Interannual variability of anthropogenic methane emission estimated by an inverse model using GOSAT and surface observations

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IWGGMS18
13 July 2022, Japan

Background

We used methane observations from global surface observation networks and GOSAT satellite in a high-resolution methane inverse model to infer surface anthropogenic fluxes over major emitting countries.

We have conducted two sets of inversion using *surface observations only* and *surface plus GOSAT* observations.

The results on *country-scale anthropogenic emissions*, *comparison to prior* and *national inventories* and *the trend* of posterior emissions are discussed.

Data

Prior fluxes

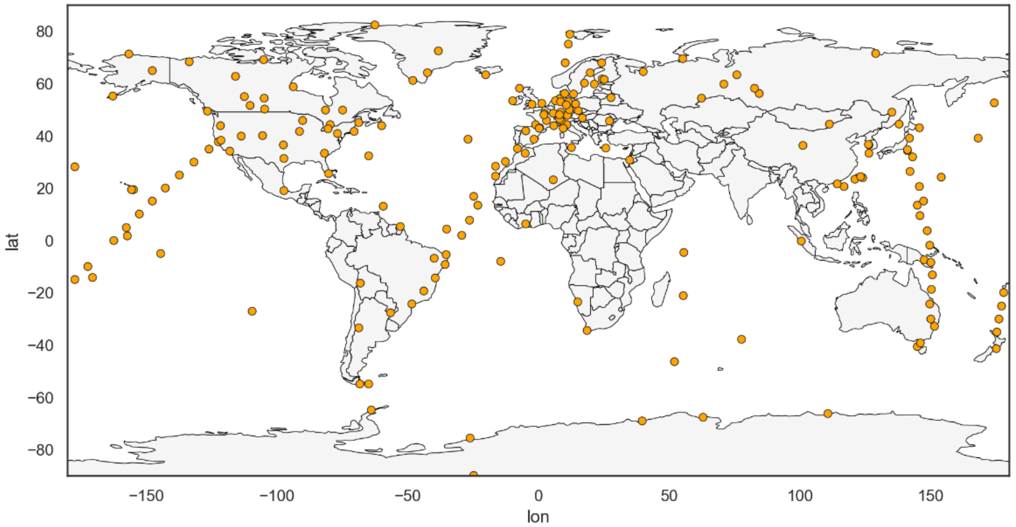
1. Monthly anthropogenic emission was from the Emissions Database for Global Atmospheric Research (EDGAR v6) at a spatial resolution of 0.1°×0.1°
2. Emissions from wetland taken from Saunois et al (2020) and soil sink follows Murgia-Flores et al (2018).
3. Emission from biomass burning was taken from Global Fire Emission Database (GFED4s) data at 0.1° resolution
4. The emission from termites was from Saunois et al (2020). The emissions due to oceanic exchange were taken from Weber et al, (2019) and geological emissions from Etiope et al., (2019)

Meteorological data

The meteorological data used were from the Japanese Meteorological Agency (JMA) Climate Data Assimilation System (JCDAS, Onogi et al., 2007) at 1.25°×1.25°

Observations used

1. Greenhouse Gas Observing Satellite (GOSAT) Observations (NIES Level 2 product, v.02.95)
2. Obspack CH_4 (v4.0) and observations from ICOS network

