WESTERN REGIONAL AIR PARTNERSHIP

Attribution of Haze Workgroup's
Technical Recommendations on Monitoring Metrics for Regional Haze Planning
9/22/06 DRAFT

Executive Summary

The Attribution of Haze Workgroup recommends the following forms of monitoring metrics be used by states and tribes for assessing all visibility-protected Class I Federal areas of the WRAP region in the December 2007 regional haze implementation plans:

- The revised IMPROVE light extinction equation as developed and approved in 2005 by the IMPROVE Steering Committee to convert from mass concentration measurements to light extinction for visibility analysis and regional haze planning;
- The 2000-04 baseline period IMPROVE visibility monitoring data reported using the revised IMPROVE equation, as available on the Technical Support System;
- The alternative 2064 natural visibility conditions estimates of total light extinction and individual light extinction species using the revised IMPROVE equation, as developed and recommended by the Inter-RPO Monitoring & Data Analysis Discussion Group; and
- The 2018 planning milestone projected visibility value (using the Relative Reduction Factor or RRF), as calculated using a scaling factor from 2000-04 baseline period monitoring data (WRAP method) applied to a ratio of historic and projected regional gridded air quality modeling results to assess the amount of visibility improvement expected from emissions reductions across all sources by 2018.

Using the revised IMPROVE light extinction equation, applying these metrics for all WRAP region Class I areas allows a regionally consistent approach between the individual regional haze implementation plans based on the analysis of the impact of individual light extinction species (SO4, NO3, organic carbon, elemental carbon, fine soil, and coarse material) and the sources contributing to their formation. These metrics also allow the most up-to-date scientific analysis of the total visibility impact in units of light extinction or the haze index (the deciview) required in the Regional Haze Rule.

The 2000-04 baseline period monitoring data have been reviewed by the AoH WG and found to be adequate as the basis of regional haze plans. Specific monitoring sites (5) with limited data from this 5-year period have additional site-specific recommendations for their limited data record. The alternative natural conditions estimates also incorporate the revised IMPROVE equation so that progress in reducing emissions and increasing visibility across the nominal 60-year period defined in the Regional Haze Rule to achieve natural conditions in Class I areas can be better assessed in terms of natural and anthropogenic sources, as well as the degree of controllability.

Finally, the WRAP RRF projection method for future visibility conditions incorporates the default EPA method modified with a standard approach to select monitoring data for projecting regional modeling results. This allows for a better, accounting of both source strength and temporal variation to produce a consistent estimate of future visibility conditions based on modeling comprehensive emissions inventories. The revised IMPROVE equation and alternative Natural Conditions Estimates are not endorsed for individual state air program evaluation of BART modeling results for technical and process reasons discussed in the Monitoring Metrics document since these have not been incorporated into the EPA or Federal Land Managers' Air Quality Related Values Work Group (FLAG).

<u>Technical Recommendations for Haze Planning in the WRAP region</u>

1) Apply the revised IMPROVE light extinction equation as developed and approved in 2005 by the IMPROVE Steering Committee to convert from mass concentration measurements to light extinction for visibility analysis and regional haze planning at each WRAP region Class I area.

2) Use the 2000-04 Best and Worst Days' metrics as calculated and reported by VIEWS and TSS. Individual states should review the data completeness and any data substitutions for their CIAs.

3) Use the alterative Natural Conditions Estimates in combination with the 2000-04 Best and Worst Days' metrics as calculated and reported by VIEWS and TSS, utilizing the revised IMPROVE equation, for visibility analysis and regional haze planning at each WRAP region Class I area.

4) Use the alternative WRAP RRF Projection Method for projecting 2018 visibility conditions in combination with the 2000-04 Best and Worst Days' metrics as calculated and reported by VIEWS and TSS, utilizing the revised IMPROVE equation and alternative Natural Conditions Estimates, for visibility analysis and regional haze planning at each WRAP region Class I area. Study the effect of this method for Fine Soil and Coarse Material visibility modeling results before applying it to those IMPROVE light extinction species.

Attribution of Haze Workgroup's
Technical Recommendations on Monitoring Metrics for Regional Haze Planning
9/22/06 DRAFT

Background

This document summarizes the recommended monitoring metrics for application by states and tribes for regional haze planning, for the December 2007 plans' due date. The intent of this document is to identify the currently available best technical monitoring metrics and reasons for using them. The motivation behind this consensus product from the Attribution of Haze Workgroup is to lay out a regionally consistent approach for applying the following monitoring metrics at each WRAP region Class I area:

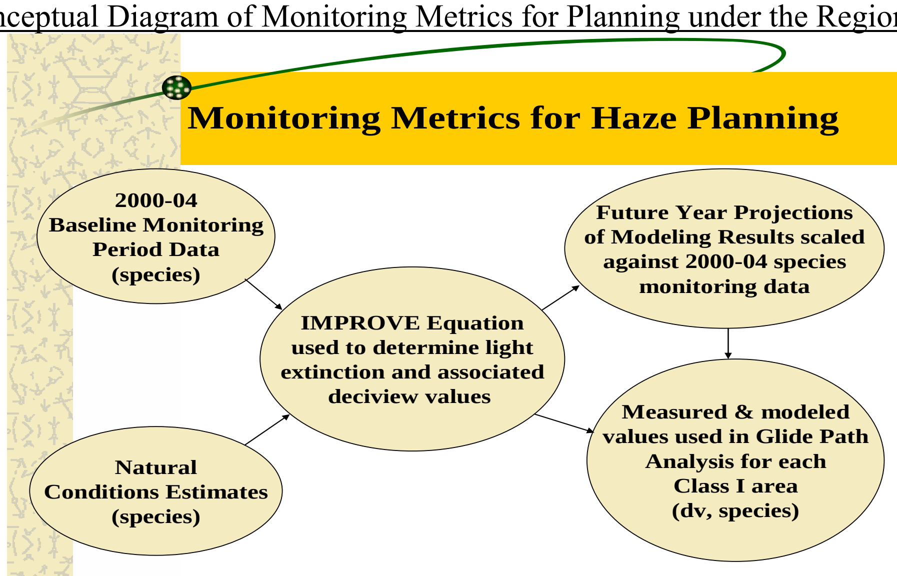
- The light extinction equation to convert from mass concentration measurements to visibility;
- The 2000-04 baseline period visibility monitoring data;
- Natural visibility conditions estimates – the 2064 goal to be defined in the 2007 haze plans; and
- The 2018 planning milestone projected visibility value (using the Relative Reduction Factor or RRF), a scaling factor from monitoring data to be applied to regional gridded air quality modeling results to assess the amount of visibility improvement expected from emissions reductions across all sources by 2018.

This document provides a protocol for applying the monitoring metrics, and can serve as a reference document for individual haze implementation plans.

Use of Monitoring Data in Support of Regional Haze Planning

The need for a consistent regional methodology for evaluating the WRAP region results from studying the nature and causes of light extinction and fundamental requirement to apply the best metrics to the regional haze planning process. Conceptually this process is shown in Figure 1.

Figure 1. Conceptual Diagram of Monitoring Metrics for Planning under the Regional Haze Rule



The Interagency Monitoring of PROtected Visual Environments (IMPROVE) national monitoring program has been designated by EPA to collect visibility impairment data representing the 156 Class I Federal areas (CIAs) with visibility protection under the Clean Air Act. More information about the IMPROVE monitoring program, the 110 monitoring sites across the nation selected to represent the 156 CIAs, and the Steering Committee managing the monitoring program in support of regional haze plans required of all 50 states under the EPA Regional Haze Rule (RHR) can be found at: http://vista.cira.colostate.edu/improve/Overview/Overview.htm. EPA has also published a broader guidance document on Visibility Monitoring, see: http://www.epa.gov/ttn/amtic/files/ambient/visible/r-99-003.pdf.

Light extinction theory

Based on aerosol research, the technical method to determine visibility impairment is to calculate the light extinction coefficient (bext). This is defined as the loss of image-forming light per unit distance due to scattering and absorption by particles and gases in the atmosphere. The light extinction coefficient is the sum of the scattering coefficient (bscat) and absorption coefficient (babs), which are similarly defined as the loss of light per unit distance by scattering and absorption mechanisms respectively. The light extinction coefficient can be represented mathematically as:

$$b_{ext} = b_{sg} + b_{ag} + b_{sp} + b_{ap} = b_{scat} + b_{abs};$$

where s, a, g, and p refer to scattering and absorption by gases and particles, respectively.

Speciated Monitoring Data

To determine visibility impairment under the RHR, filter sampling data from IMPROVE aerosol monitors are collected and analyzed following Standard Operating Procedures, see: (http://vista.cira.colostate.edu/improve/Publications/SOPs/UCDavis_SOPs/IMPROVE_SOPs.htm). These resulting mass concentration data are then converted to light extinction using an algorithm referred to as the IMPROVE equation; this equation has been reviewed and changed during the last 2 years, (see: http://vista.cira.colostate.edu/improve/Publications/GrayLit/019_RevisedIMPROVEeq/RevisedIMPROVEAlgorithm3.doc), creating a ripple effect for the monitoring metrics required for use in regional haze planning.

