Atmospheric Resources

For many years, Americans have been concerned about air pollution because of its effects on human health and the natural environment. Air pollution is a by-product in the combustion of fossil fuels for energy. People need the energy for transportation, industry, and comfortable homes and businesses. Air pollution is not confined to city boundaries but can be transported hundreds of miles from sources to impact resources in the Southern Appalachians.

A team of specialists was assembled to gather information currently known about the effects of air pollution to forest and aquatic resources in the Southern Appalachians. Public concerns in recent years led to extensive research on the impacts of acidic deposition (acid rain) and impacts of ground-level ozone on forests. Previously reported pollution trends and studies on air pollution effects on visibility, aquatic resources, and terrestrial resources were important sources of information for the team. Air quality monitoring data were also used either as the measured values, or as input into mathematical models to predict pollution concentrations across the landscape.

Air pollution is not confined to city boundaries but can be transported hundreds of miles from sources to impact resources in the Southern Appalachians.

With the assistance of the public, five questions were formulated to guide the air quality assessment:

- What are the major air pollutants that could impact the Southern Appalachians, and what areas receive the greatest exposure?
- What is the current concentration of particulate matter in the air of the Southern Appalachians?
- How good is visibility in the Southern Appalachians, and how does air pollution affect visibility?
- To what extent are aquatic resources in the SAA area being affected by acid deposition?
- What impact does ground-level ozone have on forests in the SAA region?

Not all of the questions could be answered with complete certainty from available information. In its work, therefore, the team identified new information that would have been helpful in answering the questions. Filling these information gaps will be useful if another assessment is conducted in the future.

Major Air Pollutants Become Secondary Pollutants

Many pollutants are released into the atmosphere from both natural sources and human activities. The chemicals that are released are called "primary pollutants." The primary pollutants discussed in the report are the major ones that could impact natural resources of the Southern Appalachians. There are others not reported that affect human health. Many of these primary pollutants impacting natural resources go through chemical reactions in the atmosphere and form "secondary pollutants." The primary pollutants of greatest concern in the Southern Appalachians are sulfur dioxide, nitrogen oxides, volatile organic compounds, and particulate matter. Secondary pollutants formed from these reduce visibility, acidify soils and streams, and injure vegetation.

Visibility has deteriorated considerably since the 1940s with the poorest visibility in the summer, which is the major tourist season. Studies have shown there is a strong correlation between the emission of sulfur dioxide and haziness.

Sulfur Dioxide and Visibility Impairment

Sulfur dioxide is a gas released into the atmosphere during the combustion of fossil fuels that contain sulfur. In the atmosphere, sulfur dioxide is transformed into sulfate particles that reduce visibility and acidify soils and streams in the study area. For visitors and residents, spectacular views are major attractions in the Southern Appalachians, and many people are concerned because they think visibility in the region is declining. Long-term measurements show that they are correct. Visibility has deteriorated considerably since the 1940s with the poorest visibility in the summer, which is the major tourist season (fig. 64). Studies have shown there is a strong correlation between the emission of sulfur dioxide and haziness (fig. 65).

Figure 64
Haze in the James River Face Wilderness, and throughout the Southern Appalachians, is worse in summer (top) than in winter (bottom). Haze reduces the distance a person can see and the clarity of an object being viewed.

Despite this national decrease, the U.S. Environmental Protection Agency (EPA) has reported that sulfur dioxide emissions in EPA Regions 3 and 4, which include the SAA, have increased slightly between 1985 and 1994.

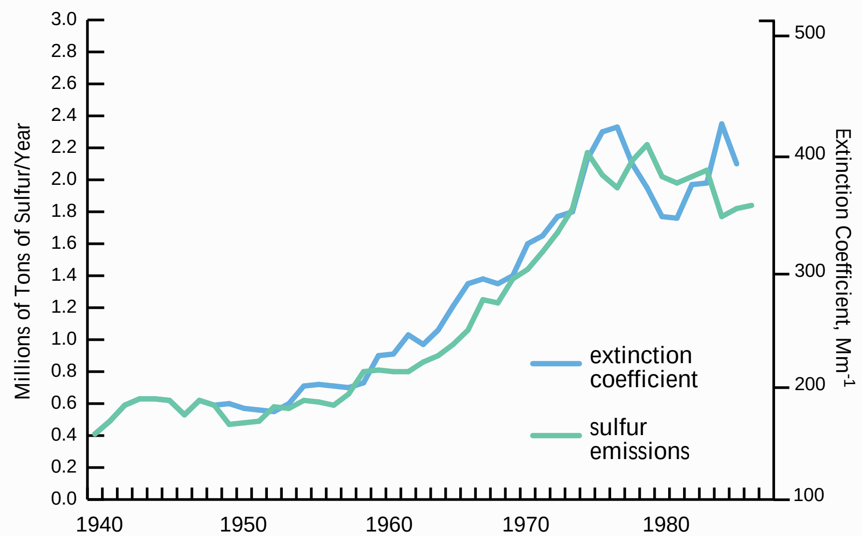

Figure 65 Studies have shown a strong correlation between the emission of sulfur dioxide and haziness. (Source: Trijonis and others 1991)

