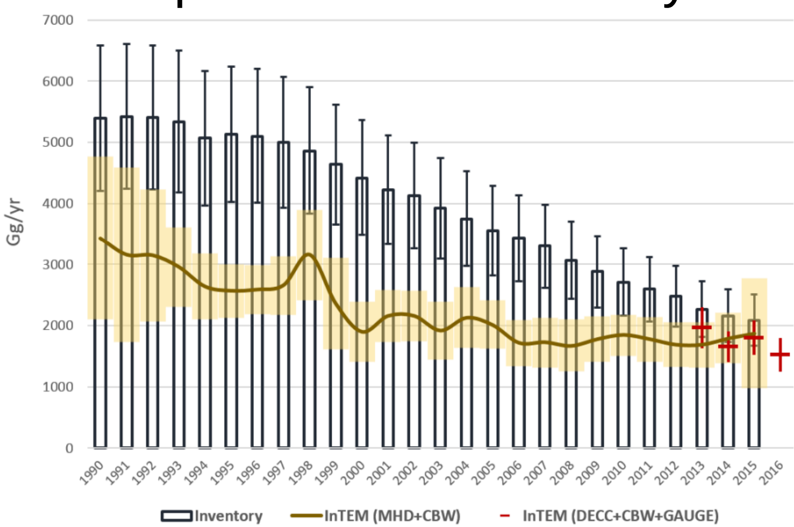
Transport modeling: map CH_4 sensitivity to emissions (every 3 h)



Inverse modeling: emissions

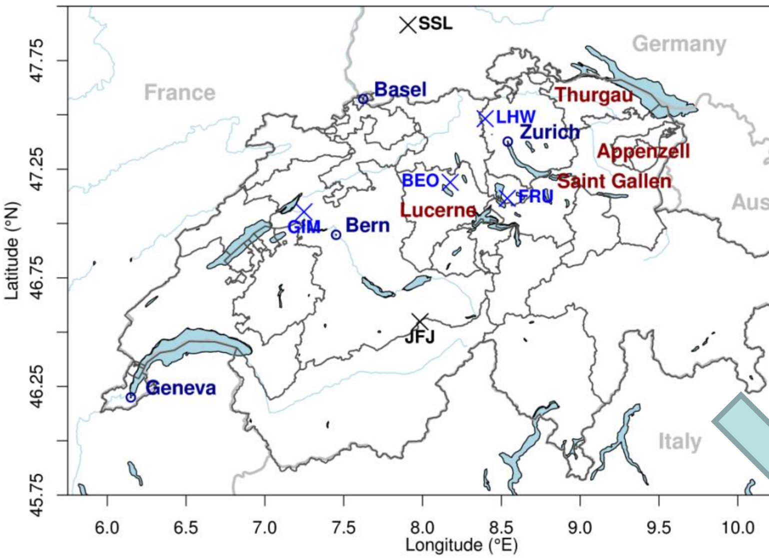


Comparison with inventory



Switzerland National Inventory Report 2017

observations



The best inverse estimate of total Swiss CH4 emissions for the observation period March 2013 to February 2014 is 196±18 kt yr-1.

This is in close agreement with the NIR value reported in 2015 for the years 2012 and 2013 of 206±33 kt yr-1

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a) inventory

b) inverse model

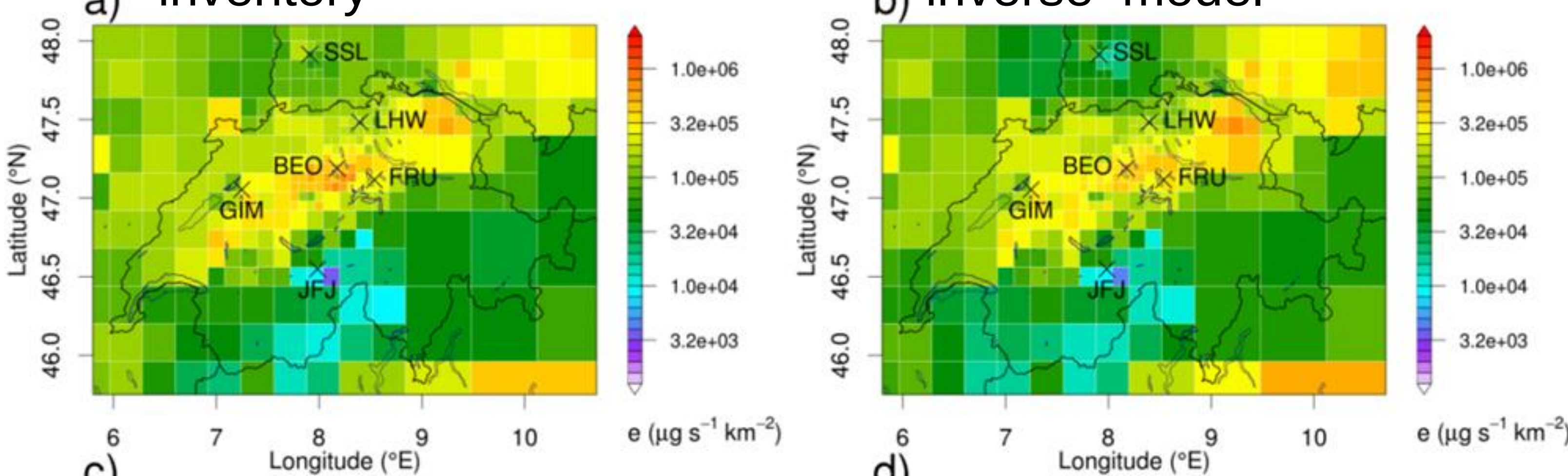
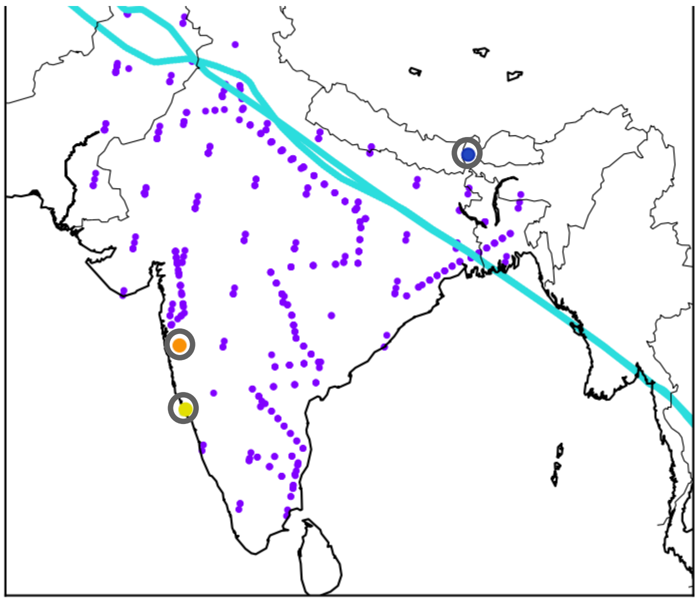


