Air Quality

Ami Pate

Objectives
Determine seasonal and inter-annual trends in nitrogen deposition, sulfur deposition and visibility reducing pollutants.

Introduction
Federal land management areas are classified as Class I, II, or III areas to facilitate implementation of the Clean Air Act. Mandatory Class I areas, the most protected from increases in air pollution, were designated by Congress in 1977. The Class I areas consist primarily of national parks and national forest lands with designated wilderness. Since Organ Pipe Cactus National Monument (OPCNM) became a wilderness area in 1978, the monument falls under Class II status. Class II areas also receive protection under the act, but to a lesser degree. The Sonoran Desert Inventory & Monitoring Network has identified several sensitive air quality related values for OPCNM: visibility, vegetation, surface waters, soils and fish and wildlife.

Visibility is an important air quality related value to NPS visitors. Air and light pollution affect the visual experience of wilderness vistas, landscape features and dark night skies. Impairment occurs as a result of the scattering and absorption of light by particles and gases in the atmosphere. Emissions of sulfur dioxide (SO_2) into the atmosphere and resulting fine particulate (less than 2.5 microns) formation are a major cause of visibility impairment, and contribute to deposition to sensitive terrestrial and aquatic ecosystems.

Atmospheric deposition of nitrogen and sulfur compounds affects ecosystems in a variety of ways, including acidification, fertilization, and eutrophication. In the Sonoran Desert Network, nitrogen deposition and its fertilization effects can cause changes in soil that affect microorganisms, plants, and trees, ultimately leading to changes in plant community structure and diversity (NPS 2005).

Although a copper smelter 24km north of the monument in the town of Ajo was closed in 1983 and local visibility-impairing emissions were reduced, new threats to air resources are increasing. Agricultural activities on the Mexican border affecting air quality include field burning, garbage burning, pesticide and herbicide use, and truck traffic on dirt roads. New industrial and urban developments are planned in the Sonoyta, Sonora area and increasing tourist and truck traffic through the monument have the potential to dramatically increase air pollutants. OPCNM is also affected by regional haze sources such as urban southern California, the industrialized Gulf coasts of Mexico and Texas and the smelter regions of Arizona and New Mexico (Baron 1991). More proximate sources of air pollution include metropolitan Phoenix and Hermosillo, Sonora, and a power plant at Puerto Libertad, Sonora.

Cooperative Agencies
Currently the monument operates sites for the National Atmospheric Deposition Program and the Arizona Department of Environmental Quality, to monitor aspects of air quality. Additionally, OPCNM participated in a NPS Air Resources Division passive ozone monitoring study 1996-2003. The monument also funded a visibility camera, 1997-2004.

National Atmospheric Deposition Program (NADP)
This program was initiated in 1978 to track geographical patterns and temporal trends in the chemical climate of North America. Rain samples are collected weekly at sites throughout the country and chemistry measurements are performed both in the field and at a Central Analytical Laboratory. It is administered by the National Atmospheric Deposition Program/

National Trends Network (NADP/NTN) Coordination Office at Colorado State University. Various cooperating agencies across the country provide personnel and equipment for the program. OPCNM, 1 of 4 current NADP sites in Arizona, began sampling in 1980.

Arizona Department of Environmental Quality (ADEQ)

ADEQ regulates air quality as mandated by the Federal Clean Air Act and Arizona State Statutes. Environmental Protection Agency plans for air quality standards are followed by the Department. Among ADEQ projects is ambient monitoring of airborne particulates with a dichotomous (dichot) sampler. Sites monitored by ADEQ include areas with urban-related pollution, emissions from industrial facilities, and dust from agricultural operations and also areas distant from these sources, such as National Park Service sites. A dichot sampler, measuring coarse and fine particulates less than 10 microns in diameter (PM_{10}), was in place at OPCNM until 2002 (Before that, a high volume air sampler measured particulates with less resolution than the dichot method.) In 2003 an IMPROVE (Interagency Monitoring of Protected Visual Environments) site was installed.

IMPROVE

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program is a cooperative air quality monitoring effort between federal land managers; regional, state, and tribal air agencies; and the Environmental Protection Agency. The IMPROVE monitoring program was established in 1985 to aid in the implementation of the 1977 Clean Air Act goal of preventing future and remedying existing visibility impairment in Class I areas. The network began operating in 1988 and currently consists of 175 monitoring sites. The network is working towards reducing regional haze by establishing current visibility conditions and identifying the chemical species and emission sources responsible for existing visibility impairment.

In 2004, a nephelometer was installed at the IMPROVE monitoring shed. Nephelometers measure the amount of light scattered by particles and gases in the atmosphere. This measurement combined with estimates of the obsorption coefficient (from aerosol monitoring filters) can be used to determine the average total light extinction.

National Park Service Gaseous Pollutant Monitoring Program

In 1996, the NPS Air Quality Division initiated a passive ozone sampling program as a low cost method to monitor ozone levels. The samplers were designed to provide basic information on ozone exposures and provide a baseline by which the need for additional, more intensive monitoring could be judged. Monitoring involved exposing the passive samplers for one week period during the 3-5 month summer “ozone season,” retrieving the samplers, and mailing them to the analysis contractor. This program was discontinued in 2004 due to budget cuts.

From 1997-2004, Organ Pipe Cactus National Monument operated an automatic visibility camera to document baseline vista conditions on the U.S./Mexico border near Lukeville, AZ and Sonoyta, Sonora. In 2000, the monument cooperated with the Pinacate Biosphere Reserve to install an automatic visibility camera in the reserve, also to document baseline visibility conditions on the U.S./Mexico border.

Methods

National Atmospheric Deposition Program

The OPCNM NADP site equipment consists of an Aerochem Metrics wet/dry precipitation collector and a Belfort Universal rain gauge with event pen. During precipitation events, the wet-side collection bucket was automatically uncovered, then covered when the event had ended. Cumulative weekly rain samples were collected. The Belfort Universal rain gauge recorded precipitation event times and precipitation amount on chart paper. In the OPCNM lab, the bucket was weighed to determine precipitation amount. If rainfall was of sufficient volume, measurements of pH and specific conductance were then made (These field chemistry measurements were discontinued in 2005). The samples were sent to the NADP Central Analytical Lab in Champaign, Illinois, where more extensive chemistry measurements were performed: specific conductance, ph, hydrogen, ammonium, calcium, magnesium, sodium, potassium, sulfate, nitrate and chloride.

