

Annual Data Summary
MAMMOTH CAVE NATIONAL PARK
1998
National Park Service
Gaseous Air Pollutant Monitoring Network



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At Mammoth Cave National Park, the ARD specifically recognizes Bob Carson for performing the technical and administrative skills required to help produce the data presented within this report.

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1.0 INTRODUCTION

1.1 THE NATIONAL PARK SERVICE GASEOUS POLLUTANT MONITORING NETWORK

Gaseous air pollutants, including ozone and sulfur dioxide, are of concern to the National Park Service (NPS). Pollutants like these can affect park unit biological resources as well as the health of park unit residents and visitors. The NPS established a gaseous pollutant monitoring program for several pollutants linked to effects on NPS resources. This program was designed to meet certain resource management objectives.

The primary objective of this monitoring program is to establish the status and trends of park unit air quality conditions and to determine if a park unit is exceeding the National Ambient Air Quality Standards established by the U.S. Environmental Protection Agency (EPA) to protect public health and welfare. In addition, such monitoring is designed to detect changes or trends in pollution levels over time. A monitoring station may also be established if there is documented biological injury due to air pollution in a park unit. Information on ambient air pollution levels is an important part of research on effects of air pollutants on NPS resources, and can help confirm suspected causes of observed effects.

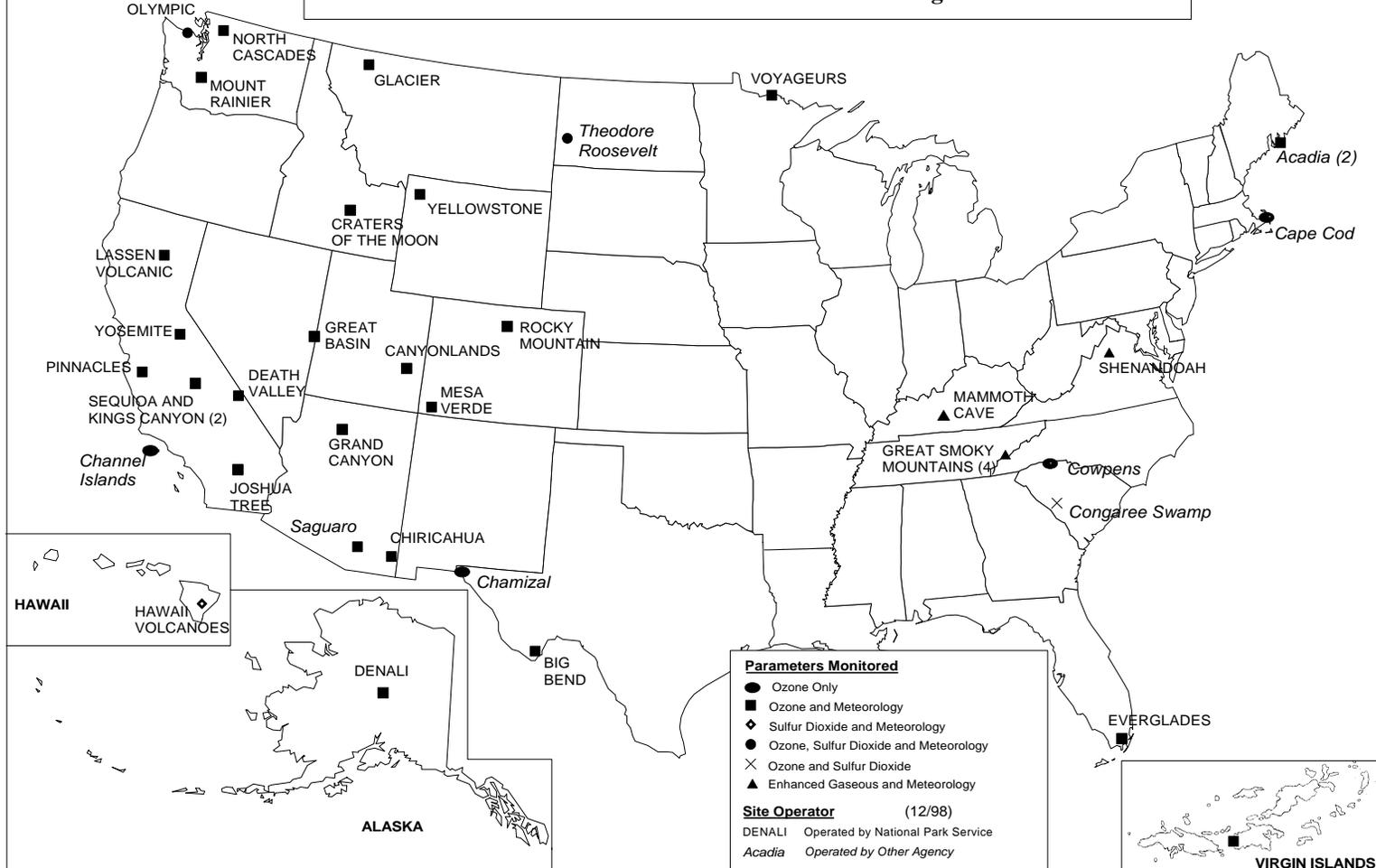
Other monitoring objectives call for the collection of data to support the National Park Service's required involvement in both the development of state air quality control plans, and the evaluation of permit applications for new or expanding air pollution sources wishing to locate near park units. The Clean Air Act gives federal land managers and superintendents 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 unit resources and values. Information on air quality levels in NPS units can also be used to evaluate the performance of atmospheric models that simulate how pollutants are transported into park units and predict impacts on the park unit caused by air pollution sources.

The National Park Service Gaseous Pollutant Monitoring Network site locations and measured parameters collected in this reporting year are shown on the map on the following page. During this reporting period, 40 monitoring sites in 35 units of the National Park System had some combination of ozone, sulfur dioxide, meteorological, and CASTNet dry deposition monitoring. Monitoring methods and quality assurance procedures used in the national park network meet the applicable 40 CFR Part 58 EPA requirements. This allows for the direct comparison of NPS collected data with that collected by the EPA, and state and local air pollution control agencies. Data collected by this network are incorporated in the EPA Aerometric Information Retrieval System (AIRS) database which is a national database of all air quality data collected throughout the country. These data are also stored in the NPS Air Resources Division's Information Management Center (IMC) that allows for easy access and analysis of data.

This report includes a variety of data summaries for data collected at an individual monitoring site at a national park unit during this reporting period. These summaries highlight the average range and frequency of the data collected during the year. A PC-compatible diskette containing a digital copy of all data collected during the year and data summary products included in this report is available. Individual reports are generated for each site where monitoring was conducted in the national park network.

**NATIONAL PARK SERVICE
GASEOUS POLLUTANT MONITORING NETWORK**

1998 Ozone and Sulfur Dioxide Monitoring Sites



1.2 MAMMOTH CAVE NATIONAL PARK

Mammoth Cave National Park, a Class I area, is located in west central Kentucky. It is noted primarily for its subsurface features which include the largest and longest limestone cave system in the world. This system encompasses more than 300 miles of known subterranean passages. Its location and site specifications are presented on the following page.

The park is the centerpiece of one of the greatest cave regions in the world. The area, with its multitude of limestone caves, underground rivers, springs, and sinkholes, is known as a karst landscape.

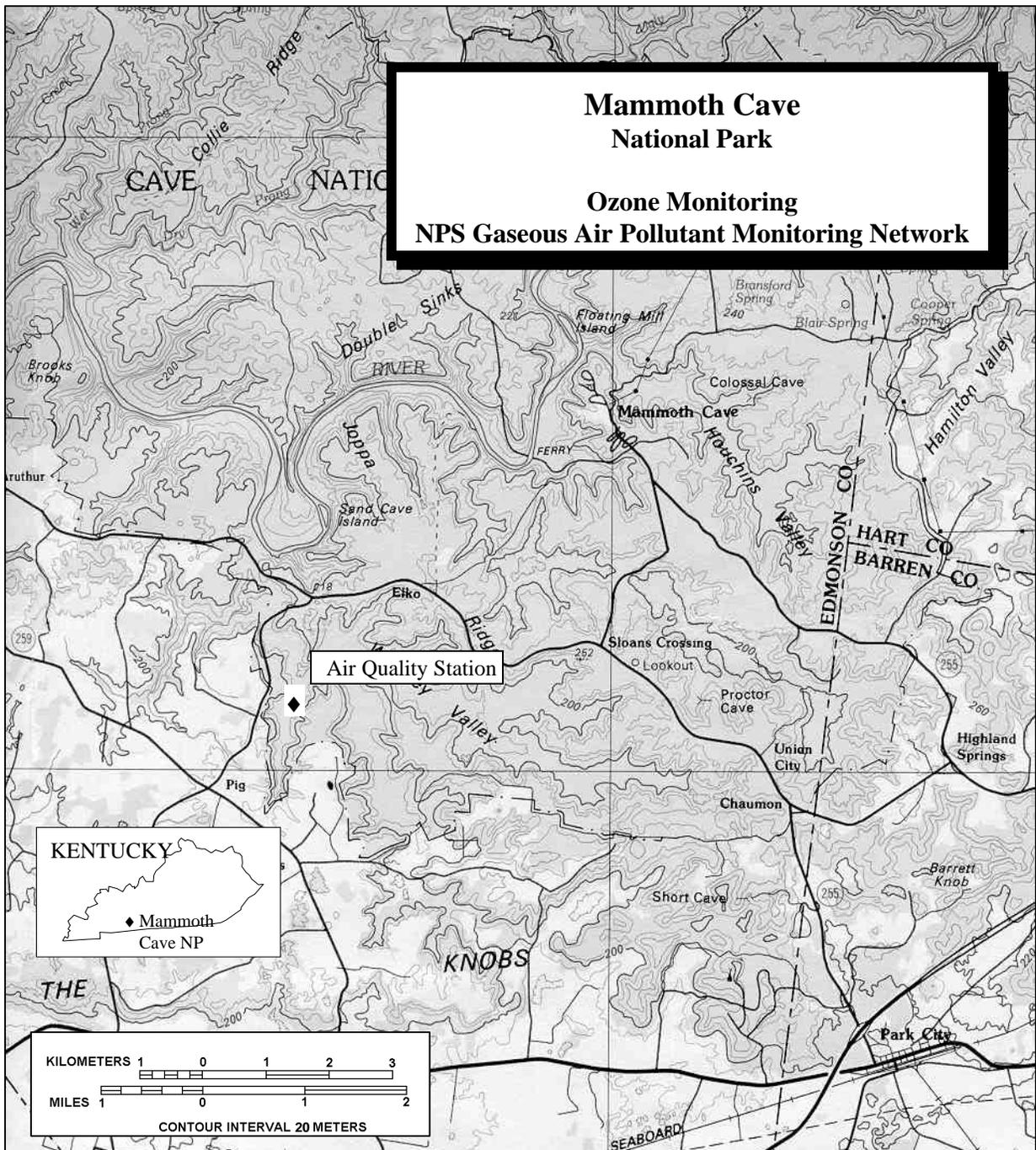
An act to provide for the establishment of Mammoth Cave National Park was approved in 1926 "for the benefit and enjoyment of the people." The law creating the park also referenced the 1916 National Park Service Organic Act which stated that the fundamental purpose of national parks is "...to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

The dominant vegetation consists of oaks and hickories on the slopes, and of sycamore, elm, and ash along the river banks. However, botanists have identified 84 species of trees, 28 species of shrubs and vines, 29 species of ferns and over 200 species of flowering herbs. There are two areas of forest growth that apparently have never been logged and these areas contain fairly extensive stands of mature white oak, black oak, tulip tree, beech, and maple.

Over 40 species of mammals are found within the park, but the major forms are deer, raccoon, opossum, gray squirrel, rabbit, woodchuck, muskrat, red fox and bat. There are also over 100 species of fish, over 200 of birds, 18 of reptiles, and 15 of amphibians. Many of the cave animals are blind, or nearly so, and some lack skin pigments as a result of living in the total blackness of the cave.

Park lands are rich in cultural resources. Pre-Columbian Indians went into the cave passages to chip minerals off the walls and ceilings. Chipmarks, blackened ceilings from torch smoke, sandals and other clothing artifacts, and mummified remains of Indians have been found in cave passages.

Air quality is being degraded by pollutants such as ozone originating outside the park.



SITE IDENTIFICATION		MAP INFORMATION	
Site Abbreviation:	MACA-HM	Mean Elevation:	236 m
AIRS ID NO.:	21-061-0501	Longitude:	86° 08' 53"W
INSTRUMENTATION		Latitude:	37° 07' 53"N
		UTM Zone:	29
O ₃ Analyzer	SO ₂ Analyzer	Easting:	483570 m
Calibrator	Temperature	Northing:	475044 m
Wind Speed	Solar Radiation	Map Reference:	Beaver Dam
Wind Direction	Precipitation		37086-A1
Relative Humidity	Barometric Pressure		1:100,000

2.0 DATA SUMMARY

2.1 OVERVIEW

Based on the site specifications during this annual reporting period, data summaries and statistics are provided in this section.

