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

December 16, 2020

MEMORANDUM

SUBJECT: Additional Analyses of Ozone Metrics Related to Consideration of the Ozone Secondary Standard

FROM: Benjamin Wells (EPA, OAQPS)

TO: Ozone NAAQS Review Docket (EPA-HQ-OAR-2018-0279)

Table of Contents

1. OVERVIEW

This technical memorandum presents various analyses of ambient air monitoring data for ozone (O_3) concentrations in the U.S. relating to the form and averaging time of the current secondary standard and some metrics reported in environmental assessments. These metrics include the W126-based cumulative exposure index, the N100 (number of hours at or above 100 ppb), and D100 (number of days with one or more hours at or above 100 ppb). The calculation of these metrics is described in Section 2 below. These analyses describe relationships between the three environmental metrics and the design values for the current standard (the annual 4th highest daily maximum 8-hour O_3 concentration, averaged over 3 consecutive years; hereafter referred to as the "4th max metric"). The analyses presented here are an extension of analyses that are presented Section 2.4.5, Appendix 2A, and Appendix 4D of the Policy Assessment for the review (U.S. EPA, 2020).

2. DATA HANDLING

2.1 Data Retrieval and Preparation

Hourly O_3 concentration data were retrieved from the EPA's Air Quality System (AQS, *https://www.epa.gov/aqs*) database for 1,982 ambient air monitoring sites which operated between 2000 and 2018. These data were used to calculate W126 and 4^{th} max metric values for each 3-year period from 2000-2002 to 2016-2018. Before calculating these metrics, 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 at monitoring sites not meeting EPA's quality assurance or other criteria in 40 CFR part 58 were removed from the analysis. Second, data collected by multiple monitoring instruments operating at the same location were combined according to Appendix U to 40 CFR Part 50. Finally, data were combined across pairs of monitoring sites approved for such combination by the EPA Regional Offices. The final hourly O_3 concentration dataset contained 1,779 monitoring sites.

2.2 Derivation of the Metrics

The 4th max metric values were calculated according to the data handling procedures in Appendix U to 40 CFR part 50. First, moving 8-hour averages were calculated from the hourly O_3 concentration data for each site. For each 8-hour period, an 8-hour average value was calculated if there were at least 6 hourly O_3 concentrations available. Each 8-hour average was stored in the first hour of the period (e.g., the 8-hour average from 12:00 PM to 8:00 PM is stored in the 12:00 PM hour). 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 70 parts per billion (ppb). 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 metric values in units of ppb. Any decimal digits in these values were truncated for applications requiring direct comparison to a 4th max level (e.g., Table 1), otherwise, all decimal digits were retained. The 4th max metric values were considered valid if daily maximum values were available for at least 90% of the days in the O_3 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 O_3 monitoring season in any calendar year. In addition, 4th max metric values were considered valid if they were greater than the 4th max levels to which they were being compared.

The W126 metric values were calculated using the hourly O_3 concentration data in parts per million (80 FR 65374, October 26, 2015). For daytime hours (defined as the 12-hour period from 8:00 AM to 8:00 PM Local Standard Time each day), the hourly concentration values at each O_3 monitoring site were weighted using the following equation:

$$\text{Weighted } O_3 = O_3 / (1 + 4403*\exp(-126 * O_3)).$$

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 to be 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 metric values, with units in parts per million-hours (ppm-hrs). The W126 metric values were rounded to the nearest unit ppm-hr for applications requiring direct comparison to a W126 level (e.g., Table 1), otherwise, all decimal digits were retained. For consistency with the 4^{th} max metric calculations, the W126 metric values were considered valid if hourly O_3 concentration values were available for at least 90% of the daytime hours during the O_3 monitoring season on average across the three years, with a minimum of 75% of the daytime hours during the O_3 monitoring season in any calendar year. For consistency with the 4^{th} max metric calculations, the W126 metric values were considered valid if they were greater than the W126 levels to which they were being compared.

The N100 metric was calculated as the maximum number of hours with an hourly O_3 concentration of 100 ppb or greater in the three consecutive calendar months yielding the highest number in a given year. Similarly, the D100 metric was calculated as the maximum number of days with at least one hourly O_3 concentration of 100 ppb or greater in the three consecutive calendar months yielding the highest number in a given year. These metrics were considered valid if the annual data completeness rate for the O_3 monitoring season was at least 75 percent.

In the final dataset, 1,723 of the 1,779 O3 monitoring sites had sufficient data to calculate valid annual 4th max, W126, N100 and D100 values for at least one year between 2000 and 2018. The number of sites with valid annual metric values ranged from 1,055 in 2000 to 1,226 in 2014, and 608 sites had valid annual metric values in all 19 years. Additionally, 1,550 of the 1,779 O_3 monitoring sites had sufficient data to calculate valid 4th max and W126 metric values for at least one 3-year period between 2000-2002 and 2016-2018. The number of sites with valid 4th max and W126 metric values ranged from a low of 953 in 2000-2002 to a high of 1,122 in 2015-2017, and 543 sites had valid 4th max and W126 metric values for all seventeen 3-year periods.

2.3 Assignment of Monitoring Sites to NOAA Climate Regions

In order to examine regional differences, many of the further analyses were stratified into the nine NOAA climate regions (Karl and Koss, 1984), which are shown in Figure 1. 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.

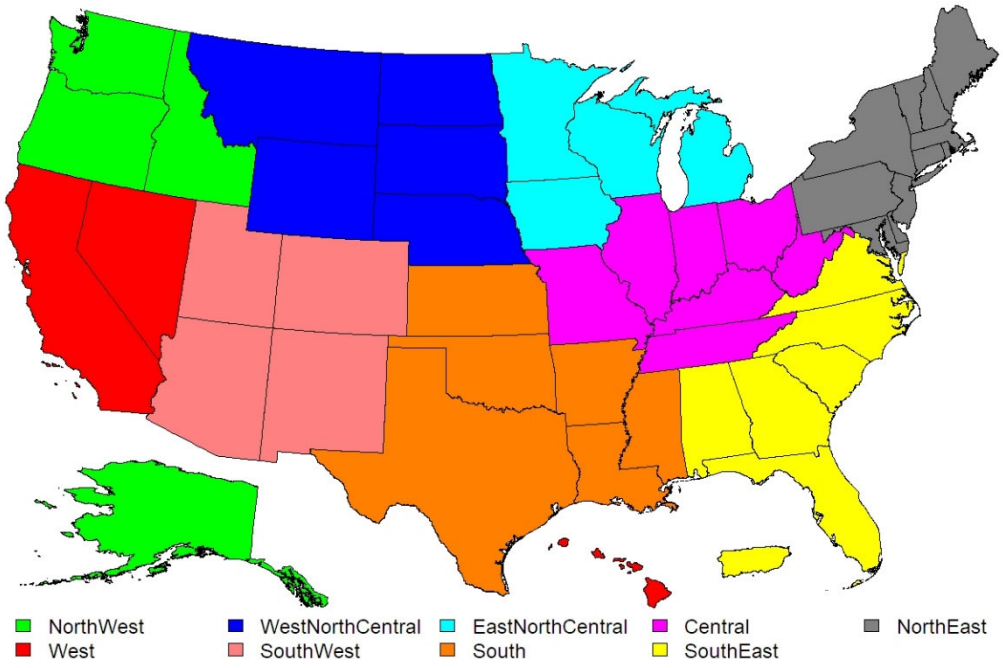

Figure 1. Map of the nine NOAA climate regions.

3. RESULTS

3.1 National Analysis Using Recent Air Quality Data

This section presents various results based on the annual 4th max, W126, N100, and D100 metrics as well as the 3-year average 4th max and W126 metrics[1] for the 2016-2018 period. Figure 2 and Figure 3 show maps of the average annual N100 and D100 values, respectively, at sites with valid 4th max metric values (design values) for 2016-2018. About 72% of the O_3 monitoring sites did not have any hourly concentrations at or above 100 ppb in 2016-2018, and an additional 15% of the sites had an average of one day or less per year where hourly O_3 concentrations reached 100 ppb or more. Sites with more than one day per year where hourly O_3 concentrations reached 100 ppb or more were generally located near large urban areas, with the most extreme values located downwind of Los Angeles, CA.

For 2016-2018, Figure 4 and Figure 5 show scatter plots comparing sites of different 4th max metric values (x-axis) with regard to N100 and D100 values (y-axis), respectively. Similarly, Figure 6 and Figure 7 compare sites of different W126 metric values (x-axis) with regard to N100 and D100 values (y-axis), respectively, for the same period. For sites meeting the current standard (i.e., 4th max metric value $\leq$ 70 ppb), the hourly O_3 concentrations reached 100 ppb or more for at most ten hours on up to three distinct days. By contrast, sites with W126 metric values as low as 5 ppm-hrs had up to ten hours with concentrations of 100 ppb or greater on up to four distinct days. Focusing on sites with W126 metric values below 20 ppm-hrs, several sites had N100 values of ten or greater and D100 values of five or greater, with individual sites having as many as 38 hours on up to seven distinct days with concentrations of 100 ppb or greater.

