Evaluation of Point Source Sensitivity Runs for the State of North Carolina

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ABSTRACT

The existing ozone (O3) standard is an 8-hour standard set to protect public health from short-term and prolonged exposures to O3. The design value for ozone is defined as: a 3-year average of the annual 4th highest daily maximum 8-hour average. If a monitored design value is > 0.084 ppm (84 ppb), that monitor is violating the standard.

In the North Carolina Metrolina (Mecklenburg, Union, Gaston, Rowan, Iredell, Lincoln, and Cabarrus Counties) nonattainment area, three monitors were violating the 8-hour ozone standard at the end of the 2006 ozone season. There are eight monitors in the Metrolina area with design values (for the 2004-2006 3-year period) ranging from 0.076 ppm to 0.088 ppm for 2006 ozone season.

The North Carolina Division of Air Quality (NCDAQ) is required to submit an attainment demonstration plan (State Implementation Plan) to the U S Environmental Protection Agency (US EPA) in June 2007 for the Metrolina nonattainment area that details the State's plan to bring the area into attainment of the Federal standard. This analysis must estimate whether selected emissions reductions will result in ambient concentrations meeting the National Ambient Air Quality Standards (NAAQS) for ozone. It must identify a set of control measures that will result in the required emissions reductions.

Considering the controls that are planned for the major utilities, the NCDAQ conducted a series of sensitivity runs for their power plant point sources to show how additional reductions would impact future design values. The results show that the model was relatively stiff considering large emission changes.

INTRODUCTION

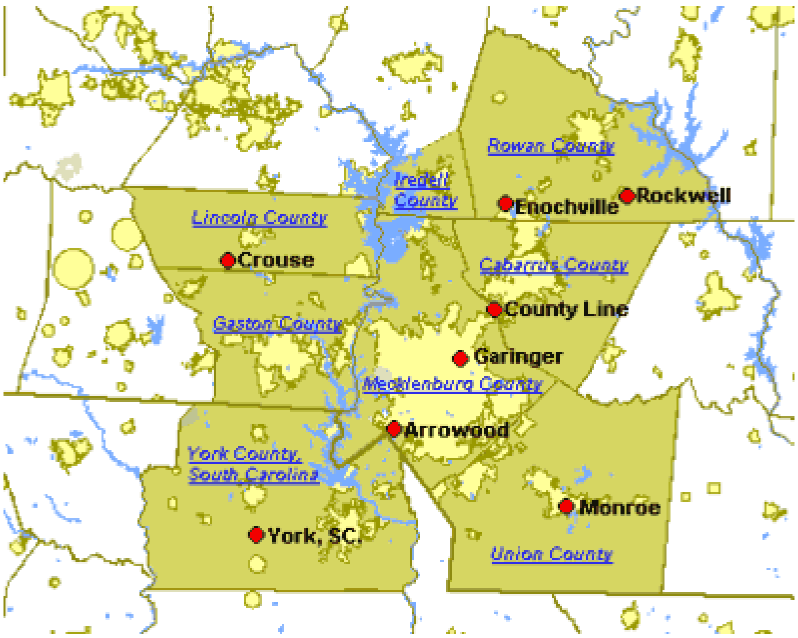
The existing O3 standard is an 8-hour standard set to protect public health from short-term and prolonged exposures to O3. The daily maximum 8-hr values are found by first calculating running or moving 8-hr values for all 24 hours in a day (for example averaging the 1-hr concentrations from 1:00am to 8:00am, then average the 1-hr values from 2:00am to 9:00am, etc.). Then the maximum value for each day is found (note that any 8-hr time period that starts in a day is assigned to that day). The design value is defined as: 3-year average of the annual 4th highest daily maximum 8-hour average. If a monitored design value is > 0.084 ppm (84 ppb), that monitor is violating the standard.

Table 1 shows that in the Metrolina nonattainment area, three monitors (County Line, Garinger, and Enochville) were violating the 8-hour ozone standard at the end of the 2006 ozone season. Figure 1 shows the locations of the monitors in the Metrolina nonattainment area.

Table 1. Metrolina 2006 ozone monitoring - 8-hour averaged ozone maximums

Site Name	County	AIRS Code	Season Highest	Days >= 85ppb	4th Highest	3year Average
Crouse	Lincoln	37-109-0004	0.096	3	0.082	0.079
Arrowood	Mecklenburg	37-119-1005	0.098	1	0.080	0.080
County Line	Mecklenburg	37-119-1009	0.102	8	0.093	0.088
Garinger	Mecklenburg	37-119-0041	0.103	7	0.091	0.088
Enochville	Rowan	37-159-0022	0.098	7	0.089	0.085
Rockwell	Rowan	37-159-0021	0.088	5	0.085	0.083
Monroe	Union	37-179-0003	0.096	2	0.080	0.078
York, SC	York	45-091-0006	0.084	0	0.079	0.076

Figure 1. Metrolina area monitor locations



Visibility Improvement State and Tribal Association of the Southeast (VISTAS) Base F4 shows one monitor, County Line, still not attaining the standard in 2009. The consequence of not attaining by the end of 2009 is that US EPA will reclassify the area from Moderate to Serious and all the mandatory requirements for Serious areas will have to be implemented. If the 4th highest value for 2009 is below the standard but the 2007-2009 design value is above the standard, NCDAQ can request a 1 year extension. If in 2010 the 2008-2010 design value continues to be above standard but the 4th highest value for 2010 is below the standard, the NCDAQ can request a 2nd year extension. The NCDAQ is required to submit an attainment demonstration to EPA in June 2007 for the Metrolina nonattainment area that details the State's plan to bring the area into attainment of the Federal standard. This analysis must estimate whether selected emissions reductions will result in ambient concentrations meeting the NAAQS for ozone. The SIP must identify a set of control measures that will result in the required emissions reductions.

The NCDAQ considered several scenarios for additional control from the point source sector. The selected emissions reductions were then determined with the Sparse Matrix Operator Kernel Emissions (SMOKE) processing system. In a subsequent step, these emissions reductions were used to predict the changes in ambient air quality using Community Multiscale Air Quality (CMAQ) Model.