Nationally, coal-fired electricity generating plants are the major sources of sulfur dioxide emissions (fig. 66). Many of these are located inside the study area in northern Alabama, northern Georgia, and eastern Tennessee. Other large sources near the study area are on the Piedmont Plateau in North Carolina, in the Ohio Valley, and on the Allegheny Plateau in West Virginia and Pennsylvania. In the nation as a whole, sulfur dioxide emissions increased between 1940 and 1970 and since then have steadily decreased to approximately 1940 levels (fig. 67). Despite this national decrease, the U.S. Environmental Protection Agency (EPA) has reported that sulfur dioxide emissions in EPA Regions 3 and 4, which include the SAA, have increased slightly between 1985 and 1994.

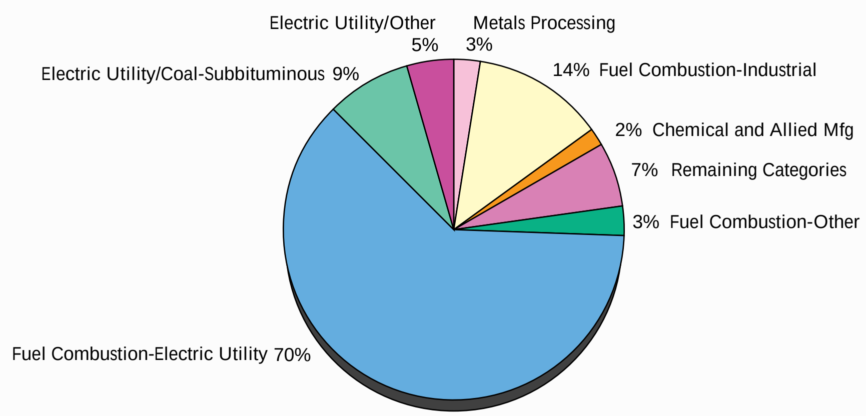

Figure 66 In 1994, electric utilities were the largest emitters of sulfur dioxide in the United States. (Source: EPA 1995a)

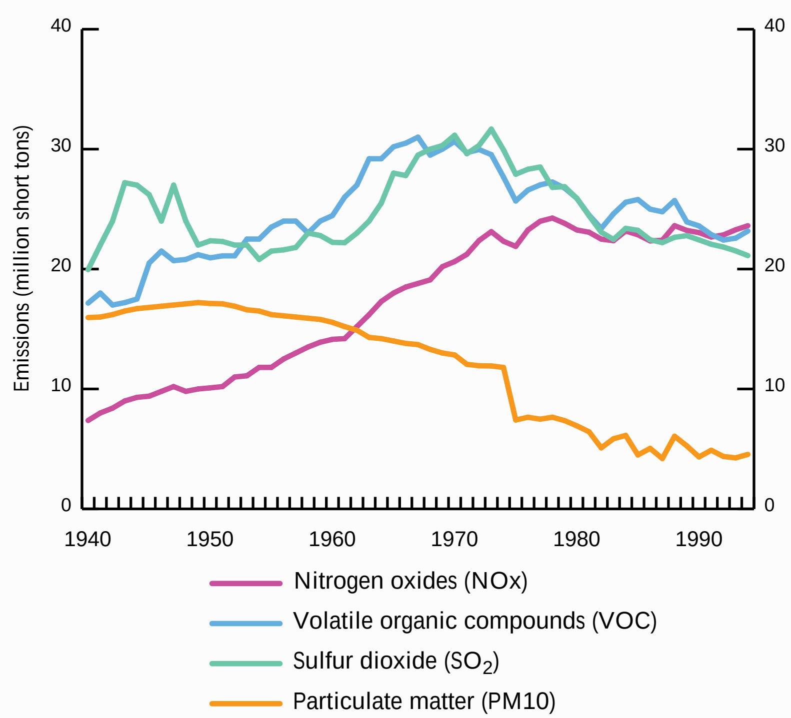

Figure 67 National trends in emissions of nitrogen oxides, volatile organic compounds, sulfur dioxide, and particulate matter. Implementation of the Clean Air Act of 1970 reduced human–caused emissions of sulfur dioxide, volatile organic compounds, and particulate matter. Emissions of nitrogen oxides have remained level or increased slightly since 1970. (Source: EPA 1995a)

Visibility in the Southeast degraded between the 1950s and 1970s, improved between the 1970s and 1980s, and has not improved since the 1980s. Current visibility data show that the standard visual range (approximately 25 miles) is far below the estimated annual average natural background of 93 ± 30 miles.