Data Collection Statistics
Mammoth Cave National Park
Houchin Meadow

Final Data

01/01/98 - 12/31/98

Parameter	Par Code	Data Recovery			Valid Data	
		No. Possible	No. Collected	% Collected	No. Valid	% Valid
Ozone Analyzer	O3	8760	8322	95.0	8300	94.7
Scalar Wind Speed	SWS	8760	8722	99.6	8707	99.4
Vector Wind Speed	VWS	8760	8721	99.6	8706	99.4
Vector Wind Direction	VWD	8760	8721	99.6	8691	99.2
Ambient Temperature (aspirated)	TMP	8760	8723	99.6	8723	99.6
Relative Humidity	RH	8760	8717	99.5	8597	98.1
Precipitation	RNF	8760	8727	99.6	8727	99.6
Solar Radiation	SOL	8760	8721	99.6	8173	93.3
Barometric Pressure	BAR	8760	8722	99.6	8722	99.6

Notes: All statistics are for hourly averages.

The number collected does not include normal maintenance or events beyond the control of the network.

The percent valid is calculated against the number possible.

Automatic zeros and spans are performed daily on most ambient gas analyzers, therefore, no ambient data can be collected during this time. As a result, the maximum percent valid for ambient gas data typically can not be greater than 95.8.

NPS Performance Goals:

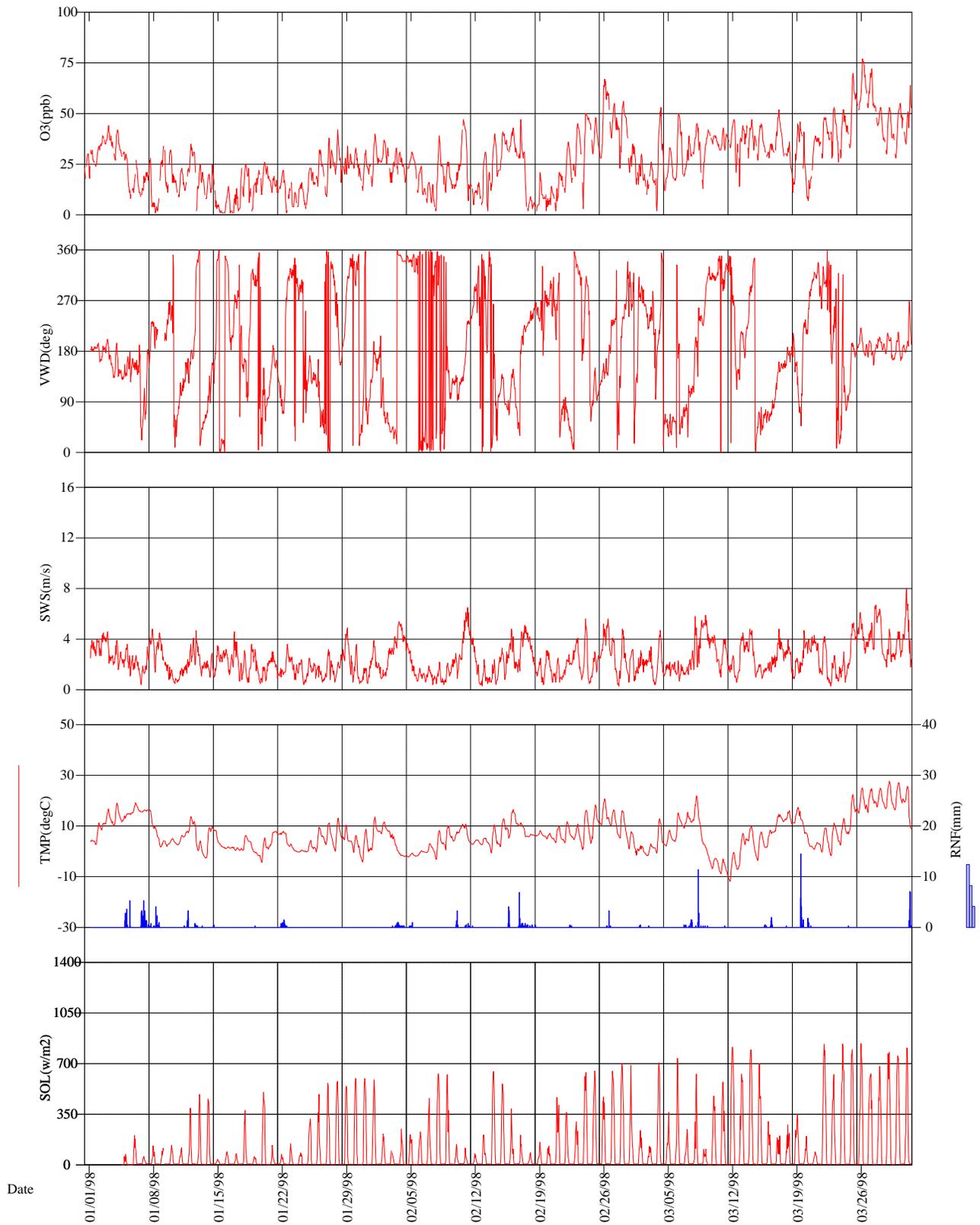
Quarterly Criteria:

100% of sites, >= 85% valid data capture
90% of sites, >= 90% valid data capture
80% of sites, >= 95% valid data capture

Monthly Criteria:

100% of sites, >= 60% valid data capture
90% of sites, >= 75% valid data capture
80% of sites, >= 85% valid data capture

Mammoth Cave National Park - Houchin Meadow

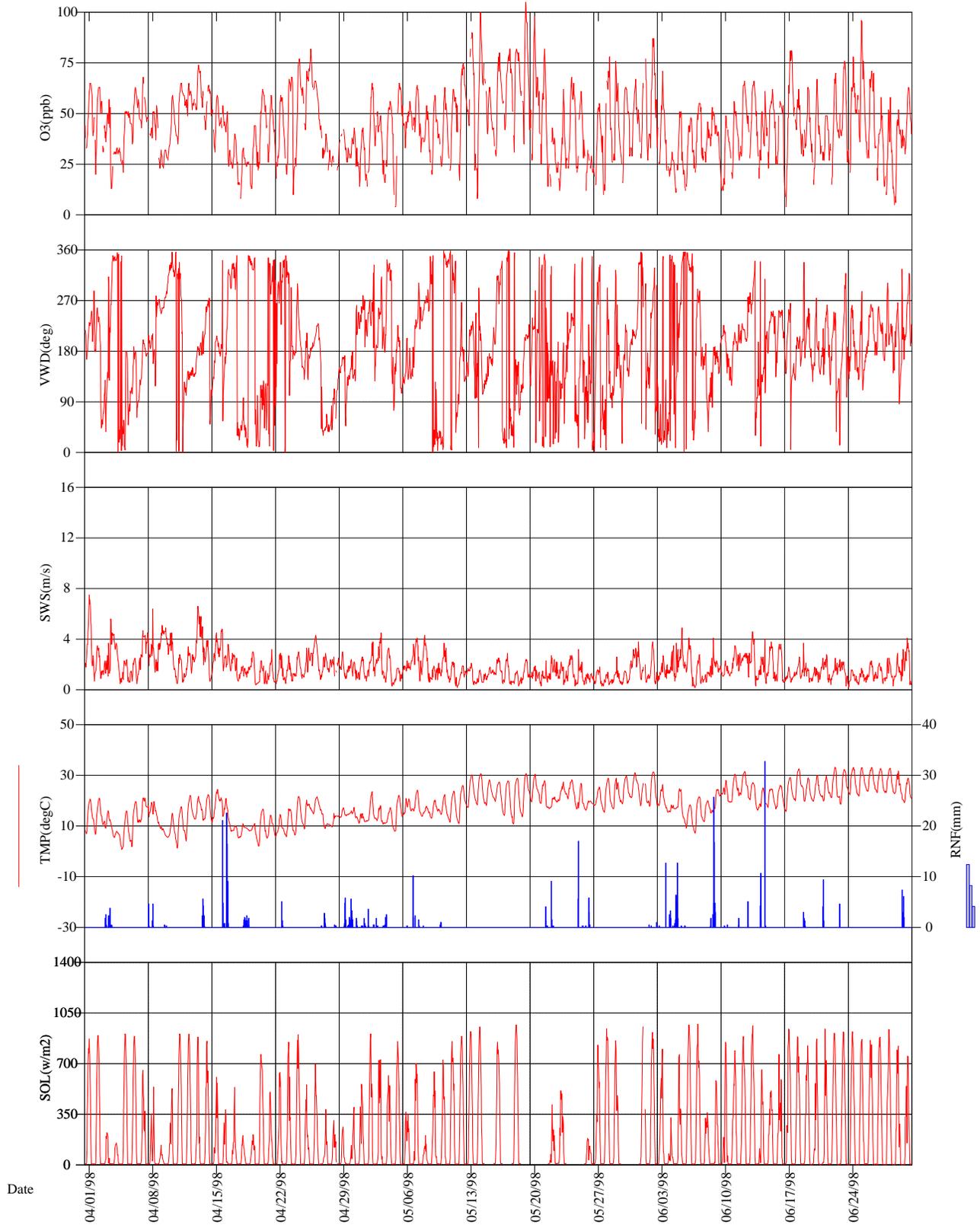


Final Validation

First Quarter 1998

mahm-hm.stk - mahm98.dat 08-23-1999

Mammoth Cave National Park - Houchin Meadow

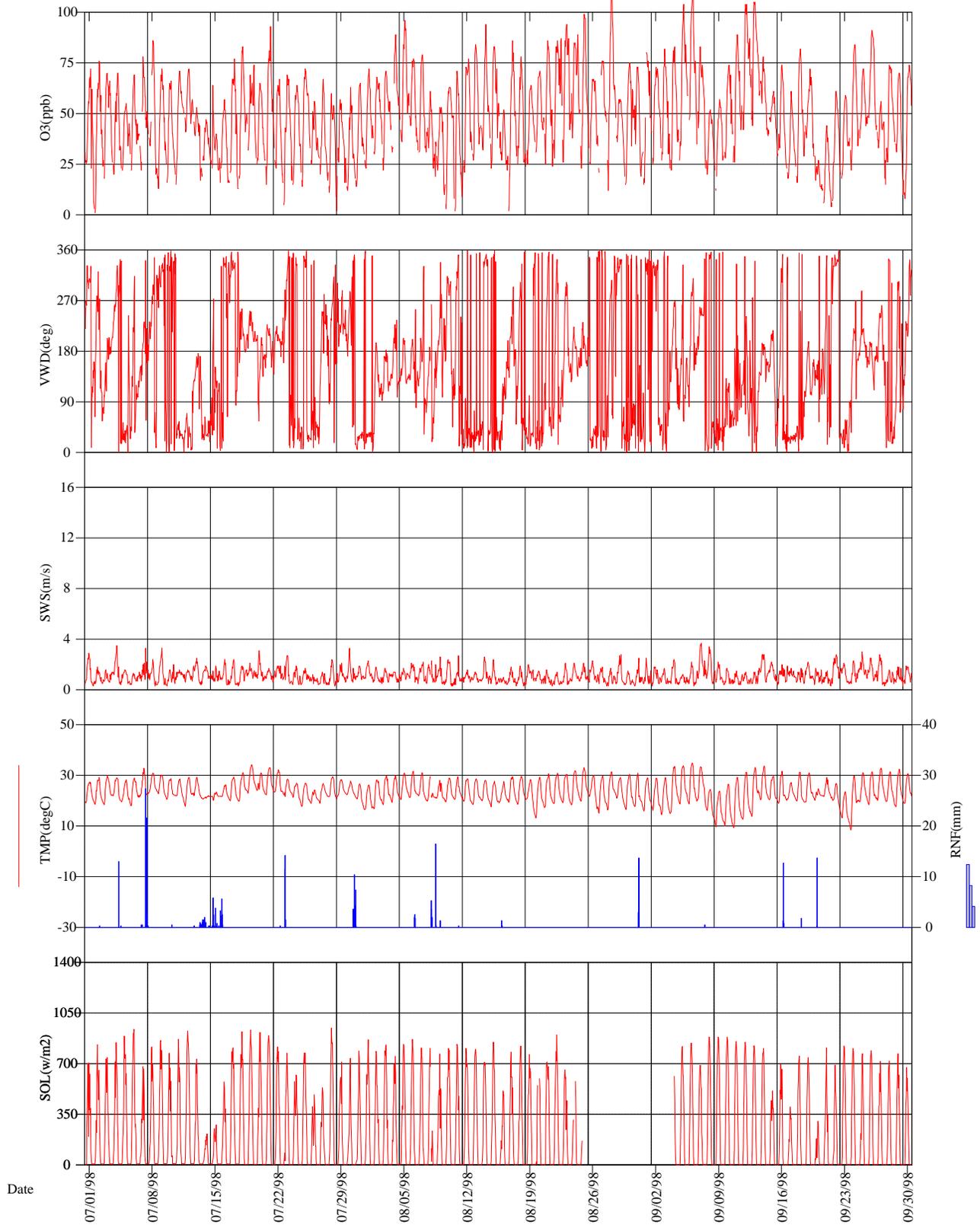


Final Validation

Second Quarter 1998

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Mammoth Cave National Park - Houchin Meadow

