UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

November 24, 2014

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

MEMORANDUM

SUBJECT: Analysis of Overlapping 8-hour Daily Maximum Ozone Concentrations

FROM: Benjamin Wells (EPA, OAQPS)

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

Overview

Appendix P to 40 CFR Part 50 contains the data handling conventions for determining whether the 2008 National Ambient Air Quality Standards (NAAQS) for ozone (O_3) are met at an ambient air quality monitoring site. This appendix contains instructions for calculating daily maximum 8-hour average (MDA8) values from hourly O_3 concentration measurements collected at ambient monitoring sites. In particular, these instructions state that "*the daily maximum 8-hour concentrations from two consecutive days may have some hourly concentrations in common. Generally, overlapping daily maximum 8-hour averages are not likely, except in those non-urban monitoring locations with less pronounced diurnal variation in hourly concentrations.*" In some situations where an O_3 monitor is affected by transport which occurs overnight, this may lead to a single exceedance of the O_3 NAAQS being counted twice. O_3 monitors in rural areas may be disproportionately impacted by this phenomenon, which could lead to additional exceedances of the O_3 NAAQS in areas which have few anthropogenic sources of ozone precursors. Therefore, it is useful to quantify the frequency and magnitude of these overlapping MDA8 values, and their potential impact on attainment of a revised O_3 NAAQS.

This memo discusses the results of a technical analysis which examines overlapping MDA8 values at ambient O_3 monitoring sites in the U.S. based on air quality data from 2004 to 2013. First, the analysis identifies the frequency of overlapping MDA8 events at each site, as well as the number of these events with concentrations that exceed the current O_3 standard level of 75 ppb and alternative levels of 70 ppb, 65 ppb, and 60 ppb. Next, the analysis examines the potential for overlapping MDA8 events to impact the annual 4th highest MDA8 concentration, the metric used to determine attainment of the O_3 NAAQS. Finally, the analysis examines two methods for eliminating overlapping MDA8 events from consideration when calculating MDA8 values, and quantifies the impact of each method on annual 4th highest MDA8 concentrations.

Data and Analysis

Hourly O_3 concentration data from 2004 to 2013 were retrieved from EPA's Air Quality System (AQS) database for 1,654 ambient O_3 monitoring sites in the U.S. For each monitored day, the MDA8 value and the starting hour of the period where the MDA8 value occurred were determined according to Appendix P to 40 CFR Part 50. Overlapping MDA8 events were defined as any pair of consecutive days where the MDA8 values were based on 8-hour periods with one or more hours in common (i.e., the starting hours were less than 8 hours apart). Data completeness criteria were then applied to the MDA8 values to remove the impact of sites with little or no data on the analysis. First, for each site, any years where valid MDA8 values were available for fewer than 50% of the days in the O_3 monitoring season were removed. Next, sites with fewer than 5 years of data were removed from the resulting data set. The final data set used in the analysis consisted of 1,261 O_3 monitoring sites.

Two methods were applied to remove the influence of overlapping MDA8 events from the final data set. Method 1 iteratively identifies each pair of overlapping MDA8 values, keeps the higher MDA8 value in each pair, and replaces the lower MDA8 value in each pair with the next highest MDA8 value on that day which does not overlap with any other MDA8 values. Method 2 calculates the MDA8 values based on the 8-hour periods starting with 7:00 AM to 3:00 PM and ending with 11:00 PM to 7:00 AM (i.e., this method removes 8-hour periods with starting hours from 12:00 AM to 6:00 AM). Effectively, Method 2 uses all 24 hourly concentration values, but reduces the number of 8-hour averages used to determine the MDA8 values. Annual 4th highest MDA8 values were determined using each method, then compared with the annual 4th highest MDA8 values calculated according to Appendix P to 40 CFR Part 50.

Results and Discussion

Frequency and Magnitude of Overlapping MDA8 Events

Nationally, overlapping MDA8 events occurred on 3.5% of all monitored days in 2004 to 2013. The percentages of these overlapping MDA8 values greater than 60, 65, 70, and 75 ppb are shown in Table 1. While the vast majority of overlapping MDA8 values were less than or equal to 60 ppb, the proportion of overlapping MDA8 values greater than each level increased below 75 ppb, roughly doubling for each 5 ppb increment.

Figure 1 shows the distribution of the start hours based on all monitored MDA8 values. Under typical conditions, ozone concentrations follow a diurnal pattern, with minimum concentrations occurring in the early morning hours and maximum concentrations occurring during the late afternoon hours. Since MDA8 values are defined by their starting hour, the peak 8-hour average values typically occur near the middle of the day, as reflected in Figure 1. However, Figure 1 also shows small spikes in the fraction of MDA8 values occurring in the first and last hours of the day. These spikes reflect transport situations where ozone formed during the daytime reaches a monitoring site downwind from the source area during the evening or early morning hours.

Next, Figures 2 and 3 show the distributions of the MDA8 start hours based on days with MDA8 values greater than 60 ppb and 75 ppb, respectively. These figures show that high MDA8 values are less likely to occur during evening or early morning hours. Less than 3% of MDA8 values greater than 60 ppb occurred between 6:00 PM and 6:00 AM, and less than 2% of MDA8 values greater than 75 ppb occurred during these hours, compared with about 12% of all monitored MDA8 values. Finally, Figure 4 shows the distribution of the MDA8 start hours based on the days with the 4 highest MDA8 values for each site and year. This distribution appears to be similar to the distribution of MDA8 values for 60 and 75 ppb, with a slight shift toward more MDA8 values occurring later in the afternoon.

Table 1. Percentage of overlapping MDA8 values greater than various MDA8 levels

MDA8 Level (ppb)	75	70	65	60
% of Overlapping MDA8 Values > Level	0.8%	1.6%	3.3%	6.3%