Figure 8 and Figure 9 show scatter plots (similar to Figure 4 and Figure 5) that compare sites having different 2016, 2017, and 2018 annual 4th max values (x-axis) with regard to the 2016, 2017, and 2018 N100 and D100 values (y-axis), respectively. As can be seen from these figures, sites where the annual 4th max value was at or below 70 ppb generally had at most five hours on two distinct days where the O_3 concentrations reached 100 ppb or more. Figure 10 and Figure 11 show similar scatter plots comparing sites having different 2016, 2017, and 2018 annual W126 values (x-axis) with regard to the 2016, 2017, and 2018 N100 and D100 values (y-axis), respectively. In contrast to the 4th max values, there were sites that had five or more hours at or above 100 ppb on up to three distinct days at W126 levels as low as 5 ppm-hrs. Focusing on sites where the annual W126 values were below 20 ppm-hrs, several sites had ten or more hours on five or more distinct days where O_3 concentrations reached 100 ppb or more.

[1] As defined in section 2.2 above, the term "W126 metric" refers to the 3-year average W126 index. The term "annual W126" is used in reference to single-year W126 index values.

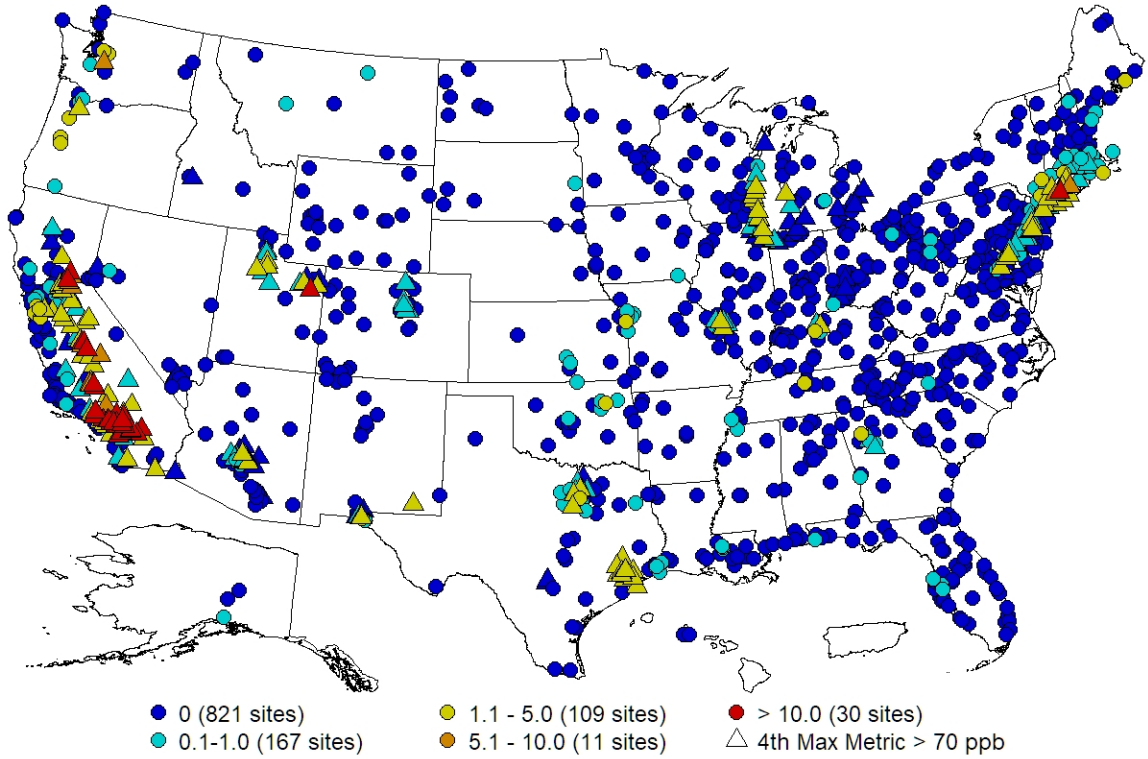

Figure 2. Map of 2016-2018 Average N100 Values at sites with valid design values.

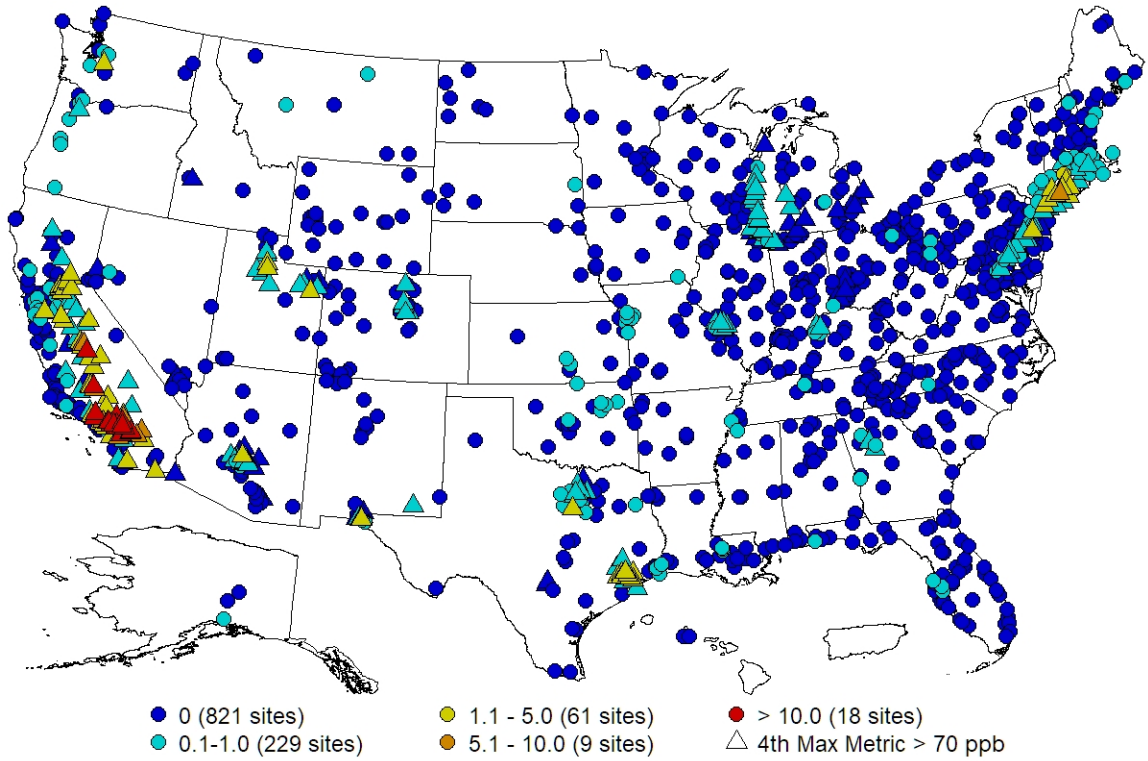

Figure 3. Map of 2016-2018 Average D100 Values at sites with valid design values.