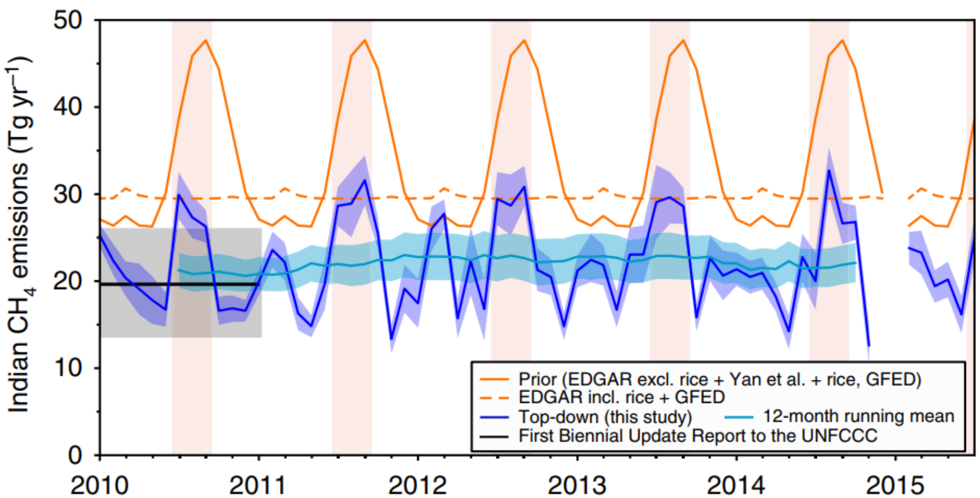
Figure A – 12: (a) *a priori* (MAIOLICA) and (b) *a posteriori* surface fluxes of CH_4

Atmospheric observations support accurate reporting of India's methane emissions



Observations: Darjeeling (dark blue), Cape Rama (yellow), Sinhagad (orange), GOSAT retrievals (purple), CARIBIC (light blue)

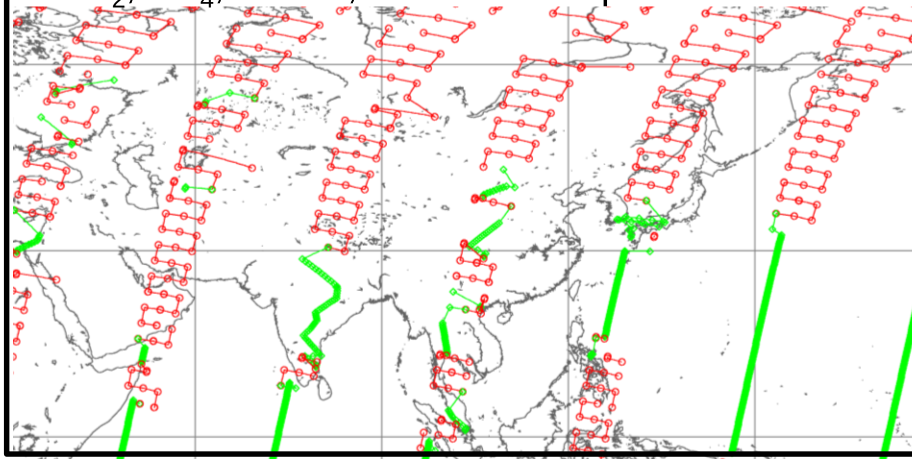
Study inferred India's CH_4 emissions for the period 2010–2015 using a combination of satellite, surface and aircraft data.
Apply a high-resolution atmospheric transport model to simulate data from these platforms to infer fluxes at sub-national scales and to quantify changes in rice emissions.
Find that average emissions over this period are 22 ± 3 Tg yr^{-1}, consistent with the emissions reported by India to the UNFCCC.



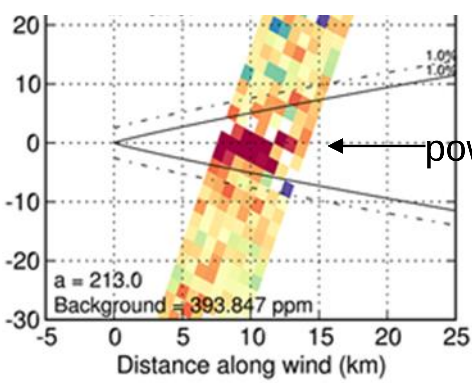
Ref: Ganesan, A. L., Rigby, M., Lunt, M. F., Parker, R. J., et al .: Atmospheric observations show accurate reporting and little growth in India's methane emissions, Nature Communications, 8, 836, 2017.

