Comments on Background Ozone Related to the Review of the Secondary Ozone NAAQS As Discussed in the Second Draft of EPA's Policy Assessment and Welfare REA

by

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I. Introduction

Because ozone (O_3) has appreciable natural sources and a lifetime in the free troposphere of weeks, the issue of background concentration becomes very important compared to the other criteria pollutants. The natural sources include transport from the stratosphere, where it occurs naturally in high concentrations, and photochemical reactions involving biogenic volatile organic carbon (VOC) species (and background methane) and naturally produced oxides of nitrogen (NO_x). Air entering the U.S. can also contain significant concentrations of ozone precursors and significant levels of O_3 formed from reactions involving non-U.S. anthropogenic emissions that can be transported from Canada, Mexico or Asia.

There are two fundamental issues involving background ozone raised by EPA's Draft Risk and Exposure Assessment and Draft Policy Assessment. The first is what EPA uses for background ozone, which depends on how it is defined and how it is estimated. The second is how EPA uses background in its policy and risk assessments which are then used to inform policy decisions made relative to the form, averaging time and level of the National Ambient Air Quality Standard (NAAQS). Both of these issues will be examined below.

II. The History of EPA's Definition of Background Ozone

In the 1997 review of the ozone (NAAQS), EPA based the ozone background values on measurements that were designed to determine the ozone concentrations in air masses entering the continental U.S. In their 1996 Staff Paper[1] on page 18, they state:

> Based on a review of the available literature, it is obvious that "natural" O_3 background is a multidimensional and complex concept. Background O_3 concentrations vary by geographic location, altitude and season. For the purposes of this document, background ozone is defined as the ozone concentrations that would be observed in the U.S. in the absence of anthropogenic or biogenic emissions of VOCs and NO_x in North America. During the summertime O_3 season in the U.S., daily 1-hr. maximum background is typically between 0.03 to 0.05 ppm. Part of this background is due to the long-range transport of anthropogenic or biogenic emissions.

EPA states that they arrived at this range after a synthesis of the literature, but they relied most heavily on the papers by Altshuller,[2] Kelly et al.,[3,4] and Lefohn and Foley.[5]

In the 2007 review of the ozone NAAQS, EPA introduced a new term, Policy Relevant Background (PRB), which they defined as "the distribution of O_3 concentrations that would be observed in the U.S. in the absence of anthropogenic (man-made) emissions of precursor emissions (e.g., VOC, NO_x, and CO) in the U.S., Canada, and Mexico."[6] The differences between this definition and the definition previously used for background are that the PRB refers to a distribution of modeled concentrations rather than a measured range and it explicitly excludes anthropogenic precursor emissions in Mexico and Canada. EPA did not include emissions from the two neighboring countries because the Agency assumed that such emissions could be regulated through international agreements. EPA further stated: "As a result of long-range transport of O_3 and its precursors from anthropogenic sources within North America, estimates of PRB O_3 concentrations cannot be derived solely from measurements of O_3, and must be based on modeling." This represented a major departure from the way background was determined in the past, which was based on data. Specifically, EPA used the global

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[1] U.S. EPA (1996), *Review of the National Ambient Air Quality Standards for Ozone Assessment of Scientific and Technical Information OAQPS Staff Paper,* EPA-452/R-96-007, June 1996.
[2] Altshuller, A.P. (1986), "Review paper: the role of nitrogen oxides in nonurban ozone formation in the planetary boundary layer over N. America, W. Europe and adjacent areas of ocean," *Atmos.Environ.*, 20:245-268.
[3] Kelly, N.A., Wolff, G.T. and Ferman, M.A. (1982), "Background pollutant measurements in air masses affecting the eastern half of the United States- I. air masses arriving from the northwest," *Atmos.Environ.*, 16:1077-1088.
[4] Kelly, N.A., Wolff, G.T. and Ferman, M.A. (1984), "Sources and sinks of ozone in rural areas," *Atmos.Environ.*, 18:1251-1266.
[5] Lefohn, A.S. and Foley, J.K. (1992) "NCLAN results and their application to the standard-setting process," *J.Air & Waste Mgt. Assoc.* 42: 1046-1052.
[6] U.S. EPA (2007), *Review of the National Ambient Air Quality Standards for Ozone: Policy Assessment of Scientific and Technical Information OAQPS Staff Paper,* EPA-452/R-07-003, January 2007.

photochemical transport model GEOS-CHEM.[7] The resulting mean PRB range was on the order of 15 - 35 ppb in the eastern U.S. in the summer and slightly higher levels at high elevation sites in the western U.S. compared to the 1996 estimate of 30 to 50 ppb.

For the present review, the first draft of the ISA continued to use PRB.[8] In the second draft of the ISA,[9] EPA stopped using the term PRB and switched to calling it North American background (NAB). EPA states: "For this document, we have focused on the sum of those background concentrations from natural sources everywhere in the world and from anthropogenic sources outside the U.S., Canada and Mexico, i.e., North American background." While they changed the term from PBR to NAB, they both had the same definition and NAB was still based on the controversial assumption that Canadian and Mexican emissions could be controlled by treaties or international agreements.

In AIR's comments[10] on the second draft of the ISA, we pointed out that their definition of NAB actually implied that Mexican and Canadian anthropogenic emissions could be eliminated by treaties or agreements and that this was not realistic. The way EPA used NAB resulted in their overestimating the risk reduction that would be achieved by lowering the NAAQS and it penalized the States because they would have to offset the Canadian and Mexican emissions in their State Implementation Plans. Instead of using NAB, AIR recommended that it was more appropriate to use a U.S. background (USB), which includes all Canadian and Mexican emissions, for the risk assessments and for control strategy development.

In the third draft of the ISA[11], EPA finally included USB in their discussions of background. This draft included three definitions of background ozone for consideration: NAB (as previously defined), USB and natural background (NB). They defined USB as the background that would exist in the absence of anthropogenic emissions from the U.S. Thus, ozone resulting from Canadian and Mexican emissions is included. EPA defines natural background as ozone "resulting from emissions from natural sources (e.g., stratospheric intrusions, wildfires, biogenic methane and more short-lived VOC emissions) throughout the globe."

In addition, the third draft also admitted the shortcomings of the "zero out" methodology EPA used to estimate NAB, USB and NB. This paragraph occurred three times in the third draft ISA:

> Note that the calculations of background concentrations presented in this chapter were formulated to answer the question, "what would O_3

[7] Fiore, A., Jacob, D.J., Liu, H., Yantosca, R.M. Farlie, T.D. and Li, Q. (2003), "Variability in surface ozone background over the United States: Implications for air quality policy", *J. Geophys. Res.*, doi:10, 1029/2003JD003855.

[8] U. S. EPA (2011), *First External Review Draft of the Integrated Science Assessment for Ozone and Related Photochemical Oxidants*, EPA/600/R-10/076a, March 2011.

[9] U. S. EPA (2011), *Second External Review Draft of the Integrated Science Assessment for Ozone and Related Photochemical Oxidants*, EPA/600/R-10/076b, September 2011

[10] Heuss, J.M., Wolff, G.T. and Kahlbaum, D.F. (2011), Review and Critique of the U. S. Environmental Protection Agency's Second External Review Draft of the "Integrated Science Assessment for Ozone and Related Photochemical Oxidants," Air Improvement Resource, Inc. Report, Prepared for The Alliance of Automobile Manufacturers, November 2011.

