Satellite-derived Indian methane emission sources with TROPOMI retrievals and WRF-GHG modelling framework

D.Pillai[1], M.Deshpande[1], A. Mishra[1], J.Marshall[2], C.Gerbig[2], O.Schneising[3], and M. Buchwitz[3]

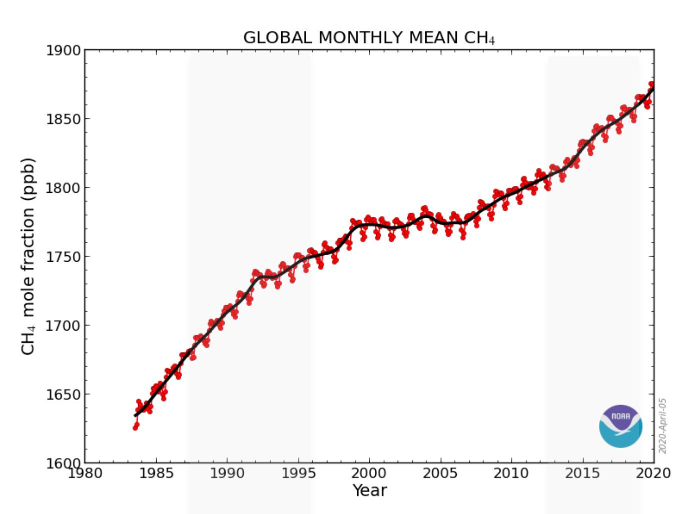
[1] Indian Institute of Science Education and Research, Bhopal, India

[2] Max Planck Institute for Biogeochemistry, Jena, Germany

[3] Institute of Environmental Physics, University of Bremen, Germany

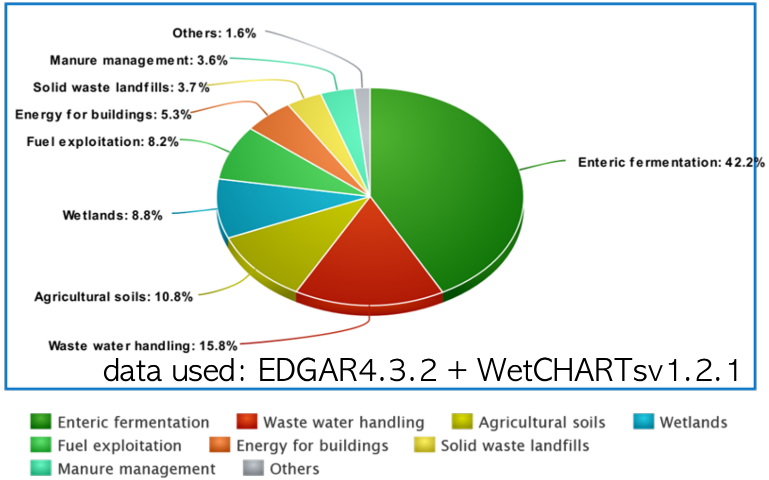
Background and Motivation

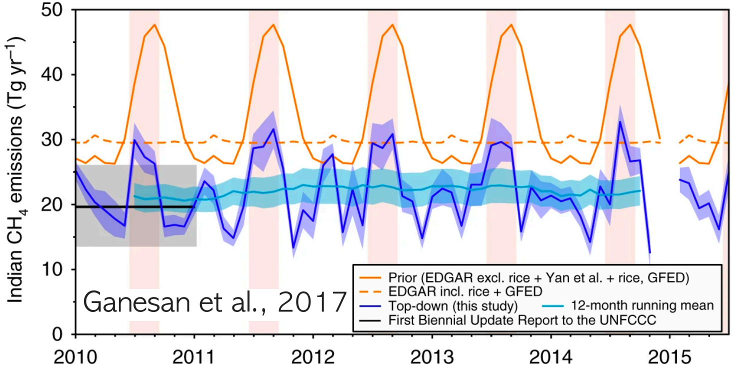
- Methane is the second largest anthropogenic contributor to climate change after CO_2.
- Complexity in CH_4 sources: Anthropogenic and natural sources are uncertain and the processes are often co-located.
- Trends in annual growth rate: To date, there is no consensus on what caused the levelling off (in 1990s), renewed growth, or accelerating rise (after 2015) of CH_4.
- Short life-time of CH_4 (~10 y) makes it an interesting target for mitigating near-term climate change (by reducing radiative forcing on fast time-scales)- "low-hanging fruit"



Ed Dlugokencky, NOAA/ESRL (www.esrl.noaa.gov/gmd)

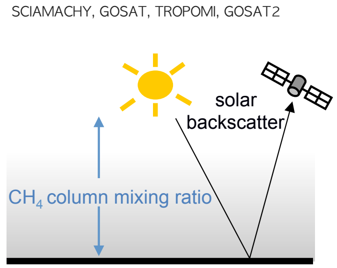
Indian Methane emissions are largely comprised by anthropogenic sources

