Seasonal and interannual variability of upper tropospheric aerosols: Sources and the role of Asian monsoon transport

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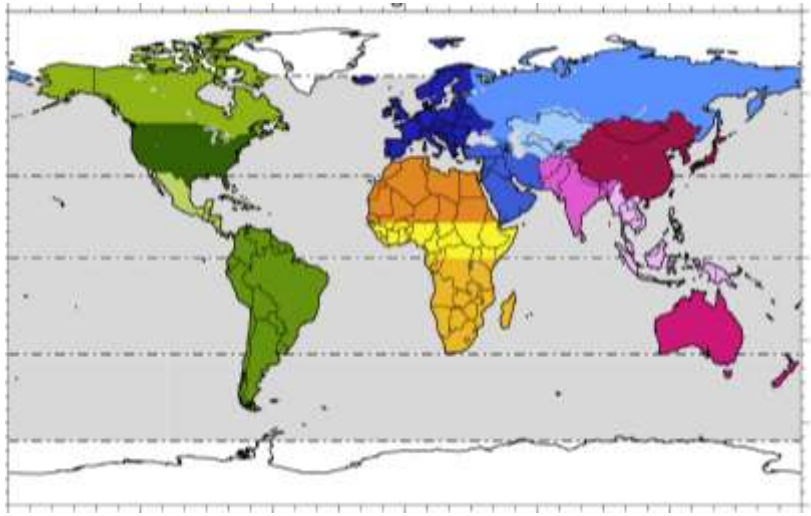
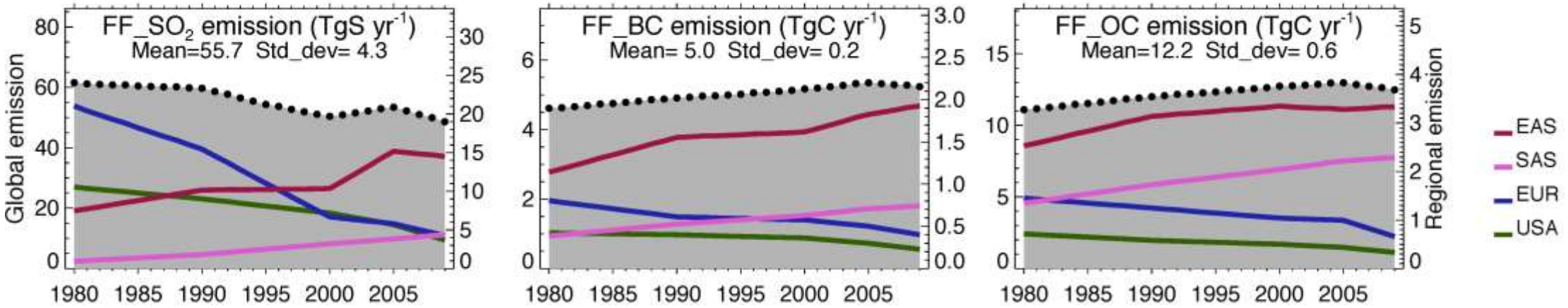
Introduction

- The origin and variability of stratospheric aerosol have drawn considerable attention because the change of such aerosol could have long-term climate effects
- Recent observations seem to suggest that the stratospheric aerosol has been increasing in the past decade without major volcanic eruptions
  - Is the increase due to the Asian anthropogenic emission?
  - Or volcanoes?
- This work uses a global model to estimate the aerosol sources in the UTLS region and to elucidate the role of Asian monsoon transport