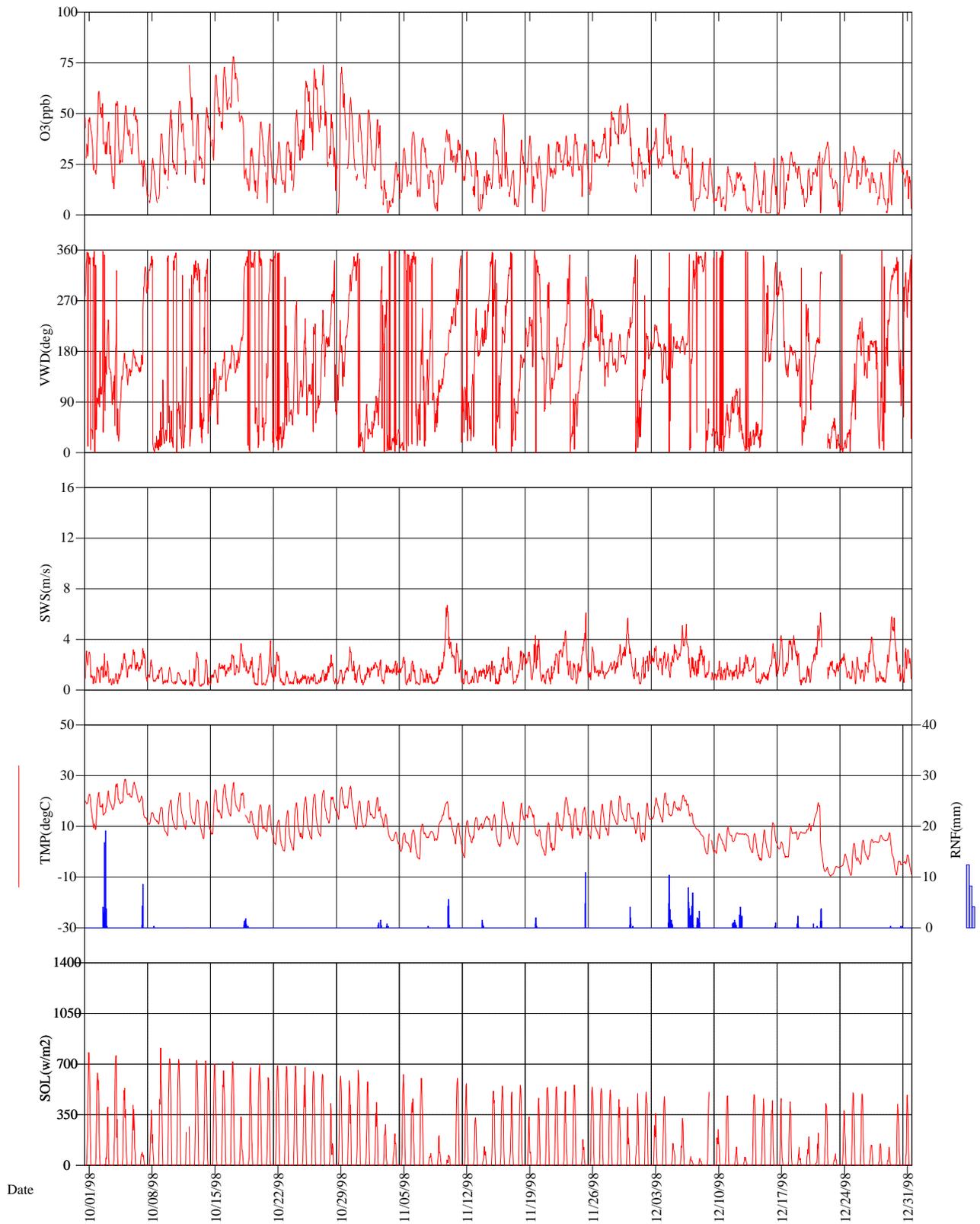


Final Validation

Third Quarter 1998

mahm-hm.stk - mahm98.dat 08-23-1999

Mammoth Cave National Park - Houchin Meadow



Final Validation

Fourth Quarter 1998

mahm-hm.stk - mahm98.dat 08-23-1999

2.2 OZONE DATA SUMMARY

Ozone Quick Look Annual Summary Statistics
Mammoth Cave National Park
Houchin Meadow
01/01/98 - 12/31/98

STATISTIC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAY-SEP	ANNUAL
DAILY 1-HR MAXIMUM	44	67	77	82	105	96	93	112	116	78	55	50	116	116
NO. OF DAYS	(31)	(28)	(31)	(30)	(31)	(30)	(31)	(31)	(30)	(31)	(30)	(31)	(153)	(365)
AVERAGE DAILY MAXIMUM	28	36	48	57	68	63	68	78	75	55	37	29	70	53
NO. OF DAYS	(31)	(28)	(31)	(30)	(31)	(30)	(31)	(31)	(30)	(31)	(30)	(31)	(153)	(365)
MAXIMUM DAILY MEAN	38	50	63	64	70	61	56	69	81	66	44	35	81	81
NO. OF DAYS	(31)	(28)	(31)	(29)	(31)	(30)	(31)	(31)	(30)	(30)	(30)	(31)	(153)	(363)
AVERAGE DAILY MEAN	19	25	37	44	47	42	44	52	51	37	25	18	47	37
NO. OF DAYS	(31)	(28)	(31)	(29)	(31)	(30)	(31)	(31)	(30)	(30)	(30)	(31)	(153)	(363)
MAX PEAK:MIN RATIO	28.000	19.500	26.500	6.800	16.250	20.250	76.000	43.000	15.250	73.000	17.500	31.000	76.000	76.000
NO. OF DAYS	(31)	(28)	(31)	(29)	(31)	(30)	(31)	(31)	(30)	(30)	(30)	(30)	(153)	(362)
AVERAGE PEAK:MIN RATIO	6.380	4.942	2.950	2.497	3.990	3.891	7.352	6.274	3.833	5.599	5.622	8.392	5.084	5.155
NO. OF DAYS	(31)	(28)	(31)	(29)	(31)	(30)	(31)	(31)	(30)	(30)	(30)	(30)	(153)	(362)
MAX 9AM-4PM AVERAGE	40	60	68	69	91	81	77	93	101	74	49	44	101	101
NO. OF DAYS	(31)	(28)	(31)	(29)	(30)	(29)	(31)	(31)	(30)	(30)	(30)	(31)	(151)	(361)
MONTHLY 9AM-4PM AVERAGE	22	29	41	50	60	53	59	69	66	46	31	23	62	46
NO. OF DAYS	(31)	(28)	(31)	(29)	(30)	(29)	(31)	(31)	(30)	(30)	(30)	(31)	(151)	(361)
MAX 7AM-7PM AVERAGE	39	56	66	66	80	72	69	85	90	70	46	40	90	90
NO. OF DAYS	(31)	(28)	(31)	(29)	(31)	(29)	(31)	(31)	(30)	(30)	(30)	(31)	(152)	(362)
MONTHLY 7AM-7PM AVERAGE	21	28	39	48	55	49	54	62	60	42	28	21	56	42
NO. OF DAYS	(31)	(28)	(31)	(29)	(31)	(29)	(31)	(31)	(30)	(30)	(30)	(31)	(152)	(362)
MONTHLY MEAN	19	25	37	44	47	42	44	52	51	37	25	18	47	37
NO. OF HOURS	(704)	(639)	(707)	(668)	(698)	(682)	(711)	(709)	(687)	(700)	(685)	(710)	(3487)	(8300)
SUM0 EXPOSURE INDEX	13334	16165	25881	29276	32754	28790	31088	37021	35119	26009	17175	13005	164772	305617
NO. OF HOURS	(704)	(639)	(707)	(668)	(698)	(682)	(711)	(709)	(687)	(700)	(685)	(710)	(3487)	(8300)
SUM60 EXPOSURE INDEX	-	629	2279	7340	12463	6989	10546	19317	17915	4815	-	-	67230	82293
NO. OF HOURS	(0)	(10)	(34)	(112)	(175)	(102)	(157)	(263)	(237)	(72)	(0)	(0)	(934)	(1162)
SUM80 EXPOSURE INDEX	-	-	-	162	2905	949	844	6216	6419	-	-	-	17333	17495
NO. OF HOURS	(0)	(0)	(0)	(2)	(33)	(11)	(10)	(71)	(71)	(0)	(0)	(0)	(196)	(198)
W126 EXPOSURE INDEX	109	754	2396	5491	9622	5488	7197	14628	14268	3856	395	109	51203	64314
NO. OF HOURS	(704)	(639)	(707)	(668)	(698)	(682)	(711)	(709)	(687)	(700)	(685)	(710)	(3487)	(8300)

Concentrations in parts per billion (ppb)

* Statistics defined in the Quick Look subsection of the Glossary

Exposures in parts per billion-hours (ppb-hr)

Frequency Distribution

Ozone Analyzer

Mammoth Cave National Park

Houchin Meadow

Monitoring Season: 04/01/98 - 10/31/98¹

Averaging Period	% Obs. ³	# Obs. ²	Min. Obs. ⁴	10	30	50	Percentile ⁵				70	90	95	99	Max. Obs.	2nd Max.	Arith. Mean	Geo. Mean	Geo. Stdv.
1-Hour	99	4855	0.028	0.046	0.057	0.065	0.073	0.086	0.096	0.105	0.116	0.112	0.0662	0.0641	1.29				
Concentrations in parts per million (ppm)																			

¹ Records for this report are selected in accordance with the AIRS Geo-Common file criteria. These criteria are based on the state-specific Monitoring Season defined in AIRS.

² The number of observations (# Obs.) includes all valid observations recorded within the Monitoring Season.

³ The percent of valid observations (% Obs.) is the percentage of valid days to the number of possible monitoring days during the Monitoring Season. A valid day is defined as a day with 9 or more valid observations between 9:00 a.m. and 9:00 p.m..

⁴ The minimum observation value (Min. Obs.) is the minimum daily maximum recorded during the Monitoring Season.

⁵ The percentiles and other statistics are derived from the daily maximums.

