



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR QUALITY PLANNING AND STANDARDS
RESEARCH TRIANGLE PARK, NC 27711

September 28, 2015

MEMORANDUM

SUBJECT: Expanded Comparison of Ozone Metrics Considered in the Current NAAQS Review

FROM: Benjamin Wells (EPA, OAQPS) 

TO: Ozone NAAQS Review Docket (EPA-HQ-OAR-2008-0699)

Overview

This memorandum provides an expansion of the analyses presented in a 2014 memorandum to the docket for the review of the National Ambient Air Quality Standards (NAAQS) for Ozone (O₃) titled "Comparison of Ozone Metrics Considered in the Current NAAQS Review" (Wells, 2014). This expansion was done in consideration of public comments on the extensive historical dataset accompanying this analysis. The 2014 memorandum included several analyses that related two metrics using ambient air quality measurement data collected at O₃ monitoring sites across the U.S. from 2001 to 2013. One metric is the design value metric for the primary and secondary O₃ standards: the annual 4th highest daily maximum 8-hour O₃ concentration, averaged over three consecutive years, in parts per billion (ppb), hereafter referred to as the "4th max" metric. The other metric is the annual W126 index, averaged over three consecutive years, in parts per million-hours (ppm-hrs), hereafter referred to as the "W126" metric.

The 2014 memorandum, while including analyses based on the full 13-year dataset, focused some of the analyses on only the most recent 3-year period. This memorandum expands those analyses to include all 11 consecutive 3-year periods covered in the 13-year dataset. The dataset used in this analysis is also available in the docket referenced above. In addition, a slight change was made to the data handling conventions for the W126 metric. The previous analyses truncated all decimal digits from both the annual and 3-year average W126 values for comparisons with various W126 levels of interest, while the analyses presented here retain all decimal digits in the annual W126 index values and round the 3-year average W126 values to the nearest unit ppm-hr. All of the tables and figures presented in the 2014 memorandum have been updated to reflect this change and included here. In general, the data analyses presented in this memorandum continue to support the conclusions drawn in the 2014 memorandum regarding the relationship between the 4th max and W126 metrics.

Data Handling

Hourly O₃ concentration data were retrieved from EPA's Air Quality System (AQS) database for 1,849 O₃ monitors which operated between 2001 and 2013. These data were used to calculate 4th max and W126 values for each 3-year period from 2001-2003 to 2011-2013. Before calculating these values, some initial processing was done on the hourly data. First, data collected using monitoring methods other than federal reference or equivalent methods, and data collected from monitoring sites not meeting EPA's quality assurance or siting criteria in 40 CFR part 58 were removed. Second, data collected by multiple monitoring instruments operating at the same site were combined by selecting the monitor with the most hourly observations each year, then filling in missing hourly concentration values using data collected from the remaining monitors at the site. Finally, data were combined across 62 pairs of monitoring sites approved by the appropriate EPA regional offices, in order to maintain a continuous data record when these sites were replaced or relocated a short distance away. The final dataset consisted of hourly O₃ concentration data for 1,672 monitoring sites.

The 4th max values were calculated according to the data handling in the proposed rulemaking notice for the O₃ NAAQS (Appendix U to 40 CFR part 50). First, moving 8-hour averages were calculated from the hourly O₃ concentration data for each site. For each 8-hour period, an 8-hour average value was calculated if there were at least 6 hourly O₃ concentrations available, and stored in the first hour of the period. Daily maximum 8-hour average values were found using the 8-hour periods beginning from 7:00 AM to 11:00 PM each day. These daily maximum values were used if at least 13 of the 17 possible 8-hour averages were available, or if the daily maximum value was greater than the 4th max level being evaluated. Finally, the annual 4th highest daily maximum value was found for each year, then averaged across each consecutive 3-year period to obtain the final set of 4th max values.

The annual 4th highest daily maximum 8-hour values and the 3-year average values were truncated to the next lowest unit ppb for applications requiring direct comparison to a 4th max level, otherwise, all decimal digits were retained in the calculations. The 4th max values were considered valid if daily maximum values were available for at least 90% of the days in the O₃ monitoring season (defined in Appendix D to 40 CFR part 58) on average across the three years, with a minimum of 75% of the days in the O₃ monitoring season in any single year. In addition, 4th max values were considered valid if they were greater than the 4th max levels to which they were being compared.

To calculate the W126 values, the hourly O₃ concentration values (in parts per million) for daytime hours (defined as the 12-hour period from 8:00 AM to 8:00 PM each day) at each site were weighted using the following equation:

$$\text{Weighted O}_3 = \text{O}_3 / (1 + 4403 * \exp(-126 * \text{O}_3))$$

These weighted values were summed over each calendar month, then adjusted for missing data (e.g., if 80% of the daytime hourly concentrations were available, the sum would be multiplied by 1/0.8 = 1.25) to obtain the monthly W126 index values. Monthly W126 index values were not

calculated for months where fewer than 75% of the possible daytime hourly concentrations were available. Next, moving 3-month sums were calculated from the monthly index values, and the highest of these 3-month sums was determined as the annual W126 index. Three-month periods spanning multiple years (e.g., November to January, December to February) were not considered in these calculations. The annual W126 index values were averaged across each consecutive 3-year period to obtain the final W126 values, with units in parts per million-hours (ppm-hrs).

In the analyses presented here, all decimal digits were retained in the annual W126 index values, and the 3-year averages of the annual values were rounded to the nearest unit ppm-hour. For all other applications, all decimal digits were retained in both the annual and 3-year average W126 values, as was done previously. The 3-year average W126 values were considered valid if hourly O₃ concentration values were available for at least 90% of the daytime hours during the O₃ monitoring season on average across the three years, with a minimum of 75% of the daytime hours during the O₃ monitoring season in any single year. In addition, W126 values were considered valid if they were greater than the W126 levels to which they were being compared.

In the final dataset, 1,430 of the 1,672 O₃ monitoring sites had sufficient data to calculate valid 4th max and W126 values for at least one 3-year period between 2001-2003 and 2011-2013. The number of sites with valid 4th max and W126 values ranged from 1,040 in 2003-2005 to 1,119 in 2011-2013, and 758 sites had valid 4th max and W126 values for all eleven 3-year periods.

Analysis

The analysis based on the 4th max and W126 values consisted of three parts. The first part focused on the metric values for the most recent period, 2011-2013, to determine how many sites had values greater than the various 4th max and W126 levels of interest, and to gain a sense of how the 4th max and W126 metrics relate to one another based on observed air quality data. The second part of the analysis focused on the 4th max and W126 values from all 11 consecutive 3-year periods (2001-2003 to 2011-2013), to examine how those values have changed over time, and to compare the 4th max and W126 values based on the full 13-year dataset to those based on the most recent 3-year period. The final part of the analysis focused on the relative changes in the 4th max and W126 values between 2001-2003 and 2011-2013, to assess how those values have responded to changes in precursor emissions, and to gain a sense of how future control programs designed to meet a revised primary O₃ standard could impact both 4th max and W126 values.

Recent Air Quality Data

The first portion of the analysis focuses on the 4th max and W126 values for the most recent 3-year period, 2011-2013. Figures 1 and 2 below show maps of the 4th max and W126 values based on 2011-2013 data. These values were compared to the various 4th max and W126 levels of interest in order to determine the number of sites with values greater than each level. Table 1 shows the number of sites with 4th max values greater than each 4th max level, and the number of sites with 4th max values less than or equal to each 4th max level. Table 2 shows the number of

sites with W126 values greater than each W126 level, and the number of sites with W126 values less than or equal to each W126 level.

The number of sites with 4th max values greater than 70 ppb was approximately double the number of sites with 4th max values greater than 75 ppb, and the number of sites with 4th max values greater than 65 ppb was approximately triple the number of sites with 4th max values greater than 75 ppb. In general, given similar points within the range of levels being considered, there were fewer sites exceeding the W126 levels than the 4th max levels. The updated data handling conventions for the W126 metric resulted in more sites with W126 values greater than each W126 level of interest. However, the magnitude of the increase in the number of sites for each level was relatively small compared to the total number of sites.