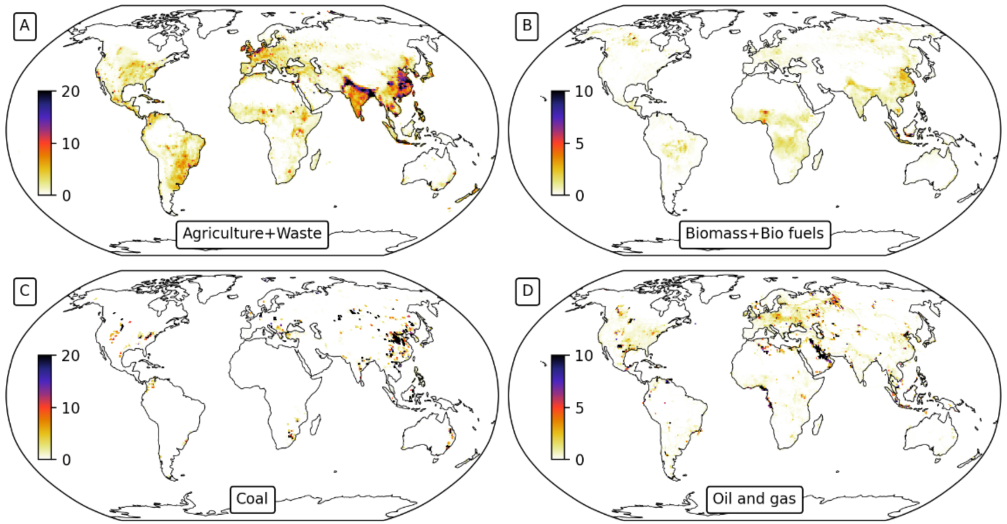


NTFVAR Inverse Modeling System

- Global Eulerian–Lagrangian coupled model NIES-TM-FLEXPART-VAR (NTFVAR)
- Consists of the National Institute for Environmental Studies (NIES-TM) model as a Eulerian three-dimensional transport model, and FLEXPART (FLEXible PARTicle dispersion model) as the Lagrangian particle dispersion model (LPDM).
- The model development were reported Belikov et al. (2016) and Maksyutov et al. (2021) and application to methane inversion reported in Janardanan et al., (2020) and Wang et al., (2019).
- Model makes flux optimization for the natural (wetland) and agriculture, biomass burning, waste, oil and gas and coal sectors of the anthropogenic emissions.
- This optimized flux, constrained by available observations are estimated on biweekly time step at 0.1 degree.
- This will allow detailed sector-wise analysis of methane emissions on a country-scale (not ready for this talk).
- The model performance was evaluated using two sets of inversions using satellite (GOSAT) and surface methane observations.
- The model uncertainty were not estimated, but the estimated flux totals were evaluated comparing recent reports on country-scale budgets and uncertainties (e.g., Worden et al., 2022).