BODY

Method

The North Carolina Division of Air Quality Attainment Planning Branch elected to perform sensitivity modeling for power plant point sources to show how additional reductions would impact future design values. Current modeling efforts for 2009 and 2018 are being undertaken by the Visibility Improvement State and Tribal Association of the Southeast. VISTAS is a collaborative effort of state governments, tribal governments, and various Federal agencies established to initiate and coordinate activities associated with the management of regional haze, visibility and other air quality issues, such as ozone, in the Southeastern United States.

VISTAS contracted with environmental consultants, ICF International, to run the Integrated Planning Model (IPM) to provide utility forecasts for 2009 under two future scenarios – Base Case and Clean Air Interstate Rule (CAIR) Case. The Base Case represents the current operation of the power system under currently known laws and regulations, including those that come into force in the study horizon. The CAIR Case is the Base Case with the proposed CAIR rule superimposed. The run results were parsed at the unit level for 2009. Additional documentation concerning inventory development can be found on the MACTEC FTP site (ftp.mactec.com).

Table 2 highlights utility emission control/reductions in the Metrolina region that are expected and were modeled in Base F4 for 2009:

Table 2. Utility NOx emission reductions since 2006 ozone season

Facility	County	Technology	Operational Date	Ozone Season NOx Reductions (tons/season)
Allen Steam Station				
Unit 2	Gaston	SNCR	Spring 2007	~300
Unit 3		SNCR	Fall 2007	
Buck Steam Station				
Units 3 & 4	Rowan	Low NOx Burners	Spring 2007	~350
Units 5 & 6		SNCR	Fall 2006	
Riverbend				
Unit 4		SNCR	Spring 2007	
Unit 5	Gaston	SNCR & Burners	Spring 2007	~325
Unit 6		SNCR & Burners	Fall 2006	
Unit 7		SNCR	Fall 2006	
Marshall Steam Station				
Unit 2		SNCR	Spring 2007	
Unit 3	Catawba	SCR	Fall 2008	~2,300
Unit 4		SNCR	Fall 2006	
Total expected reduction = 3,275 tons NOx/ozone season				

SNCR = selective non-catalytic reduction
SCR = selective catalytic reduction

<u>Sensitivity Runs Using VISTAS Base F4</u>

Considering the controls that are planned for the major utilities, in-house modeling was undertaken to determine what additional reductions would be necessary to show attainment in 2009. The point source emissions team started with hourly emissions data (pthour) from the 2009 BaseF4

VISTAS run for the May-September months. The basis for the 2009 Electric Generating Unit (EGU) point source emissions was IPM. However, the assumptions IPM made at facilities subject to the NC Clean Smokestacks Act (CSA) were not consistent with the CSA compliance plan. Therefore, it was necessary to update unit specific emissions, as specified in the compliance plan submitted for Progress Energy and Duke Energy. In March 2006 Duke Energy supplied NCDAQ with revised emissions estimates for the North Carolina Clean Air Plan (NC CAP) during the ozone season. Options given by Duke Energy are reflected in the sensitivity runs (Opt 1, Opt 2, and Opt 3 below). Ratios were developed and a simple dbase program was employed to adjust the input data files to reflect the possible emission cuts.

Ratios were developed by dividing the rate (in pounds/million BTUs) given for a unit with SCR by the rate originally assigned to a unit in the compliance plan. The NOx emissions in Duke Energy's ozone season compliance plan were multiplied by that ratio. For example, when we ran a sensitivity run to add an SCR an Allen 5, we took the ozone season compliance amount (566 tons) and multiplied it by 0.06 pounds/million BTUs (the expected rate Duke Energy assigned to facilities receiving SCR), then divided by 0.16 pounds/million BTUs (the rate given in the revised plan for 2009) to obtain 212.25 tons NOx for the ozone season.

Additionally, Duke Energy felt the IPM seasonal splits were not realistic for some of their units and provided us the compliance plan for the ozone season in addition to annual numbers. For Duke Energy 2009 we developed ratios such that each of the seven facility's totals for NOx would become what is in the compliance plan (for both ozone season and non-ozone season). Furthermore, we used the ratio developed for NOx on SO2, CO, NH3, PM10, PM2.5, PMC, and VOC to account for the seasonal emissions difference, as well as, the sensitivity being applied. Several runs were performed to evaluate the use of SCR in the Metrolina nonattainment area power plants. Duke Energy's and Progress's 2006 compliance plans have been incorporated into the latest VISTAS (Base G) modeling along with the seasonal ratios developed for Duke Energy's emissions. Table 3 shows the tons of NOx reduced from the compliance plan amounts for the various runs. Reductions backfilled with yellow are analyzed further below in PAVE plots.

The following sensitivity runs were performed to show future air quality changes:

- 06P – In this run North Carolina sources were updated with Duke Energy's 2006 ozone season compliance plan. Emissions for Progress Energy facilities were unchanged for this run.
- Opt 1 – In this run North Carolina sources were updated with Duke Energy's 2006 ozone season compliance plan with SCR at Marshall 4. Emissions for Progress Energy facilities were unchanged for this run.
- Opt 2 - In this run North Carolina sources were updated with Duke Energy's 2006 ozone season compliance plan with tweaking at Allen, Buck and Riverbend (6-11% reduction, see Note 1 below). Emissions for Progress Energy facilities were unchanged for this run.
- Opt3 – In this run North Carolina sources were updated with Duke Energy's 2006 ozone season compliance plan with SCR at Marshall 4 (68% reduction) and tweaking at Allen, Buck and Riverbend (Combination of Opt1 and Opt2). Emissions for Progress Energy facilities were unchanged for this run.

In April 2006 Duke Energy revised its NC Clean Air Plan and sensitivity runs performed from that point on used the revised plan. In the following sensitivity runs, the "06planR" refers to Duke Energy's revised plan.

