Effects of the Changing Climate and Emissions on the Air Quality in the U.S. National Parks

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Effect of Climate and AQ on Forest Systems

Rocky Mountain NP affected by Haze

- High O₃ levels injure O₃ sensitive plants, and impact the health of park visitors and employees.
- Fine particles create haze in the park, affecting visibility.
- N deposition produces loss in biodiversity.

http://www.nature.nps.gov/

About 50% of forests will be exposed to damaging O₃ by 2100; and 20% will exceed critical loads from S and N deposition by 2050 [FAO, 2007]
NCAR Community Earth System Model (CESM 1.0.3)

**CAM-Chem**
1.9x2.5 spatial resolution
26 vertical levels to ~3 hPa

**Coupler**

**Land Model (CLM 4)**

- IPCC scenarios and derived emissions (RCP 4.5 and 8.5) 2000 and 2050
- GHGs
- $O_3$ and PM Precursors
- Prescribed sea-ice and ocean data (e.g., SST and sea-ice fraction)
- Land cover data (e.g., LAI, PFTs, etc)
Model Evaluation: PM2.5

\[=\text{SO}_4^{+} + \text{NH}_4\text{NO}_3 + \text{BC} + 2\times \text{OC} + \text{Fine DST} + \text{SSLT}\]

Model 2000 with IMPROVE observations (1998-2010)

Overall, model captures the magnitude and spatial gradient of much of the IMPROVE PM2.5 observations.
Fine Dust and Seasalt were adjusted to match observations.

Emissions reduced by a factor of 2 and used an improved soil erodibility map.

Emissions reduced by a factor of 10.
Further Model Evaluation: Ozone


- $O_3$ is simulated well over western US, and overestimated over eastern US (~20 ppb).
- This strong positive bias in CESM and other models is well known [e.g., Fiore et al, 2008, Brown-Steiner and Hess, 2011].
Temperature does not explain the O₃ bias over the eastern US

- On an average, model captures the magnitude and spatial gradient of much of the temperature.
- Summer afternoon temperature is slightly overestimated.

Annual Average

Summer Afternoon (13:00-15:00) Average

eastern US
western US

Observations (C)
Model (C)
CAM-Chem returns higher isoprene when interacting with CLM

Example of diurnal variability of isoprene

2000 with interactive ISOP – 2000 FIXED ISOP from CLM output

__Important effect on the quantification of O\textsubscript{3} changes in the future__
Effects on Changes in Climate Alone

Annual Average in 2000

Temperature

2050 RCP 4.5 - 2000

↑1 °C

2050 RCP 8.5 - 2000

↑3 °C

Precipitation

↑13%

↑7%
Effects of Global Change on AQ: Ozone

Summer Daily Max 8-hr Avg. Surface $O_3$

2000

2050 RCP 8.5

2050 RCP 4.5

$\Delta$Total = 2050-2000

RCP 8.5

$\uparrow$2 ppb

$\downarrow$~4 ppb

RCP 4.5

~$\downarrow$10 ppb

< 20.0 40.0 60.0 80.0 ppb

-15.0 -5.0 5.0 15.0 ppb
Quantifying the change in O$_3$ due to changing climate and emissions

$\Delta$Anthropogenic = 2050 Anthro-2000

Important decrease in NO$_x$ emissions

Note: It includes the effect of NO$_x$ lightning and stratospheric O$_3$ exchange in response to climate

$\Delta$Climate = 2050 Clim-2000

$\Delta$Biogenic = 2050 Nat-2000

RCP4.5
Effects of Global Change on AQ: PM2.5

Annual Average PM 2.5

- 2000
- 2050 RCP 8.5
- 2050 RCP 4.5

\[ \Delta \text{Total} = 2050 - 2000 \]

\[ \Delta \text{Climate} = 2050 \text{ Clim} - 2000 \]
Change in PM2.5 due mainly to SO$_4$ and NH$_4$NO$_3$ emission reduction

Changes in Chemical Speciation

East

West

![Graphs showing changes in PM2.5 and chemical speciation for East and West regions between 2000 and 2050 for RCP4.5 and RCP8.5 scenarios.](image)
What is next?

- Better quantification of changes resulting from climate, anthropogenic and natural emissions alone.
- Consider the effects of land cover/land changes.
- Study the effect of nitrogen deposition.
- Perform high resolution (1x1 or 0.5x0.5) simulations and analyze the effect of spatial resolution on the results.
- Focus on the air quality over the U.S. NP