In the assessment, various measures of visibility were analyzed. Visibility in winter deteriorated slightly between 1960 and 1992. Summertime visibility decreased considerably between 1960 and the early 1970s, improved somewhat by 1980, and remained fairly stable since then. During the summer, increasing use of air conditioning has driven up power consumption. Scientists have suggested that the changes from a winter maximum in haze in the 1960s to a summer maximum in the 1980s can be attributed in part to increased sulfate from increased sulfur dioxide emissions at coal-fired electricity generating plants. Another cause may be more complete conversion of precursors (nitrogen oxides, sulfur dioxides, and organics) to particulate matter during the summer. Other changes in trends and patterns are due to the complex interplay between emissions and meteorology.

Sulfur dioxide emissions are expected to decrease in the Southern Appalachians in the years ahead.

Changes in visibility patterns and trends are caused by changes in the concentration of fine particles in the lower atmosphere, primarily sulfates in the southeastern United States. It has been reported that these changes can be attributed to (1) changes in emissions of sulfates and sulfur dioxide; (2) changes in photochemical smog, which influences the rate of formation of sulfate; or (3) changes in meteorological conditions that influence sulfate formation and aerosol size.

Aerosol samples collected twice a week for several years show that sulfates are the largest contributors to haziness in the region. On an average day, sulfates account for 60 percent of haze. On days with the worst visibility, sulfates account for nearly 80 percent of the fine particulate mass. Analysis of fine particulate data from the Shenandoah and Great Smoky Mountains National Parks shows an annual increase in sulfate of 2 to 3 percent each year between

1982 and 1992. This increasing trend was even more pronounced in the summer, when sulfate concentration increased 4 percent each year. Based on this information, the apparent lack of improvement in visibility conditions since the early 1980s is understandable. What is more elusive is why sulfate would be increasing at such a steady rate when sulfur dioxide emissions are stable or only increasing slightly.

Poor visibility in the summer is also a function of the weather. In that season, stagnant air masses often hang over the Southeast, trapping pollution and allowing concentrations to increase. High concentrations of pollutants, high temperatures, and high humidity interact to increase haziness. In particular, high relative humidity has a significant impact on visibility. At high relative humidity, sulfate aerosols are more likely to grow to the size fraction most likely to cause haziness. The same sulfate particulate mass will have greater impact on visibility at higher humidities.

Sulfur dioxide emissions are expected to decrease in the Southern Appalachians in the years ahead. Nationally, the 1990 Clean Air Act (CAA) Amendments will reduce sulfur dioxide emissions by 10 million tons below the 1980 level, and there will be a cap on emissions from utilities and industrial sources. Reductions in and near the assessment area are uncertain, however, because local emitters could choose to purchase emission credits from other regions of the country.

Once they are fully implemented, the CAA Amendments of 1990 should lead to reduced haziness (improved visibility by 2 to 3 deciviews – roughly 4 miles) in the summertime in the Southern Appalachians (fig. 68). For comparison, an example of current median visibility and what visibility is predicted to be like after implementation of the CAA are shown in figure 68. Will the predicted improvement in visibility as a result of CAA regulations be noticeable to the public and will the public be satisfied? If the public is not satisfied with these improvements, further analysis will be needed to determine the technical feasibility and economic reality of further improvements. Continued monitoring of visibility and public reactions to what is observed will provide answers to these questions.

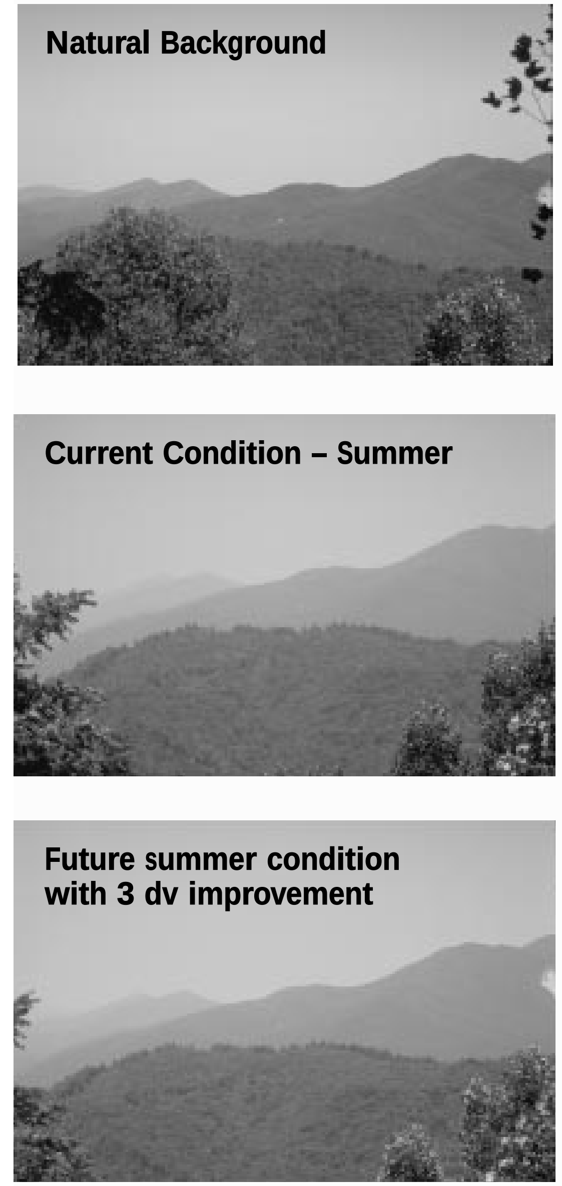

Figure 68
These photographs depict what a 3-deciview decrease in haziness (visibility improvement) would look like compared with the current median summer condition and natural background visibility. The view is James River Face Wilderness in Virginia.

