Modeling the Potential Impacts of Climate Change on Air Quality and Deposition Over the Northeastern U.S.

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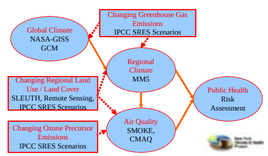
New York Climate & Health Project

Introduction

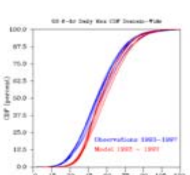
- Future air quality is likely to be affected by changes in global and regional climate through processes such as the change of chemical reaction rates and modifications of synoptic flow patterns
- In addition, local-scale changes such as urbanization and associated changes in the magnitude and spatial allocation of emissions also may affect future air quality
- The aim of this study are to establish a modeling framework to
  - Simulate the effects of regional climate change on pollutant concentrations and the frequency of high pollution events over the eastern U.S.
  - Asses the potential air quality impacts of changes in land use and associated changes in emissions over urban areas

Modeling System

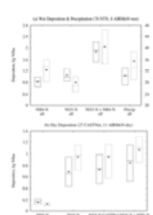


- Global and Regional Climate Modeling
  - The GISS coupled global ocean/atmosphere model driven by the IPCC A2 (high CO_2 growth) and B2 (low CO_2 growth) greenhouse gas scenarios was used to simulate global climate
  - The MM5 regional climate model was used to simulate regional climate and takes initial and boundary conditions from the GISS GCM
- Land Use Changes
  - Future urban land use distributions consistent with the pessimistic A2 scenario were simulated with the SLEUTH model
- Emissions Processing
  - 1996 anthropogenic U.S. emissions were processed by SMOKE taking into account meteorology-dependant emission processes for each scenario
- Air Quality Modeling
  - Using output from MM5 and SMOKE, the CMAQ photochemical model was run at 36km over the eastern U.S. to simulate ozone and particulate matter
  - Simulation periods – summers only:
    - Summer 1993-1997
    - Summer 2023-2027 with the A2 Greenhouse Gas Scenario
    - Summer 2053-2057 with the A2 Greenhouse Gas Scenario
    - Summer 2053-2057 with the B2 Greenhouse Gas Scenario
    - Summer 2083-2087 with the A2 Greenhouse Gas Scenario
- More details can be found in Hogrefe et al. (2004a,b)

Model Evaluation



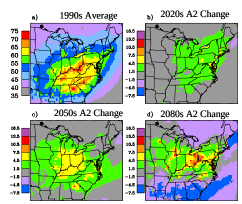
Left: Cumulative Distribution Functions of summertime daily maximum 8-hr ozone concentrations for the observed and modeled summers of 1993 – 1997 over the entire modeling domain. Each individual curve represents ozone concentrations from one summer.



Right: Observed (solid lines) and predicted (broken lines) summer season N (a) Wet deposition and precipitation, 78 NTN and 7 AIRMoN-wet sites, and (b) dry deposition, 27 CASTNet and 11 AIRMoN-dry sites. For dry deposition, results are shown for CASTNet only and for both CASTNet and AIRMoN-dry sites.

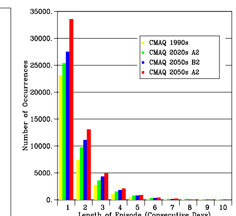
Changes in Pollutant Concentrations and the Frequency and Duration of Extreme Pollution Events as a Result of Regional Climate Change

Changes in Summertime Average Daily Maximum 8-hr O_3



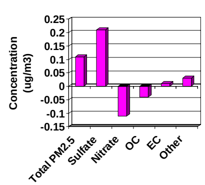
- Left: Maps of a) summertime average daily max. 8-hr O_3 for the 1990s, b) Difference 2020s – 1990s, c) Difference 2050s – 1990s, and d) Difference 2080s – 1990s
- Simulated regional climate change causes increases in summertime average O_3 concentrations over substantial portions of the modeling domain

Changes in High Ozone Events

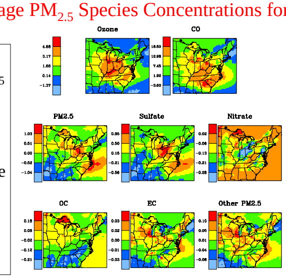


- Left: The number of high ozone events (8-hr daily maximum concentration > 84 ppb) determined from the simulations with current and future regional climate scenarios.
- Simulated regional climate change may cause an increase in the frequency of high ozone events over the eastern U.S.