Anthropogenic emission

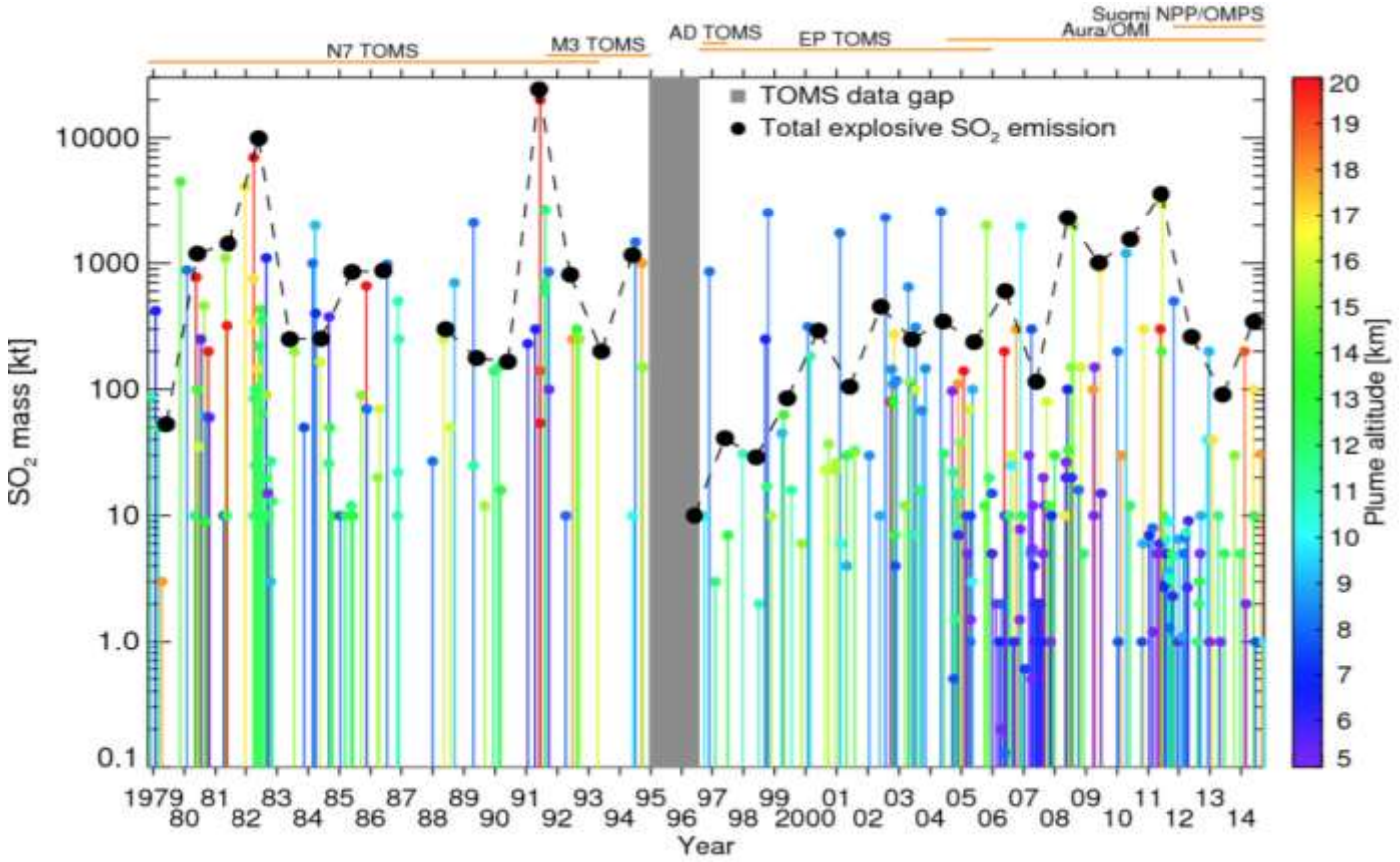
- Anthropogenic SO_2 (and other pollutants as well) emissions in East Asia and South Asia have increased significantly in the last decade
- EAS emission is much higher than SAS
- The question is: How efficient the transport is to lift surface pollution to the UTLS?





(Figures from Chin et al., 2014)

Volcanic SO_2 emission



SO_2 emission from eruptive volcanoes from 1979 to 2014. Data source: Carn et al., 2015).