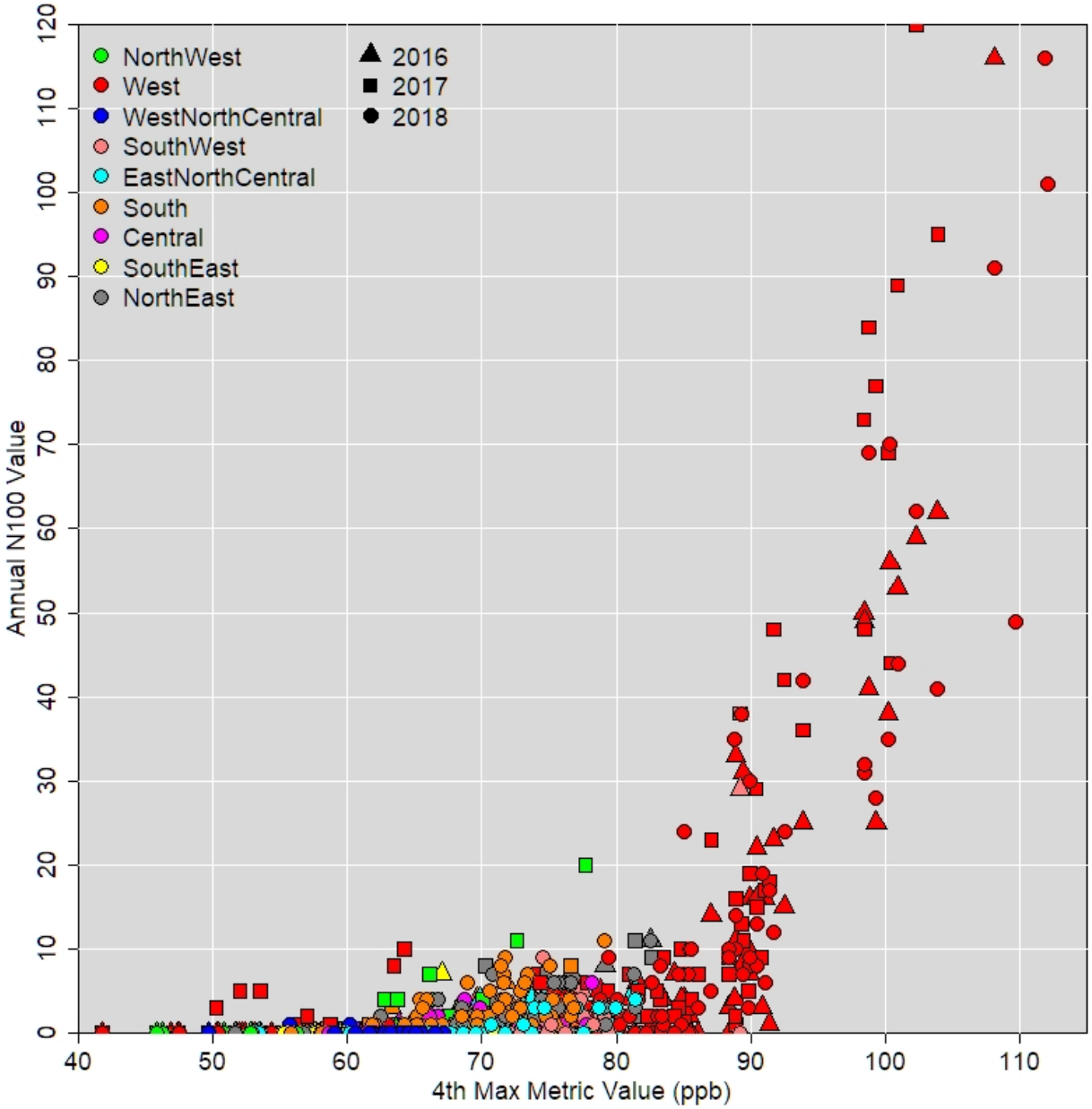

Figure 4. Scatter plot of annual N100 values (y-axis) versus 4th max metric values (design values, x-axis) based on 2016-2018 monitoring data.

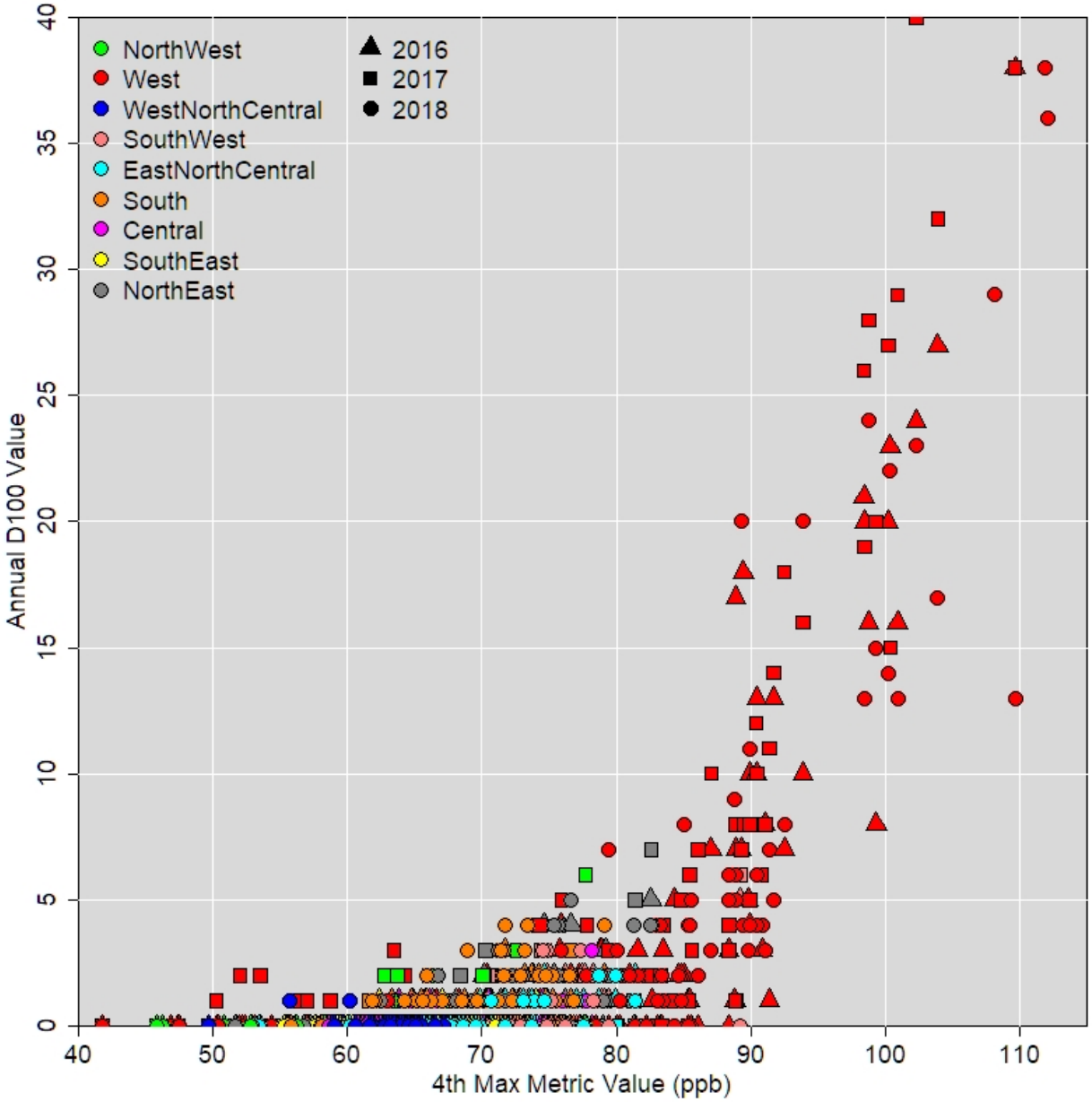

Figure 5. Scatter plot of annual D100 values (y-axis) versus 4th max metric values (design values, x-axis) based on 2016-2018 monitoring data.

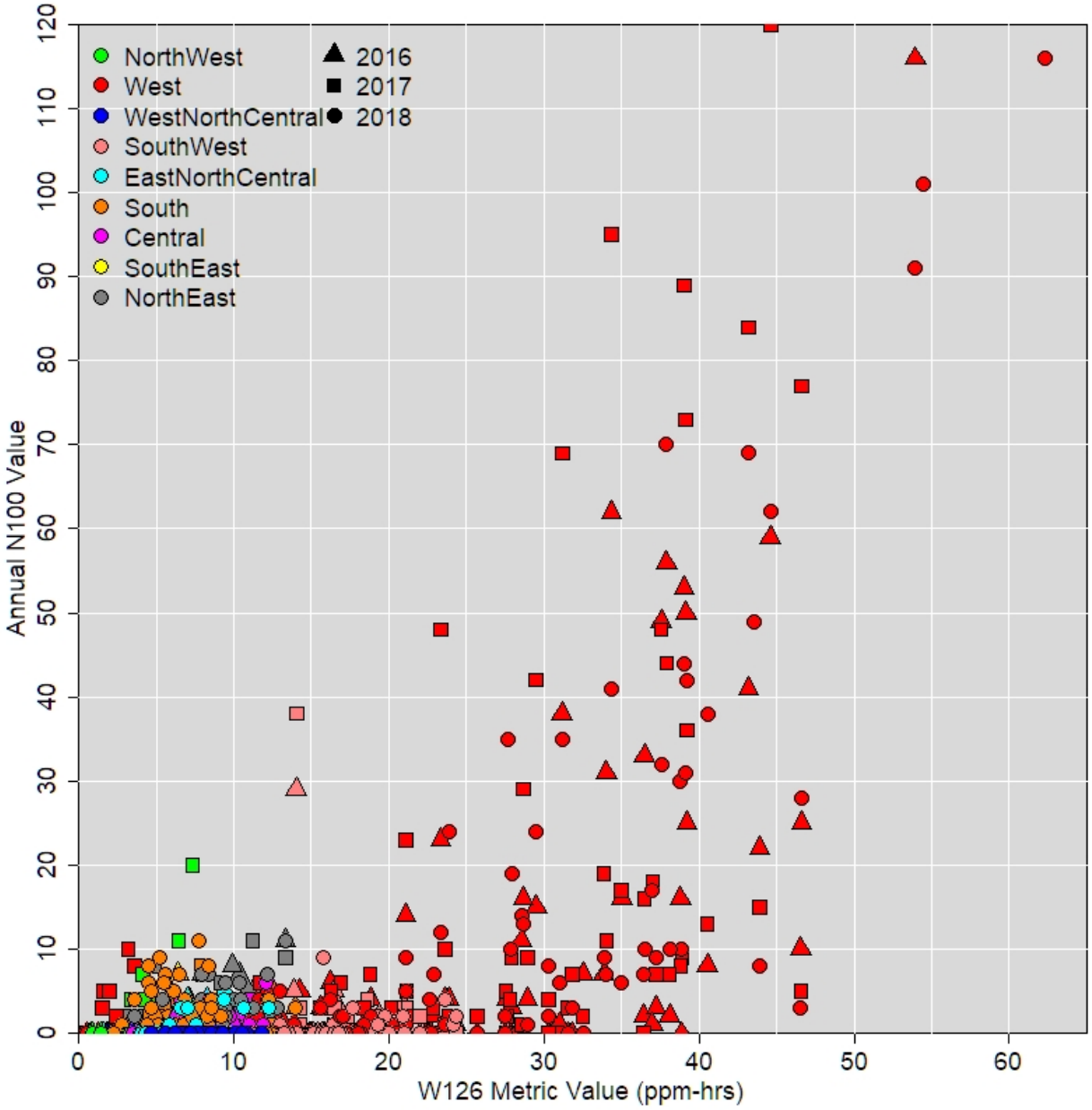

Figure 6. Scatter plot of annual N100 values (y-axis) versus W126 metric values (x-axis) based on 2016-2018 monitoring data.