The 4th max and W126 values were also compared to each combination of 4th max and W126 levels of interest based on 2011-2013 data. First, Table 3 shows the number of sites with 4th max values greater than each 4th max level, and W126 values less than or equal to each W126 level (e.g., 269 sites had 4th max values greater than 70 ppb and W126 values less than or equal to 13 ppm-hrs). Next, Table 4 shows the number of sites with 4th max values less than or equal to each 4th max level, and W126 values greater than each W126 level (e.g., 22 sites had 4th max values less than or equal to 70 ppb and W126 values greater than 13 ppm-hrs). Finally, Table 5 shows the number of sites with 4th max values greater than each 4th max level, and W126 values greater than each W126 level (e.g., 283 sites had 4th max values greater than 70 ppb and W126 values greater than 13 ppm-hrs).

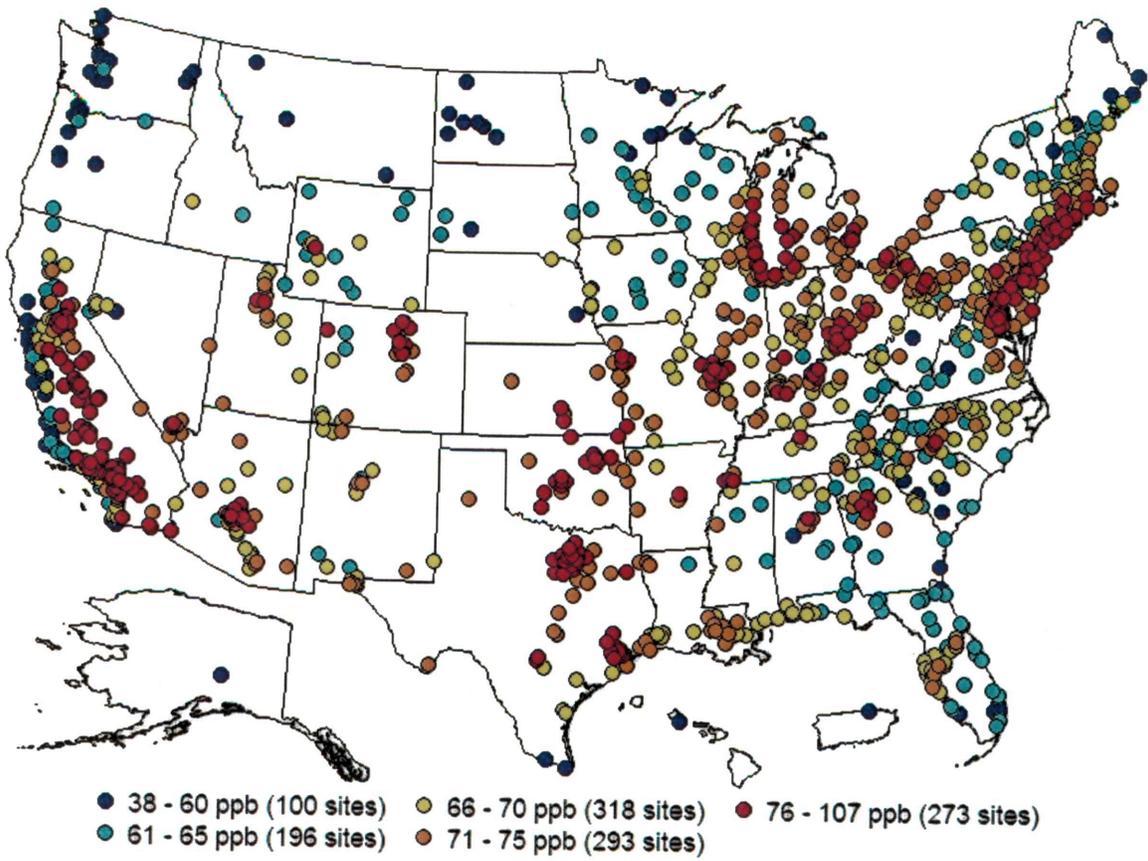


Figure 1. Map of 4th max values based on 2011-2013 data

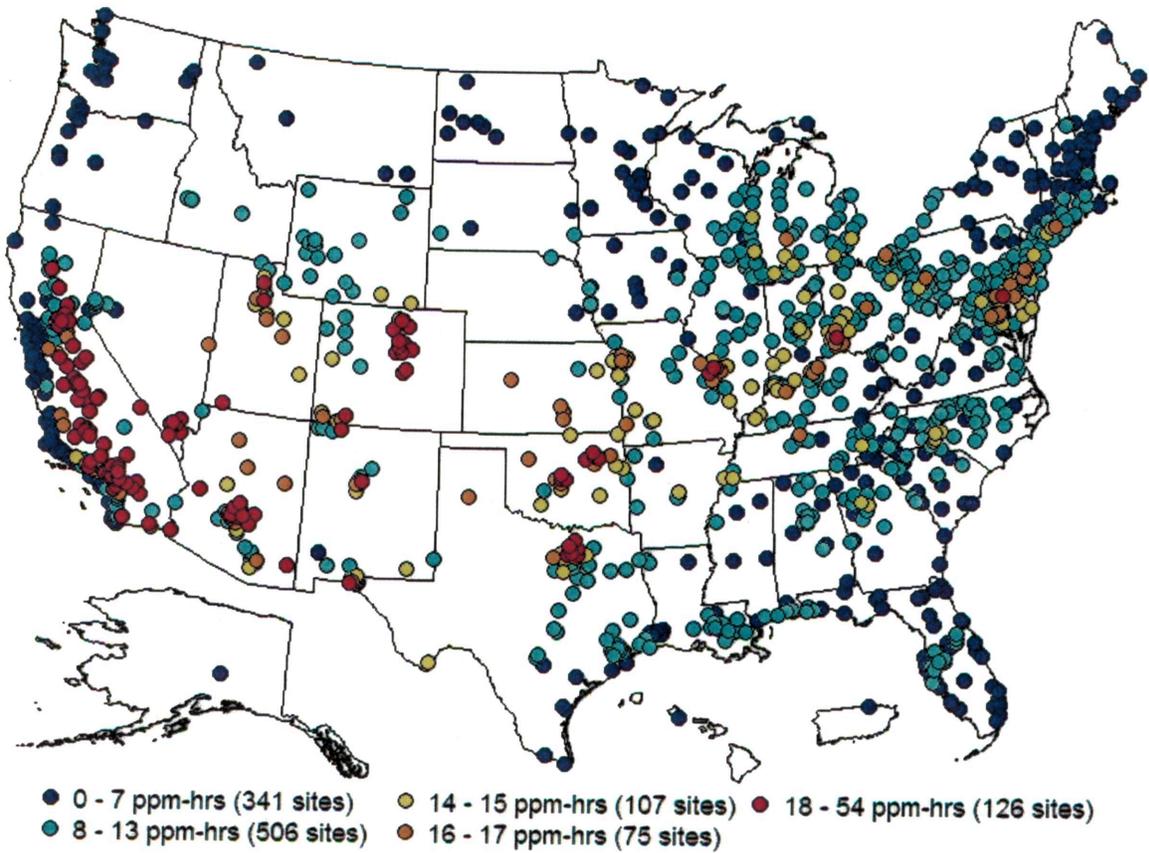


Figure 2. Map of W126 values based on 2011-2013 data

Table 1. Number of sites with 4th max values greater than various 4th max levels of interest based on 2011-2013 data

4 th Max Level (ppb)	75	70	65	60
# of Sites > Level	273	566	884	1080
# of Sites ≤ Level	842	561	276	100

Table 2. Number of sites with W126 values greater than various W126 levels of interest based on 2011-2013 data

W126 Level (ppm-hrs)	19	17	15	13	11	7
# of Sites > Level	93	126	201	308	440	814
# of Sites ≤ Level	1021	988	916	816	688	341

Table 3. Number of sites with 4th max values greater than various 4th max levels of interest and W126 values less than or equal to various W126 levels of interest based on 2011-2013 data

# of Sites > 4 th Max Level AND ≤ W126 Level		W126 Level (ppm-hrs)					
		19	17	15	13	11	7
4 th Max Level (ppb)	75	184	166	118	71	32	1
	70	452	419	355	269	163	10
	65	739	706	634	534	406	95
	60	916	883	811	711	583	237

Table 4. Number of sites with 4th max values less than or equal to various 4th max levels of interest and W126 values greater than various W126 levels of interest based on 2011-2013 data