Model estimated anthropogenic fluxes

Prior



Global total emissions

Surface=> 573 Tg yr^{-1}

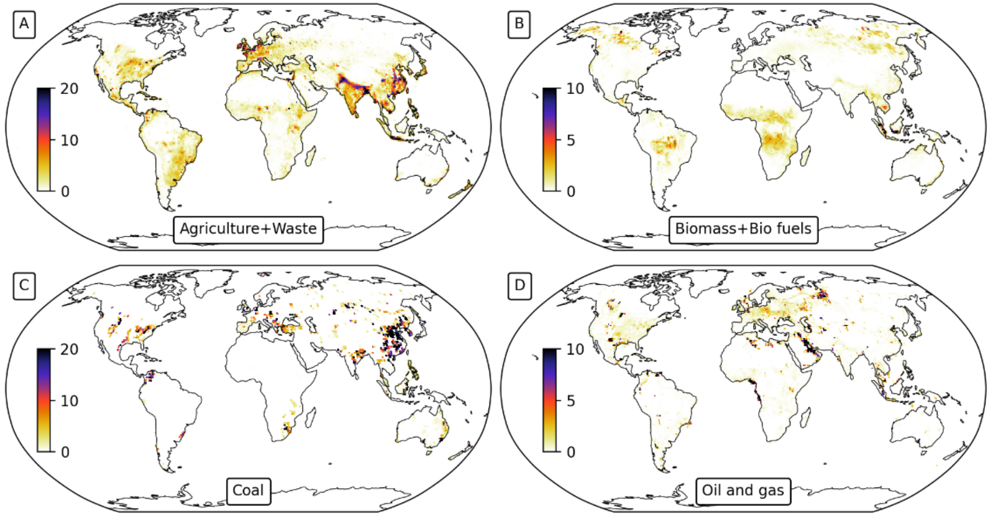
GOSAT => 586 Tg yr^{-1}

Anth. Total GOSAT => 388 Tg yr^{-1}

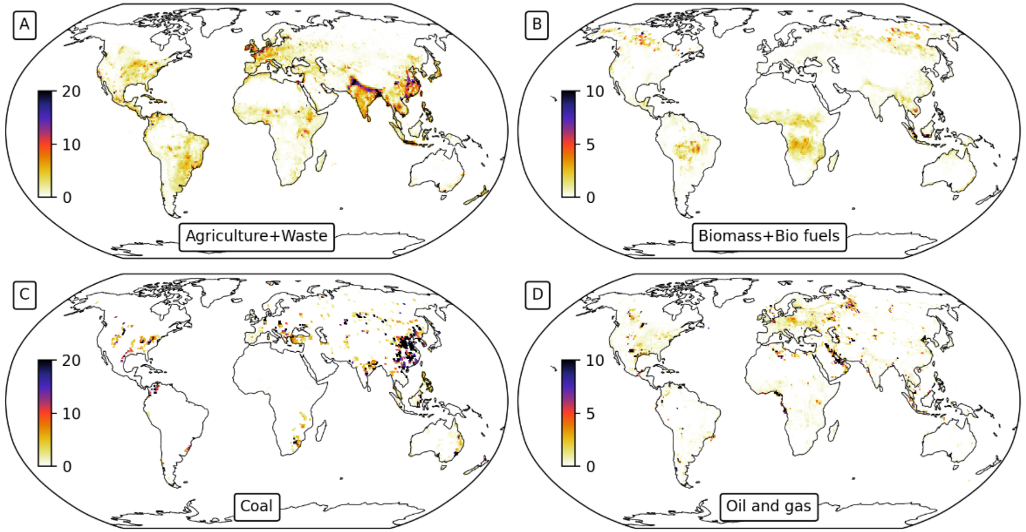
Anth. Total Surface => 398 Tg yr^{-1}

- India and China corrections stronger with surface data
- South American regions, Middle East adjusted greater by GOSAT