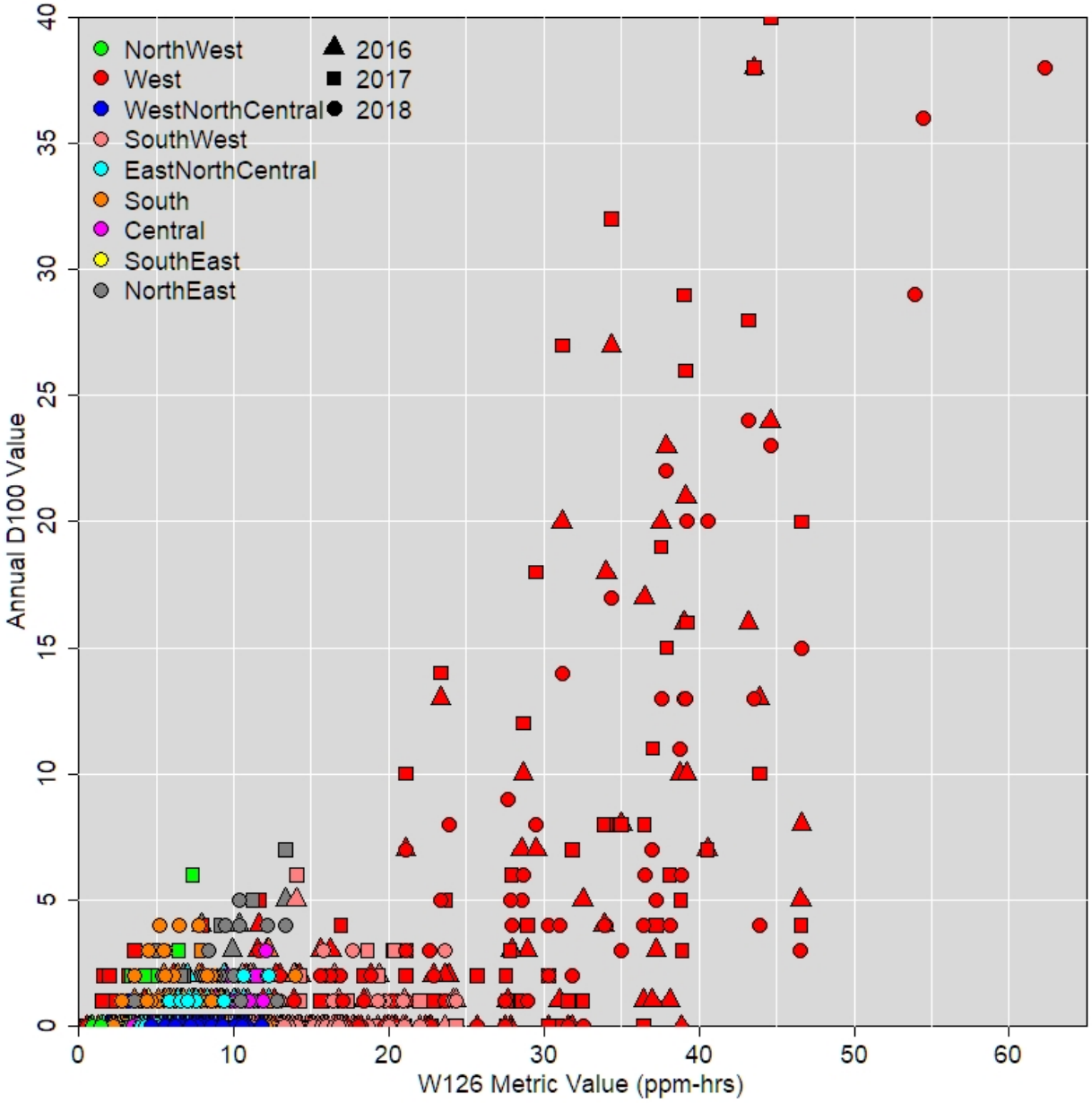

Figure 7. Scatter plot of annual D100 values (y-axis) versus W126 metric values (x-axis) based on 2016-2018 monitoring data.

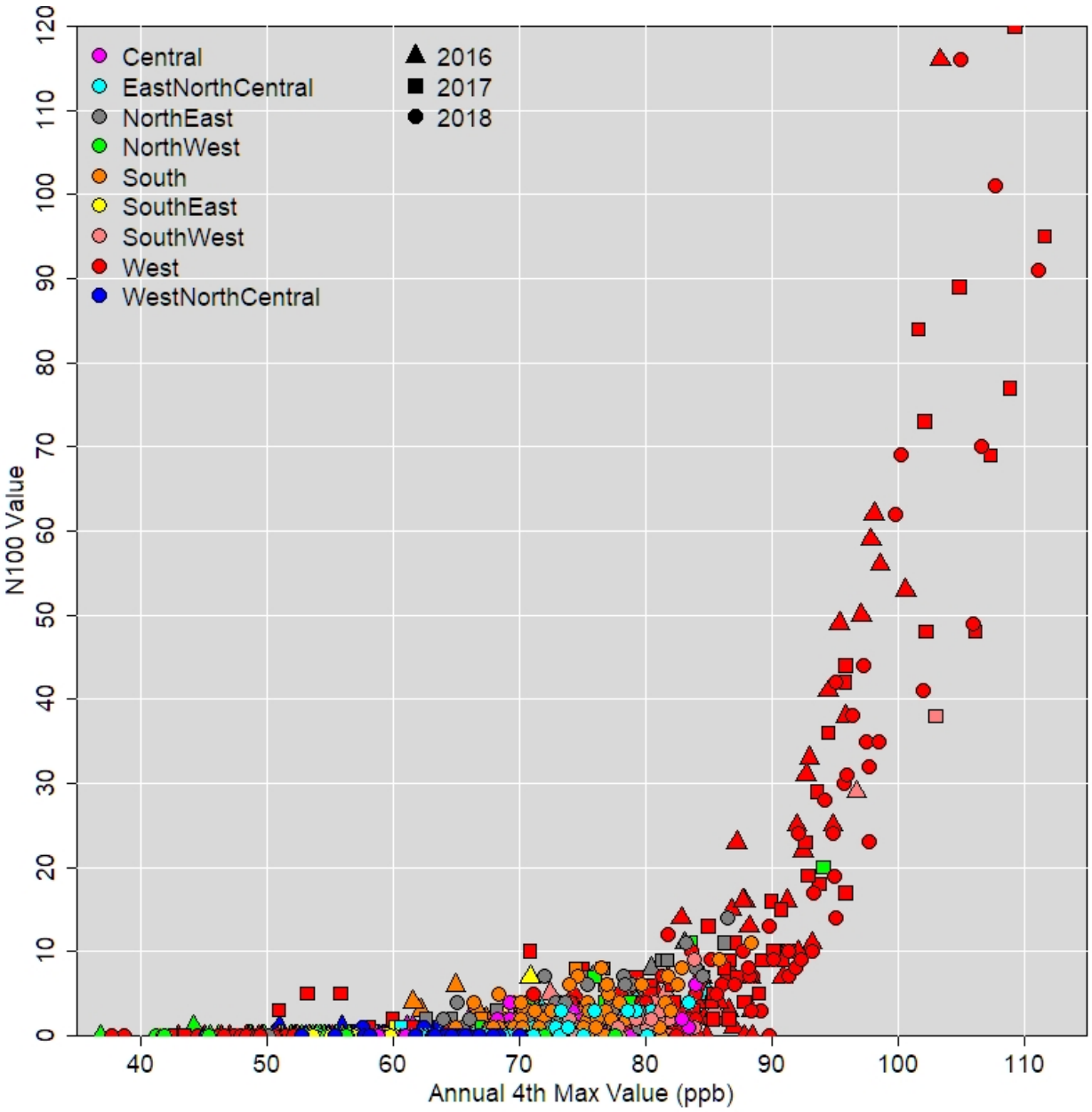

Figure 8. Scatter plot of annual N100 values (Y-axis) versus annual 4th max values (x-axis), based on 2016-2018 monitoring data.

