

March 14, 2011

Subject: W. C. ADAMS COMMENT ON EPA MEMORANDUM

Transmittal Note:

As the Clean Air Scientific Advisory Committee (CASAC) continues its deliberation on the prior NAAQS ozone record, please review the attached short comment filed by William C. Adams responding to Dr. James Brown's memorandum to the ozone docket dated June 14, 2007 as **Attachment 1**. This comment can be found in the ozone docket as EPA-HQ-OAR-2005-0172-4783.

Subject: PRB STUDIES AVAILABLE IN PRIOR NAAQS OZONE RECORD

Transmittal Note:

At the March 3, 2011 CASAC Teleconference there was a discussion on ozone PRB and specifically what information was available during the prior review. Below please find some of the studies then published listed in **Attachment 2**, and a highlighted discussion of those studies. This information can be found in the ozone docket as EPA-HQ-OAR-2005-0172-12897.1.

**ATTACHEMNT 1**

**EPA DOCKET  
ID No. EPA-HQ-OAR-2005-0172**

**COMMENT ON EPA MEMORANDUM: THE EFFECTS OF  
OZONE ON LUNG FUNCTION AT 0.06 PPM IN HEALTHY ADULTS  
OCTOBER 9, 2007**

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Following retirement from the University of California, Davis, in September, 2004, I have published two studies in *Inhalation Toxicology* (2006a, 2006b) emanating from research supported by the American Petroleum Institute which was completed in 2003. I have also completed a consulting contract with the Environmental Protection Agency in March, 2005, in which I assisted in the updating of human O<sub>3</sub> exposure response research for the Criteria Document. Further, I participated as a member of the University of California Office of the President's appointment of a review panel to evaluate the drafts of the California Air Resources Board Staff's Report and Technical Support Document for O<sub>3</sub> (2005) and for NO<sub>2</sub> (2006). The comments I am providing here are my personal opinion and do not represent the University of California or any organization identified above.

At the end of the first paragraph of the memorandum, Dr. Brown states that the principal issue raised is the extent to which lung function responses observed in healthy young adult subjects in my two exposures to 0.06 ppm O<sub>3</sub> (2006a) for a 6.6 h exposure while engaged in moderate exercise were or were not statistically significant. Because I was interested in the time-course of pulmonary function and symptoms responses to filtered air (FA) and three O<sub>3</sub> concentrations (viz., 0.04, 0.06, and 0.08 ppm), including both square-wave and triangular protocols at the latter two concentrations, I used a two-way ANOVA with repeated measures and a Scheffe post-hoc test to determine statistical significance. Dr. Brown and the EPA contend that while this procedure reduces the probability of Type I error (false positive), the Scheffe test is overly conservative and may have also increased the probability of a Type II error (false negative). However, Dr. Mark Nicolich (ExxonMobil Biomedical Sciences, Inc., April 9, 2007) repeated my statistical analysis using the Dunnett post hoc test (a notably less conservative test than Scheffe), and found the same significant FEV<sub>1</sub> differences as those I reported (Adams, 2006a) (i.e., only at 0.08 ppm O<sub>3</sub>).

On page 2 of Dr. Brown's memorandum, it is stated that although the FEV<sub>1</sub> responses to 0.06 ppm O<sub>3</sub> square-wave and triangular exposures in my 2006a study were not significantly greater than for FA, they diverge, as depicted in Fig. 1, from the responses to FA and 0.04 ppm O<sub>3</sub> and concludes that "a cursory evaluation of the Adams (2006a) data as described above, strongly suggests that exposure to 0.06 ppm O<sub>3</sub> causes small group mean FEV<sub>1</sub> decrements in

healthy adults.” However, the net mean response at 6.6 h was only -2.82%, compared to the net mean response for the two 0.08 ppm O<sub>3</sub> exposures which was (-6.54%), i.e., 2.3 times greater, even though the O<sub>3</sub> concentration increase from FA was 0.08 ppm, or only 1/3 greater than that for the increase from FA to the 0.06 O<sub>3</sub>). Further, in the discussion section of my published paper (Adams, 2006a), it was pointed out that subtraction of the FEV<sub>1</sub> responses for the two 0.06 ppm exposures from those observed for the two 0.08 ppm exposures gave results not statistically significant from the net values obtained upon subtracting the final FA value from those for the post-exposure values observed for the two 0.08 ppm O<sub>3</sub> exposures.

On page 3 (2<sup>nd</sup> paragraph), it is stated that simple pre- to post-exposure analysis of the effects of O<sub>3</sub> versus filtered air on FEV<sub>1</sub> has been used by others (Horstman et al., 1990; McDonnell et al., 1991). However, the former used an ANOVA procedure before applying paired t tests to determine whether significant FEV<sub>1</sub> responses were apparent in the same subjects undergoing square-wave exposure to 0.08, 0.10, and 0.12 ppm O<sub>3</sub>. McDonnell et al. (1991) used two different subject pools to examine the effects on FEV<sub>1</sub> response to 0.08 and 0.10 ppm O<sub>3</sub>, employing paired t tests for each separately to determine statistical significance of responses at each concentration. In the memorandum, it appears that paired t tests were applied to my data without an initial ANOVA to examine whether there was statistical significance in pre- versus post-exposure FEV<sub>1</sub> response across multiple exposure conditions. If this were done, it would necessitate a post-hoc correction of the paired t test results that might or might not result in the statistical significance for the FEV<sub>1</sub> response reported in the memorandum. Statistical texts (e.g., Neter et al., 1996) routinely recommend that ANOVA is preferable because the t-test is too extreme (non-conservative). Multiple t tests may be suitable for exploratory experiments or hypothesis generating experiments, but are probably not appropriate for setting regulations.

The use of only pre- compared to post-exposure FEV<sub>1</sub> values is better substantiated with square-wave exposures than with triangular exposure patterns in which earlier significant responses have been consistently observed at a mean O<sub>3</sub> concentration of 0.12 ppm (Adams, 2006b; Hazucha et al., 1992) and 0.08 ppm (Adams, 2006a) than in the square-wave comparison exposures. However, no such tendency is apparent for FEV<sub>1</sub> response with time in the two 0.06 ppm exposures in Fig. 1 of the memorandum. Rather, there is a non-significantly greater drop from 4.6 h to 5.6 h for the 0.06 ppm square-wave exposure than for the 0.06 ppm triangular exposure. This is additional evidence that 0.06 ppm response patterns differ from those at 0.08 ppm and support the need to conduct additional studies in the region below 0.08 ppm before relying on questionably significant 0.06 ppm responses justified on the basis of paired t tests.

In the first full paragraph of page 4, it is stated that “studies conducted by the U.S. EPA in Chapel Hill, NC have commonly utilized a paired t test to assess the statistical significance pre- to post-exposure changes in FEV<sub>1</sub> between an air and an O<sub>3</sub> exposure.” At the end of this paragraph, it is stated that “the goal here is not to critique the statistical approaches of any study, but rather: 1) to note differences in the statistical methods between studies and 2) to analyze FEV<sub>1</sub> responses to low O<sub>3</sub> exposure concentrations from the Adams’ studies in the same manner as the studies conducted by the U.S. EPA in Chapel Hill, N.C.” However, in one reference cited

(Horstman et al., 1990), which examined the pre- vs. post-exposure FEV<sub>1</sub> response to 0.08, 0.10, and 0.12 ppm O<sub>3</sub>, the non-parametric Williams test was utilized before applying paired t tests.

Near the top of p. 5, it is stated that “We conclude that, although appropriate for the design and intent of the Adams’ studies, the multiple comparison correction is overly conservative (increased Type II error and decreased power) for the evaluation of pre- to post-exposure changes in FEV<sub>1</sub> between an air and an O<sub>3</sub> exposure and we adopted the standard approach used by other researchers.” One of the three supporting references listed (Hazucha et al., 1992), however, used a 2-way ANOVA first to determine if pre- vs. post-exposure FEV<sub>1</sub> differences in three exposures (FA, 0.12 ppm O<sub>3</sub> square-wave, and 0.12 ppm O<sub>3</sub> triangular) were significant before using post hoc paired t tests. In another reference listed (Horstman et al., 1995), the authors mention use of ANOVA for a split-plot design to test the hypothesis that pre-minus post-exposure differences for the air and O<sub>3</sub> exposures were the same for a group of asthmatics as for a group of nonasthmatics.

On page 5 (near the end of the 1st full paragraph), it is stated that the “CASAC panel members supported the approach adopted in the OAQPS Staff Paper to evaluate the statistical significance of O<sub>3</sub>-related lung function responses associated with pre- vs. post-exposure responses. The CASAC Panel members also supported use of the paired t test approach as the preferred method for analyzing the pre- minus post-exposure lung function responses.” (Regarding the latter, Dr. Nicolich has advised me that he and a colleague do not recall such an assertion by a CASAC member during the teleconference, nor have they found in transcripts and subsequent writings of the panel members any such reference). While I agree that pre- vs. post-exposure responses may be an acceptable means of evaluating pulmonary function responses to a prolonged (i.e., 6.6 h or 8 h) square-wave O<sub>3</sub> exposure, I do not consider it appropriate for a triangular exposure (Adams, 2006a, 2006b; Hazucha et al., 1992). Further, I do not consider a paired t test preferable to the statistical approach used in my study (Adams, 2006a), even if it is preceded by an appropriate ANOVA test indicating statistical significance and followed by a Bonferroni correction. This opinion also applies to the assertions regarding the probabilities of significance given in the following paragraph in which no correction for post hoc application is used (which would result in their increase by 5 times).

I agree partially with the assertion near the bottom of page 5 that Fig. 2, showing only data from square-wave exposures in my two studies (Adams, 2002 and 2006a) illustrates that the relatively small effects of 0.06 ppm O<sub>3</sub> exposure (compared to that for exposure to 0.08 ppm O<sub>3</sub>) on FEV<sub>1</sub> response appear to be consistent with the trend in responses observed for exposures to 0.04 ppm and 0.08 ppm O<sub>3</sub>. However, as stated above, the net mean response at 6.6 h was only -2.86% for the 0.06 ppm O<sub>3</sub> square-wave exposure which was less than one-half of the net mean response for the square-wave 0.08 ppm O<sub>3</sub> exposure (-6.07%), even though the O<sub>3</sub> concentration increase from FA was 0.06 ppm, or  $\frac{3}{4}$  of that for the 0.08 ppm O<sub>3</sub> exposure.

At the bottom of p. 5 of the memorandum, it is pointed out that while “the average FEV<sub>1</sub> response to 0.06 ppm O<sub>3</sub> exposure is relatively small, ..... it is important as this is an average response in young healthy adults. As observed in Attachment 1 of the memorandum, there is

considerable variability in responses between similarly exposed individuals, such that some experience distinctly larger effects even when small group mean responses are observed.” I agree with this assertion, and that exposure to 0.06 ppm O<sub>3</sub> in my study resulted in two (of 30) subjects who experience >10% net FEV<sub>1</sub> response in the square-wave and the triangular protocols. Further, this was not observed for any subject in the 0.04 ppm O<sub>3</sub> exposure. However, these two clear outliers in the 0.06 ppm exposures, violate the assumption of a normal distribution that is one of the criteria needed for appropriate use of a t test.

In summary, I conclude that the FEV<sub>1</sub> response in healthy young adults to 6.6 h exposure to 0.06 ppm O<sub>3</sub> in my study (Adams, 2006a) does not demonstrate a significant mean effect by ordinarily acceptable statistical analysis. Rather, I consider this response to be in somewhat of a gray area, both in terms of a biologically meaningful response and a statistically significant response. Further, I feel that more studies of human pulmonary function (and measurements of related physiological mechanisms) should be conducted in prolonged 0.06 ppm O<sub>3</sub> exposures as soon as possible.

Thank you for your consideration of the issues I have raised and discussed.

#### References

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- Adams, W.C. 2006a. Comparison of chamber 6.6-hour exposures to 0.04-0.08 ppm ozone via square-wave and triangular profiles on pulmonary responses. *Inhalat. Toxicol.* 18:127-136.
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- Neter, J., Kutner, M.H., Nachtsheim, J., and Wasserman, W. Applied Linear Statistical Models. Irwin, 1996 (4<sup>th</sup> edition).
- Nicolich, M.J. Some additional statistical analyses of the FEV<sub>1</sub> pulmonary response data from W.C. Adams (2006). Unpublished paper, April 7, 2007. (Epidemiology and Health Surveillance, Biomedical Sciences, Inc. P.O. Box 971, Annandale, N.J. 08801-0971).

## ATTACHMENT 2

### **The following references were available in the prior review:**

Fiore, A.M., Jacob, D.J., Liu, H., Yantosca, Fairlie, T.D., Li, Q., 2003. Variability in surface ozone background over the United States: implications for air quality policy. *Journal of Geophysical Research* 108 (D24), 4787.

Goldstein, A.H., Millet, D.B., McKay, M., Jaegle, L., Cooper, O., Hudman, R., Jacob, D.J., Oltmans, S., Clarke, A., 2004. Impact of Asian emissions on observations at Trinidad Head, California during ITCT 2K2. *Journal of Geophysical Research* 109 (D23), D23S17.

Heald, C.L., Jacob, D.J., Fiore, A.M., 2003. Asian outflow and trans-Pacific transport of carbon monoxide and ozone pollution: an integrated satellite, aircraft, and model perspective. *Journal of Geophysical Research* 108 (D24), 4804.

Henderson, R., 2007. Clean Air Scientific Advisory Committee's (CASAC) Review of the Agency's Final Ozone Staff Paper. Page C-36.

Hocking, W. K., T. Carey-Smith, D. W. Tarasick, P. S. Argall, K. Strong, Y. Rochon, I. Zawadzki, and P. A. Taylor (2007), Detection of stratospheric ozone intrusions by windprofiler radars, *Nature*, 450, 281–284.

Hudman, R. C. et al. Ozone production in transpacific Asian pollution plumes and implications for ozone air quality in California. *J. Geophys. Res.* 109, D23S10, doi:10.1029/2004JD004974 (2004).

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Starting at page “6 of 32” in the following document **highlighted** sections provide information available at the time of the prior review.

