Impacts of Climate Change on Power Sector NO_x Emissions: A Long Run Analysis of the Mid-Atlantic Region

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Abstract

We consider the long-run effects of climate change on the spatial and temporal distribution of nitrogen oxide (NO_x) emissions from the Mid-Atlantic power sector. Elevated ground-level temperatures could increase electricity demand during the summer ozone season, altering the mix of generation types and ultimately changing emission rates. A sequence of load forecasting, supply investment and operation, and power plant siting models are used to project spatial and temporal distributions of NO_x emissions. The results indicate that even if total NO_x is limited due to cap-and-trade policies, climate warming-induced changes in the timing of electric sector emissions can be significant. The downscaled emissions can be used in fate and transport models such as the Community Multiscale Air Quality (CMAQ) to project changes in tropospheric ozone due to climate change.

Motivation

Various integrated assessments have considered how air pollution might be affected by climate change. These studies generally considered standardized emissions scenarios, e.g., IPCC A2. One advantage of using such scenarios is that the results can be compared and possibly generalized across different studies. However, there are at least two shortcomings of such approach:

1. These scenarios only provide information on annual emissions, and by definition they will show zero change when emissions are capped on an annual basis, as they are for utility sources of SO2 and NOx in most of the U.S;

2. They also cannot address shifts in locations and timing of emissions from particular economic sectors (e.g., increases in summer electricity demand in response to warming climate), which can be critical to ozone formation.

As a result, these annual scenarios lack the spatial and temporal granularity necessary for use in fate and transport models, and interactions of climate change with particular pollution control policies, such as NOx caps, cannot be analyzed. We focus on analyzing the effect of climate change on NOx emissions from the mid-Atlantic power sector (Fig. 1). Climate change could alter the level and timing of electricity demands, as well as the efficiency of electricity generating units (EGUs) (e.g., heat rate and available generating capacity) . In the short run, with a given capital stock of EGUs, the result will be changes in their operations and emissions. In the long run, the mix of various plant types will adjust in response to fuel and emissions allowances prices as well as climate-induced changes in the intra-annual distribution of electricity demands. Thus, in order to understand the effects of climate change on tropospheric ozone, impacts upon spatial and temporal distributions of EGU NOx emissions must be considered.

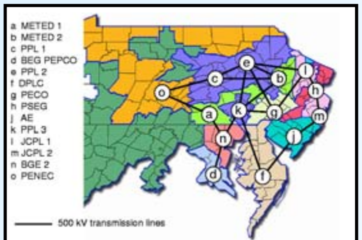

Fig. 1: Schematic of linearized DC network for study region

Research Objectives

1. How might long run (mid-21st century) spatial and temporal distributions of NO_x emissions from power plants in the mid-Atlantic region shift as a result of climate change?
2. How might inter-year variability of climate impact electricity consumption and NO_x emissions, which could potentially in turn, impact the frequency of summertime ozone episodes?

Approach

We rely upon a sequence of power sector load forecasting and supply models to address these questions. These models predict locations of new generation capacity, and temporal and spatial distributions of air emissions from power sector. To model inter-year variability, we use 14 years of simulated ground-level temperatures from the GISS (Goddard Institute of Space Sciences) GCM, where the years 1991-1998 represent normal climate conditions, and years 2050-2055 represent a warmer climate. Detailed steps are summarized in the Fig. 2

Step 1: Construct load duration curves using outputs from NEMS

Step 2: Estimate the amount of new generating technologies at the utility level using transmission–unconstrained least-cost capacity models

Step 3: Allocate new capacity to utility level using transmission-constrained least-cost capacity expansion models

Step 4: Assess county siting probability using empirical logit models

Step 5: Site new capacity using mixed integer nonlinear models

Step 6: Generate hourly NO_x emissions using short run least-cost dispatch models

Fig 2: Flow Chart of Analysis Procedure

Results

Table 1: Summary of new capacity

	2050s Climate			2050s Climate		
Node[MW]	Coal	CC	CT	Coal	CC	CT
ME1	0	1,481	0	0	4,040	0
ME2	0	1,680	0	0	5,348	0
PPL1	0	9,468	0	0	957	1,676
BGEPEP	0	9,349	0	0	9,980	2,384
PPL2	0	1,076	0	0	2,820	1,864
DPL	15	963	0	0	1,144	0
PECO	0	0	0	0	0	0
PSEG	0	2,848	0	0	941	0
AE	0	7,431	0	0	8,926	0
PPL3	6,043	0	0	4,176	1,841	0
JC1	0	0	0	0	0	0
JC2	0	350	0	0	1,331	921
BGE2	0	721	0	0	0	0
PN	0	2,558	0	0	6,621	882
ECAR	24,337	40,514	0	26,346	42,653	0
Total	30,395	78,439	0	30,522	86,602	7,727

