# Visibility in the Southern Appalachians

Question 3:

### How good is visibility in the Southern Appalachians, and how does air pollution affect visibility?

The Southern Appalachians can summon images of cool clear streams, forested mountains, birds and other wildlife, or perhaps a special place that has a spectacular view of distant ridges. Viewing scenery is one of the most often cited reasons for visiting national forests and parks. However, visibility in the Southern Appalachians has deteriorated over the past 40 years, and the degradation is linked to sulfur emissions from the combustion of fossil fuels, such as coal and oil. The same pollutants that lead to visibility impairment also contribute to human health effects and acidic deposition effects on streams, soils, and vegetation.

Many people think of visibility in terms of the distance between themselves and a clearly viewed object. But visibility is more closely associated with the conditions that allow appreciation of landscape features than with distance. The texture of different cloud formations, the color of fall foliage, and the form and clarity of a geologic outcropping are all important indicators of visibility and visual air quality.

In addition to being an important component of the recreational experience, visibility is protected by federal law. The Clean Air Act (CAA) Amendments of 1977 declared as a national goal "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I federal areas where impairment results from manmade air pollution." Class I areas are those wildernesses larger than 5,000 acres and national parks exceeding 6,000 acres, which were in existence as of August 7, 1977. The majority of the available visibility data for the Southern Appalachian Assessment (SAA) area has been collected at the Class I areas to determine the amount of visibility impairment occurring from manmade pollutants. There are seven Class I areas in the Southern Appalachians: James River Face Wilderness and Shenandoah National Park in Virginia; Linville Gorge, Shining Rock, and Joyce Kilmer-Slickrock Wildernesses in North Carolina; Cohutta Wilderness in Georgia; and Great Smoky Mountains National Park in Tennessee and North Carolina. Sipsey Wilderness in Alabama and Dolly Sods Wilderness in West Virginia are Class I areas located just outside the assessment area boundary, but are included in this report to represent the northwest and southwest extremities of the assessment area. Figure 4.1 shows the locations of

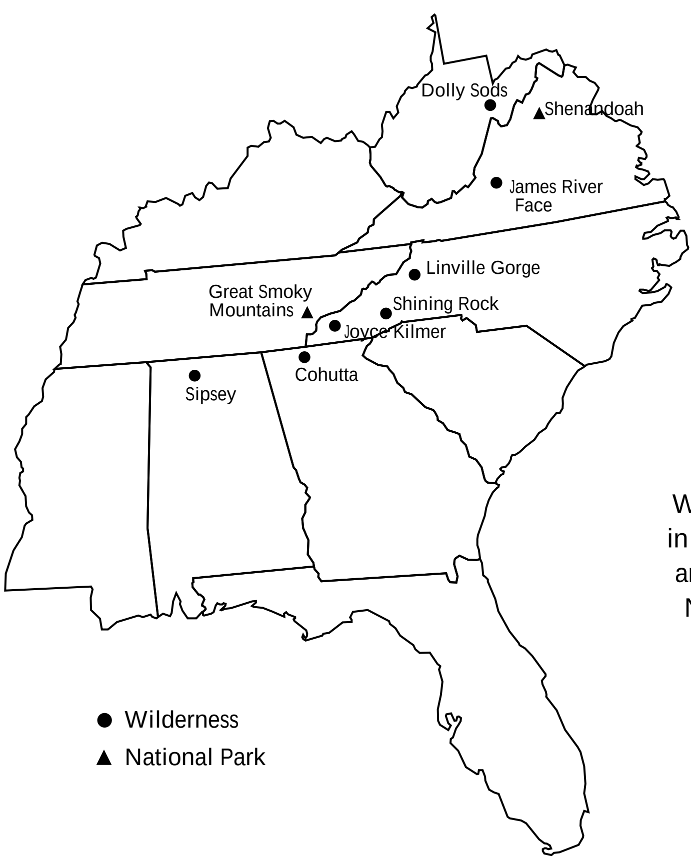


**Figure 4.1** Location of southeastern Class I areas where visibility monitoring has been conducted.

these Class I areas. The purpose of this chapter is to present information on historical visibility conditions, compare those with current conditions, and predict future trends. However, before launching into discussion of visibility conditions and trends, this next section will provide background information which explains the causes of visibility impairment and methods of measuring visibility.

## *Background Information to Understand Visibility*

### Causes of Visibility Impairment

Visibility impairment is most simply described as the haze which obscures clarity, color, texture, and form. Several components interact to determine visibility conditions: the object being viewed, the atmospheric conditions influencing the sight path, the lighting conditions, and the viewer. Visibility impairment is caused by aerosols (solid or liquid particles dispersed in the air) or gases in the atmosphere that scatter or absorb light, thereby reducing visibility. Knowledge of the chemistry and physical properties of the aerosols responsible for visibility impairment can provide insight into the causes of visibility problems. Scattering efficiency for visible light is greatest for particles and aerosols with diameters in the 0.1-1.0 micron range. Fine particles, with diameters less than 2.5 microns (PM2.5), contribute greatly to the scattering and absorption of light, the sum of which is called light extinction. The significant chemical components in fine aerosols are sulfates, nitrates, organic carbon, soot (light-absorbing carbon), and soil dust.

A wide variety of pollutants may result from daily activities that include driving cars to work, generating electricity to light homes and businesses, and producing consumer goods. Depending on the location, time of the year, and atmospheric conditions, these human-caused pollutants can significantly reduce visibility. Table 4.1 illustrates the principal types of sources responsible for emissions of pollutants which lead to regional haze.