[11] U. S. EPA, (2012), *Third External Review Draft of the Integrated Science Assessment for Ozone and Related Photochemical Oxidants*, EPA/600/R-10/076c, June 2012.

> concentrations be if there were no anthropogenic sources." This is different from asking, "how much of the O_3 measured or simulated in a given area is due to background contributions." Because of potentially strong non-linearities—particularly in many urban areas—these estimates should not be used by themselves to answer the second question posed above. The extent of these non-linearities will generally depend on location and time, the strength of concentrated sources, and the nature of the chemical regime. Further work is needed on how these estimates of background concentrations can be used to help determine the contributions of background sources of O_3 to urban concentrations.

In previous comments by AIR[12] on the first draft of the ISA, this non-linearity issue was brought to EPA's attention. AIR recommended:

> The contribution of natural sources and other PRB sources to North America cannot be realistically assessed in the absence of U.S. anthropogenic emissions. To realistically estimate the contribution of PRB sources, the PRB sources should be shut down in the presence of U.S. sources.

In subsequent comments on the third draft, AIR recommended two approaches that could be used to obtain the impact of USB on US ozone concentrations:

> We suggest two approaches that should be used. In the first, the USB should be set to zero. In other words, all non-U.S. anthropogenic emissions should be set to zero as well as all of the natural sources. The difference between that scenario and the base case scenario, where all sources and emissions are included, would provide an estimate of the contribution of USB to the base case ozone. In the second approach, a photochemical grid model with an embedded source apportionment module should be used. CAMx is one such modeling system with a source-apportionment module. With USB designated as a separate source category, the estimated contribution of USB to the base case ozone would be computed directly. A comparison of the USB contributions estimated from these two approaches with the estimates of USB derived from the approach described in the ISA would provide information of the linearity or degree on non-linearity of the system.[13]

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[12] Wolff, G.T., (2011), Comments on Policy Relevant Background Ozone As Discussed in EPA's Draft Integrated Science Assessment for Ozone and Related Photochemical Oxidants. Prepared for the Utility Air Regulatory Group, May 5, 2011.

[13] Heuss, J.M., Wolff, G.T. and Kahlbaum, D.F., (2012), Review and Critique of the U. S. Environmental Protection Agency's Third External Review Draft of the "Integrated Science Assessment for Ozone and Related Photochemical Oxidants," Air Improvement Resource, Inc. Report, Prepared for The Alliance of Automobile Manufacturers, August 2012.

To their credit, EPA uses CAMx to estimate USB in the second draft of the PA.[14] Unfortunately, however, the specific source apportionment module that they used to track the various source contributions to USB is not appropriate for addressing the question, "how much of the O_3 measured or simulated in a given area is due to background contributions." As a result, all of the resulting USB estimates in the PA are biased low. This will be discussed in detail in the next section.

III. Background O_3 Estimates in the PA

A. Methodologies used in the PA

The EPA makes extensive calculations of USB and they are contained in Chapter 2 of the PA and in Appendix 2A of the PA. They estimate USB using two different procedures: 1) by using the GEOS-Chem/CMAQ modeling system and zeroing out anthropogenic emissions in the US, and 2) by using CAMx with the Anthropogenic Precursor Culpability Assessment (APCA) tool, which has the capability of tracking the contributions of different sources (i.e.: boundary conditions, biogenic VOCs, biogenic NO_x etc.) to USB. In general, the CMAQ results in slightly higher estimates of USB than CAMx which EPA attributes to the inability of the zeroing out procedure to capture the non-linearities in the ozone chemistry. EPA states:

> While the zero-out approach has traditionally been used to estimate background ozone levels, the methodology has some acknowledged limitations. First, from a policy perspective, the purely hypothetical and ultimately unrealizable zero manmade emissions scenarios have limited application in this regard. Secondly, the assumption that background ozone is what is left after specific emissions have been removed within the model simulation can be misleading in locations where ozone chemistry is highly non-linear. Depending upon the local composition of ozone precursors, NO_x emissions reductions can either increase or decrease ozone levels in the immediate vicinity of those reductions. For those specific urban areas in which NO_x titration of ozone can be significant, zero-out modeling can result in inflated estimates of background ozone when these NO_x emissions are completely and unrealistically removed. Paradoxically, in certain times and locations in a zero-out scenario there can be more background ozone than actual ozone within the model (EPA, 2014).[15]

As to the application of CAMx with the APCA tool, EPA states:

> A separate modeling technique attempts to circumvent these limitations by apportioning the total ozone within the model to its contributing source terms. This basic approach is referred to as "source apportionment" modeling.

[14] U. S. EPA, (2014), *Policy Assessment for the Review of the Ozone National Ambient Air Quality Standards, Second External Review Draft*, EPA–452/P–14–002, January 2014.
[15] Ibid, at p. 2A-7.

and,

> The source apportionment modeling attempts to determine how much of the modeled ozone has resulted from background sources.[16]

1**. USB Estimates from CAMx**

Unfortunately, the APCA tool was not designed to "determine how much of the modeled ozone has resulted from background sources," but, rather, as its name implies, to attribute maximum culpability to controllable anthropogenic precursors. As a result, the USB estimates generated by the APCA tool are negatively biased. The best way to illustrate this is with examples.

Example 1: A biogenic VOC molecule interacts with an anthropogenic NO_x molecule to form an O_3 molecule. CAMx/APCA counts the resulting O_3 as an anthropogenic O_3 molecule and not USB even though it would not exist without the contribution of the biogenic VOC. Similarly a naturally emitted NO_x molecule that reacts with an anthropogenic VOC to form O_3 would also be counted as an anthropogenic O_3 molecule.

Example 2: An O_3 molecule entering the US from Canada is initially counted as boundary condition O_3 that is included in USB. However, should that molecule encounter an NO molecule emitted from a U.S. anthropogenic source and react to form NO_2, which is subsequently photolyzed and results in the formation of an ozone molecule, that ozone molecule is counted by APCA as anthropogenic even though it would not have existed if not for the parent O_3 molecule that traveled from Canada.

Example 3: An O_3 molecule enters the US and encounters an anthropogenic VOC (olefin) that react to form an aldehyde which is subsequently photolyzed to form an ·OH radical. The ·OH radical is capable of participating in a chain reaction with NO_x and VOCs to produce many O_3 molecules. APCA would count all of the O_3 formed in this manner as anthropogenic even though they would not have existed if not for the imported initial O_3 molecule.

There are numerous other examples that could be used. For example, an O_3 molecule formed naturally in the stratosphere and transported to the troposphere would be subjected to the same accounting procedure as the ones that travel across the border into the US.

APCA is designed to identify the controllable anthropogenic emissions that if reduced would result in lower ozone. In the case of USB, it identifies the additional reductions that would be needed to offset the USB impacts and not the contribution of USB to observed O_3. In reality, the impact of imported O_3 or NB O_3 can be propagated throughout the US by subsequent generations of reaction products that would not exist if not for the initial O_3 molecules that were transported into the US or formed naturally. In the APCA accounting procedure, the impact of these initial molecules is terminated as soon as they react with a molecule of anthropogenic origin. Thus, the CAMx/APCA modeling system underestimates the impact of USB on ambient O_3 concentrations.

