Air Quality in the Triangle Region

Prepared For:

Greater Triangle Regional Council
Air Quality Task Force

By:

North Carolina Department of Environment and Natural Resources, Division of Air Quality

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1. Introduction

In July 2003, the Greater Triangle Regional Council (GTRC) formed an air quality task force to promote and coordinate strategies to improve air quality in the Triangle region of North Carolina. The GTRC asked the North Carolina Division of Air Quality (NCDAQ) to provide a report that would inform GTRC and Triangle community members about the current and projected status of air quality and air pollution control in the greater Triangle region. NCDAQ has developed this report to respond to that request.

The Triangle area is in violation of the federal 8-hour standard for ground-level ozone, and will be designated as nonattainment of this standard by the U.S. Environmental Protection Agency in April 2004. This report focuses on ozone because it is the pollutant of greatest concern, from both a health and regulatory perspective, at this time. However, NCDAQ is also concerned about fine particle levels in the Triangle, which are currently meeting the federal standard but are close to the level of the standard. Fine particles pose a potentially serious health risk to some members of the public, and are addressed in this report.

This report discusses: (1) the levels, health risks, and sources of ground-level ozone and fine particles; (2) current and proposed state and federal controls on emissions contributing to these pollutants; (3) current and projected future levels of ozone precursor emissions; and (4) actions needed to sustain good air quality in future years.

The emissions data presented in this report are for the greater Triangle region comprising Chatham, Durham, Franklin, Granville, Harnett, Johnston, Lee, Moore, Orange, Person, Vance, Wake and Warren counties. GTRC requested that the report address these 13 counties, which comprise the region addressed by the Research Triangle Regional Partnership, a partner organization of the GTRC.

The North Carolina Division of Air Quality is a division of the North Carolina Department of Environment and Natural Resources (NCDENR). NCDAQ is responsible for protecting and improving outdoor air quality in North Carolina. To carry out this mission, NCDAQ has programs for monitoring air quality, permitting and inspecting air emissions sources, and educating and informing the public about air quality issues. NCDAQ also enforces state and federal air pollution regulations. For more information on NCDAQ programs, please visit the NCDAQ website at ***www.ncair.org***.

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2. Overview of Air Quality in the Triangle

2.1 Air Quality Regulatory Structure and Triangle Pollutants of Concern

Outdoor air quality in the United States is regulated by the U.S. Environmental Protection Agency (EPA) under the authority of the federal Clean Air Act. The EPA sets National Ambient Air Quality Standards (NAAQS) for six "criteria pollutants" that are considered harmful to human health and the environment.[1] These six pollutants are carbon monoxide, lead, ozone, nitrogen dioxide, particulate matter and sulfur dioxide. Particulate matter is further classified into two categories: PM 10, or airborne particles with diameters of 10 micrometers or less, and PM 2.5, airborne particles with diameters of 2.5 micrometers or less. Levels of a pollutant above the health-based standard pose an unacceptable risk to human health.

The North Carolina Division of Air Quality monitors levels of all six criteria pollutants in the Triangle region and across North Carolina, and reports these levels to the EPA. According to the most recent data, the Triangle region is meeting national ambient standards for five of the pollutants, but is not meeting the federal 8-hour standard for ground-level ozone. Therefore ozone is the pollutant of greatest concern in the Triangle at this time.

PM 2.5, also called fine particulate matter or fine particle pollution, is also a pollutant of concern in the Triangle. PM 2.5 levels measured at Triangle monitors do not currently exceed federal standards. However, annual averages in Durham and Wake counties are close to the standard. The potentially serious health effects of fine particle exposure justify continued vigilance regarding PM 2.5 levels as the Triangle continues to grow.

2.2 Triangle Ozone Levels

The NAAQS for ground-level ozone is 0.08 parts per million (ppm) averaged over 8 consecutive hours. Federal enforcement of the ozone NAAQS is based on a 3-year monitor "design value". The design value for each monitor is obtained by averaging the annual fourth highest 8-hour ozone values over three consecutive years. Thus, the three highest 8-hour ozone concentrations recorded by a monitor during a given year are not included in the design value calculation. If a monitor's design value exceeds the NAAQS, that monitor is in violation of the standard, and some area around the monitor must be designated nonattainment. If even one monitor in a metropolitan statistical area (MSA) violates the NAAQS, the EPA may designate part or all of the metropolitan area as nonattainment. Due to rounding convention, a monitor's design value is considered to exceed the NAAQS when it equals or exceeds 0.085 ppm.

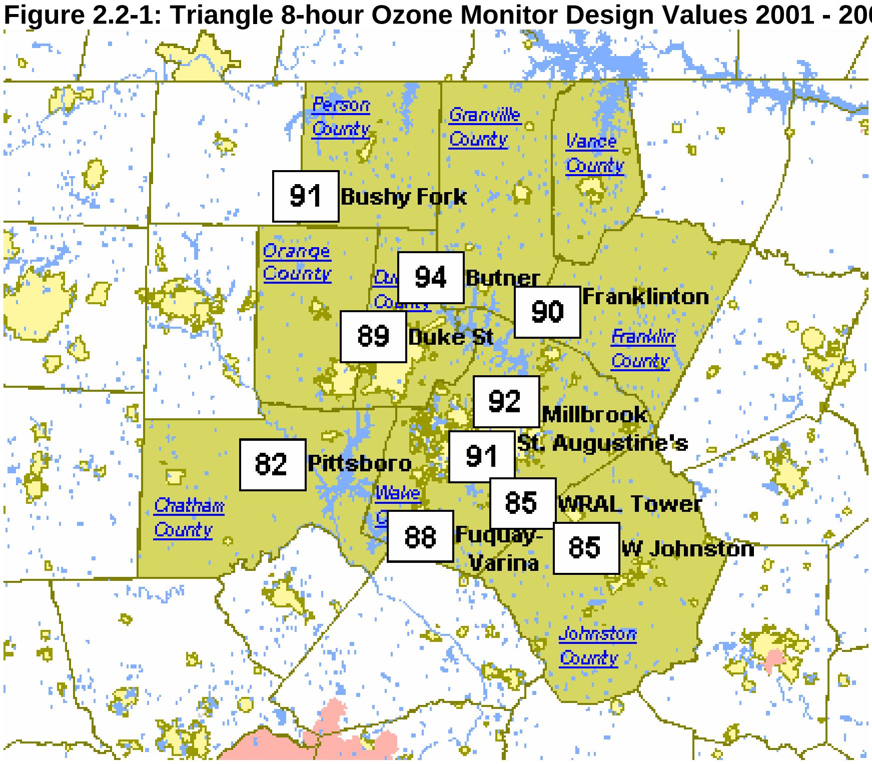
There are ten (10) ozone monitors in the greater Triangle region. For the 3-year periods 2000 – 2002 and 2001 – 2003, nine of these monitors were in violation of the ground-level ozone NAAQS (table 2.2-1, figure 2.2-1). Therefore, some portion of the Triangle region will be designated nonattainment by the EPA in April 2004.

Table 2.2-1. Triangle 8-hour Ozone Monitor Design Values 1994 - 2003
8-hour ozone values in parts per million (ppm)

Monitor Name	County	94-96	95-97	96-98	97-99	98-00	99-01	00-02	01-03
Millbrook	Wake	0.082	**0.086**	**0.092**	**0.101**	**0.098**	**0.094**	**0.092**	**0.092**
St.Augustine	Wake	**0.086**	**0.091**	**0.095**	**0.097**	**0.095**	**0.093**	**0.094**	**0.091**
Butner	Granville	**0.087**	**0.094**	**0.097**	**0.098**	**0.094**	**0.092**	**0.094**	**0.094**
Duke St.	Durham	0.084	0.083	**0.086**	**0.088**	**0.091**	**0.087**	**0.091**	**0.089**
Franklinton	Franklin	0.083	**0.086**	**0.092**	**0.093**	**0.090**	**0.086**	**0.091**	**0.090**
Bushy Fork	Person			**0.093**	**0.095**	**0.091**	**0.089**	**0.090**	**0.091**
Tower	Wake	0.084	**0.089**	**0.093**	**0.099**	**0.094**	**0.088**	**0.085**	**0.085**
W. Johnston	Johnston	0.084	**0.087**	**0.089**	**0.095**	**0.091**	**0.087**	**0.085**	**0.085**
Fuquay-Varina	Wake	**0.087**	0.082	**0.087**	**0.088**	**0.092**	**0.086**	**0.087**	**0.088**
Pittsboro	Chatham	0.079	**0.085**	**0.086**	**0.088**	**0.085**	0.081	0.083	0.082

8-hour ozone NAAQS = 0.08 parts per million (ppm), equivalent to 80 parts per billion (ppb). Design values are considered to exceed the NAAQ Standard when they equal or exceed 0.085 parts per million of ozone. Values showing exceedence are in **bold** type.

Figure 2.2-1: Triangle 8-hour Ozone Monitor Design Values 2001 - 2003



Note: The green shading indicates the Triangle ozone forecast area. Harnett, Lee, Moore, and Warren Counties are not included in the forecast area, and do not contain ozone monitors.

Eight ozone action days, or days on which at least one area monitor exceeded the standard, occurred in the Triangle in 2003. One of these days was a code red, or unhealthy, ozone action day; the remaining seven were code orange, or unhealthy for sensitive groups, days. While this is a lower number of ozone action days than in many previous years, the levels of some of the exceedences were relatively high. Table 2.2-2 lists the highest and fourth-highest values, and number of exceedences, for each Triangle area monitor in 2003. All monitors exceeded the standard on at least one day. Fourth-highest values exceeding the NAAQS are shown in bold type.

Table 2.2-2. 2003 Ozone Levels at Triangle Monitors: Highest, fourth-highest, and total number of exceedences.

Monitor Name	County	Highest 2003 8-hour value (ppm)	Number of exceedences in 2003	Fourth Highest 2003 value (ppm)
Millbrook	Wake	**0.115**	5	**0.089**
St.Augustine	Wake	**0.099**	3	0.079
Butner	Granville	**0.105**	5	**0.090**
Duke St.	Durham	**0.098**	3	0.084
Franklinton	Franklin	**0.094**	4	**0.087**
Bushy Fork	Person	**0.096**	3	0.083
Tower	Wake	**0.093**	3	0.084
W. Johnston	Johnston	**0.091**	2	0.080
Fuquay-Varina	Wake	**0.100**	4	**0.089**
Pittsboro	Chatham	**0.090**	1	0.075

More than one monitor exceeded the NAAQS on some days. Eight 8-hour ozone exceedence days (a day when at least one monitor exceeded the NAAQS) occurred in the Triangle in 2003.

2.3 Triangle PM 2.5 levels

EPA has set two standards for fine particles, or PM 2.5: (1) a 24-hour standard of 65 micrograms per cubic meter (µg/m^3) averaged over 24 hours, and (2) an annual standard of 15 µg/m^3 averaged over one year.

Since PM 2.5 monitoring began in 1999, no 24-hour PM 2.5 concentration above the 65 µg/m^3 standard has been measured by any Triangle-area monitor. However, 24-hour concentrations have occasionally reached the code orange "unhealthy for sensitive groups" level, which for PM 2.5 is set at 40.5 µg/m^3, below the regulatory standard of 65 µg/m^3.

Enforcement of the annual PM 2.5 standard is based on annual mean concentrations, averaged over 3 years for each monitor. For the 3-year period 1999-2001, PM 2.5 levels in Durham and Wake Counties exceeded the annual standard of 15 µg/m^3 (table 2.3-1). More recent 3-year averages show compliance with the annual standard, as well as a downward trend for all monitored Triangle counties. However, 3-year averages remain close to the standard, especially in Durham and Wake Counties. At this time, it is expected that no area in the Triangle will be designated nonattainment for PM 2.5.

Table 2.3-1: 3-year average annual PM 2.5 concentrations for monitored Triangle counties, in micrograms per cubic meter (μg/m^3)

County	January 1999 – December 2001	January 2000 – December 2002	July 2000 – June 2003
Chatham	13.4	12.8	12.5
Durham	**15.3**	14.9	14.4
Orange	14.3	13.6	13.4
Wake	**15.3**	14.6	14.3

Values shown are from each county's one-day or three-day monitoring site with the highest mean. Values of 15.0 μg/m^3 or higher exceed the NAAQ standard and are in bold type.

2.4 Forecasting and Reporting of Air Quality to the Public

The North Carolina Division of Air Quality forecasts daily peak ozone levels from May 1 to September 30 for the Triangle, Fayetteville, Charlotte, Hickory and Asheville areas. Beginning on May 1, 2004, NCDAQ will also forecast daily ozone levels for the Rocky Mount Area. NCDAQ forecasts daily peak fine particle levels year-round for the Charlotte area, and will begin forecasting fine particle levels for the Hickory area on May 1, 2004. Ozone and fine particle forecasts for the Triad area are issued by the Forsyth County Environmental Affairs Department. Ozone and fine particle forecasts, collectively called air quality forecasts, are issued to the public using the EPA's Air Quality Index color code system. The AQI color codes standardize the reporting of different pollutants by classifying pollutant concentrations according to relative health risk, using colors and index numbers to describe categories of health risk. The Air Quality Index is also used to report the previous day's air quality to the public. In the Triangle area, the forecasts and previous day air quality reports appear on the weather page of local newspapers, and the ozone forecasts are broadcast on television and radio news. Table 2.4-1 shows the AQI color codes used for air quality reporting, and lists the regulatory standard and AQI breakpoints for ozone and PM 2.5

Table 2.4-1: Ozone and PM2.5 regulatory standards and Air Quality Index public reporting levels

		Pollutant concentration ranges for Air Quality Index color codes and corresponding health risk levels				
Pollutant/ Standard	**Standard Value**	**Green AQI 0– 50 Good**	**Yellow AQI 51-100 Moderate**	**Orange AQI 101-150 Unhealthy for Sensitive Groups**	**Red AQI 151-200 Unhealthy**	**Purple AQI 201-300 Very Unhealthy**
Ozone/ 8-hour average	0.08 ppm averaged over 8 hours	0-0.064 ppm	0.065-0.084 ppm	0.085-0.104 ppm	0.105-0.124 ppm	0.125-0.374 ppm
PM 2.5/ 24-hour average	65 $\mu g/m^3$ averaged over 24 hours	0-15.4 $\mu g/m^3$	15.5-40.4 $\mu g/m^3$	40.5-65.4 $\mu g/m^3$	65.5-150.4 $\mu g/m^3$	150.5-250.4 $\mu g/m^3$
PM 2.5/ Annual Arithmetic Mean	15 $\mu g/m^3$ averaged over one year	*There is no Air Quality Index for annual average PM 2.5.*				

3. Ozone and its Health Effects and Sources

3.1 Overview of Ozone

Ozone (O_3) is a tri-atomic ion of oxygen. In the stratosphere or upper atmosphere, ozone occurs naturally and protects the Earth's surface from ultraviolet radiation. Ozone in the lower atmosphere (troposphere) is often called ground-level ozone, tropospheric ozone, or ozone pollution to distinguish is from upper-atmospheric or stratospheric ozone. Ozone does occur naturally in the lower atmosphere, but only in relatively low background concentrations of about 0.025 to 0.045 ppm, well below the NAAQS.[2]

In the lower atmosphere, ozone is formed when airborne chemicals, primarily nitrogen oxides (NOx) and volatile organic compounds (VOCs), combine in a chemical reaction driven by heat and sunlight. These ozone-forming chemicals are called precursors to ozone. Man-made NOx and VOC precursors contribute to ozone concentrations above natural background levels. Because ozone formation is greatest on hot, sunny days with little wind, elevated ozone concentrations occur during the warm weather months, generally May through September. In agreement with EPA's guidance, North Carolina operates ozone monitors from April 1 through October 31 in order to capture all possible events of high ozone.

The term "smog" is often used to refer to ozone pollution. However, the brownish or dirty haze known as smog is a combination of ozone and airborne particles. Ozone levels may be elevated even on clear days with no obvious "smog".

3.2 Ozone Health Effects

The form of oxygen needed for animal and plant metabolism is O_2. The ozone ion of oxygen, O_3, has an oxidizing effect on materials such as rubber and fabrics, and on plant and animal cells and tissues. Breathing ozone irritates the lungs and respiratory passages. Short-term, infrequent exposure to ozone can result in throat and eye irritation, difficulty drawing a deep breath, and coughing. Long-term and repeated exposure to ozone concentrations above the NAAQS can result in reduction of lung function as the cells lining the lungs are damaged. Repeated cycles of damage and healing may result in scarring of lung tissue and permanently reduced lung function. Health studies have indicated that high ambient ozone concentrations may impair lung function growth in children, resulting in reduced lung function in adulthood. In adults, ozone exposure may accelerate the natural decline in lung function that occurs as part of the normal aging process. Ozone may also aggravate chronic lung diseases such as emphysema and bronchitis and reduce the immune system's ability to fight off bacterial infections in the respiratory system.

Asthmatics and other individuals with respiratory disease are especially at risk from elevated ozone concentrations. Ozone can aggravate asthma, increasing the risk of asthma attacks that require a doctor's attention or the use of additional medication. According to the EPA, one reason for this increased risk is that ozone increases susceptibility to allergens, which are the most common triggers for asthma attacks. In addition, asthmatics are more severely affected by the reduced lung function and irritation that ozone causes in the respiratory system. There is increasing evidence that ozone may trigger, not just exacerbate, asthma attacks in some individuals. Ozone may also contribute to the development of asthma. A recent study published in the British medical journal *The Lancet* found a strong association between elevated ambient ozone levels and the development of asthma in physically active children.[3]

All children are at risk from ozone exposure because they often spend a large part of the summer playing outdoors, their lungs are still developing, they breathe more air per pound of body weight, and they are less likely to notice symptoms. Children also have a high incidence of diagnosed or undiagnosed asthma. A survey of North Carolina 7th and 8th graders conducted during the 1999-2000 school year found that 10% had diagnosed asthma, and an additional 17% had wheezing symptoms, indicating possible undiagnosed asthma.[4]

Children and adults who frequently exercise outdoors are particularly vulnerable to ozone's negative health effects, because they may be repeatedly exposed to elevated ozone concentrations while breathing at an increased respiratory rate.[5]

Numerous studies have found correlations between elevated ground-level ozone concentrations and increased hospital admissions and emergency room visits for respiratory symptoms. These health effects are associated with increased monetary and societal costs. According to the North Carolina Department of Health and Human Services, ozone pollution caused an estimated 868 to 1900 respiratory-related hospital admissions in North Carolina between April and October of 1997. The estimated cost of these hospital admissions was between $8,723,730 and $19,095,724.[6] Ozone also caused an estimated 5,700 respiratory-related emergency room visits and 240,000 asthma attacks in North Carolina during this time period.[7] The U.S. EPA has estimated that during the summer months, as many as 10 to 20% of the total respiratory-related hospital admissions in the northeastern United States are due to ozone. Ozone's adverse health effects also result in missed school days and lost productivity, as parents take time from work to care for children with respiratory problems.