- 06planR – In this run North Carolina sources were updated with Duke Energy's revised ozone season compliance plan.
- 06planR_AS5 – In this run SCR was imposed at Allen Steam #5.

- 06planR_AS5-T – In this run SCR was imposed at Allen Steam #5 and tweaking at Allen, Riverbend, and Buck. See note on "tweaking" below.
- 06planR_A5M3T - In this run SCR was imposed at Allen Steam #5, SCR was imposed at Marshall Steam #3, and tweaking at Allen, Riverbend, and Buck.
- 06planR_MS3 – In this run SCR was imposed at Marshall Steam #3.
- 06planR_MS3-T – In this run SCR was imposed at Marshall Steam #3 and tweaking at Allen, Riverbend, and Buck.
- 06planR_MS3-4-T – In this run SCR was imposed at Marshall Steam #3 and #4 and tweaking at Allen, Riverbend, and Buck.
- 06planR_C6-7 – In this run units 1-4 at Cliffside were replaced by Cliffside 6&7 with an increased emission rate (see Note 2 about units 6&7 below).

In addition to sensitivity runs involving added controls on Duke Energy Power facilities, two further sensitivities were run.

- 06planR_NR - In this run North Carolina sources were updated with Duke Energy's revised ozone season compliance plan. This run was merged with updated area sources using the newest non-road model.
- ZeroC – This run used the 06planR compliance plan emissions. In addition we zeroed emissions for Celanese Acetate in York County, South Carolina (Celanese Acetate products include cellulose acetate flake and acetate tow.); this had a negligible impact (see Table 4) on ozone Future Design Values (DVFs) in the Metrolina nonattainment area (2009 NOx emissions are approximately 2,400 tons/year for Celanese Acetate).

Note 1: The tweaking referred to in the above runs was an adjustment made for Allen, Buck and Riverbend for ozone season emissions, which was a projected fine tuning (lower SNCR through controls optimization and control of ammonia slip feedback) of those units to get a little better emission rate. For example Allen units 1-5 were projected to emit at 0.16 lb/MMBTU and the tweaking suggested by Duke Energy is that they get 0.15 lb/MMBTU.

Note 2: Emissions preparation for Cliffside 6-7 run. We started with the 2009 emissions files from 06planR, which contained the emissions projections from the revised 2006 compliance plan for Duke Energy. We made seasonal adjustments to the file for the Duke Energy facilities, as well as, removed Cliffside units 1 through 4 and added Cliffside units 6 & 7. The Duke Energy revised 2006 ozone season compliance plan states that SO2 in the 2009 ozone season will be 1209 tons for Cliffside units 1-5. With a shutdown of Cliffside 1-4 and addition of 6-7 at the same rate as 5, NOx would increase to 1500 tons during the ozone season. These runs were performed before the utility commission ruling that Cliffside can only proceed with one 800-megawatt plant.

Table 3. NOx differences from compliance plan, tons/O3 season for Duke Energy Power sensitivity runs

Sensitivity run	OPT1	OPT2	OPT3	AS5	AS5-T	A5M3-T	MS3	MS3-T	MS3-4-T	C6-7
NOx tons/season	-1319	-445	-1764	-354	-507	-1810	-1267	-1456	-2674	+291

Emissions Modeling

The Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system is an emissions modeling system that generates hourly gridded, speciated emission inputs of mobile, nonroad, area, point, fire and biogenic emission sources for photochemical grid models. SMOKE (v2.1) was run and the Package for Analysis and Visualization of Environmental data (PAVE) visualization tool was used to graphically view the data to ensure the data appears reasonable both spatially and temporally. PAVE plots were summed for all layers. The following figures show examples of visualizing the reductions through PAVE with SCR imposed at Allen Steam unit 5 (Figure 2), SCR imposed at Allen Steam unit 5 and Marshall Steam unit 3, along with tweaking at Allen, Buck, and Riverbend (Figure 3), and lastly, SCR imposed at Marshall Steam units 3 and 4, along with tweaking at Allen, Buck, and Riverbend (Figure 4). PAVE plots show location and relative amount of NOx reductions from the various sensitivity runs.

Running many sensitivity runs for whole 12km domain could be very time consuming. In order to speed up the process of SMOKE and final merge runs with less manual work, scripts were written to fulfill this task. After each run, we went through Quality Assurance (QA) process as described in the following section.