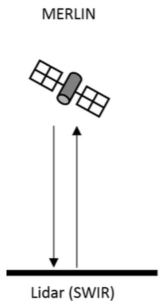


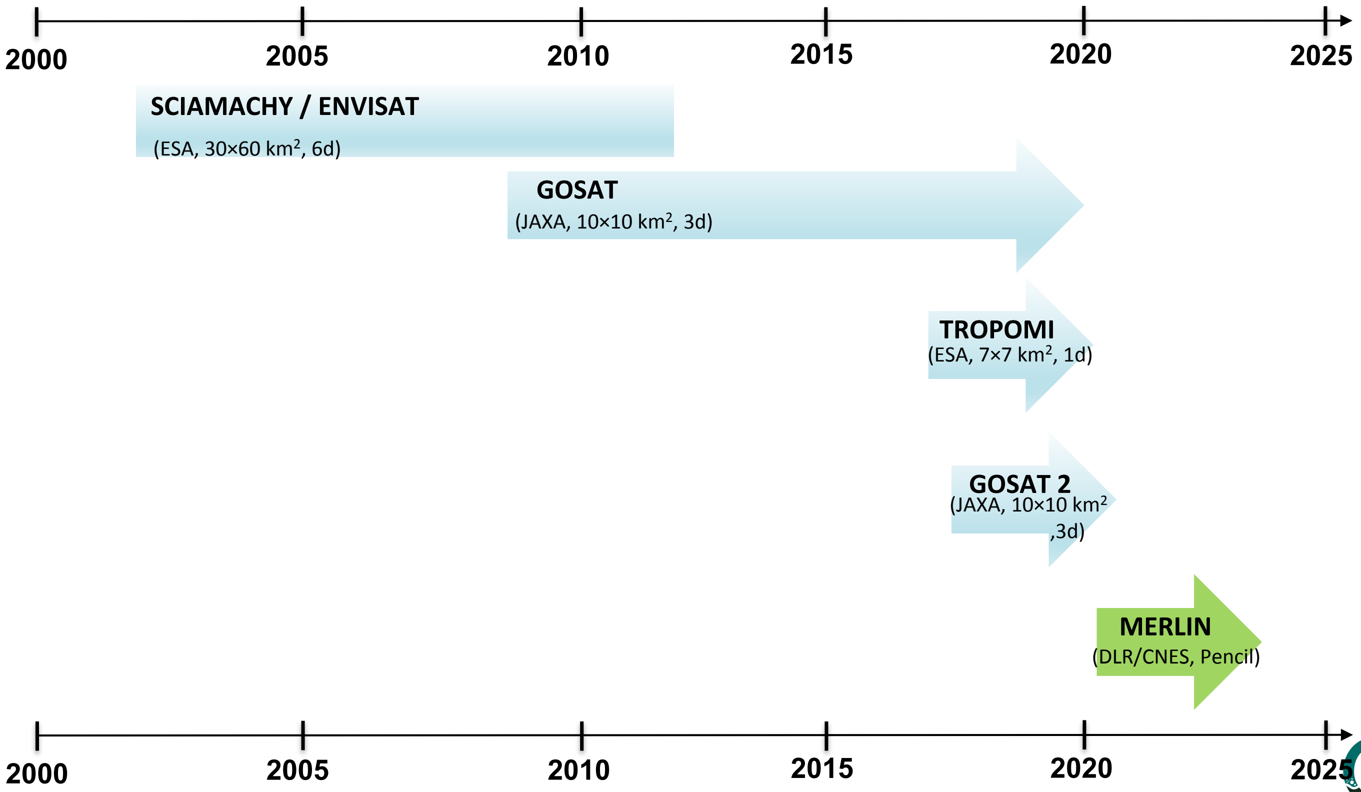


- Largest contribution from ruminants, followed by waste water, fossil fuels and rice paddies. Range of contributions differ significantly from inventory to inventory
- Wetland (natural source) emission contribution range from ~0.5 to 9% depending on the wetland model used.
- Rice and biomass burning emissions exhibit seasonality
- Independent emission verification: No sufficient surface measurements available