There is no threshold or "safe" level of ozone at which health effects do not occur. Even below the NAAQS, ozone may cause subtle health effects in sensitive groups and may noticeably affect particularly sensitive individuals.

3.3 Ozone Sources

Ozone-forming pollutants, or precursors, are volatile organic compounds (VOCs) and nitrogen oxides (NOx).

3.3.1 Volatile Organic Compounds

Volatile organic compounds (VOCs) are a highly reactive class of hydrocarbons, and are sometimes referred to as hydrocarbons. However, it is important to note that hydrocarbons, as a class of chemical compounds, include less-reactive compounds not considered VOCs. In other words, although all VOCs are hydrocarbons, not all hydrocarbons are VOCs.

VOCs are typified by easily evaporating substances with strong odors. Examples of substances high in VOCs are gasoline fumes, lighter fluid, paint thinner, nail polish remover, printing ink, perfumes, and some types of paints.

In North Carolina and the Triangle, a large portion of precursor VOCs is produced by natural, or biogenic, sources, primarily trees. Man-made, or anthropogenic, VOCs also contribute to ozone production, particularly in urban areas. Major sources of anthropogenic VOCs include unburned gasoline fumes evaporating from gas stations and cars, industrial emissions, and consumer / industrial products such as paints and solvents.

3.3.2 Nitrogen Oxides

Nitrogen oxides (NOx) are produced when fuels are burned, and result from the reaction of atmospheric nitrogen at the high temperatures produced by burning fuels. Major sources of NOx are highway motor vehicles, coal-fired power plants, and off-road vehicles such as construction equipment, lawn care equipment, trains, airplanes and airport ground support equipment, and motorboats.

Other NOx sources include "area" sources (small, widely-distributed sources) such as fires (forest fires, backyard burning, house fires, etc.), and natural gas hot water heaters. Other residential combustion sources such as oil and natural gas furnaces and wood burning also produce NOx, but these sources generally do not operate during warm-weather months when ground-level ozone is a problem. In general, area sources contribute only a very small portion of ozone-forming NOx emissions.

North Carolina, including the Triangle, is generally considered to be "NOx-limited", meaning that reducing NOx emissions is believed to be the most effective way to reduce ozone levels, because of the abundance of biogenic VOC emissions. Therefore, current ozone strategies focus on reducing NOx. However, VOC reduction strategies, such as control of evaporative emissions from gas stations and vehicles, could reduce ozone in highly urbanized areas where biogenic VOC emissions are not as high as in rural or less urbanized areas.

3.3.3 Source Category definitions

The five source categories generally used to describe NOx and VOC emissions are defined below.

Biogenic: Trees and other natural sources.

Mobile: Vehicles traveling on paved roads: cars, trucks, buses, motorcycles, etc.

Nonroad: Vehicles not traveling on paved roads: construction, agricultural, and lawn care equipment, motorboats, airplanes, locomotives, etc.

Point: “Smokestack” sources: industry and electric utilities.

Area: Sources not falling into above categories. For VOCs, area sources include gas stations, dry cleaners, print shops, consumer products, etc. For NOx, area sources include forest and residential fires, natural gas hot water heaters, etc.

4. PM 2.5 and its Health Effects and Sources

4.1 Overview of PM 2.5

Particulate matter is a mixture of solid particles and liquid droplets suspended in ambient air. Some of these particles are directly emitted from sources or condense from a gaseous form immediately upon release. Other particles result from secondary formation as chemicals react or combine in the atmosphere. Particles are made up of a variety of components, including acids such as nitrates and sulfates, organic chemicals, metals, elements from soil or dust, and allergens like pollen fragments and mold spores.

Fine particles, or PM 2.5, are particles with diameters of 2.5 micrometers or smaller. By comparison, a human hair is about 70 micrometers in diameter. These very small particles are particularly dangerous to human health, because they can evade the respiratory system’s defenses and penetrate deeply into the lungs. Some of the chemical constituents of these particles may be absorbed though lung tissues into the bloodstream; some cardiac effects of particles may be related to the cardiovascular system’s reaction to these absorbed chemicals.

4.2 PM 2.5 Health Effects

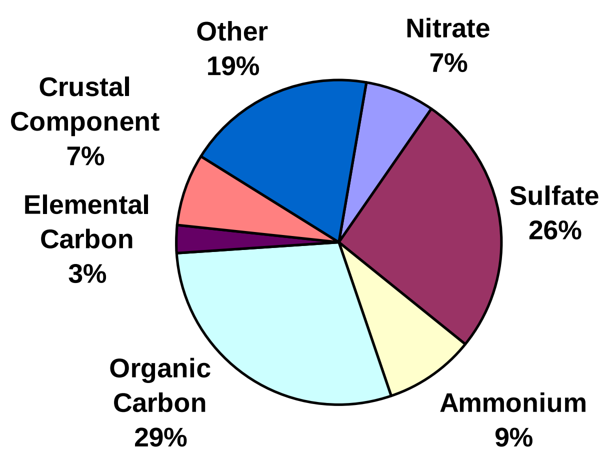
The most serious effects of particles are associated with aggravation of heart or lung disease. Numerous studies have linked airborne particles to increased hospital admissions and emergency room visits, and even to death from heart or lung diseases. Short-term exposure may aggravate respiratory conditions such as asthma and bronchitis. Recent evidence suggests that exposures as brief as one hour may result in cardiac effects such as heart attacks and cardiac arrhythmias (irregular heart rhythms). Particles may also alter the lung's defenses, increasing susceptibility to respiratory infections.

Groups most at risk from elevated fine particle levels include: (1) people with heart or lung disease such as such as coronary artery disease, congestive heart failure, and asthma or chronic obstructive pulmonary disease (COPD); (2) older adults; and (3) children. Older adults may be at increased risk because they may have undiagnosed heart or lung disease or diabetes. Studies show that when particle levels are high, older adults are more likely to be hospitalized, and some may die of aggravated heart or lung disease. Children are vulnerable to particulate health effects for many of the same reasons that they are especially sensitive to ozone effects: their lungs are still developing, they breathe a higher volume of air in relation to body weight, and they may spend more time at a higher activity level. They are also more likely to have asthma or other respiratory conditions. People with diabetes may also be at increased risk, possibly because they are more likely to have underlying cardiovascular disease.

4.3 PM 2.5 Sources

Particles come from a variety of sources. Figure 4.3-1 shows the average chemical speciation, or makeup, of particles in North Carolina. Many particulate sources are the same as those contributing to ozone pollution, especially motor vehicles and industry, including power plants. The nitrogen oxides and sulfur oxides emitted by vehicles and industry contribute to secondary formation of particles. Carbon particles are also emitted by vehicles, especially diesel vehicles. Smoke, a mixture of gases and fine particles, can contribute significantly to elevated particle levels. Smoke from forest fires, sometimes traveling hundreds of miles from remote fires, has caused some of the higher particle "events" in North Carolina. Residential wood burning can also contribute to high fine particle levels. After the December 2002 ice storm and resulting widespread power outage, many Triangle residents burned wood in fireplaces and wood stoves for heat. An atmospheric inversion on December 6-7, 2002 concentrated the wood smoke in the lower atmosphere, resulting in code orange fine particle levels in the Triangle.

Figure 4.3-1: North Carolina PM 2.5 Speciation



Data 1/3/2003 - 8/13/2003; 224 samples.

4.3.1 Probable sources of PM2.5 species

The sources contributing to fine particle pollution are not completely understood. The list below cites some probable sources for the fine particle species shown in figure 4.3-1. However, this is not a comprehensive list. Research is ongoing on the sources, formation, and dispersion of fine particle pollution.

Nitrate (NO3):	Industrial boilers, electric utilities, gasoline and diesel vehicle exhaust.
Sulfate (SO4):	Coal-fired electric utilities, gasoline and diesel vehicle exhaust.
Ammonium (NH4):	Agricultural livestock operations, wastewater treatment plants.
Organic Carbon:	Gasoline and diesel vehicle exhaust, wood combustion, meat cooking (restaurant char-grilling operation, etc.), road dust, secondary formation from VOC emissions.
Elemental Carbon:	Wood smoke.

Crustal Component: Minerals associated with the earth's surface such as aluminum, silicon, calcium, iron, and titanium. Sources may include dirt roads, farm fields, and quarrying operations.

5. Nonattainment Designation and Regulatory Schedule

"Nonattainment" is the designation given by the EPA to areas with at least one monitor measuring levels of a criteria pollutant in violation of the National Ambient Air Quality Standard, when averaged over a 3-year period. Nonattainment areas must develop and implement, on a federally mandated schedule, a plan to improve air quality to the level of the federal standard. Although states have a great deal of discretion in developing control measures, EPA requires that three regulatory measures, transportation conformity, general conformity, and new source review, be implemented in all nonattainment areas. The following section describes, in general terms, regulatory actions and schedules related to nonattainment designation. Many details, such as effective designation date and attainment date, will be specified in either the April 2004 EPA announcement or the following Federal Register notice, and are thus unknown at this time.

5.1 Effective date of designation

Nonattainment area designations are published in the Federal Register after being announced by the EPA. In the past, the Federal Register notice has been published about two weeks after the designation announcement. The Federal Register notice will specify the effective date of designation, which is generally 30 to 60 days following the notice. Thus if 8-hour ozone designations are announced on April 15, 2004, the effective date of designations will likely be between late May and early July 2004.

5.2 State Implementation Plan (SIP)

For each area in North Carolina designated nonattainment, the North Carolina Division of Air Quality (NCDAQ) must submit a State Implementation Plan (SIP) to the EPA. The SIP sets budgets, or allowable levels, for emissions from mobile, nonroad and other source categories, and describes the emission control measures that will be implemented, or have already been implemented, to improve air quality to meet the NAAQS. NCDAQ must demonstrate, through computer modeling results detailed in the SIP, the emissions and pollutant reductions expected from control measures. The SIP is usually due to EPA three years after the effective date of nonattainment designation.

5.3 Attainment Date and Maintenance Redesignation

Nonattainment areas must demonstrate attainment of the NAAQS by a certain number of years following designation. This attainment date generally depends upon the severity of the area's NAAQS violation. NCDAQ projects that the Triangle will be required to show attainment by 2009, five years after designation. If all monitor 3-year design values show compliance with the NAAQS by this date, the area will be redesignated as maintenance. Maintenance designation ensures that pollution controls continue and that air quality continues to meet the NAAQS. Some controls, notably transportation conformity and general conformity, remain in place under maintenance designation, while others, notably new source review, are lifted. On redesignation, NCDAQ must submit a maintenance plan to EPA. This plan will contain emissions projections and contingency measures to be implemented if pollutant levels exceed the standard during the maintenance period.

If all 3-year monitor design values do not show compliance with the standard by the attainment date, the EPA may take one of several actions. EPA may grant an attainment date extension under certain circumstances, e.g. if no exceedences occurred during the most recent year. Alternatively, EPA may issue a SIP call requiring a new SIP containing additional control measures to be submitted. If a control measure in the SIP has not been implemented, EPA may issue a Finding of Failure to Implement, triggering further federal enforcement actions and penalties.

An area may apply to EPA for early redesignation to maintenance status before the attainment deadline. NCDAQ can apply to the EPA for redesignation as soon as the most recent 3-year design values at all area monitors comply with the NAAQS. The first of the three data years can be prior to the nonattainment designation; i.e. the 3-year design value "clock" for maintenance re-designation does not start at nonattainment designation.

Maintenance designation remains in place for 20 years following redesignation. The maintenance plan submitted at the time of redesignation will contain emissions projections for the first 10-year period. Eight years following redesignation, NCDAQ must develop submit a second maintenance plan containing emissions projections for the last 10-year period.

If a maintenance area exceeds the NAAQS during the maintenance period, the contingency measures included in the maintenance plan may be implemented. These measures may include controls such as stricter controls on industrial emissions or even re-instatement of new source review requirements.

5.4 Transportation Conformity

Transportation conformity is a process ensuring that federal funding and approval goes to transportation activities that are consistent with air quality goals. The Clean Air Act requires that transportation plans, programs, and projects in nonattainment or maintenance areas that are funded or approved by the Federal Highway Administration (FHWA) or Federal Transit Agency (FTA) conform to emissions budgets specified by the SIP. Transportation planning agencies must demonstrate that their long-range transportation infrastructure plans will not result in vehicle emissions over SIP budgets. If conformity is not demonstrated, federal funding of transportation projects or programs may be withheld.

In the Triangle, transportation planning agencies such as metropolitan planning organizations (MPOs) work with the N.C. Department of Transportation (NCDOT) and NCDAQ to forecast future vehicle traffic patterns, known as travel demand. Travel demand forecasts predict future year vehicle miles traveled (VMT) for a projected mix of road and vehicle types. These forecasts are based on transportation plans and socio-economic factors such as anticipated employment rates and residential and retail growth. Vehicle emission factors are applied to VMT projections to estimate future vehicle emissions, which are compared to SIP budgets. This process is known as conformity determination. The SIP assigns vehicle emission budgets for each county in the nonattainment / maintenance area, so conformity must be determined for each county.

Conformity determinations are submitted to the U.S. Department of Transportation for review. The first conformity determination following nonattainment designation must be completed by one year after the effective date of designation. Because this deadline is two years prior to the deadline for SIP completion, a vehicle emissions budget will not yet be determined. Instead of comparison to a budget, this first determination will apply an emission reduction test to projected emissions. This test may consist of a “build/no-build” test, which compares emissions impacts of implementing the proposed transportation plan to the impacts of not implementing the plan, a “less than baseline year” test, which compares emissions impacts of the transportation plan to emissions in a baseline year, or another test as determined by federal guidance.

Following this initial determination, conformity determinations must be made at least every three years, or as changes are made to transportation plans. As stated above, transportation conformity requirements remain in place throughout the nonattainment and maintenance periods.

5.5 General Conformity

The purpose of general conformity, like transportation conformity, is to ensure that federal funds or actions do not contribute to degradation of air quality in a nonattainment or maintenance area. Emission sources using federal funds or requiring a federal action such as approval of a permit, e.g. airports, must demonstrate that modifications will not result in emissions exceeding the corresponding SIP budget. General conformity requirements take effect immediately upon the effective date of nonattainment designation and remain in place throughout the nonattainment and maintenance periods.

5.6 New Source Review

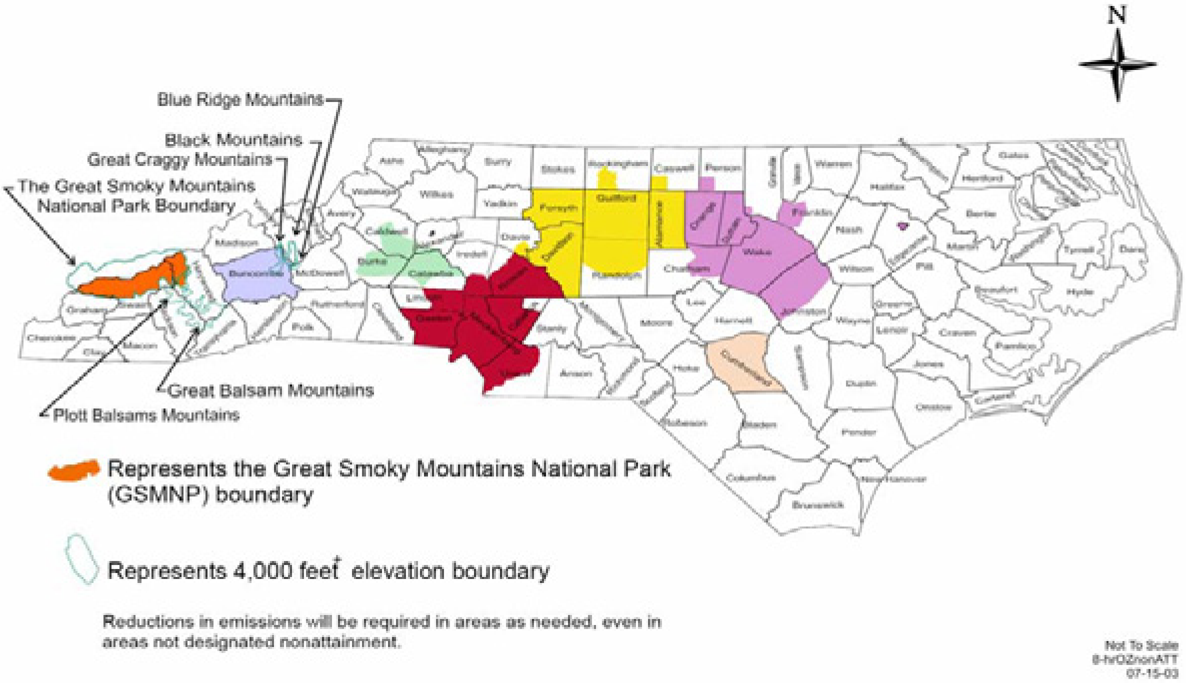
The total emissions of permitted point sources in a nonattainment area cannot exceed the point source emissions produced in a baseline year. In the case of 8-hour ozone designation, this base year will likely be 2002. Therefore, any new industry requiring an air quality permit and wishing to locate within the nonattainment area, or any existing industry wishing to expand its operation, must install the strictest available emission controls. New or expanding industry will also need to obtain offset credits, from other industry in the same nonattainment area, for its emissions. NCDAQ is currently developing an emissions credit banking and trading system in anticipation of new source review requirements. The practical implication of new source review is that many industries will not locate within a nonattainment area because the requirements increase the cost of doing business when compared to an attainment area.

New source review requirements take effect immediately upon nonattainment designation. The requirements are lifted when the area is redesignated as maintenance, but may be re-instated if air quality again dclines and the area falls out of attainment of the NAAQS during the 20-year maintenance period.

5.7 8-hour Ozone Nonattainment Designation Process and Schedule

Under EPA rules, states recommend nonattainment area boundaries; these boundaries must then be approved by EPA. On July 15, 2003, North Carolina submitted boundary recommendations for seven ozone nonattainment areas (figure 5.1-1, also see http://daq.state.nc.us/news/pr/2003/nonattain_map.pdf). EPA responded to these recommendations on December 3, 2003. EPA's response recommends that entire counties be designated as nonattainment, rather than the partial counties recommended by North Carolina in several areas. For the Triangle, EPA recommends that the entire counties of Durham, Orange, Wake, Chatham, Franklin, Johnston, Granville, and Person be designated nonattainment. In February 2004, NCDAQ responded to EPA's recommendations and reiterated its rationale for partial county designations EPA will promulgate final 8-hour ozone nonattainment designations by April 15, 2004.

Figure 5.1-2: North Carolina's recommendations for 8-hour ozone nonattainment area boundaries (recommendations submitted to US EPA July 15, 2003)



5.8 PM 2.5 Nonattainment Designation

EPA expects to designate nonattainment areas for fine particles by December 31, 2004. Because many ozone control measures will also reduce fine particles, the EPA may allow states to submit a unified SIP for areas designated as nonattainment for both ozone and PM 2.5, due 3 years after PM 2.5 designations.

