Study the influence of the Asian Summer Monsoon on the Upper Troposphere and Lower Stratosphere Using Methane Distributions

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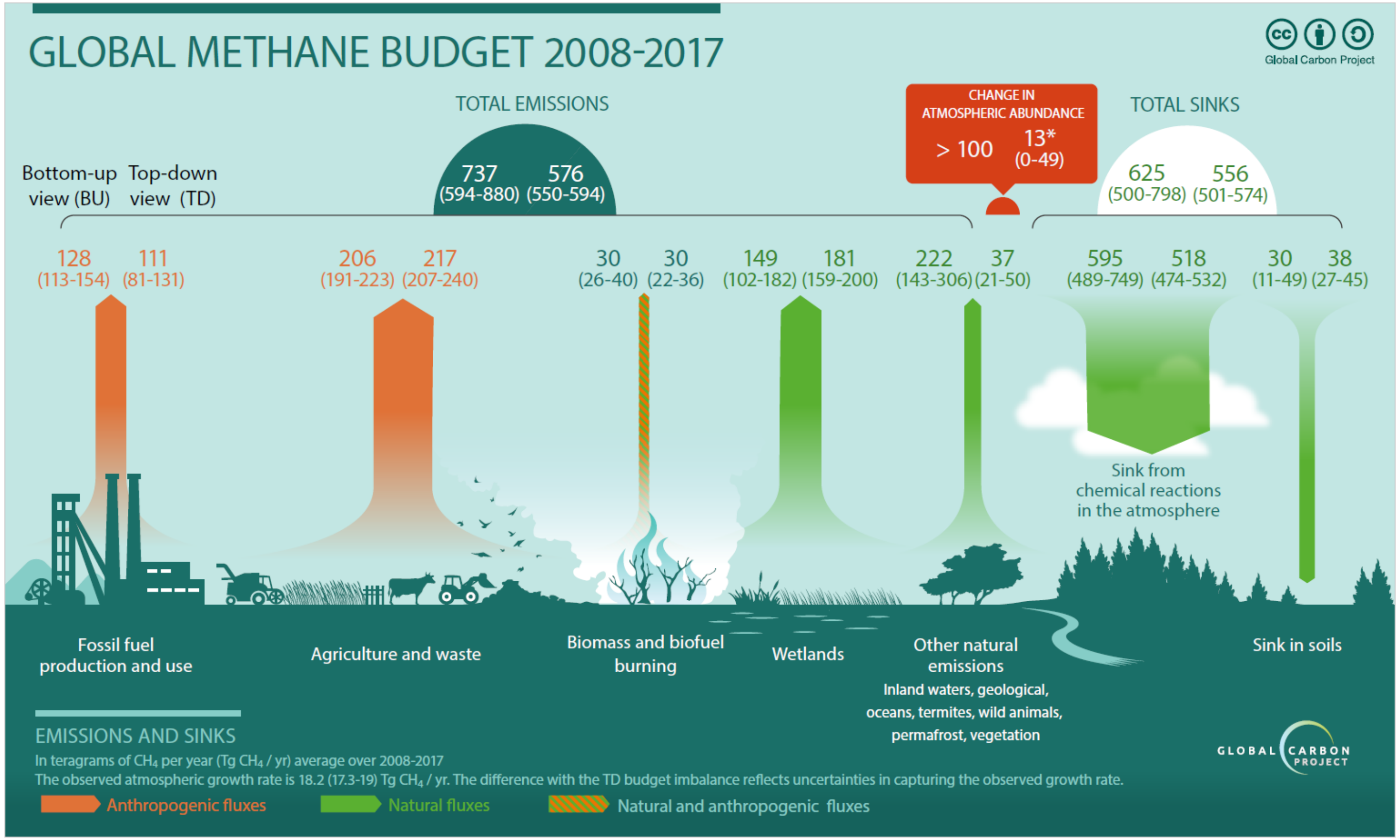
Introduction

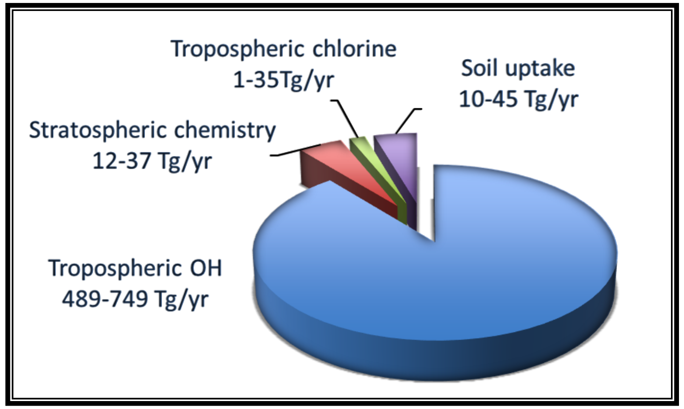
- The atmospheric lifetime of CH_4 is **~9±2** years, making it a very good tracer for tracking medium-term (1-2 months) transport.

- Relatively well studied spatial and temporal patterns of CH_4 in UT/LS using:
  - **Satellite Remote Sensing**
  - **Modeling and Data Assimilation**
  - Ground-Based Remote Sensing
  - Aircraft Campaigns
  - High-Altitude Balloons

- Relatively well resolved spatial and temporal patterns of emissions: 550-594 Tg-$CH_4 yr^{-1}$

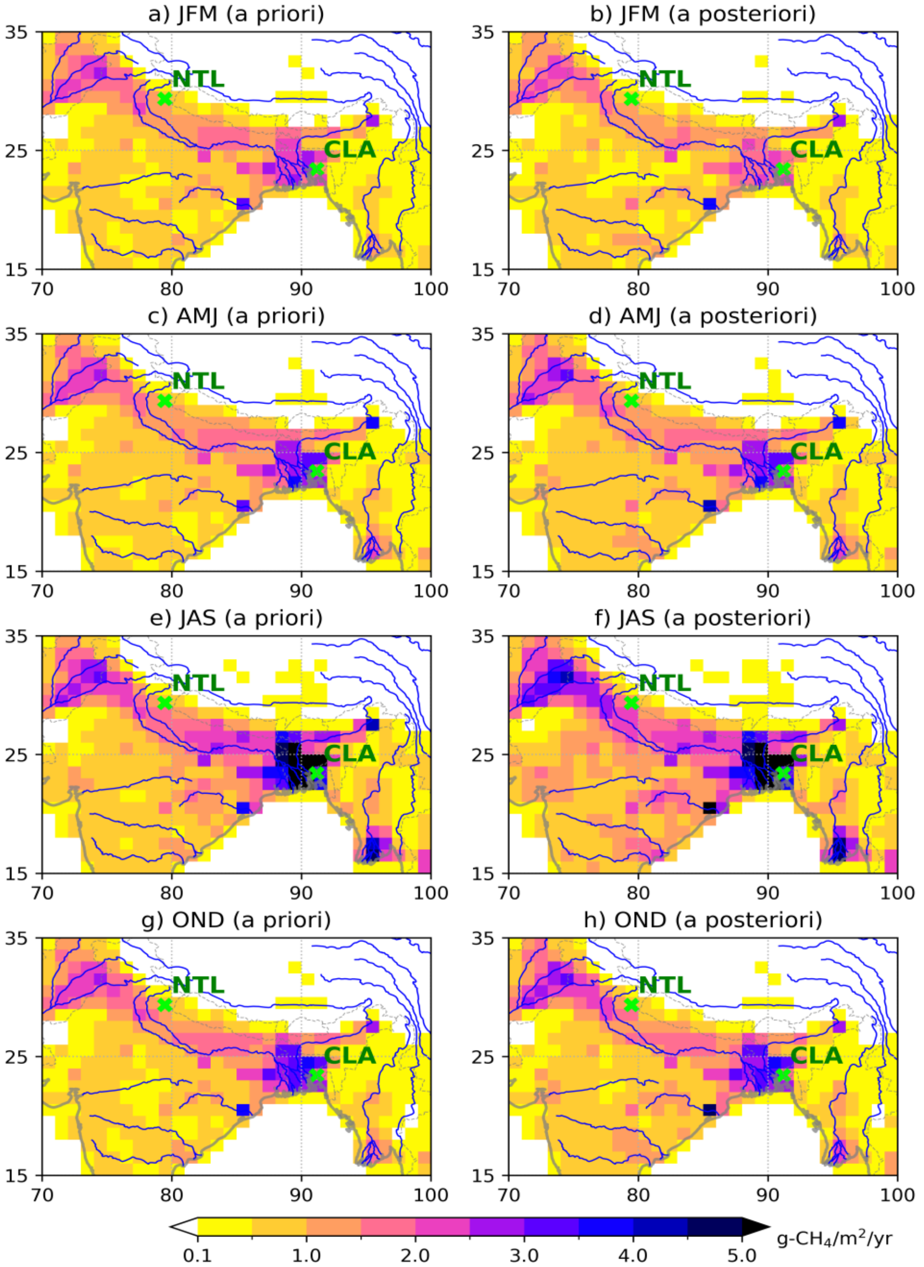
- Tropospheric hydroxyl (**OH**) concentration determines CH_4 lifetime, but its variability and trends are highly uncertain.