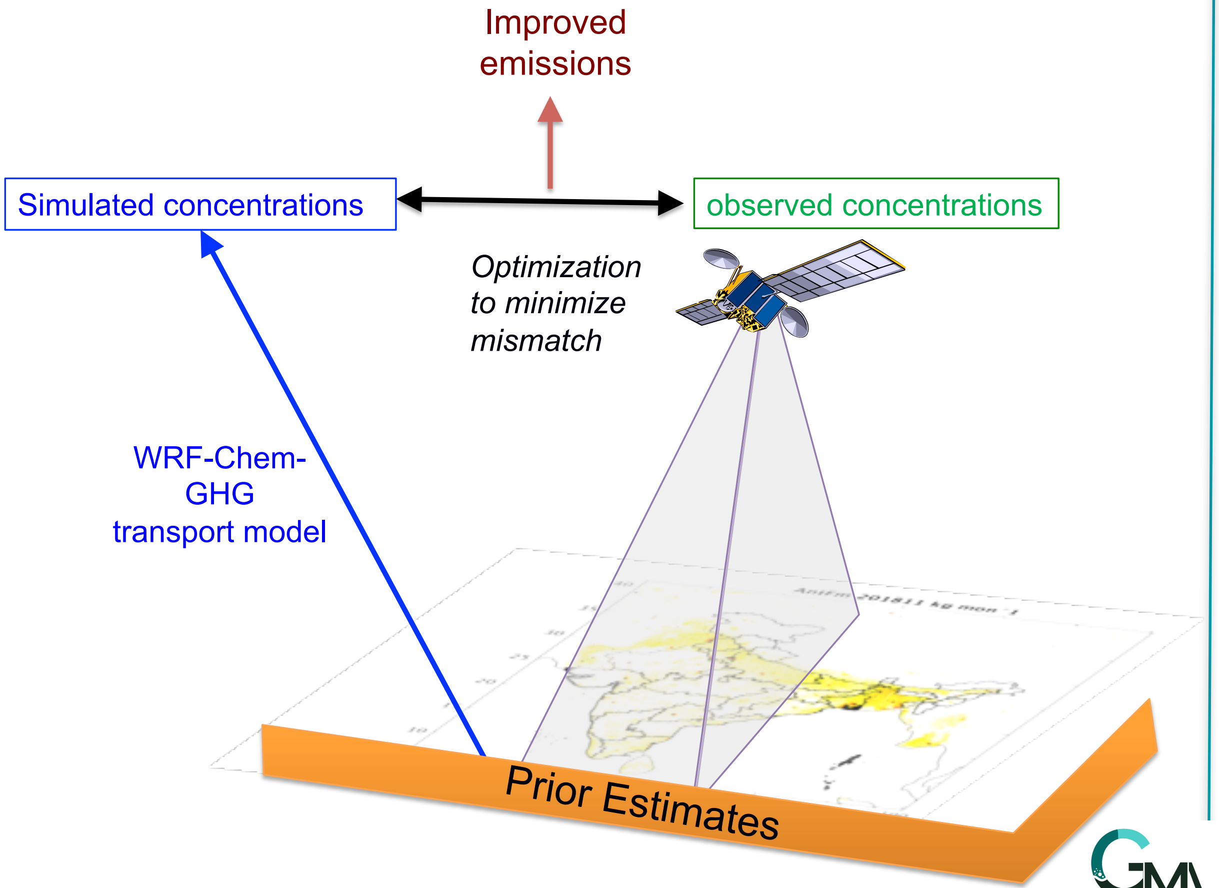
Good news is the expansion of satellite fleet for observing Methane at high precision and accuracy







Our approach uses TROPOMI observations to improve emission inventories



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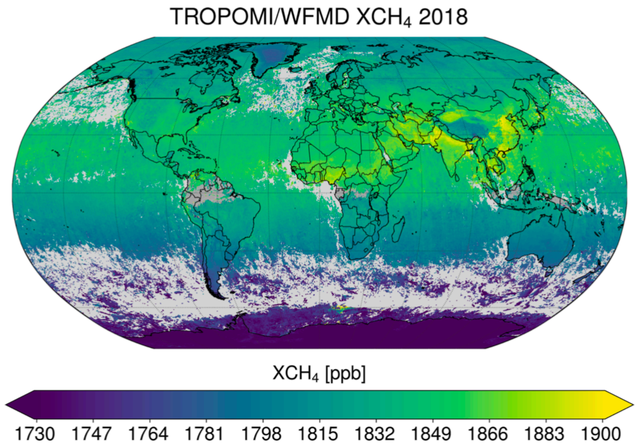
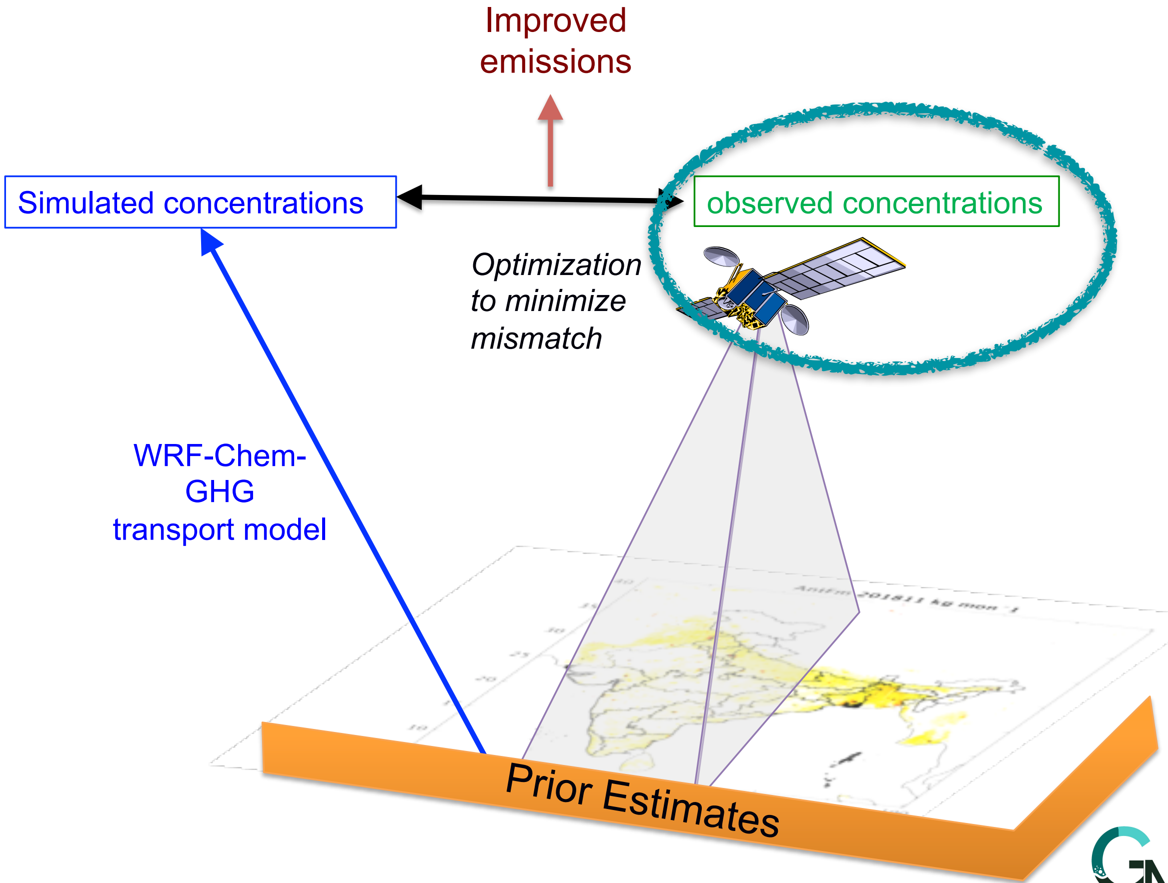


