



Annual Data Summary 2009

Gaseous Pollutant Monitoring Program

Natural Resource Data Series NPS/NRPC/ARD/NRDS—2010/086



ON THE COVER

Acadia National Park (Eagle Lake), Maine.

Photograph courtesy of the National Park Service/Sheridan Steele.

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The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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Introduction

This report focuses on the gaseous air pollutant concentrations measured in national parks during 2009 as part of the National Park Service, Air Resources Division (NPS ARD) monitoring program. It is mostly a statistical summary and feedback for park staff. The primary air pollutants reported, including ozone (O_3), sulfur dioxide (SO_2), and inhalable particulate matter ($PM_{2.5}$), are known to cause human health problems and to injure natural resources. The U.S. Environmental Protection Agency (EPA) sets standards to which we can compare the monitored data. More information on air quality conditions and trends in the parks can be found in the Division's annual performance reports (<http://www.nature.nps.gov/air/index.cfm>).

In recent years ozone pollution at surface monitoring sites in the national parks has been decreasing. In 2009, only 3 parks where NPS performs monitoring had ozone concentrations that exceeded the National Ambient Air Quality Standard (NAAQS), which is currently at 75 ppb for an 8-hour average. Parks with high ozone are listed below with NAAQS relevant statistics.

All three of these parks are in California and have air pollutants transported into them from more populated areas to the west. A fourth park unit, Mojave National Preserve, has been found to have high ozone based on portable ozone monitors, with the 4th highest 8-hour concentration of 80 ppb and 12 exceedance days. The Mojave station had higher ozone concentrations than the nearby Death Valley station that in recent years exceeded the NAAQS of 75 ppb, but in 2009 had lower ozone.

Other gaseous pollutants are measured in fewer parks. $PM_{2.5}$ is now being measured with continuous monitors in 13 park units. Unhealthy conditions, as defined by the NAAQS for $PM_{2.5}$, occur in 2 parks: Hawaii Volcanoes and Yosemite. SO_2 is measured by the National Park Service in Hawaii Volcanoes, Great Smoky Mountains, and Mammoth Cave, but only Hawaii Volcanoes has extreme SO_2 concentrations that far exceed the current NAAQS of 75 ppb as a daily 1-hour maximum. More information on the volcanic emitted SO_2 and $PM_{2.5}$ can be found in the Highlighted Park section.

Both current and past data from NPS monitoring sites is available on the Web:

- Current air quality (<http://www.nature.nps.gov/air/data/current/index.cfm>).
- Interactive data and report products access to validated archive database (<http://ard-request.air-resource.com/data.aspx>).
- AirNow has current air quality conditions and forecasts for national parks and urban locations (http://airnow.gov/index.cfm?action=airnow.national_summary).
- Maps of air quality concentrations and monitoring locations can be obtained from the interactive Web site "Air Atlas" (<http://www.nature.nps.gov/air/Maps/AirAtlas/index.cfm>).

Park	2009 4 th high 8-hr	Exceedances	3-yr avg 4 th high 8-hr
Sequoia and Kings Canyon	98 ppb	72 days	103 ppb
Joshua Tree	93 ppb	59 days	100 ppb
Yosemite	79 ppb	9 days	87 ppb

Monitoring Results

The NPS ARD issues this annual data summary for their Gaseous Pollutant Monitoring Program (GPMP). These summaries present only O₃, SO₂, PM, and meteorological data from continuous monitors that report hourly data. Other gas, particulate, and precipitation monitoring is performed under the visibility and deposition programs and is reported separately.

Data collected by this monitoring program are incorporated into 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://www.nature.nps.gov/air/Monitoring/network.cfm#data>.

GPMP Network Monitoring

The locations of monitoring sites that operated during 2009 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 that park unit. 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 portable ozone monitoring systems (POMS) to the GPMP in 2003. The POMS monitors have recently been designated by the EPA as a federal equivalency method (FEM) to measure certifiable ozone data. Although the POMS are not currently operated according to this protocol, the data are equivalent to the certified monitors and can be used for survey monitoring to obtain air quality baseline information. POMS site names in tables and figures have been underlined to distinguish them from monitoring sites meeting all EPA guidelines.

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 O₃, SO₂, PM, and meteorological data submitted by states to the EPA AQS are retrieved for inclusion in this report.

Annual Ozone Summaries

In 2008 the primary National Ambient Air Quality Standard (NAAQS) for ozone changed from 0.08 ppm (85 ppb equivalent) over an 8-hour period to 0.075 ppm (75 ppb equivalent) over an 8-hour period (http://www.epa.gov/ttn/naaqs/standards/ozone/s_o3_index.html). The ozone standard is again under review and a new standard between 0.060 and 0.070 ppm is expected to be set by 2011. According to the current standard, an exceedance of the standard occurs when an 8-hour average ozone concentration is greater than or equal to 76 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 76 ppb. The secondary ozone standard defined by the EPA, which is intended to protect the environment, is the same as the primary standard. In this report, ozone concentrations are compared to the NAAQS that was in place during the period reported.

Table 2 summarizes O₃ 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 8-hour standard. At each site with an EPA-certified monitor, 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 standard during 2009. Note that other sites may have experienced fewer than four exceedances of the standard, and are not color coded. Ozone summary statistics for POMS are highlighted bold where exceedances occurred. These sites should be compared to EPA standards for reference purposes only.

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. Values 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.

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.

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. Violations of the (old) 85 ppb standard are indicated in orange and red. Those values that would violate the new standard of 75 ppb are outlined with a black box.

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 76 ppb. Table values in parentheses indicate that EPA data completeness requirements for the 3-year period were not met. However, annual fourth highest daily maximum 8-hour ozone concentrations greater than or equal to 76 ppb for calendar years not meeting EPA data completeness requirements are included in the NAAQS violation computation.

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.

- W126 – A cumulative index that is calculated as the maximum 3-month sum of the 0800-2000 hourly average 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.
- 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 SUM06¹.

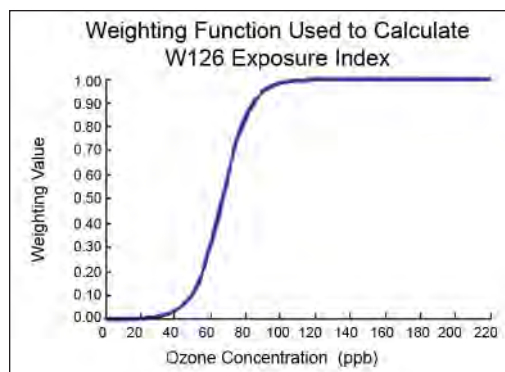
The W126 is expressed as a 3-month sum of all hourly ozone concentrations where each concentration is weighted by a sigmoidal function that gives greater emphasis to the higher hourly concentrations while still including the lower ones. In the latest use of W126, only the daytime hours of 8 am to 8 pm (12 hours) are used in the expression. This weighting function provides a weighting value that is unique for each hourly ozone concentration. The weighting function, as described by Lefohn, Laurence, and Kohut² is:

$$w_i = \frac{1}{1 + 4403 \exp^{- (126c_i)}}$$

where

w_i = weighting value for hourly concentration c_i , and c_i = hourly concentration i in ppb.

W126 and SUM06 thresholds for ozone effects to vegetation		
Growth Reduction	W126	SUM06
Tree seedlings - natural forest stands	7-13 ppm-hrs	10-15 ppm-hrs
Tree seedlings/saplings - plantations	9-14 ppm-hrs	12-16 ppm-hrs
Visible Foliar Injury		
Plants in natural ecosystems	5-9 ppm-hrs	8-12 ppm-hrs



The graph of weighting value versus ozone concentration, in the figure above, illustrates the greater weights given to higher hourly ozone concentrations. Each hour's weighting value is multiplied by its corresponding hourly concentration. This product is summed over all the valid daytime hours in each month to calculate the monthly W126 exposure. Thus, the monthly W126 exposure is:

$$W126 = \sum_{i=1}^n w_i * c_i$$

where

W126 = monthly W126 exposure index,

w_i = weighting value for hourly concentration i ,

c_i = hourly concentration i in ppb, and

n = number of hours in the month with valid ozone concentrations.

EPA is considering the maximum daytime consecutive 3-month value of the W126 for the secondary standard. The exposure units are ppb-hr.

Because each hour contributes to this exposure index, the number of hours with valid observations (n) is an important factor in calculating the W126. The EPA usually considers air quality statistics to be "valid" (i.e., representative of the parameter being estimated for the time interval in question) only if 75% or more of the total possible observations have been measured during that time interval. Therefore, one should exercise caution when comparing these statistics between months and sites, particularly those that are not averages (e.g., maxima and exposures) whenever the number of valid observations is less than 75% of the total possible. EPA is developing fill-in rules for missing hourly data that may be issued when the revision to the ozone standard is announced in 2010³.

Table 4 presents the ozone exposure indices summary statistics for 2009. Summaries for POMS are included for comparison only. Since portable sites are deployed for seasonal use, there may be significant biases in W126 and SUM06 exposure indices calculated from their data.

Figure 5 presents the 3-month maximum W126 exposure index for all network sites listed in Table 4. Figure 6 presents the annual 3-month maximum SUM06 exposure index for the same sites. Index values are color-coded to represent three distinct levels of cumulative exposure. Data from portable sites (no color) are included for reference only.

¹Heck, W.W. and E.B. Cowling, 1997. The Need for a Long-term Cumulative Secondary Ozone Standard - An Ecological Perspective. Environmental Management. January: 23-33.

²Lefohn, A.S.; Lawrence, J.A.; Kohut, R.J. (1988). A comparison of indices that describe the relationship between exposure to ozone and reduction in the yield of agricultural crops. Atmospheric Environment. 22:1229-1240.

³U.S. EPA, 2010, Proposed Rule, National Ambient Air Quality Standards for Ozone, Federal Register/Vol. 75, No. 11/Tuesday, January 19, 2010.

Sulfur Dioxide Summaries

During 2009, the primary NAAQS for sulfur dioxide was 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 was a 3-hour mean of 0.50 ppm, not to be exceeded more than once per year. The EPA revised the SO₂ standard in June 2010. Table 5 summarizes sulfur dioxide measurements for comparison to the standards that were in place during 2009 and lists the number of exceedances for each. Maximum hourly concentrations for each site are also presented in the table for reference.

Kilauea Volcano is the source of sulfur dioxide in Hawaii Volcanoes National Park. Sulfur dioxide data are collected in the park using a lower range and an upper range. The lower range does not capture values higher than 1 ppm (1,000 ppb), but is considered to be an EPA equivalency method. The upper range captures values above 1 ppm accurately, but is not an EPA equivalent range. 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.

