Chapter 9. Regional Haze Rule Progress Tracking Metrics

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9.1 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) established the Regional Haze Rule (RHR, U.S. EPA, 1999) to achieve the national visibility goal established by the Clean Air Act, which called for the virtual elimination of anthropogenic visibility impairment in 156 areas designated as Class I federal areas (CIAs), (i.e., principally large national parks and wilderness areas). The RHR requires periodic state implementation plans (SIPs) from each state to demonstrate "reasonable progress" toward achieving RHR-defined natural visibility conditions by a nominal target date of 2064. The initial baseline SIPs must include a long-term strategy for emissions reductions and Best Available Retrofit Technology (BART) on certain existing sources and set "reasonable progress goals" for the conditions with the most impaired visibility (worst visibility days) and least impaired visibility (best visibility days) at each CIA, to be achieved in the first planning period. Toward that end, the RHR requires a comprehensive assessment of current conditions and causes of visibility impairment that includes analyses of IMPROVE particulate data and use of comprehensive air quality modeling for source apportionment assessment to support the development of individual SIPs. These technical assessments were conducted by five Regional Planning Organizations (http://www.epa.gov/visibility/regional.html), composed of state, federal, and tribal air quality representatives, and included stakeholder participation and funding support by the EPA. For further reading, the EPA and others have provided additional documentation and evaluations related to the RHR (U.S. EPA, 2005, 2006, 2007; Moore and Brewer, 2007; Brewer and Moore, 2009).

The RHR also mandates periodic 5-year assessments of progress in meeting the SIP visibility progress goals. This chapter includes information that is pertinent to the first required progress assessment. Specifically, it contains an analysis of the changes in visibility conditions and major species contributions to light extinction within the 5-year baseline period (i.e., 2000–2004) and the first 5-year progress period (i.e., 2005–2009) for the IMPROVE monitoring sites identified as representing the CIA. As such, this information should be useful input to the states responsible for preparing mid-SIP progress assessments. However, this report does not contain everything that might be required, such as emissions trends analysis, assessment of the relative role of emission changes and variations in meteorological factors, to explain visibility changes at each site. It also does not include additional assessments that could be helpful, such as characterizing the role of highly variable natural sources (wildfire and windblown dust) and international contributions to worst haze levels. These labor-intensive and sophisticated assessments are outside the scope of this report. The last section in this chapter presents case studies of five locations and briefly illustrates some of the analyses that should be included in the mid-SIP progress assessments.

9.2 REGIONAL HAZE RULE ASSESSMENT

The following is a brief overview of the RHR assessment of visibility progress trends analysis. For a more complete description, see discussions provided by the EPA (U.S. EPA, 2003a,b). The first RHR baseline SIPs to determine and control emissions that lead to regional haze were due in December 2007, with a progress report due in 2013. The RHR calls for improvements in the average of the 20% haziest ("worst") days from the 2000–2004 baseline period to ultimately reach the goal of worst haze level caused solely by natural sources by the 2064 target year for each CIA. The RHR also calls for no degradation of visibility for the average of least hazy ("best") 20% days for each CIA. To mitigate the impacts of interannual variability in determining progress towards these goals, the RHR mandates the use of non-overlapping, 5-year-averaged values of both the annual mean 20% best and 20% worst days determined for each site. The baseline period is defined as 2000 through 2004 and the first trend period as being 2005 through 2009. The visibility index used is based on the deciview (dv) scale, a logarithmic transformation of light extinction, which for the RHR is derived from IMPROVE aerosol composition data (as described below). There are 110 IMPROVE monitoring sites, referred to here as the regional haze tracking sites (RHTSs), that were selected to represent 155 visibility-protected regions.

9.2.1 Uniform Rate of Progress

The EPA published default natural-conditions targets to be achieved at each CIA by 2064. The presumption of the RHR was that anthropogenic emissions could be reduced in a gradually declining fashion to reach natural conditions for the worst haze conditions over the nominal 60-year duration of the RHR. Each of the 50 states is required to submit a complete baseline regional haze SIP addressing the various requirements of the RHR. The analyses in this chapter focus on the

- IMPROVE data for the 2000–2004 RHR baseline period at the IMPROVE RHTS monitoring sites;
- IMPROVE data for the first progress period (period 1) of 2005–2009 under the RHR; and
- the nominal default 2018 uniform rate of progress (URP) value for each CIA as defined in the RHR and supporting guidance documents.

Central to setting the individual CIA 2018 "reasonable progress" planning goals by each state under the RHR is the concept of the URP. The URP is the yearly rate of change required to achieve natural dv conditions by 2064 in a linear fashion beginning in 2004. The URP provides a reference to evaluate progress made in the context of the long-term emissions reductions and associated improvement in visibility required to reach natural conditions in 60 years. The conceptual glide path example of URP provided by the EPA in the 1999 RHR is shown as the solid black line in Figure 9.2.1. Baseline and period 1 dv values are based on the mean of five yearly values of the 20% best and 20% worst visibility days at each site. Natural conditions are marked with the dashed line. For each CIA, if the state-selected 2018 reasonable progress target value for the 20% worst visibility days in dv units is not on or below the glide path, the state must explain why the 2018 URP goal cannot be reasonably achieved and specify the additional time required to achieve natural conditions beyond 2064. The state must also verify that the 20% best visibility days are not projected to degrade.

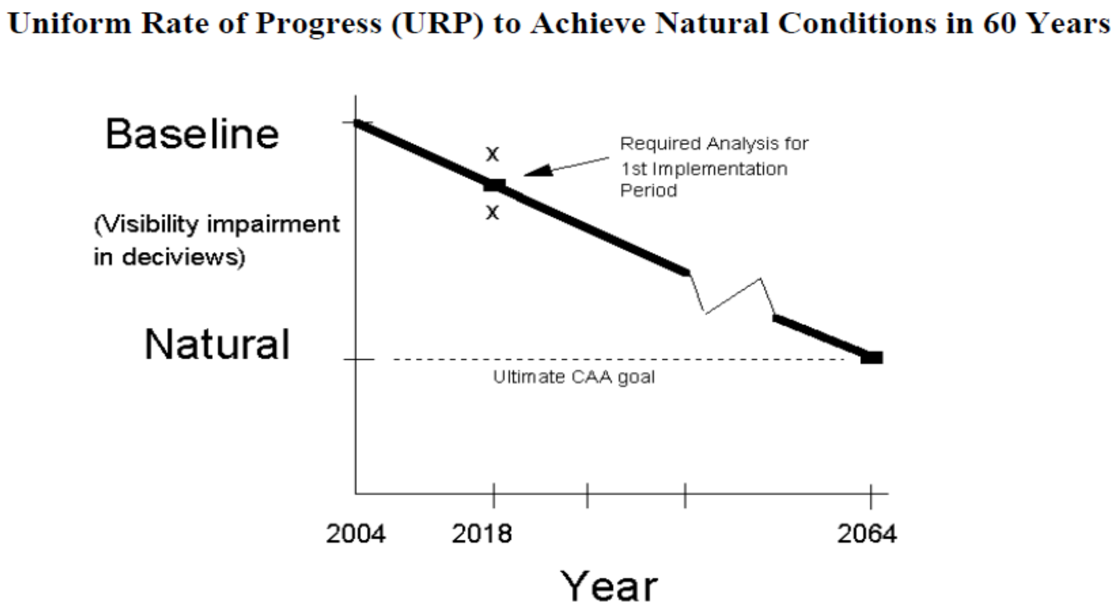


Figure 9.2.1. Depiction of the conceptual uniform rate of progress (URG) glide path (EPA, 1999).

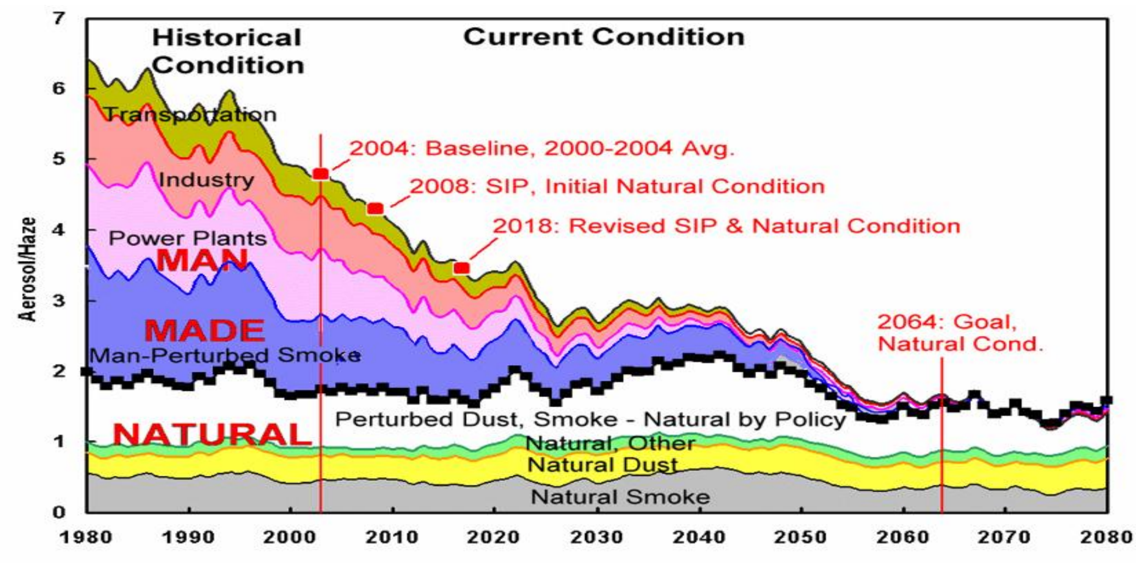


Figure 9.2.2. Depiction of realistic uniform rate of progress (URG) glide path (Husar, 2003).

It should be noted that the nature of emissions control programs plus the intermittent activity of some sources make it likely that actual progress will be somewhat erratic and that failure to achieve the URP at any point in the process should be considered in the context of changes to emissions inventories. A more realistic depiction of the variability in haze due to different sources is shown in Figure 9.2.2. The magnitude of haze in this schematic is displayed on the y-axis, versus time on the x-axis. For RHR planning, states worked with RPOs to define aerosol sources and their historical contributions to regional haze, as well as projected future emissions, which for many categories were difficult to predict. Biomass smoke and windblown dust sources are significant contributors to haze at many RHTSs, though their contributions to haze are often episodic and vary from one year to another. Unlike the depiction in Figure 9.2.2, the contributions by sources of smoke, dust, and other aerosol components are not known a priori from the IMPROVE measurements, and separating the contributions from anthropogenic versus natural sources of smoke, dust, and other contributors to haze is problematic. Though not explicitly illustrated in Figure 9.2.2, emissions from international sources can be major contributors to haze, due to both anthropogenic (e.g., marine shipping) and natural causes (e.g., fire and North African or Asian dust).

As anthropogenic U.S. emissions sources continue to decline, the effects of emissions reductions for well-characterized sources of sulfur dioxide and oxidized nitrogen are predictable, particularly where those sources dominate visibility impairment. However, there is significant variability in other sources and species that impair visibility in CIAs that need to be understood. Future RHR planning in the most pristine CIAs will be sensitive to the defined classification of the sources (i.e., controllable versus uncontrollable, natural versus anthropogenic). Over the long term, even CIAs that are currently among the most visibility impaired will become increasingly dominated by impacts from natural and/or uncontrollable sources such as wildland fire and geogenic sources, as well as proportionally larger contributions from international sources of both natural and anthropogenic origin.

There are a number of RHR SIP requirements not related directly to IMPROVE monitoring. The RHR SIPs were developed by using regional and state data to define emissions-reduction strategies and controls for anthropogenic sources and consider partially controllable, quasi-natural sources such as fire and dust. The individual states have the authority and responsibility to set their own reasonable progress goals for each CIA for 2018. The 2018 goals chosen must improve visibility on the 20% worst visibility days and not allow the 20% best visibility days to degrade. We do not attempt to evaluate state-selected goals in this report, instead confining our analyses to the 2009 point value on the slope of the nominal URP line in deciviews, as well as selected hypothetical species-specific light extinction coefficients; we also evaluate the progress in visibility conditions from Period 1 compared to the baseline for each CIA.