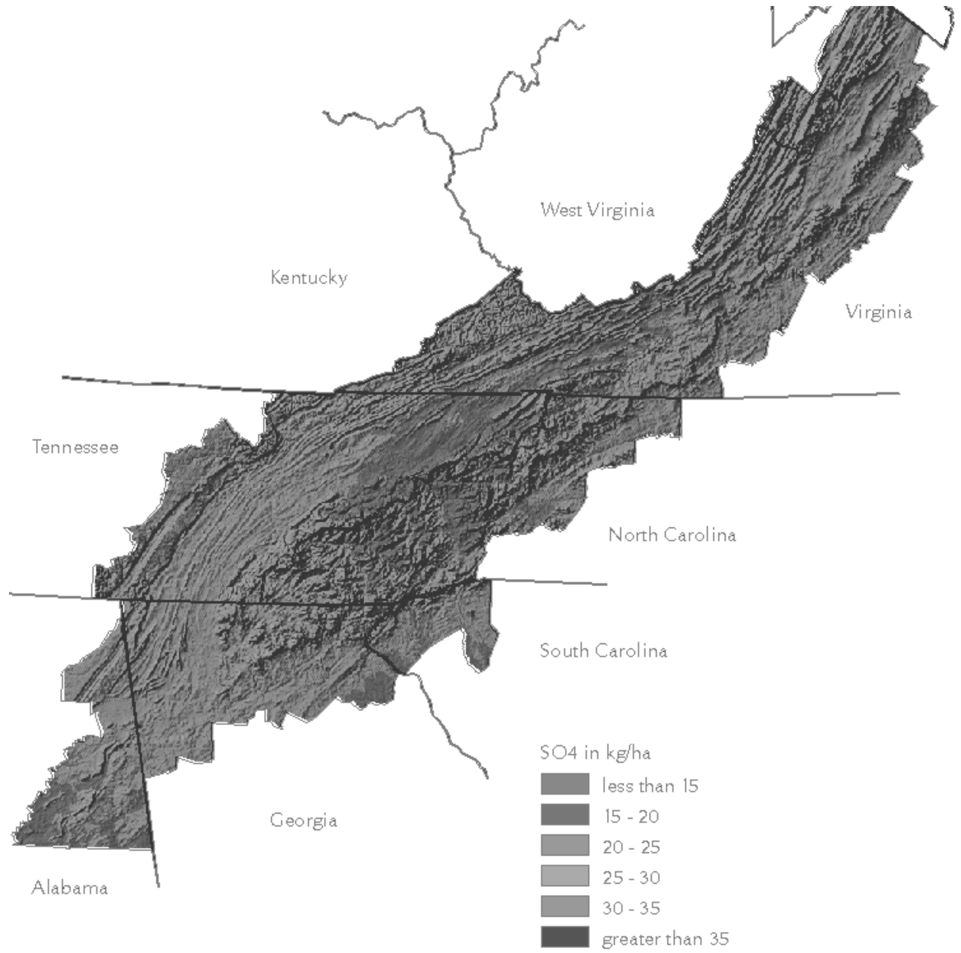

Figure 69
Modeled distribution of wet sulfate deposition in the Southern Appalachians, 1983-1990. Deposition of sulfate in rainfall is greatest at high elevations and in the northern part of the Southern Appalachians.

Acid Deposition and Aquatic Effects

In addition to improving visibility, reductions in sulfur dioxide emissions are predicted to reduce the amount of acid deposition in the Southern Appalachians. Acid rain became a prominent news story in the 1980s. Forests at high elevations in the Southern Appalachians were among those thought to be at risk, and considerable research was done there in the National Acid Precipitation Assessment Program. That program's National Stream Survey was a primary source of information about effects of acid deposition on aquatic systems. Another was the National Atmospheric Deposition Program's National Trends Network. Six of its deposition measuring sites are in the assessment area.

The primary acidifying chemicals in rainfall are sulfates and nitrates. Technical problems make measurement of cloudwater and dry deposition difficult. As a result, estimates of the amounts of acid-forming chemicals entering high-elevation ecosystems that receive significant cloudwater deposition are consistently low.

