Modulating Emissions from Electric Generating Units as a Function of Meteorological Variables

William Battye
and
Steven Fudge

EC/R Incorporated, Chapel Hill, NC

William Warren-Hicks
EcoStat Incorporated, Mebane, NC

Thomas Pierce
Air Resources Laboratory, NOAA, RTP, NC

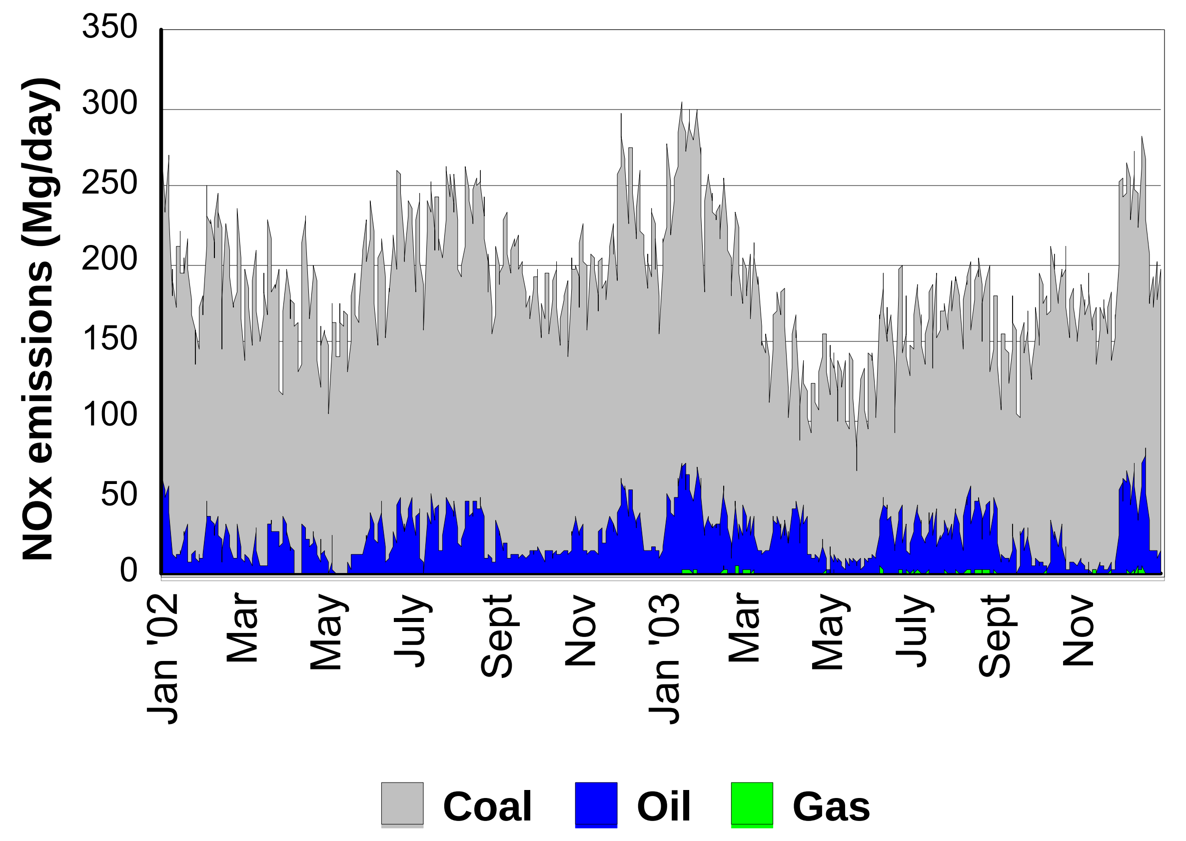
Purpose

Use Continuous Emissions Monitoring System (CEMS) data to relate NO_X emissions from Electric Generating Units (EGUs) to temperature and other meteorological variables. These relationships will be used in the National Air Quality Forecast System to adjust for the influence of changing meteorological conditions on daily EGU emissions.

Background

- NOAA and EPA have developed the National Air Quality Forecast System to provide air quality forecasts for ozone, $PM_{2.5}$ and other pollutants.
- CMAQ model is used for ozone , coupled with the Eta meteorological model
- Currently, emissions estimates for EGUs are based on summer averages, adjusted by weekly and diurnal temporal allocation factors.
- However, emissions from EGUs vary with short-term demands for electricity, such as increased air conditioning during a heat wave.
- CEMS data provide a resource for correlating EGU emissions with temperature and other meteorological variables.