# **Comments on EPA's Proposal to Revise the National Ambient Air Quality Standards for Ozone**

**Docket No. EPA-HQ-OAR-2005-0172**

March 2010

**Submitted To:  
Docket No. EPA-HQ-OAR-2005-0172  
Environmental Protection Agency  
Mail code 6102T  
1200 Pennsylvania Ave., NW.,  
Washington, DC 20460.**

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# Executive Summary

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These comments were prepared in response to EPA's recent proposal to lower the National Ambient Air Quality Standards for ozone (as detailed at 75 FR 2938, published on January 19, 2010). EPA has proposed reducing the ozone National Ambient Air Quality standard to between 0.060 ppm to 0.070 ppm (three year average of the 4<sup>th</sup> highest concentration). "EPA assesses risks to human health and environmental effects from O<sub>3</sub> levels in excess of PRB (policy relevant background) concentrations" (EPA, 2006). The use of PRB was used to address population risk assessment and was pivotal in establishing the level of the proposed standard. EPA has used GEOS-CHEM modeling results to assert that PRB is 15 to 35 ppb (mean concentration) over the continental US. There are many technical issues associated with the information EPA used and the methodology followed in setting the current PRB level particularly in the Western US, at higher elevations, and likely in rural areas in general. These comments assemble data indicating that in western rural and mountainous areas of the United States, the background ozone concentration (PBR) often greatly exceeds 35 ppb. Compliance with an ozone standard in the range of 0.070 to 0.060 ppm will be very difficult if not impossible to achieve as illustrated in by this document.

EPA should utilize a broad stakeholder process involving technical experts from the states, tribes, industry, consulting firms, etc. to:

- Develop an analysis protocol for re-evaluating PRB;
- Re-evaluate PRB; and
- Review the results of the re-evaluation of PRB and open it up to public comment

All available tools should be used in determining PRB including modeling, surface ozone monitoring data, upper air ozone data from ozonesondes and aircraft measurements, and satellite ozone data, etc.

EPA also needs to consider how higher PRB affects the implementation of a new standard and the development of control strategies for attainment of the NAAQS. EPA needs use a broad stakeholder process to assist in development of policies for implementation of and addressing the ozone NAAQS.

## **Policy Relevant Background Determination Issues**

EPA asserts that the level of PRB for ozone in the United States is 15 – 35 ppb (mean). The basis that EPA has used for PRB considers transboundary transport of pollutants from Canada and Mexico as part of PRB as controllable, having little effect, and not considered in establishing the PBR. PRB was not determined using the same 3-year average of the 4<sup>th</sup> highest maximum daily 8-hour average form equivalent to the standard, but rather a monthly average daily diurnal profile for less than 1 year of data. Also, the PRB determination was based only on 12 cities at lower elevations and did not consider elevated or rural areas. Furthermore, the PRB determination neglected the modeling issues of the models ability to accurately simulate temporal variations in ozone, large grid cell size, and meteorological data averaging;

These comments conclude it is necessary that EPA revise their determination of PRB to address:

- 1) Inclusion of Mexico and Canada transboundary pollutant transport as part of PRB;
- 2) Improve the GEOS-CHEM model ability to accurately simulate temporal ozone variability;
- 3) Address the modeling deficiencies of terrain and meteorological averaging brought about by the large grid cell size and meteorological time steps;
- 4) Determine PRB by using the 4<sup>th</sup> highest 8-hour maximum daily average concentration;
- 5) Use more recent and documented emissions inventories;
- 6) Evaluate PRB for elevated terrain and rural areas; and
- 7) Vary PRB as a function of season, altitude, and total O<sub>3</sub> level.

## **Western Ozone Issues**

The intermountain West has unique ozone issues including high ozone in remote areas, high ozone levels measured by satellite and high ozone in the spring – likely due to intercontinental transport and stratospheric-tropospheric exchange (STE). EPA has not addressed these issues in their determination of policy relevant background. Also, EPA has not developed protocols for the states and tribes to identify

and exclude “exceptional events” of ozone due to natural events (such as STE) or intercontinental transport from monitoring data or modeling analyses. EPA has also not provided the states and tribes with the necessary tools or protocols to address compliance with the standard in light of the evidence for frequent exceptional events causing high concentrations.

These comments conclude that EPA also needs to consider the following western ozone issues in re-determination of PRB for ozone as well as policies for implementing and addressing the ozone NAAQS in the intermountain west:

- 1) The role of international cross-boundary transport (including Mexico and Canada) in observed ozone levels, particularly on a periodic high monitored ozone day basis;
- 2) The role of regionally transported ozone and precursors in observed ozone levels, particularly in the Intermountain West and on a periodic high monitored ozone day basis; and
- 3) The role of stratospheric-tropospheric exchange in high ozone episodes at the surface, particularly at higher elevations in the Western US.

EPA, through a broad technical stakeholder group, also needs to develop a protocol for use by states and tribes for routinely and promptly evaluating if ozone monitored is from natural events or cross-boundary transport and therefore can be excluded from the nonattainment designation as an exceptional event.

### **Ozone Modeling Issues**

Photochemical ozone modeling is the primary tool for estimating ozone impacts and the only tool EPA used to determine PRB. As pointed out in these comments, current models are glaringly deficient, particularly with respect to their application to rural and mountainous areas. The models need additional refinement, testing, and verification. Ozone model evaluation is critical and needs to examine all performance displays and metrics against monitoring data where it is available. Meteorological modeling is currently inaccurate and fails to replicate observed data. Further investigation is needed in this area. Boundary conditions from GEOS-CHEM model represent the largest contribution to predicted ozone concentrations in CAM<sub>x</sub> and CMAQ model simulations (which are used typically for SIP modeling) yet no verification has been done regarding the accuracy of the modeled boundary conditions. Issues have been found with the vertical mixing algorithms of CAM<sub>x</sub> and CMAQ that have shown over prediction of spring ozone in the intermountain west. CAM<sub>x</sub> has been modified to address this issue; however, CMAQ still requires modification of the vertical mixing algorithms. Furthermore, GEOS-CHEM should be evaluated to determine if the same issue regarding vertical mixing exists. Also, many SIP and NEPA ozone modeling analyses are being done without regional coordination resulting in inconsistent data and methodologies. Ozone modeling should be done a regional level.

As part of the PRB reevaluation and the ozone implementation process, EPA should utilize a broad based stakeholder process to assist EPA with in addressing the following modeling issues:

- 1) Improvement of the model performance evaluation procedures;
- 2) Improvement of meteorological modeling accuracy;
- 3) Verification of boundary conditions accuracy;
- 4) Repairing and testing the vertical mixing algorithms;
- 5) Establishing regional ozone modeling; ; and
- 6) Addressing how to use models in a relative manner in monitor data sparse regions.

### **Concentration Form of the Standard**

EPA's requirement to express ozone in a volume/volume (ppm) concentration results in a lower ozone mass concentration and perhaps more stringent standard for areas of high altitude. EPA has not addressed how elevation and the reduction in mass exposure changes ozone health risk at higher elevations. The more stringent standard at high elevations is not justified without supporting health effects studies.

Current O<sub>3</sub> monitoring expressed as a volume/volume concentration can continue to be used. However, the concentration should be converted to a mass/volume basis under actual conditions before comparison to the equivalent mass/volume concentration of the O<sub>3</sub> NAAQS value at standard conditions.

# 1.0 Introduction

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EPA has proposed reducing the ozone National Ambient Air Quality standard to between 0.060 ppm to 0.070 ppm (three year average of the 4<sup>th</sup> highest concentration). EPA must establish the primary ozone standard based on health criteria. EPA uses background ozone concentrations referred to as Policy Relevant Background (PRB) for purposes of informing decisions about NAAQS. According to the 2006 “Air Quality Criteria for Ozone and Related Photochemical Oxidants,” PRB “concentrations are those concentrations that would occur in the United States in the absence of anthropogenic emissions in continental North America (defined here as the United States, Canada, and Mexico). Policy Relevant Background concentrations include contributions from natural sources everywhere in the world and from anthropogenic sources outside these three countries. Background levels so defined facilitate separation of pollution levels that can be controlled by U.S. regulations (or through international agreements with neighboring countries) from levels that are generally uncontrollable by the United States. **EPA assesses risks to human health and environmental effects from O<sub>3</sub> levels in excess of PRB concentrations.**” (EPA, 2006)

EPA has used GEOS-CHEM modeling results to assert that PRB is 15 to 35 ppb over the continental US. The PRB levels that EPA has estimated through GEOS-CHEM modeling influence the determinations of health effects from different potential NAAQS levels along with the benefits achieved by each potential NAAQS level. There are many technical issues associated with the information EPA used and the methodology followed in setting the current PRB level of 15 – 35 ppb – particularly in the Western US, at higher elevations, and likely in rural areas in general. The issues associated with the determination of PRB related to the ozone standard are discussed in detail in Section 2 and supported by the later sections. Section 3 discusses several western air quality issues including high ozone in remote areas, satellite analysis of ozone in the US, high ozone in the spring, intercontinental transport, stratospheric-tropospheric exchange (STE) and recommendations regarding addressing these issues regarding PRB determination. Section 4 addresses ozone modeling areas of concern. Currently, photochemical modeling is the primary tool used to estimate ozone concentrations and global modeling was the only tool (GEOS-CHEM) that EPA used to determine PRB. At present, these models are imperfect and need to be rigorously evaluated using available information and tools such as surface monitoring ozone data, upper air ozone data from ozonesondes and aircraft measurements, and satellite ozone data. The models should be used in combination with available data sources to establish PRB, rather than relying on modeling alone. Section 5 addresses further concerns with the mixing ratio (i.e., ppm) form of the standard. The current standard is potentially more restrictive at higher elevations because the mass loading for an equivalent volume/volume standard is lower at higher elevations than at sea level and no elevation dependent health effects studies have been considered or provided by EPA.

EPA must establish the primary ozone standard based on health criteria, however, from a policy perspective, EPA has not addressed how this standard can be achieved or implemented in a cost effective manner. Compliance with an ozone standard in the range of 0.070 to 0.060 ppm will be very difficult if not impossible to achieve as illustrated in the remainder of this document. Potential exceedances of the proposed ozone standard levels cannot, in many cases, be attributed to local or US sources amenable to control. As an example, monitors in pristine areas, such as Yellowstone and Big Bend National Parks, that have few to no local sources are likely to be in violation of the contemplated levels of the ozone standard. Classical compliance strategies that have been used to improve ozone levels in the past are likely to be ineffective for these rural ozone exceedances. Urban control strategies will result in substantial additional costs to the public and ultimately may not result in any measurable air quality improvement.

EPA cannot rely on previous control strategies to achieve compliance with the primary standard and therefore needs to rethink how rural areas may achieve compliance. It is recommended that as part of the final revised ozone standard EPA must develop a process that can be implemented to address rural ozone compliance and that this process needs to include stakeholder input.

## 2.0 Policy Relevant Background

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EPA defines PRB concentrations as “those concentrations that would occur in the United States in the absence of anthropogenic emissions in continental North America (defined here as the United States, Canada, and Mexico).” “Background levels so defined facilitate separation of pollution levels that can be controlled by U.S. regulations (or through international agreements with neighboring countries) from levels that are generally uncontrollable by the United States. **EPA assesses risks to human health and environmental effects from O<sub>3</sub> levels in excess of PRB concentrations.**” (EPA, 2006)

EPA has used GEOS-CHEM modeling output to assert that PRB is 15 to 35 ppb over the continental US. The PRB levels that EPA determined influence the determinations of health effects from different potential NAAQS levels along with the benefits achieved by each potential NAAQS level. There are many technical issues associated with the information EPA used and the methodology followed in setting the current PRB standard of 15 – 35 ppb – particularly in the Western US, at higher elevations, and likely in rural areas in general. These technical considerations; coupled with the extensive body of studies, information, and understanding developed since the Fiore et al 2003 paper which EPA relied on to set the current PRB level, require that EPA reconsider the determination of PRB, taking into account current information and using current tools. Details regarding many of the issues associated with the determination PRB related to the ozone standard are discussed below.

### 2.1 Sources Included in PRB

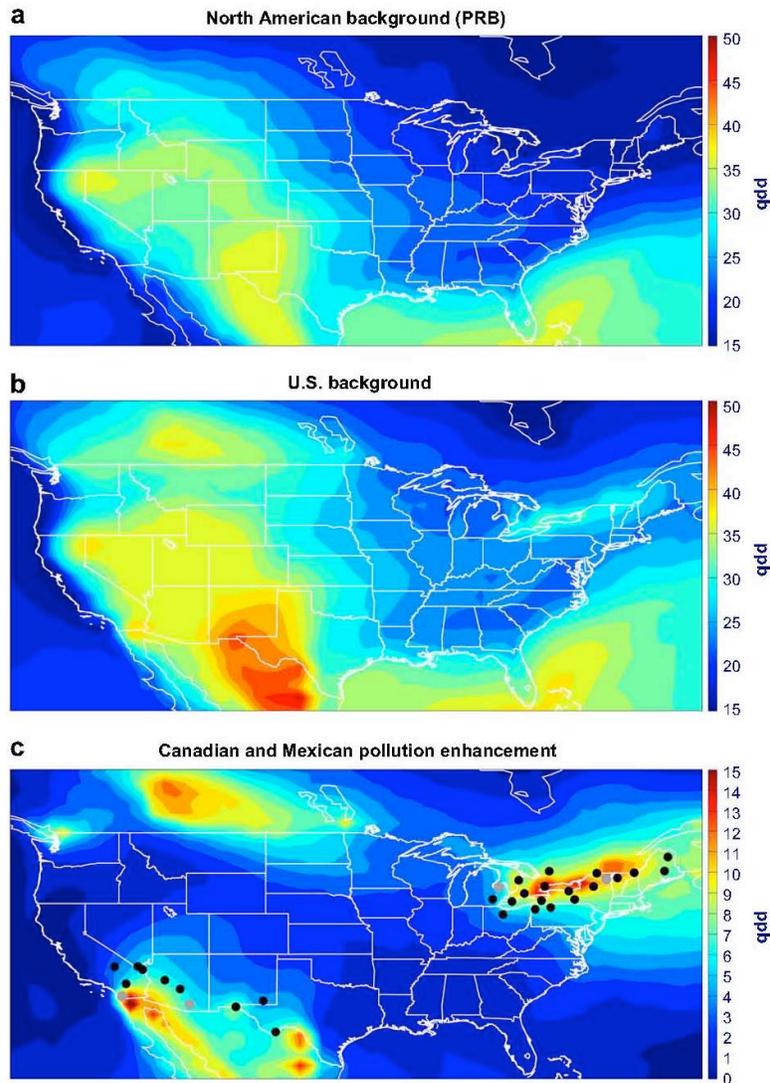
EPA, perhaps erroneously, assumes that emissions from Canada and Mexico can be controlled to achieve US air quality objectives and considers this in establishing PRB. However, there is no direct process that EPA can use to affect emission standards in Canada or Mexico. It is unlikely that these countries would achieve US emission standards even if US states or sources funded installation of pollution control on Mexican or Canadian sources and there is no clear evidence that controls have been imposed on Mexican or Canadian sources in order to meet US air quality objectives.