Schneising et al., 2019



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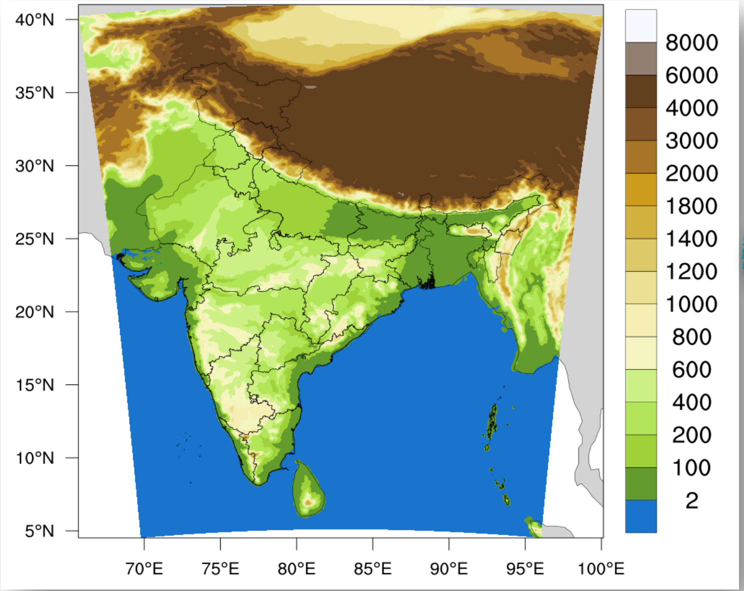
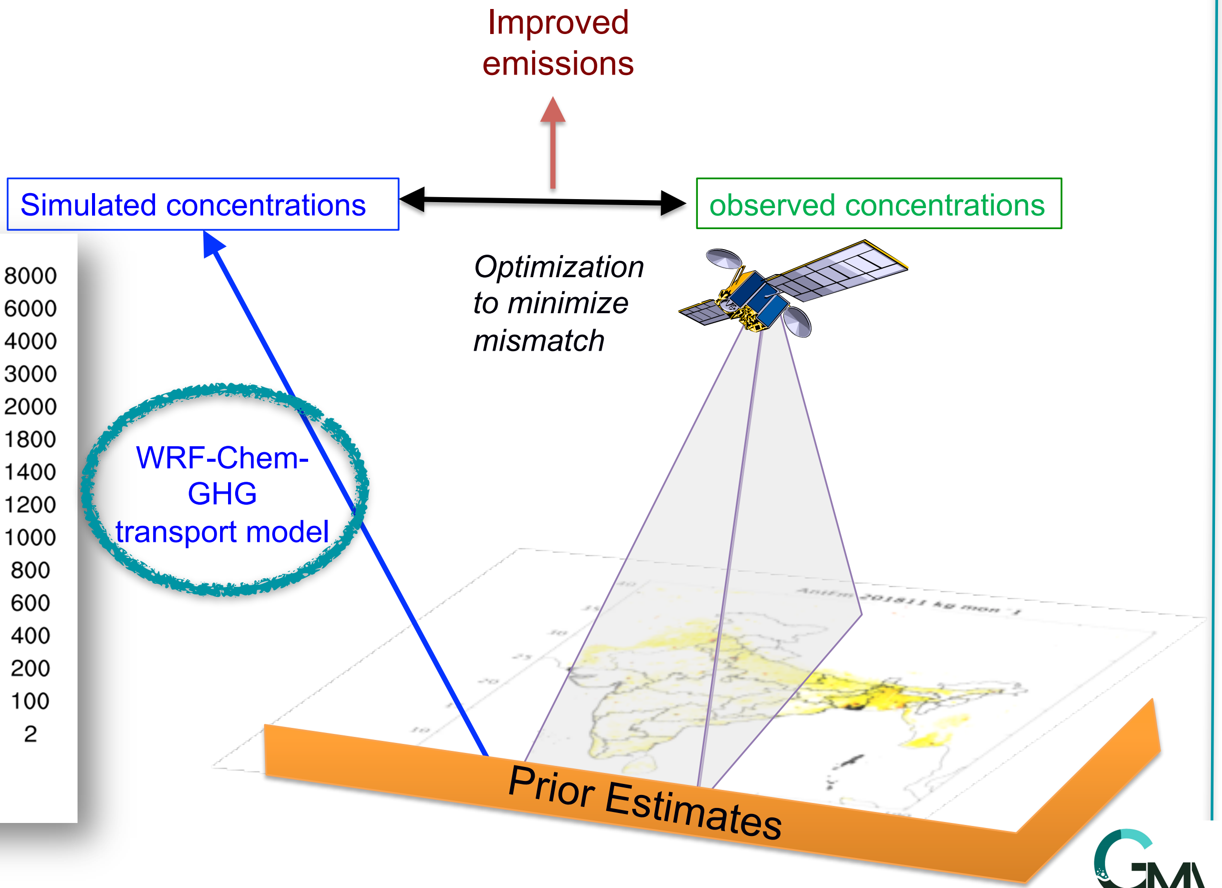
WRF-GHG Model domain
showing terrain height