On February 17, 2004, North Carolina submitted boundary recommendations for PM 2.5 nonattainment areas. According to the most recent three years of data (2001-2003), only two monitors in the state, one each in Davidson and Catawba counties, are violating the PM 2.5 annual standard. North Carolina recommended that all of Davidson County and the portion of Catawba County within in Unifour MPO planning boundary be designated nonattainment for PM 2.5. Because no Triangle-area monitors are currently violating either the 24-hour or annual PM 2.5 standard, no areas in the Triangle were recommended for PM 2.5 nonattainment designation.

6. Existing Federal and State Emissions Control Measures

Several control measures already in place or being implemented over the next few years will reduce point and mobile source emissions contributing to ozone and fine particles. These control measures were included in the assumptions used for 2007 ozone modeling. The proposed nonroad diesel Tier 4 rules described in section 6.2.6 were not included in 2007 modeling because they have not been finalized.

6.1 State Control Measures

6.1.1 North Carolina Clean Air Bill

The 1999 Clean Air Bill expanded the vehicle emissions inspection program from 9 counties to 48, and improved the testing method. Vehicles will be tested using the onboard diagnostic system, which will indicate NOx emissions, among other pollutants. The previously used tailpipe test did not measure NOx.

6.1.2 NOx SIP Call Rule

North Carolina is participating in the 1998 NOx SIP Call, a federal measure requiring 22 states to reduce summertime NOx emissions from power plants and other industries by 69 percent between 2000 and 2006. The North Carolina Environmental Management Commission adopted rules requiring the reductions in October 2000.

6.1.3 Clean Smokestacks Act

In June 2002, the N.C. General Assembly enacted the Clean Smokestacks Act, requiring coal-fired power plants to reduce annual NOx emissions by 77% by 2009. These power plants must also reduce annual sulfur dioxide emissions by 49% in 2009 and by 73% in 2013. The reductions are required for year-round emissions. One of the first state laws of its kind in the nation, this legislation provides a model for other states in controlling multiple air pollutants from old coal-fired power plants.

6.2 Federal Control Measures

6.2.1 Tier 2 Vehicle Standards

Federal Tier 2 vehicle standards will require all passenger vehicles in a manufacturer's fleet, including light-duty trucks and sport-utility vehicles (SUVs), to meet an average standard of 0.07 grams of NOx per mile. Implementation will begin in 2004, and most vehicles will be phased in by 2007. Tier 2 standards will also cover passenger vehicles over 8500 pounds gross vehicle weight rating (the largest pickup trucks and SUVs), which are not covered by current Tier 1 regulations. For these vehicles, the standards will be phased in beginning in 2008, with full compliance in 2009. The new standards require vehicles to be 77% to 95% cleaner than those on the road today. Tier 2 rules will also reduce the sulfur content of gasoline to 30 parts per million (ppm) by 2006, as described in section 6.1.4 above. Sulfur occurs naturally in gasoline but interferes with the operation of catalytic converters in vehicle engines. Lower-sulfur gasoline is necessary to achieve Tier 2 vehicle emission standards. Most gasoline currently sold in North Carolina has a sulfur content of about 300 ppm.

6.2.2 Heavy-Duty Gasoline and Diesel Highway Vehicle Standards

New U.S. EPA standards designed to reduce NOx and hydrocarbon (HC, includes VOCs) emissions from heavy-duty gasoline and diesel highway vehicles will begin to take effect in 2004. A second phase of standards and testing procedures, beginning in 2007, will reduce particulate matter (PM) from heavy-duty highway diesel engines, and will also reduce highway diesel fuel sulfur content to 15 ppm, because emission control devices are damaged by sulfur.

The total program is expected to achieve a 90% reduction in PM emissions and a 95% reduction in NOx emissions, compared to existing engines using higher-sulfur content fuel.

6.2.3 Small Spark-Ignition Engine Phase 2 Standards

EPA regulations group small spark-ignition engines into handheld and non-handheld categories. Handheld engines are those in brush cutters, leaf blowers, chainsaws, string trimmers, etc. Non-handheld engines are used in walk-behind lawnmowers, lawn and garden tractors, air compressors, commercial turf equipment, and similar applications. Phase 1 standards affected 1997 and newer handheld and non-handheld engines and were projected by the EPA to reduce hydrocarbon (HC) emissions from these engines by 32%. Phase 2 standards took effect for non-handheld engines in 2001 and for handheld engines in 2002. The standards will phase in until 2007. EPA expects the standards to reduce combine HC and NOx emissions by 59% from non-handheld engines, and by 70% from handheld engines, beyond the Phase 1 reductions.

6.2.4 Nonroad Large Spark-Ignition Engine and Recreational Engine Standard

These new standards will regulate NOx, HC and carbon monoxide (CO) for groups of previously unregulated nonroad engines. The new standard will apply to all new engines in these categories sold in the US and imported after these standards begin. Affected engines include large industrial spark-ignition engines (forklifts, electric generators, airport ground service equipment), recreational vehicles (off-highway motorcycles and all-terrain-vehicles), and recreational marine diesel engines over 50 horsepower (hp). The regulation varies based on the type of engine or vehicle.

Large spark-ignition (SI) engines contribute to ozone formation and ambient CO and PM levels in urban areas. Tier 1 of the large SI engine standard takes effect in 2004 and Tier 2 is scheduled to start in 2007. Like large SI engines, recreational vehicles contribute to ozone formation and ambient CO and PM levels. They can also be a factor in regional haze and other visibility problems in both state and national parks. Recreational marine diesel engines over 50 hp, such as those used in yachts and cruisers, contribute to ozone formation and PM levels, especially in marinas. Standards for recreational vehicles and recreational marine diesel engines begin taking effect in 2006. Implementation dates vary according to the vehicle type and engine.

When all of the standards are fully implemented, EPA expects a 72% reduction in HC, an 80% reduction in NOx, and a 56% reduction in CO emissions by 2020.

6.2.5 Tier 2 and Tier 3 Nonroad Diesel Standards

Tier 1 standards for nonroad diesel engines were phased in between 1996 and 2000 and affected almost all new nonroad diesel engines, such as those used in bulldozers, backhoes, and farm tractors. Smaller diesel engines under 50 hp were regulated under Tier 1 standards beginning in 1999. The standards did not apply to locomotives and marine vessels. Tier 1 standards varied according to the size of the engine and primarily addressed NOx emissions.

Tier 2 and Tier 3 standards will set more stringent standards for NOx and will also regulate HC, CO, and PM. Tier 2 standards are phasing in from 2001-2006, and apply to most new nonroad diesel engines, including engines under 50 hp. Tier 3 standards will set stricter standards for engines over 50 hp and will be implemented from 2006-2008. Start years and standards for Tiers 2 and 3 will vary depending on engine power rating. The standards will only apply to new engines, and will not apply to locomotives, marine engines over 50 hp, and underground mining equipment.

The EPA projects that Tier 2 and 3 standards will reduce emissions from each nonroad diesel engine type by as much as two-thirds from the levels of previous standards. EPA analyses predict that nationwide NOx inventories will be reduced by approximately one million tons per year by 2010, with benefits increasing annually as older equipment is replaced with new equipment conforming to the standards.

6.2.6 Proposed Tier 4 Nonroad Diesel Engines Standard

The U.S. EPA has proposed new Tier 4 rules for nonroad diesel engines of all sizes, from less than 25 hp to greater than 750 hp. The proposed standards would be phased in between 2008 and 2014. The proposed rules would also reduce the allowable sulfur in nonroad diesel fuel by over 99 percent. Nonroad diesel fuel currently averages about 3,400 ppm sulfur. The proposed rules limit nonroad diesel sulfur content to 500 ppm in 2007 and 15 ppm in 2010. The combined engine and fuel rules would reduce NOx and particulate matter emissions from large nonroad diesel engines by over 90 percent, compared to current nonroad engines using higher-content sulfur diesel.

As stated above, the proposed nonroad diesel Tier 4 standards have not been included in the modeling of 2007 ozone levels.

7. Estimated NOx and VOC emissions in 2000 and 2007

7.1 Emissions Inventory Overview

The emissions inventory process estimates amounts of specific pollutants, in this case NOx and VOCs, that are emitted into the atmosphere during a specific time period. As part of the inventory, NCDAQ estimates the amount of pollutant emitted by each known source type, such as light-duty highway vehicles, diesel construction, electric utilities, etc. These source estimates are based on activity data for each source, e.g. vehicle miles traveled, the mix of vehicle types, point source air quality permit information, construction equipment fleet information, etc.

Weather conditions affect emissions; for example, VOC emissions increase with hotter temperatures. Therefore, computer modeling is used to estimate total emissions. The computer model processes source activity information through a set of meteorological factors to estimate emissions. NCDAQ uses actual meteorological data from specific high ozone episodes in previous years to generate these estimates.

NCDAQ has estimated NOx and VOC emissions for an average summer day for 2000 and 2007. The 2007 estimates take into account all state and federal control measures that will be implemented by 2007 (listed in sections 6.1.1 – 6.2.5 of this report). NCDAQ also uses predicted source activity information to develop future year estimates. For example, projected vehicle fleet turnover rates (percentage of older vehicles being replaced by newer vehicles) and shifts in fleet vehicle mix (e.g. a decrease in light-duty passenger cars and an increase in light trucks and SUVs) are incorporated into future year mobile source emission inventories.

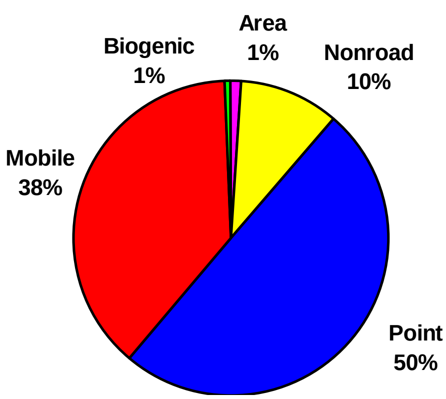
NCDAQ has completed future year inventories for 2007 because Early Action Compact areas are required to attain the 8-hour ozone standard in 2007. Early Action Compact (EAC) areas are areas not attaining the 8-hour ozone standard, which have formed regional agreements with the U.S. EPA to achieve early reductions in ozone levels. EAC areas will be designated nonattainment in April 2004, but the effective date of nonattainment designation, along with corresponding federal controls, will be deferred until 2007, at which time the EAC areas must demonstrate attainment of the standard. EAC areas in North Carolina are the Triad, Hickory/Unifour, Fayetteville, and Asheville/Mountain areas. NCDAQ will also estimate emission inventories for the required attainment year in the Triangle and other North Carolina nonattainment areas, and for five and ten year intervals following the attainment/maintenance redesignation year. These inventories have not been completed.

7.2 2000 and 2007 NOx emissions

7.2.1 Triangle NOx Emissions from Source Categories

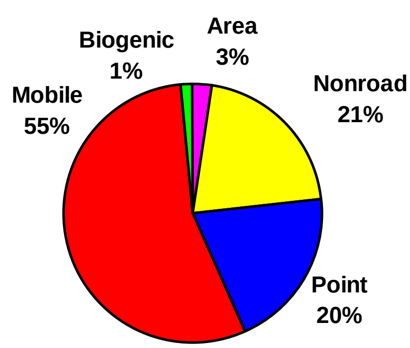
Figures 7.2-1and 7.2-2 show the estimated relative contributions of different source categories to average summer day NOx levels in 2000, and projected for 2007. The same meteorology was used for both years. The total NOx emissions for the Triangle area decrease by 54% from about 474 tons per day (TPD) in 2000 to 216 TPD in 2007.

Figure 7.2-1: 2000 Triangle Area NOx Emissions



2000 total NOx, Triangle area:
474.25 tons per day
Average summer weekday

Figure 7.2-2: 2007 Triangle Area NOx Emissions (Projected)



2007 total NOx, Triangle area:
216.14 tons per day
Average summer weekday

Table 7.2-1 compares the actual amounts of NOx, in tons per day, emitted by each source category in 2000 and 2007. These amounts correspond to the percentages shown in figures 7.2-1 and 7.2-2. The largest source category change is in point source emissions, which decrease from about 235 tons per day in 2000 to 43 TPD in 2007, due largely to controls on electric utilities and industrial boilers. Biogenic emissions are the same for both years because these emissions are dependent upon meteorology and amount and type of vegetative cover. The same meteorology was used for both years, and vegetative cover is not expected to change significantly.

Table 7.2-1: Estimated NOx emissions in tons per day, 2000 and 2007, Greater Triangle Area, average summer weekday

Source	NOx 2000	NOx 2007
Area	5.34	5.64
Nonroad	48.78	44.85
Point	234.92	42.94
Mobile	182.11	119.61
Biogenic	3.10	3.10
Total Emissions	**474.25**	**216.14**

7.2.2 Breakdown of Triangle NOx Emissions from On-Road Mobile Sources

Categories of on-road vehicles are defined as follows:

Heavy-duty diesel vehicles (HDDV): Diesel trucks over 8500 pounds gross vehicle weight rating (GVWR). This generally includes large trucks and buses. The largest diesel sport-utility vehicles (SUVs) also fall into this category.

Heavy-duty gasoline vehicles (HDGV)= Gasoline trucks over 8500 pounds GVWR. The largest gasoline SUVs fall into this category.

Light-duty gasoline vehicles (LDGV): Gasoline-powered passenger cars. This category does not include minivans, pickup trucks, or SUVs.

Light-duty gasoline trucks 1 (LDGT1): Gasoline trucks, including pickup trucks, minivans, and SUVs, under 6000 pounds GVWR. This category includes federal “light light-duty truck” categories LDT1 and LDT2.

Light-duty gasoline trucks 2 (LDGT2): Gasoline trucks, including pickup trucks, minivans, and SUVs, over 6000 pounds and under 8500 pounds GVWR. This category includes federal “heavy light-duty truck” categories LDT3 and LDT4.

Other: Motorcycles, light-duty diesel passenger vehicles, and light-duty diesel trucks (under 8500 pounds GVWR).

Figure 7.2-3 shows the relative contributions of these vehicle types to on-road mobile emissions in 2000 and 2007 in the 13 Greater Triangle region counties. Heavy-duty diesel vehicles contribute the majority of NOx emissions in both years. The second and third-largest contributors are gasoline passenger cars and gasoline trucks under 6000 pounds GVWR.

Figure 7.2-3: On-Road Mobile NOx sources, Greater Triangle Region, 2000 and 2007

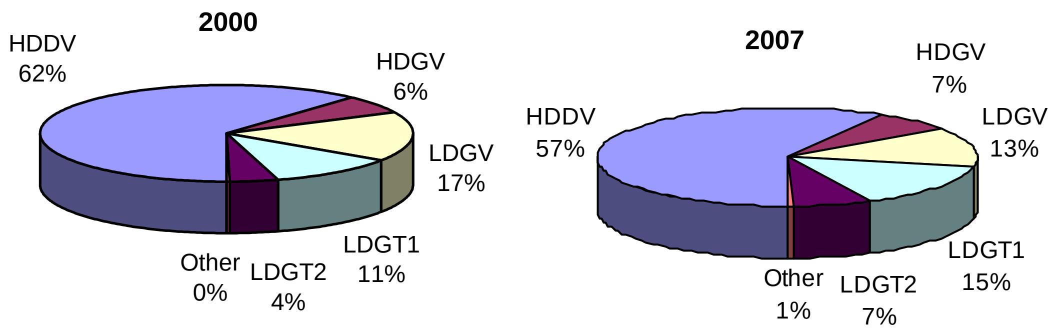


Table 7.2-2 compares the actual amounts of NOx, in tons per day, emitted by each vehicle type in 2000 and 2007. Each vehicle type's emissions are shown as a percentage of on-road mobile NOx emissions (corresponding to figure 7.2-3), and also as a percentage of the total NOx emissions from all sources for that year.

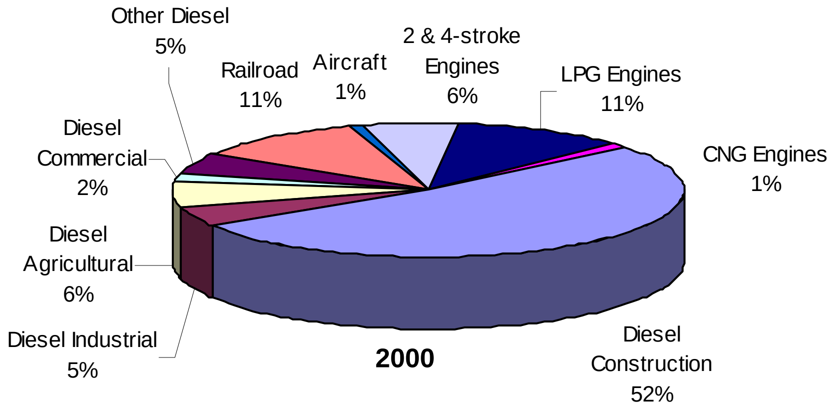
Table 7.2-2: Estimated NOx emissions from on-road mobile sources in 2000 and 2007, Greater Triangle Area, in tons per day (TPD) and as a percentage of Triangle on-road and total NOx inventories

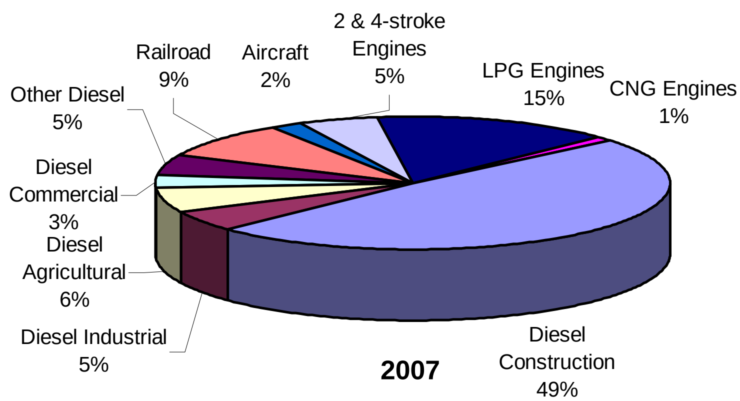
Source	**TPD 2000**	**Percent of Triangle on-road mobile NOx inventory, 2000**	**Percent of Triangle total NOx inventory, 2000**	**TPD 2007**	**Percent of Triangle on-road mobile NOx inventory, 2007**	**Percent of Triangle total NOx inventory, 2007**
Heavy-duty diesel vehicles	112.43	61.74%	23.71%	69.64	58.22%	32.22%
Heavy-duty gasoline vehicles	11.06	6.07%	2.33%	8.26	6.90%	3.82%
Light-duty gasoline vehicles	30.50	16.75%	6.43%	15.51	12.97%	7.18%
Light-duty gasoline trucks (1)	19.79	10.87%	4.17%	17.72	14.81%	8.20%
Light-duty gasoline trucks (2)	7.62	4.19%	1.61%	7.81	6.53%	3.61%
Other	0.72	0.39%	0.15%	0.68	0.57%	0.32%
Total	**182.11**	**100.00%**	**38.40%**	**119.61**	**100.00%**	**55.34%**

7.2.3 Breakdown of Triangle NOx Emissions from Nonroad Mobile Sources

Figure 7.2-4 shows the relative contributions of nonroad (or off-road) vehicle types to nonroad mobile NOx emissions in 2000 and 2007 in the 13 Greater Triangle region counties. In both years, diesel construction vehicles contribute about one-half of nonroad NOx emissions.