The preamble for the proposed NAAQS for ozone states “cross border O<sub>3</sub> contributions from within North America (Canada and Mexico) entering the U.S. are generally thought to be small. Section 179B of the Clean Air Act allows designated nonattainment areas to petition EPA to consider whether such a locality might have met a clean air standard “but for” cross border contributions.”

However, the study “Surface ozone background in the United States: Canadian and Mexican pollution influences” by Wang et al. (2009) shows that “simulations for summer 2001 indicate **mean** North American and US background concentrations of  $26 \pm 8$  ppb and  $30 \pm 8$  ppb, as obtained by eliminating anthropogenic emissions in North America vs. in the US only.” “The Canadian and Mexican pollution enhancement averages  $3 \pm 4$  ppb in the US in summer but can be occasionally much higher in downwind regions of the northeast and southwest, peaking at 33 ppb in upstate New York (on a day with 75 ppb total ozone) and 18 ppb in southern California (on a day with 68 ppb total ozone).” Furthermore, the study found that “exceedances of the 75 ppb US air quality standard in eastern Michigan, western New York, New Jersey, and southern California are often associated with Canadian and Mexican pollution enhancements in excess of 10 ppb.” In the 2009 analysis Wang concludes that “Unlike intercontinental transport that manifests itself mainly through enhancement of the hemispheric ozone background, pollution plumes from Canada and Mexico can be transported in the continental boundary layer to affect US areas immediately downwind” (Wang, 2009) (**Attachment A**). It should be noted that this study only considered impacts from emissions originating in Mexico and Canada for the July through August (summer) time period and does not address potential influences during the March through May time period (spring) when many Western sites exhibit high ozone levels. This study needs to be extended and the influence of Mexican and Canadian emissions understood prior to a re-evaluation of PRB and setting of lower standards. It is also important for EPA to quantify the ozone effects from emissions from Mexico and Canada to be considered consistent with the statistical form of the standard (3-year average of the 4<sup>th</sup>

highest daily 8-hour average) or on an event basis. Figure 1 from Wang et al (2009) shows the June-August mean daily 8-hour maximum ozone concentrations for North America background (PRB), US background, and the Canadian and Mexican enhancements.

**Figure 1: June-Aug Mean Daily 8-hour Maximum Ozone Concentrations (Wang, 2009)**



**Fig. 2.** Jun–Aug mean daily-8 h-max ozone concentrations in surface air for (a) North American background, (b) US background, (c) Canadian and Mexican pollution enhancement (determined as the difference between the US and North American backgrounds). The circles in (c) show the observation sites used for model evaluation. The grey circles identify the sites used in the time series plots of Fig. 4 (time series plots for other sites are included in supplementary materials).

As indicated in Figure 1, there is a **mean** enhancement of daily average 8-hr ozone concentrations during the summer. However, compliance with the ozone standard is based on extreme concentrations (not mean concentrations) and to identify the actual ozone impact of emissions from Mexico and Canada of ozone compliance in the US a more event driven analysis is required.

**In conclusion, EPA must do the following:**

- 1. EPA needs to completely analyze the impact of Mexican and Canadian emissions on US ozone levels in a comprehensive analysis that delineates: emission inventories used, meteorology used, model accuracy and model sensitivity (grid size etc.). Such a study should be subjected**

to stakeholder comment. It is not appropriate for EPA to simply reference a summary journal article as the basis for such an important assessment of ozone impacts;

2. Canadian and Mexican ozone contributions should be included in the quantification of PRB;
3. The study should be extended to the full year and the impact of Canadian and Mexican emissions on high ozone days over the entire US should be quantified; and
4. The PRB risk assessment regarding ozone exposure that EPA used to establish the level of the standard should be recalculated to account for a higher PRB which does not exclude emissions from Canadian and Mexican sources.

## 2.2 Accuracy of PRB Modeling

EPA relied on a summary GEOS-CHEM modeling journal article published by Fiore et al in 2003, to establish the current PRB level and to estimate the impacts of global emission sources on ozone levels in the US (included in PRB). There have been numerous papers that have described the impacts of Asian emissions on the US<sup>1</sup>. The EPA Staff Paper cites Goldstein et al. (2004) "Impact of Asian emissions on observations at Trinidad Head, California during ITCT 2K2" as a reference indicating that the GEOS-CHEM modeling provides an accurate quantification of PRB. In that study detailed analyses were conducted to exclude local impacts in the monitoring data so that an accurate comparison of model accuracy could be made. The authors comment that "neither model matched (GEOS-CHEM or Mozart) the observed temporal variability in ozone." This limitation is very significant because the GEOS-CHEM model does not resolve the temporal variations observed in the monitoring data. **Since EPA has proposed an ozone standard based on extreme statistics (3 year average of the 4<sup>th</sup> highest maximum daily 8-hour average), the PRB should be developed on a similar extreme statistic basis as the health standard.** However, as demonstrated in Goldstein et al. model performance may not be capable of accurately resolving such extremes in the measurements (Figure 2). Comparison in the bottom panel in Figure 2 indicates the poor performance of GEOS-CHEM in replicating the temporal variations in the measurements.

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<sup>1</sup> Goldstein, A.H., Millet, D.B., McKay, M., Jaegle, L., Cooper, O., Hudman, R., Jacob, D.J., Oltmans, S., Clarke, A., 2004. Impact of Asian emissions on observations at Trinidad Head, California during ITCT 2K2. *Journal of Geophysical Research* 109 (D23), D23S17.

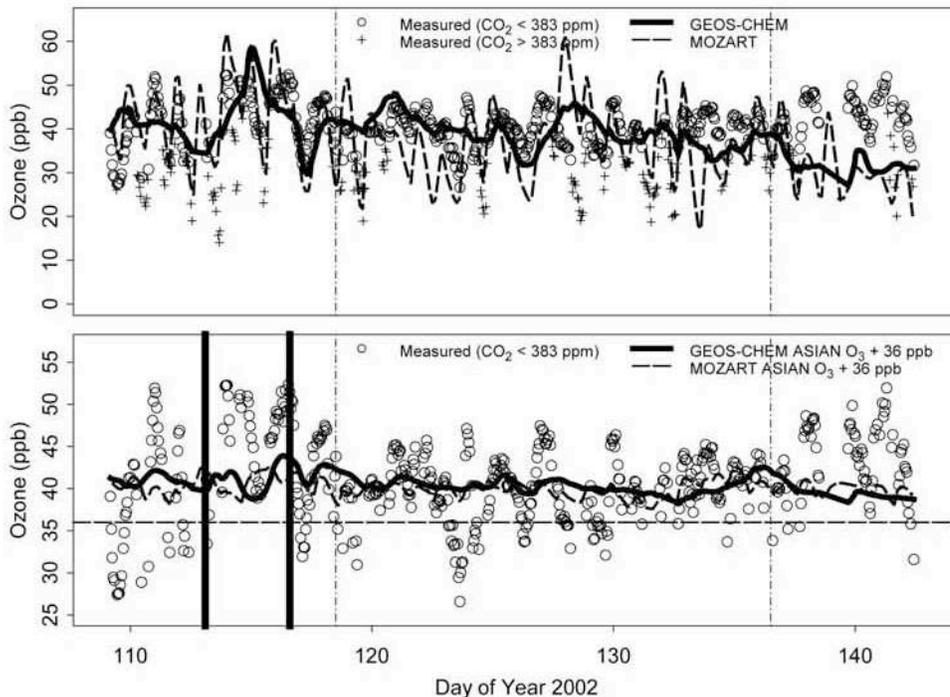
Liu, H., D. J. Jacob, I. Bey, R. M. Yantosca, B. N. Duncan, and G. W. Sachse, Transport pathways for Asian pollution outflow over the Pacific: Interannual and seasonal variations, *J. Geophys. Res.*, 108(D20), 8786, doi:10.1029/2002JD003102, 2003.

Jaffe, D., I. McKendry, T. Anderson, and H. Price, Six "new" episodes of trans-Pacific transport of air pollutants, *Atmos. Environ.*, 37, 391–404, 2003.

Cooper, O. R., Parrish, D. D., Stohl, A., Trainer, M., Ne'de'lec, P., Thouret, V., Cammas, J. P., Oltmans, S. J., Johnson, B. J., Tarasick, D., Leblanc, T., McDermid, I. S., Jaffe, D., Gao, R., Stith, J., Ryerson, T., Aikin, K., Campos, T., Weinheimer, A., and Avery, M. A., 2010, "Increasing springtime ozone mixing ratios in the free troposphere over western North America", *Nature*, Vol. 463, 21 January, 2010, doi:10.1038, nature08708.

Jaffe, D., H. Price, D. Parrish, A. Goldstein, and J. Harris (2003b), Increasing background ozone during spring on the west coast of North America, *Geophys. Res. Lett.*, 30(12), 1613, doi:10.1029/2003GL017024.

**Figure 2: Comparison of Ozone Concentration Differentiated by CO<sub>2</sub> Concentration and GEOS-CHEM and MOZART Model Predictions (Goldstein, 2004)**



**Figure 8.** (a) Ozone concentration timeline differentiated by CO<sub>2</sub> concentration indicating times when vertical stability caused local decreases in O<sub>3</sub> (pluses, CO<sub>2</sub> > 383 ppm), and times with stronger vertical mixing (open circles, CO<sub>2</sub> < 383 ppm). Total O<sub>3</sub> simulated by the GEOS-CHEM and MOZART models are also shown. (b) O<sub>3</sub> timeline filtered to remove regional influences (CO<sub>2</sub> > 383 ppm) along with GEOS-CHEM and MOZART model simulations of O<sub>3</sub> produced from Asian emissions. 36 ppb O<sub>3</sub> was added to the model simulation to allow comparison of predicted and observed variability. Solid vertical lines indicate one high ozone period (Day 117) and one low ozone period (Day 113) for which vertical profiles from ozone sondes are shown in Figure 9. Dot-dashed vertical lines at days 118.5 and 136.5 indicate the most likely times that the influence of Asian emissions may have been discernable as plumes, and backward trajectories are shown for these times in Figure 5.

In Fiore's 2003 paper, which EPA relied on in setting the current PRB levels, she noted that background ozone tends to be lower during high ozone events due to the stagnation which occurs in conjunction with these events. Although this may be true for the low elevation Eastern and Southeastern sites evaluated, it is almost assuredly not correct for the springtime high ozone episodes in the Western US, particularly at the higher elevation sites. This presumption of the inverse relationship between high ozone periods and background, used in setting the current PRB, should be reevaluated for the entire year and all areas of the US.

### 2.3 Other PRB Technical Modeling Issues

In addition to the unresolved accuracy of Asian impacts on the US, there are other technical issues regarding the accuracy of GEOS-CHEM predictions over the US to determine PRB. One important issue is modeling grid size for both the GEOS-CHEM and meteorological models. In addition, the meteorological time step associated with the modeling of PRB is a concern.

In general the grid size in the PRB modeling has used a 2 degree by 2.5 degrees grid (approximately 24,000 square miles) for GEOS-CHEM and the meteorological modeling. Given the large size of the horizontal grids used and the terrain and meteorological averaging that occurs over such a large grid, it is

difficult for either the photochemical model or the meteorological model to resolve fine scale vertical mixing that will mix elevated plumes from intercontinental transport to the ground. This is especially true in elevated and complex terrain.

A second concern is the time step used in the meteorological model. A 3-hour time step was used for mixing height and a 6-hour time step was used for winds and convective masses and other three-dimensional variables. Again, given the large grid size and the large time step of the meteorological model, it is unlikely that the model will be able to resolve fine scale vertical motion which is believed to be an important physical process in the quantification of PRB.

Modeling conducted in the intermountain West (Stoeckenius et al, 2009) found that using a 4 kilometer and 12 kilometer grids with CAM<sub>x</sub> and CMAQ identified high ozone concentrations in early spring in elevated terrain. The model simulations found that both models were overstating vertical mixing of elevated plumes. Subsequently, vertical velocity algorithms in the CAM<sub>x</sub> model have been revised. In spring the CAM<sub>x</sub> and CMAQ models overstated vertical velocity and resulting ozone concentrations. Analysis of monitoring data revealed elevated concentrations of ozone during this time period. Thus, the models and the monitoring data both indicate that downward mixing of vertical plumes is an important attribute of spring time ozone in the intermountain West. Unless GEOS-CHEM is capable of simulating such meteorological conditions, the model cannot accurately represent PRB in the West.

## **2.4 Averaging Time of PRB**

EPA claims that policy relevant background for ozone in the US is 0.015-0.035 ppm based on a study using the GEOS-CHEM 3-D chemical transport model (CTM) using emissions estimates from only 2001 (Fiore et al., 2003). The range of 0.015-0.035 ppm is a monthly daily diurnal profile for 12 US cities for only April-October of one year, not the 3 year average of the 4<sup>th</sup> highest maximum daily 8-hour average as the ozone NAAQS. EPA is using a policy relevant background that is not in the same form as the ozone NAAQS. EPA should model 3 years of data for the entire year, not just part of one year looking at 3 year average of the 4<sup>th</sup> highest maximum daily 8-hour average. The averaging time of the modeled PRB must be consistent with the averaging time of the ozone standard (8-hour). Modeling of extreme concentrations raises the question of the accuracy of time series model predictions.