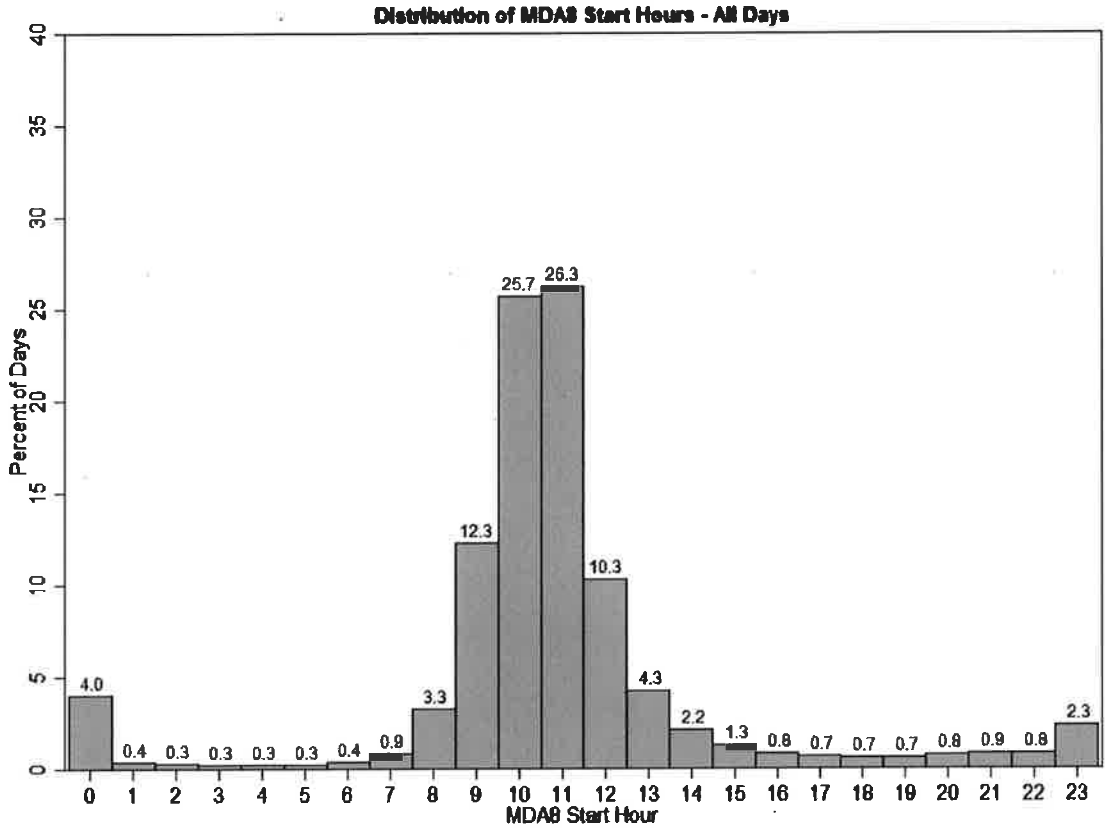


Figure 1. Distribution of MDA8 start hours based on all monitored days

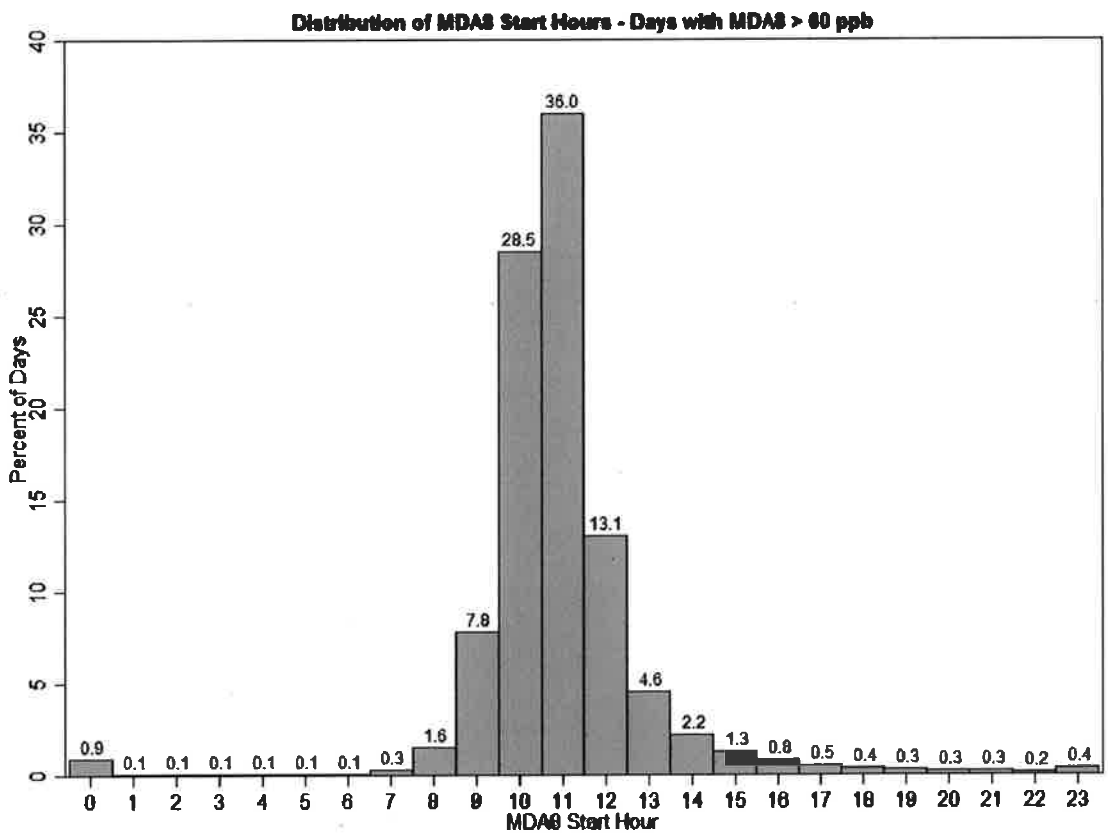


Figure 2. Distribution of MDA8 start hours based on days with MDA8 values greater than 60 ppb

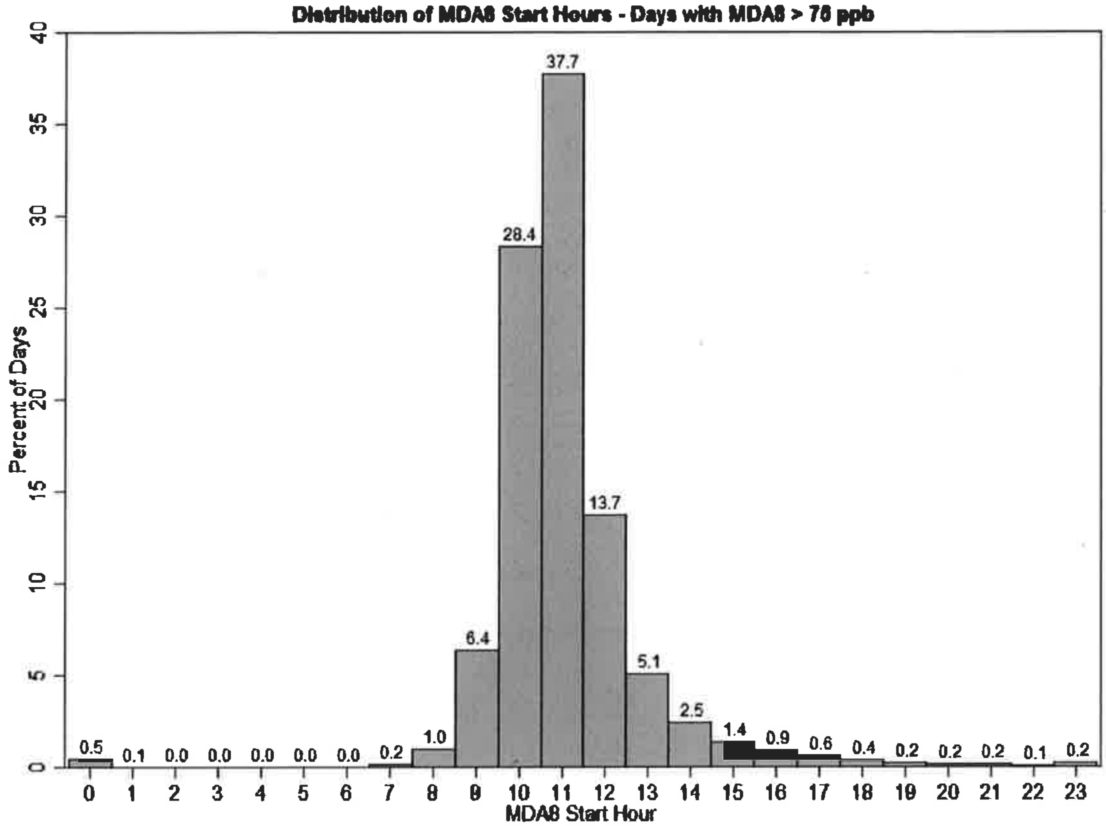


Figure 3. Distribution of MDA8 start hours based on days with MDA8 values greater than 75 ppb

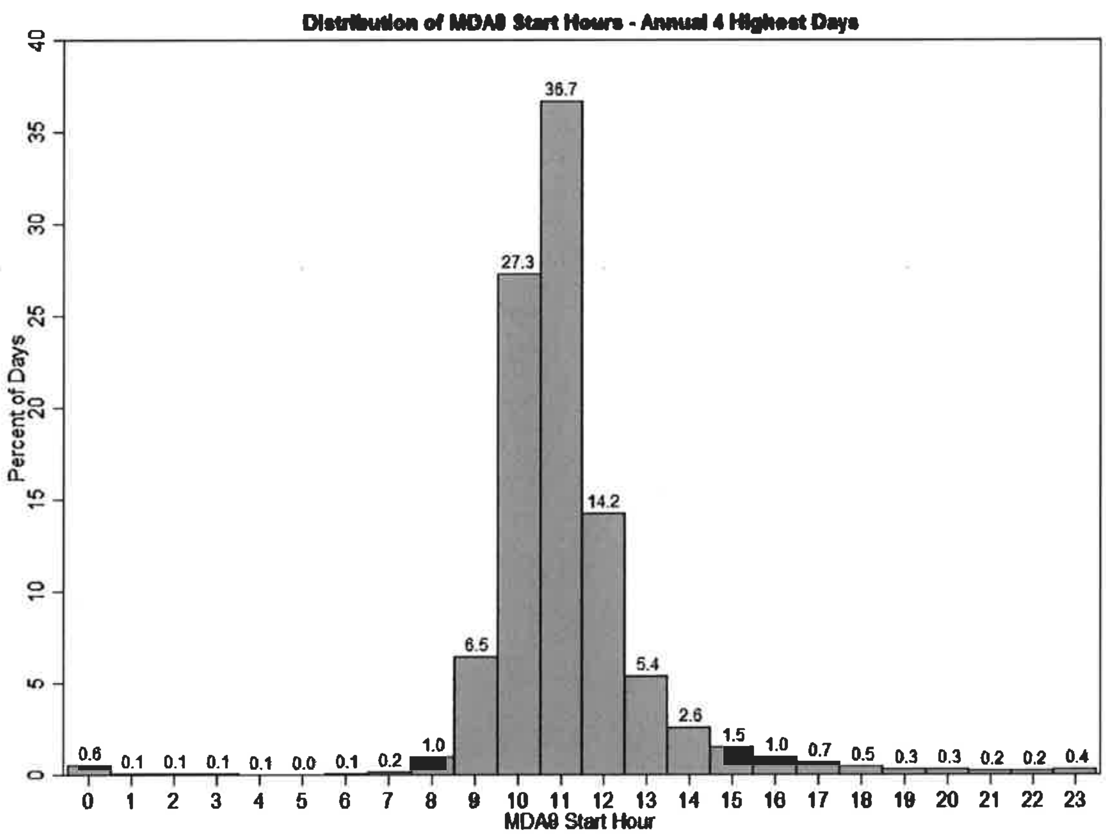


Figure 4. Distribution of MDA8 start hours based on the annual 4 highest MDA8 values at each monitoring site

Figure 5 shows a map of the annual average number of overlapping MDA8 events at each monitoring site based on 2004-2013 air quality data. Nationally, 99.5% of all monitors recorded at least one overlapping MDA8 event during this period, 81% of all monitors had an average of at least one event per year, and 12% of all monitors had an average of ten or more overlapping MDA8 events per year, up to a maximum of 60 events per year. Furthermore, Figure 5 shows that the occurrence of overlapping MDA8 events does not appear to be limited to rural areas.