Haze Index- The Deciview (dv)

The RHR also requires that the light extinction data from the IMPROVE equation be analyzed and presented in terms of a "haze index" value called the deciview (dv); the dv index is related to total light extinction, described at: http://vista.cira.colostate.edu/improve/Publications/NewsLetters/apr_93.pdf. As such, light extinction for regional haze planning could be analyzed in terms of its component contributors to light extinction as defined in the old and revised IMPROVE equations, and/or as the associated deciview values.

IMPROVE Light Extinction Equation – Original vs. Revised

The original IMPROVE light extinction equation was adopted by the Steering Committee and used in their principle publications (see: http://vista.cira.colostate.edu/improve/Publications/Principle_pubs.htm) since the early 1990s. The equation has also been widely evaluated and used in peer-reviewed journal articles as well as urban visibility studies. For those reasons, the EPA adopted this equation in their 2003 guidance document on Tracking Progress Under the Regional Haze Rule. See: http://www.epa.gov/ttn/oarpg/t1/memoranda/rh_tpurhr_gd.pdf.

The equation uses additive extinction by chemical species as measured by the IMPROVE aerosol monitor, combined with the effect of Relative Humidity (RH), to estimate the scattering of light by fine and coarse particles. The original IMPROVE equation, as adopted by EPA in their guidance document, is used to estimate total light extinction for the purposes of planning under the RHR:

$$\begin{aligned} b_{sp} = &(3) f_{SO4}(RH)[SULFATE] \\ &+(3) f_{NO3}(RH)[NITRATE] \\ &+(4) f_{org}(RH)[OMC] \\ &+(1)[SOIL] \\ &+(0.6)[CM] \end{aligned}$$

The brackets in this equation indicate the species concentration. The factors 3, 4, 1, and 0.6 are the m^2/g dry specific scattering efficiency for each of the respective species. . Thus, a sulfate particle is three times more effective in scattering light than a particle of soil.

To account and control for relative humidity effects in the light extinction data to be used in regional haze planning, EPA sponsored a project to examine measured hourly relative humidity data over a 10-year period (1988-1997) within the United States to derive month-specific climatological mean humidity correction factors designed to represent each CIA. The hourly RH measurements from each site were converted to *f(RH)* values using a nonlinear weighting factor curve. Values above 95% RH were set equal to the *f(RH)* corresponding to 95% RH.

Appendix A of: http://www.epa.gov/ttn/oarpg/t1/memoranda/rh_tpurhr_gd.pdf presents these values. Determination of the humidity factors is described in section 3.6 of that document. Using over 370 humidity monitoring locations across the country, monthly *f(RH)* values were calculated. In most regions there is a seasonal cycle of relative humidity, which is accounted for by generating the appropriate monthly *f (RH)* values, as in Appendix A. The 12 monthly averaged *f (RH)* values are listed for each IMPROVE or IMPROVE protocol site and their corresponding Class I areas. The site specific values are listed for each CIA and are recommended to be used for all visibility and tracking progress calculations for that CIA. These values are provided in Table A-2. A table of 12 monthly-averaged *f(RH)* values for each CIA is also provided in Table A-3 for informational purposes.

Overview of revised IMPROVE equation

The IMPROVE light extinction equation was analyzed, revised, and approved by the Steering Committee during 2005. A detailed discussion of the revised equation and the reasons for changing it can be found at: http://vista.cira.colostate.edu/improve/Publications/NewsLetters/IMPNews4thQtr2005.pdf. A summary of the differences between the original and revised equations follows.

The original IMPROVE equation produces reasonable estimates of light scattering over a broad range of conditions. However, it tends to underestimate the highest extinction values and overestimate the lowest extinction values. Since EPA adopted the equation for use in RHR planning, the original IMPROVE equation has been scrutinized carefully to assess deficiencies that could bias the implementation of the RHR. With those concerns identified, the IMPROVE Steering Committee initiated an internal review resulting in recommendations for revisions of the light extinction equation. The review team of scientists from the National Park Service and the Cooperative Institute for Research in the Atmosphere developed a revised algorithm that reduces biases in light extinction estimates and is as consistent as possible with the current scientific literature. Review of the original equation and suggested revisions are presented at: http://vista.cira.colostate.edu/improve/Publications/NewsLetters/IMPNews2ndQtr2005.pdf.

In July 2005, the equation review results and proposed revisions were presented to the IMPROVE Steering Committee. A subcommittee was formed to further investigate the proposed equation. The subcommittee included scientists who worked on the initial review, as well as scientists who have been critical of the original IMPROVE equation. Their work resulted in the final version of the equation, which was again presented to the Steering Committee. In December 2005, the IMPROVE Steering Committee voted to adopt this revised equation for use by IMPROVE as an alternative to the current approach.

The new equation splits ammonium sulfate, ammonium nitrate, and organic carbon compound concentrations into two size fractions: small and large. The equation for estimating the light extinction for the RHR is:

$$
\begin{aligned}
b_{ext} \approx\ & 2.2 \text{ x } f_s(RH) \text{ x [small sulfate]} + 4.8 \text{ x } f_L(RH) \text{ x [large sulfate]} \\
& + 2.4 \text{ x } f_s(RH) \text{ x [small nitrate]} + 5.1 \text{ x } f_L(RH) \text{ x [large nitrate]} \\
& + 2.8 \text{ x [small organic mass]} + 6.1 \text{ x [large organic mass]} \\
& + 10 \text{ x } [\textit{elemental carbon}] \\
& + 1 \text{ x } [\textit{fine soil}] \\
& + 1.7 \text{ x } f_{ss}(RH) \text{ x [sea salt]} \\
& + 0.6 \text{ x } [\textit{coarse mass}] \\
& + \text{Rayleigh scattering (site-specific)} \\
& + 0.33 \text{ x } [NO_2 \text{ (ppb)}]
\end{aligned}
$$

Though not explicitly shown, the organic mass concentration used is 1.8 times the organic carbon mass concentration, (changed from 1.4 times carbon mass the original equation uses). New terms have also been added for sea salt and for absorption by NO_2. The apportionment of the total concentration of sulfate compounds into the concentrations of small and large size fractions is accomplished using the following equations:

$$
\begin{aligned}
&[\textit{large sulfate}] = \text{[total sulfate] x [total sulfate], for [total sulfate]} < 20\ \mu g/m^3 \\
&[\textit{large sulfate}] = [\textit{total sulfate}],\ \textit{for}\ [\textit{total sulfate}] \geq 20\ \mu g/m^3 \\
&[\textit{small sulfate}] = [\textit{total sulfate}] - [\textit{large sulfate}]
\end{aligned}
$$

The same equations are used to apportion total nitrate and total organic mass into small and large size fractions. Sea salt is calculated as 1.8 x [*chloride*], or 1.8 x [*chlorine*] if the chloride measurement is below detection limits, missing, or invalid. The new equation contains three distinct water growth terms, designated f_S, f_L, and f_{SS} for the small and large sulfate and nitrate fractions, and for sea salt, respectively.

Technical justification for revisions

The new IMPROVE equation for estimating light extinction for the RHR contains five major revisions from the original equation:

1) A sea salt term has been added. Sea salt is a particular concern for coastal locations where the sum of the major components of light extinction and mass has been deficient.
2) The assumed organic mass to organic carbon ratio has been changed from 1.4 to 1.8, to reflect more recent peer-reviewed literature on the subject.
3) The Rayleigh scattering factor has been changed from a network-wide constant to a site-specific value. This factor is based on the elevation and annual average temperature of individual monitoring sites.
4) A split component extinction efficiency model for sulfate, nitrate, and organic carbon components has been developed. The model includes new water growth terms for sulfate and nitrate to better estimate light extinction at the high and low extremes of the range of extinction.

5) An NO_2 light absorption term has been added. This term can only be used at sites with available NO_2 concentration data.

Comparison of original versus revised equation

One of the most compelling reasons for developing a revised equation was to reduce the biases in light scattering estimates at the extremes, when compared to nephelometer measurements a direct measure particle scattering. To assess the performance of the new equation, the fractional bias for each sample period was calculated as the difference in estimated aerosol light scattering divided by the measured light scattering using collocated nephelometers. These biases were then averaged into quintiles to indicate the bias in each of those five subsets of data. Analysis shows that the revised equation has lower fractional bias than the original equation, in all but the haziest conditions.

Scatter plots (Figures 2 and 3) of light scattering estimates from the original and revised equations versus nephelometer data for all available data at 21 monitoring sites were used to view the overall performance differences. These figures show bias at the extremes is reduced using the revised, compared to the original, equation (i.e., the points tend to be better centered on the one-to-one line). However, they also show the somewhat reduced precision of the revised equation compared to the original (i.e., points are more broadly scattered).