Satellite observations of GHG in atmosphere

GOSAT, Japan, since 2009
CO_2, CH_4, 10 km, 1 observation per 4 seconds



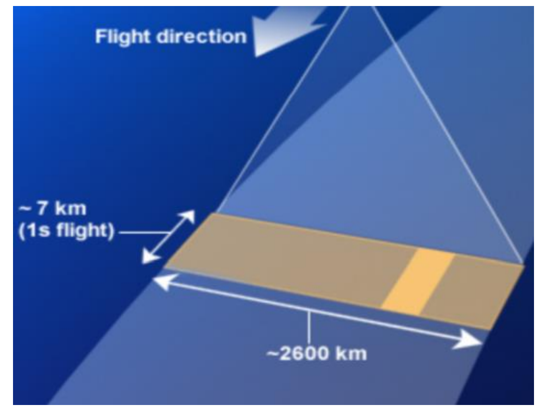
OCO-2, USA, since 2014
CO_2, 1.6x2.2 km, 8 observations per 0.4 seconds

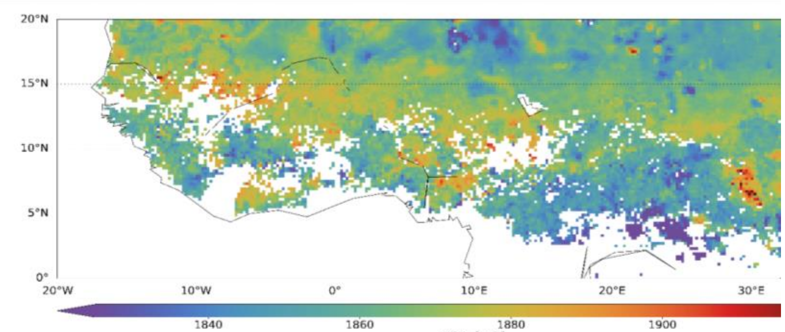


powerplant plume

Recent missions: TanSAT, TROPOMI, others
(public data release planned soon)

Tropomi, EU-Holland, since 2017/12
CH_4, 7 km, ~200 observations per sec.





CH_4 (biomass burning) over Africa 2017/12

Learning materials: Guidebook on use of GHG observations by satellites

Ministry of Environment, Japan and National Institute for Environmental Studies supported preparation of a Guidebook on use of greenhouse gas (GHG) observations by satellites for estimating surface emissions (https://www.nies.go.jp/soc/en/documents/guidebook/)

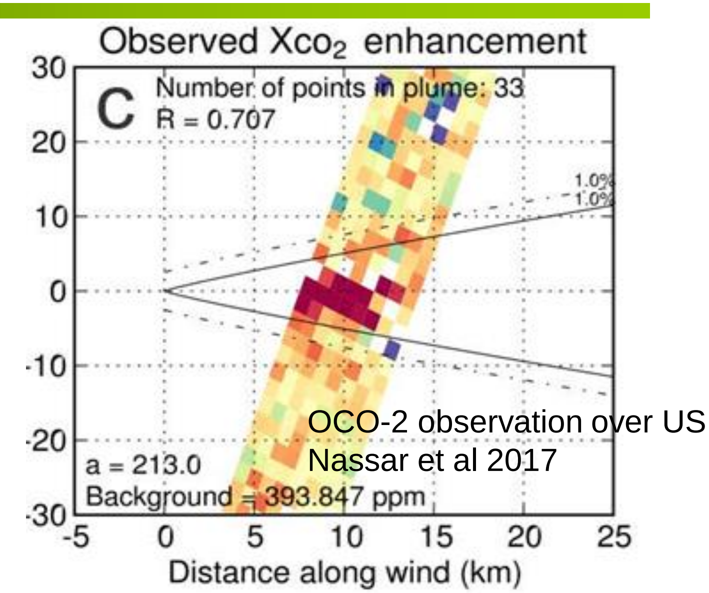
The purpose of the Guidebook is to facilitate use of satellite GHG concentration observations for estimating the emissions, at a city to national scale, for applications such as national emission inventory improvement and verification in support of implementation of the Paris agreement on the gradual reductions of the GHG emissions

The timing and schedule of the Guidebook preparation was set to provide a contribution to 2019 Refinements to 2006 IPCC Guidelines on Emission Inventories.

Guidebook include overview, introduction to satellite GHG data analysis methodology and a number of case studies, based on published research papers.

Several case studies from the guidebook are introduced in this presentation.

Emission estimation methods



OCO-2 observation over US, Nassar et al 2017

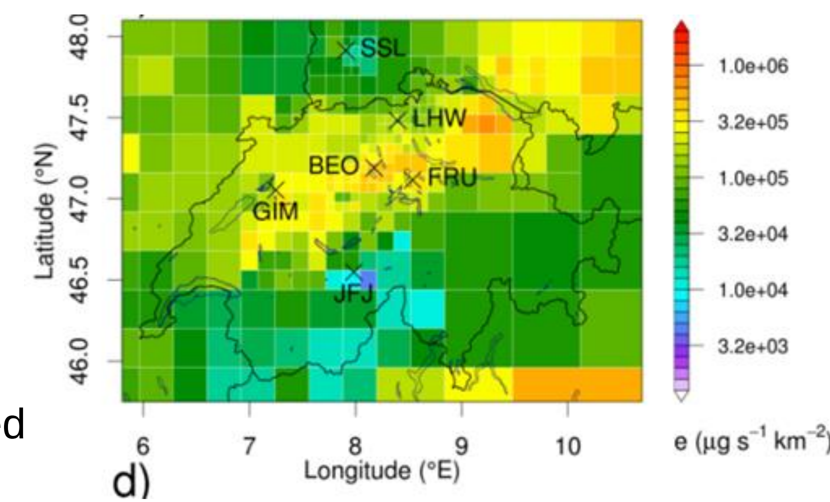
Observing local concentration enhancements

Anthropogenic emissions of CO_2, CH_4, lead to buildup of the concentration above the emission area and transport of a high concentration plume by wind downstream the emission source (city, powerplant, etc.). Satellites observe increased column GHG concentration when the plume is in the observation footprint. The plumes are identified either by using transport model, or by subtracting mean background. Processed mean enhancements are related to fluxes using high resolution transport model.