9.2.2 Regional Haze Rule Metric

Haziness in deciview units is derived from light extinction coefficients (b_{ext}) calculated using the “original” IMPROVE algorithm (designated as RHR1 in the IMPROVE dataset) or the “revised” IMPROVE algorithm (designated as RHR2) (Pitchford et. al., 2007). Since nearly all states used the RHR2 algorithm for SIP development, modeling, and source apportionment, the RHR2 algorithm was applied in this chapter. The daily b_{ext} values were calculated using the following equation:

$$\begin{aligned} b_{ext} = \; & 2.2f_S(RH)[\text{small ammonium sulfate}] + 4.8f_L(RH)[\text{large ammonium sulfate}] + \\ & 2.4f_S(RH)[\text{small ammonium nitrate}] + 5.1f_L(RH)[\text{large ammonium nitrate}] + \\ & 2.8[\text{small particulate organic matter}] + 6.1[\text{large particulate organic matter}] + \\ & 10[\text{light absorbing carbon}] + 1[\text{soil}] + 1.7f_{SS}(RH)[\text{sea salt}] + 0.6\,[\text{coarse mass}] + \\ & \text{site-specific Rayleigh scattering} \end{aligned} \qquad (9.1)$$

Note that the first three major particle species (i.e., ammonium sulfate, ammonium nitrate, or particulate organic matter) in equation 9.1 are separated each into "small" and "large" components, which refers to a partitioning of the particles containing those particles into two size distributions within the $PM_{2.5}$ size range (i.e., diameter < 2.5 μm). The small and large mode concentrations of any of the first three components are computed using equations 9.2 and 9.3 for component concentrations less than 20 μg/m^3:

$$\text{"Large Concentration"} = \frac{\text{Component Concentration}}{20\ \mu\text{g m}^{-3}} \cdot \text{Component Concentration} \qquad 9.2$$

"Small Concentration" = Component Concentration – "Large Concentration" 9.3

When the component concentration exceeds 20 μg/m^3, all of the component mass concentration is assumed to be in the "large" size distribution. Humidification factors (e.g., f_S(RH) and f_L(RH)) are applied for a specific size mode. Units of b_{ext} and Rayleigh scattering are in inverse megameters (Mm^{-1}).

Most component mass concentrations were computed consistent with the previous IMPROVE report (Debell, 2006) but differed for some components in this report (e.g., ammonium sulfate was computed from elemental sulfur concentrations rather than sulfate ion concentrations; see Table 2.1 in Chapter 2). Mass concentrations of aerosol species have units of μg m^{-3}, and mass scattering and absorption efficiencies have units of m^2 g^{-1}. Values of mass scattering efficiencies correspond to the small and large size modes (e.g., 2.2 m^2 g^{-1} and 4.8 m^2 g^{-1}, respectively, for ammonium sulfate). Recall that in other chapters of this report, b_{ext} was computed using a modified RHR1 IMPROVE equation (see equation 3.4 in Chapter 3) that differs from the RHR2.

Deciview values (dv) were calculated from daily b_{ext} values, using equation 9.4:

$$dv = 10\ln(b_{ext}/10) \qquad 9.4$$

The RHR guidance requires a given site to have at least 3 "complete" years of data out of each 5-year period. Some patching of missing aerosol concentration data under certain specific conditions is allowed. The data presented in this chapter have been processed with a patching algorithm described in the EPA Tracking Progress guidance document (U.S. EPA, 2003a). For the 2000–2009 period at IMPROVE RHTSs, 116,168 valid observations were collected. Of those, 1,464 (~1%) were patched for coarse mass, 421 for ammonium nitrate, 17 for organic carbon and light absorbing carbon, and 6 for fine soil.

Eighteen RHTSs did not meet the completeness criteria for the 2000–2004 baseline period. For these 18 sites, substitutions were performed for missing data by inserting data from a nearby donor site, using a regression analysis technique (Archuleta, et. al., 2007). Seventeen sites with substituted data are presented in this chapter (i.e., BALD1, BOWA1, CAPI1, CHAS1, COHU1, GLAC1, KAIS1, MING1, NOCA1, RAFA1, SAMA1, SEQU1, SHRO1, SWAN1, THRO1, TONT1, and TRIN1). BRET1 is the eighteenth substituted site, and it is not presented because there were insufficient data from 2005 through 2009.

For 2005–2009, three of the 110 IMPROVE RHTSs did not have enough data to be considered in this chapter (Zion National Park (NP), Utah, ZION1; Sierra Ancha Wilderness Area (WA), Arizona, SIAN1; and Breton WA, Louisiana, BRET1). Data for SIAN1 will be substituted for the 2005–2009 period, but the analysis was not completed in time to be included in this chapter. Zion NP was represented by two monitors: ZION1 from 2000 through 2004 and ZICA1 from 2003 through 2009. Evaluating changes across these two sites was beyond the scope of this chapter. Some of the 2009 data have not been fully quality-assured, and minor changes to the concentration values could be made in 2011. While any changes are likely to have little effect on the 2005–2009 haze metrics, the reported values this chapter are not considered final regulatory values but are used for evaluation purposes.

9.3 ASSESSMENT OF CHANGE IN REGIONAL HAZE FROM THE BASELINE (2000–2004) TO PERIOD 1 (2005–2009)

For each RHTS with adequate data (i.e., 107 of the 110), the worst and best haze metrics for the baseline and first 5-year trend period (i.e., period 1), as well as the estimated 2064 natural haze level values, have been determined. These values are displayed in figures and tables in Appendix G. The figures showing the worst haze conditions include the site-specific URP trend lines to facilitate comparisons between the period 1 value and the progress goal for 2009. The tables include these values as well as the individual annual best and worst 20% mean visibility metric values. To gain further insights into the changes between the baseline and period 1, the baseline, period 1, and 2064 natural levels for the major aerosol component's contributions to b_{ext} were also determined and displayed in the tables and figures of Appendix G.

Examples and additional descriptions of the site-specific information from Appendix G are contained in section 9.4 (e.g., Figures 9.4.1 and 9.4.2). The remainder of this section is a national-scale overview description of the results, using maps that show patterns of RHR metrics and the b_{ext} components changes between the baseline and period 1 for some of the components. A complete set of maps is also available towards the end of Appendix G. Note that the natural levels used here were developed to be consistent with the revised IMPROVE algorithm (Copeland et al., 2008) and differ slightly from the natural background as described in the EPA guidance document (2003b).

The change in the 20% worst haze days RHR metric can be examined two ways: as absolute change and as the percent of change compared to the URP goal for each site (i.e., the difference between period 1 and baseline divided by the dv change required to attain the URP for each site). Color dot maps depicting the fractional and absolute worst haze RHR metric changes are shown in Figures 9.3.1 and 9.3.2, respectively. Figure 9.3.3 is a color dot map display of the absolute difference between baseline and period 1 for the 20% best haze RHR conditions.

Broad improvement in the worst 20% visibility levels is apparent across the eastern United States into the Ozark region (see Figure 9.3.1). Increased haze was observed in the Great Lakes region CIAs (Voyageurs NP, VOYA2; Boundary Waters Canoe Area WA, BOWA1; Isle Royale NP, ISLE1; and Seney WA, SENE1). The western United States is characterized by regional improvements in haze especially in the middle and southern Rocky Mountains, Pacific Northwest, and southern California. Western RHTS sites that experienced large changes in dv on the worst 20% visibility days are often influenced by wildfire impacts. Absolute changes in dv from the baseline to period 1 on the 20% worst visibility days are shown in Figure 9.3.2. The spatial patterns in absolute change in dv are similar to those shown in Figure 9.3.1.

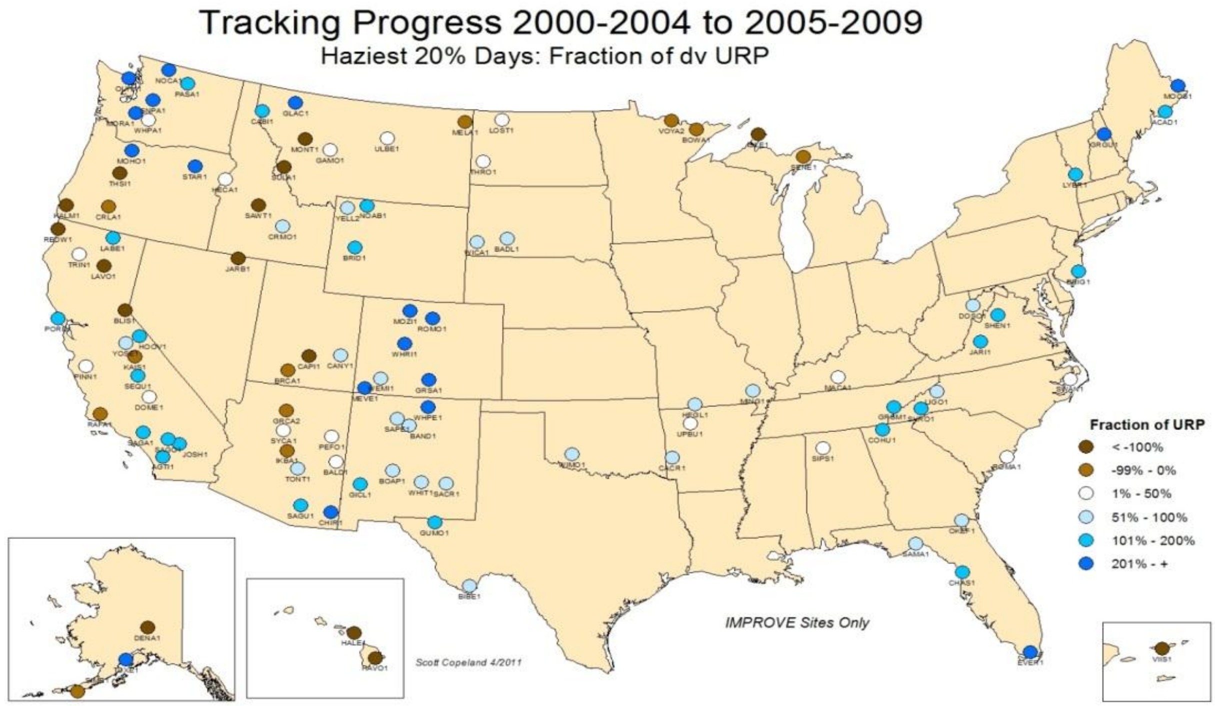


Figure 9.3.1. Fraction of dv uniform rate of progress (URP) from the baseline (2000–2004) to period 1 (2005–2009) for the 20% worst visibility days at 107 of the 110 IMPROVE regional haze tracking sites. Brown circles indicate degradation in the worst 20% visibility days, while blue circles represent improvement in worst 20% visibility days. The two darkest shades of blue indicate progress that is at or better than the 2009 point value on the slope of the nominal URP line.

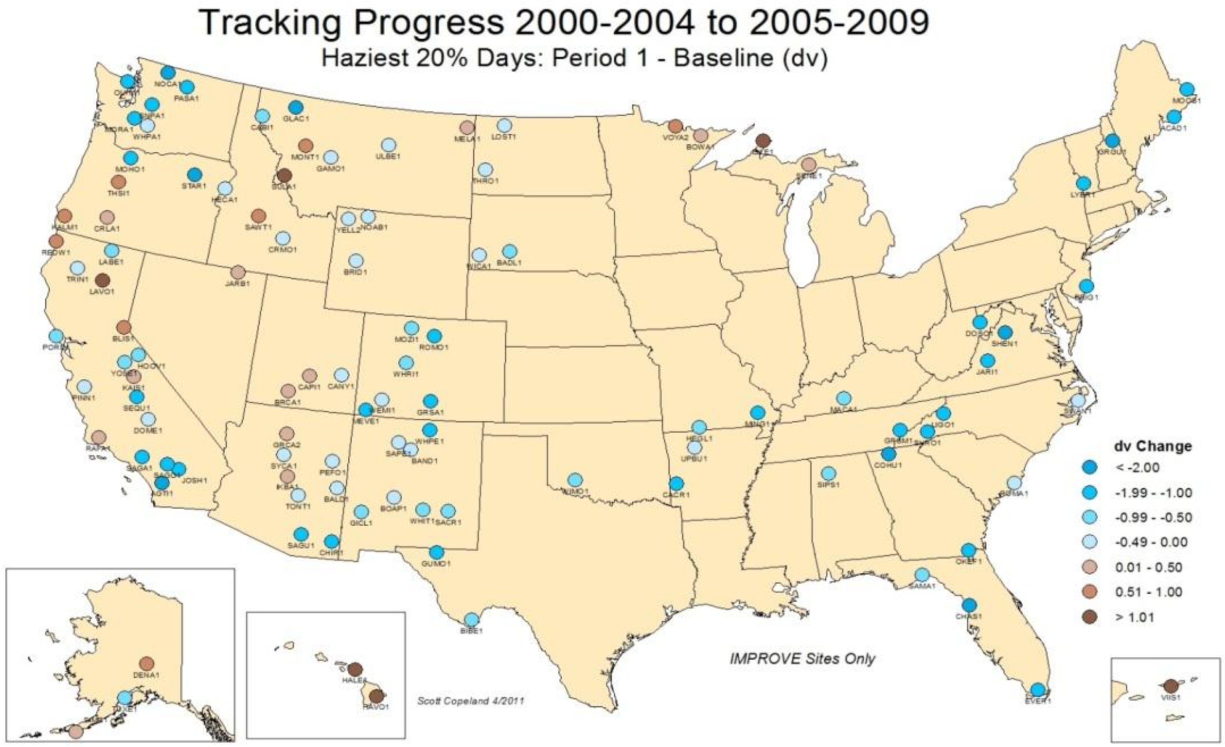


Figure 9.3.2. Absolute change in dv from the baseline (2000–2004) to period 1 (2005–2009) for the 20% worst visibility days at 107 of the 110 IMPROVE regional haze tracking sites. Brown circles indicate degradation in the worst 20% visibility days, while blue circles represent improvement in worst 20% visibility days.

