# Relationship between methane enhancements observed by GOSAT and country scale anthropogenic emissions in Asia


Rajesh Janardanan[1]*, Shamil Maksyutov[1], Akihiko Ito[1], Yukio Yoshida[1], Tsuneo Matsunaga[1]

1 National Institute for Environmental Studies, Japan

Email: rajesh.janardanan@nies.go.jp, shamil@nies.go.jp


## Data

- **Meteorological data** used for transport simulation is from Japanese Meteorological Agency (JMA) Climate Data Assimilation System (JCDAS) on a regular 1.25°×1.25° grid and 40 vertical hybrid sigma-pressure levels. The temporal resolution of input data is 6 h.
- **Satellite $XCH_4$** used is the National Institute for Environmental Studies (NIES) GOSAT Short-wave InfraRed (SWIR) $XCH_4$ Level 2 product (v2.072) subjected to a standard filtering and screening applied for general distribution.
- **Biomass burning** (GFASv1.0) calculates biomass burning emissions at 0.1° by assimilating Fire Radiative Power (FRP) observations from the MODIS instruments onboard the Terra and Aqua satellites.
- **Biospheric fluxes** were simulated by Vegetation Integrative Simulator of Trace gases (VISIT) at 0.1°
- **Anthropogenic methane** - Emission Database for Global Atmospheric Research (EDGAR v4.3.2)

## Methods

**Transport model simulation**

- Analysis period from June 2009 until December 2016
- Lagrangian Particle Dispersion model **FLEXPART** with anthropogenic emission to simulate the local abundance in $XCH_4$ ($\Delta XCH_{4,lag}$) to classify GOSAT observations as from background and polluted sites.
- Coupled transport model (**NIES-TM+FLEXPART**) for simulating GOSAT $XCH_4$ using anthropogenic, biomass burning and wetland emissions calculated at resolution (0.1°) comparable to GOSAT observation footprint

**ΔXCH4 from GOSAT**

- **Background** ($XCH_{4,bgo}$) **-** We calculate the mean of observations ($XCH_4$) for locations corresponding to $\Delta XCH_{4,lag}$ <1ppb (clean pixels) for each monthly subsets in 10°×10° rectangular regions. Similarly, coupled model simulations ($XCH_{4,sim}$) were used to calculate background ($XCH_{4,bgs}$) at locations identified by Lagrangian simulations.
- **Emission influenced-** observations on locations where simulated enhancements due to anthropogenic emissions ($\Delta XCH_{4,lag}$) exceed 1 ppb
- $\Delta XCH_{4,obs}$ is then calculated as difference between observations and the monthly regional background and analogously for simulated $XCH_4$

$$\Delta XCH_{4,obs} = XCH_{4,obs} - XCH_{4,bgo}$$

$$\Delta XCH_{4,sim} = XCH_{4,sim} - XCH_{4,bgs}$$

- categorized in to **2 ppb bins** based on $\Delta XCH_{4,sim}$. These values were aggregated for the whole period of study and subjected to linear regression with the model calculated values.
- The **weighted linear regression** was carried out for regions/countries with weight to the standard error in mean observed and simulated enhancements in each bin using York method.