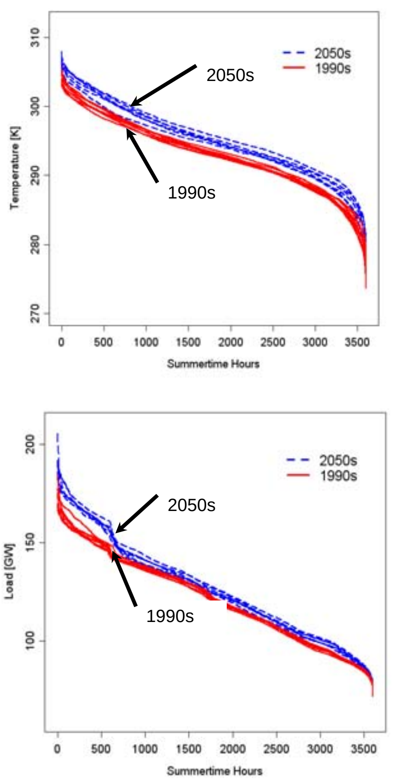

Fig. 3: Summertime temperature (upper) and load (bottom) duration curves for study region (mid-Atlantic and partial ECAR) for 1990s and 2050s climates, which show the number of hours that each respective quantity exceeds the value given at *y*-axis.

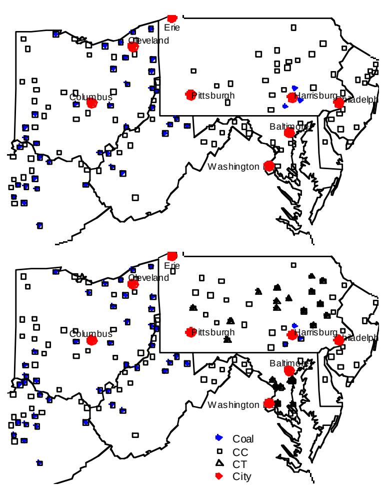

Fig. 4: County level allocation of new capacity under 1990s (upper) and 2050s (lower) climate scenarios.

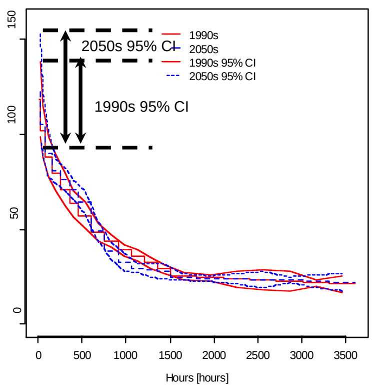

Fig. 5: Average summer NO_x duration curves for mid-Atlantic&ECAR for 1990s and 2050s climate conditions.

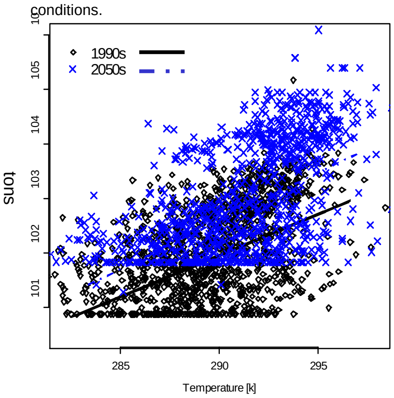

Fig. 6: Scatter plots of the ECAR hourly NO_x emissions at each 2:00 p.m. versus ambient temperature during summertime

Conclusions

1. The results show that climate-induced changes in the quantity and temporal distribution of electricity demand could also modify the mix of generation types and distribution of pollution emissions in the long run, even in the presence of a seasonal emissions cap.
2. Significantly higher emissions during peak demand hours will occur, possibly worsening regional air quality and could contribute to increases in this frequency in the future. Thus, in addition to a current seasonal cap system, a separate cap or pollution tax that applies only under forecast extreme weather conditions may be needed to prevent worsening air quality during such times.

References

1. Amato, A. D.; Ruth, M.; Kirshen, P.; Horwitz, J., Regional energy demand responses to climate change: methodology and application to the commonwealth of Massachusetts. *Climatic Change* **2005,** *71*, 175-201.
2. Civerolo, K. L.; Hogrefe, C.; Lynn, B.; Rosenzweig, C.; Goldberg, R.; Rosenthal, J.; Knowlton, K.; Kinney, P. L., Simulated effects of climate change on summertime nitrogen deposition in the eastern US. *Atmospheric Environment* **2008,** *42* (9), 2074-2082.

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