# of Sites ≤ 4 th Max Level AND > W126 Level		W126 Level (ppm-hrs)					
		19	17	15	13	11	7
4 th Max Level (ppb)	75	10	25	49	102	191	506
	70	0	0	8	22	44	235
	65	0	0	0	0	0	35
	60	0	0	0	0	0	0

Table 5. Number of sites with 4th max values greater than various 4th max levels of interest and W126 values greater than various W126 levels of interest based on 2011-2013 data

# of Sites > 4 th Max Level AND > W126 Level		W126 Level (ppm-hrs)					
		19	17	15	13	11	7
4 th Max Level (ppb)	75	81	99	149	198	239	270
	70	93	126	193	283	392	552
	65	93	126	201	308	440	773
	60	93	126	201	308	440	813

According to Table 4, there were no sites with 4th max values less than or equal to 70 ppb and W126 values greater than 17 ppm-hrs, and there were no sites with 4th max values less than or equal to 65 ppb and W126 values greater than 11 ppm-hrs. Figure 3a shows the locations of the 25 sites with 4th max values less than or equal to 75 ppb and W126 values greater than 17 ppm-hrs, as well as the 22 sites with 4th max values less than or equal to 70 ppb and W126 values greater than 13 ppm-hrs. All of these sites are located in the southwestern U.S. (i.e., the region bounded by the red border in Figure 3a), which indicates that there may be regional differences in the relationship between the 4th max and W126 metrics. Figure 3b shows an enlarged version of the same map focused on the southwestern U.S.

In order to examine these differences, many of the further analyses were stratified into the nine NOAA climate regions (Karl and Koss, 1984), which are shown in Figure 4. Since the NOAA climate regions only cover the contiguous U.S., Alaska was added to the Northwest region, Hawaii was added to the West region, and Puerto Rico was added to the Southeast region.

Figure 5a shows a scatter plot comparing the 4th max (x-axis) and W126 (y-axis) values based on 2011-2013 data, with points colored by region, while Figure 5b shows an enlarged version of the same scatter plot with emphasis on the region containing the 4th max and W126 levels of interest. These figures indicate that there is a strong, positive, non-linear relationship between the 4th max and W126 metrics. The amount of variability in the relationship between the 4th max and W126 metrics appears to increase as the metric values themselves increase. The relationship between the 4th max and W126 metrics also appears to vary across regions. In particular, the Southwest and West regions (i.e., the southwestern U.S.) appear to have higher W126 values relative to their respective 4th max values than the rest of the U.S.

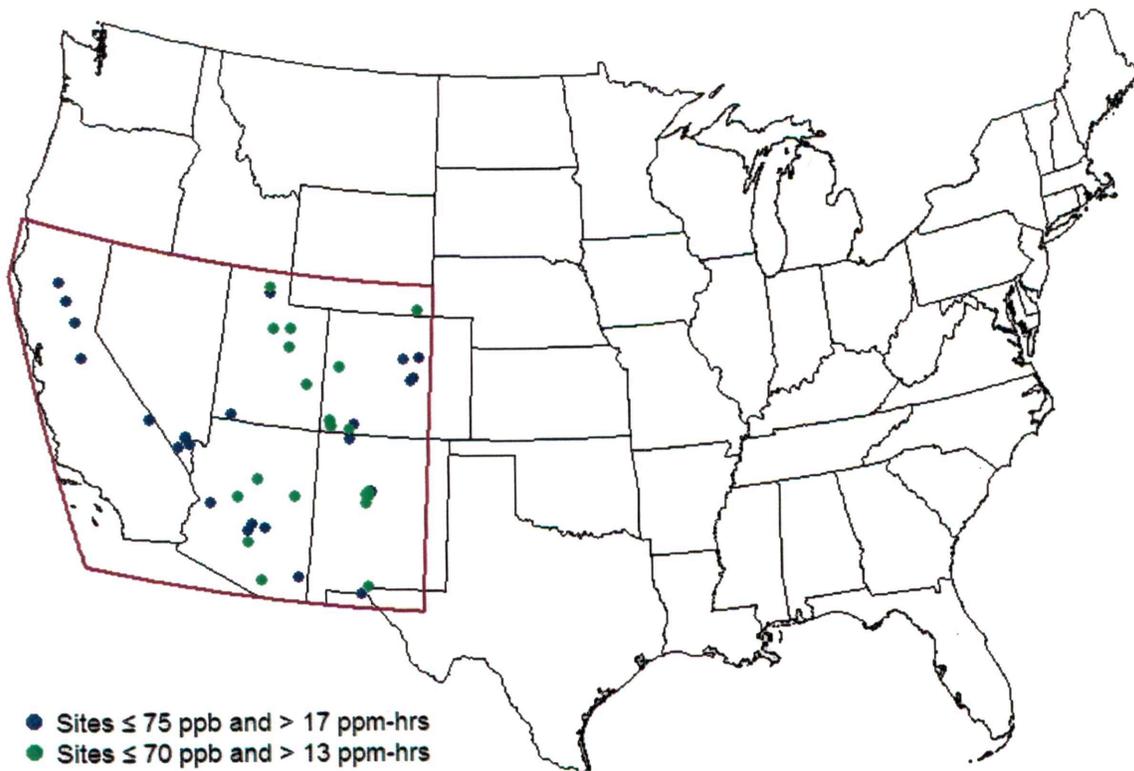


Figure 3a. Map of sites with 4th max values less than or equal to 75 ppb and W126 values greater than 17 ppm-hrs, and sites with 4th max values less than or equal to 70 ppb and W126 values greater than 13 ppm-hrs. The red border indicates the southwestern U.S. region enlarged in the figure below.

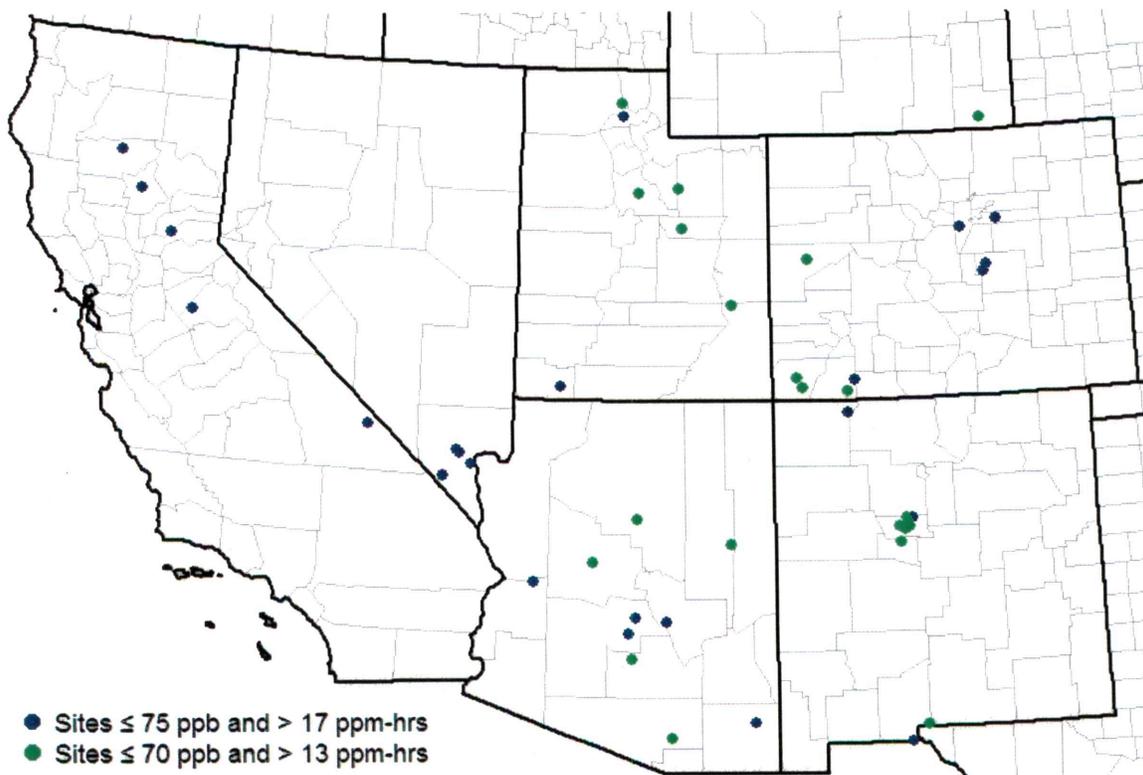


Figure 3b. Map of sites with 4th max values less than or equal to 75 ppb and W126 values greater than 17 ppm-hrs, and sites with 4th max values less than or equal to 70 ppb and W126 values greater than 13 ppm-hrs, enlarged for emphasis on the southwestern U.S. region.