Next, Figures 6 through 9 show maps of the annual average number of overlapping MDA8 values greater than 60 ppb, 65 ppb, 70 ppb, and 75 ppb, respectively. These figures show that the vast majority of high overlapping MDA8 values occur in rural areas. Physically, this pattern is consistent with the underlying principles of atmospheric chemistry related to ozone formation and titration. Near urban areas, higher NOx levels favor increased O_3 titration rates, which cause O_3 concentrations to decrease quickly after sunset. By contrast, in rural areas with lower NOx levels, titration rates are much slower, and ozone molecules may be transported long distances overnight.

Based on Figures 6 through 9, the monitors which most frequently measured high overlapping MDA8 values tended to fall into one of two categories. The first category is mountainous areas or regions with complex terrain. Specifically, many monitors in the Appalachians, the Ozark Plateau, the inter-mountain West, and the mountain ranges of eastern California appear to be frequently impacted by high overlapping MDA8 values. These regions are often characterized by flatter diurnal patterns in O_3 concentrations, especially higher nighttime concentrations, thus O_3 transport events are more likely to cause higher overlapping MDA8 values in these regions. The second category is coastal areas downwind from major urban areas. Specifically, monitors along the Northeast Atlantic coast, the Gulf of Mexico, and the Great Lakes region appear to be frequently impacted by high overlapping MDA8 values. Low NOx emissions and high winds make favorable conditions for O_3 transport over open water, often resulting in high overlapping MDA8 values downwind from large coastal cities such as Chicago and New York.

Finally, Table 2 shows percentages of monitors with various frequencies of overlapping MDA8 values greater than 60, 65, 70, and 75 ppb. Table 2 shows that overlapping MDA8 values exceeding the current O_3 standard of 75 ppb are relatively infrequent, but the frequency of these occurrences increases for levels of 70, 65, and 60 ppb. Thus, there is a greater potential for exceedances of the NAAQS to be counted twice at levels below the current standard.