Once emitted into the atmosphere, the fate of these pollutants will be largely determined by meteorological conditions, especially winds, relative humidity, and solar radiation. According to an EPA report (EPA 1995a), most visibility impairment results from the transport by winds of emissions and secondary particles, often over great distances (typically hundreds of miles). Consequently, visibility impairment is usually a regional problem, rather than a local one. Regional haze is caused by the combined effects of emissions from many sources distributed over a large area, rather than of individual plumes caused by a few sources at specific sites. Stable atmosphere conditions known as stagnation areas also inhibit movement of pollutants, sometimes leading to severe haze episodes in the Southeast (Holzworth and Fisher 1979).

Relative humidity is another weather parameter that affects visibility. Certain kinds of

**Table 4.1** Percentage contribution by source category to pollutants which affect visibility in the eastern United States.

| Source Category | $SO_x$ | Organic Particles | VOC | Elemental Carbon | Suspended Dust | $NH_3$ | $NO_x$ |
|---|---|---|---|---|---|---|---|
| Electric utilities | 78 | — | — | — | — | — | 39 |
| Diesel-fueled mobile sources | 1.5 | — | — | 47 | — | — | 16 |
| Gasoline vehicles | 1 | 34 | 31 | 29 | — | — | 26 |
| Petroleum and chemical industries | 4.5 | — | 11 | — | — | — | — |
| Industrial coal combustion | 7 | — | — | — | — | — | — |
| Residental wood burning | — | 20 | 13 | 15 | — | — | — |
| Fugitive dust (on/off-road traffic) | — | — | — | — | 100 | — | — |
| Feedlots and livestock waste management | — | — | — | — | — | 66 | — |
| Miscellaneous | 8 | 46 | 45 | 9 | — | 34 | 19 |

$SO_x$ - sulfur oxides
VOC - volatile organic compounds
$NH_3$ - ammonia
$NO_x$ - nitrogen oxides
(Source: National Research Council 1993)

particles, especially sulfates, are hygroscopic, which means they attract water. In a humid atmosphere, sulfate particles combine with water and grow to a size that makes them more efficient light scatterers. For a given level of pollution, an atmosphere with higher relative humidity will have more haze than if relative humidity was lower (Sisler and others 1993).

### Visibility Measurements

Scientists and resource managers use several different types of equipment to measure visibility conditions, each of which differs in terms of cost, siting restrictions, ease of operation, and usefulness of data. The most common types of optical visibility-monitoring equipment include the transmissometer and nephelometer. These tools directly measure the light-extinction coefficient and scattering coefficient, respectively. Scenic monitoring utilizes interpretation of 35-mm photographic slides. Aerosol monitors measure the particles in the atmosphere that affect visibility. Combinations of these types of equipment are used to describe and define visibility.

Several different parameters are used to express visibility. Standard visual range (SVR), derived from photographs, has been the most commonly used measure of visibility by the Forest Service. SVR, usually expressed in kilometers, is the greatest distance at which an observer can barely see a black object viewed against the horizon sky. The higher the SVR value, the better the visibility conditions.

Another common measure of visibility is the light-extinction coefficient or $B_{ext}$. The light-extinction coefficient represents the ability of the atmosphere to absorb and scatter light. As the light-extinction coefficient increases, visibility decreases. Direct relationships exist between concentrations of particles in the air and their contribution to the extinction coefficient. These relationships are often presented in an annual extinction-budget plot showing the percentage of light extinction attributed to each particle type. The extinction budget, as discussed in a later section, is an important method for assessing the causes of visibility impairment.

Neither SVR nor extinction coefficient has a consistent direct relationship to perceived visual changes caused by uniform haze. Depending on baseline visibility conditions, a specific change in SVR or extinction coefficient can result in a visual change which is either obvious or imperceptible relative to the total SVR. For example, an improvement of 10 miles in SVR may be quite perceptible at an eastern location with an annual average visibility of 40 miles, but a 10-mile change in SVR may not be perceptible at a western location with an annual average visibility of 150 miles. The deciview (dv), a visibility index designed to describe changes in visibility perception across locations with all types of baseline conditions, is another commonly used measure of visibility (Pitchford and Malm 1994). It is designed to be perceptually linear (similar to the decibel scale for sound), meaning that a change of any given dv should appear to have approximately the same magnitude of visual change on any scene regardless of baseline visibility conditions. A 1-dv change is about a 10 percent change in the extinction coefficient – a small but perceptible scenic change. The dv value increases as haze increases, so it is known as a haziness index.

## *Visibility Assessment Techniques*

Visibility data collected at airports since the 1950s were used in this assessment to examine historic conditions and trends over the past 40 years. Current conditions are described from data collected through the Interagency Monitoring of Protected Visual Environments (IMPROVE) network (Sisler and others 1993), and data obtained from pictures taken at many of the wildernesses beginning in 1987. Predictions of future visibility trends were made by the EPA based on estimated changes in pollutant concentrations resulting from implementation of the 1990 CAA Amendments.

## *Visibility – Past, Present, and Future*

In the eastern United States, annual average natural background visibility is considered to be 93 ± 30 miles (150 ± 45 kilometers) (Trijonis and others 1991), which corresponds to an average range of 7 to 13 dv. Natural background visibility is defined as the visibility condition without the addition of anthropogenic (human-caused) pollution. Currently, the annual average visibility in the Southern

Appalachians is 20 miles (32 kilometers) (Sisler and others 1993), which corresponds to 24 dv. With the implementation of the CAA Amendments of 1990, which call for sulfur dioxide reductions, visibility in the Southern Appalachians is predicted to improve by 2 to 3 dv (3 to 7 miles) (EPA 1993a). This section describes past and present visibility conditions and expectations for the future.

## Historical Visibility in the Southeastern United States

Visibility data collected at airports for more than 40 years give an idea of the direction of long-term trends in visibility. Daylight observations of pre-selected visibility markers, large dark objects at known distances from the observation point, are used to determine the most distant visible marker. The shortcoming of this technique is a lack of targets far from the observer. Visual range is estimated as the distance to the farthest identifiable marker, when, in fact, visual range could be greater with a more distant target. The reported visual range is always an underestimate of the actual visual range. For example, an observation reported as 10 miles means that visual range is greater than 10 miles. In spite of this problem, visual range estimates from airport data do allow us to look at relative change over time.