**Ozone Standards Report and
Daily Maximum 1-Hour Concentrations (ppm)**

Mammoth Cave National Park

Houchin Meadow

01/01/98 - 12/31/98

Day	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98	Dec-98
1	.032 T	.040 S	.043 S	.065 W	.043 F	M	.072 W	.072 S	.080 T	.052 T	.052 S	.033 T
2	.039 F	.037 M	.030 M	.063 T	.065 S	.087 T	.076 T	.068 S	.073 W	.061 F	.047 M	.043 W
3	.044 S	.033 T	.026 T	.057 F	.051 S	.071 W	.070 F	.071 M	.082 T	.055 S	.017 T	.043 T
4	.042 S	.031 W	.053 W	.033 S	.056 M	.031 T	.070 S	.089 T	.083 F	.056 S	.026 W	.050 F
5	.031 M	.031 T	.033 T	.051 S	.065 T	.051 F	.055 S	.096 W	.104 S	.054 M	.033 T	.039 S
6	.027 T	.024 F	.050 F	.063 M	.056 W	.048 S	.069 M	.077 T	.116 S	.053 T	.041 F	.034 S
7	.021 W	.016 S	.039 S	.068 T	.064 T	.055 S	.078 T	.079 F	.083 M	.031 W	.038 S	.033 M
8	.028 T	.039 S	.045 S	.054 W	.054 F	.046 M	.086 W	.061 S	.052 T	.028 T	.025 S	.026 T
9	.034 F	.026 M	.042 M	.049 T	.059 S	.053 T	.072 T	.053 S	.057 W	.040 F	.025 M	.028 W
10	.032 S	.028 T	.040 T	.059 F	.063 S	.049 W	.066 F	.063 M	.074 T	.052 S	.042 T	.014 T
11	.023 S	.047 W	.043 W	.065 S	.062 M	.056 T	.071 S	.071 T	.089 F	.056 S	.037 W	.024 F
12	.035 M	.016 T	.047 T	.065 S	.075 T	.066 F	.072 S	.077 W	.104 S	M	.032 T	.021 S
13	.026 T	.031 F	.044 F	.074 M	.090 W	.066 S	.056 M	.084 T	.105 S	.050 T	.031 F	.019 S
14	.025 W	.040 S	.047 S	.064 T	.100 T	.061 S	.047 T	.094 F	.078 M	.053 W	.022 S	.026 M
15	.019 T	.041 S	.045 S	.059 W	.067 F	.062 M	.064 W	.083 S	.061 T	.069 T	.038 S	.022 T
16	.014 F	.043 M	.035 M	.054 T	.080 S	.056 T	.057 T	.055 S	.074 W	.073 F	.050 M	.028 W
17	.013 S	.047 T	.052 T	.040 F	.082 S	.081 W	.077 F	.086 M	.061 T	.078 S	.022 T	.029 T
18	.025 S	.011 W	.036 W	.033 S	.082 M	.062 T	.083 S	.078 T	.082 F	.064 S	.037 W	.031 F
19	.022 M	.021 T	.046 T	.044 S	.105 T	.063 F	.074 S	.064 W	.072 S	.033 M	.039 T	.026 S
20	.026 T	.014 F	.041 F	.062 M	.098 W	.067 S	.065 M	.071 T	.035 S	.046 T	.029 F	.023 S
21	.019 W	.021 S	.039 S	.059 T	.082 T	.049 S	.093 T	.086 F	.044 M	.045 W	.035 S	.031 M
22	.022 T	.036 S	.048 S	.059 W	.043 F	.070 M	.067 W	.086 S	.061 T	.036 T	.036 S	.036 T
23	.016 F	.045 M	.053 M	.068 T	.062 S	.076 T	.069 T	.094 S	.059 W	.036 F	.039 M	.023 W
24	.016 S	.050 T	.052 T	.077 F	.068 S	.078 W	.064 F	.089 M	.084 T	.052 S	.040 T	.031 T
25	.023 S	.048 W	.070 W	.082 S	.061 M	.096 T	.072 S	.099 T	.072 F	.066 S	.035 W	.034 F
26	.032 M	.067 T	.077 T	.072 S	.032 T	.071 F	.056 S	.067 W	.091 S	.072 M	.037 T	.029 S
27	.038 T	.060 F	.072 F	.044 M	.055 W	.058 S	.067 M	.076 T	.056 S	.074 T	.043 F	.023 S
28	.042 W	.056 S	.054 S	T	.078 T	.058 S	.060 T	.112 F	.074 M	.050 W	.051 S	.021 M
29	.034 T		.053 S	.042 W	.076 F	.052 M	.057 W	.060 S	.070 T	.073 T	.054 S	.026 T
30	.033 F		.055 M	.043 T	.063 S	.063 T	.063 T	.075 S	.074 W	.058 F	.055 M	.032 W
31	.032 S		.064 T		.067 S		.065 F	.073 M		.050 S		.023 T
Valid Days	31	28	31	29	31	29	31	31	30	30	30	31
Maximum	.044	.067	.077	.082	.105	.096	.093	.112	.116	.078	.055	.050
Violations	0	0	0	0	0	0	0	0	0	0	0	0

8300 Total Samples
94.7 % Possible
362 Valid daily maxima

0 Daily-maxima exceeding the standard of .12 ppm (starred[*])
3 Missing days assumed to be less than the standard
0 Daily maximas exceed the alert level of .200 ppm

Concentrations in parts per million (ppm)

Mammoth Cave National Park

1998 Attainment Status With U.S. Environmental Protection Agency (EPA)
PRIMARY Ozone National Ambient Air Quality Standard

Ozone Season: April through October

The primary National Ambient Air Quality Standard for ozone is designed to protect human health. The level of the primary ozone standard promulgated by the EPA on July 18, 1997 is 0.08 parts per million (ppm) [80 parts per billion, (ppb)], daily maximum 8-hour average. The primary ozone standard is met at an ambient monitoring site when the 3-year average of the annual fourth-highest daily maximum 8-hour average ozone concentration is less than or equal to 0.08 ppm. This standard is not met when the 3-year average is greater than 0.08 ppm. Using the EPA's rounding convention, a computed 3-year average ozone concentration of 0.085 ppm (85 ppb) is the smallest value that is greater than the level of the 0.08 ppm standard.

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. The percent data completeness is the percent of valid ozone monitoring days. A day is valid if valid 8-hour averages are available for at least 75 percent of possible hours in the day (i.e., at least 18 of the 24 averages). An 8-hour average is considered valid if at least 75 percent (or 6) of the hourly averages for the 8-hour period are available.

The table below lists the 3-year average fourth-highest daily maximum 8-hour ozone concentration based on data collected during the reported year and the two previous years. This is the number to compare to the level of the new primary standard. The 3-year average data completeness percent and the reported year highest five daily maximum 8-hour averages are also tabulated. A 'No' in the Data Comp % Met? column indicates EPA data completeness requirement was not met for the three-year period.

Year	3-Year Avg 4th High Daily Max 8-hr Ozone (ppb)	3-Year Avg Data Complete %	Data Complete % Met?	Annual 1st High Daily Max 8-hr Ozone (ppb)	Annual 2nd High Daily Max 8-hr Ozone (ppb)	Annual 3rd High Daily Max 8-hr Ozone (ppb)	Annual 4th High Daily Max 8-hr Ozone (ppb)	Annual 5th High Daily Max 8-hr Ozone (ppb)
1998	*	*	*	*	*	*	*	*

* Data completeness has not been met

Ozone
 Ten Highest Daily 1-Hour Average Maximum Concentrations
 Mammoth Cave National Park
 Houchin Meadow
 Final Data
 01/01/98 - 12/31/98

Rank	Date	Hour	Concentration (ppb)
1	09/06/98	16	116*
2	08/28/98	14	112*
3	05/19/98	12	105*
4	09/13/98	11	105*
5	09/05/98	15	104*
6	09/12/98	12	104*
7	05/14/98	13	100*
8	08/25/98	13	99*
9	05/20/98	12	98
10	06/25/98	11	96**

* Other high value(s) were also recorded during one or more hours in the day.

** This value was also recorded on one or more days later in the reporting period.

Episodes with 1-Hour Ozone Concentrations
 ≥ 100 ppb and > 124 ppb
 Mammoth Cave National Park
 Houchin Meadow

Final Data
 01/01/98 - 12/31/98

Date	Beginning Hour	No. Hours		Max (ppb)
		> 100 ppb	>124 ppb	
05/14/98	13	1	0	100
05/19/98	12	2	0	105
08/28/98	13	4	0	112
09/05/98	14	2	0	104
09/06/98	12	5	0	116
09/12/98	11	3	0	104
09/12/98	15	1	0	104
09/13/98	10	5	0	105
Total		23	0	116

Note: The primary and secondary national ambient air standard for ozone that applied in 1996 is 0.12 ppm over a one hour period not to be exceeded more than once per year. (A value greater than .12 ppm, 124 ppb, or 235 ug/m³ exceeds the standard.) (40 CFR 50.9 with reference to Appendix D and H.)

Episodes with 8-Hour Average Ozone Concentrations > 84 ppb
Mammoth Cave National Park
Houchin Meadow

Final Data
01/01/98 - 12/31/98

Date	Start and End Time of Daily Maximum 8-Hour Average > 84 ppb (hr)	Daily Maximum 8-Hour Average (ppb)	Number of 8-Hour Averages > 84 ppb During the Day
05/13/98	09 - 16	86	1
05/14/98	11 - 18	87	2
05/19/98	11 - 18	94	5
08/05/98	11 - 18	89	3
08/23/98	13 - 20	88	6
08/25/98	11 - 18	88	3
08/28/98	11 - 18	100	8
09/05/98	11 - 18	93	6
09/06/98	10 - 17	103	9
09/12/98	11 - 18	98	9
09/13/98	10 - 17	100	9
09/26/98	12 - 19	87	3
12	Days with 8-hour average concentrations > 84 ppb		

Note: This table presents episodes of high ozone based on running 8-hour averages. In 1997, the EPA published new primary and secondary national ambient air quality standards for ozone based on 8-hour average ozone concentrations. Attainment of the new primary standard is reached if the annual fourth highest daily maximum 8-hour ozone concentration, averaged over three years, does not exceed 0.08 ppm (84 ppb or 157 ug/m³). (40 CFR 50.10.)

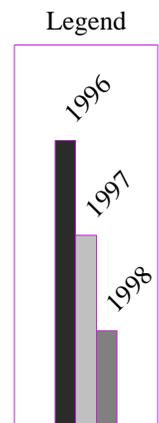
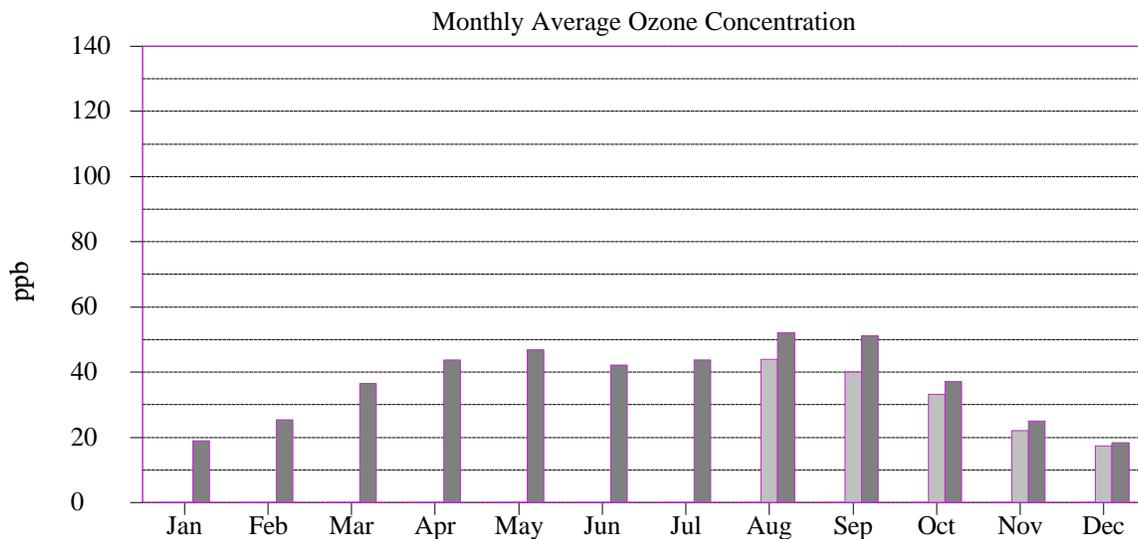
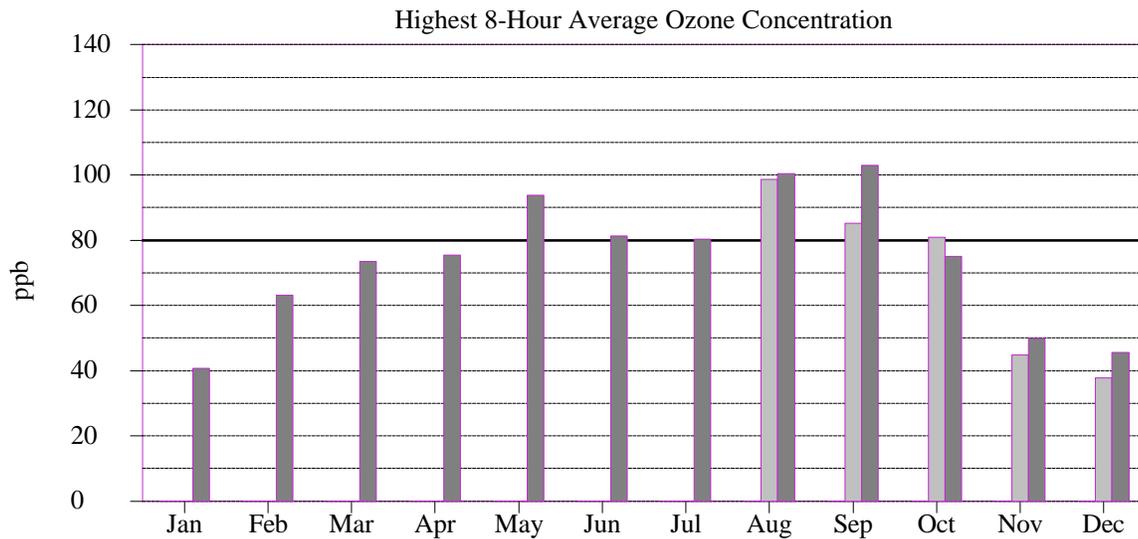
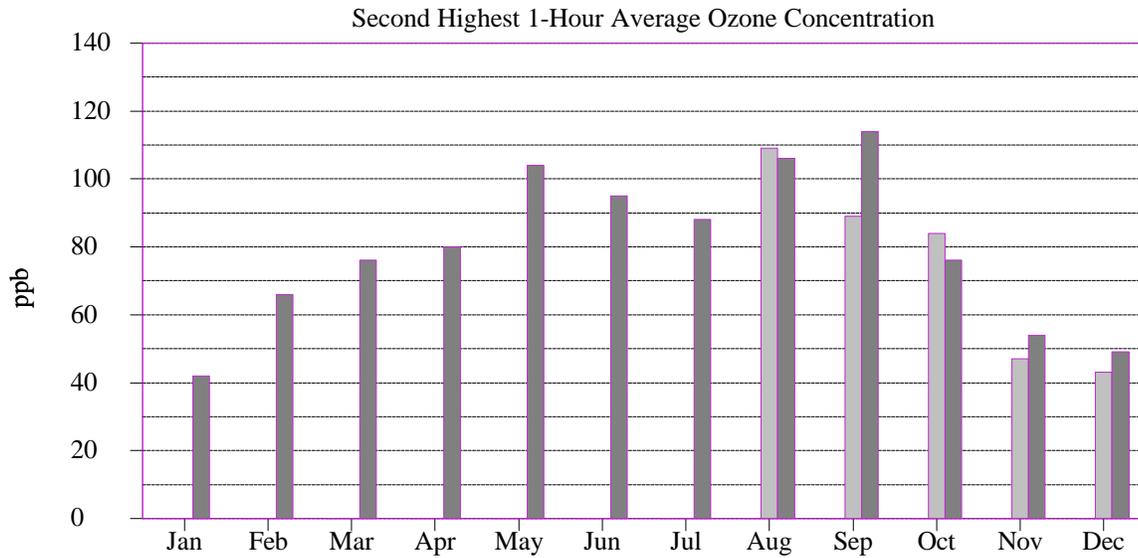
Ozone Rank Listings of Second Highest 1-Hour Average Concentrations, 4th Highest 8-Hour Average Concentrations, and Annual SUM60 Exposure Index for All NPS Monitoring Sites