Figure 2. Scatter plot of the original IMPROVE equation-estimated particle light scattering versus measured particle light scattering.

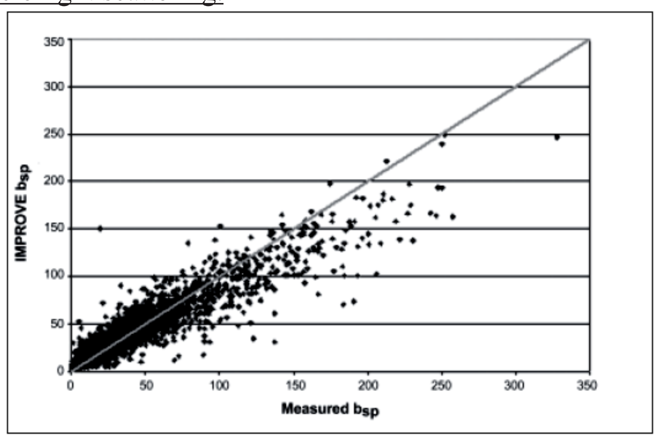
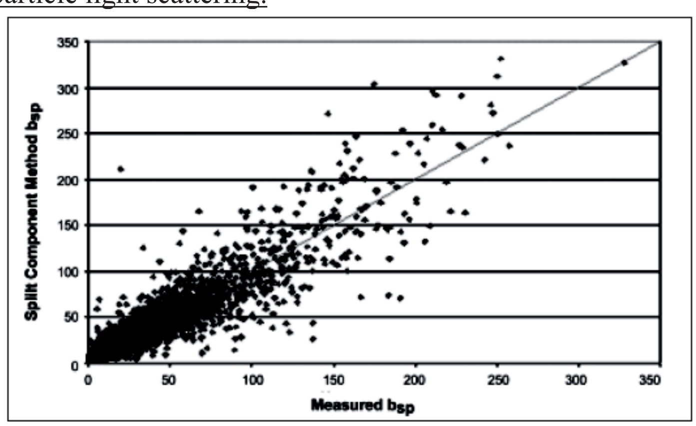


Figure 3. Scatter plot of the revised IMPROVE equation-estimated particle light scattering versus measured particle light scattering.



Directly measured light scattering data from collocated Optec NGN-2 nephelometers were used to evaluating the performance of the original IMPROVE equation, as well as for development and performance evaluation of several possible versions of the revised equation, leading to the final revised equation approved by the IMPROVE Steering Committee. The 21 nephelometer sites used in the evaluation were:

Acadia National Park, Maine
Big Bend National Park, Texas
Boundary Waters Canoe Area Wilderness, Minnesota
Columbia River Gorge National Scenic Area, Oregon
Dolly Sods Wilderness, West Virginia
Gila Wilderness, New Mexico
Grand Canyon National Park, Arizona
Great Gulf Wilderness, New Hampshire
Great Smoky Mountains National Park, Tennessee/North Carolina
Jarbidge Wilderness, Nevada
Lone Peak Wilderness, Utah
Lye Brook Wilderness, Vermont
Mammoth Cave National Park, Kentucky
Mount Rainier National Park, Washington
Mount Zirkel Wilderness, Colorado
Okefenokee National Wildlife Refuge, Georgia
Shenandoah National Park, Virginia
Shining Rock Wilderness, North Carolina
Snoqualmie Pass, Washington
Three Sisters Wilderness, Oregon
Upper Buffalo Wilderness, Arkansas

The revised IMPROVE equation reduces the biases compared to measurements at the high and low extremes, and is most apparent for the hazier eastern sites. The composition of "best and worst days" is very similar by the original and new equations. Most of the reduction of bias associated with the revised equation is attributed to the use of the split component extinction efficiency method for sulfate, nitrate, and organic components that permitted variable extinction efficiency depending on the component mass concentration. The revised equation also contains specific changes incorporating a better understanding of the atmosphere based on recent scientific literature. It reflects a more complete accounting for contributors to haze (e.g., sea salt and NO_2 terms), and uses site-specific Rayleigh scattering terms to reduce elevation-related bias. EPA has prepared monthly average f(RH) terms for all IMPROVE monitoring sites for the revised equation. The revised equation has been added to the suite of data analysis tools on the Visibility Information Exchange (VIEWS - http://vista.cira.colostate.edu/views/) and the WRAP Technical Support System (TSS - http://vista.cira.colostate.edu/tss/Results/Monitoring.aspx) web sites. A complete discussion and report is available on the IMPROVE Web site at http://vista.cira.colostate.edu/IMPROVE/Publications/GrayLit/Gray_literature.htm.

Effects on Regional Haze Planning in the WRAP Region: Original vs. Revised IMPROVE Equation

The effects of the revised IMPROVE equation on the data used for regional haze planning under the RHR have been evaluated by the AoH Workgroup on a December 9, 2005 call and in more detail at a Workgroup Meeting on January 24-25, 2006. The detailed presentation at: http://wrapair.org/forums/aoh/meetings/060124m/Review_of_New_IMPROVE_Equ_012406_ARS.pdf, was the basis for the following observations from the AoH Workgroup. Analysis of the nature and causes of visibility impairment at the more than 100 CIAs in the WRAP region strongly suggests that control strategies for regional haze planning be evaluated using the revised IMPROVE equation, and that results be presented in units of both b_{ext} and dv.

For the purposes of regional haze planning, the revised IMPROVE equation has benefits, as it:

- incorporates new terms to more completely account for haze;
- uses updated research information;
- was developed by comparing to directly-measured optical light scattering data at collocated sites; and
- reduces known biases.

For regional haze planning purposes, using the revised IMPROVE equation has some tradeoffs, as it:

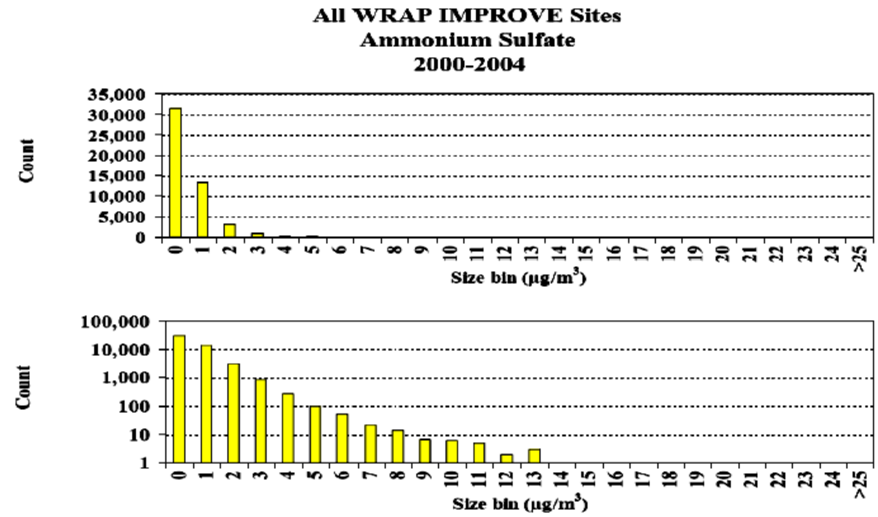
- is a national data analysis and addresses data distribution for the whole country, with the associated large sulfate impact dominating Eastern US visibility, and does not as directly address the mix of light extinction causes at Western Class I area monitoring sites;
- requires that in using the revised equation to the 2000-04 baseline monitoring period would also require that it be applied to as well to natural conditions estimates, to insure a consistent calculation of the glide path for each Class I area;
- has a somewhat greater uncertainty that causes it to mis-select the 20 % worst visibility days for the RHR a little more frequently, although little difference was observed with respect to the composition on those 20 % worst visibility days;
- chooses a "better fit" for all data across the distribution at the sites tested over the better precision of the original IMPROVE equation for individual data points in the middle of the distribution; and
- has little consequence for SO_4 and NO_3 in the WRAP region in terms of the "split component extinction efficiency method", as Figures 4 and 5 below show – Figure 6 shows that this new method for Organic Mass would have a more profound impact in the WRAP region, as expected from the episodic impacts of wildland fire emissions, as shown on the following page.