PM_{2.5} Data Summaries

The primary NAAQS for PM_{2.5} are an annual arithmetic mean of 15 µg/m³ and a daily arithmetic mean of 35 µg/m³. An exceedance of the standard occurs when either an annual arithmetic mean is greater than 15.0 µg/m³ or a daily arithmetic mean is greater than 35 µg/m³. 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 µg/m³ or the 3-year average of the 98th percentile daily mean concentrations is greater than 35 µg/m³.

Table 6 summarizes PM_{2.5} measurements with respect to both the daily 24-hour average maximum concentrations and the annual arithmetic mean. 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 35 µg/m³. No violation summaries for PM_{2.5} data are presented.

PM₁₀ Data Summaries

The primary NAAQS for PM₁₀ is a daily arithmetic mean of 150 µg/m³. An exceedance of the standard occurs when a daily arithmetic mean is greater than 150 µg/m³. An exceedance of the standard is not the same as a violation. A violation occurs when a 24-hour average

concentration greater than 150 µg/m³ occurs more than once per year on average over three years.

Table 7 summarizes PM₁₀ measurements with respect to both the daily 24-hour average maximum concentrations and the annual arithmetic mean. 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 8 presents the same summaries for sites that collected PM₁₀ using non-equivalency methods.

Table 9 presents a PM₁₀ 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 EPA data completeness requirements were included in the NAAQS violation computation if the resulting 24-hour average exceeds the standard.

Meteorological Data Summaries

Table 10 presents a summary of selected meteorological data for all sites. The parameters included are wind speed, ambient temperature, relative humidity, and precipitation.

Highlighted Park

Why is Hawaii Volcanoes National Park Violating the National Standard for SO₂?

The extremely high concentrations of sulfur dioxide (SO₂) and violations of the National Ambient Air Quality Standard (NAAQS) reported in Table 5 for Hawaii Volcanoes National Park needs some explanation. Since monitoring for sulfur dioxide began in the park in 1986, the SO₂ National Ambient Air Quality Standard has been violated routinely. Because the volcanic source is natural, exceedances of the standard are considered to be “exceptional events” by EPA, although EPA has not specifically provided for such events in their rules. EPA states that for exceptional events, protection of public health is the highest priority and that the public should get timely information and measures be taken to safeguard their health.

In 2008 the Kilauea Volcano began to emit more SO₂, specifically at the Halema’uma’u crater vent (Figures A and B), going from about 150 tonnes/day SO₂ to over 2,000 tonnes/day. Additional days with high SO₂ concentrations and higher

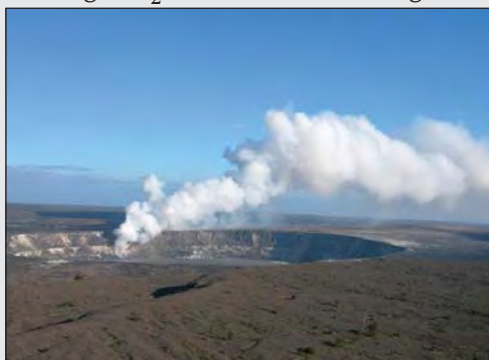


Figure A. View of the Halema’uma’u vent within the Kilauea caldera. (USGS photo)

concentrations than previously observed were the result. The SO₂ concentrations have been measured at levels that affect even healthy individuals. The local Civil Defense and the park responded with additional measuring equipment and procedures to protect the public. Emissions rates continue to be higher than previously at the Halema’uma’u vent (Figure C). This is especially important because the source is very close to visitor activities and park facilities. USGS raw emissions data are available on <http://volcanoes.usgs.gov/hvo/activity/kilaueastatus.php>.

Hawaii Volcanoes is unique in the National Park System because of the extremely high SO₂ concentrations – far higher than any other national park or even urban areas. The EPA sets human health standards (the NAAQS) for SO₂. Actually, SO₂ is a toxic gas that irritates the skin and mucous membranes of the eyes, nose, throat, and lungs. Children, asthmatics, people with heart or lung disease, and people engaged in vigorous physical activity are those most susceptible to SO₂ health problems. In June 2010, EPA revised the standard from a 24-hour average of 0.144 ppm to a 1-hour average of 0.075 ppm. Figure D shows how there were frequent exceedances of the old standard over the years and even more since 2008. Table A shows the conditions relative to the new 1-hour standard. The relevant metric for the 3-year average SO₂ at Hawaii Volcanoes is 2.388 ppm compared to the standard of 0.075 ppm; this represents an extremely severe violation of the standard. Based on the new standard, the measured 99th percentile for the last three years is 30 times the new standard. The number of SO₂ exceedances based on the new standard at Hawaii Volcanoes National Park (HVO) is projected at over 100 exceedance days per year.



Figure B. Map of Kilauea Volcano summit area. The active vent at Halema’uma’u and monitoring sites are indicated. Active lava flows at Puu’O’oo are several miles east (to the right) of this map.

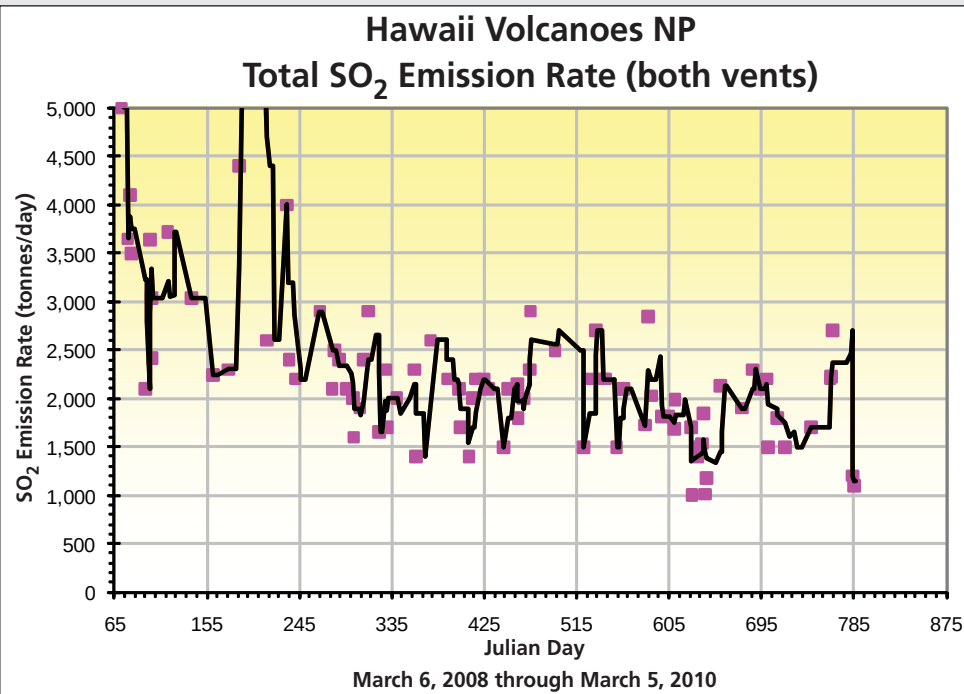


Figure C. Combined emission rates of SO₂ from the Halema'uma'u and Puu'O'oo vents in tonnes/day. (Data from USGS).

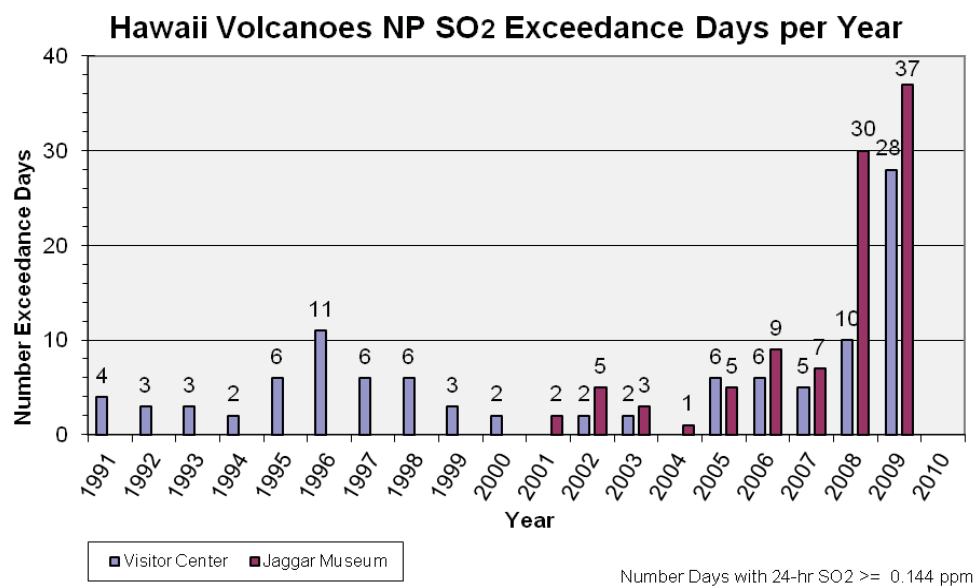


Figure D. The SO₂ concentrations at Hawaii Volcanoes have exceeded the older national standard for many years. With the new, lower SO₂ standard, the number of exceedances is higher (see Table A).

Table A. Calculated concentrations of SO₂ in pm for comparison to the new standard of 0.075 ppm at Hawaii Volcanoes NP.