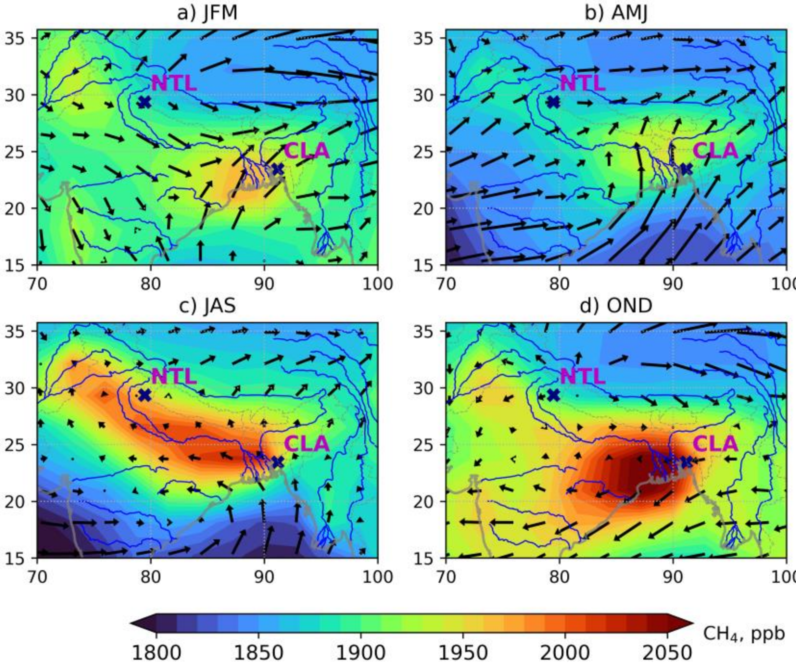


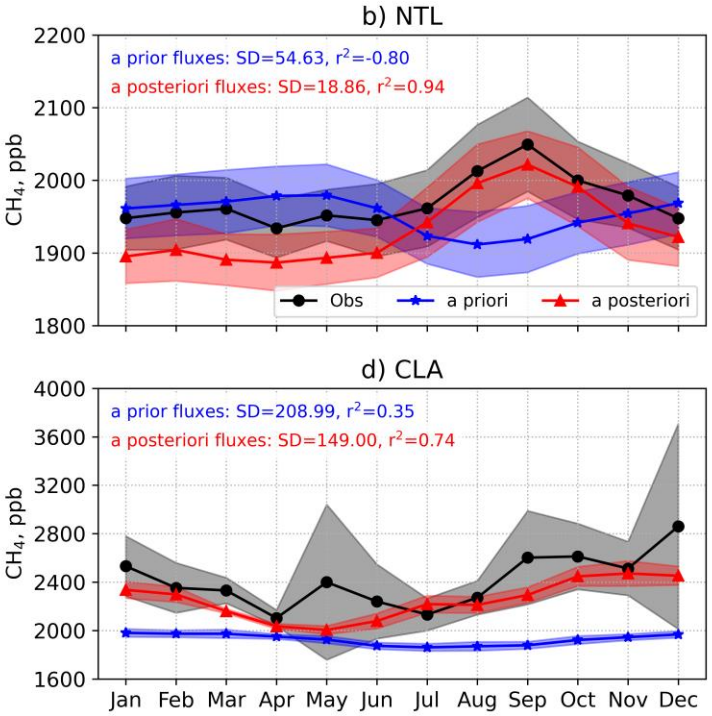


Saunois et al. 2016; 2020, ESSD

Introduction



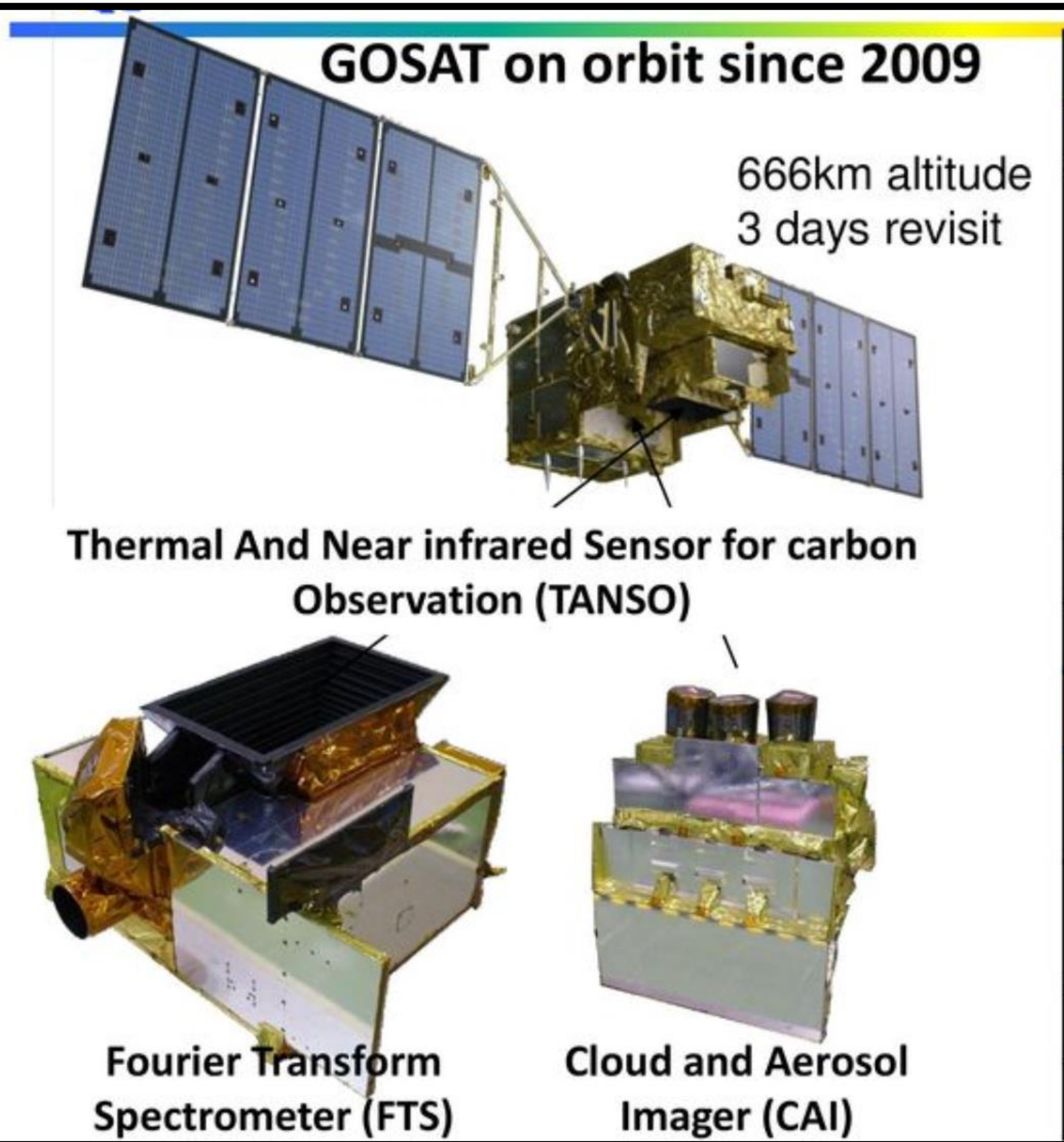




Belikov et al., PEPS, 2024

- Indo-Gangetic Plain (IGP) is densely populated region with strong emissions of various tracers due to human activity.
- The recent economic growth has led to a significant increase in industrial emissions of CH_4 in the IGP.
- The Asian Summer Monsoon Anticyclone (ASMA) is a dominant circulation pattern in the Upper Troposphere and Lower Stratosphere (UT/LS) in the northern hemisphere in summer