The work of Husar, Elkins, and Wilson (1994), based on airport visual range data, shows that haze has intensified over a large contiguous region east of the Mississippi River during the past 40 years. In the 1960s, the poorest visibility conditions in the eastern United States were recorded for the cold season in the area surrounding Lake Erie and the New York-Washington megalopolis. By the 1980s the haziest conditions were found in Tennessee and the Carolinas in the summer. The haze situation has not changed significantly in the 1990s. The poorest visibility in the Southeast still occurs in the summer months.

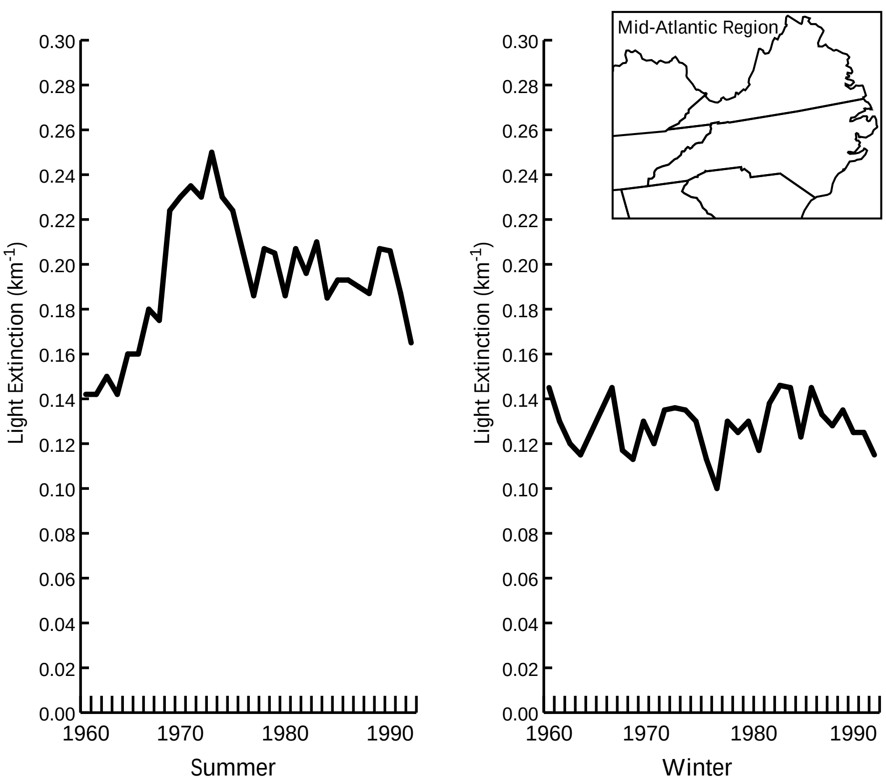


**Figure 4.2** Historical trends in winter and summer haze (light extinction) from airport data for the mid-Atlantic region, including the southern Appalachian area (1960-1992). As light extinction increases, haze increases and visibility deteriorates. Visibility deteriorated slightly between 1960 and 1992 in the winter months. Summertime visibility worsened between 1960 and the early 1970s, then improved somewhat by 1980. Since then summertime visibility conditions have remained fairly stable. (Source: Husar and others 1994)

Figure 4.2 shows the historical trends in winter and summer haze for the southeastern area as reported by Husar and others (1994). During the 1960s visibility deteriorated slightly in winter and substantially in summer. In 1961 the haze pattern was fairly constant throughout the year. By 1970, a strong summertime peak had emerged that was roughly twice the magnitude of the winter haze. Summertime visibility then improved somewhat in the late 1970s and has remained fairly stable since then. Husar and others (1994) suggest that the "changes from a winter maximum in haze in the 1960s to summer maximum in the 1980s can be attributed in part to increased sulfate from increased sulfur dioxide emissions due to increased combustion of coal to produce electrical power for air conditioning or to increased photochemical smog which leads to 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." Causes of visibility impairment will be further discussed following the description of current visibility conditions.

## Current Visibility Conditions in the Southern Appalachians

Visibility conditions in many Class I areas across the nation are currently monitored using IMPROVE protocols. Cameras and/or special samplers for particulate matter (aerosol samplers) are present near these Class I areas to characterize, describe, and define visibility over time. Many sites also directly monitor the optical characteristics of the atmosphere using nephelometers.

Shenandoah National Park and Great Smoky Mountains National Park are fully equipped IMPROVE sites which collect optical and aerosol data as well as scene data using cameras. These sites have been in operation since the early 1980s. Visibility monitoring of Forest Service Class I areas began in the late 1980s with the installation of a camera-monitoring network to "affirmatively protect visibility conditions" under the CAA Amendments. The first sites were installed in 1987 near the James River Face Wilderness in Virginia and Dolly Sods Wilderness in West Virginia. In 1989, cameras were installed for four other Forest Service Class I Wildernesses in the assessment region – Linville Gorge, Shining Rock, and Joyce Kilmer-Slickrock in North Carolina; and Cohutta in Georgia.

