1997 AIR QUALITY STATUS AND TRENDS--VISIBILITY

Units of the National Park System are experiencing air pollution-related effects: reduced visibility, injury to vegetation, changes in lake and stream chemistry and deterioration of cultural resources. Under the Clean Air Act, the Organic Act, and other legislation, the Department of the Interior has a responsibility to protect resources within national park units from these effects.

Background

Since the late 1970s the National Park Service has monitored visibility conditions and ambient levels of fine particles, ozone, sulfur dioxide, and wet deposition in national parks. Visibility monitoring, including photographic, optical and fine particle monitoring, is conducted as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE)--a national visibility monitoring cooperative among the U.S. Environmental Protection Agency (EPA) and Federal land managing agencies. Wet deposition monitoring is conducted as part of the Service's participation in the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). The Service has developed its own network for gaseous pollutant and meteorological monitoring, although a few states supplement NPS efforts at a few locations. These networks are essential to the understanding the impacts of air pollutants to park ecosystems previously presumed to be relatively free of anthropogenic stresses. Before the Service's networks were established, there was relatively little monitoring being conducted in national parks, because EPA and states placed priority on health-related monitoring in urban areas. Additional funding provided by Congress in 1986 and 1987 allowed the Service to expand its monitoring network and establish a data center to process, validate, and archive NPS data. Ozone, sulfur dioxide, and meteorological data collected by NPS are entered into EPA's national database for use by EPA and state agencies and researchers. Visibility and wet deposition data are available via the Internet.

Current Status

Fine Particles and Visibility

Until 1988 when the IMPROVE visibility monitoring network became operational, the NPS visibility monitoring program was the only source of visibility information in Class I areas (areas identified by the Clean Air Act as requiring special protection). NPS has maintained visibility monitoring in many of its parks since 1978. Visibility monitoring includes three types of monitoring: photographic monitoring, optical monitoring, and fine particle sampling. Scene monitoring documents the condition of a scene or scenes in a park three times a day using a 35-mm camera. Optical monitoring is performed using instruments that actually measure the visibility condition of the atmosphere. This monitoring provides a record of visibility conditions in parks on an hourly basis. Fine particle sampling allows NPS to determine the causes, i.e., the pollutant and the source types or the source regions responsible for the observed impairment to visibility in our parks. Twenty-four hour average fine particle samples are collected twice weekly at each monitoring location.

Figures 1 through 8 show: 1) NPS locations where visibility (optical and fine particle), ozone, and wet deposition monitoring is currently being conducted by either the NPS or by other agencies as of 1997, 2) total fine particle and particulate sulfate concentrations and visibility conditions (displayed as deciviews) for the period 1992-1995, 3) wet deposition pH, sulfate and nitrate ion concentrations for 1996, and 4) 1994-1996 average ozone concentrations (displayed as a three-year average of the annual fourth highest daily maximum eight-hour concentration) at NPS monitoring sites.

Spatial Trends

Fine Particles and Visibility

Estimates of natural background concentrations for fine particles are 3.3 and 1.5 $\mu g/m^3$ in the East and West, respectively. Corresponding estimates of natural background sulfate concentrations are 0.2 and 0.1 $\mu g/m^3$. Natural visibility conditions are estimated to be about 9.5 and 5.0 deciviews (dv) for the corresponding regions. The dv scale is chosen so that a value of zero represents excellent visibility, i.e, visibility unimpaired by manmade or natural particles suspended in the air. The dv scale is a mathematical transform of the more traditional visual range and atmospheric indices. For example, 30 dv and 10 dv correspond to 19 km and 144 km standard visual, respectively.

Fine particle concentrations in the East are typically three to four times higher than in the West, but measurements from both regions, while well above the natural background estimates, are below the annual average EPA National Ambient Standard (NAAQS) for particulate matter of 15 $\mu g/m^3$. This standard, with its companion twenty-four hour standard, if met, should protect the health of people from the adverse effects of fine particulate matter in the air. Though not shown here, all sites monitored appear to be in compliance with the twenty-four hour NAAQS as well.

Because of its important relationship to visibility impairment and acid deposition, sulfate concentrations are also shown (there is no NAAQS for sulfate). Observed sulfate concentrations are factors of six to ten and thirty to forty times natural background estimates in the West and East, respectively.

Visibility conditions display similar patterns to those just discussed. Much greater improvements in the East (about 20 dv) would be needed to improve conditions to those corresponding to natural background; The West would require about a four-deciview improvement (California excepted), on the average.

Fine Particles and Visibility in Prototype Inventory and Monitoring Parks

Three of the NPS units conducting prototype ecological monitoring are monitoring visibility: Denali National Park, Great Smoky Mountains National Park, and Shenandoah National Park. These three units, which are part of the IMPROVE visibility network, monitor particulate matter and the optical properties of the atmosphere that are important in understanding the effect that air pollutants have on visual air quality.

Figures 9, 10, and 11 present three-year average fine particulate matter concentrations in micrograms per cubic meter for the three parks. Fine particulate matter is characterized by particles with diameters less than 2.5 micrometers, and is referred to as PM-2.5. The graphs display the average concentrations associated with the best visibility days (marked as 10^{th} percentile), average visibility days (50^{th} percentile), and worst visibility days (90^{th} percentile). The year indicated on the graph axis is the center year of a three-year period. Average PM-2.5 concentrations at Great Smoky Mountains and Shenandoah National Parks are approximately 20, 10 and 5 micrograms/cubic meter $\mu g/m^3$) on best, average and worst visibility days. The Denali PM-2.5 concentrations on worst visibility days (2-4 $\mu g/m^3$) are less than the concentrations on the best visibility days at the two eastern sites. Denali fine particle concentrations are generally the lowest of all those measured in the IMPROVE network.

The fine particulate matter collected in the IMPROVE network is analyzed to determine its chemical composition. The chemical species found at most IMPROVE sites can be categorized into five chemical types: sulfates, nitrates, mass associated with organic carbon, light absorbing carbon, and soil. In the East, sulfate is usually the greatest contributor to visibility impairment. On best, average and worst visibility days in the East sulfate contributes about 50%, 60% and 70% of the impairment, respectively. For western IMPROVE sites, sulfate contributes about 30%, 35%, and 30%, respectively. The next largest chemical contributors to impairment in both the East and West are organic carbon and light absorbing carbon. Nitrates contribute more towards visibility impairment in the West than in the East. Figures 12, 13, and 14 plot average winter and summer season sulfate concentrations at the three parks. The two eastern sites indicate a seasonal trend observed at most continental IMPROVE monitoring sites. Summer sulfate (as well as total fine particulate) concentrations are several times greater than those measured in the winter season. In Denali, winter sulfate concentrations exceed summer ones. However, both summer and winter season sulfate concentrations at Denali are very low. Summer sulfate concentrations at the eastern sites are over twenty times greater than those measured at Denali and over ten times greater than those at western continental IMPROVE monitoring sites.