Arizona Department of Environmental Quality

The dichotomous particulate (PM_{10}) sampler at Organ Pipe was located near the NADP sampling equipment. Two filters collected coarse and fine particulate samples for a 24-hour period every six days. The filters were sent to ADEQ for gravimetric and optical density analysis. This sampler was discontinued in 2002 with the installation of a more comprehensive IMPROVE particulate sampling site.

IMPROVE

The IMPROVE particle monitor consists of four independent sampling modules. Three modules collect only fine particles (PM2.5), while the fourth collects both fine and coarse particles (PM10). The IMPROVE monitor measures mass, chemical elements, sulfate, nitrate, organics, and elemental carbon. The samplers run for 24 hours every third day collecting the particulate matter on filters. These filters are retrieved once a week and sent to contracted laboratories for physical and chemical analyses.

The nephelometer is mounted on a north-facing 14-foot tower at the IMPROVE monitoring site. The nephelometer draws ambient air into a chamber where light of known intensity is emitted over a a path parallel to a photodiode detector. A direct estimate of atmoshpheric scattering is made by measuring the light scattered from the front, back and sides of the optical chamber. Data is logged by a Campbell Scientific logger, and transmitted by phone modem to data managers.

National Park Service Gaseous Pollutant Monitoring Program

The passive ozone samplers consisted of cylinders containing 2 nitrite-coated filter pads and a clip-on badge support. Each sampler was placed at a height of 3 m beneath a rain shield and exposed to ambient air for 7 days. When the devices were exposed to air, ozone oxidized the nitrite coating on the filters to nitrate. After exposure, the devices were returned to a laboratory where ion chromatography was used to determine the amount of nitrate formed and hence the overall ozone exposure.

The OPCNM visibility camera was installed 15 miles north of the U.S./Mexico border to capture a southern vista of the Sierra Cubabi in Sonora. A timer-activated camera took slides daily at 1500. Slides were processed and qualitative visibility analysis was performed by NPS contractor Air Resource Specialists, Inc. The Pinacate Biosphere Reserve camera was installed approximately 20 miles south of the U.S./Mexico border, with a vista target of the Sierra Pinta in southwestern Arizona.

Results

National Atmospheric Deposition Program

The data from these sites were included in national summary maps of weighted mean concentrations and deposition estimates for various ions. These national summary maps along with annual, seasonal, and weekly data summaries for each site in the NADP network are available from the program website: http://nadp.sws.uiuc.edu/

Arizona Department of Environmental Quality

Dichot particulate sampler results through 1997 were sent to OPCNM. It is unknown whether 1998-2002 data summaries are available.

IMPROVE

Data summaries are available at the IMPROVE website: http://vista.cira.colostate.edu/IMPROVE/

National Park Service Air Quality Division
Summaries from the NPS passive ozone program are available at the NPS website: http://www2.nature.nps.gov/air/Studies/Passives.cfm

Representative visibility conditions for the monument, 1997-2004, are shown in Figure 1.

Discussion

National Atmospheric Deposition Program
NH_4, NO_3, SO_4 and pH results for 1997-2004 precipitation samples (Figures 12-19 through 12-26) followed a pattern similar to previous years. At OPCNM, climate is characterized by 2 rainfall seasons, winter storms generally originating from the Pacific Ocean, and summer/fall monsoons from the Gulf of Mexico and Gulf of California. Consistently, precipitation samples have higher pH and lower NO_3 and SO_4 concentrations for February–March winter rainfall samples, and much lower pH (more acidic) during summer and fall winter months, with associated higher NO_3 and SO_4. NADP annual trend plots from 1980-2004 show a post-Ajo copper smelter peak of sulfate levels in the period of 1996-1999, and a corresponding lower pH. Trends for NO_3 and NH_4 are increasing.

IMPROVE
Comparing 1991-1997 dichot results for PM_{10} and SO_4 with 2003-2004 IMPROVE particulate sampler results for the same parameters shows slightly higher concentrations in 2003-2004 (Figures 12-3 and 12-4). Also, peak values for both parameters are much higher than earlier years. The seasonal patterns were similar as well, with the lowest concentrations usually in the winter months, and elevated concentrations in spring and summer. Since the fine particulates present in PM_{10} can impair visibility, these results may explain the monument's generally good winter visibility and frequently impaired summer and fall visibility. In the desert Southwest, sulfates account for approximately 60% of visibility impairment (Malm 1992).

Also, 2003-2004 IMPROVE results for SO_4, NO_3, organic carbon, soil, and $PM_{2.5}$ (very fine particulate matter) were compared between OPCNM, Saguaro National Park, and Chiricahua National Monument. (Figures 12-5 through 12-14). SO_4 concentrations were much higher at OPCNM than at the southeastern Arizona sites.

A study showed that Arizona/Sonora copper smelters and southern California refining, generating, and auto emissions were the most probable sources of sulfates at Chiricahua (Malm 1999). However, with recent smelter closures and reduction of sulfur levels in California fuels, a decline in sulfate levels in the southwest should be occurring. A study of temporal trends in the U.S. showed a decrease in sulfate concentrations in monitoring sites west of the Rocky Mountains (Malm et al. 2002). Further data analysis and source attribution modeling would be useful in explaining the trend of increasing SO_4 at OPCNM.

Nitrate levels were more pronounced for OPCNM in the late summer- winter months than at the other sites. All sites recorded a spike in organic carbon concentrations in late October 2003, coinciding with the southern California fire events.

Passive ozone
From 1997 to 2003, weekly ozone concentrations followed a trend of higher values in early summer than late summer (Figures 12-1 and 12-2).
In 1999, the highest and lowest values were measured: 59.8 parts per billion in late May, and 18.7 parts per billion in late August.

Visibility
The Pinacate visibility camera recorded many more layered haze events than the OPCNM visibility camera (Tables 12-1 and 12-2). The Pinacate camera captured a vista farther to the west, which may be influenced by agriculture and development in Yuma, Arizona and San Luis R.C., Sonora. Figure 12-31 shows a regional haze event in June 2002 at OPCNM. Figure 12-32 shows a layered haze event in December 2002 at the

Pinacate Biosphere Reserve.