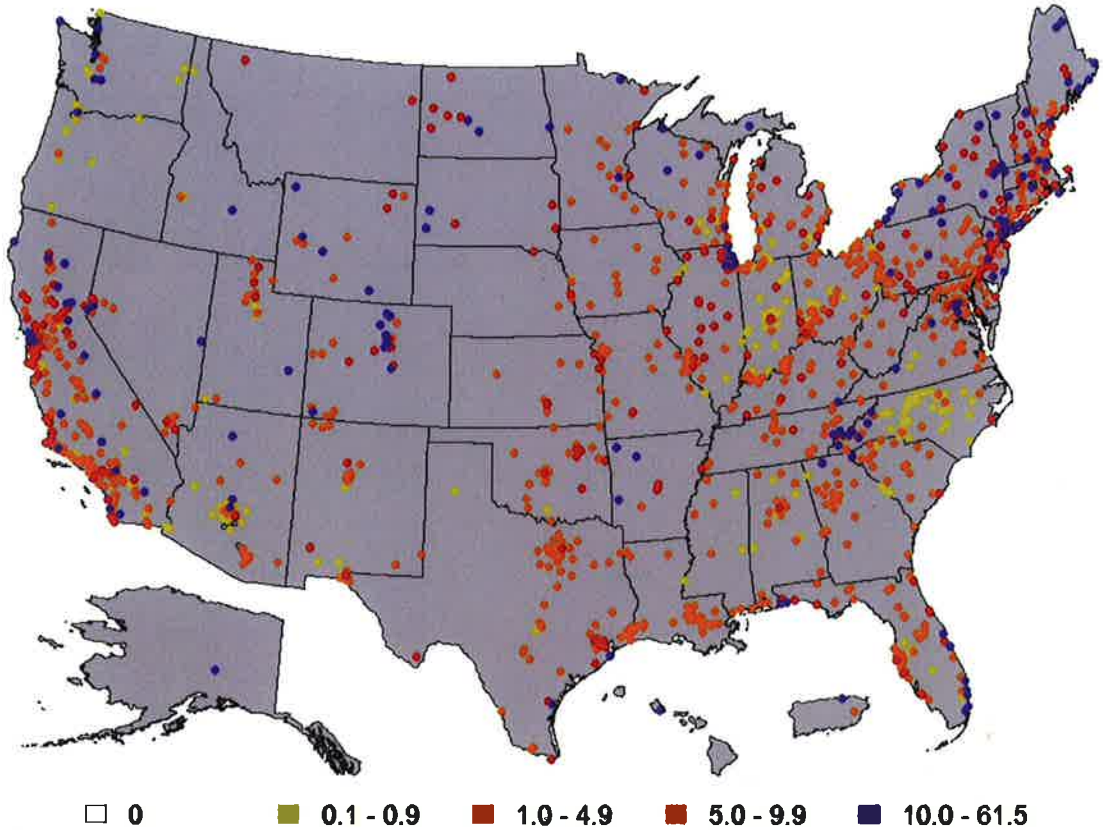


Figure 5. Average annual number of overlapping MDA8 events

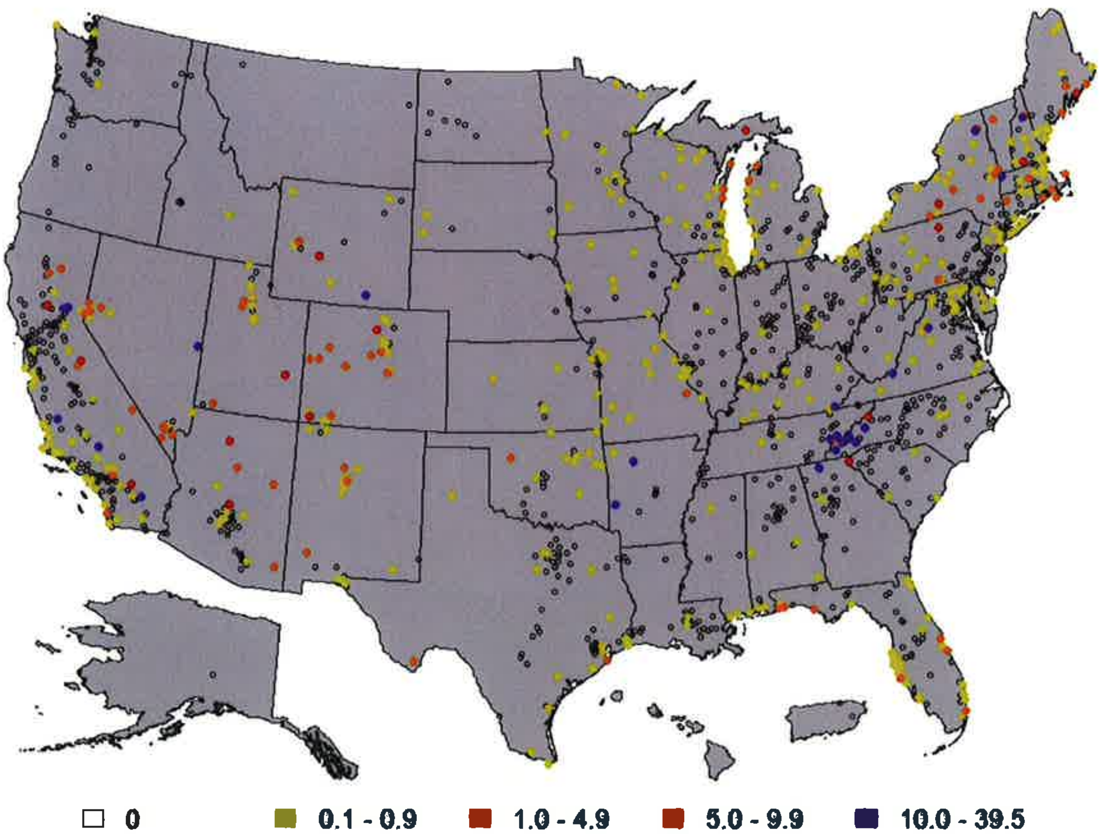
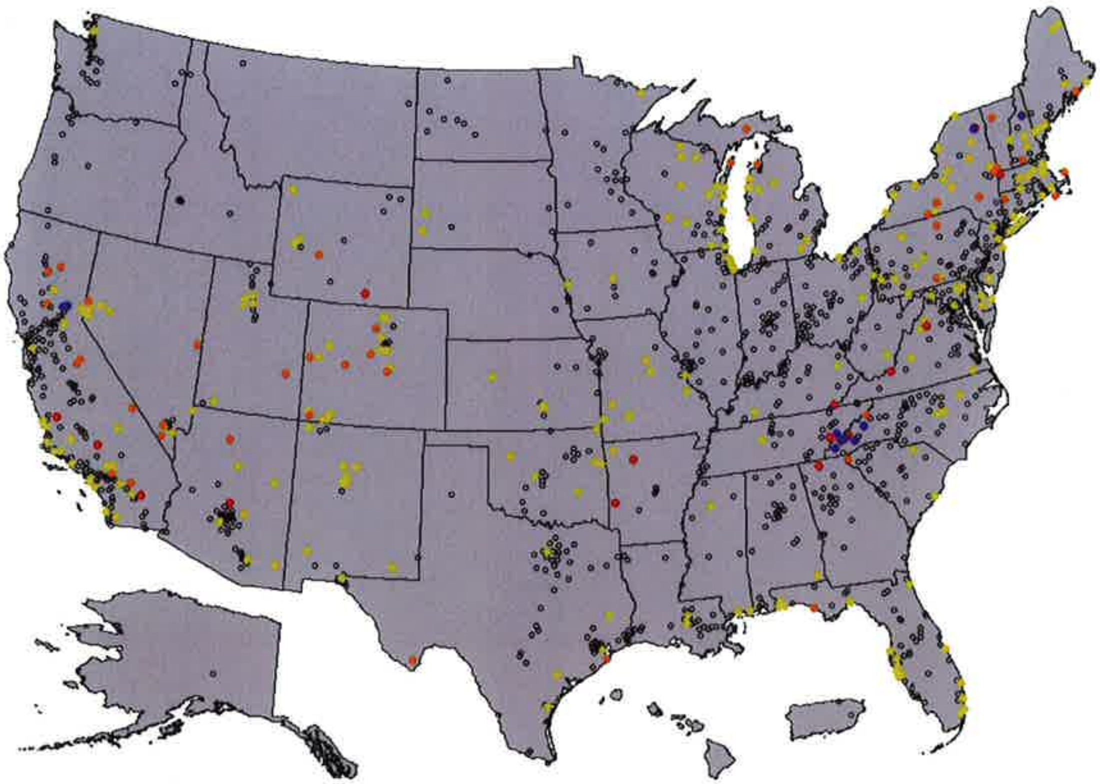
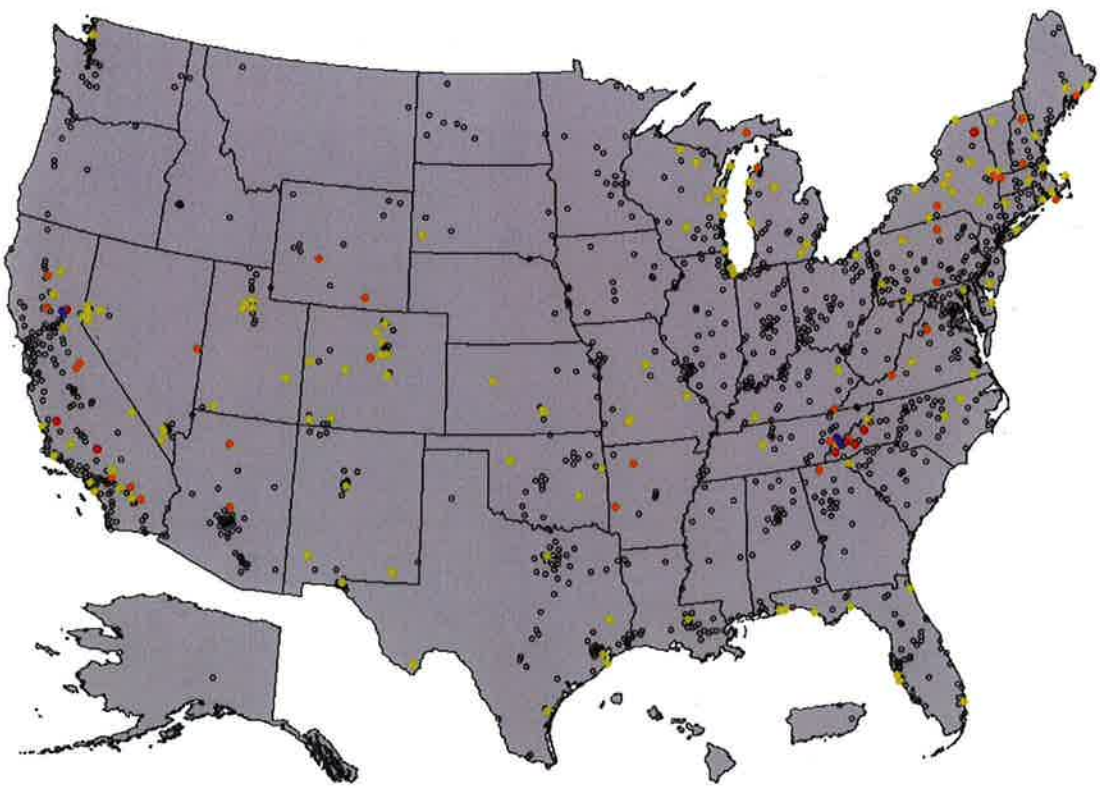


Figure 6. Average annual number of overlapping MDA8 values greater than 60 ppb



□ 0 ■ 0.1 - 0.9 ■ 1.0 - 4.9 ■ 5.0 - 9.9 ■ 10.0 - 22.4

Figure 7. Average annual number of overlapping MDA8 values greater than 65 ppb



□ 0 ■ 0.1 - 0.9 ■ 1.0 - 4.9 ■ 5.0 - 9.9 ■ 10.0 - 11.6

Figure 8. Average annual number of overlapping MDA8 values greater than 70 ppb

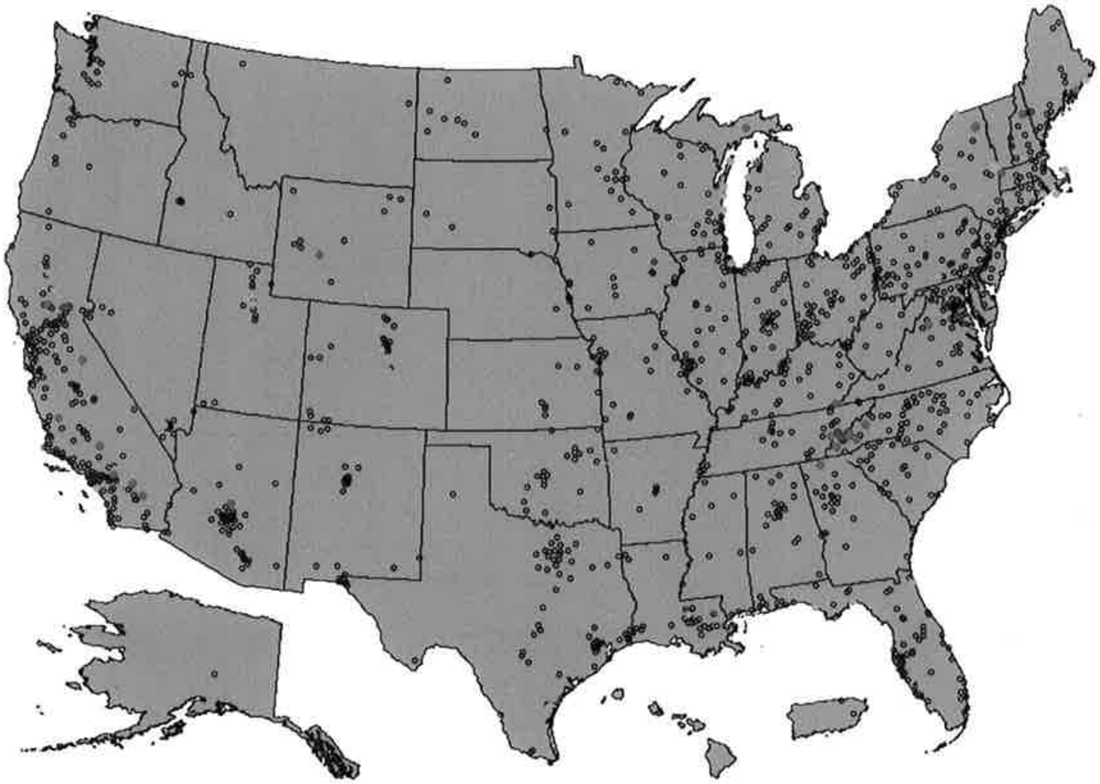


Figure 9. Average annual number of overlapping MDA8 values greater than 75 ppb

Table 2. Percentages of sites with various frequencies and levels of overlapping MDA8 values

Frequency of overlapping MDA8 values (% of sites)	Occurrence of any overlapping MDA8 values	One or more overlapping MDA8 values per year	Five or more overlapping MDA8 values per year	Ten or more overlapping MDA8 values per year
All Days	99.5	80.9	29.0	11.7
MDA8 > 60 ppb	37.7	7.7	3.3	1.9
MDA8 > 65 ppb	23.3	5.1	1.8	0.8
MDA8 > 70 ppb	13.8	3.1	0.9	0.2
MDA8 > 75 ppb	8.3	2.1	0.3	0.0

Alternative Methods for Calculating MDA8 Values

The second portion of the analysis focused on the impact of the two methods for removing overlapping MDA8 values, as described previously, on the distribution of MDA8 values and the annual 4th highest MDA8 values. In general, while Method 1 was designed to remove the fewest 8-hour average values necessary to ensure that there were no overlapping MDA8 values, this method was also more challenging to implement and required more computational resources than Method 2. In practice, Method 1 could also present challenges for real-time O_3 data reporting systems, because MDA8 values for any given day could be affected by concentrations measured on the following day.