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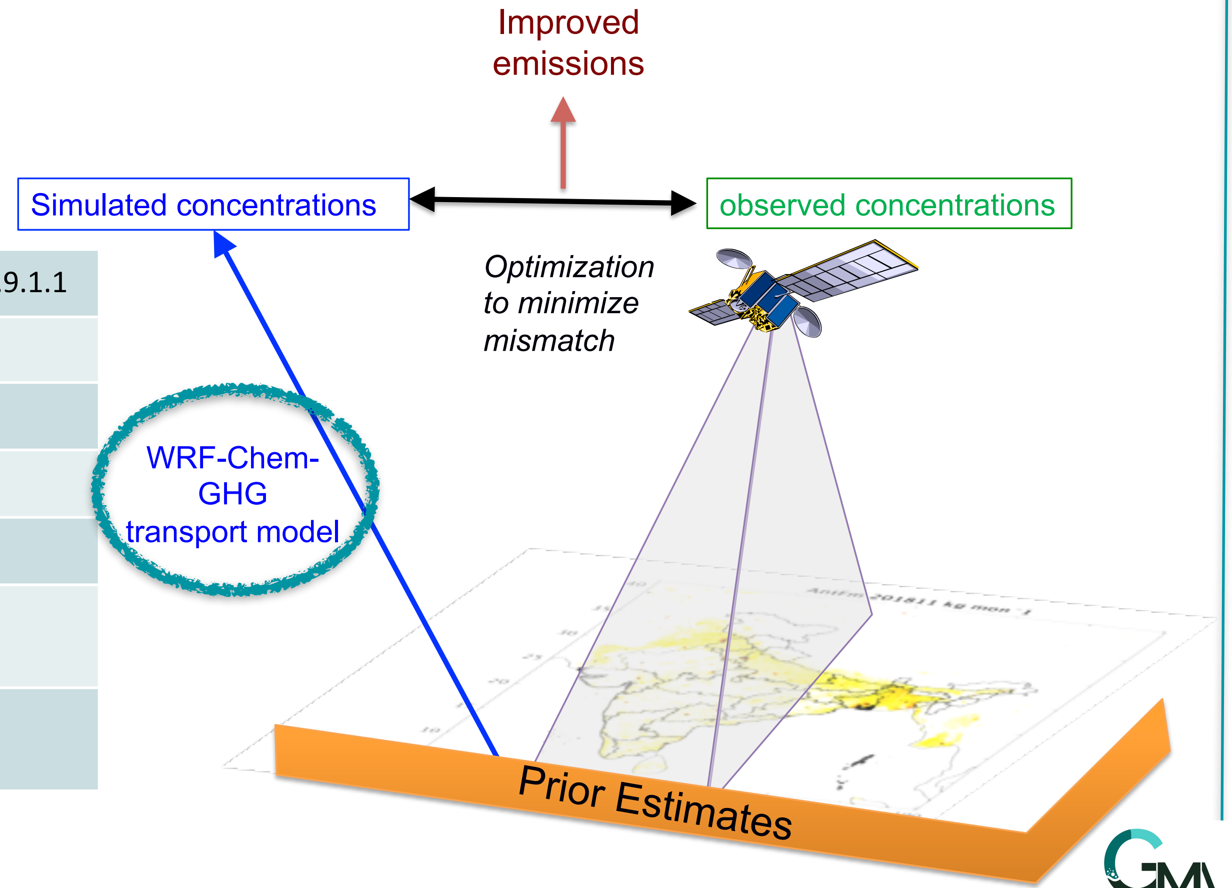
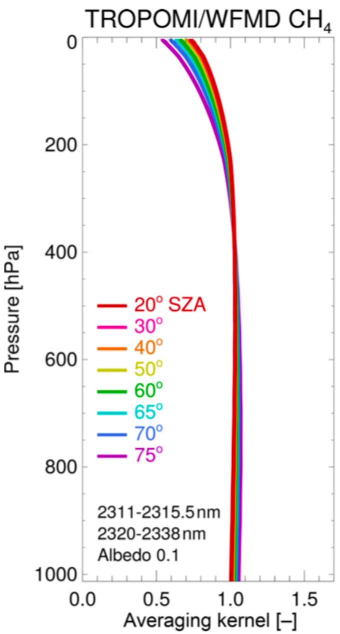
WRF-GHG Model Configuration