Figure 2. Sensitivity run 06plan R minus AS5

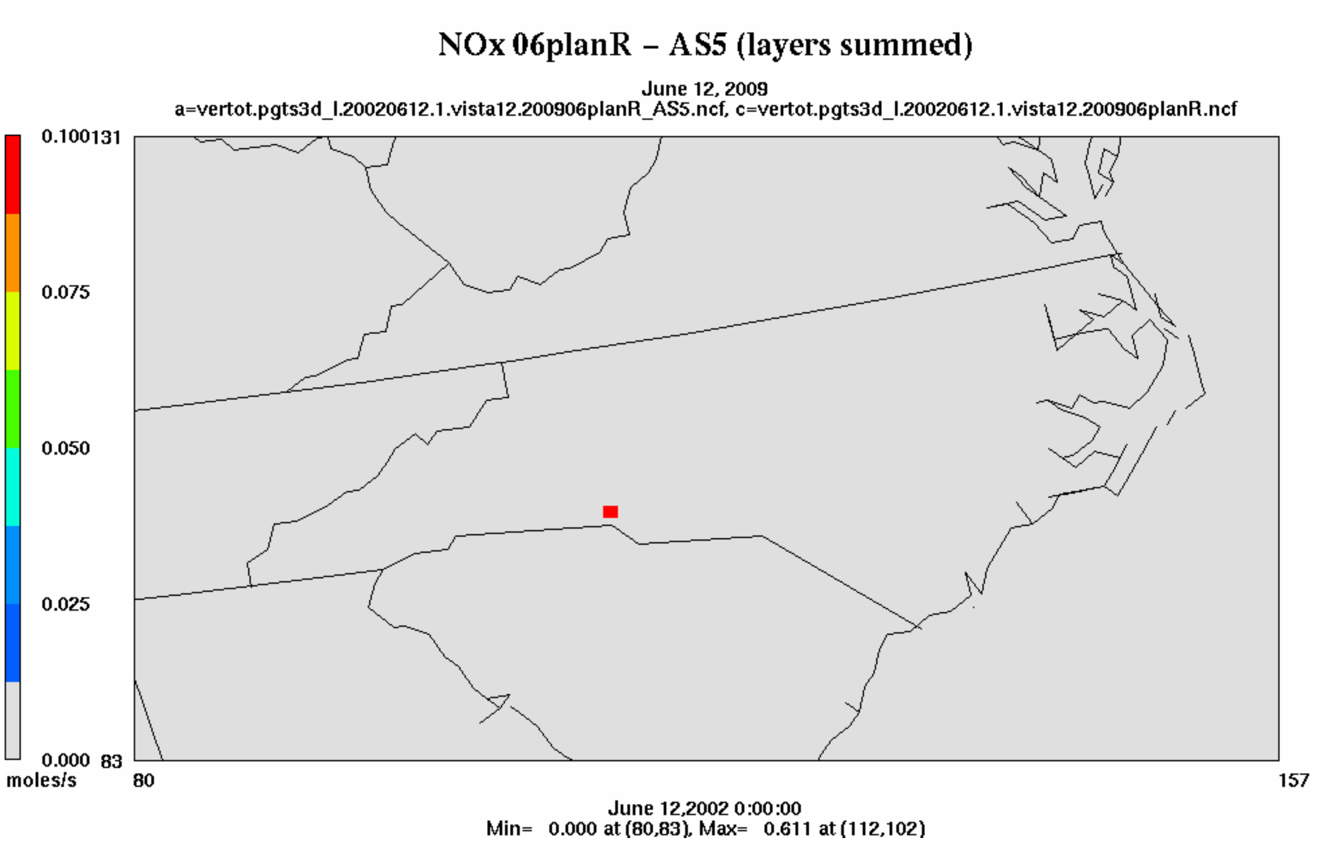


Figure 3. Sensitivity run 06plan R minus A5M3T

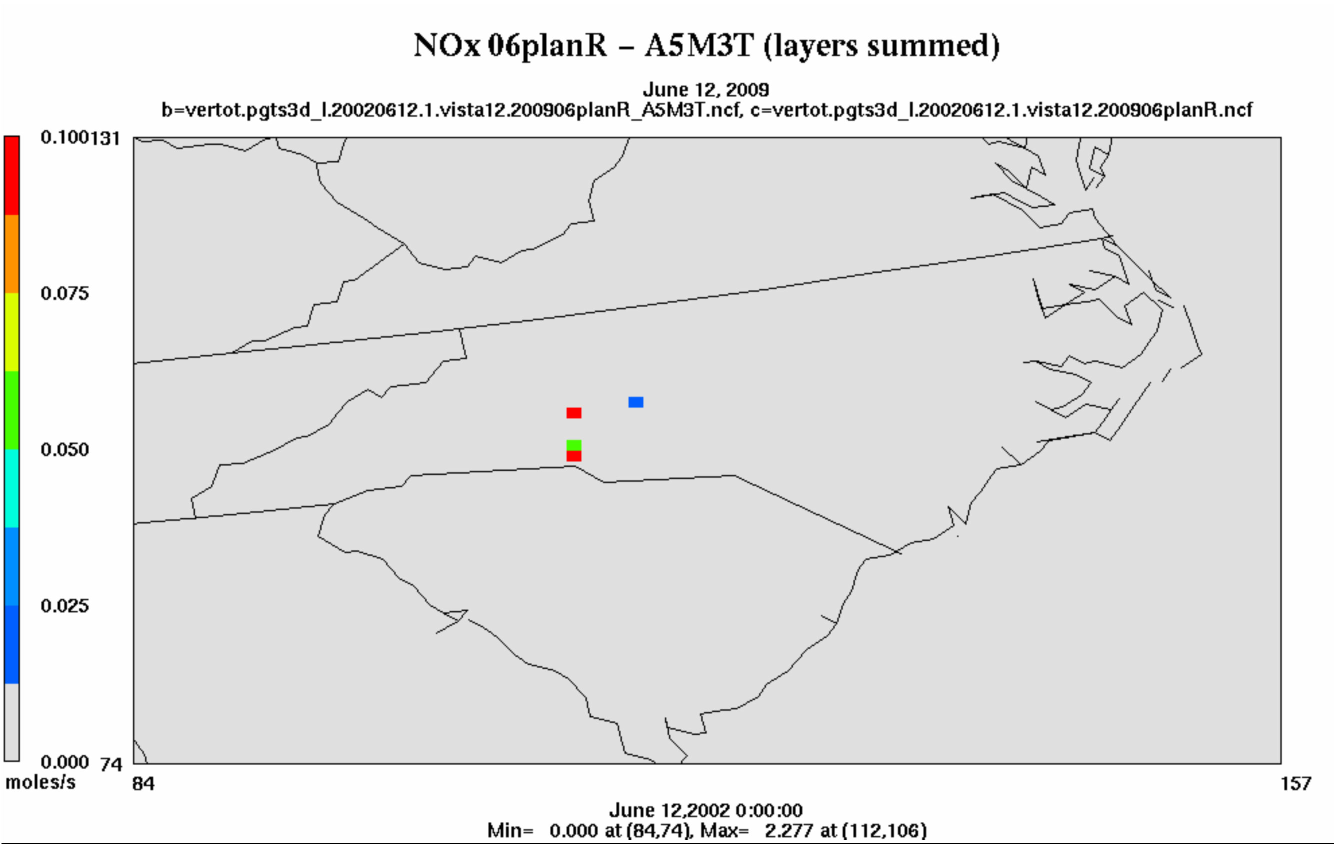
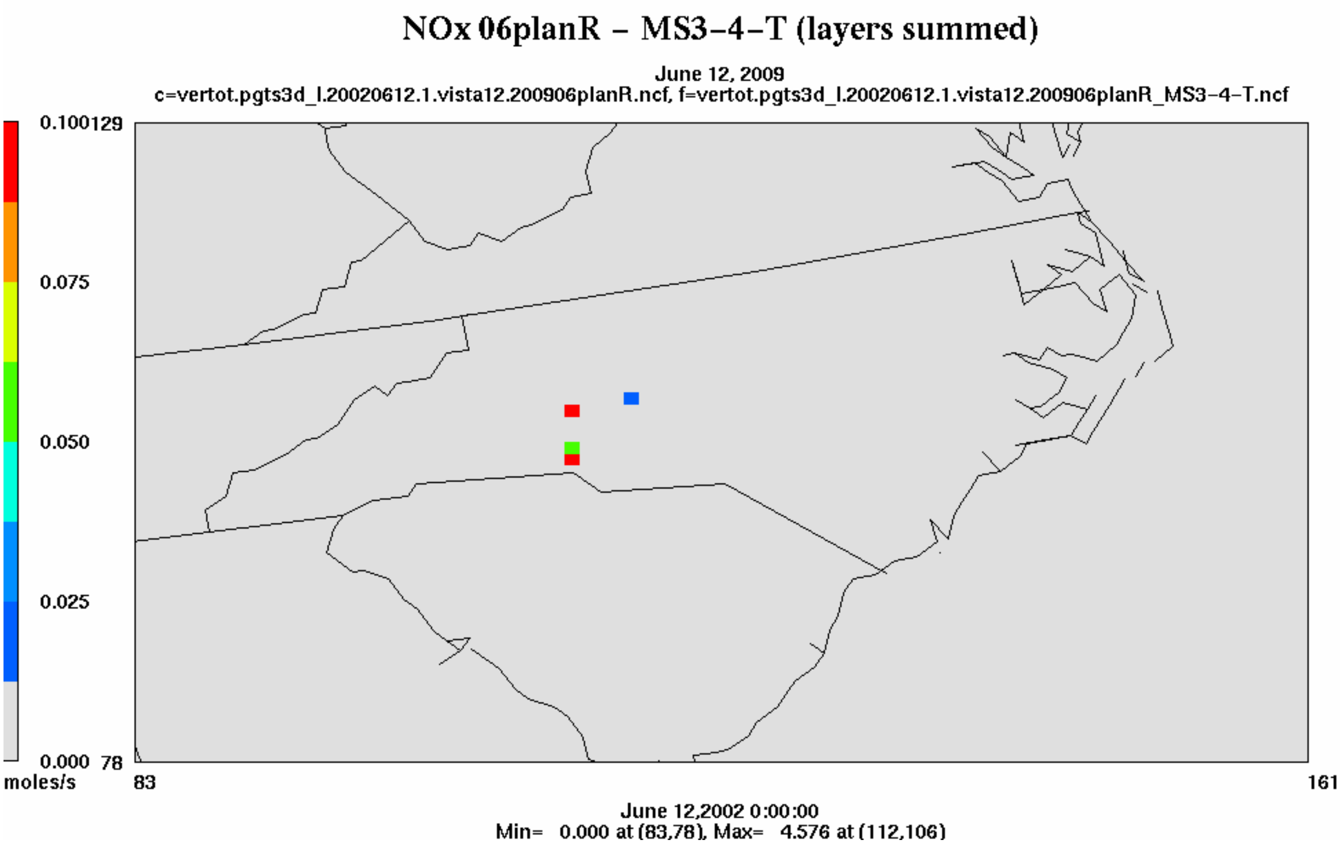


