Connections between Stratospheric Pollution and the Asian Summer Monsoon

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Motivation:
The Asian Summer Monsoon circulation can influence upper tropospheric and stratospheric aerosol concentrations [1]. Further, stratospheric background aerosol concentrations have increased since 2000 [2]. This leads to the question: Does significant amounts of non-volcanic aerosol reach the stratosphere, and accumulate?

Does the model simulate the Asian Tropopause aerosol layer?

GISS-modelE-MATRIX

Aerosol Optical Thickness July 2006

Zonal Averaged Chemical Composition in [µg/m³] for the Longitude Bands 45°E – 88°E

- The model shows high AOD concentrations over India and its neighboring states during the Asian Summer Monsoon season.
- A small fraction of the high tropospheric gas and aerosol concentrations reaches the stratosphere during the Monsoon season.
- The comparison between models AOD and CALIPO back scatter shows that the model simulates the ATAL in the correct season.
- The largest mass concentrations, and thus explaining most of the increased Stratospheric AOD (SAOD) signal, is caused by natural aerosols.
- Sulfate aerosols provide the largest ‘background’ concentration in the Stratosphere even during years without major volcanic eruptions.

What type of Aerosol reaches the Stratosphere via the Asian Monsoon?

GISS-modelE-MATRIX vs. GISS-modelE-OMA

- MATRIX: The largest mass concentrations, and thus explaining most of the increased Stratospheric AOD (SAOD) signal, is caused by desert dust aerosols.
- OMA: Organic aerosols (OA) are calculated to significantly contribute to the SAOD. Dust, the other possible contributor to SAOD, is calculated to peak earlier in the year, contrary to the MATRIX simulations. Differences in atmospheric dynamics, precipitation patterns and wind speed at surface can contribute to this discrepancy, but also the calculated dust size distribution.

The correction of the dust seasonality in OMA, or the inclusion of semi-volatile organics in MATRIX, can independently help explain the discrepancy between the model and the SAOD measurements.

Does Pollution Accumulate in the Stratosphere?

GISS-modelE-MATRIX


- Stratospheric AOD: Model simulations, including (red, blue) and excluding (grey) volcanic SO₂ emissions, and two Satellite retrieved datasets by Vernier (green) and Sato (orange).
  - Stratospheric AOD since 1980 is dominated by the two major eruptions, El Chichon (1982) and Mt Pinatubo (1991). The models deviation is explained by too fast polar transport of the Stratospheric plume.
  - The satellite data show an increasing trend since 2000.
  - The model without volcanic emissions doesn’t show any trend. Leading to the following conclusions:
    1. The model doesn’t show any accumulation of pollution in the Stratosphere.
    2. SAOD variations since 2000 are explained by smaller volcanic eruptions.
    3. No anthropogenic aerosol contribute to the trend in SAOD.

Model:
The climate model used in this study is the NASA GISS climate model, ModelE2 with 2° by 2.5° horizontal resolution and 40 vertical layers, having the model top at 0.1hPa [3]. We use two aerosol schemes: MATRIX which resolves aerosol microphysics [4] and OMA which includes secondary OA formation [5].

References:
(1) Vernier et al, 2015, JGR
(2) Solomon et al, 2011, Science
(3) Schmidt et al, 2014, JGR
(4) Bauer et al, 2008, ACP
(5) Tsigaridis et al, 2013, ACP