Origin and decadal-scale variations of UTLS aerosols
Mian Chin (revised November 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 origins and transport pathways of aerosols in the UTLS region (e.g., convective transport, advection, chemical formation, 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 Chemistry Climate Model Initiative (CCMI).

Model simulation:

<table>
<thead>
<tr>
<th>Emissions (see AeroCom Phase III wiki for access to the emission files):</th>
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<tbody>
<tr>
<td><strong>Emission amount</strong></td>
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<tr>
<td>- Anthropogenic: CMIP6</td>
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<tr>
<td>- Biomass burning: CMIP6</td>
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<tr>
<td>- Volcanic: Carn dataset, SO$_2$ from eruptive and degassing volcanoes</td>
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<tr>
<td>- Natural (dust, seasalt, biogenic): Model-calculated or specified</td>
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<tr>
<td><strong>Emission height</strong></td>
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<tr>
<td>- Anthropogenic: Surface layer</td>
</tr>
<tr>
<td>- Biomass burning: Boundary layer</td>
</tr>
<tr>
<td>- Volcanic: Eruptive: top listed in Carn dataset. Degassing: crater to 1km above</td>
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</table>
Model experiments (see AeroCom wiki for access to the emission files):

**Tier 1:**
- Simulation period: 2003-2012 (10 years)
- BASE: Model simulation with all emissions
- VOL0: Same as BASE but without volcanic emissions
- FIR0: Same as BASE but without fire emissions
- ANT0: Same as BASE but without fossil fuel/biofuel emissions

**Tier 2:**
- Simulation period: Same as Tier 1 but with longer time period and additional tagged runs
  - BASE: Model simulation with all emissions
  - VOL0: Same as BASE but without volcanic emissions
  - FIR0: Same as BASE but without fire emissions
  - ANT0: Same as BASE but without fossil fuel/biofuel emissions
  - EAS0 (use region mask): Same as BASE but without East Asian fossil fuel/biofuel emissions
  - SAS0 (use region mask): Same as BASE but without South Asian fossil fuel/biofuel emissions
  - Region mask: [Link to region mask](https://tropo.gsfc.nasa.gov/gocart/products/xchange/aerocom/aerocom3/region_code/)

Transport tracer: CO with prescribed sources (will be provided) and 50-day lifetime (see description in “Tracer for transport” on AeroCom Phase III 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 Phase III wiki page)

Output: File specification on AeroCom Phase III wiki page under “UTLS”

**Observations:**

**Satellite:**
- Column SO₂: OMI 2004 (later half) – 2018
- UTLS SO₂ (with vertical information): MIPAS 2003 – 2012, MLS 2004 (later half) – 2018
- UTLS CO: MLS 2004 (later half) – 2018
- Stratospheric aerosol vertical profile:
  - SAGE II 1998 – 2005
  - OSIRIS 2001 – 2018
  - SCIAMACHY 2003 – 2018
  - GOMOS 2003 – 2012
  - CALIOP 2006 (later half) – 2018
  - OMPS LP 2012 – 2018

**Aircraft observation:**
- UT aerosol (S, C) concentration: CARIBIC 2004 – 2012
- SO₂, sulfate vertical profiles:
  - ICARTT 2004
  - INTEX-B 2006
  - ARCTAS 2008
- Aerosol vertical profiles:
  - HIPPO (BC) 2009 – 2011, 5 deployments
  - ATom 2016 – 2018, 4 deployments
  - StratoClim 2017