Climate response to changing United States aerosol sources: historical and projected aerosol burdens

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How do US aerosols affect climate?

We are using GEOS-Chem and the model framework of Chen et al. [submitted] to conduct transient climate simulations including the aerosol direct and indirect effects.

Sensitivity simulations with GEOS-Chem and the GISS GCM allow us to quantify the impact of U.S. emissions on regional and global climate.
GEOS-Chem Simulations

Model info:

- v8-01-01 at 2°x2.5° (1yr spin-up at 4°x5°/dec)
- GEOS-4 meteorology for 2001
- Full Chemistry (54 tracers, RPMARES)
- Historical Emissions of FF+BF SO$_2$ and NO$_x$ from EDGAR and BC/OC from Bond [2007]
- SO$_2$, NO$_x$, BC, and OC scale factors from David Streets following A1B
- Other emissions are held constant (i.e. constant NH$_3$, CO, etc.)

Control - Reconstructed Emissions and A1B

0 U.S. SO$_2$, NO$_x$, and OC Emissions

0 U.S. SO$_2$, NO$_x$, BC, and OC Emissions

- **Black Carbon – Bond [2007]**
  - Gradient captured, miss hot spots

- **Organic Carbon – Bond [2007]**
  - Gradient captured, underestimated in western U.S.

- **Nitrate – EDGAR**
  - Gradient captured, underestimate

- **Sulfate – EDGAR**
  - Simulated well
Trends in Anthropogenic Emissions

Note: All future emissions shown above follow IPCC SRES A1B!
Trends in Tropospheric Burdens

Large biogenic/biomass sources dampen trend in OC; Nitrate increases with lessening sulfate, but still biased low; Sulfate responds to US/Europe (2000) and Asian emissions
Changes to Aerosol Optical Depth

The change in global aerosol optical depth is mainly driven by changes in sulfate, but regionally, changes to carbonaceous aerosols are important.
Future Work

- Complete GEOS-Chem sensitivity simulations
- Complete GCM Simulations with CDNC-calculated and aerosol radiative forcings

1950

- **Control** - Reconstructed Emissions

2010

- 0 U.S. SO₂ and Carbonaceous PM
- Constant 2010 emissions of U.S. SO₂ and carbonaceous PM

2050

- 0 U.S. SO₂ and Carbonaceous PM Emissions
- 0 U.S. SO₂ and Scattering OC PM Emissions

- Large dataset of reconstructed/projected aerosol concentrations - Additional applications?

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Extra Material
Large-scale changes in the gas-ratio for $\text{NH}_3$ and total nitrate allow for less aerosol nitrate.

**Formation of $\text{NH}_4\text{NO}_3$ is:**

\[
\text{Gas Ratio} = \frac{[\text{NH}_3] + [\text{NH}_4^+] - 2[\text{SO}_4^{2-}]}{[\text{HNO}_3^-] + [\text{NO}_3^-]}
\]
Change in Surface Nitrate

1950 Annual Mean Nitrate

1960 Annual Mean Nitrate

1970 Annual Mean Nitrate

1980 Annual Mean Nitrate

1990 Annual Mean Nitrate

2001 Annual Mean Nitrate - GEOS-Chem EDGAR, IMPROVE, CASTNET

0.00 1.00 2.00 3.00 4.00 µg/m³
Change in Surface Sulfate

1950 Annual Mean Sulfate

1960 Annual Mean Sulfate

1970 Annual Mean Sulfate

1980 Annual Mean Sulfate

1990 Annual Mean Sulfate

2001 Annual Mean Sulfate - GEOS-Chem EDGAR, IMPROVE, CASTNET

\[ \mu g/m^3 \]
Total Aerosol Optical Depth

Annual Mean AOD - 2000