Regional Impacts of Reduced NOx Emissions on Ozone Concentrations in the Eastern USA: Maximum O_3 levels reduced by 10%

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A

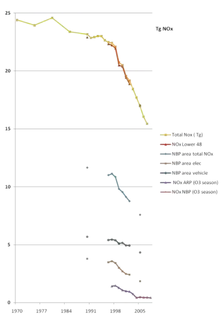

Fig. 1 NOx Emissions for US, and the NBP area. The emissions for ARP and NBP are for the O_3 season (May – Sept.). All other NOx emissions data are annual.

Since the Acid Rain Program (ARP) was promulgated under the Clean Air Act Amendments (CAAA) in 1990, cap and trade programs have successfully been implemented to reduce emissions (Fig. 1) and improve air quality. **The NO_x Budget Trading Program (NBP) is a voluntary cap and trade program created by the Environmental Protection Agency (EPA) to help states meet their National Ambient Air Quality Standards for ozone.** The NBP was implemented in 2003 and 2004 as an emission reduction program for large combustion sources . Here we assess the impacts of reduced NOx emissions from both the ARP and NBP for the period 1997 to 2007.

We have used **Random Coefficient Models to quantify the relation between NOx emissions during the ozone season (May to September) and ozone concentrations** at both rural and urban locations in the Eastern USA (Fig. 2) from 1997 to 2007. The random coefficient models allow us to summarize this relationship taking into account the grouping of the measurements over the years within sites.

We use **average maximum daily 8-hr ozone concentrations as the dependent variable**. These values are meteorologically adjusted to compensate for year to year variability due to temperature and humidity. It is appropriate to use the maximum 8-hr values, because reducing maximum ozone concentrations is a major objective of ozone mitigation legislation. **We use the NOx emissions record from the ARP program as the dependent variable**, since this data set includes the most complete record of ozone season emissions from large stationary sources from 1997 to 2007 (Fig. 1). **Source regions for NOx emissions are based on multi-year 24-hr air mass back trajectories** at 500 m and 1000 m above ground level (generally 750 to 1000 km upwind of sites) from the NOAA-ARL HYSPLIT trajectory model .

The regression of NOx emissions on ozone concentrations for this period is highly significant ($p < 0.001$) for all regions (Northeast, Mid Atlantic, Southeast, Midwest and the Eastern US as a whole). The models were then used to compare the pre-NBP period (1997 to 2000) to post-NBP implementation (2004-2007), and future reductions proposed for 2015 (formerly the Clean Air Interstate Rule (CAIR). These results (Figure 2) are also compared with the actual ozone data from the sites for 1997-2000 vs 2004 to 2007.

Fig. 2 Rural (CASTNET) and Urban (AQS) locations of ozone monitoring sites used in this study. Four sites in eastern Texas are not shown here, but were included in the Eastern US analysis.

B

Maximum 8-hr O_3 concentration (ppb)
O_3 season mean value

	Before NBP	After NBP	
	1997-2000	**2004-2007**	**% Change**
Eastern U.S.	**56.35**	**50.44**	**10.5%**
Northeast	**52.22**	**47.66**	**8.7%**
Mid-Atlantic	**59.30**	**52.14**	**12.1%**
Southeast	**57.44**	**50.51**	**12.1%**
Midwest	**57.60**	**52.07**	**9.6%**

Table 1

Regional declines in O_3 after NBP, and predicted changes with further NOx reductions