Three-year average visibility conditions (expressed as deciview) in at the three parks are displayed in Figures 15, 16, and 17. The NPS investigated trends in the three-year average deciview over the years 1988-1996. For the worst visibility days, the trend analysis indicated no or insignificant change in three-year average deciview at Shenandoah National Park, an improvement in visibility (about 0.2-0.4 dv/year) at Denali, and was statistically inconclusive for Great Smoky Mountains National Park. With respect to the average visibility days, all three parks showed an improvement in average visibility conditions. The estimated improvements were about 0.3-0.5 dv/year at Denali, 0.02-0.1 dv/yr at Great Smoky Mountains, and 0.1-0.2 dv/year at Shenandoah. The trend for the best visibility days also indicated an improvement at each of the three sites. An improvement of about 0.3-0.4 dv/yr, 0.1-0.2 dv/yr, and 0.1-0.2 dv/yr were estimated for Denali, Great Smoky Mountains, and Shenandoah National Parks, respectively.

Reference:

Sisler, J.F. and R. Damberg. In press. Interpretation of Trends of PM-2.5 and Reconstructed Visibility From the IMPROVE Network. Journal of the Air and Waste Management Association.

Figure 1

Air Quality Monitoring in National Parks for 1997, by Type

Parks in underline indicates partial funding provided by other agency

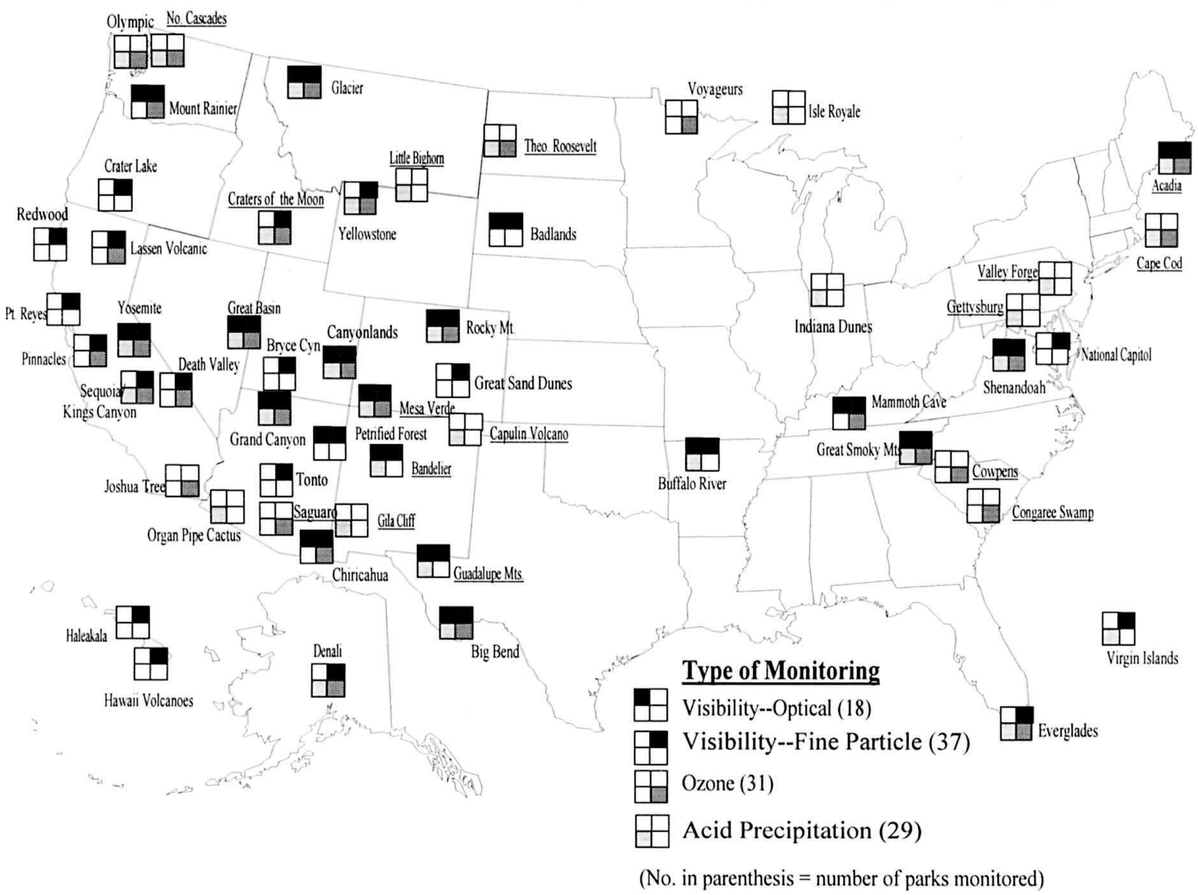


Figure 2. Average fine particle concentrations (in μg/m^3) for each site in the IMPROVE network for March 1992 through February 1995.

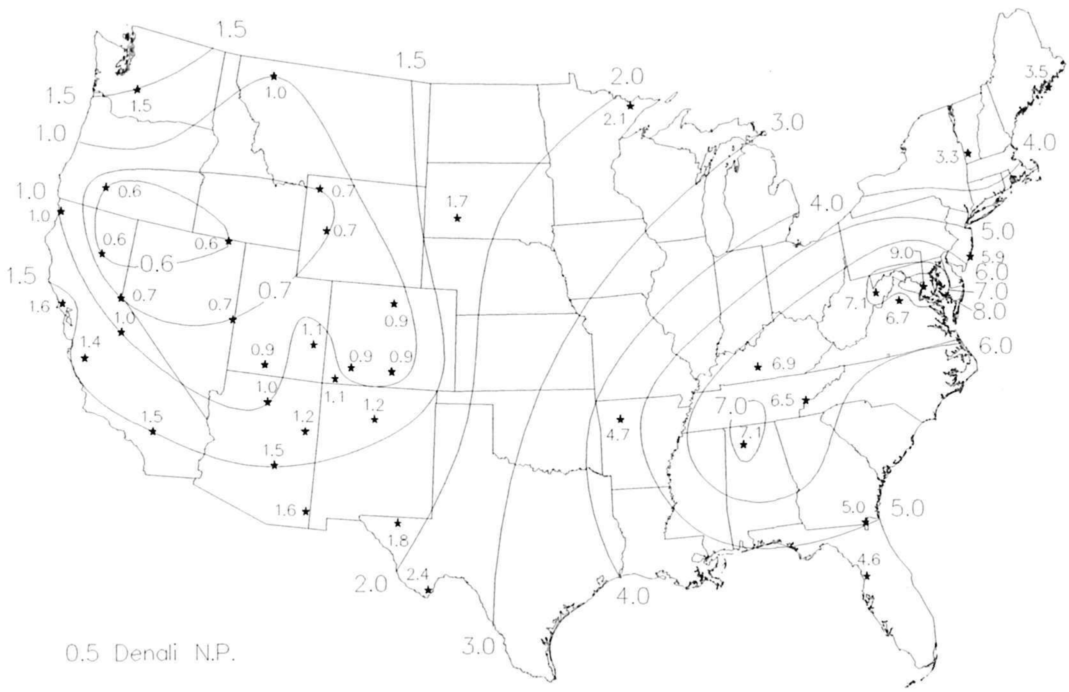


Figure 3 Average fine sulfate aerosol concentrations (in $\mu g/m^3$) for each site in the IMPROVE network for March 1992 through February 1995.

