National Park Service
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Natural Resource Program Center
Air Resources Division

Annual Data Summary 2006

Gaseous Pollutant Monitoring Program Ozone, Sulfur Dioxide, Particulate Matter, Meteorological Observations

Natural Resource Technical Report NPS ARD/NRPC/NRTR-2007/058

ON THE COVER
Arches National Park, Utah
Photograph by Debbie Miller/NPS

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Gaseous Pollutant Monitoring Program Ozone, Sulfur Dioxide, Particulate Matter, Meteorological Observations

Natural Resource Technical Report NPS ARD/NRPC/NRTR-2007/058

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Air Resource Specialists, Inc.

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Photo by Dave Beichley/ Air Resource Specialists, Inc.

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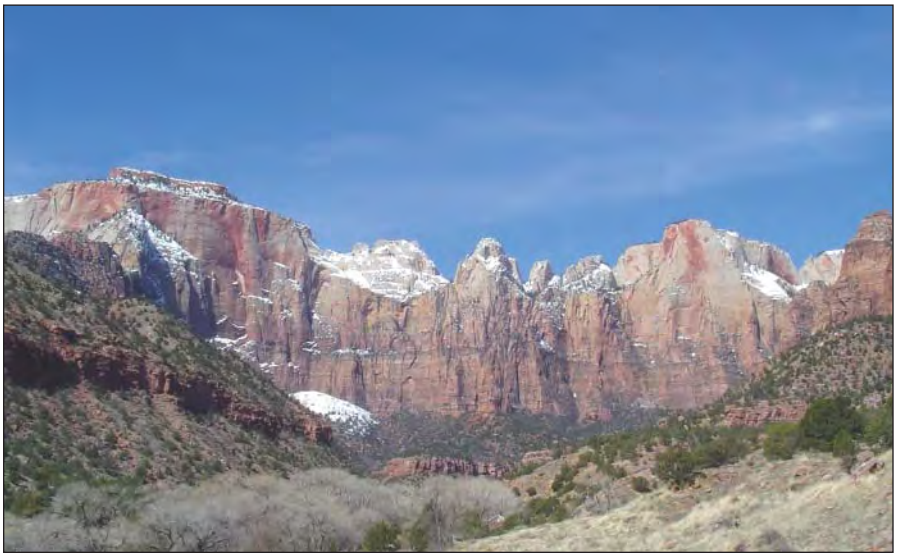
Zion National Park, Utah
Photo by Joe Adlhoch/
Air Resource Specialists, Inc.



Foreword

Air quality and meteorological data from the National Park Service (NPS) monitoring sites for 2006 has been fully validated and made available to the Environmental Protection Agency (EPA), the parks, and the public. This report provides summary tables and graphics to help understand how the measured pollutant concentrations compare to National Ambient Air Quality Standards and to concentrations measured in previous years. Additional tables and graphs can be viewed and hourly data retrieved from the National Park Service Air Resources Division (ARD) Web site (*http://www2.nature.nps.gov/air/data/current/index.cfm*).

Changes in 2006

Several report changes have been made this year to emphasize results from the monitoring and to include more analysis. Two significant sections have been moved to the Web: the ozone trends plots for individual parks and the quality assurance tables showing data capture rates and results of precision and accuracy checks. In the first case, this change allows for more trend plots to be made available and in the second, to reduce the number of pages devoted to bookkeeping tables.

Proposed Monitoring Strategy

The ARD has looked at anticipated budgets for five years into the future and has started to adjust programs accordingly. Monitoring plans have been formulated around a new proposed monitoring strategy and updated objectives. Some monitoring will be eliminated, some types of monitoring will be expanded, new parameters will be added, and new tools will be applied to gathering data. Look for the draft monitoring strategy on the ARD Web site to see what is being proposed.

Portable Ozone Monitoring Systems

The portable ozone monitoring systems (POMS) are continuing to be used and the program expanded. The self-contained ozone monitoring systems can be placed in a wide variety of locations because they use solar power and satellite data communications along with a small, low-power ozone analyzer. Extensive testing of these systems has yielded equivalent results for summertime ozone measurements when compared to the full EPA-certified instruments at fixed-location stations. The NPS Inventory and Monitoring program is beginning to use more POMS to fill in baseline data at park locations that have never had air quality monitoring.

Lake Mead National Recreation Area, Arizona
Portable Ozone Monitoring System
Photo by Mike Slate/
Air Resource Specialists, Inc.

In 2006, Joshua Tree National Park used POMS stations to get a West-East transect with six ozone monitoring sites. Summary data appear in this report's tables, a more thorough publication will have final results later. Use of these systems helped update and expand on monitoring done with passive ozone monitors in the past. If your park has an interest in deploying a POMS, please contact John Ray. For more information on the POMS, visit: *http://www2.nature.nps.gov/air/studies/portO3.cfm*.

Highlights in 2006

During 2006, only six sites, in four parks exceeded the 8-hour ozone standard, as indicated in the table below. An exceedance occurs when an 8-hour average ozone concentration is equal to or greater than 85 ppb. Four parks were in violation of the ozone standard based on the 3-year averages. Twelve monitors experienced one or more exceedances of the ozone standard during the year. Sequoia-Kings Canyon and Joshua Tree continue to experience the most ozone exceedances. Of the parks that monitor sulfur dioxide, only Hawaii Volcanoes violated the sulfur dioxide standard. This is a result of toxic gas venting from the volcano rather than from anthropogenic sources.

Park/Site	4th Highest Daily Maximum 8-Hour Avg. O_3 Concentration (ppb)	Number of Exceedances
Great Smoky Mountains:		
Clingmans Dome	86	4
Look Rock	85	6
Joshua Tree - Black Rock	103	36
Sequoia and Kings Canyon:		
Ash Mountain	104	49
Lower Kaweah	97	17
Yosemite - Turtleback Dome	85	4

Network Quality Assurance

Overall data capture for NPS ozone monitoring continues to be high (97%) and exceeds NPS objectives and EPA requirements. The EPA accepts data from the NPS ARD as high quality and uses it to determine park areas that are in violation of the standards and in non-attainment. NPS data are used in peer-reviewed publications and in several government agency reports, and are submitted to the EPA Air Quality System (AQS) database (*http://www.epa.gov/air/data/*) and to AIRNow for presentation daily on the Web (*http://airnow.gov*).

The Gaseous Pollutant Monitoring Program (GPMP) acknowledges and thanks all the park employees who perform the station checks and keep everything operating smoothly. Air quality monitoring would not be possible without your help. Thank you for a job well done.

Dr. John D. Ray

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Canyonlands National Park, Utah
NPS stock photo

Introduction

The Air Resources Division (ARD) is responsible for providing policy and technical support to national parks on air quality issues. ARD has established monitoring networks for gaseous pollutants, wet and dry deposition, and visibility. This 2006 annual data summary report summarizes data from the ozone monitoring network. Dry deposition data are summarized by the Clean Air Status and Trends Network (CASTNet) ; wet deposition by the National Atmospheric Deposition Program (NADP); and visibility by the Interagency Monitoring of Visual Environments (IMPROVE) program.

Air Resources Division
Air Quality Monitoring Objectives

- Provide data to make pollutant risk assessments of adverse effects to natural resources (Air Quality Related Values)
- Provide data related to National Ambient Air Quality Standards (NAAQS) and New Source Review
- Determine trends that assist in compliance predictions, policy objectives, and regional assessments at non-urban parks
- Provide specific answers from special studies that assist modeling, regional pollution transport issues, State Implementation Plan (SIP) development, and national control strategies
- Provide timely information to the public and researchers to assess current conditions in parks

The overall purpose of the National Park Service (NPS) Gaseous Pollutant Monitoring Program (GPMP) is to monitor the status and trends of ambient air quality conditions in national park units. This purpose is outlined by the Clean Air Act of 1963 (including the 1970, 1977, and 1990 amendments) and the Organic Act of 1916, which assign the federal land managers the responsibility of protecting the natural resources in national parks. Several monitoring objectives have been derived from this purpose.

The NPS monitoring objectives call for the collection of data to support the National Park Service's required involvement in both the development of state air quality control plans, and the evaluation of permit applications for new or expanding air pollution sources wishing to locate near park units. The Clean Air Act gives federal land managers an affirmative responsibility to protect air quality related values in Class I areas and to assess whether new sources will have an adverse impact on park resources and values. Information on air quality in NPS units can also be used to evaluate the performance of atmospheric models that simulate transport and impacts of pollutants.

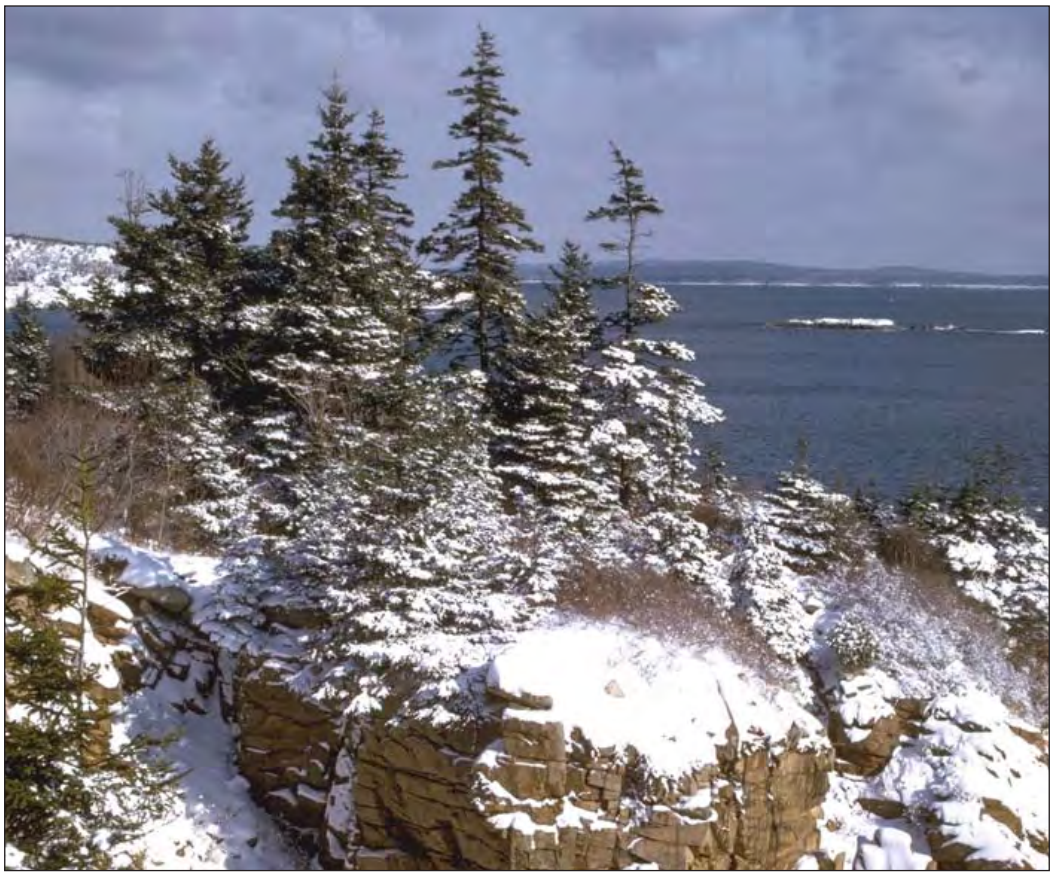
To meet these objectives the NPS Air Resources Division (ARD) has established an air quality monitoring program. This data summary report presents only ozone (O_3), sulfur dioxide (SO_2), particulate matter (PM), and meteorological data from continuous monitors that report hourly data. Other gas, particulate, and precipitation monitoring are performed under the visibility and deposition programs and are reported separately.

Ozone, meteorological, and some SO_2 monitoring methods and quality assurance procedures adopted by the GPMP network were developed in accordance with the EPA regulations of 40 CFR, Part 58, Appendix D. These regulations, although addressing primarily health-effects based monitoring in areas of high population, are generally pertinent to the GPMP. These design criteria allow for the direct comparison of data collected by the NPS with that collected by the EPA, and state and local air pollution control agencies. As a supplement to the basic network, the ARD also conducts short-term air quality monitoring including portable ozone and special studies monitoring in selected parks. In addition, the ARD cooperates with other national

and state programs that monitor ambient gases, meteorology, deposition chemistry, particulate matter, and visibility.

Data collected by this network are incorporated in the EPA Air Quality System (AQS) database, which is a national database of air quality data collected throughout the country. These data are also stored in the NPS ARD's Information Management Center (IMC), and are publicly available through the NPS ARD's Web site at *http://www2.nature.nps.gov/air/Monitoring/network.cfm#data*.

Acadia National Park, Maine
NPS stock photo



Network Description

The POMS are intended for short-term seasonal use at locations where reference method monitoring has not occurred or is not practical.

The NPS air quality monitoring strategy has focused primarily on Class I areas defined by the Clean Air Act Amendments of 1977. The GPMP network consists of individual stations located in park units throughout the United States. The NPS also participates with other agencies in cooperative monitoring programs. This section describes the GPMP network and cooperating programs.

GPMP Network Monitoring

During 2006, eighty-three (83) monitoring sites in fifty-nine (59) units of the National Park System conducted some combination of ozone, sulfur dioxide, particulate matter, and meteorological monitoring. Of these, the NPS ARD supported forty-seven (47) monitoring sites in thirty-eight (38) units.

Abraham Lincoln Birthplace National Historic Site, Kentucky Portable Ozone Monitoring System Photo by Mike Slate/ Air Resource Specialists, Inc.

The locations of the sites that operated during the year are presented on the map in Figure 1. The parameters monitored at each park unit are indicated with colored flags. The CASTNet flag identifies sites where the NPS operates Clean Air Status and Trends Network monitoring systems in cooperation with EPA to estimate dry atmospheric deposition. The enhanced gaseous and/or particulates flag indicates that the NPS sponsors additional or high-resolution gaseous or particulate monitoring at the park. Monitoring agencies and park units with more than one monitoring site are indicated. Site specifications, including site names, abbreviations, AQS identification numbers, locations, and monitored parameters are listed in Table 1.

In addition to monitoring for regulatory compliance, the NPS added non-certified portable ozone monitoring systems (POMS) to the GPMP in 2003. These sites employ portable ozone analyzers and meteorological sensors, generally configured for solar and battery power. Throughout this report, POMS site names in tables and figures have been underlined to distinguish them from monitoring sites meeting all EPA guidelines.

Cooperating Programs

Data from cooperating programs are reported by those programs and are not included in this report. The exception to that is ozone, sulfur dioxide, particulate matter, and meteorology collected in NPS units by state agencies which supplement the data collected by the GPMP.

State Programs
The NPS cooperates with a number of state agencies. At some sites, state air quality agencies provide measurement and operations support, and data are generally shared directly among cooperating agencies. Relevant O_3, SO_2, PM, and meteorological data submitted by states to the EPA AQS are retrieved for inclusion in this report.

There are also numerous sites near park units operated by state or other agencies, independent of the NPS. Data from these sites are also retrieved from the EPA AQS for inclusion in this report, but are presented separately from data collected by state sites in cooperation with the NPS.

Throughout this report, state-operated monitoring site names in tables and figures are indicated in italics.

CASTNet
Most GPMP stations operate cooperatively with the EPA Clean Air Status and Trends Network (CASTNet). Weekly integrated particulate samples are collected on filter packs at CASTNet sites. The samples are analyzed for ambient atmospheric nitrates, sulfates, ammonium, sulfur dioxide, and nitric acid, and the results are used to estimate atmospheric dry deposition. More information is available at the CASTNet Web site: *http://www.epa.gov/castnet*.

Chiricahua National Park, Arizona Air Quality Monitoring Station Photo by Martin Valvur/ Air Resource Specialists, Inc.

IMPROVE
The Interagency Monitoring of Protected Visual Environments (IMPROVE) is a consortium of federal and state agencies which conduct visibility monitoring in Class I areas, including national parks. A number of instruments are used to monitor visibility, including:

- Aerosol samplers, which collect 24-hr integrated particle samples every three days on a series of filter media. Filters are later analyzed for $PM_{2.5}$ and PM_{10} mass, elements, ions, and carbon.
- Transmissometers, which directly measure the atmospheric light extinction over a sight path of several kilometers.
- Nephelometers, which perform point optical measurements of the scattering component of atmospheric light extinction.
- Cameras, which document the appearance of a scene as viewed through the atmosphere. Digital images from many sites are posted to the Internet along with relevant air quality data and other information in near real-time for public viewing.

More information is available at the IMPROVE Web site at *http://vista.cira.colostate.edu/improve*.

NADP/NTN and NADP/MDN
The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) includes wet deposition monitoring at over 250 sites nationwide. The NADP network has been collecting data for over 20 years, and is coordinated from the Program Office at the Illinois State Water Survey in Champaign, Illinois. Data for all major ions are available in concentrations (mg/L) and depositions expressed by kilograms/hectare (kg/ha). The National Atmospheric Deposition Program/ Mercury Deposition Network (NADP/MDN) includes wet mercury deposition monitoring at over 80 sites nationwide. More information about both of these programs is available at the NADP Web site: *http://nadp.sws.uiuc.edu/*.

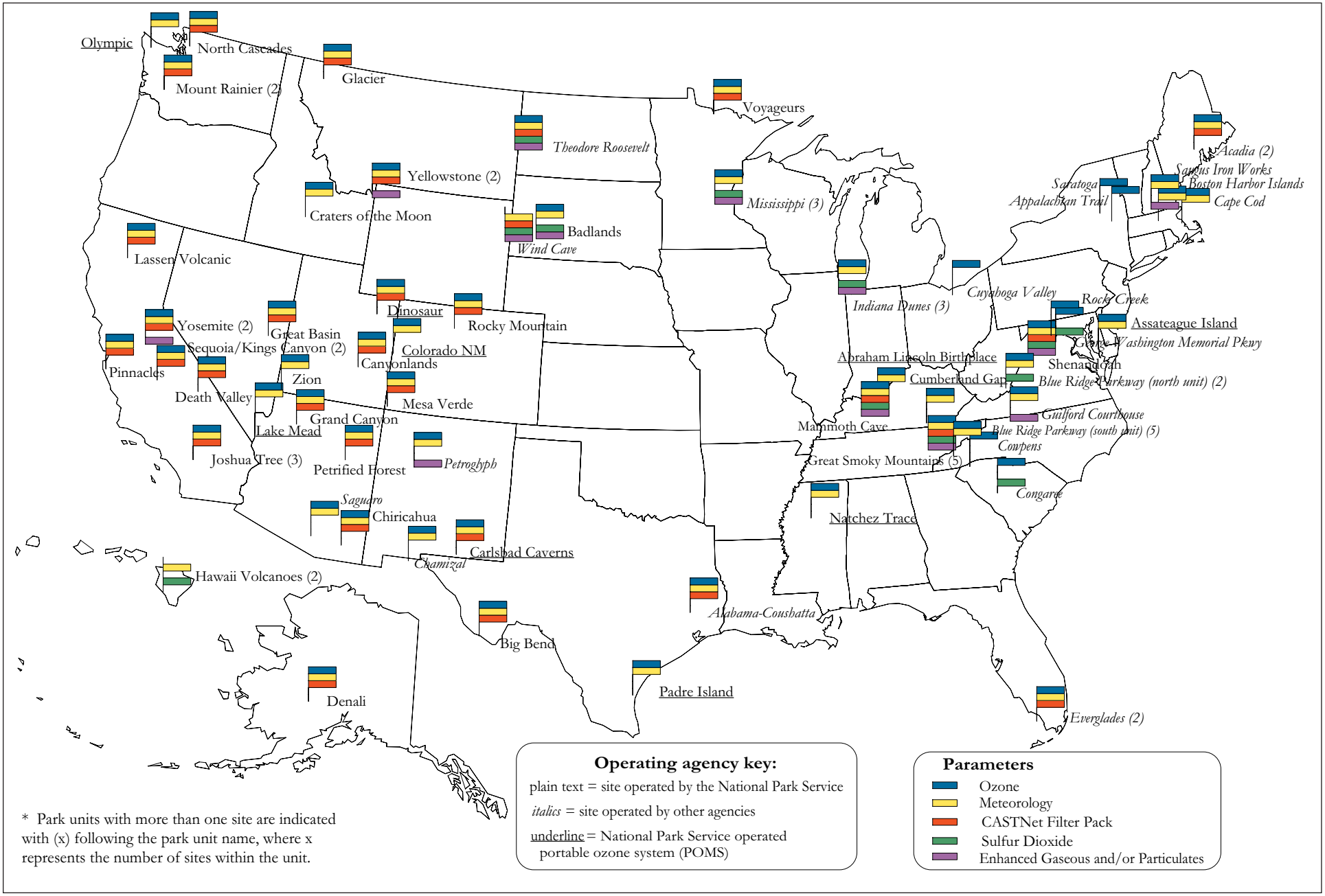


Figure 1. Air quality monitoring in or nearby park units.