Year	Observatory / Jaggar Museum			Visitor Center		
	Annual 99 th Percentile	3-year Average 99 th Percentile	# Days Exceedances	Annual 99 th Percentile	3-year Average 99 th Percentile	# Days Exceedances
2007	1.142	1.079	93	0.923	1.069	87
2008	2.447	1.520	123	1.342	1.164	102
2009	3.575	2.388	138	2.487	1.584	113

* Start of Halema'uma'u additional SO₂ emissions

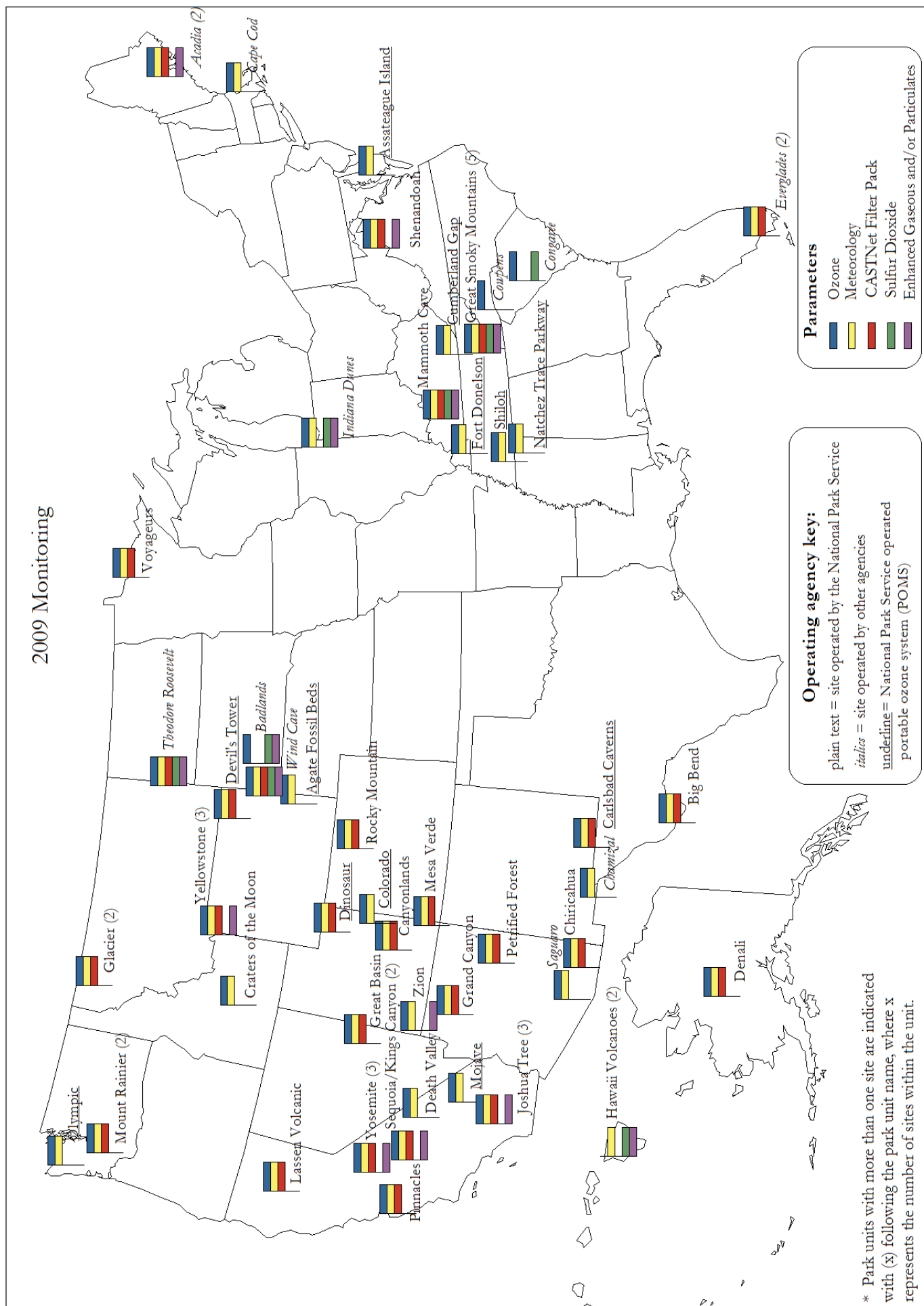


Figure 1. 2009 Air quality monitoring in or nearby park units.

Table 1. 2009 Site specifications.

National Park Unit	Site Name	State	NPS Abbr.	CASTNet Abbr.	AQS ID Number	Latitude (degrees north)	Longitude (degrees west)	Elev. (m)	O ₃ Years ^a	SO ₂	PM	WD	WS	TMP	RH	RNF	WET	DTP	SOL	Filter Pack ^b
Sites operated by the National Park Service																				
Agate Fossil Beds	Residence Area	NE	AGFO-RA	---	31-155-1001	42.4283	103.7294	1344	3	---	---	X	X	X	X	X	---	---	X	---
Assateague Island	Maintenance Area	MD	ASIS-MA	---	24-047-1001	38.2511	75.1594	3	5	---	---	X	X	X	X	X	---	---	X	---
Big Bend	K-Bar Ranch Road	TX	BIBE-KB	BBE401	48-043-0101	29.3022	103.1772	1052	20	---	---	X	X	X	X	X	X	X	X	X
Canyonlands	Island in the Sky	UT	CANY-IS	CAN407	49-037-0101	38.4586	109.8211	1809	18	---	---	X	X	X	X	X	X	X	X	X
Carlsbad Caverns	Maintenance Area	NM	CAVE-MA	---	35-015-3001	32.1783	104.4406	1349	4	---	---	X	X	X	X	X	---	---	X	X
Chiricahua	Entrance Station	AZ	CHIR-ES	CHA467	04-003-8001	32.0092	109.3892	1570	19	---	---	X	X	X	X	X	X	X	X	X
Colorado	Maintenance Yard	CO	COLM-MY	---	08-077-1001	39.1067	108.7411	1740	4	---	---	X	X	X	X	X	---	---	X	---
Craters of the Moon	Visitor Center	ID	CRMO-VC	---	16-023-0101	43.4606	113.5622	1815	18	---	---	X	X	X	X	---	---	---	X	---
Cumberland Gap	Hensley Settlement	TN	CUGA-HS	---	21-013-1002	36.6719	83.5264	1013	4	---	---	X	X	X	X	X	---	---	X	---
Death Valley	Park Village	CA	DEVA-PV	---	06-027-0101	36.5092	116.8481	125	17	---	---	X	X	X	X	X	---	---	X	---
Denali	Headquarters	AK	DENA-HQ	DEN417	02-068-0003	63.7258	148.9633	661	23	---	---	X	X	X	X	X	X	X	X	X
Devil's Tower	Joyner Ridge Trail	WY	DETO-JR	---	56-011-1013	44.5969	104.7047	1200	2	---	---	X	X	X	X	X	---	---	X	X
Dinosaur	West Entrance Housing	UT	DINO-WE	---	49-047-1002	40.2917	108.9417	2072	5	---	---	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
Fort Donelson	Visitor Center	TN	FODO-VC	---	---	36.4825	87.8622	172	2	---	---	X	X	X	X	---	---	---	---	---
Glacier	Saint Mary's Ranger District	MT	GLAC-SM	---	30-035-1001	---	---	---	1	---	---	X	X	X	X	X	---	---	X	---
Glacier	West Glacier Horse Stables	MT	GLAC-WG	GLR468	30-029-8001	48.5103	113.9956	976	18	---	---	X	X	X	X	X	X	X	X	X
Grand Canyon	The Abyss	AZ	GRCA-AS	GRC474	04-005-8001	36.0597	112.1822	2073	17	---	---	X	X	X	X	X	X	X	X	X
Great Basin	Maintenance Yard	NV	GRBA-MY	GRB411	32-033-0101	39.0053	114.2158	2060	17	---	---	X	X	X	X	X	X	X	X	X
Great Smoky Mountains	Clingmans Dome	TN	GRSM-CD	---	47-155-0102	35.5619	83.4981	2021	17	---	---	X	X	X	X	X	---	---	X	---
Great Smoky Mountains	Cove Mountain	TN	GRSM-CM	---	47-155-0101	35.6967	83.6086	1243	22	X	---	X	X	X	X	X	---	---	---	---
Great Smoky Mountains	Look Rock	TN	GRSM-LR	GRS420	47-009-0101	35.6331	83.9422	793	22	---	X	X	X	X	X	X	X	X	X	X
Hawaii Volcanoes	Observatory /Jaggar Museum	HI	HAVO-OB	---	15-001-0007	19.4203	155.2881	1123	---	X	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	17	---	---	X	X	X	X	X	X	X	X	X
Joshua Tree	Cottonwood Canyon	CA	JOTR-CC	---	06-065-0008	33.7411	115.8206	984	5	---	X	X	X	X	X	X	---	---	X	---
Joshua Tree	Pinto Wells	CA	JOTR-PW	---	06-065-1004	33.9397	115.4108	326	4	---	---	X	X	X	X	X	---	---	X	X
Lassen Volcanic	Manzanita Lake Fire Station	CA	LAVO-ML	LAV410	06-089-3003	40.5403	121.5764	1756	23	---	---	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	15	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	2165	17	---	---	X	X	X	X	X	X	X	X	X
Mojave	Kelso Mountains	CA	MOJA-KM	---	06-071-1001	35.1019	115.7767	1212	3	---	---	X	X	X	X	X	---	---	X	---

Table 1. 2009 Site specifications (continued).