GOSAT thermal infrared (TIR) and shortwave infrared (SWIR) bands

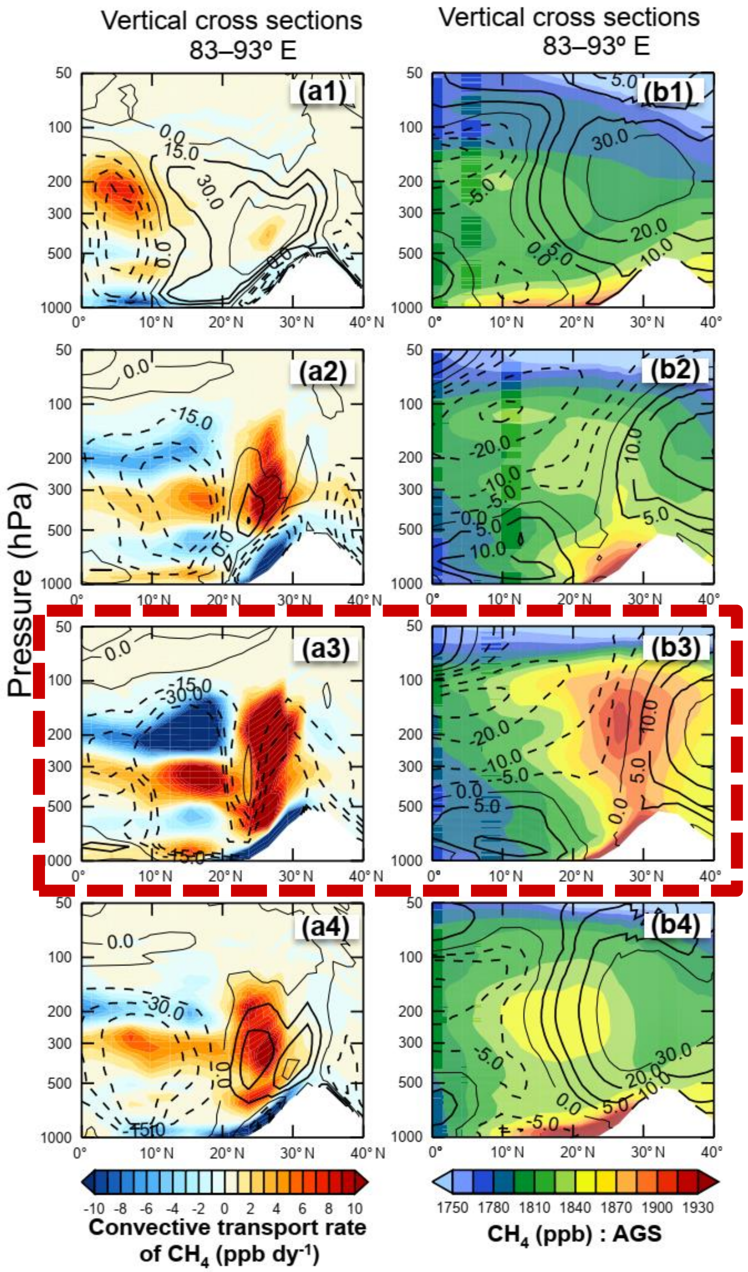


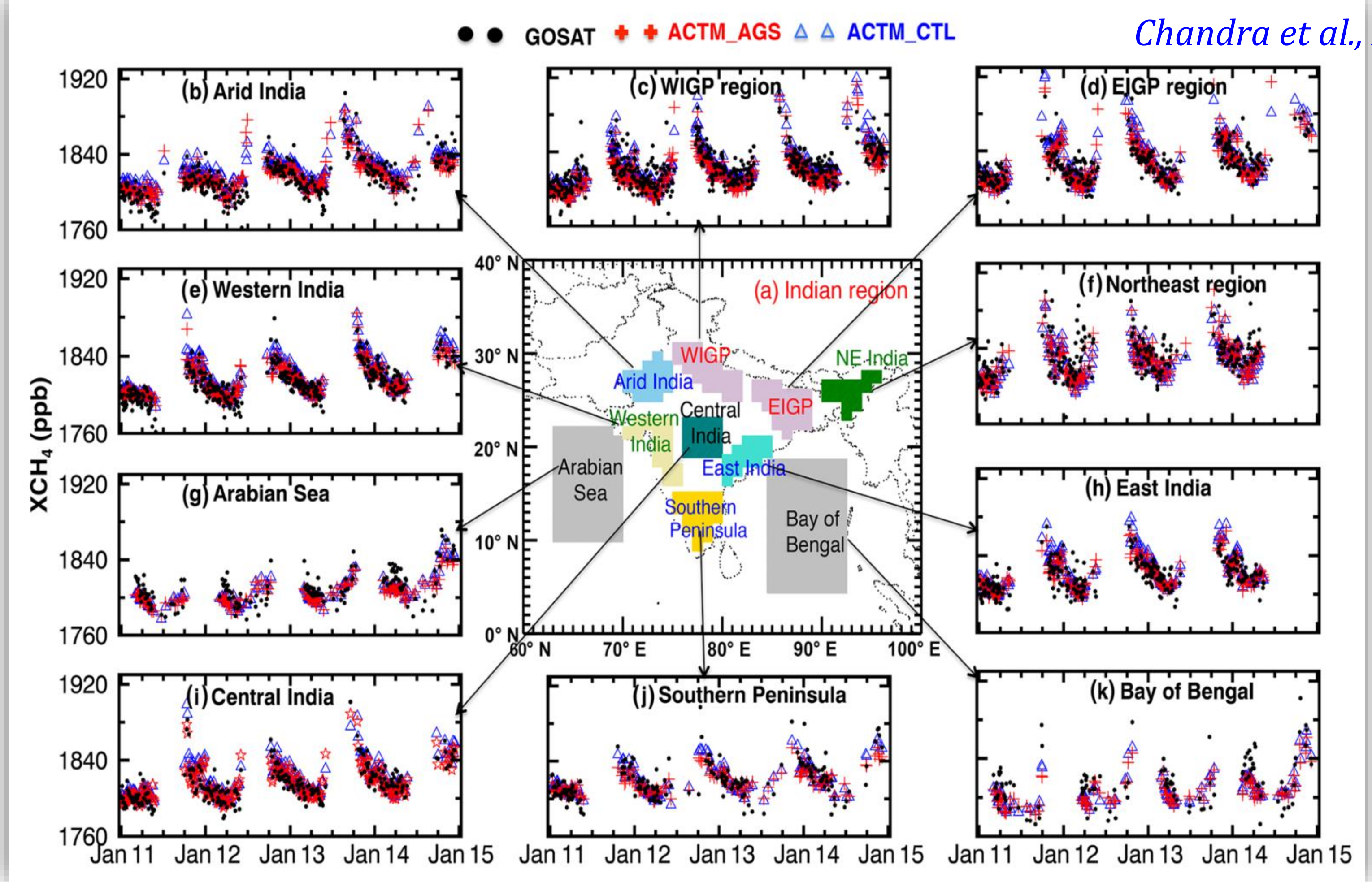
Fourier Transform Spectrometer (FTS)	
Mission	GHGs measurements
Band	SWIR-0.76μm, 1.6μm, 2.0μm bands with P/S polarization (O_2-A, CO_2, CH_4, H_2O band)
	TIR-5.5~14.3μm (CO_2, CH_4, O_3 band)
SPC Res.	0.2cm^{-1}
Swath	750km(3 points every 260km)
IFOV	10.5km