Table 1. Site specifications.

National Park Unit	Site Name	State	NPS Abbr.	CASTNet Abbr.	AQS ID Number	Latitude	Longitude	Elev. (m)	O_3 Years[a]	SO_2	VWD[b]	SWS[c]	TMP	RH	RNF	WET	DTP	SOL	Filter Pack[d]
Sites operated by the National Park Service																			
Abraham Lincoln Birthplace	Visitor Center	KY	ABLI-KC	---	---	37.5314	85.7347	240	2	---	X	X	X	X	X	---	---	X	---
Assateague Island	Maintenance Area	MD	ASIS-MA	---	---	38.2511	75.1594	3	2	---	X	X	X	X	X	---	---	X	---
Badlands	Visitor Center	SD	BADL-VC	---	46-071-1001	43.7436	101.9414	739	10	X	X	X	X	X	X	---	---	X	---
Big Bend	K-Bar Ranch Road	TX	BIBE-KB	BBE401	48-043-0101	29.3022	103.1772	1052	17	---	X	X	X	X	X	X	X	X	X
Canyonlands	Island in the Sky	UT	CANY-IS	CAN407	49-037-0101	38.455	109.8217	1813	15	---	X	X	X	X	X	X	X	X	X
Carlsbad Caverns	Maintenance Area	NM	CAVE-MA	---	---	32.1783	104.4406	1349	1	---	X	X	X	X	X	---	---	X	X
Chiricahua	Entrance Station	AZ	CHIR-ES	CHA467	04-003-8001	32.0092	109.3892	1570	16	---	X	X	X	X	X	X	X	X	X
Colorado	Maintenance Yard	CO	COLM-MY	---	---	39.1067	108.7411	1740	1	---	X	X	X	X	X	---	---	X	---
Craters of the Moon	Visitor Center	ID	CRMO-VC	---	16-023-0101	43.4606	113.5622	1815	15	---	X	X	X	X	---	---	---	X	---
Cumberland Gap	Hensley Settlement	KY	CUHA-HS	---	---	36.6719	83.5264	1013	1	---	X	X	X	X	X	---	---	X	---
Death Valley	Park Village	CA	DEVA-PV	DEV412	06-027-0101	36.5092	116.8481	125	14	---	X	X	X	X	X	X	X	X	X
Denali	Headquarters	AK	DENA-HQ	DEN417	02-290-0003	63.0539	150.8547	661	20	---	X	X	X	X	X	X	X	X	X
Dinosaur	West Entrance Housing	UT	DINO-WE	---	---	40.4372	109.3047	1463	2	---	X	X	X	X	X	---	---	X	X
Everglades	Beard Center	FL	EVER-BC	EVE419	12-086-0030	25.3911	80.6806	2	---	---	X	X	X	X	X	X	X	X	X
Glacier	West Glacier Horse Stables	MT	GLAC-WG	GLR468	30-029-8001	48.5103	113.9956	976	15	---	X	X	X	X	X	X	X	X	X
Grand Canyon	The Abyss	AZ	GRCA-AS	GRC474	04-005-8001	36.2828	113.0958	1433	14	---	X	X	X	X	X	X	X	X	X
Great Basin	Maintenance Yard	NV	GRBA-MY	GRB411	32-033-0101	39.005	114.2158	2067	14	---	X	X	X	X	X	X	X	X	X
Great Smoky Mountains	Clingmans Dome	TN	GRSM-CD	---	47-155-0102	35.6967	83.6097	1265	14	---	X	X	X	X	X	---	---	X	---
Great Smoky Mountains	Cove Mountain	TN	GRSM-CM	---	47-155-0101	35.6967	83.6086	1243	19	X	X	X	X	X	X	---	---	X	---
Great Smoky Mountains	Look Rock	TN	GRSM-LR	GRS420	47-009-0101	35.59	83.0775	1500	19	---	X	X	X	X	X	X	X	X	X
Hawaii Volcanoes	Observatory	HI	HAVO-OB	---	15-001-0007	19.4203	155.2881	1123	---	X	X	X	X	X	X	---	---	---	---
Hawaii Volcanoes	Visitor Center	HI	HAVO-VC	---	15-001-0005	19.4308	155.2578	1215	---	X	X	X	X	X	X	---	---	X	---
Joshua Tree	Black Rock	CA	JOTR-BR	JOT403	06-071-9002	34.0714	116.3906	1244	14	---	X	X	X	X	X	X	X	X	X
Joshua Tree	Cottonwood Canyon	CA	JOTR-CC	---	06-065-0008	33.7411	115.8206	984	2	---	X	X	X	X	X	---	---	X	---
Joshua Tree	Pinto Wells	CA	JOTR-PW	---	---	33.9397	115.4108	326	1	---	X	X	X	X	X	---	---	X	X
Lake Mead	Meadview	AZ	LAME-ME	---	---	36.0194	114.0686	881	6	---	X	X	X	X	X	---	---	X	---
Lassen Volcanic	Manzanita Lake Fire Station	CA	LAVO-ML	LAV410	06-089-3003	40.5403	121.5764	1756	20	---	X	X	X	X	X	X	X	X	X
Mammoth Cave	Houchin Meadow	KY	MACA-HM	MAC426	21-061-0501	37.1319	86.1478	243	12	X	X	X	X	X	X	X	X	X	X
Mesa Verde	Resource Management Area	CO	MEVE-RM	MEV405	08-083-0101	37.1983	108.4903	2177	14	---	X	X	X	X	X	X	X	X	X
Mount Rainier	Tahoma Woods	WA	MORA-TW	MOR409	53-053-1010	46.7581	122.1225	423	16	---	X	X	X	X	X	X	X	X	X
Mount Rainier	White River	WA	MORA-WR	---	---	46.8919	121.5972	1193	1	---	X	X	X	X	X	---	---	X	---

Table 1. Site specifications (continued).

National Park Unit	Site Name	State	NPS Abbr.	CASTNet Abbr.	AQS ID Number	Latitude	Longitude	Elev. (m)	O_3 Years[a]	SO_2	VWD[b]	SWS[c]	TMP	RH	RNF	WET	DTP	SOL	Filter Pack[d]
Sites operated by the National Park Service																			
Natchez Trace Parkway	Dancy Ranger Station	MS	NATR-DR	---	---	33.6636	89.0622	94	1	---	X	X	X	X	X	---	---	X	---
North Cascades	Marblemount Ranger Stn	WA	NOCA-MM	NCS415	53-057-0013	48.5397	121.4472	109	11	---	X	X	X	X	X	X	X	X	X
Olympic	Hurricane Ridge Portable	WA	OLYM-HP	---	---	47.995	123.3847	939	3	---	X	X	X	X	X	---	---	X	---
Padre Island	Malaquite Visitor Center	TX	PAIS-MV	---	---	27.4267	97.2983	6	2	---	X	X	X	X	X	---	---	X	---
Petrified Forest	South Entrance	AZ	PEFO-SE	PET427	04-017-0119	34.8225	109.8919	1723	5	---	X	X	X	X	X	X	X	X	X
Pinnacles	SW of East Entrance Station	CA	PINN-ES	PIN414	06-069-0003	36.485	121.1556	317	20	---	X	X	X	X	X	X	X	X	X
Rocky Mountain	Long's Peak	CO	ROMO-LP	ROM406	08-069-0007	46.4411	105.7539	3597	22	---	X	X	X	X	X	X	X	X	X
Sequoia and Kings Canyon	Ash Mountain	CA	SEKI-AS	SEK430	06-107-0009	36.4894	118.8269	457	8	---	X	X	X	X	X	X	X	X	X
Sequoia and Kings Canyon	Lower Kaweah	CA	SEKI-LK	---	06-107-0006	36.5658	118.7772	1890	23	---	X	X	X	X	X	---	---	X	---
Shenandoah	Big Meadows	VA	SHEN-BM	SHN418	51-113-0003	38.5231	78.4347	1073	24	X	X	X	X	X	X	X	X	X	X
Voyageurs	Sullivan Bay	MN	VOYA-SB	VOY413	27-137-0034	48.4128	92.8292	429	11	---	X	X	X	X	X	X	X	X	X
Yellowstone	Old Faithful	WY	YELL-OF	---	56-039-1012	44.4569	110.8314	2246	---	---	X	X	X	X	---	---	---	---	---
Yellowstone	Water Tank	WY	YELL-WT	YEL408	56-039-1011	44.5597	110.4006	2400	11	---	X	X	X	X	X	X	X	X	X
Yosemite	School Yard	CA	YOSE-SY	---	---	37.7478	119.5917	1234	1	---	X	X	X	X	X	---	---	X	---
Yosemite	Turtleback Dome	CA	YOSE-TD	YOS404	06-043-0003	37.7133	119.7061	1605	14	---	X	X	X	X	X	X	X	X	X
Zion	Dalton's Wash	UT	ZION-DW	---	49-053-0130	37.1983	113.1506	1213	3	---	X	X	X	X	X	---	---	X	---
# active park units: 38	**# active park sites: 47**																		
Sites operated by cooperating state agencies																			
Acadia	Cadillac Mountain	ME	ACAD-CM	---	23-009-0102	44.3472	68.2278	466	12	---	X	X	X	X	---	---	---	---	---
Acadia	McFarland Hill	ME	ACAD-MH	ACA416	23-009-0103	44.3739	68.2606	129	9	---	X	X	X	X	X	X	X	X	X
Cape Cod	Cape Cod	MA	CACO-XX	---	25-001-0002	41.9758	70.0247	41	20	---	X	X	X	X	---	---	---	X	---
Chamizal	Chamizal	TX	CHAM-XX	---	48-141-0044	31.7656	106.455	1128	15	---	X	X	X	X	---	---	---	X	---
Congaree	Congaree Bluff	SC	COSW-BL	---	45-079-0021	33.8147	80.7811	34	7	X	---	---	---	---	---	---	---	---	---
Cowpens	State Monitor	SC	COWP-SM	---	45-021-0002	35.1303	87.8164	297	19	---	---	---	---	---	---	---	---	---	---
Great Smoky Mountains	Cades Cove	TN	GRSM-CC	---	47-009-0102	35.5619	83.4981	2021	14	---	X	X	X	X	X	---	---	X	---
Great Smoky Mountains	Purchase Knob	NC	GRSM-PK	---	37-087-0036	35.59	83.0775	1500	12	---	---	---	---	---	---	---	---	---	---
Saguaro	Pima County	AZ	SAGU-PC	---	04-019-0021	32.1744	110.7364	938	15	---	---	---	---	---	---	---	---	---	---
Theodore Roosevelt	Painted Canyon Visitor Cntr	ND	THRO-VC	THR422	38-007-0002	46.8947	103.3778	850	9	X	X	X	X	X	X	X	X	X	X
Wind Cave	Visitor Center	SD	WICA-VC	WNC429	46-033-0132	43.5578	103.4839	1292	3	X	X	X	X	X	X	X	X	X	X
Yosemite	Village	CA	YOSE-VI	---	06-043-1001	37.7458	119.6028	1216	---	---	---	---	---	---	---	---	---	---	---
# active park units: 10	**# active park sites: 12**																		

Table 1. Site specifications (continued).

National Park Unit	Site Name	State	NPS Abbr.	CASTNet Abbr.	AQS ID Number	Latitude	Longitude	Elev. (m)	O_3 Years[a]	SO_2	VWD[b]	SWS[c]	TMP	RH	RNF	WET	DTP	SOL	Filter Pack[d]
Nearby sites operated by other agencies																			
Alabama-Coushatta	CASTNet Site	TX	ALCO-CA	ALC188	---	38.8689	89.6228	164	19	---	X	X	X	X	X	X	X	X	X
Appalachian Trail	Mount Greylock Summit	MA	APTR-MG	---	25-003-4002	42.6367	73.1686	1140	18	---	---	---	---	---	---	---	---	---	---
Blue Ridge Parkway	7510 Blue Ridge Parkway	NC	BLRI-75	---	37-011-0002	35.9717	81.9342	987	8	---	---	---	X	X	---	---	---	---	---
Blue Ridge Parkway	Barnet Knob Firetower Road	NC	BLRI-BK	---	37-099-0005	35.5244	83.2361	1433	8	---	---	---	---	---	---	---	---	---	---
Blue Ridge Parkway	Blue Ridge Parkway	NC	BLRI-BR	---	37-199-0003	35.7378	82.2853	1982	15	---	---	---	---	---	---	---	---	---	---
Blue Ridge Parkway	Frying Pan Mountain	NC	BLRI-FP	---	37-087-0035	35.3792	82.7925	1585	13	---	---	---	---	---	---	---	---	---	---
Blue Ridge Parkway	Route 191	NC	BLRI-RO	---	37-021-0030	35.5	82.6	675	18	---	---	---	---	---	---	---	---	---	---
Blue Ridge Parkway	Ranger Station	VA	BLRI-RS	---	51-163-0003	37.6261	79.5131	280	8	---	---	---	---	---	---	---	---	---	---
Blue Ridge Parkway	Vinton Elementary	VA	BLRI-VE	---	51-161-1004	37.2856	79.8842	346	26	X	---	---	---	---	---	---	---	---	---
Boston Harbor Islands	Former Nike Missile Site	MA	BOHA-NM	---	25-025-0041	42.3175	70.9689	10	9	---	X	X	X	X	---	---	---	X	---
Cuyahoga Valley	800 Patterson	OH	CUVA-PA	---	39-153-0020	41.1061	81.5039	305	27	---	---	---	---	---	---	---	---	---	---
Everglades	Cutler Road	FL	EVER-CR	---	12-086-0029	25.5861	80.3269	4	22	---	---	---	---	---	---	---	---	---	---
George Washington Pkwy	Alexandria Health	VA	GEWA-AH	---	51-510-0009	38.8108	77.0447	23	38	X	---	---	---	---	---	---	---	---	---
Guilford Courthouse	Mendenhall Middle School	NC	GUCO-NM	---	37-081-0013	36.1092	79.8011	247	6	---	---	X	X	X	X	---	X	X	---
Indiana Dunes	Ammunition Bunker	IN	INDU-AB	---	18-089-0022	41.5733	87.3047	183	14	---	X	X	X	X	---	---	---	X	---
Indiana Dunes	Gas Station	IN	INDU-GS	---	18-091-0005	41.7169	86.9075	187	31	X	X	X	X	---	---	---	X	---	---
Indiana Dunes	Water Treatment Plant	IN	INDU-WT	---	18-127-0024	41.6175	87.1992	183	24	---	---	---	---	---	---	---	---	---	---
Mississippi	Anoka County Airport	MN	MISS-AC	---	27-003-1002	41.1397	93.2075	281	28	X	---	---	---	---	---	---	---	---	---
Mississippi	Somerset Town Hall	WI	MISS-ST	---	55-109-1002	45.1244	92.6625	278	40	---	X	X	---	---	---	---	---	---	---
Mississippi	Washington County	MN	MISS-WC	---	27-163-6015	45.1189	92.855	0	10	---	---	---	---	---	---	---	---	---	---
Petroglyph	Westside Taylor Ranch	NM	PETR-WT	---	35-001-0027	35.1519	106.6836	5111	8	---	---	---	X	---	---	---	---	X	---
Rock Creek	Achbold Parkway	DC	ROCR-AP	---	11-001-0025	38.9753	77.0228	91	27	---	---	---	---	---	---	---	---	---	---

Table 1. Site specifications (continued).

National Park Unit	Site Name	State	NPS Abbr.	CASTNet Abbr.	AQS ID Number	Latitude	Longitude	Elev. (m)	O_3 Years[a]	SO_2	VWD[b]	SWS[c]	TMP	RH	RNF	WET	DTP	SOL	Filter Pack[d]
Nearby sites operated by other agencies																			
Saratoga	Stillwater	NY	SARA-ST	---	36-091-0004	43.0122	73.6489	120	19	---	---	---	---	---	---	---	---	---	---
Saugus Iron Works	Lynn Water Treatment	MA	SAIR-LW	---	25-009-2006	42.4744	70.9725	52	15	---	X	X	X	X	X	---	---	X	---
# active park units: 15	# active park sites: 24																		

[a] The values in this column represent the number of years an ozone analyzer has been operational at the site.

[b] Cape Cod reports wind direction as scalar wind direction rather than vector wind direction.

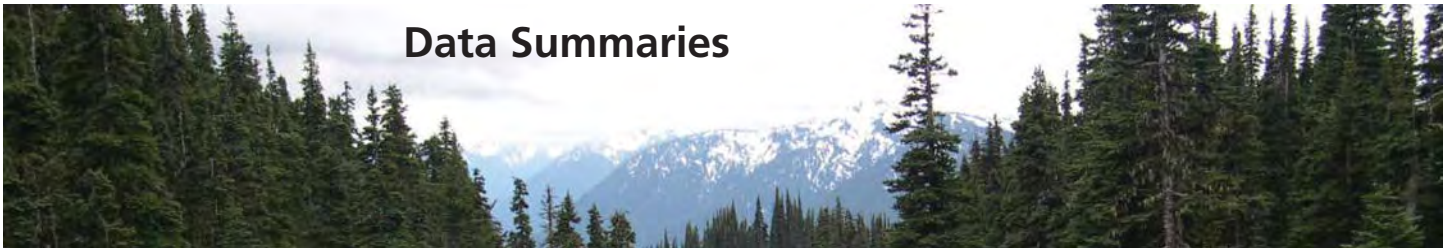
[c] Saguaro reports wind speed as vector wind speed rather than scalar wind speed.

[d] A filter pack is a part of the CASTNet network and is used to measure dry deposition using the "inferential method." This method combines air quality concentration data with meteorological measurements and land use functions to compute deposition velocities. Ambient air is drawn across the filter at either 3.0 or 1.5 liters per minute. The filter is then analyzed in a lab to yield weekly average concentrations of particulate sulfate (SO_4^{2-}), particulate nitrate (NO_3^-), particulate ammonium (NH_4^+), sulfur dioxide (SO_2), and nitric acid (HNO_3). In some cases, the positive ions Na^+, K^+, Ca^{2+}, and Mg^{2+} are also measured from the filter samples.

