CO_2 and CH_4 over the India: A study based on surface flask measurements and an atmospheric transport zoom model

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SOFIE
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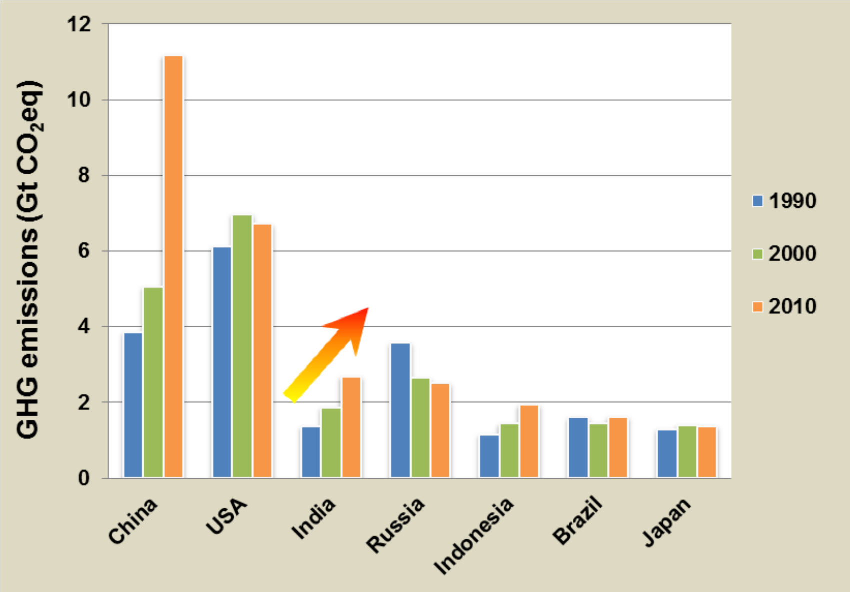
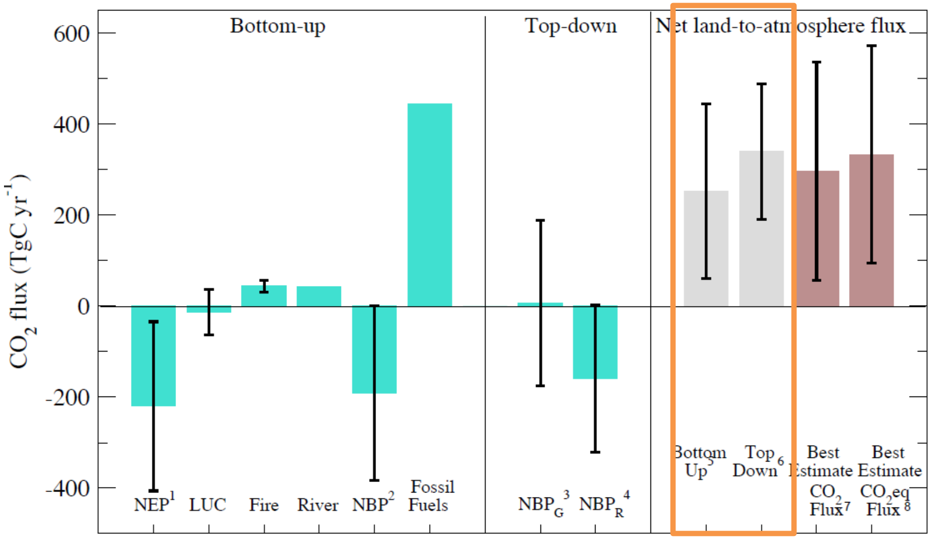
SOFIE LSCE/PKU Workshop, October 14th 2014

LSCE cea cnrs Institut Pierre Simon Laplace UNIVERSITÉ DE VERSAILLES SAINT-QUENTIN-EN-YVELINES C-MMACS ASTRIUM AN EADS COMPANY

Background

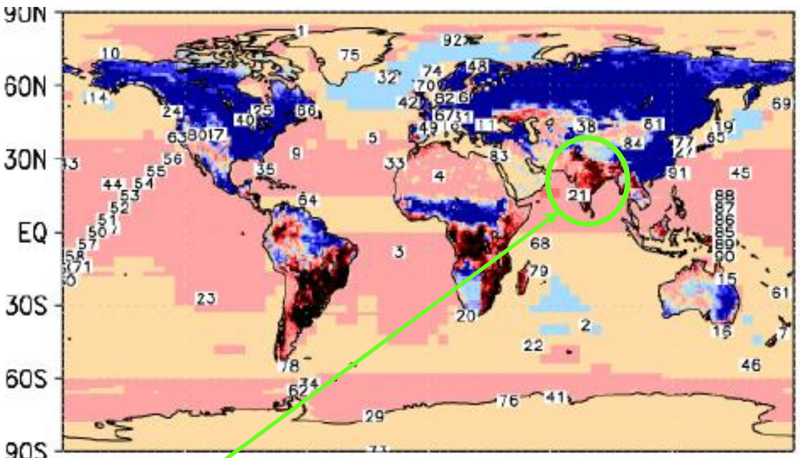


Sources: Emission Database for Global Atmospheric Research (EDGAR), release version 4.2

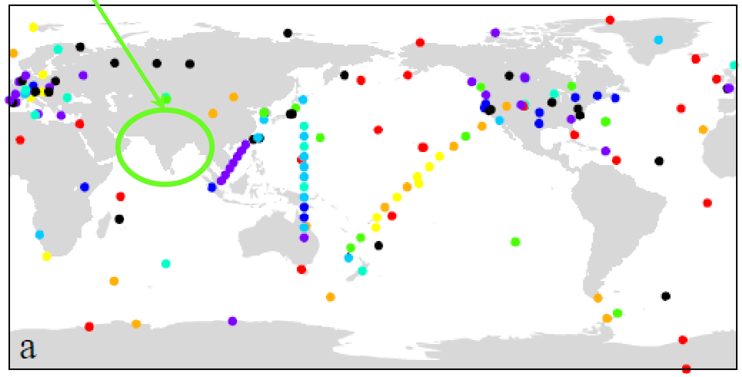


Patra et al. (2013)

GLOBALVIEW-CO_2 in Patra *et al.* (2011)

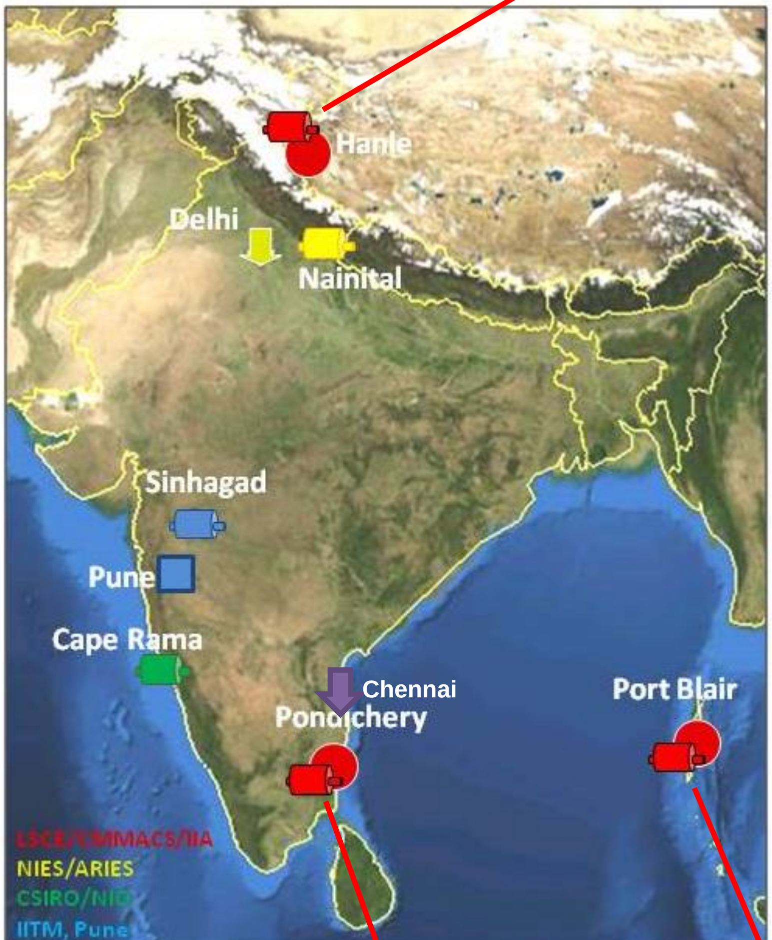


Data paucity



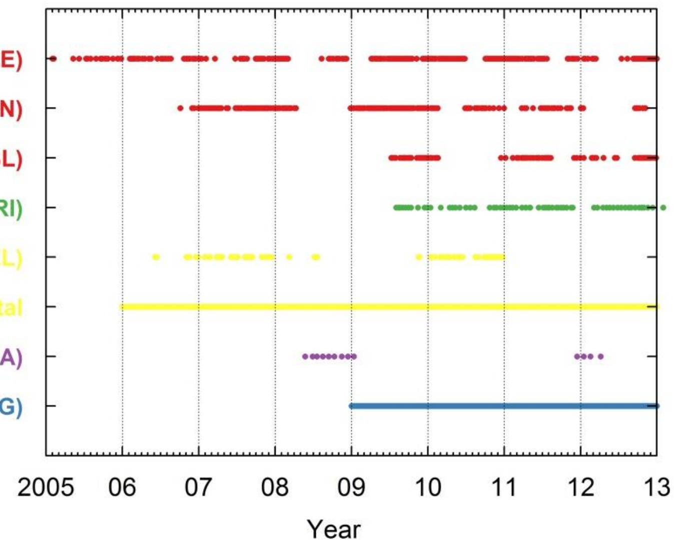
Sites in TRANSCOM-CO_2 (Peylin *et al.*, 2013)

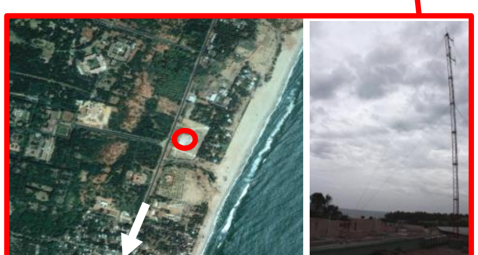
Background



	Lat	Lon	Alt
HLE	32.78°N	78.96°E	4517 m
PON	12.01°N	79.86°E	20 m
PBL	11.65°N	92.76°E	20 m

Time ranges of observations





Outline

- Part I: CO_2 and CH_4 flask measurements at the three ground stations in India
- Part II: CO_2 and CH_4 forward simulation with an atmospheric transport zoom model