Figure 7.2-4: Nonroad Mobile NOx sources, Greater Triangle Region, 2000 and 2007





Tables 7.2-3 compares the actual amounts of NOx, in tons per day, emitted by each nonroad vehicle type in 2000 and 2007. Each vehicle type's emissions are shown as a percentage of nonroad mobile NOx emissions (corresponding to figure 7.2-3), and also as a percentage of the total NOx emissions from all sources in that year. Diesel construction emissions do not decrease greatly from 2000 and 2007, reflecting the continued use of older diesel equipment not conforming to newer EPA standards. The contribution of diesel construction vehicles to the total Triangle NOx inventory nearly doubles between 2000 and 2007 from 5.3% to 10.2%. Issues relating to diesel construction emissions are discussed in greater detail in Appendix D of this report.

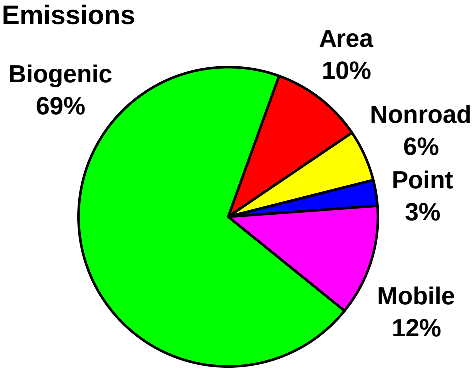
Table 7.2-3: Estimated NOx emissions from nonroad mobile sources in 2000 and 2007, Greater Triangle Area, in tons per day (TPD) and as a percentage of Triangle nonroad and total NOx inventories

Source	TPD 2000	Percent of Triangle nonroad NOx inventory, 2000	Percent of Triangle total NOx inventory, 2000	TPD 2007	Percent of Triangle nonroad NOx inventory, 2007	Percent of Triangle total NOx inventory, 2007
Diesel Construction	25.16	51.58%	5.31%	21.97	49.26%	10.18%
LPG Engines	5.60	11.48%	1.18%	6.77	15.19%	3.14%
Railroad	5.26	10.78%	1.11%	3.87	8.68%	1.79%
Diesel Agricultural	3.11	6.38%	0.66%	2.82	6.31%	1.31%
2 & 4-Stroke Engines	2.74	5.61%	0.58%	2.39	5.35%	1.11%
Diesel Industrial	2.36	4.84%	0.50%	2.16	4.85%	1.00%
Other Diesel	2.24	4.59%	0.47%	2.10	4.70%	0.97%
Diesel Commercial	1.06	2.17%	0.22%	1.16	2.61%	0.54%
Aircraft	0.73	1.50%	0.15%	0.74	1.66%	0.34%
CNG Engines	0.52	1.08%	0.11%	0.62	1.38%	0.29%
Total	**48.78**	**100%**	**10.30%**	**44.61**	**100%**	**20.67%**

7.3 2000 and 2007 VOC Emissions

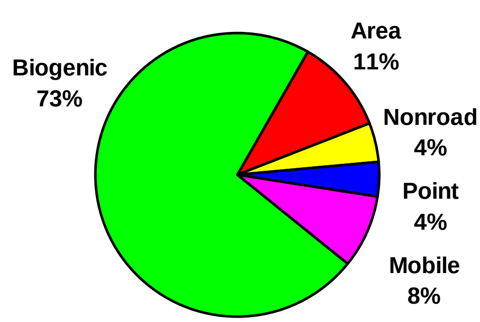
Figures 7.3-1 and 7.3-2 show estimated Triangle area VOC emissions in 2000 and 2007. Total VOC emission decrease minimally, about 4%, between 2000 and 2007. Mobile and nonroad VOCs show the greatest decreases, as seen in table 7.3-1. As in the NOx inventories, biogenic emissions are the same for both years because the same meteorology was used for both years, and vegetative cover is not expected to change significantly.

Figure 7.3-1: 2000 Triangle Area VOC Emissions



2000 Total VOC, Triangle Area: 726.79 tons per day

Figure 7.3-2: 2007 Triangle Area VOC Emissions (Projected)



2007 total VOC, Triangle Area: 698.32 tons per day

Table 7.3-1 compares the actual amounts of NOx, in tons per day, emitted by each source category in 2000 and 2007. These amounts correspond to the percentages shown in figures 7.3-1 and 7.3-2.

Table 7.3-1: Estimated VOC emissions in tons per day, 2000 and 2007, Greater Triangle Area, average summer weekday

Source	VOC 2000	VOC 2007
Area	73.38	76.25
Nonroad	40.16	31.21
Point	20.57	26.80
Mobile	86.08	57.45
Biogenic	506.60	506.60
Total Emissions	**726.79**	**698.32**

8. Projected attainment status in 2007

Computer modeling, using the emissions inventories described above, is used to project peak ozone levels at each monitor in the state. Meteorological data from previous high ozone levels is applied to estimated NOx and VOC emissions to estimate resulting ground-level ozone concentrations. Appendix A describes the modeling process in greater detail.

NCDAQ's preliminary modeling indicates that by 2007, all Triangle ozone monitors will attain the federal 8-hour standard. Most other ozone monitors in the state will also attain the standard. However, 5 monitors in the Charlotte area still show exceedences of the standard in 2007. Preliminary modeling for the year 2010 indicates that all monitors in the state will attain the standard in that year.

These results should not be interpreted as a guarantee of future attainment. NCDAQ inventory and modeling staff take great care to insure that emission inventories and pollutant models account for future source activity, changes due to regulations and improved control technologies, and all other factors affecting the model outcome, to the fullest extent possible. However, such modeling necessitates numerous estimations and assumptions regarding factors ranging from population growth to heavy-duty diesel fleet turnover. The best modeling efforts cannot accurately predict all factors contributing to ozone exceedences. An unusually hot, dry summer could result in higher ozone concentrations. Municipal growth, growth in vehicle miles traveled, or changes in vehicle mix different than those anticipated by the model could result in ozone concentrations exceeding the standard.

While these modeling results could potentially be interpreted to negate the need for further action to improve air quality, it should be remembered that attainment must be demonstrated within a certain time frame (possibly by 2009), and that stricter enforcement actions may ensue if this deadline is not met. Alternatively, if attainment can be demonstrated before the attainment deadline, redesignation to maintenance status can occur early. Once attainment is demonstrated and maintenance redesignation occurs, new source review requirements on industry will be lifted, increasing economic growth and employment opportunities for communities. However, if air quality declines to a level not complying with the NAAQS during the 20-year maintenance period, these restrictions could be reinstated, and additional control measures may be implemented. Proactive measures to improve air quality will provide a margin of safety to ensure that the attainment deadline is met and attainment is maintained. Additionally, because there is no “safe” level of ozone at which health effects do not occur, actions to reduce ozone levels will pay dividends in decreased health care costs, decrease school absenteeism, and increased productivity.

9. Ozone transport and its effect on local ozone concentrations

Ozone precursors and ozone itself can be transported from distant locations in upper-level winds, and can affect Triangle area ozone concentrations. In order to gauge the effectiveness of local control strategies, decision-makers must have some understanding of the relative contribution of transported ozone and precursors, which local controls will not affect. The N.C. Division of Air Quality considers transported ozone and precursors by including in its ozone modeling emissions from part or all of every state east of the Mississippi River. Appendix A describes the geographic/spatial scales incorporated in NCDAQ modeling scenarios and how ozone transport is considered in modeling.

Transport varies widely from day to day depending on wind speed, direction, and other meteorological factors. It is impossible to determine the exact amount by which transported ozone and precursors affect local ozone concentrations. However, one method of gauging the possible contribution of transport to a local high ozone event is through back trajectories. By analyzing where a parcel of air came from, and how long it took to travel, back trajectories can indicate if a parcel of air from an urban area may have contributed to a high ozone event. Appendix B describes back trajectories in greater detail and includes several examples of back trajectories for Triangle Code Red ozone days. Some of these show transport from other areas affecting Triangle air quality; some show stagnant air over the Triangle, in which locally produced pollution likely results in high ozone concentrations; and some show re-circulation of Triangle air back into the Triangle.

Pollution is often diluted and dispersed during transport. Appendix C describes NOx footprint modeling of pollution dispersion and dilution, indicating that the effect of transported precursors may be weak on many days.

If local production of ozone precursors is high, even a small amount of pollution transported into the area can cause ozone levels to exceed the NAAQS. Current evidence indicates that transport of ozone and ozone precursors from other states does increase ozone levels in the Triangle and other areas of North Carolina on some days, and that the amount of transported pollution can be sufficient, when combined with locally-produced emissions, to trigger ozone exceedences at area monitors. However, NCDAQ believes that in the Triangle and other urban areas of North Carolina, local emissions are by far the largest contributors to high ozone levels. In order for our area to attain the NAAQS, it is important that all emission sources, including transport, be controlled. The state of North Carolina is currently seeking emissions reductions from other states through the EPA's Clean Air Act Section 126 petition process. However, control of local emissions is critical to continued attainment of the NAAQS.

10. Future Needs for Air Quality Improvement

Although technological improvements such as power plant controls and cleaner vehicles will improve air quality a great deal, action is needed to maximize the benefits from these controls, make sure air quality is improved sooner rather than later, and ensure that the benefits of controls are retained into the future. As stated in section 8, action to improve air quality will provide a margin of safety to insure that the attainment deadline is met and that air quality remains in compliance with the NAAQS through the maintenance period. Such action will protect the economic and social benefits of early and sustained attainment.

The following are major action areas in which further air quality improvements could be realized. This is not a comprehensive list of potential actions; state and local governments, as well as non-governmental groups, organizations, and businesses around the country, have developed many creative solutions to address air quality problems.

10.1 Vehicle Miles Traveled, Travel Demand Management, and Land Use Planning

Vehicle miles traveled (VMT) will continue to increase. The current rate of North Carolina VMT increase, as well as EPA national projections, suggests that VMT will continue to increase at a rate of 2 to 3 percent annually. Given a 2% annual increase, VMT in Wake County will more than double between 2004 and 2031. This growing VMT will decrease the air quality benefits from vehicle emission controls, add to transportation infrastructure expense, increase the conversion of open space to streets and highways, and have a significant impact on quality of life, as people spend more time in their cars, drive longer distances, and experience greater traffic congestion.

The most pressing future need is the reduction of vehicle miles traveled. While many other contributors to ozone air pollution are being addressed by measures such as improved vehicle emissions controls and more stringent industry and utility controls, VMT is not controlled by any state or federal measure. Local and regional growth planning that reduces the number and length of vehicle trips, and increases the feasibility of transit use, is critical to the reduction of VMT. "Smart Growth" or sustainable development principles such as mixed-use development, brownfields redevelopment, neighborhood schools, higher density (where appropriate), and transit-oriented development will reduce VMT and may significantly improve quality of life in our communities. Better public transit infrastructure is needed and should be tied to growth planning to co-locate greater residential densities, businesses, retail, and transit. Businesses should be encouraged to locate near residential centers and transit infrastructure. In other words, we will continue to grow, but our challenge is to grow efficiently. Many of these decisions must occur at the local level, and jurisdictions within a region must cooperate to maximize the benefits of sustainable development practices.

Travel demand management (TDM) techniques, such as commuter trip reduction initiatives, can also reduce VMT while encouraging the use of transportation modes other than the single-occupancy vehicle. Carpooling, vanpooling, transit use, and telecommuting can reduce VMT and congestion, while reducing transportation costs for commuters. Various local, state, and federal programs have been established to promote TDM activities. The federal Commuter Choice program provides tax incentives to businesses that offer trip reduction incentives, such as transit and vanpool subsidies, to employees. The Best Workplaces for Commuters program, being launched in the Triangle on April 20, 2004, provides national recognition to employers providing travel demand incentives to employees. Locally, Durham County has passed an ordinance requiring large employers to implement travel demand reduction plans, and SmartCommute@RTP has had great success in promoting alternative transportation modes to commuters in the Research Triangle Park. Education and outreach programs such as the NC Air Awareness Program promote transportation alternatives to the public and employers.

10.2 Green Construction and Energy Efficiency

Green building techniques hold much promise for increasing energy efficiency, decreasing pollution from electricity generation, and reducing energy costs for building owners and tenants. Governments and private industry are encouraged to use green building techniques and energy efficiency measures whenever possible.

Energy conservation at existing facilities can significantly reduce electricity costs while reducing demand on electric power plants. Especially on hot summer days when the increased use of air conditioning sometimes necessitates the use of utility peaking units, energy conservation can reduce emissions and improve air quality. By getting an energy audit and implementing the audit recommendations, some industrial electricity customers have realized energy savings equaling thousands of dollars annually. The North Carolina State Energy Office can provide information on energy audits and energy conservation techniques.

10.3 Accelerated Heavy-Duty Diesel Engine Turnover

Heavy-duty diesel vehicles constitute a large percentage of both on-road and nonroad mobile source NOx inventories. Although recently promulgated and proposed federal regulations are already making cleaner diesel engines available, the long life (sometimes 20 years or more) and high cost of diesel engines will slow turnover of older, higher-emitting engines to newer, cleaner engines. Programs to promote engine re-power and replacement will increase turnover. Various U.S. states and municipalities have implemented programs ranging from construction bid requirements for cleaner diesel engines, to incentive programs providing grants for engine re-power and replacement. Please see Appendix D for more detail on diesel emissions reduction issues.

11. References

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7. Ibid.

Appendix A: Ozone Modeling and Atmospheric Transport Issues

The North Carolina Division of Air Quality (NCDAQ) performs computer modeling to predict future pollutant levels. Air quality modeling is a complex process that integrates information on emissions and meteorology over a multi-state area to predict ozone concentrations at specific locations. Transport of pollutants within the multi-state area is considered in the modeling. This appendix describes, in general terms, the ozone modeling process and the atmospheric transport issues associated with modeling. Statewide North Carolina ozone precursor emissions levels estimated by modeling are also included in this appendix.

Overview of Modeling Process

Ozone modeling is a multi-step process that begins with estimating emissions from pollutant sources and ends with estimating ozone concentrations at a specific monitor. The general steps involved in modeling are emissions inventory, meteorological modeling, and photochemical modeling.

Emissions Inventory: This process estimates nitrogen oxide (NOx) and volatile organic compound (VOC) emissions from numerous sources. Inventories are grouped into source categories such as on-road mobile, nonroad mobile, point and area sources.

On-road mobile sources: Emissions vary according to vehicle type (passenger car, light truck, heavy-duty gas or diesel vehicle, etc.), speed, and travel patterns (continuous flow, stop and go, etc). Average speed and travel patterns vary according to road type. NCDAQ collects data from sources such as the North Carolina Department of Transportation (NCDOT) to estimate numbers of each type of vehicle using different road types. Data on daily vehicle miles traveled (VMT) on each road type is also used. These data are combined with emissions factors for each vehicle type to estimate emissions. VMT projections, long-range transportation plans, and information on the implementation of future vehicle emissions control technologies are used to estimate on-road mobile emissions in future years.

Nonroad mobile sources: Nonroad mobile sources include such sources as construction equipment, airplanes, rail locomotives, boat and ship motors, and lawn and garden equipment. Each of these source types is inventoried using activity data specific to the source. For example, NCDAQ collects information from railroad freight companies on numbers and types of locomotives, and rail miles traveled in North Carolina. Airports supply information on types of aircraft and numbers of landing and takeoff cycles at the airport. These data are combined with emissions factors to estimate resulting emissions.

Point sources: The point source inventory estimates current and future emissions from stationary sources with an air quality permit. These sources range from relatively small sources, such as industrial boilers at small manufacturing facilities, to the largest electric power plants. For current year inventories, air quality permit information provides daily emission totals. For future year inventories, activity for various industrial types is predicted using economic growth factors developed by the federal government, and adjusted to reflect projected growth and employment statistics for North Carolina industry. Emission factors which account for fuel type and for anticipated pollution controls are then applied to these activity data. For modeling episodes, electric utility companies provide hour-by-hour emissions projections based on anticipated electricity demand.

Area sources: These sources include small sources such as gas stations, dry cleaners, print shops, fires such as structure and forest fires, natural gas hot water heaters, agricultural chemical use, etc. For each source type, activity data collected from U.S. Census economic data, forestry and agriculture agencies, and other sources are combined with emissions factors to estimate emissions.

For all source categories, current and future emissions are estimated for the entire modeling domain, shown in figure A6.

Meteorological and Photochemical Modeling: The emissions of ozone precursors vary according to meteorology. For example, evaporative emissions of volatile organic compounds can increase with higher air temperatures. The formation of ozone from precursor emissions is greatly affected by heat, humidity, solar radiation, and air currents.

DAQ models ozone formation episodes in order to estimate future ozone concentrations. Each modeled episode simulates a day or range of days. Actual meteorology that occurred during past high ozone episodes is re-created in the modeling. The modeling applied this simulated meteorology to the predicted emissions to estimate the amount of precursors generated, and how these precursors are transported as a result of air currents. Then the modeling predicts the level of ozone formation at specific monitor locations, given the predicted emissions and meteorology. Ozone is formed by the combination of precursor chemicals in a photochemical reaction that is driven by meteorological conditions. The modeling which simulates this process is referred to as photochemical modeling.

Summary of Modeling System:

NCDAQ uses three major models in its future year ozone projections: the Pennsylvania State University/National Center for Atmospheric Research mesoscale meteorological model (MM5), the Sparse Matrix Operator Kernal Emissions model (SMOKE), and the Multiscale Air Quality Simulation Platform (MAQSIP).

The MM5 meteorological model is designed to simulate or predict mesoscale atmospheric circulation. Several pre- and post-processing programs support the model. The MM5 modeling system is one of the leading meteorological models available for air quality modeling exercises.

The SMOKE emissions model was created to allow emissions data processing methods to integrate high-performance-computing (HPC) sparse-matrix algorithms. The SMOKE system has greatly enhanced support for decision-making about emissions controls for both urban and regional applications, and has provided a mechanism for preparing specialized inputs for regulatory air quality modeling. SMOKE supports area, mobile, and point source emission processing and also includes biogenic emissions modeling.

MAQSIP is a fully modularized three-dimensional photochemical model with various options for representing the physical and chemical processes describing regional- and urban-scale atmospheric pollution.