National Park Unit	Site Name	State	NPS Abbr.	CASTNet Abbr.	AQS ID Number	Latitude (degrees north)	Longitude (degrees west)	Elev. (m)	O ₃ Years ^a	SO ₂	PM	WD	WS	TMP	RH	RNF	WET	DTP	SOL	Filter Pack ^b
Sites operated by the National Park Service																				
Mount Rainier	Tahoma Woods	WA	MORA-TW	MOR409	53-053-1010	46.7583	122.1244	415	19	---	---	X	X	X	X	X	X	X	X	X
Natchez Trace Parkway	Buzzard Roost Springs	MS	NATR-BR	---	01-033-1003	34.7589	88.0139	148	1	---	---	X	X	X	X	X	---	---	X	---
Olympic	Deer Park	WA	OLYM-DP	---	53-009-0016	47.9492	123.2653	1607	1	---	---	X	X	X	X	X	---	---	X	---
Petrified Forest	South Entrance	AZ	PEFO-SE	PET427	04-017-0119	34.8225	109.8919	1723	8	---	---	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	335	23	---	---	X	X	X	X	X	X	X	X	X
Rocky Mountain	Long's Peak	CO	ROMO-LP	ROM406	08-069-0007	40.2778	105.5453	2743	25	---	---	X	X	X	X	X	X	X	X	X
Sequoia and Kings Canyon	Ash Mountain	CA	SEKI-AS	SEK430	06-107-0009	36.4894	118.8292	457	11	---	X	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	26	---	---	X	X	X	X	X	---	---	X	---
Shenandoah	Big Meadows	VA	SHEN-BM	SHN418	51-113-0003	38.5231	78.4347	1073	27	---	X	X	X	X	X	X	X	X	X	X
Shiloh	Russian Tenant Field	TN	SHIL-RT	---	---	35.1572	88.3394	---	2	---	---	X	X	X	X	---	---	---	---	---
Voyageurs	Sullivan Bay	MN	VOYA-SB	VOY413	27-137-0034	48.4128	92.8292	429	14	---	---	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	X	---	---	---	---	---
Yellowstone	Water Tank	WY	YELL-WT	YEL408	56-039-1011	44.5597	110.4006	2400	14	---	---	X	X	X	X	X	X	X	X	X
Yosemite	School Yard	CA	YOSE-SY	---	06-043-1004	37.7478	119.5917	1234	4	---	---	X	X	X	X	X	---	---	X	---
Yosemite	Turtleback Dome	CA	YOSE-TD	YOS404	06-043-0003	37.7133	119.7061	1605	17	---	---	X	X	X	X	X	X	X	X	X
Zion	Dalton's Wash	UT	ZION-DW	---	49-053-0130	37.1983	113.1506	1213	6	---	X	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	15	---	---	X	X	X	X	---	---	---	---	---
Acadia	McFarland Hill	ME	ACAD-MH	ACA416	23-009-0103	44.3769	68.2608	158	12	---	X	X	X	X	X	X	X	X	X	X
Badlands	Visitor Center	SD	BADL-VC	---	46-071-0001	43.7436	101.9414	739	12	X	X	---	---	---	---	---	---	---	---	---
Cape Cod	Cape Cod	MA	CACO-XX	---	25-001-0002	41.9758	70.0247	41	23	---	---	X	X	X	X	---	---	---	X	---
Chamizal	Chamizal	TX	CHAM-XX	---	48-141-0044	31.7656	106.455	1128	18	---	---	X	X	X	X	---	---	---	X	---
Congaree	Congaree Bluff	SC	COSW-BL	---	45-079-0021	33.8147	80.7811	34	10	X	---	---	---	---	---	---	---	---	---	---
Cowpens	State Monitor	SC	COWP-SM	---	45-021-0002	35.1303	87.8164	297	22	---	---	---	---	---	---	---	---	---	---	---
Everglades	Cutler Road	FL	EVER-CR	---	12-086-0029	25.5861	80.3269	4	25	---	---	---	---	---	---	---	---	---	---	---
Great Smoky Mountains	Cades Cove	TN	GRSM-CC	---	47-009-0102	35.6042	83.7831	564	17	---	---	X	X	X	X	X	---	---	X	---
Great Smoky Mountains	Purchase Knob	NC	GRSM-PK	---	37-087-0036	35.59	83.0775	1500	15	---	---	---	---	---	---	---	---	---	---	---
Indiana Dunes	Ammunition Bunker	IN	INDU-AB	---	18-089-0022	41.5733	87.3047	183	17	X	X	X	X	X	X	---	---	---	X	---
Mount Rainier	Jackson Visitor's Center	WA	MORA-JV	---	53-053-0012	46.7853	121.7378	1615	12	---	---	---	---	---	---	---	---	---	---	---
Saguaro	Pima County	AZ	SAGU-PC	---	04-019-0021	32.1744	110.7364	938	18	---	---	X	X	X	X	---	---	---	X	---

Table 1. 2009 Site specifications (continued).

National Park Unit	Site Name	State	NPS Abbr.	CASTNet Abbr.	AQS ID Number	Latitude (degrees north)	Longitude (degrees west)	Elev. (m)	O ₃ Years ^a	SO ₂	PM	WD	WS	TMP	RH	RNF	WET	DTP	SOL	Filter Pack ^b
Sites operated by cooperating state agencies																				
<i>Theodore Roosevelt</i>	Painted Canyon Visitor Cntr	ND	THRO-VC	THR422	38-007-0002	46.8947	103.3778	850	12	X	X	X	X	X	X	X	X	X	X	X
<i>Wind Cave</i>	Visitor Center	SD	WICA-VC	WNC429	46-033-0132	43.5578	103.4839	1292	6	X	X	X	X	X	X	X	X	X	X	X
<i>Yellowstone</i>	West Yellowstone	MT	YELL-WS	---	30-031-0017	44.6569	111.0894	2030	---	---	X	X	X	X	---	---	---	---	---	---
<i>Yosemite</i>	Village	CA	YOSE-VI	---	06-043-1001	37.7458	119.6028	1216	---	---	X	---	---	---	---	---	---	---	---	---
# active park units: 15 # active park sites: 17																				

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

^b 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 (SO₄²⁻), particulate nitrate (NO₃⁻), particulate ammonium (NH₄⁺), sulfur dioxide (SO₂), and nitric acid (HNO₃). In some cases, the positive ions Na⁺, K⁺, Ca²⁺, and Mg²⁺ 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

underline = site operated by the National Park Service, but consisting of non-EPA certified portable instrumentation

Parameter key: O₃ = ozone analyzer (ppb)
SO₂ = sulfur dioxide analyzer (ppb)
PM = particulate matter (μg/m³)
WD = wind direction (degrees)
WS = wind speed (m/s)
TMP = ambient temperature (degrees C)
RH = relative humidity (%)
RNF = precipitation (mm/hr)
WET = wetness (% on)
DTP = delta temperature (degrees C)
SOL = solar radiation (watts/m²)

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

Table 2. 2009 Summary of 8-hour average ozone concentrations (ppb).

National Park Unit	Site Name	Valid Number of Days	1 st Highest	2 nd Highest	3 rd Highest	4 th Highest ^a	5 th Highest	# Days with 8-Hour Average O ₃ Values ≥76 ppb ^a
Sites operated by the National Park Service								
Big Bend	K-Bar Ranch Road	350	73	70	67	65	63	0
Canyonlands	Island in the Sky	327	74	72	70	68	68	0
Chiricahua	Entrance Station	361	79	67	66	65	65	1
Craters of the Moon	Visitor Center	360	59	58	58	58	58	0
Death Valley	Park Village	344	86	77	72	70	69	2
Denali	Headquarters	351	56	55	54	54	54	0
Glacier	West Glacier Horse Stables	354	61	58	56	55	54	0
Grand Canyon	The Abyss	349	67	67	66	66	65	0
Great Basin	Maintenance Yard	330	74	73	70	69	69	0
Great Smoky Mountains	Clingmans Dome	178	72	71	71	71	68	0
Great Smoky Mountains	Cove Mountain	361	74	72	70	70	69	0
Great Smoky Mountains	Look Rock	360	84	71	70	69	68	1
Joshua Tree	Black Rock	331	104	102	95	93	93	59
Joshua Tree	Cottonwood Canyon	333	85	84	84	81	80	11
Lassen Volcanic	Manzanita Lake Fire Station	356	66	65	64	64	63	0
Mammoth Cave	Houchin Meadow	345	69	67	66	65	65	0
Mesa Verde	Resource Management Area	358	73	71	70	69	69	0
Mount Rainier	Tahoma Woods	328	59	59	58	58	58	0
Petrified Forest	South Entrance	358	69	64	63	62	62	0
Pinnacles	SW of East Entrance Station	347	73	72	71	71	71	0
Rocky Mountain	Long's Peak	345	75	70	68	68	68	0
Sequoia and Kings Canyon	Ash Mountain	355	100	99	98	98	96	72
Sequoia and Kings Canyon	Lower Kaweah	360	85	83	81	80	80	18
Shenandoah	Big Meadows	357	72	71	70	70	69	0
Voyageurs	Sullivan Bay	349	63	63	63	62	61	0
Yellowstone	Water Tank	358	93	67	64	63	63	1
Yosemite	Turtleback Dome	353	86	83	79	79	78	9
Zion	Dalton's Wash	335	78	72	71	68	68	1
Sites operated by cooperating state agencies								
<i>Acadia</i>	Cadillac Mountain	208	85	77	75	74	68	2
<i>Acadia</i>	McFarland Hill	360	86	77	73	73	64	2
<i>Badlands</i>	Visitor Center	364	57	55	55	54	53	0
<i>Cape Cod</i>	Cape Cod	177	82	78	73	72	69	2
<i>Chamizal</i>	Chamizal	349	72	69	68	66	65	0
<i>Congaree</i>	Congaree Bluff	359	65	61	60	59	58	0
<i>Cowpens</i>	State Monitor	348	60	59	58	57	57	0
<i>Everglades</i>	Cutler Road	352	76	71	68	62	61	1
<i>Great Smoky Mountains</i>	Cades Cove	253	67	65	63	62	61	0
<i>Great Smoky Mountains</i>	Purchase Knob	208	67	66	66	65	65	0
<i>Indiana Dunes</i>	Ammunition Bunker	176	62	60	59	59	59	0
<i>Mount Rainier</i>	Jackson Visitor's Center	330	59	57	56	54	54	0
<i>Saguaro</i>	Pima County	363	69	67	67	67	64	0
<i>Theodore Roosevelt</i>	Painted Canyon Visitor Cntr	356	61	58	56	56	55	0
<i>Wind Cave</i>	Visitor Center	246	65	65	62	61	61	0

Table 2. 2009 Summary of 8-hour average ozone concentrations (ppb) (continued).

National Park Unit	Site Name	Valid Number of Days	1 st Highest	2 nd Highest	3 rd Highest	4 th Highest ^a	5 th Highest	# Days with 8-Hour Average O ₃ Values ≥76 ppb ^a
Portable ozone monitoring systems^b								
<u>Agate Fossil Beds</u>	Residence Area	104	62	62	60	59	58	0
<u>Assateague Island</u>	Maintenance Area	154	62	62	62	61	61	0
<u>Carlsbad Caverns</u>	Maintenance Area	75	68	66	65	63	63	0
<u>Colorado</u>	Maintenance Yard	161	62	61	60	58	57	0
<u>Cumberland Gap</u>	Hensley Settlement	150	68	64	63	63	62	0
<u>Devil's Tower</u>	Joyner Ridge Trail	163	66	63	62	61	61	0
<u>Dinosaur</u>	West Entrance Housing	159	66	64	64	63	63	0
<u>Fort Donelson</u>	Visitor Center	39	61	59	58	58	56	0
<u>Glacier</u>	Saint Mary's Ranger District	138	66	62	60	58	57	0
<u>Joshua Tree</u>	Pinto Wells	86	81	75	74	73	72	1
<u>Mojave</u>	Kelso Mountains	174	85	83	81	80	80	12
<u>Natchez Trace Parkway</u>	Buzzard Roost Springs	137	59	56	56	53	53	0
<u>Olympic</u>	Deer Park	---	---	---	---	---	---	---
<u>Shiloh</u>	Russian Tenant Field	49	49	47	47	46	46	0
<u>Yosemite</u>	School Yard	176	66	66	64	63	63	0

^a The primary and secondary National Ambient Air Quality Standard for ozone is 0.075 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 76 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 76 ppb.) Exceedances of the standard are highlighted here in orange or red.

^b The Gaseous Pollutant Monitoring Program Portable Ozone Monitoring Systems (POMS) do not meet EPA standards for regulatory monitoring. However, ozone summary statistics from portable systems can be compared to EPA standards for reference purposes.