Sulfate deposition is highest at the highest elevations and in the northern portion of the Southern Appalachians (fig. 69). Unfortunately, portions of streams at high elevations are probably least able to neutralize or "buffer" incoming acidity. Sulfate concentrations in precipitation seem to be decreasing in the Southern

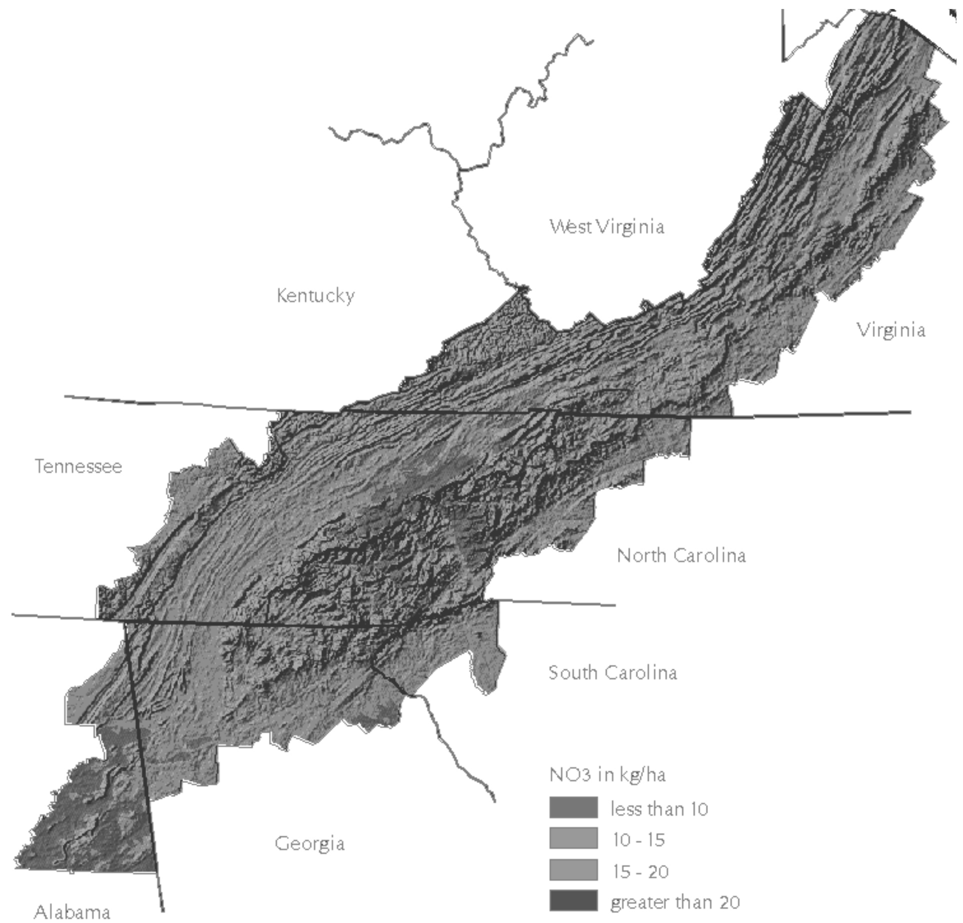

Figure 70
Modeled distribution of wet nitrate deposition in the Southern Appalachians, 1983-1990. As with sulfate, deposition in rainfall is greatest at high elevations and in the northern part of the Southern Appalachians.

Appalachians, but so are the concentrations of buffering chemicals that can offset the acid effects of sulfates and nitrates. Consequently, acidity of rainfall has not improved.

Fixed nitrogen is an important nutrient for plant growth, but as forests mature, a balance is reached between plant use and recycling back into the system by decaying plant materials. Insect defoliation causes rapid recycling of nitrogen, so gypsy moth defoliation could add to the problem as this insect moves southward through the study area. Nitrate loadings (concentrations of chemicals) from rainfall are highest in the northern portion of the SAA and at some high elevation sites (fig. 70). Nitrogen saturation is expected to play an increasing role in stream acidification in the future. The current extent of nitrogen saturation is not known, but it does appear to be occurring at one high elevation site, the Great Smoky Mountains National Park.

Sulfate concentrations in precipitation seem to be decreasing in the Southern Appalachians, but so are the concentrations of buffering chemicals that can offset the acid effects of sulfates and nitrates.

Nitrogen saturation is expected to play an increasing role in stream acidification in the future.

Occasional or chronic acidification of streams by sulfates and nitrates can lead to elevated levels of dissolved aluminum, which can reduce survival and diversity of macroinvertebrate and fish populations in sensitive streams. The Southern Appalachians is a popular region for fishing, and acid deposition may continue to reduce the number of streams suitable for sensitive fish species in some locations of the SAA region.

Decreases in acid deposition are expected as the CAA Amendments of 1990 are fully implemented. The regulations will decrease emissions of both sulfates and nitrates from electricity-generating plants. Vehicle emissions are a second major source of nitrogen compounds. However, the importance of that source is expected to grow as the population of the study area increases. In the northern portion of the assessment area, implementation of the CAA Amendments should maintain the same proportion of chronically acidic streams as in 1985, unless nitrogen saturation occurs. Under current deposition levels, streams in the Southern Blue Ridge are susceptible to acidification. Streams in the northern portion of the Southern Appalachians and upper reaches of the southern portion of the assessment area, particularly in wildernesses, are more sensitive than those surveyed by the National Stream Survey. The Direct Delay Response Program estimated that a 30 to 50 percent reduction in sulfate deposition would prevent further acidification of streams in the Southern Blue Ridge. The 1990 CAA Amendments are predicted to accomplish a reduction of sulfate in that range. However, even with reduced sulfate deposition, streams may continue to acidify in watersheds that are losing the capacity to buffer incoming sulfur.