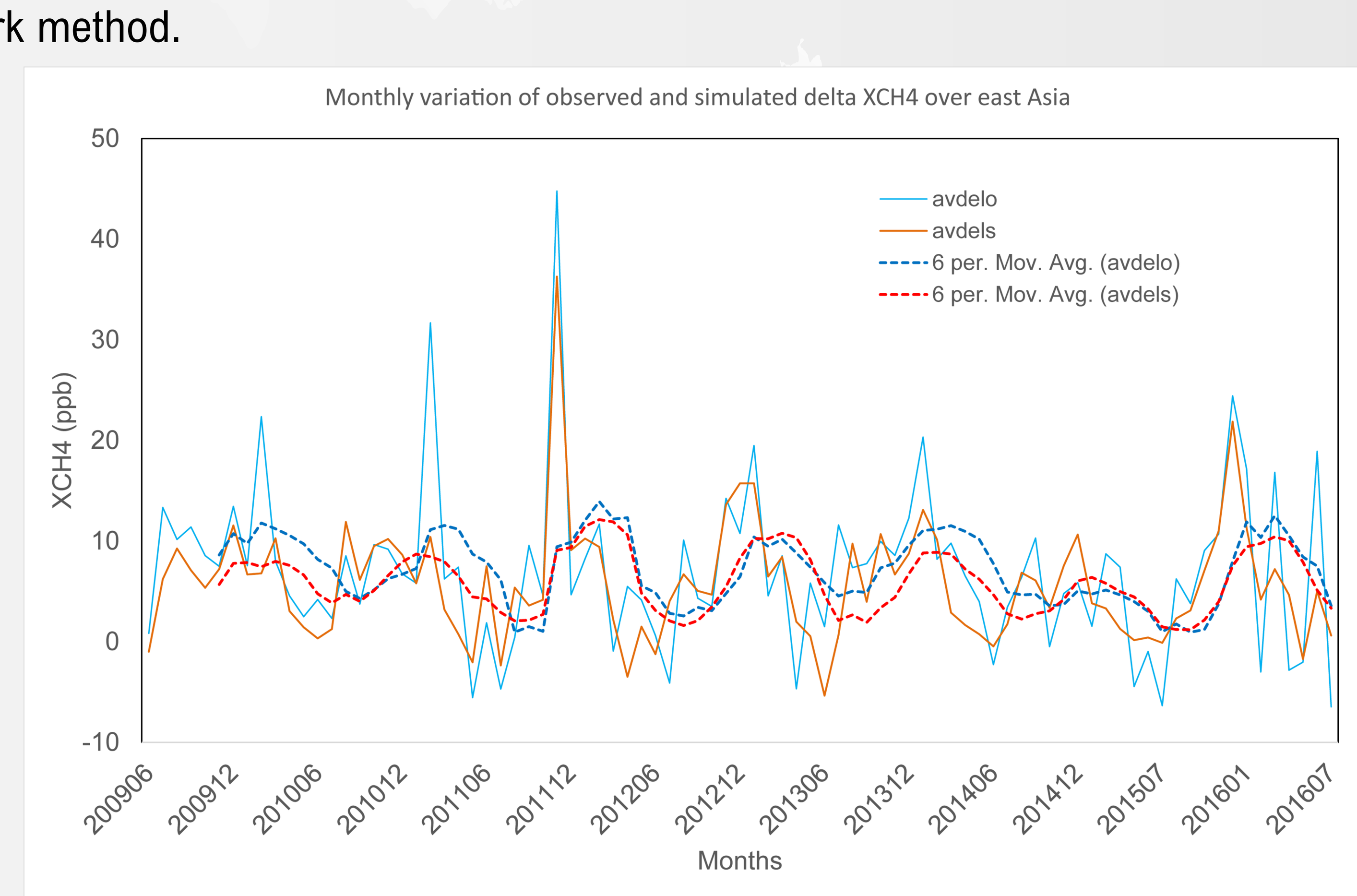


Figure 1. Monthly variations of delta $XCH_4$ averaged over East Asia and the 6 month moving average


**References**

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## Results

- The $XCH_4$ abundance due to anthropogenic emissions over India, China and Middle East countries calculated by a global coupled transport model (NIES-TM and FLEXPART) and those estimated from GOSAT observation show linear relations (Fig. 1)
- Over Middle East countries, the regression analysis gave a lowest slope value (0.49±0.05) indicating an upward bias in the emission (Fig. 2)
- Indian emissions were found to be overestimated by ~20% (slope 0.82±0.10).
- China also has a slope value less than one (0.94±0.06) showing overestimated emission.
- Including a global Eulerian model facilitate more realistic representation of the background concentration and enabled this analysis over a spatial scale of large countries which was not possible with the method in Janardanan et al, 2017, with a Lagrangian model only.