The collection of camera data provides a valuable first step towards characterizing visibility conditions in the Southern Appalachians. These data were summarized for each Forest Service Class I area in reports by Air Resource Specialists, Inc. (ARS 1995). Results of the camera-based monitoring (table 4.2) reflect the same seasonal patterns seen in the historical data. For a recent 6-year period (1987-1993), median winter SVR has been roughly four times greater than median summer SVR. The median SVR is similar for all sites during the months of

**Table 4.2** Median camera-based standard visual range (SVR) estimates, in miles (mi) and kilometers (km), and haziness values in deciview (dv), for the summer and winter seasons (for the combined years 1987–1993). These seasons represent the worst and best visibility conditions in the Southern Appalachians. The National Forest Class I Wildernesses are arranged by summer visual range, beginning with the areas having the poorest visibility.

| | Summer (July/Aug) | | | Winter (Dec/Jan) | | |
|---|---|---|---|---|---|---|
| | SVR | | Haze | SVR | | Haze |
| Class I Wildernesses | mi | km | dv | mi | km | dv |
| James River Face, VA | 15 | 25 | 27.5 | 66 | 106 | 13.1 |
| Cohutta, GA | 15 | 25 | 27.5 | 76 | 122 | 11.7 |
| Dolly Sods, WV | 17 | 27 | NA | NA | NA | NA |
| Joyce Kilmer–Slickrock, NC | 17 | 28 | 26.4 | 151 | 244 | 4.7 |
| Linville Gorge, NC | 19 | 30 | 25.7 | 87 | 140 | 10.3 |
| Shining Rock, NC | 19 | 30 | 25.7 | 138 | 220 | 5.8 |

NA = not available
(Source: Air Resource Specialists, Inc. 1995)

**Table 4.3** Annual camera-based standard visual range (SVR) estimates in miles (mi) and kilometers (km), and haziness values in deciview (dv), for the combined years 1987–1993. Class I areas are arranged with the haziest site first and progressively clearer sites following.

| | Median[1] | | | Best[2] | | | Worst[3] | | |
|---|---|---|---|---|---|---|---|---|---|
| | SVR | | Haze | SVR | | Haze | SVR | | Haze |
| Class I Wildernesses | mi | km | dv | mi | km | dv | mi | km | dv |
| Dolly Sods, WV | 26 | 42 | 22.3 | 87 | 140 | 10.3 | 9 | 15 | 32.6 |
| James River Face, VA | 36 | 58 | 19.1 | 117 | 189 | 7.3 | 11 | 18 | 30.8 |
| Cohutta, GA | 40 | 65 | 17.9 | 125 | 201 | 6.7 | 14 | 22 | 28.8 |
| Linville Gorge, NC | 42 | 68 | 17.5 | 132 | 212 | 6.1 | 16 | 26 | 27.1 |
| Shining Rock, NC | 48 | 78 | 16.1 | 171 | 276 | 3.5 | 14 | 23 | 28.3 |
| Joyce Kilmer–Slickrock, NC | 55 | 89 | 14.8 | 206 | 331 | 1.7 | <14 | <22 | 28.8 |

[1]Median SVR represents the visual range estimate for the conditions defined as the median, where 50 percent of the observations were better, 50 percent were worse.

[2]Best SVR represents the visual range estimate for the best visibility conditions. Of all the observations, only 10 percent were better than this, 90 percent were worse.

[3]Worst SVR represents the visual range estimate for the worst visibility conditions. Of all the observations, 90 percent were better than this figure, only 10 percent were worse.

(Source: Air Resource Specialists, Inc. 1995)



**Figure 4.3** Photographs of James River Face Wilderness depicting seasonal variation in visibility conditions. The photograph on top shows annual median visibility for the summer months. The photograph on the bottom shows annual median visibility for the winter months. There is a difference of 14 deciview (81 miles standard visual range.)

July and August: 15 to 19 miles. Poor summertime visibility is a function of weather as well as air pollution. In the summer, stagnant air masses remain over much of the southeastern United States, trapping pollution and allowing concentrations to increase. High pollution concentrations, high temperatures, and high relative humidity lead to haziness and poor visibility. Pictures of James River Face Wilderness in figure 4.3 show this dramatic difference between winter and summer visibility.

All camera data collected at each of the southeastern Forest Service Class I areas were combined and analyzed to determine the annual median, worst, and best visibility (table 4.3). Median, worst, and best visibility conditions are defined as:

**Median** - The visibility value occuring at the midpoint of all observations.

**Best** - Only 10 percent of the observations were better and 90 percent were worse.

**Worst** - Only 10 percent of the observations were worse and 90 percent were better.

The camera data documents that current annual median SVR is between 26 and 55 miles (42 and 89 kilometers). Visibility appears to be better farther south in the assessment area. The West Virginia and Virginia Class I areas have the poorest visibility. For these two areas, the best SVR is less than 124 miles (200 kilometers), the median is between 26 and 36 miles (42 and 58 kilometers), and the worst is less than 12 miles (20 kilometers) (fig. 4.4). Class I areas in North Carolina and Georgia have slightly better visibility. The best SVR for these sites is greater than 125 miles (201 kilometers), the median is between 40 and 55 miles (65 and 90 kilometers), and the worst is around 15 miles (23 kilometers).

Visibility in the other Class I areas – Sipsey and Dolly Sods Wildernesses, Shenandoah National Park and Great Smoky Mountains National Park – can be described using results of aerosol monitoring. Aerosol measurements and current understanding of light-extinction efficiencies of aerosol components are used to derive a reconstructed light-extinction coefficient. The sum of the extinction coefficients is then converted to SVR. SVR estimates for sites with aerosol-monitoring data are shown in table 4.4.

Because aerosol data are collected differently than scene data, the definitions of median, best, and worst visibility are slightly different. Aerosol samples are collected for a 24-hour period of time, twice a week, resulting in approximately 100 samples per year. Median visibility is described using the middle 20 observations; best visibility conditions are explained using the 20 best observations; and the worst visibility conditions by using the dirtiest 20 observations. Because of the differences in data collection, analysis, and interpretation, SVR estimates generated by camera and aerosol data should be compared with caution. With this in mind, it appears that visibility at Sipsey and Dolly Sods Wildernesses, and at Shenandoah and Great Smoky Mountains National Parks is poorer than any other Class I area in the Southern Appalachians.


