

# Connections between air pollution and Asian winter/summer monsoon systems: Effects on surface air quality and UTLS composition



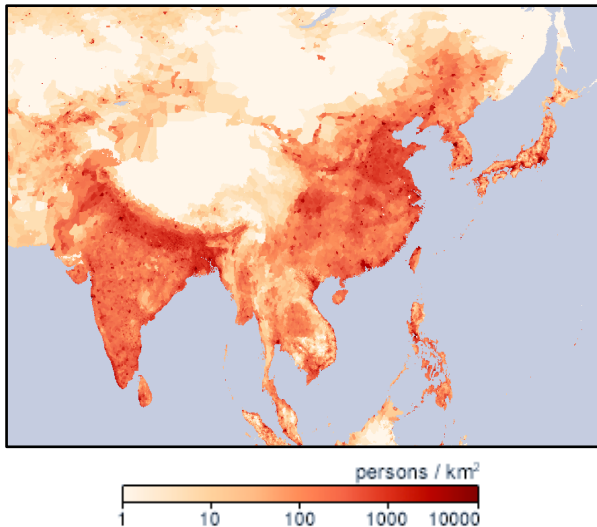
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*4<sup>th</sup> ACAM workshop, 26-28 June 2019, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia*

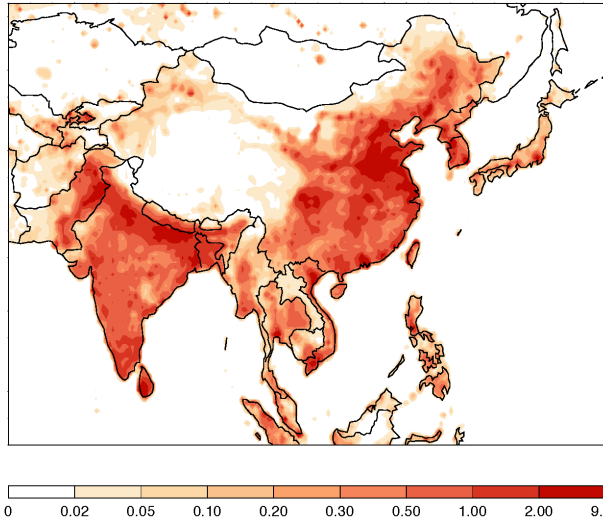
# Anthropogenic emission “hot spots” co-located with dense populations in major Asian monsoon regions

- Asian monsoon is a major climate component, comprised mainly of the South Asian and East Asian subsystems
- Asian monsoon region is an area with the highest population density overlapping with high anthropogenic emissions and the aerosol hot spots