Similarly, Figure 9.3.3 shows the absolute change in dv values on the 20% best visibility days. The goal for these days at all CIAs is no degradation, which was achieved at a substantial majority of sites across the United States. The site at Swanquarter WA (SWAN1) in North Carolina was the only IMPROVE RHTS to experience an increase of over 1 dv on the 20% best visibility days. The increase was mainly driven by roughly equal increases in b_{ext} from ammonium sulfate and sea salt. Because data were incomplete for 2005 and 2008 at SWAN1, and 2008 was a comparatively low year for b_{ext} due to ammonium sulfate at other eastern sites, the period 1 averages for SWAN1 may be skewed by missing data. When considering the annual mean of dv values, all but 12 of the IMPROVE RHTSs showed at least some improvement (see Figure 9.3.4). While the annual mean dv values were still influenced by wildfires, the influence was much less pronounced than in the values for the 20% worst visibility days.

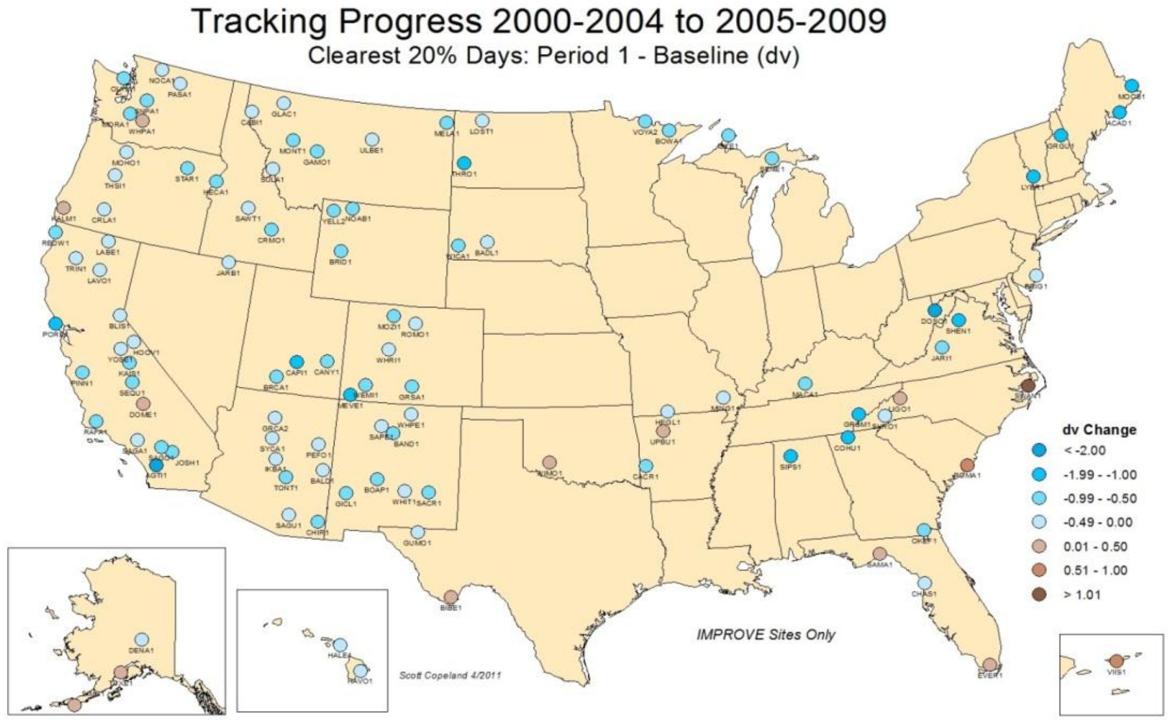


Figure 9.3.3. Absolute change in dv from the baseline (2000–2004) to period 1 (2005–2009) for the 20% best visibility days at 107 of the 110 IMPROVE regional haze tracking sites. Brown circles indicate degradation in the best 20% visibility days, while blue circles represent improvement in best 20% visibility days.

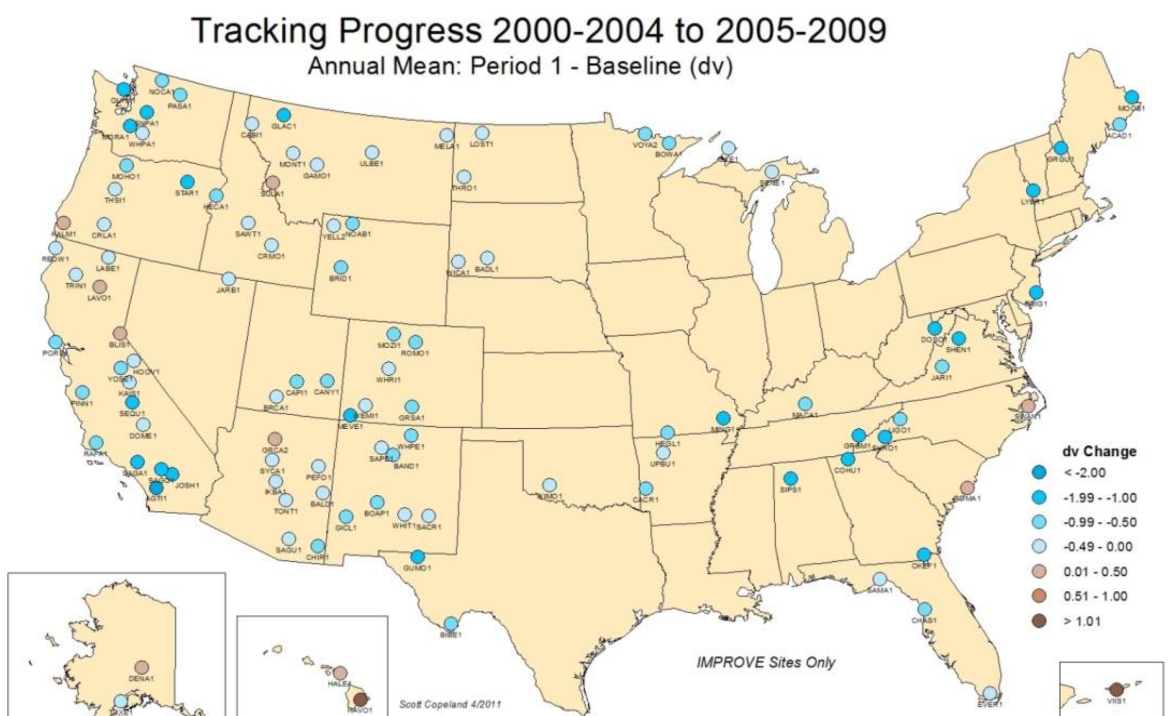


Figure 9.3.4. Absolute change in annual mean dv from the baseline (2000–2004) to period 1 (2005–2009) at 107 of the 110 IMPROVE regional haze tracking sites. Brown circles indicate degradation in annual mean dv, while blue circles represent improvement in annual mean dv.

While there are no official URP values specified in the RHR for any of the major b_{ext} components, hypothetical URP values for 2009 were generated for each site by reducing each component of b_{ext} by the same fraction that would be required in total extinction to evaluate progress toward the conceptual URP in dv. Color dot maps of the fractional change from the hypothetical URP for ammonium sulfate and ammonium nitrate are shown in Figures 9.3.5 and 9.3.6, respectively. In these maps, an asterisk in the place of a site location denotes a site with baseline 20% worst visibility days' b_{ext} below the estimated natural b_{ext} component level. This does not mean that the current conditions at that IMPROVE site are cleaner than natural conditions for any species. It is an artifact caused by selection of sample days for the period 1 worst 20% visibility that have a very different relative composition compared to the worst days in the baseline period. In theory, as anthropogenic contributions decrease over time, the measured values will converge with the estimated natural values. Note there is no figure for the sea salt fraction of URP since sea salt is assumed to be 100% natural; hence, there is no progress to be made. The sea salt concentrations used in equation 9.1 are computed as 1.8 times the chloride ion (see Chapter 2.1.5). Issues related to chloride measurements include possible losses of chloride from aged sea salt aerosols, as well as artifacts due to changing blank corrections (White, 2008). Because of these issues, we do not include sea salt mass concentration trend analyses in Chapter 6; however, we do include trends in b_{ext} due to sea salt in section 9.4 and Appendix G, but any implied sea salt trends should be viewed with caution.

The fraction of hypothetical URP for ammonium sulfate is shown in Figure 9.3.5. Many sites in the Appalachian region, New England, and Florida showed improvements in b_{ext} from ammonium sulfate (b_{ext_AS}). The Great Lakes regional CIAs and many of the sites in the western United States showed significant degradation of b_{ext_AS} with respect to the hypothetical URP. For some of these sites, the b_{ext_AS} for the 20% worst haze days are lower in period 1 than during the baseline period, though not as low as the hypothetical URP. For other of these sites, the values are higher in period 1 than during the baseline period. Trends in the worst 20% haze day RHR metric for a component are not necessarily well correlated to the particle component trends for the 90th percentile as described in Chapter 6. In Chapter 6 the trends for the various percentiles of the components were selected based on the distribution of those component concentrations, while for the 20% worst RHR metric the selection is based on the distribution of visibility conditions. In the eastern United States, where b_{ext_AS} and haze conditions are well correlated, the RHR assessment is generally consistent with the 90th percentile trends analysis. However, in the western United States, any of a number of particulate components may be responsible for the worst haze days (e.g., organic material from wildfire, wind-blown dust, etc.) and the relative numbers of these in any year can vary considerably, resulting in counterintuitive results (e.g., b_{ext_AS} reduced overall and at the 90th percentile but not on RHR worst haze days).

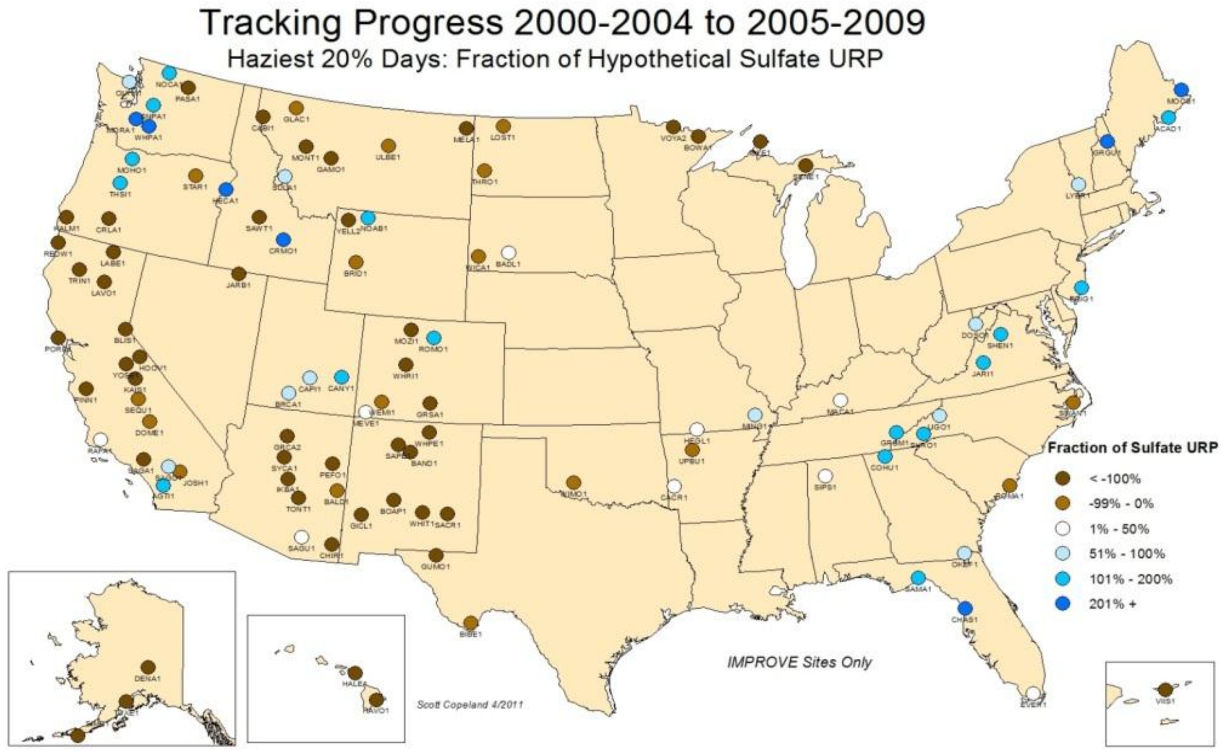


Figure 9.3.5. Fraction of hypothetical ammonium sulfate uniform rate of progress (URP) for the 20% worst visibility days at 107 of the 110 IMPROVE regional haze tracking sites from the baseline (2000–2004) to period 1 (2005–2009). Brown circles indicate degradation in the worst 20% visibility days due to ammonium sulfate extinction, while blue circles represent improvement in worst 20% visibility days due to ammonium sulfate extinction. Only the two darkest blue colored circles indicate progress that is at or better than the hypothetical ammonium sulfate extinction 2009 point value on the slope of the nominal URP line.