Recommendations

OPCNM's air quality monitoring program has documented many air quality seasonal trends and poor air quality events. Using OPCNM climate and air quality data in a back trajectory analysis would be one way to determine sources for visibility impairment and acidic rainfall events. This information could be used in interpretive displays to promote sustainable practices. The NPS Air Resources Division and the Arizona Department of Environmental Quality would be possible sources of assistance for this analysis.

Acknowledgements

Charles Conner

Literature Cited

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EPA. 1997. National Air Quality and Emissions Trend Report.

Malm, W.C. 1992. Characteristics and origins of haze in the continental United States. Earth-Science Reviews, 33:1–36.

Malm, W.C. 1999. Introduction to Visibility. Cooperative Institute for Research in the Atmosphere, NPS Visibility Program, Colorado State University, Fort Collins, CO. 79 p.

Malm, W.C., B.A. Schichtel, R.B. Ames, K.A. Gebhart. 2002. A 10-year spatial and temporal trend of sulfate across the United States. Journal of Geophysical Research, 107(D22).

Table 12-1. Qualitative 35mm slide analysis, Pinacate visibility camera. Slides were taken daily at 1200. “Uniform” haze condition includes sky condition codes “clear,” “scattered clouds,” “overcast,” and “haze concealed.”

Pinacate Biosphere Reserve	Uniform (Dataset includes atmospheric conditions)	Ground Based Layered Haze	Elevated Layered Haze	Multiple Haze Layers	Weather Obscures Scene	Cannot Be Determined
Fall 2000	85.4%	12.2%	--	--	2.4%	--
Win 2001	62.9%	25.8%	2.2%	2.2%	1.1%	5.6%
Spr 2001	97.8%	2.2%	--	--	--	--
Sum 2001	100%	--	--	--	--	--
Fall 2001	98.9%	--	1.1%	--	--	--
Win 2002	79.8%	13.5%	3.4%	3.4%	--	--
Spr 2002	100%	--	--	--	--	--
Sum 2002	98.6%	1.4%	--	--	--	--
Win 2003	67.8%	17.8%	3.3%	2.2%	8.9%	--
Spr 2003	93.9%	3%	--	--	--	3%
Sum 2003	100%	--	--	--	--	--
Fall 2003	90.6%	1.2%	2.4%	1.2%	3.5%	1.2%
Win 2004	90.1%	1.1%	3.3%	3.3%	2.2%	--
Spr 2004	34%	--	--	--	--	66%
Sum 2004	46.8%	--	--	--	6.5%	46.8%

Table 12-2. Qualitative 35mm slide analysis, Organ Pipe Cactus N.M. visibility camera. Slides were taken daily at 1500. "Uniform" haze condition includes sky condition codes "clear," "scattered clouds," "overcast," and "haze concealed."

Organ Pipe Cactus N.M.	Uniform (Dataset includes atmospheric conditions)	Ground Based Layered Haze	Elevated Layered Haze	Multiple Haze Layers	Weather Obscures Scene	Cannot Be Determined
Fall 1997	94.3%	0.6%	--	--	5.2%	--
Win 1998	86.9%	6.3%	--	--	5.6%	1.3%
Spr 1998	94.0%	0.5%	--	0.5%	4.9%	--
Sum 1998	99.4%	--	--	--	--	0.6%
Fall 1998	99.4%	--	--	--	--	0.6%
Win 1999	91.9%	1.2%	0.6%	--	--	6.4%
Spr 1999	98.8%	0.6%	--	--	--	0.6%
Sum 1999	99.4%	--	--	--	--	0.6%
Fall 1999	94.4%	5.6%	--	--	--	--
Win 2000	86.0%	14.0%	--	--	--	--
Spr 2000	100%	--	--	--	--	--
Sum 2000	100%	--	--	--	--	--
Fall 2000	100%	--	--	--	--	--
Win 2001	97.8%	2.2%	--	--	--	--
Spr 2001	68.5%	1.1%	--	--	--	30.4%
Sum 2001	67%	2.2%	--	--	1.1%	29.7%
Fall 2001	100%	--	--	--	--	--
Win 2002	97.5%	2.5%	--	--	--	--
Spr 2002	97.8%	2.2%	--	--	--	--
Sum 2002	100%	--	--	--	--	--
Fall 2002	97.8%	--	--	--	2.2%	--
Win 2003	89.3%	3.6%	--	--	7.1%	--
Spr 2003	94.2%	2.9%	--	--	2.9%	--
Sum 2003	95.6%	3.3%	--	--	1.1%	--
Fall 2003	94.3%	1.4%	--	--	4.3%	--
Win 2004	97.8%	2.2%	--	--	--	--

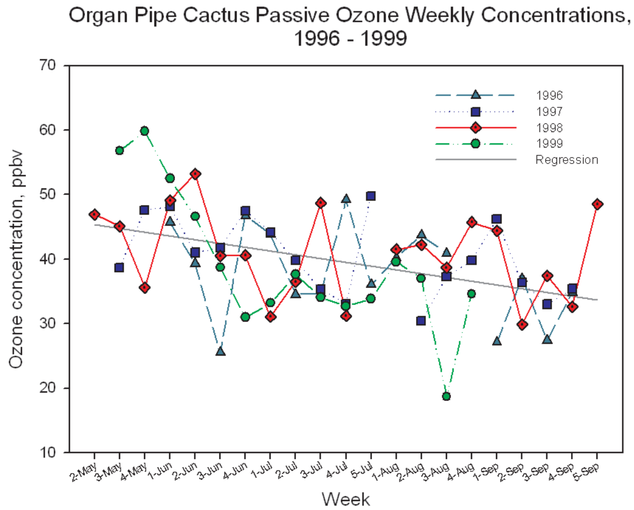

Figure 12-1. Passive ozone monitoring results, 1996-1999, Organ Pipe Cactus N.M.

