Use of atmospheric GHG observations for comparison with inventories

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Estimating anthropogenic emissions with atmopsheric observations

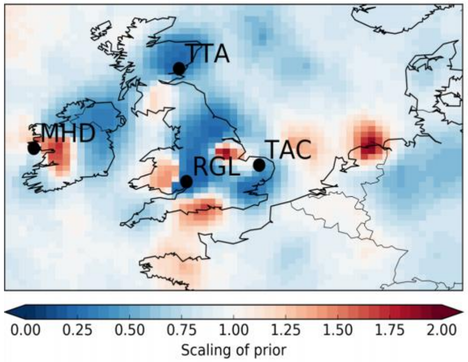
- Anthropogenic GHG emissions are recognized as cause of the climate change, so extra focus is now on slowing down and reversing global warming (Paris agreement), through GHG emission reduction by all UNFCCC parties
- UNFCCC system for monitoring emission reduction/trends is based on the countries national emission inventory reports, using 2006 IPCC Guidelines on Inventories, and updates and refinements to it.
- Every 5 years period, (eg 2016-2020) national communications will be summarized in a step called global stocktake (e.g. in 2023), and compared to observed GHG trends.
- 2019 Refinement promotes use of atmospheric observations to validate the national inventories, mentions studies made for National Emission Inventory verification targeting CH_4 emissions in Switzerland (Henne 2016), UK (Manning 2011)
- Satellite observations are being used. It was shown recently (Ganesan et al 2017), that use of GOSAT observations is useful for estimating emissions of CH_4 with inverse modeling of national scale for India.

2019 Refinement – key steps implemented in national examples

Comparison steps	Example 1 Methane emissions in Switzerland	Example 2 Methane emissions in UK	Example 3 SF_6, HFCs emissions in Australia
Step 1: **Acquisition of the concentration measurements on national GHGs network.**	CarboCount-CH measurement network (4 sites).	Advanced Global Atmospheric Gases Experiment (AGAGE) / UK DECC network, four sites.	Background AGAGE site at Cape Grim (Tasmania), and urban site at Aspendale (Victoria).
Step 2: **Preparation of the gridded prior emission data.**	Swiss Greenhouse Gas Inventory (SGHGI).	Prior estimates not used for methane	Australian national inventory.
Step3: **Preparing and operating the inverse model.**	Lagrangian particle dispersion model (LPDM) FLEXPART.	Numerical Atmospheric dispersion Modelling Environment (NAME), InTEM (Inversion Technique for Emission Modelling).	Interspecies correlation (ISC), forward CSIRO TAPM model, inverse model NAME-InTEM.
Step 4: **Quality assurance/Quality Control to the inverse model.**	Sensitivity analysis, Transport model validation.	Sensitivity analysis, Transport model validation.	Sensitivity analysis, Transport model validation.
Step 5: **Comparison, verification, and reporting.**	Estimated national CH_4 emissions of 196 $\pm$ 18 Gg yr^{-1}, agrees with SGHGI estimation of 206 $\pm$ 33 Gg yr^{-1}.	The InTEM methane emission estimates in 2013-2015 (with four DECC sites data) are consistent with UK GHG inventory.	Agreement found to within 2% for HFC-125, HFC-134a, HFC-143a and HFC-152a, within 15% for HFC-23, HFC-365mfc and SF_6, within 35% for HFC-32.

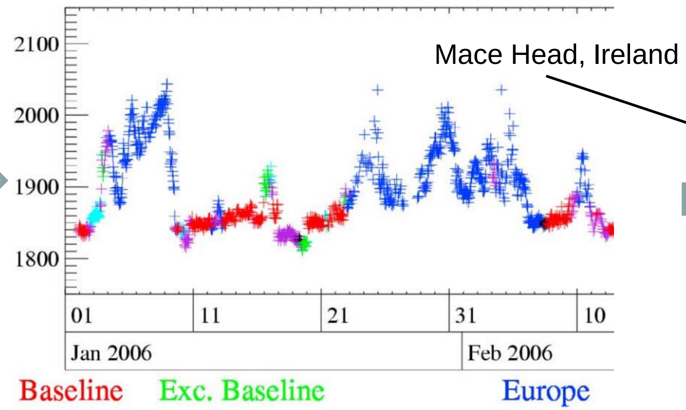
Concept diagram for use of atmospheric methane observations in inventory verification (UK National Inventory Report)

