Natural and anthropogenic aerosols in the UTLS: Sources and 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
 - It was suggested that the increase of Asian anthropogenic emission was the cause of such an increase (Hofmann et al., 2009) through the Asian monsoon transport
 - But other studies showed that small-to-medium volcanic emission trends in the past decade can explain the stratospheric aerosol changes (e.g., Vernier et al., 2011; Neely et al., 2013)
- This work uses a global model to estimate the aerosol sources in the UTLS region and to elucidate the role of convective transport

Outline

- Description of model simulation
- Comparisons with CARIBIC aircraft data
- Comparisons with satellite data
- Attributions of aerosol sources in UTLS
- Results are preliminary advices and suggestions are appreciated!

Model simulations

- Model simulations:
 - GOCART model simulations of atmospheric aerosols, driven by MERRA meteorology, at 1.25°x1° horizontal resolution, 72 vertical layers
 - Anthropogenic and biomass burning emission: A2-ACCMIP
 - Volcanic emission: A2-MAP
 - Sulfate from OCS oxidation taken from the GEOS-5/stratchem simulation (Valentina Aquila)
 - Simulations with all emissions (BASE) and with natural emission only (NAT), such that the source of aerosols at a location and time can be estimated
- Time period of this study: 2000-2009

Anthropogenic emissions



Z. Liu and D. Streets

- Anthropogenic SO₂ (and other pollutants as well) emissions in East Asia and South Asia have increased significantly in the last decade
- In the meantime anthropogenic emission has decreased significantly in US and Europe
- The question is: How efficient the transport is to lift Asia surface pollution to the stratosphere to control the stratospheric aerosol trend?

Volcanic emissions injecting to UTLS



- Volcanic emissions that reach the UTLS seem to have a positive trend as well
- And they release SO₂ at high altitudes to have a more direct influence than Asian anthropogenic sources

 SO_2 emission from eruptive volcanoes from 2000 to 2009 with injection height above 10 km. Data source: OMI, GVP, and in-situ measurements reported in literature (Diehl et al., 2012)

Comparison of total AOD with satellite data



Figure from Chin et al., ACP 2014

Comparisons of model simulated aerosol S and C with CARIBIC measurements in the UT region

- CARIBIC: measurements on Lufthansa commercial aircraft at cruise altitudes
- Aerosol data available for S and C elements with integration time of about 100 minutes
- Majority of the data are taken between 200-300 hPa
- Over Asia the data are mainly from 2007 and 2008 flights



Data provided by Bengt Martinsson, Lund University, Sweden

S and C concentrations en-route



Overall comparison: scatter plot



- Model overestimates aerosol S by ~70% but correlates with data at R=0.76
- Model has no skill to reproduce aerosol C need to better understand the measurement methods and biomass burning strength and emission altitudes

Comparison with satellite 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
- 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
- CALIOP:
 - Stratospheric AOD V2.0, monthly zonal averages at 5° latitude resolution with extinction integrated from 15 to 40 km and converted to SAGE-II wavelength of 525 nm (provided by Jean-Paul Vernier, LaRC)
 - Time series before CALIPSO launch include SAGE-II (up to 2005), GOMOS (Sep. 2005 May 2006), CALIOP (June 2006 –)

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



A. Reventador (0.08°S, Nov 2002), B. Manam (4°S, Jan 2005), C. Soufriere Hills (16°N, May 2006), D. Tavurvur (4°S, Oct 2006), E. Kasatochi (52°N, Aug 2008), F. Sarychev Peak (48°N, July 2009)

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



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- Overall, the volcanic aerosol dominates the stratospheric aerosol loading even without Pinatubo-scale large eruption
- However, near the tropopause, anthropogenic aerosol transported from troposphere to the stratosphere shows a well organized seasonal cycle
- On the other hand, the "background" sulfate aerosol from OCS oxidation is more significant than anthropogenic aerosol transport

Maximum CO and aerosol over south Asia near tropopause



Asian monsoon convective transport – sending lower tropospheric material to UTLS



Remarks

- The global model GOCART captures the basic characteristics of the observed aerosol amount and spatial/temporal variations from satellite retrievals and aircraft measurements, although the comparison with data has revealed several significant weakness of the model
- 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
 - background sulfate aerosol is more significant than anthropogenic aerosol in the stratosphere
- Strong Asian monsoon convection and higher tropopause in the Asian summer monsoon region making transport of lower tropospheric material (from Asia and beyond) to UTLS effective in the summer

Near future plans

- Examine the transport pathways/mechanisms
- Examine the formation of the aerosol layer transport of aerosol precursors (SO2) followed by chemical formation vs. direct transport of aerosols
- Examine the volcanic aerosols in the stratosphere: direct injection or transport from troposphere
- Revise the volcanic emission amount/altitudes
- Modify the model to incorporate PyroCb cases
- Extend the model simulation to more recent years and compare with more available data
- Take your suggestions