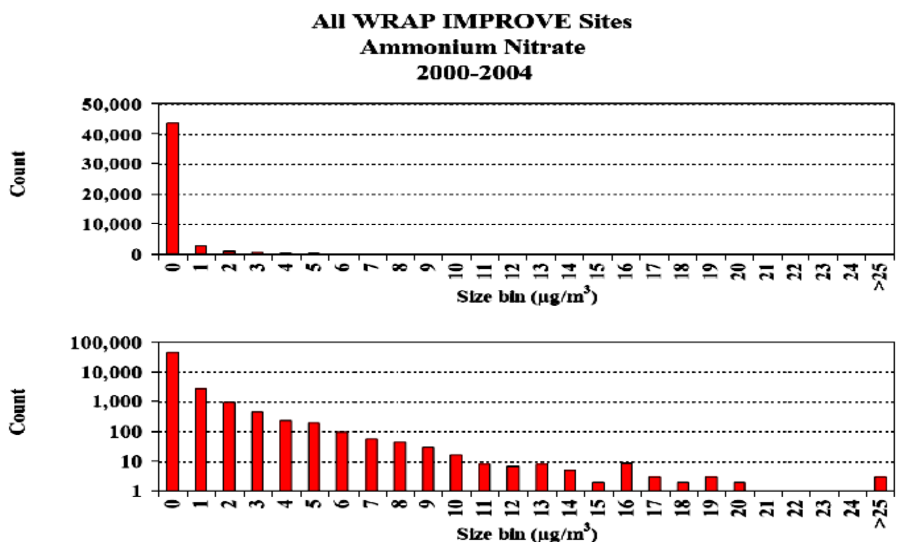
While the consistent use of the revised IMPROVE equation is recommended for regional haze planning in the WRAP region as the most useful and robust technical method to support reasonable progress analysis, the revised IMPROVE equation is not endorsed for use in evaluation of BART modeling results. The interpretation of BART modeling results for screening and subsequent determination of BART controls involves consideration of a range of various modeled values, and is a state-by-state regulatory decision; a number of WRAP region states have used the original equation in their BART determinations and are quite far along in regulatory rulemaking to determine BART controls at this time. As the BART analyses and determinations are not a comprehensive analysis of all sources contributing to or controllable for reasonable progress, and the BART regulatory findings of individual states are based on multiple factors, no recommendation or endorsement of a particular light extinction equation is needed.

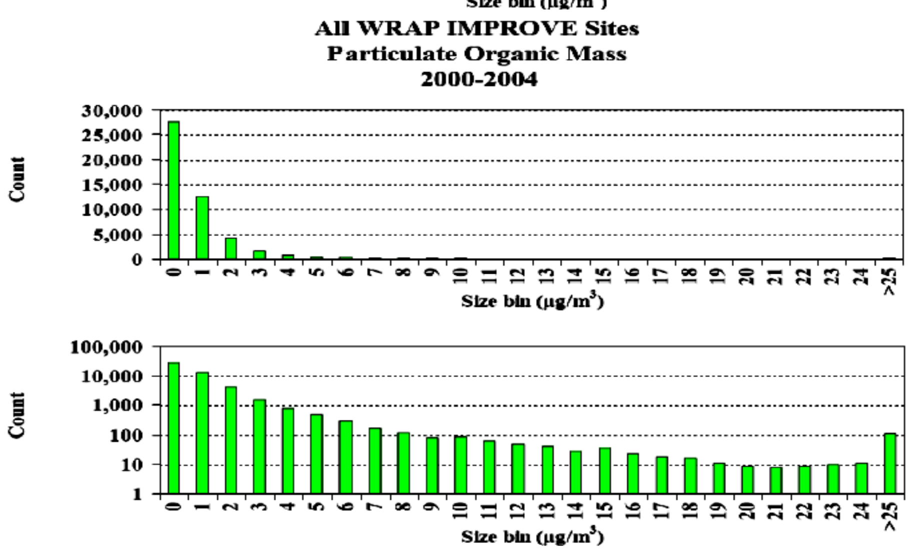
Recommendation:

Apply the revised IMPROVE light extinction equation as developed and approved in 2005 by the IMPROVE Steering Committee to convert from mass concentration measurements to light extinction for visibility analysis and regional haze planning at each WRAP region Class I area.

Figures 4, 5, 6. Histograms of Sulfate, Nitrate, and Organic Mass concentration data from all IMPROVE sites for 2000-04 in the WRAP (same data in paired charts, lower charts in logarithmic scale).







2000-04 Baseline Visibility Period Monitoring Data

The RHR requires that data from the IMPROVE monitoring sites representing CIAs for the 2000-04 baseline monitoring period is to be used to:

- Determine the current level of visibility impairment under the RHR;
- Quantify sources and pollutant species contributing to impairment;
- Assist in classifying natural and anthropogenic sources' contributions to impairment; and
- Develop regional haze implementation plans demonstrating reasonable progress across a 60-year timeline toward the Clean Air Act goal of no manmade visibility impairment in CIAs.

A short overview of the IMPROVE monitoring program operations is presented earlier in this document; additional information is at: http://vista.cira.colostate.edu/improve/.

Quality Assurance of IMPROVE Monitoring Data

The IMPROVE monitoring program has a Quality Assurance Project Plan (QAPP), see: http://vista.cira.colostate.edu/improve/Publications/QA_QC/IMPROVE_QAPP_R0.pdf, and a Quality Management Plan (QMP), see: http://vista.cira.colostate.edu/improve/Publications/QA_QC/IMPROVEAerosolQMP_May2002.PDF; both were published in 2002. The QMP and QAPP were prepared and the QA activities identified in that QMP and QAPP are executed by the laboratory and field operations contractor team for the IMPROVE aerosol sampler network, institutional members of the contractor team and locations are:

- Crocker Nuclear Laboratory – University of California, Davis, NC;
- Research Triangle Institute – Research Triangle Park, NC;
- Desert Research Institute – Reno, NV; and
- Environmental Protection Agency – coordinated by OAQPS, Research Triangle Park, NC.

Staff of the National Park Service, the U.S. Forest Service, and the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University all provide additional quality assurance checks for, and analyses of, the IMPROVE data from the contractor team. The continuity of contractor team members over time, the centralized QA efforts of the contractor team, as well as the additional QA and analytical efforts coordinated by CIRA all combine to provide a very high level of confidence in the IMPROVE data for regulatory planning purposes.

Quality Assurance of the 2000-04 Baseline Monitoring Period WRAP Region IMPROVE Data

Batches of IMPROVE aerosol sampler data are published through the VIEWS website, see: http://vista.cira.colostate.edu/views/. The publication goal for these data is quarterly, sometimes the data are published twice-yearly or an annual update is made depending when updated data are provided by Crocker Nuclear Laboratory. In October 2005, an update specific to the 2000-04 data was made, see: http://vista.cira.colostate.edu/improve/Publications/GrayLit/018_IMPROVEDataResubmission/DataRedeliverySummary2005.pdf.

Crocker Nuclear Laboratory resubmitted all of the IMPROVE aerosol data to VIEWS for the 2000-04 monitoring period in October 2005. The data were resubmitted to correct several errors and discrepancies in the data in order to provide the RHR analysts with the best available data set. There were four systematic changes that affected large blocks of data:

- New flow rate validation flags were assigned;
- Flow rates were recalculated to correct an error in the calculation that existed prior to January 2004;
- Spectral corrections were applied to sulfur and aluminum data collected beginning in December 2001, when Crocker changed the elemental analysis technique; and
- Carbon analysis data were resubmitted to correct a bias in the data.

In addition to these systematic changes, a number of site-specific data problems were resolved and the data were resubmitted as well. Examples included inadvertently swapped samples, backdated flow rate calibrations, samples requiring reanalysis, and equipment problems that were resolved after the original data had been submitted.

Attribution of Haze Workgroup Review of 2000-04 Baseline Period Monitoring Data

Data completeness was reviewed at the AoH Workgroup meeting of November 16-17, 2005, see: http://wrapair.org/forums/aoh/meetings/051116m/Summary_of_Regional_Haze_Baseline_Data_111605_ARS.pdf. This was a preliminary assessment, and the IMPROVE data have been updated since that time.

The RHR Tracking Progress guidance document published by EPA in 2003, see: http://www.epa.gov/ttn/oarpg/t1/memoranda/rh_tpurhr_gd.pdf, prescribes the method for calculating the Worst 20% and Best 20% Visibility Days' metrics to determine the baseline period values to be used in regional haze planning. The following steps to calculate these metrics are already complete in VIEWS and the TSS, using both the original and revised IMPROVE light extinction equations; specific steps are:

- Assemble daily speciated data and monthly f(RH) values from each IMPROVE site for each CIA;
- Perform allowed data substitutions as prescribed in Tracking Progress guidance, if warranted;
- Sites must have at least 3 of 5 years of "complete" data;
- Calculate daily extinction, convert to Haze Index (deciviews);
- Determine the average Haze Index of the 20% worst and best visibility days for each complete year, average these annual values for baseline period statistic; and
- Determine Glide Path by comparing the 2000-04 baseline value with natural conditions.

Five (5) WRAP region IMPROVE sites did not meet 2000-04 baseline monitoring period data completeness criteria of at least 3 years of data:

- Arizona - (BALD) Mount Baldy
- California - (KAIS) Kaiser and (RAFA) San Rafael
- Utah: - (CAPI) Capitol Reef
- Washington - (NOCA) North Cascades

A site-specific Baseline period value will be calculated for these ClAs on VIEWS and TSS, in consultation with the appropriate state. Methods may include data prior to 2000, data from nearby, representative sites, et cetera.