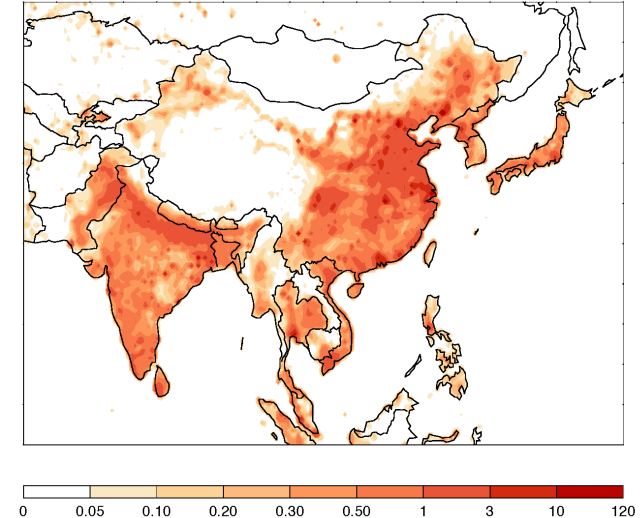
Population Density 2000



Anthro BC+OC emission (CEDS) 2010

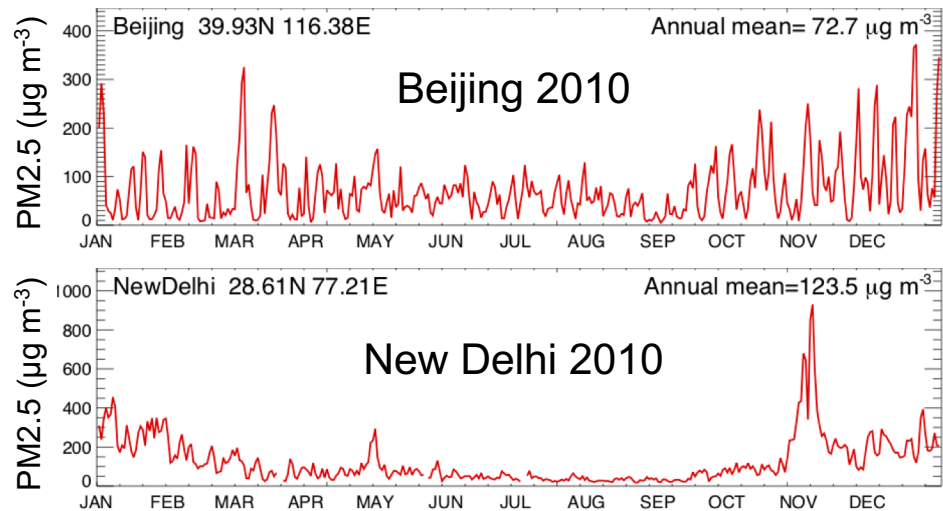


Anthro CO emission (CEDS) 2010

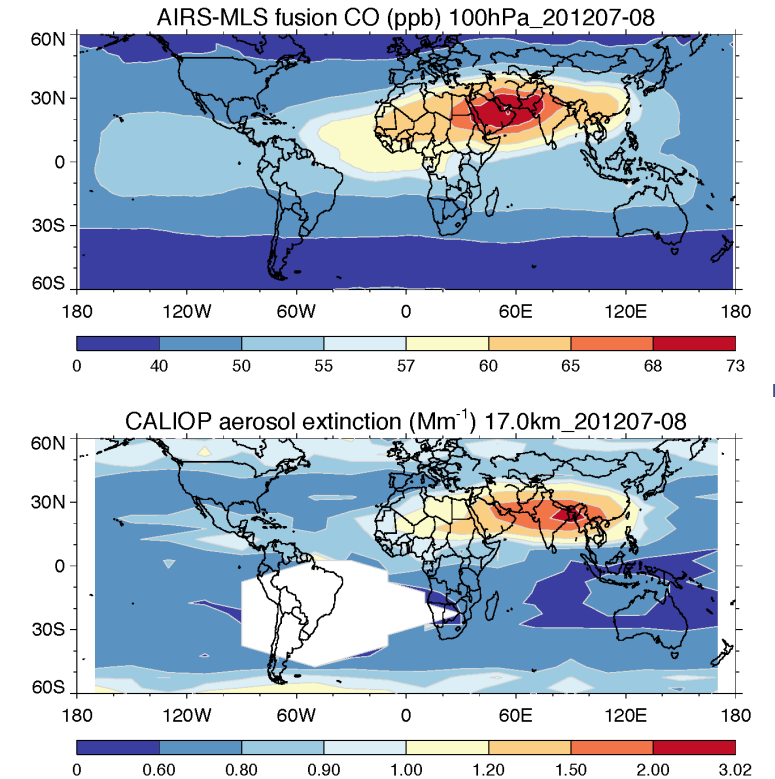


# Connections between Asian air pollution and monsoon system have shown two characteristically distinctive phenomena

- **Winter monsoon** season featured by severe air pollution problem, stagnant circulation, shallow boundary layer, and dry weather that make pollutants accumulated near the surface



- **Summer monsoon** season features strong convective transport lifting the surface pollutants to near the tropopause, where they further spread out to alter the atmospheric composition far beyond Asia



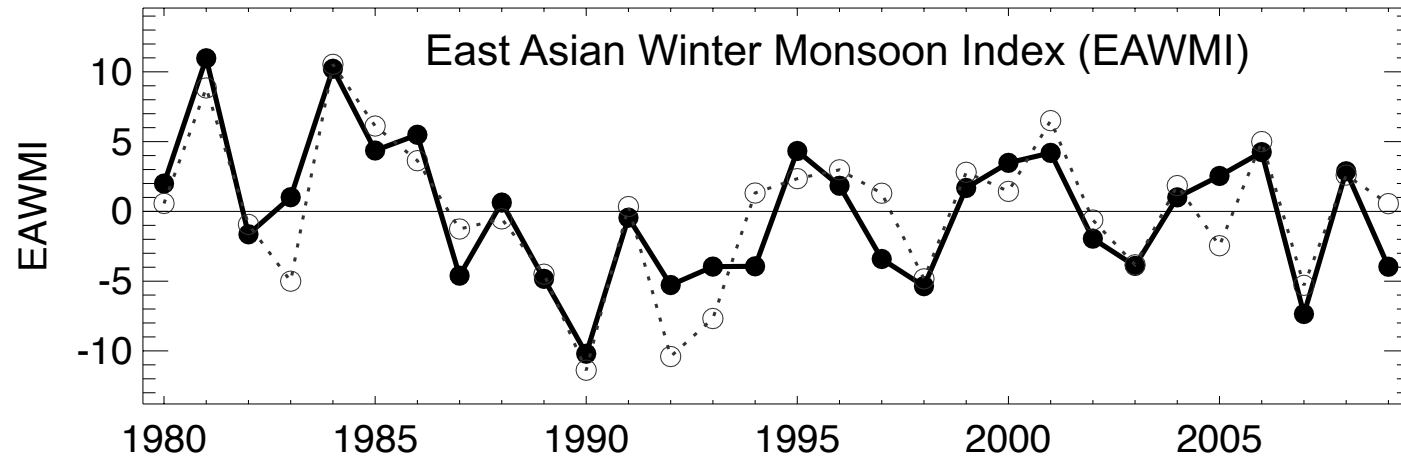
(CO data from Juying Warner)

# Winter

- Featuring severe air pollution problem, stagnant circulation, shallow boundary layer, and dry weather
- Aerosol-radiation-cloud interactions usually exacerbate the pollution problem to worsen the air quality