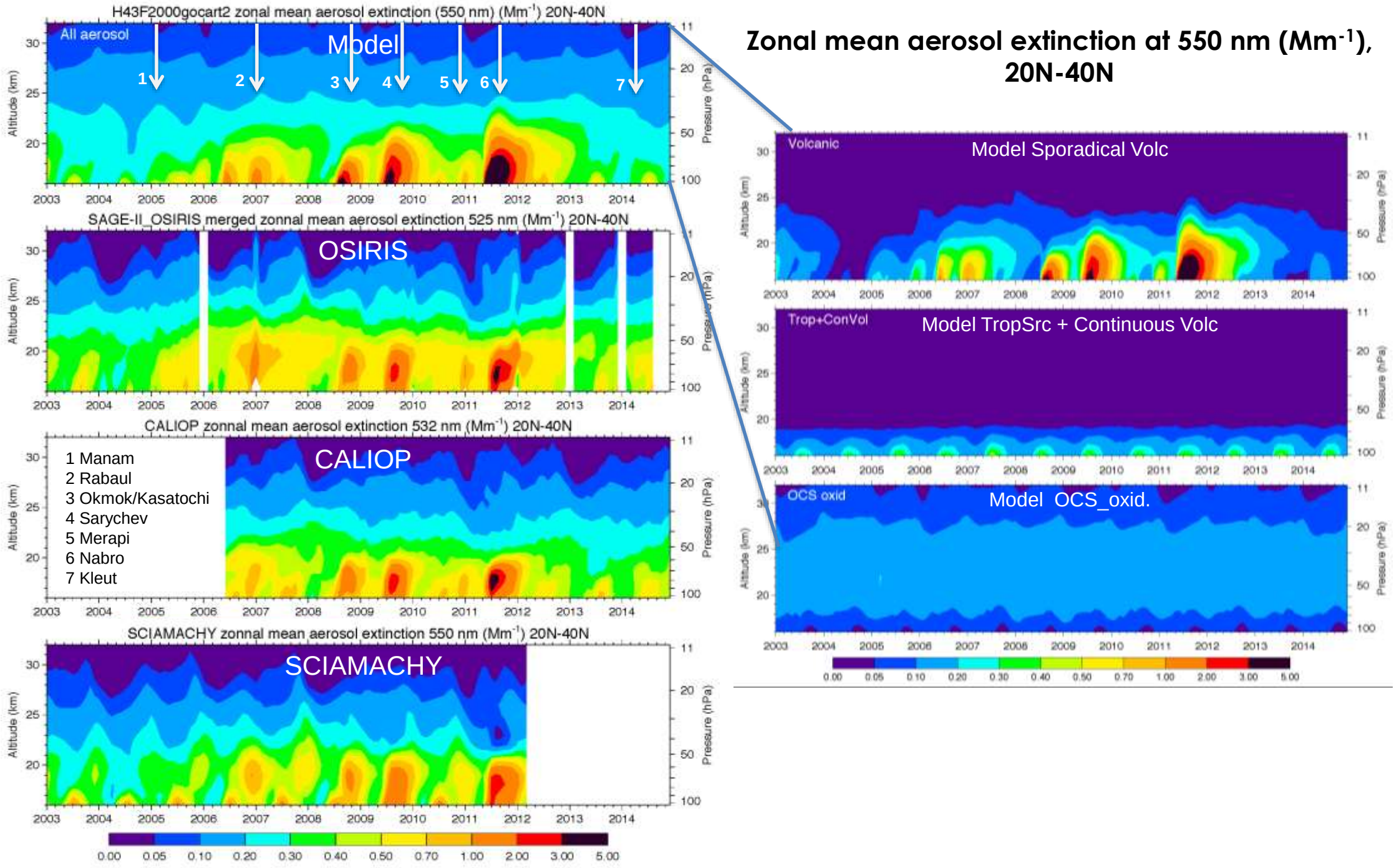
- Volcanic emissions release SO_2 usually at higher altitudes than anthropogenic emissions to have a more direct influence in the UTLS

Model simulations

- Model simulations:
  - GEOS-5 AGCM/GOCART, 2.5°lon x 2° lat horizontal resolution, 72 vertical layers
  - Anthropogenic and biomass burning emission: ACCMIP (Granier et al., 2011)
  - Volcanic emission: OMI-based sporadically erupting volcanic emission (Carn et al., 2015) + continuously erupting volcanic emission (Andres and Kasgnoc, 1998)
  - Sulfate from OCS oxidation included
  - Aerosols identified from (1) sporadically erupting volcanic source, (2) stratospheric background source (OCS oxidation), and (3) other (anthropogenic + biomass burning + non-volcanic natural + continuously erupting volcanic sources)
- Time period of this study: 2003-2014