Changes in Summertime Average $PM_{2.5}$ Species Concentrations for the 2050s



- Left: Difference between summertime average $PM_{2.5}$ species concentrations for the 2050sA2 and 1990s simulations
- These results suggest that climate change could cause an increase in sulfate and primary components and a decrease in nitrate and organic carbon during summertime



- Left: Maps of differences between summertime average O_3, CO, and $PM_{2.5}$ species concentrations for the 2050sA2 and 1990s simulations.
- These results show that simulated changes in $PM_{2.5}$ concentrations vary by species and across space

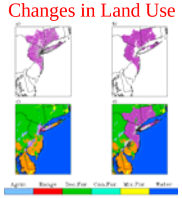
Impact of Land Use and Emission Changes on Simulated Ozone Concentrations

- Civerolo et al. (2007) investigated the potential effects of increased urbanization and associated changes in emissions under the pessimistic A2 scenario on O_3 in the greater NYC area
- Simulations were performed for two selected three-week periods at a horizontal grid spacing of 4 km, nested inside the larger domain shown above

Overview of Land Use / Emissions Sensitivity Simulations

Run	Episode	Emissions	LU
1	July 5–22, 1993	1996 Base	1990 Base
2	July 5–22, 1993	1996 Base	2050 A2
3	July 5–22, 1993	Consistent with 2050 LU	2050 A2
4	June 17–July 4, 2056	1996 Base	1990 Base
5	June 17–July 4, 2056	1996 Base	2050 A2
6	June 17–July 4, 2056	Consistent with 2050 LU	2050 A2

Changes in Land Use

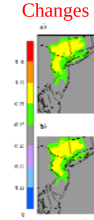


Daily total emissions (tons/day) summed over the Greater New York City 31-county area.

	1990s LU	2050s LU
CO	10,920	17,024
NOx	2,133	3,446
VOC	2,490	3,749
Isoprene	734	251

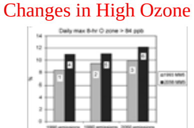
Above: (a) Urban land use simulated by SLEUTH for the 2050s. (b) The 4 km MM5 grid cells converted from non-urban in the 1990s to low density urban in the 2050s (c) The default 4 km MM5 land use in the 1990s (d) The 4 km MM5 land use in the 2050s.

Changes in Temperature



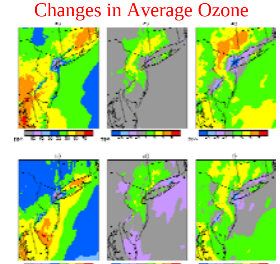
Left: Differences in afternoon average surface temperature fields for the 1993 (a) and 2056 (b) episodes, defined as ''future'' – "base'' urban land cover.

Changes in High Ozone



Above: Percentage of non-water grid cells with daily maximum 8-hr surface O_3> 84 ppb for the different CMAQ simulations.

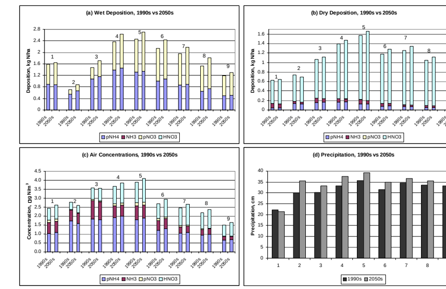
Changes in Average Ozone



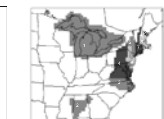
Left: Episode-average surface O_3 concentrations for a) Run 1 and b) Run 4.
c) Run 2–Run 1, d) Run 5–Run 4, e) Run 3–Run 1, f) Run 6–Run 4

→ These sensitivity simulations suggest that strong increases in low-density urban land use as simulated under the pessimistic A2 scenario, along with associated changes in emissions, may have local air quality impacts of comparable magnitude as climate change

Changes in Deposition a Result of Regional Climate Change



Above: Simulated N deposition, air concentrations, and precipitation over the nine eastern watersheds depicted on the right during the summer seasons of the 1990s and 2050s under the A2 scenario. (a) Wet deposition (kg N/ha), (b) dry deposition (kg N/ha), (c) air concentrations (µg N/m3), and (d) precipitation (cm).



- Over the eastern U.S., the modeling system simulated 3-14% increases in summertime N deposition as a result of regional climate change
- Summertime wet N deposition is predicted to increase primarily as a result of increased precipitation, while dry N deposition is predicted to increase as higher surface temperatures favor gas-phase nitric acid over particulate nitrate.

Summary

- A modeling system was developed to study the potential effects of changes in climate and land use on air quality over the eastern U.S.
- Over the Northeast, simulations indicate an increase of O_3 concentrations as well as an increase in the frequency of pollution episodes for future decades, broadly consistent with other recent studies (Mickley et al., 2004; Dawson et al., 2006, Tao et al., 2007, Nolte et al., 2007, Tagaris et al., 2007)
- Results for $PM_{2.5}$ are more complex and vary by species and season
- Changes in urban land use as simulated under the pessimistic A2 scenario, along with associated changes in emissions, may have local air quality impacts of comparable magnitude as climate change
- Both summertime wet and dry N deposition is simulated to increase as a result of climate change over most watersheds in the Northeast, suggesting that additional reductions in nitrogen oxides and/or ammonia may be needed to fully realize the anticipated benefits of planned reduction strategies including the Clean Air Interstate Rule (CAIR)

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