Building national observing network

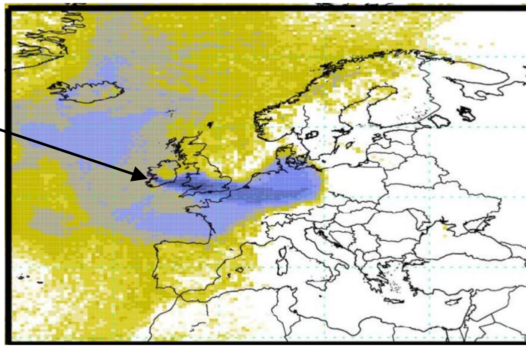


Tower locations

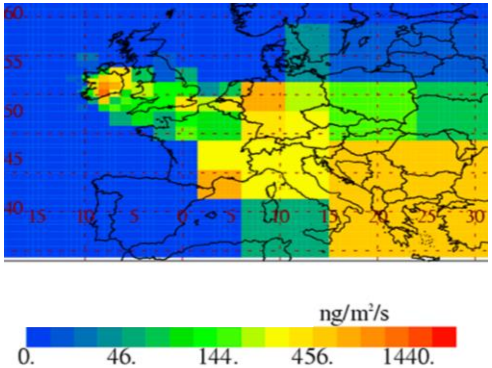
Observations: CH4 concentrations



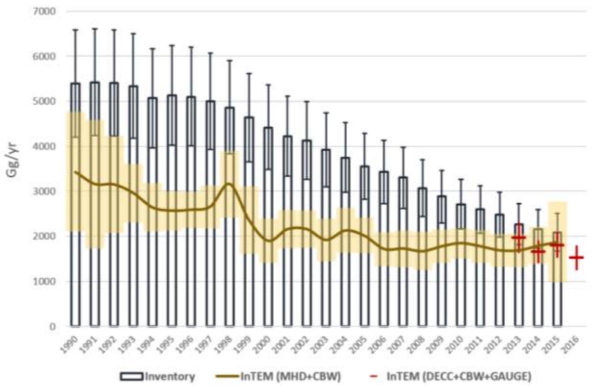
Transport modeling: map CH4 sensitivity to emissions (every 3 h)