Operating agency key: plain text = site operated by the National Park Service
italics = site operated by a state agency
<u>underline</u> = site operated by the National Park Service, but consisting of non-EPA certified portable instrumentation

Parameter key: O_3 = ozone analyzer; SO_2 = sulfur dioxide analyzer; VWD = vector wind direction; SWS = scalar wind speed; TMP = ambient temperature; RH = relative humidity; RNF = precipitation; WET = wetness; DTP = delta temperature; SOL = solar radiation

Note: Dashed lines indicate parameter not measured at that site.



Data Summaries

Ground-level ozone, sulfur dioxide, and particulate matter are regulated under the Clean Air Act, the comprehensive federal law that regulates air quality in the United States. Among other things, the Clean Air Act requires the EPA to set standards for "criteria pollutants." These standards, known as the National Ambient Air Quality Standards (NAAQS), define the national targets for acceptable concentrations of each of the criteria pollutants.

The primary NAAQS for ozone is 0.08 ppm over an 8-hour period. An exceedance of the standard occurs when an 8-hour average ozone concentration is greater than or equal to 85 ppb. An exceedance of the standard is not the same as a violation. A violation occurs when the 3-year average of the fourth highest daily maximum 8-hour average ozone concentration equals or exceeds 85 ppb. The secondary ozone standard defined by the EPA is the same as the primary standard.

This section presents 2006 data summaries for the NPS GPMP. Ozone summaries for all sites are presented first, followed by data summaries for sulfur dioxide, particulate matter, and meteorological parameters. In these data summary products, site names of EPA-certified sites operated by the NPS are indicated with plain text, site names of EPA-certified sites operated by state or other agencies are written in italics, and site names of portable ozone monitoring systems (POMS) operated by the NPS are underlined.

Throughout this report data summary tables are split according to each of these groups. Generally, four site groupings are provided in each table to compare data among sites that are operated in a similar manner.

Pollutant	***Primary and Secondary NAAQS Standards***	***Averaging Time***
Ozone (O_3)	*0.08 ppm*	*4th highest 8-hour average over 3 years*
Sulfur Dioxide (SO_2)	*0.03 ppm (primary)*	*annual arithmetic mean*
	0.14 ppm (primary)	*daily arithmetic mean*
	0.5 ppm (secondary)	*3-hour average*
Particulate Matter ($PM_{2.5}$)	*15.0 $\mu g/m^3$*	*annual arithmetic mean*
	65 $\mu g/m^3$	*daily arithmetic mean*
Particulate Matter (PM_{10})	*150 $\mu g/m^3$*	*daily arithmetic mean*

Ozone Data Summaries

Ground-level ozone, produced by the reaction of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight, is one of the most widespread pollutants affecting vegetation and public health in the U.S. Although ozone is principally viewed as an urban problem, ozone and its precursor emissions can travel long distances, resulting in elevated ozone levels in national parks. Combustion processes from power plants, automobiles, and industries are the main anthropogenic emitters of NO_x. Vehicles, industries, and natural vegetation emit VOCs.

Exposure to ozone affects human health, causing acute respiratory problems, aggravation of asthma, temporary decreases in lung capacity in some adults, inflammation of lung tissue, and impairment of the body's immune system. Ozone also affects vegetation in national parks.

Research shows that some plants are more sensitive than humans to ozone and that effects on plants occur well below the EPA National Ambient Air Quality Standards (NAAQS).

To quantify ozone exposure to plants, various indices other than the primary and secondary standards are often used. These indices, described further on page 34, are believed to be biologically relevant because they take into account both peak ozone concentrations and cumulative exposure to ozone.

Annual Ozone Summaries

Table 2 summarizes O_3 measurements with respect to the daily maximum 8-hour average concentrations at each NPS monitoring site. The five highest daily maximum 8-hour average ozone concentrations are listed, as well as the total number of days with exceedances of the NAAQS 8-hour standard (8-hour average ozone values greater than or equal to 85 ppb). At each EPA-certified monitoring site, the fourth highest value column and the number of days column are both color-coded to identify sites where the fourth highest daily maximum 8-hour average ozone value exceeded the 8-hour standard during 2006. Note that other sites may have experienced fewer than four exceedances of the 8-hour standard, but are not color coded. Ozone summary statistics from POMS are not color coded and should be compared to EPA standards for reference purposes only.

In 2006, six of the NPS and cooperating state operated sites exceeded the 8-hour standard, as compared to eight sites in 2005. From 2005 to 2006, six sites had an increase in the number of days with an exceedance of the 8-hour standard and 10 sites had a decrease.

The map in Figure 2 presents the annual fourth highest 8-hour average ozone concentrations for all network sites listed in Table 2. Ozone values for EPA-certified sites are color-coded to represent values below (green) and above (orange and red) the national standard. Data from portable sites (no color) are included for reference only.

The map in Figure 3 presents the annual number of days which exceeded the 8-hour standard for all network sites listed in Table 2. The data points are color-coded to distinguish between sites that did not exceed NAAQS (green) and those that did (orange and red). Data from portable sites (no color) are included for reference only.

The map in Figure 4 presents the annual second highest 1-hour average ozone concentrations for all network sites. Ozone values for EPA-certified sites are color-coded to represent four distinct levels. Ozone values from portable sites (no color) are included for reference only.

In 2006 there were fires near the stations at Zion National Park that contributed to some very high hourly ozone values (Figure 4). Under EPA rules these values could probably meet the "exceptional event" criteria.

Theodore Roosevelt National Park, North Dakota Webcamera view

Table 2. Summary of 8-hour average ozone concentrations (ppb).

National Park Unit	Site Name	Valid Number of Days	1st Highest	2nd Highest	3rd Highest	4th Highest[a]	5th Highest	# Days with 8-Hour Average O_3 Values ≥85 ppb[a]
Sites operated by the National Park Service								
Badlands	Visitor Center	358	74	73	71	71	69	0
Big Bend	K-Bar Ranch Road	355	67	66	66	65	65	0
Canyonlands	Island in the Sky	361	73	71	70	70	70	0
Chiricahua	Entrance Station	351	76	75	75	74	72	0
Craters of the Moon[b]	Visitor Center	0	--	--	--	--	--	--
Death Valley	Park Village	347	88	85	84	82	80	2
Denali	Headquarters	355	60	57	54	53	53	0
Glacier	West Glacier Horse Stables	346	67	63	61	59	58	0
Grand Canyon	The Abyss	360	77	74	71	70	70	0
Great Basin	Maintenance Yard	349	77	73	72	72	71	0
Great Smoky Mountains	Clingmans Dome	185	89	88	88	86	84	4
Great Smoky Mountains	Cove Mountain	359	86	85	81	80	80	2
Great Smoky Mountains	Look Rock	356	89	87	86	85	85	6
Joshua Tree	Black Rock	348	105	105	104	103	103	36
Joshua Tree	Cottonwood Canyon	270	87	81	80	79	78	1
Lassen Volcanic	Manzanita Lake Fire Station	353	77	75	75	74	74	0
Mammoth Cave	Houchin Meadow	364	74	74	72	71	71	0
Mesa Verde	Resource Management Area	360	84	79	74	74	72	0
Mount Rainier	Tahoma Woods	351	75	72	64	64	62	0
North Cascades	Marblemount Ranger Stn	348	60	60	56	53	51	0
Petrified Forest	South Entrance	307	85	73	71	71	71	1
Pinnacles	SW of East Entrance Station	355	88	82	81	78	76	1
Rocky Mountain	Long's Peak	337	91	76	76	76	74	1
Sequoia and Kings Canyon	Ash Mountain	299	109	107	104	104	103	49
Sequoia and Kings Canyon	Lower Kaweah	348	101	99	98	97	95	17
Shenandoah	Big Meadows	318	81	81	79	77	77	0
Voyageurs	Sullivan Bay	318	68	68	64	63	63	0
Yellowstone	Water Tank	338	82	70	70	69	69	0
Yosemite	Turtleback Dome	289	94	88	87	85	84	4
Zion	Dalton's Wash	354	138	137	76	75	74	2
Sites operated by cooperating state agencies								
Acadia	Cadillac Mountain	178	92	85	82	80	77	2
Acadia	McFarland Hill	359	74	72	72	70	69	0
Cape Cod	Cape Cod	178	106	104	98	82	81	3
Chamizal	Chamizal	351	89	88	79	78	77	2
Congaree	Congaree Bluff	350	81	79	74	72	71	0
Cowpens	State Monitor	355	90	81	79	76	76	1
Great Smoky Mountains	Cades Cove	241	74	73	72	71	71	0
Great Smoky Mountains	Purchase Knob	203	78	77	74	73	73	0
Saguaro	Pima County	362	80	76	76	76	76	0
Theodore Roosevelt	Painted Canyon Visitor Cntr	359	70	67	67	66	66	0
Wind Cave	Visitor Center	364	78	76	73	73	71	0
Nearby sites operated by other agencies								
Alabama-Coushatta	CASTNet site	331	83	73	72	70	69	0

Table 2. Summary of 8-hour average ozone concentrations (ppb) (continued).

National Park Unit	Site Name	Valid Number of Days	1st Highest	2nd Highest	3rd Highest	4th Highest[a]	5th Highest	# Days with 8-Hour Average O_3 Values ≥85 ppb[a]
Nearby sites operated by other agencies								
Appalachian Trail	Mount Greylock Summit	170	82	79	77	76	74	0
Blue Ridge Parkway	7510 Blue Ridge Parkway	199	72	70	68	67	67	0
Blue Ridge Parkway	Barnet Knob Firetower Road	199	85	84	83	81	80	1
Blue Ridge Parkway	Blue Ridge Parkway	49	79	69	67	61	61	0
Blue Ridge Parkway	Frying Pan Mountain	199	87	81	80	79	75	1
Blue Ridge Parkway	Route 191	213	83	78	71	71	67	0
Blue Ridge Parkway	Ranger Station	151	73	72	69	68	68	0
Blue Ridge Parkway	Vinton Elementary	212	83	82	78	76	76	0
Boston Harbor Islands	Former Nike Missile Site	174	83	83	83	79	77	0
Cuyahoga Valley	800 Patterson	213	82	80	77	77	77	0
Everglades	Cutler Road	359	95	80	78	71	69	1
George Washington Pkwy	Alexandria Health	204	118	98	94	84	83	3
Guilford Courthouse	Mendenhall Middle School	164	88	86	80	80	80	2
Indiana Dunes	Ammunition Bunker	179	78	74	73	73	68	0
Indiana Dunes	Gas Station	179	80	77	76	75	75	0
Indiana Dunes	Water Treatment Plant	182	76	75	74	70	69	0
Mississippi	Anoka County Airport	330	75	71	65	65	63	0
Mississippi	Somerset Town Hall	358	76	74	70	68	67	0
Mississippi	Washington County	180	80	72	69	68	68	0
Petroglyph	Westside Taylor Ranch	357	79	74	73	72	72	0
Rock Creek	Achbold Parkway	364	86	85	85	83	81	3
Saratoga	Stillwater	273	90	80	75	73	71	1
Saugus Iron Works	Lynn Water Treatment	346	86	84	79	78	77	1
Portable ozone monitoring systems								
Abraham Lincoln Birthplace	Visitor Center	109	79	78	78	77	75	0
Assateague Island	Maintenance Area	152	88	86	84	84	83	2
Carlsbad Caverns	Maintenance Area	107	78	77	75	74	73	0
Colorado	Maintenance Yard	150	78	76	74	73	72	0
Cumberland Gap	Hensley Settlement	154	80	79	74	71	70	0
Dinosaur	West Entrance Housing	196	69	69	68	68	67	0
Joshua Tree	Pinto Wells	120	89	85	83	83	82	2
Lake Mead	Meadview	132	87	82	82	81	79	1
Mount Rainier	White River	0	---	---	---	---	---	---
Natchez Trace Parkway	Dancy Ranger Station	170	72	70	68	67	66	0
Olympic	Hurricane Ridge Portable	82	63	63	59	59	57	0
Padre Island	Malaquite Visitor Center	150	89	83	82	80	77	1
Yosemite	School Yard	115	76	72	71	71	70	0

[a] The primary and secondary National Ambient Air Quality Standard for ozone is 0.08 ppm over an 8-hour period. (An exceedance of the standard occurs when an 8-hour average ozone concentration is greater than or equal to 85 ppb. A violation of the standard occurs when the 3-year average of the fourth highest daily maximum 8-hour average ozone concentration equals or exceeds 85 ppb.) Exceedances of the standard are highlighted here in orange or red.

[b] Ozone data at Craters of the Moon were invalid in 2006 due to a leak that was found in the inlet tubing in Spring 2007. The leak was caused during roof replacement at the visitor center in Winter 2004.

Note: The color coding break points follow the color categories used on the EPA's AIRNow Web Site (*http://www.airnow.gov*). Dashed lines represent no data available at that site.

Operating agency key: plain text = site operated by the National Park Service; *italics* = site operated by a state agency; underline = site operated by the National Park Service, but consisting of non-EPA certified portable instrumentation

Color shading key: 4th highest 8-hour average: = 85 - 105 ppb ozone concentration; > 105 ppb ozone concentration. # days with 8-hour average ≥85 ppb: = 4 - 10 days; > 10 days

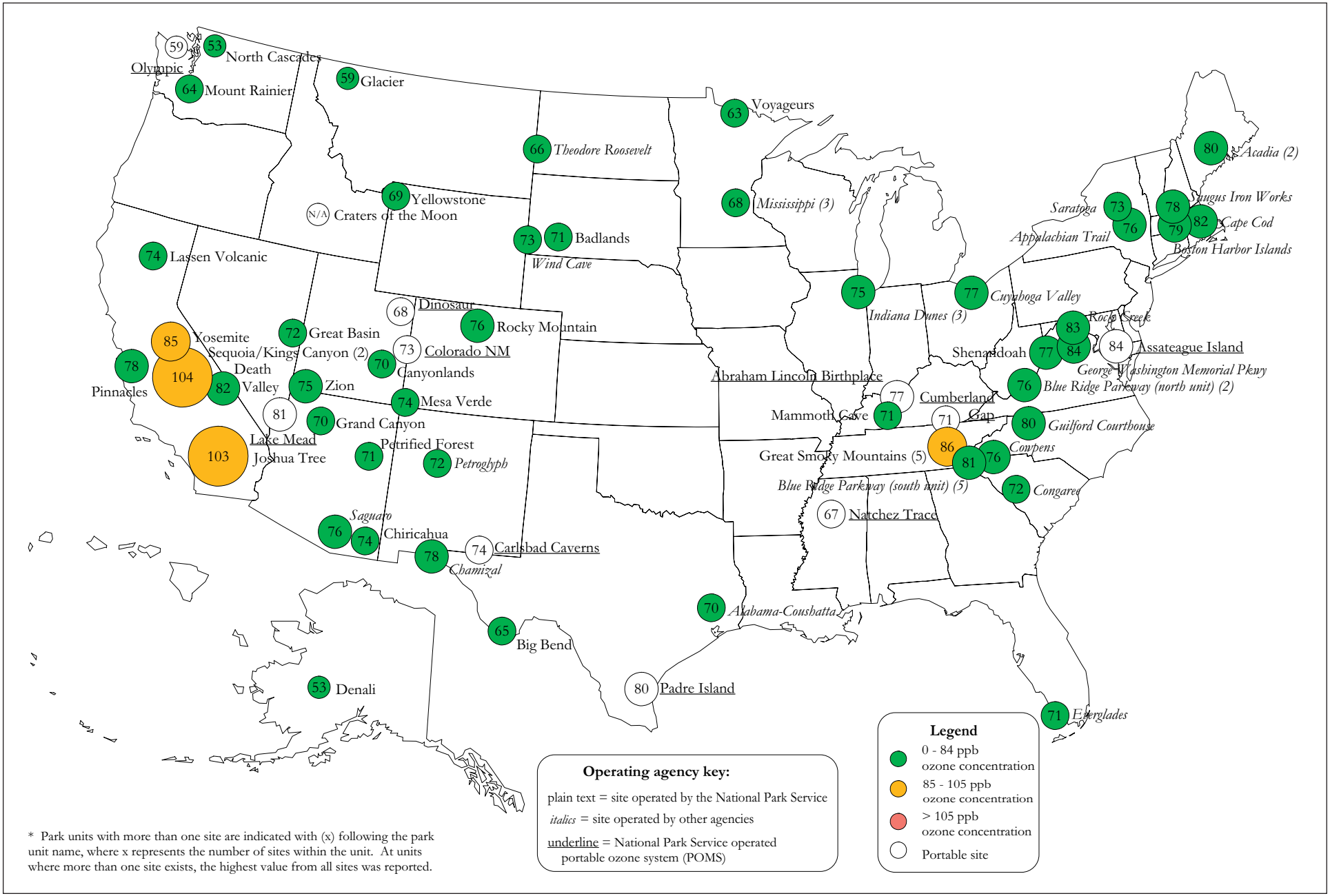


Figure 2. Annual fourth highest daily maximum 8-hour average ozone concentrations (in ppb).

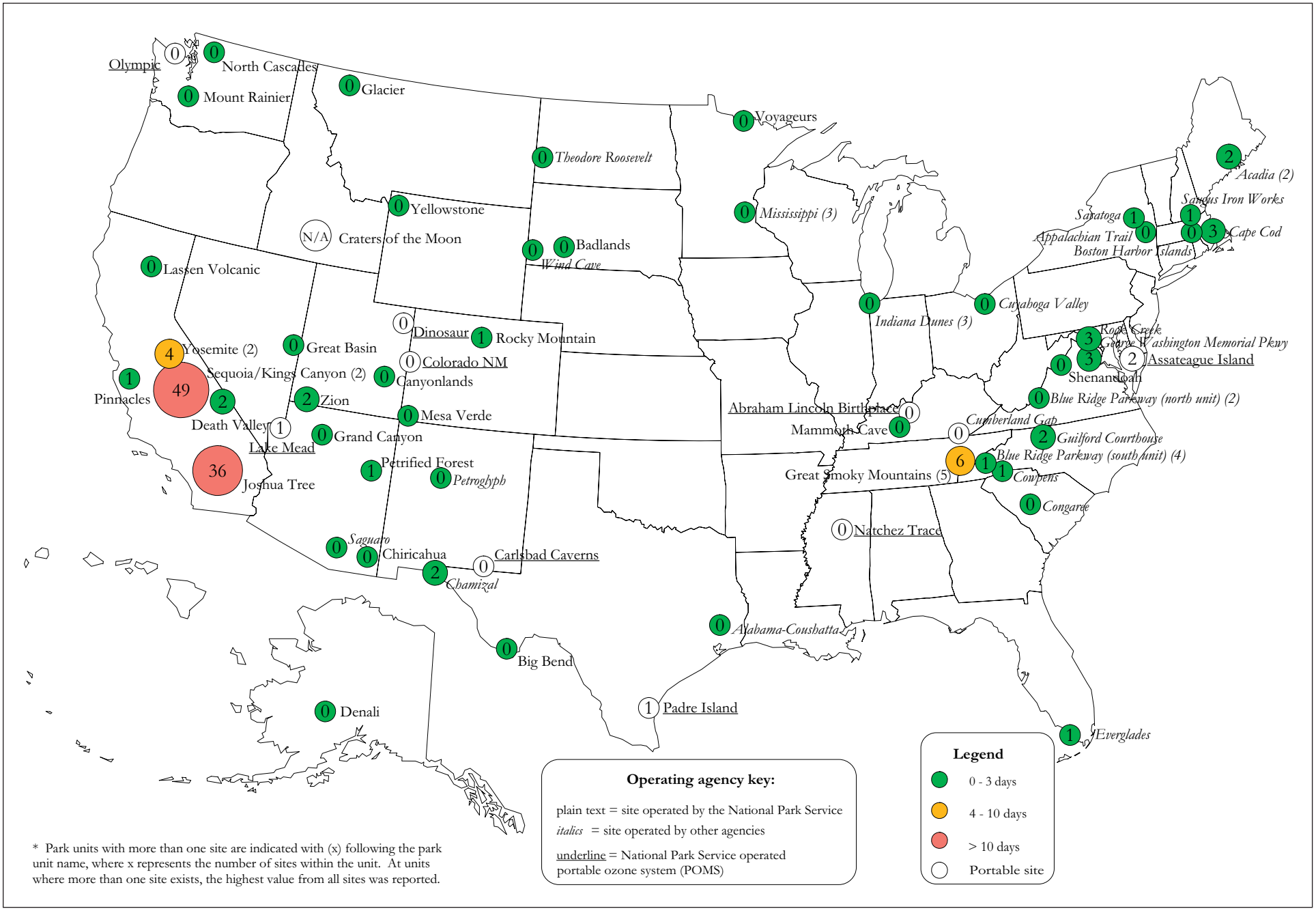


Figure 3. Annual number of days with daily maximum 8-hour average ozone values ≥85 ppb.