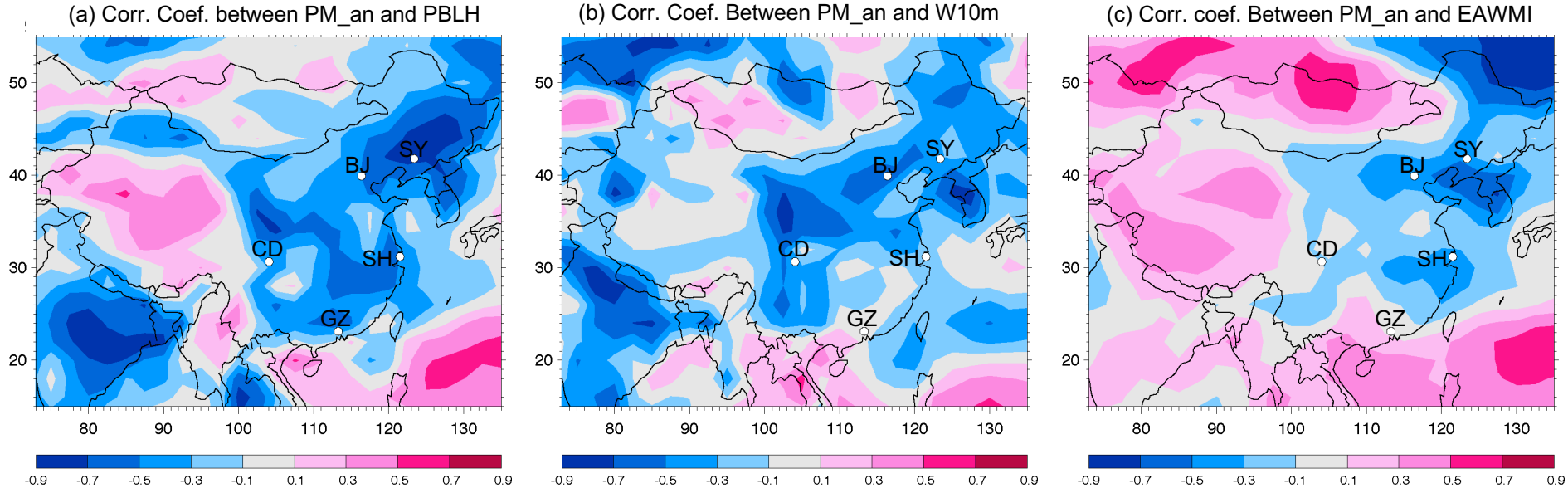
# Wintertime air quality is closely associated with the monsoon strength – Example: East Asia Winter Monsoon (EAWM)



Black solid line: Jhun and Lee, 2004. Grey dash line: Li and Yang, 2010. Winds are from MERRA-2 reanalysis

- We use the Jhun and Lee (2004) index in this work, which is defined as the difference of zonal wind speed at 300 hPa between  $[27.5-37.5^{\circ}\text{N}, 110-170^{\circ}\text{E}]$  and  $[50-60^{\circ}\text{N}, 80-140^{\circ}\text{E}]$
- Note that all EAWM indices can only well represent the monsoon characteristics over part of the East Asia, because the large domain of East Asia with complex and different climate zones

# Relationships among pollution PM, PBLH, winds, and EAWMI: GOCART model simulations with fixed anthropogenic emission (meteorology-induced changes of pollution PM), winter (DJF) 1980-2009