Recommendation:

Use the 2000-04 Best and Worst Days' metrics as calculated and reported by VIEWS and TSS. Individual states should review the data completeness and any data substitutions for their CIAs.

2064 Natural Visibility Conditions Estimates

Default natural visibility conditions estimates and the associated methodology were published by EPA in 2003 at: http://www.epa.gov/ttn/oarpg/t1/memoranda/rh_envcurhr_gd.pdf. This Estimating Natural Visibility Conditions Under the Regional Haze Rule guidance document was prepared prior to the review of the IMPROVE light extinction equation during 2005 and provided estimates of natural conditions in haze index units (deciviews) only. Numerous criticisms of these estimates have been noted, see the collection of documents at: http://www.wrapair.org/forums/aamrf/projects/NCB/index.html. These estimates are in terms of the original IMPROVE light extinction equation, and are not comparable to baseline period monitoring metrics calculated with the revised IMPROVE equation.

Regional haze planning in the WRAP region should separately assess reasonable progress toward the national visibility goal by IMPROVE light extinction species, due to the mixture of sulfate, nitrate, carbonaceous aerosols, and soil materials causing Western visibility impairment, along with the large amount of natural fire and dust emissions contributing to visibility impairment. For those reasons, Alternative Natural Conditions Estimates, in term of deciviews, total light extinction, and IMPROVE species light extinction have been developed, reviewed, and proposed for use in regional haze planning; see: http://vista.cira.colostate.edu/improve/Publications/NewsLetters/IMPNews2ndQtr2006.pdf.

Alternative Natural Visibility Conditions

EPA 2003 RHR guidance 2003 for tracking progress and estimating natural conditions were based on the original IMPROVE equation, providing a consistent set of instructions. see: http://vista.cira.colostate.edu/improve/Publications/GuidanceDocs/guidancedocs.htm. As noted earlier, a revised IMPROVE equation was developed and approved that mitigated some of the technical criticism of the original IMPROVE equation, especially as it applied to implementing the RHR through the regional haze implementation plans due in December 2007. Many of the regional planning organizations (RPOs) and states indicated their preference to use the revised equation, but to do so they need natural haze condition estimates for their CIAs determined in a consistent manner (i.e., by the new IMPROVE equation). The revised IMPROVE equation is described earlier in this document.

Estimates of natural haze levels using either equation involve applying the equation to estimates of natural species concentrations. The natural species concentration estimates used for this purpose come from the 1990 NAPAP State of Science Report 24 by John Trijonis, see: http://vista.cira.colostate.edu/improve/Publications/Principle/NAPAP_SOS/High%20Res/napap_(high).htm and are typical values for the eastern and western U.S. Some methodology is needed to adjust these typical values to estimate the 20% best and 20% worst values. A goal in developing the new values is to avoid problems identified in the EPA default approach. The Natural Haze Levels II Committee was established by the Inter-RPO Monitoring & Data Analysis Workgroup in Spring 2006 to review and refine, as appropriate, a methodology developed by Roger Ames (CIRA) for applying the new IMPROVE equation for estimating light extinction from aerosol concentrations to natural species concentration estimates. Ultimately this would provide natural haze estimates for the 20% best and 20% worst day for each of the CIAs covered by the RHR. The committee was composed of Marc Pitchford, NOAA; Bill Malm, NPS; Bruce Polkowsky, NPS; Pat Brewer, VISTAS; Tom Moore, WRAP; Ivar Tombach, consultant; John Vimont, NPS; Rich Poirot, Vermont; Roger Ames, CIRA; and Naresh Kumar, EPRI. The committee work has been summarized in an annotated presentation that is available at: http://vista.cira.colostate.edu/datawarehouse/improve/docs/naturalhazelevelsIIreport.ppt. This information was presented July 27, 2006 at the Attribution of Haze Workgroup meeting, see: http://wrapair.org/forums/aoh/meetings/060726den/index.html and on August 14 at the RPO

Monitoring/Data Analysis Workgroup conference call. Comments received by August 25, 2006 were used to generate an approved approach that was forwarded to the individual RPOs for their consideration and use.

The alternative natural conditions estimates offer a number of advantages for regional haze planning, over the default estimates in EPA guidance. The alternative conditions are divided into the 6 measured IMPROVE light extinction species, and can still be totaled to estimate total visibility in light extinction or deciviews, using the revised IMPROVE equation. The alternative estimates are based on analyzing and estimating the natural fraction of the 2000-04 baseline period monitoring data at each IMPROVE monitoring site. At more than a dozen sites, the natural fractions estimated by the alternative method for the 2000-04 data were compared to the period of record (>15 years) data for the same sites, and the alternative method for the 2000-04 period is quite similar to the long period of record since the late 1980s.

Tables 1 through 4 below show example data summaries for regional haze planning use in documenting differences between EPA default and alternative methods of estimating natural conditions at each CIA.

Both EPA default and alternative natural conditions estimates represent 2064 target values for regional haze planning purposes; the true values are not known at this time, and more analysis is needed to refine these estimates for future regional haze planning cycles, as anthropogenic emissions are reduced and natural visibility conditions are better measured.

The alternative natural conditions estimates are not used in evaluation of BART modeling results, as their use would require the use of the revised IMPROVE equation, which has not been incorporated into EPA or the Federal Land Managers' Air Quality Related Values Work Group (FLAG) guidance for the evaluating modeling results for impacts from, and control of, individual stationary sources. The application of the original IMPROVE equation and specified natural conditions in evaluation of BART modeling results is for a fundamentally different purpose than regional haze planning, as defined in the EPA BART rule.

While the consistent use of the revised IMPROVE equation is recommended for regional haze planning in the WRAP region as the most useful and robust technical method to support reasonable progress analysis, the revised IMPROVE equation is not endorsed for use in evaluation of BART modeling results. The interpretation of BART modeling results for screening and subsequent determination of BART controls involves consideration of a range of various modeled values, and is a state-by-state regulatory decision; a number of WRAP region states have used the original equation in their BART determinations and are quite far along in regulatory rulemaking to determine BART controls at this time. As the BART analyses and determinations are not a comprehensive analysis of all sources contributing to or controllable for reasonable progress, and the BART regulatory findings of individual states are based on multiple factors, no recommendation or endorsement of a particular light extinction equation is needed.

As the revised IMPROVE equation and alternative natural conditions estimates recommended for analysis of reasonable progress in the WRAP region were developed specifically based on regional haze 2000-04 baseline period monitoring data, the equation and the associated alternative natural conditions estimates were designed to be consistently integrated and used in species and total visibility impact glide paths to natural conditions; allowing assessment of the amount of visibility impairment by species to be reduced from the 2000-04 baseline period through to 2064 for each Class I area. Use of the revised IMPROVE equation and alternative natural conditions estimates in individual BART analyses process of each state is not necessary and may not be accurate, as BART controls are required for implementation by 2012, and the natural conditions already defined in the existing EPA or the Federal Land Managers' Air Quality Related Values Work Group (FLAG) guidance are sufficient for screening and evaluation purposes. Further, precise estimates of aerosol mass and size distributions at natural conditions is unknown for short-term planning purposes, and will likely by different than the alternative natural conditions current recommended, as over the next ~60 years, anthropogenic aerosol loadings decrease, more and better aerosol data are collected, and implementation of regional haze control plans move forward.

Recommendation:

Use the alterative Natural Conditions Estimates in combination with the 2000-04 Best and Worst Days' metrics as calculated and reported by VIEWS and TSS, utilizing the revised IMPROVE equation, for visibility analysis and regional haze planning at each WRAP region Class I area.