[16] Ibid.

2. USB Estimates from GEOS-Chem/CMAQ and Zeroing Out Anthropogenic US Emissions

As pointed out in the preceding section and admitted by EPA, the zeroing out of U.S anthropogenic emissions has some shortcomings. It alters the composition of the atmosphere including the all-important VOC to NO_x ratio that changes the chemistry in a non-linear manner that results in unrealistic consequences. One manifestation of this is that USB estimates in urban areas can be higher than the observed O_3 concentrations in the presence of U.S. anthropogenic emissions. Local NO emissions scavenge USB transported from upwind areas and this phenomena does not occur if anthropogenic NO_x emissions are turned off. In other words, the behavior and hence, the impact of USB on measured O_3 cannot be determined using this approach.

Since this procedure produces higher estimates of USB than the CAMx/APCA method, could they be considered reasonable upper estimates for USB? That is not the case because the non-linearities in the chemistry could produce higher estimates of USB when the impacts of USB are propagated throughout the US.

3. Recommended Methods to Measure Impacts of USB on Ambient Ozone Levels

As we recommended in our earlier comments, there are two ways to obtain more realistic estimates of the impacts of USB on ambient ozone concentration in the US. The first way is to run CAMx with all emissions and then with the boundary conditions and natural sources zeroed out. The difference between the two scenarios provides the impact of USB on US O_3 concentrations. The second way is to run CAMx with the APCA scheme modified to keep track of all the sources of odd oxygen atoms and distinguish between those that originated from the reactions involving natural emissions or imported O_3 or precursors from outside the US and those formed from U.S. anthropogenic emissions alone.

B. Concentrations Estimated in the PA

In the PA, EPA presents USB values in terms of the maximum daily 8-hour average (MDA8) and in terms of the metric chosen for the form of the secondary NAAQS - W126. The MDA8 form is used for the discussion of the primary NAAQS, but it is also relevant to the secondary NAAQS as will be shown later.

1. USB in Terms of MDA8

In terms of MDA8, EPA calculates seasonal means for USB and daily values. For reasons articulated in previous comments by AIR[17,18,19,20] seasonal means have limited value in terms of

[17] Wolff, G.W., Heuss J.M. and Kahlbaum, D.F., (2012), Review and Critique of the U. S. Environmental Protection Agency's First External Review Drafts of the "Health Risk and Exposure Assessment for Ozone" and the "Policy Assessment for the Review of the Ozone National Ambient Air Quality Standards," Air Improvement Resource, Inc. Report, Prepared for The Alliance of Automobile Manufacturers, October 2012.
[18] Heuss et al., supra note 10.

the NAAQS, since the NAAQS are based on an 8-hour extreme value statistic. For a secondary NAAQS with a W126 form, seasonal means are not relevant either, because the seasonal sum of the daily W126 indices are heavily weighted by the days with the highest O_3 concentrations. Consequently, our focus is on the daily USBs.

The distributions of the daily USB values and the fraction of MDA8 as USB estimated using CAMx with the APCA tool appear in the PA in Figures 2-13 and 2-14, which we have reproduced here as Figures 1 and 2. The explanation EPA gives for the box and whisker plots is as follows:

> a. the median concentration (black horizontal line) per bin,
> b. the inter-quartile range (blue colored box) which represents the 25th-75th percentile range in values within the distribution,
> c. the "whiskers" (dark gray vertical lines with top and bottom whiskers) which represent the range of values within 1.5 times the inter-quartile range, and
> d. the "outliers" (gray points) which are any values outside the whiskers.

Figures 1 and 2 contain the modeled USB and MDA8 O_3 concentrations at O_3 monitoring sites throughout the U.S. Even though, the CAMx/APCA estimates are biased low for the reasons stated above, Figures 1 and 2 show the USB contributes significantly to the modeled MDA8 concentrations across the U.S. In their discussion in the PA, EPA focuses on the medians and the interquartile ranges of the USB which peak at an MDA8 between 45 - 55 ppb and decrease at higher values of MDA8. It must be noted, however, that there are values above the 75th percentile that do occur and there are certain occurrences of the USB approaching or exceeding 60 ppb on days when the MDA8 exceeds the current NAAQS level and the alternative levels that EPA is considering for a NAAQS. This is important because the current primary and secondary NAAQS are based on an extreme 98th percentile statistic and W126 gives significantly more weight to the higher O_3 days.

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[19] Wolff, supra note 12.
[20] Heuss et al., supra note 13.

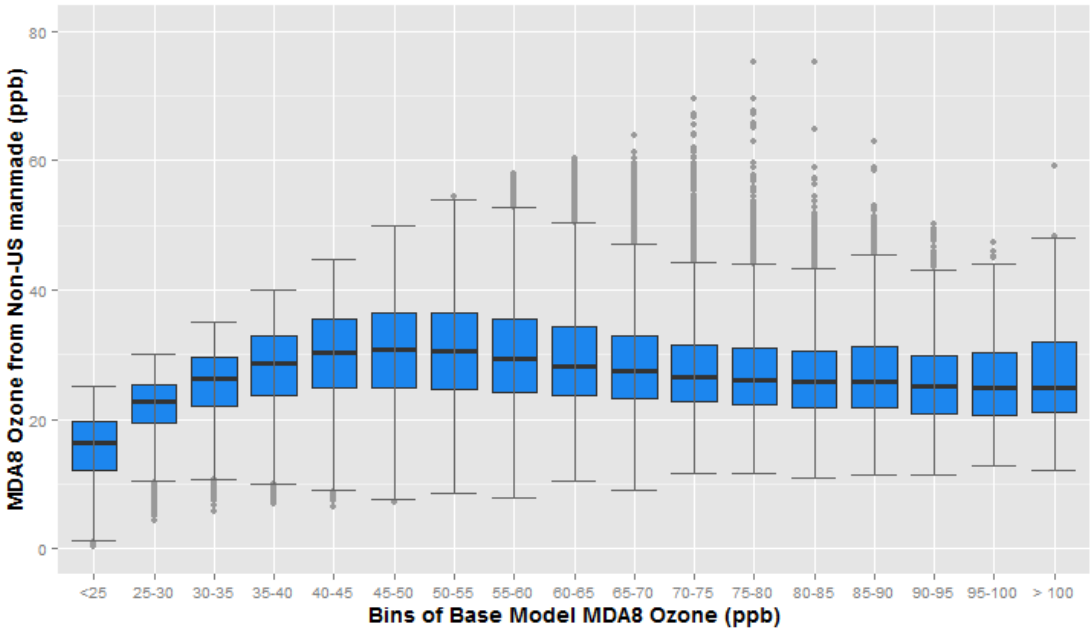

Figure 1: Distribution of MDA8 ozone contributions from non-U.S. manmade sources (USB) in ppb at monitoring locations across the U.S. (Apr-Oct), binned by base modeled site-day MDA8, as estimated by 2007 CAMx simulations.