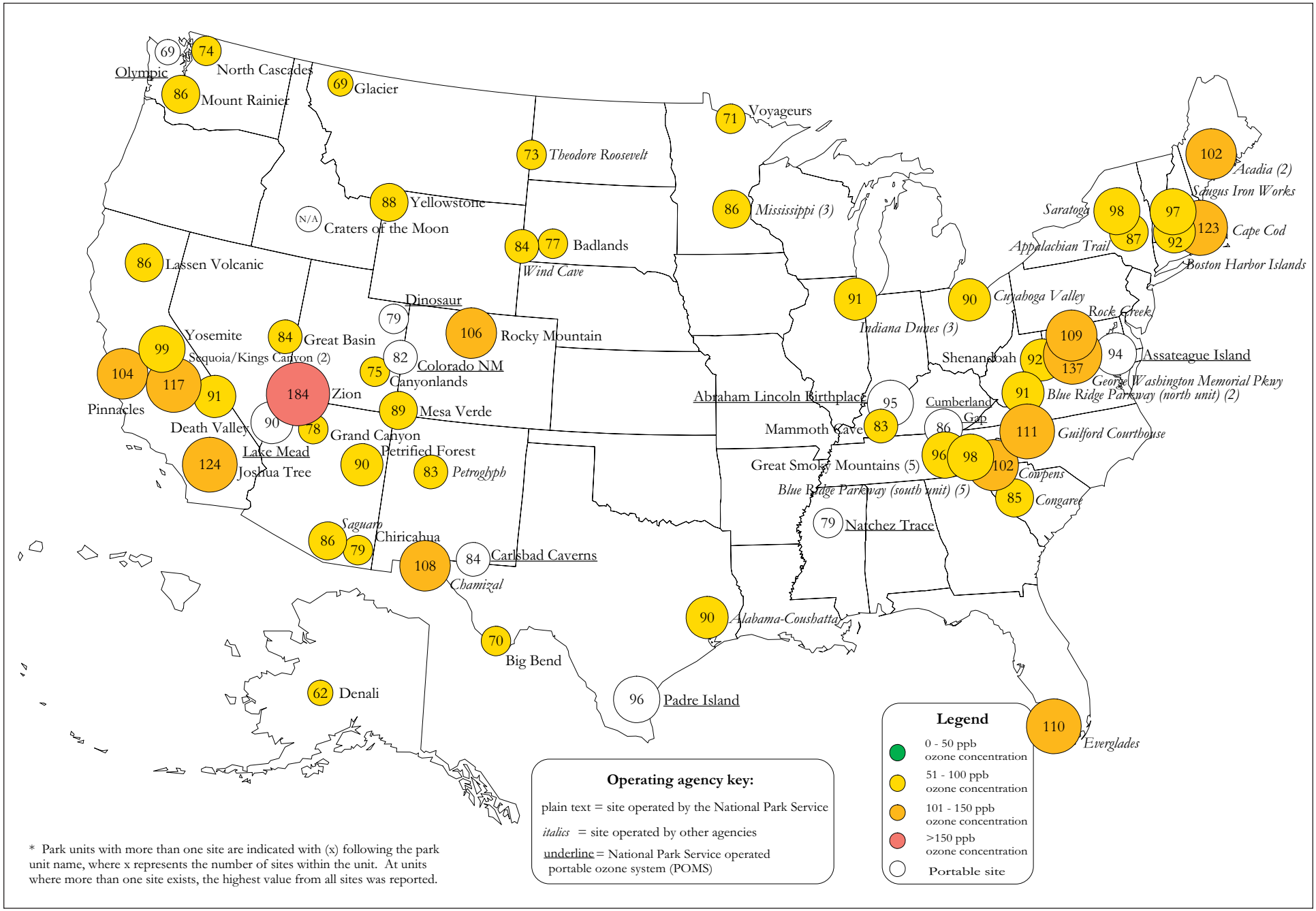


Figure 4. Annual second highest 1-hour average ozone concentrations (in ppb).

Grand Canyon National Park, Arizona
Photo by Joe Adlhoch/ Air Resource Specialists, Inc.

Ozone Violation Summaries

Table 3 presents ozone violation summaries for NPS-operated and cooperating sites for all 3-year periods over the last 10 years, with violations indicated in orange and red. For sites operating independently of the NPS, only the 2003-2005 and 2004-2006 violation summaries are presented. A violation of the standard occurs when the 3-year average of the fourth highest daily maximum 8-hour average ozone concentration equals or exceeds 85 ppb. Table values in parentheses indicate that the EPA data completeness requirement for the 3-year period was not met. However, annual fourth highest daily maximum 8-hour ozone concentrations greater than or equal to 85 ppb for calendar years not meeting the EPA data completeness requirement are included in the NAAQS violation computation.

In 2006, four of the NPS and cooperating state-operated sites within three national park units were in violation of the NAAQS 8-hour standard, down from six sites within five units in 2005. No sites that operated independently of the NPS recorded a violation in 2006.

Figure 5 presents a ranked list of sites based on the 2004-2006 ozone violation summary data presented in the first column of Table 3. Only sites with a 3-year average fourth highest daily maximum 8-hour average of 80 ppb or greater are presented in this figure.

Table 3. Ozone violation summary - primary standard[a].

National Park Unit	Site Name	2004 - 2006	2003 - 2005	2002 - 2004	2001 - 2003	2000 - 2002	1999 - 2001	1998 - 2000	1997 - 1999
Sites operated by the National Park Service									
Badlands	Visitor Center	67	(66)	(64)	(67)	---	---	---	---
Big Bend	K-Bar Ranch Road	63	63	62	62	(62)	(63)	66	65
Canyonlands	Island in the Sky	69	71	72	70	(71)	(71)	73	70
Chiricahua	Entrance Station	72	71	70	69	69	70	70	68
Craters of the Moon[b]	Visitor Center	---	---	67	(65)	(63)	(63)	66	(64)
Death Valley	Park Village	82	81	80	81	81	79	80	79
Denali	Headquarters	51	52	53	54	49	49	48	53
Glacier	West Glacier Horse Stables	54	56	55	53	49	48	51	47
Grand Canyon	The Abyss	73	74	74	74	73	72	73	73
Great Basin	Maintenance Yard	72	72	72	70	72	72	73	72
Great Smoky Mountains	Clingmans Dome	(80)	(79)	(87)	(92)	(98)	(98)	(102)	(98)
Great Smoky Mountains	Cove Mountain	77	78	86	92	96	96	101	(100)
Great Smoky Mountains	Look Rock	84	86	91	92	94	96	104	104
Joshua Tree	Black Rock	103	105	106	99	94	92	102	109
Joshua Tree	Cottonwood Canyon	(62)	(45)	---	---	---	---	---	---
Lassen Volcanic	Manzanita Lake Fire Station	69	68	71	72	74	77	78	76
Mammoth Cave	Houchin Meadow	72	73	77	80	84	88	94	(92)
Mesa Verde	Resource Management Area	73	70	68	67	69	69	70	(66)
Mount Rainier	Tahoma Woods	(58)	(61)	63	61	56	60	57	51
North Cascades	Marblemount Ranger Stn	(48)	(51)	51	50	46	48	46	43
Petrified Forest	South Entrance	(70)	(71)	(66)	(64)	(55)	---	---	---
Pinnacles	SW of East Entrance Station	75	75	80	81	81	(79)	(82)	82
Rocky Mountain	Long's Peak	74	77	82	81	78	74	77	74
Sequoia and Kings Canyon	Ash Mountain	(103)	(105)	(105)	(107)	(105)	(104)	(105)	(105)
Sequoia and Kings Canyon	Lower Kaweah	96	97	101	101	98	(94)	(93)	(96)
Shenandoah	Big Meadows	77	(80)	82	87	85	87	93	96
Voyageurs	Sullivan Bay	64	66	64	65	(64)	67	68	70
Yellowstone	Water Tank	63	61	63	65	65	67	67	65
Yosemite	Turtleback Dome	86	88	90	90	89	86	88	86
Zion	Dalton's Wash	80	(82)	(74)	---	---	---	---	---
# park units with violations:		**3**	**4**	**4**	**5**	**5**	**6**	**6**	**6**
# sites with violations:		**4**	**5**	**7**	**8**	**8**	**9**	**9**	**9**
Sites operated by cooperating state agencies									
Acadia	Cadillac Mountain	80	82	88	94	93	89	87	(89)
Acadia	McFarland Hill	71	74	80	87	84	85	83	(90)
Cape Cod	Cape Cod	84	86	88	95	93	96	89	(95)
Chamizal	Chamizal	73	72	78	79	81	75	(79)	(76)
Congaree	Congaree Bluff	71	71	74	77	77	(74)	(73)	---
Cowpens	State Monitor	74	75	80	84	87	87	92	93
Great Smoky Mountains	Cades Cove	67	(67)	73	76	79	81	(85)	(83)
Great Smoky Mountains	Purchase Knob	75	78	82	86	88	87	90	90
Saguaro	Pima County	76	(76)	(75)	(76)	(54)	(33)	(33)	(33)
Theodore Roosevelt	Painted Canyon Visitor Cntr	60	59	60	61	59	58	(57)	(56)
Wind Cave	Visitor Center	(71)	(70)	---	---	---	---	---	---
# park units with violations:		**0**	**1**	**2**	**3**	**4**	**4**	**4**	**4**
# sites with violations:		**0**	**1**	**2**	**4**	**4**	**5**	**5**	**5**

Table 3. Ozone violation summary - primary standard[a] (continued).

National Park Unit	Site Name	2004 - 2006	2003 - 2005	2002 - 2004	2001 - 2003	2000 - 2002	1999 - 2001	1998 - 2000	1997 - 1999
Nearby sites operated by other agencies									
Alabama-Coushatta	CASTNet Site	(71)	(72)						
Appalachian Trail	Mount Greylock Summit	(78)	(80)						
Blue Ridge Parkway	7510 Blue Ridge Parkway	69	71						
Blue Ridge Parkway	Barnet Knob Firetower Road	(73)	(72)						
Blue Ridge Parkway	Blue Ridge Parkway	(70)	76						
Blue Ridge Parkway	Frying Pan Mountain	78	78						
Blue Ridge Parkway	Route 191	74	74						
Blue Ridge Parkway	Ranger Station	(69)	71						
Blue Ridge Parkway	Vinton Elementary	74	74						
Boston Harbor Islands	Former Nike Missile Site	81	81						
Cuyahoga Valley	800 Patterson	81	85						
Everglades	Cutler Road	68	66						
George Washington Pkwy	Alexandria Health	81	81						
Guilford Courthouse	Mendenhall Middle School	(81)	(82)						
Indiana Dunes	Ammunition Bunker	75	76						
Indiana Dunes	Gas Station	76	78						
Indiana Dunes	Water Treatment Plant	76	78						
Mississippi	Anoka County Airport	66	68						
Mississippi	Somerset Town Hall	67	(69)						
Mississippi	Washington County	(67)	(68)						
Petroglyph	Westside Taylor Ranch	71	72						
Rock Creek	Achbold Parkway	80	78						
Saratoga	Stillwater	83	83						
Saugus Iron Works	Lynn Water Treatment	77	82						
# park units with violations:		**0**	**1**						
# sites with violations:		**0**	**1**						

[a] The primary and secondary National Ambient Air Quality Standard for ozone is 0.08 ppm over an 8-hour period. (An exceedance of the standard occurs when an 8-hour average ozone concentration is greater than or equal to 85 ppb. A violation of the standard occurs when the 3-year average of the fourth highest daily maximum 8-hour average ozone concentration equals or exceeds 85 ppb.) Exceedances of the standard are highlighted here in orange or red.

[b] Ozone data at Craters of the Moon were invalid in 2006 due to a leak that was found in the inlet tubing in Spring 2007. The leak was caused during roof replacement at the visitor center in Winter 2004.

Note: The color coding break points follow the color categories used on the EPA's AIRNow Web Site (*http://www.airnow.gov*).

Operating agency key: plain text = site operated by the National Park Service
italics = site operated by a state agency
underline = site operated by the National Park Service, but consisting of non-EPA certified portable instrumentation

Color shading key: 4th highest 8-hour average
= 85 - 105 ppb ozone concentration
> 105 ppb ozone concentration

Note: A number in parenthesis ( ) indicates that data completeness was not met. The primary standard requires 90 percent data completeness, on average, during the 3-year period, with no single year within the period having less than 75 percent data completeness. This data completeness requirement would have to be satisfied in order to determine that the standard has been met at a monitoring site. However, calendar years with less than 75 percent data completeness are included in the computation if the annual fourth-highest daily maximum 8-hour concentration is greater than the level of the standard. A site could be found not to have met the standard with less than complete data.

Dashed lines represent no data available at that site.

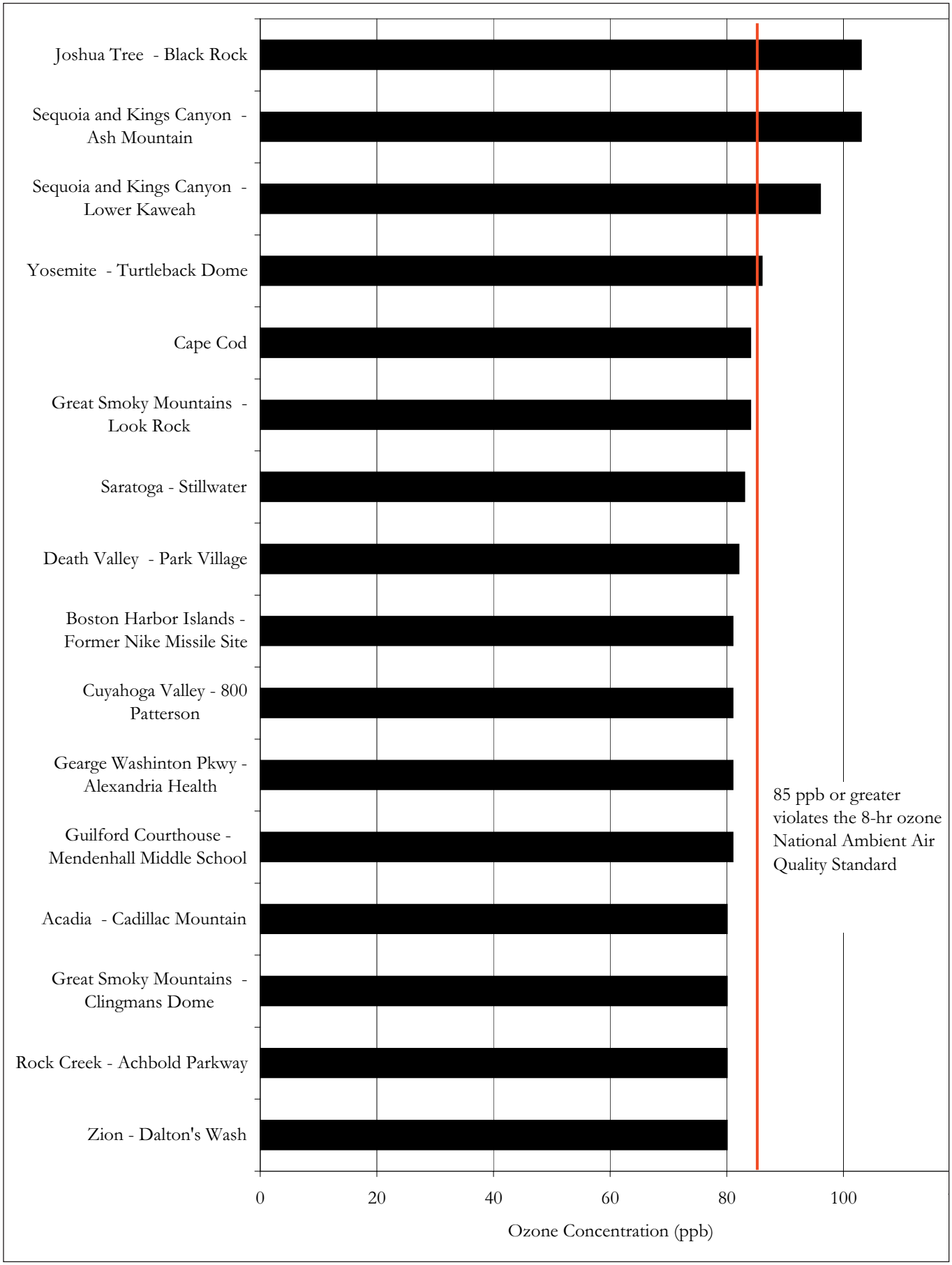


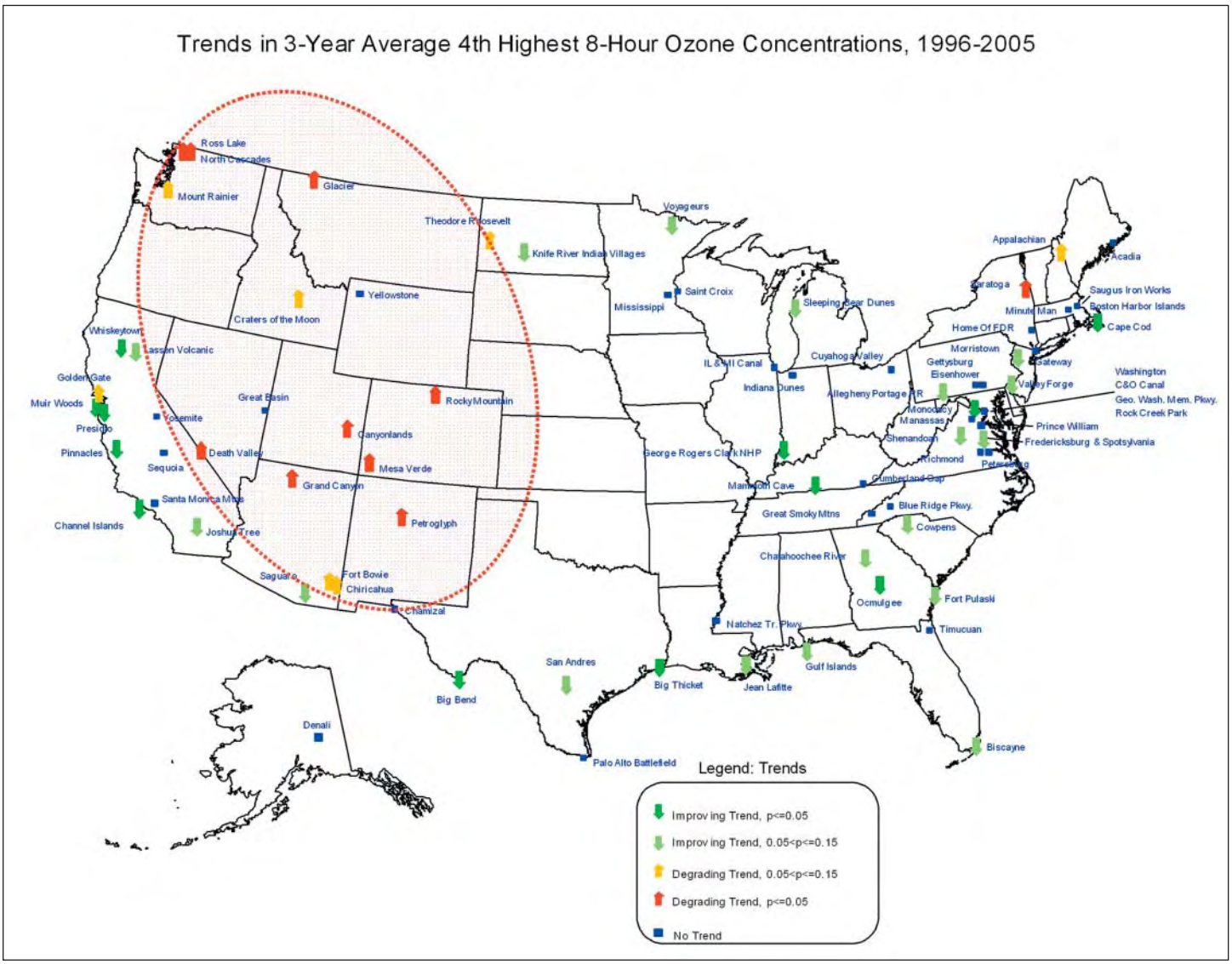
Figure 5. Three-year running average ozone violation summary ranking (sites ≥ 80 ppb), 2004-2006.