Table 1 – Comparison of Natural Visibility Conditions Estimates using EPA Default and New Alternative Methods, including the change in Regional Haze Rule Uniform Rate of Progress 2018 Target Values

Mandatory Federal Class I Area	State	Monitoring Site Code	20% Best Days 2064 Natural Conditions		20% Worst Days 2000-04 Baseline Period Monitoring Data		20% Worst Days 2064 Natural Conditions		Uniform Rate of Progress: 2018 Haze Planning Milestone for 20% Worst Days		Uniform Rate of Progress: 2018 Visibility Improvement Increment for 20% Worst Days	
			Default method (dv)	Alt. method (dv)	Default method (dv)	Alt. method (dv)	Default method (dv)	Alt. method (dv)	Default method (dv)	Alt. method (dv)	Default method (dv)	Alt. method (dv)
Agua Tibia Wilderness Area	CA	AGTI1										
Arches NP	UT	ARCH1										

Table 2 – Light Extinction Component s of 20% Worst Visibility Days for 2064 Natural Visibility Conditions Estimates (revised IMPROVE light extinction equation & alternative method for estimating Natural Visibility Conditions)

Mandatory Federal Class I Area	State	Monitoring Site Code	20% Worst Days 2064 Natural Conditions Estimates (dv) (from Table 1)	20% Worst Days 2064 Natural Conditions Estimates (1/Mm)	Light Extinction Components of 20% Worst Days 2064 Natural Visibility Conditions Estimates					
					Sulfate (1/Mm)	Nitrate (1/Mm)	Organic Material (1/Mm)	Elemental Carbon (1/Mm)	Fine Soil (1/Mm)	Coarse Material (1/Mm)
Agua Tibia Wild. Area	CA	AGTI1								
Arches NP	UT	ARCH1								

Table 3 – Light Extinction Components of 20% Best Visibility Days for 2064 Natural Visibility Conditions Estimates (revised IMPROVE light extinction equation & alternative method for estimating Natural Visibility Conditions)

Mandatory Federal Class I Area	State	Monitoring Site Code	20% Best Days 2064 Natural Conditions Estimates (dv) (from Table 1)	20% Best Days 2064 Natural Conditions Estimates (1/Mm)	Light Extinction Components of 20% Best Days 2064 Natural Visibility Conditions Estimates					
					Sulfate (1/Mm)	Nitrate (1/Mm)	Organic Material (1/Mm)	Elemental Carbon (1/Mm)	Fine Soil (1/Mm)	Coarse Material (1/Mm)
Agua Tibia Wild. Area	CA	AGTI1								
Arches NP	UT	ARCH1								

Table 4 - Uniform Rate of Progress: 2018 Haze Planning Milestone for 20% Worst Days and 2018 Visibility Improvement Increment for 20% Worst Days, by light extinction component, using Alternative Natural Conditions Estimates

Mandatory Federal Class I Area	State	Monitoring Site Code	Uniform Rate of Progress: 2018 Haze Planning Milestone: Light Extinction Components on 20% Worst Days (1/Mm)						Uniform Rate of Progress: 2018 Visibility Improvement Increment: Light Extinction Components on 20% Worst Days (1/Mm)					
			Sulfate	Nitrate	Organic Material	Elemental Carbon	Fine Soil	Coarse Material	Sulfate	Nitrate	Organic Material	Elemental Carbon	Fine Soil	Coarse Material
Agua Tibia Wilderness Area	CA	AGTI1												
Arches NP	UT	ARCH1												

2018 Planning Milestone Visibility Projection Values

In order to prepare regional haze implementation plans for the initial RHR milestone date of 2018, air quality modeling results comparing the impacts of historic and projected emissions estimates using consistent meteorology have to be projected in terms of monitored visibility values, using monitoring data from the 2000-04 baseline period as a controlling term. The concept is that both historic and future modeling results contain errors, but by using the monitoring data to control the predictions of the model, the relative change in model results from 2000-04 to 2018 can be a reasonable assessment of likely air quality changes. Several questions about which monitoring are representative and the best to use are discussed next. Information about the air quality model is also reviewed.

The EPA default guidance method is to use "2002 worst monitored days" to project future visibility conditions in "draft" 2001 EPA guidance, even though the RHR requires monitoring data from 2000-04 baseline period to be used as the basis of the regional haze implementation plans. This guidance also applies to interpreting the modeling results for $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) attainment demonstrations, and is also closely related to attainment demonstrations required for the Ozone NAAQS. The EPA guidance is found at: http://www.epa.gov/scram001/guidance/guide/draft_pm.pdf. The purpose of applying the EPA guidance was to develop a series of relative Reduction Factors (RRFs) using monitoring data to control and "fit" historic and projected model predictions, assuming that the air quality model is better at predicting relative changes in concentration than absolute concentrations.

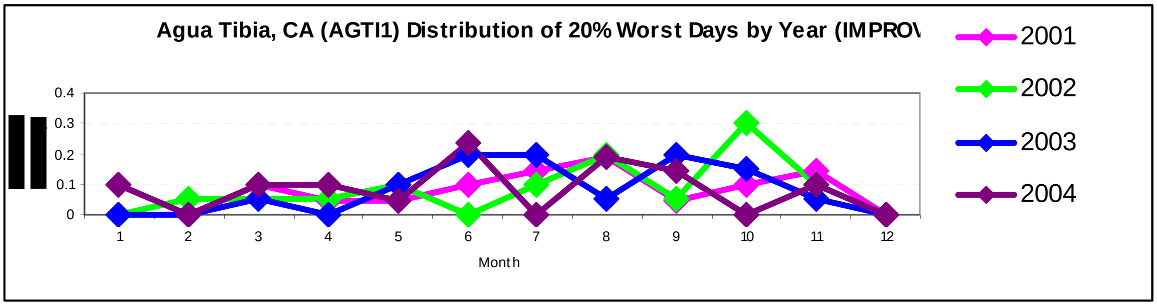
Basic steps for applying the EPA RRF guidance to project visibility conditions in 2018 at each CIA are:

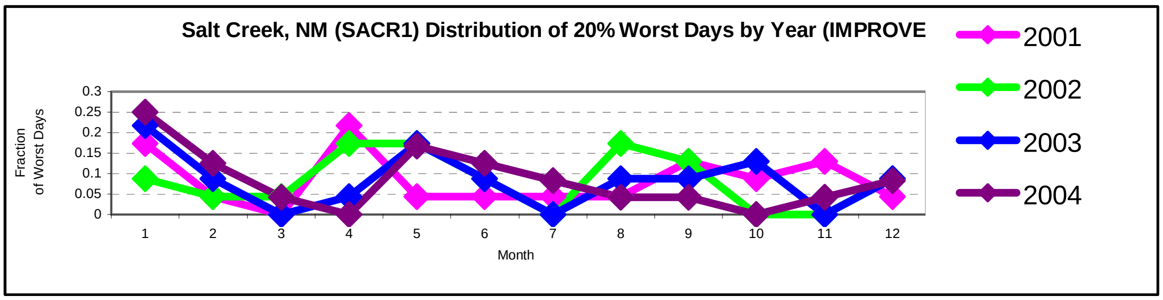
- *Model species concentrations for 2002;*
- *Model species concentrations for 2018 scenario;*
- *Determine a species-specific RRF for the average of the 20% worst monitored days (selected from 2002 IMPROVE data), where, for example:*
  - *RRF sulfate = 2018 sulfate/2002 sulfate*
- *Using the selected 20% worst days for 2002, apply the RRF values, such that:*
  - *2018 concentration = Average [RRF x Baseline concentration]*
- *Calculate projected 2018 visibility values for 20% worst days for each CIA.*

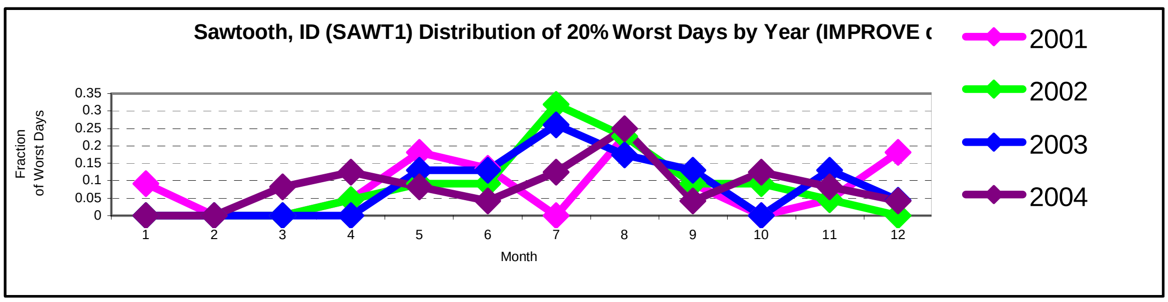
The 20% best visibility days are projected in the same manner, selecting the 20% best monitored days from 2002 IMPROVE data. Several issues with this approach are evident when analyzing the regional haze monitoring data and model performance.

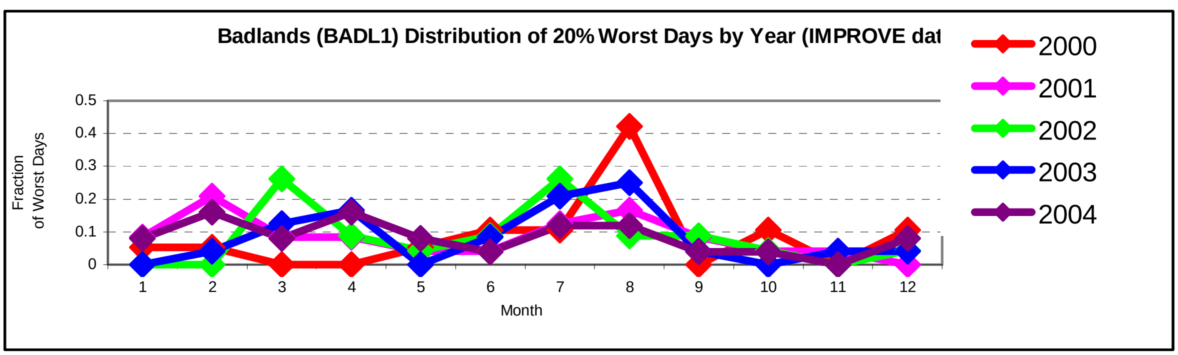
Figures 7 through 11, below show the monthly variation in the fractional occurrence of worst days at 5 randomly-selected IMPROVE monitoring sites. These figures clearly show a fair amount of inter-annual variation in the distribution of 20% worst monitored visibility days. As the EPA guidance requires the use of specific days only from 2002, these figures demonstrate that 2002 is not similar to other years in the 2000-04 baseline period, likely due to variation in [mostly] fire and dust emissions, and differences in meteorology from year to year. For this reason, the use of only 2002 for projecting visibility in 2018 is not in keeping with the requirements of the RHR.