Figure 9.3.6 shows a general improvement in 20% worst visibility days corresponding to ammonium nitrate (b_{ext_AN}). Exceptions include three of the Great Lakes region CIAs and the southern Appalachian sites. It can be difficult to discern whether a change in 20% worst visibility days was indicative of decreased emissions or merely an artifact of a shift to the other aerosol components. Therefore it was especially useful to determine overall changes in b_{ext_AS} and b_{ext_AN} by considering the changes in the 5-year annual mean values of b_{ext} from baseline to period 1. Annual mean b_{ext_AN} decreased at all but four of the RHTSs (see Figure 9.3.7), suggesting that the increases in worst 20% visibility days from ammonium nitrate seen in Figure 9.3.6 are likely to have resulted from changes to the distribution of other species' contributions to b_{ext}, not an increase in b_{ext_AN} overall. This change in distribution of worst 20% visibility days will be further illustrated in section 9.4. A similar map for b_{ext_AS} is shown in Figure 9.3.8. Several sites in the western United States corresponded to an increase in b_{ext_AS}, while most sites in the eastern United States were associated with decreases in b_{ext_AS}.

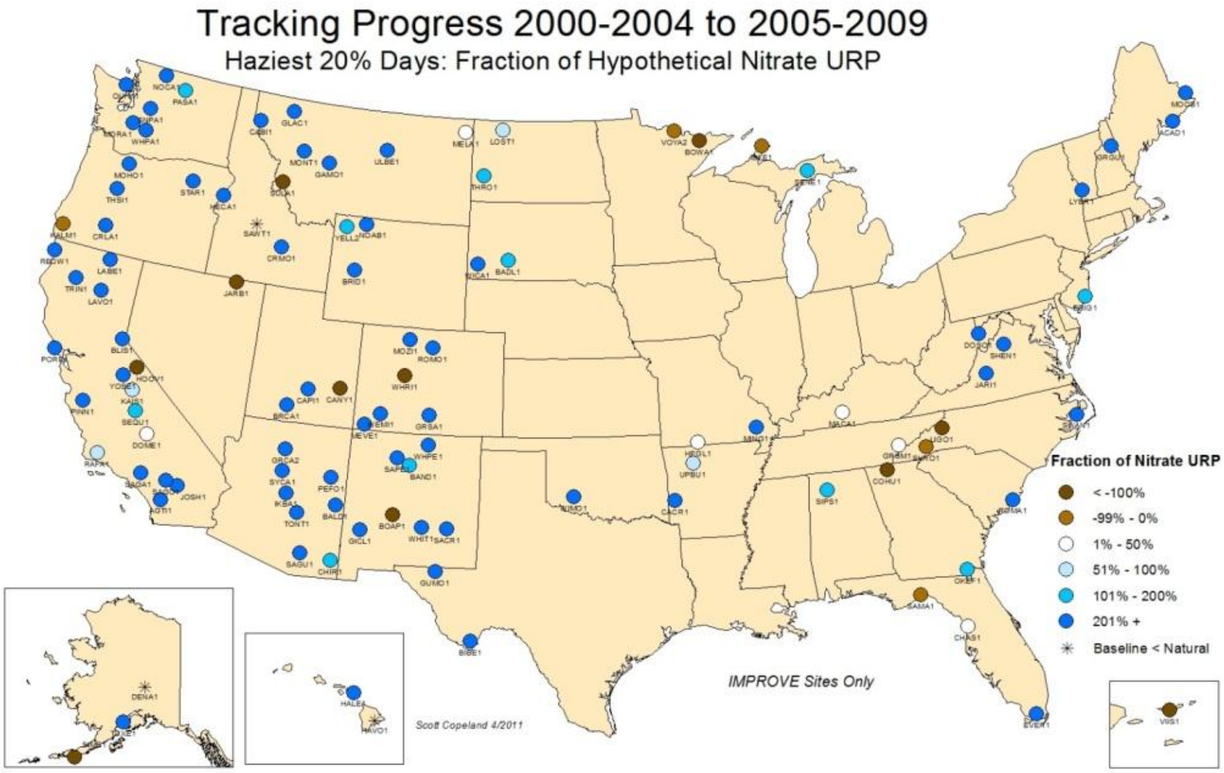


Figure 9.3.6. Fraction of hypothetical ammonium nitrate uniform rate of progress (URP) for the 20% worst visibility days at 107 of the 110 IMPROVE regional haze tracking sites from the baseline (2000–2004) to period 1 (2005–2009). Brown circles indicate degradation in the worst 20% visibility days due to ammonium nitrate extinction, while blue circles represent improvement in worst 20% visibility days due to ammonium nitrate extinction. Only the two darkest blue colored circles indicate progress that is at or better than the hypothetical ammonium sulfate extinction 2009 point value on the slope of the nominal URP line.

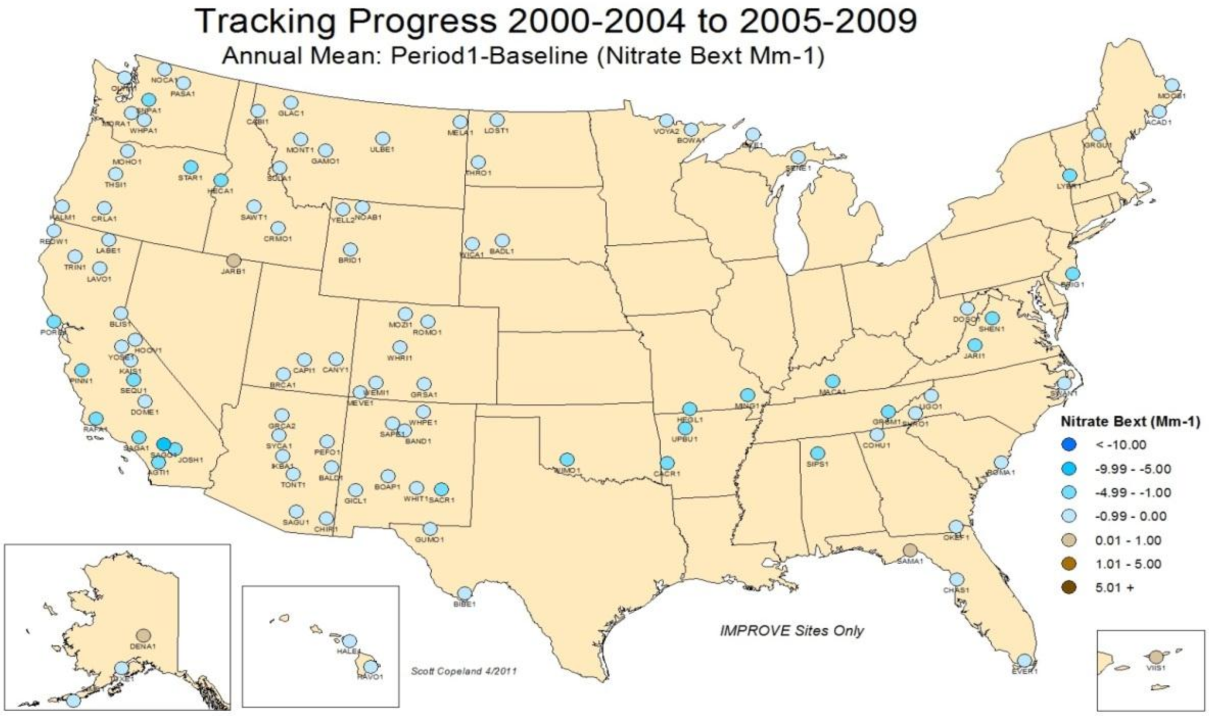


Figure 9.3.7. Change in annual mean ammonium nitrate extinction (b_{ext_AN}, Mm^{-1}) at 107 of the 110 IMPROVE regional haze tracking sites from the baseline (2000-2004) to period 1 (2005-2009). Brown circles indicate an increase of the annual mean b_{ext_AN}, while blue circles represent decreases in annual mean b_{ext_AN}.

Figure 9.3.8. Change in annual mean ammonium sulfate extinction (b_{ext_AS}, Mm^{-1}) at 107 of the 110 IMPROVE regional haze tracking sites from the baseline (2000–2004) to period 1 (2005–2009). Brown circles indicate an increase of the annual mean b_{ext_AS}, while blue circles represent decreases in annual mean b_{ext_AS}.

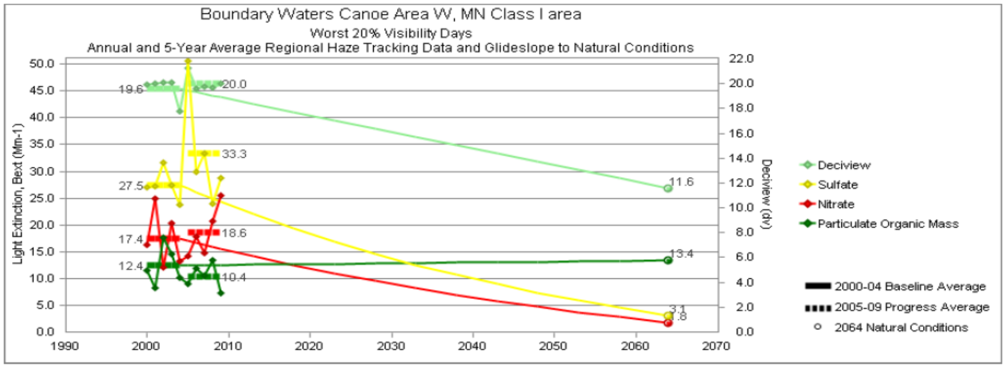
Additional maps summarizing changes in annual mean, 20% best b_{ext}, and 20% worst b_{ext} for ammonium sulfate, ammonium nitrate, particulate organic matter, light absorbing carbon (or EC), soil, and coarse mass are provided toward the end of Appendix G. In addition, figures for the fractional URP for the 20% worst visibility days for other species are also provided in Appendix G.

9.4 CASE STUDIES OF REGIONAL HAZE RULE PROGRESS

The maps presented in section 9.3 summarized the progress toward achieving the national visibility goal for CIAs at each IMPROVE RHTS across the United States. This section provides a first look at five specific RHTSs that are representative of their regional visibility conditions. For each of the five case studies, the contribution from individual species to the 20% worst and best visibility days for the baseline and period 1 are displayed, as well as daily data for selected years. We include the nominal 2064 default natural conditions visibility targets and in some cases illustrate the projected improvement in visibility by species from the 2018 control strategies included in regional analyses. These five case studies offer a framework for review and assessment of the detailed results for 107 of the 110 RHTSs provided in Appendix G, where the baseline and period 1 averages and the natural conditions targets for tracking progress under the RHR are presented. Detailed composition data for every site can be found on the VIEWS website (http://views.cira.colostate.edu/web/Composition/). More detailed assessments for every RHTS are needed in order to understand whether the emissions control programs cited in the RHR SIPs are yielding the projected changes in visibility conditions, but such analysis are well beyond the scope of this report.