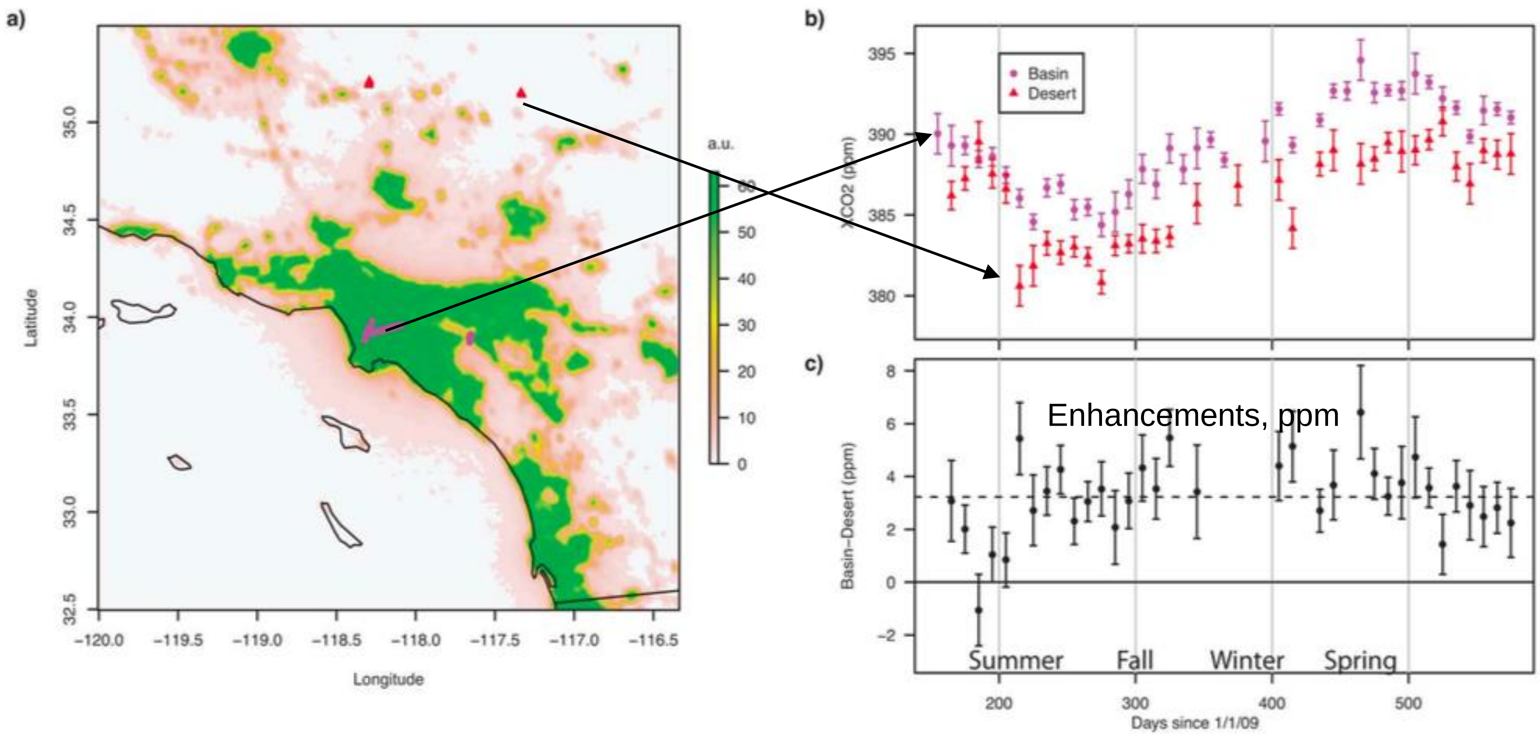
Inverse modeling

Inverse model optimizes fluxes by providing flux corrections that reduce misfit/difference between observations and high resolution transport model simulations.

The inverse model provides fluxes at grid-point resolution, that can be used to estimate regional/national emissions by summing over selected (country) area.



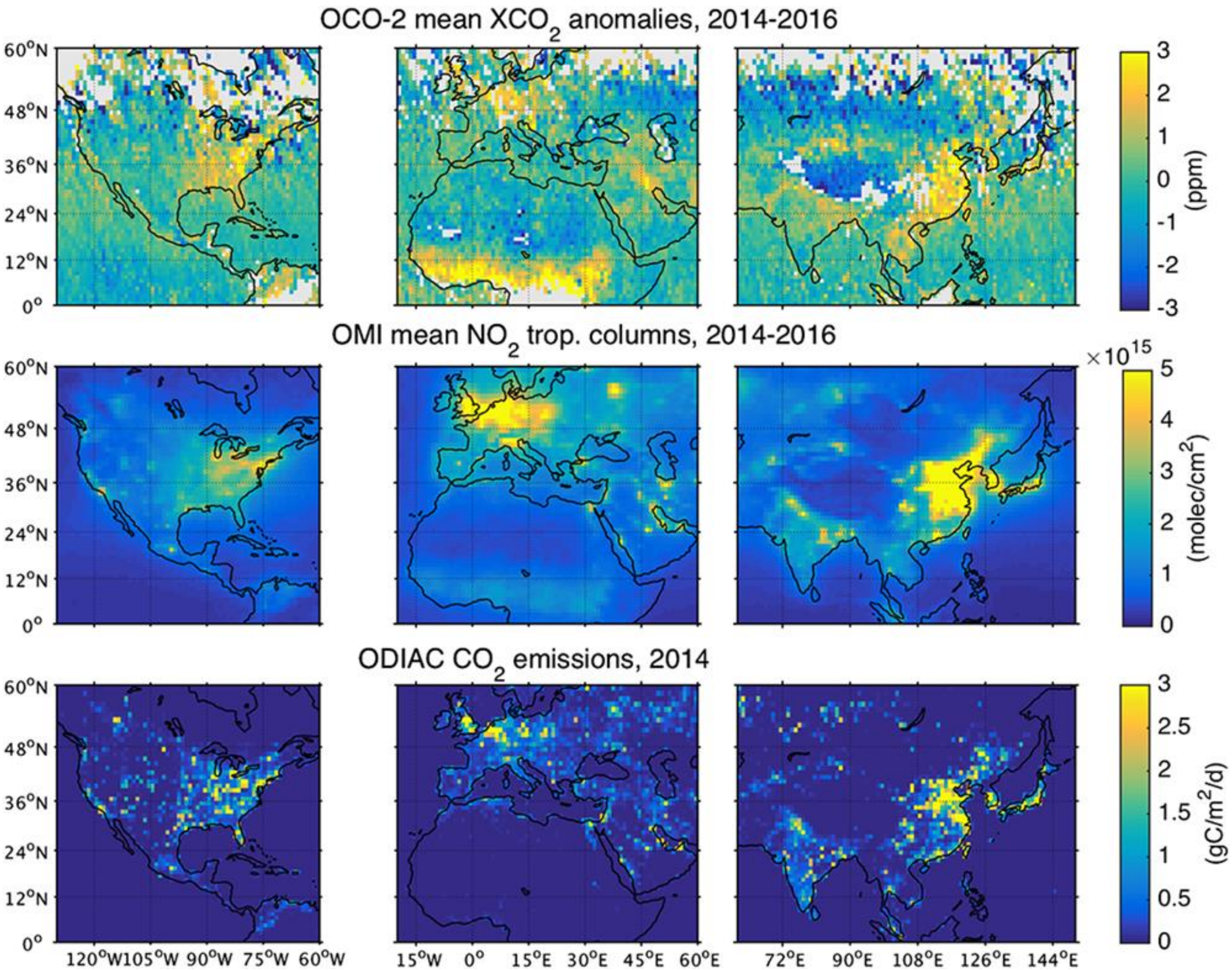
Space-based observations of megacity carbon dioxide *(with* GOSAT)