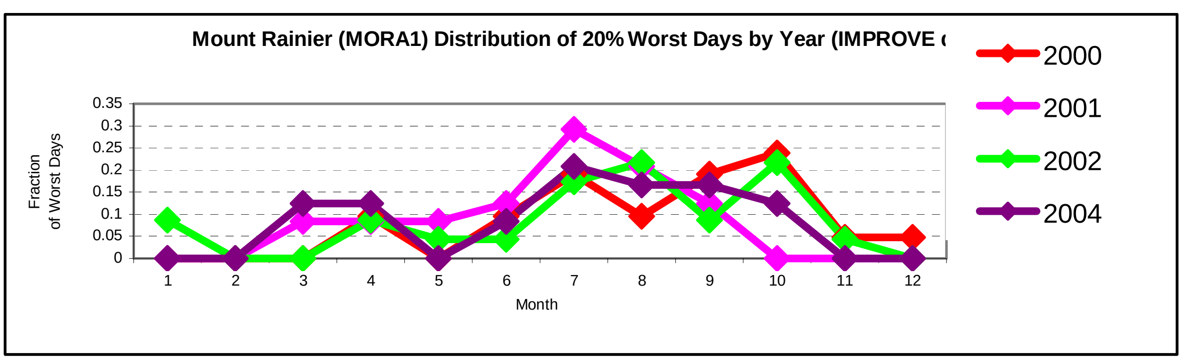
Figures 7, 8, 9, 10, 11. Time Series of Monthly Variation in the Fraction Variation of the 20% Worst Monitored Days at randomly-selected WRAP region Class I areas.











Air quality modeling in support of regional haze implementation planning is conducted by the WRAP Regional Modeling Center (RMC), see: http://pah.cert.ucr.edu/aqm/308/. The RMC uses state of the art, regional gridded photochemical models for aerosol modeling called CMAQ and CAMx. Extensive and numerous air quality modeling studies have been performed by the RMC over the past 6 years to support regional haze planning in the WRAP region.

Performance of the RMC models for 2002-specific emissions and meteorology is done by comparing air quality modeling results to 2002 monitored results from the IMPROVE and other monitoring networks' by species; see: http://pah.cert.ucr.edu/aqm/308/reports/final/2002_MPE_report_main_body_FINAL.pdf. Fire and dust air quality modeling results, and their projection using RRFs was considered at a WRAP workshop in May 2006, see: http://www.wrapair.org/forums/ioc/meetings/060523m/. Aerosol sampling at IMPROVE sites is 24 hours in duration, midnight to midnight, conducted every-3rd-day, and the hourly modeling results are summed and matched in time. The RMC models provide hourly estimates of visibility and aerosol species concentrations. The modeled gaseous and aerosol species are "mapped" to the IMPROVE and other networks' observational species, to calculate mass and aerosol light extinction in comparable terms. More information on RMC species mapping is shown in Tables 5 and 6 below.

Table 5 – Mapping of Gaseous RMC Model Species to Gaseous Observational Species

Compound	Observation Species			Model Species	
	IMPROVE	CASTNet	AQS	CMAQ	CAMx
				Gaseous Species	
O_3			O3	O3	O3
CO			CO	CO	CO
NO			NO	NO	NO
SO_2			SO2	SO2	SO2
SO_2 ($\mu g/m^3$)		TOTAL_SO2		2617.6*SO2	2617.6*SO2
HNO_3				HNO3	HNO3
HNO_3 ($\mu g/m^3$)		NHNO3 (nylon filter)		2576.7*HNO3	2576.7*HNO3
NO_y				NO + NO2 + HONO + NO3 + 2*N2O5 + HNO3 + PAN + XNO2 + TPAN + HNO4	NO + NO2 + HONO + NXOY + HNO3 + PAN + NTR

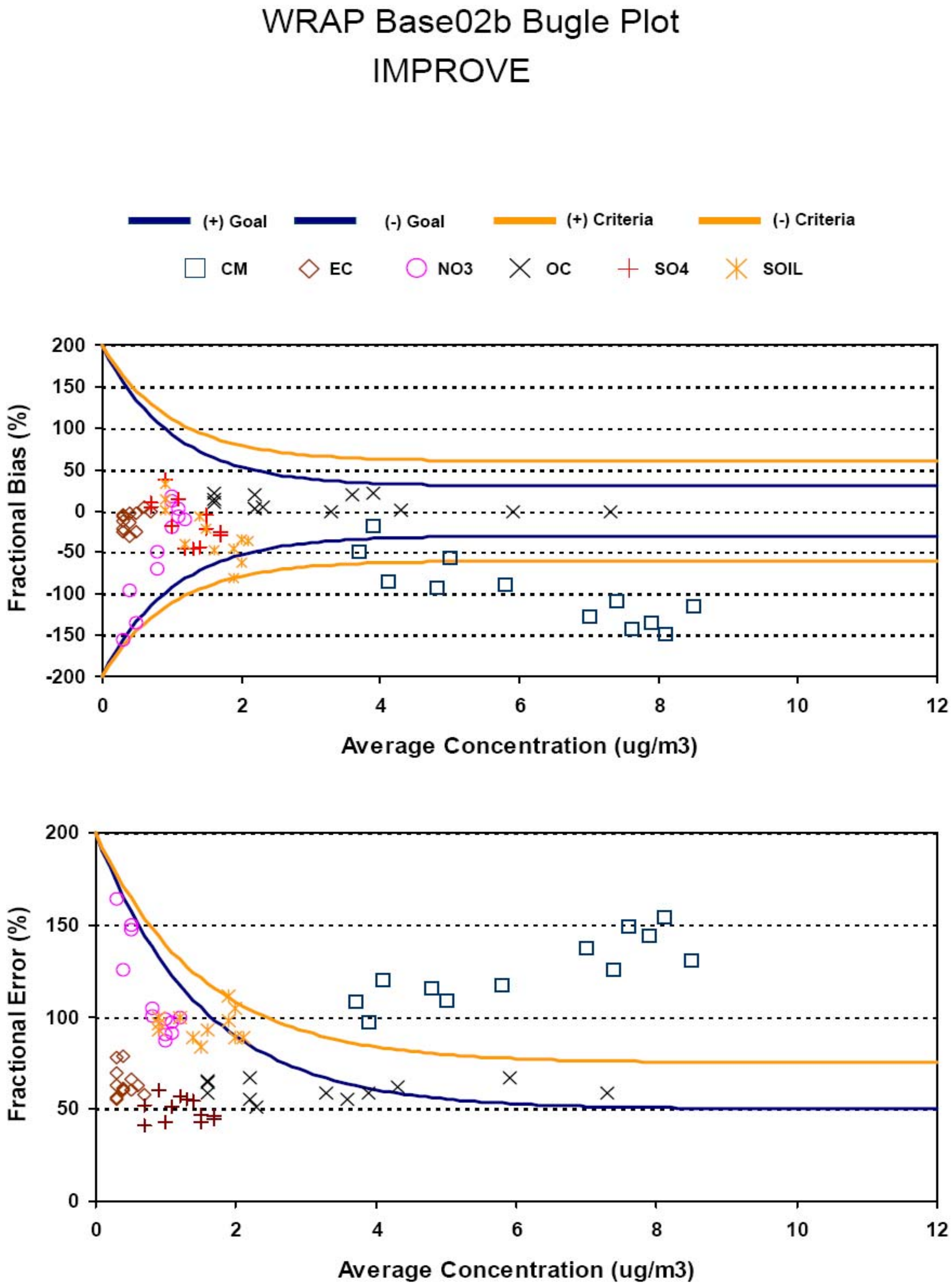
Table 6 – Mapping of Particulate RMC Model Species to Particulate Observational Species

Table 4-3b. Mapping of particulate model species to particulate observation species.