Figure 4. Sensitivity run 06plan R minus MS3-4-T



<u>Quality Assurance</u>

Most input files were prepared by VISTAS. The exception was the input files with the adjustments using the data provided by Duke Energy and Progress Energy. These files were developed in-house at the NCDAQ. The following paragraphs discuss the various post-processing QA measures performed.

Log files generated for each run for each day were reviewed for problems. These log files reflect that the subroutines completed normally with no errors.

SMOKE reports, generated during emissions processing, use the SMOKE intermediate files to create a large variety of emissions and activity data totals to be used for the QA of the emissions data. This QA is in addition to the QA performed by other SMOKE programs for checking file formats and input quality, and it focuses on analysis of the emissions values processed and output by SMOKE. County reports were generated for various days of the modeling period and reviewed. Weekend and holiday profiles were compared to weekday profiles and judged to be accurate.

Visualization is an important part of the QA/QC procedure. Viewing bar charts and pie charts of the data verifies that the more populous urban counties have greater emissions than the rural counties. Additionally, the PAVE visualization tool was used to graphically view the data to make sure that the data appears reasonable both spatially and temporally.

<u>Air Quality Model</u>

The US EPA’s Models-3/Community Multiscale Air Quality (CMAQ) modeling system is a ‘One-Atmosphere’ photochemical grid model capable of addressing ozone, particulate matter (PM), visibility and acid deposition at the regional scale for periods up to one year. CMAQ Version 4.5 was run with the secondary organic aerosol, SOAmods enhancement. The formulation of the CMAQ

Secondary Organic Aerosol (SOA) module is described in Binkowski and Roselle (2003). SOA is formed primarily from aromatic VOCs and biogenic terpenes. The biogenic SOA precursors were modeled with the Biogenic Emissions Information System – Version 3 (BEIS3) model. CMAQ was set up and exercised on a nested 36/12 km grid, employing one-way grid nesting. That is, boundary conditions for the 12 km grid simulation are extracted from the 36 km run. A total of 19 vertical layers were implemented, extending up to a region top of 100 mb (approximately 15 km AGL). The following figures show percent reductions in ozone with SCR imposed at Allen Steam, unit 5; SCR imposed at Allen Steam, unit 5 and Marshall Steam, units 3, along with tweaking at Allen, Buck, and Riverbend; and SCR imposed at Marshall Steam, units 3 and 4, along with tweaking at Allen, Buck, and Riverbend. The air quality plots that were available included zeroing emissions from Celanese Acetate along with the 06planR. This is acceptable for comparison because we know that zeroing those emissions had no effect on DVFs. Controls on power plants have a much greater impact on air quality in the Metrolina nonattainment area than the non-EGU facility in York County, SC. When viewing these figures keep in mind that it is the results of the sensitivity run divided by the results of the 06planR-ZeroC. So for instance in Figure 5 there was close to zero percent difference. In Figures 6 and 7 there was a decrease of 1-2% in ozone in the shaded area. Even for the most aggressive sensitivity run, MS3-4-T, where NOx was reduced by 2,674 tons during the ozone season, there is only a 1-2% difference in ozone as a result.