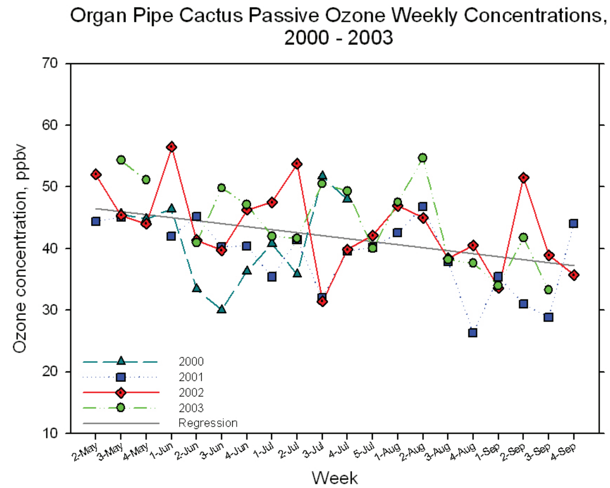

Figure 12-2. Passive ozone monitoring results, 2000-2003, Organ Pipe Cactus N.M.

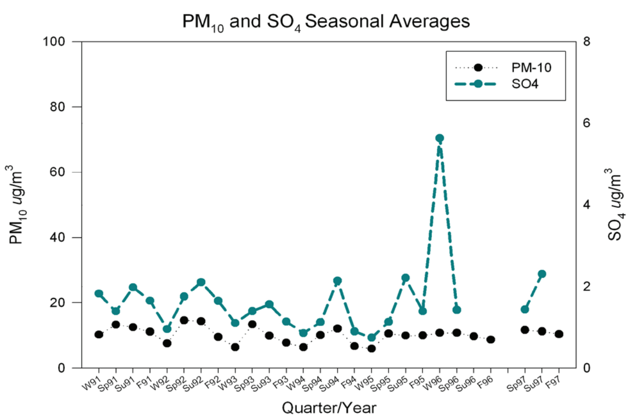

Figure 12-3. PM_{10} and SO_4 concentrations from dichot particulate sampler, 1991-1997, Organ Pipe Cactus N.M.

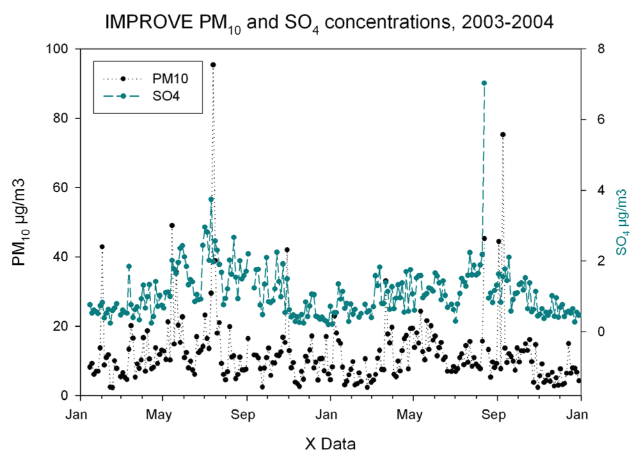

Figure 12-4. PM_{10} and SO_4 concentrations from IMPROVE particulate sampler, 2003-2004, Organ Pipe Cactus N.M.

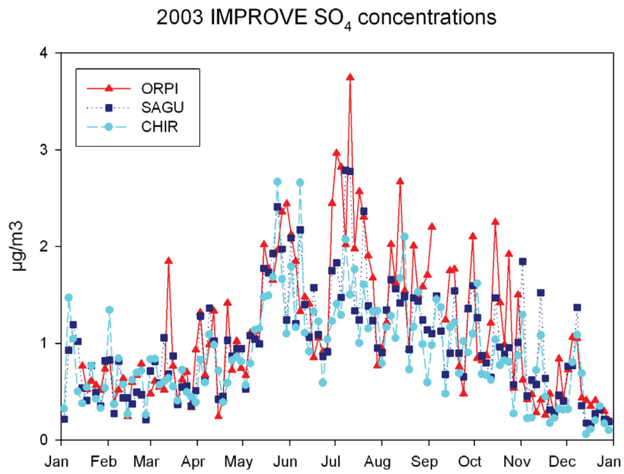

Figure 12-5. 2003 SO_4 concentrations for Organ Pipe Cactus National Monument, Saguaro National Park and Chiricahua National Monument. Data from IMPROVE particulate sampler.

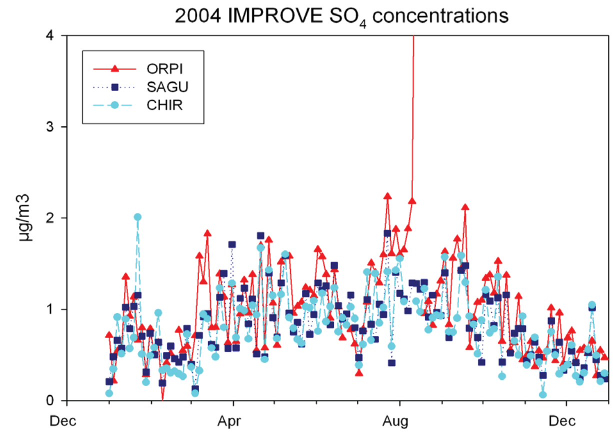

Figure 12-6. 2004 SO_4 concentrations for Organ Pipe Cactus National Monument, Saguaro National Park and Chiricahua National Monument. Data from IMPROVE particulate sampler. (Value out of range = 7.03 µg/m^3 on August 13, 2004.)

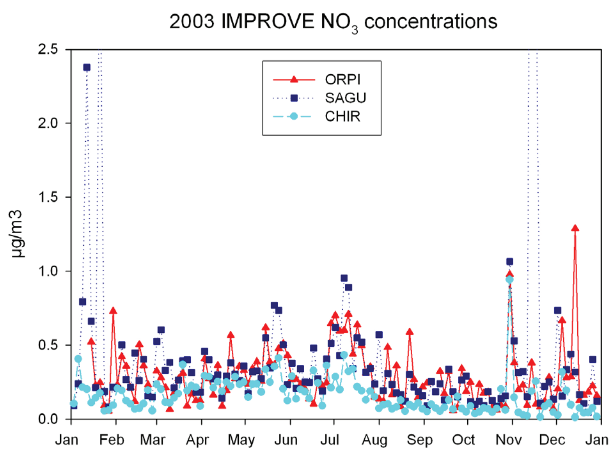

Figure 12-7. 2003 NO_3 concentrations for Organ Pipe Cactus National Monument, Saguaro National Park and Chiricahua National Monument. Data from IMPROVE particulate sampler. (Values out of range = 3.27 µg/m^3 on January 21, 2003 and 3.13 µg/m^3 on November 17, 2003.)