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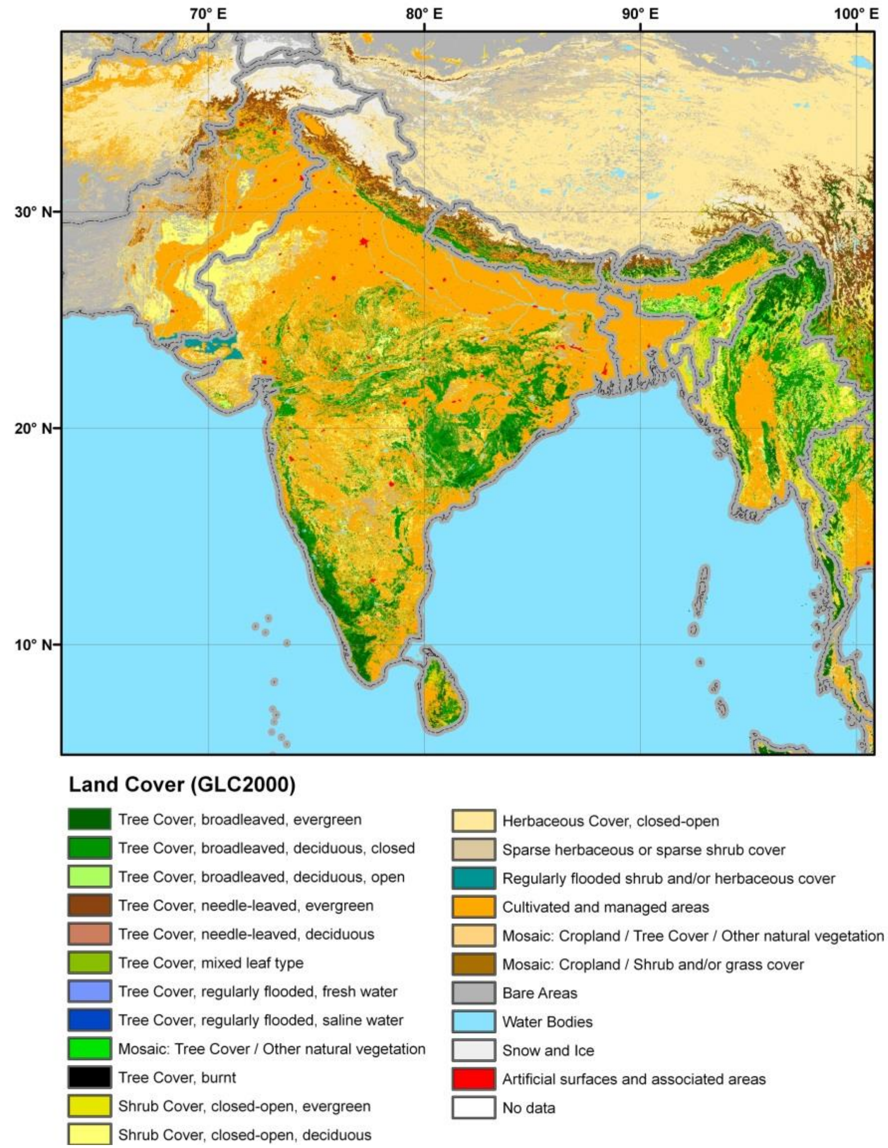
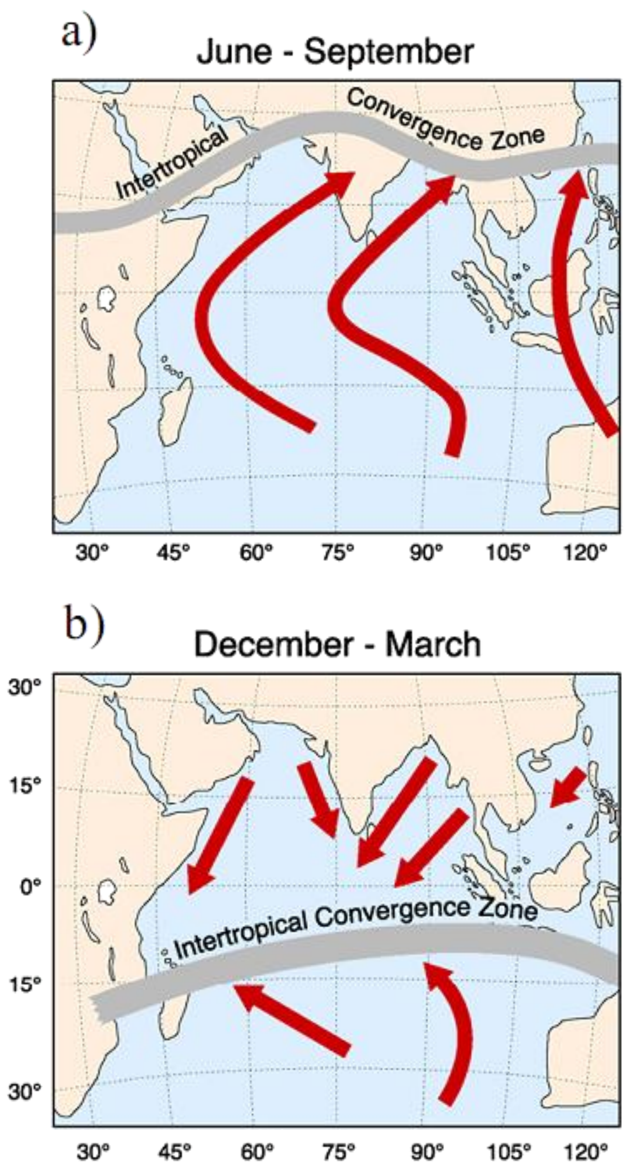
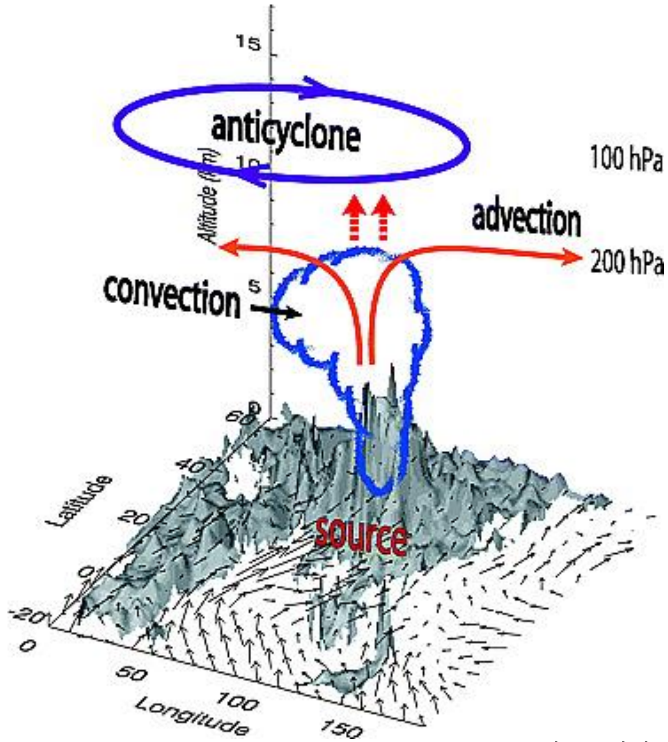
Facts about India: Geography and vegetation



- NE India (Indo-Gangetic Plain) and S India are the most populous regions
- Croplands account for 50-60% of the total land area

Facts about India: Monsoon circulations



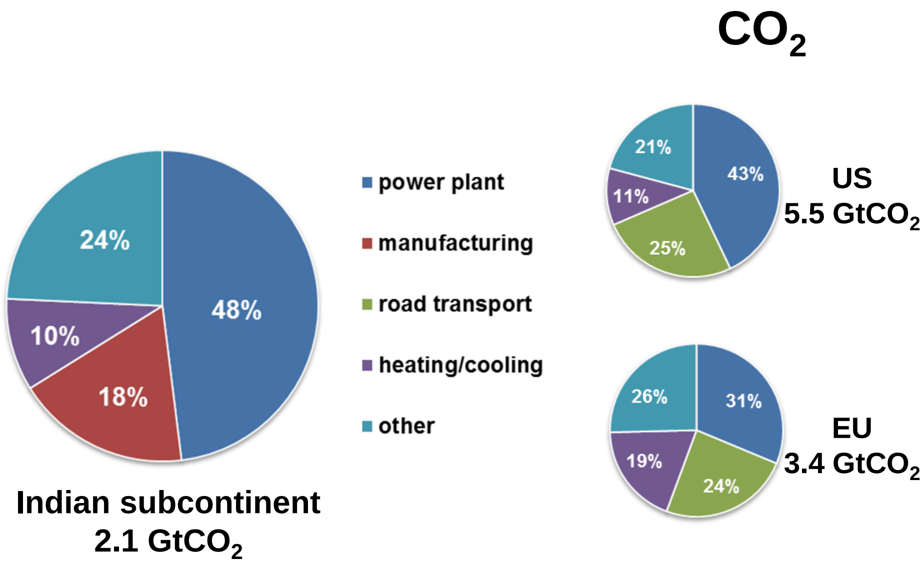


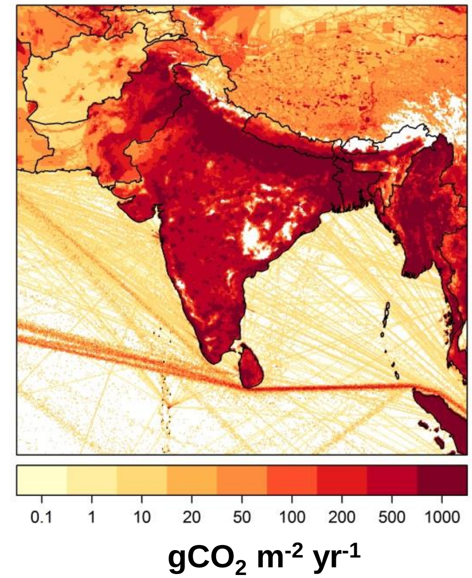
Park *et al.* (2009)

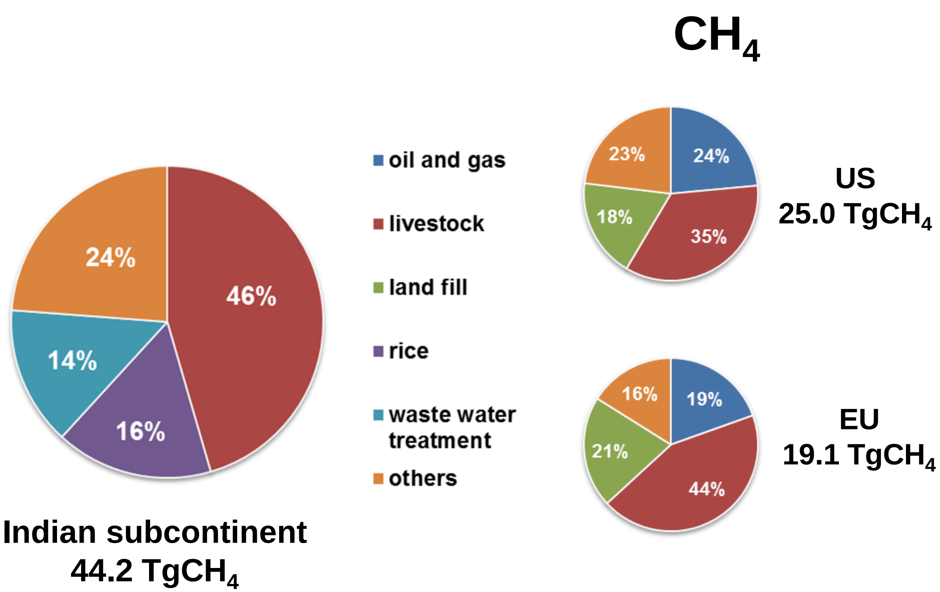
Influences on transport and airmass origins

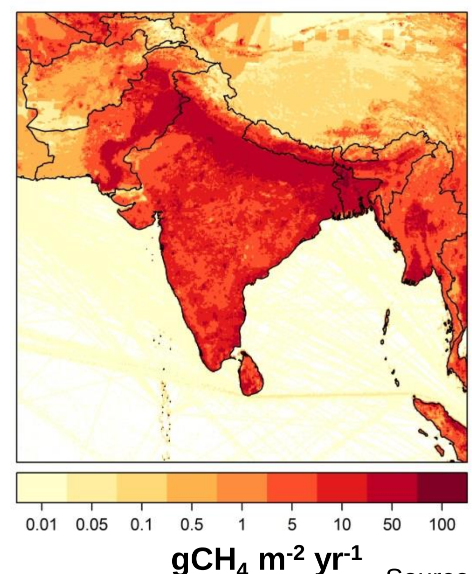
- The progress/retreat of SW/NE monsoon and movement of ITCZ transport airmass of different origins to the observation sites
- Deep convection associated with SW monsoon rapidly transport surface (polluted) airmass vertically to UTLS