Cloud and Aerosol Imager (CAI)	
Mission	Cloud detection and aerosol correction within FTS IFOV
Band	Nadir view 0.38, 0.67, 0.87, 1.60μm band
Swath	750-1000km
Footprint	0.5 and 1.5km

by Kei Shiomi, JAXA

CH_4 from GOSAT-SWIR and the ACTM transport model

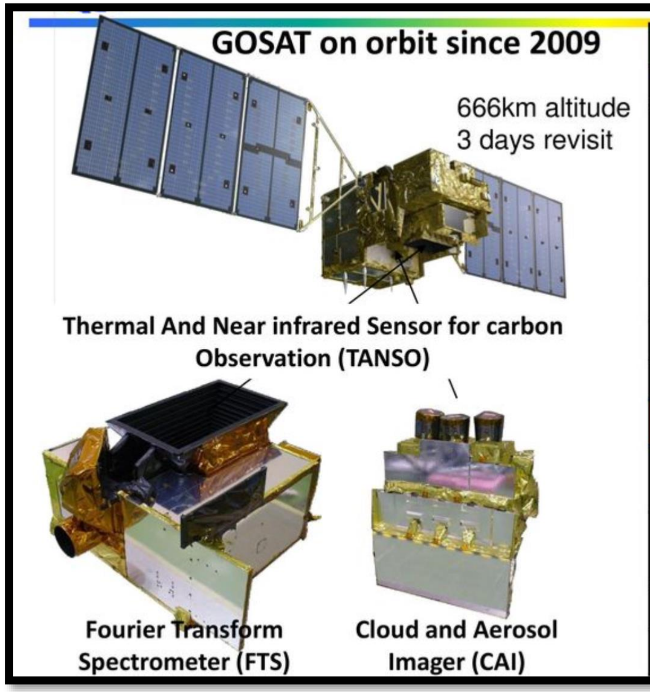




Chandra et al., ACP, 2017

- The CH_4 seasonal cycle is controlled by the surface emissions and the influence of the global monsoon circulations. The large contrast between monsoon, and pre- and post-monsoon profiles of CH_4
- A strong difference between seasons in the middle and upper troposphere is caused by convective transport.

GOSAT thermal infrared (TIR) and shortwave infrared (SWIR) bands



Fourier Transform Spectrometer (FTS)	
Mission	GHGs measurements
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	TIR-5.5~14.3μm (CO_2, CH_4, O_3 band)
SPC Res.	$0.2cm^{-1}$
Swath	750km(3 points every 260km)
IFOV	10.5km
Cloud and Aerosol Imager (CAI)	
Mission	Cloud detection and aerosol correction within FTS IFOV
Band	Nadir view 0.38, 0.67, 0.87, 1.60μm band
Swath	750-1000km
Footprint	0.5 and 1.5km

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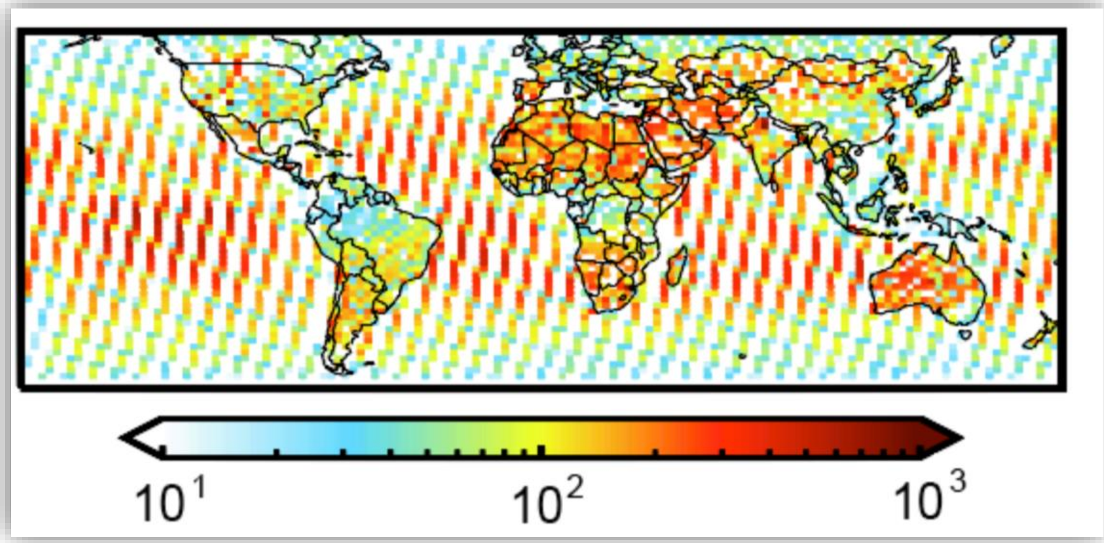
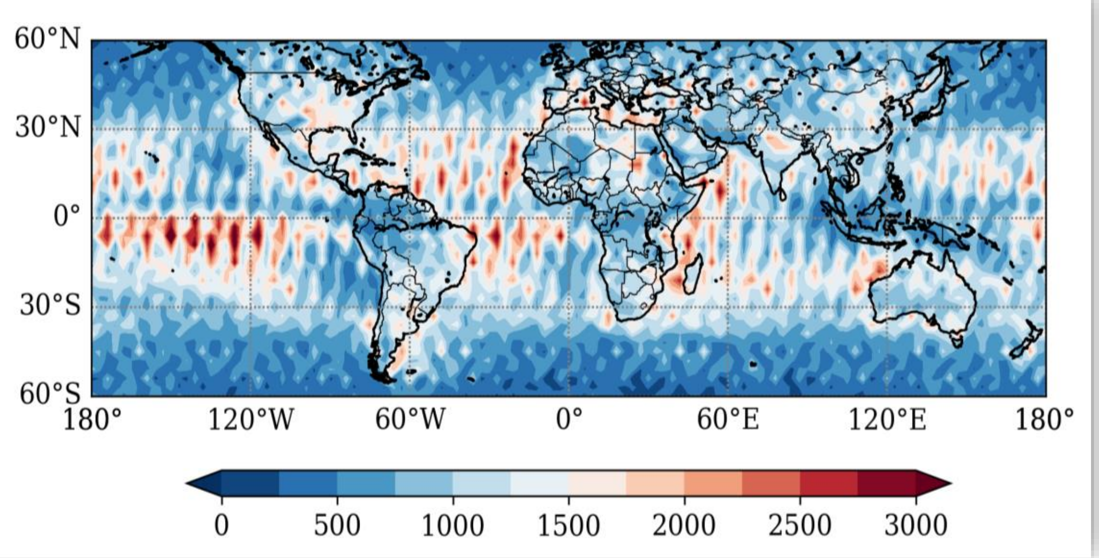
GOSAT-TIR benefits

- Observations could be performed at night and during heavy cloud conditions
- Captures signal at 22 layers from the top of the atmospheric boundary layer (ABL) up to UT/LS (800-150 hPa)
- The sensitivity maximum at the levels of 200–400 hPa