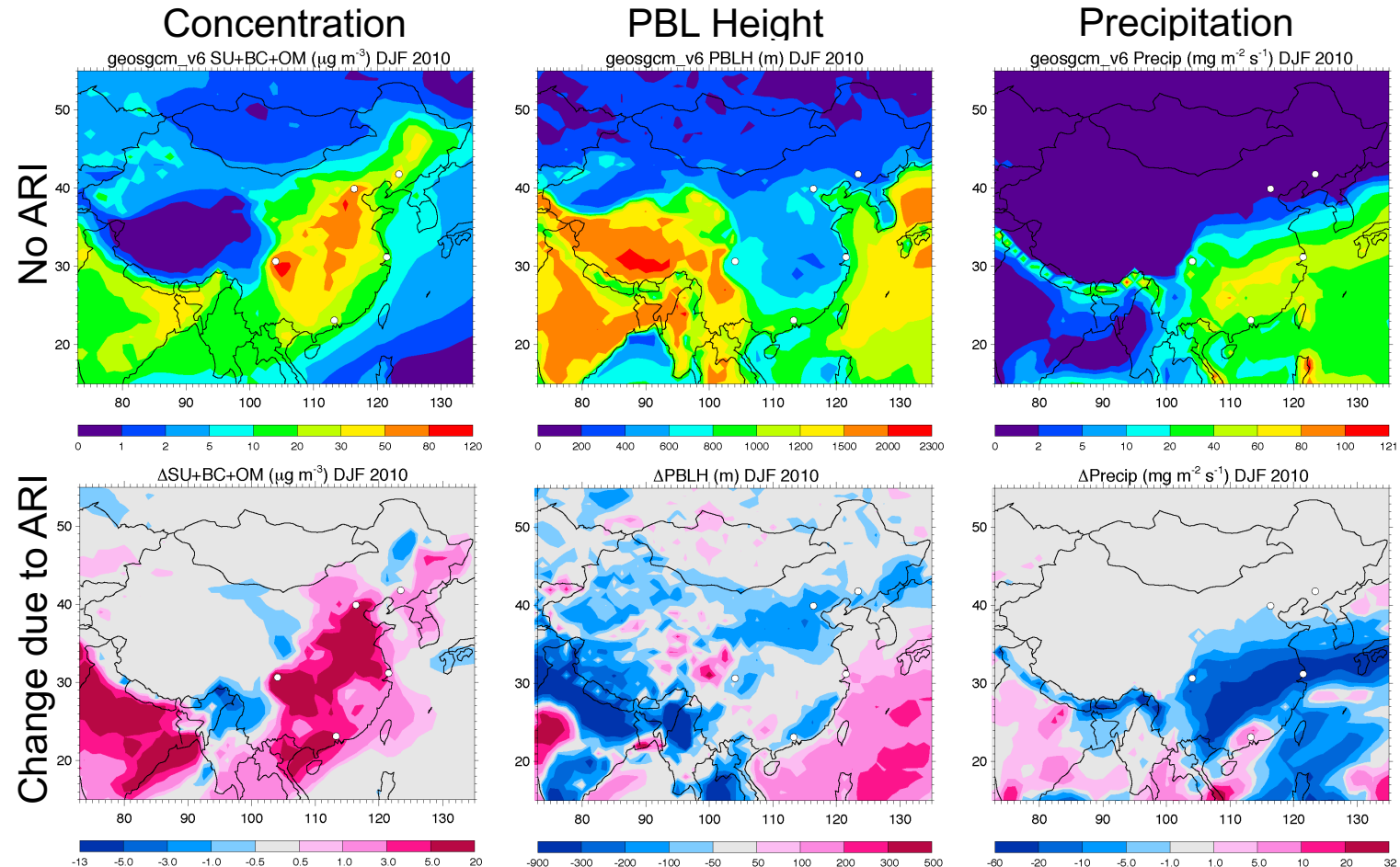


Chin et al., 2017

- PBLH and near-surface winds (indicated by W10m) are the most influential meteorological variables affecting pollution PM concentrations
- Pollution PM concentrations in East China are negatively correlated with PBLH, W10m, and EAWMI: The weaker the EAWM, the shallower the PBL, the weaker the W10m, and the higher the PM concentrations
- This EAWMI does not work for western China where the PM levels are low and are mostly from non-EAS source



# Aerosol-radiation-cloud interactions are particularly important processes that could exacerbate the wintertime poor air quality problem in Asia

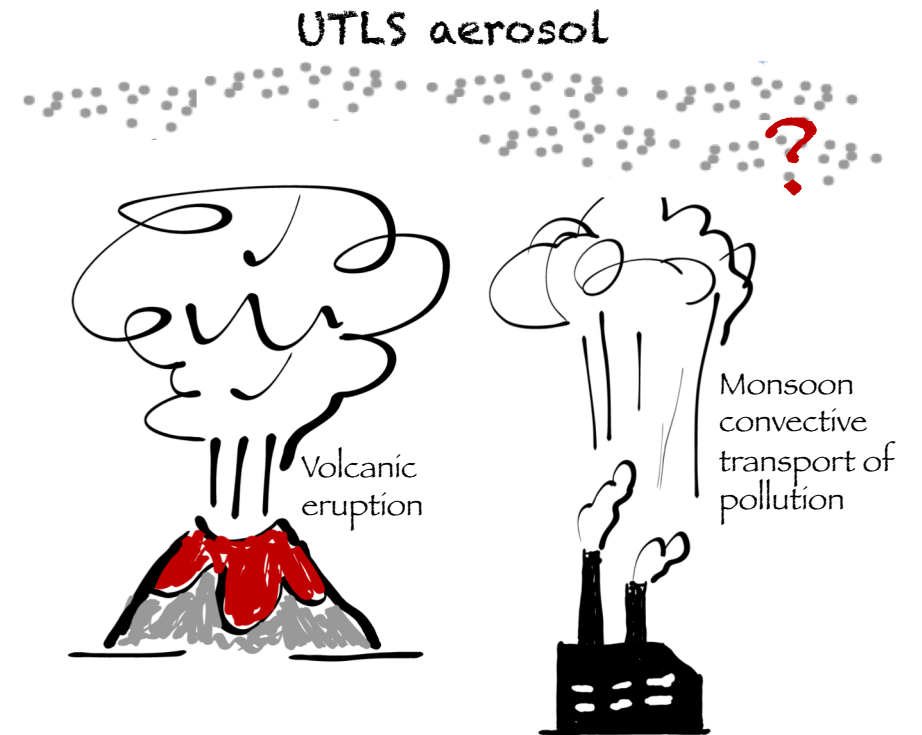


GEOS/GOCART model simulations showed that absorbing aerosols interacting with radiation in winter time can suppress the PBL height and reduce the precipitation, thus trapping more pollutants near the surface