Figure 5. CMAQ results for sensitivity run AS5. Values indicate percent of ozone in AS5 sensitivity run compared to 06planR/ZeroC run

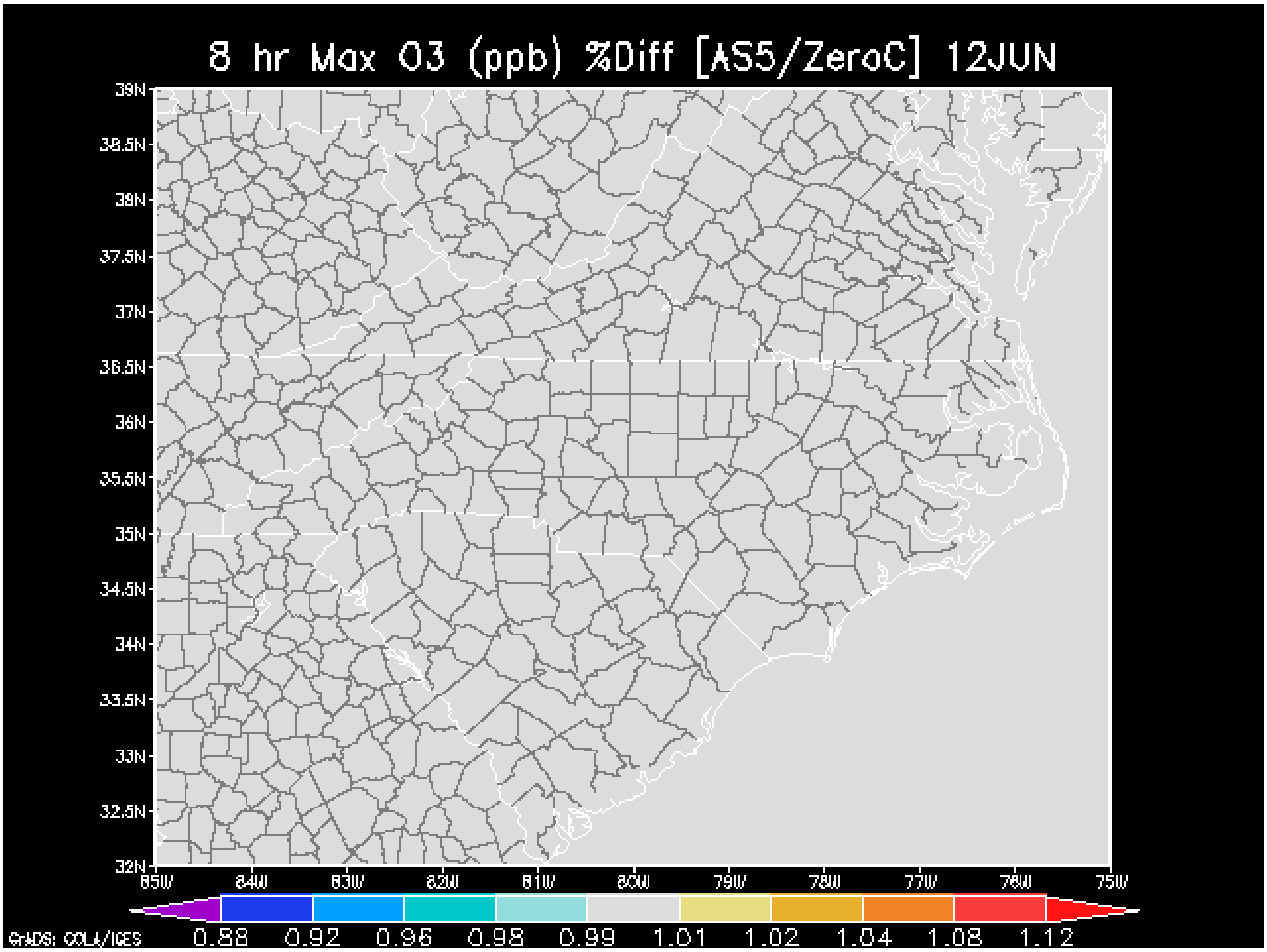


Figure 6. CMAQ results for sensitivity run A5M3T. Values indicate percent of ozone in A5M3T sensitivity run compared to 06planR/ZeroC run