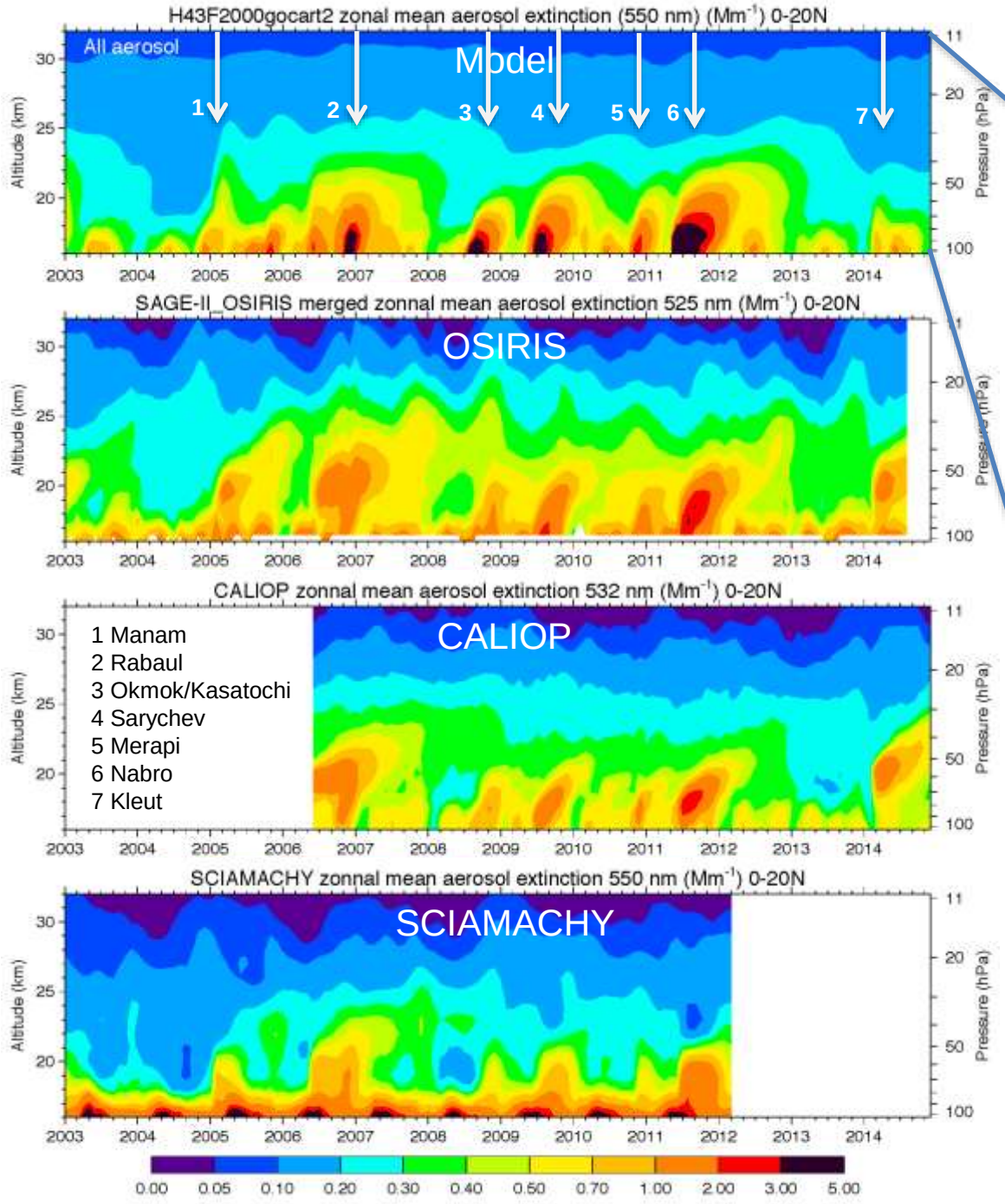
Comparison with satellite aerosol data

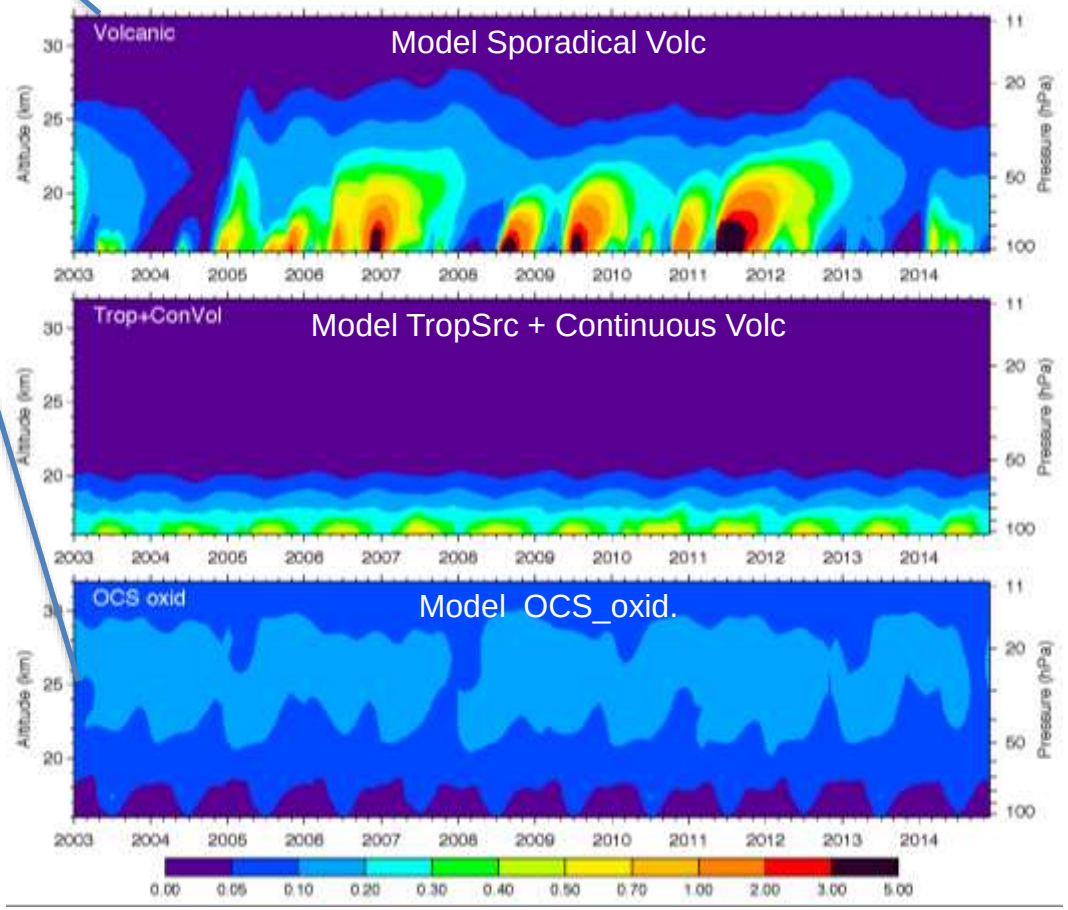
- OSIRIS:
  - V5-07 level-3 monthly zonal averages at 5° latitude resolution and 1-km vertical resolution from 0-40 km (provided by U. Saskatchewan group, POC: Landon Rieger)
  - Merged SAGE-II and OSIRIS: extinction at 525 nm
- CALIOP:
  - Stratospheric aerosol V6, monthly zonal average extinction at 532 nm at 5° latitude resolution, 8 to 40 km (provided by Jean-Paul Vernier, LaRC)
- SCIAMACHY:
  - V1.1. level 3 monthly averages at 5°x5° horizontal resolution and 1-km vertical resolution from 9-40 km (provided by U. Bremen group, POC: Alexei Pozanov)
  - 550 nm extinction was interpolated from 470 and 750 nm using the Angstrom Exponent