**Figure 4.4** Photographs of James River Face Wilderness in southwest Virginia depict the measured range of visibility.

**Table 4.4** Annual standard visual range (SVR) estimates in miles (mi) and kilometers (km) for combined years of sampling. These SVR estimates are derived from light extinction coefficients, reconstructed from measured aerosol mass and composition.

| | | Median[1] SVR | | Best[2] SVR | | Worst[3] SVR | |
|---|---|---|---|---|---|---|---|
| Class I Area | Years of Data | mi | km | mi | km | mi | km |
| Sipsey Wilderness, AL | 1992-1994 | 19 | 30 | 32 | 52 | 13 | 21 |
| Dolly Sods Wilderness, WV | 1991-1994 | 20 | 33 | 42 | 67 | 9 | 15 |
| Shenandoah National Park, VA | 1988-1994 | 24 | 37 | 47 | 75 | 11 | 18 |
| Great Smoky Mountains National Park, NC/TN | 1988-1994 | 24 | 38 | 46 | 74 | 12 | 19 |

[1]Median SVR represents the visual range estimate from the median 20 observations.
[2]Best SVR represents the visual range estimate from the cleanest 20 observations.
[3]Worst SVR represents the visual range estimate from the dirtiest 20 observations.
(Source: IMPROVE data)

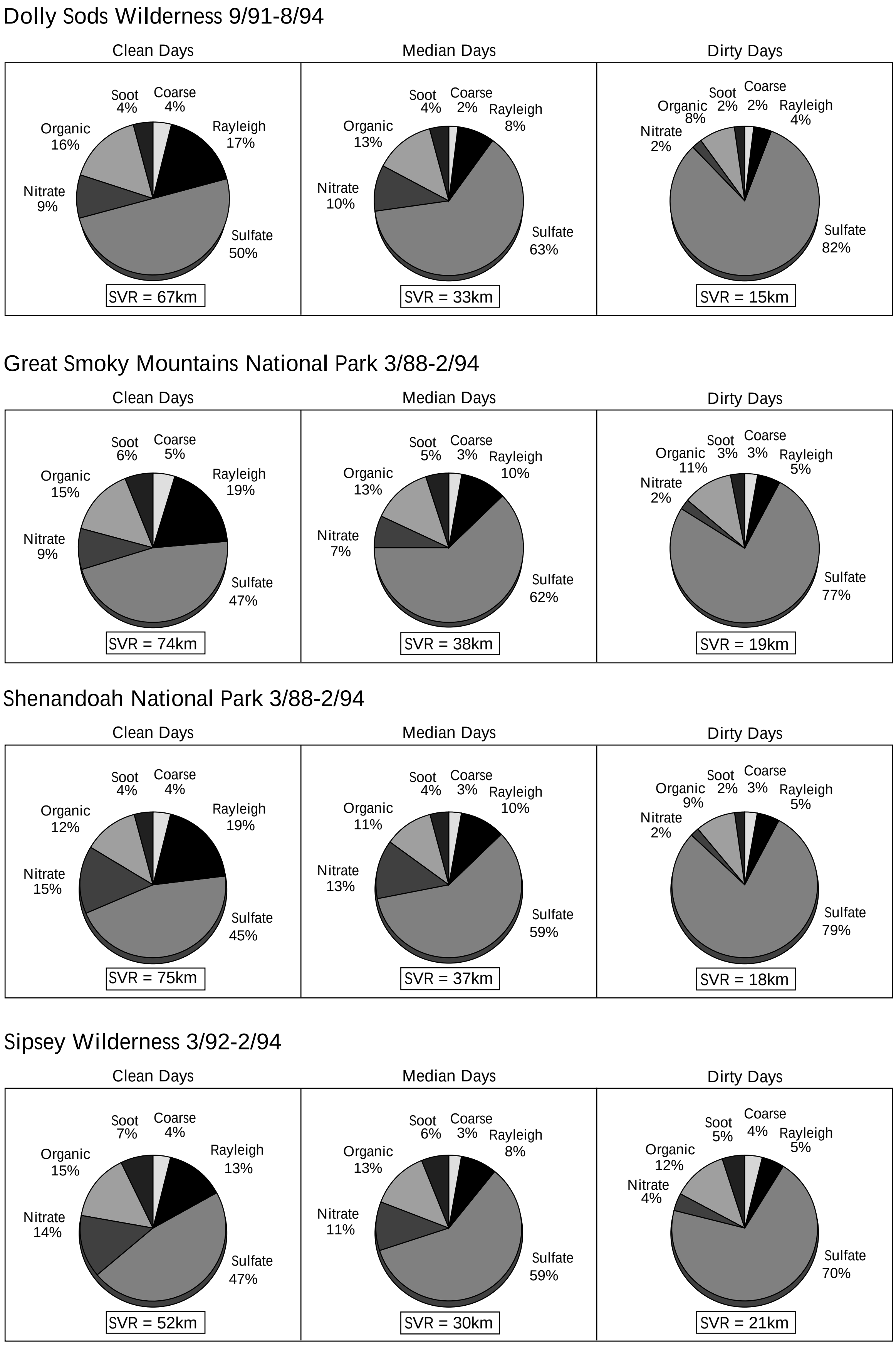


**Figure 4.5** Annual visibility extinction budgets derived from aerosol measurements for Class I areas in the southeastern United States. The charts clearly show the predominant role of sulfate in visibility reduction. (Source: IMPROVE data)

## Causes of Visibility Impairment in the Southern Appalachians

Aerosol samples collected twice a week for several years through IMPROVE provide information on particles in the atmosphere which can be correlated with optical camera measurements of visibility. Extinction budget plots (fig. 4.5) for four southeastern sites show the relative contribution to atmospheric extinction of each aerosol species plus natural light scattering. The extinction budget shows that aerosols account for about 90 percent of the light extinction (aerosols being comprised of sulfate, nitrate, organics, coarse dust, and soot). Sulfate accounts for approximately 60 percent of the extinction on days with median visibility, making it the primary cause of haziness. On days with the worst visibility, sulfate accounts for closer to 80 percent of the extinction. Sulfate is recognized as the primary cause of light extinction in the Southern Appalachians (National Research Council 1993, Sisler and others 1993), and as sulfate increases so does haziness. A detailed description of how each species of aerosol contributes to atmospheric extinction can be found in the IMPROVE publication, "Spatial and Temporal Patterns and the Chemical Composition of the Haze in the United States" (Sisler and others 1993).