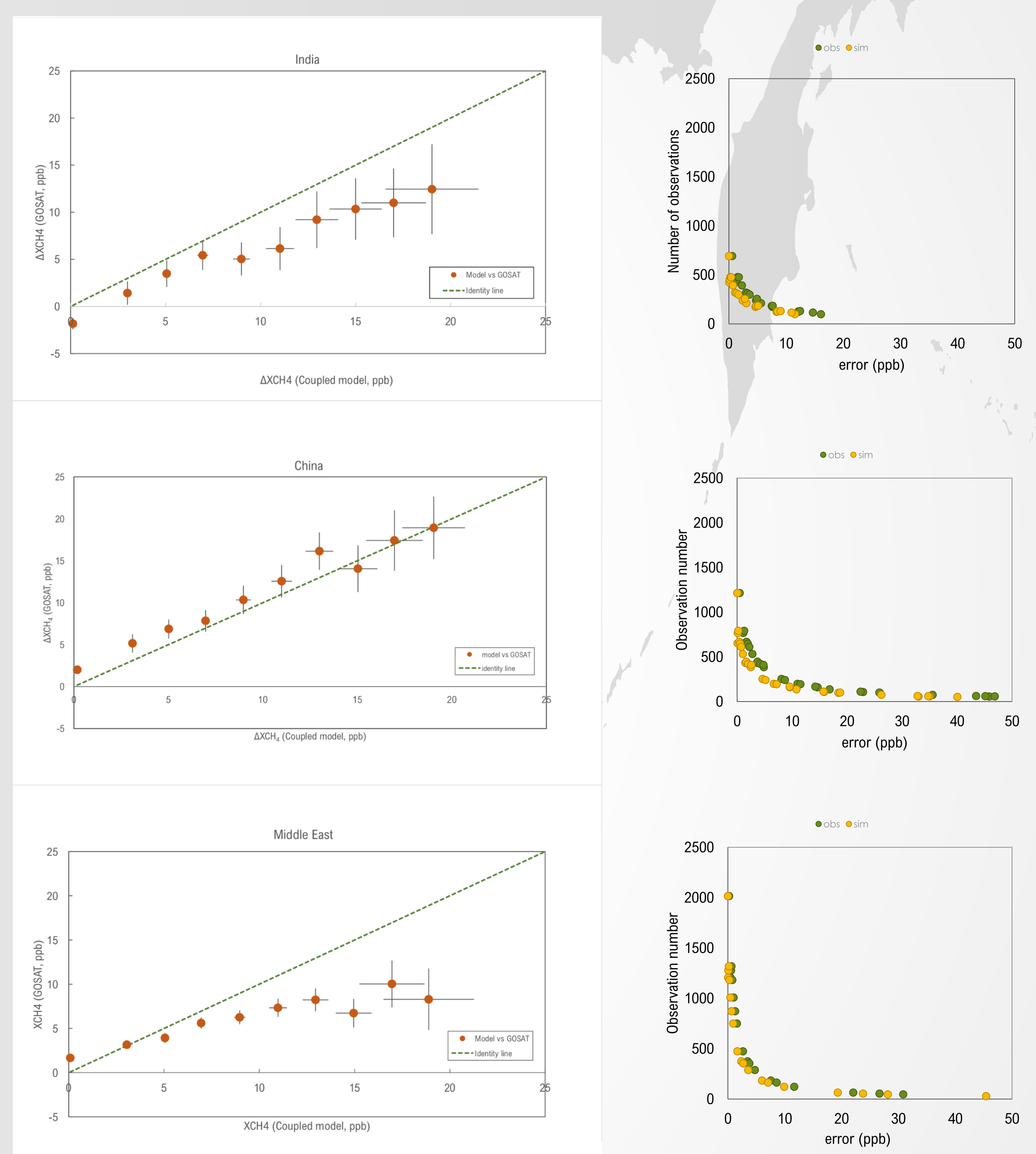


Figure 2. Scatter plots of modelled versus observed delta $XCH_4$ over India, China and the Middle East countries. Green dashed line is the identity line the error bars represent the standard error in both delta $XCH_4$ bin averages. Right panel shows the error reduction as a function of number of observations in each region.

## Summary

- A coupled transport model with GOSAT L2 $CH_4$ data was used for verification of anthropogenic emissions on spatial scale of countries like India and China.
- The slope of regression of simulated $XCH_4$ abundance against observed, for India is 0.82±0.10, for China 0.94±0.06 and for Middle East is 0.49±0.05
- These three countries/region show overestimation in anthropogenic $CH_4$ emission inventory
- These results agree with recent studies reported over these regions.
- Coupled transport model helps to more realistically represent the background concentration and thus facilitates analysis on spatial scales as small as large countries.
- The results shows the potential of GOSAT observations of $CH_4$ in monitoring biases in regional anthropogenic emissions.
- Number of available GOSAT observations are lowest for India and hence large uncertainty in the slope
- Analysis covers eight years, and need more frequent observation of target locations for annual or biennial monitoring on country-scale.


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