Episode Description

NCDAQ has used four previous high-ozone episodes in its modeling: one in July 1995, two in June 1996 and one in July 1997. The first episode (July 10-15, 1995) is dominated by a strong upper level blocking high pressure system over the midwest which produced extremely high 1-hour peaks throughout many areas of the Eastern US. The second (June 20-24, 1996) and third (June 26-30, 1006) episodes are separated by the passage of a cold front. Exceedences of the 1-hour and 8-hour standards are confined primarily to NC. The June 20-24, 1996 segment is heavily influenced by a stationary front to the north and an area of high-pressure southwest of the state. A stronger cold front moved through NC during the middle of the episode and cleaned out most of the ozone as an upper level ridge developed to the west. A Canadian surface high pressure system moved in behind the front and was the dominant feature of the June 26-30, 1996 segment as it moved south into NC. These two segments were modeled and evaluated as one episode and represents a full synoptic cycle. In the last episode (July 10-15, 1997), no exceedances of the 1-hour standard occurred in NC. There were few exceedences of the 1-hour standard anywhere in the eastern US; however, 8-hour exceedences were widespread.

Model Performance

The United States Environmental Protection Agency (USEPA) has developed guidance documents for assessing model performance that suggest specific tests and comparisons. Model performance can be based on how well the model replicates observed concentrations of ozone and/or precursors. The underlying rationale is that if the model correctly characterizes changes in concentrations accompanying a variety of meteorological conditions, then some confidence is gained that the model can correctly characterize future concentrations under similar conditions.

USEPA's draft guidance on the use of models and other analyses in attainment demonstrations for the 8-hour ozone National Ambient Air Quality Standard (NAAQS) gives various thresholds for acceptable model performance for various metrics. Although no objective criterion for satisfactory model performance is given, EPA suggests that modeling simulations used for regulatory applications should meet values of 5-15% for mean normalized bias, 30-35 % for mean normalized gross error, and 15-20% for unpaired peak prediction accuracy. NCDAQ's model performance for each episode falls within these ranges.

Federal and State Control Measures Modeled

Modeling performed by NCDAQ estimates NOx and VOC emissions for an average summer day, given the specific meteorological conditions of the episodes and using emission inputs based on current emission inventories and anticipated control measures. Projections for 2007 take into account all state and Federal control measures expected to operate at that time, including Federal vehicle emissions controls, NOx SIP Call controls, and North Carolina Clean Smokestacks controls. The total NOx emissions in NC decrease by 58% from about 2,347 tons per day (TPD) in 2000 to 1,359 TPD in 2007. Changes in source categories are shown in Figure A1. Figures A2 and A3 show the estimated relative contributions of different source categories to average summer day NOx levels in 2000, and projected for 2007.

Figure A1: Estimated Tons Per Day of NOx in NC, 2000 and 2007, per source category

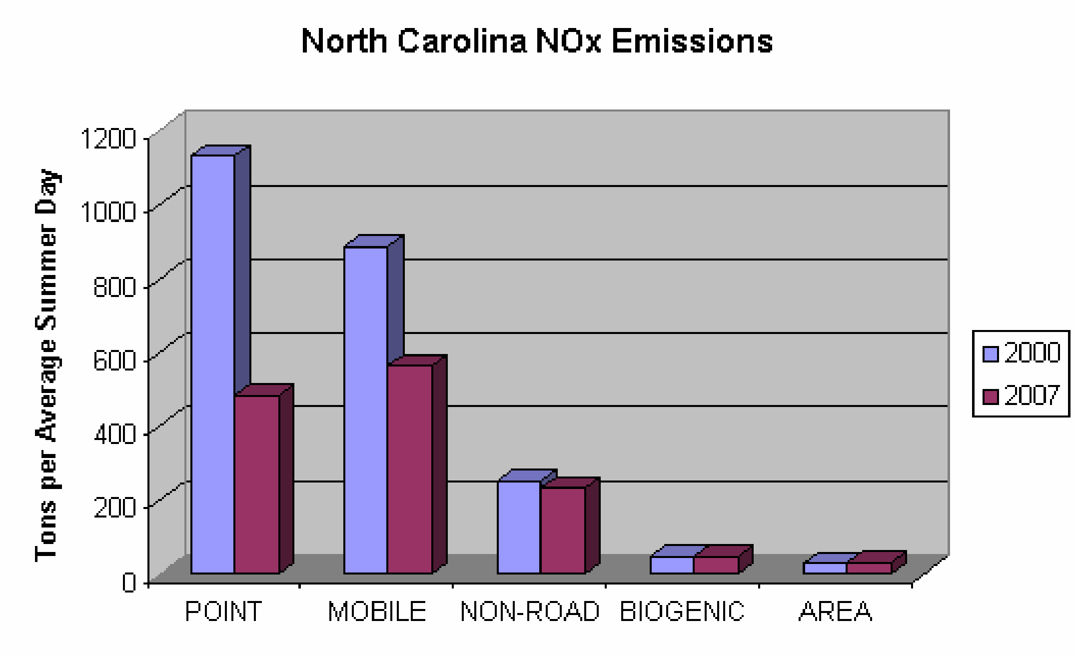


Figure A2: 2000 North Carolina NOx Emissions

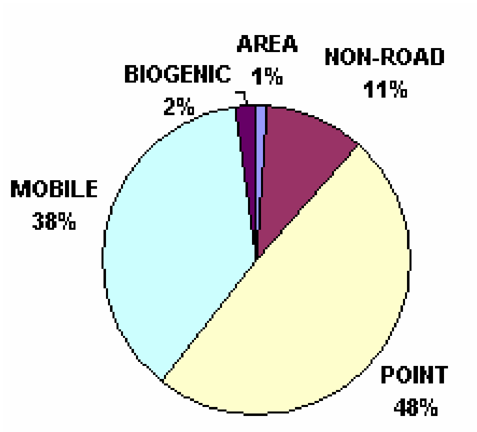
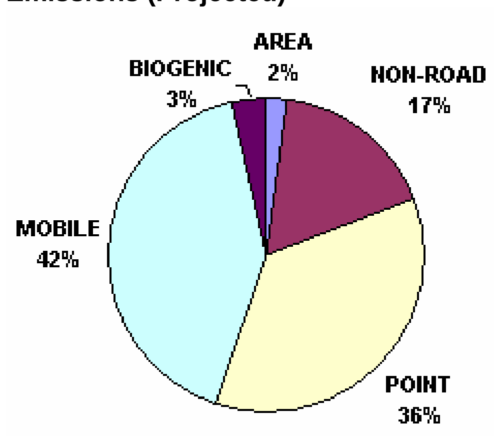


Figure A3: 2007 North Carolina NOx Emissions (Projected)



Figures A4 and A5 show the estimated relative contributions of different source categories to average summer day VOC levels in 2000, and projected for 2007. Little change is expected for VOC emissions, although mobile and nonroad VOCs decrease slightly by 2007. Biogenic emissions are the same for both years because the same meteorology was used and the amount and type of vegetation is not expected to change significantly.

Figure A4: 2000 North Carolina VOC Emissions

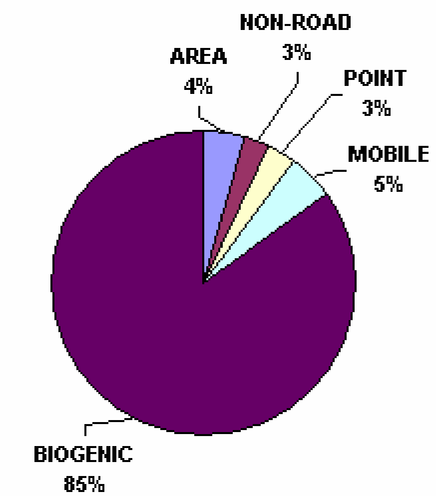
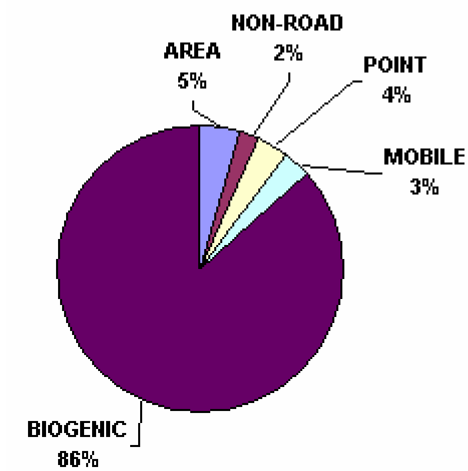


Figure A5: 2007 North Carolina VOC Emissions (Projected)



Modeled Attainment Test

The USEPA draft modeling guidance for demonstrating attainment of the 8-hour ozone standard suggests a methodology for applying air quality models to determine if a given set of emissions controls is likely to show attainment in the future. Specifically, the draft guidance defines a modeled attainment demonstration as:

a) Analyses which estimate whether selected emissions reductions will result in ambient concentrations that meet the NAAQS, and
b) An identified set of measures, which will result in the required emissions reductions.

Part (a) above necessitates the use of a modeled attainment test that uses the modeling results in a relative sense rather than an absolute sense. The various steps of the modeled attainment test, as described in the draft guidance, are explained below.

1. ***Calculate the current site-specific design value (DVC) from monitored data***
2. ***Use air quality modeling results to estimate a site-specific relative reduction factor (RRF)***
3. ***Compute site-specific future year design value (DVF)***
   *DVF = DVC * RRF*

Repeat steps (1) through (3) above for all sites with DVC >= 75 ppb

If DVF at each site is less than or equal to 0.084 ppm, the modeled attainment test has been passed.

Preliminary Modeling Results

Preliminary modeling results and a rigorous application of the modeled attainment test suggests that 41 of the 46 monitoring locations in North Carolina will attain the 8-hour ozone standard in 2007. Again, the control measures included in the modeling are those already in place or those phasing in over the next few years. Of the 5 monitors not showing attainment in 2007, 4 of them are in the Charlotte region with DVFs ranging from 0.089-0.090 ppm. The other location is between the Charlotte and Triad areas and is barely over the standard with a DVF of 0.085 ppm. Table A1 below summarizes the average design value reductions per metropolitan area.

Table A1: Average Future Design Value Reductions (ppb)

Area	Average Design Value Reduction by 2007 (ppb)
Triangle	12
Triad	12
Hickory	12
Charlotte	10
Down East	10
Fayetteville	9
Asheville (ridges)	9
Asheville (valleys)	9

Additional analyses will be performed to better understand what additional controls will be most effective in bringing the 5 monitors that are not showing attainment in the 2007 modeling. NCDAQ is working closely with municipal and county governments to reduce air pollution in these areas.

Atmospheric Transport Considerations

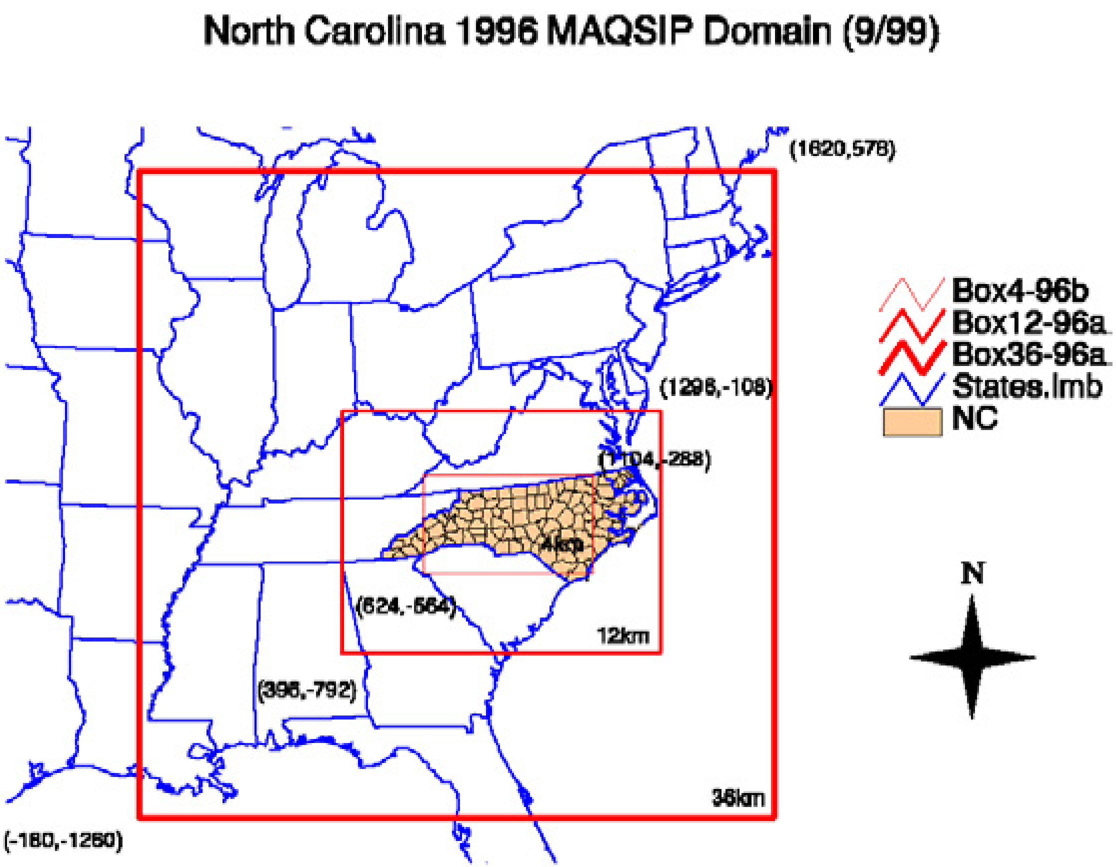
Long range and short distance atmospheric transport of emissions, precursor pollutants, ozone, etc. is captured by appropriately configured grid-based photochemical models. The nested grid domain concept applied in NCDAQ modeling aids in more efficient model execution while still accounting for pollution sources both far and near. NCDAQ employs three modeling domains (see Figure A6 below) to incorporate meteorological conditions, emissions, and resulting air quality across a large expanse of the eastern United States into the photochemical model.

The 36km domain is an outer domain that coarsely establishes all major emissions sources from the larger region surrounding North Carolina, including all of the major metropolitan regions and industrial sources of the Northeast, the eastern Mississippi River Valley, and the Ohio Valley. The emissions and meteorological data throughout the 36km domain are processed by the photochemical model. The 36km domain then provides all of the meteorological and air quality information to the smaller and nested 12km domain at the 12km domain boundaries, based on air/parcel movement in the meteorological model.

The 12km or regional domain is spatially more sensitive to the placement and distribution of emissions sources, as well as the major geographical/topographical influences of the region. This domain is also confined to a smaller area immediately surrounding North Carolina, or the approximate distance any air parcel could travel in a typical day. The 36km domain information is incorporated, along with the more spatially resolved emissions and meteorological data at 12km, and processed again by the photochemical model. Similar to the 36km domain, the 12km domain then provides all of the meteorological and air quality information to the much smaller and nested 4km domain at the 4km domain boundaries based on air/parcel movement in the meteorological model.

At the 4km or urban domain, emissions sources are highly resolved in the counties and cities across North Carolina, and small-scale geographical/topographical influences are recognized. The 4km domain is the most demanding and time consuming domain to prepare, set up, model, and evaluate. In NCDAQ's modeling, the 4km domain stretches across the central two-thirds of North Carolina. All of the meteorological and air quality information processed first at the 36km and next at the 12 km level is lastly integrated with the highly resolved and spatially allocated emissions sources at 4km, and again processed through the photochemical model. Through this entire process, an emission source several thousand miles away or just a few miles away from a specific location in North Carolina can potentially influence the resulting air quality conditions at that specified location.

Figure A6: 36, 12, and 4km Modeling Domains

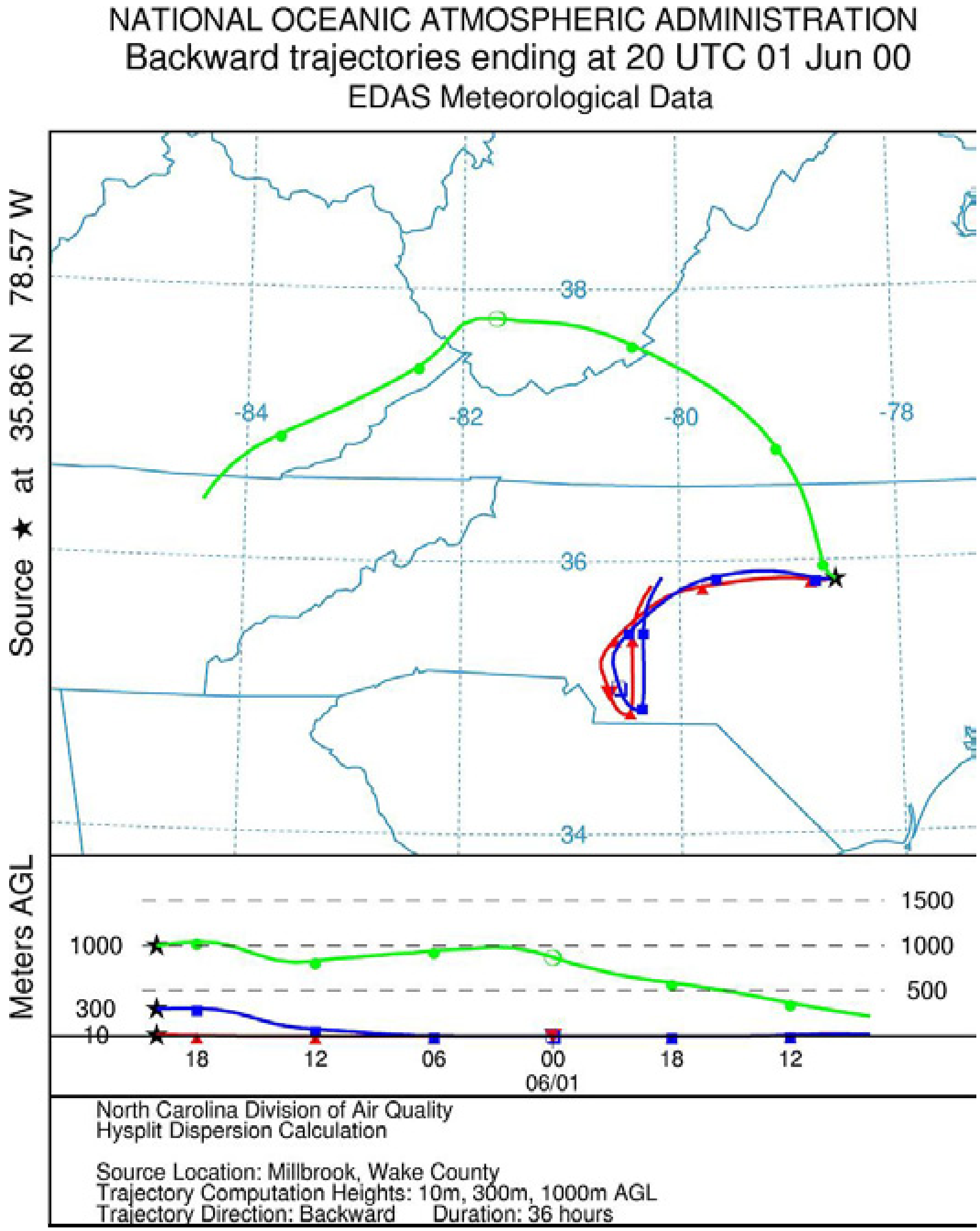


Appendix B: Backward Trajectories for Code Red Ozone Action Days in the Triangle

- Backward trajectories (or back trajectories) begin at a known end point, in this case an ozone monitor, and are run backwards in time to determine the origin in space and time of the air parcel affecting that end point. The initial source or origin of the parcel is, of course, linked to the length of time the parcel is tracked backwards.
- Trajectories were run backwards for code red Ozone Action Days in the Triangle to assess the path the parcel took in arriving at the monitored end point. The NOAA Air Resources Laboratory's (ARL) Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) Model was used to calculate the back trajectories.
- Trajectories are run from the ARL's HYSPLIT model using the Eta model archived data (EDAS). The Eta model is the primary meteorological forecast model used by the National Weather Service. The EDAS data has a grid spatial resolution of 40km, and has the greatest horizontal and vertical resolutions of any data available to be used with the HYSPLIT model.
- Trajectories are all run with the terminal point (monitor location) at the lat/long of the point of interest. For the purposes of this investigation, the Millbrook ozone monitor site located in Raleigh was used as the terminal point. Therefore, the trajectories can be thought of as showing the origin of the air impacting the Triangle on a particular day. The lat/long associated with this monitor is given on the left edge of each trajectory plot.
- Trajectory heights are 10 meters, at approximately 1000 millibars (mb) atmospheric pressure, 300 meters (~950mb), and 1000 meters (~900mb). The lowest trajectory height of 10m (red) is intended to capture the transport at ground level where wind speeds are generally low. The second trajectory height of 300m (blue) is intended to capture the above surface transport from nearby sources. The highest trajectory of 1000m (green) is intended to capture long-range transport from sources well above the surface or far away from the receptor point. The longer the trajectories, the greater the distance the air traveled. Similarly, the shorter the trajectories, the smaller the distance the air traveled. In general, for days during which recirculation occurs, the trajectories are short, and for days in which significant transport occurs, the trajectories are long.
- A duration of 36 hours was used for all trajectories, which allows enough time to sufficiently determine the most significant source contributions to the parcel while limiting the amount of uncertainty that comes with longer duration trajectories.
- The end time of the trajectories is 4:00 PM (2000UTC) on the day of the exceedence at the receptor location. This is typically the time when the