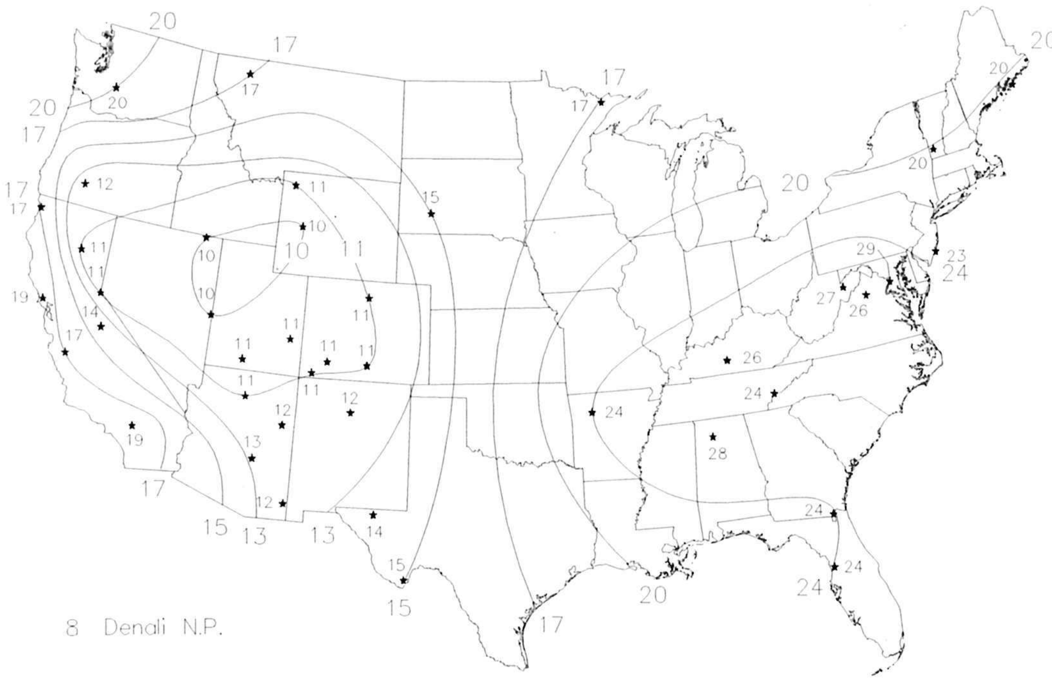
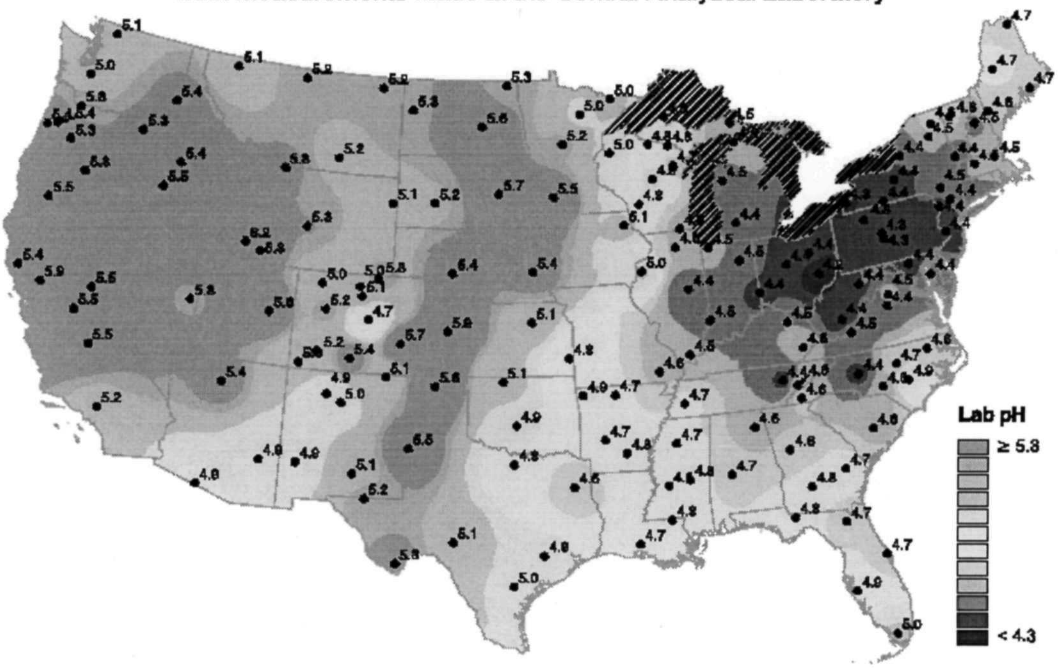


Figure 4 Average visibility impairment in deciviews calculated from total (Rayleigh included) reconstructed light extinction for three years of IMPROVE, March 1992 through February 1995.

Figure 5

Hydrogen ion concentrations as pH for 1996
from measurements made at the Central Analytical Laboratory