01/01/98 - 12/31/98

Second Highest 1-Hour Average Concentration		
Site	Rank	Concentration (ppb)
JOTR-YV	1	138
GRSM-LR	2	134
SEKI-LK	3	125
SHEN-BM	4	124
ACAD-CM	5	123
GRSM-CM	6	123
CHAM-XX	7	122
COWP-XX	8	122
GRSM-CD	9	117
SEKI-LP	10	117
CACO-XX	11	115
MACA-HM	12	114
PINN-ES	13	113
COSW-XX	14	106
GRSM-CC	15	105
YOSE-TD	16	105
ROMO-LP	17	100
SAGU-PC	18	94
LAVO-ML	19	91
EVER-BC	20	90
DEVA-PV	21	88
GRBA-MY	22	83
CHIS-XX	23	81
CHIR-ES	24	80
BIBE-KB	25	78
CANY-IS	26	78
VOYA-SB	27	78
GRCA-AS	28	76
MEVE-MY	29	73
YELL-WT	30	72
CRMO-VC	31	69
MORA-TW	32	69
GLAC-WG	33	63
OLYM-VC	34	62
THRO-VC	35	60
DENA-HQ	36	57
NOCA-MM	37	53
VIIS-LP	38	49

4th Highest 8-hour Average Concentration		
Site	Rank	Concentration (ppb)
GRSM-LR	1	110
JOTR-YV	2	110
GRSM-CM	3	107
SHEN-BM	4	107
GRSM-CD	5	106
SEKI-LP	6	99
MACA-HM	7	98
COWP-XX	8	97
ACAD-CM	9	95
SEKI-LK	10	94
YOSE-TD	11	94
CHAM-XX	12	89
PINN-ES	13	88
GRSM-CC	14	86
CACO-XX	15	84
COSW-XX	16	82
DEVA-PV	17	82
ROMO-LP	18	80
LAVO-ML	19	78
SAGU-PC	20	77
GRCA-AS	21	73
CANY-IS	22	72
EVER-BC	23	72
GRBA-MY	24	71
BIBE-KB	25	70
CHIR-ES	26	68
MEVE-MY	27	68
VOYA-SB	28	68
YELL-WT	29	67
CHIS-XX	30	66
CRMO-VC	31	66
GLAC-WG	32	58
DENA-HQ	33	55
THRO-VC	34	55
MORA-TW	35	51
OLYM-VC	36	46
NOCA-MM	37	43
VIIS-LP	38	39

Annual Sum60 Exposure Index			
Site	Rank	Sum60 Count	
GRSM-CM	1	198342	2702
GRSM-CD	2	187437	2577
SHEN-BM	3	170745	2387
GRSM-LR	4	164447	2231
JOTR-YV	5	127317	1769
DEVA-PV	6	93818	1403
YOSE-TD	7	92922	1338
SEKI-LP	8	92214	1230
SEKI-LK	9	84666	1144
MACA-HM	10	82293	1162
COWP-XX	11	70877	970
CANY-IS	12	68500	1075
GRCA-AS	13	63994	996
ROMO-LP	14	59083	897
SAGU-PC	15	57929	869
GRSM-CC	16	52679	742
ACAD-CM	17	45061	638
CACO-XX	18	44769	651
PINN-ES	19	43209	609
CHIR-ES	20	35885	565
GRBA-MY	21	35229	551
LAVO-ML	22	33289	501
MEVE-MY	23	32220	511
CHAM-XX	24	31595	434
BIBE-KB	25	26226	409
COSW-XX	26	26019	364
CRMO-VC	27	17194	274
EVER-BC	28	16065	239
YELL-WT	29	9932	157
CHIS-XX	30	9696	150
VOYA-SB	31	8985	137
GLAC-WG	32	1407	23
MORA-TW	33	638	10
OLYM-VC	34	307	5
THRO-VC	35	181	3
DENA-HQ	36	0	0
NOCA-MM	37	0	0
VIIS-LP	38	0	0

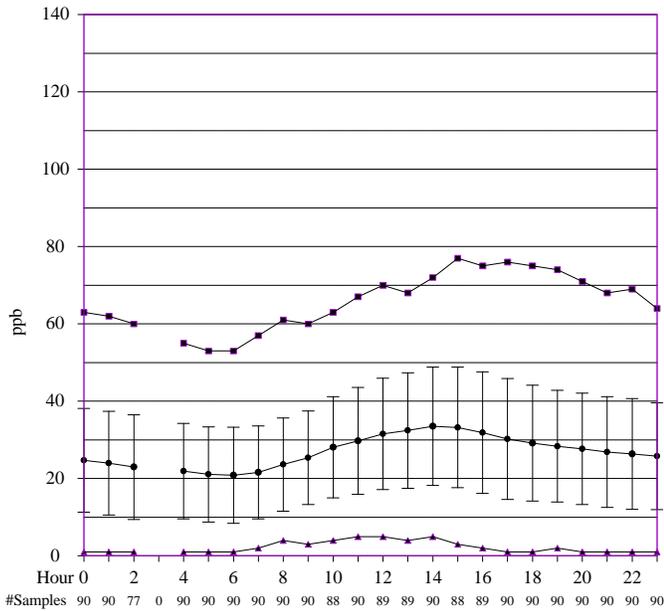


**NATIONAL PARK SERVICE
GASEOUS POLLUTANT MONITORING NETWORK**

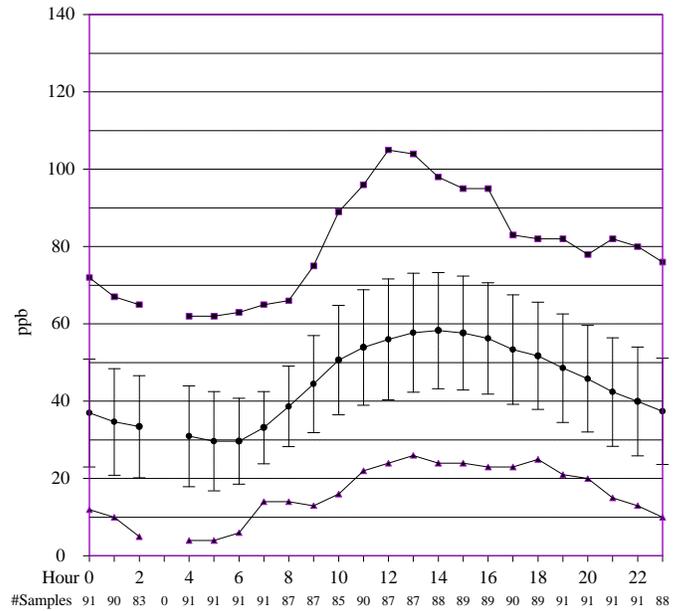
1998 Second Highest 1-Hour Ozone Concentrations



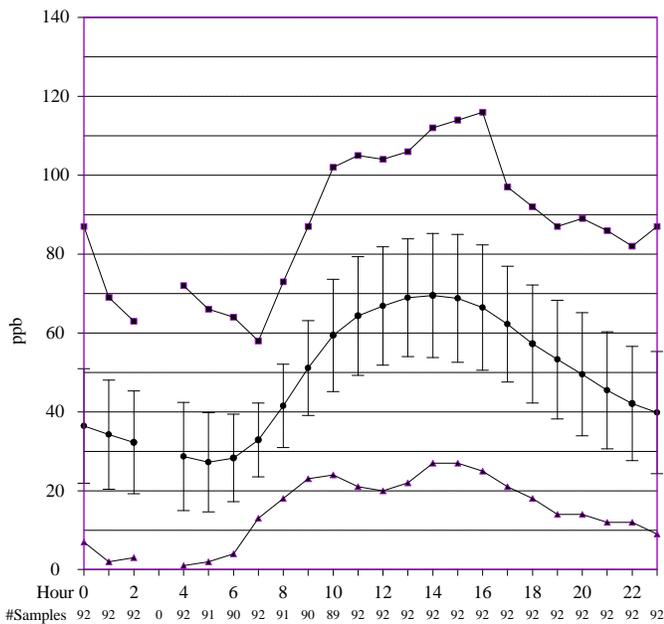
FIRST QUARTER (JAN-MAR)



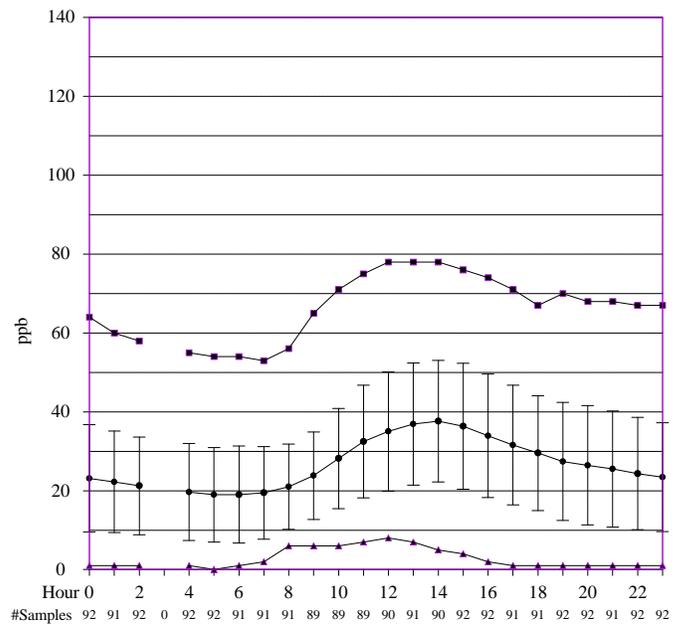
SECOND QUARTER (APR-JUN)