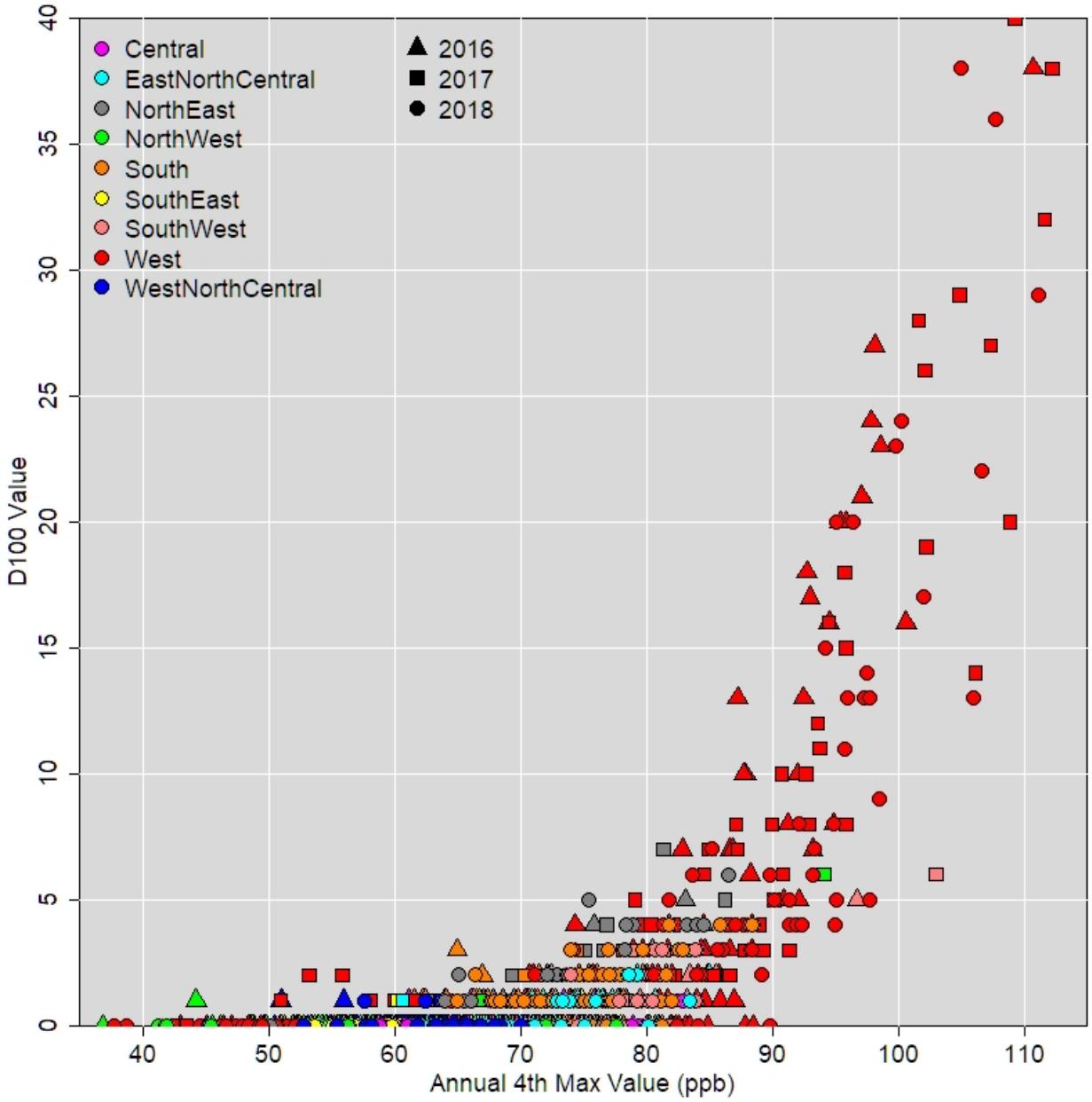

Figure 9. Scatter plot of annual D100 values (Y-axis) versus annual 4th max values (x-axis), based on 2016-2018 monitoring data.

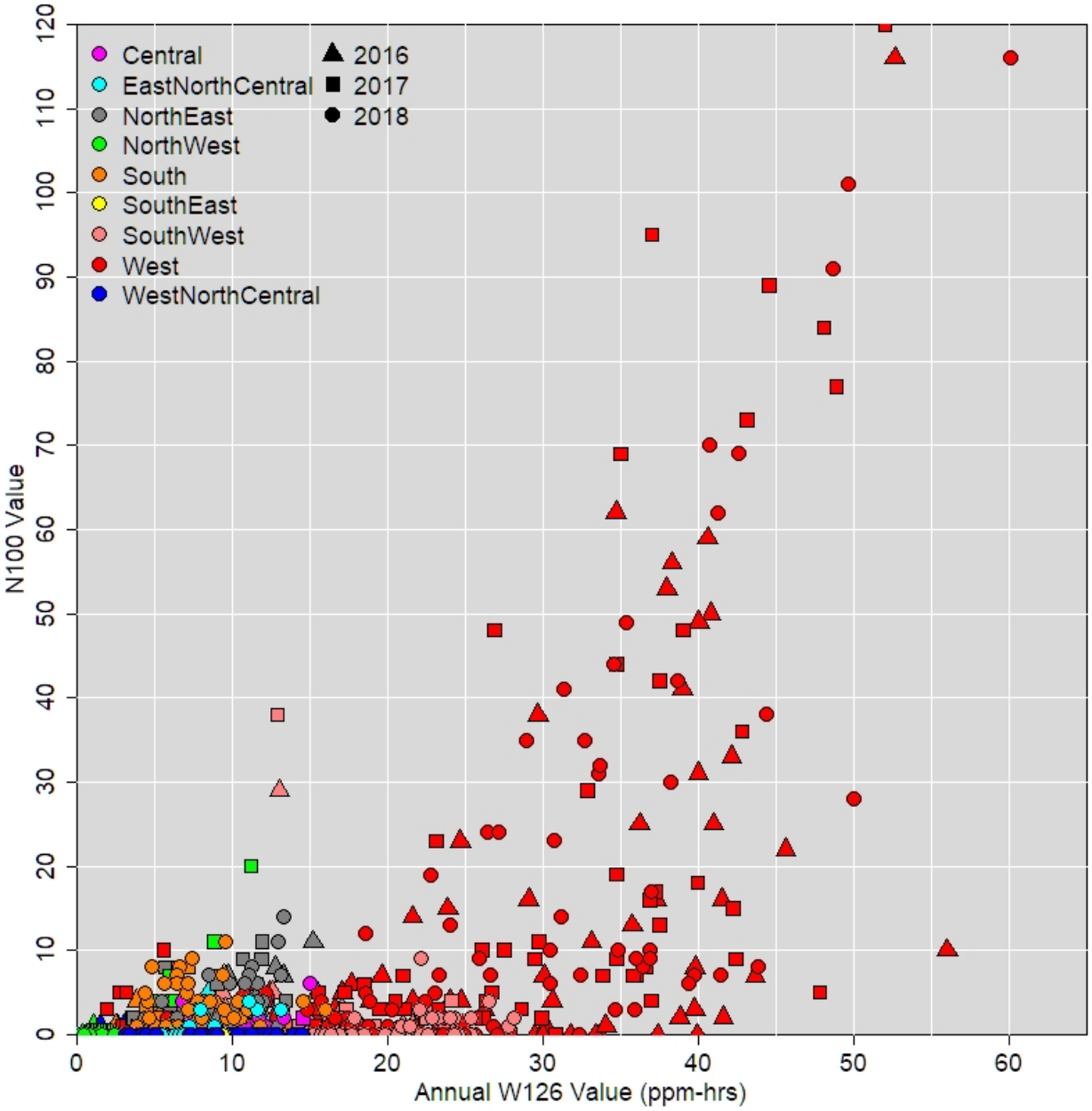

Figure 10. Scatter plot of annual N100 values (Y-axis) versus annual W126 values (x-axis), based on 2016-2018 monitoring data.