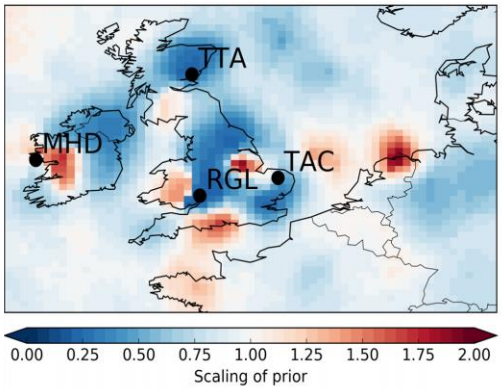
Inverse modeling: emissions



Comparison with inventory:
Grey - inventory

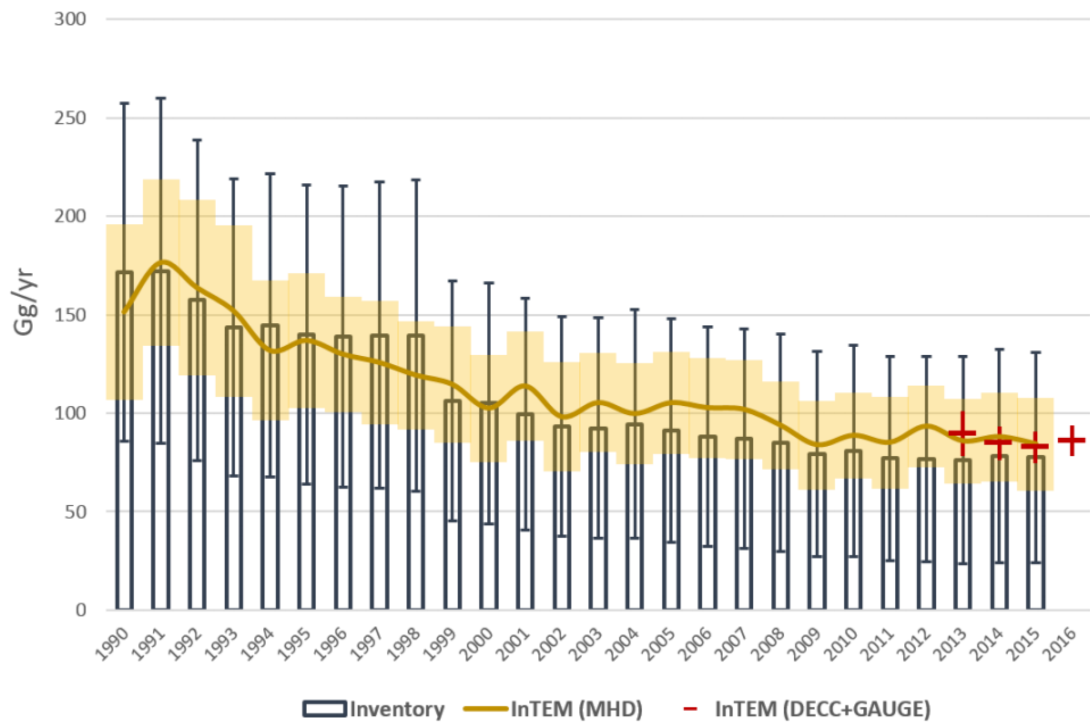


N_2O emissions in UK NIR

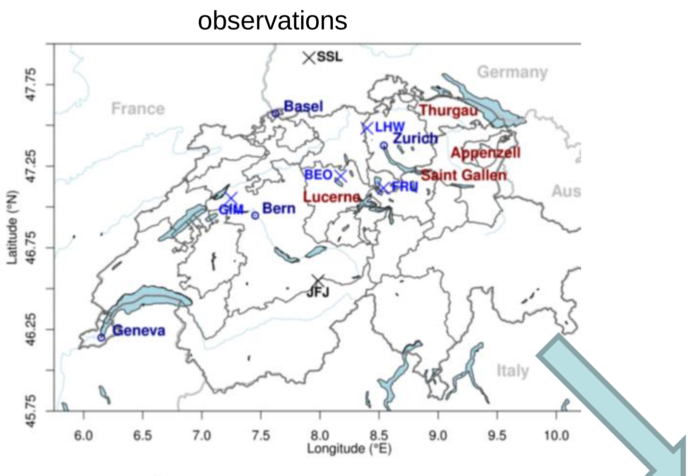


Consistency between emission estimates from atmospheric observations and inventory achieved via improving atmospheric transport model inversion scheme and inventory

Figure A 6.4 **Verification of the UK emission inventory estimates for nitrous oxide in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC+GAUGE) estimates are shown in red.**



Switzerland National Inventory Report 2017



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

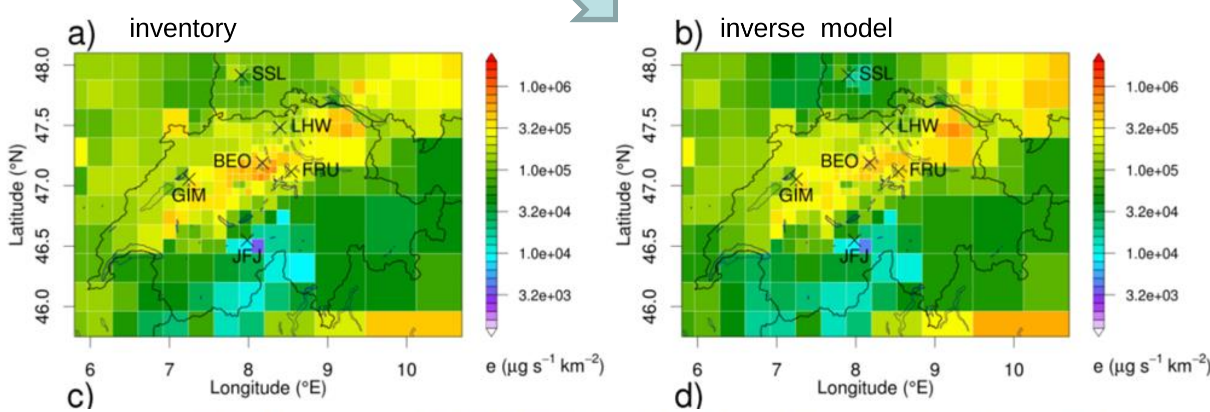
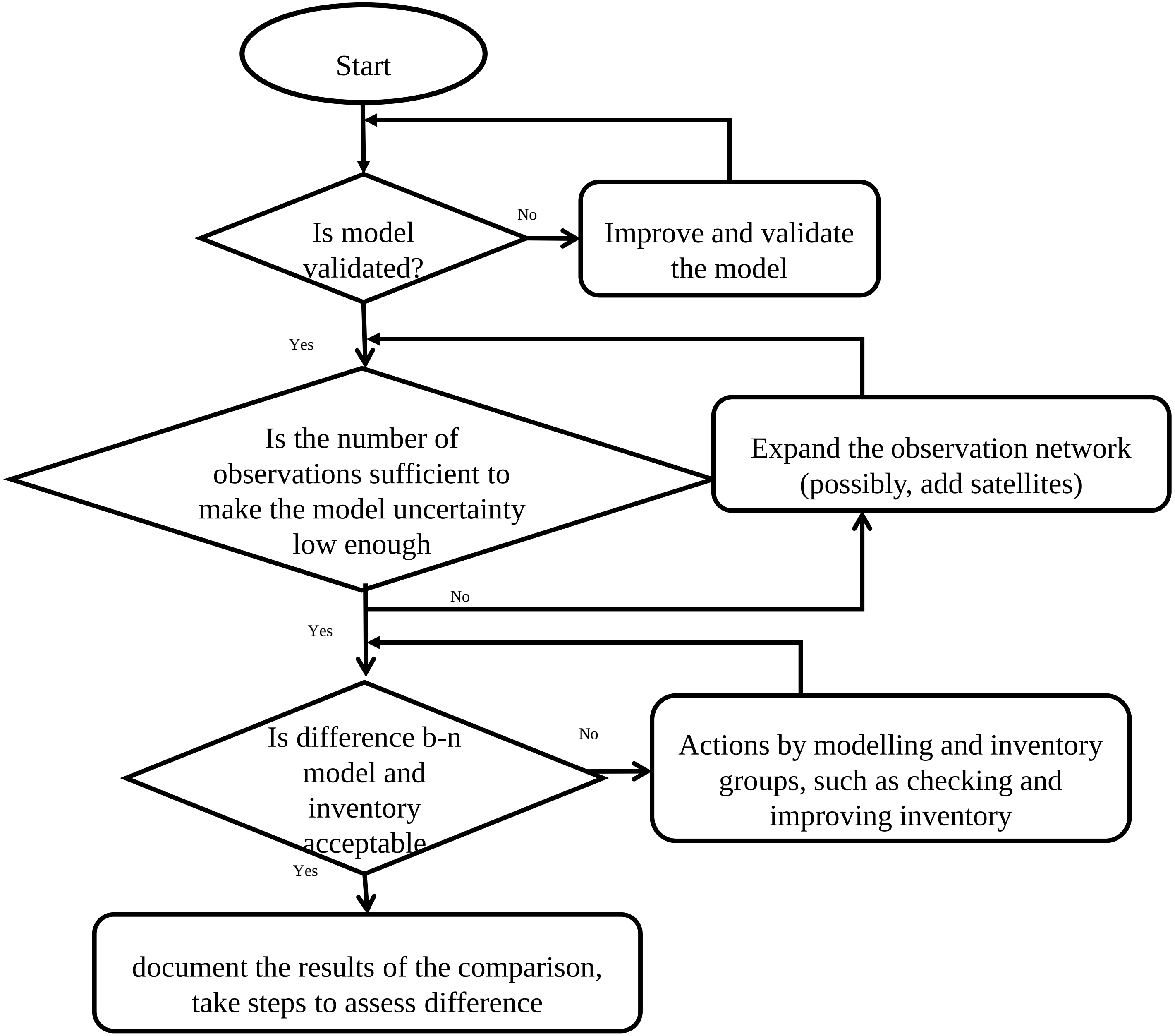