Observed X_{CO2} urban dome of Los Angeles from June 2009 to August 2010. (a) Nightlights map of the Los Angeles megacity and surroundings. Selected GOSAT observations within the basin (pink circles near 34ºN, 118ºW) and in the desert (red triangles near 35ºN, 117–118ºW). (b) Time-series for basin and desert observations. (c) The difference between 10-day block averages of basin and desert observations. The dashed line: average difference (3.2 ±1.5 ppm)

Kort, E. A., et al (2012), Geophys. Res. Lett., 39, L17806

Direct space-based observations of anthropogenic CO_2 emission areas from OCO-2

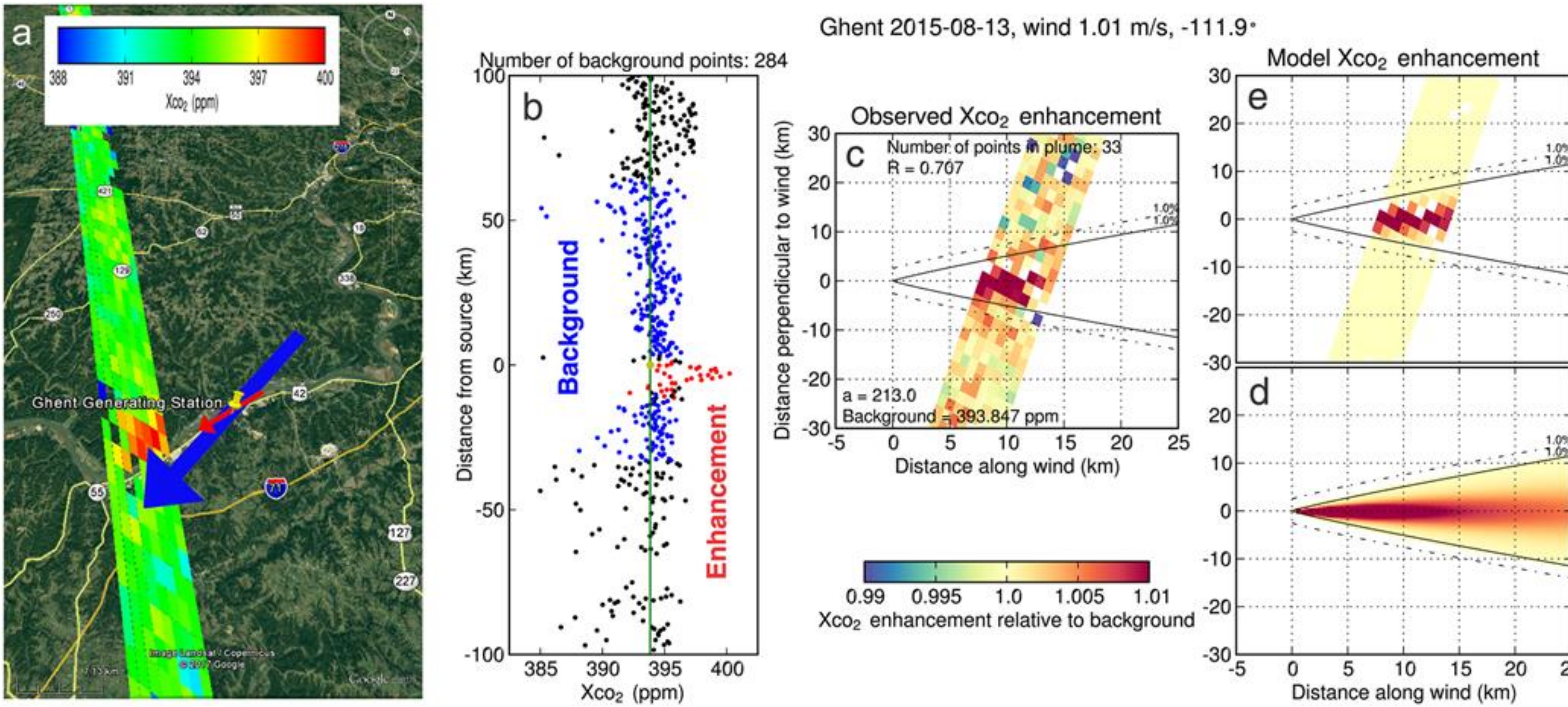


Authors developed a novel methodology to derive CO_2 anomaly maps, solely based on satellite-based OCO-2 CO_2 measurements with high spatial coverage and detail.