Facts about India: Anthropogenic emissions



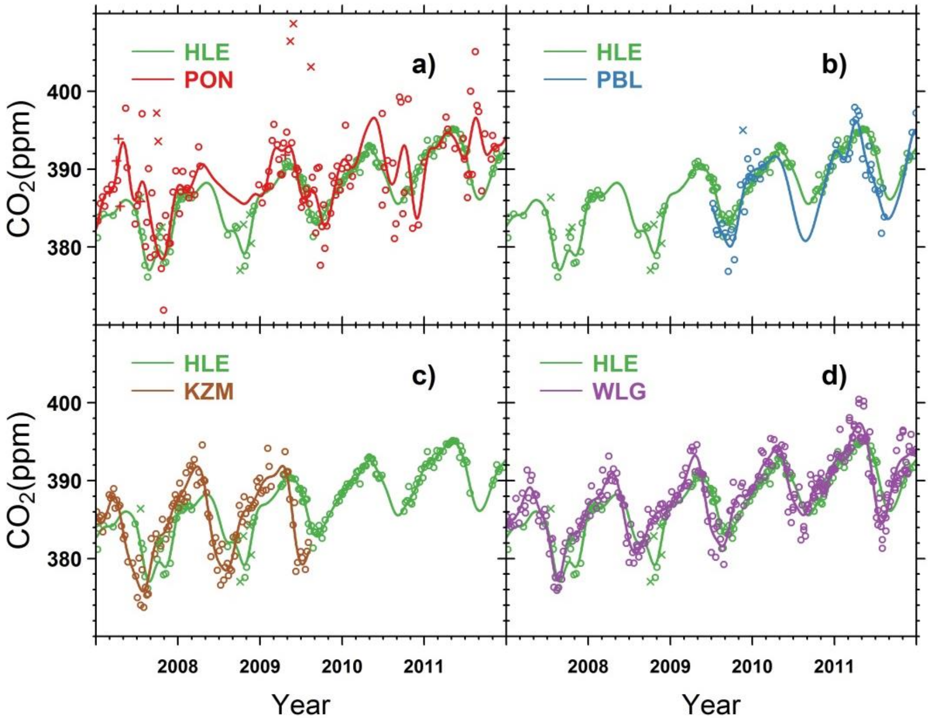


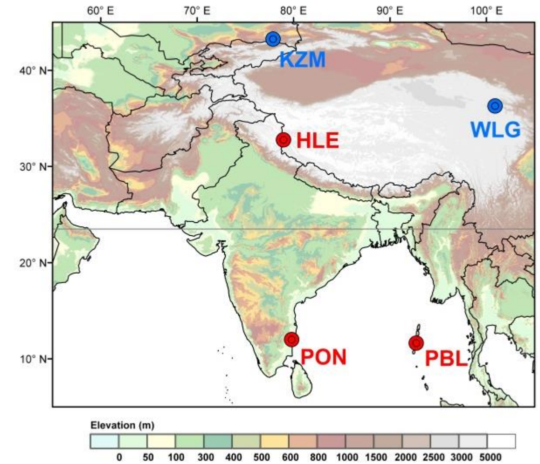




Sources: EDGARv4.2

CO_2: time series

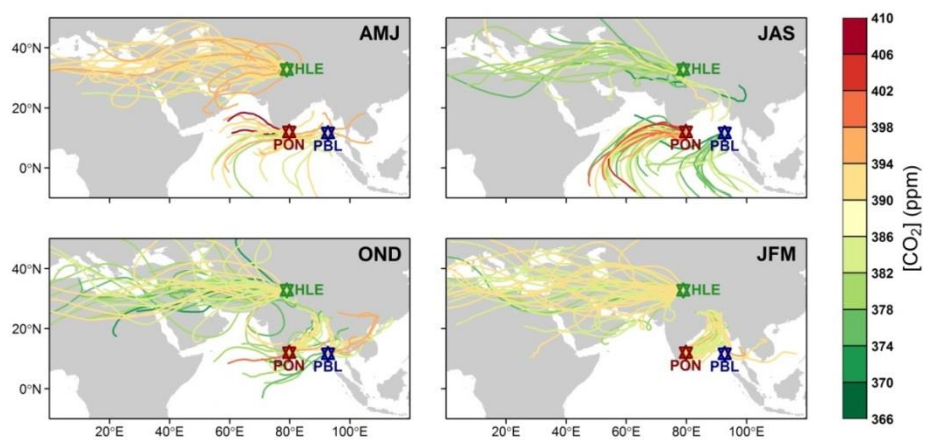




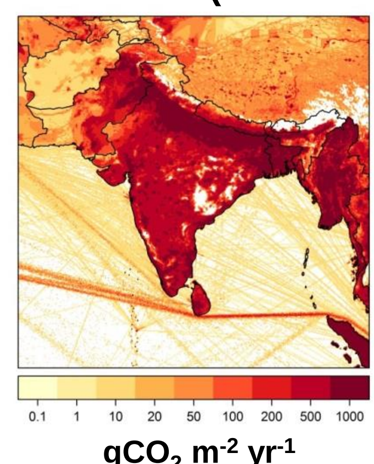
Gradients of annual mean CO_2 between ground stations

India	HLE	PON	PBL	KZM	WLG
ΔCO_2 (ppm)	0.0	1.3-3.0	-1.6	0.7	1.0

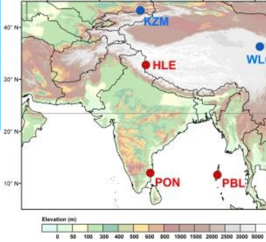
5-day backtrajectories



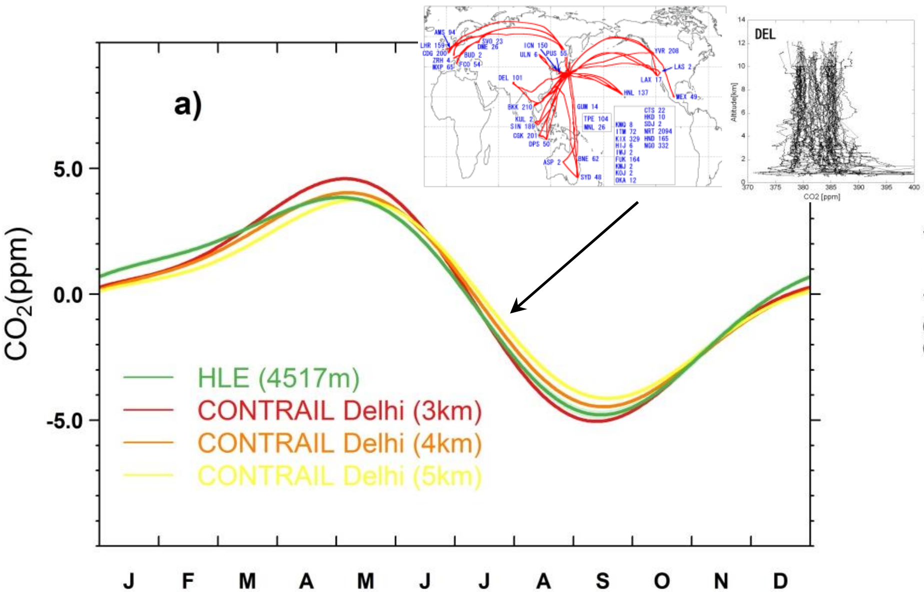
CO2 Emissions (EDGARv4.2)

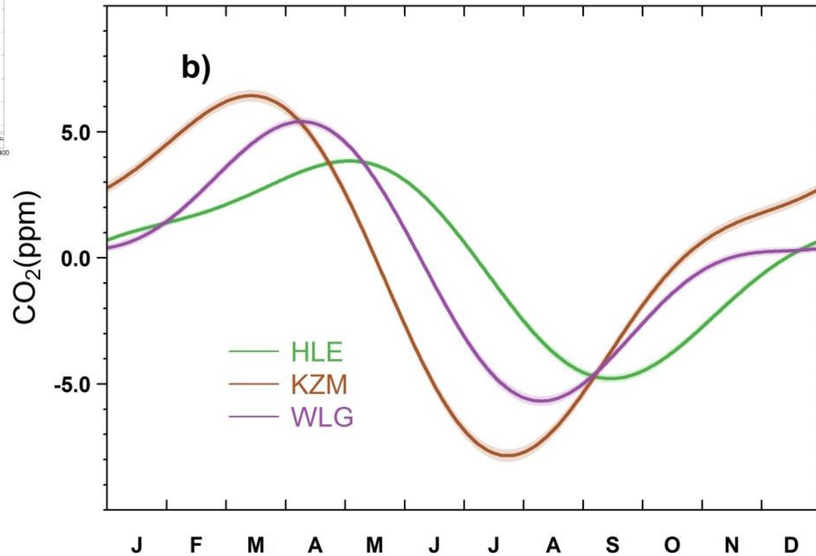


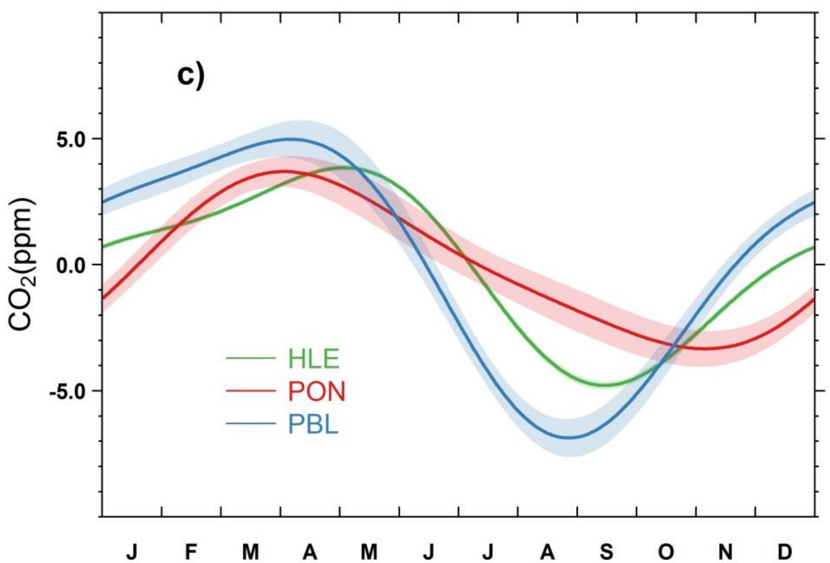
CO_2: seasonal cycle



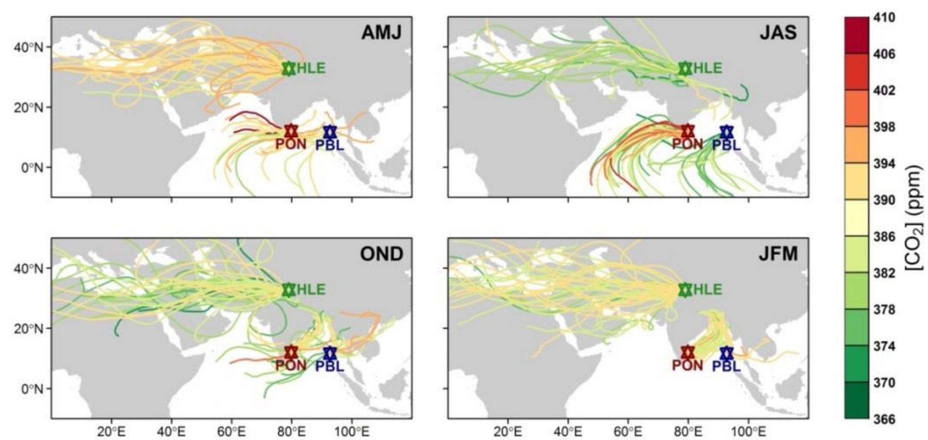
CONTRAIL
Comprehensive Observation Network for Trace gases by Airliner