Figure A – 12: (a) *a priori* (MAIOLICA) and (b) *a posteriori* surface fluxes of CH_4

2019 Refinement – Strengths, problems and prospects of using atmospheric measurements for verification of GHG emissions

Gas	Strengths/Successes	Problems/Weaknesses	Future Development/Possibilities
CO_2	Large number of observations, although historically focusing on natural fluxes.	With sparse observing networks, uncertainties of models may be significantly higher than those of national anthropogenic CO_2 emission inventories.	Need more CO_2 observations targeting anthropogenic emissions, complemented by APO and radiocarbon observations.
CO_2 city-scale	City-scale studies show some degree of success. Inventory uncertainties are relatively larger than at national scale.	Even with dense observation networks, errors in emission estimates are large, due to interference from strong vegetation fluxes. Not used in national reporting.	Large efforts are ongoing to develop observation networks, pilot projects for tracking urban emissions, trends. Radiocarbon, oxygen, satellite observations also expected to contribute.
CH_4	Large anthropogenic emission fraction. National reporting: UK, Switzerland. National-scale emission estimates: EU-28, USA, India, China and others.	Few countries have observations, transport and inverse models have uncertainties, interference from natural emissions (wetlands) cited.	Regional observation networks and satellite observations are expanding.
N_2O	National reporting: UK, Switzerland National-scale emission estimates: EU-28, US, and others.	Observation sites are few, gridded inventories are simplified, large contribution from natural sources.	Expansion of surface networks will contribute to better model estimates.
HFCs, SF_6	Dominant anthropogenic emission fraction. National reporting: UK, Switzerland, Australia. National-scale emission estimates: China, US, EU.	Measurements are sophisticated and expensive. Observation sites are few, gridded inventories are simplified.	Expanding the monitoring network depends on funding.

2019 Refinement – A decision tree for checking the conditions for using the inverse model estimates in the National Inventory verification