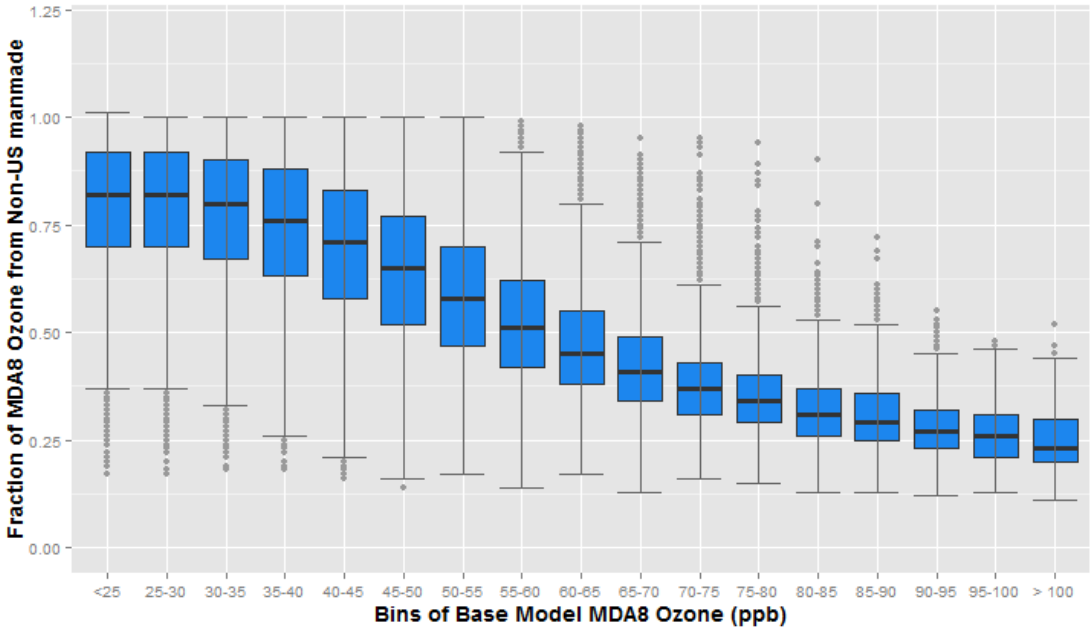

Figure 2: Distribution of MDA8 ozone fractions from non-U.S. anthropogenic sources (USB) at monitoring locations across the U.S. (Apr-Oct), binned by base modeled site-day MDA8, as estimated by the 2007 CAMx simulation.

The PA does note that there are cases where the model predicts much larger background proportions, but EPA says: "these infrequent episodes usually occur in relation to a specific event, and occur more often in specific geographical locations, such as high elevations or wildfire prone areas during the local dry season." Unfortunately, EPA does not provide any supporting evidence and does not provide plots for individual sites. However, EPA did calculate daily estimates of USB and MDA8 for 12 "urban case study areas" that were used in the Health REA.[21] Although the PA only contains annual averages of USB and MDA8, AIR was able to obtain the daily estimates from EPA's Office of Air Quality Planning and Standards. AIR generated box and whisker plots similar to Figures 1 and 2 for each of the 12 urban areas. Since the plots are similar, two areas were selected for illustrative purposes. The values for Denver, which represents a western, high-elevation city and Atlanta, which represents an eastern city, are plotted in Figures 3 and 4, respectively.

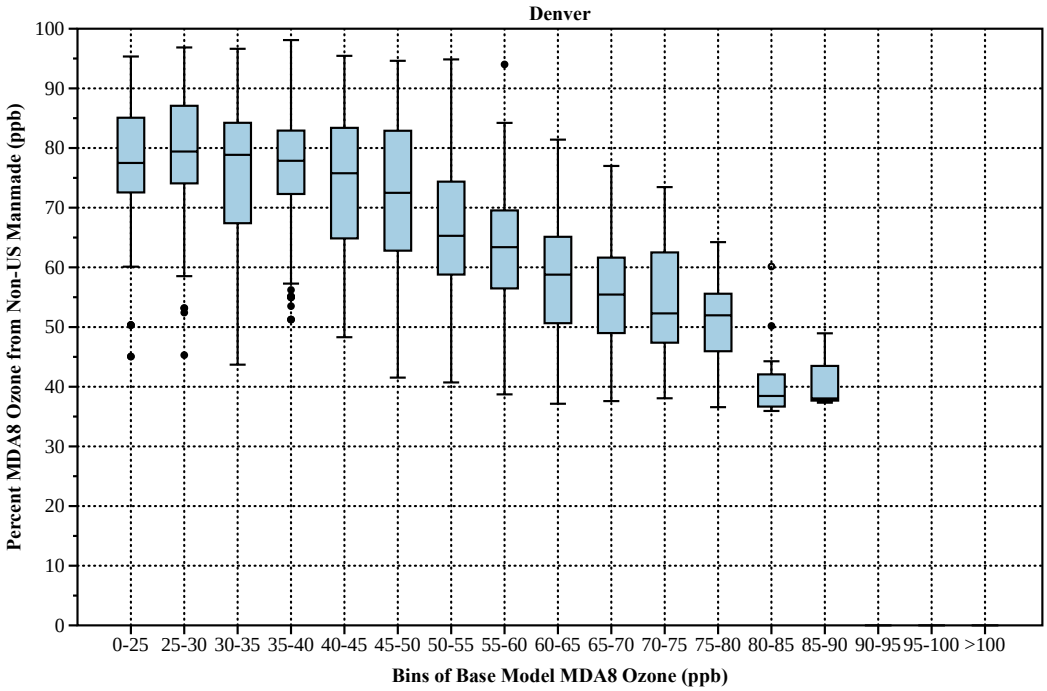

Figure 3: Distribution of MDA8 ozone fractions from non-U.S. anthropogenic sources (USB) for Denver, binned by base modeled site-day MDA8, as estimated by the 2007 CAMx simulation.

[21] U. S. Environmental Protection Agency, (2014), *Health Risk and Exposure Assessment for Ozone, Second External Review Draft*, EPA-452/P-14-004a, February 2014.

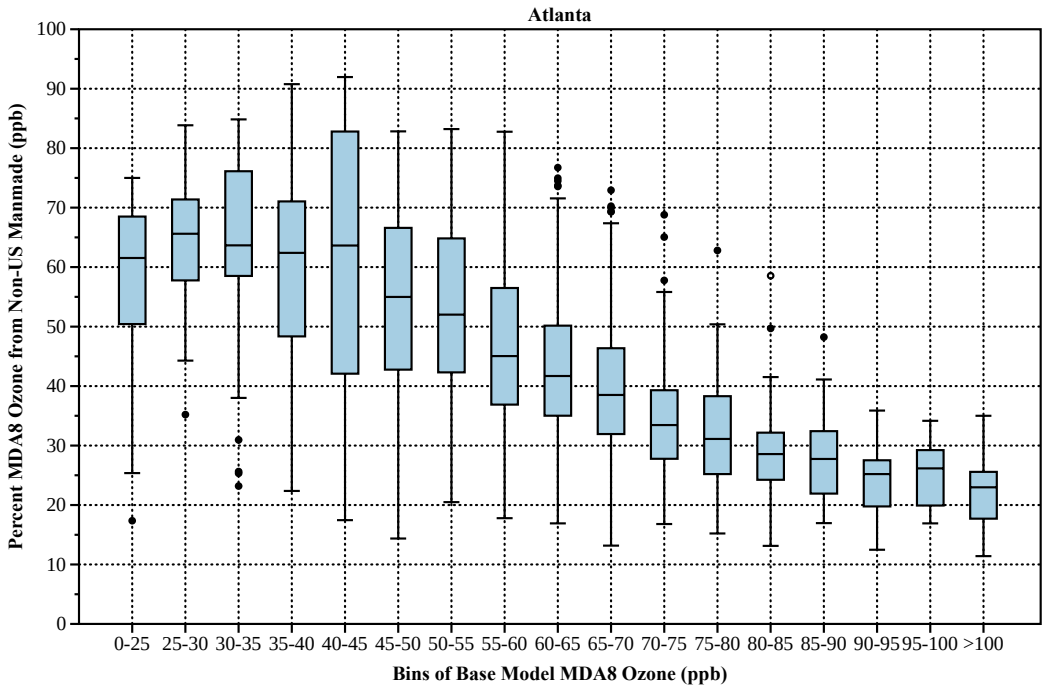

Figure 4: Distribution of MDA8 ozone fractions from non-U.S. anthropogenic sources (USB) for Atlanta, binned by base modeled site-day MDA8, as estimated by the 2007 CAMx simulation.