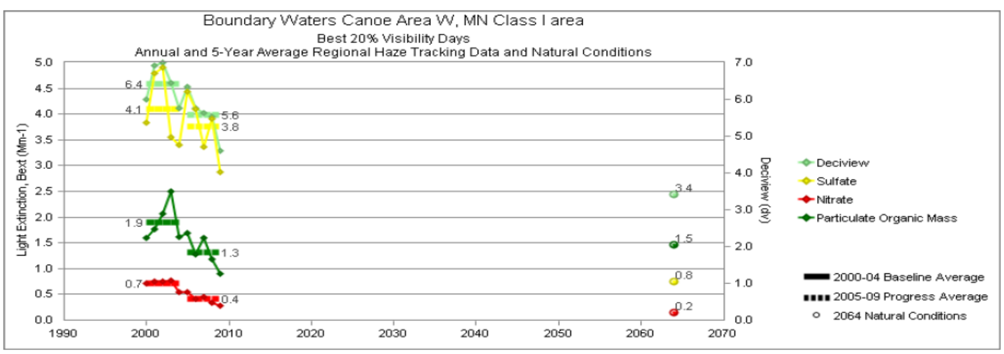
9.4.1 Boundary Waters Canoe Area Wilderness, Minnesota

The Boundary Waters Canoe Area Wilderness (BOWA1) is located on the United States-Canadian border in northern Minnesota. Data from BOWA1 were largely consistent with the other three nearby CIAs (Voyageurs NP, VOYA2; Isle Royale NP, ISLE1; and Seney WA, SENE1). The RHR metric on the worst 20% days increased from 19.6 dv to 20.1 dv between the baseline and period 1. This was principally due to an increase in light extinction by ammonium sulfate (b_{ext_AS}) of about 6 Mm^{-1} (22%) (Figure 9.4.1.1a). There do not seem to be any wildfire influences in this trend, as particulate organic matter (POM, also referred to as OMC) and light absorbing carbon (LAC, also referred to as EC) contributions remained relatively constant (see bottom panel of Figure 9.4.1.1a). Light extinction due to ammonium nitrate (b_{ext_AN}) also increased slightly from the baseline to period 1 for the worst 20% visibility days. In contrast to the worst days, the best 20% b_{ext_AS} and b_{ext_AN} decreased at BOWA1 from the baseline to period 1 (see Figure 9.4.1.1b). Figures 9.4.1.2a and 9.4.1.2b show the daily derived b_{ext} for each aerosol component from 2001 and 2005, respectively. Note the different vertical axis scales. A number of high summer b_{ext_AS} episodes in 2005 could explain the bulk of the increase in the 5-year average worst 20% b_{ext_AS}. The b_{ext} data from 2006 through 2009 were similar to the b_{ext} during the baseline period at BOWA1, ISLE1, and VOYA2. SENE1 also experienced very high b_{ext_AS} episodes in 2007; the cause is unknown. Levels of b_{ext_AS} were relatively high in 2005 across the eastern United States.



Parameter	2000-2004	2005-2009	2064 NC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Boundary Waters - Worst 20% Visibility Days – 5-Year Average, Natural Conditions and Annual Data													
Deciview (dv)	19.6	20.1	11.6	19.9	20.0	20.1	20.1	17.8	21.3	19.6	19.8	19.7	20.0
Sulfate Bext	27.4	33.3	3.1	27.0	27.3	31.7	27.4	23.8	50.4	30.0	33.4	24.1	28.7
Nitrate Bext	17.4	18.6	1.8	16.4	25.0	12.1	20.3	13.3	14.3	17.8	14.8	20.6	25.5
POM Bext	12.4	10.4	13.4	11.5	8.3	17.6	14.6	10.1	8.9	11.9	10.4	13.4	7.4
EC Bext	3.1	2.9	0.4	4.4	3.0	3.3	2.6	2.2	3.5	3.2	3.0	2.7	2.3
Soil Bext	0.5	0.5	0.6	0.8	0.4	0.6	0.4	0.4	0.5	0.4	0.6	0.5	0.5
Coarse Mass Bext	2.6	2.1	3.1	3.7	2.1	2.5	2.2	2.2	2.5	1.9	1.5	1.7	2.8
Sea Salt Bext	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.6	0.1

Figure 9.4.1.1a. Deciview and light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate, ammonium nitrate, and particulate organic mass (POM) for the baseline (2000–2004), period 1 (2005–2009), and 2064 natural conditions estimates for the worst 20% visibility days at Boundary Waters Canoe Area Wilderness, MN. Values of b_{ext} for other species, including elemental carbon (EC), soil, coarse mass and sea salt are listed in the table below the graph (data and graphs obtained at http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).



Parameter	2000-2004	2005-2009	2064 NC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Boundary Waters - Best 20% Visibility Days – 5-Year Average, Natural Conditions and Annual Data													
Deciview (dv)	6.4	5.6	3.4	6.0	6.9	7.0	6.5	5.8	6.3	5.7	5.6	5.5	4.6
Sulfate Bext	4.1	3.8	0.7	3.8	4.8	4.9	3.6	3.4	4.6	4.1	3.4	3.9	2.9
Nitrate Bext	0.7	0.4	0.2	0.7	0.8	0.7	0.8	0.5	0.6	0.4	0.4	0.3	0.3
POM Bext	1.9	1.3	1.5	1.6	1.8	2.1	2.5	1.6	1.6	1.3	1.6	1.2	0.9
EC Bext	0.6	0.4	0.1	0.6	0.4	0.7	0.7	0.4	0.4	0.5	0.4	0.3	0.3
Soil Bext	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Coarse Mass Bext	0.7	0.5	0.5	0.5	0.7	0.6	0.8	0.7	0.5	0.5	0.5	0.6	0.5
Sea Salt Bext	0.2	0.1	0.1	0.0	0.6	0.0	0.0	0.1	0.1	0.1	0.3	0.1	0.1

Figure 9.4.1.1b. Deciview and light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate, ammonium nitrate, and particulate organic mass (POM) for the baseline (2000–2004), period 1 (2005–2009), and 2064 natural conditions estimates for the best 20% visibility days at Boundary Waters Canoe Area Wilderness, MN. Values of b_{ext} for other species, including elemental carbon (EC), soil, coarse mass and sea salt are listed in the table below the graph (data and graphs obtained at http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

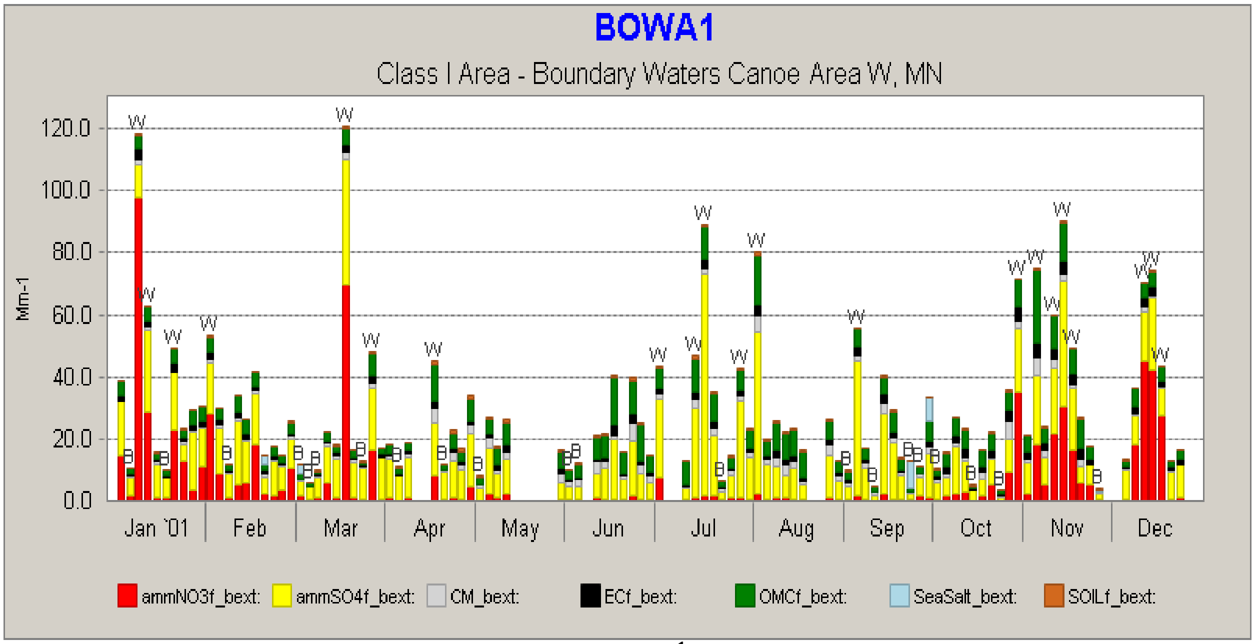


Figure 9.4.1.2a. Daily light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate (ammSO4f_bext), ammonium nitrate (ammNO3f_bext), particulate organic matter (OMCf_bext), coarse mass (CM_bext), elemental carbon (EC_bext), soil (soil_bext) and sea salt (seasalt_bext) for 2001 Boundary Waters Canoe Area (BOWA1). Worst 20% days are marked with a "W" above the bar for that day, and similarly, best 20% days are marked with a "B" (from http://views.cira.colostate.edu/web/Composition/).

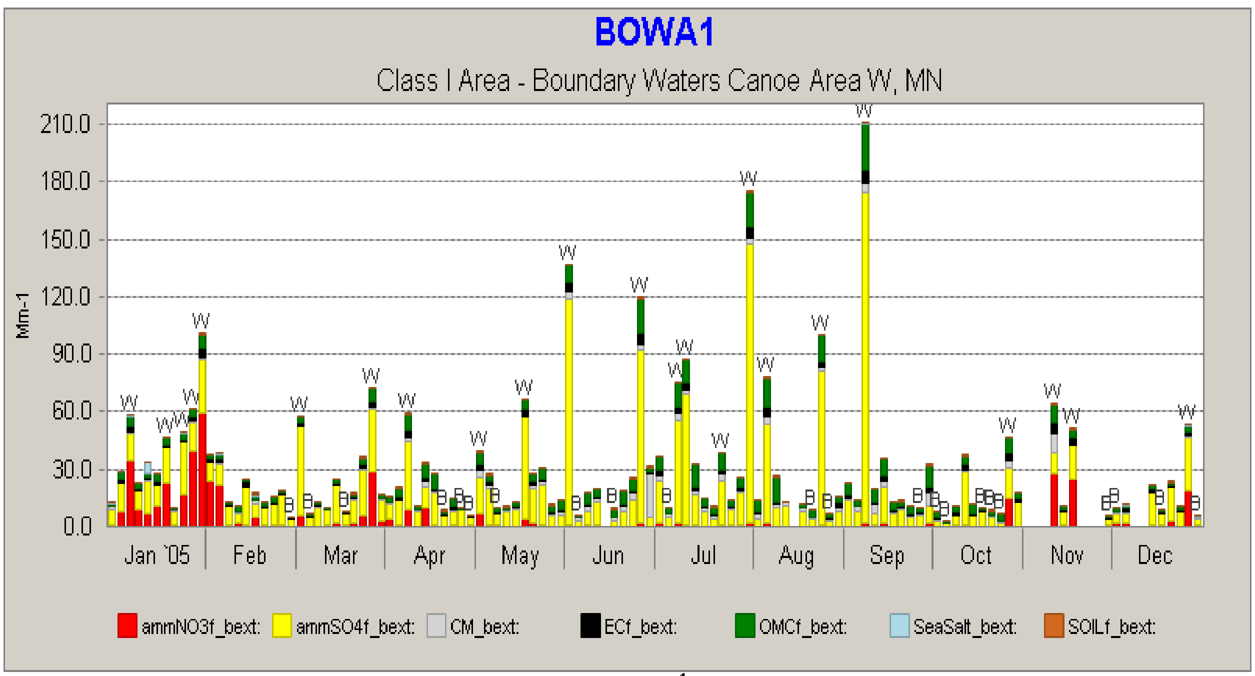
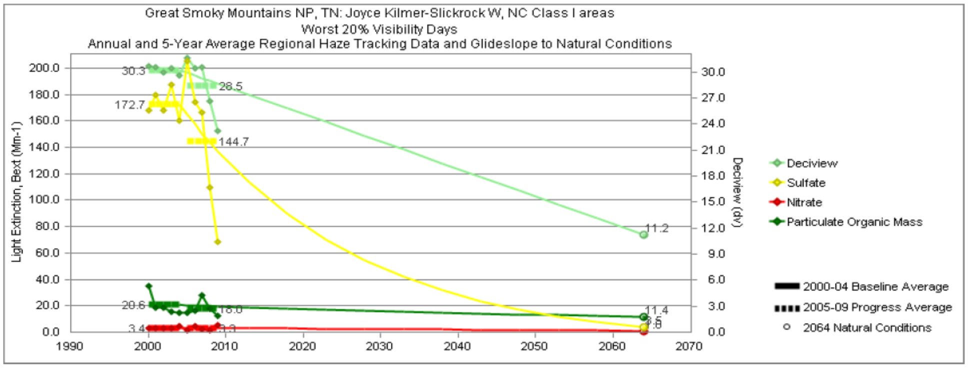


Figure 9.4.1.2b. Daily light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate (ammSO4f_bext), ammonium nitrate (ammNO3f_bext), particulate organic matter (OMCf_bext), coarse mass (CM_bext), elemental carbon (EC_bext), soil (soil_bext) and sea salt (seasalt_bext) for 2005 Boundary Waters Canoe Area (BOWA1). Worst 20% days are marked with a "W" above the bar for that day, and similarly, best 20% days are marked with a "B" (from http://views.cira.colostate.edu/web/Composition/).