National Atmospheric Deposition Program/National Trends Network

Printed: 09/01/97

Figure 6

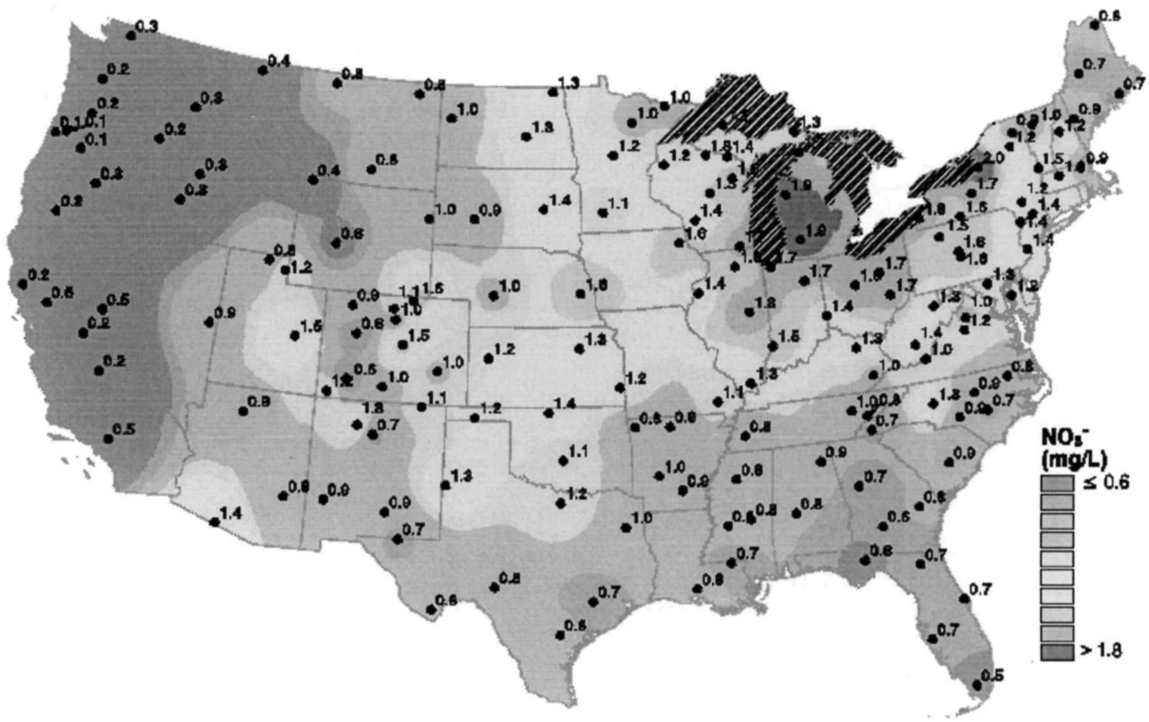
Sulfate ion concentrations for 1996

National Atmospheric Deposition Program/National Trends Network

Printed: 09/01/97

Figure 7

Nitrate ion concentrations for 1996



National Atmospheric Deposition Program/National Trends Network

Printed: 09/01/97

Figure 8

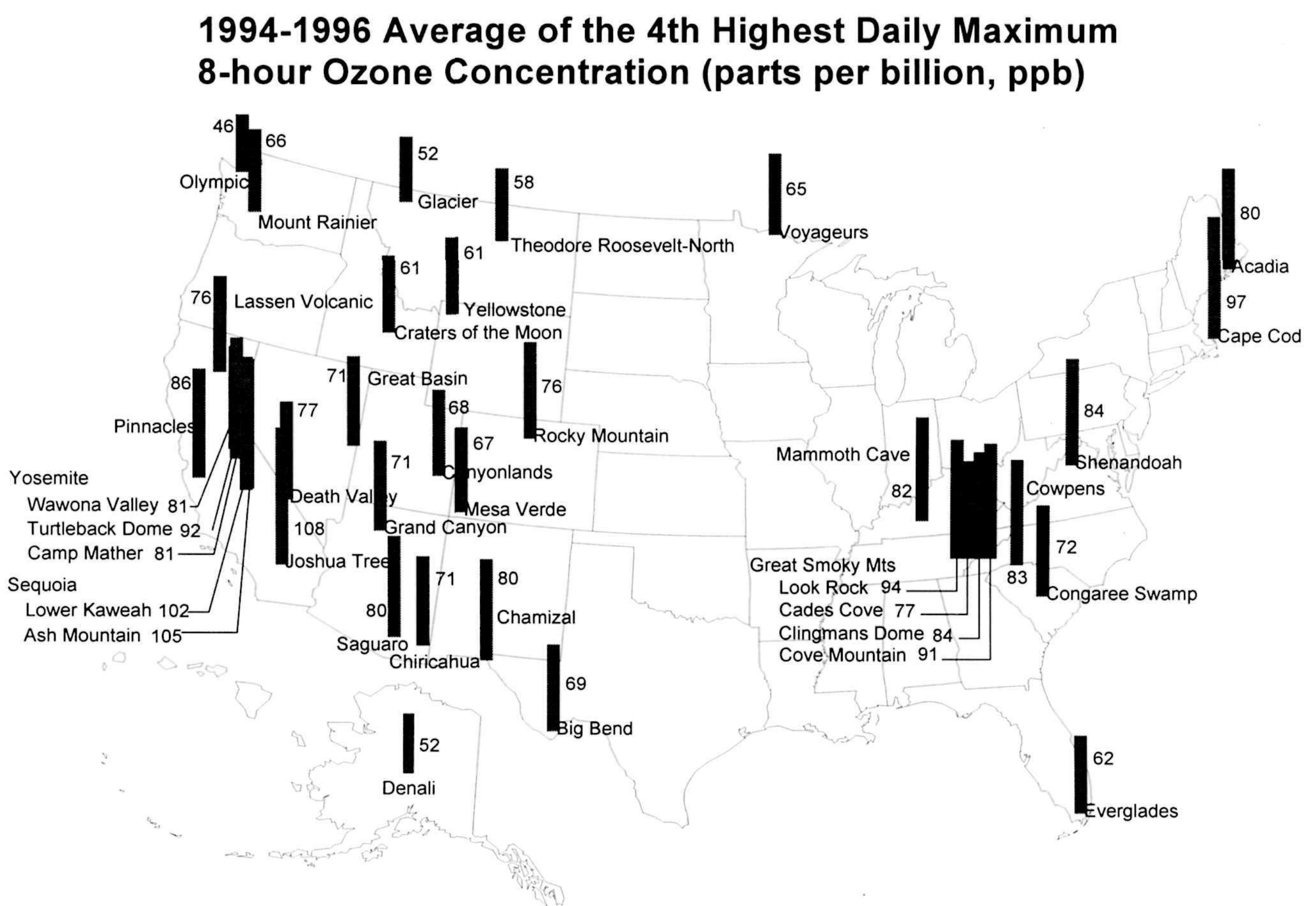

1994-1996 Average of the 4th Highest Daily Maximum
8-hour Ozone Concentration (parts per billion, ppb)
46
Olympic
66
Mount Rainier
52
Glacier
58
Theodore Roosevelt-North
65
Voyageurs
80
Acadia
97
Cape Cod
61
Yellowstone
61
Craters of the Moon
76
Lassen Volcanic
86
Pinnacles
71
Great Basin
68
76
Rocky Mountain
77
67
Canyonlands
Mesa Verde
71
Death Valley
108
Grand Canyon
Joshua Tree
84
Shenandoah
Mammoth Cave
82
Cowpens
83
72
Congaree Swamp
Yosemite
Wawona Valley 81
Turtleback Dome 92
Camp Mather 81
Sequoia
Lower Kaweah 102
Ash Mountain 105
80
Saguaro
71
Chiricahua
80
Chamizal
69
Big Bend
Great Smoky Mts
Look Rock 94
Cades Cove 77
Clingmans Dome 84
Cove Mountain 91
52
Denali
62
Everglades