Daily variation in NO_X emissions from EGUs (Virginia)



Methods

- Inputs
  - Hourly CEMS data preprocessed for SMOKE
  - NCDC Integrated Surface Hourly Observations
- Regression analysis
  - Multistep approach based on autoregressive time-series models
  - Evaluated different meteorological parameters
    - Maximum daily temperature, average daily temperature, maximum dew point, average dew point, maximum wind speed, average wind speed, etc.
  - Evaluated different levels of geographic resolution
    - Metropolitan areas
    - States
    - Larger areas based on electricity-sharing regions
  - Evaluated importance of fuel type on the modulation factor

Regression Model

$$F_d = (E_d - E_{avg}) \big/ E_{avg}$$

- Modulation factor

  Where

  F_d = Modulation factor

  E_d = day-specific NOX emission in a given region (g/sec)

  E_{avg} = average NO_X emissions rate in the region (g/sec) over the ozone season

$$F_d = \alpha + \beta_1 \ln(T_{max}) + \beta_2 \ln(Dp_{avg}) + \beta_3 \ln(W_{avg}) + \beta_4 \ln(C) + \beta_5 Dt$$

- Final regression equation

  Where

  α,β = parameters calculated in the regression model

  T_{max}= maximum daily temperature (K)

  Dp_{avg} = average dew point (K)

  W_{avg} = average wind speed (km/hour)

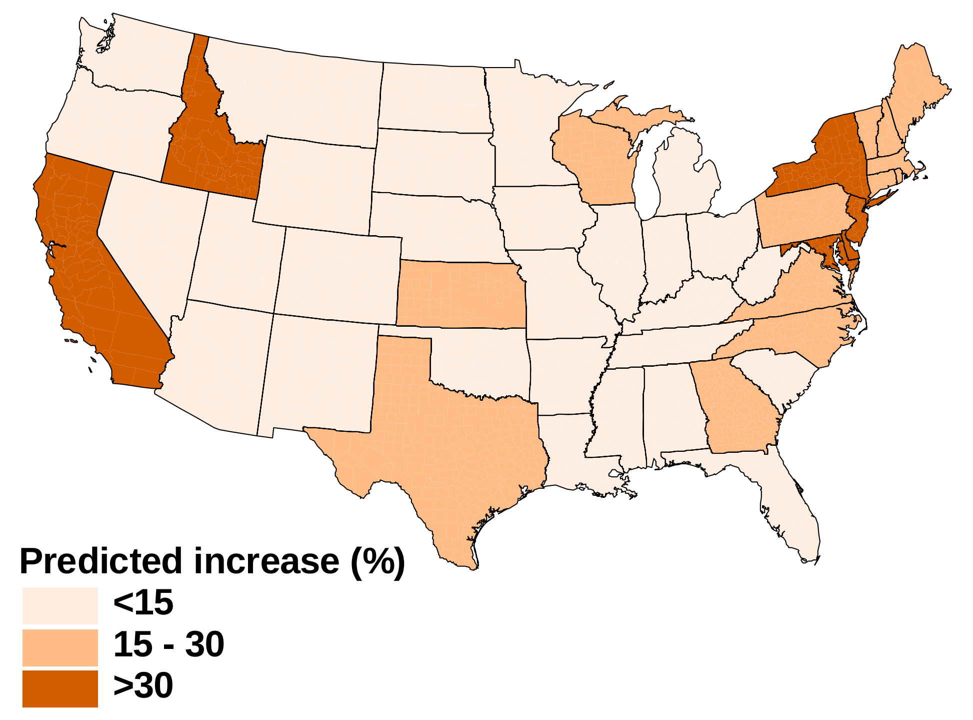
  C = cooling degree day number (K)

  Dt = binary day-type variable (0=weekday; 1=weekend/holiday)