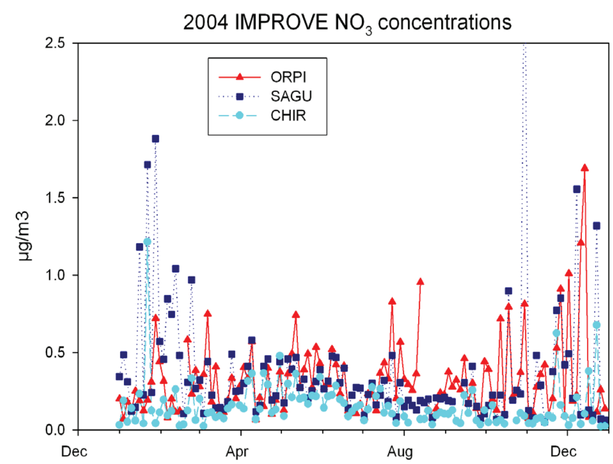

Figure12-8. 2004 NO_3 concentrations for Organ Pipe Cactus National Monument, Saguaro National Park and Chiricahua National Monument. Data from IMPROVE particulate sampler. (Value out of range = 3.38 µg/m^3 on October 30, 2004.)

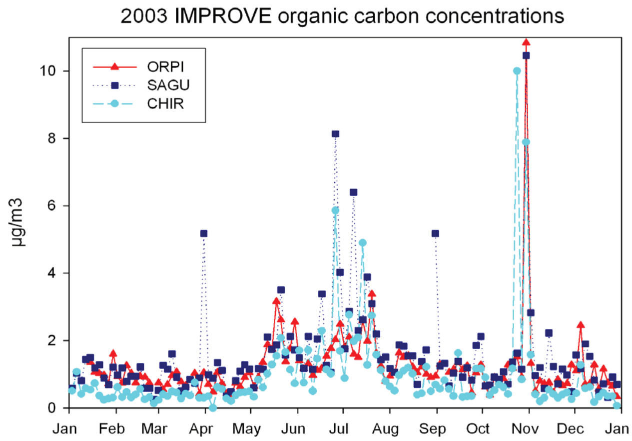

Figure 12-9. 2003 organic carbon concentrations for Organ Pipe Cactus National Monument, Saguaro National Park and Chiricahua National Monument. Data from IMPROVE particulate sampler.

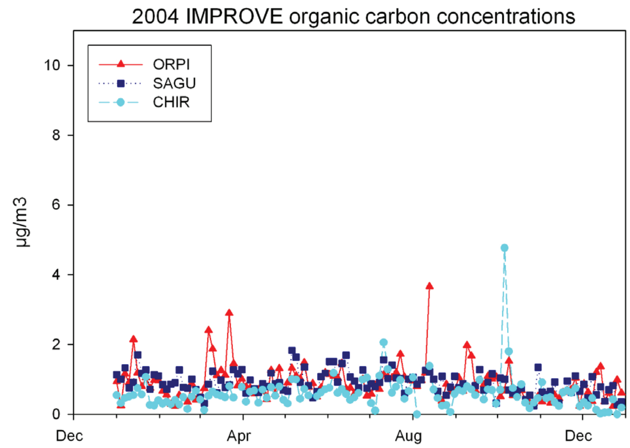

Figure 12-10. 2004 organic carbon concentrations for Organ Pipe Cactus National Monument, Saguaro National Park and Chiricahua National Monument. Data from IMPROVE particulate sampler.

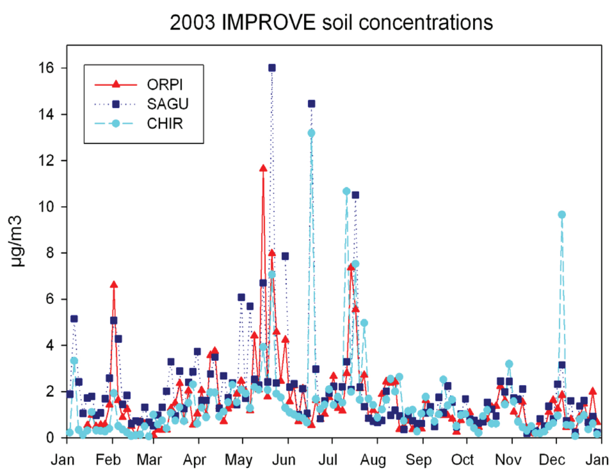

Figure 12-11. 2003 soil concentrations for Organ Pipe Cactus National Monument, Saguaro National Park and Chiricahua National Monument. Data from IMPROVE particulate sampler.

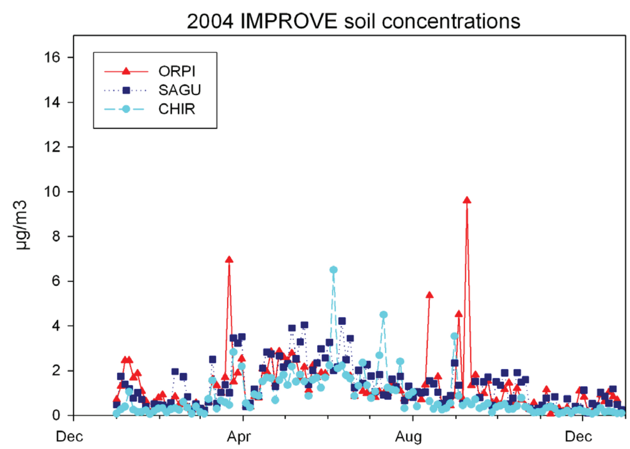

Figure 12-12. 2004 soil concentrations for Organ Pipe Cactus National Monument, Saguaro National Park and Chiricahua National Monument. Data from IMPROVE particulate sampler.