Further recommendations on implementing national observing system

IG³IS implementation plan for national objective

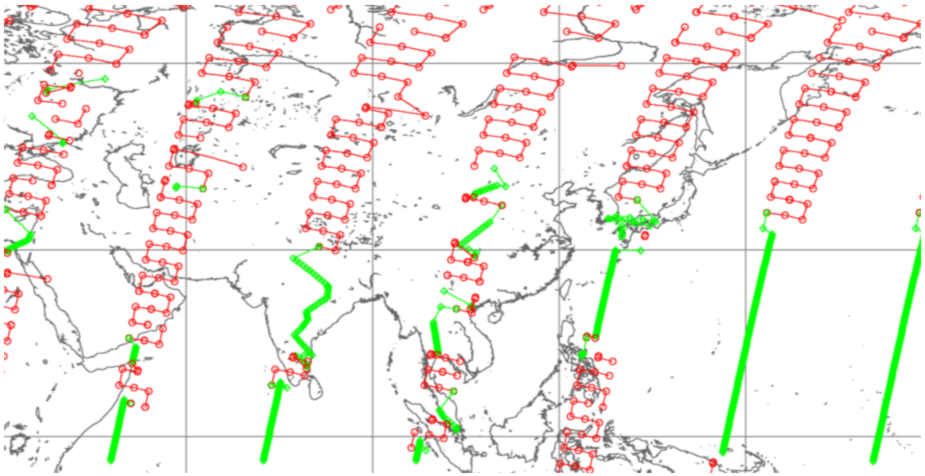
Increasing model complexity →

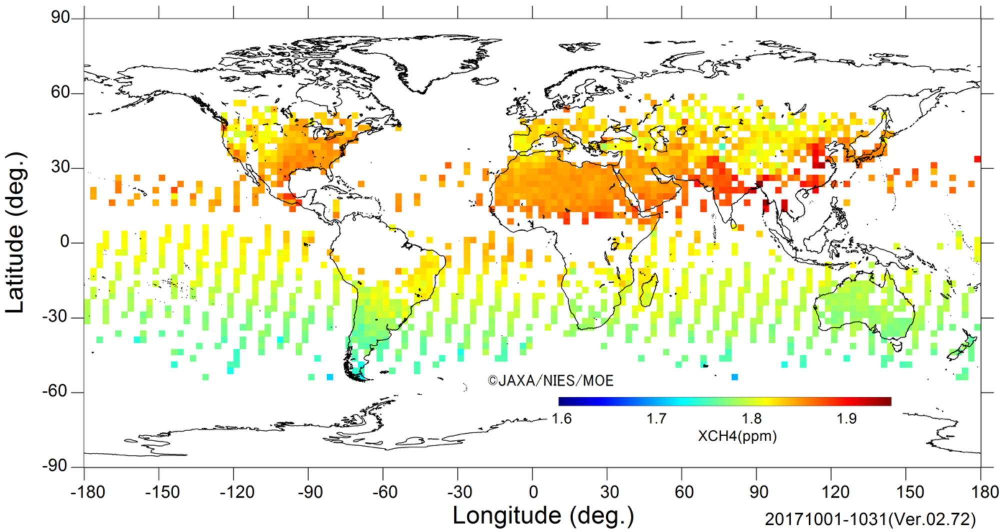
↓ Increasing measurement complexity

		Tier 1 Use established (global) model and inversion system, operated by external experts	Tier 2 Use established (global) model and inversion system; develop local expertise to operate the system	Tier 3 Taylored high-resolution modeling and inversion system, operated by local experts
Tier 1	Single representative station in country or station every 500-1000 km	Trend in total emissions in area of influence of site(s)	Total emissions and their trend in area of influence of site(s)	Total emissions and their trend with higher accuracy in area of influence of site(s)
Tier 2	Network of sites covering all parts of country, simple measurement infrastructure	Trend in country total emissions, no separation between anthropogenic and biospheric fluxes	Total country emissions and their trend, no separation between anthropogenic and biospheric fluxes	Total country emissions and their trend with higher accuracy, no separation between anthropogenic and biospheric fluxes
Tier 3	Network of sites covering all parts of country, additional tracers (radon, radiocarbon, isotopes)	Trend in country total emissions, separation between anthropogenic and biospheric fluxes, sector-specific information	Total country emissions and their trend, separation between anthropogenic and biospheric fluxes, sector-specific information	Total country emissions and their trend with higher accuracy, separation between anthropogenic and biospheri fluxes, sector-specific info.

Satellite observations of GHG in atmosphere

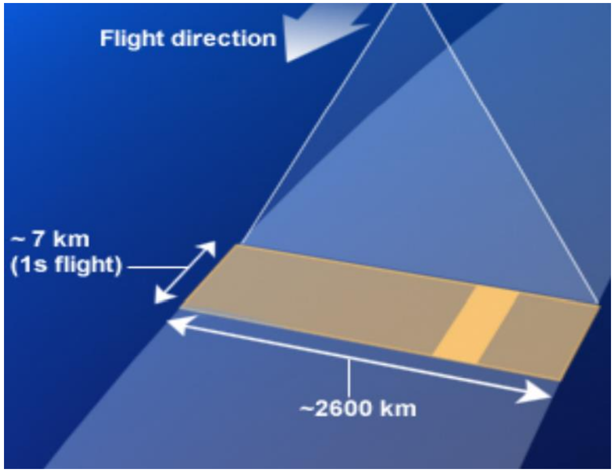
GOSAT, Japan, since 2009
CO_2, CH_4, 10 km, 1 observation/ 4 seconds