Mean number of observations per year



GOSAT-SWIR

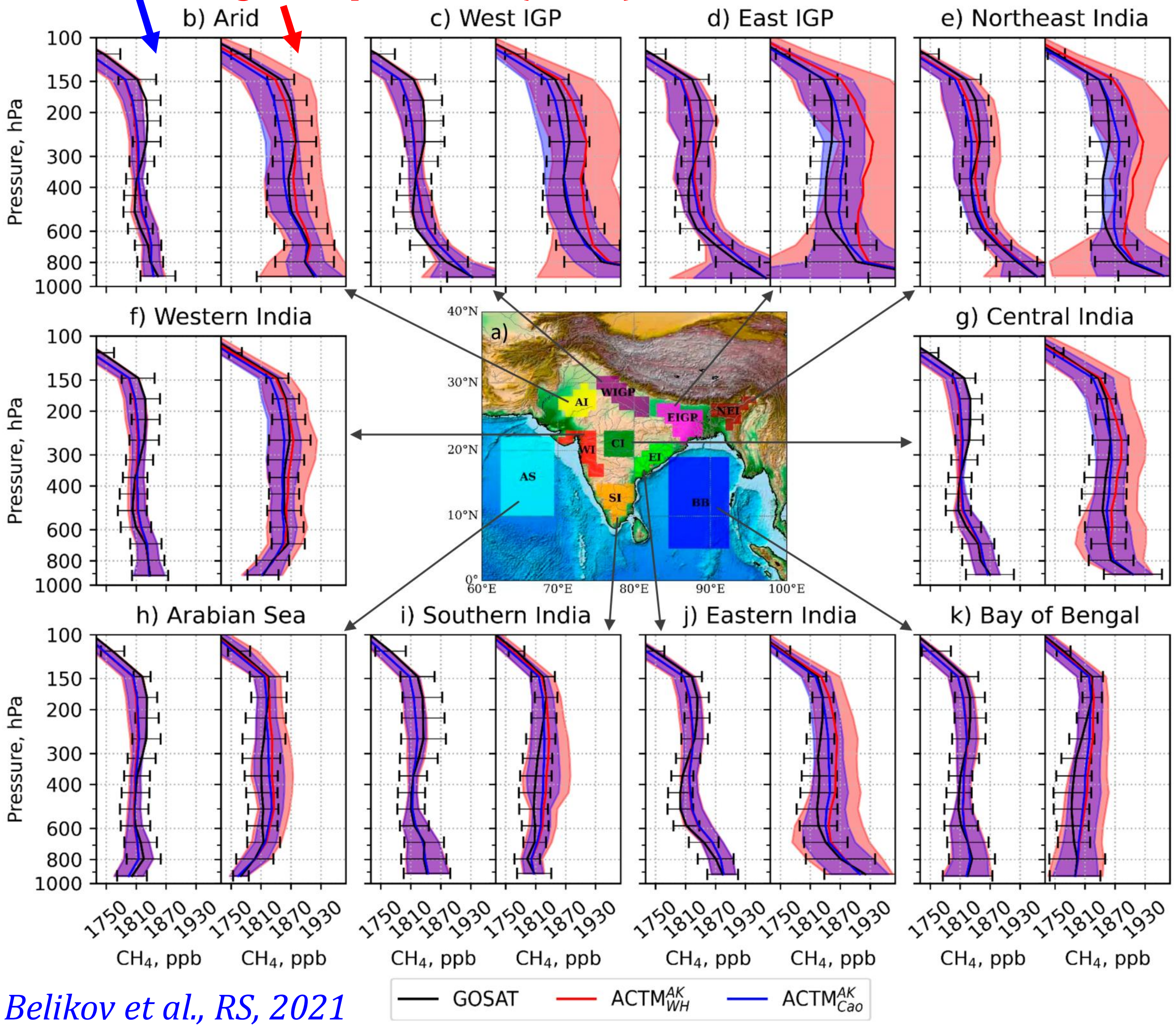


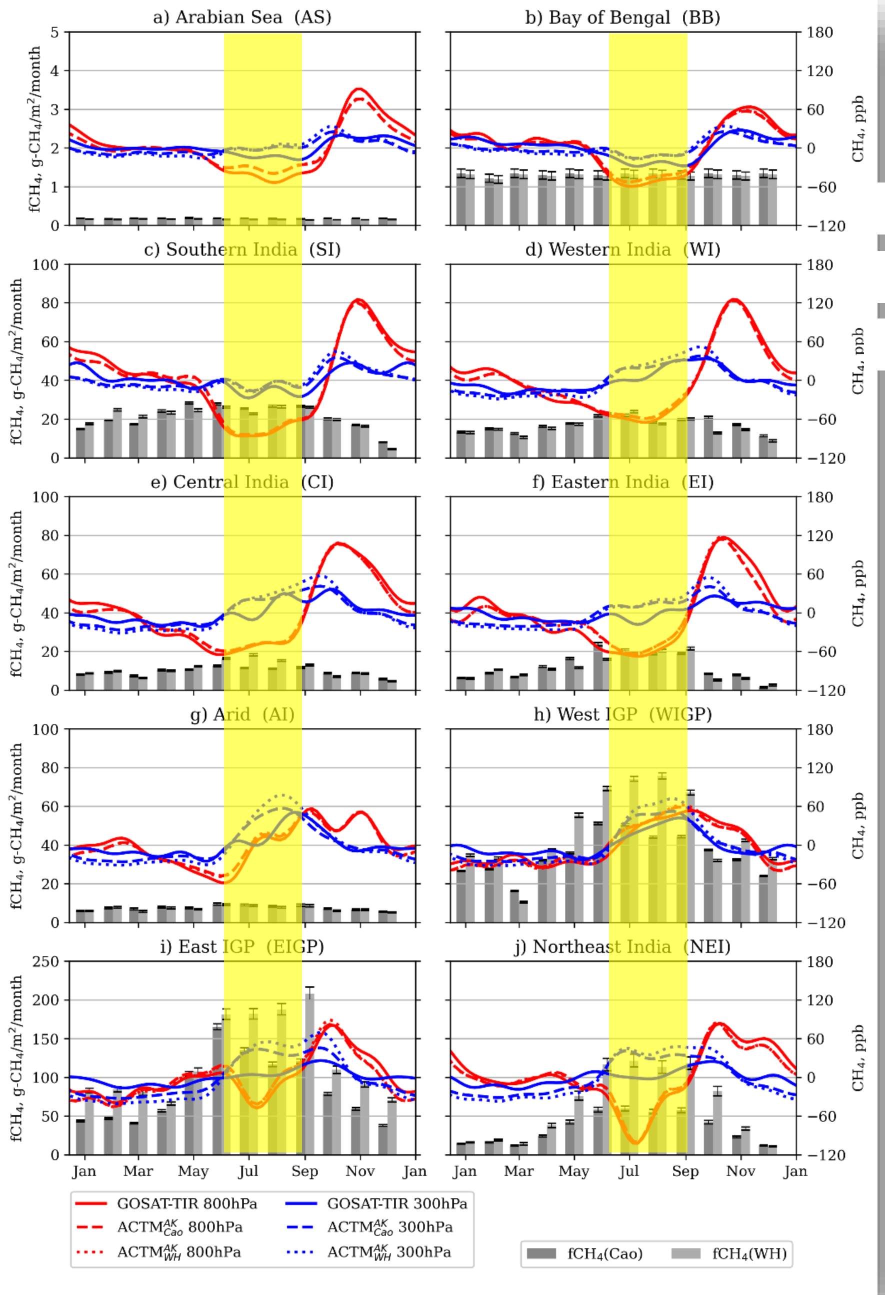
GOSAT-TIR

CH_4 from GOSAT-TIR and the MIROC4-ACTM transport model

Left subpanel: AMJ (pre-monsoon)

Right subpanel: JAS (ASMA)