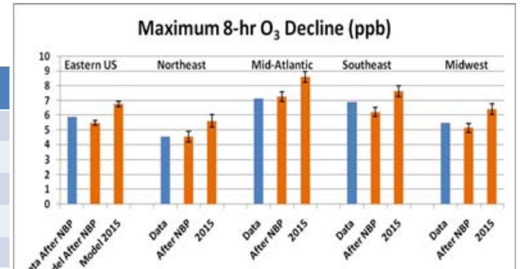

Fig. 3

Declines in O_3 concentration for the eastern US and sub-regions after NBP implementation period are shown in Table 1 and Fig. 3. The models predict the monitored data well. Blue bars on graph represent measured data from 95 sites (63 urban and 32 rural) comparing 1997- 2000 data (before NBP) to 2004-2007 data (after NBP implementation). The first orange bar for each region are model results using NOx emissions data for the same time periods. The second brown bar for each region are model predictions using estimated NOx emissions data for 2015, which are projected to be 61% less than the emissions for 2003. These reductions were formerly proposed under the Clean Air Interstate Rule (CAIR), which no longer exists. However, a similar program is now in development. Error bars are based on the standard error of the slope of the model regression lines.

Post-NBP declines for the eastern US are 5 to 6 ppb, a 10.5% decline in max 8-hr O_3 concentration. The mid-Atlantic and Southeast regions show a 12.2% and 10.6% decline. The Midwest and the Northeast show declines of 8.9% and 8.6%, respectively. Over ½ of NOx reductions formerly proposed by CAIR have already occurred, so further declines in O_3 concentrations may not be substantial. **Significant future reductions in O_3 levels should also focus on vehicle NOx emissions as well as stationary sources.**

Urban versus Rural Impacts

C

When 8-hr O_3 concentrations measured at AQS sites (urban) and CASTNET sites (rural) are analyzed separately there are significant differences in O_3 reductions in most of the Eastern U.S. regions (Fig. 4). There are **greater declines in O_3 concentrations at the rural sites** in the Northeast and the Eastern U.S. as a whole ($p < 0.05$). To a lesser extent this is the case in the Southeast and the Midwest too ($p < 0.10$). Urban areas are more likely influenced by other NOx sources such a vehicle emissions as well as other O_3 precursors (e.g. CO and VOC's) not regulated under ARP, NBP and CAIR (or whatever acronym wins the contest to replace it).

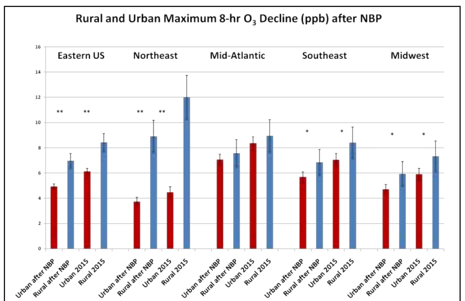

Fig. 4. Declines in daily maximum 8-hr ozone concentrations for urban (red) and rural (blue) sites due to implementation of NBP, and also with future proposed NOx reductions by 2015 (originally under the auspices of CAIR) , as compared with pre-NBP ozone concentrations (1997 to 2000). ** indicates that the urban and rural differences are statistically significant at $p < 0.05$. Similarly, * indicates statistically significant differences between rural and urban sites for a region at $p < 0.10$. Error bars are based on the standard error of the slope of the model regression lines.

Summary

D

1) Stationary source NOx reductions from NBP have reduced high level O_3 concentrations on the order of 10% for the Eastern US. Depending on the region, this is a reduction of 4.5 to 7.0 ppb below levels seen before implementation.

2) There have been greater O_3 reductions in rural areas than in urban areas for most regions. Other NOx sources, which are more difficult to regulate (e.g. vehicular NOx), and the presence of other O_3 precursors (CO, VOC's) probably account for this difference between urban and rural areas.

3) The Random Coefficient models used here predict that proposed further NOx reductions will reduce 8-hr maximum daily O_3 concentrations by 1 to 2 ppb. This is largely due to the fact that over half of the NOx reductions proposed by CAIR have already been achieved.

4) Further significant reductions in O_3 will most likely require significant reductions from other NOx sources, such as vehicle NOx emissions, which account for over ½ of total U.S. NOx emissions.

Further information on the NBP is available at: http://www.epa.gov/airmarkt/progress/NBP_2.html