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

Bold = Ozone summary statistics for POMS are highlighted bold where exceedances occurred. These sites should be compared to EPA standards for reference purposes only.

Color shading key: 4th highest 8-hour average  = 76 - 104 ppb ozone concentration # days with 8-hour average ≥76 ppb  = 4 - 10 days
 ≥ 105 ppb ozone concentration  > 10 days

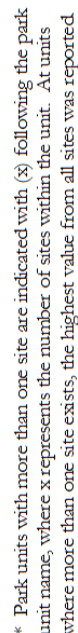
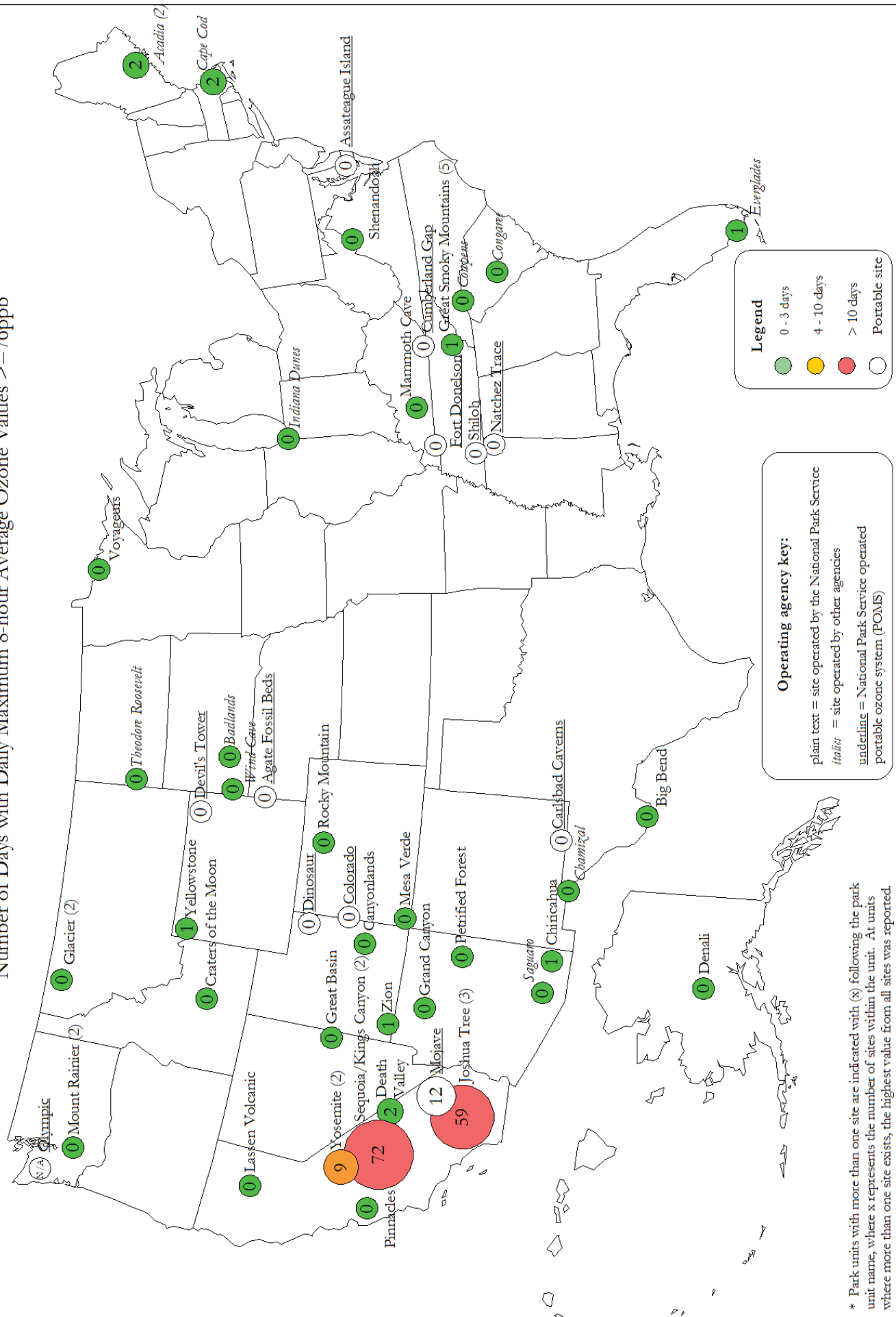


Figure 2. 2009 Annual fourth highest daily maximum 8-hour average ozone concentrations (in ppb).

Number of Days with Daily Maximum 8-hour Average Ozone Values ≥ 76 ppb



* Park units with more than one site are indicated with (x) following the park unit name, where x represents the number of sites within the unit. At units where more than one site exists, the highest value from all sites was reported.

Figure 3. 2009 Annual number of days with daily maximum 8-hour average ozone values ≥ 76 ppb.

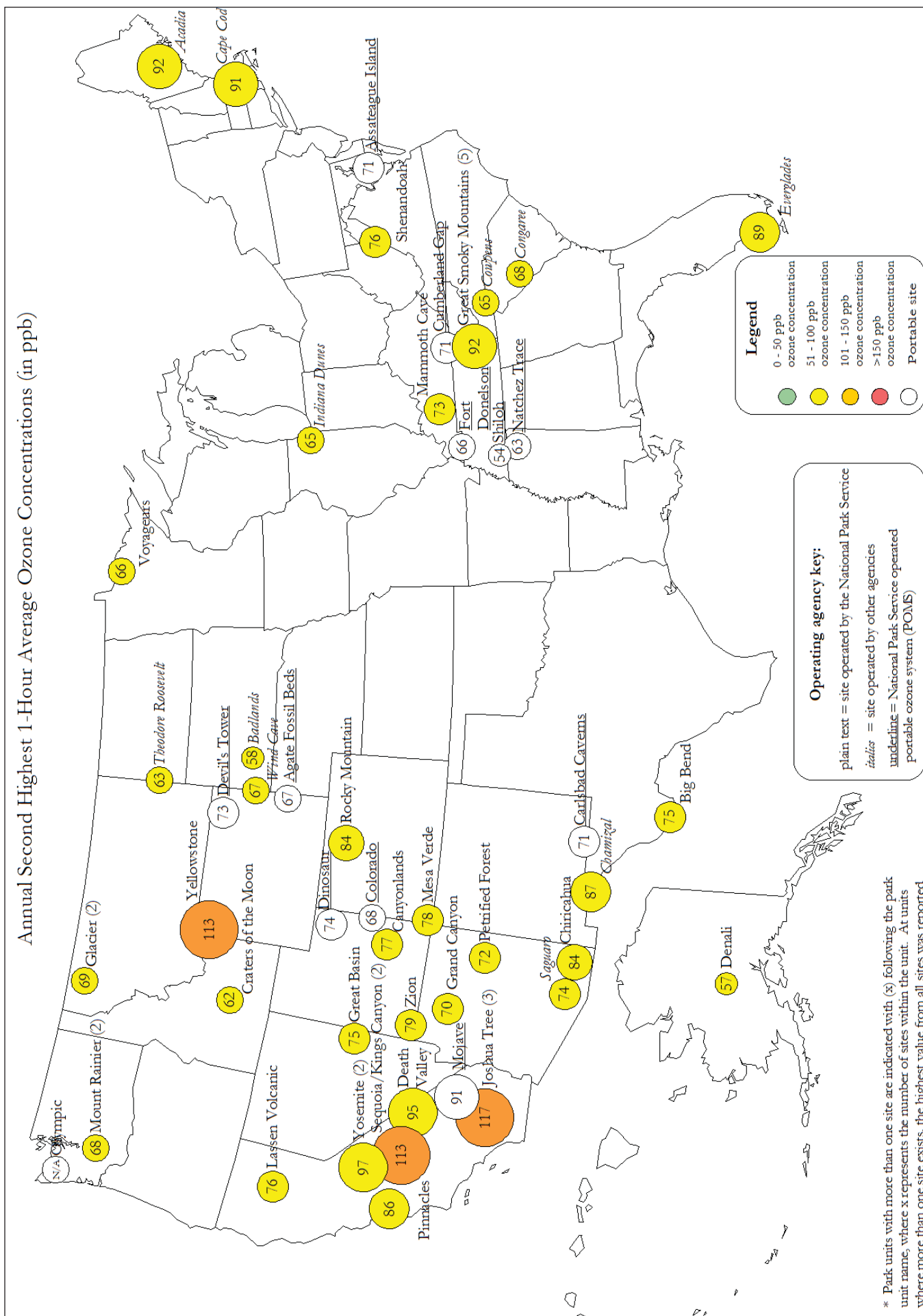


Figure 4. 2009 Annual second highest 1-hour average ozone concentrations (in ppb).

Table 3. 2009 Ozone violation summary - primary standard^{a,b}.