Were able to identify the major anthropogenic CO_2 emission regions, such as Europe, USA and China. In addition, several smaller isolated emitting areas, like individual cities, were detected.

Hakkarainen, J., et al. (2016), Geophys. Res. Lett., 43, 11,400–11,406.

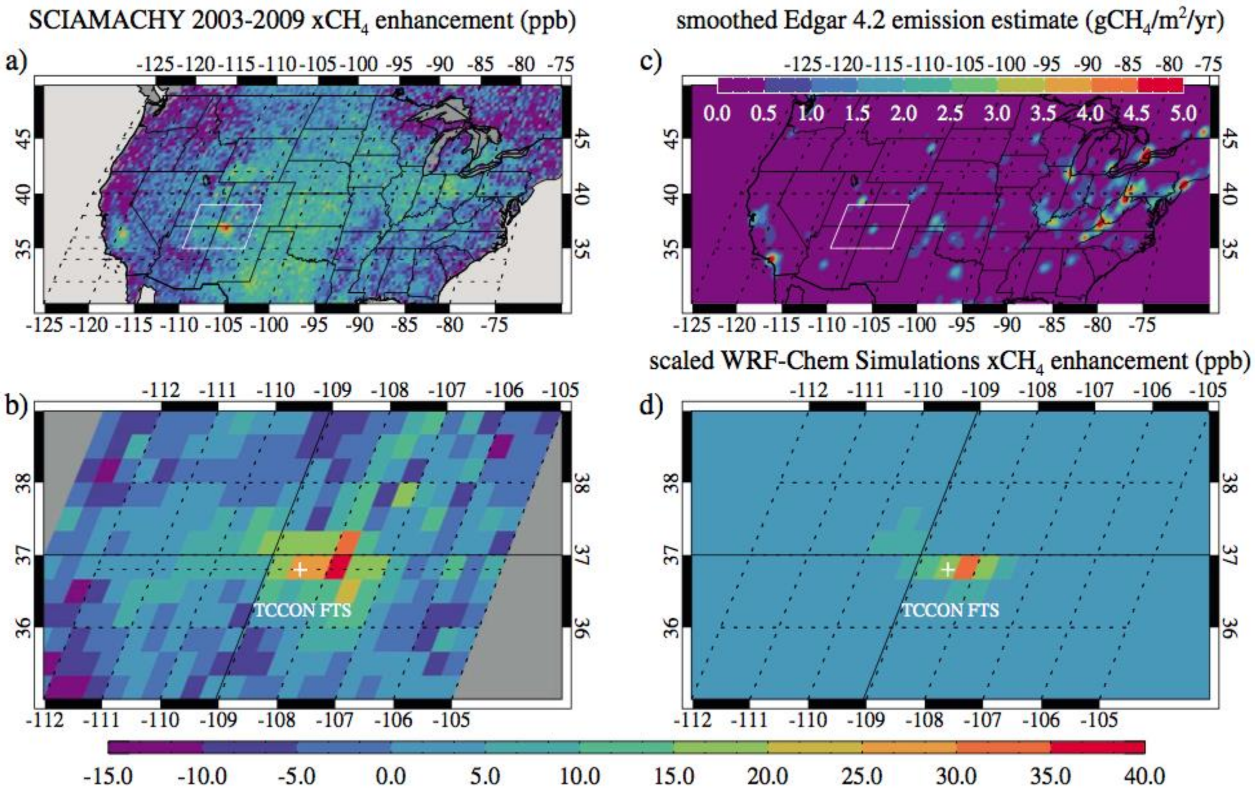
Simple gaussian plume modeling for quantifying CO_2 emissions from individual coal power plants with OCO-2 observations



"CO_2 observations from OCO-2 can be used to quantify daily CO_2 emissions from individual middle- to large-sized coal power plants by fitting the data to plume model simulations. Emission estimates for U.S. power plants are within 1–17% of reported daily emission values. "

Nassar, R., et al (2017). Quantifying CO_2 emissions from individual power plants from space. Geophysical Research Letters, 44, 10,045–10,053.

Four corners: The largest US methane anomaly viewed from space

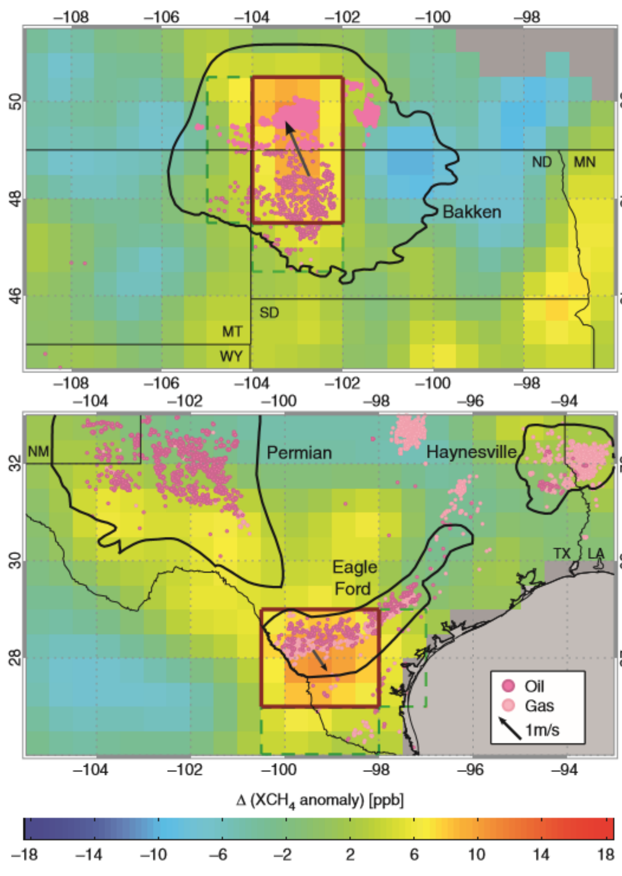


Kort et al. (2014) found the Four Corners to be the largest single methane source in the continental US (0.59 Tg a^{-1}) on the basis of SCIAMACHY and TCCON observations, with a magnitude 3.5 times larger than EDGARv4.2 and 1.8 times larger than reported by the US EPA Greenhouse Gas Reporting Program (EPA, 2014).