Figure 9

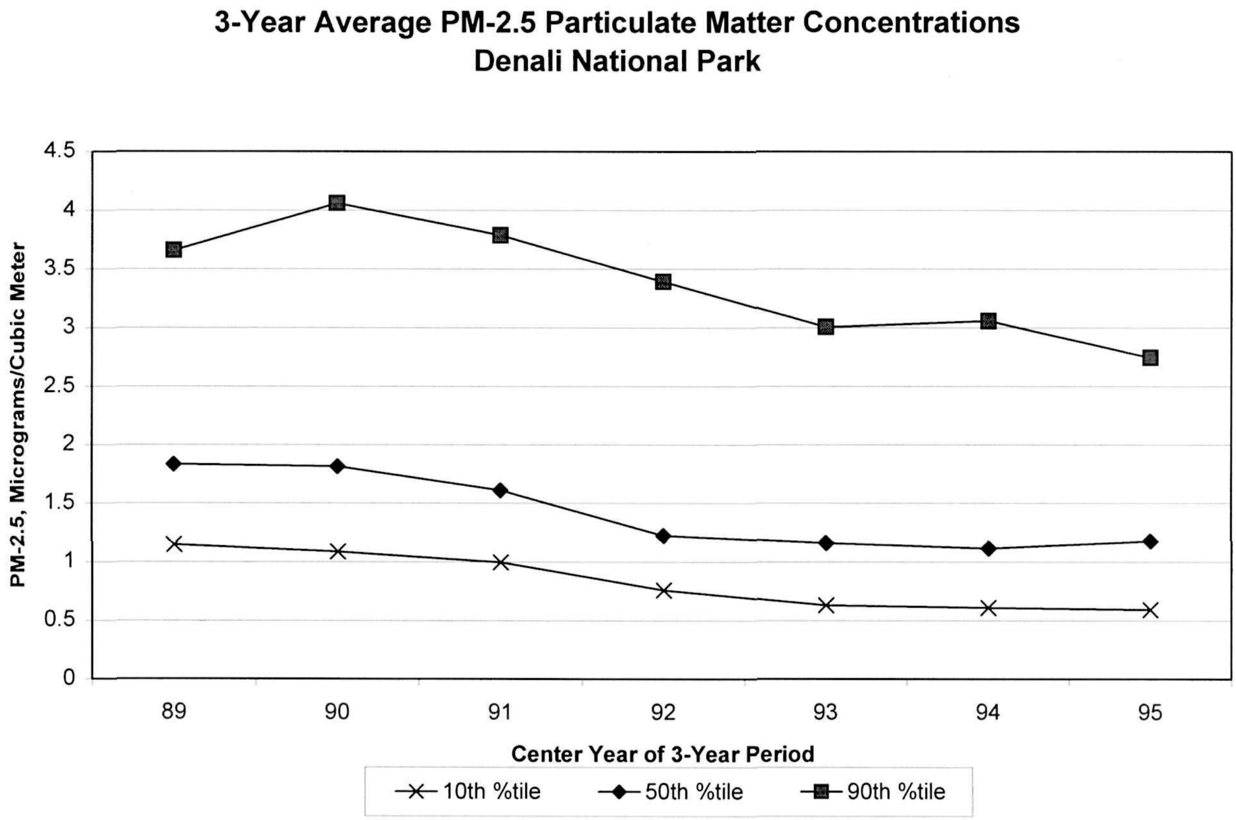

3-Year Average PM-2.5 Particulate Matter Concentrations
Denali National Park
PM-2.5, Micrograms/Cubic Meter
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
89
90
91
92
93
94
95
Center Year of 3-Year Period
10th %tile
50th %tile
90th %tile

Figure 10

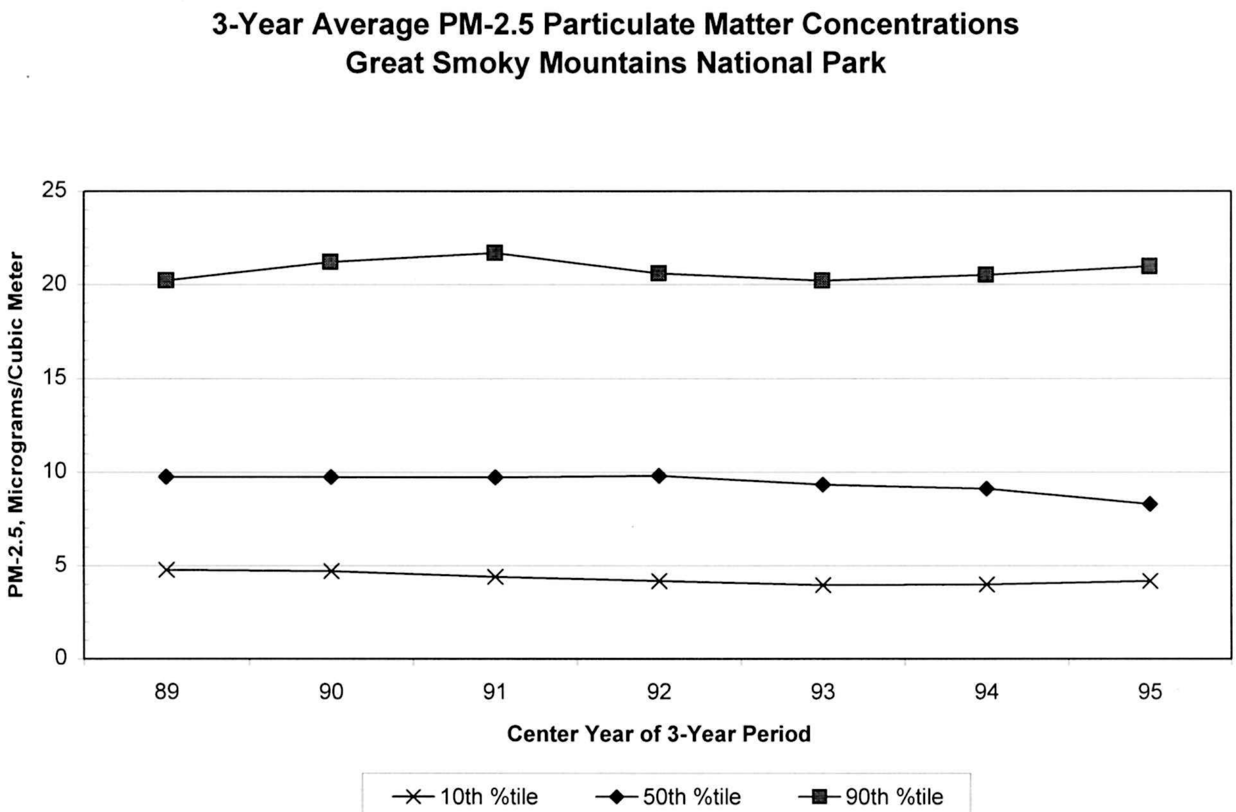

3-Year Average PM-2.5 Particulate Matter Concentrations
Great Smoky Mountains National Park
PM-2.5, Micrograms/Cubic Meter
25
20
15
10
5
0
89
90
91
92
93
94
95
Center Year of 3-Year Period
10th %tile
50th %tile
90th %tile