National Park Unit	Site Name	2007–2009	2006–2008	2005–2007	2004–2006	2003–2005	2002–2004	2001–2003	2000–2002
Sites operated by the National Park Service									
Big Bend	K-Bar Ranch Road	66	66	66	63	63	62	62	(62)
Canyonlands	Island in the Sky	70	71	70	70	71	72	70	(71)
Chiricahua	Entrance Station	66	69	71	72	71	71	70	70
Craters of the Moon	Visitor Center	(64)	(67)	(67)	---	---	67	(65)	(63)
Death Valley	Park Village	77	81	84	82	81	80	81	81
Denali	Headquarters	58	58	52	51	52	53	54	49
Glacier	West Glacier Horse Stables	51	53	55	54	56	55	53	49
Grand Canyon	The Abyss	68	70	72	73	74	74	74	73
Great Basin	Maintenance Yard	71	72	73	72	72	72	70	(72)
Great Smoky Mountains	Clingmans Dome	(79)	(84)	(83)	(80)	(79)	(87)	(92)	(98)
Great Smoky Mountains	Cove Mountain	79	82	82	77	78	86	92	96
Great Smoky Mountains	Look Rock	79	85	86	84	86	91	92	94
Joshua Tree	Black Rock	100	104	103	103	105	106	99	94
Joshua Tree	Cottonwood Canyon	(80)	(79)	(66)	(62)	(45)	---	---	---
Lassen Volcanic	Manzanita Lake Fire Station	74	77	72	69	68	71	72	74
Mammoth Cave	Houchin Meadow	72	74	76	72	73	77	80	84
Mesa Verde	Resource Management Area	69	71	73	73	70	68	67	69
Mount Rainier	Tahoma Woods	(56)	58	(56)	(58)	(61)	63	61	56
Petrified Forest	South Entrance	(67)	(70)	(70)	(70)	(71)	(66)	(64)	(55)
Pinnacles	SW of East Entrance Station	77	79	74	75	76	81	81	81
Rocky Mountain	Long's Peak	74	76	76	74	78	82	81	78
Sequoia and Kings Canyon	Ash Mountain	(103)	(105)	(103)	(103)	(105)	(105)	(107)	(105)
Sequoia and Kings Canyon	Lower Kaweah	90	96	95	96	97	101	101	98
Shenandoah	Big Meadows	73	76	77	77	(80)	82	87	85
Voyageurs	Sullivan Bay	(61)	(61)	(65)	64	66	64	65	(64)
Yellowstone	Water Tank	64	66	64	63	61	63	65	65
Yosemite	Turtleback Dome	87	(89)	86	86	88	90	90	89
Zion	Dalton's Wash	69	71	78	79	(82)	(74)	---	---
# park units with violations (0.08 ppm standard):		3	4	4	3	4	4	5	5
# sites with violations:		4	5	5	4	5	7	8	8
Sites operated by cooperating state agencies									
Acadia	Cadillac Mountain	78	79	82	80	82	88	94	93
Acadia	McFarland Hill	73	72	74	71	74	80	87	84
Badlands	Visitor Center	56	62	68	67	(66)	(64)	(67)	---
Cape Cod	Cape Cod	76	79	84	84	86	88	95	93
Chamizal	Chamizal	71	75	74	73	72	78	79	81
Congaree	Congaree Bluff	66	71	73	72	73	74	77	77
Cowpens	State Monitor	67	74	73	74	75	80	84	87
Everglades	Cutler Road	69	72	69	68	66	---	---	---
Great Smoky Mountains	Cades Cove	69	72	70	67	(67)	73	76	79
Great Smoky Mountains	Purchase Knob	74	77	77	75	78	82	86	88
Indiana Dunes	Ammunition Bunker	(68)	73	82	75	76	---	---	---
Mount Rainier	Jackson Visitor's Center	(56)	(59)	61	(60)	(59)	---	---	---
Saguaro	Pima County	71	74	76	76	(76)	(76)	(73)	72

Table 3. 2009 Ozone violation summary - primary standard^{a,b} (continued).

National Park Unit	Site Name	2007–2009	2006–2008	2005–2007	2004–2006	2003–2005	2002–2004	2001–2003	2000–2002
Sites operated by cooperating state agencies									
<i>Theodore Roosevelt</i>	Painted Canyon Visitor Cntr	59	63	63	(60)	(59)	60	61	59
<i>Wind Cave</i>	Visitor Center	(62)	66	70	(71)	(70)	---	---	---
# park units with violations (0.08 ppm standard):		0	0	0	0	1	2	3	4
# sites with violations:		0	0	0	0	1	2	4	4

^a The new primary and secondary National Ambient Air Quality Standard for ozone is 0.075 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 76 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 76 ppb.) For reference, values that would violate the new standard are outlined with a black box. The first 3-year period that the new standard will apply to is 2008-2010.

^b The old 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.) Violations of the old standard are highlighted here in orange and red. The old standard applies to all 3-year periods prior to 2008-2010.

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 - 104 ppb ozone concentration
 ≥ 105 ppb ozone concentration
 ≥ 76 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.

Table 4. 2009 Summary of indices for resource injury (SUM06 and W126).

National Park Unit	Site Name	O ₃ % Valid	SUM06 ^a (ppm-hr)	W126 ^b (ppm-hr)
Sites operated by the National Park Service				
Big Bend	K-Bar Ranch Road	98.5	6	8
Canyonlands	Island in the Sky	93.0	7	11
Chiricahua	Entrance Station	99.1	12	12
Craters of the Moon	Visitor Center	99.5	1	5
Death Valley	Park Village	96.3	21	15
Denali	Headquarters	98.9	0	3
Glacier	West Glacier Horse Stables	98.5	0	1
Grand Canyon	The Abyss	96.7	9	10
Great Basin	Maintenance Yard	93.4	9	10
Great Smoky Mountains	Clingmans Dome	98.3	5	7
Great Smoky Mountains	Cove Mountain	99.8	10	9
Great Smoky Mountains	Look Rock	99.5	9	7
Joshua Tree	Black Rock	95.3	55	40
Joshua Tree	Cottonwood Canyon	92.1	22	18
Lassen Volcanic	Manzanita Lake Fire Station	98.8	8	7
Mammoth Cave	Houchin Meadow	95.9	7	6
Mesa Verde	Resource Management Area	99.5	19	15
Mount Rainier	Tahoma Woods	95.8	2	2
Petrified Forest	South Entrance	99.1	6	9
Pinnacles	SW of East Entrance Station	97.4	16	11
Rocky Mountain	Long's Peak	96.9	13	11
Sequoia and Kings Canyon	Ash Mountain	98.0	69	55
Sequoia and Kings Canyon	Lower Kaweah	99.3	41	29
Shenandoah	Big Meadows	99.4	8	7
Voyageurs	Sullivan Bay	98.2	4	4
Yellowstone	Water Tank	99.3	5	7
Yosemite	Turtleback Dome	98.2	38	25
Zion	Dalton's Wash	94.2	15	12
Sites operated by cooperating state agencies				
<i>Acadia</i>	Cadillac Mountain	99.3	5	5
<i>Acadia</i>	McFarland Hill	99.5	3	4
<i>Badlands</i>	Visitor Center	99.9	0	2
<i>Cape Cod</i>	Cape Cod	97.2	5	5
<i>Chamizal</i>	Chamizal	99.2	7	6
<i>Congaree</i>	Congaree Bluff	99.4	2	3
<i>Cowpens</i>	State Monitor	97.9	1	2
<i>Everglades</i>	Cutler Road	99.2	2	3
<i>Great Smoky Mountains</i>	Cades Cove	99.3	4	5
<i>Great Smoky Mountains</i>	Purchase Knob	95.1	3	4
<i>Indiana Dunes</i>	Ammunition Bunker	98.5	1	2
<i>Mount Rainier</i>	Jackson Visitor's Center	89.5	1	1
<i>Saguaro</i>	Pima County	99.8	12	11
<i>Theodore Roosevelt</i>	Painted Canyon Visitor Center	99.3	0	3
<i>Wind Cave</i>	Visitor Center	67.4	4	5

Table 4. 2009 Summary of indices for resource injury (SUM06 and W126) (continued).

National Park Unit	Site Name	O ₃ % Valid	SUM06 ^a (ppm-hr)	W126 ^b (ppm-hr)
Portable ozone monitoring systems				
<u>Agate Fossil Beds</u>	Residence Area	70.8	2	4
<u>Assateague Island</u>	Maintenance Area	99.8	2	3
<u>Carlsbad Caverns</u>	Maintenance Area	61.2	7	7
<u>Colorado</u>	Maintenance Yard	99.9	1	3
<u>Cumberland Gap</u>	Hensley Settlement	99.3	0	3
<u>Devil's Tower</u>	Joyner Ridge Trail	94.9	3	5
<u>Dinosaur</u>	West Entrance Housing	99.1	5	8
<u>Glacier</u>	Saint Mary's Ranger District	93.0	1	3
<u>Joshua Tree</u>	Pinto Wells	58.9	17	12
<u>Mojave</u>	Kelso Mountains	99.8	26	19
<u>Natchez Trace</u>	Buzzard Roost Springs	94.0	0	1
<u>Olympic</u>	Deer Park	0.0	--- ^c	--- ^c
<u>Yosemite</u>	School Yard	99.3	5	6

^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 0800-2000 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. The value reported here represents a three-month maximum value during the ozone season. Units are ppm-hr. For more information on the W126 exposure index go to http://www.nature.nps.gov/air/maps/AirAtlas/docs/air_quality_glossary.pdf.

^c In 2009, data capture at this station was not high enough to present values in this table.

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

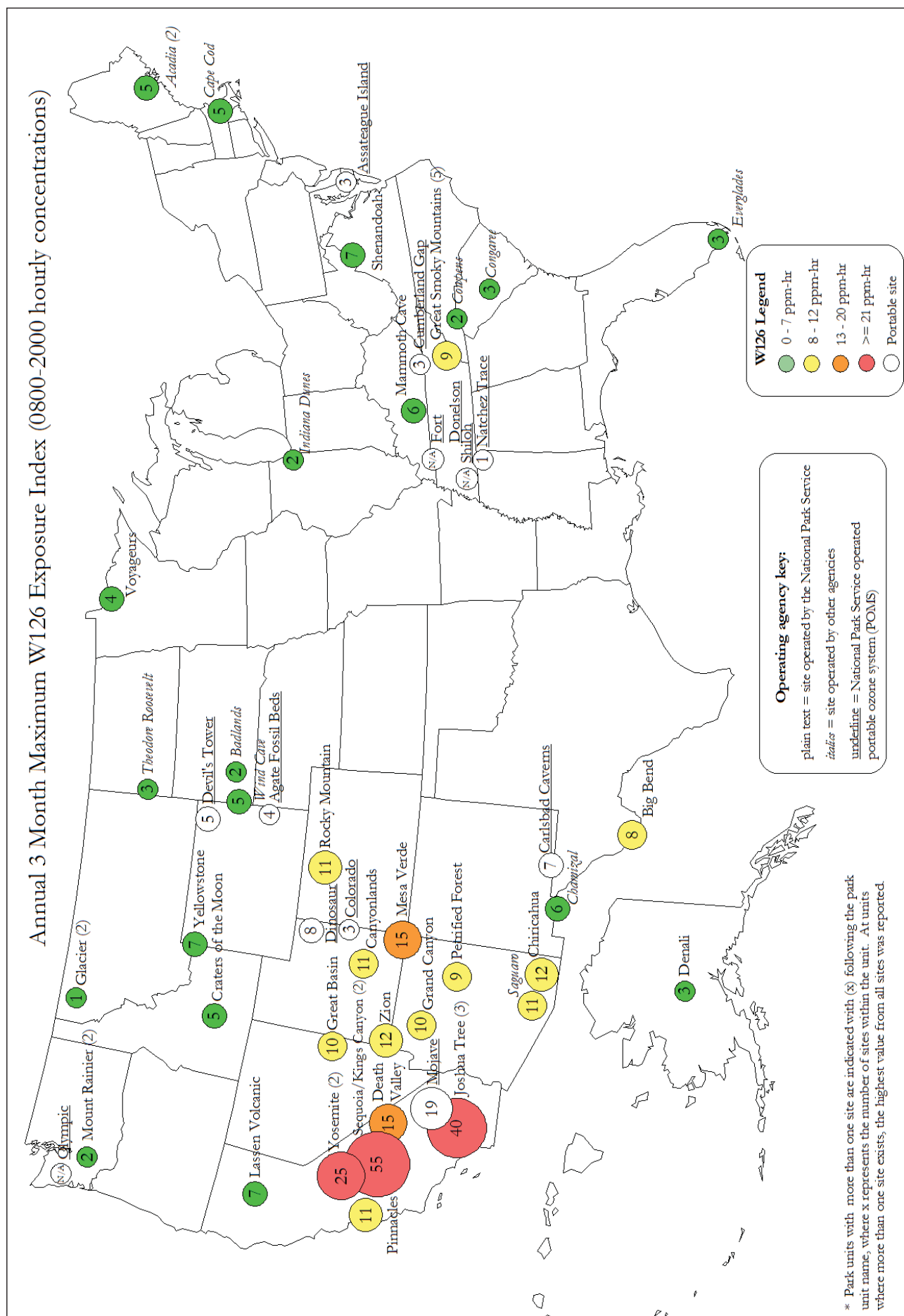


Figure 5. 2009 3-month maximum W126 exposure index during the ozone season (0800-2000 hourly concentrations).