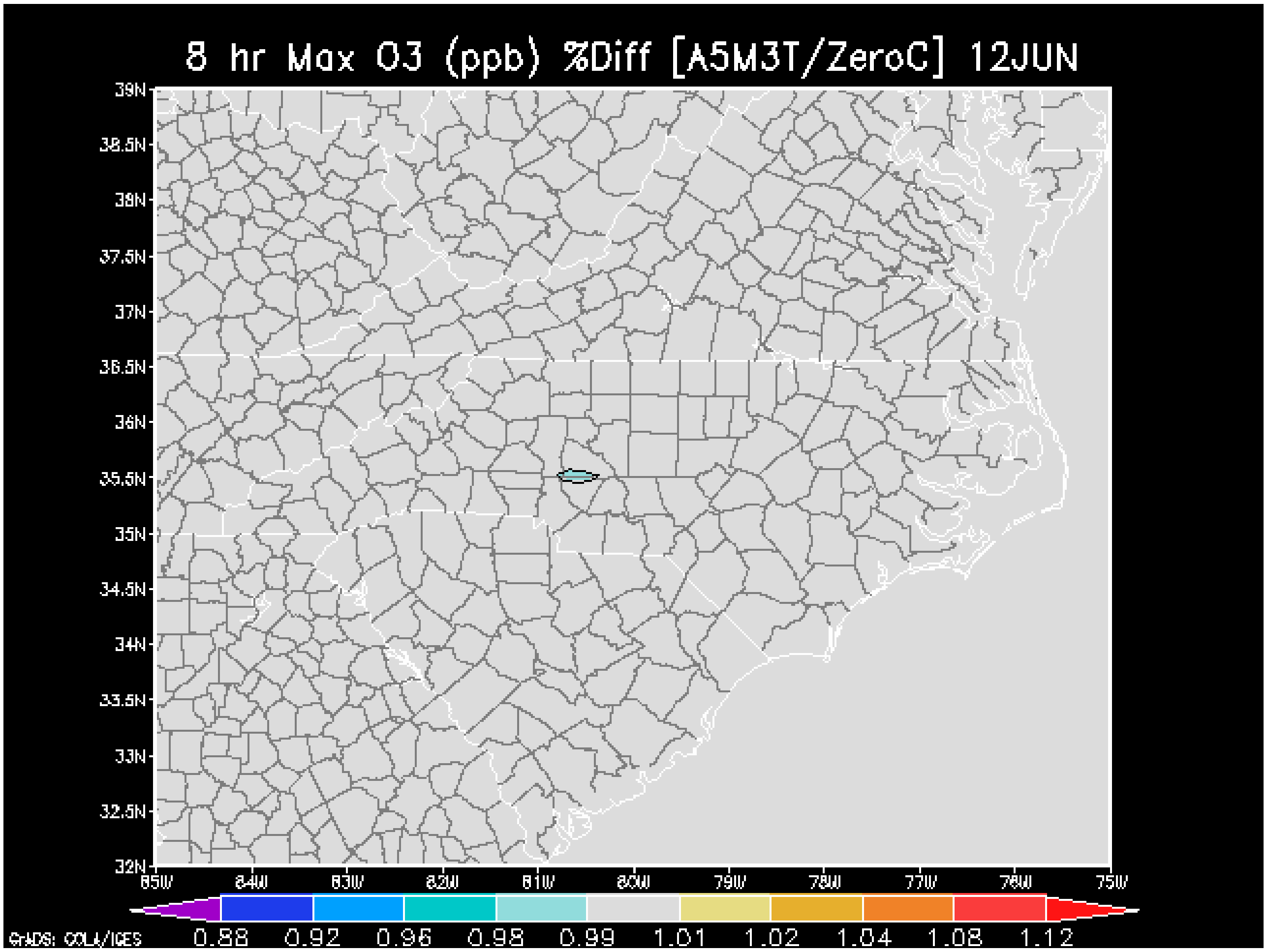
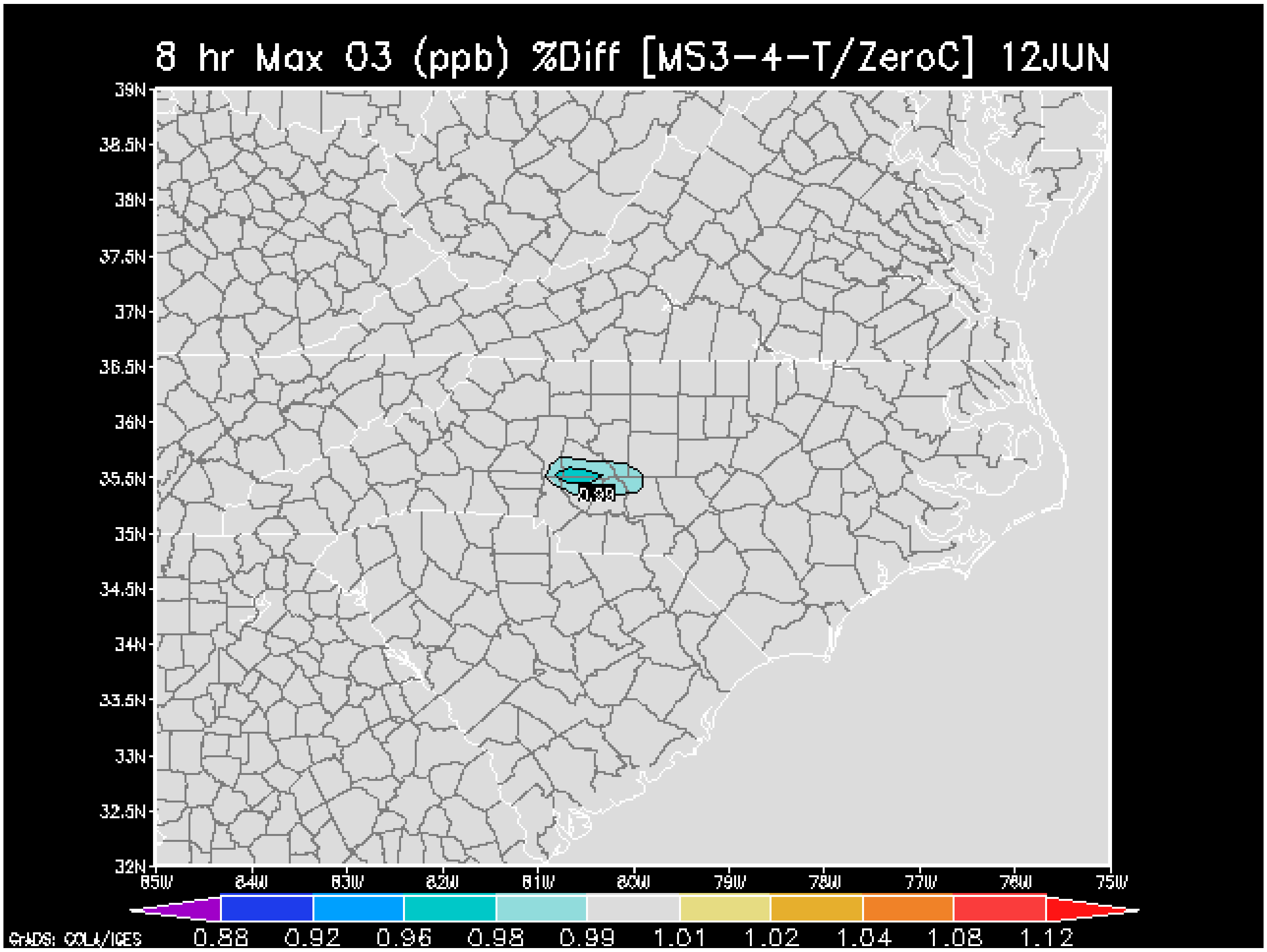