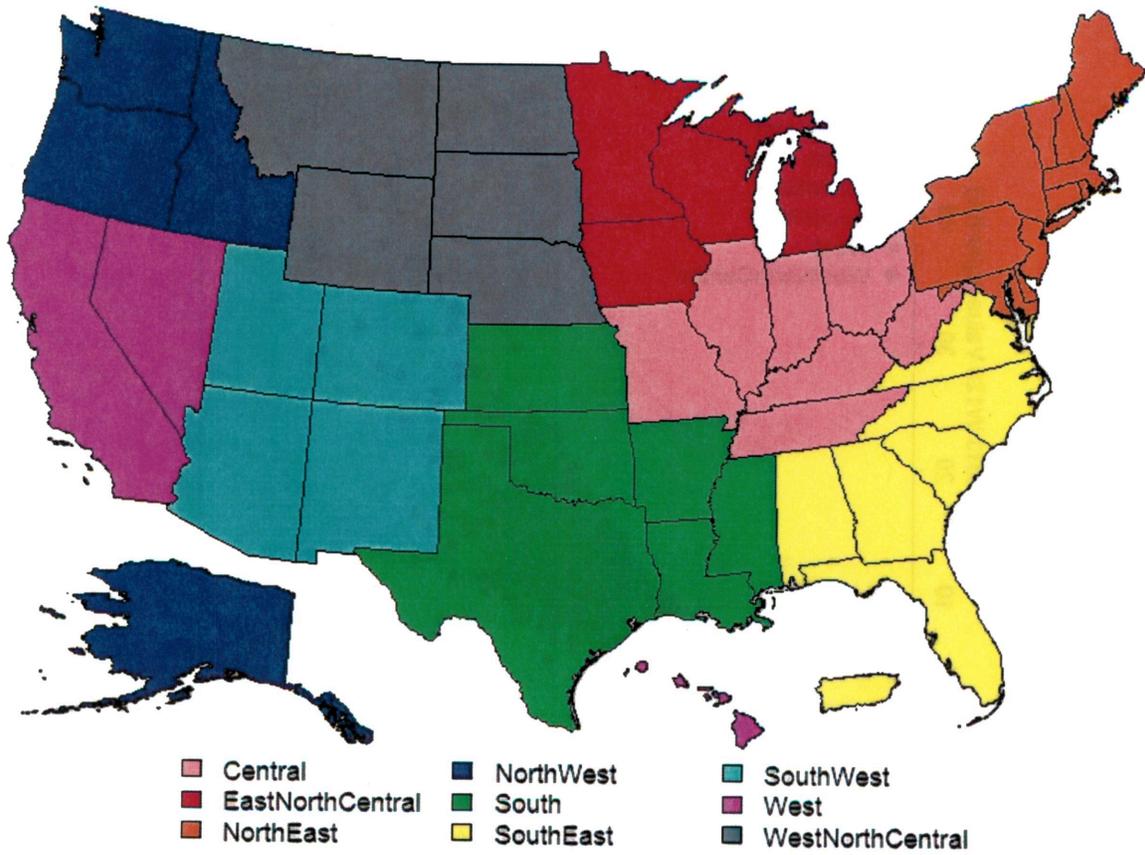


Figure 4. Map of the nine NOAA climate regions

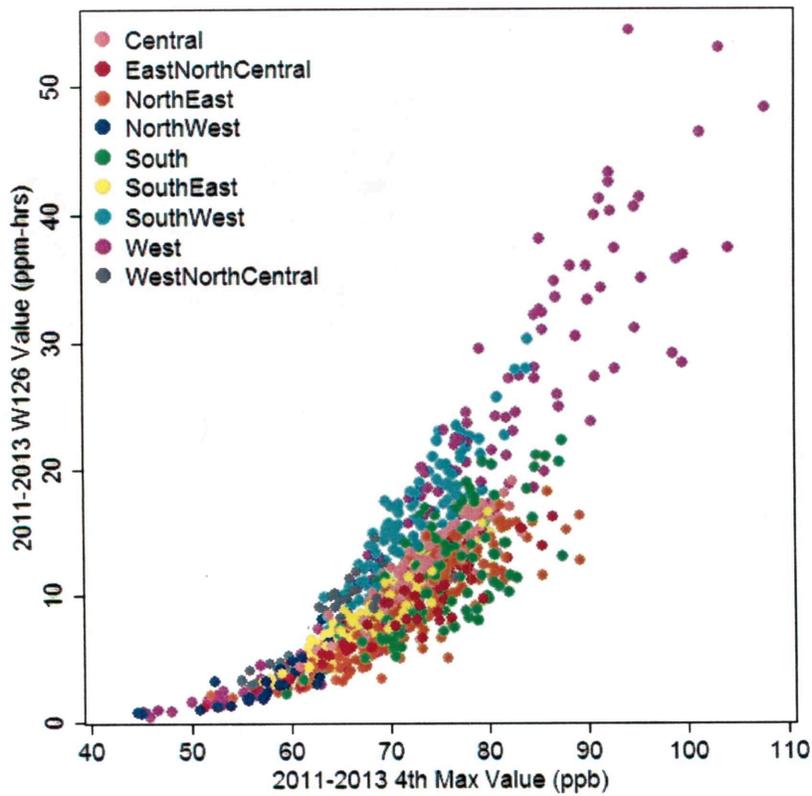


Figure 5a. Scatter plot comparing the 4th max (x-axis) and W126 (y-axis) values based on 2011-2013 data

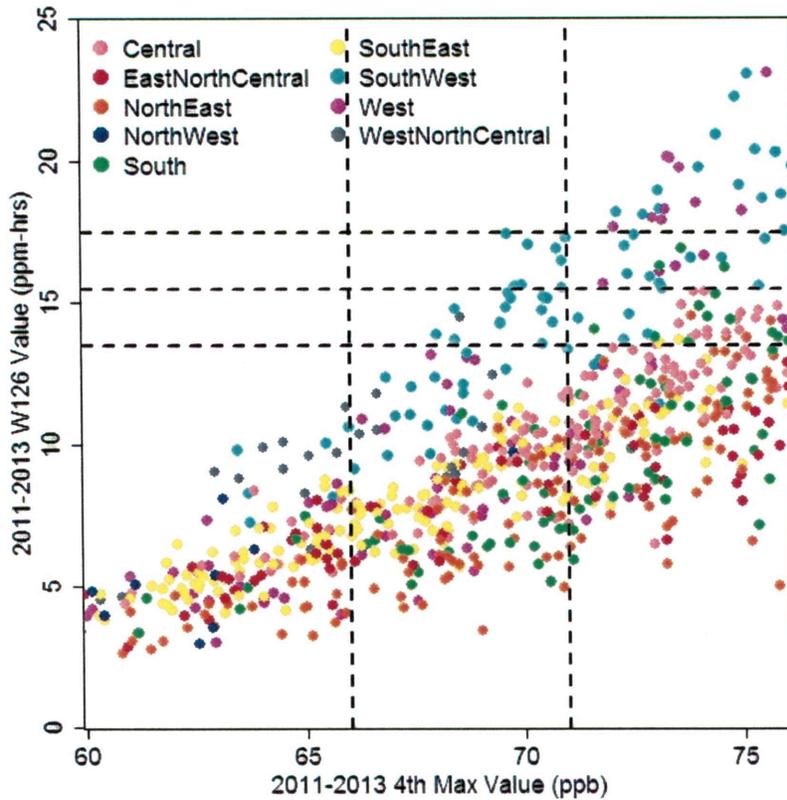


Figure 5b. Scatter plot comparing the 4th max (x-axis) and W126 (y-axis) values based on 2011-2013 data, enlarged to emphasize points within the range of 4th max and W126 levels of interest. Dotted lines mark cutoffs for meeting 4th max levels of 65 and 70 ppb, and meeting W126 levels of 13, 15, and 17 ppm-hrs.