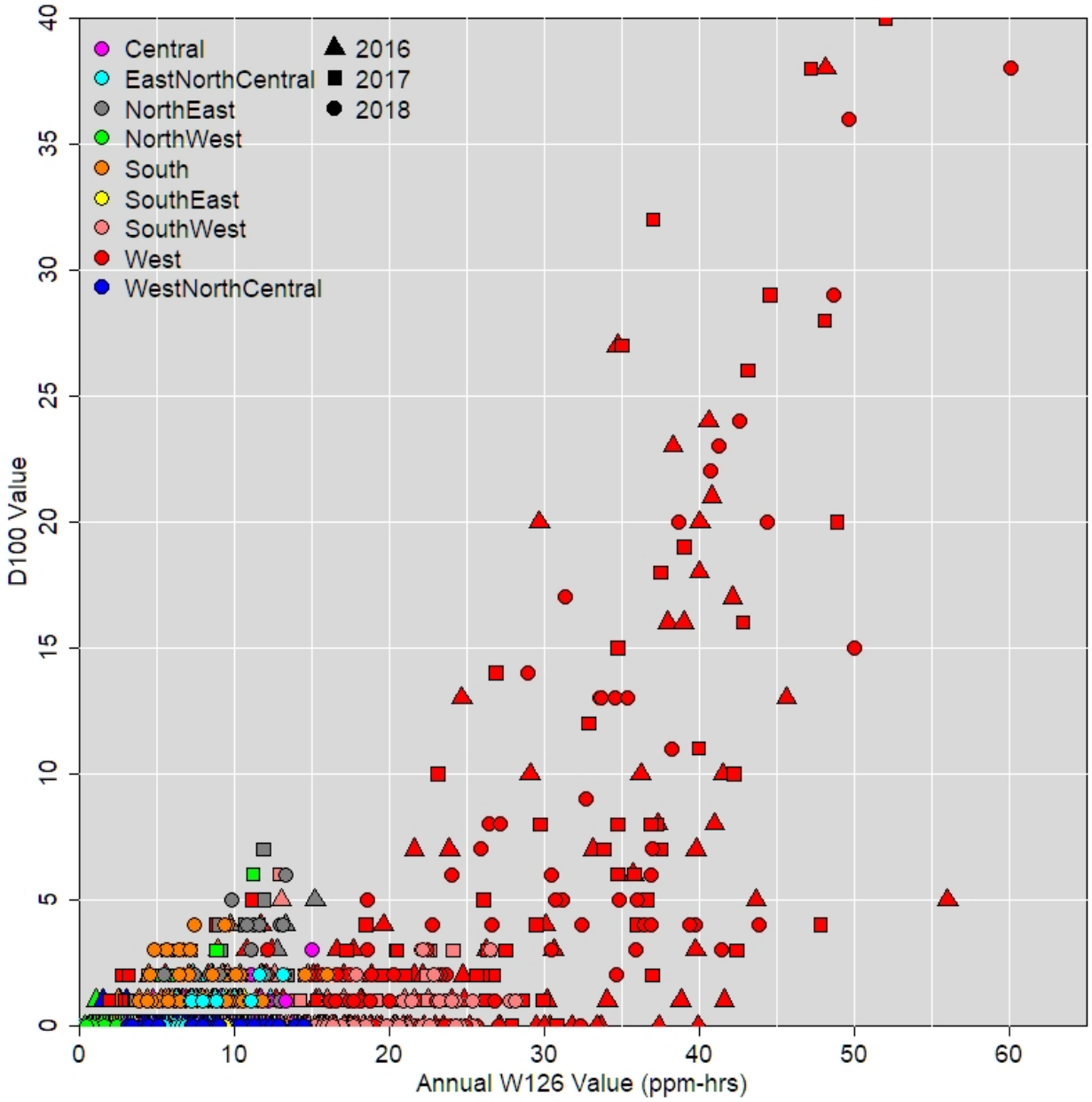

Figure 11. Scatter plot of annual D100 values (Y-axis) versus annual W126 values (x-axis), based on 2016-2018 monitoring data.

Table 1 below shows the number of sites where the 2016-2018 4th max metric values meet the current standard or the number of instances (i.e., site-years) where the 2016, 2017, and 2018 annual 4th max values are at or below the level of the current standard and the 2016, 2017, and 2018 N100 or D100 values are above various thresholds. The table also shows number of sites where the 2016-2018 W126 metric values are at or below specific W126 levels or the number of instances where the 2016, 2017, and 2018 annual W126 values are at or below specific W126 levels and the 2016, 2017, and 2018 N100 or D100 values are above various thresholds. The number of sites or instances where the N100 and D100 values were nonzero are always equal, because having at least one hour where the concentration is at or above 100 ppb guarantees having at least one day where the maximum hourly concentration is at least 100 ppb. The number of sites or instances where the D100 values exceeded 2 and 5 were generally similar to the number of sites or instances where the N100 values exceeded 5 and 10, respectively.

With regard to sites at or below specific annual 4th max and W126 values in any of the three years, according to Table 1, there were only four instances out of over 2,600 site-years (0.2%) where the N100 value exceeded 5 for sites during a year where the annual 4th max value was at or below the level of the current standard. Additionally, there were only seven sites out of over 800 (less than 1%) that met the current standard based on 2016-2018 data and also had N100 values exceeding 5 in one or more years. By contrast, there were 47 instances out of over 3,300 (1.4%) where the N100 value exceeded 5 for sites that had an annual W126 value at or below 19 ppm-hrs; and additionally 37 sites out of over 1,000 (more than 3%) that had a 2016-2018 W126 metric value was at or below 17 ppm-hrs and a N100 value exceeding 5 in one or more years. Even when looking at sites at or below a W126 level of 7 ppm-hrs, there were twice as many sites (14) with N100 values exceeding 5 than for sites meeting the current standard (7).

Table 2 shows the same statistics as in Table 1 for the annual 4th max and annual W126 values broken out into individual years, with the maximum annual value across the three years for each combination of 4th max/W126 and N100/D100 thresholds highlighted in light blue. This table shows that while there is considerable inter-annual variation in the 4th max and W126 values across years, the annual W126 values always have a higher proportion of sites below the threshold and above the N100 or D100 thresholds compared to those of the annual 4th max values. Further, during the highest year for the different N100 and D100 thresholds, the proportion of sites exceeding those thresholds is greater for the sites at/below the different annual W126 levels than it is for sites with design values at/below 70 ppb. This is also evident in comparing Figure 5 to Figure 11 and Figure 4 to Figure 10.

Table 1. Number of instances where 4th max or W126 values are at or below various thresholds and N100 or D100 values are above various thresholds based on O_3 monitoring data from recent years (2016-2018).

	Total*	Number of instances where: N100 > 0	N100 > 5	N100 > 10	Number of instances where: D100 > 0	D100 > 2	D100 > 5
		Number of sites exceeding threshold in one or more years					
3-year Total**	1,113	315 (28%)	86 (8%)	39 (4%)	315 (28%)	87 (8%)	39 (4%)
3-year 4th Max ≤ 70	853	121 (14%)	7 (0.8%)	0 (0%)	121 (14%)	3 (0.4%)	0 (0%)
3-year W126 ≤ 19	1,043	245 (23%)	38 (4%)	6 (0.6%)	245 (23%)	36 (3%)	3 (0.3%)
3-year W126 ≤ 17	1,031	237 (23%)	37 (4%)	6 (0.6%)	237 (23%)	34 (3%)	3 (0.3%)
3-year W126 ≤ 15	1,002	225 (22%)	34 (3%)	6 (0.6%)	225 (23%)	30 (3%)	3 (0.3%)
3-year W126 ≤ 7	667	114 (17%)	14 (2%)	2 (0.3%)	114 (17%)	10 (2%)	1 (0.1%)
		Total number of instances (site/years) exceeding threshold					
Annual Total***	3,607	533 (15%)	154 (4%)	85 (2%)	533 (15%)	168 (5%)	83 (2%)
Annual 4th Max ≤ 70	2,630	114 (4%)	4 (0.2%)	0 (0%)	114 (4%)	2 (0.1%)	0 (0%)
Annual W126 ≤ 25	3,479	416 (12%)	57 (2%)	16 (0.5%)	416 (12%)	64 (2%)	9 (0.3%)
Annual W126 ≤ 19	3,370	366 (11%)	47 (1%)	10 (0.3%)	366 (11%)	49 (2%)	4 (0.1%)
Annual W126 ≤ 17	3,318	349 (11%)	44 (1%)	9 (0.3%)	349 (11%)	45 (1%)	4 (0.1%)
Annual W126 ≤ 15	3,235	331 (10%)	44 (1%)	9 (0.3%)	331 (10%)	43 (1%)	4 (0.1%)
Annual W126 ≤ 7	2,134	141 (7%)	14 (0.7%)	0 (0%)	141 (7%)	11 (0.5%)	0 (0%)

* Total number of sites where the 3-year 4th max or W126 value is at or below the threshold, or the total number of instances (i.e., site/years) where the annual 4th max or W126 value is at or below the threshold.

** First column shows the number of sites with sufficient data to calculate valid 3-year 4th max and W126 values. Subsequent columns tally the subset of those sites where the N100 or D100 value exceeds the threshold in one or more years.

*** First column shows the number of instances where a site had sufficient data to calculate valid annual 4th max and W126 values. Subsequent columns tally the subset of those instances where the N100 or D100 value exceeds the threshold.

Table 2. Number of instances where annual 4th max or W126 values are at or below various thresholds and N100 or D100 values are above various thresholds based on O_3 monitoring data from 2016-2018