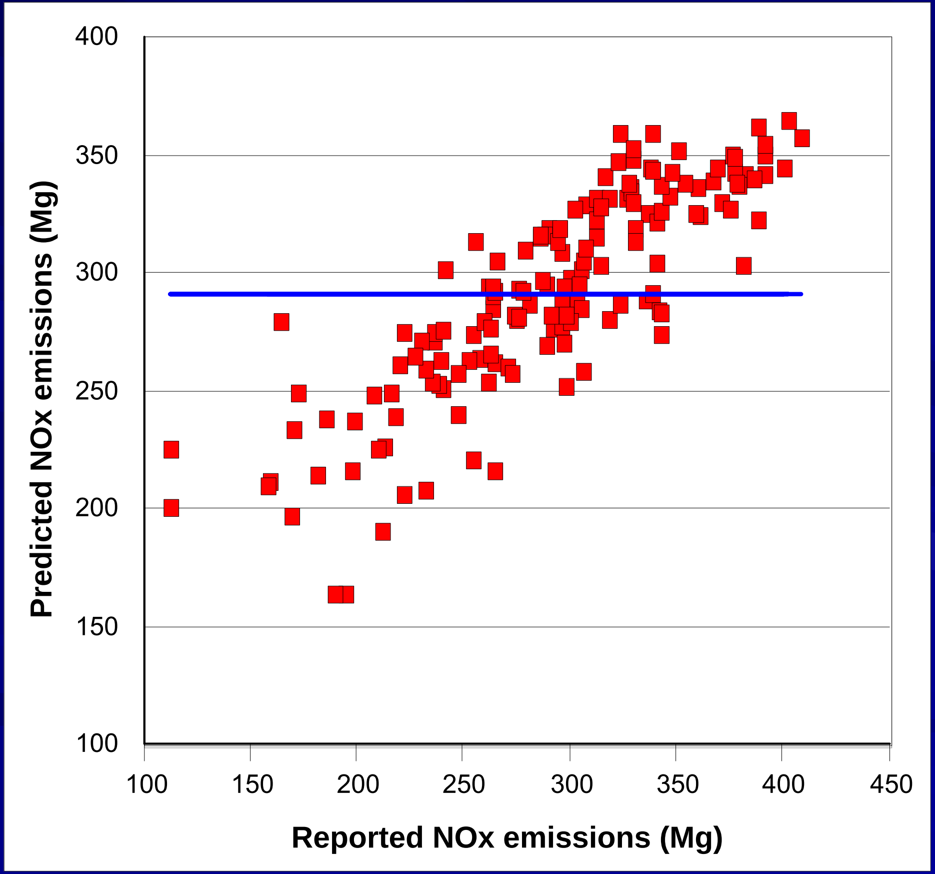
Regression Analysis Results

Area	Explained error (r^2)	F-factor predictions		F-factor limits	
		10th pctile	90th pctile	Minimum	Maximum
Alabama	0.72	-0.08	0.07	-0.33	0.20
Arizona	0.83	-0.12	0.09	-0.27	0.18
Arkansas	0.72	-0.24	0.16	-0.71	0.43
California	0.94	-0.72	0.65	-0.90	1.34
Colorado	0.80	-0.11	0.11	-0.25	0.19
Delaware	0.77	-0.50	0.46	-0.84	1.24
Florida	0.74	-0.09	0.08	-0.29	0.23
Georgia	0.83	-0.19	0.16	-0.54	0.61
Idaho	0.67	-0.80	0.94	-1.00	3.68
Illinois	0.93	-0.32	0.28	-0.70	0.67
Indiana	0.83	-0.14	0.13	-0.42	0.29
Iowa	0.86	-0.18	0.14	-0.37	0.34
Kansas	0.74	-0.20	0.21	-0.56	0.44
Kentucky	0.75	-0.17	0.17	-0.49	0.43
Louisiana	0.73	-0.14	0.13	-0.44	0.39
Maryland and DC	0.87	-0.44	0.39	-0.80	0.88
Michigan, lower	0.89	-0.27	0.54	-0.54	0.88
Minnesota	0.67	-0.10	0.08	-0.51	0.26
Mississippi	0.68	-0.15	0.16	-0.35	0.47
Missouri	0.84	-0.21	0.16	-0.46	0.40
Montana	0.54	-0.17	0.12	-0.68	0.35
Nebraska	0.84	-0.20	0.17	-0.52	0.29
Nevada	0.82	-0.29	0.15	-0.55	0.27
New England	0.79	-0.22	0.25	-0.46	1.13
New Jersey	0.85	-0.55	0.46	-0.86	1.40
New Mexico	0.78	-0.13	0.11	-0.51	0.18
New York	0.82	-0.30	0.36	-0.54	0.75
North Carolina	0.86	-0.27	0.19	-0.66	0.45
North Dakota	0.84	-0.17	0.16	-0.39	0.28
Ohio	0.75	-0.14	0.10	-0.34	0.27
Oklahoma	0.79	-0.16	0.16	-0.36	0.37
Oregon	0.92	-0.84	0.34	-1.00	0.73
Pennsylvania	0.86	-0.21	0.18	-0.55	0.67
South Carolina	0.70	-0.11	0.09	-0.33	0.32
South Dakota	0.81	-0.08	0.12	-1.00	0.27
Tennessee	0.84	-0.23	0.19	-0.45	0.32
Texas	0.89	-0.13	0.12	-0.28	0.36
Utah	0.61	-0.08	0.06	-0.35	0.18
Virginia	0.83	-0.23	0.20	-0.57	0.48
Washington	0.80	-0.31	0.60	-1.00	1.28
West Virginia	0.73	-0.15	0.14	-0.57	0.56
Wisconsin and upper MI	0.90	-0.20	0.20	-0.50	0.49
Wyoming	0.70	-0.13	0.12	-0.37	0.22

Estimated impact of a 10ºC change in temperature on NO_X emissions



Comparison of predicted and observed daily NO_X emissions (North Carolina)



Summary and Future Plans

- Daily summer NO_X emissions from EGUs can be correlated to temperature and other meteorological parameters.
- Regression results show that the impact of meteorological parameters on NO_X can be significant.
- NOAA is currently testing the regression models for NO_X emissions in its ETA-CMAQ ozone forecast model system.

Contact: William Battye (email: battye.bill@ecrweb.com)

Acknowledgements: The authors gratefully acknowledge the assistance of William Benjey in obtaining the CEM data, the programmatic support of Paula Davidson and Steve Fine of NOAA, and the counsel of Tanya Otte, Rohit Mathur, and George Pouliot.

Disclaimer: The research presented here was performed under the Memorandum of Understanding between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) and under agreement number DW13921548. This work constitutes a contribution to NOAA's Air Quality Program. Although it has been reviewed by EPA and NOAA and approved for publication, it does not necessarily reflect their policies or views.