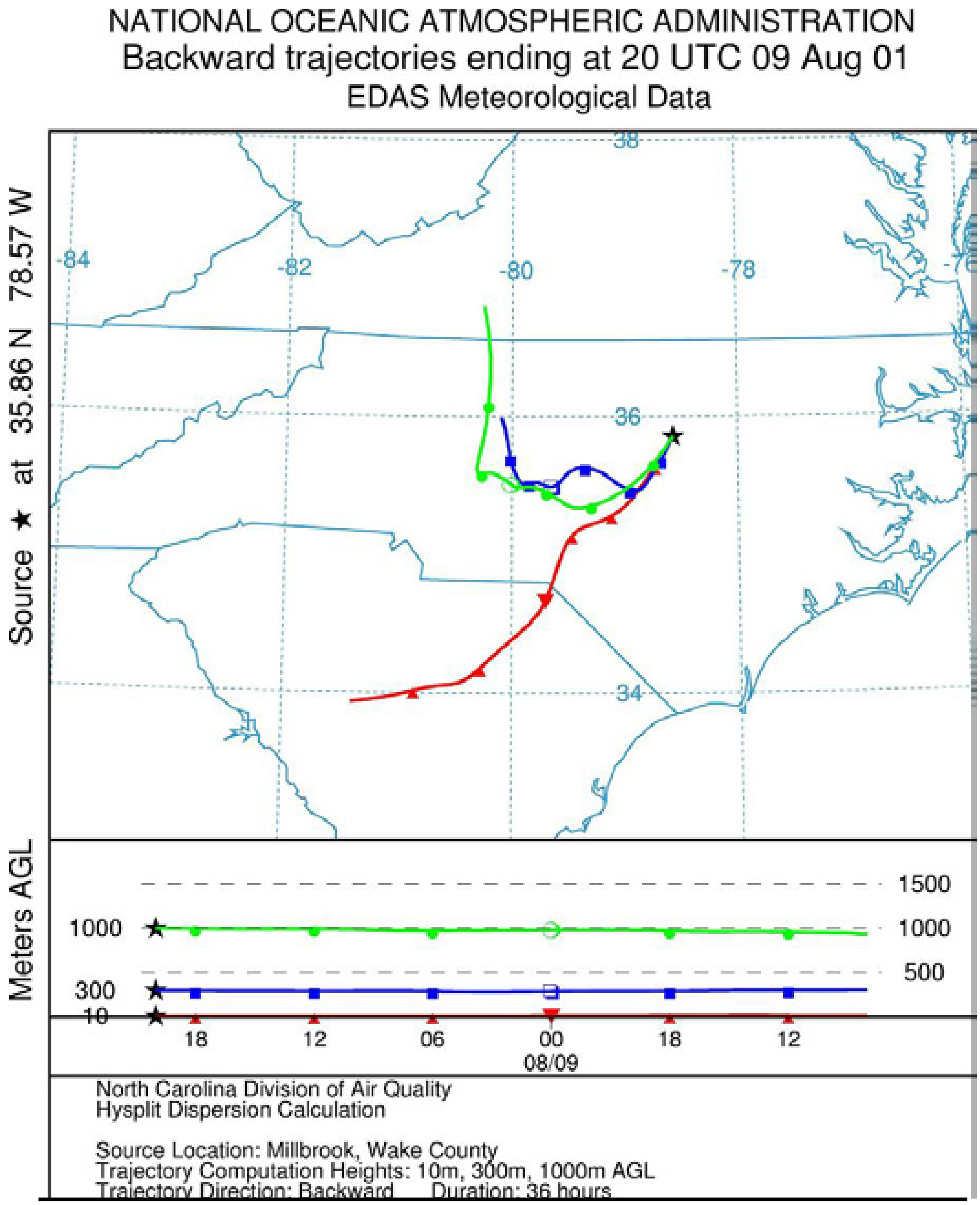
highest concentrations of ozone are observed, although the actual peak can vary by several hours.

Figure B1: Back Trajectory for June 1, 2000



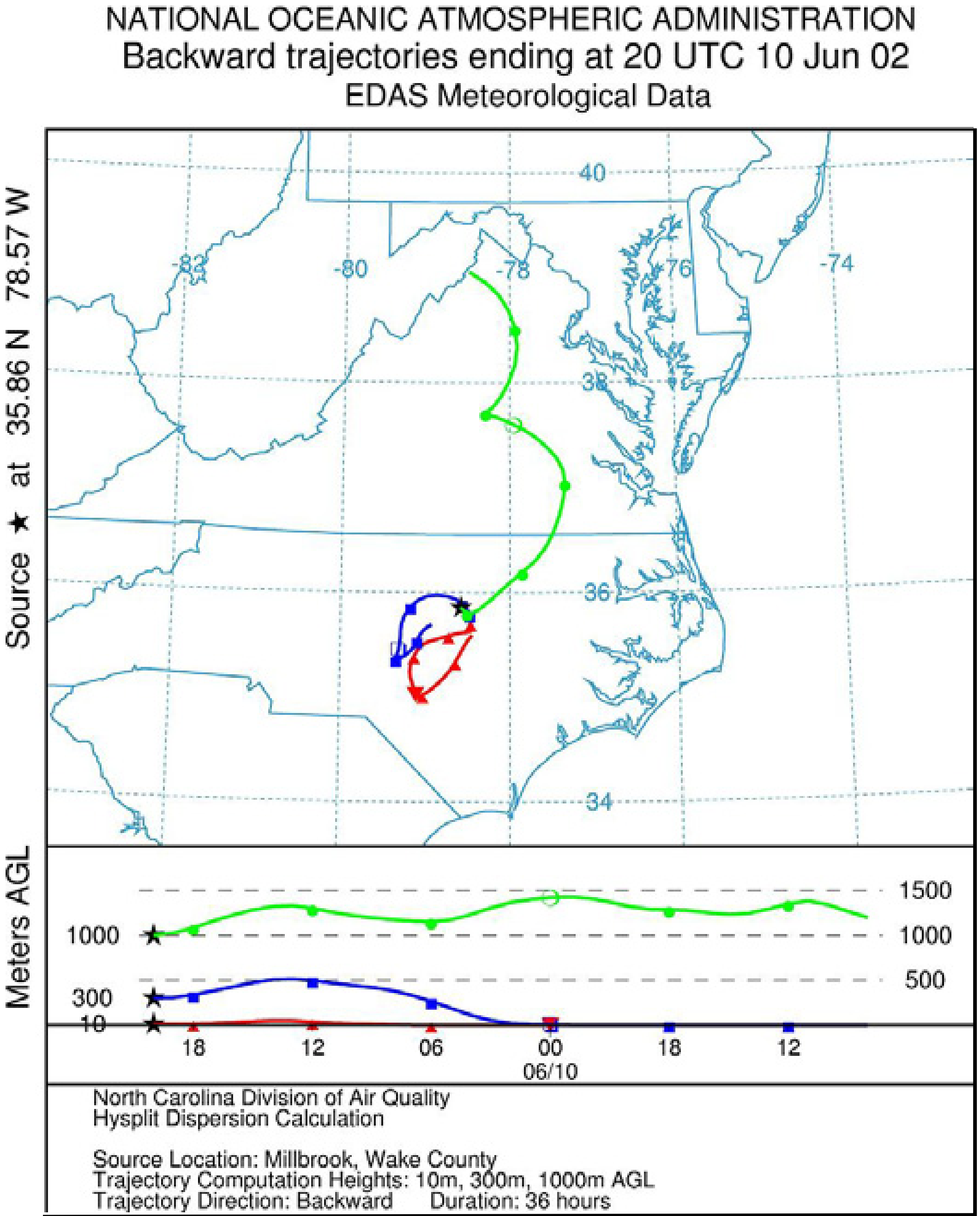
June 1, 2000. Code Red Ozone Action Day in the Triangle. Back trajectories indicate stagnant air during the afternoon of the 1st, indicated by the short segment near the star. Also, contribution from Charlotte region and states to the north and west is possible.

Figure B2: Back Trajectory for August 9, 2001



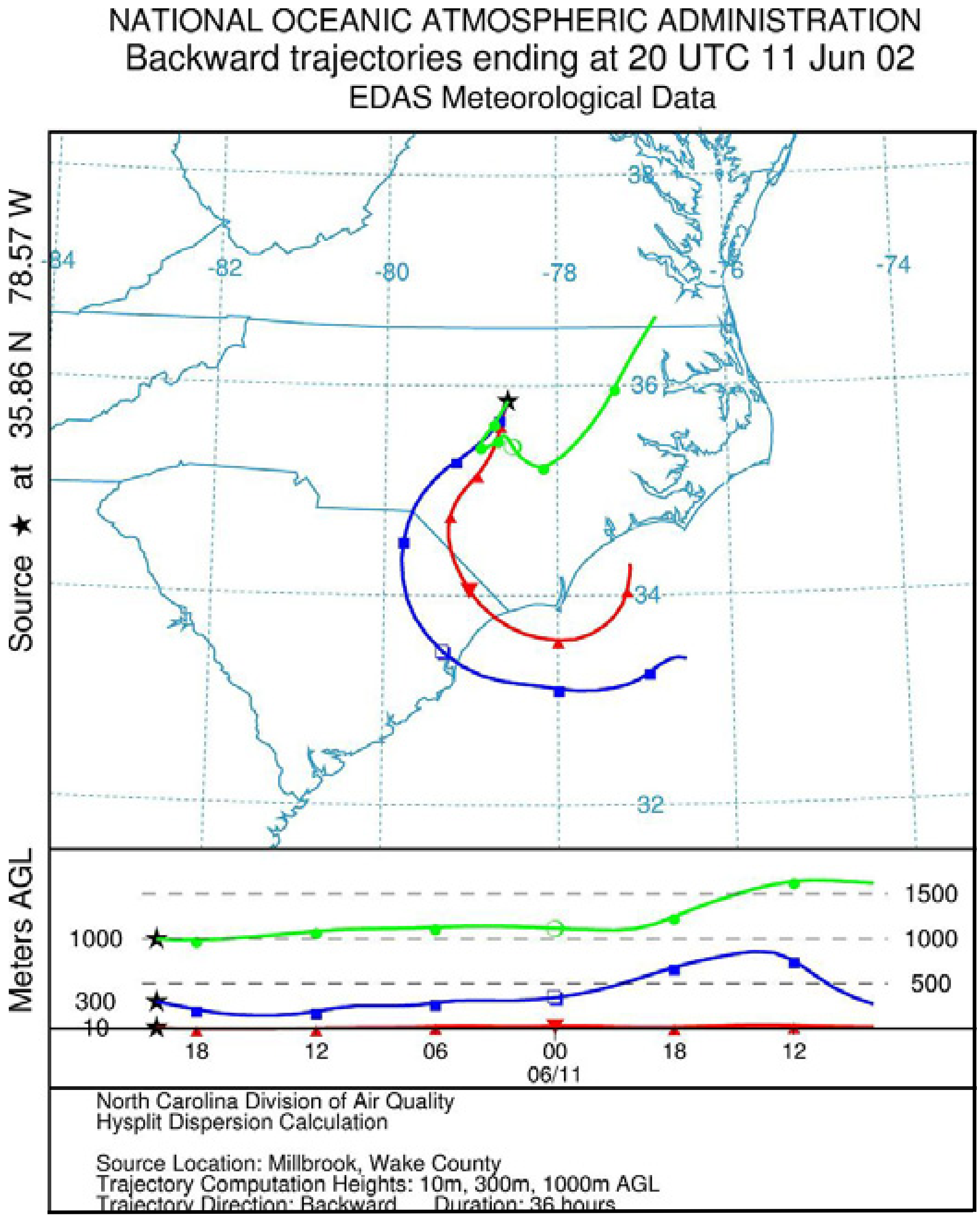
August 9th, 2001. Code Red Ozone Action Day in the Triangle. Back trajectories show stagnant air over The Triangle again, indicated by the short segments near the star. Also, very little very motion in the atmosphere is present, indicated by the flat lines at 1000m, 300m, and 10m below the map.

Figure B3: Back Trajectory for June 10, 2002



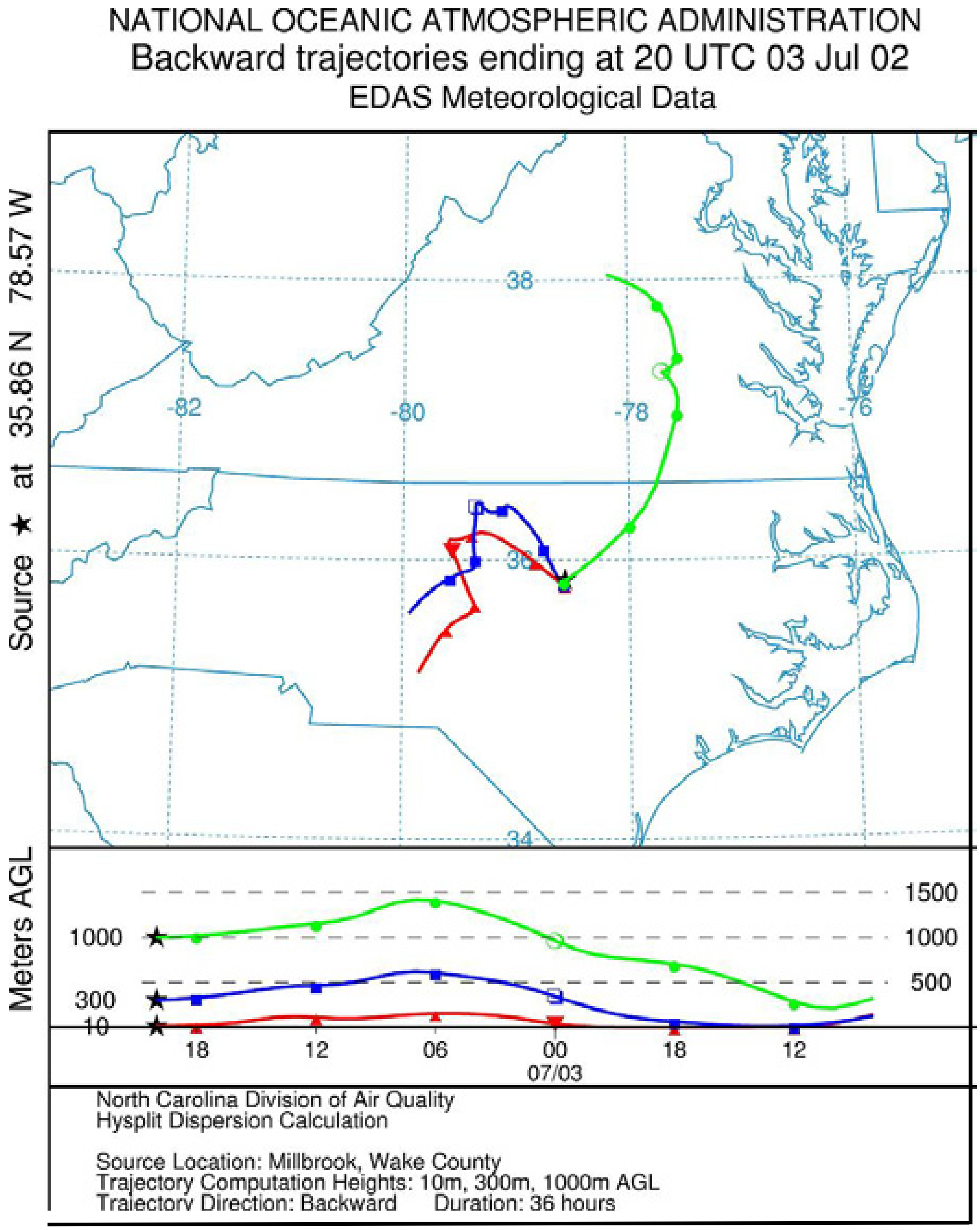
June 10th, 2002. Code Red Ozone Action Day in the Triangle. This is a perfect example of a recirculation pattern, indicated by the short, spiraling trajectories over The Triangle. In this case, pollution created in The Triangle would affect the same area for several days in a row. The 1000m trajectory indicates a possible contribution of emissions transported from the north.