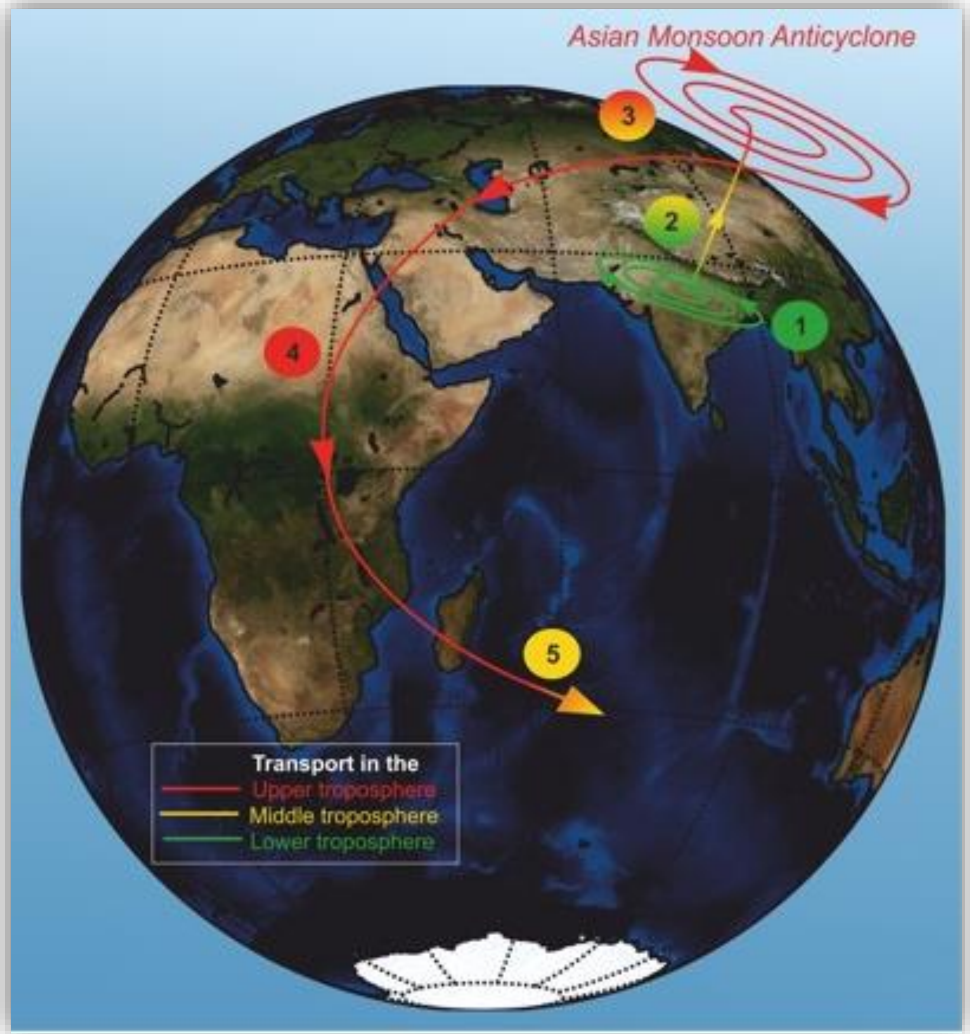
300hPa

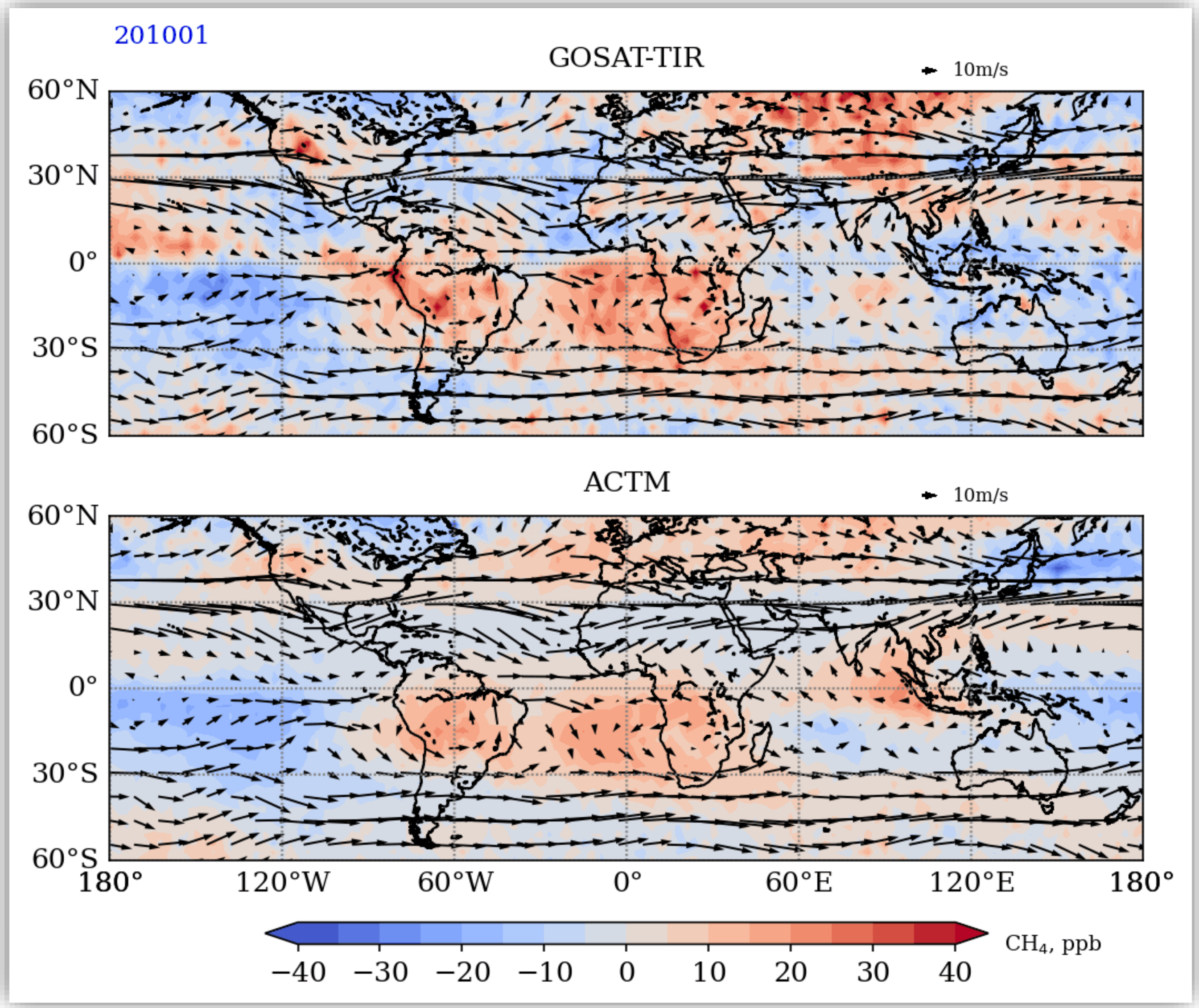
800hPa

CH4 flux

Belikov et al., RS, 2021

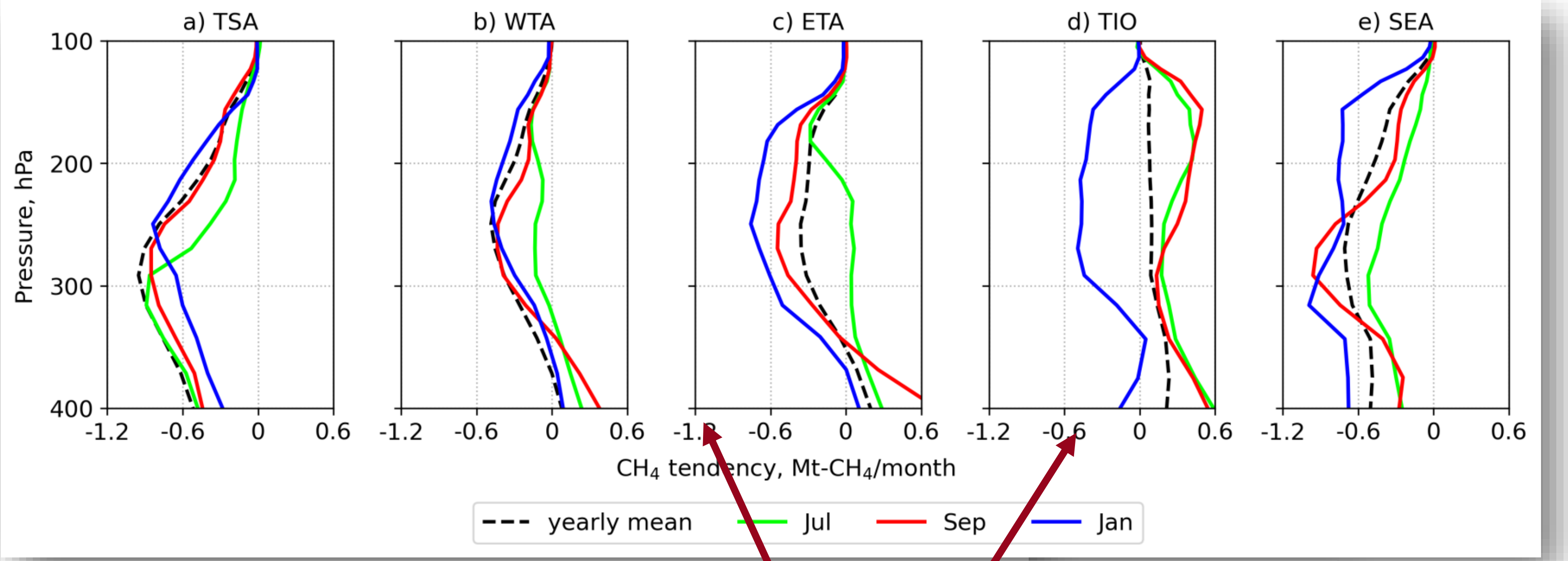
Pathways of CH_4 Interhemispheric transport (IHT)