## **2.5 Emission Inventories Used in PRB**

One of the major limitations of modeling PRB is the accuracy of the global emission inventory used as input to the model. Fiore et al (2003) used a global emission inventory for 2001. In that modeling study, global NO<sub>x</sub> emissions from combustion excluding aircraft were 25.6 Tg N/yr (US 6.3 for the US) In addition, global NO<sub>x</sub> biomass burning emissions were 6.5 Tg N/yr. A uniform global concentration of 1750 ppbv of methane was used. Global emissions of isoprene and monoterpenes of 340 Tg C/yr and 130 Tg C/yr were used. In this paper there is no discussion of other global VOC emissions.

Several important points need to be made regarding the modeled emissions. In the development of PRB, EPA must provide detailed documentation on the origin of the estimates as well as what species were modeled. Further, because of the uncertainty of the emissions, model sensitivity analyses should be conducted to evaluate the ultimate level of PRB to uncertainty in emissions. Another important point is that the inventory used to develop PRB is 9 years old. Given the large amount of economic development that has occurred in the last 9 years in Asia, the existing PRB modeling is very dated. EPA must develop more recent emission inventories, verify the accuracy of the modeling versus actual monitoring data where it exists, conduct sensitivity analyses, and reanalyze PRB concentrations.

## 2.6 Determination of PRB

In the EPA determination of PRB, monthly daily diurnal average concentrations were computed at the following cities: 1) Atlanta, GA; 2) Boston, MA; 3) Chicago, IL; 4) Cleveland, OH; 5) Detroit, MI; 6) Houston, TX; 7) Los Angeles, CA; 8) New York, NY; 9) Philadelphia, PA; 10) Sacramento, CA; 11) St. Louis, MO; and 12) Washington, DC. A very important omission regarding where PRB was calculated is that it did not include any locations at elevated terrain or in rural areas. Quantification of PRB at receptors with elevated terrain and rural areas is imperative and a necessary step in setting the primary ozone standard. What is important to note is that the modeling estimates of PRB for these 12 cities all occur in spring. This indicates that the importance of natural sources, intercontinental transport, and the mixing of elevated plumes to the ground over the entire continental US.

## 2.7 Level of PRB

EPA claims that policy relevant background for ozone in the US is 0.015-0.035 ppm based on a 2002 GEOS-CHEM model by Fiore et al (2003). The study found "incidences of 40-50 ppbv at high altitude western sites in the spring." At Yellowstone, the study found "7, 15, and 14 days when afternoon average background concentrations exceed 45 ppbv in March, April, and May of 2001, with upper limits in May of 58, 40, and 25 ppbv, for the background, natural, and stratospheric O<sub>3</sub> levels, respectively." The report stated that "**we expect higher-altitude western sites to be more frequent recipients of subsidence events that transport high concentrations of O<sub>3</sub> from the free troposphere to the surface.**" Furthermore, the study also suggested that "**an appropriate background for use in risk assessments should vary as a function of season, altitude, and total O<sub>3</sub> level.**" Dr. Barbara Zielinska, a member of the EPA's CASAC Ozone Panel, stated in her written testimony (Henderson, 2007): "As shown by Lefohn (2007), the diurnal O<sub>3</sub> concentrations that were measured in Trinidad Head, CA (background site), in April (the highest O<sub>3</sub> month) ranged from 0.030 to 0.050 ppm and the maximum hourly value reported at 0.066 ppm." EPA has not looked at policy relevant background differently as a function of season, altitude, and total ozone level as recommended by the report, but rather has assumed the same background for the whole US. Clearly, as shown by Yellowstone and the other national parks analyzed by Hanna et al (2010) discussed later in the comments, background concentrations of ozone are greater at higher elevations. Policy relevant background as the basis of establishing an ozone standard in the context of only 12 cities is inappropriate, especially when the modeling used as the basis does not match actual monitored data.

## 2.8 Recommendation for Policy Relevant Background

In conclusion, the current EPA determination of PRB is not justifiable in the context of establishing a primary ozone standard for the entire US. EPA must address the following deficiencies in the current PRB determination.

- 1) Sources included in PRB (particularly the role of Mexican and Canadian emissions);
- 2) Model accuracy
- 3) Modeling deficiencies
- 4) Averaging time of PRB
- 5) Emissions inventories used in determining PRB
- 6) Inclusion of elevated terrain and rural areas
- 7) Level of PRB

**Based on this review, it is imperative that EPA revise their determination of PRB to address the identified and unresolved technical issues. In doing this work, EPA should use all available tools, including actual monitored data, and not rely on one model or the output from a single modeling study. In addition before such reevaluation is conducted, EPA should develop an analysis protocol that is subject to peer-review and stakeholder input. Further, the results of such an analysis should be subjected to the same level of review and comment before the results are used in a regulatory setting.**

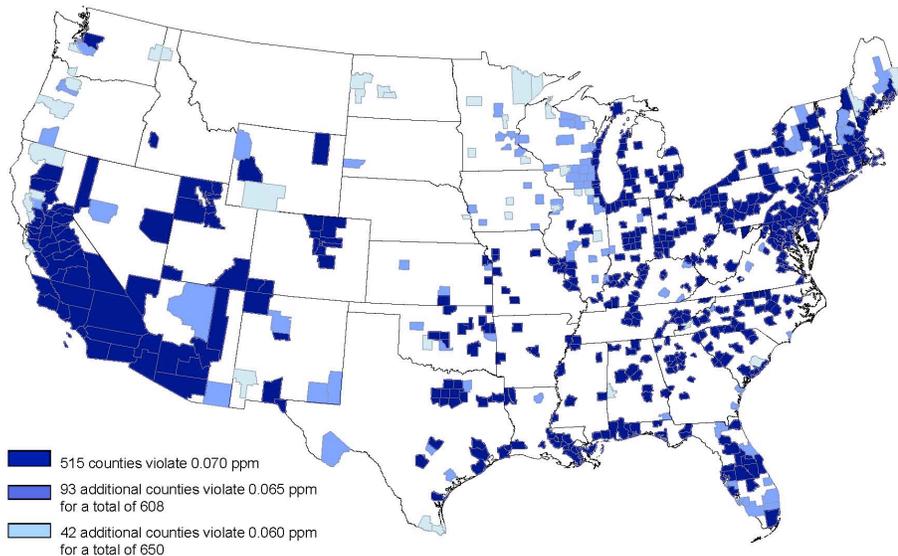
# 3.0 Western Ozone Issues

EPA has proposed reducing the ambient ozone air quality standard to between 0.060 ppm to 0.070 ppm (three year average of the 4<sup>th</sup> highest concentration). Analysis of ozone levels in the rural intermountain West indicates that if this action occurs, most of the counties where ozone monitors exist in this area could violate the ozone standard. In addition, the implementation of the secondary W126 standard will result in additional nonattainment areas.

Figure 3 and Figure 4 present US maps that indicate likely areas where the proposed ozone standards (primary and secondary) will be exceeded. It is important to note especially in the intermountain West that the majority of the areas in white are unclassified because of a lack of monitoring data. As EPA's own analysis shows, some 96%, 90%, or 76% of counties with monitors would violate an ozone standard set at the 0.060, 0.065, and 0.070 ppm thresholds respectively. There is no reason to presume that this pattern would not be repeated as more rural monitors are installed in the intermountain West, and additional areas which exceed the a lower ozone standard are likely.

**Figure 3: EPA's Map of Counties with Monitors Violating Proposed Primary 8-hour Ground-level Ozone Standards 0.060-0.070 parts per million.**

Counties With Monitors Violating Proposed Primary 8-hour Ground-level Ozone Standards  
0.060 - 0.070 parts per million  
(Based on 2006 - 2008 Air Quality Data)  
EPA will not designate areas as nonattainment on these data, but likely on 2008 - 2010 data which are expected to show improved air quality.



**Notes:**

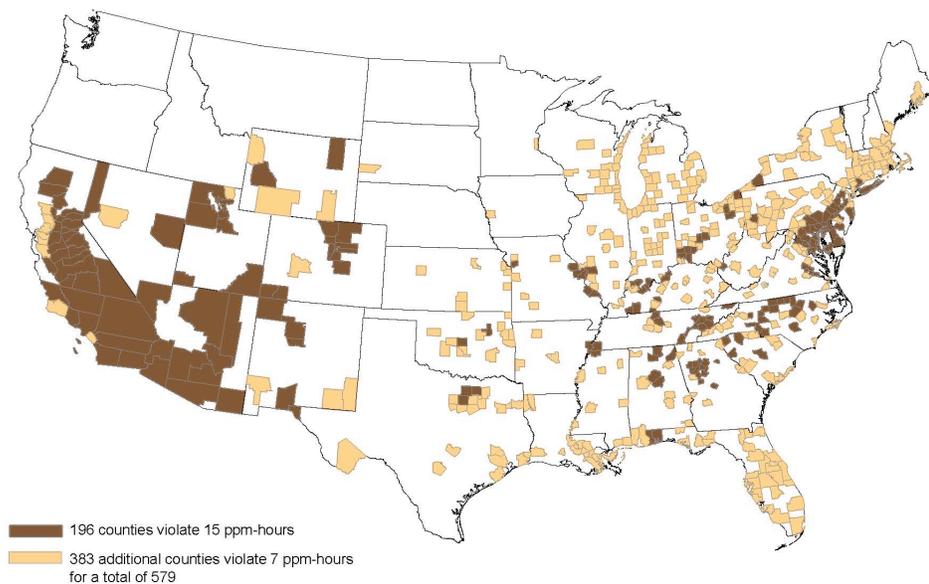
1. No monitored counties outside the continental U.S. violate.
2. EPA is proposing to determine compliance with a revised primary ozone standard by rounding the 3-year average to three decimal places.

**Figure 4: Counties with Monitors Violating Proposed Secondary Seasonal Ground-Level Ozone Standards 7-15 parts per million - hours**

Counties With Monitors Violating Proposed Secondary Seasonal Ground-Level Ozone Standards  
7 – 15 parts per million - hours

(Based on 2006 – 2008 Air Quality Data)

EPA will not designate areas as nonattainment on these data, but likely on 2008 – 2010 data which are expected to show improved air quality.



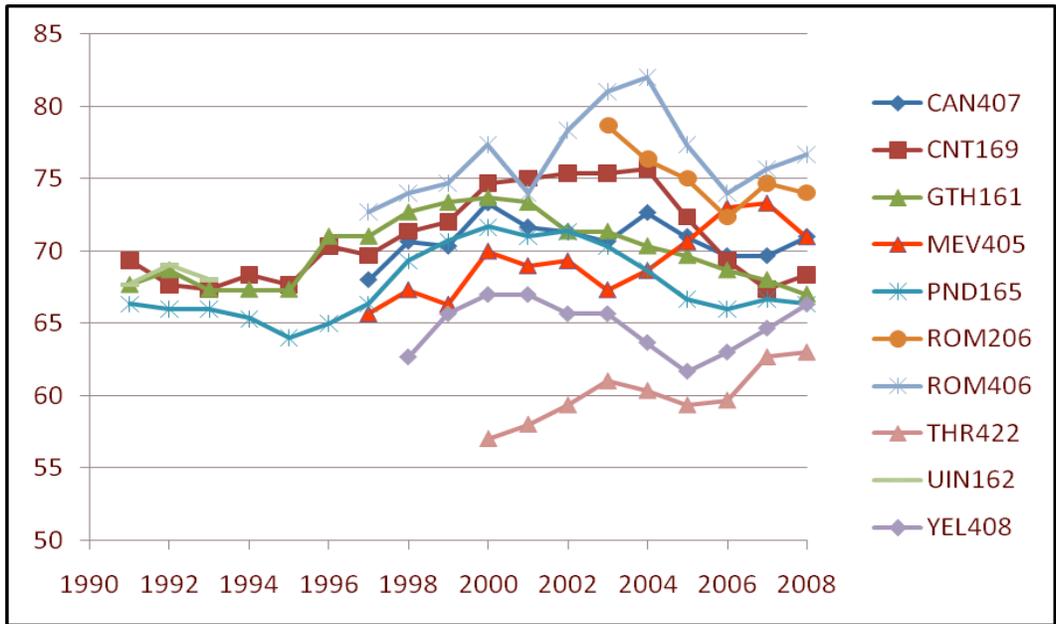
No monitored counties outside the continental U.S. violate.

The intermountain West has several ozone issues including high ozone in remote areas, high ozone levels measured by satellite, high ozone in the spring, intercontinental transport, stratospheric-tropospheric exchange (STE). These issues must be addressed in determining PRB and hence in setting a new ozone standard.

### 3.1 Ozone in Remote Areas

The paper “Air Quality Trends in U.S. Western Mountain States” by Hanna, et al. (2010) analyzed western CASTNET ozone monitoring data (**Attachment B**). Figure 5 from the report indicates that over the period of record (1989-present) all western CASTNET ozone monitoring sites, except Theodore Roosevelt, would have violated the proposed ozone standard at some point in time (regardless of the level). However, as Table 1 shows, Theodore Roosevelt is at a much lower elevation than the other locations.