In Denver, the percentage of MDA8 that is due to USB does decrease with increasing MDA8. However, on 25% of the days in the 60 - 65 ppb bin, the USB accounts for 65 to 81% of the MDA8 and the median contribution is 59%. While insufficient to cause a NAAQS exceedance by itself, the USB is clearly the largest contributor to the MDA8. In Atlanta, the USB contribution is only slightly lower for the 60 - 65 ppb bin. The upper quartile range in USB contributions is 50 - 76% while the median contribution is 42%. Similar observation can be made for the other 10 urban areas.

In summary, at the 12 urban areas examined, there are a significant number of days when the USB contribution exceeds 50% of the MDA8 values and the MDA8 values are within the range being considered for the primary NAAQS (60 - 75 ppb). This situation is likely to be even more prevalent in rural areas which generally have fewer local anthropogenic emissions. In addition, it must be kept in mind that these USB estimates are biased low.

2. USB in Terms of W126

a. Calculation of W126

As noted above, in the 1996 Staff Paper, EPA chose a background O_3 range for the U.S. to be 30 - 50 ppb. This background range was one of the factors that the Administrator considered when initially choosing the SUM06 index as the form for an alternative secondary NAAQS. SUM06 only considers O_3 exposures that are $\geq$ 60 ppb. Thus the initial 1996 proposal only considered welfare risks that occurred above background. In the 2008 review, EPA staff concluded that the

W126 index was more biologically-relevant and argued that this form was also not likely to be impacted by background concentrations due to the low weight given to lower O_3 concentrations by the W126 index. Ultimately, in both the 1996 and 2008 review, the Administrator chose to set the secondary NAAQS equal to the primary NAAQS.

In the current review, EPA staff has again chosen the W126 index as the most appropriate form for the secondary NAAQS. To calculate W126, first the sums of the weighted hourly O_3 concentrations within each month are calculated resulting in a monthly index value. Since most tree and plant species are photochemically active only during daylight hours, only O_3 concentrations from 8 AM to 8 PM local time are included. The W126 monthly index values are calculated according to the following equation:

$$\boldsymbol{Monthly\ W126} = \sum_{d=1}^{N} \sum_{h=8}^{19} \frac{C_{dh}}{1 + 4403 * \exp\left(-126 * C_{dh}\right)}$$

where: *N* is the number of days in the month, *d* is the day of the month, *h* is the hour of the day, and C_{dh} is the hourly O_3 concentration in parts per million. Next, the annual index is computed as the sum of the three consecutive months of the year with highest monthly values. A 3-year index is calculated as the average of the annual index values using the same 3-month period in 3 consecutive years.

To get a feel for how this equation weighs different concentrations, the equation was evaluated for four simple examples. It was assumed that the O_3 concentrations remained constant every daylight hour of every day for 3 months. At concentrations of 20 ppb (0.02 ppm), 40 ppb, 50 ppb, and 60 ppb the annual index values computed to be 0.06, 1.5, 5.9 and 19.7 ppm-hours, respectively. This compares to the range of values being considered for the secondary NAAQS of 7 to 17 ppm-hours.

b. Observed W126

For the period 2006-2008, EPA determined the 3-year average W126 for all the U.S. monitoring sites and, using a geographic smoothing technique, generated a map (Figure 4-5 in the Welfare REA), which is reproduced in Figure 5. Several issues stand out on the map. First is that if the lower range, 7 ppm-hours, is chosen for the level of the secondary NAAQS, most of the country will be nonattainment. Second, two areas of maximum W126 impact are apparent, the eastern US and the southwestern US. Most of these two areas will likely be nonattainment even if the upper end (17 ppm-hours) of the range being considered is selected. Figure 6 shows the geographic distribution of anthropogenic NO_x emissions throughout the country. The high W126 regions in the East are near or downwind of high NO_x emission density areas. In the West, however, there is a disconnect between high NO_x source areas and areas of high W126. Although there is uncertainty introduced in Figure 5 due to the sparse number of monitors in the West, clearly something other than anthropogenic U.S. emissions are controlling the high W126 areas in the West.

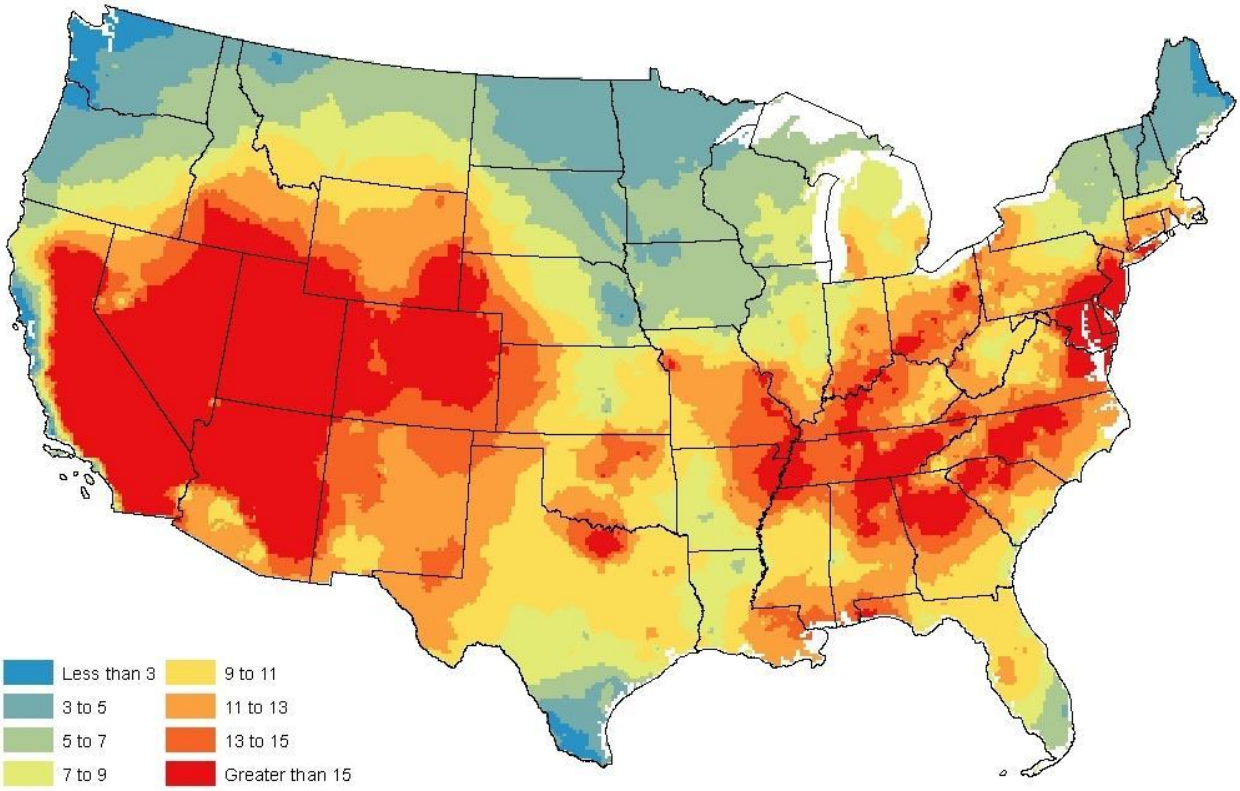

Figure 5: National surface of observed 2006-2008 average W126 concentrations in ppm-hours.