Chin et al., 2017

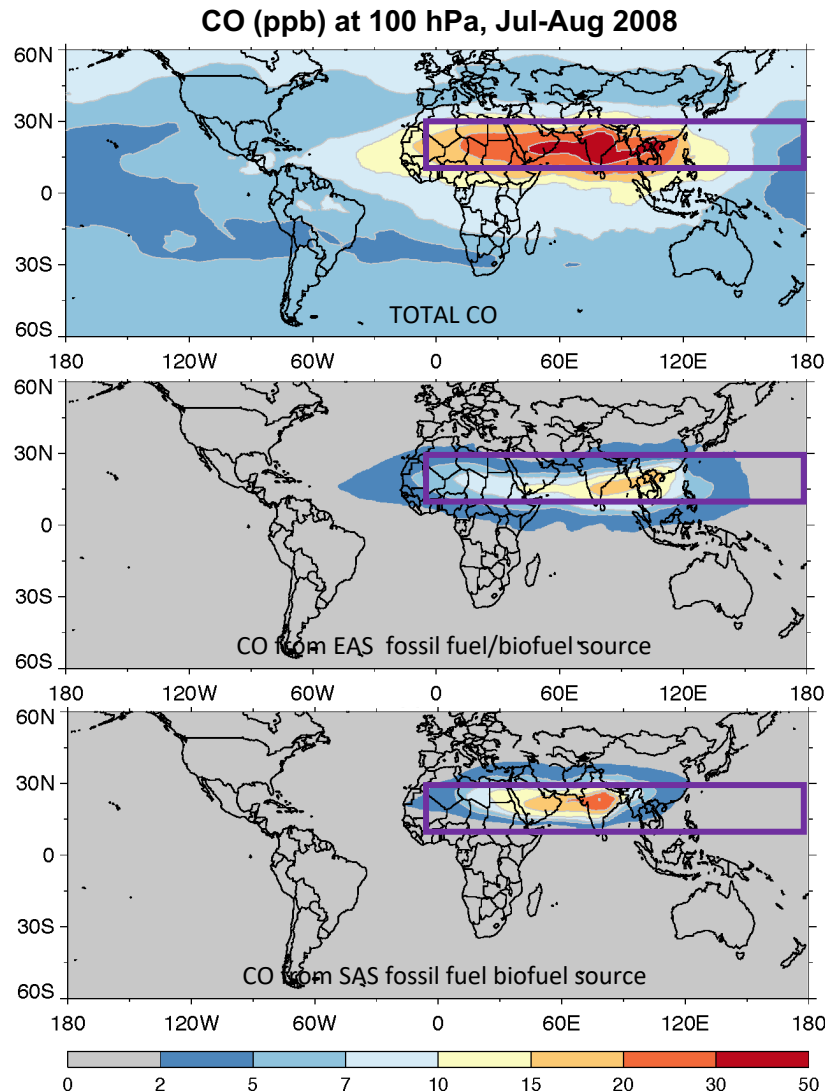
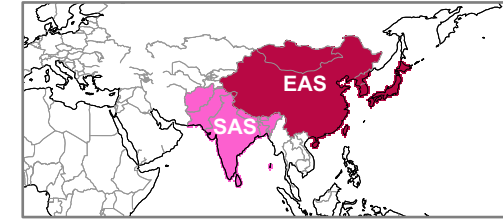
# Summer

- Featuring strong convective transport lifting the surface pollutants to near the tropopause, where they further spread out to alter the atmospheric composition far beyond Asia
- Anthropogenic aerosols (from Asia) seems dominating the UTLS in the neighborhood of tropopause in the tropical and subtropical area while volcanic aerosols dominating the stratosphere in general