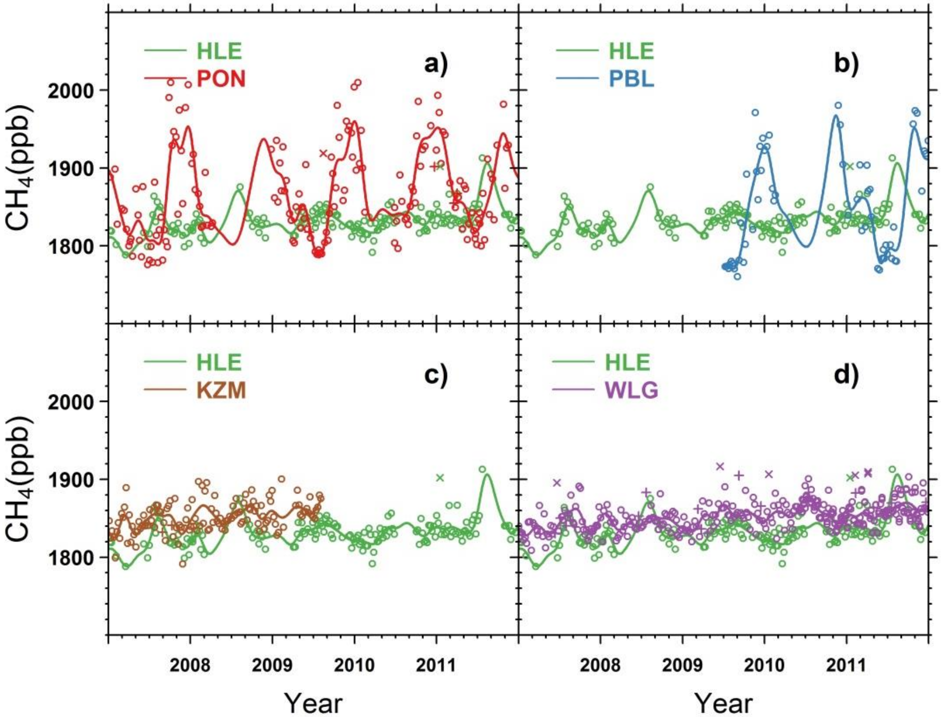


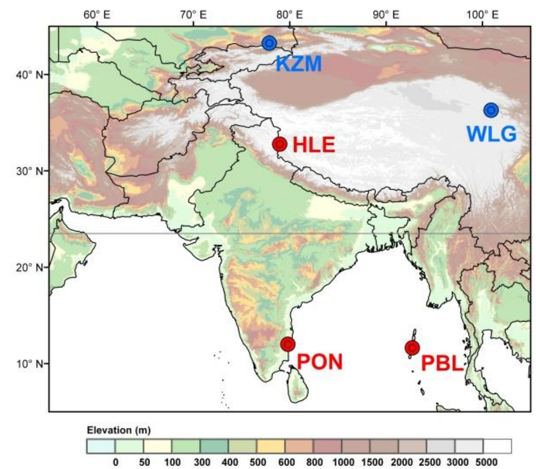


5-day backtrajectories



CH_4: time series

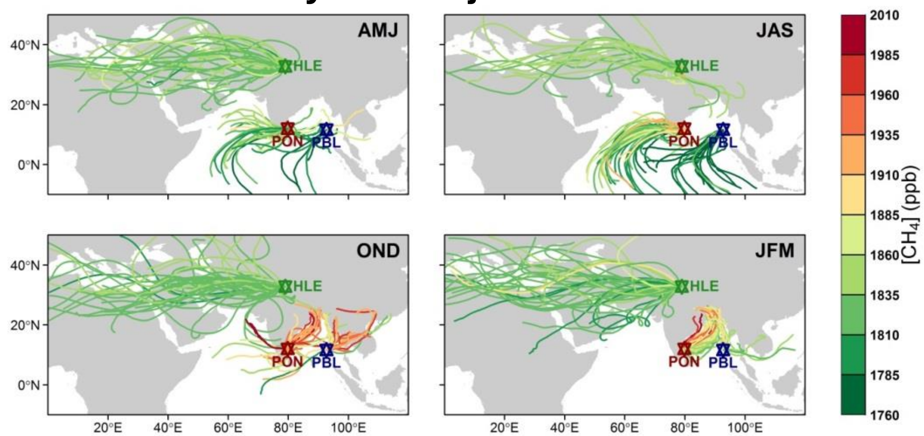


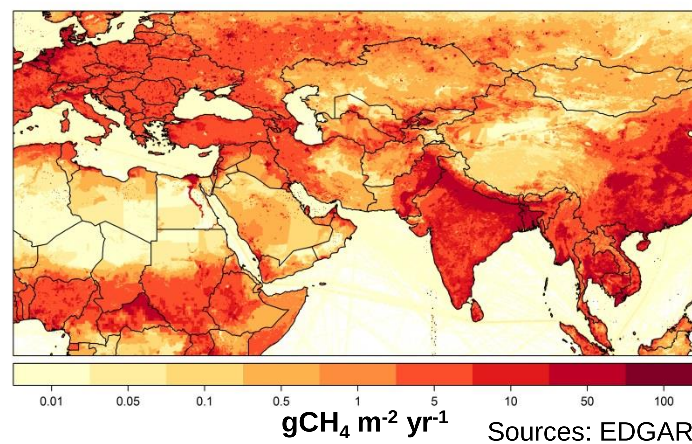


Gradients of annual mean CH_4 between ground stations

India	HLE	PON	PBL	KZM	WLG
ΔCH_4 (ppb)	0.0	36.9	20.8	25.9	19.6

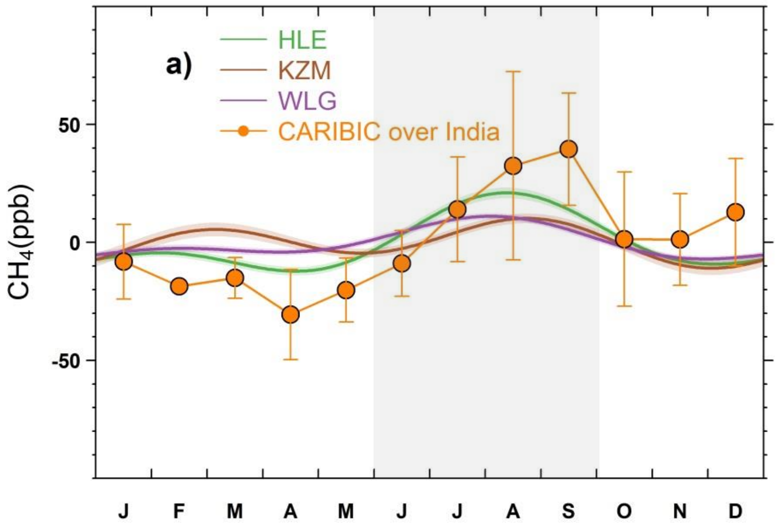
5-day backtrajectories

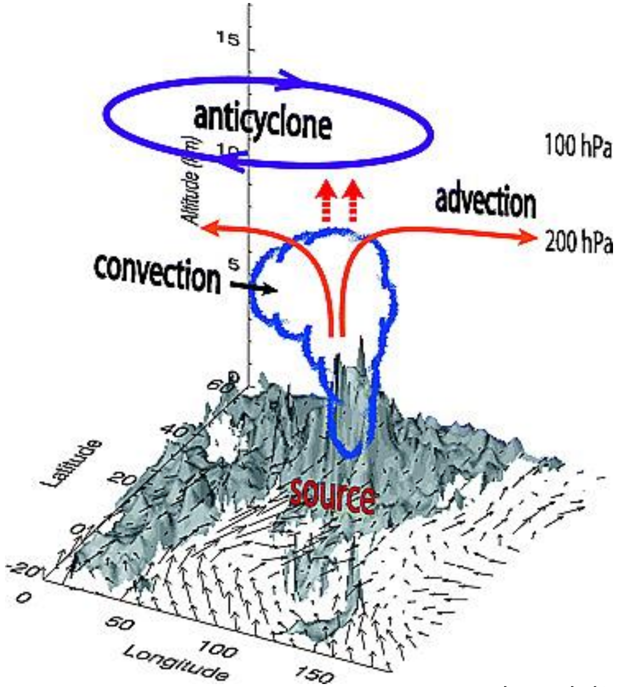




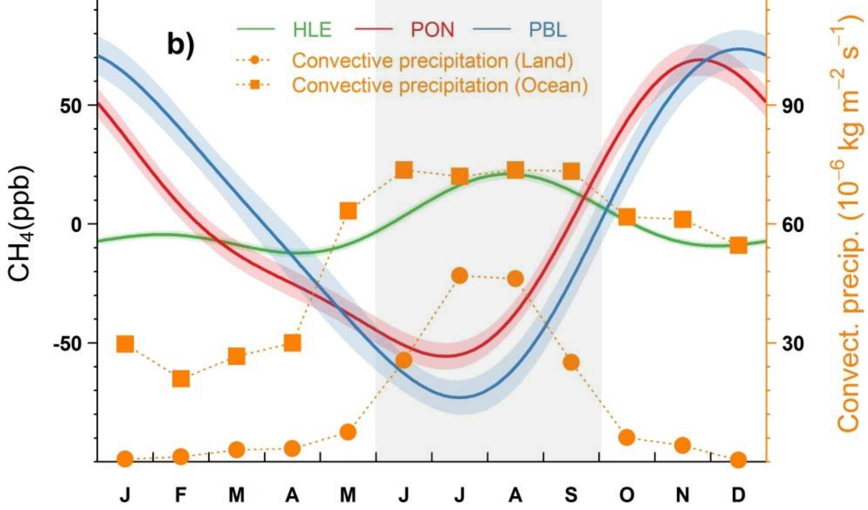
Sources: EDGARv4.2

CH_4: seasonal cycle

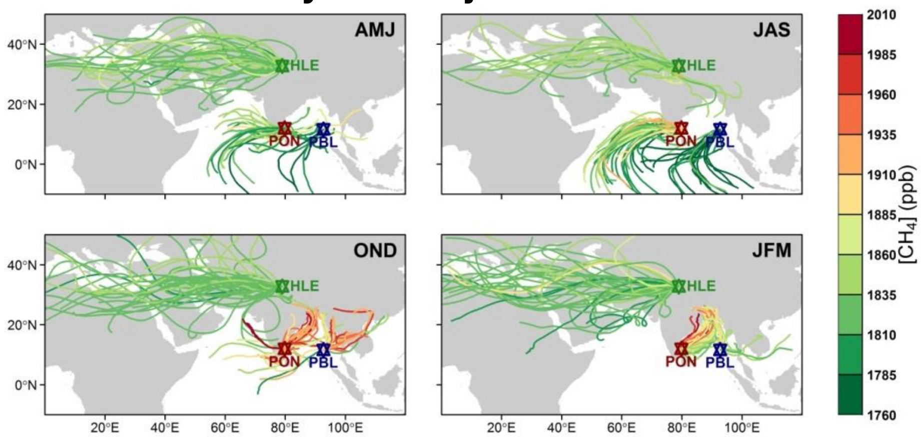




Park *et al.* (2009)



