Influence of chemistry-climate interactions and emission controls on 21st century U.S. surface O₃ seasonality, variability, and extreme events

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Motivation

Projected changes (CMIP5/ACCMIP) in Annual Mean Surface O₃ averaged over N. America (land only)

- How do seasonal cycles and summertime high-O₃ events respond to emission controls and climate warming?
- Why does O₃ increase in RCP8.5 despite >75% reductions in North American NOx emissions?
- What processes contribute most to the large differences across models?

As a first step, we investigate here the role of emission controls and climate interactions on surface O₃ in one model

21st Century Scenarios

2005-2025 2045 2085 2105

Future reversal of surface O₃ seasonal cycle over NE USA?

Motivation

Projected changes (CMIP5/ACCMIP) in Annual Mean Surface O₃ averaged over N. America (land only)

- Difference between RCP8.5 and RCP8.5_2005CH4:chem (RCP8.5) + Changes in emissions dominate changes in seasonal cycle
- RCP4.5 demonstrates large impact of NOx controls, +10-15 ppb in summer
- RCP4.5_WMGG (Ox precursors remain at 2005 levels) suggests that climate warming will increase O₃ by a few ppb in NE USA in summer and Mtn. W USA in early spring and decrease it slightly in Mtn W USA, with little change in other seasons. Caveat: Regional climate responses not necessarily robust across models

Global Mean Temperature (>500 hPa)

- Enables separation of roles of changing climate from changing air pollutant emissions
- There is no significant warming in RCP8.5_WMGG

RCP4.5_WMGG 2006-2015

GFDL CM3 model and evaluation

- Modeled ensemble mean and full range are shown

- RCP4.5_WMGG
- RCP4.5
- RCP8.5

Monthly mean surface O₃ (ppb)

- Observations (1988-2009 mean) vs. CM3 model (1990-2005 mean)

- Distributions are constructed from 10 years of simulations (95% confidence interval)

- Differences between RCP8.5 and RCP8.5_WMGG (2091-2100)–(2006-2015)

- Note different scales

- Large regional NOx decreases in RCP4.5 fully offset any climate-driven increases; O₃ decreases most under polluted conditions

- Doubleing of CH₃ in RCP8.5 raises baseline surface O₃ by 4 ppb (ensemble mean) but detailed changes vary across ensemble members

REFERENCES

4. Levy et al., 2013; Naik et al., revised.