Model, Version	WRF-Chem-GHG, 3.9.1.1
Horizontal resolution	10 km x 10 km
Temporal resolution	1 hour
Domain area	3080 x km²
Vertical grid	40 layers
Initial tracer & Met. fields	CAMS, ERA5
Prior fluxes	EDGAR, GFAS, and WetCHARTs

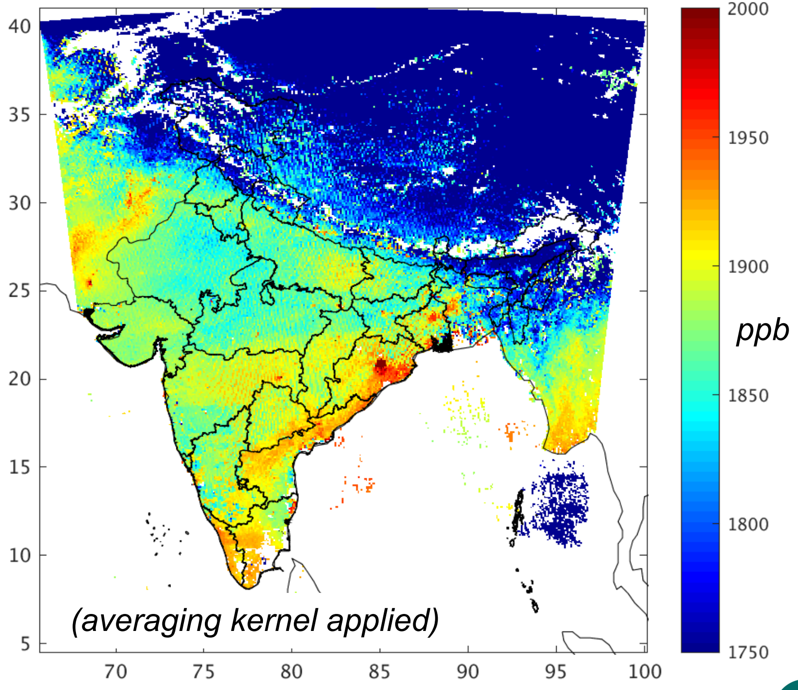


Model predictions of atmospheric XCH_4 after applying temporal sampling and averaging kernel