Figure 11

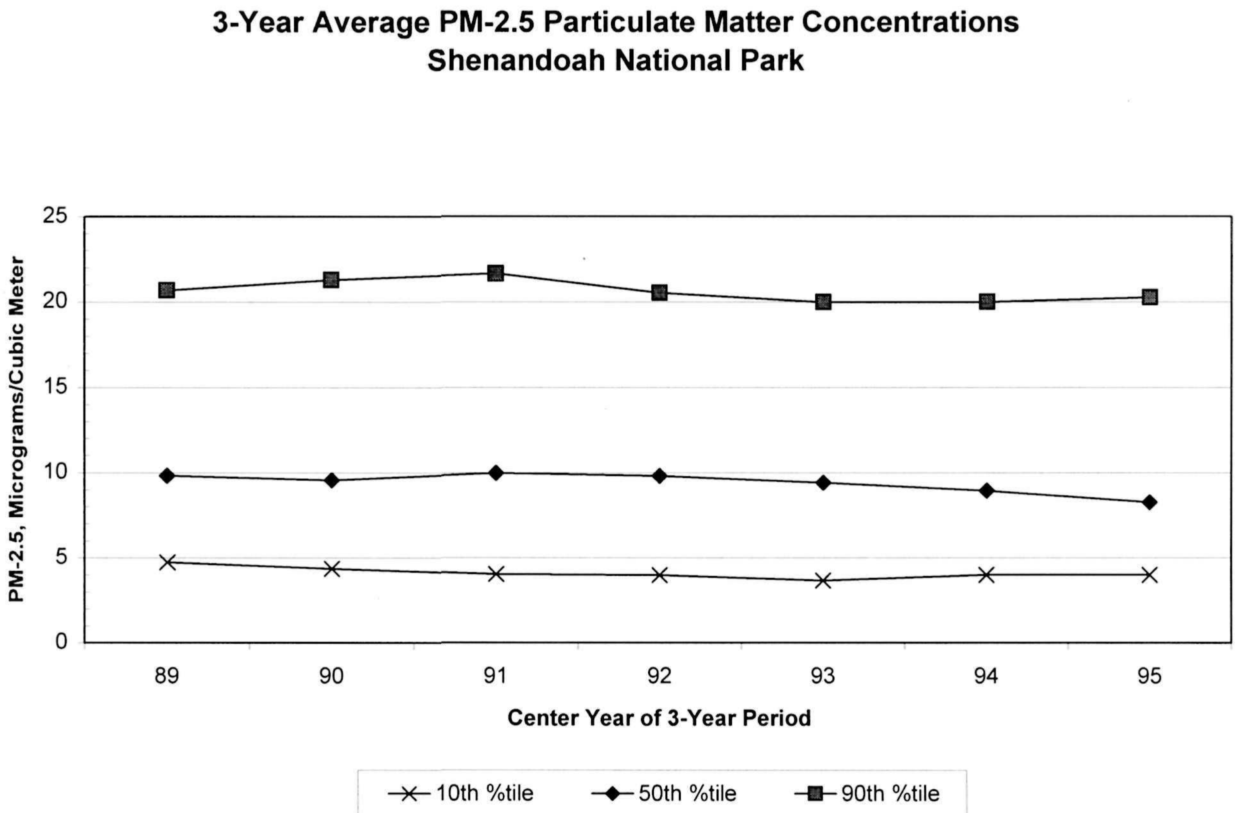
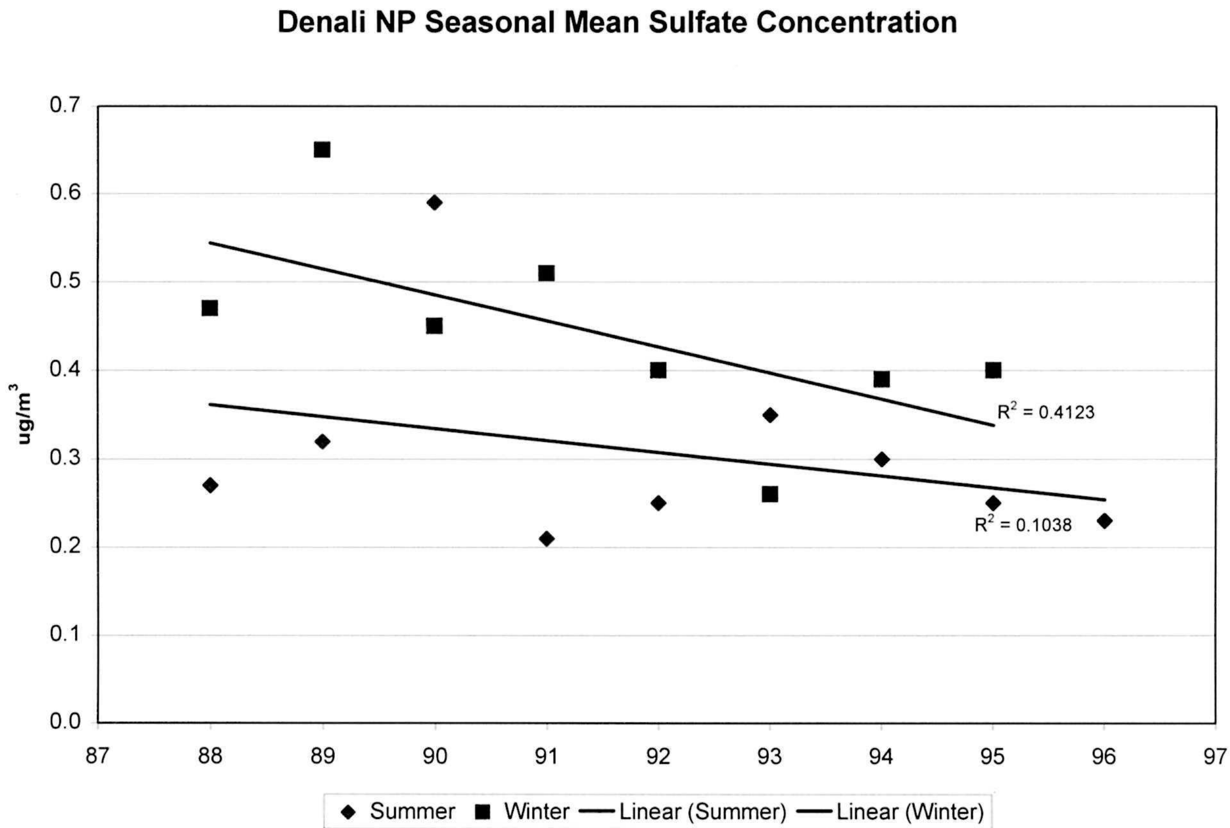

3-Year Average PM-2.5 Particulate Matter Concentrations
Shenandoah National Park
PM-2.5, Micrograms/Cubic Meter
0
5
10
15
20
25
89
90
91
92
93
94
95
Center Year of 3-Year Period
10th %tile
50th %tile
90th %tile

Figure 12



Denali NP Seasonal Mean Sulfate Concentration
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ug/m^3
87
88
89
90
91
92
93
94
95
96
97
R^2 = 0.4123
R^2 = 0.1038
Summer
Winter
Linear (Summer)
Linear (Winter)