Ozone Trends

An important objective of the GPMP network is determining ozone trends, usually calculated based on 1-hour average (old NAAQS metric) or 8-hour average (current NAAQS metric) ozone concentrations. Trend analysis can help scientists relate changes in ozone levels to factors that control its concentration, including precursor emissions, climate changes, changing transport patterns, global transport, and short-term events such as wildfires. Some of the methods used for trend analysis and the usefulness of the resulting information were discussed in the 2005 Annual Data Summary Report[1]. This report presents some factors to consider in trends evaluations and includes details on trends from several specific parks and regions.

As part of the annual Government Performance and Results Act (GPRA) report, each year the NPS ARD estimates ozone trends from monitoring stations in or very near park units using the Theil method[2]. (For more detail on these trend results, consult the 2007 GPRA report.) As can be seen in Figure 6, most GPMP network sites show either an improvement in ozone concentrations or no change. This is especially true in the Eastern United States and in California, with a couple of exceptions. However, some mountainous regions in the West show degrading ozone concentrations. Figure 7 displays areas of the country that are currently classified by the EPA as non-attainment areas based on the ozone standard. Reviewing ozone trends from parks in or near these areas reveals that most sites next to non-attainment areas show improving or stable ozone conditions. Rocky Mountain National Park is an exception to this since it exhibits an increasing trend in ozone concentrations. (Denver is listed as an Early Action Area, not technically a non-attainment area.)

Figure 6. Map showing a simplified version of ozone trends based on three categories. Trends analysis based on the Theil method as used for the GPRA report.



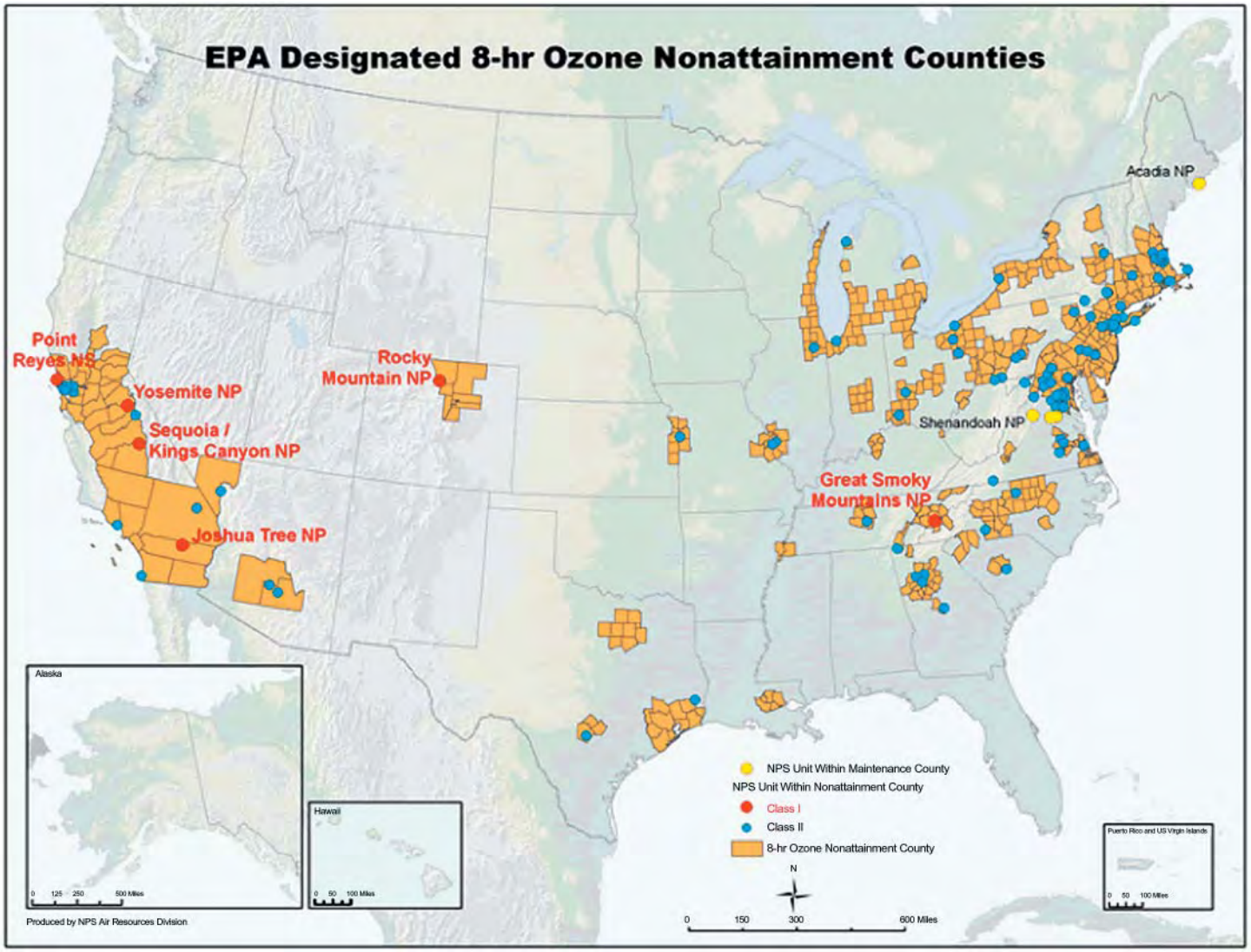


Figure 7. Map of ozone non-attainment areas with park units within the areas marked by red and blue dots. Based on information from *http://www.epa.gov/air/data/nonat.html?us~USA~United%20States.*

Acadia National Park in Maine and Shenandoah National Park in Virginia are examples of two Eastern park units that are close to violation of the standard, but due to recent decreases in ozone concentrations are currently in attainment. Two monitoring stations operate in Acadia National Park: McFarland Hill and Cadillac Mountain. The McFarland Hill station returned to compliance of the ozone standard in the mid-1990s and has remained just below the 8-hour average standard ever since. At the Cadillac Mountain site, which is at a higher elevation than McFarland Hill, the ozone concentrations are slightly higher and the station came into compliance only in the last couple of years. At Shenandoah-Big Meadows, ozone increased during the 1990s to above the 8-hour average standard, but since the peak in 1999, the ozone concentrations have decreased and the park is currently below and in attainment of the standard. Although these two parks are currently in attainment, since the start of monitoring at these two parks the net change in the highest ozone concentrations has shown no improvement at Cadillac Mountain and Big Meadows. At McFarland Hill in Acadia, there has been a decrease in ozone concentrations since the high in 1988, but there are large swings in annual highest concentrations. Ozone should be watched carefully at these two parks to see if the current improving trend persists.

Ozone trends based on changes in the 3-year average of the annual fourth highest daily maximum 8-hour concentration over a 10-year period using the Theil analysis technique have been widely reported and serve as the basis for the ARD GPRA report. This trend is expressed as a change in ozone concentrations (in ppb) per year where negative slopes correspond to improving ozone conditions. This approach does not consider if ozone concentrations are high or low at individual sites, but only if ozone concentrations are trending upward or downward. To identify potential trends early, a statistical significance based on a more lenient p-value of 0.15 is used, rather than a stricter, more robust p-value of 0.05. The Theil trends, as presented in the GPRA report, are included in Table 4. Trends with p-values less than or equal to 0.15 are indicated in dark green. Three trend categories are provided in this table: a degrading trend (highlighted in blue), no change in trend (no highlight), and improving trend (highlighted in light green). There are more parks with improving (a decreasing trend) or no change than with degrading (an increasing trend) ozone air quality. Thirteen (13) parks show a strongly significant trend based on a p-value of 0.05 or better.

In any trend determination there is an uncertainty band in which Improving or Degrading air quality is indeterminate. Various factors contribute to this No Change band, including the following:

Lack of statistical significance – Trends with a statistical significance of p = 0.05 or less can be considered acceptable. P-values in the range of 0.05 to 0.15 have greater uncertainty but are considered in the GPRA report as statistically significant. P-values greater than 0.15 should be considered no trend.

Trend change is small – The slope of a trend is also important. Very small slopes are indistinguishable from a slope of zero. A slope of 0.10 ppb/yr, for example, represents a change of only 1 ppb over 10 years. This is not an important change and because of instrument uncertainties, would be very hard to distinguish. As a practical matter, an overall change in ozone of 3-5 ppb over 10 years is needed. For this analysis, the range within which a trend is considered too small to be determined is -0.5 to 0.5 ppb per year.

Table 4. Ozone trends based on the 1997-2006 10-year period[a] using Theil analysis.

	Theil Trend[a]	
Park	ppb/yr	p-value
Mammoth Cave	-3.67	0.00
Channel Islands	-2.00	0.04
Big Thicket	-1.83	0.00
Shenandoah	-1.50	0.15
Cowpens	-1.00	0.11
Joshua Tree	-1.00	0.15
Cape Cod	-1.00	0.02
Pinnacles	-1.00	0.00
Big Bend	-0.83	0.00
Voyageurs	-0.58	0.09
Lassen Volcanic	-0.57	0.15
Yellowstone	-0.53	0.20
Saguaro	-0.50	0.11
Great Smoky Mountains	-0.14	0.43
Sequoia / Kings Canyon	-0.14	0.36
Great Basin	0.00	0.24
Yosemite	0.13	0.36
Denali	0.14	0.30
Canyonlands	0.33	0.04
Grand Canyon	0.33	0.00
Craters of the Moon	0.40	0.15
Mesa Verde	0.43	0.02
Death Valley	0.50	0.00
Theodore Roosevelt	0.67	0.14
Acadia	0.83	0.18
Glacier	0.83	0.02
Mount Rainier	0.83	0.15
Rocky Mountain	1.00	0.01
North Cascades	1.29	0.00

[a] As reported in the GPRA report for 2007 (1997-2006).

italics = site operated by a state agency

Improving

Degrading

Statistically Significant at <0.15

Method, site, and instrument uncertainties – Errors in trend determination are introduced if other variability in data is not considered. Over the 20 or more years that air quality monitoring stations have been in the parks, changes in instruments, shelter types, inlet configurations, inlet heights, shelter locations, operators, calibration equipment, and standard operating procedures have all changed slightly. These factors affect the trend assessments and have not always been taken into account when reporting trends. Table 5 lists monitoring stations that have moved location in the past. Trend data from these sites should be treated carefully.

Between 1995 and 1997, most monitoring stations had inlet configuration changes and inlet height changes from 3.5 meters to 10 meters as part of standardization to CASTNet procedures. Although there is little indication that the inlet change made much difference in ozone concentrations, recent comparisons of ozone analyzers at different inlet heights have shown differences during daily periods when the atmospheric boundary layer is changing rapidly after sunrise and around sunset. Since these periods do not coincide with peak daily ozone, there is no effect on metrics such as the 4th highest daily maximum 8-hour ozone.

Data from multiple monitoring sites are available – Some park units have multiple monitoring sites that show slightly different ozone concentrations and patterns. In the GPRA report, only the station with the largest trend is reported. As Table 6 shows for Great Smoky Mountains, the station and time period selected makes a difference in trend analysis. All of the Great Smoky Mountains ozone stations have reported an improvement in ozone concentrations since 1999, yet the regression slopes reported in Table 6 have no consistent agreement. The Purchase Knob station record is too short for an accurate comparison to the other stations.

Table 5. Station moves that may have affected ozone data collection. Combine data for trends with caution.

Park Name	Old Site ID	Location 1	Dates	Location 2	Dates	New Site ID
Yellowstone	YELL-LY	Lake	1987-1996	Water Tank	1996-present	YELL-WT
Mammoth Cave	MACA-OC	Onyx Cave	1984-1997	Houchin Meadow	1997-present	MACA-HM
Joshua Tree	JOTR-LH	Lost Horse	1987-1993	Black Rock (Yucca Valley)	1993-present	JOTR-BR
Voyageurs	VOYA-BB	Black Bay	1987-1996	Sullivan Bay	1996-present	VOYA-SB
Acadia	ACAD-HQ	Headquarters	1982-1997	McFarland Hill	1998-present	ACAD-MH

Table 6. Comparison of trend statistics for Great Smoky Mountains ozone monitoring stations.

Site	Years of data	Elevation (m)	Regression Slope (to 2006)	R^2	Theil Slope 1996-2005	p-value 1996-2005
Cades Cove	13	564	-1.08	0.38	-1.00	0.15
Look Rock	22	793	0.27	0.07	-1.13	0.05
Cove Mountain	19	1243	0.11	0.01	-1.33	0.15
Purchase Knob	7	1500	-3.00	0.96	-1.00	0.13
Clingmans Dome[a]	14	2021	-0.19	0.01	-0.14	0.43

[a] Operated during the summer season only.

A simple approach to trends was used in the 2005 Annual Data Summary Report that presented the difference between a base year and the present. There are a number of parks where direct ozone monitoring since 1990 has occurred and the change in the 8-hour ozone metric used for the NAAQS can be used for a trend. In contrast to the Theil analysis previously discussed, this analysis, presented in Table 7, allows for a comparison between current values and the standard. The number of parks violating the NAAQS and the number within 80% of the NAAQS have been decreasing (air quality improving). Thus, the number of parks in Table 7 with ozone above the NAAQS dropped from seven to two between 1990 and 2006. Seven parks show a long-term degradation in air quality, while nine show a long-term improvement. Notable successes in ozone reduction at eastern parks have occurred at Great Smoky Mountains, Mammoth Cave, and Shenandoah, where ozone at these parks has dropped below the NAAQS. The parks showing increases in ozone levels include: Denali, Great Basin, Joshua Tree, Rocky Mountain, Saguaro, Voyageurs, and Yellowstone. Parks violating the standard in California have not improved and still have a significant number of days when ozone concentrations exceed the standard.

Table 7. Trends based on the 1990 reference period compared to the latest 3-year average for the NAAQS ozone metric.

EPA Region	Park Name	1988-1990 4th Highest Daily Maximum 8-Hour	2004-2006 4th Highest Daily Maximum 8-Hour	1990-2006 % Change
1	*Acadia National Park - Cadillac Mountain*	93	80	-14
1	*Cape Cod National Seashore*	110	84	-24
4	*Cowpens National Battlefield*	75	74	-1
10	Denali National Park	49	51	4
9	Great Basin National Park	54	72	33
4	Great Smoky Mountains NP - Cove Mountain	84	77	-8
4	Great Smoky Mountains NP - Look Rock	84	84	0
9	Joshua Tree National Park - Black Rock	98	103	5
9	Lassen Volcanic National Park	73	69	-5
4	Mammoth Cave National Park	92	72	-22
9	Pinnacles National Monument	83	75	-10
8	Rocky Mountain National Park	67	74	10
9	*Saguaro National Monument*	74	76	3
9	Sequoia National Park - Lower Kaweah	95	96	1
3	Shenandoah National Park - Big Meadows	86	77	-10
8	*Theodore Roosevelt National Park - South*	64	60	-6
5	Voyageurs National Park	57	64	12
8	Yellowstone National Park	61	63	3

Codes:

- Less than 80% of NAAQS
- Greater than 80% of NAAQS
- Violation of the NAAQS
- Trend: Degrading ozone
- Trend: Improving ozone

italics = site operated by a state agency

Trends for Parks in Non-Attainment and Nearby Areas

Table 8 presents ozone trends for areas that are in non-attainment. In the last six years, ozone concentrations at Mammoth Cave, Great Smoky Mountains, Shenandoah, Cape Cod, and Cowpens have decreased so that none of these parks are currently in violation of the NAAQS. This decrease is important from a regulatory standpoint and indicates a decreased likelihood of resource injury. As shown in Figure 8, these sites had a large increase in ozone peaking around 1999, followed by a rapid decrease, a sequence that confounds the statistical trends and probably relates to ozone precursor emissions in the region. Trend plots for other rural monitors in the region around Great Smoky Mountains National Park are given for comparison. Peak ozone values occurred around 1999-2000 and have decreased since. If the entire periods of record are used, the statistical trend methods suggest no change or a slight decrease. In the next two years, the Theil method is likely to show a strong decrease in ozone as the 10-year period includes more points since 1999.

Another view of ozone at Great Smoky Mountains can be gained by taking a climatic approach. In Figures 9 and 10, the seasonal mean ozone concentrations are plotted by year and color-coded contours to help to illustrate the changes in ozone by time of day and year. This approach shows the lower elevation site at Look Rock follows a diurnal pattern with peak ozone concentrations in late afternoon. Ozone increases for the 5 pm hour until about 1999 (the dashed hour-17 line on the Mean Ozone Climatic Pattern moves from green, through yellow and orange to red) then starts to decrease again. The 9 am hour and 5 pm hour ozone values are plotted in the time series below to help present the trend.