	Total Number of Sites*	Number of sites where:			Number of sites where:		
		N100 > 0	N100 > 5	N100 > 10	D100 > 0	D100 > 2	D100 > 5
		Number of sites exceeding threshold in the maximum year of the three					
3-year 4th Max ≤ 70	853	53 (6%)	4 (0.5%)	0 (0%)	53 (6%)	2 (0.2%)	0 (0%)
Annual 4th Max ≤ 70	See Below	43 (5%)	3 (0.3%)	0 (0%)	43 (5%)	2 (0.2%)	0 (0%)
Annual W126 ≤ 25		165 (14%)	25 (2%)	6 (0.5%)	165 (14%)	25 (2%)	4 (0.3%)
Annual W126 ≤ 19		145 (13%)	21 (2%)	4 (0.4%)	145 (13%)	20 (28%)	3 (0.3%)
Annual W126 ≤ 17		138 (13%)	20 (2%)	4 (0.4%)	138 (13%)	18 (2%)	3 (0.3%)
Annual W126 ≤ 15		130 (13%)	20 (2%)	4 (0.4%)	130 (13%)	18 (2%)	3 (0.3%)
Annual W126 ≤ 7		59 (7%)	8 (1%)	0 (0%)	59 (7%)	6 (1.0%)	0 (0%)
		Number of sites exceeding threshold in individual years					
2018 Total**	1,187	208 (18%)	62 (5%)	28 (2%)	208 (18%)	64 (5%)	25(2%)
2017 Total**	1,205	179 (15%)	52 (4%)	29 (2%)	179 (15%)	59 (5%)	31 (3%)
2016 Total**	1,215	146 (12%)	40 (3%)	28 (2%)	146 (12%)	46 (4%)	27 (2%)
2018 4th Max ≤ 70	801	32 (4%)	0 (0%)	0 (0%)	32 (4%)	0 (0%)	0 (0%)
2017 4th Max ≤ 70	931	43 (5%)	1 (0.1%)	0 (0%)	43 (5%)	0 (0%)	0 (0%)
2016 4th Max ≤ 70	898	39 (4%)	3 (0.3%)	0 (0%)	39 (4%)	2 (0.2%)	0 (0%)
2018 W126 ≤ 25	1,142	165 (14%)	25 (2%)	6 (0.5%)	165 (14%)	25 (2%)	2 (0.2%)
2017 W126 ≤ 25	1,163	138 (12%)	19 (2%)	5 (0.4%)	138 (12%)	23 (2%)	4 (0.3%)
2016 W126 ≤ 25	1,174	113 (10%)	13 (1%)	5 (0.4%)	113 (1%)	16 (1%)	3 (0.3%)
2018 W126 ≤ 19	1,090	145 (13%)	21 (2%)	4 (0.4%)	145 (13%)	20 (2%)	1 (0.1%)
2017 W126 ≤ 19	1,128	120 (11%)	17 (2%)	4 (0.4%)	120 (11%)	17 (2%)	3 (0.3%)
2016 W126 ≤ 19	1,152	101 (9%)	9 (0.8%)	2 (0.2%)	101 (9%)	12 (1%)	0 (0%)
2018 W126 ≤ 17	1,066	138 (13%)	20 (2%)	3 (0.3%)	138 (13%)	18 (2%)	1 (0.1%)
2017 W126 ≤ 17	1,113	114 (10%)	16 (1%)	4 (0.4%)	114 (10%)	16 (1%)	3 (0.3%)
2016 W126 ≤ 17	1,139	97 (9%)	8 (0.7%)	2 (0.2%)	97 (9%)	11 (1%)	0 (0%)
2018 W126 ≤ 15	1,029	130 (13%)	20 (2%)	3 (0.3%)	130 (13%)	18 (2%)	1 (0.1%)
2017 W126 ≤ 15	1,092	109 (10%)	16 (1%)	4 (0.4%)	109 (10%)	15 (1%)	3 (0.3%)
2016 W126 ≤ 15	1,114	92 (8%)	8 (0.7%)	2 (0.2%)	92 (8%)	10 (0.9%)	0 (0%)
2018 W126 ≤ 7	625	47 (8%)	8 (1%)	0 (0%)	47 (8%)	6 (1%)	0 (0%)
2017 W126 ≤ 7	788	59 (7%)	5 (0.6%)	0 (0%)	59 (7%)	4 (0.5%)	0 (0%)
2016 W126 ≤ 7	721	35 (5%)	1 (0.1%)	0 (0%)	35(5%)	1 (0.1%)	0(0%)

* Total number of sites where the annual 4th max or W126 value is at or below the threshold.

** First column represents the number of sites with sufficient data to calculate a valid annual 4th max value. Subsequent columns tally the subset of those sites where the N100 or D100 value exceeds the threshold in one or more years.

3.2 National Analysis Using Historical Air Quality Data

Figure 12 and Figure 13 show the trend in national 10th percentile, median, 90th percentile and mean N100 and D100 values, respectively, based on 808 U.S. O_3 monitoring sites with complete data for 2000 to 2018. A site must have 75% annual data completeness in terms of the 4th max metric (see section 2.2) for at least 15 of the 19 years, with no more than two consecutive years missing to be included in the trend. As can be seen from the figures, the median N100 and D100 values in the U.S. have been zero since 2006, meaning over half of the monitoring sites have N100 and D100 values of zero. The mean N100 value has decreased from more than ten in 2000-2002 to less than two in recent years, a decline of more than 80%. Similarly, the mean D100 value has decreased from four or more in 2000-2002 to less than one in recent years, also a decline of more than 80%. The 90th percentile values of both metrics have decreased at an even faster rate.

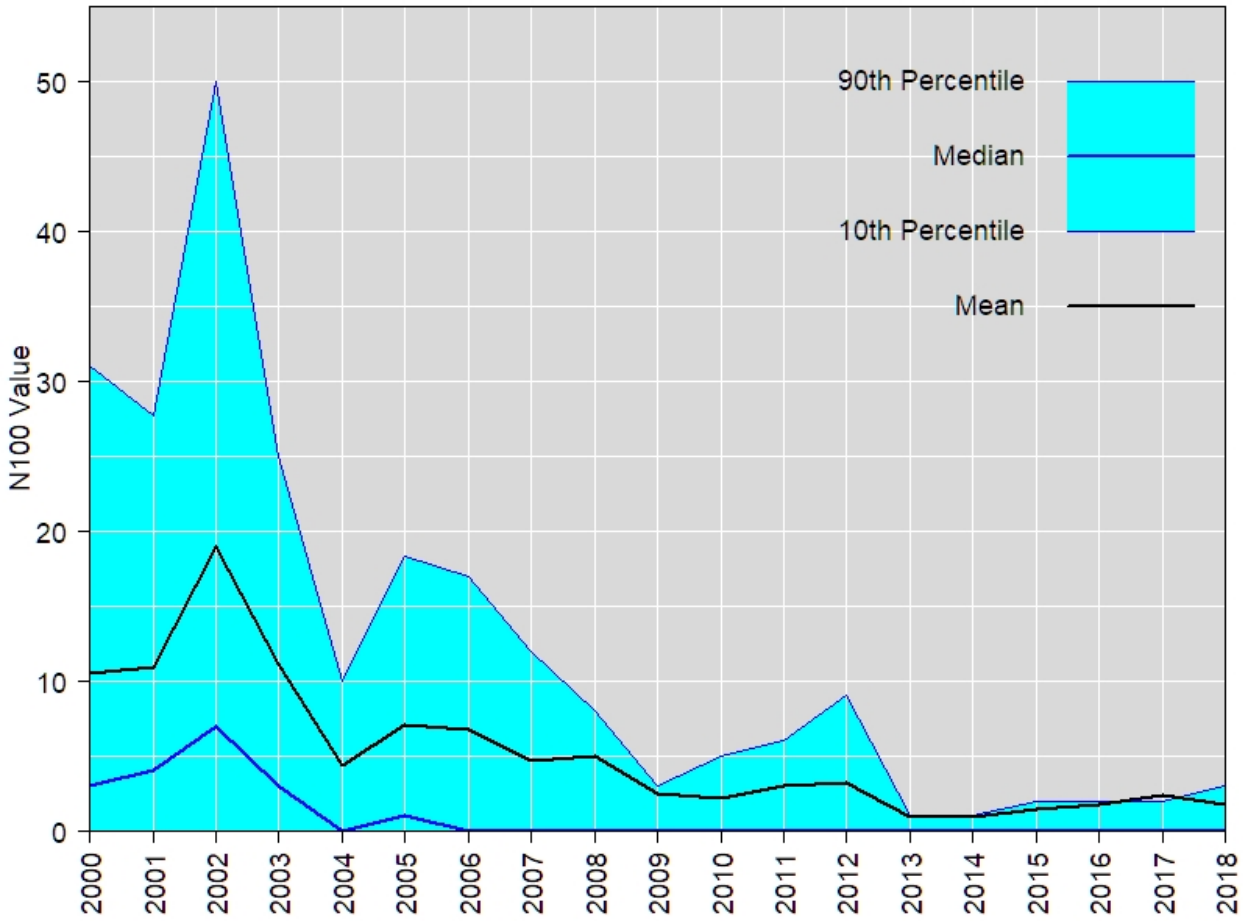

Figure 12. Trend in N100 values from 2000 to 2018 based on data from 808 U.S. O_3 monitoring sites