5-day backtrajectories



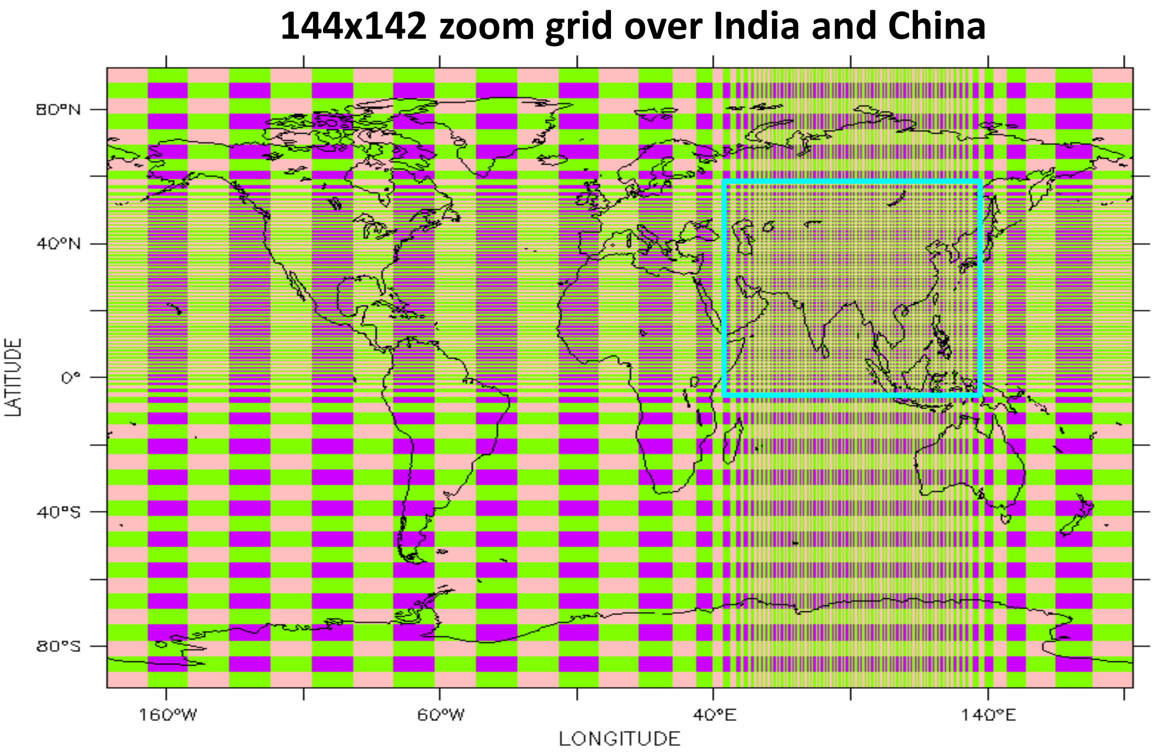
Short summary

- The cross-station gradients of annual means suggest significant emission sources of CO_2 and CH_4
- Although they have the potential to provide useful constraints on GHG fluxes over India (particularly NE and S India), a more comprehensive observation network is required.
- To quantify effects of various sources/sinks and atmospheric transport on observations at different spatio-temporal scales, we need atmospheric transport models force with meteorological data and surface GHG fluxes.

Outline

- Part I: CO_2 and CH_4 flask measurements at the three ground stations in India
- Part II: CO_2 and CH_4 forward simulation with an atmospheric transport zoom model

Setup of the model: LMDZORINCA with Asian zoom



- **LMDZORINCA** is a global model that couples a general circulation model (**LMD**) to a terrestrial biosphere module (**ORCHIDEE**) and an aerosol and chemistry module (**INCA**)
  - Horizontal resolution: 144×142
  - Vertical resolution: 19 layers from 3.88 to 1013 hPa
  - 'GES' version is used, which includes CH_4 and CO chemistry
- Setup of Asian zoom
  - 0.51° (lat.)×0.66° (lon.) for a region centered over India and China
  - 4.62° ×4.64° for other regions

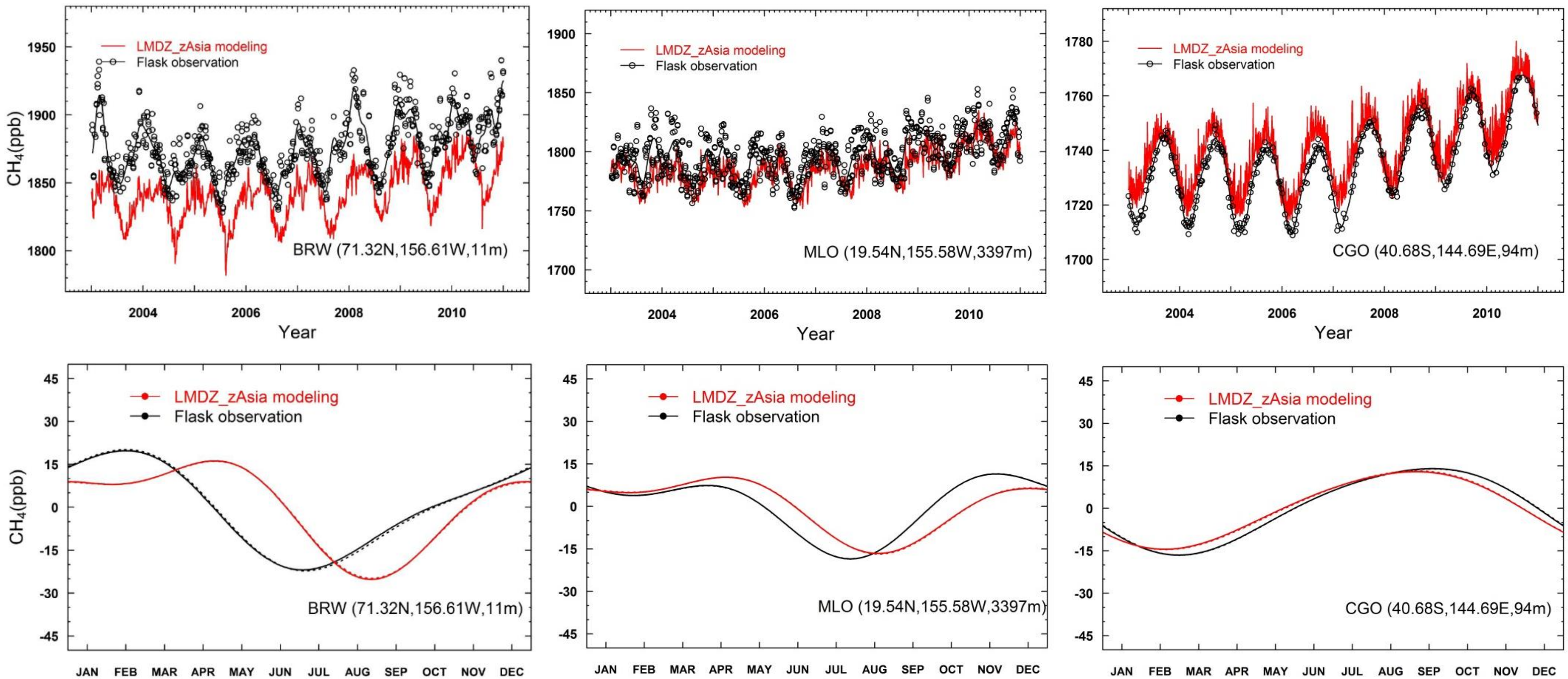
Setup of the model: Original flux maps

CO_2	Data source	interann./clim.	time step	resolution
Anthropogenic	IER products for CARBONES; GEOCARBON products	interannual	monthly	1°
Biomass burning	GFEDv3.1	interannual	monthly	0.5°
Land flux (NEE)	ORCHIDEE outputs for CARBONES	interannual	daily	0.72°
Ocean flux	NOAA/AOML product; Park et al. (2010)	interannual	monthly	4° ×5°
CH_4	**Data source**	**interann./clim.**	**time step**	**resolution**
Anthropogenic	EDGARv4.2	interannual	yearly	0.1°
Wetland	Kaplan et al. (2006)	climatological	monthly	1°
Biomass burning	GFEDv3.0	interannual	monthly	0.5°
Termite	Sanderson et al. (1996)	climatological	monthly	1°
Soil	Ridgwell et al. (1999)	climatological	monthly	1°
Ocean	Lambert & Schmidt (1993)	climatological	monthly	1°

As model input, each flux map was re-gridded into 144x142 Asian zoom grid.

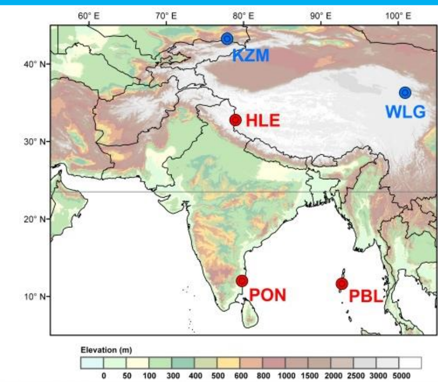
CH_4: Model vs. OBS at NOAA/ESRL stations

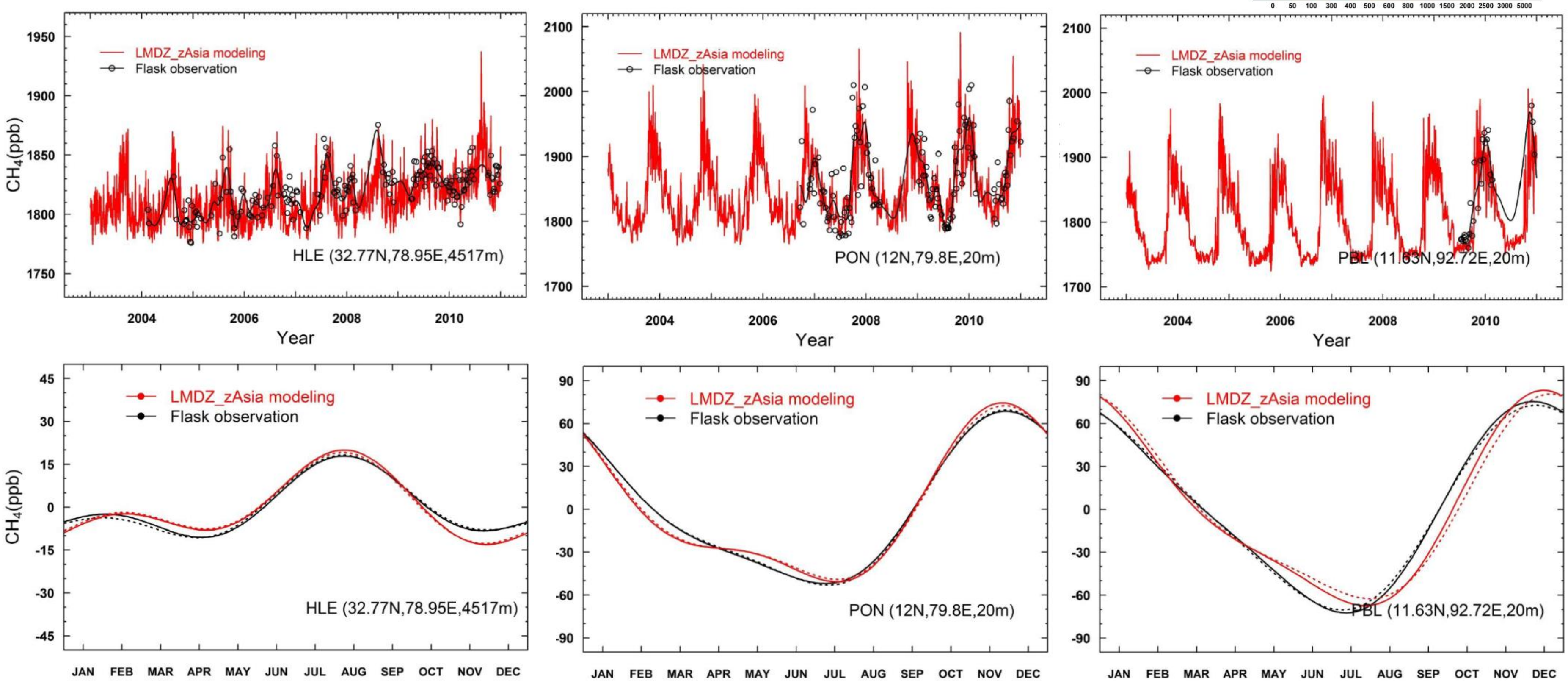
- Well capture of long-term trends and interannual variability
- Smaller N-S gradient due to faster inter-hemispheric mixing
- Well capture of seasonal cycle amplitudes
- Shifts in seasonal cycle phases



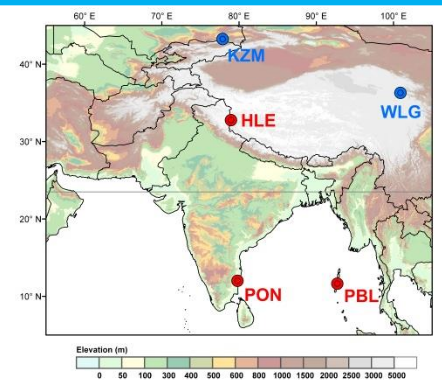
CH_4: Model vs. OBS at Indian stations

- Well capture of annual means and interannual variability
- Well capture of seasonal cycle amplitudes and phases