The high elevation Clingmans Dome site has a different diurnal pattern with peak ozone concentrations late at night and the lowest ozone values during mid-day. This site also has an ozone peak around 1999 with decreasing values afterwards. The noon hour and midnight hour time series show this pattern. Clingmans Dome is cut off from the nighttime boundary layer, which is when it reports its highest ozone concentrations. In contrast, Look Rock reports its highest ozone concentrations during the daytime when the site is within the boundary layer. Clingmans Dome ozone data represents more of the regionally transported air pollution and Look Rock data more of the locally transported air pollution, yet both sites indicate decreasing ozone concentrations over the last 6 years. Both the highest ozone concentrations and the mean concentrations of ozone are decreasing at Great Smoky Mountains.

Table 8. Status of Clean Air Act Class I parks and their ozone trends.

Non-attainment Areas Park Name	2004-2006 O_3 3-year Average[a]	Trend[b]	Slope ppb/yr	p-value[c]
Yosemite - Turtleback Dome	86	⇔	+0.13	0.36
Sequoia - Ash Mountain	103	⇔	-0.14	0.36
Joshua Tree - Black Rock	103	⇩	-1.00	0.15
Rocky Mountain	74	⇧	+1.00	0.01
Great Smoky Mountains - Look Rock	84	⇔	-0.14	0.43
Maintenance Areas[d]				
Shenandoah	77	⇩	-1.50	0.15
Acadia - Cadillac Mountain	80	⇩	-1.00	0.05

[a] 4th highest annual daily maximum 8-hr average ozone, ppb.
[b] Theil technique, 4th highest 8-hour O_3, 10-year period, break points by p-value.
[c] p-values greater than 0.15 indicate trends are not significant.
[d] Maintenance areas are designated when an area comes out of non-attainment, but is still near the standard.

italics = site operated by a state agency

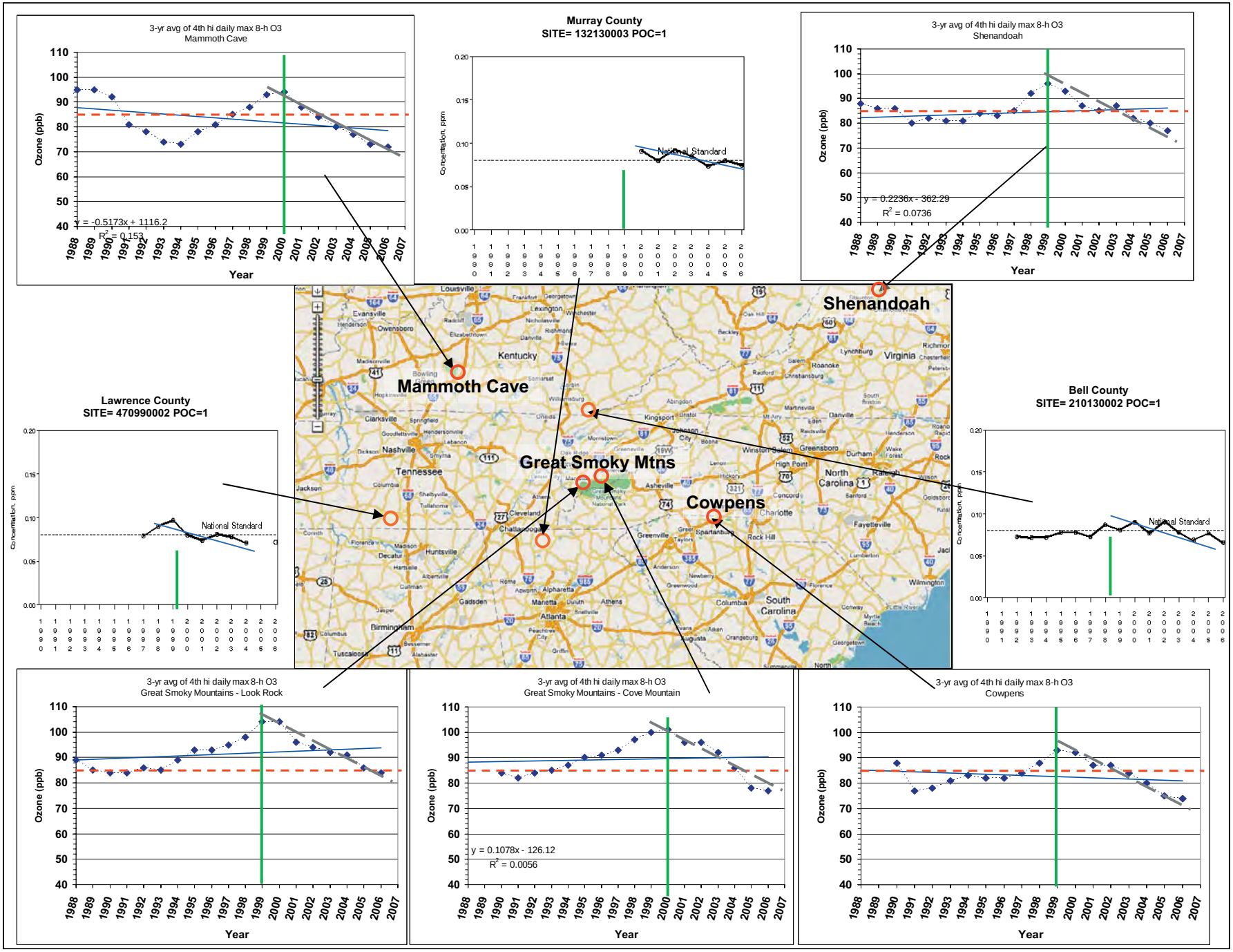


Figure 8. Time series plots for Great Smoky Mountains NP and some non-urban monitors in the region.

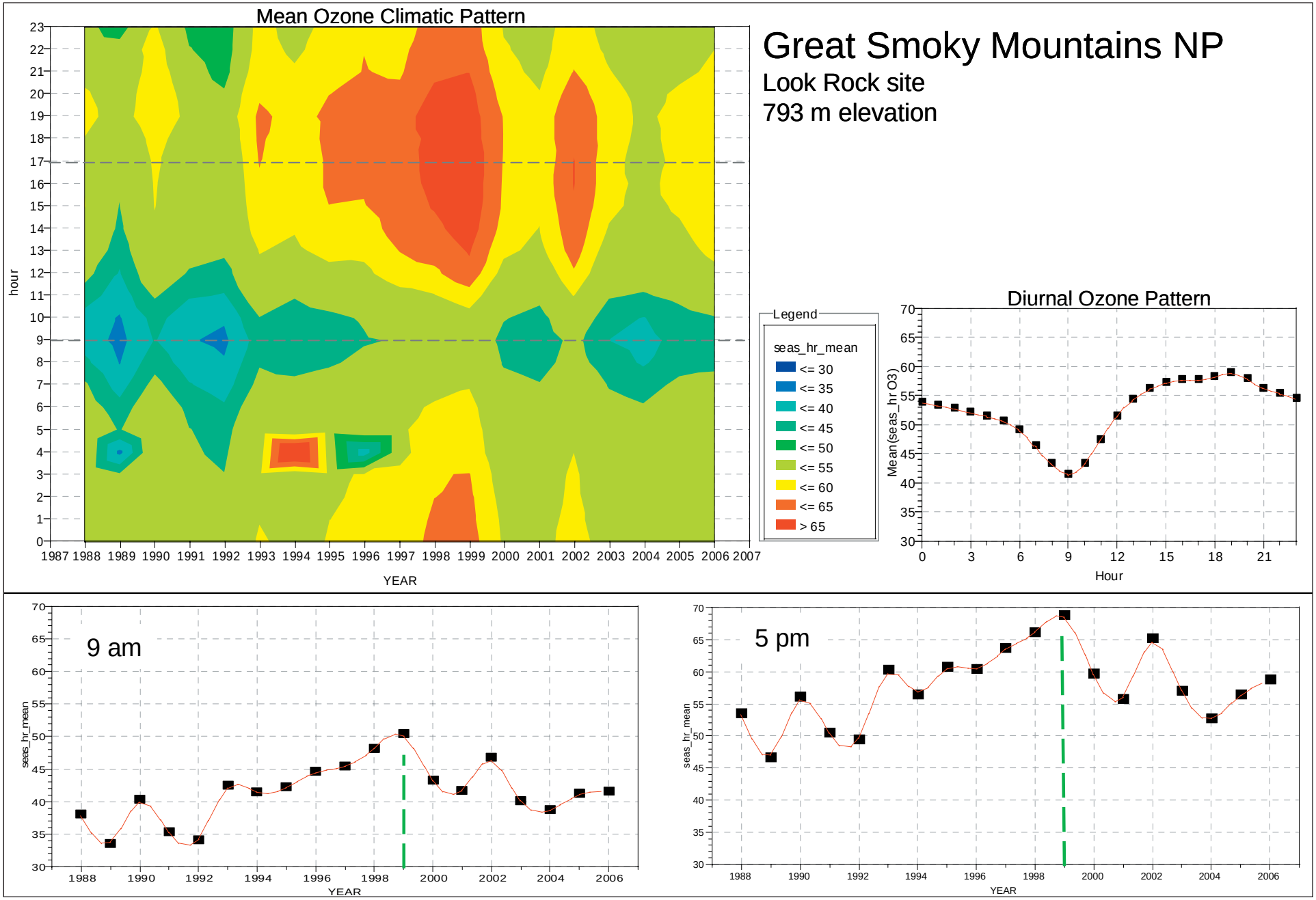


Figure 9. Climatic trend plots for mean hourly ozone over the summer seasons at the Great Smoky Mountains - Look Rock site, TN.

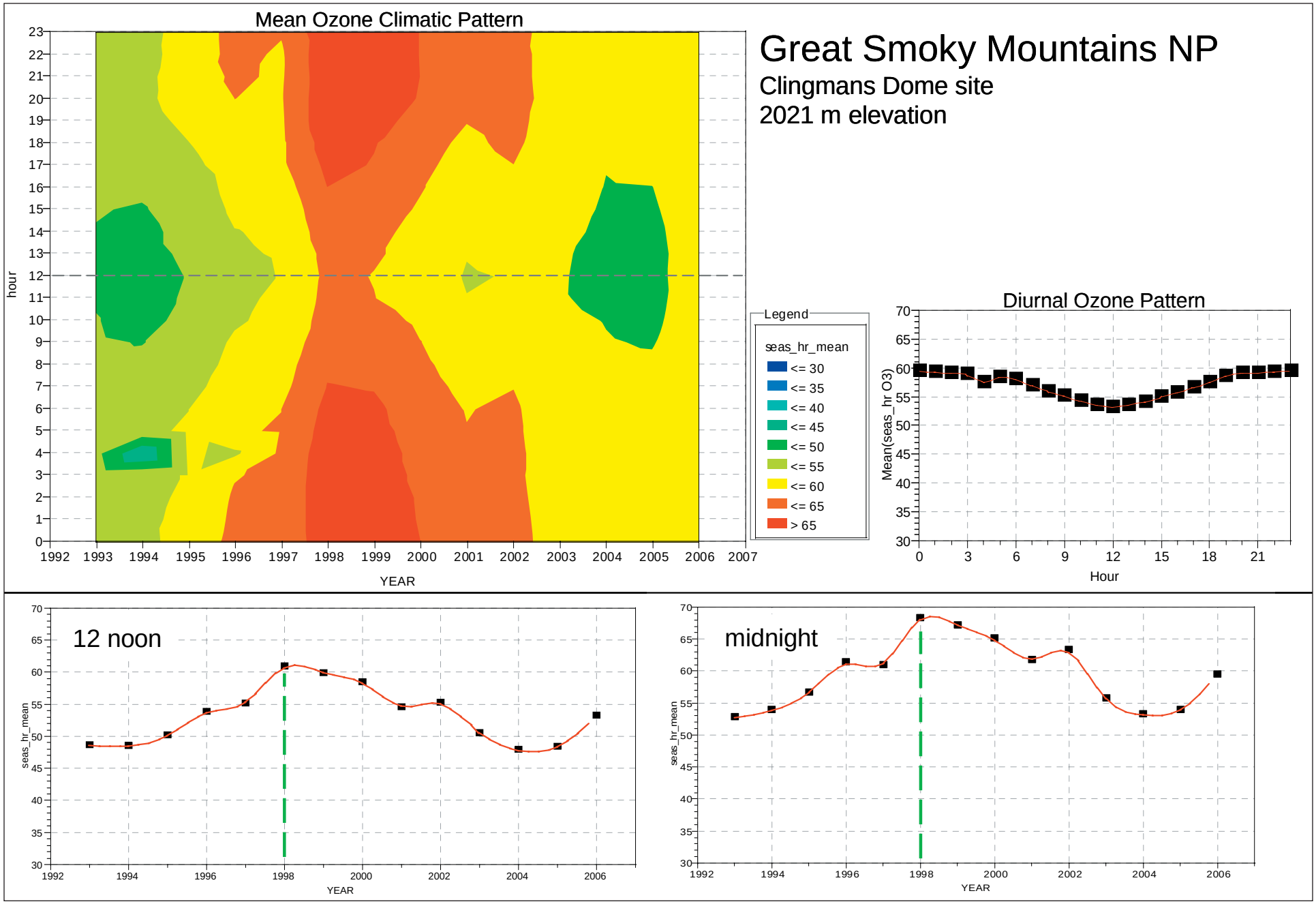


Figure 10. Climatic trend plots for mean hourly ozone over the summer seasons at the Great Smoky Mountains - Clingmans Dome site, TN.

Western Parks De-Seasonalized Trends
A number of western NPS monitoring sites were selected for additional trends analysis that uses monthly statistical values rather than just a single ozone summary statistic for each year. Relatively remote sites were chosen that were mostly unaffected by nearby pollution sources (Jaffe and Ray, 2007[3]) and had extended periods (15 years or more) of ozone data. Hourly averages were converted into daytime (10 am - 6 pm local time) monthly means. The seasonal component was removed from the monthly means using the seasonal decomposition procedure in SPSS (statistical analysis) software. The month-to-month seasonal variation was removed by subtracting from each monthly concentration the mean monthly values for the whole period being examined. Linear regression analysis was then conducted on the de-seasonalized values .This procedure gives a robust measure of the trend, so long as the trend is present and relatively uniform in all seasons.

The de-seasonalized monthly means trend results are presented in Table 9. Good agreement was obtained using the regression technique and the Theil method on the de-seasonalized monthly means. Rocky Mountain and Yellowstone show degrading ozone conditions of about 0.5 ppb/year. Rocky Mountain National Park is closer to the national ozone standard than Yellowstone, therefore the effect that increasing ozone concentrations has on park resources and visitors may be evident there first. Greater detail on the trend technique summarized here can be found in Jaffe and Ray, 2007[3].

Table 9. Trend analysis using linear regression and Theil's method on de-seasonalized monthly mean O_3 concentrations, daytime data (1000-1800 LST). R^2 and p-value refer to the regression trend. Values in bold are significant with a p-value ≤ .01.

Site	Mean	# days > 80 ppb in data record[a]	Regression trend	R^2	p-value	Theil trend (ppbv/year)
Rocky Mountain	47.2	19	0.51	0.22	**<0.01**	0.48
Yellowstone	43.6	0	0.50	0.32	**<0.01**	0.45
Lassen Volcanic	43.3	6	0.33	0.17	**<0.01**	0.32
Canyonlands	48.0	0	0.28	0.11	**<0.01**	0.26
Craters of the Moon	44.0	0	0.22	0.05	**0.01**	0.22
Denali	32.4	0	0.08	0.02	0.06	0.13
Glacier	32.8	0	0.00	0.00	0.45	-0.08

[a] This column gives the number of days in the data record with 8-hour daily maximum O_3 concentrations greater than 0.08 ppm.

Everglades National Park, Florida
NPS stock photo

Web Resources to Plot Ozone Trends for Parks

Trends plots for GPMP ozone monitoring stations can be plotted interactively from the NPS Web site at: *http://www2.nature.nps.gov/air/monitoring/o3Plots/index.cfm*. At this Web site several different statistical metrics can be used (Figure 11).

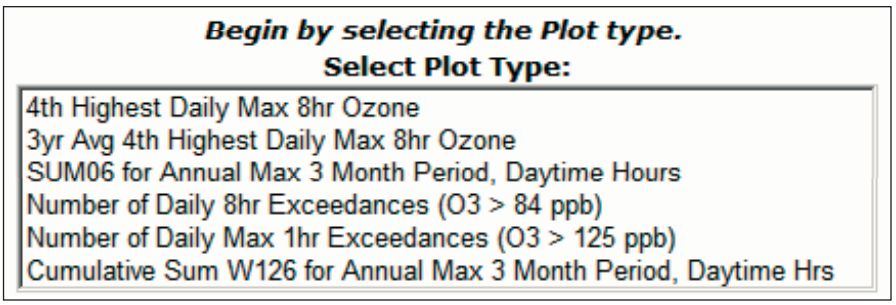


Figure 11. Statistical metrics available for ozone trend plots.

Previously, selected trend plots were included in the Annual Data Summary Report. Now all of these plots for all sites are available from the Web site.

Reviewing trends plots based on these different statistics allows for a more complete picture of ozone changes over time in park units. On the Web page, an example trend plot is shown for Rocky Mountain National Park, that has remained below the ozone standard based on the 3-year average used to determine violations. However, the trend in ozone has been upward and recent data approach the standard. When plotting the number of exceedances (refer to *http://www.epa.gov/airtrends/ozone.html*) infrequent exceedances of 85 ppb based on daily maximum 8-hour ozone concentrations appear. In 2002 and 2003, six and seven exceedances occurred, respectively. These two high years correspond to hot, drought conditions in Colorado. Emissions from wildfires in Colorado and other Western states likely contributed to ozone formation during these two years. The high variability from year to year and the influence of multiple factors, even when a strong trend appears to be present, is illustrated by this example.

Other ozone trends information for CASTNet and state operated monitoring locations is available on the Internet at: *http://www.epa.gov/castnet/site.html*.

The EPA has two Web sites for ozone trends. Trends in the NAAQS metric (annual 4th highest daily average 8-hour ozone) are available at: *http://www.epa.gov/airtrends/ozone.html*. Use the map at the bottom of the Web page to select a state and then select a monitoring station.

Meteorologically adjusted ozone trends for selected sites are plotted at *http://www.epa.gov/airtrends/weather.html*. The adjusted trends posted here remove weather variations due to temperature and humidity fluctuations that occur between years so that a more accurate relationship between ozone and emissions can be assessed.

More information on the Web

- Annual 4th highest 8-hr concentrations in parks *http://www2.nature.nps.gov/air/monitoring/docs/2006_O3ParkConc.pdf*
- Annual NAAQS exceedance counts in parks *http://www2.nature.nps.gov/air/monitoring/docs/2006_O3ParkExceedDays.pdf*
- Performance measures (GPRA report on trends) *http://www2.nature.nps.gov/air/who/npsPerfMeasures.cfm*
- Ozone interpolation maps as 5-year averages (Air Atlas) *http://www2.nature.nps.gov/air/maps/AirAtlas/index.cfm*
- NPS GIS map products for ozone *http://www2.nature.nps.gov/air/maps/AirAtlas/gisprojects.cfm*

References

[1] Annual Data Summary Report for 2005; NPS Gaseous Pollutant Monitoring Program, Air Resources Division, July 2006. *http://www2.nature.nps.gov/air/Monitoring/ads/ADSReport.cfm*

[2] 2007 GPRA report, *http://www2.nature.nps.gov/air/who/npsPerfMeasures.cfm*

[3] Dan Jaffe and John Ray, Increase in surface ozone at rural sites in the Western U.S, *Atmospheric Environment*, 41, 5452-5463 (2007).