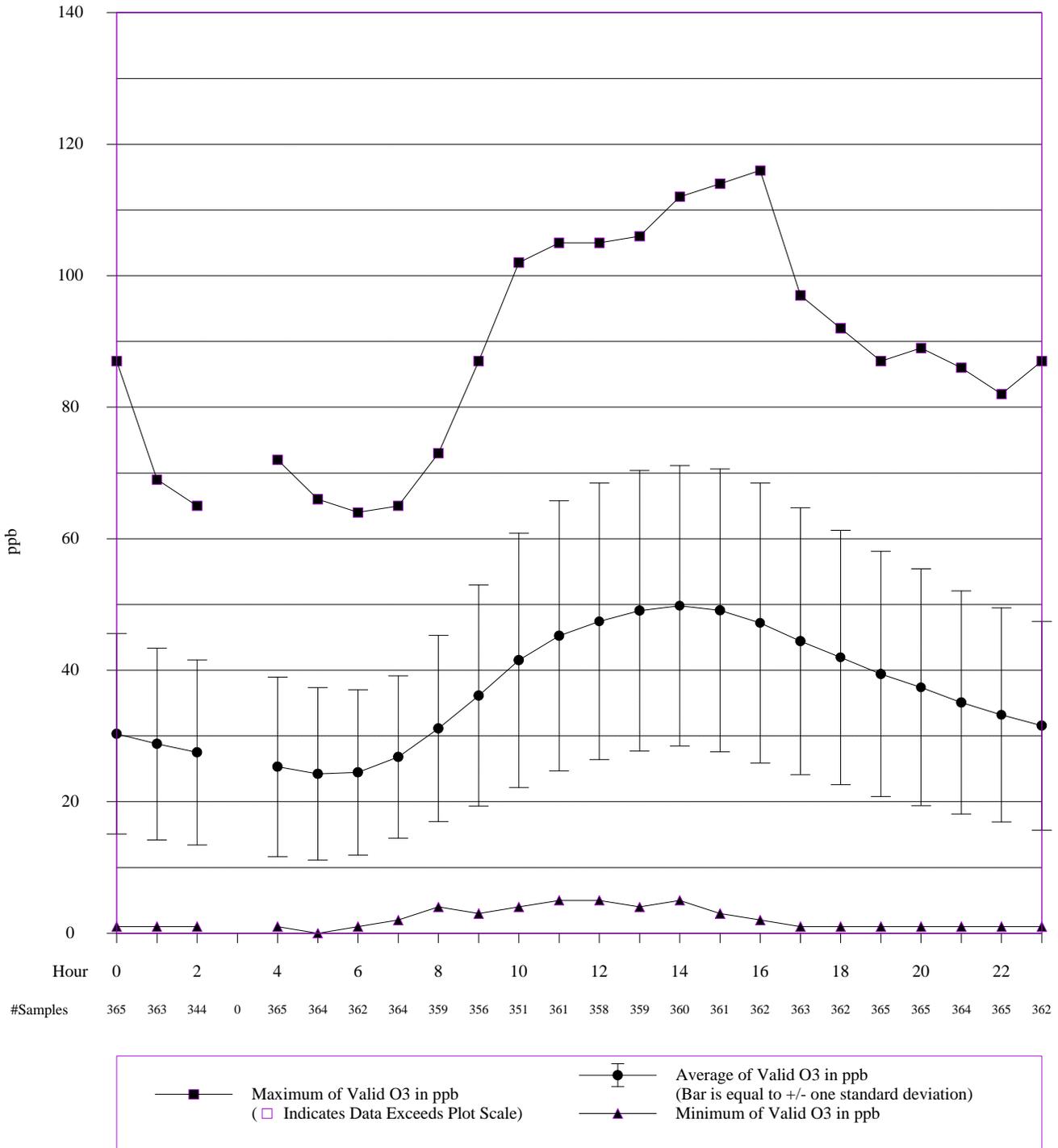
THIRD QUARTER (JUL-SEP)



FOURTH QUARTER (OCT-DEC)



—■— Maximum of Valid O3 in ppb
 (□ Indicates Data Exceeds Plot Scale)
 —●— Average of Valid O3 in ppb
 (Bar is equal to +/- one standard deviation)
 —▲— Minimum of Valid O3 in ppb

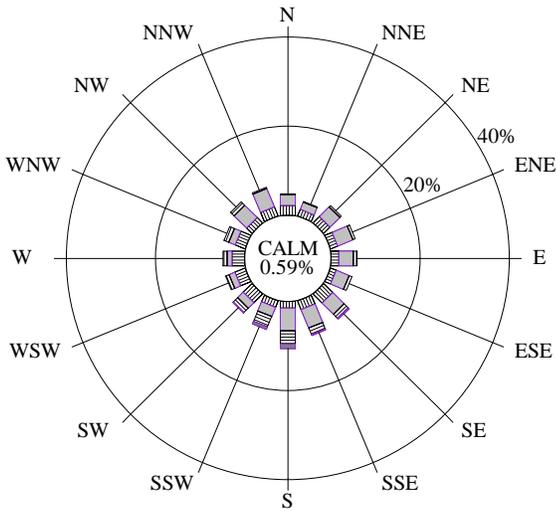


Mammoth Cave
National Park
Houchin Meadow

Quarterly Ozone
Pollutant Rose

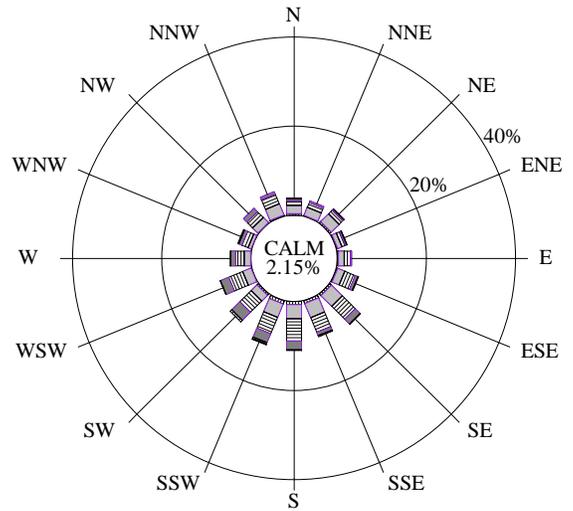
1998

FIRST QUARTER (JAN-MAR)



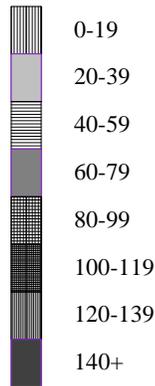
94.3% Collected 93.6% Valid
2160 Possible /2036 Collected /2022 Valid

SECOND QUARTER (APR-JUN)

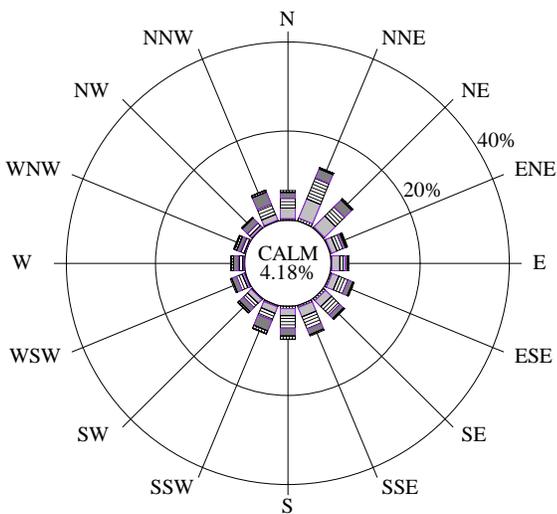


94.2% Collected 93.8% Valid
2184 Possible /2057 Collected /2048 Valid

Ozone (ppb)

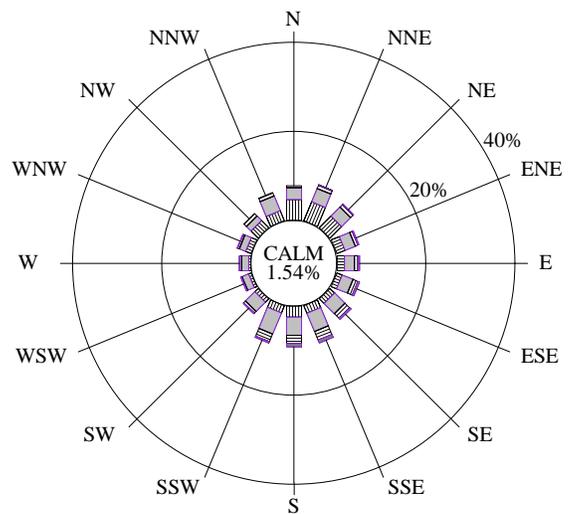


THIRD QUARTER (JUL-SEP)

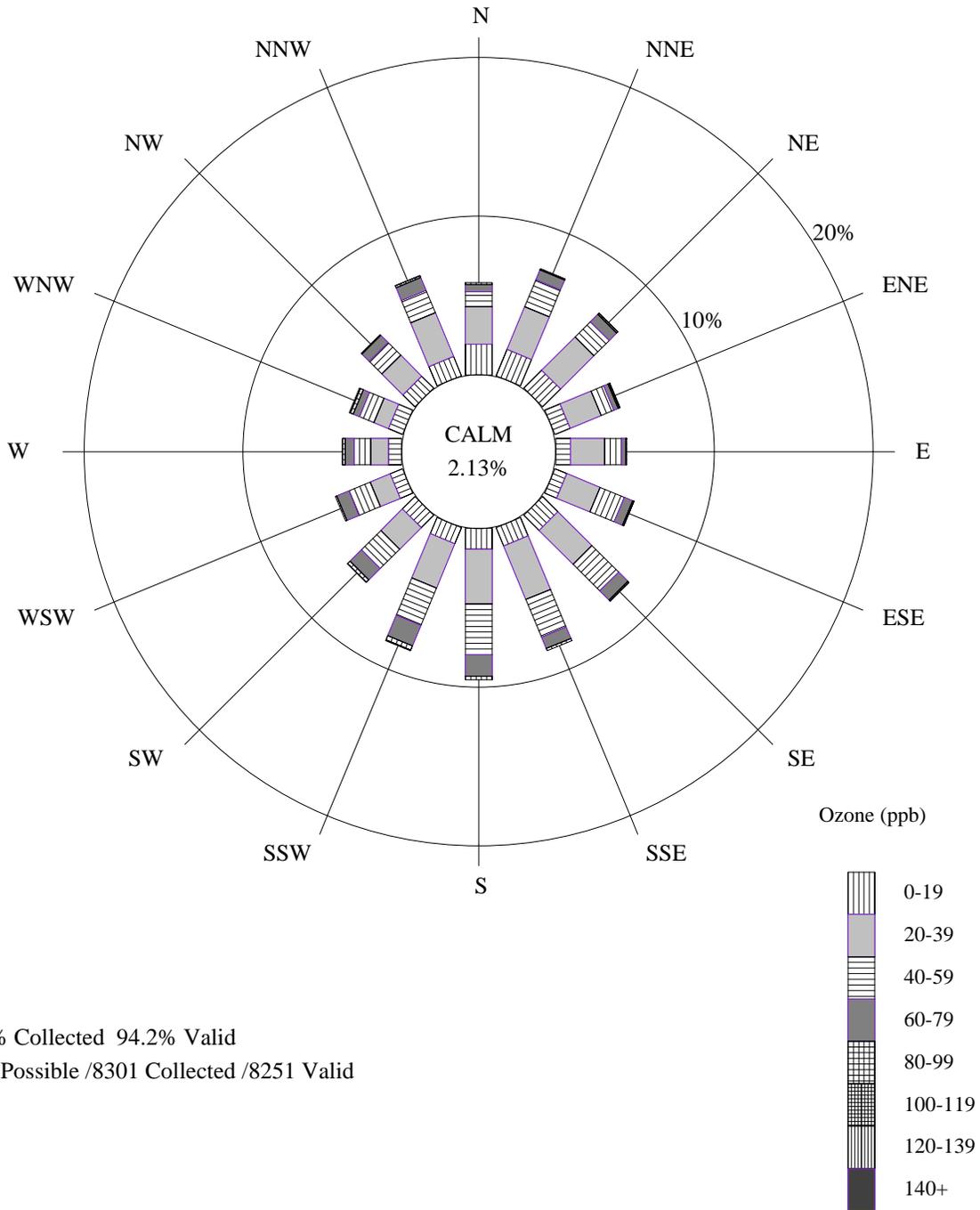


95.6% Collected 95.4% Valid
2208 Possible /2110 Collected /2106 Valid

FOURTH QUARTER (OCT-DEC)



95.0% Collected 94.0% Valid
2208 Possible /2098 Collected /2075 Valid



94.8% Collected 94.2% Valid
8760 Possible /8301 Collected /8251 Valid

Ozone Precision Check Summary
Mammoth Cave National Park
Houchin Meadow

Precision checks are required by the Environmental Protection Agency (EPA) of all monitoring instruments collecting data which are to be submitted to the EPA Aerometric Information Retrieval System (AIRS). A precision check is performed by challenging the pollutant analyzer with a known concentration of gas (between 0.08 and 0.10 ppm for ozone and sulfur dioxide) from the pollutant transfer standard. This precision check must be performed at least every 14 days of monitoring operation. The percent difference between the analyzer and the transfer standard is then calculated. According to NPS Standard Operating Procedures, the pollutant analyzer must respond within 10% of the transfer standard.² The table below gives the number of precision checks performed during each quarter, the average of all the individual precision check percent differences for the quarter, and the upper and lower 95% probability limits for precision checks. The probability limits represent the interval having a 95% chance of containing the true average percent difference. The quarterly average percent difference and probability limits should ideally be within +/- 10%.

