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Seasonal and interannual variability of aerosols in the UTLS : Connection to sources and transport process

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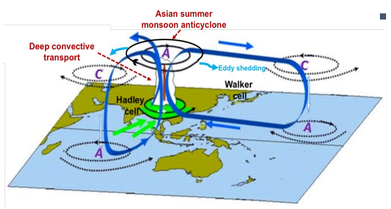
Introduction

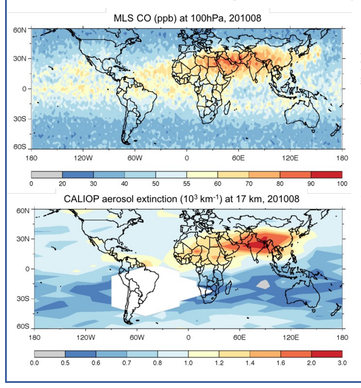
The Asian summer monsoon dynamic system coupled with other atmospheric circulation patterns to transport pollutants from the most polluted regions to UTLS

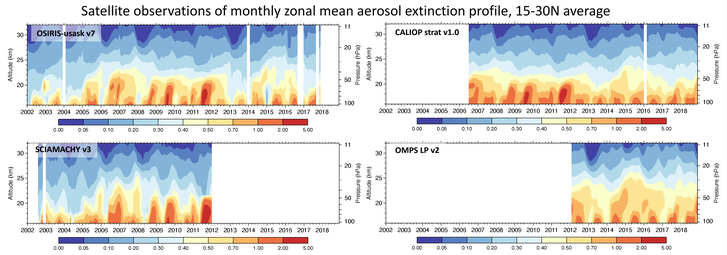


[Figure adapted from CLIVAR, https://www.clivar.org/asian-australian-monsoon]

- The Asian summer monsoon convective system features
  - A low-level cyclonic flow over South and East Asia
  - A persistent deep convective motion
  - A strong upper-level anticyclonic circulation
  - Sub-seasonal eddy shedding to the east and west
  - Coupling with large-scale circulations

Satellite data showing evidence of pollutants hot spots near the tropopause over the Asian summer monsoon area





Although volcanic eruptions frequently produce the most pronounced aerosol amount in the stratosphere, there are clear seasonal cycles of aerosols around the tropopause altitudes, showing evidence of tropospheric aerosol intrusion every summer associated with the summer monsoon dynamics

Objectives of modeling and analysis of UTLS aerosols and related species

- Compare and evaluate the model simulated aerosol extinction in the UTLS with satellite data
- Assess the origin, composition, transport pathways, and sub-seasonal to decadal ivariabilities of UTLS aerosols
- Coordinate with other international projects, particularly AeroCom (Aerosol Comparisons between Observations and Models) and ACAM (Atmospheric Composition and the Asian Monsoon)

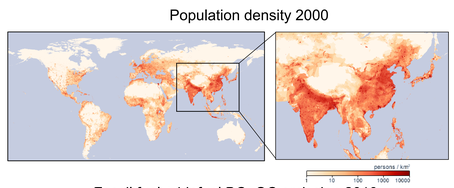
Model setup

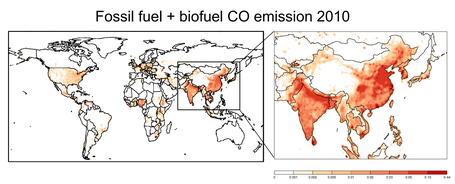
GEOS model setup

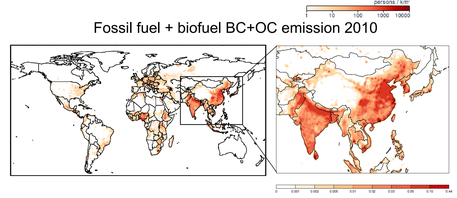
Years:	2002-2018
Base emissions:	Anthropogenic and biomass burning emissions from CEDS (2017 release, Hoesly et al., 2018) Volcanic emissions from Carn et al. 2015, 2016 (OMI-based) Other emissions (dust, sea salt, biogenic) calculated in model
Tagged source runs:	Tagged source origins of anthropogenic emissions from East and South Asia, global biomass burning emissions, global volcanic emissions
Transport tracer CO50:	Sources: 12-monthly CO emission + fixed CO production from CH4. Sink: 50-day lifetime
Deposition tracer ^{210}Pb:	Source: Formation from ^{222}Rn radiative decay Sink: Sulfate-like dry and wet scavenging by large-scale and convective precipitation