**Figure 5: Three Year Average of 4th Highest Daily 8-hour Average Ozone from Western CASTNET Sites (Hanna, 2010)**



**Table 1: Elevation of CASTNET Monitors**

CASTNET Site	Elevation (m)
Canyonland, UT	1809
Centennial, WY	3178
Gothic, CO	2926
Mesa Verde, CO	2165
Pinedale, WY	2388
Rocky Mt, CO	2743
Theodore Roosevelt Park, ND	850
Yellowstone, WY	2400

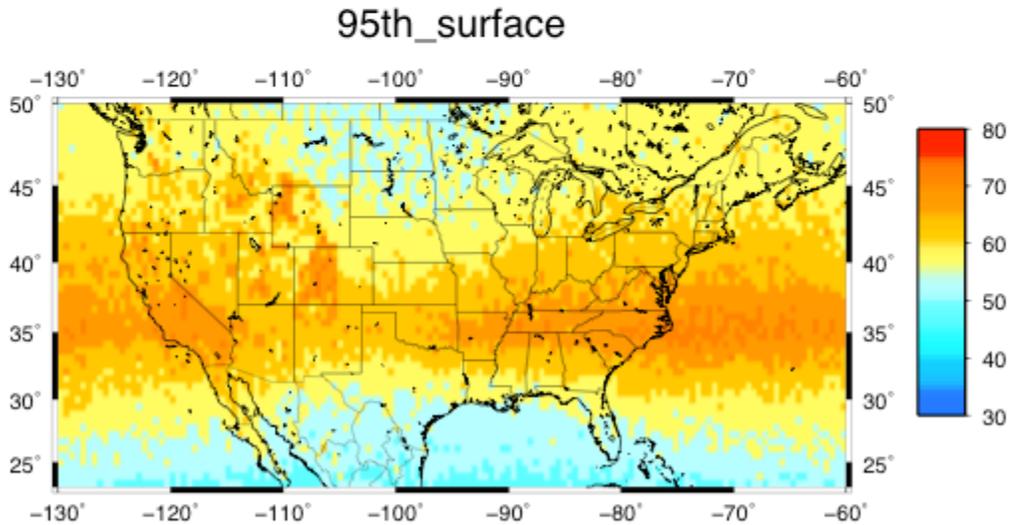
Furthermore, trend analysis was performed on the monitoring data and “the results are mixed, with some sites showing a significant uptrend, others sites showing a significant downtrend, and most sites showing no significant trends” (Hanna, 2010). Also, “no site has a consistent monotonic increase or decrease.” Over the time period 1989 to present there have likely been substantial changes in ozone precursor emissions and changes in these emissions have not resulted in any measurable change in rural ozone concentrations.

It is important to note that the CASTNET ozone monitoring sites are located in pristine areas (many in national parks) with few or no anthropogenic sources nearby; therefore, ozone is likely a result of transport or natural sources. Local anthropogenic sources are regulated by the state where the ozone monitor is located with the state having no regulatory control over sources of transport, especially if outside of the United States. It will be difficult if not impossible for states to bring the areas where the CASTNET sites are located, such as Yellowstone National Park, into attainment. It seems almost unreasonable that a national park, without significant proximate sources of anthropogenic emissions, ever be designated as nonattainment. **In consideration of the ozone levels at the national parks, it is important that EPA gain a more complete understanding of sources contributing to each ozone event that is above the standard in order to develop an effective control strategy, particularly if the causation is determined to be from natural or intercontinental transport sources (PRB).**

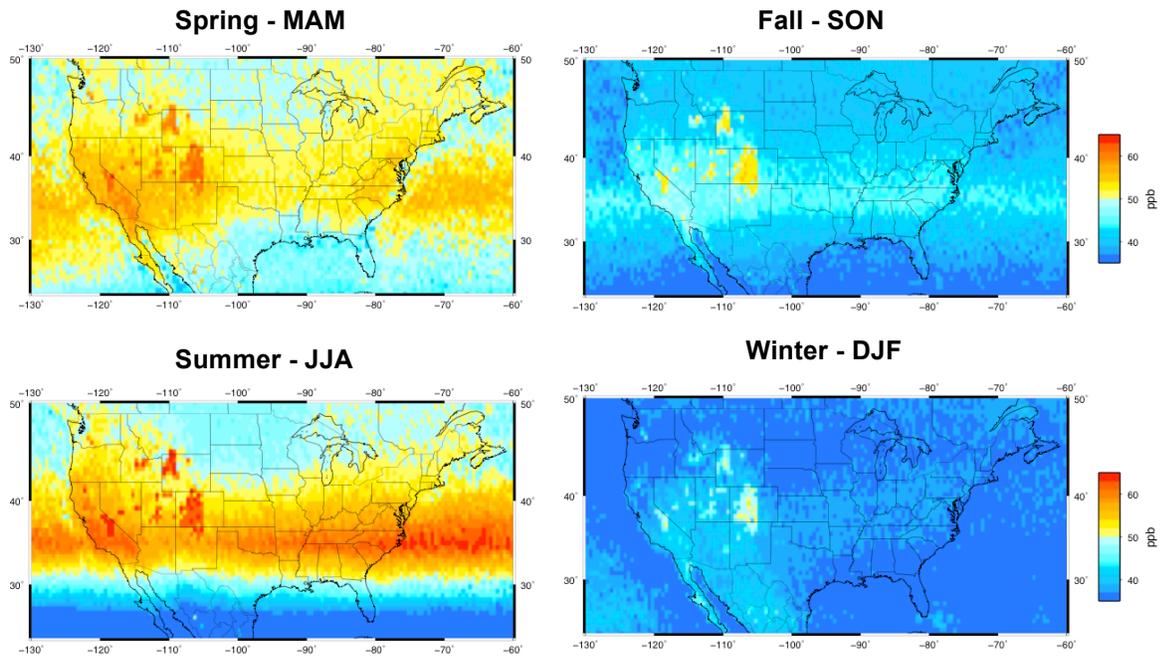
### 3.2 Satellite Analysis of US Ozone Levels

The Ozone Monitoring Instrument (OMI) aboard NASA's Aura satellite measures global ozone at 18 vertical levels in the atmosphere on a daily basis. The 95<sup>th</sup> percentile ozone concentration at the surface during 2006 as measured by OMI instrument is shown in Figure 6 (Smith-Downey, 2010). The 95<sup>th</sup> percentile ozone concentration is the value at which 95% of the measured concentrations in a given year are less than this value, and 5% are above. From this, it is clear that much of the United States has ozone values exceeding 60 to 70 ppb for more than 5% of the year. Seasonally, ozone is highest in spring and summer, and Figure 7 shows that large areas of the US have **average** seasonal ozone concentrations approaching the level of the proposed standard. Figure 8 summarizes the number of days over one year that OMI observed ozone concentrations above a given value. From this, it is clear that large areas of the United States will violate the ozone standard on a regular basis. The OMI tropospheric ozone data are a preliminary product, and have not yet been validated against surface and ozonesonde data.

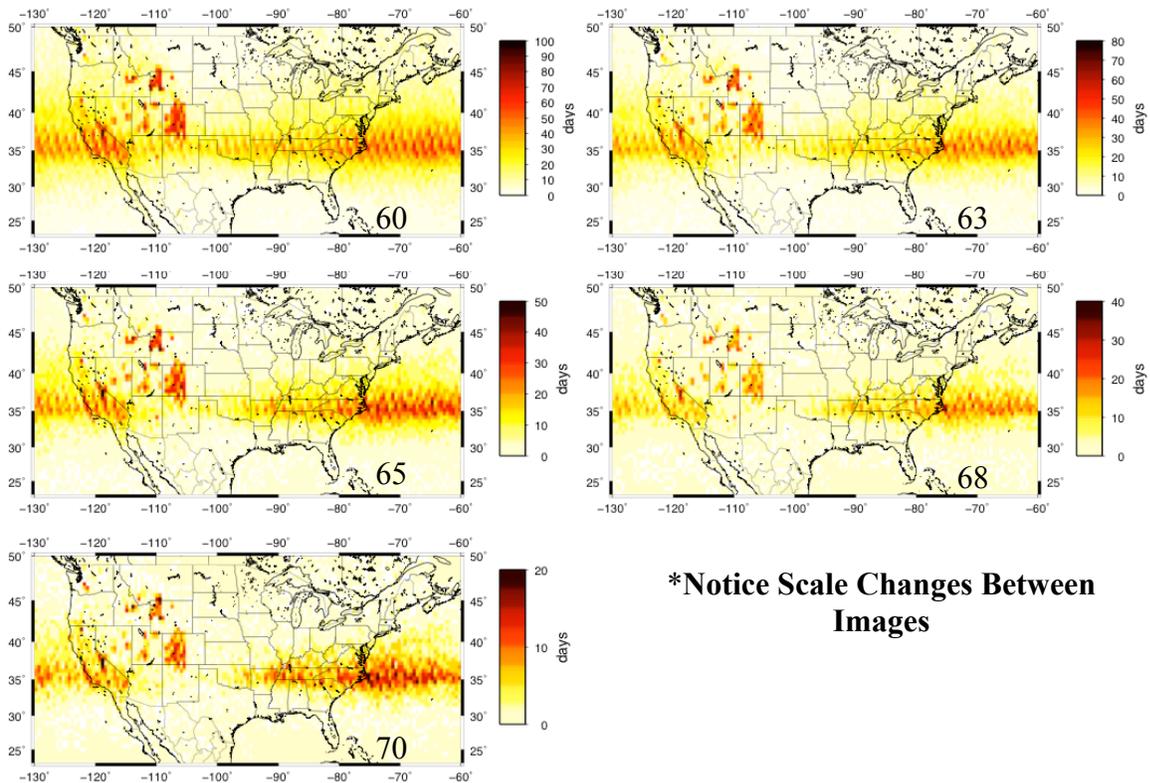
Figure 6: 95th Percentile Ozone in 2006 from OMI (Smith-Downey, 2010)



**Figure 7: Mean Seasonal O<sub>3</sub> in 2006 from OMI Corresponding to the Surface US (Smith-Downey, 2010)**



**Figure 8: # of OMI ozone measurements per year above a given value (60-70ppb) (Smith-Downey, 2010)**



**\*Notice Scale Changes Between Images**

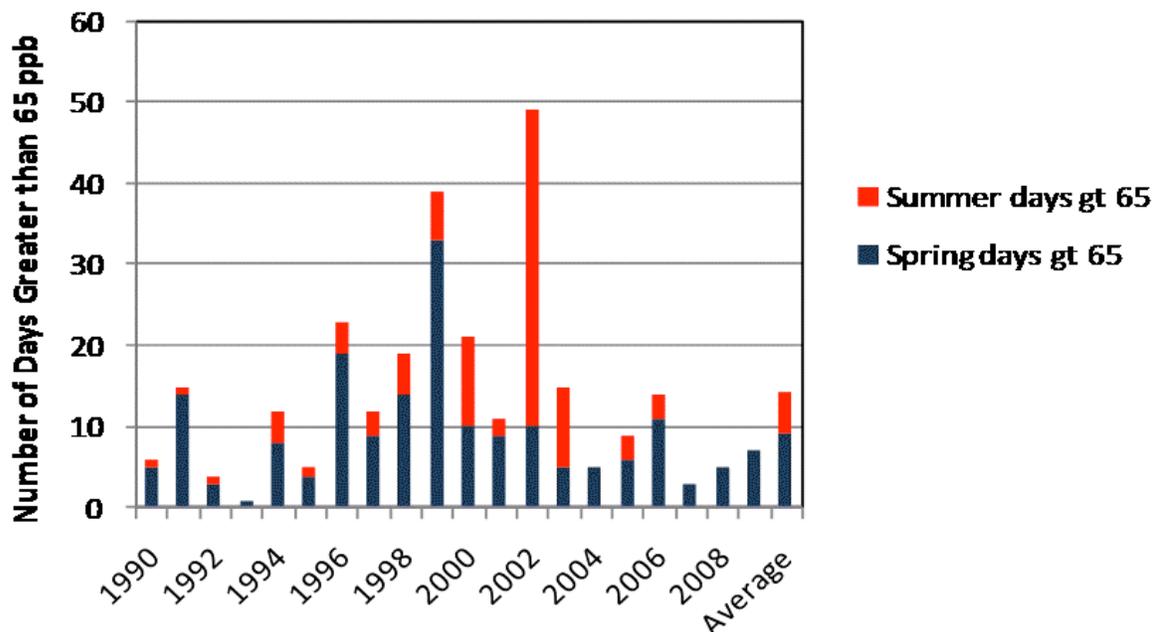
### 3.3 Spring Time Events

Further review of the CASTNET ozone monitoring data indicates that a large percentage of the monitored values in elevated terrain with concentrations above 0.065 ppm occur during the spring as shown on the Table 2 from the presentation “Ozone Trends in the Rural Intermountain West” (Blewitt, 2009) (**Attachment C**). Figure 9, presents the occurrence of ozone concentrations in excess of 0.065 ppm for spring and summer events at the Gothic CASTNET site (located in elevated terrain in rural Colorado). With the exception of 2000, 2002 and 2003, the majority of the concentrations in excess of 0.065 ppm have occurred in the spring. Additionally, this site has no local ozone precursor sources in the vicinity.