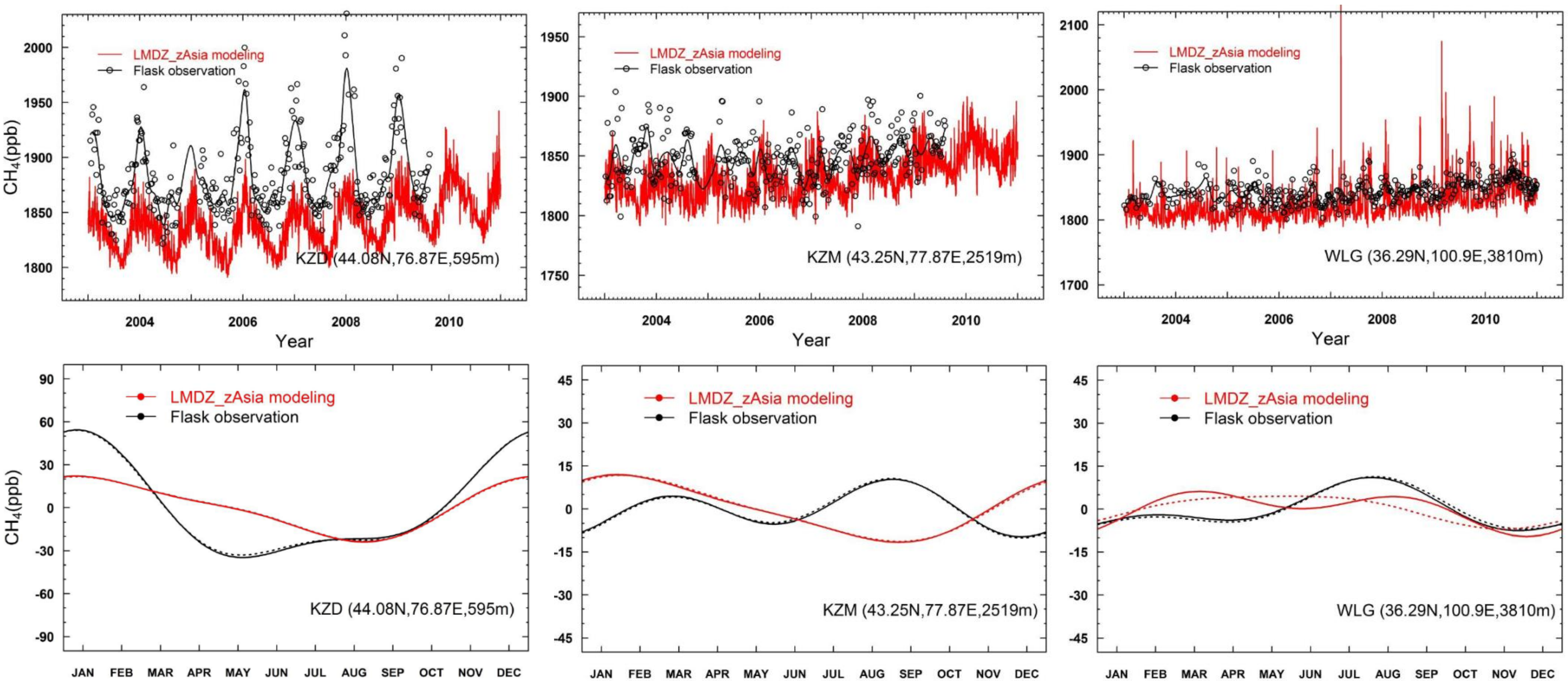




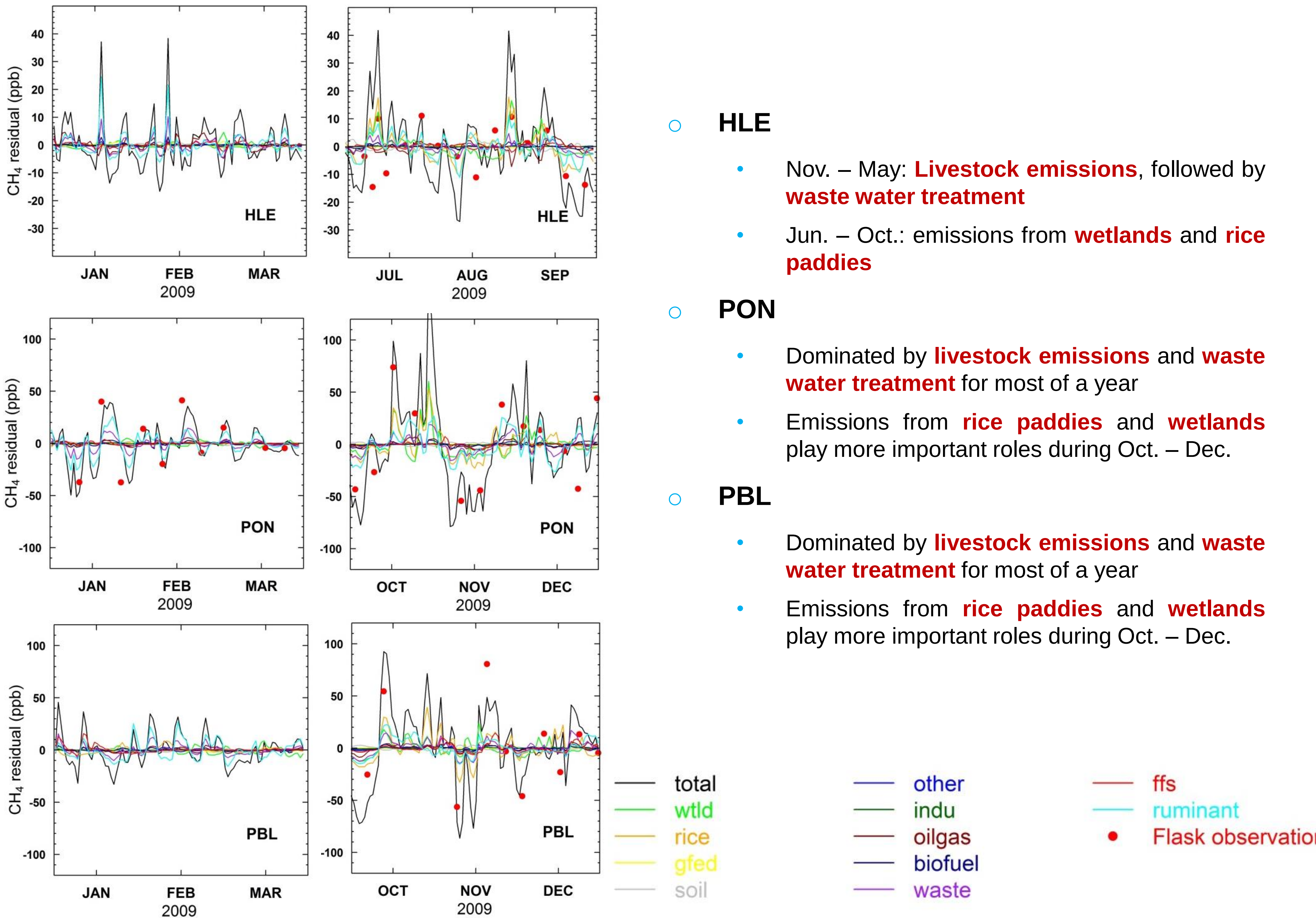
CH_4: Model vs. OBS at other Asian stations



- Significant underestimation of annual means at KZD
- Seasonal cycles are not well captured at KZD, KZM, and WLG



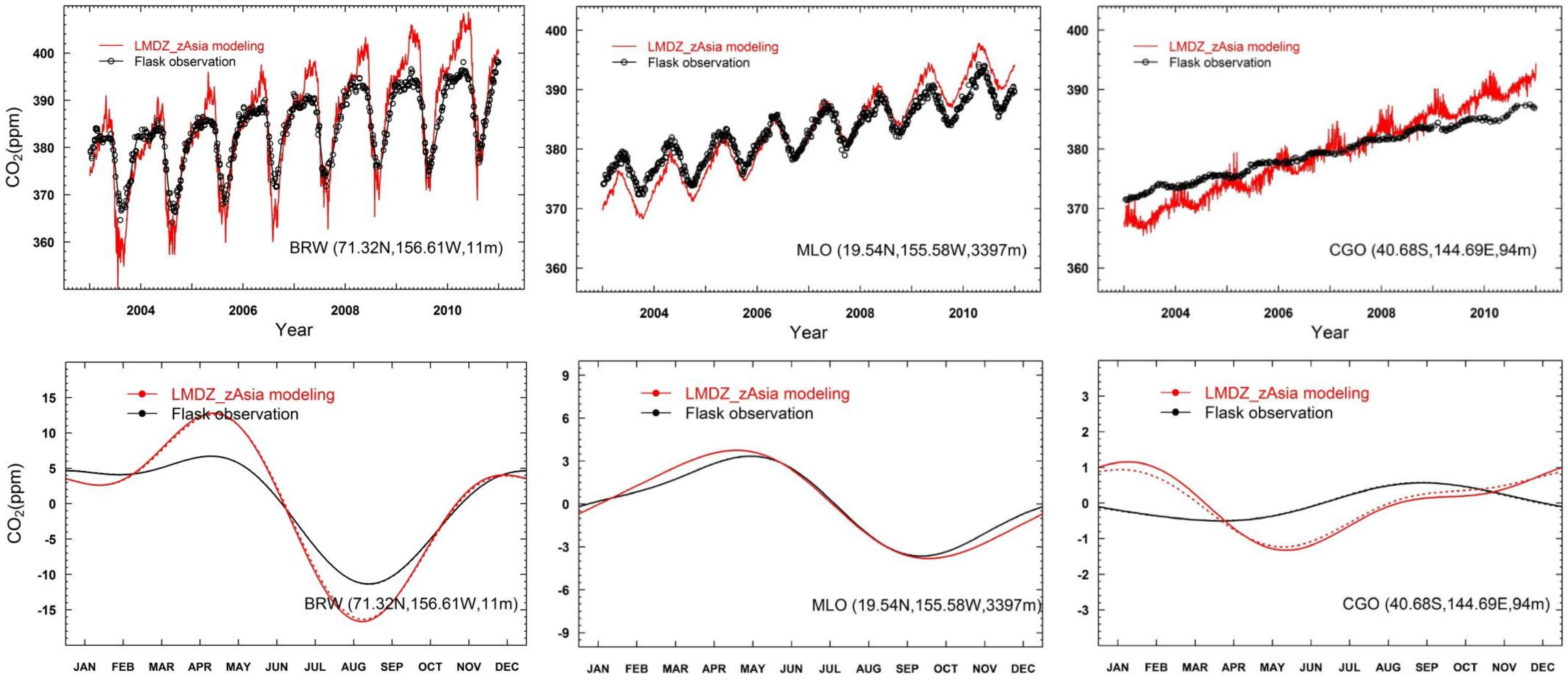
Attribution of CH_4 synoptic variations



- **HLE**
  - Nov. – May: **Livestock emissions**, followed by **waste water treatment**
  - Jun. – Oct.: emissions from **wetlands** and **rice paddies**
- **PON**
  - Dominated by **livestock emissions** and **waste water treatment** for most of a year
  - Emissions from **rice paddies** and **wetlands** play more important roles during Oct. – Dec.
- **PBL**
  - Dominated by **livestock emissions** and **waste water treatment** for most of a year
  - Emissions from **rice paddies** and **wetlands** play more important roles during Oct. – Dec.