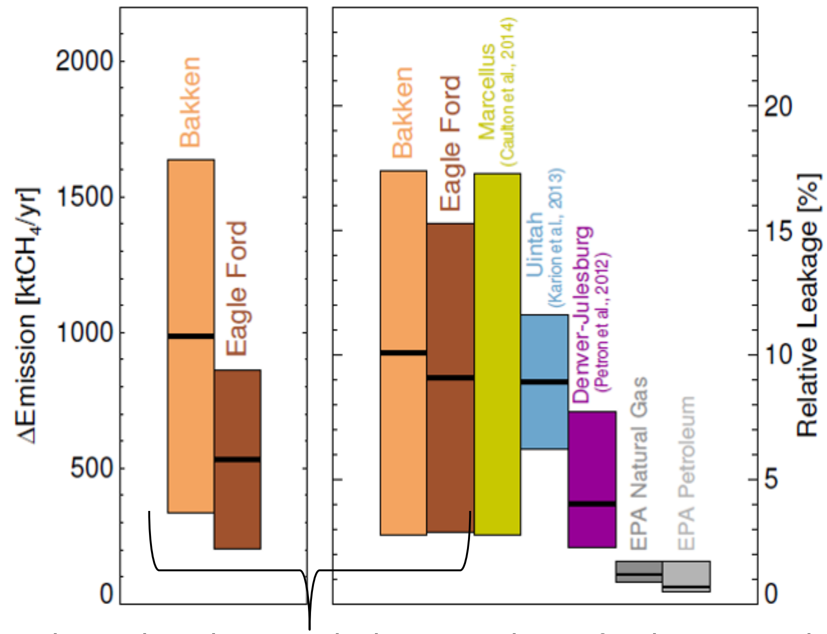
Column methane anomalies and emissions over the U.S. (a) Average SCIAMACHY anomaly from 2003 to 2009. (b) Average anomaly over just the Four Corners region 2003 to 2009. (c) EDGAR v4.2 gridded methane emissions (smoothed). (d) WRF-Chem simulated methane anomaly using 3.5 times EDGAR v4.2 emissions for the Four Corners region.

Kort, E. A., C. Frankenberg, K. R. Costigan, R. Lindenmaier, M. K. Dubey, and D. Wunch (2014), Geophys. Res. Lett., 41, 6898-6903, doi:10.1002/ 2014GL061503

Remote sensing of fugitive methane emissions from oil and gas production in North American tight geologic formations



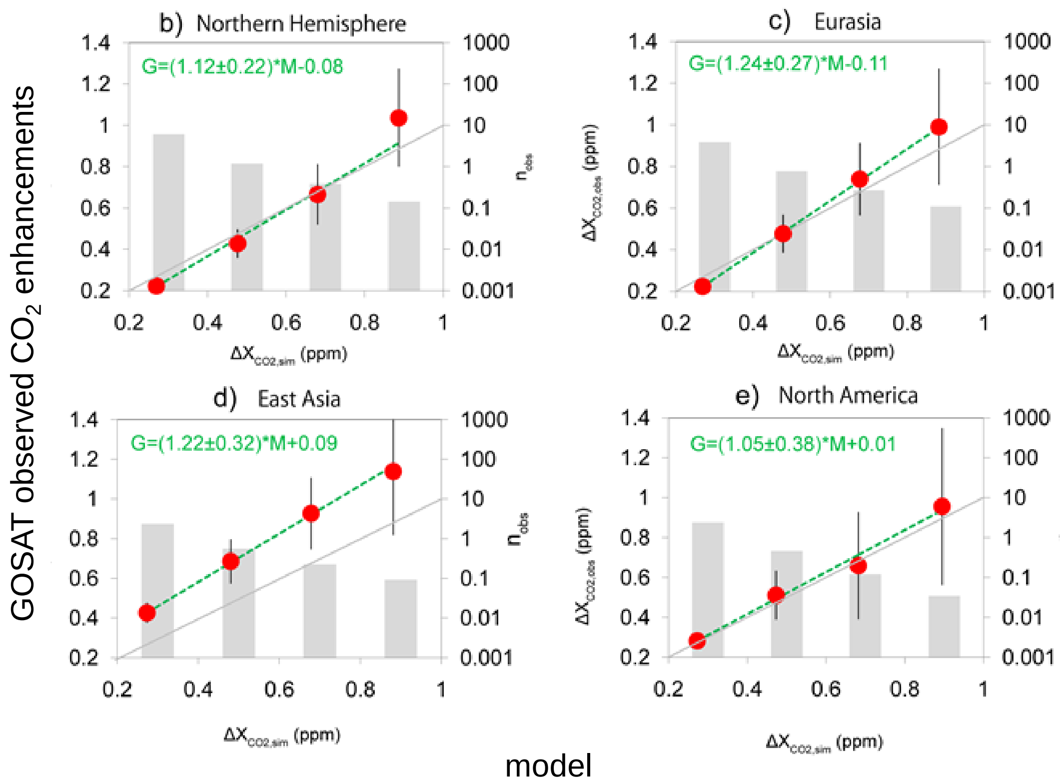
The difference between the SCHIAMACHY mole fraction anomalies of methane, for the period 2009–2011 relative to the period 2006–2008. The locations of the oil and gas wells are shown in pink. Well positions are taken from the Fracking Chemical Database [SkyTruth, 2013]