Figure B4: Back Trajectory for June 11, 2002



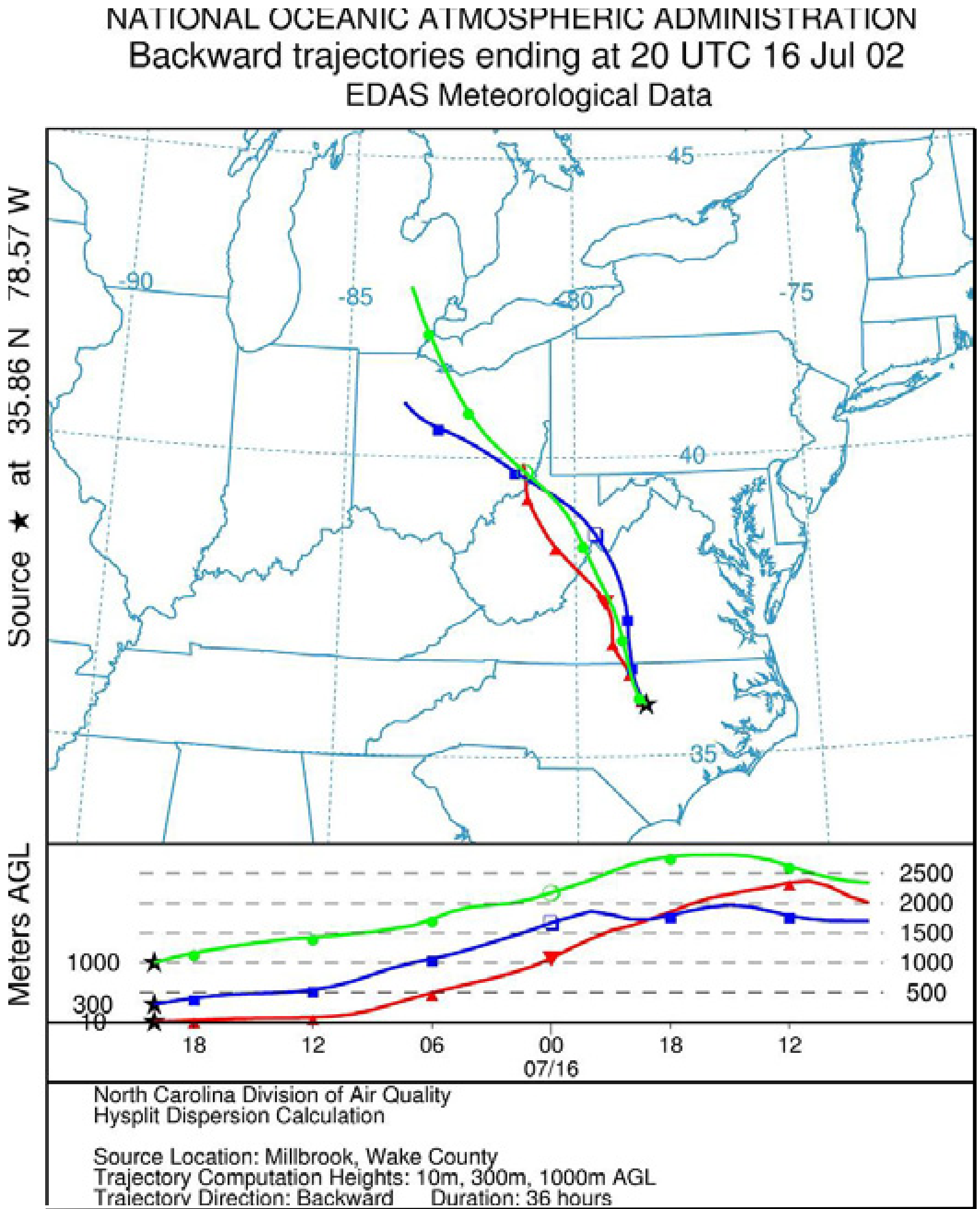
June 11th, 2002. Code Red Ozone Action Day in the Triangle. Again, relatively short trajectories occur on the day of the exceedence. The trajectory pattern is indicative of dominant high pressure and stagnation.

Figure B5: Back Trajectory for July 3, 2002



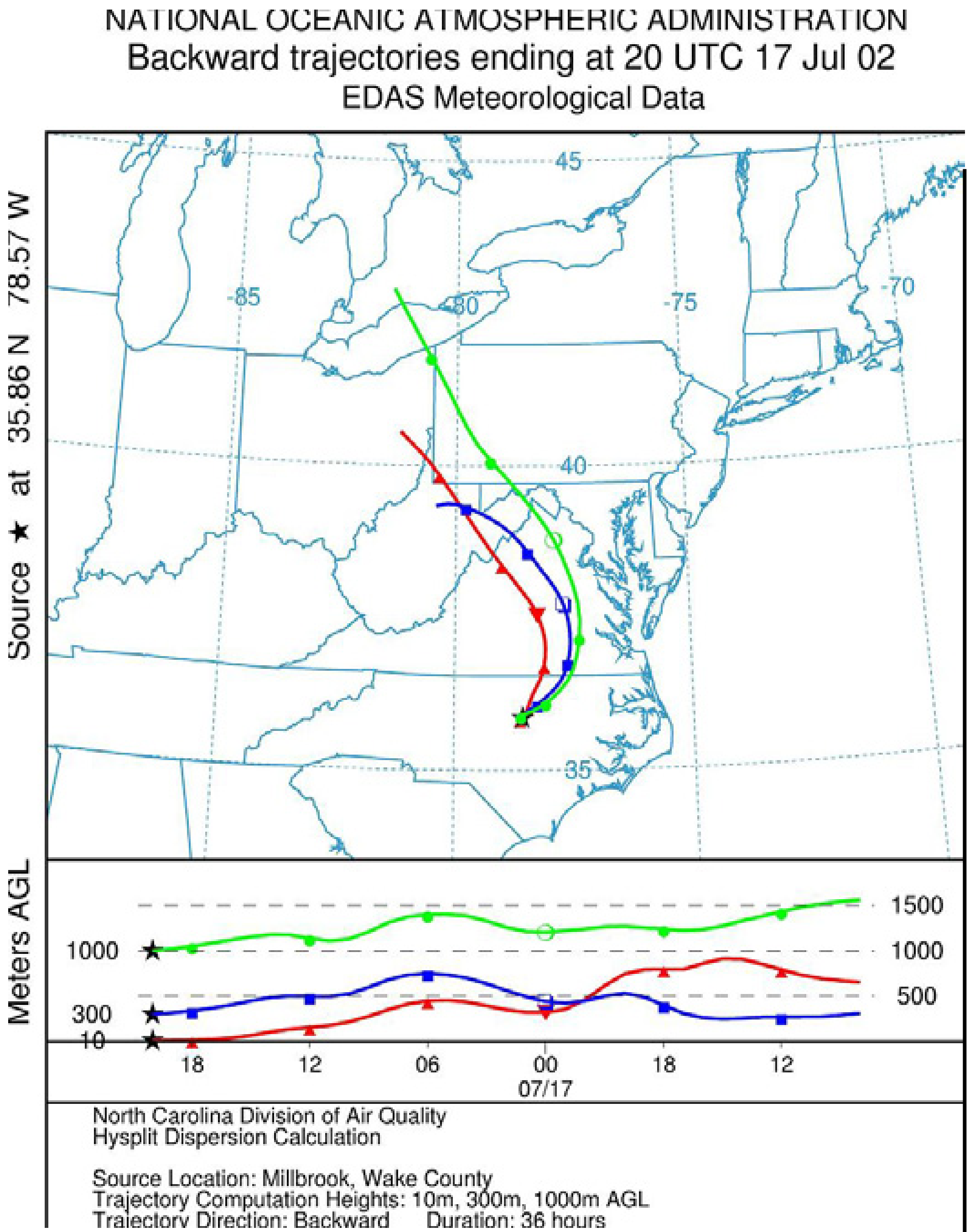
July 3rd, 2002. Code Red Ozone Action Day in the Triangle. Short trajectories are indicative of stagnation and recirculation, as well as very little very mixing. Pollution sources on this day would be The Triangle and possibly some contribution form the Triad.

Figure B6: Back Trajectory for July 16, 2002



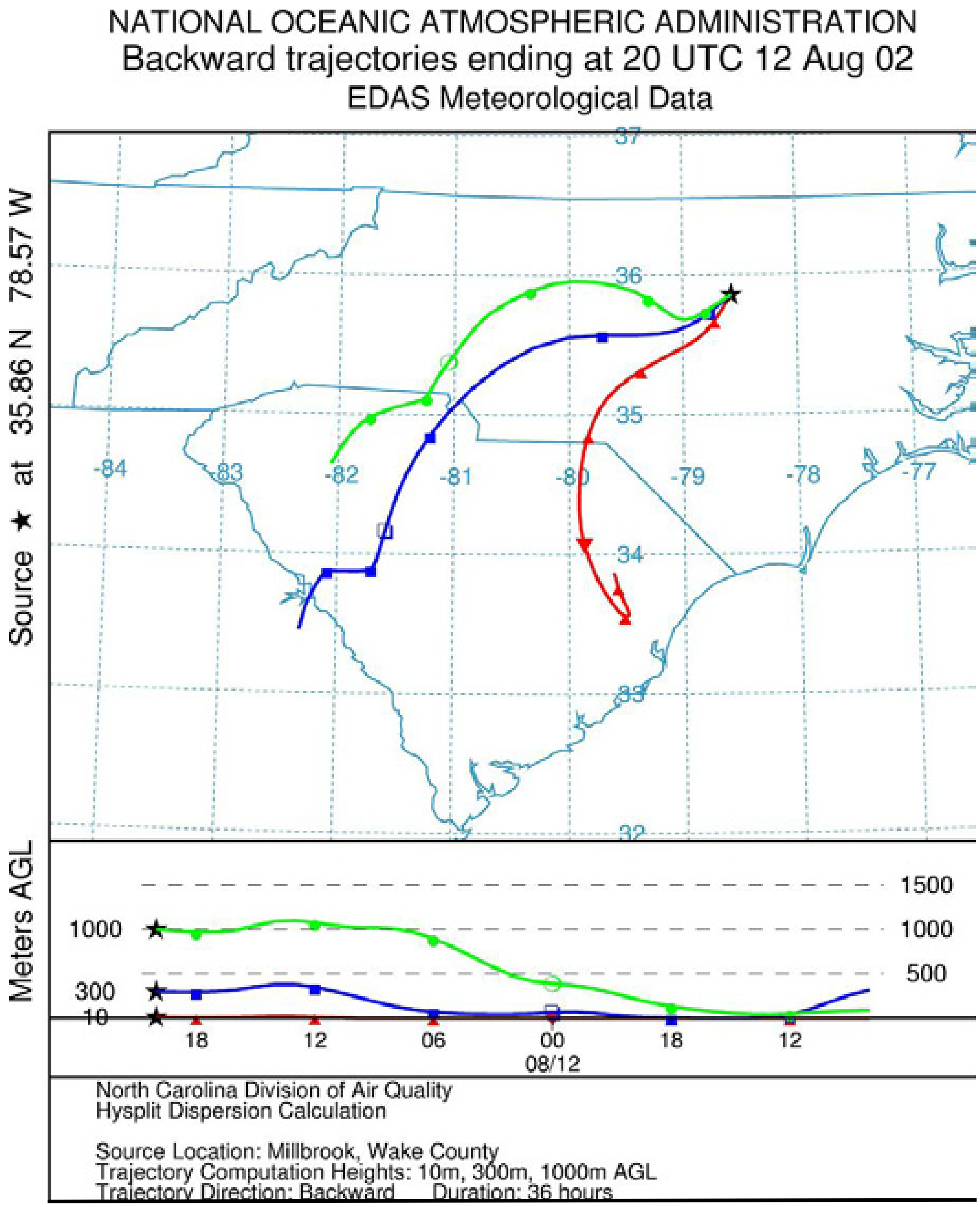
July 16th, 2002. Code Red Ozone Action Day in the Triangle. Unlike the previous days, the trajectories for this day indicate transport to be the dominant issue resulting in the Code Red Ozone Action Day. In particular, the Ohio Valley could be implicated as the source of pollution and/or precursors, since all the trajectories originate in the Ohio Valley region. Note that there is significant power generation in the Ohio Valley.

Figure B7: Back Trajectory for July 17, 2002



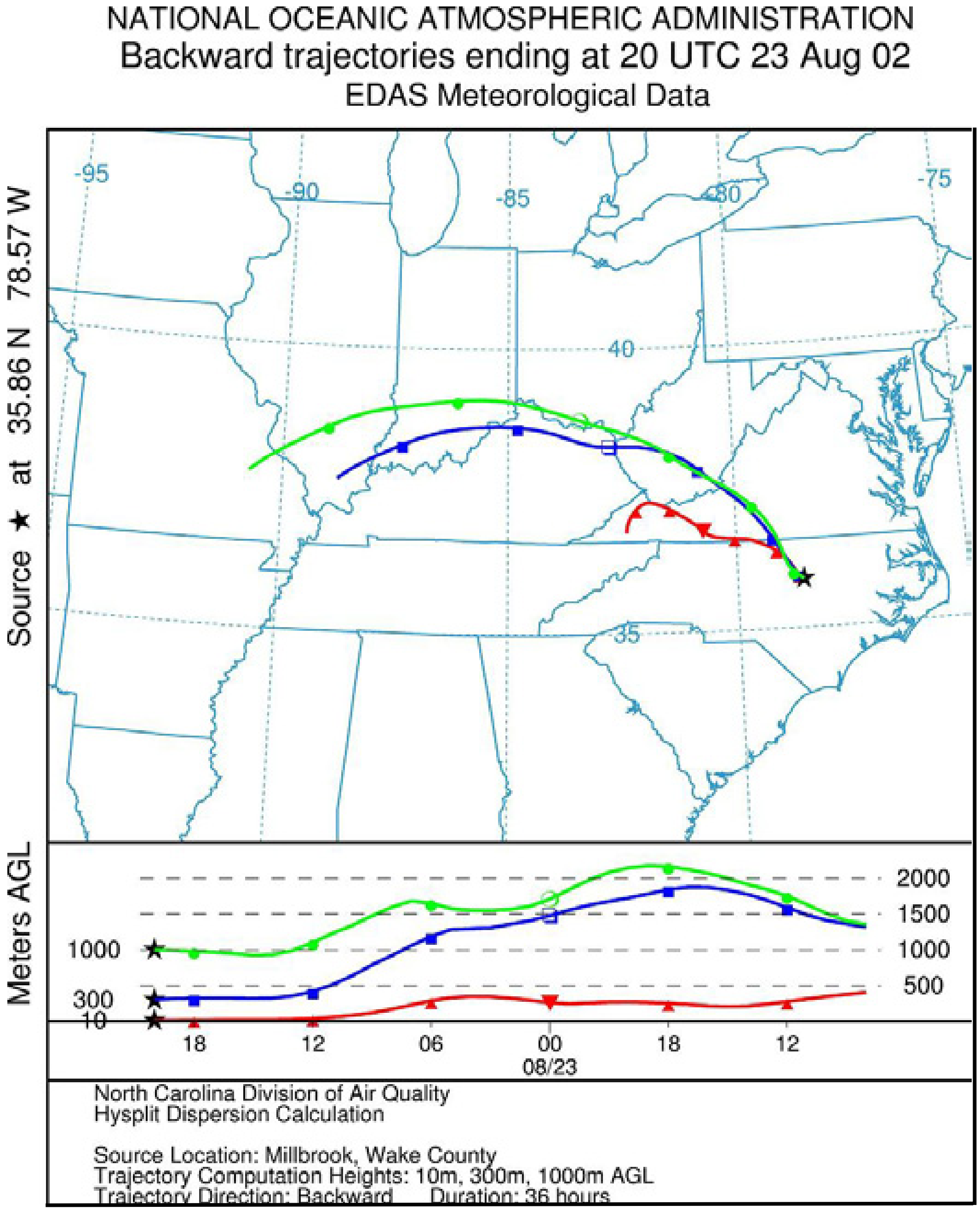
July 17th, 2002. Code Red Ozone Action Day in the Triangle. Trajectories are similar to the previous day, with the trajectories originating in the Ohio Valley. The curvature of the trajectories also suggests high pressure dominating the area. In this case, the trajectory segments become very short near The Triangle, which would indicate stagnation. Therefore, the Code Red ozone levels on this day most likely resulted from a combination of transport and stagnation.

Figure B8: Back Trajectory for August 12, 2002



August 12th, 2002. Code Red Ozone Action Day in the Triangle. Trajectories are relatively short, so local pollution from the Triangle is a possible cause of the exceedence. Since a couple of the trajectories point back to Charlotte, transport from the Charlotte region is a possible contributor as well.

Figure B9: Back Trajectory for August 23, 2002



August 23rd, 2002. Code Red Ozone Action Day in The Triangle. These trajectories indicate a stagnation issue near the ground, indicated by the short 10-meter (red) trajectory, and a potential contribution from transport, indicated by the 300 and 1000-meter trajectories.

Appendix C: NOx Footprint Modeling

NOx footprint modeling is designed to simulate physical and chemical processes as they happen in the atmosphere. These include (but are not limited to) pollutant movement and dispersion. The simple example below illustrates transport and dispersion processes. The purpose of the example is to simply assess where pollutants would travel in the absence of chemical transformation and removal processes. NOx emitted from the portion of the Triangle area shaded in red in Figure C1 is moved and dispersed by simulated meteorology for a period of 11 days. The meteorology experienced in most of that 11-day period is representative of the meteorology during high ozone events. The resulting maximum pollutant (NOx) field is shown in Figure C2. A study of this figure reveals that the pollutants originating from the Triangle can be transported into other portions of NC and even into other states. But the magnitude of the pollutant concentrations decreases significantly as the pollutant gets further from the source due to dispersion processes.