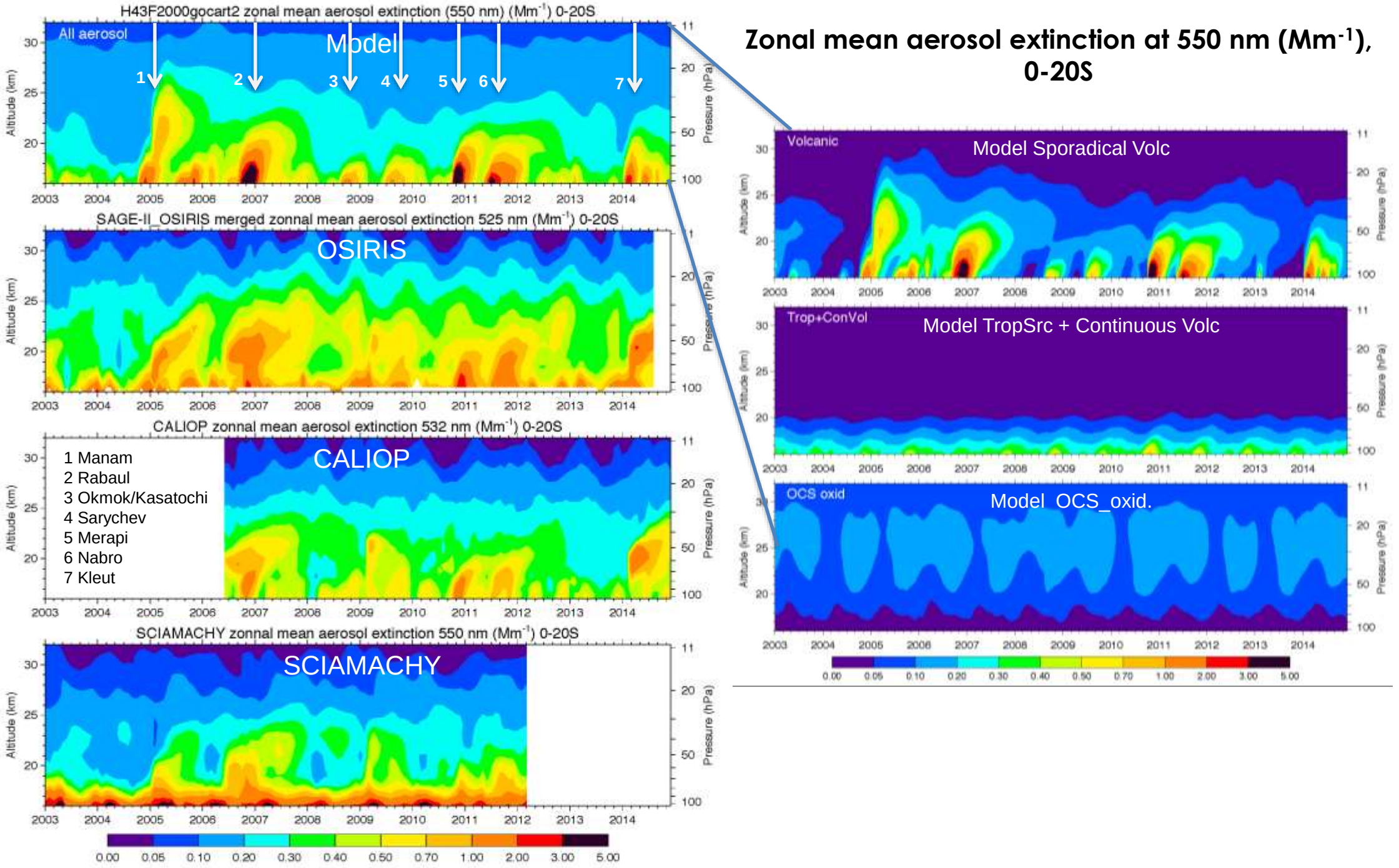


Zonal mean aerosol extinction at 550 nm (Mm^{-1}), 20N-40N

Zonal mean aerosol extinction