The impact of SO$_2$ emissions reductions on US carbon uptake

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CESM BGC Working Group Meeting 2016

Partial support DOE RGCM program — Biogeochemistry – Climate Feedbacks Scientific Focus Area (SFA)
Aerosols impact climate via radiative forcing and biogeochemical cycling

Fig. 2. Aerosol direct and indirect (cloud albedo) radiative forcing (W/m²), which translates to NPV Abatement costs for different 2100 representative concentration pathways estimated aerosol radiative forcing (W/m²), equivalent to a radiative forcing of 0.24 – 0.7 W/m² compared to other aerosols (ppm) and decreases for the micronutrient iron is probably different, affecting the lifetime of the cloud (cloud lifetime 28–36 years), this cooling of the planet is likely to allow increasing temperatures to increase public health costs for different 2100 emissions. Aerosol effects are counteracting warming from greenhouse gases and the deposition of these aerosols onto land and the ocean. There may be additional sink of carbon may arise from the ocean or land ecosystem, and thereby fertilize many land ecosystems that are nitrogen-limited (fertilizing a rate of 0.4 to 1.0 PgC/year (compare to other aerosols)).

Before the recent decrease in aerosol emissions. Aerosol effects are limited (fertilizing a rate of 0.4 to 1.0 PgC/year (compare to other aerosols)).

Aerosol Direct Effect

Aerosol Indirect Effect (Cloud Albedo)

Aerosol Indirect Effect (Biogeochemical Cycles)

Radiative Forcing (W/m²)

-2 -1 0
Aerosol impact climate via radiative forcing and biogeochemical cycling
Simulations show a large increase in ecosystem carbon uptake due to diffuse PAR

NEE due to Diffuse PAR: 1950-1980

Mercado et al., 2009
Most aerosols over the United States are secondary aerosol from gas-phase emissions.
Aerosol Optical Depth (AOD) has decreased over the eastern US

Data: NASA MISR
Visibility in Great Smoky Mountains
1990 vs 2010

Dr. Jenny Hand, CIRA
Testing photosynthesis responses to AOD in CLM

SO2 Emissions (short tons / yr)

SO2 Emissions

Annual Emissions:
- EPA CEMS SO2 data
- All Acid Rain Program sources (NAPAPR 2011 Fig 2-1)
- EPA SO2 total without wildfires
- EPA SO2 total stationary fuel combustion + industrial and other processes
- EPA SO2 total stationary fuel combustion

Average = 0.72 ± 0.04
No difference between Acid Rain Program Phase I (1995-1999) and Acid Rain Program Phase II (2000+).

Fraction_CEMS_TotalFuelIndust

Photosynthesis [µmol/m²/s]

diffuse and direct radiation
CAM4 with Bulk Aerosol Model (BAM) simulates decrease in AOD over US with EPA SO$_2$ emissions
Trend in AOD over eastern US comparable to observed trend from MISR
Diffuse solar radiation shows statistically significant increase over eastern US
CESM simulates a reduction of 0.5 Pg C per year
Photosynthesis in CLM4.5 decreases where diffuse solar radiation declines.
Photosynthesis in CLM4.5 decreases where diffuse solar radiation declines.
Can we evaluate CESM simulations?

Cheng et al., 2015
Relative trend in GPP from upscaling observational constraints is ~4x weaker than CLM4.5
CLM4.5 shows different sensitivity to diffuse light than FLUXNET sites with observational constraints
Discussion

CLM4.5 shows reduction in photosynthesis in response to SO2 emissions reductions, albeit a larger decrease than FLUXNET.

Response of CLM4.5 to diffuse radiation reductions is significantly smaller than previously reported values.

Continuing to develop an upscaling approach for observed sensitivities that accounts for errors on drivers.