9.4.2 Great Smoky Mountains National Park, Tennessee/North Carolina

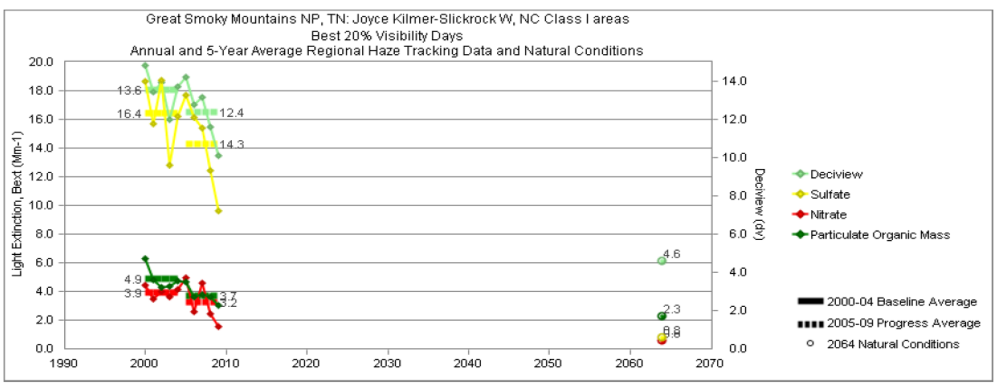
Great Smoky Mountains National Park (GRSM1) straddles the border between Tennessee and North Carolina. Data from GRSM1 were similar to data from other Appalachian region sites and most eastern sites with respect to significant reductions in the worst 20% b_{ext_AS}. Data from period 1 show 5-year-average decreases of roughly 28 Mm^{-1} (16%) in the 20% worst b_{ext_AS} (Figure 9.4.2.1a). Extinction coefficients due to other species (e.g., ammonium nitrate, particulate organic matter, elemental carbon, and soil) also decreased or remained steady in period 1, with the exception of coarse mass and sea salt. As with worst days, the best 20% b_{ext_AS} and b_{ext_AN} decreased at GRSM1 (see Figure 9.4.2.1b). Figures 9.4.2.2a and 9.4.2.2b show the daily derived b_{ext} for each aerosol component from 2001 and 2008, respectively. Note the slightly different vertical axis scales. Light extinction coefficients due to ammonium sulfate are generally lower in 2008 compared to 2001. A likely explanation for the decrease in b_{ext_AS} is reduced emissions of sulfur dioxide from coal-fired electric generating units across the United States by 32% from 2000 to 2008 (U.S. EPA, 2011) as a result of emissions controls and the economic slowdown. Specific to GRSM1, emissions reductions under the North Carolina Clean Smokestacks Act (Air Quality/Electric Utilities Bill (SB 1078), which required sulfur dioxide reductions from electric utilities beginning in 2005) and from electric utilities in eastern Tennessee beginning in 2009 may also have contributed to the trends in Figure 9.4.2.1a. Table 9.4.2 is taken from the EPA's proposed partial approval of the Tennessee Regional Haze State Implementation Plan (40 CFR 52 33662) and illustrates the 2018 reasonable progress goals for GRSM and Joyce Kilmer-Slickrock Wilderness are lower (better improvement in visibility) than the 2018 URP. The observed visibility in 2009 (Figure 9.4.2.1a) is lower than the 2018 reasonable progress goal.



Parameter	2000-2004	2005-2009	2064 NC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Deciview (dv)	30.3	28.5	11.2	30.7	30.6	29.9	30.5	29.6	31.6	30.5	30.6	26.7	23.2
Sulfate Bext	172.7	144.7	3.5	167.8	179.9	168.3	187.3	160.3	205.1	174.2	166.3	109.6	68.6
Nitrate Bext	3.4	3.3	1.0	3.5	3.0	2.7	3.2	4.6	1.8	5.0	2.7	1.7	5.4
POM Bext	20.6	18.0	11.4	35.1	18.9	18.8	15.7	14.6	14.5	16.3	28.3	18.1	12.6
EC Bext	5.7	5.1	0.3	8.1	5.0	4.8	5.8	4.7	6.1	5.6	5.9	4.2	3.9
Soil Bext	0.8	0.8	0.9	0.6	0.8	1.0	0.7	1.0	0.6	0.9	0.9	0.9	0.6
Coarse Mass Bext	1.9	3.7	2.9	2.6	2.4	2.0	1.5	1.2	4.9	4.6	4.2	2.6	2.1
Sea Salt Bext	0.2	0.3	0.4	0.0	0.5	0.0	0.0	0.3	0.1	0.3	0.3	0.2	0.3

Great Smoky Mountains - Worst 20% Visibility Days – 5-Year Average, Natural Conditions and Annual Data

Figure 9.4.2.1a. Deciview and light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate, ammonium nitrate, and particulate organic mass (POM) for the baseline (2000–2004), period 1 (2005–2009), and 2064 natural conditions estimates for the worst 20% visibility days at Great Smoky Mountains NP, TN and Joyce Kilmer-Slickrock WA, NC. Values of b_{ext} for other species, including elemental carbon (EC), soil, coarse mass and sea salt are listed in the table below the graph (data and graphs obtained at http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).



Parameter	2000-2004	2005-2009	2064 NC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Deciview (dv)	13.6	12.4	4.6	14.8	13.4	13.9	12.0	13.7	14.3	12.7	13.2	11.6	10.1
Sulfate Bext	16.4	14.3	0.8	18.7	15.7	18.7	12.8	16.2	17.7	16.2	15.4	12.4	9.6
Nitrate Bext	3.9	3.2	0.6	4.5	3.5	4.0	3.6	4.1	5.0	2.6	4.6	2.5	1.6
POM Bext	4.9	3.7	2.3	6.3	4.8	4.3	4.4	4.7	4.6	3.6	3.8	3.6	3.0
EC Bext	2.2	1.8	0.1	3.0	2.0	2.0	2.0	2.1	2.3	2.0	1.8	1.6	1.2
Soil Bext	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2
Coarse Mass Bext	1.3	1.4	0.9	1.5	1.5	1.1	1.0	1.5	1.7	1.2	1.1	1.4	1.5
Sea Salt Bext	0.2	0.2	0.1	0.1	0.3	0.2	0.0	0.4	0.2	0.2	0.3	0.2	0.1

Great Smoky Mountains - Best 20% Visibility Days – 5-Year Average, Natural Conditions and Annual Data

Figure 9.4.2.1b. Deciview and light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate, ammonium nitrate, and particulate organic mass (POM) for the baseline (2000–2004), period 1 (2005–2009), and 2064 natural conditions estimates for the best 20% visibility days at Great Smoky Mountains NP, TN and Joyce Kilmer-Slickrock WA, NC. Values of b_{ext} for other species, including elemental carbon (EC), soil, coarse mass and sea salt are listed in the table below the graph (data and graphs obtained at http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

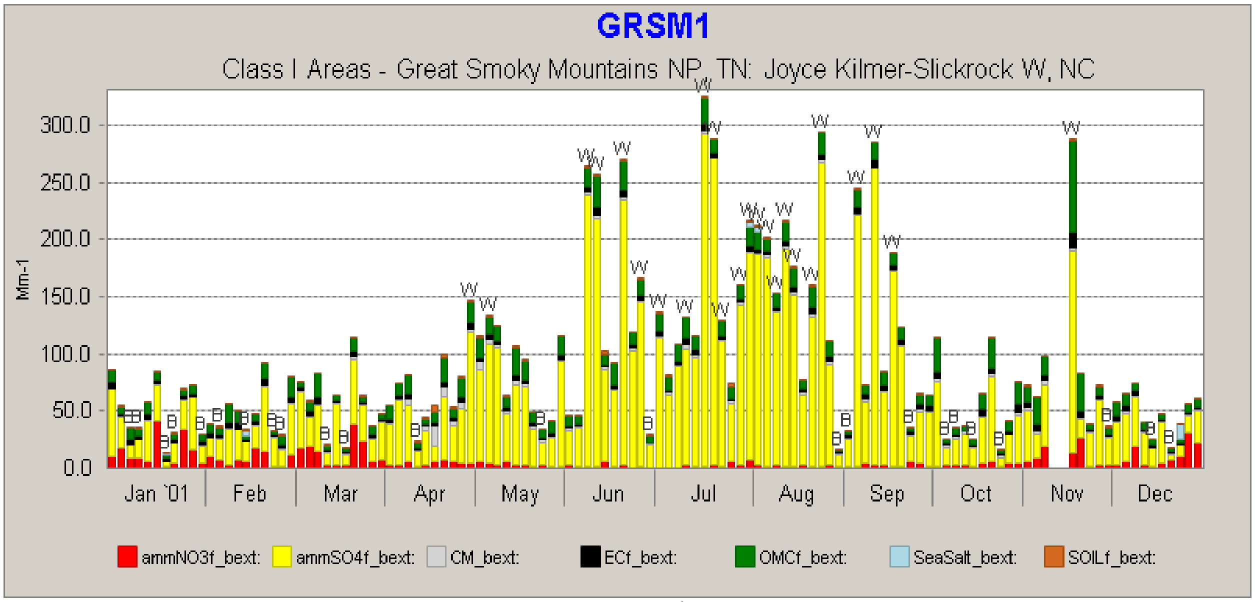


Figure 9.4.2.2a. Daily light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate (ammSO4f_bext), ammonium nitrate (ammNO3f_bext), particulate organic matter (OMCf_bext), coarse mass (CM_bext), elemental carbon (EC_bext), soil (soil_bext) and sea salt (seasalt_bext) for 2001 Great Smoky Mountains NP, TN (GRSM1) and Joyce Kilmer-Slickrock WA, NC. Worst 20% days are marked with a "W" above the bar for that day, and similarly, best 20% days are marked with a "B" (from http://views.cira.colostate.edu/web/Composition/).

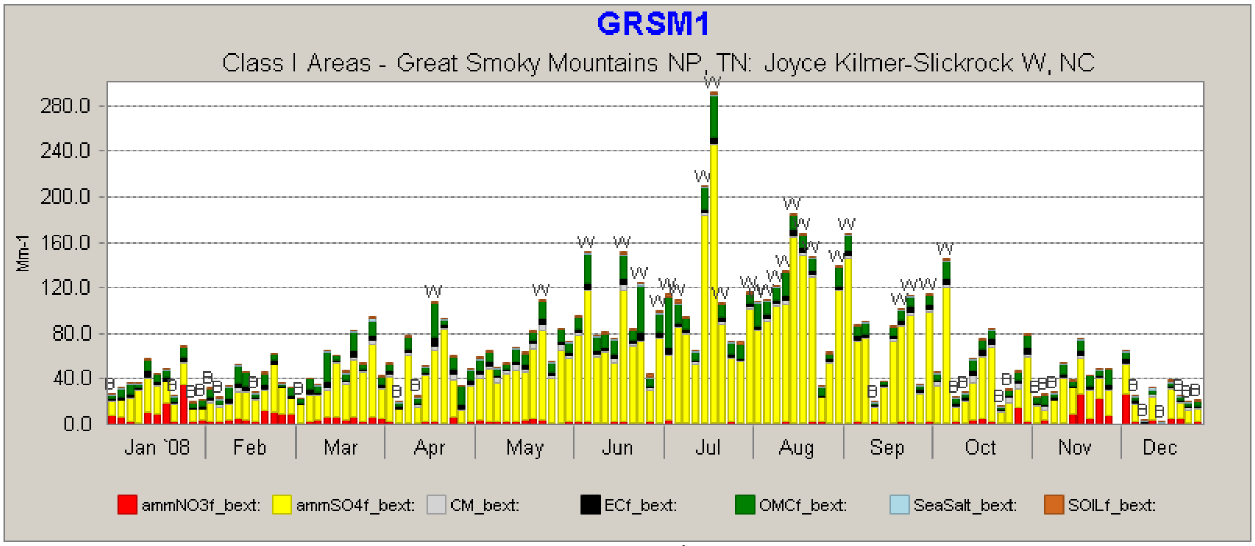


Figure 9.4.2.2b. Daily light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate (ammSO4f_bext), ammonium nitrate (ammNO3f_bext), particulate organic matter (OMCf_bext), coarse mass (CM_bext), elemental carbon (EC_bext), soil (soil_bext) and sea salt (seasalt_bext) for 2008 at Great Smoky Mountains NP, TN (GRSM1) and Joyce Kilmer-Slickrock WA, NC. Worst 20% days are marked with a "W" above the bar for that day, and similarly, best 20% days are marked with a "B" (from http://views.cira.colostate.edu/web/Composition/).