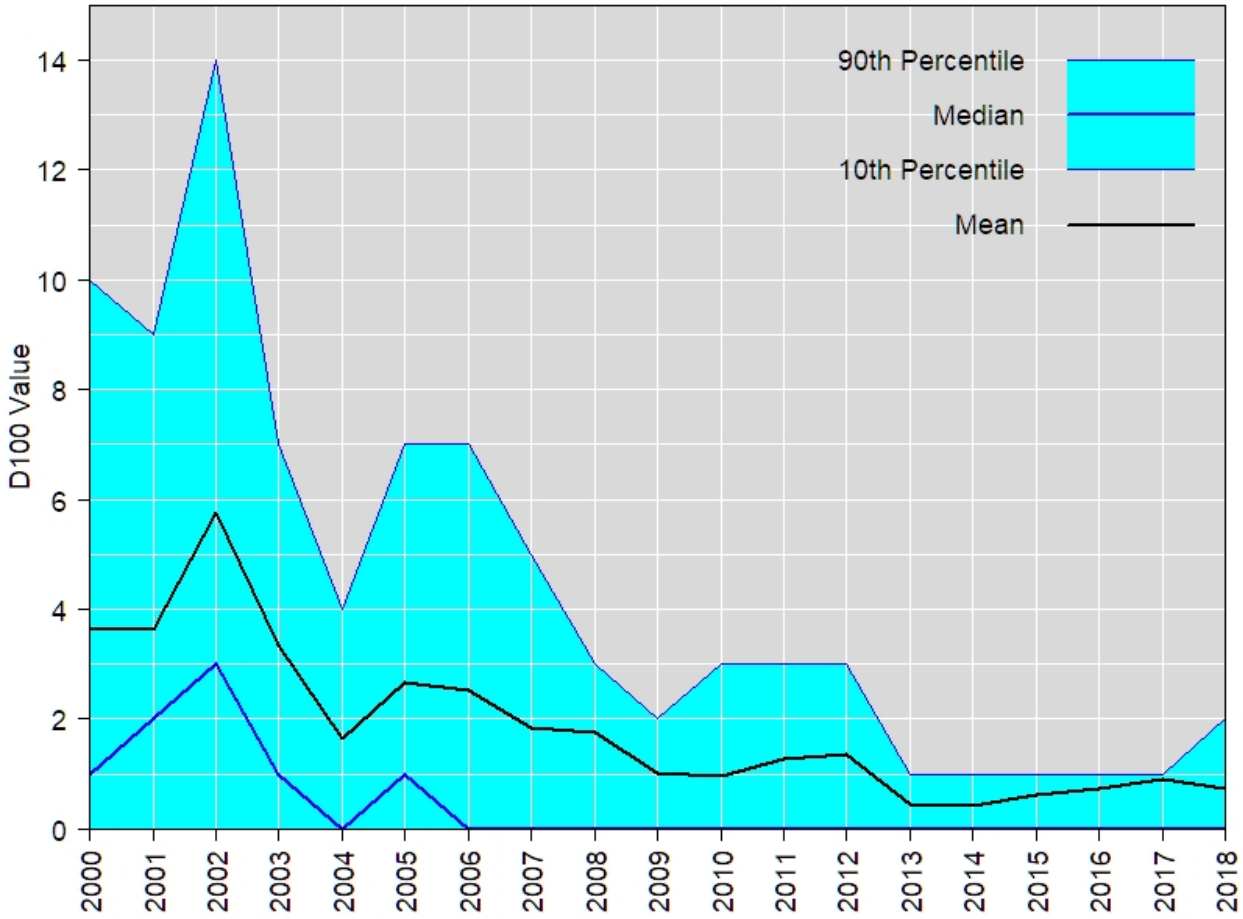

Figure 13. Trend in D100 values from 2000 to 2018 based on data from 808 U.S. O_3 monitoring sites

Table 3 below shows the number of instances (site-years) where a site had an annual 4th max value or 4th max metric value at or below the level of the current standard and an annual N100 or D100 value above various thresholds based on the full dataset spanning years 2000 to 2018. The table also shows number of instances (site-years) where a site had an annual W126 value or W126 metric value at or below specific W126 levels and N100 or D100 values above various thresholds based on the full 2000-2018 dataset. The numbers in Table 3 are generally proportionally similar to those shown previously in Table 1.

According to Table 3, there were only 9 instances where the N100 value exceeded 5 at a site with an annual 4th max value at or below the level of the current standard, and only 89 instances out of over 8,000 (about 1%) that met the current standard and also had N100 values exceeding 5 in one or more of the three years of the design value period. By contrast, there were over 1,500 instances where the annual W126 value was less than or equal to 19 ppm-hrs and the N100 value in that year exceeded 5, and nearly 2,500 instances (more than 16%) where the

W126 metric value was at or below 17 ppm-hrs and the N100 value exceeded 5 in one or more years of the 3-year period. Even when looking at sites at or below a W126 level of 7 ppm-hrs, there were more instances with N100 values exceeding 5 (145) than for sites meeting the current standard (89).

Table 3. Number of instances where 4th max or W126 values are at or below various thresholds and N100 or D100 values are above various thresholds based on data from all years (2000-2018)

		Number of instances where:			Number of instances where:		
		N100 > 0	N100 > 5	N100 > 10	D100 > 0	D100 > 2	D100 > 5
	Total*	Number of instances where site exceeds threshold in one or more years					
3-year Total**	17,879	9,306 (52%)	4,661 (26%)	3,063 (17%)	9,306 (52%)	4,658 (26%)	2,364 (13%)
3-year 4th Max ≤ 70	8,116	1,371 (17%)	89 (1%)	14 (0.2%)	1,371 (17%)	74 (0.9%)	7 (0.1%)
3-year W126 ≤ 19	15,804	7,319 (46%)	2,987 (19%)	1,616 (10%)	7,319 (46%)	2,928 (19%)	1,002 (6%)
3-year W126 ≤ 17	15,000	6,621 (44%)	2,492 (17%)	1,263 (8%)	6,621 (44%)	2,432 (16%)	729 (5%)
3-year W126 ≤ 15	13,865	5,716 (41%)	1,926 (14%)	902 (7%)	5,716 (41%)	1,869 (13%)	495 (4%)
3-year W126 ≤ 7	6,059	1,201 (20%)	145 (2%)	39 (0.6%)	1,201 (20%)	133 (2%)	23 (0.4%)
		Total number of instances (site/years) exceeding threshold					
Annual Total***	22,102	7,489 (34%)	3,500 (16%)	2,232 (10%)	7,489 (34%)	3,468 (16%)	1,640 (7%)
Annual 4th Max ≤ 70	10,265	501 (5%)	9 (0.1%)	0 (0%)	501 (5%)	5 (<0.1%)	0 (0%)
Annual W126 ≤ 25	20,684	6,165 (30%)	2,356 (11%)	1,234 (6%)	6,165 (30%)	2,295 (11%)	687 (3%)
Annual W126 ≤ 19	18,941	4,836 (26%)	1,529 (8%)	713 (4%)	4,836 (26%)	1,456 (8%)	334 (2%)
Annual W126 ≤ 17	17,941	4,179 (23%)	1,183 (7%)	516 (3%)	4,179 (23%)	1,128 (6%)	228 (1%)
Annual W126 ≤ 15	16,661	3,455 (21%)	853 (5%)	315 (2%)	3,455 (21%)	815 (5%)	140 (0.8%)
Annual W126 ≤ 7	8,612	709 (8%)	61 (0.7%)	3 (<0.1%)	709 (8%)	49 (0.6%)	2 (<0.1%)

* Total number of sites where the 3-year 4th max or W126 value is at or below the threshold, or the total number of instances (i.e., site/years) where the annual 4th max or W126 value is at or below the threshold.

** First column shows the number of sites with sufficient data to calculate valid 3-year 4th max and W126 values. Subsequent columns tally the subset of those sites where the N100 or D100 value exceeds the threshold in one or more years.

*** First column shows the number of instances where a site had sufficient data to calculate valid annual 4th max and W126 values. Subsequent columns tally the subset of those instances where the N100 or D100 value exceeds the threshold.

4. SUMMARY

The presentation here shows various analyses of ambient air monitoring data for O_3 concentrations in the U.S. relating to the form and averaging time of the current secondary standard, the W126-based cumulative exposure index, the N100 metric (number of hours at or above 100 ppb) and D100 metric (number of days with one or more hours at or above 100 ppb).

- About 72% of the O_3 monitoring sites with valid design values in 2016-2018 did not have any hourly concentrations at or above 100 ppb, and another 15% had only a single day where hourly O_3 concentrations reached 100 ppb or more (Figure 2 and Figure 3).
- Based on data from 2016-2018, sites where the current standard was met (4^{th} max metric value was at or below 70 ppb) had a maximum annual N100 count of 10 and D100 count of 3 (Figure 4 and Figure 5). Sites with W126 metric values as low as 5 ppm-hrs had a maximum annual N100 count of 10 and D100 count of 4. At sites with W126 metric values below 20 ppm-hrs, several sites had N100 values of ten or greater and D100 values of five or greater, with individual sites having as many as 38 hours on up to seven distinct days with concentrations of 100 ppb or greater (Figure 6 and Figure 7).
- In 2016-2018, sites where the annual 4^{th} max value was at or below 70 ppb had a maximum annual N100 count of 6 and D100 count of 3 (Figure 8 and Figure 9). Sites with annual W126 values as low as 5 ppm-hrs had a maximum N100 count of 8 and D100 count of 3. At sites with annual W126 values below 20 ppm-hrs, some sites had ten or more hours on up to seven distinct days where O_3 concentrations reached 100 ppb or more (Figure 10 and Figure 11).
- Based on data from 2016-2018, less than 1% of sites that met the current standard had an N100 value exceeding 5 in one or more years. By comparison, more than 3% of sites where the W126 metric value was at or below 17 ppm-hrs had an N100 value exceeding 5 (Table 1). While there was considerable variability across individual years, there were always far fewer sites with N100 values exceeding 5 among sites with annual 4^{th} max values at or below the level of the current standard than among sites with annual W126 values at or below 19 ppm-hrs (Table 2).
- Based on data from 2000-2018, about 1% of design values that met the current standard had N100 values exceeding 5 in one or more years of the 3-year period. By comparison, about 17% of W126 metric values at or below 17 ppm-hrs had N100 values exceeding 5 in one or more years of the 3-year period (Table 3).
- Since 2000-2002, the national mean N100 and D100 values have decreased by more than 80% (Figure 12 and Figure 13).

5. REFERENCES

Karl, T and Koss, WJ (1984). Regional and national monthly, seasonal, and annual temperature weighted by area, 1895-1983. 4-3. National Environmental Satellite and Data Information Service (NESDIS). Asheville, NC.

U.S. EPA (2020). Policy Assessment for the Review of National Ambient Air Quality Standards for Ozone. Office of Air Quality Planning and Standards, Health and Environmental Impacts Divison. Research Triangle Park, NC. U.S. EPA. EPA-452/R-20-001. May 2020.