Evaluating Ammonium, Nitrate and Sulfate Aerosols in 3-Dimensions

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Background & Motivation

The effect aerosols have on climate and air quality is a function of their chemical composition, concentration and spatial distribution. These parameters are controlled by emissions, heterogeneous and homogeneous chemistry, where thermodynamics plays a key role, transport, which includes stratospheric-tropospheric exchange, and depositional sinks. In this work we demonstrate the effect of some of these processes on the SO2-NH3-N2O system using the GISS ModelE2 Global Circulation Model (GCM).

- **Motivation:** NOx aerosol is poorly constrained throughout the troposphere, especially above surface level.
- **Mission:** Bridge this knowledge gap with a collection of surface and airborne data and aerosol models.
- **Relevant studies:** Bauer et al., 2007, Bellouin et al., 2011, Aan de Brugh et al., 2012, Huijgens et al. et al., 2014, Paulot et al., 2015

Objective: evaluate the GISS ModelE2 aerosol schemes and pin key process either included or missing in the model

How does NOx aerosol form?
- 1. Gas phase: NOx is soluble in water: 
  \( \text{HNO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{NO}_2^- \) 
- 2. Dissolve in water: 
  \( \text{HNO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{NO}_2^- \) 
- 3. Dissolve into ions: 
  \( \text{HNO}_3 \rightarrow \text{H}^+ + \text{NO}_2^- \) 
- 4. Ionic solution – salt equilibrium: 
  \( \text{HNO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{NO}_2^- \) 

Set-up:
- 2°×2.5° resolution, 40 vertical layers
- Fully interactive trop and str chemistry
- Onland wind nudges: 6-hourly NCEP
- SST and ice Cover prescribed from obs
- Emissions: CMIP
  - RCP4.5 (2005 onwards)
- Biosphere burning: GFED
- Agricultural NH3 imposed seasonally according to zero path angle

GISS Aerosol Schemes

- MATRIX: microphysics model, mixing state
- OMA: bulk aerosol, includes heterogeneous uptake on dust
- ISOROSA II: calculates the thermodynamics as data and methods

Data and Methods

Monthly mean surface data of SO2, NH3, NH4, NO3, measured using the IMPROVE (USA) and EMEP-NILU (EU) networks during 2000-2010 is used to compare against the simulations. From the climatological mean (Figure 4) we adopt a regional approach (black frames in Figures 3,4), where the mean, standard deviation, normalized mean bias and correlation coefficients are calculated for the stations within a region along with their matching model grid boxes.

During 2001-2011, 14 flight campaigns took place in the NH and measured SO2, NH3, HNO3, NO3, (Figure 3). The flights were predominantly during spring and summer time and deployed the AMS instrument. With a regional approach we parse out transit flights and for flights within the ARC, ESA, WUSA regions we use the data within the regional boundaries to calculate a campaign mean per model layer. We sample our simulations according to the flight location.

References