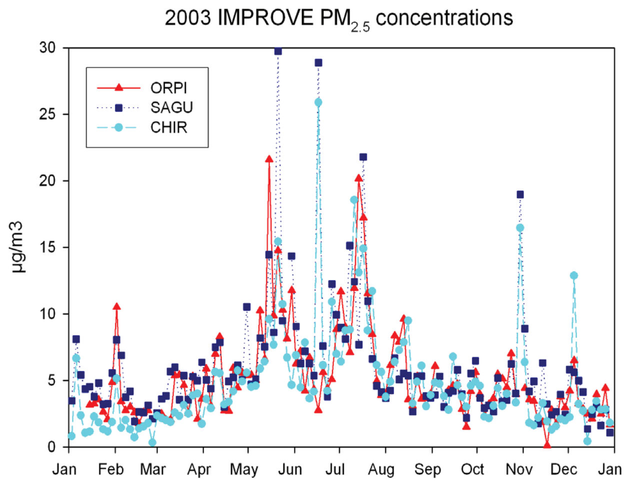

Figure 12-13. 2003 $PM_{2.5}$ concentrations for Organ Pipe Cactus National Monument, Saguaro National Park and Chiricahua National Monument. Data from IMPROVE particulate sampler.

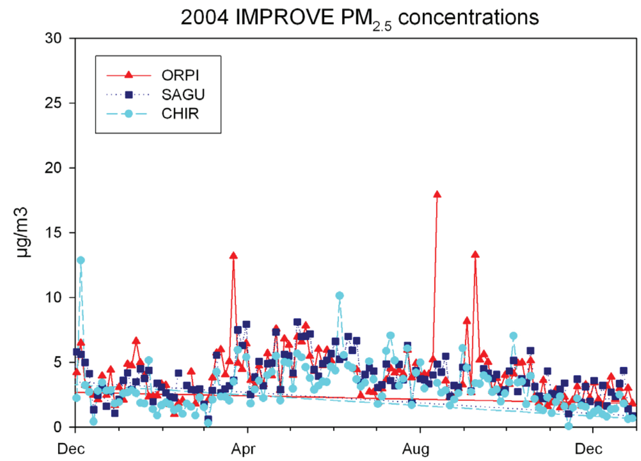

Figure 12-14. 2004 $PM_{2.5}$ concentrations for Organ Pipe Cactus National Monument, Saguaro National Park and Chiricahua National Monument. Data from IMPROVE particulate sampler.

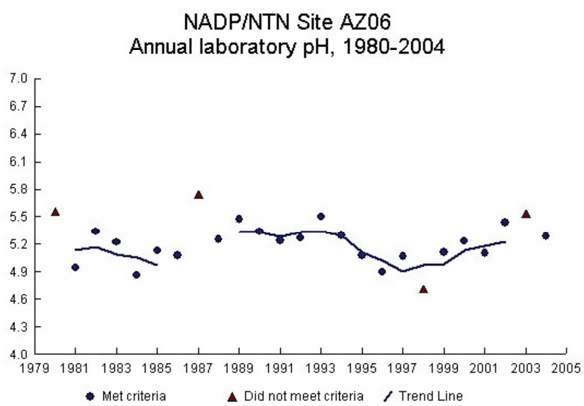

Figure 12-15. Trend plot for annual laboratory pH, 1980-2004, Organ Pipe Cactus N.M. wet deposition site, National Atmospheric Deposition Program.

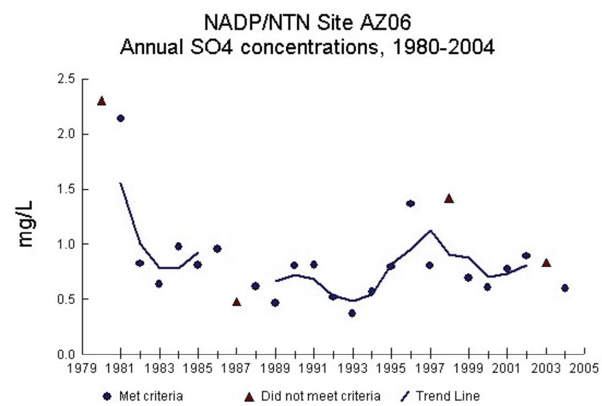

Figure 12-16. Trend plot for annual SO4 concentrations, 1980-2004, Organ Pipe Cactus N.M. wet deposition site, National Atmospheric Deposition Program.

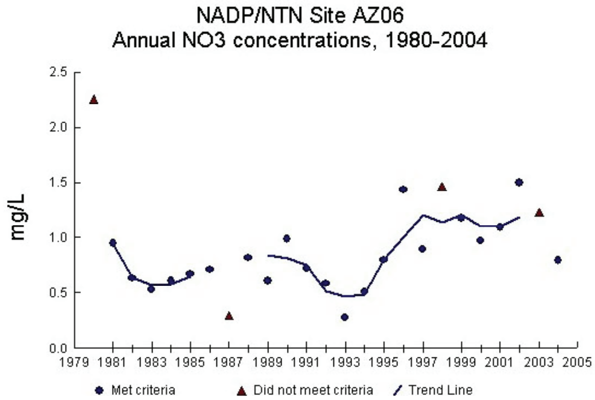

Figure 12-17. Trend plot for annual NO_3 concentrations, 1980-2004, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program.

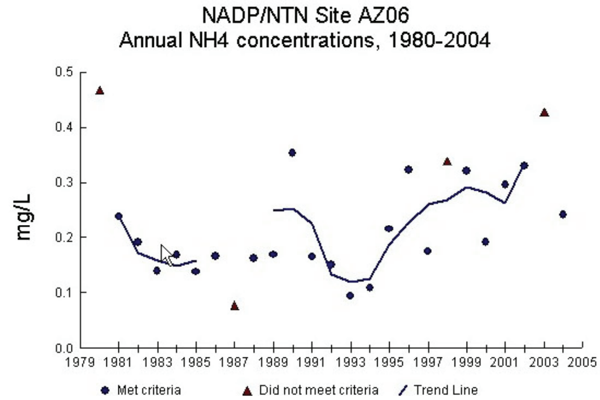

Figure 12-18. Trend plot for annual NH_4 concentrations, 1980-2004, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program.