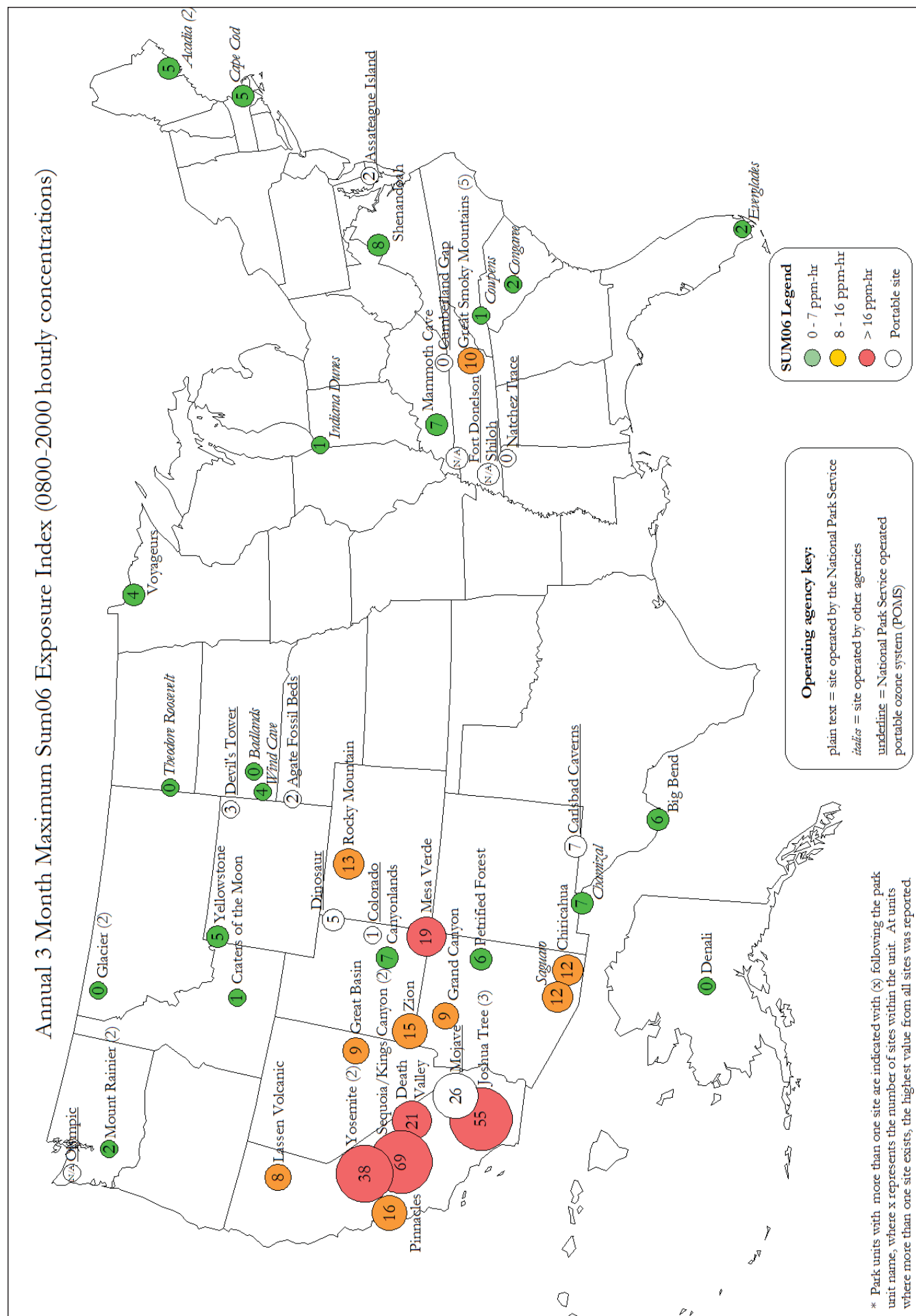


Figure 6. 2009 3-month maximum SUM06 exposure index during the ozone season (0800-2000 hourly concentrations).

Table 5. 2009 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)			
			1 st Highest	2 nd Highest	3 rd Highest	4 th Highest	No. of Days with 24-Hour Average ≥ 145 ppb	1 st Highest	2 nd Highest	3 rd Highest	4 th Highest	No. of Days with 3-Hour Maximum ≥ 550 ppb	1 st Highest	2 nd Highest	3 rd Highest	4 th Highest
Sites operated by the National Park Service																
Great Smoky Mountains	Cove Mountain	1	3	3	2	2	0	5	5	5	5	0	9	7	7	7
Hawaii Volcanoes *	Observatory / Jaggar Museum	47	907	538	528	528	37	3901	2446	2155	1884	39	4311	3825	3598	3564
Hawaii Volcanoes *	Visitor Center	35	628	521	507	474	28	2667	2094	1497	1340	27	4555	2562	2543	2459
Mammoth Cave	Houchin Meadow	1	4	4	3	3	0	16	7	7	7	0	23	10	9	9
Sites operated by cooperating state agencies																
Badlands	Visitor Center	1	3	3	3	3	0	6	5	5	4	0	7	6	5	5
Congaree	Congaree Bluff	1	9	9	8	7	0	36	32	32	29	0	75	63	54	49
Indiana Dunes	Ammunition Bunker	2	20	16	12	11	0	57	53	50	45	0	75	72	68	59
Theodore Roosevelt	Painted Canyon Visitor Ctr	1	7	6	4	3	0	16	15	13	11	0	18	15	11	9
Wind Cave	Visitor Center	1	6	3	3	2	0	14	12	11	7	0	32	20	9	9
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/m³ 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/m³ 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/m³ 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																

Table 6. 2009 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/m ³)	Highest Daily 24-Hour Average Concentrations ^c (µg/m ³)					No. of Days with 24-Hour Average >35 µg/m ³
					1 st Highest	2 nd Highest	3 rd Highest	4 th Highest	98 th Percentile Value	
Sites operated by the National Park Service										
Great Smoky Mountains	Look Rock	TEOM	99.0	10.0	26	26	26	24	21	0
Hawaii Volcanoes	Observatory / Jaggar Museum	SHARP	98.1	11.0	75	75	66	63	60	32
Sequoia and Kings Canyon	Ash Mountain	BAM	86.3	10.8	47	33	32	29	21	1
Shenandoah	Big Meadows	TEOM	98.8	5.0	18	17	17	15	14	0
Yellowstone	Old Faithful	BAM	61.5	3.5	8	7	7	7	6	0
Zion	Dalton's Wash	FRM or FEM	91.1	3.8	15	14	14	12	12	0
Sites operated by cooperating state agencies										
Acadia	McFarland Hill	TEOM	97.9	2.0	21	21	18	17	11	0
Badlands	Visitor Center	BAM	94.6	3.8	17	16	16	14	10	0
Indiana Dunes	Ammunition Bunker	TEOM	99.1	11.8	29	28	27	26	25	0
Theodore Roosevelt	Painted Canyon Visitor Ctr	TEOM	98.1	5.3	16	16	15	13	11	0
Wind Cave	Visitor Center	BAM	94.1	6.0	268	122	113	38	15	4
Yellowstone	W. Yellowstone State Site	BAM	96.3	3.5	12	12	11	10	9	0
Yosemite	Village	BAM	90.1	11.5	47	43	39	38	36	7

^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 35 µg/m³. (An exceedance of the standard occurs when a 24-hour average PM_{2.5} concentration is greater than 35 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 35 µg/m³.) (40 CFR 50.7.)

* TEOM = tapered element oscillating microbalance
BAM = beta attenuation monitor
SHARP = synchronized hybrid ambient real-time particulate monitor
FRM = federal reference method monitor
FEM = federal equivalent method monitor

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

Color shading key: Annual arithmetic mean > 15 µg/m³
98th percentile value > 35 µg/m³

Table 7. 2009 Summary of PM₁₀ data from reference and equivalency methods.

National Park Unit	Site Name	Sampler Type*	% Valid ^a	Annual Arithmetic Mean ^b (µg/m ³)	Highest Daily 24-Hour Average Concentrations ^c (µg/m ³)				
					1 st Highest	2 nd Highest	3 rd Highest	4 th Highest	No. of Days with 24-Hour Average >150 µg/m ³
Sites operated by cooperating state agencies									
Badlands	Visitor Center	BAM	99.8	7	40	30	30	30	0
Wind Cave	Visitor Center	BAM	99.5	9	340	140	130	70	1

^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 PM₁₀ is an annual arithmetic mean of 50 µg/m³. (An exceedance of the standard occurs when an annual arithmetic mean of PM₁₀ concentrations is greater than 50 µg/m³. A violation of the standard occurs when the 3-year average of the weighted annual mean PM₁₀ concentrations is greater than 50 µg/m³ (40 CFR 50.6.)

^c The primary daily National Ambient Air Quality Standard for PM₁₀ is a 24-hour average concentration of 150 µg/m³. (An exceedance of the standard occurs when a 24-hour average PM₁₀ 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 in a calendar year.) (40 CFR 50.6.)

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

Color shading key: ■ >50 µg/m³ annual arithmetic mean, >150 µg/m³ 24-hour average

italics = site operated by a state agency

Table 8. 2009 Summary of PM₁₀ data from non-equivalency methods.