Ozone and Potential Vegetation Damage

Ozone, a chemical composed of three oxygen atoms linked together, is highly beneficial in the upper atmosphere. At ground level, however, it is a powerful oxidizing agent that is capable of killing tissues. Small amounts of ozone occur naturally, but the large quantities measured at ground level are formed primarily through chemical reactions between nitrogen oxides, volatile organic compounds, and sunlight.

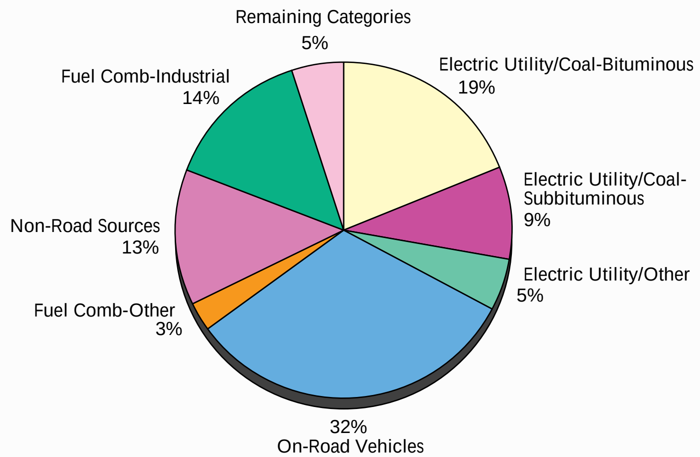

Figure 71 The two largest emission sources of oxides of nitrogen are motor vehicles and electricity-generating plants that burn fossil fuels. (Source: EPA 1995a)

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The two largest emission sources of oxides of nitrogen are motor vehicles and electricity-generating plants that burn fossil fuels (fig. 71). These two sources have approximately equal annual emissions. Various oxides of nitrogen quickly react in the atmosphere to form nitrogen dioxide, which can be seen as a brownish haze when it is sufficiently concentrated. Nationally, emissions of nitrogen oxides in the United States rose between 1940 and 1994. Part of the increase in the Southern Appalachians is attributable to a rise in the number of vehicle miles driven and part to increases in electricity generation. Title IV of the 1990 CAA Amendments requires a reduction in nitrogen oxide emissions from utility boilers by 2 million tons from the 1980 level, but there is no cap on emissions to keep emissions at or below levels in 1980. Emissions of nitrogen oxides in the Southern Appalachians are projected to increase by 2010 as vehicle miles increase and as electrical power demand rises with an increasing population.

The other chemicals for the formation of ground level ozone are volatile organic compounds. Many types of volatile organic compounds are emitted into the atmosphere. In the Southern Appalachians, stationary sources release only a small proportion of

Throughout the SAA area, ozone exposures and soil moisture availability in most years are sufficient to cause growth losses in highly sensitive species, such as black cherry.

the total (fig. 72). Trees are the largest source of volatile organic compounds with vehicle emissions ranking second. Nationally, emission of volatile organic compounds from human activities increased between 1940 and the 1970s, but has decreased since the 1970s. Overall, future emission levels in the Southern Appalachians are projected to increase by 2010 as vehicle miles traveled increase with an increasing population.

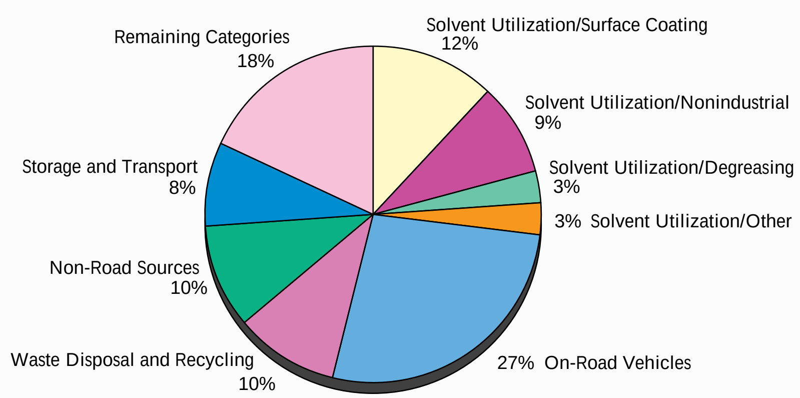

Figure 72 Many types of volatile organic compounds are emitted into the atmosphere. (Source: EPA 1995a)

Ozone is highly damaging to tissues inside of plant leaves, which it enters through small pores called stomates. Symptoms of ozone injury in leaves are well known, and these symptoms have been observed on the leaves of sensitive species throughout the Southern Appalachians. Species and individual plants of a given species vary widely in their sensitivity.