Historical Air Quality Data

The second portion of the analysis focuses on 4th max and W126 values from all 11 consecutive 3-year periods included in the analysis (2001-2003 to 2011-2013). Figure 6 shows the trend in the 4th max values, and Figure 7 shows the trend in the W126 values based on the 759 sites which collected sufficient data to calculate valid 4th max and W126 values for all 3-year periods. In general, the trends in both the 4th max and W126 values were decreasing. The amount of variability in the 4th max and W126 values also tended to decrease over time (i.e., the 90th percentile values decreased more quickly than the 10th percentile values), especially for the W126 values. In general, Figure 7 appears to be nearly identical to its respective counterpart in the 2014 memorandum, indicating that the updated data handling procedures had little effect on these analyses.

Next, Figure 8 compares sites based on their 4th max values relative to 70 ppb, and their W126 values relative to 17 ppm-hrs. Figure 8 uses four panels to group these trends: the top left panel shows the trend in the number of sites with 4th max values less than or equal to 70 ppb and W126 values greater than 17 ppm-hrs; the top right panel shows the trend in the number of sites with 4th max values greater than 70 ppb and W126 values greater than 17 ppm-hrs; the bottom left panel shows the trend in the number of sites with 4th max values less than or equal to 70 ppb and W126 values less than or equal to 17 ppm-hrs; and the bottom right panel shows the trend in the number of sites with 4th max values greater than 70 ppb and W126 values less than or equal to 17 ppm-hrs. The bars in each panel are colored to show the number of sites located within each NOAA climate region for each 3-year period.

Figure 8 shows that fewer than four sites would have 4th max values less than or equal to 70 ppb and W126 values greater than 17 ppm-hrs in any given 3-year period, and that these sites are predominately located in the Southwest region. The number of sites with 4th max values less than or equal to 70 ppb and W126 values less than or equal to 17 ppm-hrs has increased over time, while the number of sites with 4th max values greater than 70 ppb and W126 values greater than 17 ppm-hrs has decreased by a similar amount. The number of sites with 4th max values greater than 70 ppb and W126 values less than or equal to 17 ppm-hrs has remained relatively constant over the past decade.

Finally, Tables 6 to 10 present similar information to Tables 1 to 5, respectively, except that the values shown in each cell contain the number of occurrences summed over all 11 consecutive 3-year periods (2001-2003 to 2011-2013) instead of just 2011-2013. For example, Table 9 shows that over all 11 consecutive 3-year periods, there were 131 occurrences where sites had 4th max values less than or equal to 70 ppb and W126 values greater than 13 ppm-hrs. In general, the relative magnitudes of the numbers shown in Tables 6 to 10 compare well to their respective counterparts in Tables 1 to 5. Consistent with the trends shown in Figures 6 to 8, there were generally more sites with 4th max and W126 values greater than each level in the earlier 3-year periods than in the later 3-year periods. According to Table 9, there have been only four occurrences over the entire 13-year period where a site has had a 4th max value less than or equal to 70 ppb and a W126 value greater than 17 ppm-hrs.

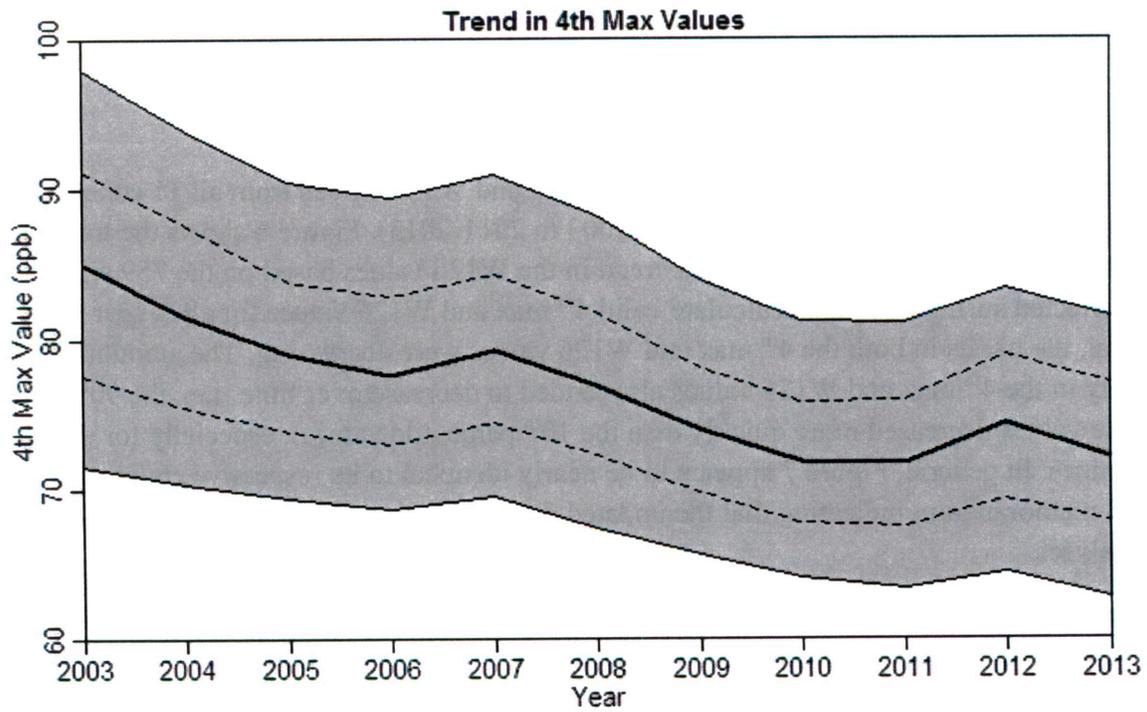


Figure 6. Trend in 4th max values, 2001-2003 to 2011-2013. The bold center lines show median values, the dotted lines show 25th and 75th percentile values, and the outer lines containing the shaded area show 10th and 90th percentile values.

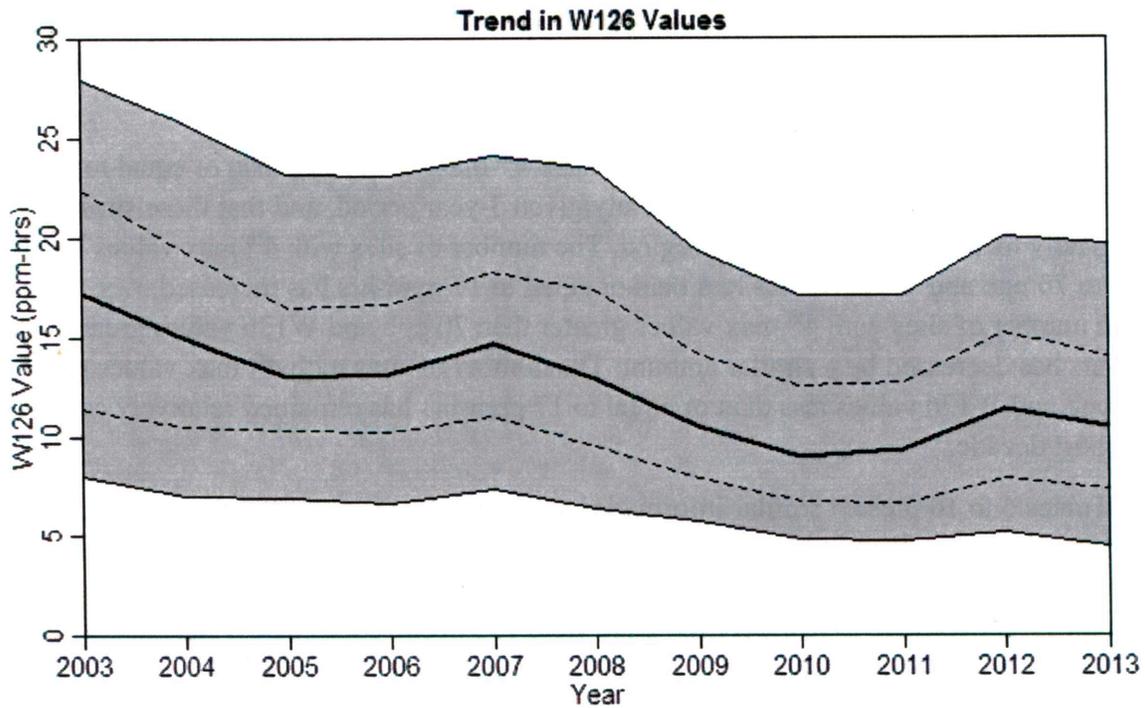


Figure 7. Trend in W126 values, 2001-2003 to 2011-2013. The bold center lines show median values, the dotted lines show 25th and 75th percentile values, and the outer lines containing the shaded area show 10th and 90th percentile values.