Surface

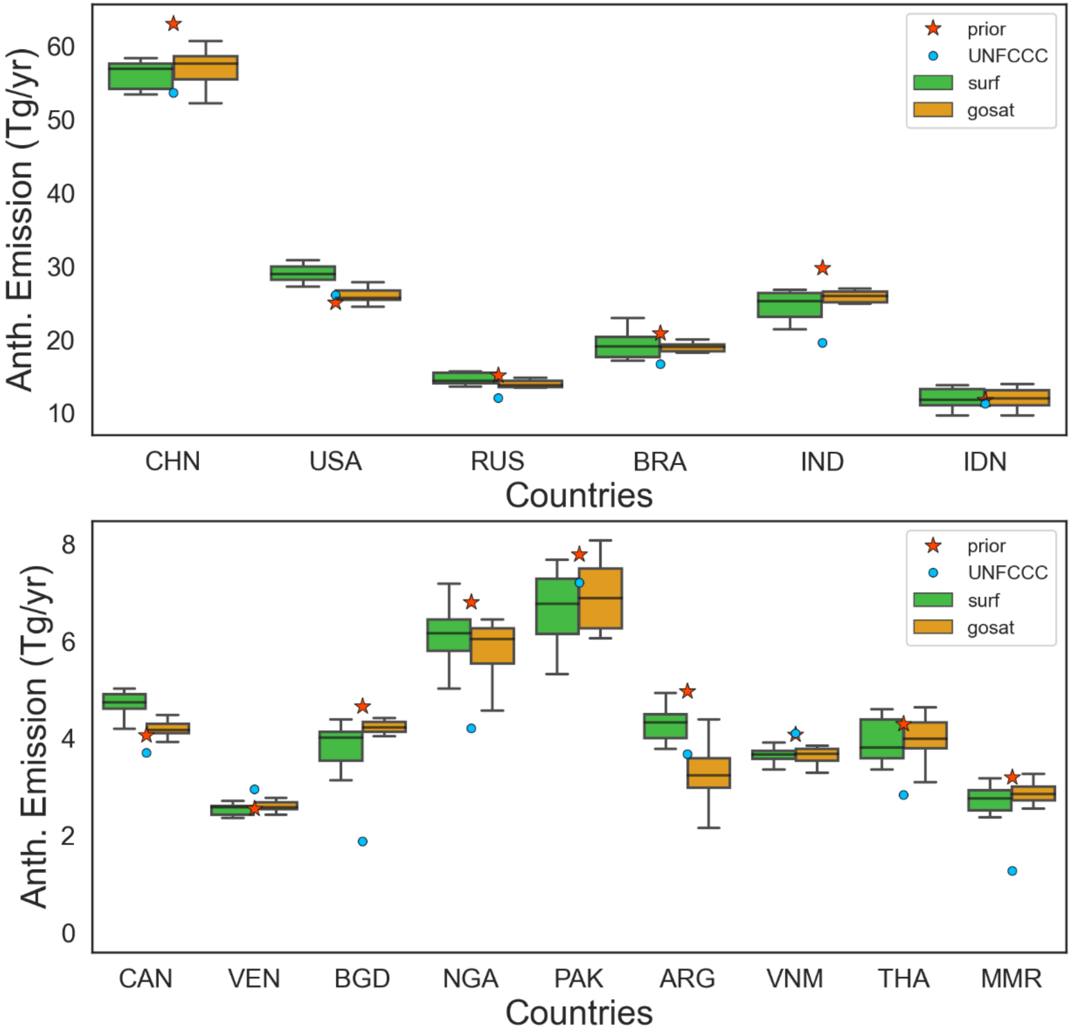


GOSAT



Country total anthropogenic emissions

- Largest flux correction for China-Both inversions reduced the anthropogenic flux for China (~-10.6%) from 63 Tg to 55.6-57 Tg
- Both inversions suggest positive revision for USA (~9.6%) (25.9-28.9 Tg)
- Consistent downward correction for Brazil (20.8; 18.7-19.1; -9%) and India (29.6; 25.5-24.5; -15.6%)
- Mexico (2.4%) and Canada (9.7) has upward correction

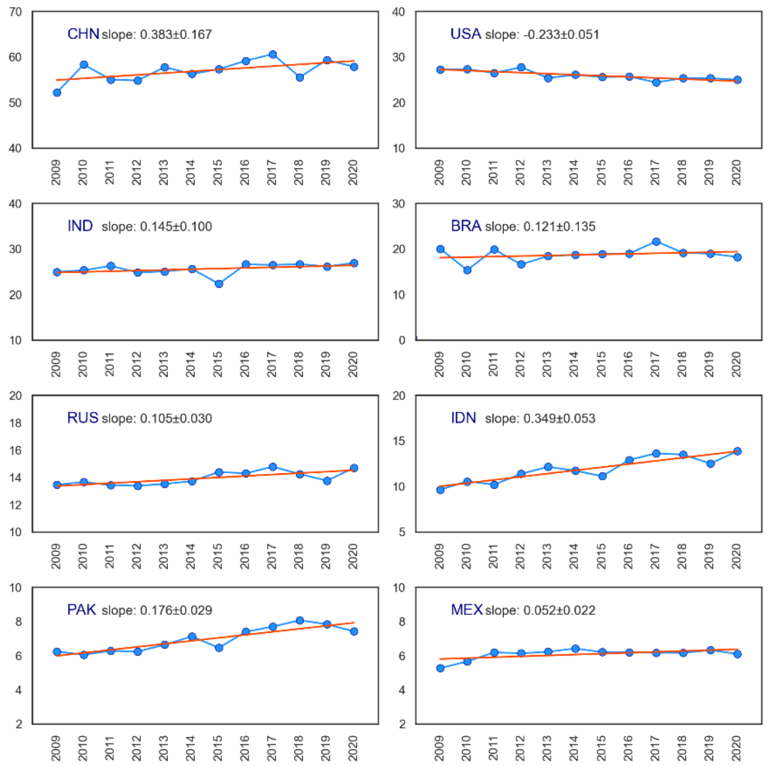


- 2009-2020 country total anthropogenic emissions
- UNFCC values for last reported year