No published reports or data document the amount of growth loss (damage) caused by exposure of trees to ambient ozone in the Southern Appalachians. The Atmospheric Team identified areas where ozone damage has the greatest potential to occur by examining data on ozone exposures and soil moisture. Throughout the SAA area, ozone exposures and soil moisture availability in most years are sufficient to cause growth losses in highly sensitive

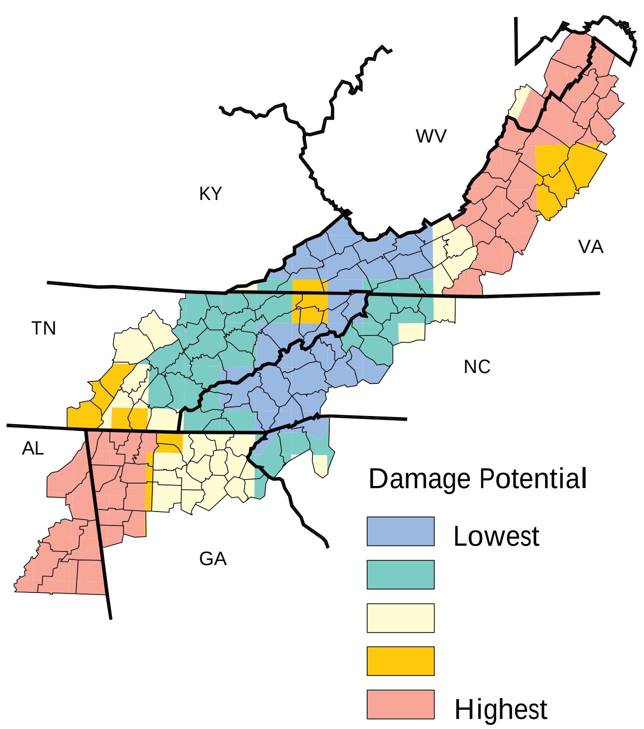

Figure 73
Areas with the greatest frequency of potential ozone damage to vegetation, 1983-1990.

species, such as black cherry. Little to no growth losses are likely in moderately sensitive species, such as yellow-poplar; or in resistant species, such as red oak. Low moisture in the mid-1980s reduced tree growth considerably. Ozone is believed to have had only a minimal role in these growth losses. Damages from drought and ozone exposure are believed to be inversely related. Drought is thought to minimize ozone effects because it causes stomates to close, preventing ozone from entering the leaves. Between 1983 and 1990, highly sensitive vegetation in the northern and southern portions of the SAA area may have experienced the greatest frequency of ozone damage (fig. 73).

Ozone-sensitive species growing at high elevations may be more sensitive to ozone exposure than those growing at lower

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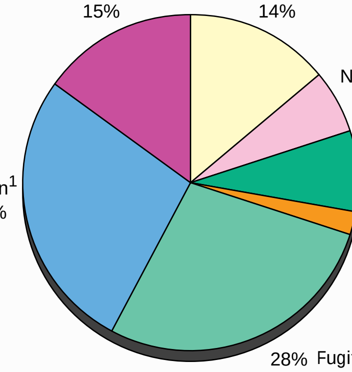

Figure 74 Nationally, the major source of particulate matter 10 microns or smaller are fugitive dust from roads, construction, and agriculture. (Source: EPA 1995a)

[1]Construction emissions represent the majority of the miscellaneous-fugitive dust-other category.
[2]Natural sources/wind erosion emissions are discussed as fugitive dust sources throughout this report.
[3]Point and fugitive process sources are all sources except the fugitive dust sources.
[4]Includes miscellaneous-agriculture and forestry-agricultural livestock and miscellaneous-fugitive dust-other excluding construction.

elevations. Sufficient moisture to prevent stomatal closure at high elevations may be obtained from cloudwater, thus allowing more ozone to be absorbed even in relatively dry periods.

What are the implications of ozone exposures on the health of forests in the Southern Appalachians? The forest products industry may be concerned if ozone reduces tree growth and impacts future timber supplies. Ozone exposures could also be reducing the genetic diversity of some species, such as white pine. Furthermore, little is known about the effect ozone exposures may have on rare and endangered plant species.

Particulate Matter and Prescribed Burning

Particles in the atmosphere include wind-blown soil, soot, smoke, and liquid droplets. Nationally, the major source of particulate matter 10 microns or smaller are fugitive dust sources from roads, construction, and agriculture (fig. 74). Nationally, between 1940 and 1994, particulate matter emissions from stationary sources have decreased significantly, but point sources only comprise 8 percent of the total emission. Overall, particulate matter emissions are expected to remain constant to the year 2010.

Violations of the National Ambient Air Quality Standard (NAAQS) for particulate matter have not occurred at any monitoring site in the Southern Appalachians. The standard sets upper limits for the annual average (50 microns per cubic meter of air) and for the average for any 24-hour period (150 microns per cubic meter). In both cases, only airborne particles and aerosols 10 microns or less in size are measured.