**Table 2: CASTNET Occurrence of the 4th Highest Ozone in Spring in Elevated Terrain** (Blewitt, 2009)

Site	Percent of the 4th Highest 8-hour Ozone >65 ppb and in Spring	Comments
Canyonland, UT	33	No measurements in March and April
Centennial, WY	46	No measurements in April
Mesa Verde CO	77	
Pinedale, WY	44	
Rocky Mountain, CO	21	
Gothic, CO	62	
Yellowstone, WY	73	

**Figure 9: Seasonal Ozone 8-Hour Daily Maximum Greater Than 65 ppb at the Gothic, CO CASTNET Monitor**



These springtime events cannot be explained by local source impacts since they are in pristine areas with no local sources and possible sources of ozone precursors could be:

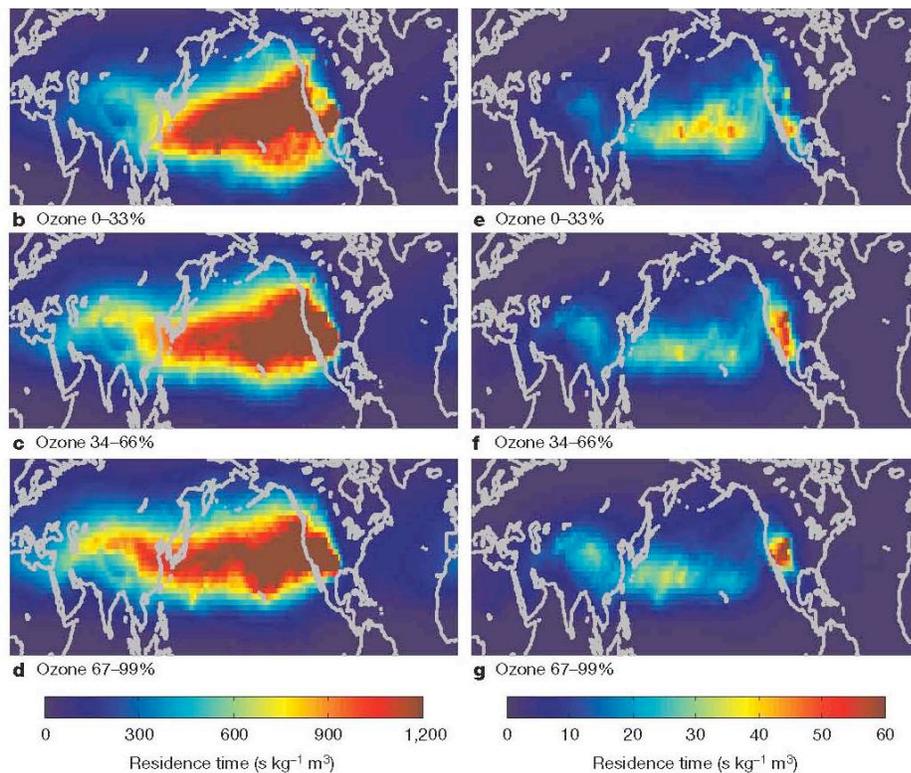
- Regional anthropogenic sources;
- Global anthropogenic sources; or
- Natural events (downward mixing of stratospheric ozone or stratospheric-troposphere exchange)

EPA has determined that global sources of ozone (or precursors) and downward mixing of stratospheric ozone can be defined as “exceptional events” that can be excluded from the determination of attainment status. The analysis given in the section also shows that EPA does not take enough of these global sources of ozone into account for their PRB determination, since the PRB is much lower than the ozone measured from these events. **EPA needs to develop a protocol for routinely and promptly evaluating the causes of unusual ozone events (stratospheric intrusion, fires, international cross boundary transport, etc.) to determine if the event is caused by a natural event or an anthropogenic source outside the US and can therefore be excluded from nonattainment designation. The end product of such an analysis is for the affected state to submit an “Exceptional Events Analysis” to EPA to provide justification to exclude the event from a nonattainment determination.**

### **3.4 Intercontinental Transport**

A recent paper by Cooper et al (2010) finds that transport from Asia is affecting free troposphere ozone levels over the US and that elevated springtime ozone events in the West may be a result of Asian emissions and associated long range transport (**Attachment D**). One of the findings of the Cooper analysis was “We suggest that the observed increase in springtime background ozone mixing ratio may hinder the USA's compliance with its ozone air quality standard.” Figure 10 from study shows the spring-time ozone distribution in the mid-troposphere and air mass source regions.

**Figure 10: Ozone in the Troposphere between 3-8 km Various Percentile Ranges (Cooper et al, 2010)**



**Figure 1 | Springtime ozone distributions for 1984, 1995–2008 in the mid-troposphere (3.0–8.0 km), and air mass source regions. a**, Distributions of springtime ozone measurements made in the troposphere between 3.0 and 8.0 km (stratospheric samples have been filtered out). The green line and data points are the median, and the yellow data points are means. The upper and lower blue lines (and data points) indicate the 95th and 5th percentiles. The upper and lower red lines (and data points) indicate the 67th and 33rd percentiles. Ozone sample sizes range from 1,663 in 1984 to 8,587 in 2006 (see the Supplementary Information). Also shown are the ozone rates of increase for 1984–2008 and 1995–2008, as determined from the slope of the linear regression. The range on the slope indicates the 95% confidence limit that the slope lies within that range. Ozone data were gathered over mid-latitude western

North America (25°–55° N, 130°–90° W), as shown in the Supplementary Information. The transport history of each ozone measurement was determined by calculating a retroplume with the FLEXPART PDM (see Methods and Supplementary Information). Every retroplume consisted of 40,000 back-trajectory particles released from the time and location of each measurement and advected backwards in time for 15 days. **b–d**, The average 1984–2008 retroplume for three ranges of ozone measurements, expressed as column residence times. **e–g**, The corresponding retroplume residence times in the lowest 300 m of the atmosphere (the footprint layer). Ozone percentile ranges: **b** and **e**, 0–33rd; **c** and **f**, 34th–66th; **d** and **g**, 67th–99th. Column and footprint sample sizes are equal because every 15-day retroplume has some degree of transport through the lowest 300 m of the atmosphere.

**Ground level ozone concentrations from global emissions transport, even though included within EPA’s definition of policy relevant background, may be very high and there is no protocol by EPA to determine and exclude such transport.** The policy relevant background level that EPA has set of 0.015–0.035 ppm (monthly daily diurnal profile for 12 US cities during 3-month ozone season) needs to be reconsidered in light of this new information and is likely significantly too low, particularly for the elevated terrain in the West. As indicated in the Cooper et al (2010) paper, intercontinental transport from Asia in particular has been found to be high and increasing over the past few decades. Cooper et al (2010) stated that the results of their study “support earlier work that indicates that rising Asian ozone precursor emissions would cause springtime surface ozone to increase in western North America since the 1980s, despite decreasing domestic emissions. Finally, summertime extreme ozone events in many US urban areas have decreased, while some rural and marine sites in the western US show increasing ozone, possibly due to increasing background ozone.” An earlier study by Hudman et al entitled “Ozone production in transpacific Asian pollution plumes and implications for ozone air quality in California” found “a mean Asian pollution enhancement of 7 ppbv ozone at Sequoia National Park in May 2002 on those days when the 8-hour average ozone concentration exceeded 80 ppbv.” Also, a study in 2001 that integrated satellite observations and air craft measurements measured plumes from Asia with “8–17 ppb ozone enhancement, driven by decomposition of peroxyacetyl nitrate (PAN) to nitrogen oxides (NO<sub>x</sub>). This result suggests that

PAN decomposition in trans-Pacific pollution plumes subsiding over the United States could lead to significant enhancements of surface ozone” (Heald et al, 2003). **These studies suggest that intercontinental cross boundary transport produces a higher background ozone level that must be considered in a re-determination of PRB and when developing policies and standards to address ozone.**

### 3.5 Stratospheric-Tropospheric Exchange

Another source of pollutants that impacts the PRB level and may inhibit compliance with the ozone standard in the West is stratospheric-tropospheric exchange (STE). STE refers to the transport of material across the tropopause. STE has direct implications on the distribution of atmospheric ozone, in particular, the decrease of lower stratospheric ozone and the increase of tropospheric ozone” (Cordero et al). STE is also known as stratosphere-to-troposphere transport (STT) or stratospheric intrusion. Langford et al examined STE along Colorado’s Front Range during the spring of 1999 (Langford, 2009) using lidar and surface measurements. “A deep tropopause fold brought ~215 ppbv of O<sub>3</sub> to within 1 km of the highest peaks in the Rocky Mountains on 6 May 1999. One-minute average O<sub>3</sub> mixing ratios exceeding 100 ppbv were subsequently measured at a surface site in Boulder, and daily maximum 8-hour O<sub>3</sub> concentrations greater or equal to the 2008 NAAQS O<sub>3</sub> standard of 0.075 ppmv were recorded at 3 of 9 Front Range monitoring stations.” This study showed that the stratospheric contribution to surface ozone is significant and can lead to exceedances of the ozone NAAQS. A study by Hocking et al using wind profiler radars found “numerous intrusions of ozone from the stratosphere into the troposphere in southeastern Canada. **On some occasions, ozone is dispersed at altitudes of two to four kilometers, but on other occasions it reaches the ground, where it can dominate the ozone density variability**” (Hocking, 2007). Higher elevations, as found in Colorado or other areas in the West, are at greater risk of having ozone from the stratosphere reach the ground.

STE is considered a natural event. STE should be carefully and completely evaluated in relation to re-evaluation of PRB. As a natural event, STE can be excluded from determination of compliance with the ozone NAAQS; however, EPA has not developed a protocol to help states or tribes identify and exclude natural events from monitoring data or modeling analyses. The proposed lower ozone standard will make STE a larger issue with demonstrating compliance with the revised ozone standard at higher elevations.

### 3.6 Recommendations Regarding Policy Relevant Background

**EPA’s determination of “policy relevant background” for ozone needs to be revisited.** Further, EPA needs to consider how a higher policy relevant background affects the implementation of a new standard and the development of control strategies for attainment of the NAAQS. In particular, EPA needs to reconsider:

- a. The role of international cross-boundary transport in observed ozone levels, particularly on a periodic high monitored ozone day basis.
- b. The role of regionally transported ozone and precursors in observed ozone levels, particularly in the Intermountain West and on a periodic high monitored ozone day basis.
- c. The role of stratospheric - tropospheric exchange in high ozone episodes at the surface, particularly at higher elevations in the Western US.

# 4.0 Ozone Modeling Issues

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Photochemical ozone modeling is the primary tool used to estimate ozone impacts and was the only tool used to determine PRB. Ozone modeling will become more important as the PRB level is reevaluated and under the proposed ozone standard due to the increase in development of State Implementation Plans (SIPs) for nonattainment areas. At present, such models are imperfect and need additional refinement, testing and verification. Collaborative research is needed to better evaluate these models. Areas of concern are:

1. Model evaluation procedures;
2. Meteorological modeling;
3. Boundary conditions;
4. Vertical mixing algorithms; and
5. Use of ozone models in a regulatory setting.

**As part of the PRB reevaluation and the ozone implementation process, EPA must develop a broad based stakeholder process to provide EPA with guidance on addressing the modeling issues listed above including technical experts from EPA, the states, industry, consulting firms, etc.**

## 4.1 Model Evaluation Procedures

Model evaluation is an important part of ozone modeling. An ozone model performance evaluation needs to examine all performance displays and metrics. Such an evaluation needs to be performed where monitors are located as well as over the entire modeling domain. In addition to evaluating ozone concentrations, precursor, indicator and product species should also be evaluated.

Models should be rigorously tested to evaluate their ability to reproduce the temporal patterns observed at the surface. Currently, models are evaluated in a mean sense, and it is important that they are also capable of reproducing the daily variability that leads to an exceedance event. Because, the form of the standard is the 3-year average 4<sup>th</sup> highest 8-hour average, models should be evaluated for reproducing the same exceedance events observed at the surface.

One of the challenges of ozone modeling is using a model in a relative mode in a monitoring data sparse region. Simply applying the EPA MATS program is not an appropriate solution.

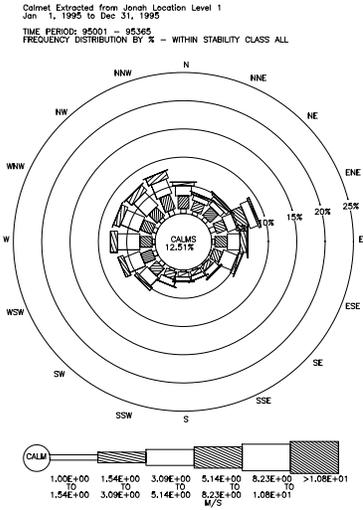
Additional development regarding model performance evaluation is needed and should be done through a stakeholder processes.

## 4.2 Meteorological Modeling

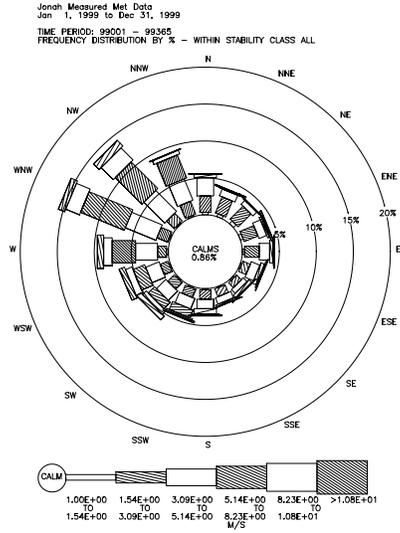
In order to accurately predict ozone concentrations, accurate meteorological modeling is required. Current guidance on the accuracy of meteorological modeling has been published; however, there is considerable uncertainty in such modeling. Figures 11 through 13 present MM5 wind rose simulations and a measured wind rose for Jonah, Wyoming. The MM5 modeling was conducted with a grid size of 4, 12, and 36 kilometers. As indicated by these figures, MM5 modeling at 12 and 36 kilometers do not reflect the actual measured meteorological conditions. At a grid size of 4 kilometers, MM5 replicates the observed data only when MM5 was nudged with extensive surface observations.

**Figure 11: 36 Kilometer Comparison between MM5 and Observed Wind Roses for Jonah, Wyoming**

**Jonah MM5/CALMET  
Predicted**



**Jonah Observed**

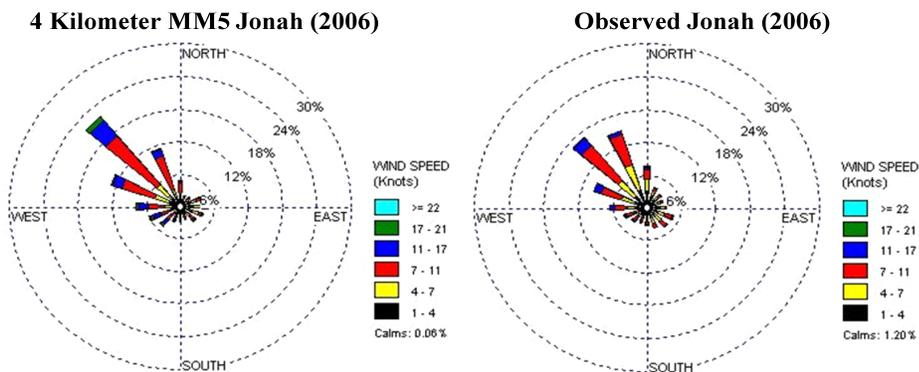


**Figure 12: 12 Kilometer Comparison between MM5 and Observed Wind Roses for Jonah, Wyoming**

**Jonah CALMET/MM5 Predicted**

**Jonah Measured**

**Figure 13: 4 Kilometer Comparison between MM5 and Observed Wind Roses for Jonah, Wyoming with Local Surface Measurements Nudging**



The uncertainty of meteorological conditions (especially wind speed and direction) has an important effect on accurately predicting local, regional and long range source impacts. This is an area that has not been adequately investigated by EPA or the scientific community.