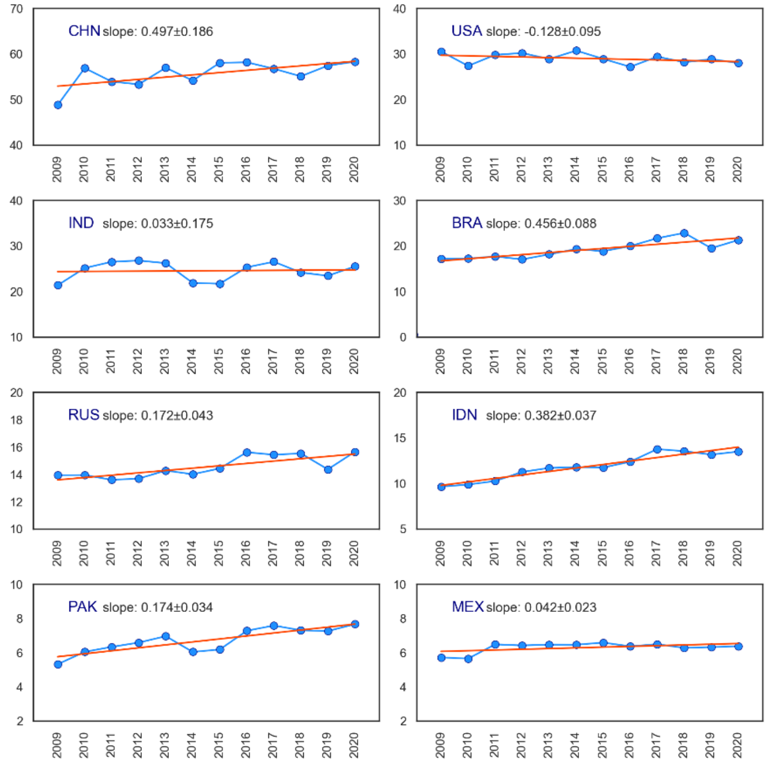
Trend in anthropogenic emissions

GOSAT

- significant positive trend for China (0.38±0.2 Tg yr^{-2}), Indonesia (0.35±0.05 Tg yr^{-2})
- A decreasing trend is found for USA (0.23±0.05 Tg yr^{-2}). EPA -0.8% yr^{-1} (Lu et. al., 2022).



USA- Coal, Landfills
China- Coal, Gas
Indonesia- Coal production
Brazil-Agriculture