Figures 10 and 11 show the distribution of MDA8 start hours for all monitored days based on Methods 1 and 2, respectively. Method 1 has only a small impact when compared to the original distribution of MDA8 start hours in Figure 1. Method 1 appears to reduce the frequency of MDA8 values occurring in the first and last hours of the day, while slightly increasing the frequency of MDA8 values occurring throughout the rest of the day. Method 2 has a larger impact upon the distribution, since by design this method does not allow MDA8 values to occur between midnight and 6:00 AM. According to Figure 11, there is a substantial increase in the number of MDA8 values occurring at 7:00 AM, and smaller increases in the frequency of MDA8 values occurring throughout the rest of the day.

Next, the analysis focused on the impact of the two methods on the annual 4th highest MDA8 values. Figure 12 shows the distribution of the MDA8 start hour based on the 4 highest MDA8 values for each site and year based on Method 1, while Figure 13 shows the same distribution based on Method 2. Given the tendency for the vast majority of peak O_3 concentrations to occur during the daytime hours, it is not surprising that neither method has a large impact upon the distribution of the annual 4 highest MDA8 values.

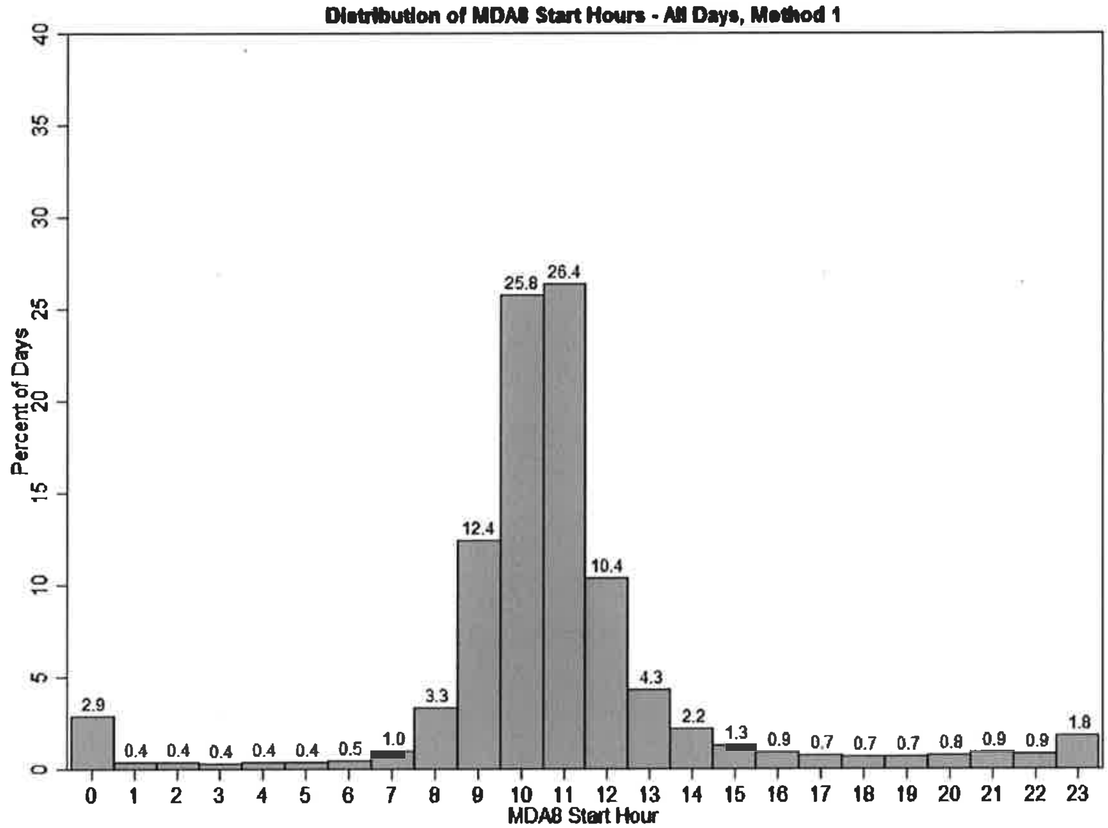


Figure 10. Distribution of MDA8 start hours based on all monitored days, with overlapping MDA8 values removed using Method 1

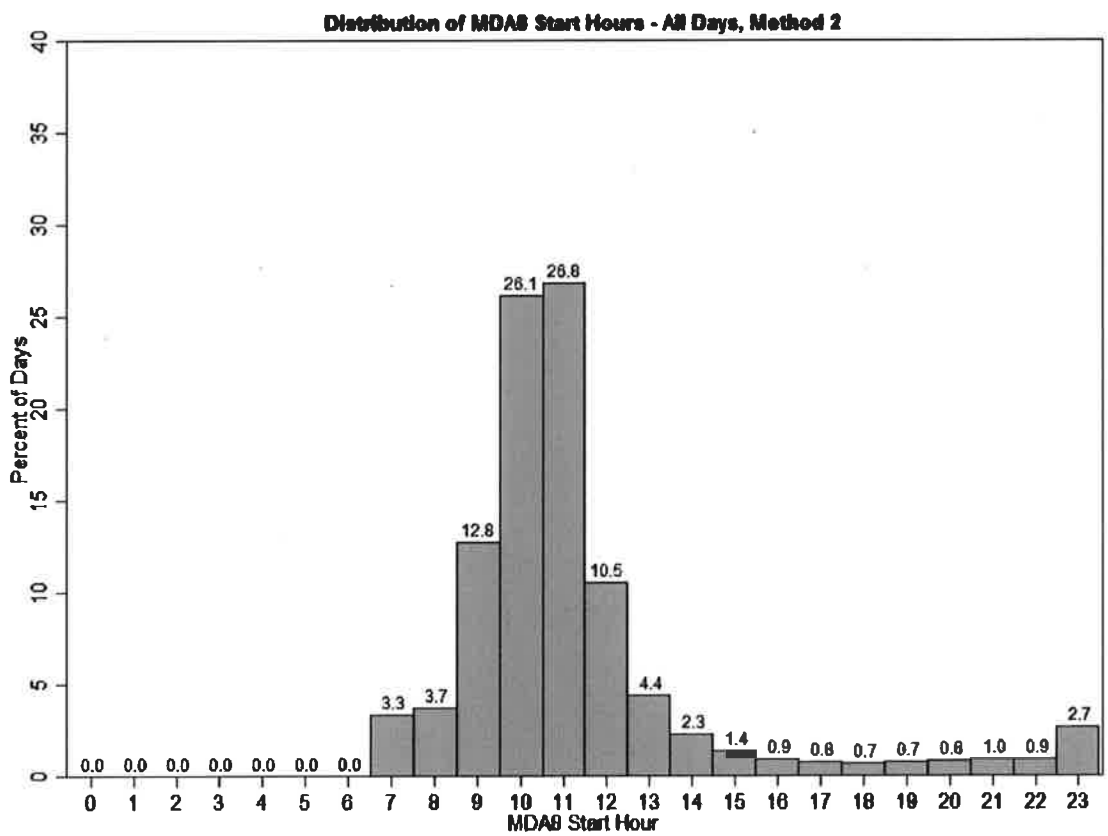


Figure 11. Distribution of MDA8 start hours based on all monitored days, with overlapping MDA8 values removed using Method 2