at 550 nm (Mm^{-1}), 0-20N







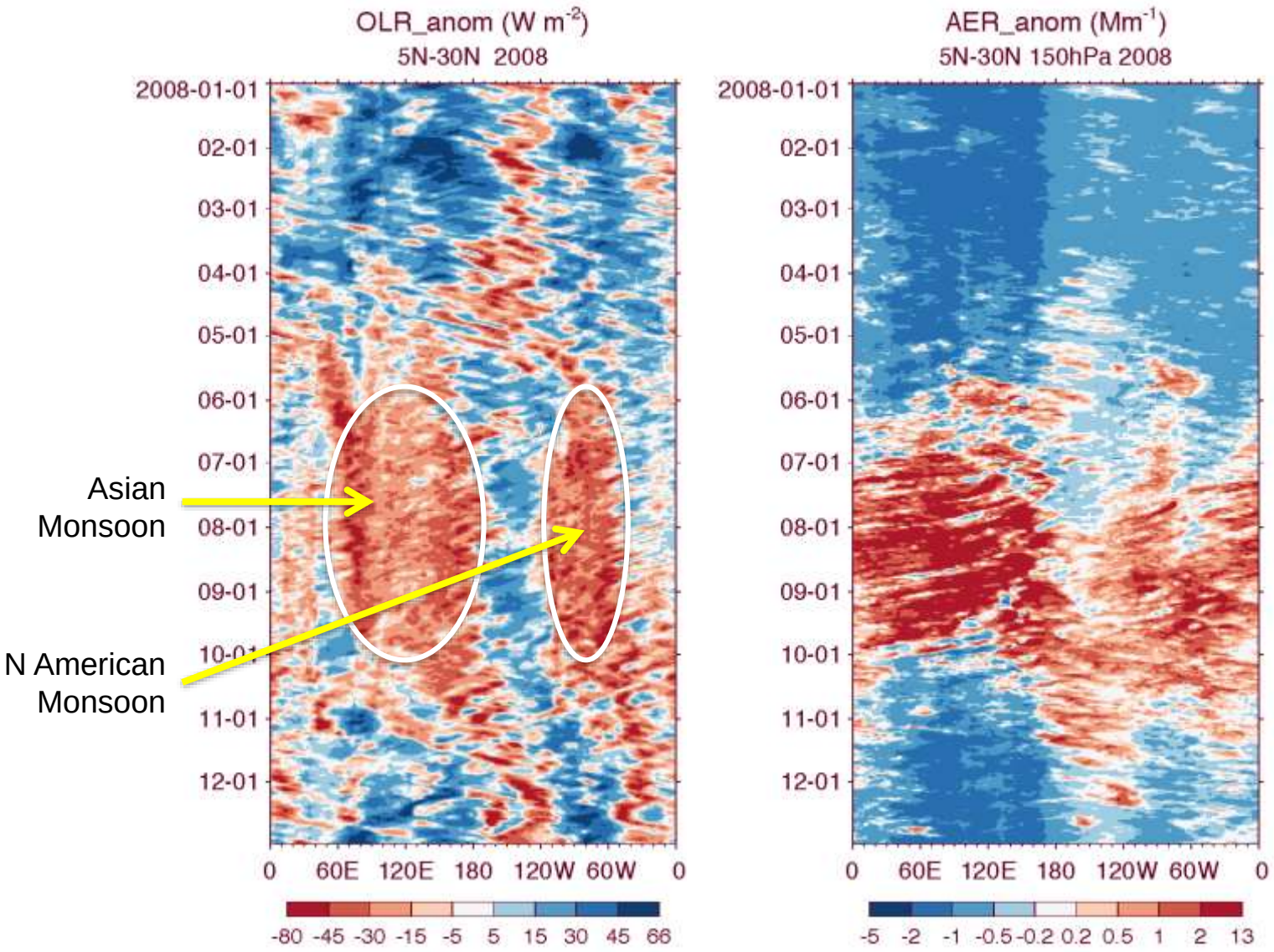
Zonal mean aerosol extinction at 550 nm (Mm^{-1}), 0-20S