Figure 13

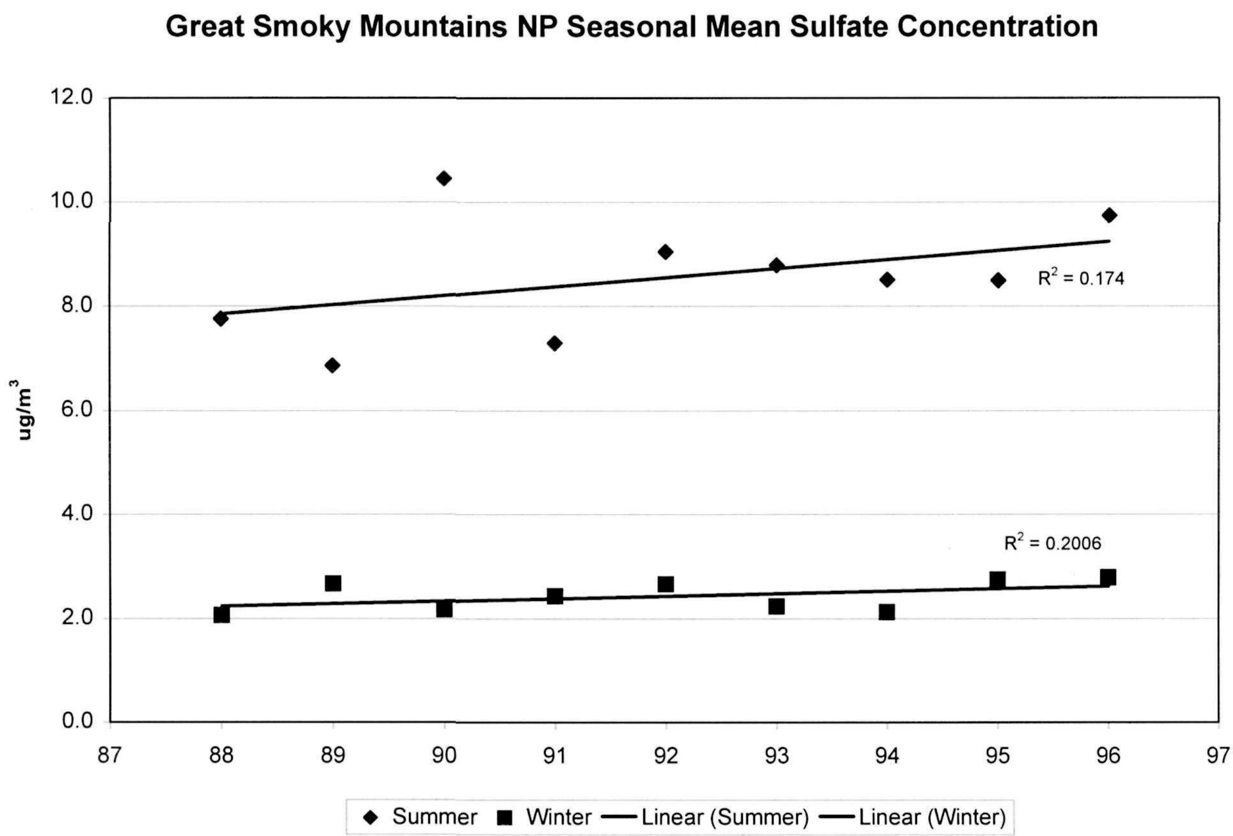

Great Smoky Mountains NP Seasonal Mean Sulfate Concentration
12.0
10.0
8.0
6.0
4.0
2.0
0.0
ug/m3
R2 = 0.174
R2 = 0.2006
87
88
89
90
91
92
93
94
95
96
97
Summer
Winter
Linear (Summer)
Linear (Winter)

Figure 14

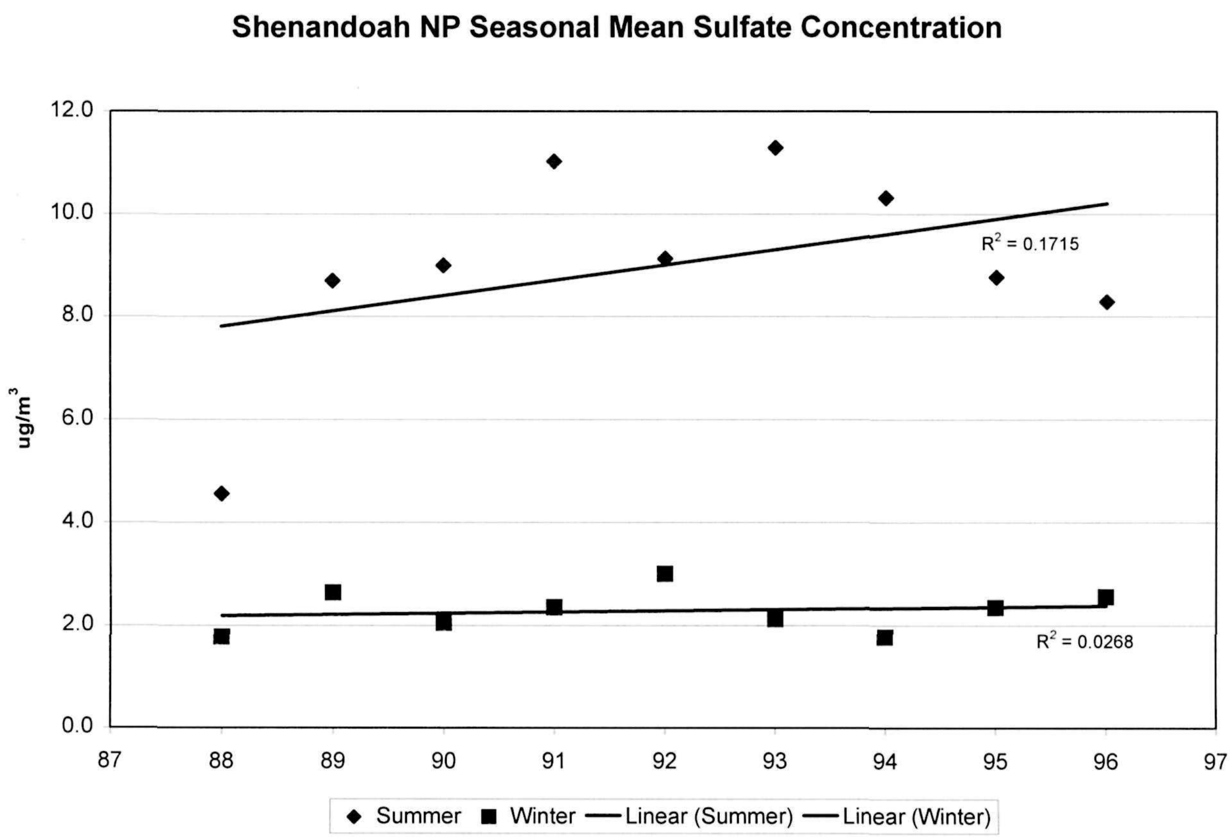
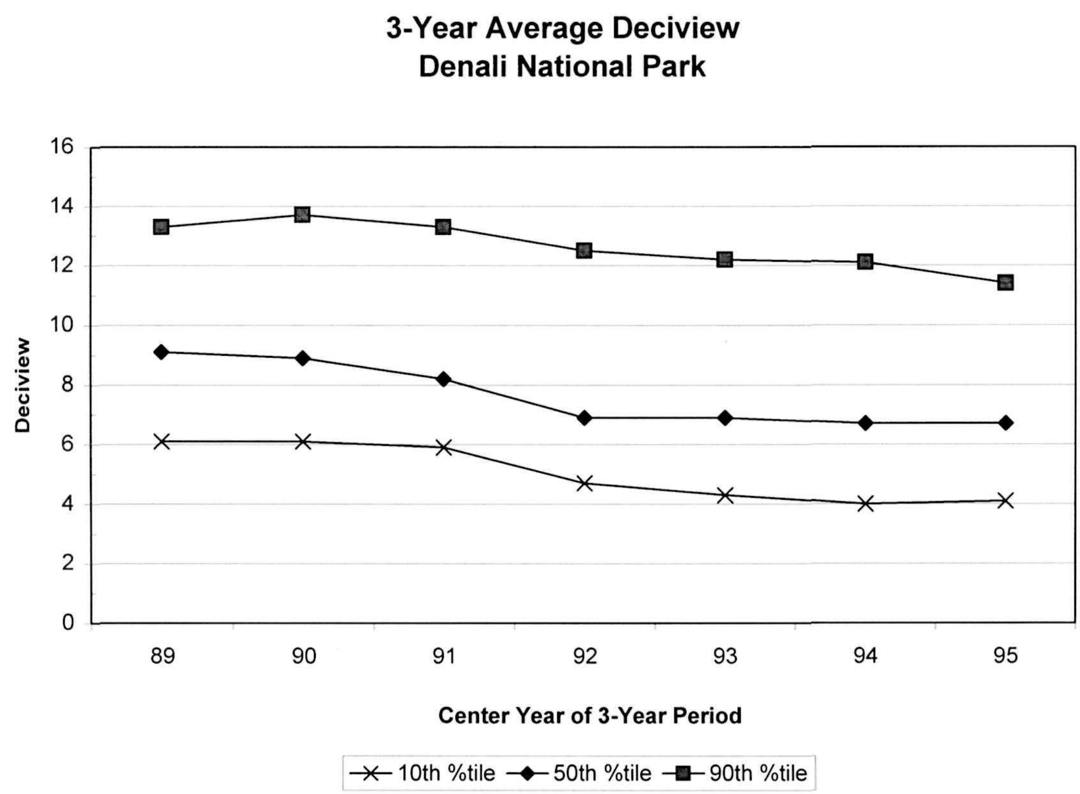