Table 9.4.2. 2018 Reasonable progress goals compared to baseline visibility and uniform rate of progress, from the Tennessee and North Carolina regional haze state implementation plans.

Class I Area	2000-2004 Baseline Visibility - 20% Worst Days (Mm^{-1})	2018 Uniform Rate of Progress - 20% Worst Days(Mm^{-1})	2018 Reasonable Progress Goal – 20% Worst Days (Mm^{-1}) (Improvement)	2018 Baseline Visibility - 20% Best Days (Mm^{-1})	2018 Reasonable Progress Goal - 20% Best Days (Mm^{-1}) (Improvement)
Great Smoky Mountains National Park	30.28	25.79	23.50 (6.78)	13.58	12.11 (1.47)
Joyce Kilmer-Slickrock Wilderness	30.28	25.79	23.50 (6.78)	13.58	12.11 (1.47)

9.4.3 Mesa Verde National Park, Colorado

For this and the next two sections, we provide additional summary data prepared by the Western Regional Air Partnership (WRAP) regional analyses in support of RHR planning in the western United States. These summaries include IMPROVE monitoring data, estimated 2064 natural conditions, the 2018 URP values discussed in 9.2.1, and projected changes in visibility conditions and emissions by 2018. These data were generated using the WRAP technical support system (TSS) (http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

Mesa Verde National Park (MEVE1) is located in the Four Corners area of southwestern Colorado. Light extinction coefficients for ammonium sulfate, ammonium nitrate, and particulate organic matter for the baseline, period 1, and 2064 are shown for the 20% worst and 20% best visibility days in Figures 9.4.3.1a and 9.4.3.1.b, respectively. The data are summarized in Tables 9.4.3.1 and 9.4.3.2 for the 20% worst and 20% best visibility days, respectively. MEVE1 is illustrative of one category of western RHTS sites, with the baseline period corresponding to relatively high fire activity, followed by a comparatively low fire activity in period 1. As a result, MEVE1 exceeded the URP in dv (see Figure 9.3.1), yet most of this change was related to the decreased fire activity. The low fire activity associated with period 1 did not result in an increase in b_{ext_AS} and b_{ext_AN} contributions to the 20% worst visibility days, as might have been anticipated. An increase was expected because the high fire activity during the baseline period suppressed the contributions to b_{ext} from non-fire-related species. This can in part be attributed to relatively little of the expected seasonality in sulfate and nitrate. Daily values of speciated b_{ext} are shown in Figures 9.4.3.2a and 9.4.3.2b for 2004 and 2008, respectively.

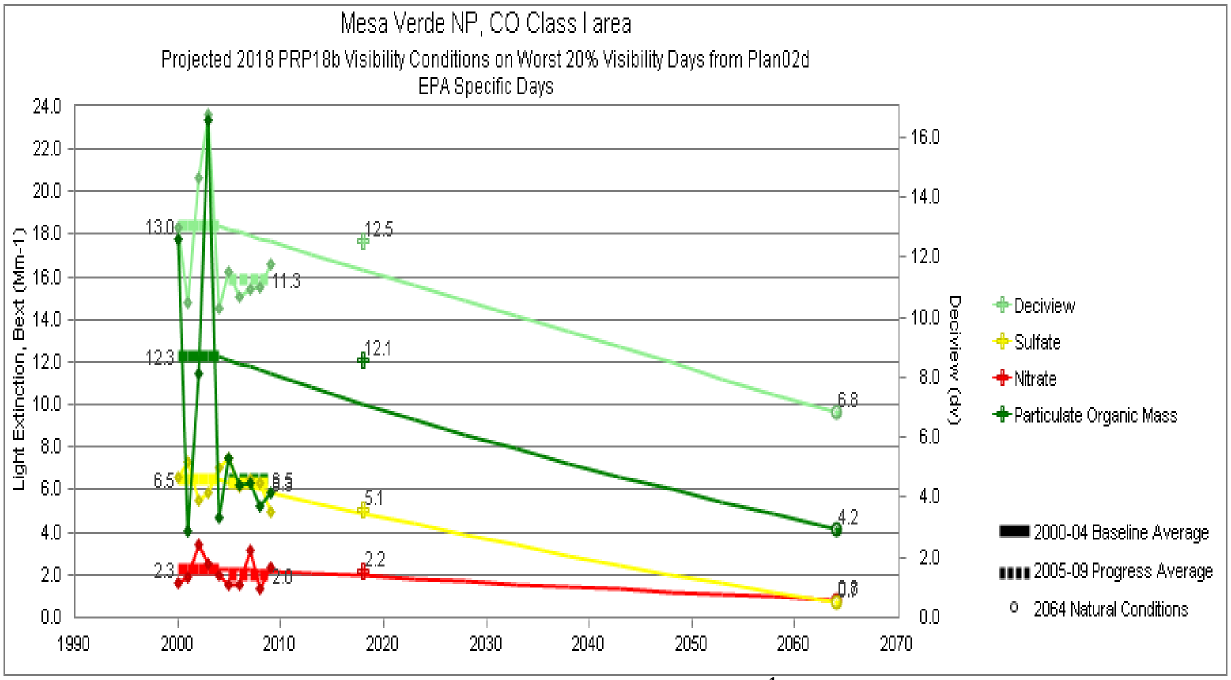


Figure 9.4.3.1a. Deciview and light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate, ammonium nitrate, and particulate organic mass (POM) for the baseline (2000–2004), period 1 (2005–2009), and 2064 natural conditions estimates for the worst 20% visibility days at Mesa Verde NP, CO. Values of b_{ext} for other species, including elemental carbon (EC), soil, coarse mass, and sea salt are listed in the table below the graph (data and graphs obtained at http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

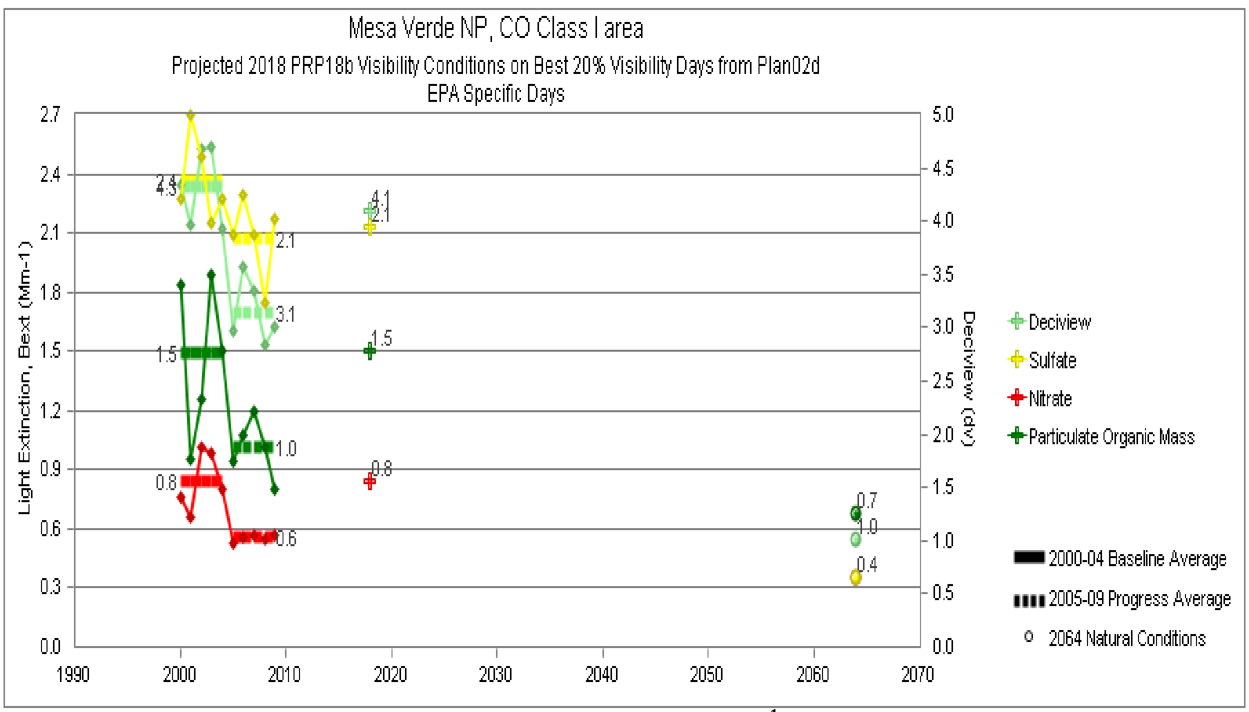


Figure 9.4.3.1b. Deciview and light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate, ammonium nitrate, and particulate organic mass (POM) for the baseline (2000–2004), period 1 (2005–2009), and 2064 natural conditions estimates for the best 20% visibility days at Mesa Verde NP, CO. Values of b_{ext} for other species, including elemental carbon (EC), soil, coarse mass, and sea salt are listed in the table below the graph. (Data and graphs obtained at http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

Table 9.4.3.1. Monitored, estimated, and projected 2018 visibility conditions and emissions changes for the worst 20% visibility days from WRAP regional analyses for Mesa Verde NP, CO (MEVE1) (from http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

Class I Area Visibility Summary: Mesa Verde NP, CO Class I area
Visibility Conditions: Worst 20% Days
Model Relative Response Factor Calculation Method: Specific Days (EPA)
Emissions Scenarios for Projected 2018 Emissions & Visibility Changes: WRAP 2000-04 Baseline (plan02d) & 2018 PRPb (prp18b)

	Monitored		**Estimated**		**Projected**			
	2000-04 Baseline Conditions (Mm-1)	2005-09 1st Progress Period Conditions (Mm-1)	2064 Natural Conditions (Mm-1)	2018 Uniform Rate of Progress Target (Mm-1)[1]	2018 Projected Visibility Conditions (Mm-1)	Baseline to 2018 Change in Statewide Emissions (tons / %)	Baseline to 2018 Change in Upwind Weighted Emissions[2] (%)	Baseline to 2018 Change in Anthropogenic Upwind Weighted Emissions[2] (%)
Sulfate	6.46	6.3	0.73	4.90	5.09	-58,907 -51%	-30%	-30%
Nitrate	2.3	2.0	0.83	1.94	2.18	-123,497 -30%	-27%	-28%
Organic Carbon	12.28	6.5	4.19	10.06	12.13	-439 -1%	0%	-1%
Elemental Carbon	2.37	1.6	0.36	1.87	1.84	-2,833 -23%	-20%	-40%
Fine Soil	2.51	2.0	1.16	2.18	2.76	-1,232 -6%	7%	10%
Coarse Material[3]	6.52	4.6	4.3	5.97	Not Applicable	9,024 9%	7%	12%
Sea Salt[3]	0.04	0.1	0.04	0.04		Not Applicable		
Total Light Extinction	41.48	23.0	20.63	35.29	39.57			
Deciview	13.03	11.3	6.81	11.58	12.5			

Table 9.4.3.2. Monitored, estimated, and projected 2018 visibility conditions and emissions changes for the best 20% visibility days from WRAP regional analyses for Mesa Verde NP, CO (MEVE1) (from http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

Class I Area Visibility Summary: Mesa Verde NP, CO Class I area **Visibility Conditions:** Best 20% Days **Model Relative Response Factor Calculation Method:** Specific Days (EPA) **Emissions Scenarios for Projected 2018 Emissions & Visibility Changes:** WRAP 2000-04 Baseline (plan02d) & 2018 PRPb (prp18b)								
	Monitored		**Estimated**		**Projected**			
	2000-04 Baseline Conditions (Mm-1)	2005-09 1st Progress Period Conditions (Mm-1)	2064 Natural Conditions (Mm-1)	2018 Uniform Rate of Progress Target (Mm-1)[1]	2018 Projected Visibility Conditions (Mm-1)	Baseline to 2018 Change in Statewide Emissions (tons / %)	Baseline to 2018 Change in Upwind Weighted Emissions[2] (%)	Baseline to 2018 Change in Anthropogenic Upwind Weighted Emissions[2] (%)
Sulfate	2.37	2.1	0.36	Not Applicable	2.13	-58,907 -51%	-30%	-30%
Nitrate	0.84	0.9	0.36	Not Applicable	0.84	-123,497 -30%	-30%	-31%
Organic Carbon	1.49	1.5	0.68	Not Applicable	1.5	-439 -1%	-1%	-3%
Elemental Carbon	0.6	0.4	0.11	Not Applicable	0.44	-2,833 -23%	-19%	-41%
Fine Soil	0.4	0.2	0.17	Not Applicable	0.45	-1,232 -6%	8%	11%
Coarse Material[3]	0.74	0.4	0.4	Not Applicable	Not Applicable	9,024 9%	8%	15%
Sea Salt[3]	0.01	0.0	0	Not Applicable		Not Applicable		
Total Light Extinction	15.46	4.8	11.08	Not Applicable	15.13			
Deciview	4.32	3.1	1.01	Not Applicable	4.1			

1) 2018 Uniform Rate of Progress Target for Best 20% Days is not defined.
2) Results based on Weighted Emissions Potential analysis using the 2000-04 Baseline (plan02d) & 2018 PRPb (prp18b) emissions scenarios.
3) Visibility projections not available due to model performance issues.