Between 1985 and 1994, average annual particulate matter concentrations appear to have declined in the SAA area. For particles of 10 microns or less, the annual mean for the region declined from 44 to 24 microns per cubic meter. It should be noted, however, that during the period the focus of measurement shifted from total suspended particulates to particles of 10 microns or less. This shift led to the replacement of sampling equipment. As a result, measurements of long-term change may not be completely reliable.

A small or moderate increase in prescribed fires should not cause a problem with the annual NAAQS for particulate matter.

At most monitoring stations, particulate matter concentrations are currently well below NAAQS values. New sources that emit modest amounts of particulate matter, therefore, will not cause violations of the annual standard. Annual average concentrations of particulate matter do not differ substantially by state, and urban monitored values do not differ greatly from those for rural sites. In the area as a whole, averages for spring and summer are about 12 percent higher than the annual mean.

Like annual averages, maximum 24-hour concentrations appear to be declining. Between 1985 and 1994, 24-hour concentrations at specific locations seldom exceeded 90 percent of the NAAQS maximum. Land managers must be concerned about exceeding 24-hour particulate standards in the vicinity of prescribed forest burns. Stationary air sampling equipment is seldom close enough to a prescribed forest burn to be helpful. Some special sampling has been done near such fires in Florida and Texas. In nine-tenths of the cases, particulate matter concentration was below 150 microns per cubic meter 1 mile away from the outer edge of the fire. In two-thirds of the cases, the standard was maintained as close as 0.5 mile from the outer edge.

There is a growing interest among land managers to increase the amount of prescribed fires in the region for numerous purposes, such as habitat improvement for rare and endangered species. A small or moderate increase in prescribed fires should not cause a problem with the annual NAAQS for particulate matter. For those rural areas where prescribed fire is used, there is a potential to violate the 24-hour air quality standard within 1 mile of a prescribed fire. The EPA is examining the current NAAQS for particulate matter. A tighter standard may result in prescribed fire activities receiving greater attention from air regulatory agencies. Prescribed fires may cause violations of any new standards if federal levels are reduced or the focus is on the amount of smaller particles (2.5 microns or less in size). Most of the particles produced by prescribed fires are smaller than 1 micron. There is concern about the effects of these small particles on human health.

Airborne emissions and the resulting impacts to forested ecosystems are regional problems requiring regional solutions.

Some forest ecologists believe there is a need to return fire to its role in the ecosystem, reducing combustible fuel and enhancing wildlife and plant habitat, especially for fire-dependent pine ecosystems. This policy would be accomplished through increased use of prescribed fire. Is there an upper level of prescribed fire over a given time period that would exceed NAAQS for particulate matter? To answer this question, additional monitoring of particulate concentrations would be needed in rural areas; most particulate monitors are currently located in urban areas.

Regional Cooperation

Airborne emissions and the resulting impacts to forested ecosystems are a regional problem requiring regional solutions. Air pollution impacts to natural resources in the Southern Appalachians are caused by sources inside and outside the Southern Appalachians. Managers of Class I wildernesses and national parks and state and local air quality agencies in the SAA region have come to the same conclusion. To address regional air quality problems, the Southern Appalachian Mountain Initiative (SAMI) was formed. SAMI stakeholders include a wide array of federal, state, and local agencies, environmental representatives, concerned citizens, and industry representatives. SAMI may recommend emission management options to help reduce airborne emissions, perhaps beyond what is mandated by the 1990 CAA Amendments. It is hoped that these further reductions will benefit the highly sensitive, high-elevation Class I areas and reduce pollution impacts throughout the Southern Appalachians.

Research and Monitoring Needs

As the Atmospheric Team was answering the questions that were posed, we noted the kinds of information that would help answer the questions more fully or help decision makers select appropriate responses to the problems that were identified. These research and monitoring needs are:

- Increase air quality monitoring in the Southern Appalachians for particulate matter, aerosol, acid deposition (including cloudwater and dry deposition), and ground-level ozone.

- Refine the amount of damage to highly sensitive and moderately sensitive species using current exposures (both cumulative and number of hours greater than or equal to 0.10 ppm) found in Southern Appalachia. Also, research needs to be completed to determine what impact ozone is having on fruit and nut production, and the extent of soil moisture effects on the openings in leaves (called stomates) so ozone can penetrate.

- Study further the economic impacts of air pollutants on the Southern Appalachians, and the effect of regional meteorology on air pollution dispersal. An area-source database, to estimate pollution emissions from smaller point sources, mobile sources, etc., for states surrounding the Southern Appalachians is also needed prior to the next assessment

- Develop public participation process that assists with the definition of acceptable and unacceptable visibility conditions.

- Relate episodic acidification in streams with changes in biological populations using in situ observations and experiments. Models are needed to determine dose-response relationships for aquatic biota.

- Evaluate the impact of continued sulfate deposition on the "delayed" acidification of streams as sulfate is released from soils once they become saturated.