Shenandoah NP Seasonal Mean Sulfate Concentration
12.0
10.0
8.0
6.0
4.0
2.0
0.0
ug/m3
87
88
89
90
91
92
93
94
95
96
97
R2 = 0.1715
R2 = 0.0268
Summer
Winter
Linear (Summer)
Linear (Winter)

Figure 15



3-Year Average Deciview
Denali National Park
Deciview
16
14
12
10
8
6
4
2
0
89
90
91
92
93
94
95
Center Year of 3-Year Period
10th %tile
50th %tile
90th %tile

Figure 16

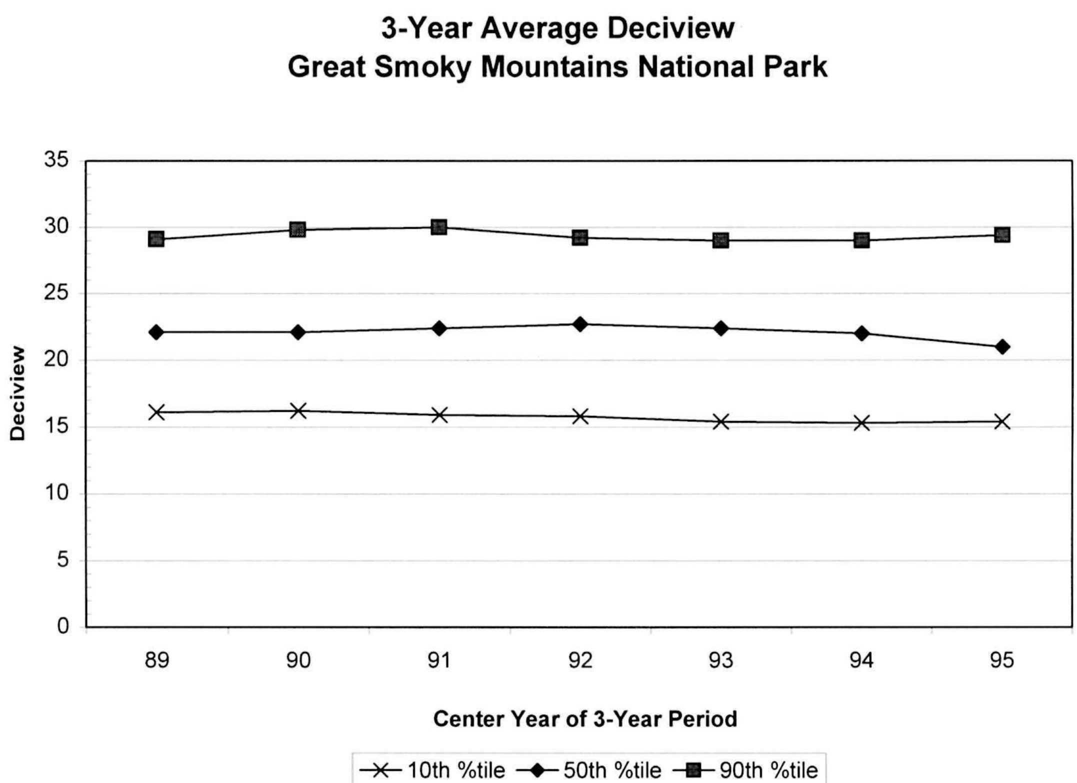
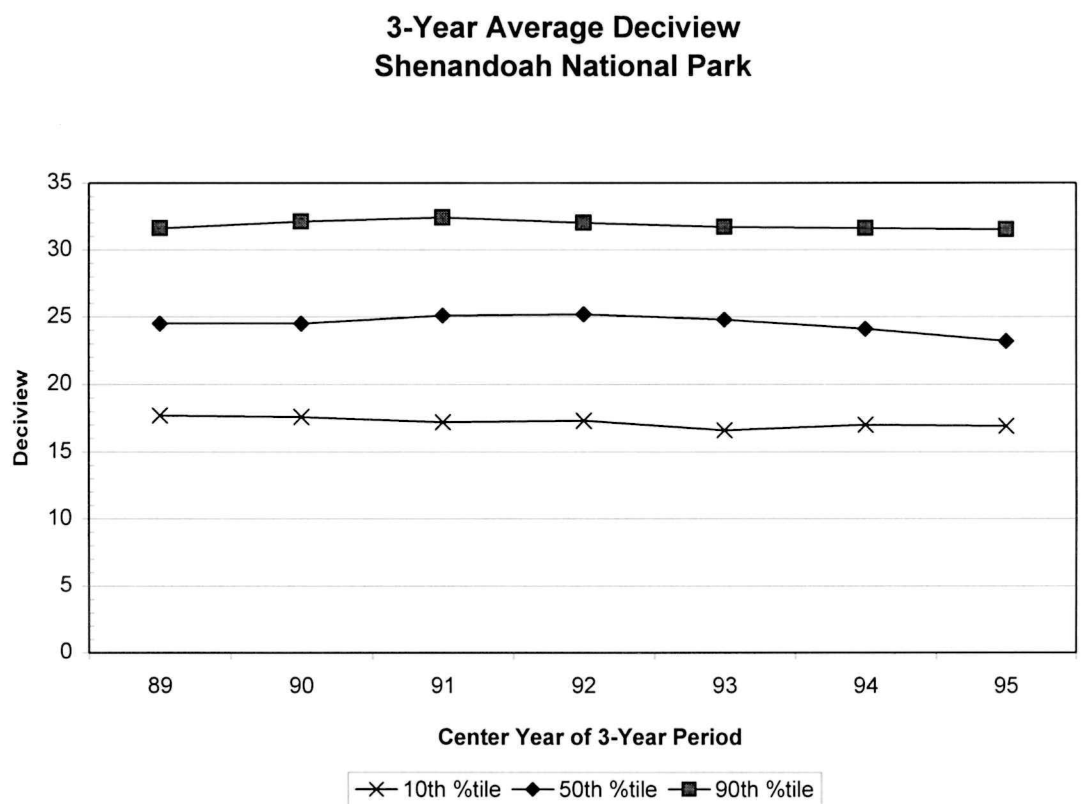

3-Year Average Deciview
Great Smoky Mountains National Park
Deciview
35
30
25
20
15
10
5
0
89
90
91
92
93
94
95
Center Year of 3-Year Period
10th %tile
50th %tile
90th %tile

Figure 17



SOURCE: Air Resources Division, National Park Service, U.S. Department of the Interior

Entered: 1999