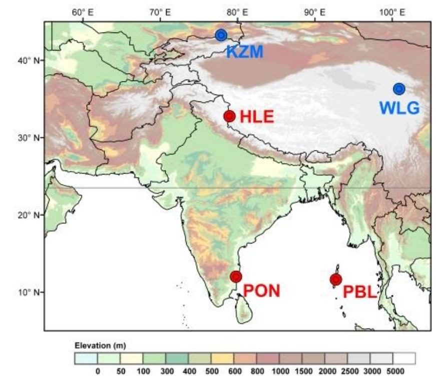
CO_2: Model vs. OBS at NOAA/ESRL stations

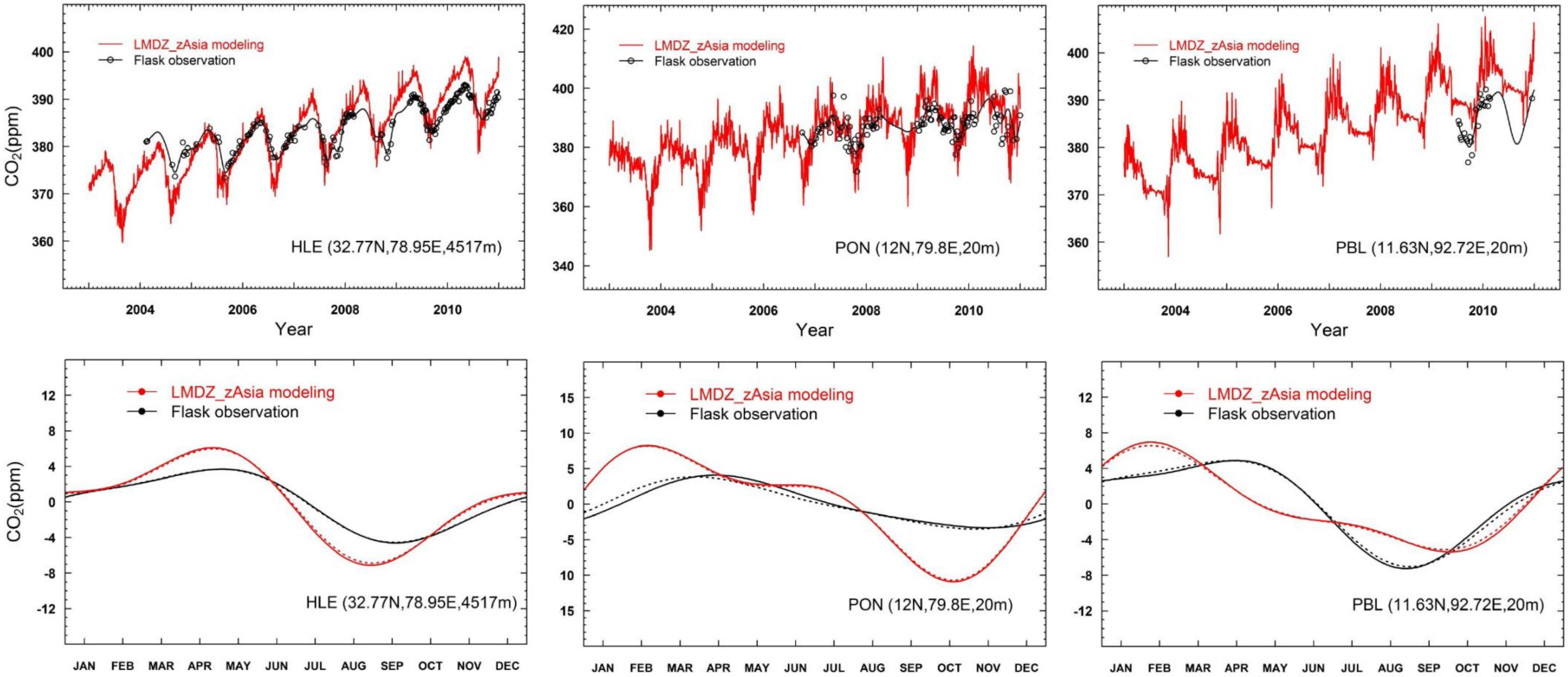
- **Overestimation of long-term trends**
- **Northern Hemisphere stations**
  - Well capture of seasonal cycle phases
  - Overestimation of seasonal cycle amplitudes
- **Southern Hemisphere stations**
  - Poor ability to reproduce the small CO_2 seasonal cycle



CO_2: Model vs. OBS at Indian stations

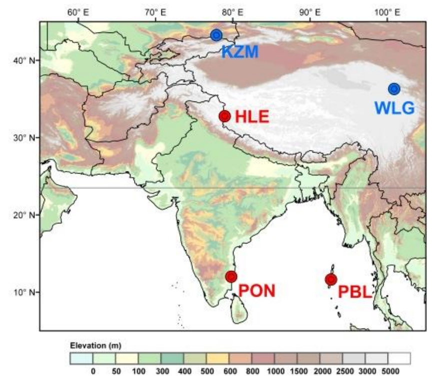
- **Overestimation of long-term trends**
- **HLE** – advance in seasonal cycle phase, overestimation of magnitude
- **PON** – advance in seasonal cycle phase, overestimation of magnitude, extremely low value in Oct.
- **PBL** – advance and extension in CO_2 drawdown phase

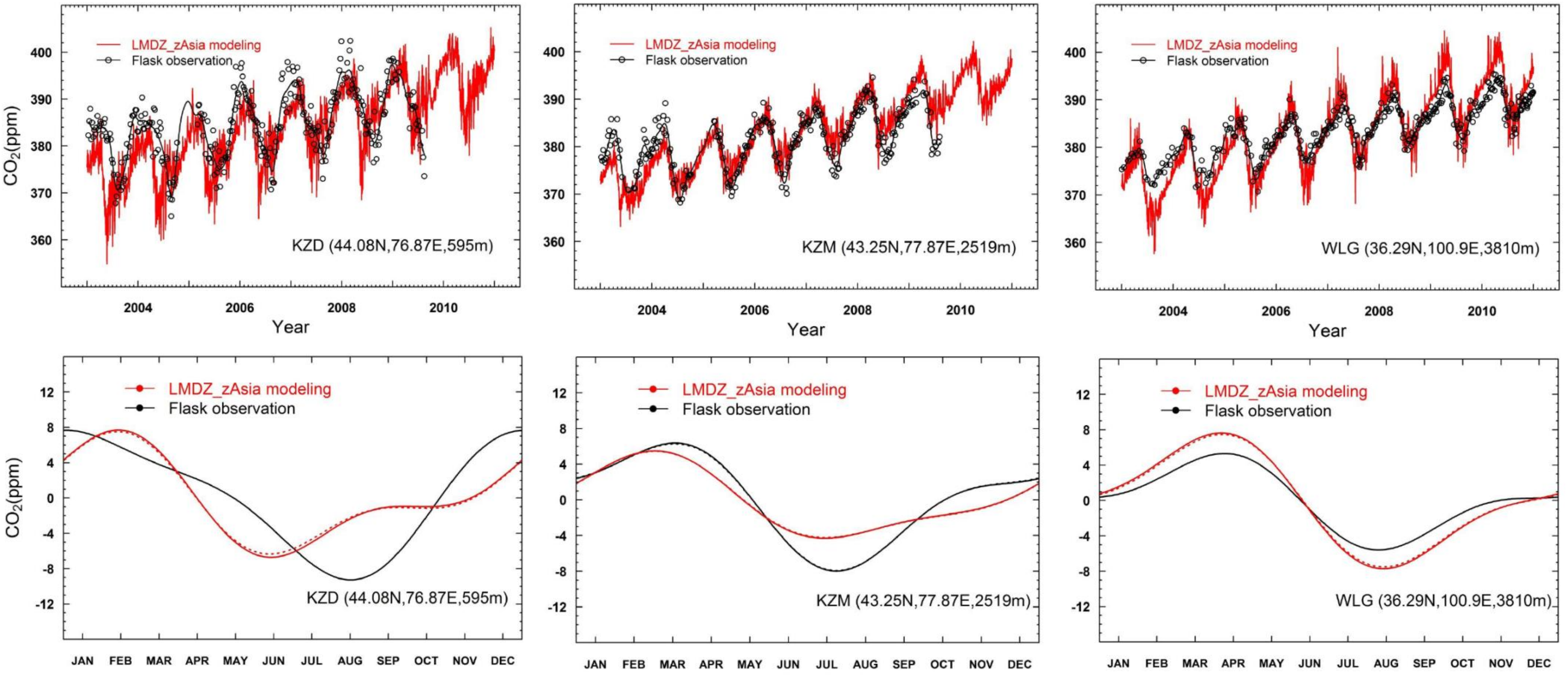




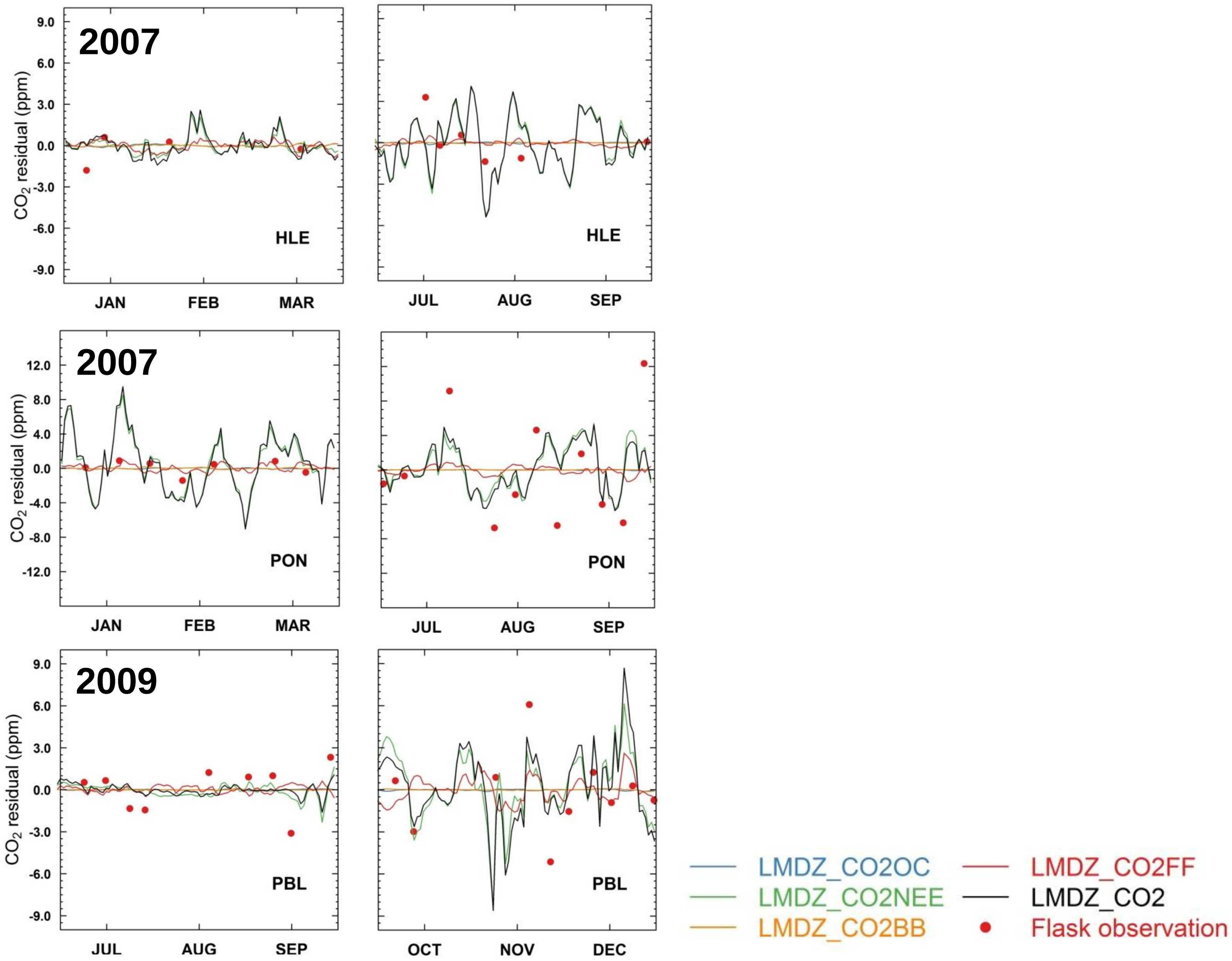
CO_2: Model vs. OBS at other Asian stations