Compound	Observation Species				Model Species	
	IMPROVE	CASTNet	STN	NADP/ NTN	CMAQ	CAMx
Particulate Species						
SO_4	3*S	TSO4 (Teflon filter)	SO4	wSO4	ASO4J + ASO4I	PSO4
NO_3	NO3	TNO3 (Teflon filter)	NO3	wNO3	ANO3J + ANO3I	PNO3
Particulate NO_3+SO_4		0.29*TNO_3 + 0.375*TSO_4			0.29*(ANO3I + ANO3J) + 0.375*(ASO4I + ASO4J)	0.29*PNO3 + 0.375*PSO4
Total NO_3 (gas+particle)		TOTAL_NO_3			ANO3I + ANO3J + 0.9841*2576.7*HNO3	PNO3 + 0.9841*2576.7*HNO3
NH_4	0.375*SO4 + 0.29*NO3	TNH4 (Teflon filter)	NH4	wNH4	ANH4J + ANH4I	PNH4
OC	1.4*(OC1+ OC2 + OC3 + OC4 + OP)		OC		AORGAJ + AORGAI + AORGPAJ + AORGPAI + AORGBJ + AORGBI	POA + SOA1 + SOA2 + SOA3 + SOA4
EC	EC1 + EC2 + EC3 - OP		EC		AECJ + AECI	PEC
TCM			OC+EC			
SOIL	2.2*Al + 2.49*Si + 1.63*Ca + 2.42*Fe + 1.94*Ti				A25I +A25J	FCRS + FPRM
CM	MT - FM				ACORS + ASEAS + ASOIL	CCRS + CPRM
$PM_{2.5}$	FM		PM25		ASO4J + ASO4I + ANO3J + ANO3I + ANH4J + ANH4I+ AORGAJ + AORGAI + AORGPAJ + AORGPAI + AORGBJ + AORGBI + AECJ + AECI + A25J + A25I	PSO4 + PNO3 + PNH4 + POA + SOA1 + SOA2 + SOA3 + SOA4 + PEC + FCRS + FPRM
RCFM	1.375*SO4 + 1.29*NO3 + EC + OC + SOIL				1.375*(ASO4J + ASO4I) + 1.29*(ANO3J + ANO3I) + AORGAJ + AORGAI + AORGPAJ + AORGPAI + AORGBJ + AORGBI + AECJ + AECI + A25J + A25I	1.375*PSO4 + 1.29*PNO3 + POA + SOA1 + SOA2 + SOA3 + SOA4 + PEC + FCRS + FPRM
PM_{10}	MT				PM25 + CM	PM25 + CM

Model results often do not precisely match monitoring data due to temporal, spatial, chemical, and physical limitations in the emissions estimates, the accuracy and precision of the meteorology data employed in the models, and/or the chemical and physics parameterizations in the CMAQ and CAMx models. This is especially true for Coarse Material, and to a lesser degree, Fine Soil, see Figure 12 below. Most dust emissions contributing to modeled fine soil and coarse material have been held constant from 2002 to 2018 in RMC modeling, due to the lack of acceptable methods to project factors causing changes in dust emissions over time. In contrast, the RMC has applied average fire emissions of carbonaceous aerosols for the period 2000-04, and believe that those modeling simulations, called the "Plan02" series, provide reasonable modeling approximations of visibility impacts in the 2000-04 baseline monitoring period. Other emissions in the Plan02 modeling series are from 2002 and are thought to be representative of the 5-year baseline period. Only 2002 meteorology is used in the Plan02 series; for more information on the Plan02 series, see Plan02 references in Table 1 at: http://pah.cert.ucr.edu/aqm/308/cmaq.shtml.

Figure 12. Example Model Performance "Bugle Plot" for 2002 RMC Model Results versus IMPROVE Monitoring Data for all WRAP region Class I areas in the RMC modeling domain.



<u>*WRAP RRF Projection Method*</u>

An alternative "WRAP RRF projection method" to use 2000-04 distribution of worst days at each IMPROVE site is proposed for use in lieu of the EPA default RRF method. Due to model performance issues discussed above, the fine soil and coarse material projection values will need to be subjected to additional analysis before using this approach. For sulfate, nitrate, and carbonaceous aerosols, the basic steps for applying the WRAP RRF projection method for visibility conditions in 2018 at each CIA are:

- *Determine daily modeled species concentrations for 2000-04 baseline period using Plan02c modeling results;*
- *Determine daily modeled species concentrations for 2018 using Base18b [and subsequent scenarios] modeling results;*
- *Determine the distribution and average monthly number of 20% worst monitored visibility days in deciviews for each CIA monitoring site [examples shown in Figures 7-11 above, by converting the fraction of days by month to the nearest integer value for each month, totaling 24 values across 12 months] – this becomes the number of modeled days to select in the next step;*
- *Starting with the highest modeled 20% worst days, choose values in order by month from Plan02c and Base18b model results for the associated 2000-04 average monthly number of worst monitored days as shown above;*
- *Apply the modeled ratio by to each IMPROVE light extinction species, for example:*
  - *WRAP RRF January highest day modeled sulfate concentration = (2018 January modeled sulfate/2002 January modeled sulfate)*
- *Report projected 2018 average 20% worst visibility values for each CIA; and*
- *For the appropriate number of worst modeled days by month, also report the deciview, total light extinction, and species extinction and species mass concentration values for each CIA.*

The 20% best visibility days would also be projected for 2018 in the same manner, using modeled best days' values for the Plan02c and Base18b modeling simulation results', using the distribution and average monthly number of 20% best monitored visibility days.

The concept of selecting ratios of visibility modeling results to project future visibility conditions, fitted to the distribution of 20% worst and best monitored days by month for the 2000-04 baseline monitoring period better represents the "20% Worst and Best" visibility days for the RHR visibility metric than the EPA default guidance approach of selecting specific days in 2002. The worst and best days are not likely to happen on exactly the same days in 2018, and the fractional monthly variation over the 2000-04 time period is substantial. The WRAP RRF Projection Method works around data completeness issues:

- *Missing data and/or incomplete data for worst and best days' monitored distributions from 2002 – a number of WRAP region sites are affected;*
- *The systematic bias of the 1 in 3-day sampling frequency of the monitored observations from the 1 in 1-day [actually hourly] frequency of the modeling results; and*
- *The episodic and substantial nature of dust and fire impacts on individual IMPROVE samplers and CIAs in a particular year.*

The WRAP RRF Projection Method provides additional benefits for regional haze analysis:

- *Determines a common monthly distribution of 20% Worst and Best visibility days to allow a standardized method to compare modeling and monitoring results.*

- *Allows regional haze planning to be based on the most complete estimates of historic and projected air quality conditions, with longer-term (5 years) of monitoring data used to ground the modeled values.*
- *Allows consideration of the quality of emissions and meteorological inputs to the air quality model in conjunction and in balance with limitations of monitoring data for regional haze planning for complex air quality issues such as the impact of fire and dust emissions.*

While the consistent use of the revised IMPROVE equation is recommended for regional haze planning in the WRAP region as the most useful and robust technical method to support reasonable progress analysis, the revised IMPROVE equation is not endorsed for use in evaluation of BART modeling results. The interpretation of BART modeling results for screening and subsequent determination of BART controls involves consideration of a range of various modeled values, and is a state-by-state regulatory decision; a number of WRAP region states have used the original equation in their BART determinations and are quite far along in regulatory rulemaking to determine BART controls at this time. As the BART analyses and determinations are not a comprehensive analysis of all sources contributing to or controllable for reasonable progress, and the BART regulatory findings of individual states are based on multiple factors, no recommendation or endorsement of a particular light extinction equation is needed.

As the revised IMPROVE equation and alternative natural conditions estimates recommended for analysis of reasonable progress in the WRAP region were developed specifically based on regional haze 2000-04 baseline period monitoring data, the equation and the associated alternative natural conditions estimates were designed to be consistently integrated and used in species and total visibility impact glide paths to natural conditions; allowing assessment of the amount of visibility impairment by species to be reduced from the 2000-04 baseline period through to 2064 for each Class I area. Use of the revised IMPROVE equation and alternative natural conditions estimates in individual BART analyses process of each state is not necessary and may not be accurate, as BART controls are required for implementation by 2012, and the natural conditions already defined in the existing EPA or the Federal Land Managers' Air Quality Related Values Work Group (FLAG) guidance are sufficient for screening and evaluation purposes. Further, precise estimates of aerosol mass and size distributions at natural conditions is unknown for short-term planning purposes, and will likely by different than the alternative natural conditions current recommended, as over the next ~60 years, anthropogenic aerosol loadings decrease, more and better aerosol data are collected, and implementation of regional haze control plans move forward.

<u>Recommendation:</u>

Use the alternative WRAP RRF Projection Method for projecting 2018 visibility conditions in combination with the 2000-04 Best and Worst Days' metrics as calculated and reported by VIEWS and TSS, utilizing the revised IMPROVE equation and alternative Natural Conditions Estimates, for visibility analysis and regional haze planning at each WRAP region Class I area. Study the effect of this method for Fine Soil and Coarse Material visibility modeling results before applying it to those IMPROVE light extinction species.