Figure 7. CMAQ results for sensitivity run MS3-4-T. Values indicate percent of ozone in MS3-4-T sensitivity run compared to 06planR/ZeroC run



Attainment Test

Future design values for ozone were estimated at existing North Carolina monitoring sites by multiplying a modeled relative reduction factor (RRF) at locations "near" each monitor by the observed monitor-specific ozone design value. The resulting projected site-specific "future design value" was compared to the NAAQS. If all such future site-specific design values are less than or equal to 84 ppb, the test is passed.

Results

The future design value (DVF) is defined as the estimated value for the time attainment is required, in ppb. It is determined from the following formula (US EPA, 2005):

DVF=(RRF)(DVC)
where,
RRF = the relative reduction factor, the ratio of the model's future to current (baseline) predictions at ozone monitors and
DVC = current design value, the baseline concentration monitored at a site in ppb.

Table 4 shows that future ozone design values for the County Line monitor in Mecklenburg County will violate the NAAQS for ozone in 2009 for most scenarios. Only the most aggressive runs, A5M3T and MS3-4-T, show the area achieving attainment at all monitor locations.

Table 4. Resulting 2009 DVFs (ppb) from sensitivity runs conducted by North Carolina. DVFs in red signify monitors not meeting the 8-hour ozone standard

AIRS ID	SITE	BF4	06P	06PR	OPT03	ZERO C	AS5	MS3	MS3-T	AS5-T	A5M3T	MS3-4-T	C6-7	06PR-NR
37-109-0004	Crouse	78		79	77	79	78	78	78	78	78	77		
37-119-1005	Arrowood	74	74	74	74	74	74	74	74	74	74	74	76	76
37-119-1009	County Line	85	85	85	85	85	85	85	85	85	84	84	86	86
37-119-0041	Garinger	84	84	84	84	84	84	84	84	84	84	84	85	85
37-159-0022	Enochville	84	84	84	83	84	84	84	84	84	84	83	85	85
37-159-0021	Rockwell	84	83	83	83	83	83	83	83	83	83	83	84	84
37-179-0003	Monroe	73	73	73	75	73	72	72	72	72	72	72	78	78

The results show that the model was relatively stiff considering some large emission changes. Between Duke Energy's 06 and 06R plans NOx, VOC, PM2.5, PM10 all go up slightly, while NH3, SO2, and PMC all go down slightly (due to installation of scrubbers). There was negligible change in CO. Adding SCR at Allen 5, Marshall 3 and 4 only lead to a very small improvement in air quality and would be very costly. Tweaking at Allen, Buck, and Riverbend produced no difference in the resulting DVFs. For the run that eliminated Cliffside 1-4 and added 6 and 7, the results show that NOx, CO, and PM all go up between 06planR and 06planR_C6-7 and SO2 goes down significantly (again due to installation of scrubbers). In general, the impacts of adjustments at Cliffside are felt at the monitoring sites closest to the facility.

CONCLUSIONS

The NCDAQ elected to adopt NOx only contingency measures since the Metrolina nonattainment area is NOx limited. The CMAQ model remained relatively "stiff" despite some fairly significant NOx reductions from power plants. In addition to these controls being costly, they would also take more time than is available to implement. Therefore, the focus for future reductions for the Metrolina nonattainment area cannot be on point source reductions alone. The NCDAQ's contingency plan consists of both Federal and State measures.

The Federal measures result from the fleet turnover of the light and heavy-duty engine standards from the on-road mobile sector, and the non-road engine standards. The NCDAQ has estimated that there will be approximately 8.5 tons per day of NOx emissions reduced each year from the mobile sector. As the older vehicles in the fleet retire and are replaced with newer vehicles meeting the Federal standards, the NOx emissions will continue to decrease, even though vehicle miles traveled continue to increase. Similarly, as newer off-road equipment is purchased and older equipment is retired, the NOx emissions will see a downward trend.

The State measure is lowering the NOx RACT applicability level from 100 tons per year potential emissions to 50 tons per year potential emissions. The NCDAQ took this rule to public hearing on March 14, 2007. The NCDAQ anticipates that the Environmental Management Commission will adopt this amended rule at its May 10, 2007 meeting, and that the rule will become effective on July 1, 2007.

The utility sector is expected to be a source of NOx emission reductions that will occur between now and the 2009 attainment year. The Clean Smokestacks Act requires the two large North Carolina utilities (Duke Energy and Progress Energy) to meet annual NOx emission budgets for 2007 and a tighter budget for 2009. Several of the Duke Energy units are still expected to have controls come on line over the next two years. However, sensitivity runs show that attainment cannot be achieved from utility cuts alone. The combination of the mobile source and utility NOx emission reductions that are expected in the Metrolina area since the end of the 2006 ozone season and before the beginning of the 2009 attainment year is significant. The additional NOx emission reductions in the nonattainment area should ensure that the Metrolina area will attain the NAAQS by the prescribed attainment year.

It is relatively easy to apply simple programs to ratio hourly emissions for sensitivity runs to show effects of controls at point sources. Furthermore, scripts can be written to reduce the manual work and speed up SMOKE processing and merging.

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KEY WORDS

Ozone
Point Source
Sensitivity Run
Attainment
Control Measures
Design Value
SMOKE
CMAQ
Compliance Plan
NCDAQ