Figure C1: NOx originating in the Triangle: NOx footprint simulation

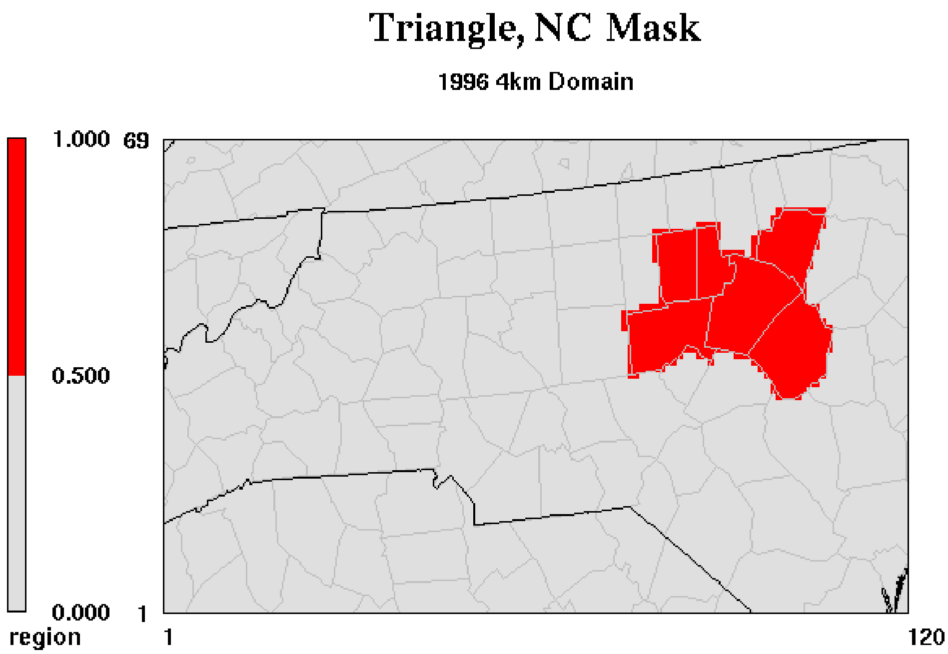
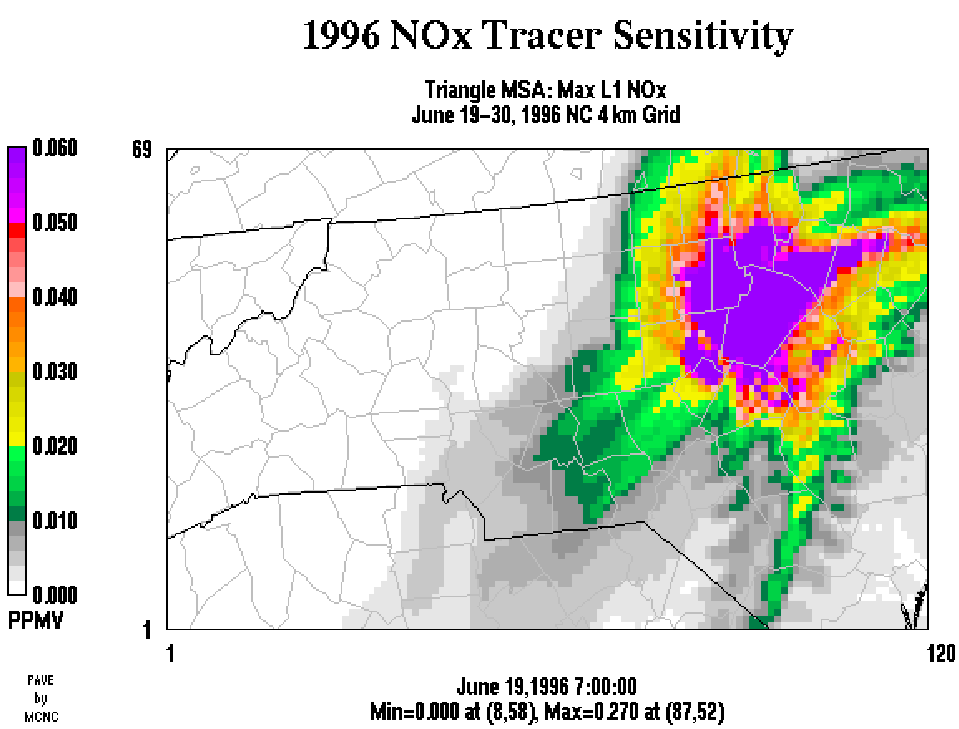


Figure C2: NOx concentrations after transport from the Triangle area: NOx footprint simulation



Similar examples are provided for the Triad area and the Charlotte area in Figures C3 through C6 below. Again, while emissions from the Triad and Charlotte areas can reach the Triangle area, the magnitude or concentrations are significantly lower due to dispersion processes.

Figure C3: NOx originating in the Triad: NOx footprint simulation

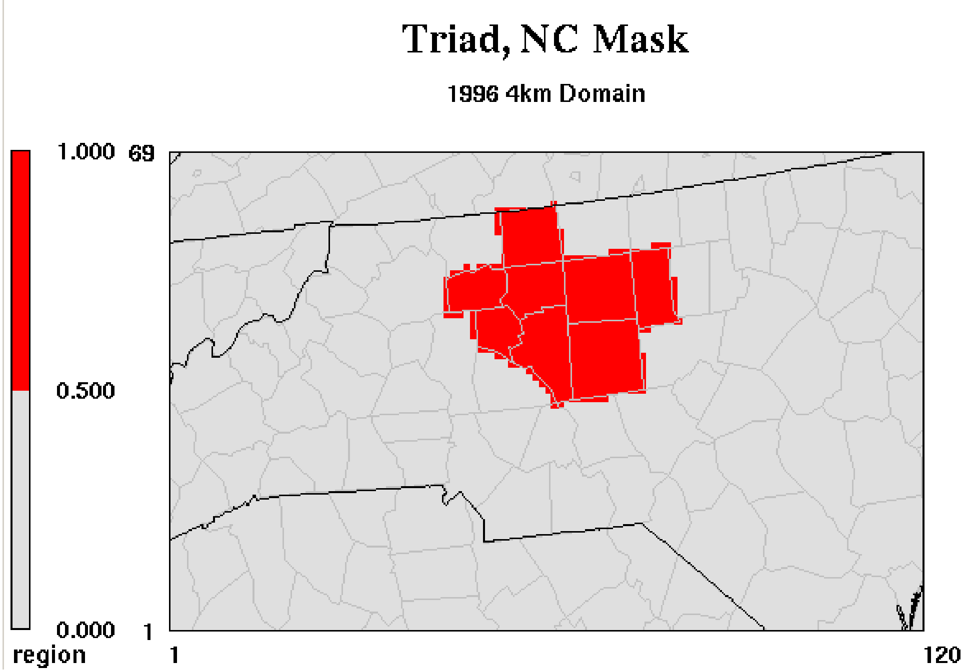


Figure C4: NOx concentrations after transport from the Triad: NOx footprint simulation

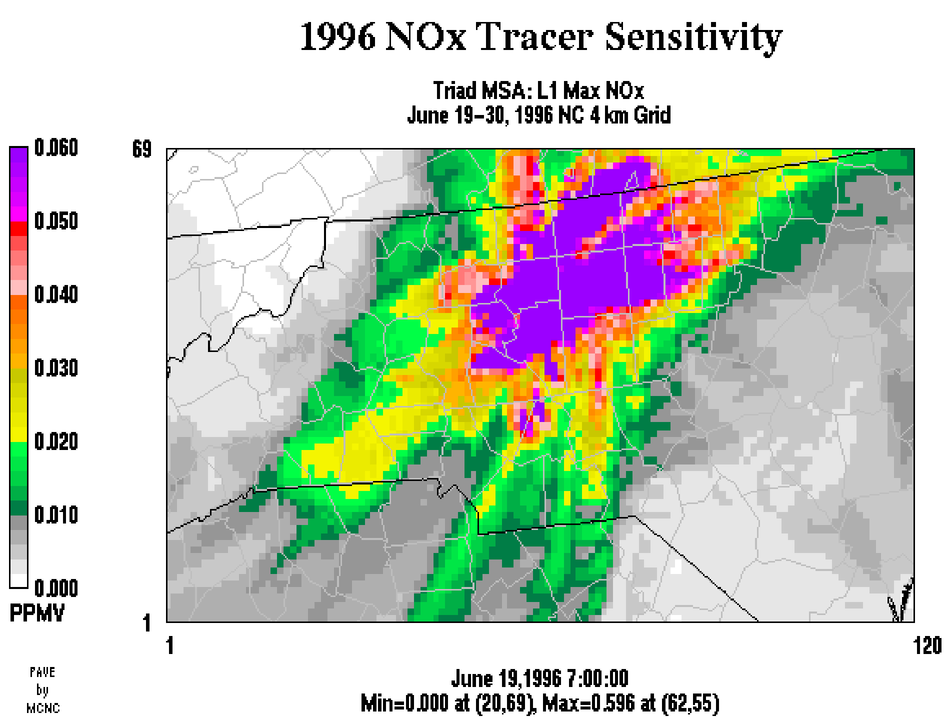


Figure C5: NOx originating in the Charlotte area: NOx footprint simulation

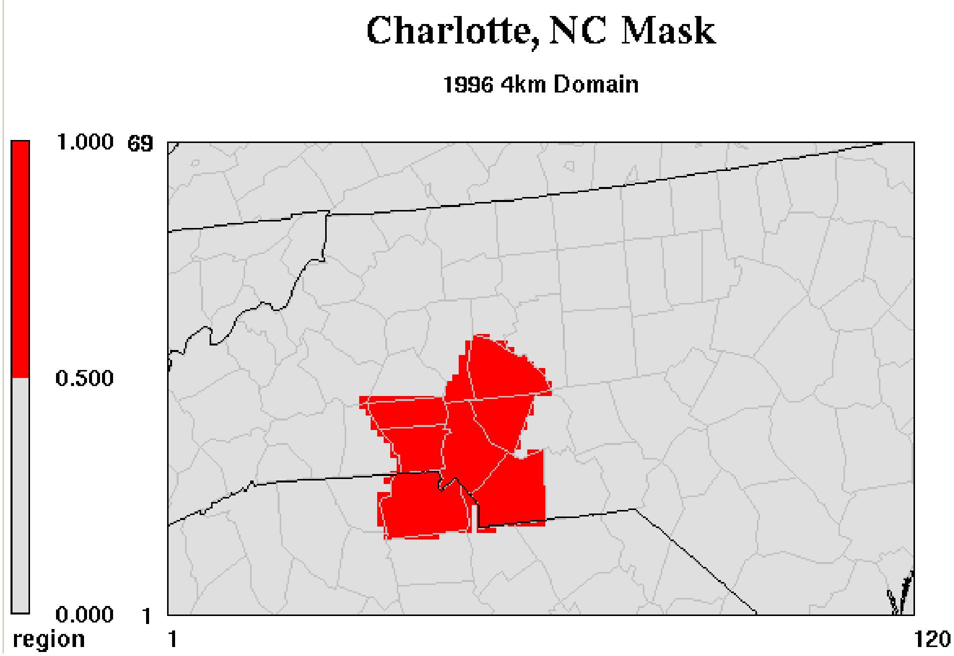
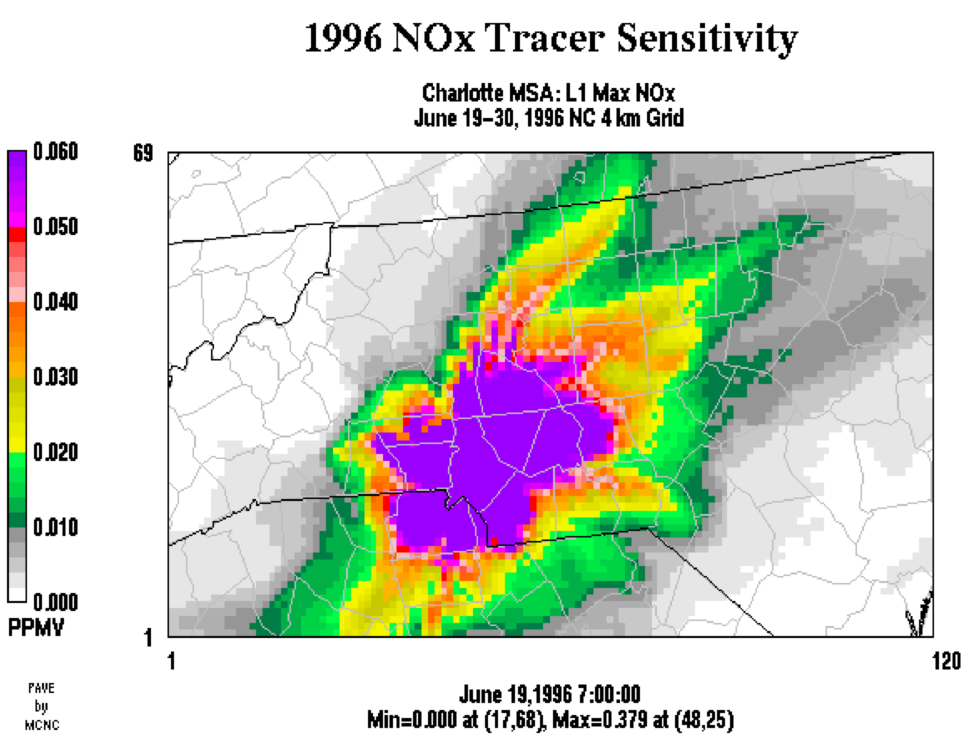


Figure C6: NOx concentrations after transport from the Charlotte area: NOx footprint simulation



Appendix D: Issues associated with reducing emissions from diesel construction vehicles

Diesel construction vehicles contribute about one-half of all nonroad NOx emissions in the greater Triangle area. As discussed in section 7.2.3 of this report, diesel construction vehicles contributed 52% of Triangle area nonroad emissions in 2000, and are expected to contribute 49% of Triangle area nonroad emissions in 2007.

The percentage contribution of diesel construction vehicles to the total inventory of NOx from all Triangle sources is projected to double from 5% in 2000 to 10% in 2007, due to large reductions from point and mobile (on-road) source sectors, but only small reductions from diesel construction vehicles.

Nonroad, mobile, and point sources are the largest NOx source sectors. Between 2000 and 2007, NCDAQ projects a 82% decrease in Triangle area point source emissions from 235 tons per day (TPD) to 43 TPD. Mobile sources are expected to decrease by 35%, from 182 TPD to 119 TPD. However, nonroad NOx emissions are projected to decrease by only 8%, from 49 TPD to 45 TPD. Emissions from diesel construction vehicles, the largest contributors to nonroad NOx, are projected to decrease by about 12%, from 25 TPD to 22 TPD.

NOx emissions from nonroad diesel engines are regulated by federal standards, as described in section 6.2.5 of this report. Tier 1 standards were implemented between 1996 and 2000, and stricter Tier 2 and 3 standards are phasing in between 2001 and 2008. However, these standards apply only to new engines. Heavy-duty diesel engines are extremely durable, sometimes lasting 20 years or more. Emissions from older uncontrolled or minimally controlled engines may contribute to nonroad NOx emissions for many years. Strategies which accelerate construction fleet turnover to newer, lower-emitting engines would help to speed improvement in the Triangle's air quality.

On December 9 and 10, 2003, the Greater Triangle Regional Council hosted a series of diesel emissions workshops for the Triangle community. Tim Totten of the Emission Retrofit Solutions Group of Caterpillar Inc. presented information at these workshops about issues involved with reducing emissions from diesel construction vehicles. The following information is drawn from the workshop presentation.

<u>NOx Emissions</u>

The only currently available, proven way to reduce NOx emissions from a non-stationary nonroad diesel vehicle is repowering. There are no aftertreatment options to reduce NOx emissions in non-stationary nonroad diesel vehicles. Repowering involves taking the old engine out of the vehicle and replacing with a newer, lower-emitting engine. The replacement engine can be a new or remanufactured. Repowering is not the same as retrofitting, in which engine components are replaced or added.

The cost of repowering an engine is $40,000 to $150,000, depending on the size and type of engine, as well as the level of emissions reduction. Replacing an unregulated engine (pre-1996) with a Tier 2 engine may be more expensive than replacing the same unregulated engine with a Tier 1 engine.

Emissions from stationary nonroad diesel engines can be reduced through selective catalyst reduction (SCR). The cost of applying SCR ranges from $100,000 to $150,000.

<u>PM Reduction</u>

Particulate matter (PM) emissions from nonroad diesel engines can be reduced through repowering, or through the application of oxidation catalysts or diesel particulate filters (DPF) to existing engines. Retrofitting an engine with oxidation catalysts or DPF is less expensive than repowering the vehicle with a new engine. The cost of an oxidation catalyst is between $800 and $4,500, depending on the vehicle. Oxidation catalysts can reduce PM by 20% to 25% and hydrocarbons (HC) and carbon monoxide (CO) by over 90%. Ultra low-sulfur diesel (ULSD) fuel is not required for the operation of oxidation catalysts, but emissions reductions are greater with ULSD.

DPFs cost between $5,000 and $10,000, depending on the vehicle. ULSD fuel is required for DPF operation, and the filters must be cleaned at regular intervals. DPFs also reduce HC and CO emissions

<u>Fuels</u>

Ultra Low-Sulfur Diesel Fuel: Ultra low-sulfur diesel (ULSD) fuel contains 15 parts per million (ppm) or less of sulfur. Current nonroad diesel fuel averages 3,400 ppm sulfur. ULSD fuel will be required in 2007 for on-road diesel. EPA's proposed Tier 4 nonroad rules limit nonroad diesel sulfur content to 500 ppm in 2007, and require ULSD with 15 ppm sulfur or less in 2010.

ULSD fuel is necessary for the operation of diesel particulate filters, and increases the effectiveness of oxidation catalysts. Future aftertreatment technologies may also require the use of ULSD. ULSD fuel has a lower lubricity than higher-sulfur diesel, and also contains somewhat less energy, so that more fuel may be needed.

Biodiesel: Biodiesel fuel is produced from vegetable oils, commonly soybean oil. Biodiesel is usually blended with petroleum diesel for use in engines. The designation B20 refers to fuel that is 20% biodiesel and 80% petroleum diesel. Biodiesel has excellent lubricity characteristics. The use of biodiesel can significantly reduce PM emissions. However, biodiesel can slightly increase NOx emissions; a rule of thumb is that NOx emissions increase 1% for every 10% of biodiesel in the fuel blend.

Caterpillar has not tested the performance of biodiesel fuel blends in aftertreatment technologies.

PuriNOx: PuriNOx is a water-emulsified fuel containing 20% water. Caterpillar has approved the use of PuriNOx for old "pump and line" systems. The use of

PuriNOx can achieve a 7% to 17% reduction in NOx and a 40% reduction in PM. However, the water blend reduces the energy content of the fuel, so that more fuel is needed.

Ethanol: Caterpillar does not recommend the use of ethanol-based fuels in diesel engines due to the lower flash point and unstable nature of ethanol fuels.

<u>Incentive programs in other states to accelerate nonroad construction fleet turnover</u>

Texas Emissions Reduction Plan (TERP): This program operates in nonattainment areas and other “affected” counties and provides grants for the purchase, lease, replacement, repower, or retrofit of a variety of engine types, including nonroad equipment. The program is funded through fees and surcharges established by the Texas Legislature. To be eligible, projects must meet a cost-effectiveness standard not exceeding $13,000 per ton of NOx reduced. More information on the TERP program may be found at http://www.tnrcc.state.tx.us/oprd/sips/terp.html.

California’s Carl Moyer Memorial Air Quality Standards Attainment Program: The Carl Moyer program provides grants to fund the incremental cost of cleaner-than-required engines and equipment. The cost-effectiveness criteria for nonroad engine projects is $13,600 or less per ton of NOx reduced. More information on the Carl Moyer program may be found at http://www.arb.ca.gov/msprog/moyer/moyer.htm.