Final Data 01/01/98 - 12/31/98				
Calendar Quarter	Number of Precision Checks	Average Percent Difference ^{1,2}	Lower 95% Probability Limit ³	Upper 95% Probability Limit ³
1	13	-1.71	-4.21	0.80
2	14	-2.69	-7.99	2.61
3	13	-1.36	-4.41	1.70
4	12	-1.44	-5.95	3.06

¹ Percent Difference = $\frac{\text{analyzer} - \text{transfer std}}{\text{transfer std}} \times 100$.

² Average Percent Difference is the mean of all individual precision check percent differences during the quarter.

³ Upper/Lower 95% Probability Limits = (Average Percent Difference) +/- (1.96)(Standard Deviation of precision check percent differences in the quarter.)

2.3 METEOROLOGICAL DATA SUMMARY

Summary of Selected Meteorological Data

Mammoth Cave National Park

Houchin Meadow

Final Data

01/01/98 - 12/31/98

Parameter	Value	Units	Number	Std Dev
SCALAR WIND SPEED				
Average	1.8	m/s	8707	1.1
Maximum	8.0	m/s		
Percent calm = 2.18				
AMBIENT TEMPERATURE				
Average	14.9	degC	8723	9.3
Maximum	34.9	degC		
Minimum	-11.9	degC		
RELATIVE HUMIDITY				
Average	76	percent	8597	18
Maximum	100	percent		
Minimum	20	percent		
PRECIPITATION (Rainfall or Snow melt)				
Average non-zero rate	2.1	mm/hr	591	3.7
Maximum non-zero rate	32.8	mm/hr		
Minimum non-zero rate	.3	mm/hr		
Accumulated during period	1267.8	mm		
SOLAR RADIATION				
Average Daily Total	11,917,264	joules/m2day	365	6,705,587
Maximum Daily Total	25,734,400	joules/m2day		
Minimum Daily Total	816,000	joules/m2day		

Note: Calms are included in the average scalar wind speed and are defined as winds less than 0.5 m/s (1.0 mph).

Solar radiation terms are based on the calculation of the total amount of solar energy incident on a unit area during each day. The maximum and minimum daily totals are selected from the list of daily totals. The totals for all days are then added and divided by the number of days to yield the average daily total. Only days with 24 valid values are included in these statistics.

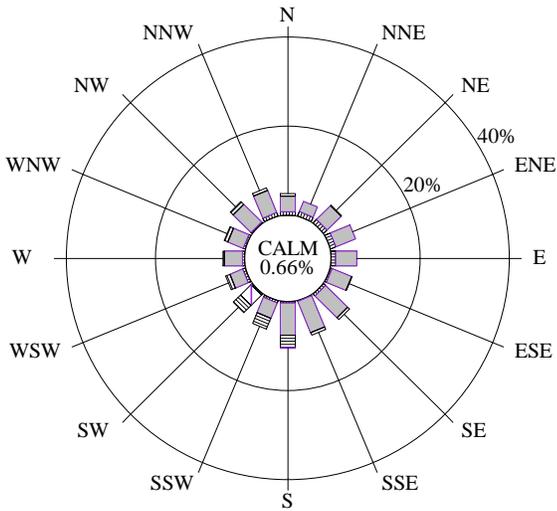
NA indicates instrument not available.

Mammoth Cave
National Park
Houchin Meadow

Quarterly Wind Rose

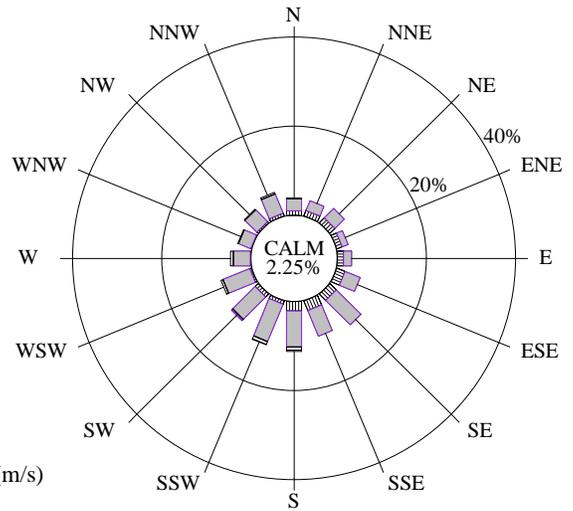
1998

FIRST QUARTER (JAN-MAR)



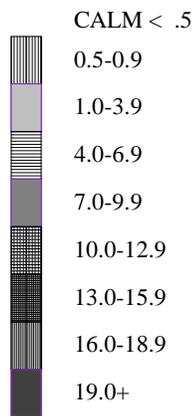
99.2% Collected 98.5% Valid
2160 Possible /2142 Collected /2127 Valid

SECOND QUARTER (APR-JUN)

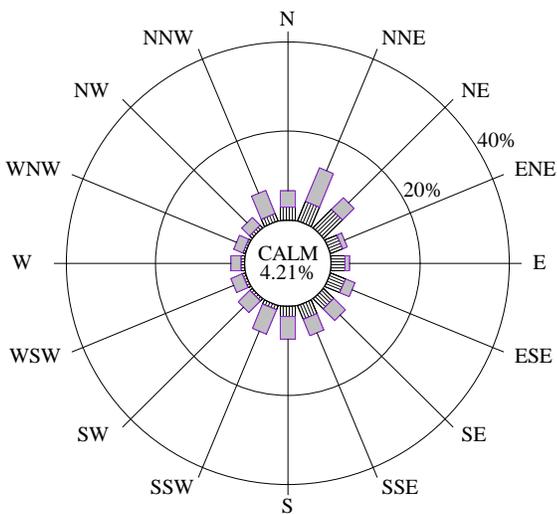


99.7% Collected 99.7% Valid
2184 Possible /2177 Collected /2177 Valid

Scalar Wind Speed (m/s)

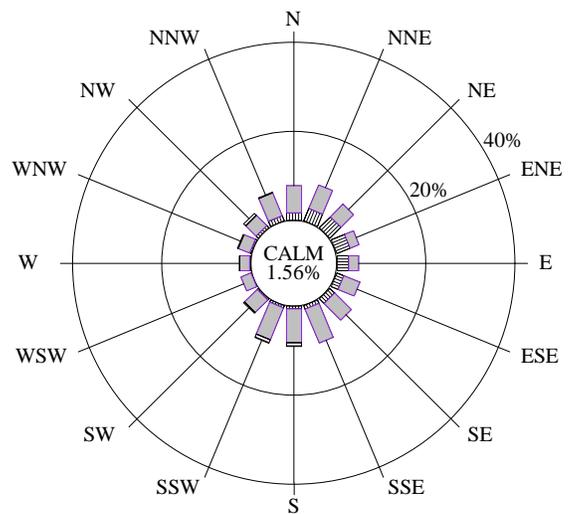


THIRD QUARTER (JUL-SEP)

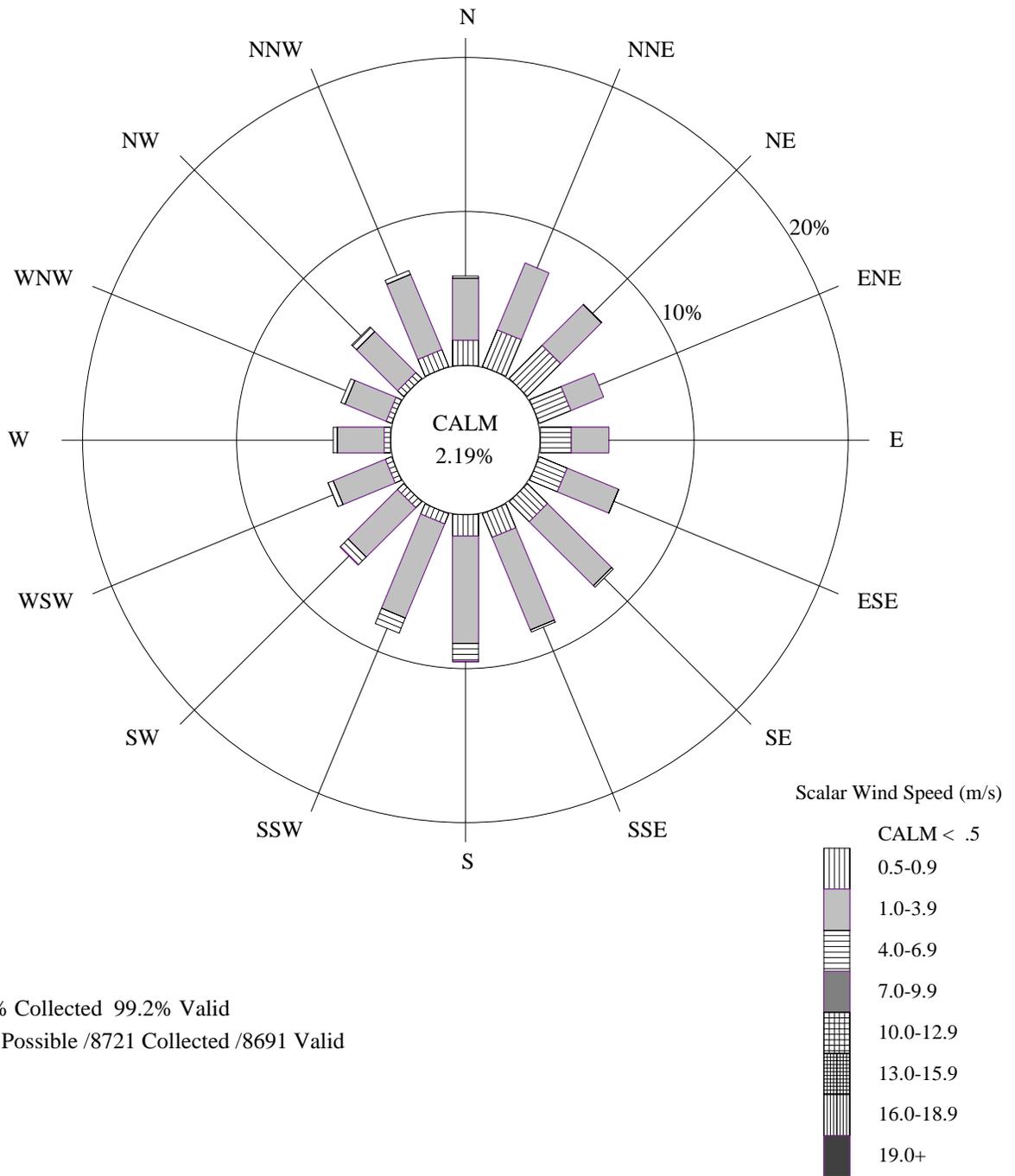


100.0% Collected 100.0% Valid
2208 Possible /2207 Collected /2207 Valid

FOURTH QUARTER (OCT-DEC)



99.4% Collected 98.7% Valid
2208 Possible /2195 Collected /2180 Valid



99.6% Collected 99.2% Valid
8760 Possible /8721 Collected /8691 Valid

3.0 NATIONAL PARK SERVICE AIR RESOURCES DIVISION DATA SOURCES

3.1 GUIDE TO ATTACHED DATA DISKS

Data disks containing ASCII files of the validated hourly data, as shown in the following table are available. Please return the enclosed postcard or contact the address below. These data may be imported into other programs to perform additional data processing and analysis. The data format of each file is included within each file. The second table describes the validation codes used in the data tables to indicate why data are missing or invalid. Wind and pollutant frequency distribution tables in ASCII format are also included on the diskette if available for this site.

Data users should acknowledge the National Park Service Air Resources Division whenever using these data or any portion of this report.