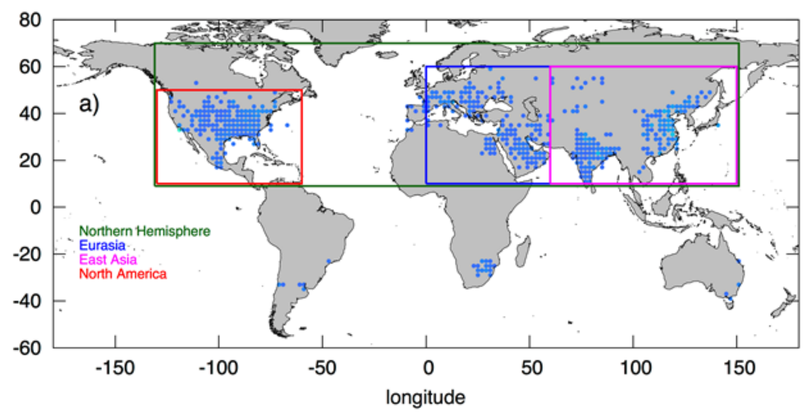


Estimated methane emissions are shown for the targeted regions Bakken in light brown, and Eagle Ford in dark brown. Shown are absolute emission increase (2009–2011 relative to 2006–2008) in the left panel, and the leakage rate relative to production in the right panel, in each case together with the 1σ-uncertainty ranges.
For comparison, leakage estimates from previous studies in Marcellus, Uintah and Denver-Julesburg (yellow, blue, and magenta) are shown together with the EPA bottom-up inventory estimates

Schneising, O., et al, Earth's Future, 2014.

Comparing GOSAT observations of localized CO_2 enhancements by large emitters with inventory-based estimates

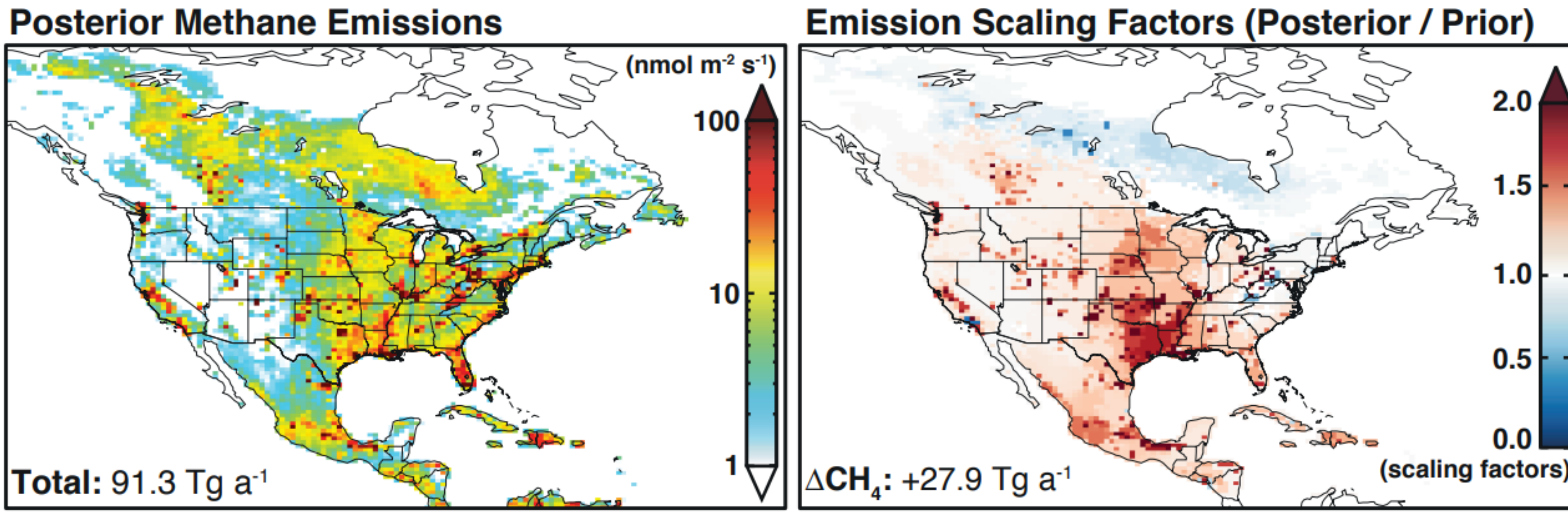




Simulated X_{CO2} enhancements agree with the observed over several continental regions across the globe, including North America with a regression slope of 1.05±0.21, but with a larger slope over East Asia (1.22±0.32).

Janardanan, R.; Maksyutov, S.; Oda, T.; Saito, M. et al, Geophysical Research Letters (2016), 43, 3486–3493

Estimating global and North American methane emissions with high spatial resolution using GOSAT satellite data



Methane emissions in North America in 2009–2011 estimated with inverse model, using global GEOS-Chem transport model with 0.5 deg resolution zoom over N. America. The left panel show posterior (optimized=best fit) emissions and the right panel shows the scaling factors, ratio of posterior(optimized)/prior

Turner, A. J., Jacob, D. J., Wecht, K. J., et al. (2015). Atmospheric Chemistry & Physics, 15, 7049.

Highlights, summary

- Several countries are supporting national inventory reporting with independent emission estimates based on atmospheric observations.
- More observations are needed in other countries to achieve such capability.
- Scientific studies of the methane emission trends in India, USA, and others started using atmospheric observation data from satellites to compensate for limited coverage with surface observations
- Use of GHG satellite data for estimating emissions at country and regional scale is expanding actively in last 5-10 years due to availability of new observational data, from GOSAT and OCO-2 satellites.
- Most widely used approaches are (1) inverse modeling and (2)comparison of the observed concentration anomalies to model estimated enhancements around large point sources
- More satellite data will be available in near future, making the emission estimates based on satellite data possible for more countries in the world.
- Review and examples of using satellite GHG data are presented in “Guidebook on use of satellite GHG observations …” published in Japan.

Opportunity for collaboration with GOSAT/GOSAT-2 project

GOSAT-2 satellite will soon be launched by Japan (in 2018-2019)

Improvements by GOSAT-2: increase by two times in observation data over GOSAT, because of a pointing system to avoid clouds, and observations of large emission sources by intensive target mode observations

Ministry of Environment, Japan, (MOE) is currently conducting the validation by comparison between satellite data and ground observations. For example, observations in Mongolia are considered.

MOE and NIES are looking for countries (or cities) who want to proceed with the verification/validation work together.