- **Overestimation of long-term trends**
- **KZD** – lag and shortening of CO_2 drawdown phase
- **KZM** – advance in seasonal cycle phase, underestimation of magnitude
- **WLG** – well capture of seasonal cycle phase, overestimation of magnitude

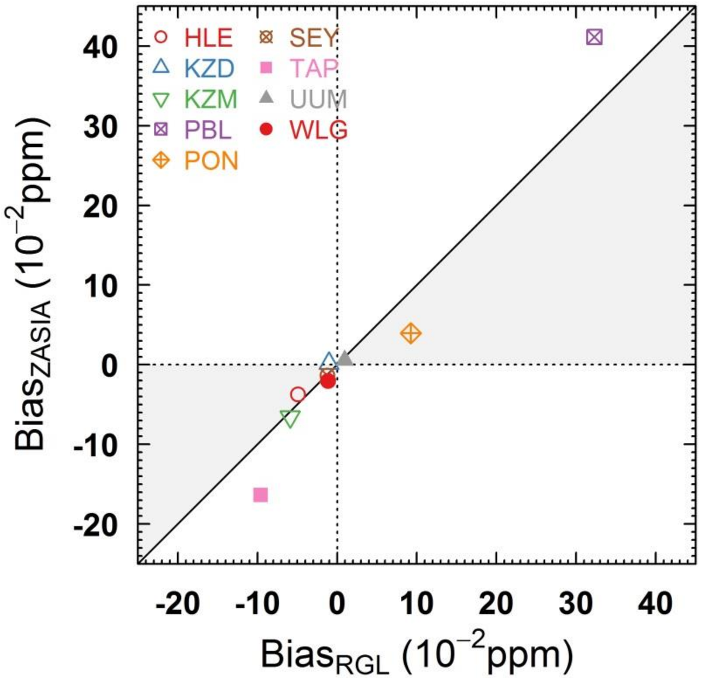


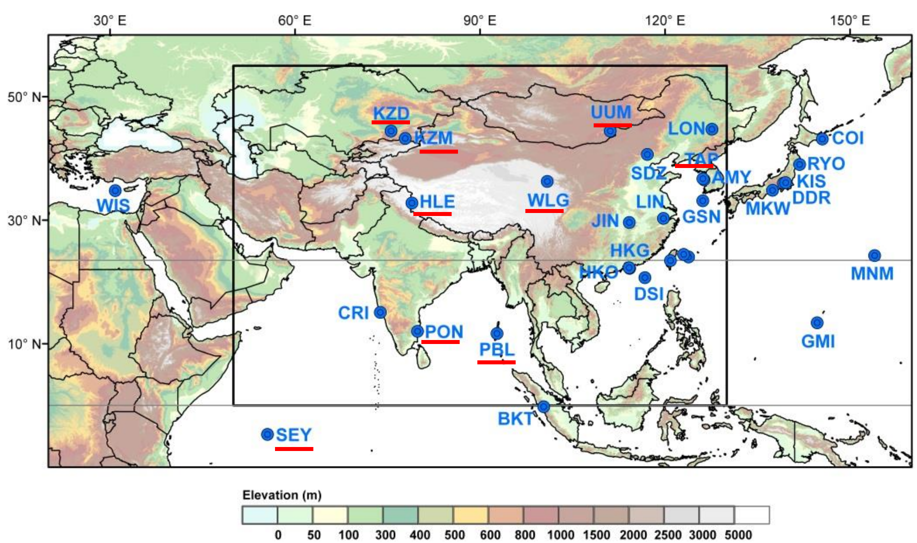


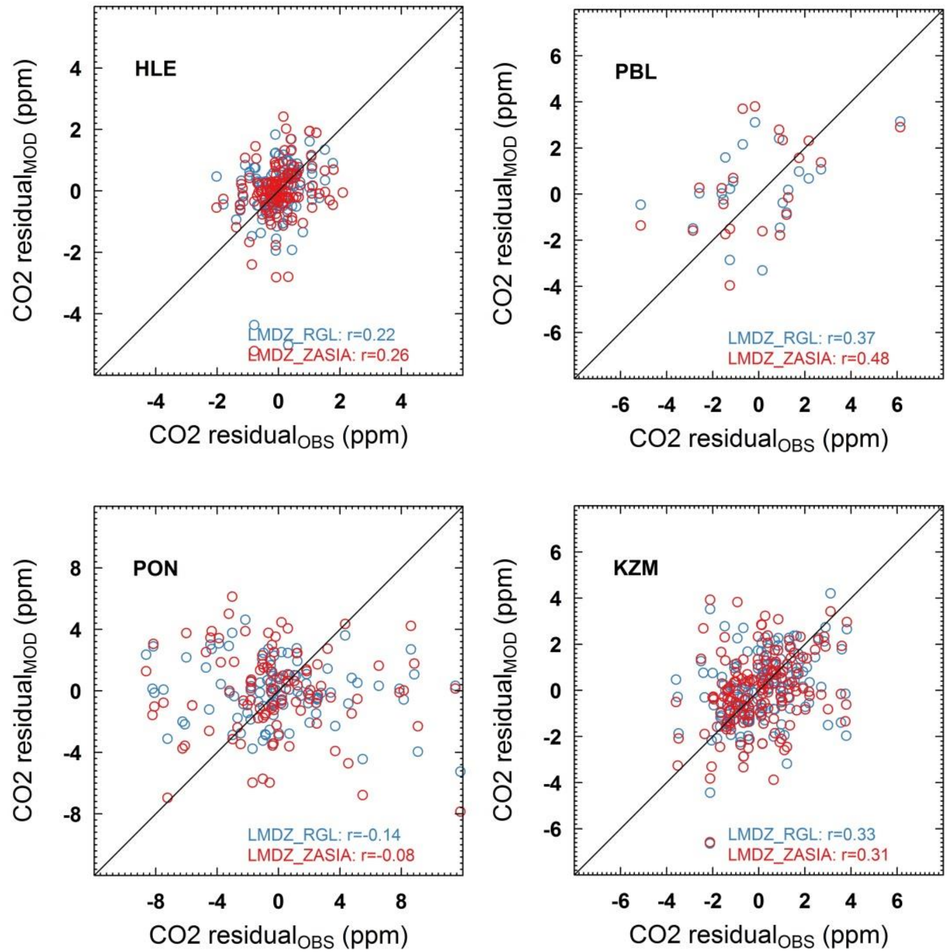
Attribution of CO_2 synoptic variations



Zoom v.s. Regular: CO_2 residuals







LMDZ_ZASIA: 0.51° (lat)×0.66° (lon) over the zoom

LMDZ_RGL: 1.25° (lat)×2.5° (lon) over the globe

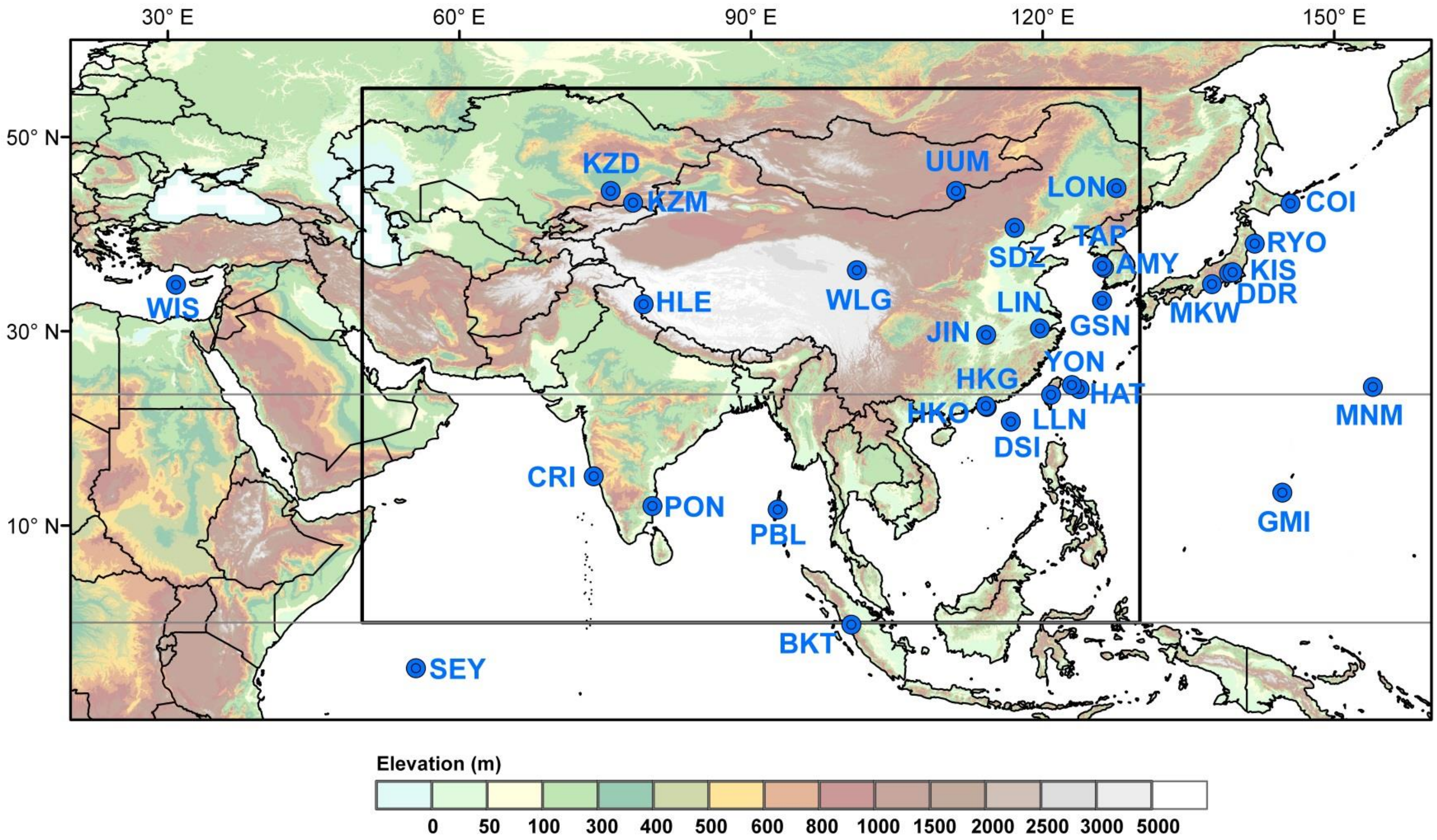
Future work

- CO_2 and CH_4 forward modeling with alternative prior fluxes
- Extend the modeling period to 2012

CO_2	Data source	interann./clim.	time step	resolution
Anthropogenic	IER products for CARBONES; GEOCARBON products	interannual	monthly	1°
Anthropogenic	**IER + PKU-CO_2**	**interannual**	**daily hourly**	**0.1°**
Biomass burning	GFEDv3.1	interannual	monthly	0.5°
Land flux (NEE)	ORCHIDEE outputs for CARBONES	interannual	daily	0.72°
Land flux (NEE)	**ORCHIDEE**	**Interannual**	**hourly**	**0.5°**
Ocean flux	NOAA/AOML product; Park et al. (2010)	interannual	monthly	4° ×5°
CH_4	**Data source**	**interann./clim.**	**time step**	**resolution**
Anthropogenic	EDGARv4.2	interannual	yearly	0.1°
Wetland	Kaplan et al. (2006)	climatological	monthly	1°
Biomass burning	GFEDv3.0	interannual	monthly	0.5°
Termite	Sanderson et al. (1996)	climatological	monthly	1°
Soil	Ridgwell et al. (1999)	climatological	monthly	1°
Ocean	Lambert & Schmidt (1993)	climatological	monthly	1°

Future work

- Evaluation of the model against more observations within and around the zoom region, focusing on model performance on seasonal, synoptic, diurnal variations and gradients between stations.



Thank you very much for your attention!