Schneising et al., 2019

WRF XCH_4 averaged for November 2018



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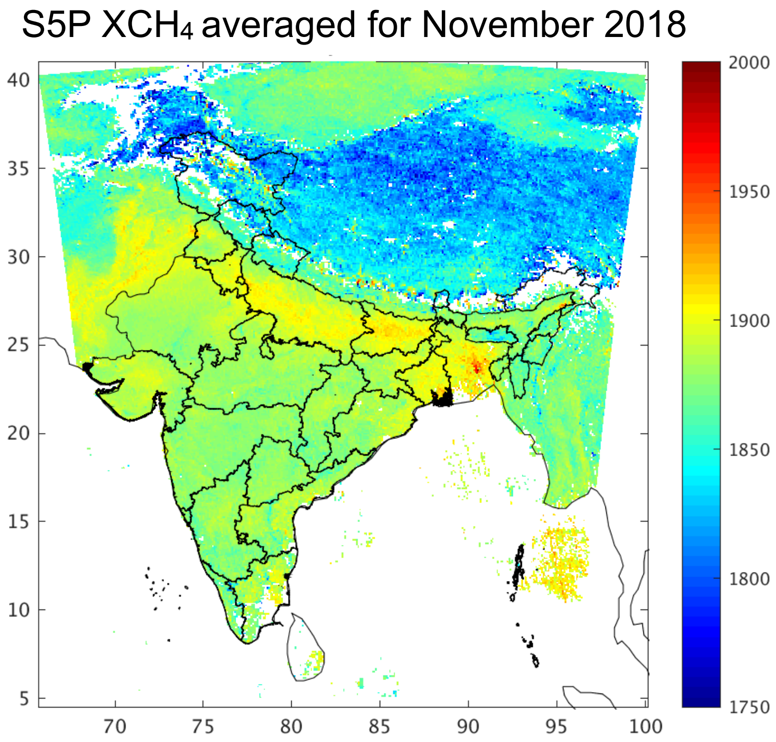
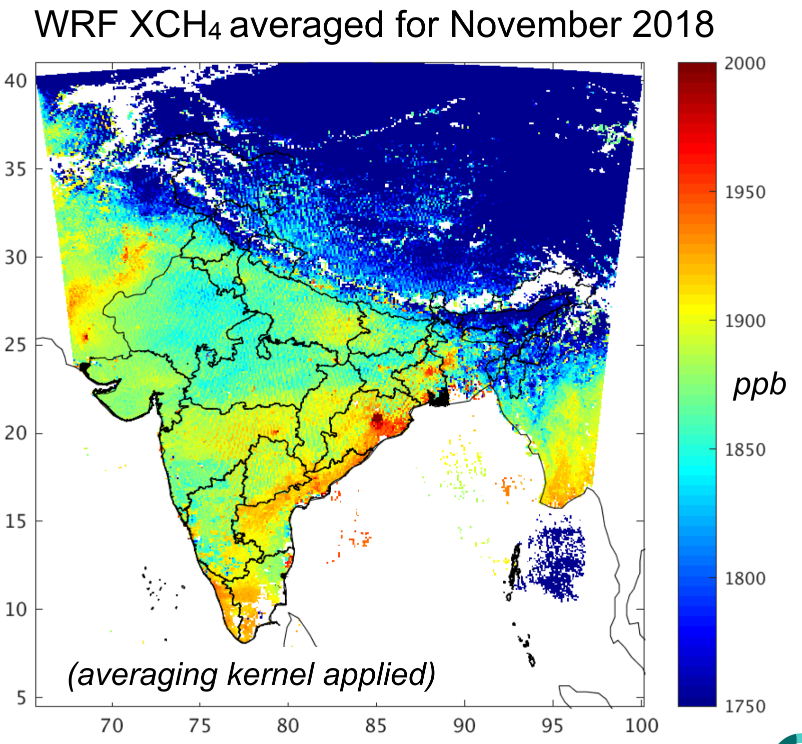
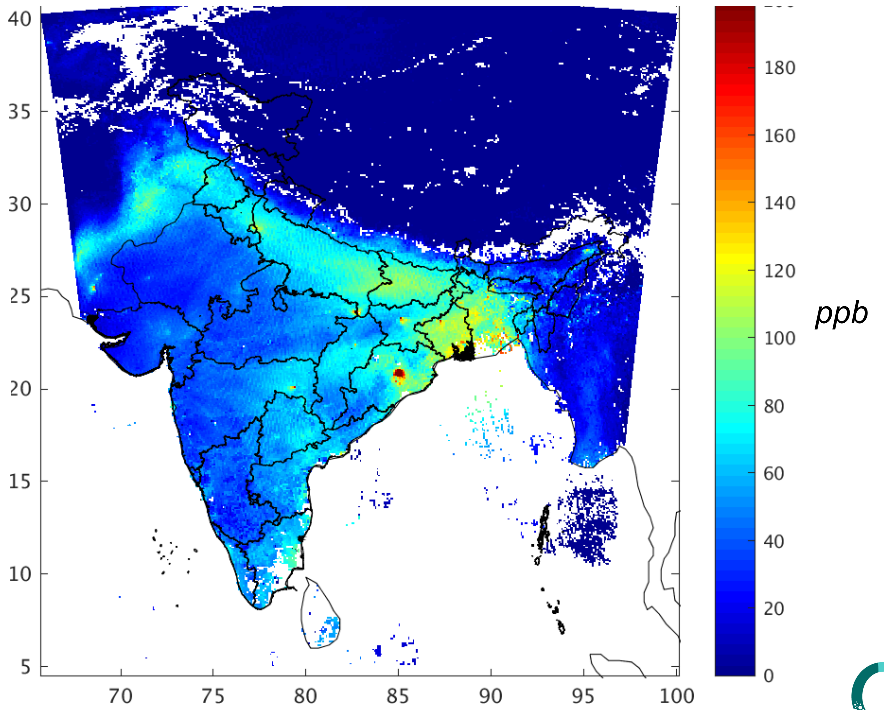




Separating tracers suggests possible overestimated anthropogenic contribution over Indian region

Anthropogenic contribution for November 2018

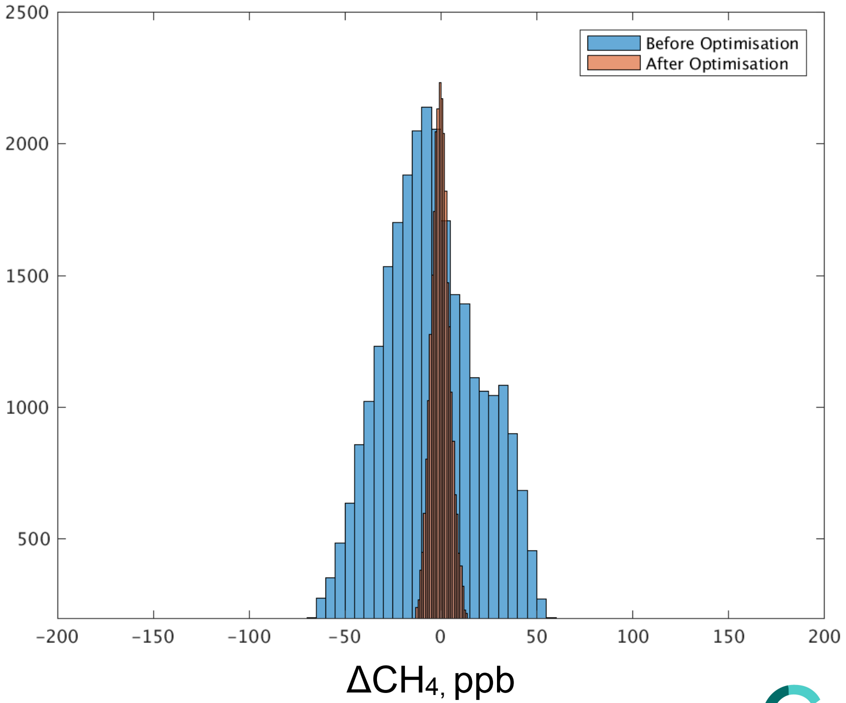


Optimisation of WRF model emission is performed by minimising the cost function

Optimisation design

- WRF tracers (contributions) are separated to understand how each one contributes independently
- Observation vector: All available good S5P column observations for November 2018
- State vector: Scaling factors for monthly averaged exchange fluxes for each political states of India
- Transport error in WRF is ignored