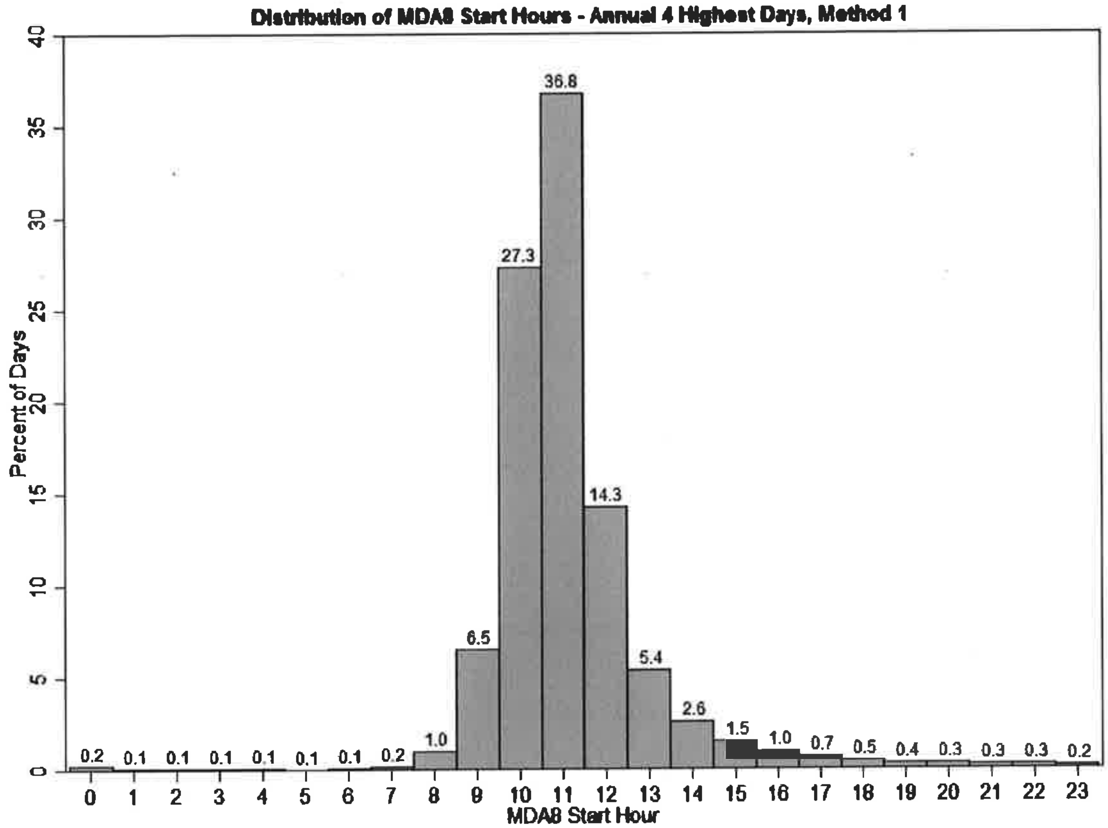


Figure 12. Distribution of MDA8 start hours based on the annual 4 highest MDA8 values at each monitoring site, with overlapping MDA8 values removed using Method 1

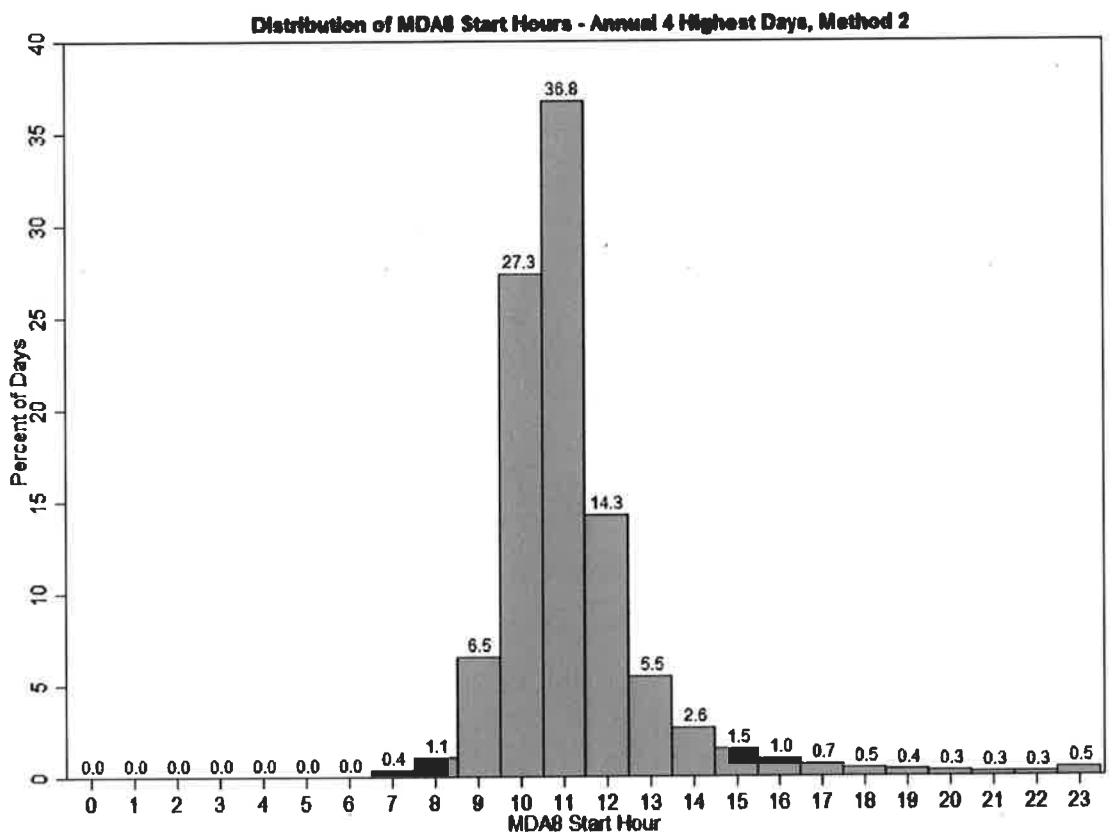


Figure 13. Distribution of MDA8 start hours based on the annual 4 highest MDA8 values at each monitoring site, with overlapping MDA8 values removed using Method 2

The analysis concludes by examining the locations where the 4th highest MDA8 values would be impacted by the removal of overlapping MDA8 values using either method. First, Figures 14 and 15 show maps of the number of years during the 2004 to 2013 period where applying Methods 1 and 2 resulted in a lower 4th highest MDA8 value. Next, Figures 16 and 17 show maps of the mean decrease in the 4th highest MDA8 value over the 2004 to 2013 period based on Methods 1 and 2. Finally, Figures 18 and 19 show maps of the maximum annual decrease in the 4th highest MDA8 values during this period based on these two methods.

Nationally, 5.5% of all monitoring sites had at least one year where the 4th highest MDA8 value decreased when applying Method 1, compared with 7.5% when applying Method 2. On average, 1.1% of sites per year had a lower 4th highest MDA8 value using Method 1, compared with 1.5% of sites per year using Method 2. The average decrease in the 4th highest MDA8 value for those site/years affected was 2.0 ppb for both methods. Overall, the impact of both methods on the 4th highest MDA8 values was relatively small, and the magnitude of the decreases in the 4th highest MDA8 values were quite similar between the two methods.

According to Figures 14 to 19, the spatial patterns in the monitoring sites affected by the two methods were quite similar. Not surprisingly, the sites where the annual 4th highest MDA8 values decreased were predominately located in rural areas, particularly the same mountainous and/or coastal areas downwind from large urban areas as identified previously. Many of these sites appeared to be affected by overlapping MDA8 events that impacted the annual 4th highest MDA8 value on a regular basis. The impact upon the 4th highest MDA8 value was less than 3 ppb in the vast majority of cases, but there were some isolated instances where both methods reduced the annual 4th highest MDA8 value by 4 ppb or more.

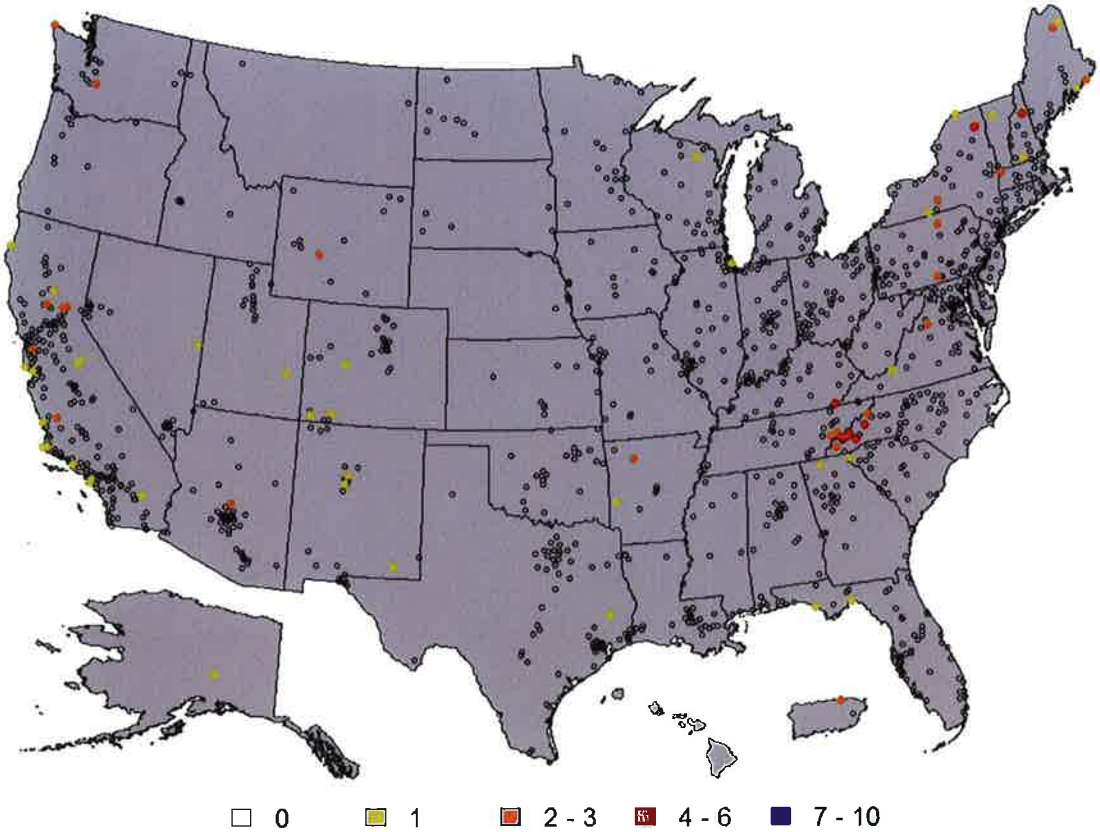


Figure 14. Number of years in 2004 to 2013 where applying Method 1 resulted in a lower annual 4th highest MDA8 value