Maximum pollutant emissions co-located with the highest population density in the major Asian monsoon regions

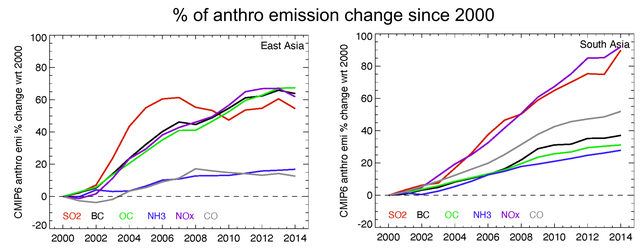
(Anthro emission source: Community Emissions Data System (CEDS), Hoesly et al., 2018)





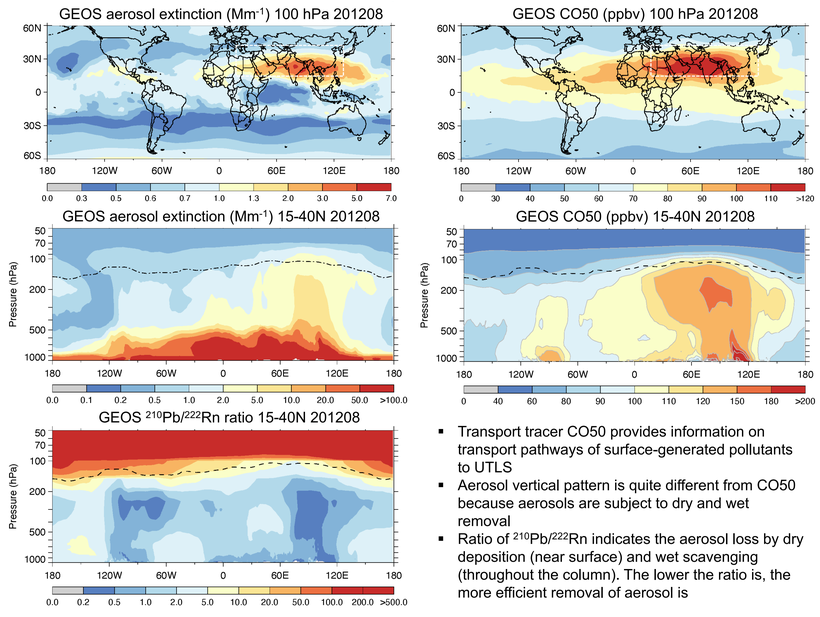


The highest anthropogenic emissions coupled with the most dynamic Asian summer monsoon to exert anthropogenic forcing in the UTLS



