Origin and decadal-scale variations of UTLS aerosols

Mian Chin (revised April 22, 2019)

Background:

The upper troposphere/lower stratosphere (UTLS) is a crucial region for Earth's climate, where changes of aerosol loading and composition can have a direct impact on the amount of radiation absorbed and emitted. Recent observations have shown an apparent increase of aerosols in the UTLS, but the cause of such increase is still under debate. Deep convection during the Asian monsoon season can lift the boundary layer anthropogenic pollutants from South and East Asia, which have shown an increasing trend in the recent decades, to the UTLS. On the other hand, strong volcanic eruptions can inject SO_2 into the UTLS to produce sulfate aerosols at high altitudes where residence time is much longer, making a disproportionately larger contribution to the aerosol loading in the UTLS. In addition, large forest fires can generate "pyro-convection" that sends aerosols and precursor gases to the upper troposphere or the lowermost stratosphere, changing aerosol composition and perturbing the energy balance. Many questions remain concerning the sources of UTLS aerosols, the processes controlling their evolution and distribution, and the cause of the apparent increase in stratospheric aerosol loading. AeroCom can make a "community contribution" to shed light on these questions with the global models and observations; on the other hand, the comparisons between observations and models can help model improvements in the UTLS regions, especially in the LS region that has not been looked at in the past AeroCom experiments.

Objectives:

- Compare and evaluate the model simulated aerosol and precursors in the UTLS regions
- Examine the pathways of aerosols in the UTLS region (e.g., roles of convective transport, chemistry, and direct injection)
- Assess the contributions of anthropogenic and volcanic emissions to the decadal variations of UTLS aerosols
- Coordinate with other community projects, such as the IGAC/SPARC Atmospheric Composition and Asian Monsoon (ACAM), and the SPARC Stratospheric Sulfur and its Role in Climate (SSiRC).

Model simulation: (default listed, modelers' own choice is the alternative.)

Emission:

Emission amount ▪ Anthropogenic: ▪ Biomass burning: ▪ Volcanic: ▪ Natural (dust, seasalt, biogenic):	 Default: ACCMIP. Default: GFEDv4. Default: Carn et al., 2015 (eruptive) + Andres and Kasgnoc 1998 (continuous). Model-calculated or specified.
Emission height ▪ Anthropogenic: ▪ Biomass burning: ▪ Volcanic:	 Default: surface layer. Default: Boundary layer. Default: Carn et al., 2015 (eruptive), crater to 1km above (continuous).

Model experiments:

Tier 1 model experiments: ▪ Simulation period: ▪ BASE ▪ VOL0 ▪ FIR0 ▪ ANT0	 2003-2012 (10 years) Model simulation with all emissions Same as BASE but with volcanic emissions turned off Same as BASE but with fire emissions turned off Same as BASE but with fossil fuel/biofuel emissions turned off
Tier 2 model experiments: ▪ Simulation period: ▪ BASE ▪ VOL0 ▪ FIR0 ▪ ANT0 ▪ EAS0 (use region mask)[1] ▪ SAS0 (use region mask)[1]	Same as Tier 1 but with longer time period and additional tagged runs 1998-2015 (18 years) Model simulation with all emissions Same as BASE but with volcanic emissions turned off Same as BASE but with fire emissions turned off Same as BASE but with fossil fuel/biofuel emissions turned off Same as BASE but with East Asian fossil fuel/biofuel emissions turned off Same as BASE but with South Asian fossil fuel/biofuel emissions turned off
Transport tracer:	CO with prescribed sources (will be provided) and 50-day lifetime (see description in "Tracer for transport" on AeroCom wiki page
Wet/dry deposition tracer:	Pb-210 produced from Rn-222 decay (5.5-day lifetime) with the removal (dry and wet deposition) process same as sulfate (see description in "Tracer for removal" on the AeroCom wiki page)
Output:	File specification on google doc (link) from AeroCom wiki page

[1]Region mask at 0.5 deg: https://tropo.gsfc.nasa.gov/gocart/products/xchange/aerocom/aerocom3/region_code/, file name = region-code_htap2_tier1_mod_0.5x0.5.nc

Observations for model evaluation during 1998-2014:

Satellite:		
Column SO_2	OMI	2004 (later half) – 2014
UTLS SO_2 (with vertical information)	MIPAS MLS	2003 – 2012 2004 (later half) – 2012
UTLS CO	MLS	2004 (later half) – 2012
Stratospheric aerosol vertical profile	SAGE II OSIRIS SCIAMACHY GOMOS CALIOP	1998 – 2005 2001 – 2012 2003 – 2012 2003 – 2012 2006 (later half) – 2012

Aircraft observation during 1998-2015:		
UT aerosol (S, C) concentration	CARIBIC	2004 – 2012
SO_2, sulfate vertical profiles	ICARTT INTEX-B ARCTAS	2004 2006 2008
Aerosol vertical profiles	HIPPO (BC)	2009 – 2011, 5 deployments