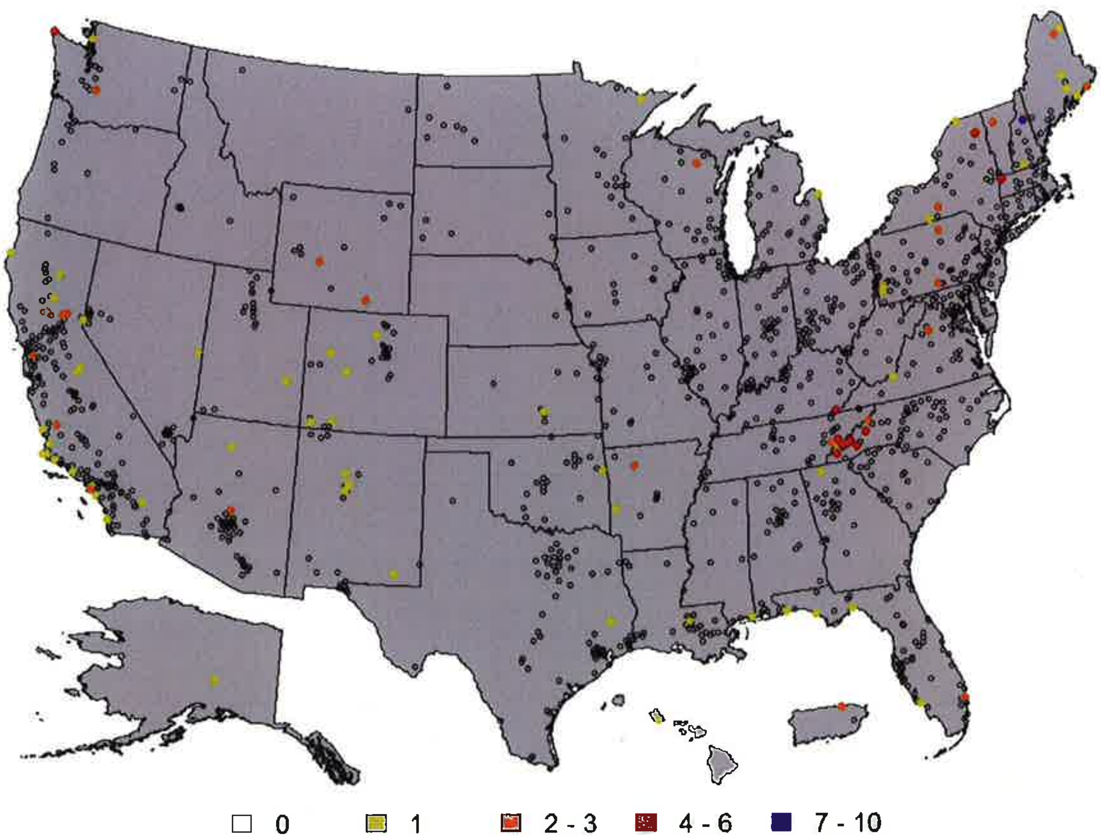


Figure 15. Number of years in 2004 to 2013 where applying Method 2 resulted in a lower annual 4th highest MDA8 value

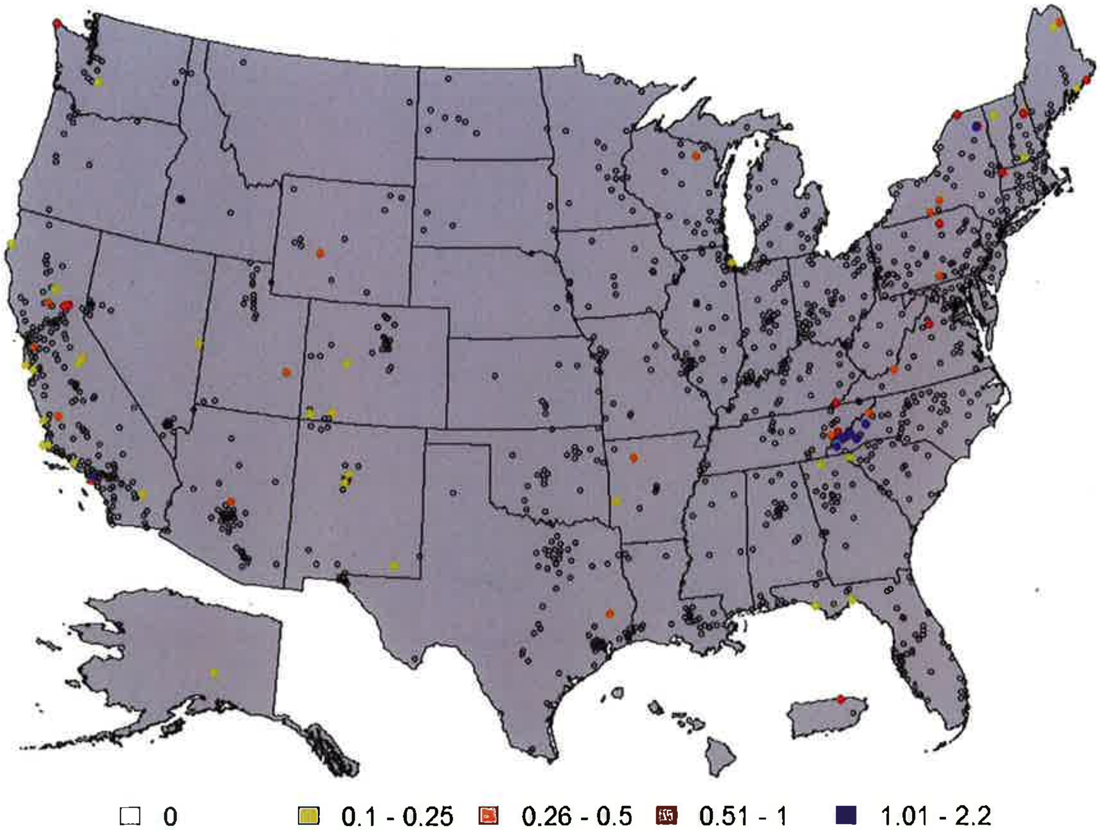


Figure 16. Average decrease in the annual 4th highest MDA8 value (ppb) based on Method 1, 2004 to 2013

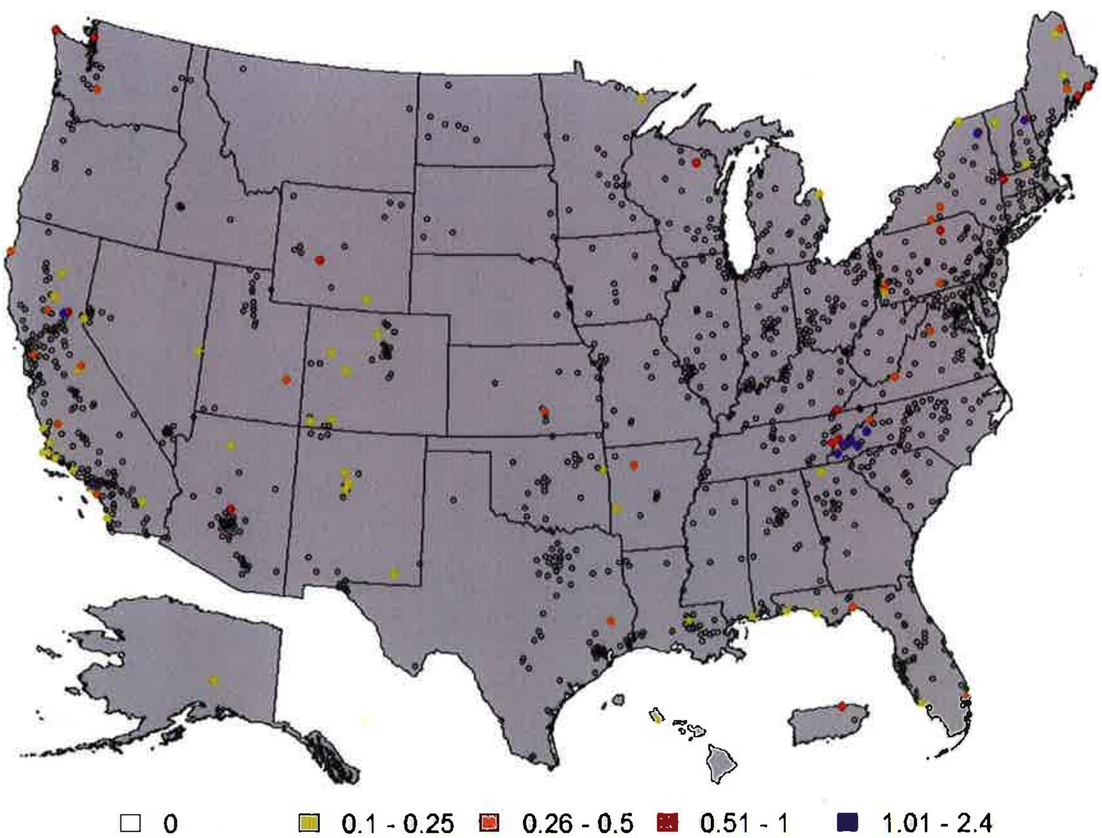


Figure 17. Average decrease in the annual 4th highest MDA8 value (ppb) based on Method 2, 2004 to 2013