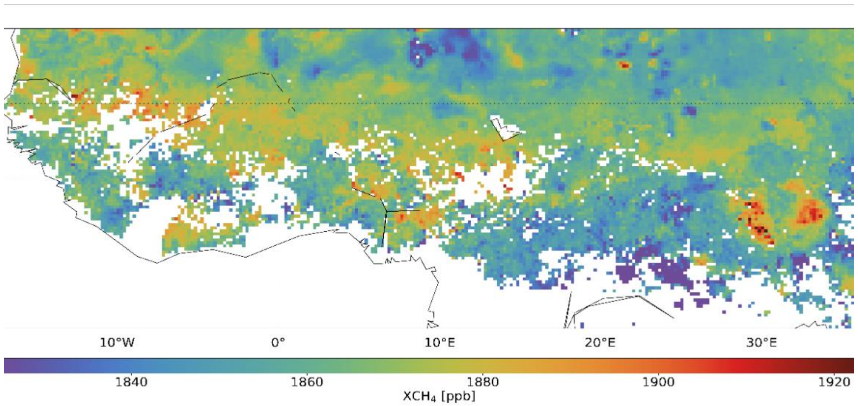




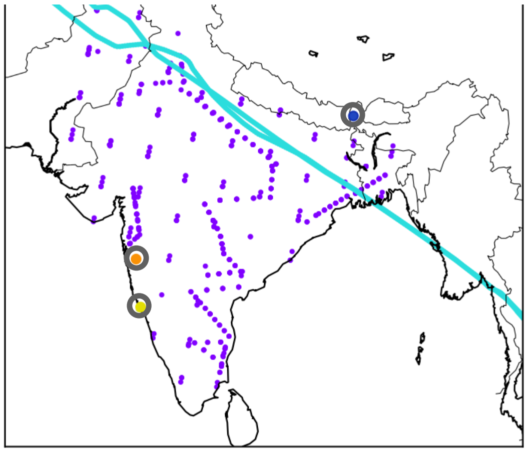
Oct 2017 Monthly Global Map of the CH4 column-averaged volume mixing ratios in 2.5 deg by 2.5 deg mesh(FTS SWIR L2 XCH4)

Tropomi, ESA, since 2017
CH_4, 7 km, ~200 per sec.





Atmospheric observations support accurate reporting of India's methane emissions

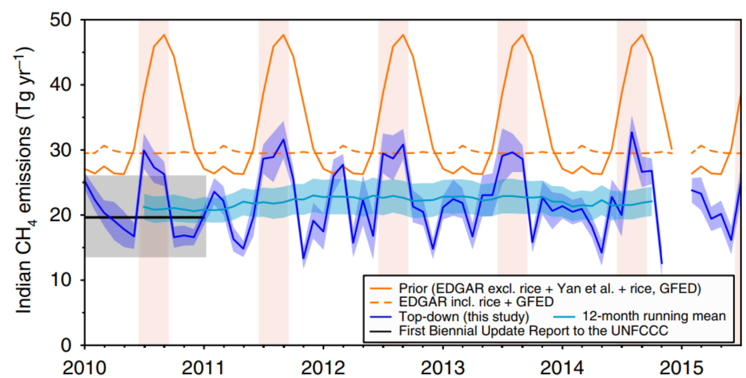


Observations: Darjeeling (dark blue), Cape Rama (yellow), Sinhagad (orange), GOSAT retrievals (purple), CARIBIC (light blue)

Study inferred India's CH4 emissions for the period 2010–2015 using a combination of satellite, surface and aircraft data.

Apply a high-resolution atmospheric transport model NAME 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 BUR to the UNFCCC.