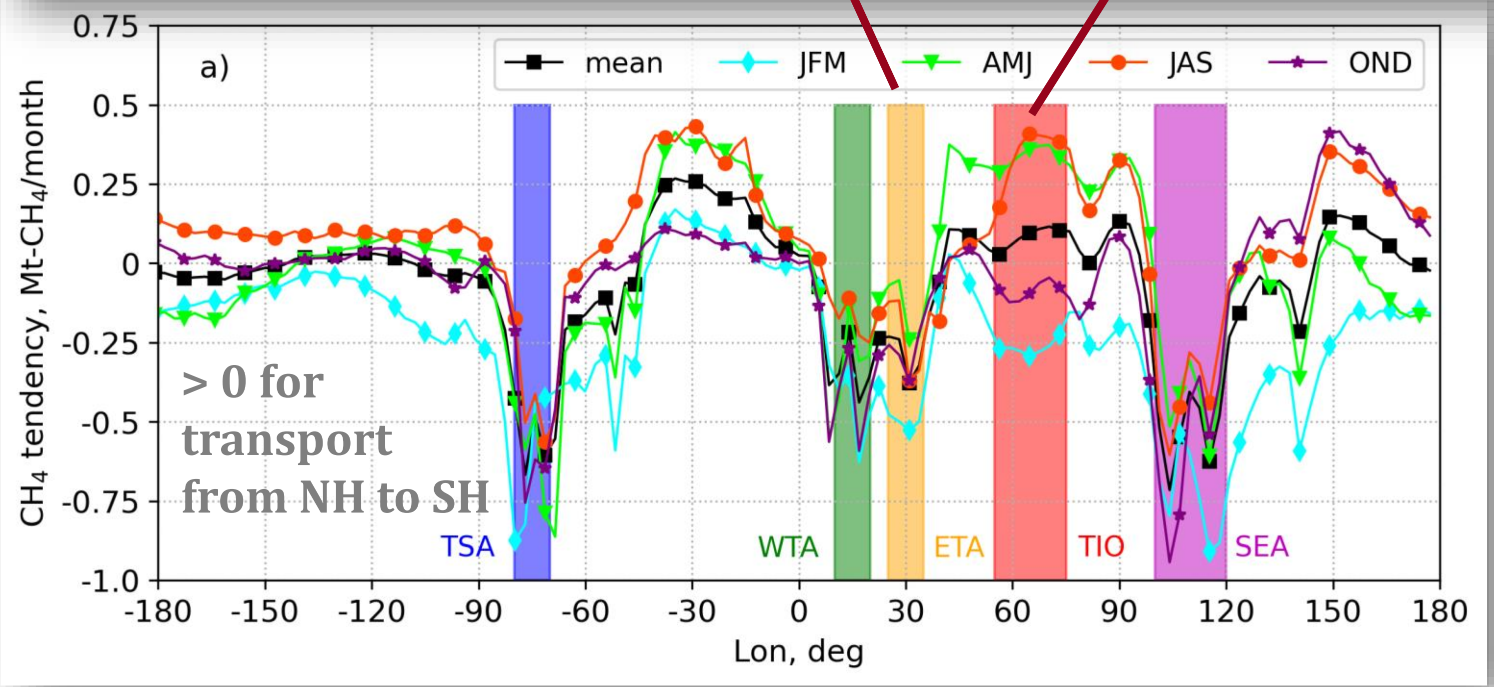




CH_4 averaged over the levels of tropopause + 200 hPa, observed by GOSAT-TIR and modeled for 2010. The zonal mean value of CH_4 was subtracted. Wind vector fields are simulated by MIROC4.

Pathways of CH_4 Interhemispheric transport (IHT)



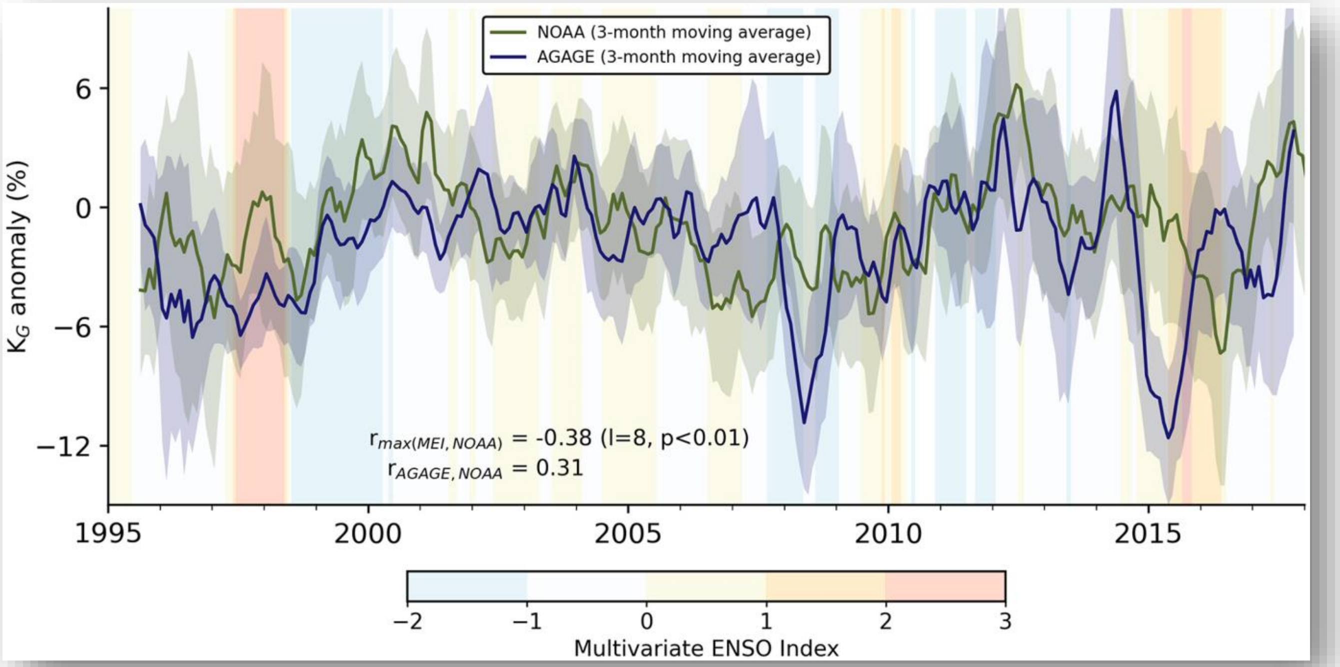


The dual role of ASMA revealed:

- Blocks IH transport in the tropical zone of the Indian Ocean (TIO) and Southeast Asia (SEA).
- Accelerate IH transport over East Africa (ETA).