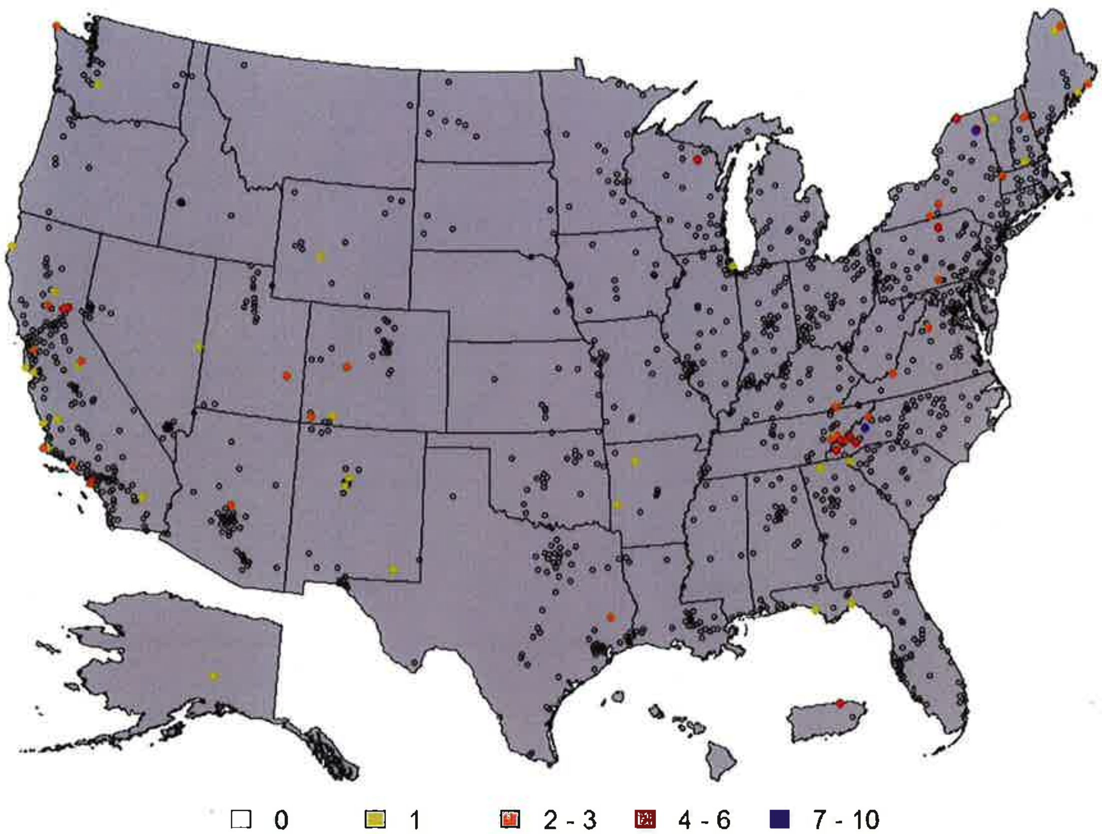


Figure 18. Maximum decrease in the annual 4th highest MDA8 value (ppb) based on Method 1, 2004 to 2013

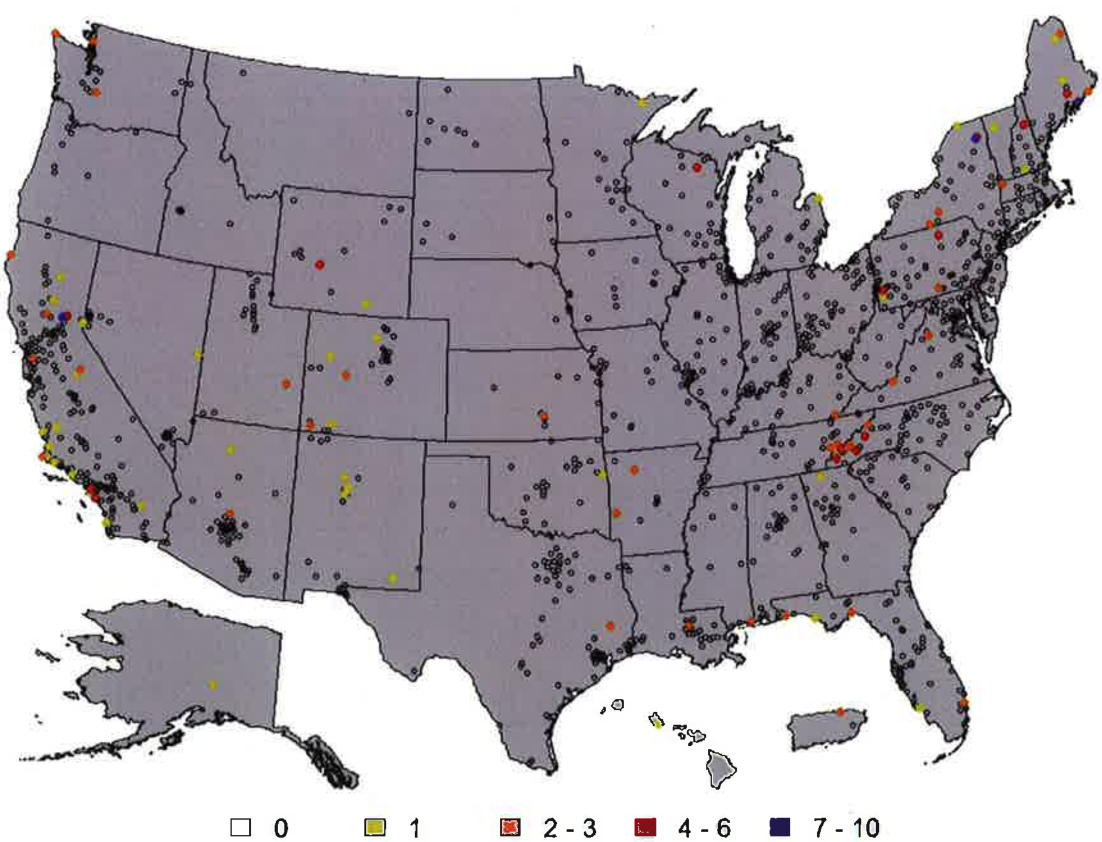


Figure 19. Maximum decrease in the annual 4th highest MDA8 value (ppb) based on Method 2, 2004 to 2013

Summary

The first part of the analysis showed that while the vast majority of MDA8 values were based on periods starting near the middle of the day, overlapping MDA8 events accounted for 3.5% of all monitored days, and these events occurred at least once at nearly every monitoring site in the U.S. during the 2004 – 2013 period. However, more than 99% of these events were associated with concentrations meeting the current O_3 standard of 75 ppb, and approximately 94% of these events were associated with concentrations less than or equal to 60 ppb. When looking at overlapping MDA8 events associated with concentrations above 60 to 75 ppb, it is immediately apparent that the vast majority of these events occur in rural areas with few local anthropogenic emissions sources for ozone precursors. Thus, high O_3 concentrations occurring during overlapping MDA8 events are most likely due to transport of O_3 to rural areas with low NOx titration rates.

The second part of the analysis evaluated two potential methods for removing the impact of overlapping MDA8 events from the calculation of the annual 4th highest MDA8 value metric used for determining compliance with the NAAQS. While there were some minor differences, in general the resulting impacts upon the annual values were quite similar in terms of the frequency, magnitude, and locations affected. On average, less than 2% of the annual 4th highest MDA8 values were affected each year using either method, and of those values impacted, both methods showed an average decrease of 2.0 ppb in the annual 4th highest MDA8 value. The monitoring sites where the annual 4th highest MDA8 values were impacted were located predominately in rural areas for both methods.

In conclusion, the ambient data analysis showed that the current data handling convention in Appendix P to CFR Part 50 whereby exceedances of the NAAQS resulting from overlapping MDA8 events may be counted twice are increasingly important as the level of the standard is lowered. In addition, this data handling practice is likely to have the greatest impact on rural areas, which could result in additional areas with few local anthropogenic sources of ozone precursors being designated nonattainment for a revised NAAQS. The likelihood of such an outcome could be minimized by using either of the two methods described in this analysis to remove overlapping MDA8 values from the annual 4th highest MDA8 calculations.