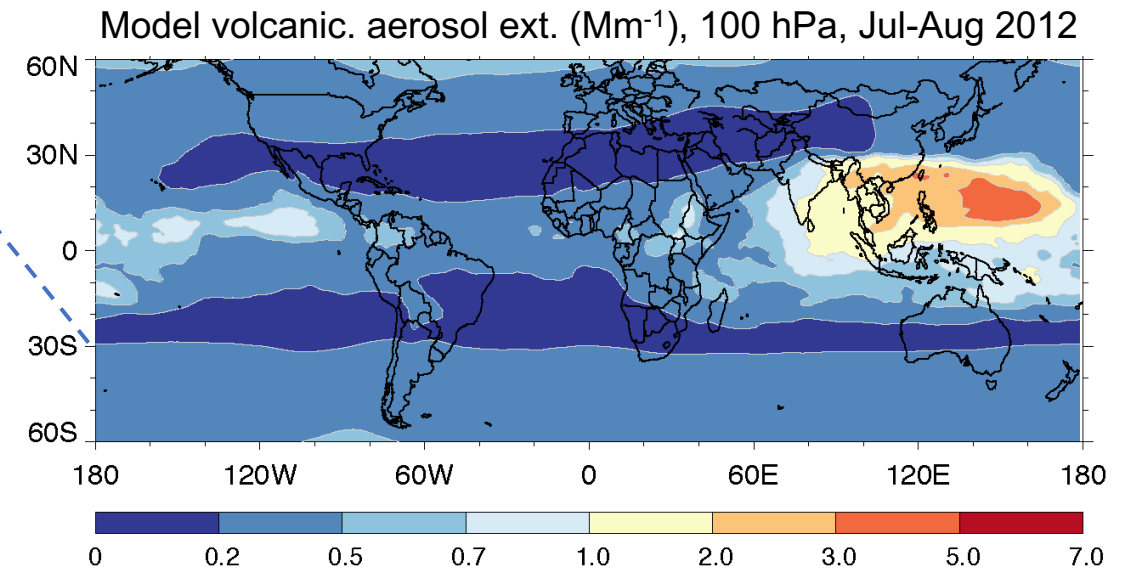
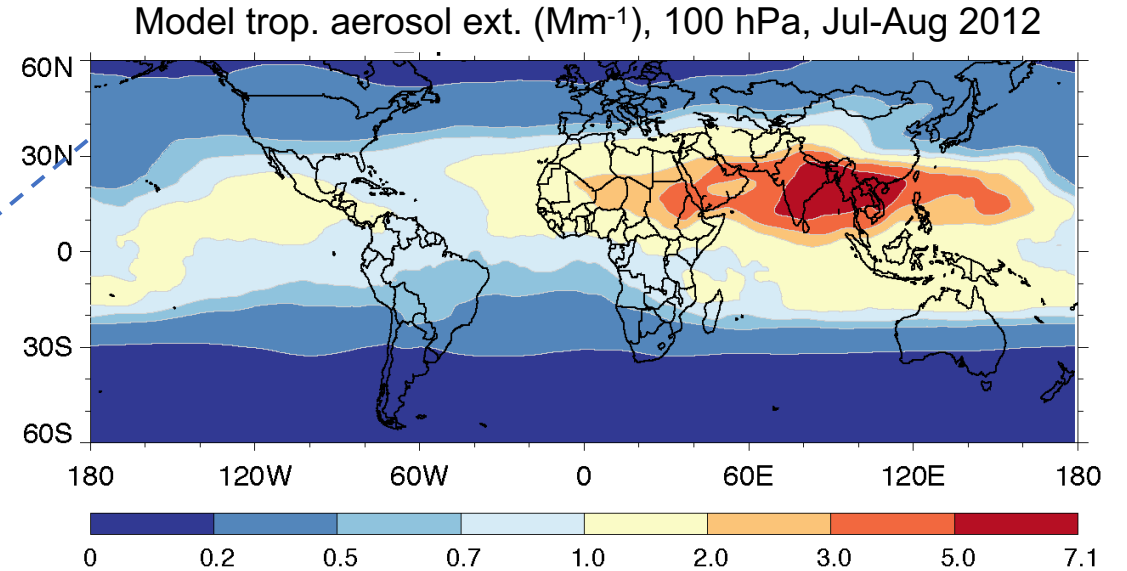
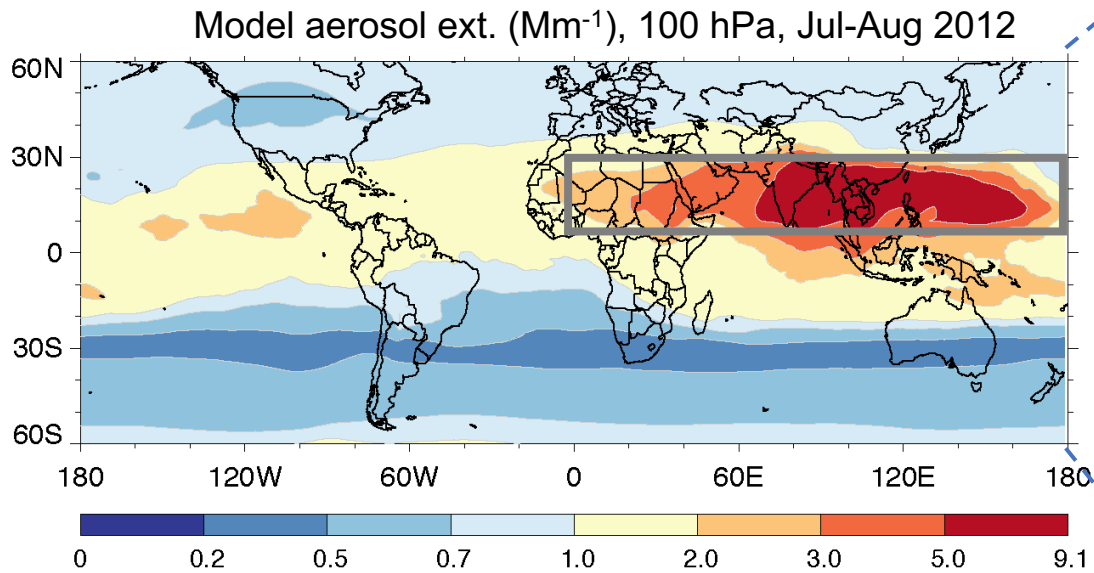