### 4.3 Boundary Conditions

Recent modeling studies e.g., Four Corners Air Quality Task Force Modeling Analysis (Stoeckenius, 2009 and 2010), indicate that during the spring in the intermountain West, boundary conditions dominate predicted (and presumably measured) ozone concentrations with very little enhancement from US anthropogenic sources. Also, during the summer, boundary conditions still dominate predicted concentrations. The boundary conditions for these simulations represent monthly average concentrations at the edge of the 12 km modeling domain shown in Figure 14 below. In any compliance modeling demonstration, local sources subject to controls only have a marginal effect between the level of the standard and boundary conditions. As such, boundary conditions represent a fixed finite concentration and in many cases represent a monthly average. Typically, no verification is made regarding the accuracy of the model boundary predictions, yet this is the largest source contribution of any source group.

In reality, as boundary condition concentrations are advected over the continental US, they represent a good surrogate for PRB (Mexico and Canada emissions are outside the 12 km domain). Thus, the boundary conditions presented in Figures 15 and 16 for the Mesa Verde, Navajo Lake and Shamrock monitoring sites represent a good surrogate for PRB. Figures 15 and 16 are 8-hour average predicted ozone concentrations for the month of April. The boundary conditions were developed by using 2002 monthly average GEOS-CHEM model predictions at the 36 km boundary. The model predictions were used as input to CAM<sub>x</sub> and the predicted concentrations represent local ozone concentrations as a result of boundary conditions. These estimates of PRB include Mexican and Canadian emissions; however, these emissions are offset by using monthly average model predictions instead of actual episodic conditions. Thus, it is believed that these estimates are a good representation of PRB for these locations. As indicated in these figures, the maximum predicted boundary conditions (1-hr) for Mesa Verde are approximately 65 ppb, for Navajo Lake 70 ppb and for Shamrock 75 ppb. It should be noted that the Shamrock monitoring site is at the highest elevation of these three sites and has the largest calculated PRB.

Figure 14: Four Corners Interagency Air Quality Task Force Modeling Domain (Stoekenius, 2009)

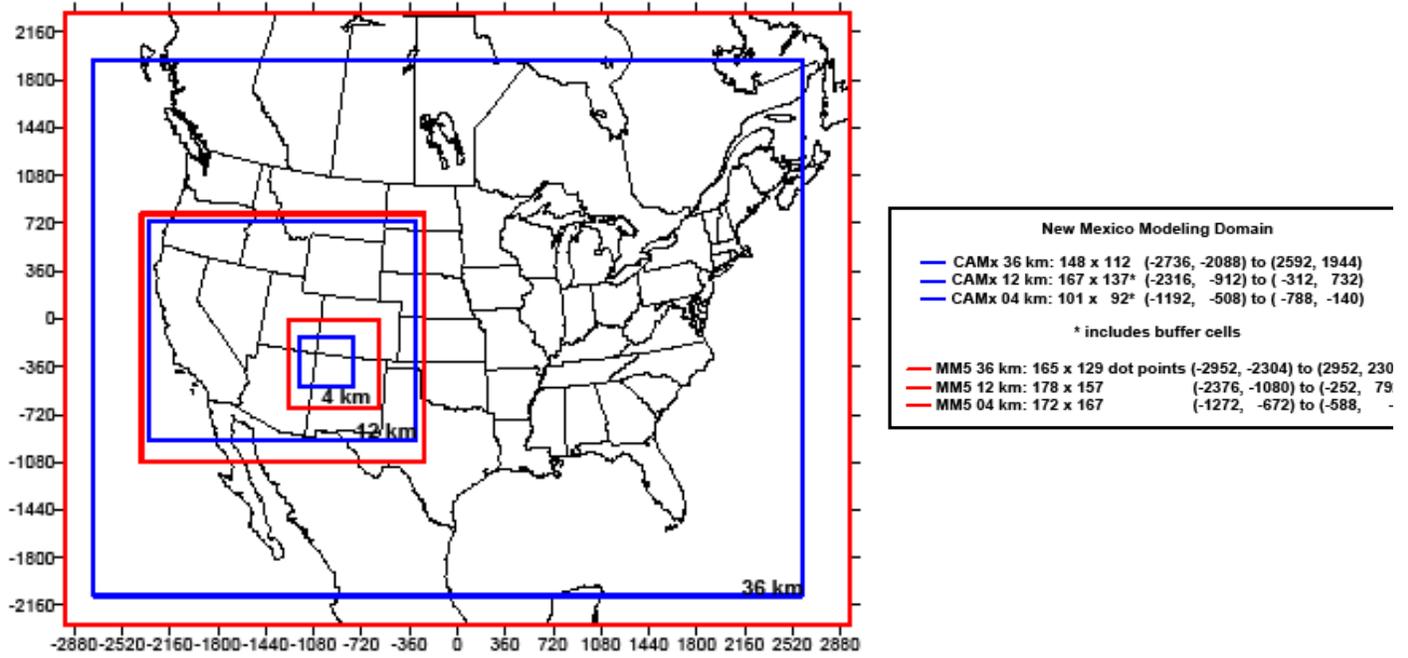
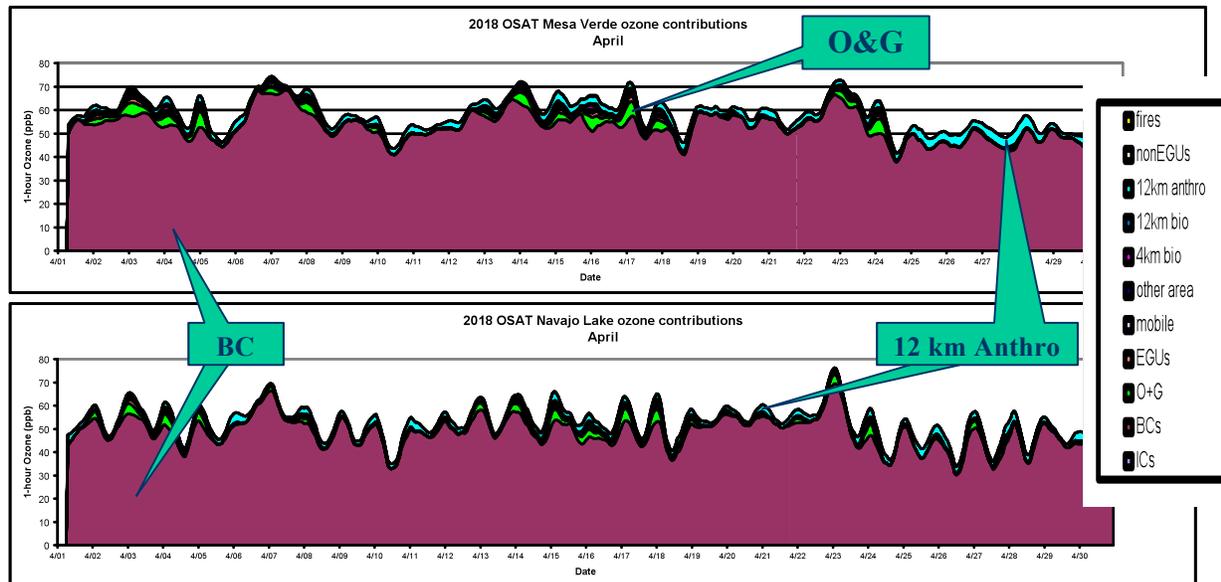
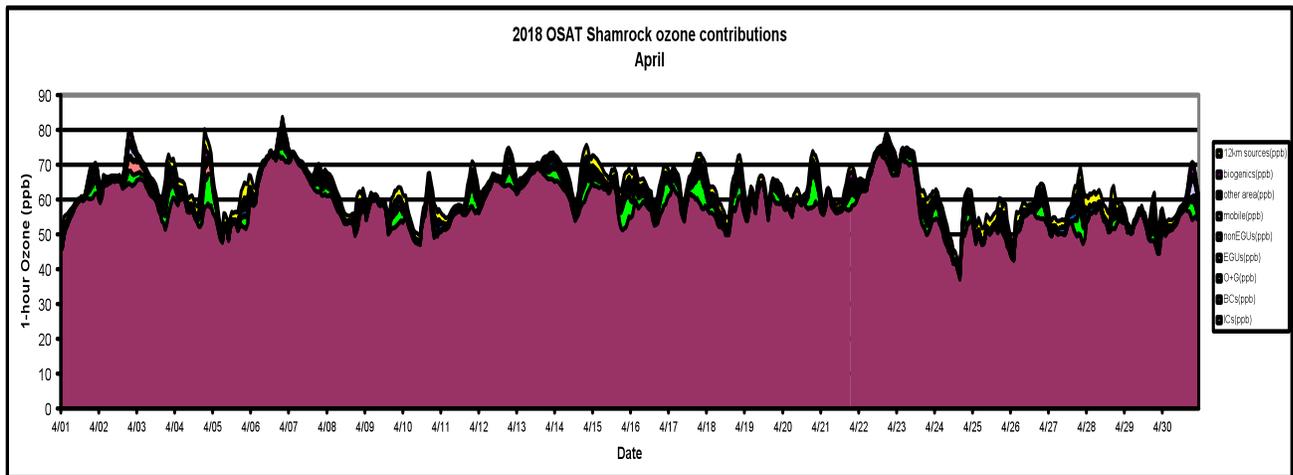


Figure 15: Source Apportionment Results for 8-Hour Average Ozone at Mesa Verde and Navajo Lake in April (Stoekenius, 2010)



BC = Boundary Conditions

**Figure 16: Source Apportionment Results for Ozone at Shamrock in April (Stoeckenius, 2010)**



#### 4.4 Vertical Mixing Algorithms

Regional photochemical grid modeling of the western U.S. using the CMAQ and CAM<sub>x</sub> models have both resulted in high spring-time ozone predictions over the complex elevated terrain of the Rocky Mountains, most notably in April and May. Comparisons against rural measurement data show that both models over predict maximum ozone levels in southwestern Colorado by 20 ppb or more in these months. A systematic investigation, as part of the Four Corners Air Quality Task Force work, using CAM<sub>x</sub> revealed that high springtime ozone lateral boundary conditions in the upper layers are transported downward in the model by excessively energetic vertical circulations over complex terrain causing ozone over predictions in the Rocky Mountains. Such high ozone concentrations are not unreasonable at these altitudes in the spring, and observational evidence during this season suggests that stratospheric ozone intrusion or impacts from Asian emissions results in occasional high ground-level ozone concentrations at the surface. However, such high surface ozone values do not occur at the frequency and intensity as estimated by the CMAQ and CAM<sub>x</sub> models. As the CMAQ and CAM<sub>x</sub> models are beginning to be used for regulatory air quality model applications in the Rocky Mountains to address the new 8-hour ozone standard and other activities (e.g., NEPA and SIP analysis), the ozone overestimation issue is of increased importance.

Both CMAQ and CAM<sub>x</sub> diagnose vertical velocities internally in the model from input horizontal wind fields, which are generated using prognostic meteorological models, and numerically solve the vertical transport using mass consistent and mass conservative algorithms.

In the Four Corners Air Quality Task Force work, an improved vertical resolution and revised vertical velocity and vertical advection algorithms were implemented in CAM<sub>x</sub> that eliminated the excessive downward transport of ozone from the top layers of the model while continuing to be both mass consistent and mass conservative (Emery et al, 2009). A similar modification to the vertical velocity treatment in the CMAQ model is required. Both the modified CAM<sub>x</sub> model and the eventual modified CMAQ model require additional testing to ensure that these necessary modifications perform and result in ozone predictions that are consistent with monitoring data.

Additionally, model evaluations of the GEOS-CHEM vertical velocity algorithms are needed to ensure that this model accurately simulates the vertical mixing in the model formulation prior to its use in reevaluation of the PRB.

While CAM<sub>x</sub> has been modified to address this important physical process, vertical mixing in elevated terrain is still an emerging issue that needs additional scientific review. EPA is encouraged to take the lead regarding this issue and engage other technical stakeholders.

## 4.5 Use of Ozone Modeling in a Regulatory Setting

Ozone modeling is required for SIPs as well as NEPA analyses for new oil and gas activities. Currently, many SIPs and NEPA analyses are being done without any regional coordination and results in inconsistent data and methodologies. In addition, in most NEPA analyses the lead agency generally does not have the expertise to lead and manage such complicated analyses. **Ozone modeling should be done at a regional level – not a project-by-project or a county-by-county approach.** Analyses should be done in a cooperative manner between agencies, industry and the public as has been done with the Four Corners Air Quality Task Force. In addition, regional control strategies are needed.

It is imperative to rethink how ozone compliance strategies should be developed. In the intermountain West, ozone modeling has indicated that only a small fraction of ozone impacts are due to local sources, particularly in the spring. The majority of the ozone impacts are a result of natural events (such as STE) or regional, trans-boundary or trans-continental precursor transport that a single state does not have any regulatory authority to control. This suggests that in order to develop an effective control strategy, regional rather than local strategies are needed. **If EPA revises the ozone standard, EPA needs to develop a stakeholder process to address how states or regions will comply with the more stringent standard.** The Four Corners Air Quality Task Force is an excellent example of the type of regional and collaborative modeling effort.