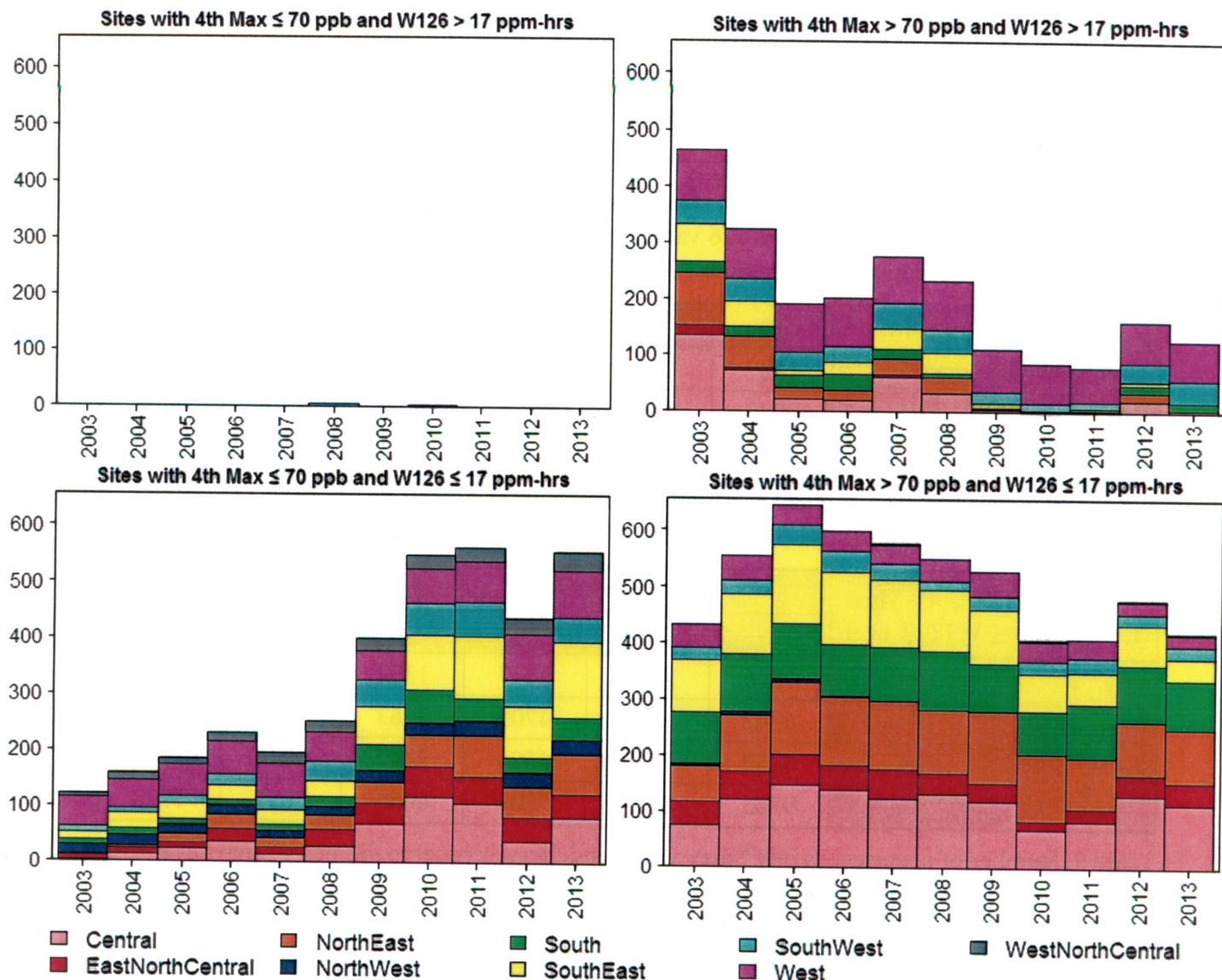


Figure 8. Trends in the number of sites with 4th max values less than or equal to 70 ppb and W126 values greater than 17 ppm-hrs (top left panel); the number of sites with 4th max values greater than 70 ppb and W126 values greater than 17 ppm-hrs (top right panel); the number of sites with 4th max values less than or equal to 70 ppb and W126 values less than or equal to 17 ppm-hrs (bottom left panel); and the number of sites with 4th max values greater than 70 ppb and W126 values less than or equal to 17 ppm-hrs (bottom right panel). Bars are colored to show the number of sites located within each NOAA climate region for the 3-year period ending with the year shown on the x-axis.

Table 6. Number of occurrences of 4th max values greater than various 4th max levels of interest based on all 11 consecutive 3-year periods (2001-2003 to 2011-2013)

4 th Max Level (ppb)	75	70	65	60
# Occurrences > Level	5198	8124	10364	11519
# Occurrences ≤ Level	6472	3687	1669	666

Table 7. Number of occurrences of W126 values greater than various W126 levels of interest based on all 11 consecutive 3-year periods (2001-2003 to 2011-2013)

W126 Level (ppm-hrs)	19	17	15	13	11	7
# Occurrences > Level	1587	2257	3199	4488	5972	9276
# Occurrences ≤ Level	9940	9290	8375	7130	5716	2606

Table 8. Number of occurrences of 4th max values greater than various 4th max levels of interest and W126 values less than or equal to various W126 levels of interest based on all 11 consecutive 3-year periods (2001-2003 to 2011-2013)

# Occurrences > 4 th Max Level AND ≤ W126 Level		W126 Level (ppm-hrs)					
		19	17	15	13	11	7
4 th Max Level (ppb)	75	3526	2966	2247	1394	684	36
	70	6242	5597	4705	3563	2299	273
	65	8259	7609	6694	5447	4034	1072
	60	9265	8615	7700	6453	5039	1938

Table 9. Number of occurrences of 4th max values less than or equal to various 4th max levels of interest and W126 values greater than various W126 levels of interest based on all 11 consecutive 3-year periods (2001-2003 to 2011-2013)

# Occurrences ≤ 4 th Max Level AND > W126 Level		W126 Level (ppm-hrs)					
		19	17	15	13	11	7
4 th Max Level (ppb)	75	65	152	347	737	1438	3882
	70	0	4	27	131	280	1348
	65	0	0	0	0	1	138
	60	0	0	0	0	0	0

Table 10. Number of occurrences of 4th max values greater than various 4th max levels of interest and W126 values greater than various W126 levels of interest based on all 11 consecutive 3-year periods (2001-2003 to 2011-2013)

# Occurrences > 4 th Max Level AND > W126 Level		W126 Level (ppm-hrs)					
		19	17	15	13	11	7
4 th Max Level (ppb)	75	1519	2092	2828	3702	4444	5125
	70	1587	2249	3164	4337	5652	7768
	65	1587	2257	3199	4490	5972	9100
	60	1587	2257	3199	4490	5974	9270

Relative Changes in 4th Max and W126 Values

The final portion of the analysis compared the respective 4th max and W126 values from 2001-2003 to those from 2011-2013 for the 815 sites with valid 4th max and W126 values in both periods. Figure 9 shows a map of the changes in the 4th max values, while Figure 10 shows a map of the changes in the W126 values. Most sites in the Eastern U.S. and California saw large, widespread decreases in both 4th max and W126 values over the past decade as a result of regional and national NOx control programs, such as the NOx SIP Call and federal mobile source emissions standards. In the inter-mountain West, where NOx control programs have been more localized, the decreases observed in the 4th max and W126 values were typically much smaller in magnitude, and a few sites even showed increases.

Figure 11 shows a scatter plot comparing the changes in 4th max (x-axis, ppb) and W126 (y-axis, ppm-hrs) values from 2001-2003 to 2011-2013. The relationship between the changes in the 4th max and W126 metrics was fairly linear and positive (Pearson correlation coefficient $R = 0.80$). The regression line shown in Figure 11 indicates that, on average, there was a change of approximately 0.7 ppm-hr in the W126 values per unit ppb change in the 4th max values. Similar to the direct comparison between the 4th max and W126 metrics based on 2011-2013 data, the amount of variability in the relative changes between these two metrics generally increased with the magnitude of the changes, and regional differences were apparent.