The historic trends in visibility follow closely the changes in sulfur dioxide emissions within the region. Figure 4.6 compares summer sulfur dioxide emissions and visibility in the Southeast for the years from 1940 to 1985. Both sulfur dioxide and light extinction increase from the late 1940s through the early 1970s and then slightly decrease or level off in the late 1970s and early 1980s. The trend in sulfur dioxide emissions for the Southeast has remained stable or increased slightly between 1985 and 1994 (EPA 1995a). This pattern deviates somewhat from the national trends in sulfur dioxide emissions, which show a sharp decline in emissions during the 1970s followed by a slightly decreasing trend since the early 1980s (fig. 2.4) (EPA 1995a). The trend in sulfur dioxide emissions for the Southeast is probably due in part to dramatic population growth in the region accompanied by increased energy demands.

There is a strong correlation between sulfur dioxide emissions and haziness for a very good reason. Sulfur dioxide is a precursor of sulfates, and sulfates are known to be the main anthropogenic or human-caused factor contributing to light scattering in the Southern Appalachians. This fact has been documented in many sources including the National Acid Precipitation Assessment Program (NAPAP) (Trijonis and others 1991); National Research Council, (1993); EPA (1994, 1995c); Sisler and others (1993); and IMPROVE (1994).

Analysis of fine particulate data from Shenandoah and Great Smoky Mountains National Parks by Eldred and Cahill (1994) shows an annual increase in sulfate of 2 to 3 percent each year between 1982 and 1992. This increasing trend was even more

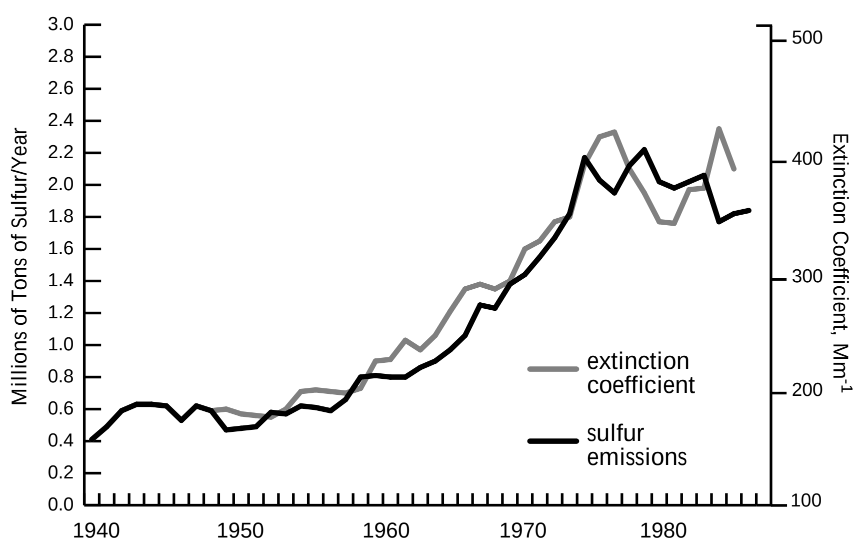


**Figure 4.6** Relationship between sulfur dioxide emissions and haziness in the southeastern United States during the summer months. (Source: Trijonis and others 1991)

pronounced in the summer months 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. 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 either 1) changes in emissions of sulfates or precursors of sulfates (such as sulfur dioxide or nitrogen oxides), 2) changes in photochemical smog (ozone) which influences the rate of formation of sulfate, or 3) changes in meteorological conditions which influence sulfate formation (Husar and others 1994).

Weather conditions such as high relative humidity and precipitation in the form of snow, rain, and fog also contribute to visibility impairment. In general, the higher the relative humidity, the greater the scattering of light by sulfate aerosols, which intensifies regional haze. The combination of high relative humidity and sulfate concentrations found in the Southern Appalachians, especially in the summer months, results in poor visibility (Sisler and others 1993). Data from Shenandoah National Park illustrate this interaction. Between 1988 and 1994, the relative humidity at Shenandoah averaged 69 percent, and the median SVR was 25 miles (40 kilometers) (23 dv). Using conversion factors developed from IMPROVE data, a reduction in mean relative humidity to 50 percent would have resulted in a median SVR of roughly 37 miles (60 kilometers) (19 dv), an improvement of 4 dv. Removing all of the sulfate from the atmosphere during that time period would have resulted in a median SVR of approximately 62 miles (100 kilometers).