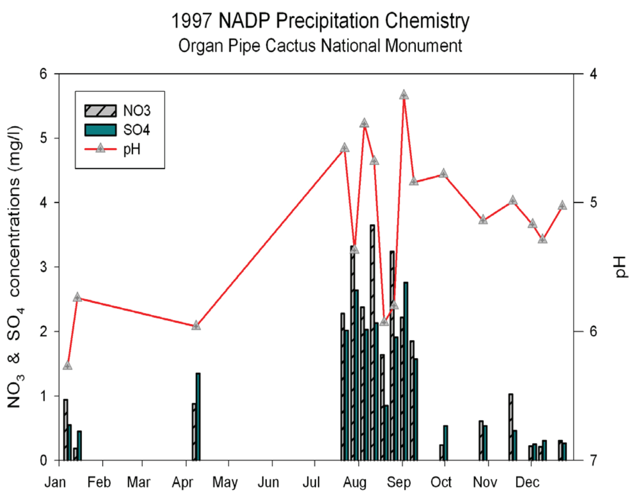

Figure 12-19. 1997 pH and NO_3 and SO_4 concentrations, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program.

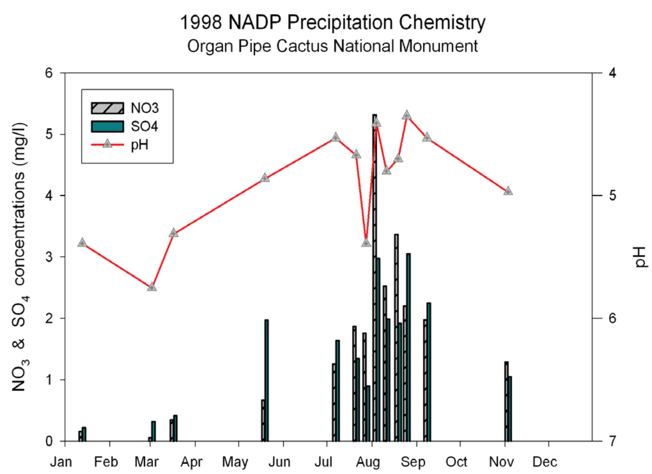

Figure 12-20. 1998 pH and NO_3 and SO_4 concentrations, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program.

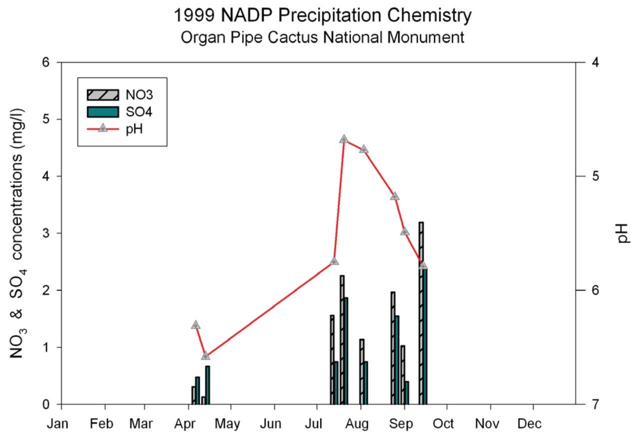

Figure 12-21. 1999 pH and NO_3 and SO_4 concentrations, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program.

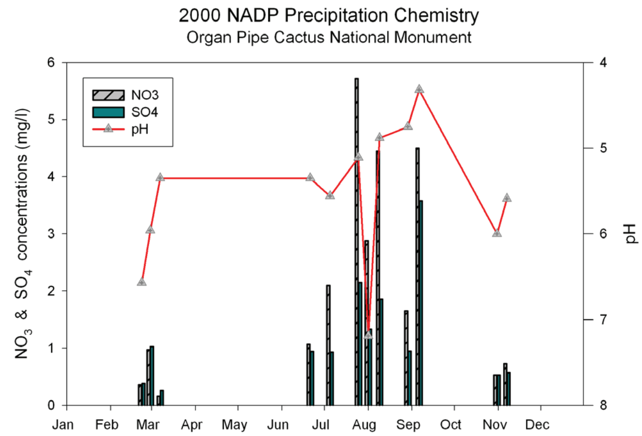

Figure 12-22. 2000 pH and NO_3 and SO_4 concentrations, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program.

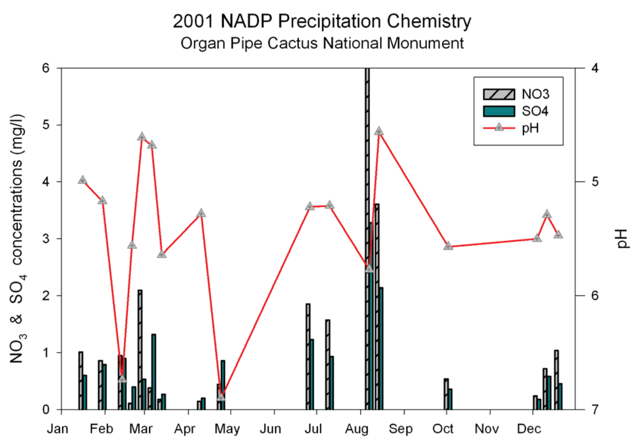

Figure 12-23. 2001 pH and NO_3 and SO_4 concentrations, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program. (Value out of range = 8.28.)

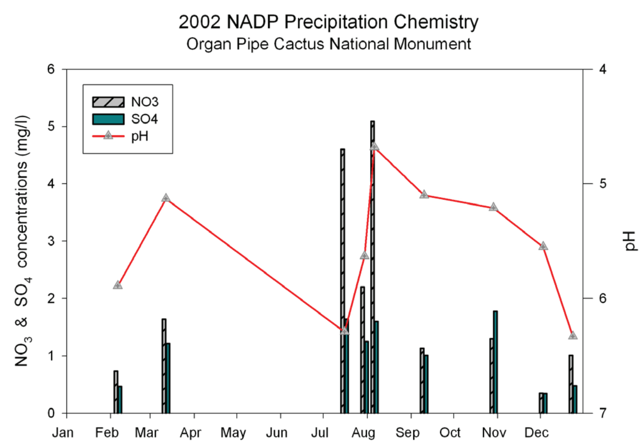

Figure 12-24. 2002 pH and NO_3 and SO_4 concentrations, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program.