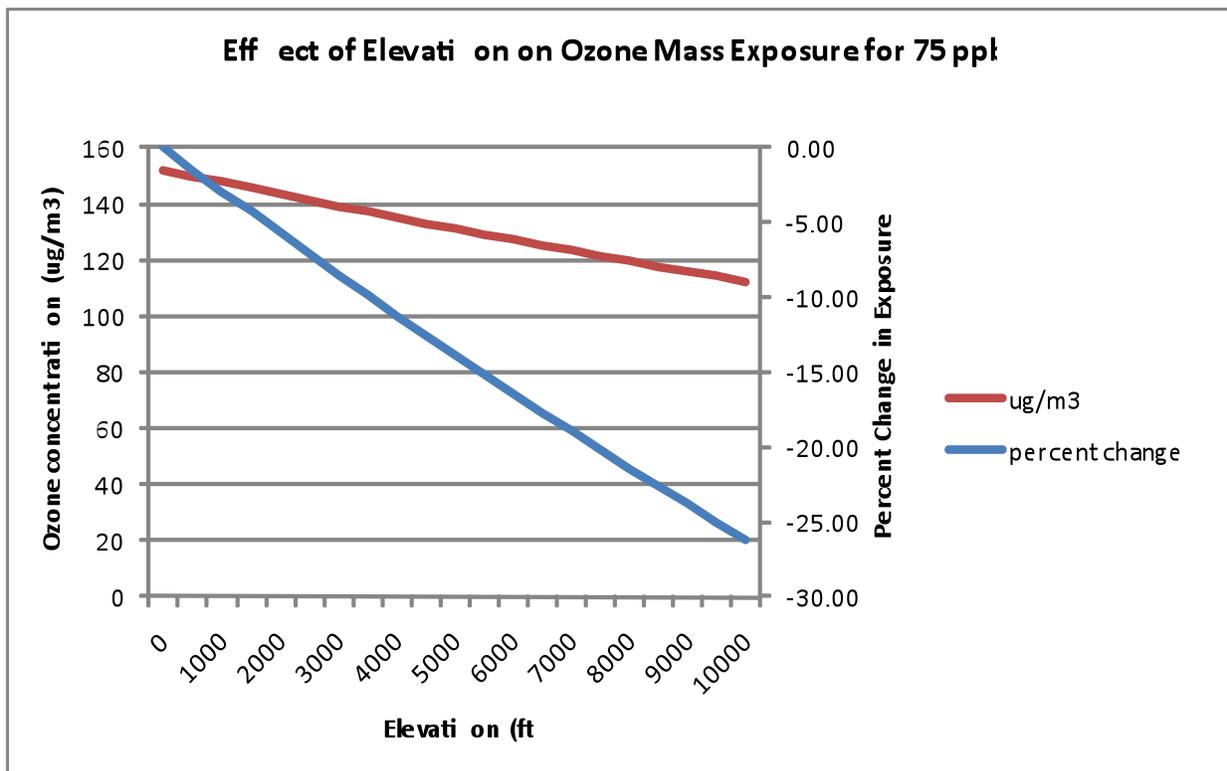
As part of any modeling effort, additional source apportionment enhancements to photochemical models are needed to ensure the models are being physically realistic, understanding source receptor relationships and informing the appropriate attainment strategies.

# 5.0 Concentration Form of the Ozone Standard

There is a potential inconsistency in the level of ozone exposure at sea level versus elevated terrain because of the manner in which the concentration levels of the proposed ozone standard are expressed. Air quality standards can be expressed as either a volume/volume (ppm) concentration or a mass/volume concentration (ug/m<sup>3</sup>). For a concentration expressed as ppm, the level of the standard does not vary with elevation. Thus, a concentration is equivalent at sea level or at an elevation of 10,000 feet. In the case of a concentration expressed as ug/m<sup>3</sup> the concentration changes with altitude because the volume of air containing a given mass of pollutant expands, resulting in lower ug/m<sup>3</sup> concentrations at altitude.

At any given temperature and pressure, these expressions of concentration are directly related. However, they are sensitive to changes in the ratio of pressure to temperature and this ratio varies with elevation. For example, with temperature fixed at 25°C, 0.075 ppm O<sub>3</sub> is equivalent to 147.2 ug/m<sup>3</sup> at sea level or 123.6 ug/m<sup>3</sup> at an elevation of 5000 ft, a 16% difference (Stoeckenius, 2009) (**Attachment E**). The mass exposure of the ozone that a person is exposed to in this example is decreased by 16 % simply by changing the elevation. Figure 17 displays the ozone concentration (ug/m<sup>3</sup>) versus elevation as well as the percent change in exposure.

**Figure 17: Graph of the Effects of Elevation on Ozone Mass Exposure for 75 ppb**



EPA has not addressed how elevation and the reduction in mass exposure changes ozone health risks and this should be a primary focus of ozone exposure research. In fact, some studies have shown a reduction in the health effects of ozone at lower pressures which correspond to higher elevations. The study “Comparative Toxicity Studies at Reduced and Ambient Pressures I. Acute Response” by McNerney and MacEwen in 1965 (**Attachment F**) stated that “the experimental results show a definite

reduction in the toxic response to the pulmonary irritants NO<sub>2</sub> and O<sub>3</sub> at reduced pressure when compared with ambient pressure exposures.” Also, according to the study “The Effect of Mixed Gas Atmospheres at 5 PSIA on the Inhalation Toxicity of O<sub>3</sub> and NO<sub>2</sub>” by MacEwen et al from 1967 **(Attachment G)**, “there was a reduction in the toxicity of O<sub>3</sub> in the 5 psia mixed-gas environment which was even further reduced in a 5 psia-100% O<sub>2</sub> environment. This reduction in toxicity was indicated to be a result of the increased partial pressure of O<sub>2</sub>, because experiments conducted at ambient pressure with a pO<sub>2</sub> of 260 mm Hg and at the same O<sub>3</sub> chamber concentration resulted in an even greater reduction in toxic response.” Further chamber studies at high elevations should be conducted in order to show justification for a stricter standard at higher elevations.

Furthermore, during the revision of the PM NAAQS in 1997, a commenter questioned the “appropriateness of the current practice of adjusting measured PM<sub>10</sub> concentrations to reflect standard conditions of temperature and pressure (25° C and 760 mm Hg, respectively)”. During that rule making, EPA concluded “that a continuation of the practice of adjusting PM<sub>10</sub> concentrations to standard conditions of temperature and pressure is not warranted or appropriate.” see 64 Fed. Reg. 38607. EPA further stated “The issue is whether the available scientific evidence on the health and welfare effects of PM provides a basis for continuing with the traditional adjustments.” EPA decided that the health and welfare effects of PM did not justify the adjustment of PM concentrations to standard conditions. We believe that the same approach should apply for ozone and PM10 and that EPA should take the same position.

Continuing to express the O<sub>3</sub> NAAQS as a volume/volume concentration results in amore stringent standard for areas at high altitude and this increased stringency is unjustified without the requisite health effects study to underpin it. Current O<sub>3</sub> monitoring expressed as a volume/volume concentration can continue to be used. However, the concentration should be converted to a mass/volume basis under actual conditions before comparison to the equivalent mass/volume concentration of the O<sub>3</sub> NAAQS value at standard conditions. Since converting to actual ambient temperature and pressure would require additional equipment and computational complexity, we recommend that the altitude correction be based on isothermal conditions, such as those assumed in Table 2 of Attachment E.

# 6.0 Conclusions

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EPA assesses risks to human health and environmental effects from O<sub>3</sub> levels in excess of PRB concentrations.” (EPA, 2006) EPA has used GEOS-CHEM modeling results to assert that PRB is 15 to 35 ppb over the continental US. There are many technical issues associated with the information EPA used and the methodology followed in setting the current PRB level of 15 – 35 ppb – particularly in the Western US, at higher elevations, and likely in rural areas in general. EPA must establish the primary ozone standard based on health criteria, however, from a policy perspective, EPA has not addressed how this standard can be achieved or implemented in a cost effective manner. Compliance with an ozone standard in the range of 0.070 to 0.060 ppm will be very difficult if not impossible to achieve as illustrated in by this document. EPA cannot rely on previous control strategies to achieve compliance with the primary or secondary standard and therefore needs to rethink how rural areas may achieve compliance.

## 6.1 Policy Relevant Background Determination Issues

EPA claims that policy relevant background for ozone in the US is 0.015-0.035 ppm (mean) based on a 2002 GEOS-CHEM model by Fiore et al (2003). The basis that EPA has used for PRB does not consider transport from Canada and Mexico as part of PRB, but instead views it as controllable and not significant. However, as shown in Section 2.1, contributions from Canada and Mexico on a **mean** daily 8-hour average over only the summer months can be in excess of 10 ppb. PRB was not determined using a 3-year average of the 4<sup>th</sup> highest maximum daily 8-hour average of modeling as the standard, but only a monthly daily diurnal profile for less than 1 year of data. Also, the PRB determination was based only on 12 cities at lower elevations and not evaluated at any elevated or rural areas. Furthermore, the PRB determination neglects the issues with the modeling basis including model accuracy of temporal variations in ozone, large grid cell size, and meteorological data averaging;

## 6.2 Western Ozone Issues

The intermountain West has several unique ozone issues including high ozone in remote areas, high ozone levels measured by satellite and high ozone in the spring – likely due to intercontinental transport and stratospheric-tropospheric exchange (STE). EPA has not addressed these issues in the determination of policy relevant background. Also, EPA has not developed protocols for the states and tribes to identify and exclude “exceptional events” of ozone such as natural events (such as STE) or intercontinental transport from monitoring data or modeling analyses. EPA has also not provided the states and tribes with tools to address compliance with the standard in light of apparently frequent exceptional event driven high ozone concentrations.

## 6.3 Ozone Modeling Issues

Photochemical ozone modeling is the primary tool for estimating ozone impacts and the only tool used to determine PRB. The models are imperfect and need additional refinement, testing, and verification. Ozone model evaluation is critical and needs to examine all performance displays and metrics against monitoring data where it is available. Meteorological modeling is currently inaccurate and fails to replicate observed data. Further investigation is needed in this area. Boundary conditions from GEOS-CHEM model represent the largest contribution to predicted ozone concentrations by the CAM<sub>x</sub> and CMAQ (which are used typically for SIP modeling) yet no verification has been done regarding the accuracy of the modeled boundary conditions. Issues have been found with the vertical mixing algorithms of CAM<sub>x</sub> and CMAQ that have shown over prediction of spring ozone in the intermountain west. CAM<sub>x</sub> has been modified to address this issue; however, CMAQ still requires modification of the vertical mixing algorithms. Furthermore, GEOS-CHEM should be evaluated to determine if the same issue exists for it. Also, many SIP and NEPA ozone modeling analyses are being done without regional coordination resulting in inconsistent data and methodologies. Ozone modeling should be done a regional level.

## **6.4 Concentration Form of the Standard**

EPA's requirement to express ozone in a volume/volume (ppm) concentration results in a more stringent standard for areas of high altitude. EPA has not addressed how elevation and the reduction in mass exposure changes ozone health risk. The more stringent standard at high elevations is not justified without supporting health effects studies.

# 7.0 Recommendations

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EPA should reevaluate PRB through a broad stakeholder process involving technical experts from the states, tribes, industry, consulting firms, etc. EPA should develop an analysis protocol for PBR evaluation that is subject to peer-review and stakeholder input. Furthermore, the results of such an analysis should be subjected to the same level of review and comment before the results are used in a regulatory setting. All available tools should be used in determining PRB including modeling, surface ozone monitoring data, upper air ozone data from ozonesondes and aircraft measurements, and satellite ozone data, etc. EPA also needs to consider how higher PRB affects the implementation of a new standard and the development of control strategies for attainment of the NAAQS. EPA needs use a broad stakeholder process for help in development of policies for implementation of and addressing the ozone NAAQS.

## 7.1 Policy Relevant Background Recommendations

EPA must revise the PRB determination to address the following to address deficiencies in the current PRB determination:

- 1) Include Mexico and Canada as part of PRB;
- 2) Improve the GEOS-CHEM model accuracy for temporal ozone variability;
- 3) Address the modeling deficiencies of terrain and meteorological averaging;
- 4) Determine PRB by looking at the 4<sup>th</sup> highest 8-hour maximum daily average concentration;
- 5) Use more recent and documented emissions inventories;
- 6) Determine PRB for elevated terrain and rural areas; and
- 7) Vary PRB as a function of season, altitude, and total O<sub>3</sub> level.

## 7.2 Western Ozone Recommendations

EPA also needs to consider the following western ozone issues in re-determination of PRB for ozone as well as policies for implementing and addressing the ozone NAAQS:

- 1) The role of international cross-boundary transport in observed ozone levels, particularly on a periodic high monitored ozone day basis;
- 2) The role of regionally transported ozone and precursors in observed ozone levels, particularly in the Intermountain West and on a periodic high monitored ozone day basis; and
- 3) The role of stratospheric-tropospheric exchange in high ozone episodes at the surface, particularly at higher elevations in the Western US.

EPA, through a broad stakeholder group, also needs to develop a protocol for use by states and Tribes for routinely and promptly evaluating if ozone monitored is from natural events and cross-boundary transport and therefore can be excluded from the nonattainment designation as an exceptional event.

## 7.3 Ozone Modeling Recommendations

As part of the PRB reevaluation and the ozone implementation process, EPA should utilize a broad based stakeholder process to provide EPA with guidance on addressing the following modeling issues:

- 1) Improvement of the model evaluation procedures;
- 2) Improvement meteorological modeling accuracy;
- 3) Verification boundary conditions accuracy;
- 4) Repairing the vertical mixing algorithms;
- 5) Regional ozone modeling; ; and
- 6) Address how the use models in a relative mode in monitoring data sparse regions.

## **7.4 Concentration Form of the Standard Recommendation**

Current O<sub>3</sub> monitoring expressed as a volume/volume concentration can continue to be used. However, the concentration should be converted to a mass/volume basis under actual conditions before comparison to the equivalent mass/volume concentration of the O<sub>3</sub> NAAQS value at standard conditions. Since converting to actual ambient temperature and pressure would require additional equipment and computational complexity, we recommend that the altitude correction be based on isothermal conditions.

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**Attachment A**  
**Surface ozone background in the United States:  
Canadian and Mexican pollution influences**

**Attachment B**  
**Air Quality Trends in U.S. Western Mountain**  
**States**

**Attachment C**  
**Ozone Trends in the Rural Intermountain West**

**Attachment D**  
**Increasing springtime ozone mixing ratios in  
free troposphere over western North America**

**Attachment E**  
**Effects of Altitude on the Determination of**  
**Ambient Ozone Concentrations Via UV**  
**Photometer**

**Attachment F**  
**Comparative Toxicity Studies at Reduced**  
**and Ambient Pressures I. Acute Response**

**Attachment G**  
**The Effect of Mixed Gas Atmospheres at 5**  
**PSIA on the Inhalation Toxicity of O<sub>3</sub> and**  
**NO<sub>2</sub>**