Model-Observations November 2018



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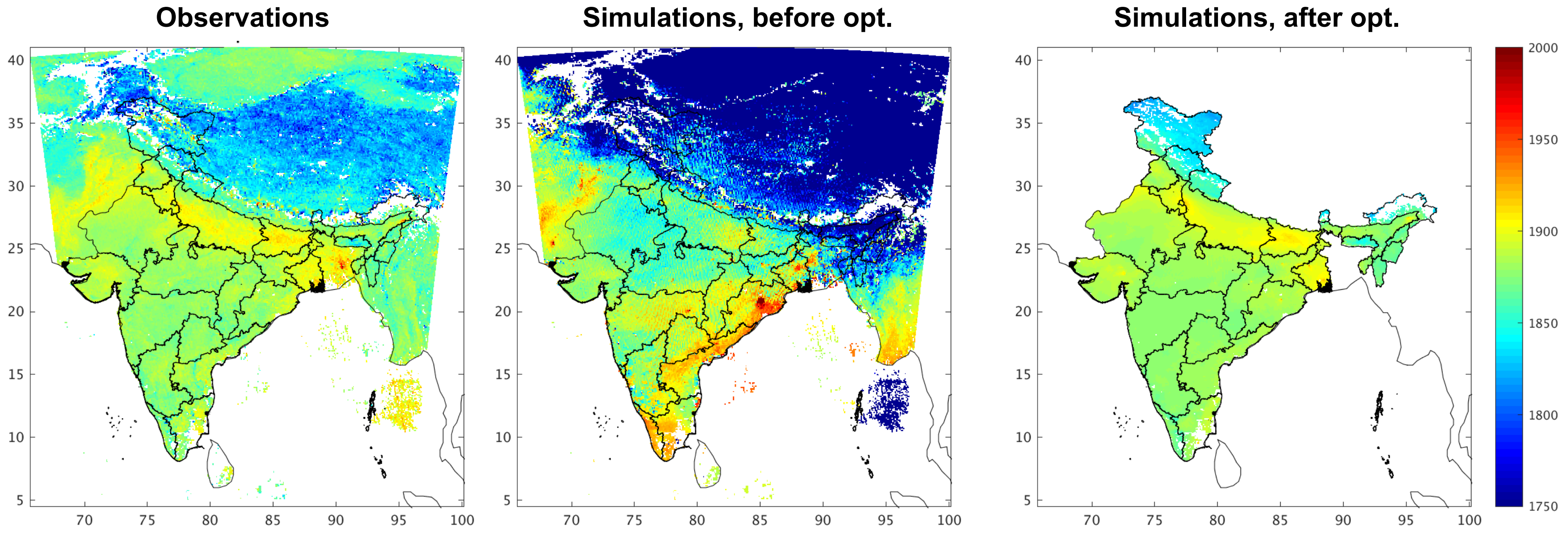

TROPOMI derived anthropogenic Methane emissions in comparison with other estimates

Top-down quantification using satellite observations

- Our estimation of Indian methane emission is consistent with Ganesan et al., 2017.

Bottom-up quantification

- Our current estimations are ~**40%** lower than that of EDGAR and ~**10%** higher than 2010 BUR report submitted to UNFCCC.

		Indian Methane emissions, Tg yr^{-1}
EDGAR v4.3.2, 2012	Bottom-up approach	**31.0**
India's BUR (Biennial Update Report to its National Communications), 2010	Bottom-up approach	**19.8**
Ganesan et al., Nature Communications, 2017	Top-down approach, GOSAT, surface and aircraft observations	**22.0***
This study	Top-down approach, TROPOMI observations	**22.0** 22.9** (including biomass burning emissions)**

*over the period 2010–2015
**November 2018

Takeaways

- Robust evaluation of national Methane emissions is necessary to improve the confidence in India's CH_4 inventory.
- TROPOMI XCH_4 observations pave the way for improving knowledge of methane emissions over India through inverse analyses. However, surface measurements are indispensable.
- A high-resolution atmospheric transport modeling system is required to simulate data from these platforms and to infer fluxes.
- By minimising the cost function, we find a better agreement by scaling down the EDGAR emissions by a factor of ~40%
- Future task: further refinement of inverse method by better taking into account of error characterisation (e.g transport error) of the solution

For questions/comments, please feel free to contact

Email: dhanya@iiserb.ac.in

Greenhouse gas Modeling and Applications Group

IISER Bhopal
INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH BHOPAL