Recent Published Articles that Use NPS Air Quality Data

Art Chappelka, Howie Neufeld, Sandy McLaughlin, Susan Sachs, and Jim Renfro, Ozone Pollution Damage to Growth and Physiology of Native Trees and Wildflowers in Great Smoky Mountains National Park, Final Report (June 2006). *http://www2.nature.nps.gov/air/Pubs/pdf/ChapelkaReport2005.pdf*

Joel D. Burley and John D. Ray, Surface ozone in Yosemite National Park, *Atmospheric Environment*, 41, 6048-6062 (2007).

Thomas J. Butler, Gene E. Likensa, Francoise M. Vermeylenc, Barbara J.B. Stunder, The impact of changing nitrogen oxide emissions on wet and dry nitrogen deposition in the northeastern USA, *Atmospheric Environment*, 39, 4851-4862 (2005).

N. E. Grulke, H. S. Neufeld, A. W. Davison, M. Roberts and A. H. Chappelka, Stomatal behavior of ozone-sensitive and –insensitive coneflowers (*Rudbeckia laciniata var. digitata*) in Great Smoky Mountains National Park, *New Phytologist* 173: 100-09 (2007).

Dan Jaffe and John Ray, Increase in surface ozone at rural sites in the Western U.S, *Atmospheric Environment*, 41, 5452-5463 (2007).

S. B. McLaughlin, M. Nosal, S. D. Wullschleger, and G. Sun, Interactive effects of ozone and climate on tree growth and water use in a southern Appalachian forest in the USA, *New Phytologist* 174: 109-124 (2007).

S. B. McLaughlin, S. D. Wullschleger, G. Sun, and M. Nosal, Interactive effects of ozone and climate on water use, soil moisture content and streamflow in a southern Appalachian forest in the USA. *New Phytologist* 174: 125-136 (2007).

Ralph J. Valente, Catherine Shea, K. Lynn Humes, Roger L. Tanner, Atmospheric mercury in the Great Smoky Mountains compared to regional and global levels, *Atmospheric Environment*, 41, 1861-1873 (2007).

Natchez Trace Parkway, Mississippi Portable Ozone Monitoring System Photo by Mike Slate/ Air Resource Specialists, Inc.

Resource Injury Indices

To quantify ozone exposure to plants, various indices other than the NAAQS primary and secondary standards are often used. These indices, defined below, take into account both peak ozone concentrations and cumulative exposure to ozone.

SUM06 thresholds

No risk
to ozone sensitive vegetation
0-7 ppm-hr

Higher risk
to ozone sensitive vegetation
8-16 ppm-hr

Highest risk
to ozone sensitive vegetation
>16 ppm-hr

- SUM06 – A cumulative index that is calculated as the maximum 3-month sum of the 0800-2000 hourly average ozone concentrations during the ozone season that are equal to or greater than 0.06 ppm (60 ppb). The units of this index are ppm-hr. Several thresholds have been developed for SUM06 (Heck and Cowling, 1997[1]).
- W126 – A cumulative index that is calculated as the sum of all hourly ozone concentrations during the EPA-designated ozone season, where a weighting function is used to give increasing significance (weights between 0 and 1) to concentrations of ozone greater than 0.04 ppm (40 ppb), and no weight to concentrations below 0.04 ppm (40 ppb). Units of this index are ppm-hr.
- N100 – The number of hours with ozone concentrations greater than or equal to 0.10 ppm (100 ppb). This index is reported without units. The N100 index is often considered along with the W126 in assessing the possible impact of the exposure. Several thresholds have been developed for W126 and N100 (Lefohn et al, 1997[2]).

Table 10 presents the ozone exposure indices summary statistics for 2006. Summaries for POMS are included for reference only. Since portable sites are deployed for seasonal use, there may be significant biases in SUM06, W126, and N100 exposure indices calculated from their data. These statistics were not calculated for sites that were operational for less than three months during the year. In 2006 there were no POMS sites that operated for less than three months.

The map in Figure 12 presents the annual 3-month maximum SUM06 exposure index for all network sites listed in Table 10. Index values are color-coded to represent three distinct levels of cumulative exposure. Data from portable sites (no color) are included for reference only.

Ozone effects depend not only on ozone exposure, but on other factors that may ameliorate or magnify the extent of ozone injury, including soil moisture, presence of other air pollutants, insects or diseases, and other environmental stresses. A high SUM06 exposure in a drought year, for example, may not result in vegetation injury because stomatal closure to prevent moisture loss will also prevent ozone uptake.

In evaluating risk to vegetation from ozone, it is useful to consider not only the SUM06 but also the W126 and N100 exposures. If more than one exposure index is above the threshold for effects, the potential for injury increases. The SUM06 risk and W126 thresholds are relative and not absolute.

In 2006, assessments were completed to evaluate the potential for ozone injury to vegetation at many national park service units. The assessments are available at *http://www2.nature.nps.gov/air/pubs/ecoeffects.cfm*. Information on ozone-sensitive plant species is available at *http://www2.nature.nps.gov/air/pubs/pdf/baltfinalreport1.pdf*.

References

[1] Heck, W.W. and E.B. Cowling. 1997. The Need for a Long-Term Cumulative Secondary Ozone Standard – An Ecological Perspective. *Environmental Management*. January.

[2] Lefohn, A.S., W. Jackson, D. Shadwick, and H.P. Knudsen. 1997. Effect of Surface Ozone Exposures on Vegetation Grown in the Southern Appalachian Mountains: Identification of Possible Areas of Concern. *Atmospheric Environment* 31(11):1695-1708.

W126 / N100 Thresholds	***W126***	***N100***
Highly Sensitive Species	*5.9 ppm-hr*	*6*
Moderately Sensitive Species	*23.8 ppm-hr*	*51*
Low Sensitive Species	*66.6 ppm-hr*	*135*

Table 10. Summary of indices for resource injury (SUM06, W126, and N100).

National Park Unit	Site Name	O_3% Valid	SUM06[a] (ppm-hr)	W126[b] (ppm-hr)	N100[c]
Sites operated by the National Park Service					
Badlands	Visitor Center	98.9	19.3	31.2	0
Big Bend	K-Bar Ranch Road	99.1	20.6	32.3	0
Canyonlands	Island in the Sky	99.2	41.4	57.1	0
Chiricahua	Entrance Station	97.8	28.7	41.1	0
Craters of the Moon[d]	Visitor Center	---	---	---	---
Death Valley	Park Village	98.4	69.4	78.5	0
Denali	Headquarters	98.8	0.4	10.2	0
Glacier	West Glacier Horse Stables	98.2	0.1	7.0	0
Grand Canyon	The Abyss	99.6	64.2	71.9	0
Great Basin	Maintenance Yard	97.5	32.1	47.9	0
Great Smoky Mountains	Clingmans Dome	98.1	69.9	72.2	1
Great Smoky Mountains	Cove Mountain	99.3	64.2	81.4	0
Great Smoky Mountains	Look Rock	98.9	64.7	82.5	0
Joshua Tree	Black Rock	96.4	127.4	144.8	84
Joshua Tree	Cottonwood Canyon	74.8	34.0	60.5	1
Lassen Volcanic	Manzanita Lake Fire Station	98.1	30.6	41.8	0
Mammoth Cave	Houchin Meadow	99.7	19.1	28.5	0
Mesa Verde	Resource Management Area	99.1	54.9	67.7	0
Mount Rainier	Tahoma Woods	97.6	5.8	8.6	0
North Cascades	Marblemount Ranger Station	97.5	1.0	3.4	0
Petrified Forest	South Entrance	97.2	34.0	40.7	0
Pinnacles	SW of East Entrance Station	99.2	25.1	31.1	2
Rocky Mountain	Long's Peak	96.3	30.7	58.7	3
Sequoia and Kings Canyon	Ash Mountain	90.9	109.2	110.7	92
Sequoia and Kings Canyon	Lower Kaweah	97.9	98.4	96.1	35
Shenandoah	Big Meadows	91.9	43.5	58.9	0
Voyageurs	Sullivan Bay	91.0	4.9	14.7	0
Yellowstone	Water Tank	97.4	21.8	44.3	0
Yosemite	Turtleback Dome	88.3	74.8	86.2	1
Zion	Dalton's Wash	98.6	49.5	51.6	4
Sites operated by cooperating state agencies					
Acadia	Cadillac Mountain	99.4	23.9	26.4	3
Acadia	McFarland Hill	99.1	10.2	19.3	0
Cape Cod	Cape Cod	97.4	25.9	32.1	11
Chamizal	Chamizal	98.8	18.7	25.9	10
Congaree	Congaree Bluff	97.9	17.3	21.2	0
Cowpens	State Monitor	99.3	20.2	31.4	2
Great Smoky Mountains	Cades Cove	98.5	21.6	26.4	0
Great Smoky Mountains	Purchase Knob	92.4	32.5	37.7	0
Saguaro	Pima County	99.4	29.8	44.3	0
Theodore Roosevelt	Painted Canyon Visitor Center	99.5	6.0	20.5	0
Wind Cave	Visitor Center	99.6	27.0	49.3	0
Nearby sites operated by other agencies					
Alabama-Coushatta	CASTNet Site	90.9	6.9	14.5	0

Table 10. Summary of indices for resource injury (SUM06, W126, and N100) (continued).

National Park Unit	Site Name	O_3% Valid	SUM06[a] (ppm-hr)	W126[b] (ppm-hr)	N100[c]
Nearby sites operated by other agencies					
Appalachian Trail	Mount Greylock Summit	92.2	20.6	25.6	0
Blue Ridge Parkway	7510 Blue Ridge Parkway	92.9	12.4	14.4	0
Blue Ridge Parkway	Barnet Knob Firetower Road	90.4	69.2	53.7	0
Blue Ridge Parkway	Blue Ridge Parkway	92.2	4.6	9.9	0
Blue Ridge Parkway	Frying Pan Mountain	92.7	48.3	47.8	1
Blue Ridge Parkway	Route 191	99.9	11.8	17.2	0
Blue Ridge Parkway	Ranger Station	98.5	10.5	14.0	0
Blue Ridge Parkway	Vinton Elementary	99.2	21.1	27.5	0
Boston Harbor Islands	Former Nike Missile Site	95.5	16.3	18.3	0
Cuyahoga Valley	800 Patterson	99.9	19.8	22.2	0
Everglades	Cutler Road	99.5	13.6	19.4	4
George Washington Pkwy	Alexandria Health	96.3	27.5	27.3	18
Guilford Courthouse	Mendenhall Middle School	94.9	29.2	30.1	4
Indiana Dunes	Ammunition Bunker	98.9	10.5	12.6	0
Indiana Dunes	Gas Station	99.2	12.0	15.5	0
Indiana Dunes	Water Treatment Plant	99.7	11.8	14.6	0
Mississippi	Anoka County Airport	91.1	7.4	11.1	0
Mississippi	Somerset Town Hall	99.0	9.7	14.8	0
Mississippi	Washington County	99.8	9.1	13.8	0
Petroglyph	Westside Taylor Ranch	99.0	28.0	32.9	0
Rock Creek	Achbold Parkway	99.6	25.1	26.3	5
Saratoga	Stillwater	75.3	10.1	14.9	0
Saugus Iron Works	Lynn Water Treatment	94.6	14.5	19.4	0
Portable ozone monitoring systems					
Abraham Lincoln Birthplace	Visitor Center	74.7	19.9	17.2	0
Assateague Island	Maintenance Area	97.3	36.1	40.6	0
Carlsbad Caverns	Maintenance Area	99.6	19.7	21.5	0
Colorado	Maintenance Yard	99.4	48.3	43.8	0
Cumberland Gap	Hensley Settlement	99.0	25.0	31.6	0
Dinosaur	West Entrance Housing	98.6	19.4	28.1	0
Joshua Tree	Pinto Wells	85.7	65.5	52.1	1
Lake Mead	Meadview	73.0	85.7	71.5	0
Mount Rainier	White River	---	---	---	---
Natchez Trace Parkway	Dancy Ranger Station	99.4	11.3	12.5	0
Olympic	Hurricane Ridge Portable	89.3	1.1	4.6	0
Padre Island	Malaquite Visitor Center	88.8	18.7	20.3	0
Yosemite	School Yard	99.9	16.9	13.3	0

[a] SUM06 exposure index represents the 0800-2000 hourly ozone concentrations equaling or exceeding 0.06 ppm. The value reported here represents a three-month maximum value during the ozone season. Units are ppm-hr.

[b] W126 exposure index represents the sum of all hourly ozone concentrations where each concentration is weighted by a function that gives greater emphasis to the higher hourly concentrations while still including the lower ones. Units are ppm-hr. For more information on the W126 exposure index go to *http://www2.nature.nps.gov/air/maps/AirAtlas/docs/air_quality_glossary.pdf*.

[c] N100 represents the number of hourly ozone concentrations greater than or equal to 0.100 ppm (100 ppb).

[d] Ozone data at Craters of the Moon were invalid in 2006 due to a leak that was found in the inlet tubing in Spring 2007. The leak was caused during roof replacement at the visitor center in Winter 2004. *Note:* Dashed lines represent no data available for that site.

Operating agency key: plain text = site operated by the National Park Service; italics = site operated by a state agency; underline = site operated by the National Park Service, but consisting of non-EPA certified portable instrumentation

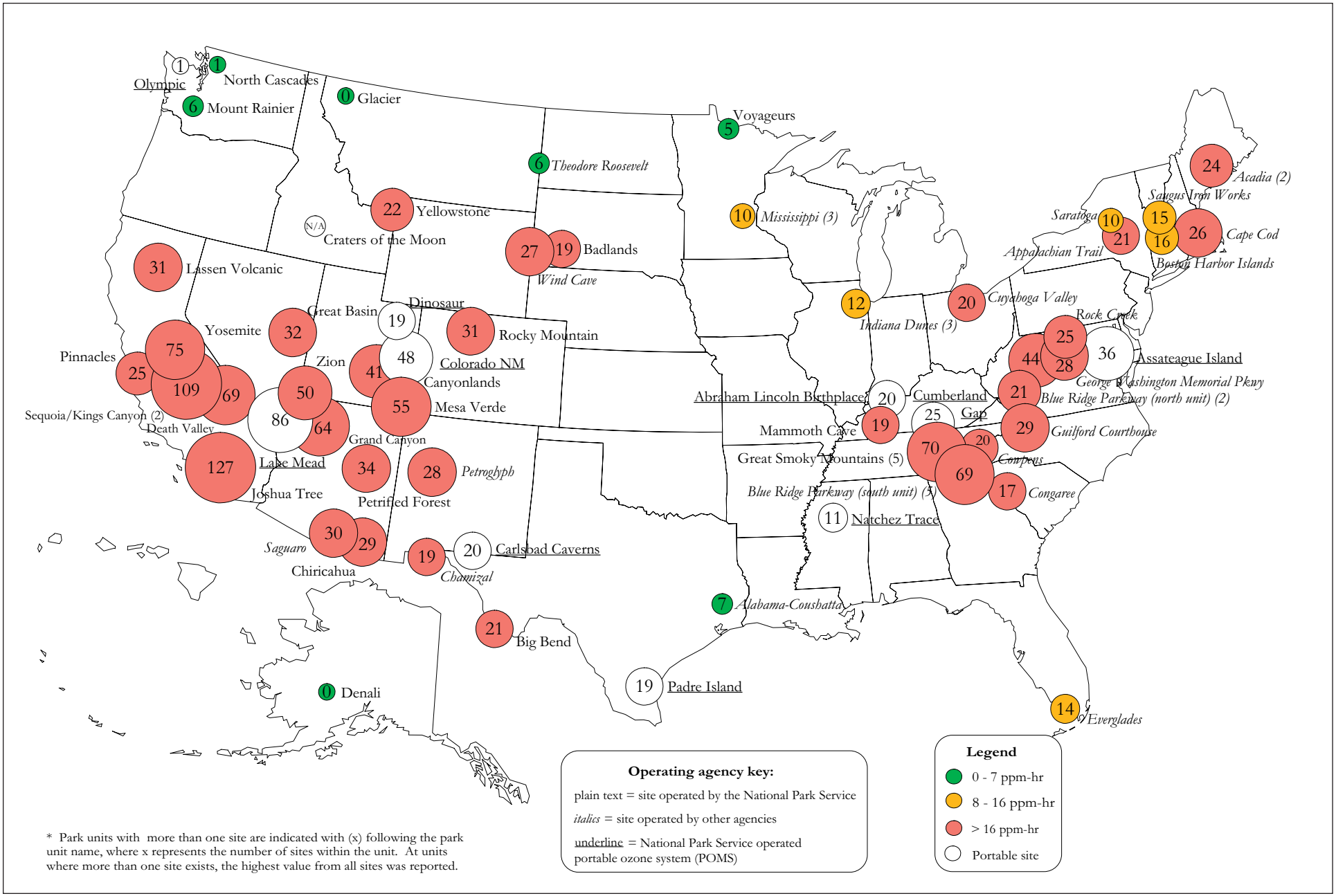


Figure 12. Annual 3-month maximum SUM06 exposure index.

Sulfur Dioxide Data Summaries

Sulfur dioxide (SO_2) is a criteria pollutant that over time undergoes chemical transformations in the atmosphere to form aqueous sulfur compounds, such as sulfuric acid, and particulate sulfate that can lead to environmental and health effects. Both sulfur dioxide and fine particulate sulfate can cause respiratory problems. Sulfur dioxide and acidic sulfate deposited on the earth's surface can affect aquatic and terrestrial ecosystems. Sulfur compounds are a major constituent of acid rain and sulfate is one of the particulate species responsible for visibility degradation and regional haze.

The primary NAAQS for sulfur dioxide are an annual arithmetic mean of 0.03 ppm and a 24-hour mean of 0.14 ppm , not to be exceeded more than once per year. The secondary NAAQS is a 3-hour mean of 0.50 ppm, not to be exceeded more than once per year. Table 11 summarizes sulfur dioxide measurements for comparison to these standards and lists the number of exceedances for each. Maximum hourly concentrations for each site are also presented in the table for reference. The SO_2 at Hawaii Volcanoes National Park violates the SO_2 NAAQS and is unhealthy.

At Hawaii Volcanoes National Park sulfur dioxide data are collected using a lower range and an upper range. The lower range does not capture values higher than 999 ppb, but is considered to be an EPA equivalency method. The upper range captures values above 999 ppb accurately, but is not an EPA reference method. The Hawaii Volcanoes National Park data presented in this report were collected using the upper range to give a more accurate representation of sulfur dioxide values.

Hawaii Volcanoes National Park, Hawaii
Pu `u `O `o After the Collapse
June 25, 2007
Photograph by Greg Funderburk/NPS

Table 11. Summary of sulfur dioxide data.