Source attribution – volcanic, anthropogenic, and background

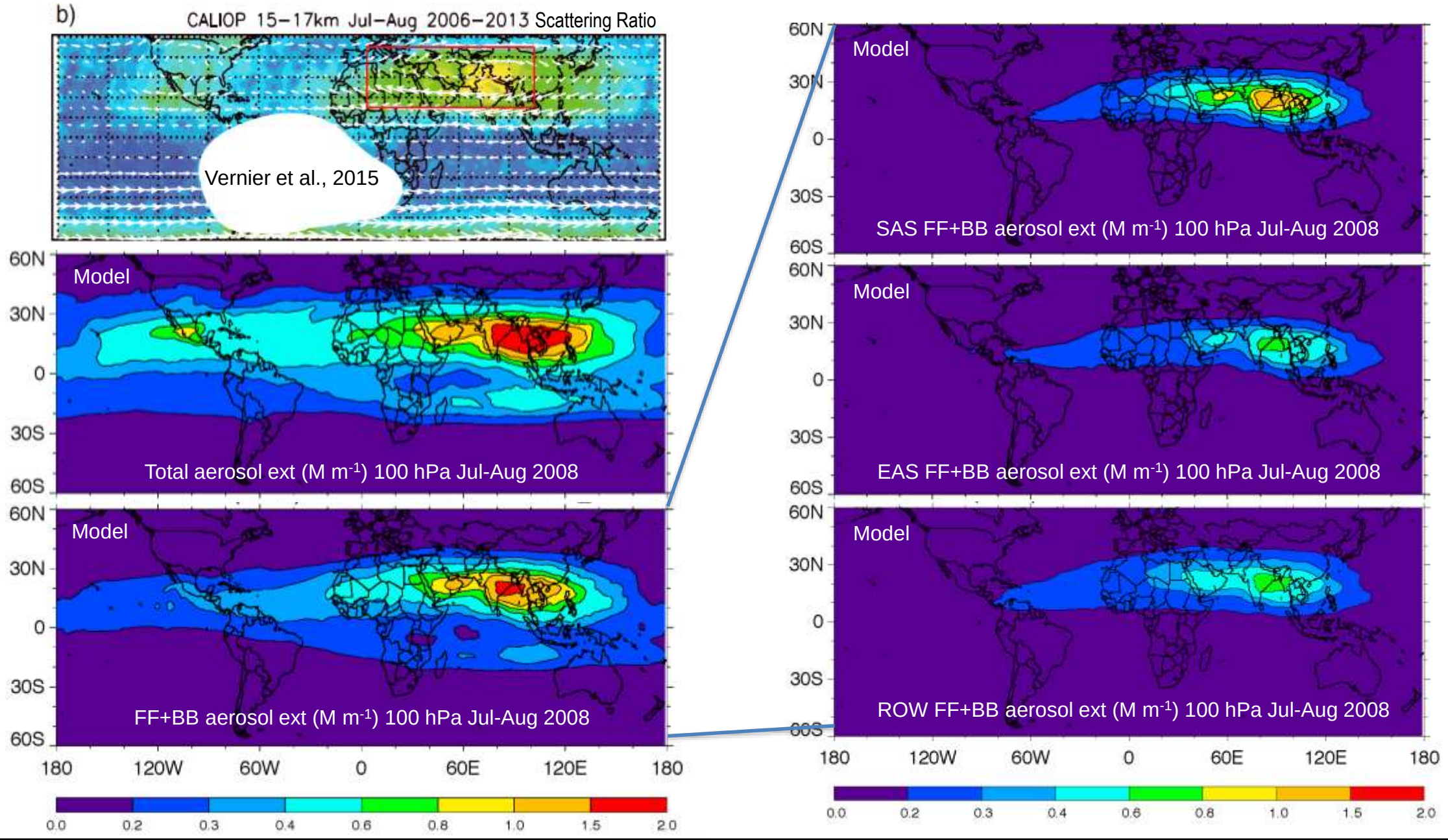
- Overall, the volcanic aerosol dominates the stratospheric aerosol loading even without Pinatubo-scale large eruption (4-5 higher than anthropogenic)
- Near the tropopause, anthropogenic aerosol shows a well organized, repetitive seasonal cycle
- The "background" sulfate aerosol from OCS oxidation is the most important aerosol source >25 km

Seasonal variations of deep convective transport: Average OLR and UT aerosol anomaly, 5-30N

- In the subtropical northern hemisphere, the most pronounced convective features are the Asian summer monsoon and the North American summer monsoon
- The monsoon convections pumps aerosols to the upper troposphere, even though the convection always associated with heavy rainfall
- Composition of UT aerosol varies from year to year depending on the variation of aerosol sources