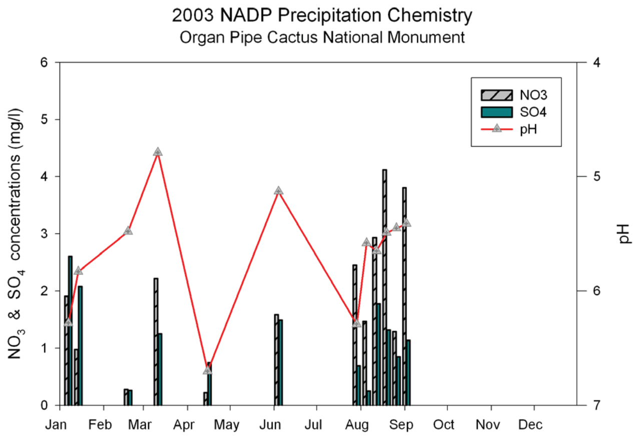

Figure 12-25. 2003 pH and NO_3 and SO_4 concentrations, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program.

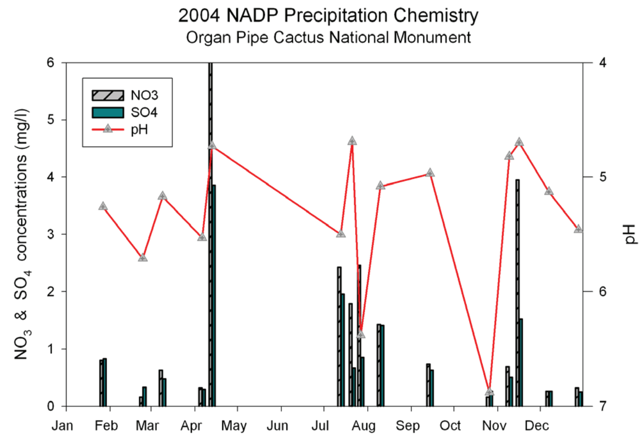

Figure 12-26. 2004 pH and NO_3 and SO_4 concentrations, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program. (Value out of range = 8.36.)

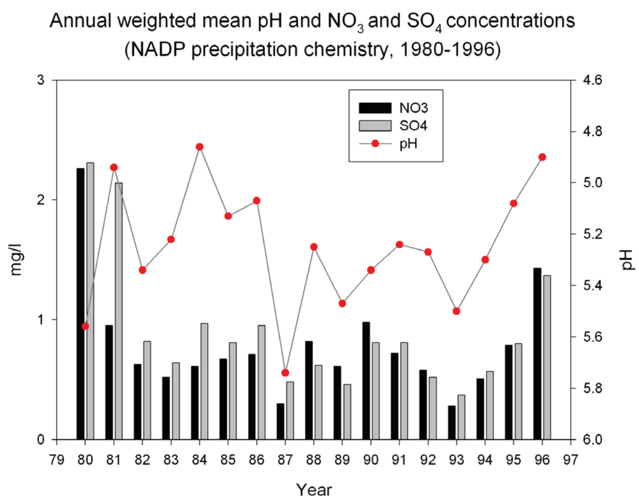

Figure 12-27. Annual weighted mean pH and NO_3 and SO_4 concentrations, 1980-1996, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program.

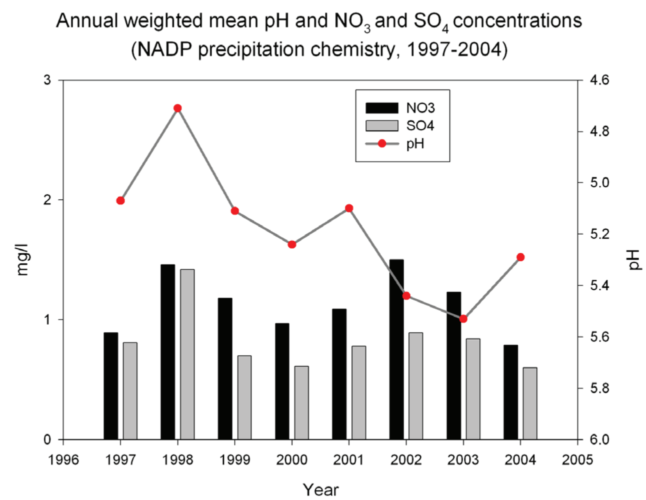

Figure 12-28. Annual weighted mean pH and NO_3 and SO_4 concentrations, 1997-2004, Organ Pipe Cactus National Monument wet deposition site, National Atmospheric Deposition Program.

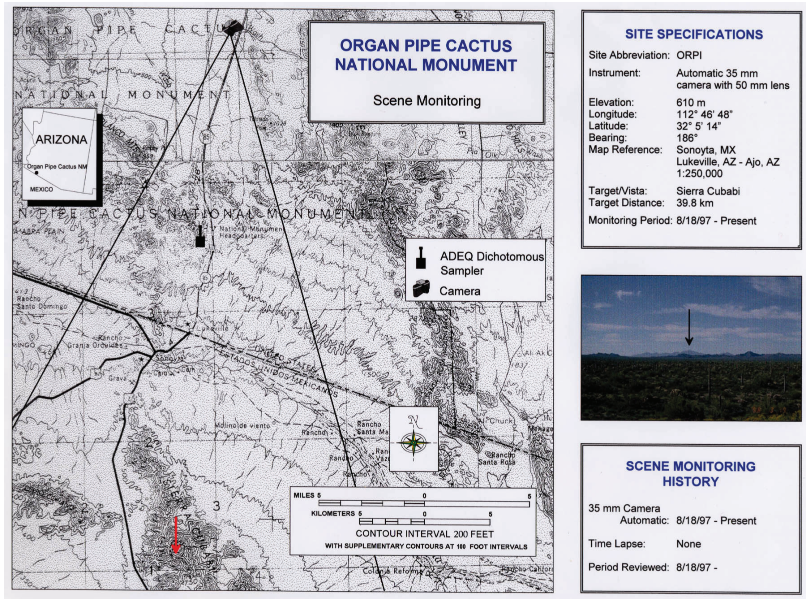

Figure 12-29. Site map of Organ Pipe Cactus National Monument visibility camera.

Figure 12-30. Representative visibility conditions, 1997-2004, from Organ Pipe Cactus National Monument visibility camera.

Figure 12-31. Regional haze event on June 7, 2002, from Organ Pipe Cactus National Monument visibility camera.

Figure 12-32. Layered haze event on December 27, 2002, from Pinacate Biosphere Reserve visibility camera.