National Park Unit	Site Name	Annual Arithmetic Mean (ppb)[a]	Highest Daily 24-Hour Average Concentration[b] (ppb)					Highest Daily Maximum 3-Hour Average Concentration[c] (ppb)					Highest Daily Maximum 1-Hour Average Concentration (ppb)			
			1st Highest	2nd Highest	3rd Highest	4th Highest	No. of Days with 24-Hour Average ≥ 145 ppb	1st Highest	2nd Highest	3rd Highest	4th Highest	No. of Days with 3-Hour Maximum ≥ 550 ppb	1st Highest	2nd Highest	3rd Highest	4th Highest
Sites operated by the National Park Service																
Great Smoky Mountains	Cove Mountain	1	6	5	5	5	0	23	21	15	13	0	40	32	26	23
Hawaii Volcanoes *	Observatory	24	292	239	224	173	11	1001	981	637	624	6	1441	1387	1009	947
Hawaii Volcanoes *	Visitor Center	18	452	255	178	171	7	1507	1026	999	938	4	2202	1741	1399	1137
Shenandoah *	Big Meadows	1	10	6	4	4	0	17	15	14	14	0	31	23	18	14
Sites operated by cooperating state agencies																
Badlands	Visitor Center	1	2	2	2	2	0	10	4	3	3	0	8	6	4	3
Congaree	Congaree Bluff	1	17	9	8	8	0	60	47	46	32	0	79	56	46	43
Theodore Roosevelt	Painted Canyon Visitor Ctr	0	2	2	2	2	0	8	7	6	6	0	10	9	9	6
Wind Cave	Visitor Center	1	3	3	3	2	0	8	8	6	6	0	8	8	7	6
Nearby sites operated by other agencies																
Blue Ridge Parkway	Vinton Elementary	2	13	10	10	8	0	23	20	19	19	0	28	25	22	20
George Washington Pkwy	Alexandria Health	3	36	17	14	12	0	67	46	46	35	0	56	55	46	45
Indiana Dunes	Gas Station	3	17	9	9	9	0	31	29	24	24	0	37	34	29	27
Mississippi	Anoka County Airport	0	5	4	4	3	0	14	14	14	10	0	20	17	16	16

[a] The primary annual National Ambient Air Quality Standard for sulfur dioxide is an annual arithmetic mean of 0.03 ppm. (A value greater than 0.03 ppm, 34 ppb, or 80 μg/m^3 exceeds the standard.) (40 CFR 50.4.)

[b] The primary daily National Ambient Air Quality Standard for sulfur dioxide is 0.14 ppm over a 24-hour period not to be exceeded more than once per year. (A value greater than 0.14 ppm, 144 ppb, or 365 μg/m^3 exceeds that standard.) (40 CFR 50.4.)

[c] The secondary National Ambient Air Quality Standard for sulfur dioxide is 0.5 ppm over a 3-hour period not to be exceeded more than once per year. (A value greater than 0.5 ppm, 549 ppb, or 1300 μg/m^3 exceeds the standard.) (40 CFR 50.5.)

* This site collected sulfur dioxide data using an instrument or a range that is not an EPA reference method.

Operating agency key: plain text = site operated by the National Park Service
italics = site operated by a state agency

Color shading key: >34 ppb annual arithmetic mean, >144 ppb 24-hour average, or >549 ppb 3-hour average

Particulate Matter Data Summaries
Particulate matter (PM), is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles. Particles smaller than about 10 micrometers in diameter (PM_{10}) can enter the human respiratory system and cause health problems. Particles smaller than about 2.5 micrometers in diameter ($PM_{2.5}$) are most significantly tied to health concerns and, additionally, predominantly responsible for visibility degradation and regional haze. Acidic particulate matter can lead to acid deposition or acid rain. Sources of particulate matter include: industrial activities, vehicle exhaust, fires, vegetation, construction activities, wind-blown dust, and gaseous emissions which undergo chemical processes in the atmosphere to condense into particulate or liquid form.

The primary NAAQS for $PM_{2.5}$ are an annual arithmetic mean of 15 $\mu g/m^3$ and a daily arithmetic mean of 65 $\mu g/m^3$. An exceedance of the standard occurs when either an annual arithmetic mean is greater than 15.0 $\mu g/m^3$ or a daily arithmetic mean is greater than 65 $\mu g/m^3$. An exceedance of the standard is not the same as a violation. A violation occurs when either the 3-year average of the annual mean is greater than 15.0 $\mu g/m^3$ or the 3-year average of the 98th percentile daily mean concentrations is greater than 65 $\mu g/m^3$.

The primary NAAQS for PM_{10} is a daily arithmetic mean of 150 $\mu g/m^3$. An exceedance of the standard occurs when a daily arithmetic mean is greater than 150 $\mu g/m^3$. Again, an exceedance of the standard is not the same as a violation. A violation occurs when a 24-hour average concentration greater than 150 $\mu g/m^3$ occurs more than once per year on average over three years.

$PM_{2.5}$ Data Summaries
Table 12 summarizes $PM_{2.5}$ measurements with respect to both the daily 24-hour average maximum concentrations and the annual arithmetic mean. Since none of the $PM_{2.5}$ monitors at these sites are EPA-certified, these comparisons are made for reference purposes only. The four highest and 98th percentile 24-hour average concentrations are listed, as well as the total number of days with 24-hour average $PM_{2.5}$ concentrations greater than 65$\mu g/m^3$. No violation summaries for $PM_{2.5}$ data are presented.

North Cascades National Park, Washington
NPS stock photo

Table 12. Summary of $PM_{2.5}$ data from reference and equivalency methods.

National Park Unit	Site Name	Sampler Type*	% Valid[a]	Annual Arithmetic Mean[b] (µg/m³)	Highest Daily 24-Hour Average Concentrations[c] (µg/m³)					
					1st Highest	2nd Highest	3rd Highest	4th Highest	98th Percentile Value	No. of Days with 24-Hour Average >65 µg/m³
Sites operated by the National Park Service										
Badlands	Visitor Center	BAM	97.8	3.5	15	14	13	13	12	0
Great Smoky Mountains	Look Rock	TEOM	97.8	13.8	43	42	41	39	32	0
Shenandoah	Big Meadows	TEOM	93.3	11.5	37	36	35	34	32	0
Yellowstone	Old Faithful	BAM	98.7	5.0	33	28	24	22	13	0
Sites operated by cooperating state agencies										
Acadia	McFarland Hill	TEOM	98.7	4.3	30	25	23	20	17	0
Theodore Roosevelt	Painted Canyon Visitor Ctr	TEOM	98.5	5.8	34	24	23	21	15	0
Wind Cave	Visitor Center	BAM	97.1	3.8	28	19	18	15	11	0
Yosemite	Village	BAM	91.8	13.5	36	34	33	30	29	0
Nearby sites operated by other agencies										
Guilford Courthouse	Mendenhall Middle School	TEOM	96.0	15.7	42	42	41	36	35	0
Mississippi	Anoka County Airport	BAM	96.8	8.3	31	30	28	28	24	0
Petroglyph	Westside Taylor Ranch	BAM	98.9	7.0	30	30	26	24	21	0

[a] At sites operated by an agency other than the National Park Service, the primary responsibility for the operation and data reporting of particulate matter belongs to the operating agency.

[b] The primary annual National Ambient Air Quality Standard for $PM_{2.5}$ is an annual arithmetic mean of 15.0 µg/m³. (An exceedance of the standard occurs when an annual arithmetic mean of $PM_{2.5}$ concentrations is greater than 15.0 µg/m³. A violation of the standard occurs when the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations is greater than 15.0 µg/m³ (40 CFR 50.7.)

[c] The primary daily National Ambient Air Quality Standard for $PM_{2.5}$ is a 24-hour average concentration of 65 µg/m³. (An exceedance of the standard occurs when a 24-hour average $PM_{2.5}$ concentration is greater than 65 µg/m³. A violation of the standard occurs when the 3-year average of the annual 98th percentile of 24-hour $PM_{2.5}$ concentrations is greater than 65 µg/m³.) (40 CFR 50.7.)

* TEOM = tapered element oscillating microbalance
BAM = beta attenuation monitor

PM_{10} Data Summaries

Table 13 summarizes PM_{10} measurements with respect to both the daily 24-hour average maximum concentrations and the annual arithmetic mean at each EPA-certified monitoring site. The four highest 24-hour average concentrations are listed, as well as the total number of days with exceedances of the NAAQS 24-hour standard. The number of days column is color-coded to identify sites where an exceedance of the 24-hour standard occurred.

Table 14 presents the same summaries for sites that collected PM_{10} using non-equivalency methods.

Table 15 presents a PM_{10} violation summary based on the 24-hour average standard for one-year periods over the last three years, with violations indicated in red. Table values in parentheses indicate that the EPA data completeness requirement was not met. However, calendar quarters not meeting the EPA data completeness requirement are included in the NAAQS violation computation if the resulting 24-hour average exceeds the standard.

Glacier National Park, Montana
NPS stock photo

Table 13. Summary of PM_{10} data from reference and equivalency methods.

National Park Unit	Site Name	Sampler Type*	% Valid[a]	Annual Arithmetic Mean (µg/m³)	Highest Daily 24-Hour Average Concentrations[b] (µg/m³) 1st Highest	2nd Highest	3rd Highest	4th Highest	No. of Days with 24-Hour Average >65 µg/m³
Sites operated by cooperating state agencies									
Badlands	Visitor Center	BAM	98.9	9	30	30	30	30	0
Wind Cave	Visitor Center	BAM	98.9	7	30	30	20	20	0

[a] At sites operated by an agency other than the National Park Service, the primary responsibility for the operation and data reporting of particulate matter belongs to the operating agency.

[b] The primary daily National Ambient Air Quality Standard for PM_{10} is a 24-hour average concentration of 150 µg/m³. (An exceedance of the standard occurs when a 24-hour average PM_{10} concentration is greater than 150 µg/m³. A violation of the standard occurs when a 24-hour average concentration greater than 150 µg/m³ occurs more than once per year on average over three years.) (40 CFR 50.6.)

* TEOM = tapered element oscillating microbalance
BAM = beta attenuation monitor

Color shading key: >150 µg/m³ 24-hour average

italics = site operated by a state agency

Table 14. Summary of PM_{10} data from non-equivalency methods.

National Park Unit	Site Name	Sampler Type	% Valid	Annual Arithmetic Mean (µg/m³)	Highest Daily 24-Hour Average Concentrations (µg/m³) 1st Highest	2nd Highest	3rd Highest	4th Highest	No. of Days with 24-Hour Average >65 µg/m³
Sites operated by the National Park Service									
Joshua Tree	Cottonwood Canyon	E-sampler	53.1	2	20	10	10	10	0

Table 15. PM_{10} summary - daily standard (µg/m³)[a].

National Park Unit	Site Name	Sampler Type*	2006	2005	2004
Sites operated by cooperating state agencies					
Badlands	Visitor Center	BAM	30	40	---
Wind Cave	Visitor Center	BAM	30	30	---

[a] The primary daily National Ambient Air Quality Standard for PM_{10} is a 24-hour average concentration of 150 µg/m³. (An exceedance of the standard occurs when a 24-hour average PM_{10} concentration is greater than 150 µg/m³. A violation of the standard occurs when a 24-hour average concentration greater than 150 µg/m³ occurs more than once per year on average over three years.) (40 CFR 50.6.)

* TEOM = tapered element oscillating microbalance
BAM = beta attenuation monitor

Note: Dashed lines represent no data available at that site.

Color shading key: > 1 24-hour average concentration >50 µg/m³

italics = site operated by a state agency

Meteorological Data Summaries
Meteorological data collected along with air quality parameters are used to better understand the local conditions and transport of air pollutants. In addition, meteorological data are essential for air quality deposition modeling efforts. Refer to Table 1 for a list of meteorological parameters collected at each site.

Table 16 presents a summary of selected meteorological data for all sites. The parameters included are wind speed, ambient temperature, relative humidity, and precipitation.

Colorado National Monument, Colorado
NPS stock photo

Table 16. Summary of selected meteorological data.

National Park Unit	Site Name	Wind Speed (Scalar[a]) (m/s) Average	Ambient Temperature (degrees C) Average	Ambient Temperature (degrees C) Maximum	Ambient Temperature (degrees C) Minimum	Relative Humidity (%) Average	Relative Humidity (%) Maximum	Relative Humidity (%) Minimum	Precipitation (mm) Annual Accumulation
Sites operated by the National Park Service									
Badlands	Visitor Center	4.0	11.2	44.3	-27.0	56	100	3	77.8
Big Bend	K-Bar Ranch Road	3.5	21.3	37.6	-3.5	36	99	3	276.2
Canyonlands	Island in the Sky	2.9	12.1	35.4	-11.0	39	99	4	189.2
Chiricahua	Entrance Station	3.1	16.0	36.1	-7.0	41	100	5	292.5
Craters of the Moon	Visitor Center	3.3	6.4	34.9	-21.2	54	100	8	---
Death Valley	Park Village	3.7	25.9	48.5	5.3	18	93	2	40.0
Denali	Headquarters	1.4	-2.3	23.0	-35.9	69	98	18	228.3
Everglades	Beard Center	2.2	22.7	32.4	4.4	80	100	24	1106.7
Glacier	West Glacier Horse Stables	0.9	8.6	34.4	-19.9	73	100	13	712.3
Grand Canyon	The Abyss	2.8	10.9	31.9	-10.6	40	99	3	323.3
Great Basin	Maintenance Yard	2.8	9.2	33.8	-16.0	42	96	4	268.3
Great Smoky Mountains	Clingmans Dome	3.8	10.8	20.3	-15.0	89	100	3	1224.5
Great Smoky Mountains	Cove Mountain	4.8	11.2	26.9	-16.2	71	100	2	1206.5
Great Smoky Mountains	Look Rock	2.5	13.4	30.1	-12.9	68	100	15	1113.0
Hawaii Volcanoes	Observatory	4.9	16.1	25.4	7.6	87	100	11	1888.8
Hawaii Volcanoes	Visitor Center	3.7	15.7	26.5	7.4	92	100	37	2798.1
Joshua Tree	Black Rock	3.0	16.3	36.8	-3.4	31	94	2	98.8
Joshua Tree	Cottonwood Canyon	3.6	19.8	39.6	-1.6	27	100	3	6.0
Lassen Volcanic	Manzanita Lake Fire Station	2.0	7.0	31.5	-14.3	61	98	6	1025.4
Mammoth Cave	Houchin Meadow	1.8	14.4	35.1	-13.1	71	100	18	1273.9
Mesa Verde	Resource Management Area	2.9	10.4	32.1	-13.6	40	98	4	310.1
Mount Rainier	Tahoma Woods	1.1	8.9	34.5	-10.4	82	100	12	1809.5
North Cascades	Marblemount Ranger Station	1.4	9.7	36.5	-5.1	76	100	5	2248.0
Petrified Forest	South Entrance	4.2	12.8	34.2	-13.5	39	99	3	157.4
Pinnacles	SW of East Entrance Station	2.2	13.9	43.6	-6.5	63	98	4	376.9
Rocky Mountain	Long's Peak	2.9	4.4	25.8	-25.1	49	99	5	412.8
Sequoia and Kings Canyon	Ash Mountain	2.5	16.7	40.8	-0.8	53	100	9	468.5
Sequoia and Kings Canyon	Lower Kaweah	1.7	9.1	29.0	-11.7	61	100	3	715.7
Shenandoah	Big Meadows	2.6	9.0	27.2	-19.5	71	100	8	1326.6
Voyageurs	Sullivan Bay	2.7	4.6	32.6	-30.1	70	100	9	520.2
Yellowstone	Old Faithful	1.8	2.3	30.0	-34.3	67	100	8	---
Yellowstone	Water Tank	1.7	1.7	27.8	-29.4	65	98	10	438.9
Yosemite	Turtleback Dome	4.0	10.8	32.4	-9.4	52	100	6	878.6
Zion	Dalton's Wash	3.0	16.2	40.5	-8.3	34	99	1	201.7
Sites operated by cooperating state agencies									
Acadia	Cadillac Mountain	6.4	13.0	27.8	-2.5	85	100	19	---
Acadia	McFarland Hill	3.3	8.2	30.1	-18.8	75	100	25	1280.1
Cape Cod	Cape Cod	2.6	10.5	33.9	-12.2	82	100	22	---
Chamizal	Chamizal	3.3	19.6	39.3	-3.3	34	96	3	---
Great Smoky Mountains	Cades Cove	1.3	13.8	33.5	-12.1	76	100	16	1366.4
Saguaro	Pima County	2.5	21.6	41.4	-0.9	28	97	1	---
Theodore Roosevelt	Painted Canyon Visitor Center	5.2	8.3	38.7	-30.1	60	100	9	200.3
Wind Cave	Visitor Center	3.0	12.3	37.6	-18.7	47	97	6	214.0

Table 16. Summary of selected meteorological data (continued).

National Park Unit	Site Name	Wind Speed (Scalar[a]) (m/s)	Ambient Temperature (degrees C)			Relative Humidity (%)			Precipitation (mm)
		Average	Average	Maximum	Minimum	Average	Maximum	Minimum	Annual Accumulation
Nearby sites operated by other agencies									
Alabama-Coushatta	CASTNet Site	2.1	19.5	34.9	-3.3	75	100	14	1555.9
Blue Ridge Parkway	7510 Blue Ridge Parkway	---	10.4	30.6	-13.7	84	100	15	---
Blue Ridge Parkway	Ranger Station	---	12.3	34.7	-12.1	69	99	10	---
Boston Harbor Islands	Former Nike Missile Site	3.2	10.1	34.9	-12.1	77	100	30	---
Guilford Courthouse	Mendenhall Middle School	1.4	15.8	35.0	-7.9	70	95	16	919.8
Indiana Dunes	Ammunition Bunker	3.7	8.0	33.9	-19.2	70	100	20	---
Indiana Dunes	Gas Station	3.4	11.3	34.3	-16.5	---	---	---	---
Mississippi	Somerset Town Hall	2.3	---	---	---	---	---	---	---
Petroglyph	Westside Taylor Ranch	---	13.4	36.4	-8.3	---	---	---	---
Saugus Iron Works	Lynn Water Treatment	2.6	10.6	35.9	-15.1	64	91	7	56.3
Portable ozone monitoring systems									
Abraham Lincoln Birthplace	Visitor Center	0.5	21.4	35.5	5.0	76	96	27	624.0
Assateague Island	Maintenance Area	1.6	21.5	35.9	5.0	78	98	30	575.4
Carlsbad Caverns	Maintenance Area	3.8	24.4	38.6	10.5	53	99	6	305.2
Colorado	Maintenance Yard	1.7	22.6	38.0	1.6	31	97	5	107.5
Cumberland Gap	Hensley Settlement	2.1	17.4	28.2	2.9	80	100	29	595.1
Dinosaur	West Entrance Housing	1.5	18.9	39.9	-6.8	40	99	6	91.2
Joshua Tree	Pinto Wells	3.2	32.8	46.0	13.6	20	74	4	0.5
Lake Mead	Meadview	4.0	27.4	42.4	5.7	22	90	4	69.7
Mount Rainier	White River	0.5	13.4	34.3	-0.4	68	100	11	32.4
Natchez Trace Parkway	Dancy Ranger Station	0.3	24.2	39.1	4.7	74	100	21	441.0
Olympic	Hurricane Ridge Portable	0.7	11.7	28.4	0.1	64	100	13	52.6
Padre Island	Malaquite Visitor Center	5.9	26.9	31.9	17.6	80	97	12	356.5
Yosemite	School Yard	0.8	19.6	36.2	1.3	52	97	11	35.3

[a] Saguaro reports wind speed as vector wind speed rather than scalar wind speed.

Note: Dashed lines represent no data available for that particular parameter at that site.

Operating agency key: plain text = site operated by the National Park Service
italics = site operated by a state agency
underline = site operated by the National Park Service, but consisting of non-EPA certified portable instrumentation

Data quality tables associated with the data presented in this report can be found at *http://ard-request.air-resource.com*. Click "Get Reports."

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