Figure 12 shows scatter plots of the changes in 4th max (x-axis) and W126 (y-axis) values from 2001-2003 to 2011-2013 in each NOAA climate region and the associated regression lines fit using the sites within each region. Table 11 provides some summary statistics based on the regional analyses. Figure 12 and Table 11 show that the positive, linear relationship between the changes in the 4th max and W126 values persists within each region, with Pearson correlation coefficients ranging from 0.58 to 0.92. The regression lines shown in Figure 12 with slopes listed in Table 11 indicate that the Southwest and West regions, which had the greatest potential for sites having 4th max values less than or equal to the various 4th max levels of interest and W126 values greater than the various W126 levels of interest, also exhibited the greatest response in W126 values per unit change in 4th max values.

The results presented in Figures 9 to 12 and the values presented in Table 11 are nearly identical to the corresponding results presented in the 2014 memorandum. Thus, the change to the data handling for W126 had very little, if any impact on the overall outcome of these analyses or any conclusions based on them.

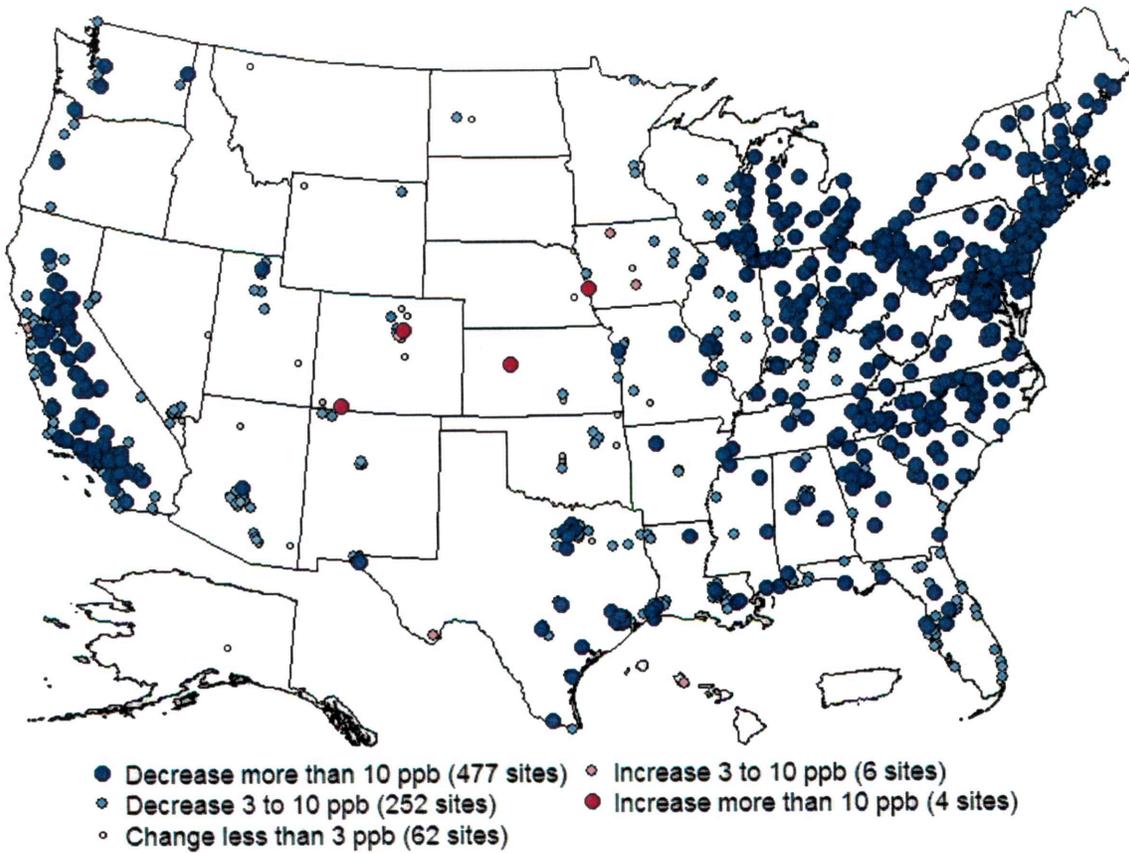


Figure 9. Map of changes in 4th max values from 2001-2003 to 2011-2013

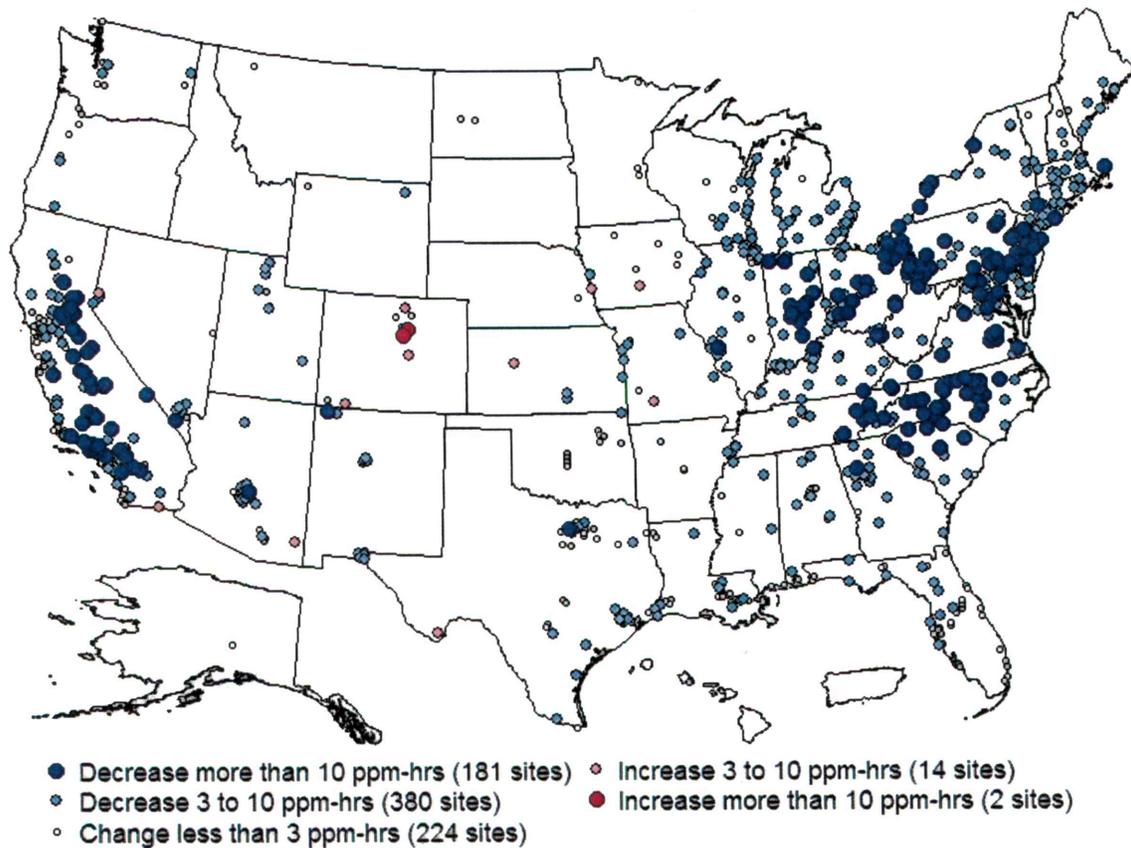


Figure 10. Map of changes in W126 values from 2001-2003 to 2011-2013

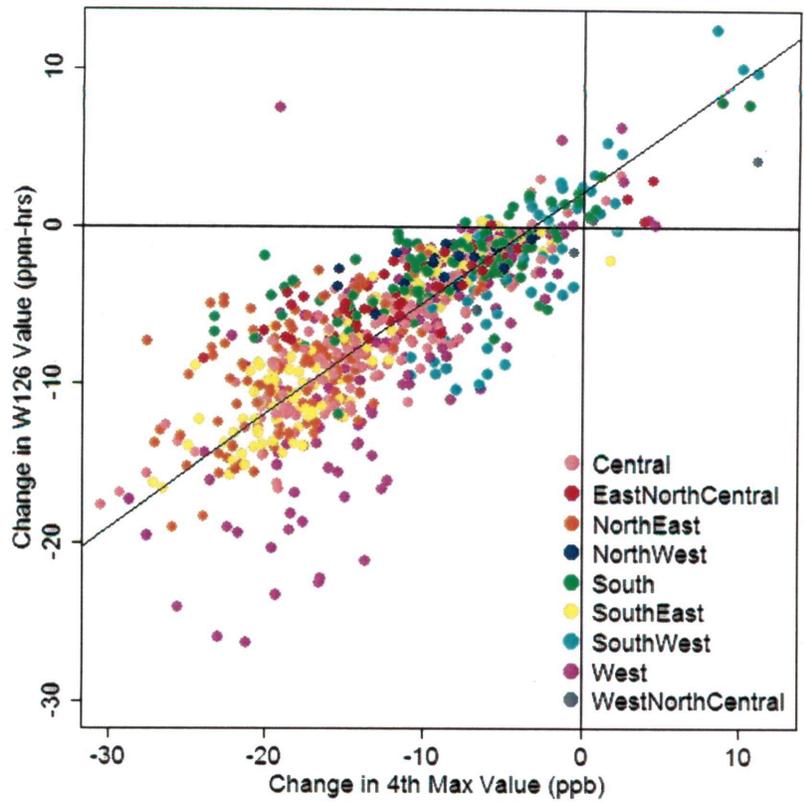


Figure 11. Scatter plot comparing the changes in 4th max (x-axis) and W126 (y-axis) values from 2001-2003 to 2011-2013.

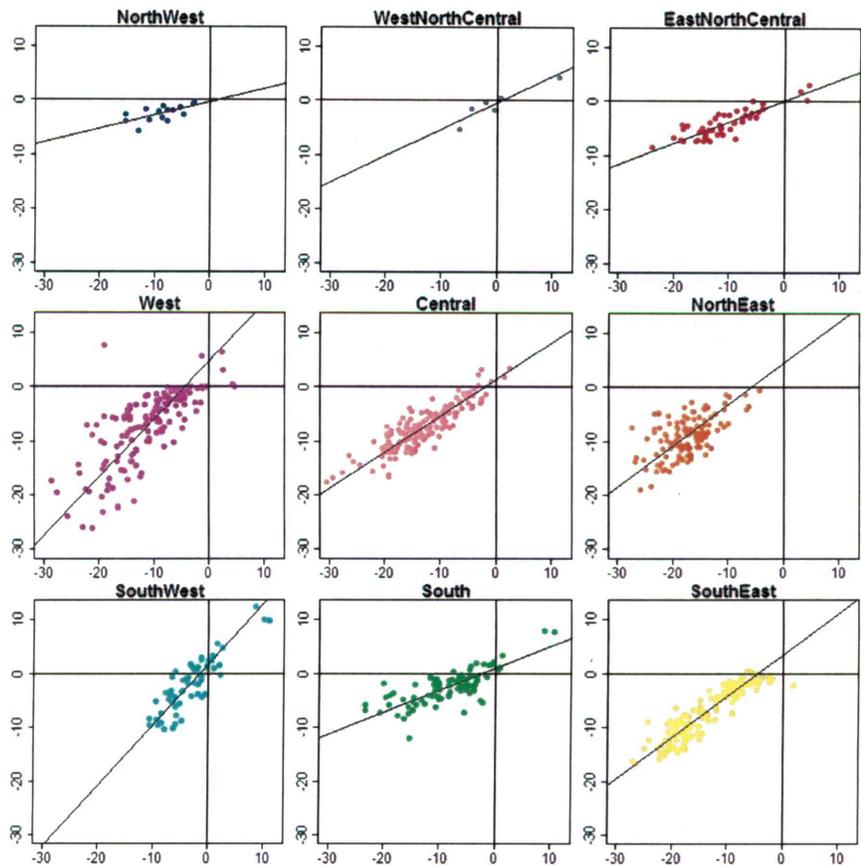


Figure 12. Scatter plots showing the changes in 4th max (x-axis, ppb) and W126 (y-axis, ppm-hrs) values for sites within each of the nine NOAA climate regions.

Table 11. Summary statistics based on regional analysis of changes in 4th max and W126 values from 2001-2003 to 2011-2013

NOAA Climate Region	Number of O₃ Sites	Mean Change in 4th Max Value (ppb)	Mean Change in W126 Value (ppm-hrs)	Regression Slope	Pearson Correlation Coefficient
Central	161	-13.0	-7.4	0.67	0.89
East North Central	60	-10.0	-3.8	0.39	0.89
Northeast	131	-17.6	-9.0	0.77	0.58
Northwest	16	-8.9	-2.5	0.24	0.63
South	100	-8.4	-2.5	0.41	0.75
Southeast	136	-13.8	-7.1	0.76	0.91
Southwest	58	-3.2	-1.9	1.13	0.87
West	146	-11.4	-7.5	1.08	0.74
West North Central	7	-0.3	-0.5	0.49	0.92
National	815	-12.0	-6.0	0.71	0.80

Summary

The analysis based on 2011-2013 data showed that roughly one-quarter of U.S. O₃ sites had 4th max values greater than 75 ppb, roughly half of U.S. O₃ sites had 4th max values greater than 70 ppb, and roughly three quarters of U.S. O₃ sites had 4th max values greater than 65 ppb. By contrast, roughly one-tenth of U.S. O₃ sites had W126 values greater than 17 ppm-hrs, and roughly one-quarter of U.S. O₃ sites had W126 values greater than 13 ppm-hrs.