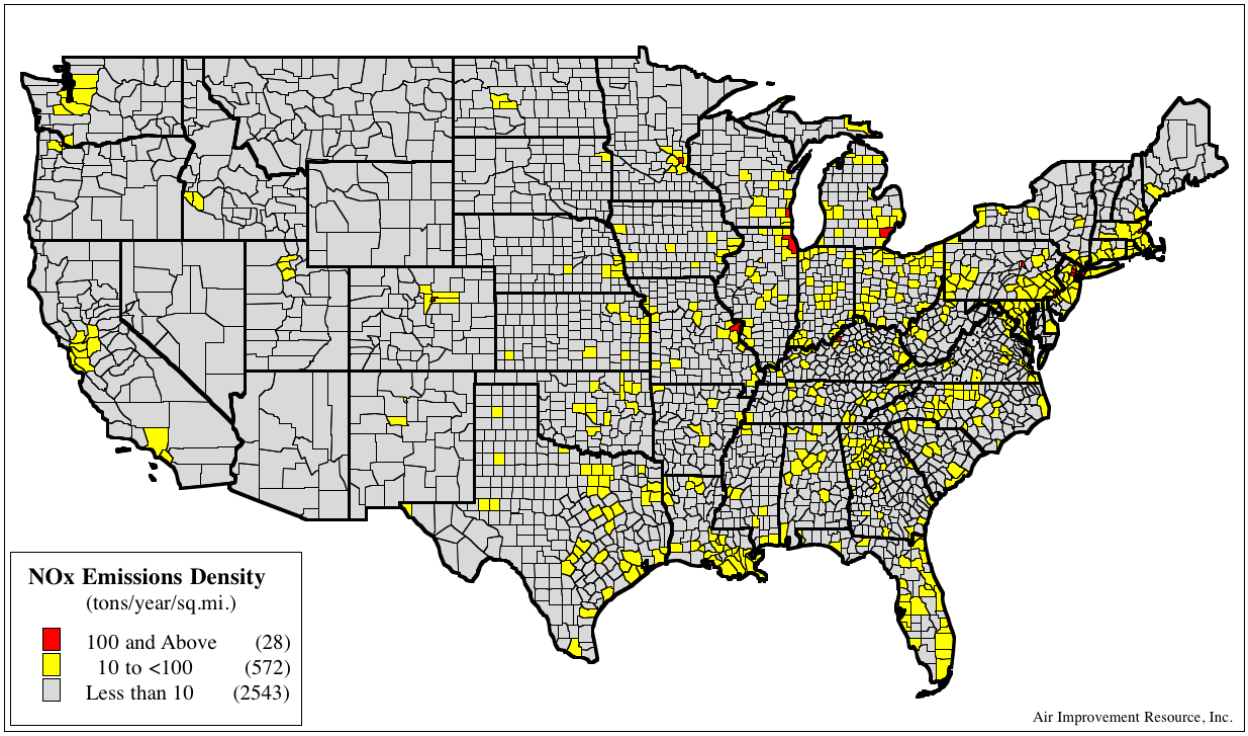

Figure 6: NO_x emission densities by county in 2011.

A recent paper by Lin et al. (2012)[22] sheds some light on this disconnect. For years, it has been known that stratospheric O_3 influences the concentrations near the surface. However, because of our inability to directly measure the stratospheric contribution as well as limited model capability to simulate the dynamics associated with stratospheric intrusions, the magnitude of this contribution was speculative. Lin et al. revisited this issue by applying a newly developed global model with fully coupled stratospheric-tropospheric chemistry at high spatial resolution in conjunction with a suite of satellite and in situ measurements made from April to June, 2010 in the western U.S. Their results show that stratospheric O_3 intrusions episodically increase surface MDA8 by 20 to 40 ppb including on days when the observed MDA8 exceeded the current NAAQS. They present their findings in Table 2 of their paper, which is produced below as Table 1.

[22] Lin, M. et al. (2012), "Springtime high surface ozone events over the western United States: Quantifying the role of stratospheric intrusions," *J.Geophys. Res.*117, D00V22, doi:10, 1029/2012JD018151.

Sources	Mean	Mean for Days > 60 ppbv
Total observed	55.3 ± 8.3	65.1 ± 4.4
Total modeled	61.0 ± 8.6	66.0 ± 8.3
NA anthropogenic	11.0 ± 5.0	11.6 ± 5.3
Total background[a]	50.0 ± 10.6	54.5 ± 10.6
Asian anthropogenic[b]	4.7 ± 2.4	5.3 ± 2.6
Stratospheric	22.3 ± 11.5	25.4 ± 12.3

[a]Includes the contribution from Asian pollution and stratospheric O_3.
[b]Based on AM3 simulations as described by *Lin et al.* [2012].

Table 1: Surface MDA8 Ozone Concentrations (in ppbv) Averaged Over 15 High-Elevation Western U.S. Sites for April–June 2010.

On average, total background, which in this case is NAB, was 50 ppb or 82% of the total O_3 while the stratospheric was 37% of the total. In summarizing their results, Lin et al. state:

> These stratospheric intrusions elevated background ozone concentrations (estimated by turning off North American anthropogenic emissions in the model) to MDA8 values of 60–75 ppbv. At high-elevation western U.S. sites, the 25th–75th percentile of the stratospheric contribution is 15–25 ppbv when observed MDA8 ozone is 60–70 ppbv, and increases to ~17–40 ppbv for the 70–85 ppbv range. These estimates, up to 2–3 times greater than previously reported, indicate a major role for stratospheric intrusions in contributing to springtime high-O_3 events over the high-altitude western U.S., posing a challenge for staying below the ozone NAAQS threshold, particularly if a value in the 60–70 ppbv range were to be adopted.

Lin et al. recognize that stratospheric contributions of this magnitude will cause violations of the current primary NAAQS and will create even bigger challenges if a lower NAAQS is chosen. Although they did not address the secondary NAAQS nonattainment status, it clearly will play a large role. However, by using the W126 metric, it is not a straightforward calculation to determine individual source contributions. This is illustrated in the next section.

c. Fractional Contribution of USB to W126 is Underestimated

The best way to illustrate this point is with an example. Let us assume that the average values reported by Lin et al. in Table 1 were the same every hour and every day for the three months. The resulting fractional contributions to MDA8 and the values for W126 and the fractional contributions to W126 are summarized in Table 2.