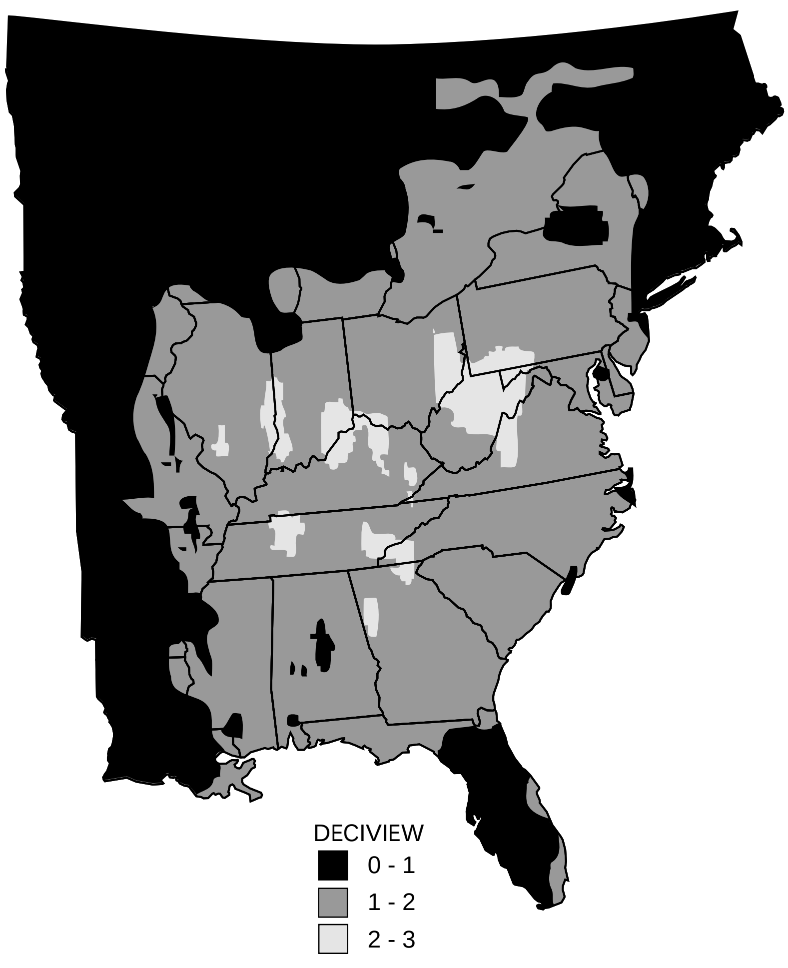


**Figure 4.7** The Regional Acid Deposition Model (RADM) predicts decreases in annual median haziness (visibility improvement) due to implementation of the Clean Air Act Amendments of 1990. (Source: EPA 1993a)

Clearly, the SAA area is exposed to high levels of sulfate derived from sulfur dioxide emissions. The worst visibility conditions are the result of high sulfate concentrations and high relative humidity occurring coincidentally.

## Future Trends in Southern Appalachian Visibility

The EPA conducted an assessment of the progress and improvements in visibility in Class I areas and reported the results to Congress in October 1993 in a report entitled "Effects of the 1990 Clean Air Act Amendments on Visibility in Class I Areas." The following information is taken from that report, which should be consulted for further detail on methodology.

To predict future visibility conditions in the southeastern United States, the EPA used the Regional Acid Deposition Model (RADM) and the RADM Engineering Model post-processor (EM-VIS). The estimated emission changes resulting from implementation of the 1990 CAA Amendments were used as inputs. The EPA predicts an improvement of 1 to 2 dv in annual median visibility throughout the Southern Appalachians by the year 2010, when full implementation of the 1990 CAA Amendments is expected to reduce sulfur dioxide by 50 percent (fig. 4.7). For example, annual average visibility at Sipsey Wilderness is predicted to increase from 19 to 21 miles. Certain areas will see slightly greater improvements. Haziness is expected to decrease by 2 to 3 dv in Dolly Sods Wilderness in West Virginia, Shenandoah National Park in Virginia, and Great Smoky Mountains National Park in eastern Tennessee and western North Carolina. At Shenandoah National Park a 3-dv improvement will increase visibility from 25 to 32 miles.

The EPA's assessment also predicts that the greatest improvements will be seen in summer when sulfates dominate light extinction. Figure 4.8 shows a predicted 2- to 3-dv improvement

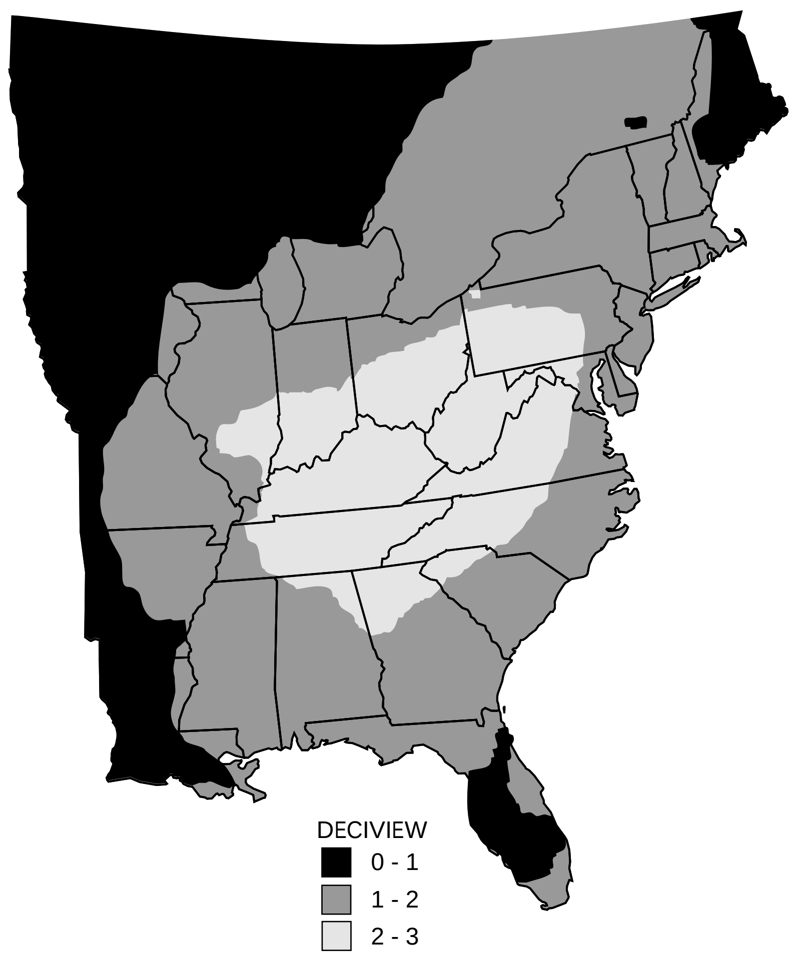


**Figure 4.8** The Regional Acid Deposition Model (RADM) predicts visibility improvements, due to implementation of the Clean Air Act Amendments of 1990 to be greatest during the summer months. (Source: EPA 1993a)

in visibility in the summer across the whole SAA region. Photographs of James River Face Wilderness in figure 4.9 show what a 3-dv (roughly 4 miles) improvement in annual average summer visibility would look like. Predicted winter improvements will be less significant; only 1 dv.