Surface

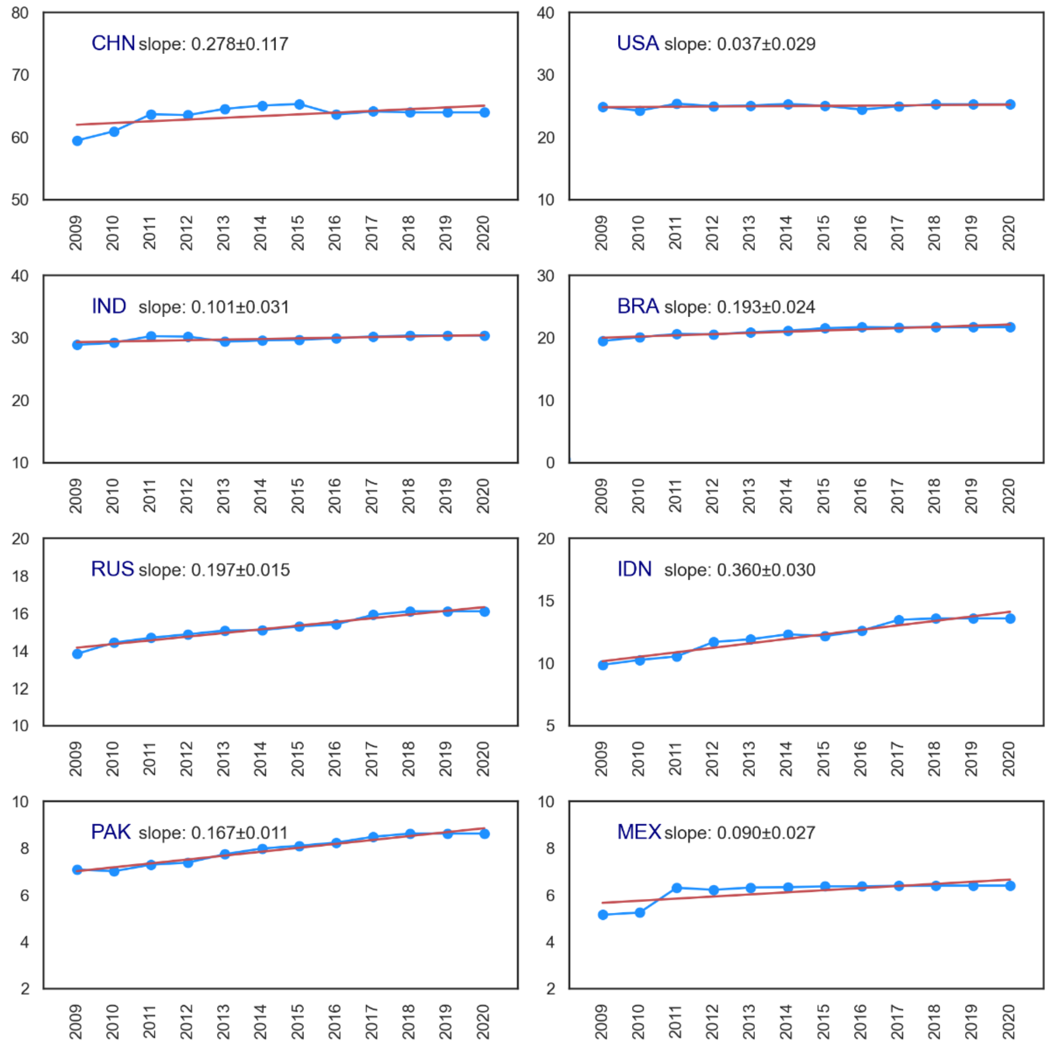
- Significant positive trend for China (0.5±0.2 Tg yr^{-2}), Brazil (0.46±0.1 Tg yr^{-2}) and Indonesia (0.38±0.04 Tg yr^{-2})
- Decreasing trend for USA (0.13±0.1 Tg yr^{-2}) not statistically significant (p=0.2).
- Russia and Pakistan showed significant upward trend for the period

Summary

- Asian countries like China and India have posterior emissions lower than EDGAR v6 prior, but higher than national inventories.
- Higher posterior emissions for United States, closer to EPA estimates (26 Tg) than some recent studies (e. g. 36 Tg by Lu et al., 2022)
- Indian emissions were lowered to 24.5-25.5 Tg, closer to the UNFCCC reported values (19 Tg).
- Mexico and Canada showed minor upward correction by the model.
- Both GOSAT and surface inversions showed a significant positive trend for China (coal, gas), Indonesia (coal), while surface inversion shows significand trend for Brazil (agriculture) as well.
- GOSAT inversion suggest decreasing trend for USA (landfills, coal).

Thank you

Prior trend



CHN slope: 0.278±0.117
USA slope: 0.037±0.029
IND slope: 0.101±0.031
BRA slope: 0.193±0.024
RUS slope: 0.197±0.015
IDN slope: 0.360±0.030
PAK slope: 0.167±0.011
MEX slope: 0.090±0.027
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020