National Park Unit	Site Name	Sampler Type	% Valid ^a	Annual Arithmetic Mean ^b (µg/m ³)	Highest Daily 24-Hour Average Concentrations ^c (µg/m ³)				
					1 st Highest	2 nd Highest	3 rd Highest	4 th Highest	No. of Days with 24-Hour Average >150 µg/m ³
Sites operated by the National Park Service									
Joshua Tree	Cottonwood Canyon	E-sampler	61.0	3	20	20	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 annual National Ambient Air Quality Standard for PM₁₀ is an annual arithmetic mean of 50 µg/m³. (An exceedance of the standard occurs when an annual arithmetic mean of PM₁₀ concentrations is greater than 50 µg/m³. A violation of the standard occurs when the 3-year average of the weighted annual mean PM₁₀ concentrations is greater than 50 µg/m³ (40 CFR 50.6.)

^c The primary daily National Ambient Air Quality Standard for PM₁₀ is a 24-hour average concentration of 150 µg/m³. (An exceedance of the standard occurs when a 24-hour average PM₁₀ 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 in a calendar year.) (40 CFR 50.6.)

Color shading key: ■ >50 µg/m³ annual arithmetic mean, >150 µg/m³ 24-hour average

Table 9. PM₁₀ summary - maximum daily 24-hour average concentration in 2007-2009 (µg/m³)^a.

National Park Unit	Site Name	Sampler Type*	2009	2008	2007
Sites operated by cooperating state agencies					
<i>Badlands</i>	Visitor Center	BAM	40	90	50
<i>Wind Cave</i>	Visitor Center	BAM	340	50	40

^a The primary daily National Ambient Air Quality Standard for PM₁₀ is a 24-hour average concentration of 150 µg/m³. (An exceedance of the standard occurs when a 24-hour average PM₁₀ 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 in a calendar year.) (40 CFR 50.6.)

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

Color shading key: ■ > 1 24-hour average concentration >150 µg/m³

italics = site operated by a state agency

Table 10. 2009 Annual summary of selected meteorological data.

		Wind Speed (m/s)	Ambient Temperature (degrees C)			Relative Humidity (%)			Precipitation (mm)
		Average	Average	Maximum	Minimum	Average	Maximum	Minimum	Annual Accumulation
Sites operated by the National Park Service									
Big Bend	K-Bar Ranch Road	3.6	20.8	38.6	-3.3	38	99	3	138
Canyonlands	Island in the Sky	2.9	12.0	35.2	-13.3	38	96	5	135
Chiricahua	Entrance Station	2.9	15.9	35.0	-5.5	43	100	4	323
Craters of the Moon	Visitor Center	3.2	4.3	32.9	-25.3	55	99	8	---
Death Valley	Park Village	3.7	26.2	48.5	3.5	18	92	2	42
Denali	Headquarters	1.4	-1.3	29.4	-37.0	65	100	14	173
Everglades	Beard Center	2.2	22.6	35.0	1.9	79	100	19	644
Glacier	West Glacier Horse Stables	0.9	4.8	31.1	-27.0	72	96	13	673
Grand Canyon	The Abyss	2.9	6.0	25.3	-8.8	39	98	4	232
Great Basin	Maintenance Yard	2.8	10.4	32.3	-17.9	42	96	5	310
Great Smoky Mountains	Clingmans Dome	3.6	10.8	19.3	-8.3	89	100	3	1658
Great Smoky Mountains	Cove Mountain	4.8	10.6	25.2	-19.1	75	100	3	1175
Great Smoky Mountains	Look Rock	2.4	12.5	27.7	-17.5	75	100	17	1649
Hawaii Volcanoes	Observatory / Jaggar Museum	4.8	15.4	26.2	7.6	87	100	10	1191
Hawaii Volcanoes	Visitor Center	3.6	15.2	27.3	6.2	91	100	14	1914
Joshua Tree	Black Rock	3.7	17.0	36.7	-3.7	31	95	2	104
Joshua Tree	Cottonwood Canyon	3.6	19.2	39.2	-0.7	27	100	5	58
Lassen Volcanic	Manzanita Lake Fire Station	1.9	7.1	29.5	-17.9	60	95	6	838
Mammoth Cave	Houchin Meadow	1.9	13.7	32.3	-18.2	72	95	22	1495
Mesa Verde	Resource Management Area	3.1	10.3	31.7	-12.4	40	97	6	272
Mount Rainier	Tahoma Woods	1.0	8.3	37.2	-14.6	82	99	14	1380
Petrified Forest	South Entrance	4.0	12.7	35.6	-12.0	40	99	4	94
Pinnacles	SW of East Entrance Station	2.3	14.5	42.2	-6.8	53	91	2	303
Rocky Mountain	Long's Peak	2.9	4.3	25.4	-23.6	50	100	4	486
Sequoia and Kings Canyon	Ash Mountain	2.5	17.0	40.4	-3.7	50	97	8	309
Sequoia and Kings Canyon	Lower Kaweah	1.7	9.3	28.8	-13.2	56	95	8	933
Shenandoah	Big Meadows	2.1	8.4	27.1	-20.7	72	98	8	1396
Voyageurs	Sullivan Bay	2.7	3.2	31.4	-32.8	76	98	15	772
Yellowstone	Old Faithful	1.6	1.3	27.7	-31.7	69	100	7	---
Yellowstone	Water Tank	1.6	0.6	26.6	-27.2	69	96	7	359
Yosemite	Turtleback Dome	4.1	11.3	30.9	-11.3	48	98	8	842
Zion	Dalton's Wash	3.8	16.2	40.2	-8.9	34	96	5	64
Sites operated by cooperating state agencies									
Acadia	Cadillac Mountain	6.0	12.7	28.9	-3.5	81	100	20	---
Acadia	McFarland Hill	2.9	6.7	30.7	-22.5	76	100	16	1427
Cape Cod	Cape Cod	2.4	9.6	32.9	-13.2	71	90	14	---
Chamizal	Chamizal	3.3	19.6	39.4	-3.6	32	98	5	---
Great Smoky Mountains	Cades Cove	1.3	12.9	30.5	-15.3	75	100	13	1663
Indiana Dunes	Ammunition Bunker	3.4	9.4	33.5	-27.3	74	100	20	---
Saguaro	Pima County	5.8	22.0	40.7	0.4	30	97	5	---
Theodore Roosevelt	Painted Canyon Visitor Cntr	5.0	5.1	33.9	-28.7	66	96	13	316
Wind Cave	Visitor Center	2.8	7.9	33.3	-22.8	55	96	8	370

Table 10. 2009 Annual summary of selected meteorological data (continued).

National Park Unit	Site Name	Wind Speed (m/s)	Ambient Temperature (degrees C)			Relative Humidity (%)			Precipitation (mm)
		Average	Average	Maximum	Minimum	Average	Maximum	Minimum	Annual Accumulation
Portable ozone monitoring systems (seasonal)									
<u>Agate Fossil Beds</u>	Residence Area	3.1	15.7	36.0	-3.0	65	100	11	341
<u>Assateague Island</u>	Maintenance Area	1.3	21.2	33.4	5.0	83	99	36	299
<u>Carlsbad Caverns</u>	Maintenance Area	4.1	24.8	38.0	9.3	44	100	5	258
<u>Colorado</u>	Maintenance Yard	1.7	21.6	35.9	1.6	29	96	5	108
<u>Cumberland Gap</u>	Hensley Settlement	2.1	18.1	27.0	4.8	85	100	28	705
<u>Devil's Tower</u>	Joyner Ridge Trail	1.4	15.6	35.1	-4.2	63	100	10	263
<u>Dinosaur</u>	West Entrance Housing	1.4	20.2	37.3	0.3	41	99	6	105
<u>Fort Donelson</u>	Visitor Center	0.8	24.6	35.4	10.1	78	98	33	---
<u>Glacier</u>	Saint Mary's Ranger District	2.4	12.9	28.6	-2.4	60	100	13	236
<u>Joshua Tree</u>	Pinto Wells	3.2	31.3	46.3	7.4	20	76	5	2
<u>Mojave</u>	Kelso Mountains	3.6	24.9	39.2	-0.4	24	94	7	28
<u>Natchez Trace Parkway</u>	Buzzard Roost Springs	0.3	23.7	35.2	5.3	83	100	28	671
<u>Olympic</u>	Deer Park	0.7	12.0	30.5	-3.4	64	100	7	108
<u>Shiloh</u>	Russian Tenant Field	0.8	24.4	34.0	12.7	84	99	40	---
<u>Yosemite</u>	School Yard	0.8	16.6	35.5	-2.7	58	98	10	179

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."

Selected Peer-Reviewed Publications Using NPS Data

Bryan, J. Bloomer, Konstantin, Y. Vinnikov, Russell R. Dickerson, Changes in seasonal and diurnal cycles of ozone and temperature in the eastern U.S., *Atmos. Environ.* 44, 2543-2551 (2010).

Brodin, M., Helmig, D., Oltmans, S. Seasonal Ozone Behavior on an Elevation Gradient in the Colorado Front Range Mountains, *Atmospheric Environment* (2010), doi: 10.1016/j.atmosenv.2010.06.033.

S.J. Oltmans, A.S. Lefohn, J.M. Harris, D.W. Tarasick, A.M. Thompson, H. Wernli, B.J. Johnson, P.C. Novelli, S.A. Montzka, J.D. Ray, L.C. Patrick, C. Sweeney, A. Jefferson, T. Dann, J. Davies, M. Shapiro, B.N. Holben, Enhanced ozone over western North America from biomass burning in Eurasia during April 2008 as seen in surface and profile observations, *Atmos. Environ.* 44, In Press (2010).

Daniel Q. Tong, Rohit Mathur, Daiwen Kang, Shaocai Yu, Kenneth L. Schere, George Pouliot, Vegetation exposure to ozone over the continental United States: Assessment of exposure indices by the Eta-CMAQ air quality forecast model, *Atmos. Environ.* 43, 724–733 (2009).

Huiqun Wang, Daniel J. Jacob, Philippe Le Sager, David G. Streets, Rokjin J. Park, Alice B. Gilliland, and A. van Donkelaar, Surface ozone background in the United States: Canadian and Mexican pollution influences, *Atmos. Environ.* 43, 1310 (2009).

Reports Containing NPS Monitoring Data

Clean Air Status and Trends Network (CASTNET); 2008 Annual Report, MACTEC Engineering and Consulting, Inc., February 2010.

National Park Service, Air Resources Division. 2009. Air quality in national parks: 2008 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2009/151. National Park Service, Denver, Colorado.

Ray, J. D. 2009. Annual data summary 2008: Gaseous pollutant monitoring program. Natural Resource Data Series NPS/NRPC/ARD/NRDS—2009/011. National Park Service, Denver, Colorado.

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Joshua Tree National Park, California
- Black Rock monitoring site