These improvements directly relate to provisions of the CAA Amendments that address control of sulfur dioxide emissions in the eastern United States. Figure 4.10 illustrates projected reduction of sulfur dioxide emissions between 1985 and 2010 in this region (EPA 1993a). The largest decreases will come from the utility industry, which accounts for the greatest portion of sulfur dioxide emissions in the East.

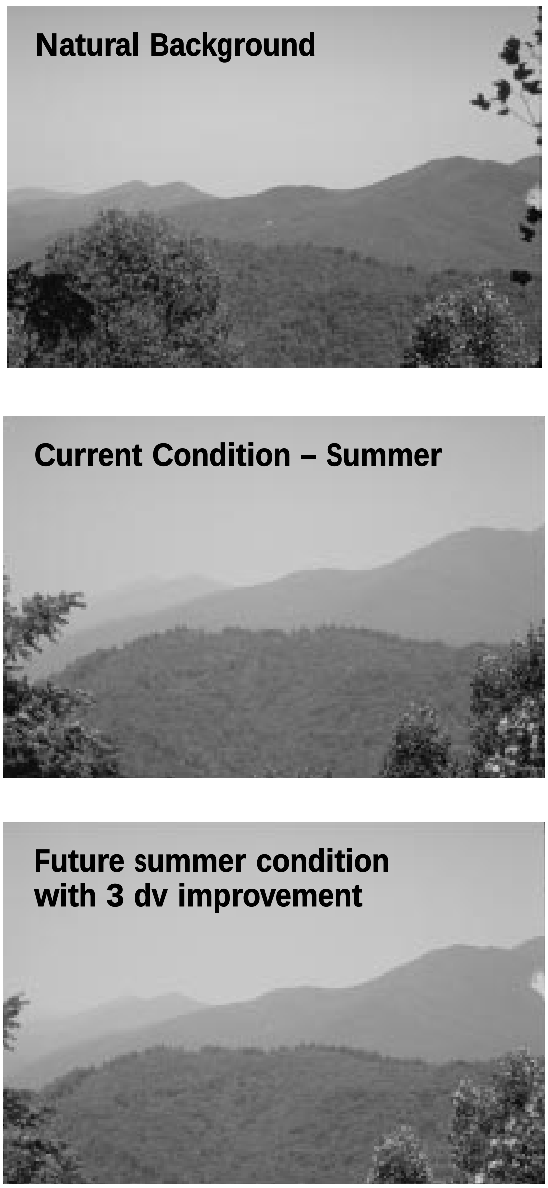


**Figure 4.9** The photographs depict what a 3-deciview decrease in haziness (visibility improvement) would look like compared with the current median summer condition and natural background visibility. The view is James River Face Wilderness in Virginia.

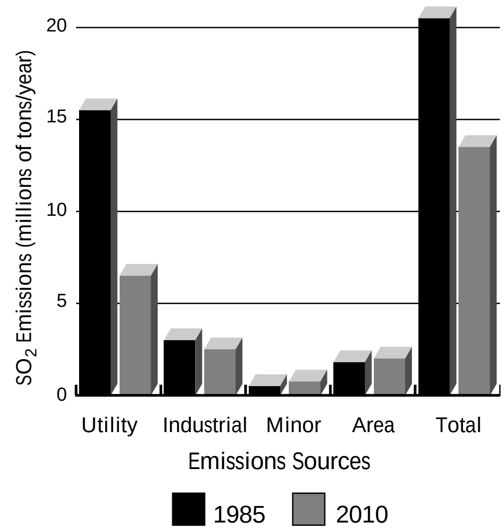


**Figure 4.10** Projected sulfur dioxide emissions in the eastern United States after the Clean Air Act Amendments of 1990 are implemented. (Source: EPA 1993a)

It is significant to note, however, while a 1993 EPA report predicts improvements in regional visibility for the Southern Appalachians, the final statement in the executive summary issues the caution, “Although visibility will improve in many eastern Class I areas..., there will still be perceptible man-made regional visibility impairment in all Class I areas nationwide” (EPA 1993a). Efforts are underway which may further reduce sulfur emissions affecting the SAA region. The Southern Appalachian Mountain Initiative (SAMI) is considering additional ways to reduce the impacts of air pollution on Class I areas of the SAA region. Reports by NAPAP and EPA on visibility (Trijonis and others 1991, EPA 1993a) indicate that visibility can be improved with reductions in sulfur emissions, predictions which inspire SAMI to develop strategies to achieve improvements.

## Key Findings

1. Visibility in the Southern Appalachians has deteriorated considerably since the 1950s.

2. The poorest visibility conditions occur in the summer months.

3. Sulfates which result from sulfur dioxide transformation in the atmosphere are the largest single human-caused contributor to haziness in the Southern Appalachians.

4. Sulfate concentrations increased 2 to 3 percent each year between 1982 and 1992.

5. Visibility can be improved by reducing sulfur dioxide emissions from human-caused sources.

6. The Clean Air Act Amendments of 1990, once implemented, should lead to improvements in summertime visibility in the Southern Appalachians. Estimated improvements may be up to 3 deciview (about 4 miles SVR).