# Transport tracer – CO tagged with regional anthropogenic emissions from EAS & SAS

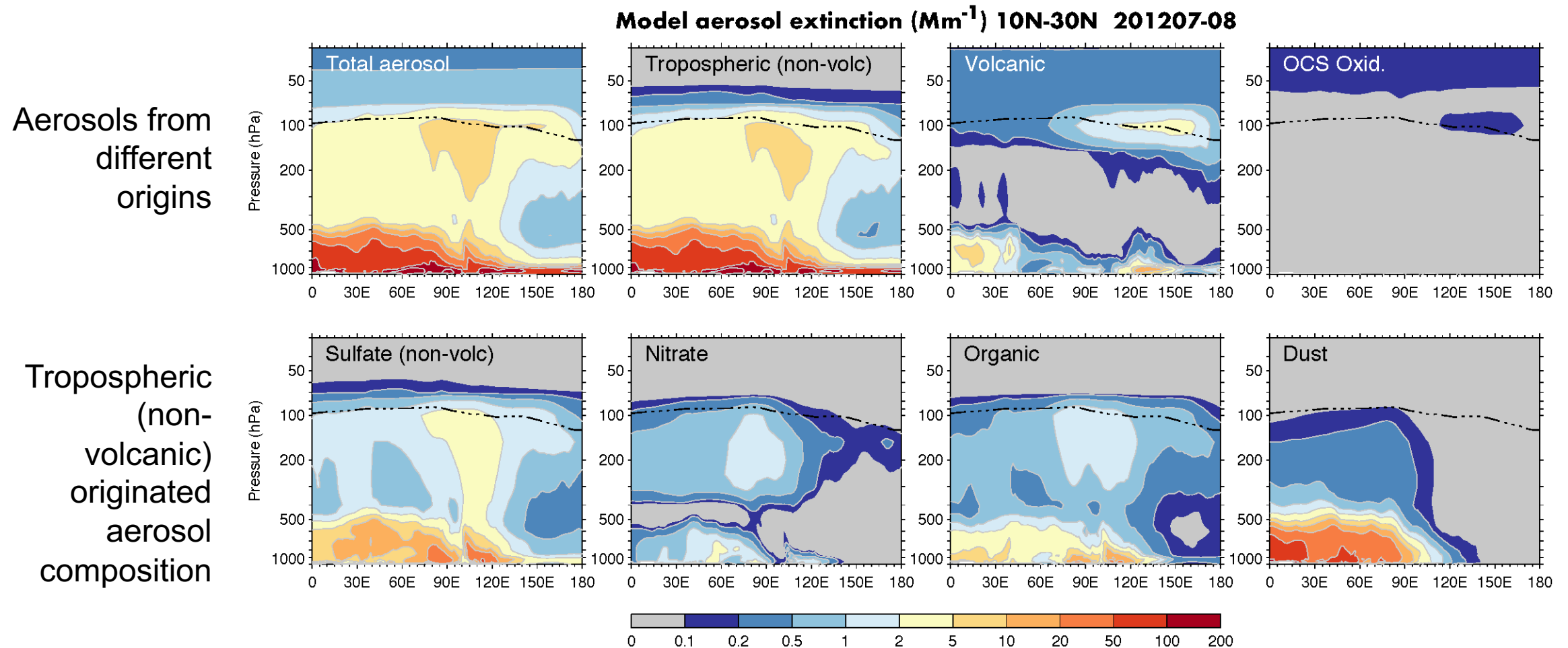


- CO is an excellent transport tracer
- Monsoon convection lifts surface pollution to the UT
- There are mainly two “stems” for such transport in the 10-30N band, one over India and one from southern China/SE Asia
- CO from Asian pollution sources further spreads out in the free troposphere to the Middle East, North Africa, northern Indian and Pacific oceans
- Pollution from East Asia affects wider area than that from South Asia in UT region

# Model simulated aerosol extinction (550 nm) at 100 hPa and its sources, Jul-Aug 2012

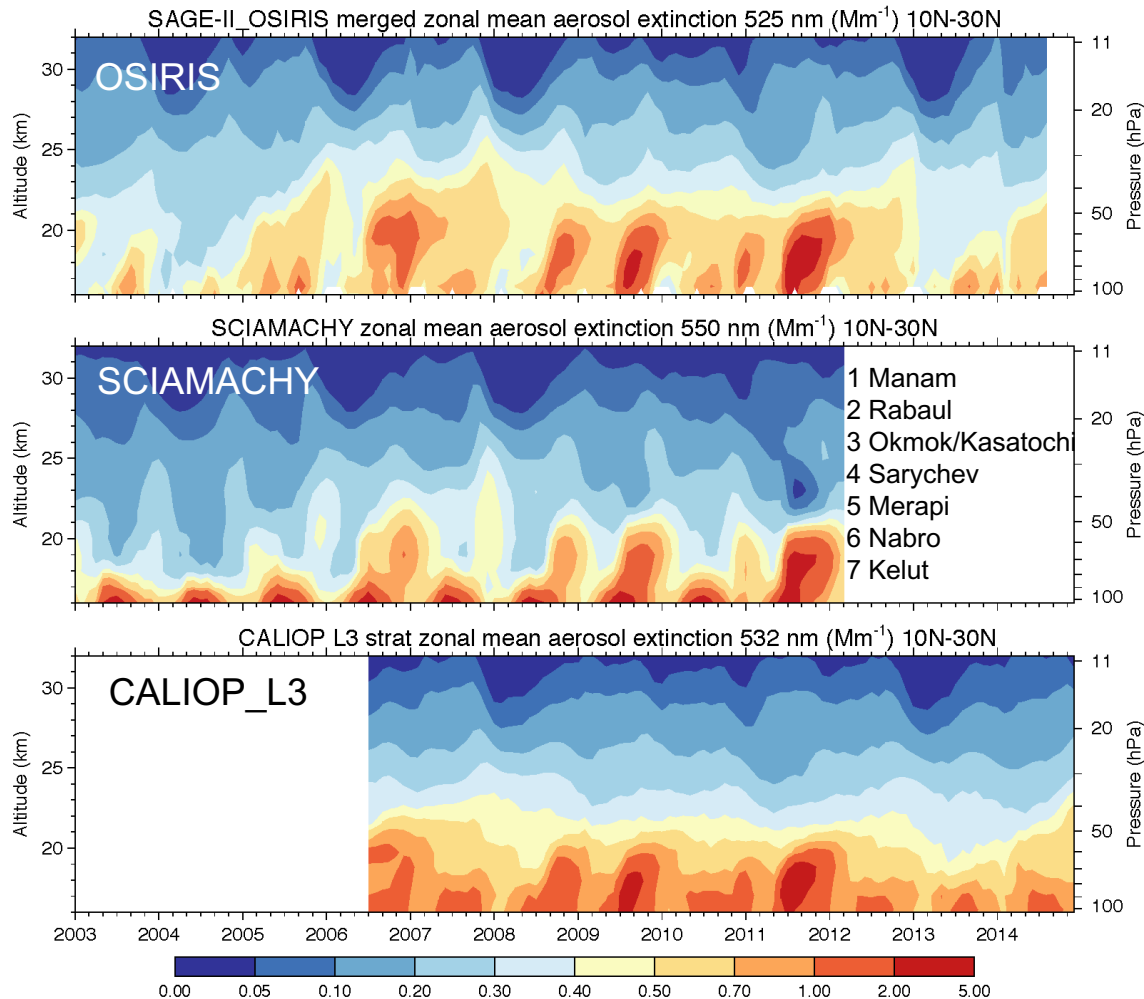


# Model simulated longitudinal aerosol extinction (550 nm) profiles averaged over 10°N-30°N, Jul-Aug 2012: Aerosol composition and origin