	MDA8 (ppb)	% of MDA8	W126 (ppm-hrs)	% of W126
Total O_3	61	100	21.8	100
NAB	50	82	5.9	27
NA anthropogenic	11	18	0.01	0.005
NAB + NA anthropogenic	61	100	5.91	0.3
stratospheric	22.3	37	0.09	.04

Table 2: Lin et al. (2012) mean model estimates and the corresponding W126 index values.

In this example, the 61 ppb produces a W126 index of 21.8 ppm-hours which is sufficient to violate any of the proposed secondary W126 standards that are being considered by EPA. The NAB contribution of 50 ppb only produces a W126 index of 5.9 ppm-hours, which is insufficient, by itself, to cause a violation of any of the W126 standards that are being considered. The stratospheric contribution of 22.3 ppb only produces a W126 index of 0.09 ppm-hours. Without the small anthropogenic contribution of 11 ppb, no violation would have occurred even though the W126 index for 11 ppb is negligible. It is this type of calculation that allows EPA to state in the PA:

> Using the counterfactual scenarios, background ozone has a relatively small impact on W126 levels across the U.S.[23]

and,

> ...we conclude the W126 sigmoidal weighting function provides the best way to weight concentrations associated with background sources. Thus, we conclude that the W126 form is best matched to the evidence associated with vegetation effects, as well as addressing the policy-relevant issue of how to weight exposures associated with background sources.[24]

EPA is aware that such a calculation does not provide a useful estimate of the contributions of any individual source category. As a result, "EPA believes it is more informative to estimate the fractional contribution of background ozone to W126 levels."[25] Their methodology is discussed in the next section.

d. Surrogate Method to Compute Fractional Contributions to W126

EPA proposes a complicated 5-step method that places higher weight on background fractions on the days that are going to contribute most substantially to the yearly W126 index. The 5-steps are:

[23] U.S. EPA, supra note 14, at p. 2A-38.
[24] Ibid, p. 6-4 - 6-5.
[25] Ibid.

• Step 1a: Calculate the MDA8 ozone values from the base and the three zero out modeling scenarios at each grid cell containing a site in an area.
• Step 1b: Calculate the W126 daily index for the base model scenario.
• Step 2: For each site, find the three months with highest summed W126 daily indices.
• Step 3: Normalize the daily MDA8 values in the base, NB, NAB, and USB scenarios by the corresponding W126 daily index from the base scenario.
• Step 4: Calculate the average W126-weighted MDA8 values over the three month period for each of the four scenarios (base, NB, NAB, USB).
• Step 5: Calculate the NB/Base, NAB/Base, and USB/Base ratios based on step 4 outputs. These values represent an estimate of the fractional influence of background ozone on modeled W126 levels.[26]

Because the calculation is so complicated, EPA only does it for 4 areas: Farmington, NM, Denver, CO, Riverside, CA and Atlanta, GA. The results of this exercise are shown in Figure 7. The results show that the fractional method computes fractional contributions of USB to W126 that are comparable to but slightly less than the USB contributions to MDA8.

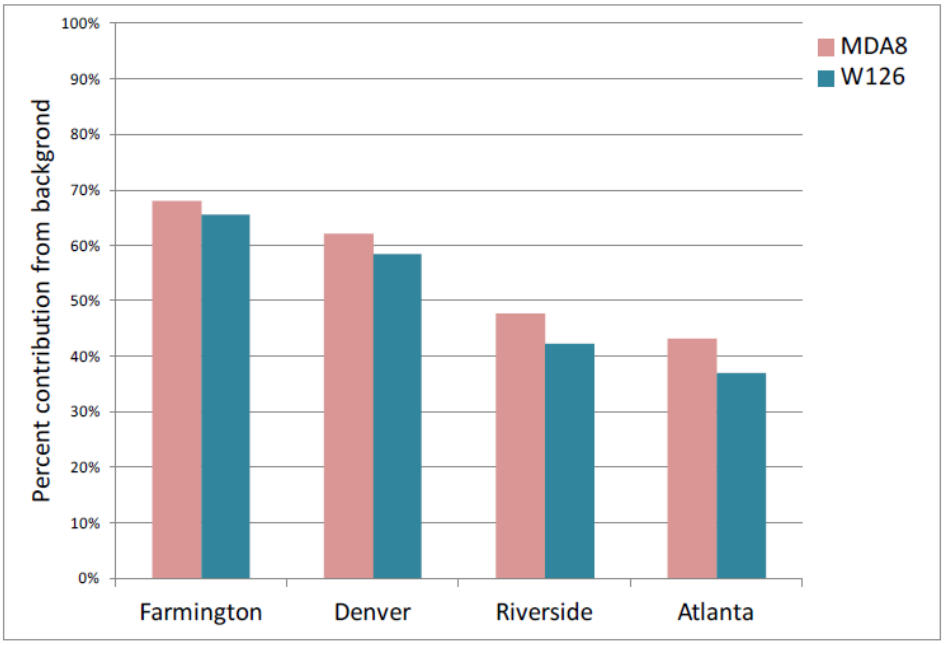

Figure 7: Fractional contribution of U.S. background to seasonal mean MDA8 ozone and W126 levels in four sample locations. Model estimates based on 2007 CMAQ zero out modeling.

There are several issues with these calculations. First, why did they use MDA8 instead of the actual 8 AM to 8 PM values? The use of MDA8 only adds an unnecessary complication that

[26] Ibid, p. 2A-39.

causes the result to deviate from the actual answer in an unknown manner and direction. Second, they estimated USB MDA8 by zeroing out U.S. anthropogenic emissions, which, as discussed above, is inappropriate. The third issues is that it is unclear why they performed the calculation at all since they do not use the result and they still conclude: " W126 form is best matched... as addressing the policy-relevant issue of how to weight exposures associated with background sources."[27]

e. Exceptional Events and W126

In their discussion of Figures 2-13 and 2-15 (Figures 1 and 2 in this report), EPA admits that there are infrequent exceptionally high occurrences of USB. EPA then states:

> These infrequent episodes usually occur in relation to a specific event, and occur more often in specific geographical locations, such as at high elevations or wildfire prone areas during the local dry season.
>
> It should be noted here that EPA has policies for treatment of air quality monitoring data affected by these types of events. EPA's exceptional events policy allows exclusion of certain air quality monitoring data from regulatory determinations if a State adequately demonstrates that an exceptional event has caused the exceedance or violation of a NAAQS.[28]

EPA's discussion in the PA suggests that a state has the option to disqualify an exceptional event that causes a violation of the primary NAAQS from being considered in regulatory determinations. As pointed out, however, in AIR's companion comments on the primary O_3 NAAQS,[29] this is a high hurdle for the states that must invest considerable resources to demonstrate that they are a victim of an exceptional event. However, the PA is silent on identifying exceptional events with respect to a W126 standard. The three-month long period that is the subject of the Lin et al. (2012) paper would seem to be an ideal test case.