3.2 OTHER SOURCES FOR RETRIEVING NATIONAL PARK SERVICE GASEOUS POLLUTANT DATA

The data contained in this report may also be obtained from the following sources:

- National Park Service AIRWeb (<http://www.aqd.nps.gov/natnet/ard>) - available after last quarter 1997
- EPA AIRS database
- Data requests directed to:

NPS Air Resources Division
Information Management Center
c/o Air Resource Specialists, Inc.
1901 Sharp Point Drive, Suite E
Fort Collins, Colorado 80525
Telephone: (970) 484-7941
Fax: (970) 484-3423
E-Mail: AIR-IMC@AIR-RESOURCE.COM

Data Disk Contents Summary	
File Name (s)	Description
Hourly	
ssssyy.DAT	All Validated Air Quality Data
ssssyymm.ppp	Monthly Data Summary Tables
ssssAN95.Rpp	Annual Wind and Pollutant Frequency Distribution
ssssQ195.Rpp	Quarter 1 Wind and Pollutant Frequency Distribution
ssssQ295.Rpp	Quarter 2 Wind and Pollutant Frequency Distribution
ssssQ395.Rpp	Quarter 3 Wind and Pollutant Frequency Distribution
ssssQ495.Rpp	Quarter 4 Wind and Pollutant Frequency Distribution
Where: ssss = site code yy = year mm = month ppp = air quality data parameter code AN = Annual Qn = Quarter 1-4 R = Wind Frequency distribution table	
CASTNet Weekly Species Summary Data	
File Name (s)	Description
CASTNet	
ssssCNyr.ASC	Weekly averages
Where: ssss = site code CN = CASTNet yr = year asc = ascii file	

NPS IMC and AIRS Invalid Data Codes			
NPS IMC VAL CODE	REASON	AIRS CODE	AIRS REASON
TO	Sample time out of limits	9973	Sample time out of limits
IW	Instrument warmup	9978	Voided by operator
OE	Operator error	9978	
BM	Begin monitoring	9979	Miscellaneous void
TL	Station temp low	9979	
OS	Off scale	9979	
EM	End monitoring	9979	
LI	Local interference	9979	
TH	Station temp high	9979	
IM	Instrument malfunction	9980	Machine malfunction
IN	Interference	9981	Bad weather
RF	Recording system failure	9983	Collection error
NA	No data	9987	Monitoring waived
PF	Power failure	9988	Power Failure
PC	Precision check	9990	Precision Check
ZS	Instrument zero/span check	9991	QC Control Points (Zero/Span)
SA	System audit	9992	QC Audit
PA	Performance audit	9992	
MT	Maintenance	9993	Maintenance/Routine Repairs
OR	Out for repair	9993	
CA	Calibration	9995	Multipoint calibration
SC	Station check	9998	Precision/zero/span

4.0 GLOSSARY

4.1 DEFINITIONS AND COMPUTATIONAL PROCEDURES FOR NATIONAL PARK SERVICE QUICK LOOK ANNUAL SUMMARY STATISTICS REPORT

The National Park Service Quick Look Annual Summary Statistics Table (Page 2-8) provides ozone summary statistics for various indices computed on a monthly basis for an entire year. Growing season (generically defined to be May 1 - September 30) and annual statistics are also presented under the "MAY-SEP" and "ANNUAL" columns, respectively. All concentrations are expressed in the units of parts per billion (PPB) and exposures in parts per billion-hours (PPB-HR). The definitions for each of the statistics appearing on the Quick Look Annual Summary Table are given below.

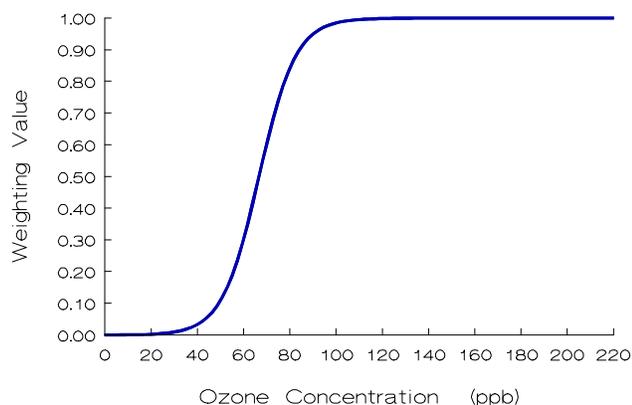
- (1) **Daily 1-Hr Maximum.** The maximum 1-hour average concentration recorded during each month, the growing season or the year regardless of the number of valid hourly observations recorded during a given day. The number in parentheses below this statistic, (N), indicates the number of days in the month, growing season, or year with valid data.
- (2) **Average Daily Maximum.** The average of all Daily 1-Hr Maxima during the month regardless of the number of Daily 1-Hr Maxima recorded during the month. For the "MAY-SEP" column the average of all the Daily Maxima recorded during the growing season is given. For the "ANNUAL" column the average of all the Daily Maxima is given. N is as in (1) above.
- (3) **Maximum Daily Mean.** The maximum of the valid daily means computed for each month, the growing season ("MAY-SEP" column), and the year ("ANNUAL" column). A valid daily mean is one for which 75% of the observations are available for each day, i.e., 18 hours. N is the number of days during each month, growing season, and year with at least 18 observations.
- (4) **Average Daily Mean.** The average of all valid daily means for the month, the growing season ("MAY-SEP" column), and the year ("ANNUAL" column). N is as in (3) above.
- (5) **Max Peak:Min Ratio.** The ratio of the Daily 1-Hr Maximum to the Daily 1-Hr Minimum. A ratio is computed only if a valid Daily Mean is computed and if the Daily 1-Hr Minimum is not equal to zero. N is the number of days with a valid Peak:Min ratio.
- (6) **Average Peak:Min Ratio.** The average of all Peak:Min ratios for the month, growing season, or year. N is as in (5) above.
- (7) **Max 9AM-4PM Average.** The maximum of all valid 9AM-4PM Averages computed for the month, growing season, or year. A valid 9AM-4PM Average is one which has 75% of the observations available during that time period (i.e., 6 hours. N is the number of days with valid averages.)

- (8) **Monthly 9AM-4PM Average.** The average of all valid 9AM-4PM Averages for the month, growing season, or year. N is as in (7) above.
- (9) **Max 7AM-7PM Average.** The maximum of all valid 7AM-7PM Averages computed for the month, growing season, or year. A valid 7AM-7PM Average is one which has 75% of the observations available during that time period, i.e., 9 hours. N is the number of days with valid averages.
- (10) **Monthly 7AM-7PM Average.** The average of all valid 7AM-7PM averages for the month, growing season, or year. N is as in (9) above.
- (11) **Monthly Mean.** The average of all 1-Hr ozone concentrations recorded during the month, growing season, or year. A mean is computed regardless of the number of hours with valid data. N is the number of hours with valid observations.
- (12) **SUM0 Exposure Index.** The monthly sum of all hourly ozone concentrations. Units are PPB-HR. The "MAY-SEP" column sums across the months of May through September to give the cumulative exposure for the growing season. The "ANNUAL" column sums across every month to give the cumulative exposure for the year. N is the number of hours with valid observations and is the same N as in (11) above.
- (13) **SUM60 Exposure Index.** The monthly sum of all hourly ozone concentrations equaling or exceeding 60 PPB. Units are PPB-HR. The "MAY-SEP" column sums across the months of May through September to give the cumulative exposure for the growing season. The "ANNUAL" column sums across every month to give the cumulative exposure for the year. N is the number of hours equaling or exceeding 60 PPB during the month, growing season, or year.
- (14) **SUM80 Exposure Index.** The monthly sum of all hourly ozone concentrations equaling or exceeding 80 PPB. Units are PPB-HR. The "MAY-SEP" column sums across the months of May through September to give the cumulative exposure for the growing season. The "ANNUAL" column sums across every month to give the cumulative exposure for the year. N is the number of hours equaling or exceeding 80 PPB during the month, growing season, or year.
- (15) **W126 Exposure Index.** The monthly 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. This weighting function provides a weighting value that is unique for each hourly ozone concentration. The weighting function, as described by Lefohn, Laurence, and Kohut¹ is:

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

where

Weighting Function Used To Calculate W126 Exposure Index



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

The graph of weighting value versus ozone concentration, in the figure to the left, 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 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.

The "MAY-SEP" column sums across the months of May through September to give the cumulative exposure for the growing season. The "ANNUAL" column sums across every month to give the cumulative exposure for the year. The exposure units are PPB-HR.

Because each hour contributes to this exposure index, N is the number of hours with valid observations and is the same N as in (11) and (12) above.

The U.S. Environmental Protection Agency usually considers air quality statistics, such as a mean, 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.

References

1. Lefohn, A.S., J. A. Laurence, and R. J. Kohut. 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.

4.2 AIR QUALITY GLOSSARY

Acid Deposition: Air pollution produced when acid chemicals are incorporated into rain, snow, fog, or mist.

Aerometric Information Retrieval System (AIRS): A computer-based database of U.S. air pollution information administered by the EPA Office of Air Quality Planning and Standards (U.S. Environmental Protection Agency).

AIRWeb: Air Resources Web, an air quality information retrieval system for U.S. parks and wildlife refuges developed by the Air Resources Division of the National Park Service and the Air Quality Branch of the Fish and Wildlife Service.

Air Pollutant: An unwanted chemical or other material found in the air.

Air Pollution: Degradation of air quality resulting from unwanted chemicals or other materials occurring in the air.

Air Quality: The properties and degree of purity of air to which people and natural and heritage resources are exposed (in the context of national parks).

Air Pollution Control Permitting Process: Process by which facilities are permitted to emit specified types and quantities of air pollutants.

Air Quality Related Values (AQRVs): Values including visibility, flora, fauna, cultural and historical resources, odor, soil, water, and virtually all resources that are dependent upon and affected by air quality. "These values include visibility and those scenic, cultural, biological, and recreation resources of an area that are affected by air quality." (*43 Fed. Reg. 15016*)

Ambient Air: Air that is accessible to the public.

Class I: Areas of the country set aside under the Clean Air Act to receive the most stringent degree of air quality protection.

Class II: Areas of the country protected under the Clean Air Act but identified for somewhat less stringent protection from air pollution damage than Class I, except in specified cases.

Clean Air Act: Originally passed in 1963, our current national air pollution control program is based on the 1970 version of the law. Substantial revisions were made by the 1990 Clean Air Act Amendments.

Continuous Sampling Device: An air analyzer that measures air quality components continuously.

Criteria: Information on health and/or environmental effects of pollution (in the context of criteria air pollutants).

Criteria Air Pollutant: A group of very common air pollutants regulated by EPA on the basis of criteria and for which a National Ambient Air Quality Standard is established (SO₂, NO₂, PM₁₀, Pb, CO, O₃).

Emissions: Release of pollutants into the air from a source.

Environmental Protection Agency (EPA): The federal agency responsible for regulating air quality.

Monitoring: Measurement of air pollution.

National Ambient Air Quality Standards (NAAQS): Permissible levels of criteria air pollutant established to protect public health and welfare.

Ozone (O₃): A criteria air pollutant that is a strong oxidizing agent, reactive with many other compounds and surfaces, and a health hazard in high concentrations. Ozone is formed by nitrogen oxides and organic compounds reacting in sunlight.

Source: Any place or object from which air pollutants are released. Sources that are fixed in space are stationary sources; sources that move are mobile sources.

Sulfur Dioxide (SO₂): A criteria air pollutant that is a gas produced by burning coal and some industrial processes.

* Recent updates to this glossary may be found on the NPSARD AIRWeb - <http://www.aqd.nps.gov/natnet/ard/glossary.htm>.

4.3 GLOSSARY OF AIR QUALITY UNITS

Units Conversion Table			
Parameter Type	Multiply	By	To Obtain
Pollutant	ppm	1000	ppb
	ppm	1960	$\mu\text{g}/\text{m}^3$ Ozone (at 25°C)
	ppm	2615	$\mu\text{g}/\text{m}^3$ Sulfur Dioxide (at 25°C)
	ppb	0.001	ppm
	ppb	1.960	$\mu\text{g}/\text{m}^3$ Ozone (at 25°C)
	ppb	2.615	$\mu\text{g}/\text{m}^3$ Sulfur Dioxide (at 25°C)
	$\mu\text{g}/\text{m}^3$ Ozone (25°C)	0.0005102	ppm
	$\mu\text{g}/\text{m}^3$ Ozone (25°C)	0.5102	ppb
	$\mu\text{g}/\text{m}^3$ Sulfur Dioxide (25°C)	0.0003824	ppm
	$\mu\text{g}/\text{m}^3$ Sulfur Dioxide (25°C)	0.3824	ppb
Wind Speed	m/s	2.05	mph
	mph	0.489	m/s
Solar Radiation	ly/min	697	w/m^2
	w/m^2	0.00143	ly/min
Precipitation	mm/hr	0.0394	in/hr
	in/hr	25.4	mm/hr
Temperature	$^{\circ}\text{C} + 17.78$	1.8	$^{\circ}\text{F}$
	$^{\circ}\text{F} - 32$	5/9	$^{\circ}\text{C}$
<p>Where:</p> <p>ppm = parts per million</p> <p>ppb = parts per billion</p> <p>$\mu\text{g}/\text{m}^3$ = micrograms per cubic meter (at 25°C)</p> <p>m/s = meters per second</p> <p>mps = miles per hour</p> <p>ly/min = langley's per minute</p> <p>w/m^2 = watts per square meter</p> <p>mm/hr = millimeters per hour</p> <p>in/hr = inches per hour</p> <p>$^{\circ}\text{C}$ = degrees centigrade</p> <p>$^{\circ}\text{F}$ = degrees fahrenheit</p>			