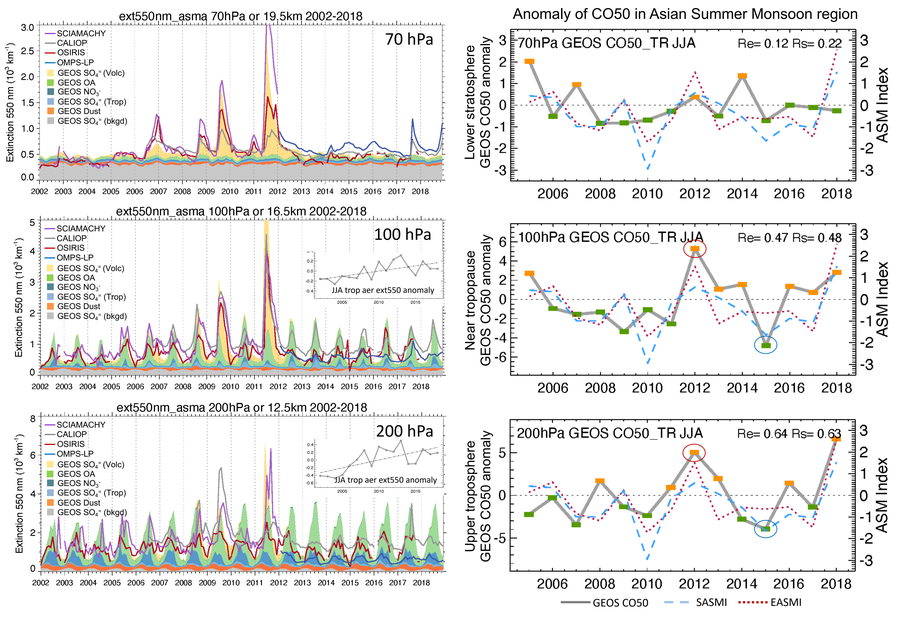
Results

Convective transport and removal processes controlling aerosols in the UTLS

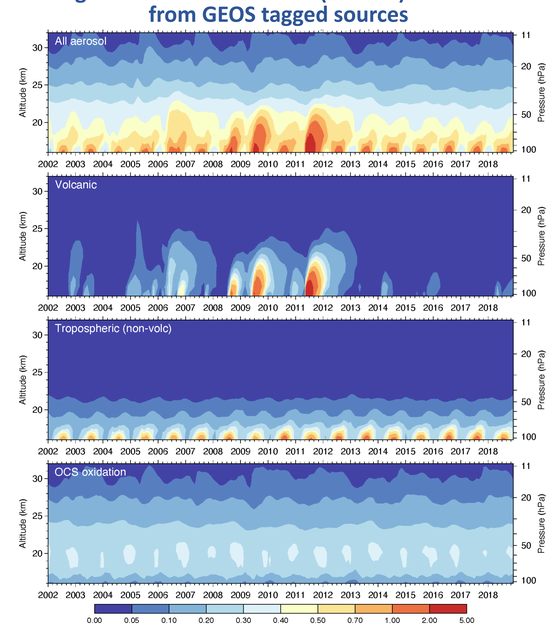


- Transport tracer CO50 provides information on transport pathways of surface-generated pollutants to UTLS
- Aerosol vertical pattern is quite different from CO50 because aerosols are subject to dry and wet removal
- Ratio of ^{210}Pb/^{222}Rn indicates the aerosol loss by dry deposition (near surface) and wet scavenging (throughout the column). The lower the ratio is, the more efficient removal of aerosol is

Interannual variability of convection and summer (JJA) UTLS aerosol in ASM region



Origin of aerosol extinction (10-30N) in the UTS from GEOS tagged sources



Conclusions

Conclusions (1)

- Both satellite observations and GEOS model simulations show effective transport of Asian air pollution to the UTLS via convective transport and horizontal spreading by the Asian summer monsoon system
- The different vertical distributions of aerosols and CO are the results of additional processes involved in aerosols (dry and wet removal, chemistry) in addition to transport
- While CO50 is an excellent tracer for diagnosing transport, ^{210}Pb/^{222}Rn ratio provides information for aerosol removal

Conclusions (2)

- In boreal summer over the Asian Summer Monsoon (ASM) region, aerosol extinction in the UT and at the tropopause is dominated by aerosol with tropospheric origin shown by GEOS
- Volcanic eruptions causing significant disturbance of stratospheric composition, but the effects are not long-lasting
- Seasonal cycle diminishes in LS with OCS-oxidation formed sulfate as the dominate aerosol source
- Convective transport of pollutants to UT and near tropopause is correlated with the Asian summer monsoon strength (indicated by East Asian and South Asian Summer Monsoon Indices)

Conclusions (3)

- GEOS reproduces the seasonal and interannual variability of satellite-observed aerosol extinction in the UTLS
- Volcanic aerosols are sporadic with large disturbance to stratospheric aerosols
- Tropospheric-produced aerosols show pronounced summer season intrusions to LS
- OCS oxidation is an important source of aerosol in stratosphere

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