Belikov et al., JGR, 2022

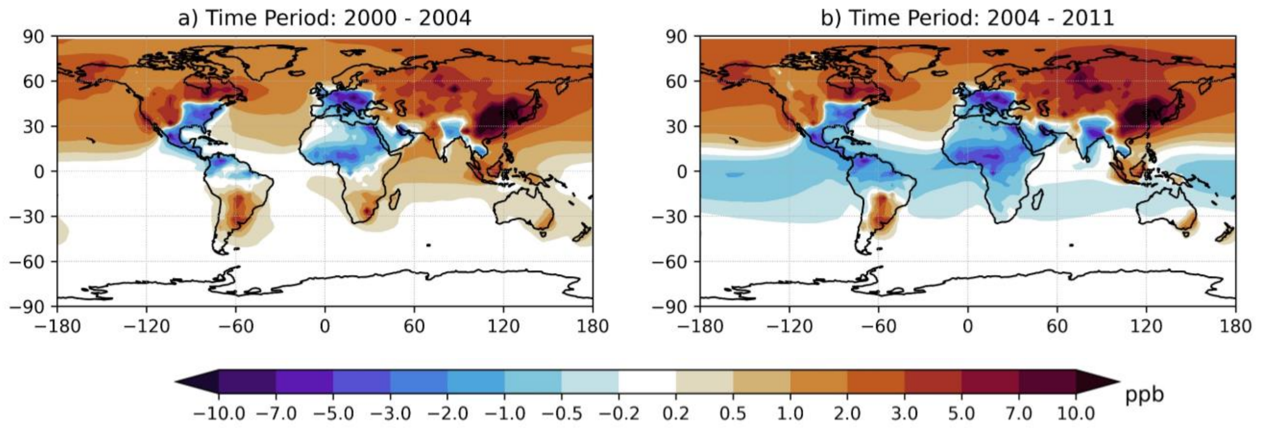
The CH_4 fluxes variation due to the OH difference



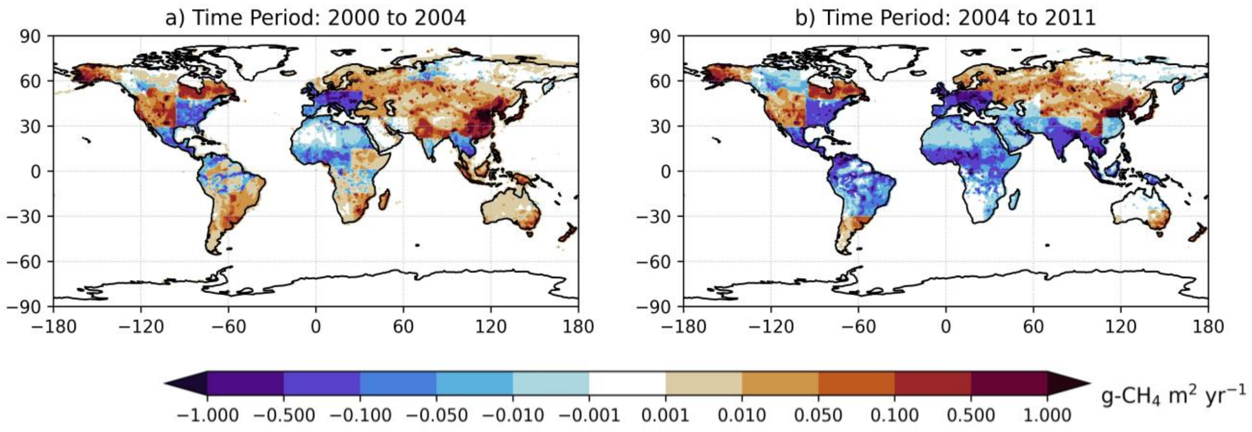
Set of OH fields

Control OH (OH_{CLM}): Climatological OH 3D field (1-year monthly resolution) is provided based on the TRANSCOM experiment (Patra et al., 2011)

Test OH (OH_{IAV}): Varying OH monthly concentrations based on estimations of tropospheric OH variability using methyl chloroform (CH_3CCl_3) (Patra et al., JGR, 2021).

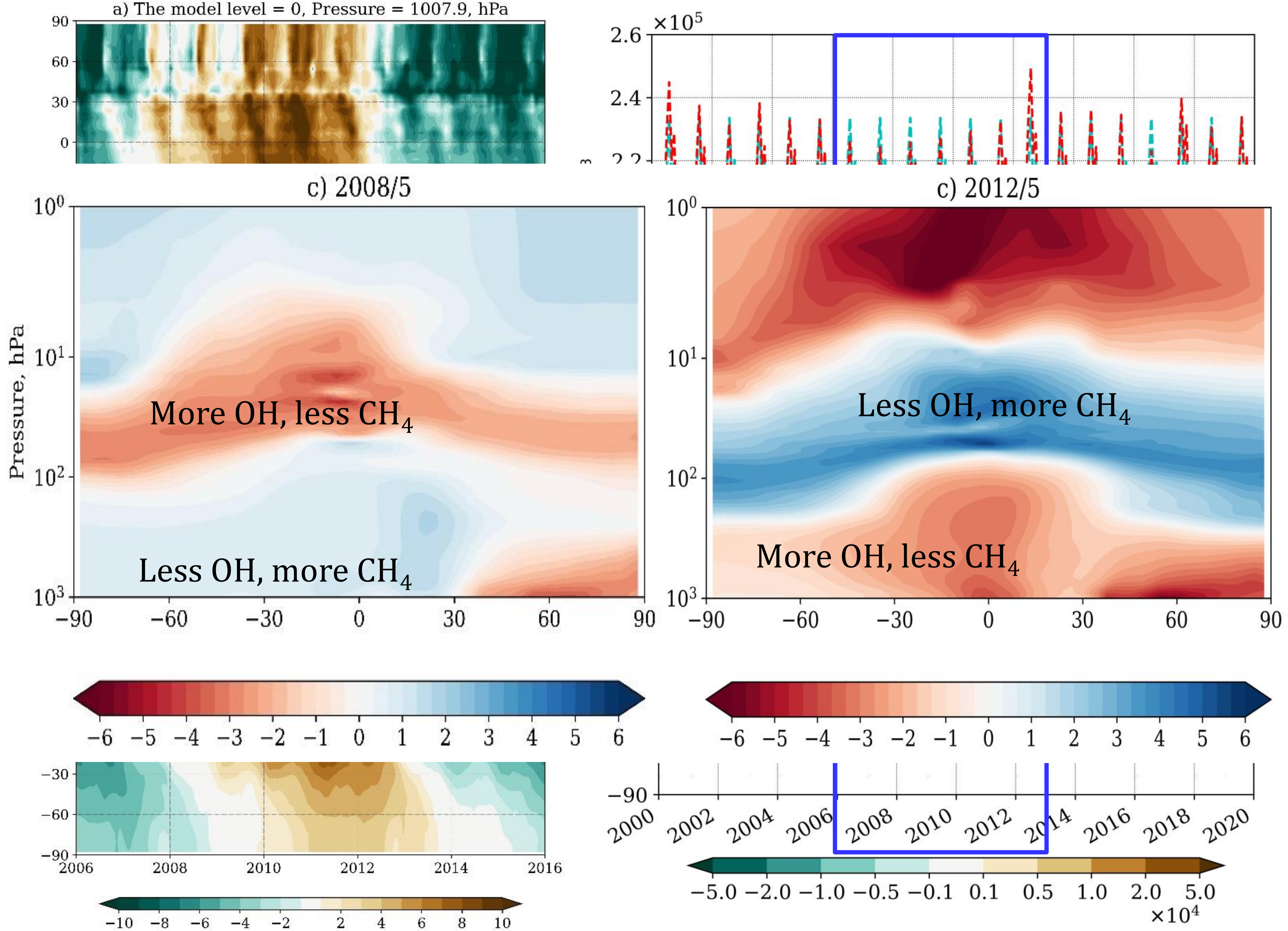


The model simulate CH_4 concentration difference



The CH_4 fluxes difference

Transitions of CH_4 concentration difference in 2008 and 2012



- Large and persistent difference in OH in the period 2007-2013
- Difference in OH causes difference in CH_4 flux and CH4 concentration (±10 ppb)
- The CH_4 concentration difference propagated with altitude
- A strong redistribution of CH_4 fluxes in the 30-60N and 0-30N bands is associated with the CH_4 concentration variation in the free atmosphere under the influence of OH loss.

Belikov et al., 2024, in prep.

Summary

1. CH_4 is a very good tracer for tracking medium-term (1-2 months) transport.
2. The major factors controlling the seasonal variation of CH_4 over the South Asia region:
   a) Change in local emission strength.
   b) Variability in atmospheric circulation and vertical convection caused by ASMA.
3. The South Asia region emission and ASMA influence transport of CH_4:
   a) In regional scale (subregional transport).
   b) In global scale (interhemispheric transport).
4. The dual role of ASMA revealed:
   a) Blocks IHT in the tropical zone of the Indian Ocean (TIO) and Southeast Asia (SEA).
   b) Accelerate IHT transport over East Africa (ETA).
5. GOSAT-TIR observations provide data coverage and density suitable to study CH_4 from the top of ABL up to UT/LS.
6. Despite the small interannual variability (±6%), the OH fields have a significant impact on CH_4 transport in UT/LS.

Tank you very much for your attention!