During the 3-month period encompassing April - June 2010, Lin et al. documented 13 individual stratospheric intrusion events that affected a large portion of the western U.S. that lasted from 1 to 6 days. The intrusions enhanced MDA8 concentrations to 70 - 86 ppb at the surface sites. As shown in Table 1, the mean measured MDA8 was 55.3 ppb while the mean modeled MDA8 was 61.0 ppb. The mean stratospheric contribution is 22.3 ppb. The 55.3 ppb corresponds to a W126 annual index of 11.6 ppm-hours, which would be in violation of the W126 standard if EPA chooses a value near the low end of the range under consideration. Would these events qualify as exceptional events?

f. Massive Additional NO_x Reductions Will Be Needed to Offset USB Contributions to W126

[27] Ibid, p. 6-5.
[28] Ibid, p. 2-17.
[29] Heuss, J.M., Wolff, G.T. and Kahlbaum, D.F., (2014), Review and Critique of the U. S. Environmental Protection Agency Second External Review Drafts of the "Health Risk and Exposure Assessment for Ozone" and the "Policy Assessment for the Review of the Ozone National Ambient Air Quality Standards," Air Improvement Resource, Inc. Report, Prepared for The Alliance of Automobile Manufacturers, March 2014.

In previous risk assessments, EPA employed the quadratic rollback method to estimate the spatial and frequency distributions of MDA8 O_3 in urban areas after just meeting any alternative NAAQS. As EPA has articulated, there are a number of limitations with this approach. As a result, EPA uses a new method in the second draft REA that we believe is a superior method. That method is to use the Community Multi-scale air quality photochemical model (CMAQ) in conjunction with the Higher order Direct Decouple Method (HDDM) to estimate the distributions of MDA8 O_3 concentrations associated with achieving alternative NAAQS. At the same time, the method estimates the degree of emission controls that the areas need to apply in order to achieve alternative NAAQS.[30] In their analysis, EPA estimated the requisite level of NO_x-only U.S. emissions reductions independently for nine distinct regions of the contiguous U.S. These regions are shown in Figure 8 and they are based on the National Oceanic and Atmospheric Administration's (NOAA) climate regions. NOAA characterizes each region as being "climatically consistent" and routinely uses these regions to describe regional climate trends. EPA felt these regions are an appropriate delineation for their analysis since geographic patterns of both O_3 and plant species are driven by climatic features such as temperature and precipitation. A single NO_x emissions perturbation was used to adjust ambient air quality data at all O_3 monitoring sites for each region and alternative standard. The magnitude of this emissions perturbation was determined independently for each region and standard by determining the smallest perturbation necessary to bring all sites within a region into attainment of the existing standard or the potential alternative standards. The resulting NO_x reductions by region are shown in Table 3.

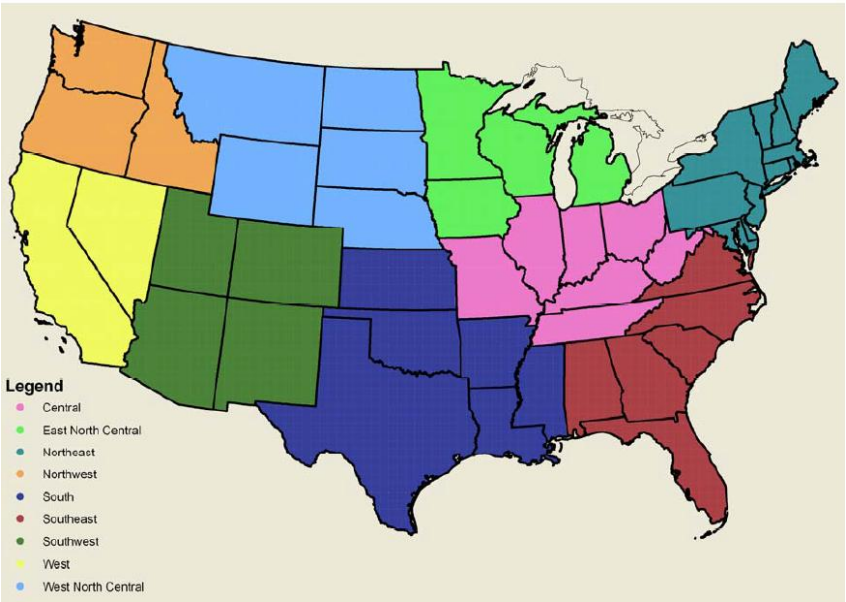

Figure 8: NOAA climate regions used in the model-based air quality adjustments.

[30] EPA notes that this was not designed to produce an optimal control scenario, but instead aimed to characterize a distribution of air quality when the monitors are meeting the alternative standards. In any event, it provides insight as to the degree of reductions that will be required to meet various standards.

Region	75 ppb	15 ppm-hrs	11 ppm-hrs	7 ppm-hrs
Central	48%	14%	58%	70%
East North Central	65%	0%	23%	61%
Northeast	96%	36%	51%	81%
Northwest	51%	0%	0%	0%
South	54%	44%	56%	66%
Southeast	64%	14%	38%	58%
Southwest	55%	67%	85%	90%
West	90%	91%	93%	95%
West North Central	23%	0%	6%	39%

Table 3: Percent reductions in U.S. anthropogenic NOx emissions used to reach existing and alternative standard the in nine climate regions.

It is quite obvious that most areas of the U.S. will need significant to massive additional NO_x emission reductions even to meet a 15 ppm-hours W126 standard with the greatest (91%) required in the west region. For a 7 ppm-hours standard, 7 out of 9 regions require additional reductions that range from 58% to 95%.

From 1980 to 2013, the U.S. has reduced anthropogenic NO_x emissions by 52% and emissions from highway vehicles by 56% and emissions from electrical generation units by 74%.[31] Such additional emissions reductions are not realistic. Not explicitly articulated is the fact that much of the reductions are needed to offset the large contribution to W126 from USB and, at least in the west and southwest, from stratospheric contributions.

IV. USB is Ignored in the Welfare REA

In the entire Welfare REA and appendices, the term "background O_3" only appears once on page 2.4 in a sentence that says stratospheric intrusions are included in the background O_3 contribution. Because of the low weight W126 gives to USB by itself, EPA apparently feels that the background is not an important consideration in considering risk. As they state in the PA:

> ...we conclude the W126 sigmoidal weighting function provides the best way to weight concentrations associated with background sources. Thus, we conclude that the W126 form is best matched to the evidence associated with vegetation effects, as well as addressing the policy-relevant issue of how to weight exposures associated with background sources.

[31] U.S. EPA, (2013), National Emissions Inventory (NEI) Air Pollution Emissions Trend Data. http://www.epa.gov/ttn/chief/trends/index.html. (accessed March 17, 2014).

Thus, EPA concludes that by using the W126 index, they can ignore any further consideration of background O_3 in their consideration of welfare risk. This ignores the fact that at most locations in the yellow, orange and red areas in Figure 5, the majority of the ozone is due to USB. In EPA's scheme of things, a background of 40 or 50 ppb produces a harmless W126 index (1.46 or 5.93 ppm-hours, respectively) by itself. If U.S. anthropogenic emissions add another 10 to 20 ppb, the ozone increases to 60 ppb which corresponds to a W126 index of 19.7 ppm-hours and all of the risk is attributed to the anthropogenic emissions, which require additional emissions reductions of 58-95%.

Such an approach completely masks the important role that USB plays in the exceedance of a potential W126 NAAQS from policymakers. It also does not fulfill the Clear Air Act mandate for CASAC to "advise the Administrator on the relative contribution to air pollution concentrations of natural as well as anthropogenic activity…"