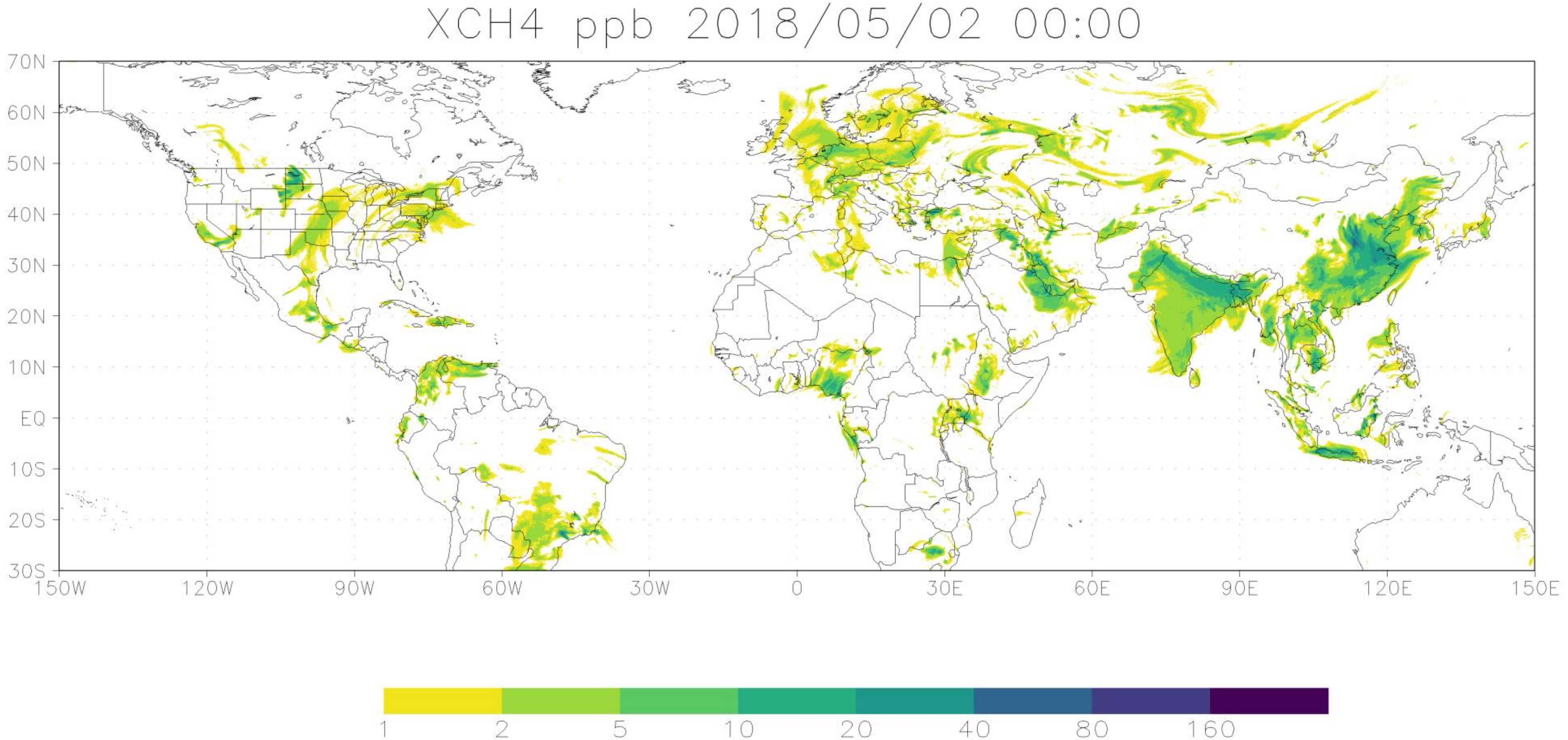
Now included in India's BUR2 (Dec 2018) submission



Ganesan, A. L., Rigby, M., Lunt, M. F., Parker, R. J., Boesch, H., Goulding, N., Umezawa, T., Zahn, A., Chatterjee, A., Prinn, R. G., Tiwari, Y. K., van der Schoot, M., and Krummel, P. B.: Atmospheric observations show accurate reporting and little growth in India's methane emissions, Nature Communications, 8, 836, 10.1038/s41467-017-00994-7, 2017.