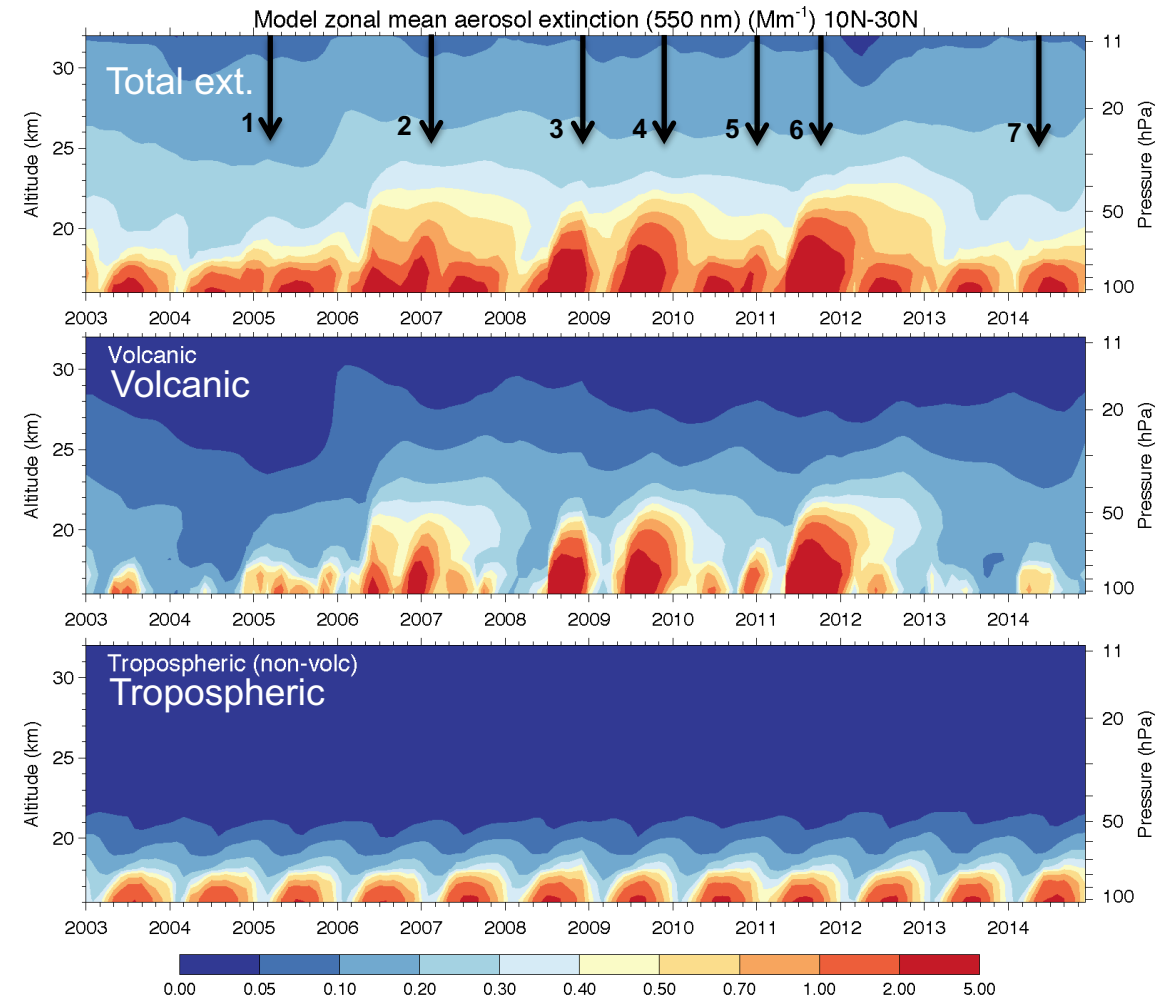


# Asian summer monsoon convective transport affects UTLS composition and possibly cirrus cloud formation near the tropopause – example of UTLS aerosol extinction, 10-30N

Satellite data. 10N-30N zonal mean

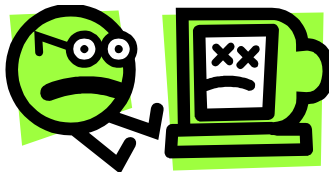


GEOS model simulation, 10N-30N zonal mean



# Questions still to be answered:

- How is the air quality in East and South Asia affected by the aerosol-PBL feedbacks and the aerosol-convection interactions?
- How does the aerosol-PBL and aerosol-convection processes affect the chemical production and removal of aerosols?
- How do the aerosol-monsoon interactions respond to the large-scale forcing from ENSO and sea surface temperature change?
- Etc. etc....
- Answering these questions need to use multi-platform observations and multi-scale modeling and analysis



# To engage international modeling communities on ACAM focused research

Mian Chin, James Crawford, Qing Liang, Xiaohua Pan, Huisheng Bian, Hans Schlager, Laura Pan, Michael Schulz

- We have an on-going AeroCom Phase III model experiment on ACAM, focusing on the sources and decadal trends of aerosols at the surface and UTLS (will be further discussed at the upcoming AeroCom workshop, September 23-26, Barcelona)
- We have proposed an "Area of Focus" as a CCMI phase-two activity on Asian monsoon transport and chemistry (to be presented and discussed at the upcoming CCMI workshop, August 7-9, Hong Kong)
- Will reach out to other communities