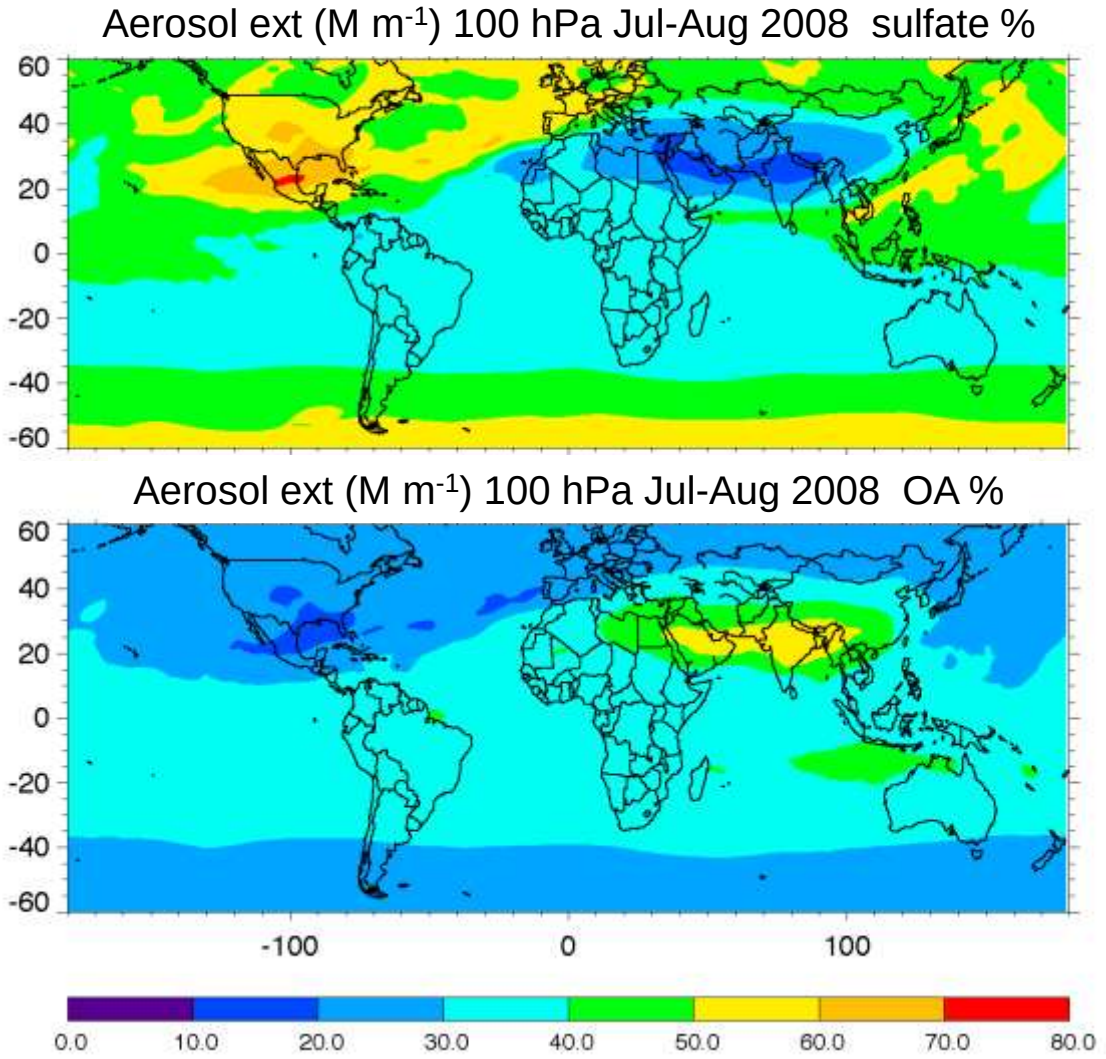


Maximum aerosol in ATAL



Aerosol composition in the UT monsoon region from GOCART simulation

- GOCART simulations suggest that over the UT Asian monsoon region, organic aerosol accounts for 50-60% of total aerosol extinction at 550 nm while sulfate only 10-30%
- We need measurements to verify aerosol composition
- Further investigation of chemical and physical mechanism determining the aerosol composition in the UT region is in progress



Concluding remarks

- By model experiments separating anthropogenic and natural sources, we have found that
  - volcanic aerosol dominates the total stratospheric aerosol amount even without very large volcanic eruptions like Pinatubo
  - anthropogenic aerosol exhibits well organized seasonal cycle in the tropopause region
- Strong summer monsoon convection in the subtropical northern hemisphere making transport of aerosols to UTLS most effective in the summer
  - SAS anthropogenic aerosol dominates the ATAL aerosol in summer (60-70%), even though EAS anthropogenic emission is much higher than SAS
  - Not all aerosols in ATAL are from Asia – other regions contribute as well
- Aerosol composition from the model suggest that OA is the most component in the UT Asian monsoon region – verification needed!