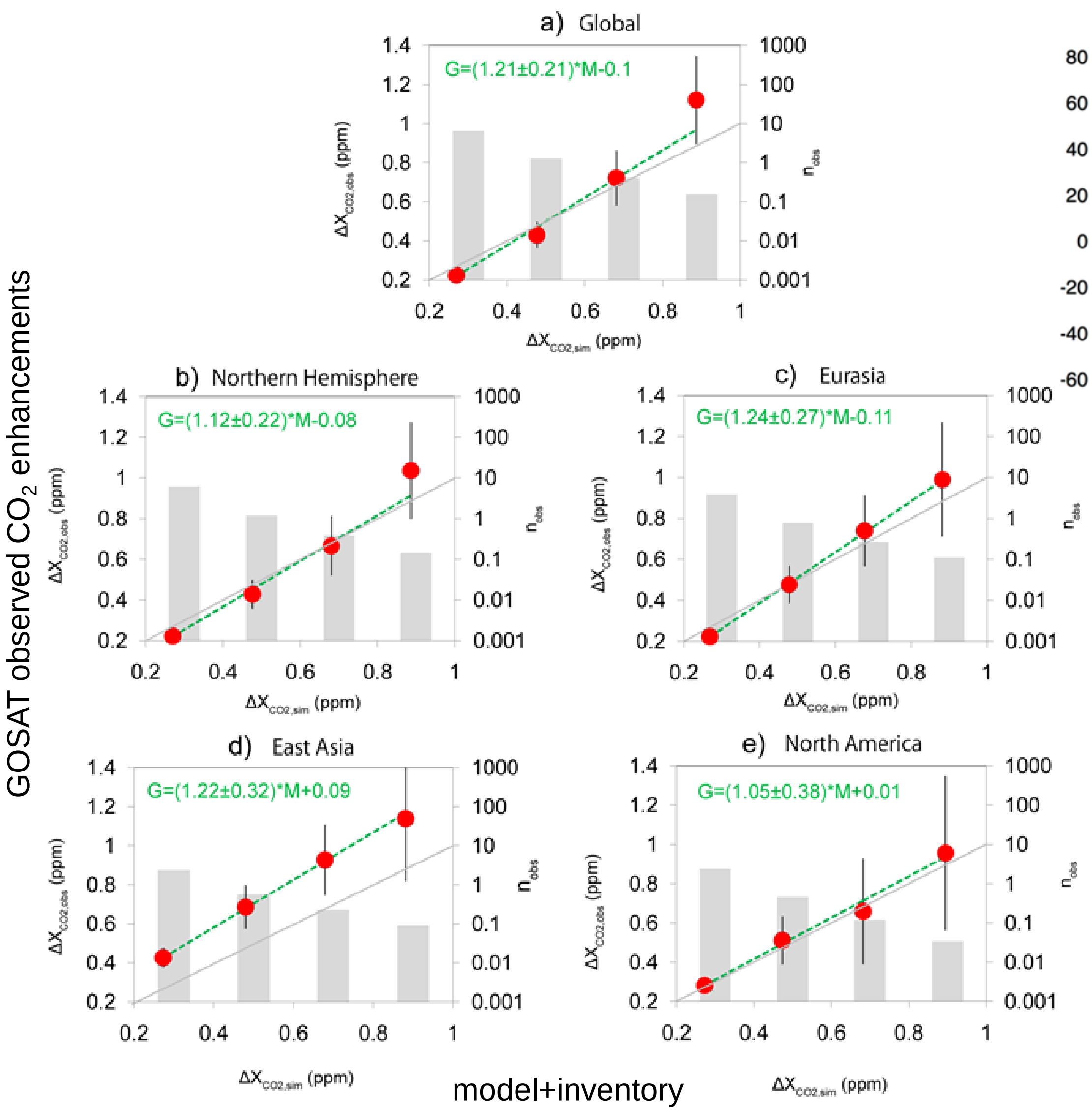
Anthropogenic GHG plumes – high resolution needed to accurately model anthropogenic methane for emission analysis

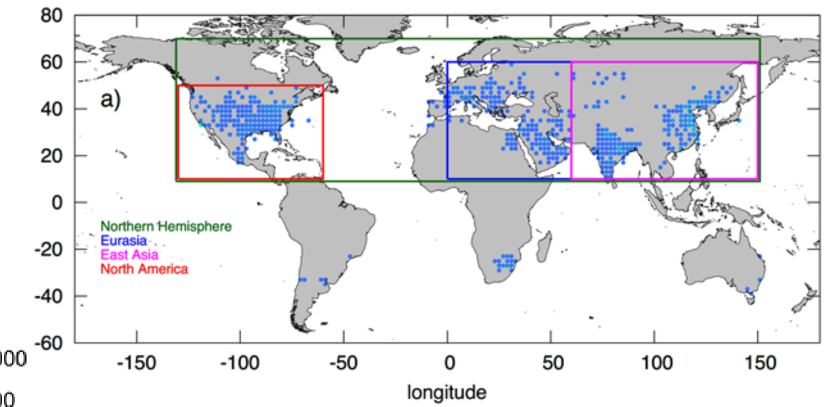
forward CH_4 simulation with Flexpart (5 km resolution)



Anthropogenic CH_4 from EDGAR emissions, vertically average concentration enhancements, ppb

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.; Kaiser, J. W.; Ganshin, A.; Stohl, A.; Matsunaga, T.; Yoshida, Y.; Yokota, T.. Geophysical Research Letters (2016), 43, 3486–3493

Summary

Ability to quantify natural and anthropogenic fluxes of GHG by atmospheric observations is important for climate change mitigation.

2019 Refinement to 2006 IPCC guidelines promotes use of atmospheric observations to validate the national inventories, mentions studies made for National Emission Inventory verification targeting CH_4 emissions in Switzerland (Henne 2016), UK (Manning 2011), India (Ganesan et al 2017)

In case there is sufficient funding and technical expertise, 2019 Refinement recommends establishing national observation network of several sites, for verifying emission inventory.

Satellite observations are also available recently. It was shown (Ganesan et al 2017), that use of GOSAT observations is useful for estimating emissions of CH_4 with inverse modeling of national scale, also included in India BUR2. The use of GOSAT data provides better capability to estimate anthropogenic emissions in case of sparse and limited ground-based observation coverage.

Learning materials: Guidebook on the Use of Satellite GHG Observation Data

Ministry of Environment, Japan and National Institute for Environmental Studies support preparation of ‘A Guidebook on the Use of Satellite Greenhouse Gases Observation Data to Evaluate and Improve Greenhouse Gas Emission Inventories’ (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

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