When examining both metrics in combination, the 2011-2013 data showed that there were 25 sites with 4th max values less than or equal to 75 ppb and W126 values greater than 17 ppm-hrs, and 10 of these sites also had W126 values greater than 19 ppm-hrs. These sites were located exclusively in the southwestern U.S (i.e., the West and Southwest climate regions). There were no sites with 4th max values less than or equal to 70 ppb and W126 values greater than 17 ppm-hrs. There were 22 sites with 4th max values less than or equal to 70 ppb and W126 values greater than 13 ppm-hrs, and 8 of these sites also had W126 values greater than 15 ppm-hrs. These sites were also located exclusively in the southwestern U.S. There were no sites with 4th max values less than or equal to 65 ppb and W126 values greater than 11 ppm-hrs.

The analysis based on the full 13-year dataset showed that both 4th max and W126 values have generally decreased over the past decade. The number of sites with 4th max values less than or equal to 70 ppb and W126 values less than or equal to 17 ppm-hrs has increased substantially, while the number of sites with 4th max values greater than 70 ppb and W126 values greater than 17 ppm-hrs has decreased by a similar amount. The number of sites with 4th max values greater than 70 ppb and W126 values less than or equal to 17 ppm-hrs has remained relatively constant

over the past decade, while occurrences of 4th max values less than or equal to 70 ppb and W126 values greater than 17 ppm-hrs has been limited to just a few instances in the southwestern U.S.

Finally, the analysis of the relative changes in the 4th max and W126 values from 2001-2003 to 2011-2013 showed that there was a positive, linear relationship between the changes in the 4th max and W126 metrics. Nationally, the W126 values decreased by approximately 0.7 ppm-hr per unit ppb decrease in the 4th max values over this period. This relationship varied across the NOAA climate regions, and the Southwest and West regions which showed the greatest potential for exceeding having 4th max values less than or equal to the various 4th max levels of interest and W126 values greater than the various W126 levels of interest also showed the greatest improvement in the W126 values per unit decrease in 4th max values.

In conclusion, the ambient data analyses showed that the 4th max and W126 metrics were highly correlated, and so were the relative changes in these two metrics over the past decade. Thus, it is expected that future control programs designed to help meet a primary O₃ standard based on the 3-year average of the 4th highest daily maximum 8-hour concentration would provide similar improvements in terms of the 3-year average of the annual W126 metric. The change from the truncation procedure used in the 2014 memorandum to the rounding procedure examined here for the W126 values did not substantively affect the results or overall conclusions. In addition, the expanded analysis focusing on the entire 13-year dataset produced results that were quite similar to those based on just the most recent 3-year period. Thus, the analyses presented here provide additional support for the conclusions drawn in the 2014 memorandum.

References

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