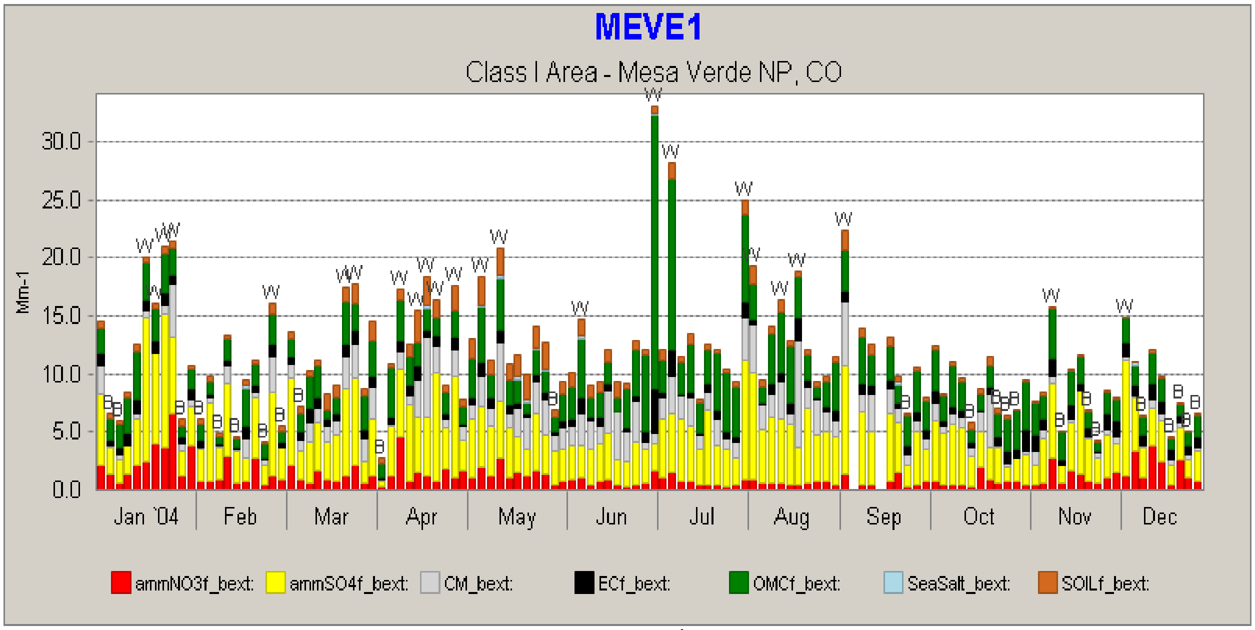


Figure 9.4.3.2a. Daily light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate (ammSO4f_bext), ammonium nitrate (ammNO3f_bext), particulate organic matter (OMCf_bext), coarse mass (CM_bext), elemental carbon (EC_bext), soil (soil_bext), and sea salt (seasalt_bext) for 2004 Mesa Verde NP, CO. Worst 20% days are marked with a "W" above the bar for that day, and similarly, best 20% days are marked with a "B" (from http://views.cira.colostate.edu/web/Composition/).

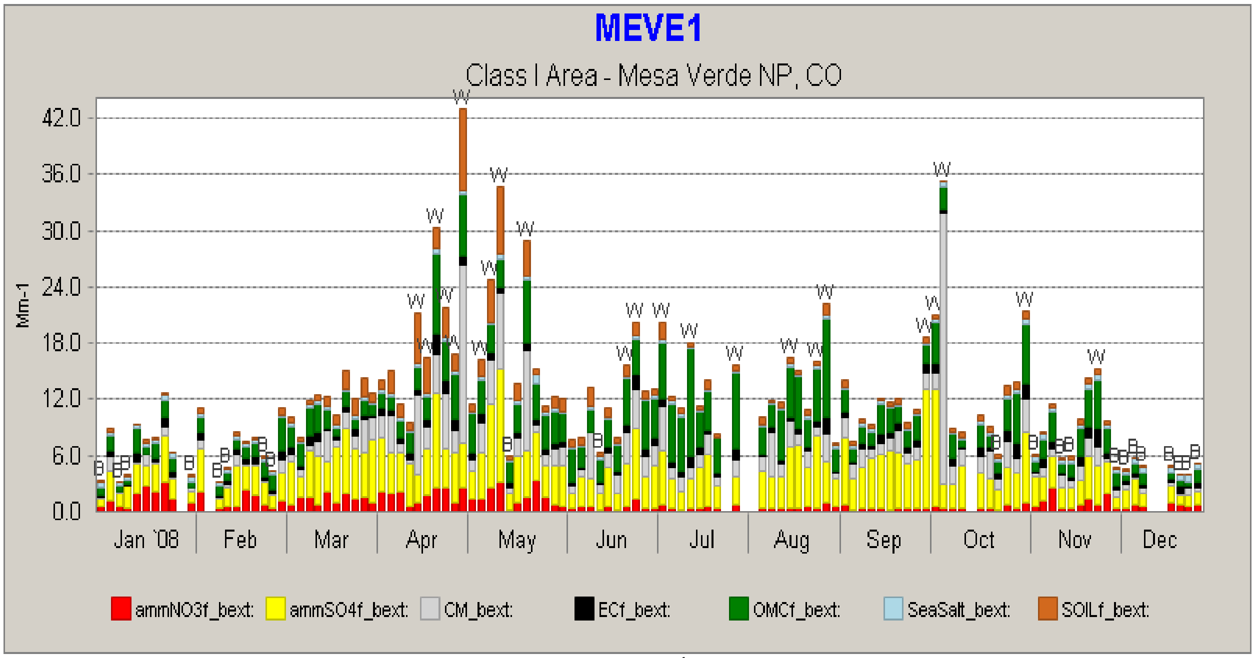


Figure 9.4.3.3b. Daily light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate (ammSO4f_bext), ammonium nitrate (ammNO3f_bext), particulate organic matter (OMCf_bext), coarse mass (CM_bext), elemental carbon (EC_bext), soil (soil_bext), and sea salt (seasalt_bext) for 2008 Mesa Verde NP, CO. Worst 20% days are marked with a "W" above the bar for that day, and similarly, best 20% days are marked with a "B" (from http://views.cira.colostate.edu/web/Composition/).

9.4.4 Hell's Canyon Wilderness, Oregon/Idaho

Hells Canyon Wilderness (HECA1) straddles the Snake River Canyon along Oregon and Idaho. Conditions at HECA1 were opposite to those at MEVE1 in the context of fire activity. Low fire activity occurred during the baseline period, followed by high fire activity in period 1. Values of b_{ext} at HECA1 exhibited the expected behavior, with b_{ext_AS} and b_{ext_AN} decreasing on the worst 20% visibility days during high fire activity (see Figures 9.4.4.1a and 9.4.4.1b for the 20% worst and 20% best visibility days, respectively). Light extinction due to ammonium sulfate is less important to total b_{ext} at Hells Canyon than at some of the other sites. The seasonality of the worst 20% visibility days in winter/summer/fall in 2004 (Figure 9.4.4.2a) changed to mostly summer in 2006 (Figure 9.4.4.2b). HECA1 also experienced a decrease in annual mean b_{ext_AN}, which can be seen by comparing the first quarter of 2006 to the first quarter of 2004. This reduction in b_{ext_AN}, coupled with a reduction in b_{ext_AS}, actually more than offset the increased fire-related b_{ext} on the 20% worst days, resulting in a net 0.5 dv improvement. This improvement was slightly less than the URP for dv but presumably without the increased fire activity would have been much greater than URP. The reason for the significant reductions in first quarter b_{ext_AN} is unknown. The data for the 20% worst and 20% best visibility days are summarized in Tables 9.4.4.1 and 9.4.4.2, respectively.

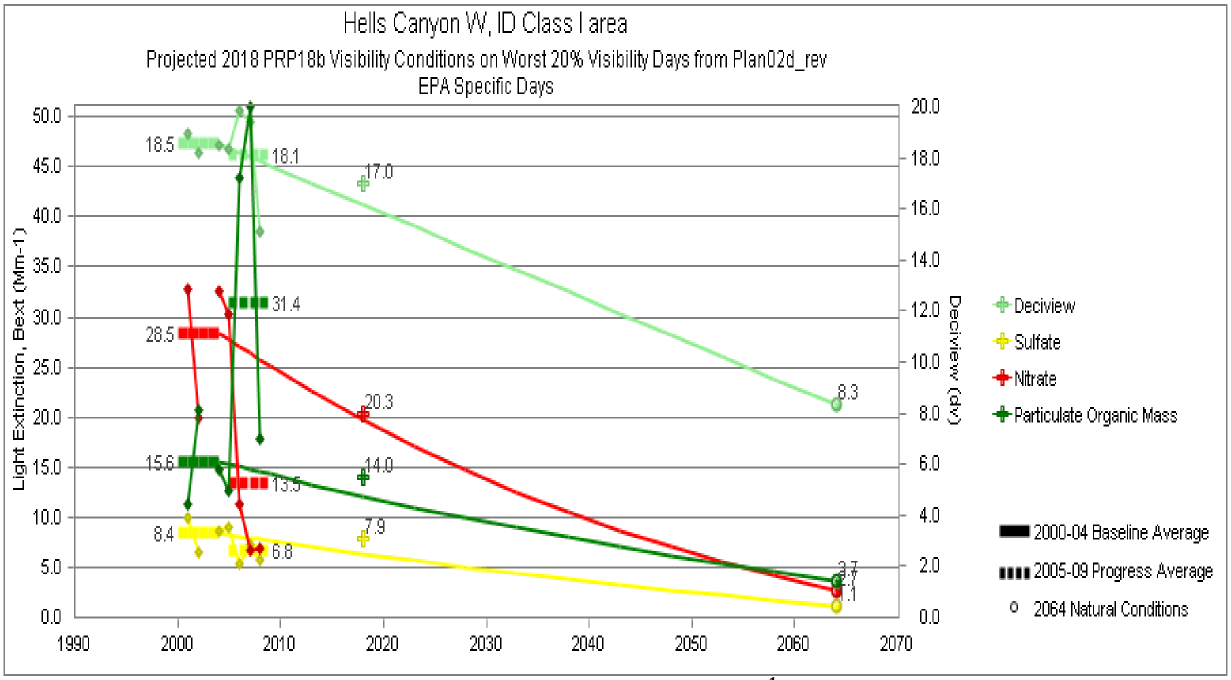


Figure 9.4.4.1a. Deciview and light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate, ammonium nitrate, and particulate organic mass (POM) for the baseline (2000–2004), period 1 (2005–2009), and 2064 natural conditions estimates for the worst 20% visibility days at Hell's Canyon WA, OR/ID. Values of b_{ext} for other species, including elemental carbon (EC), soil, coarse mass, and sea salt are listed in the table below the graph (data and graphs obtained at http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

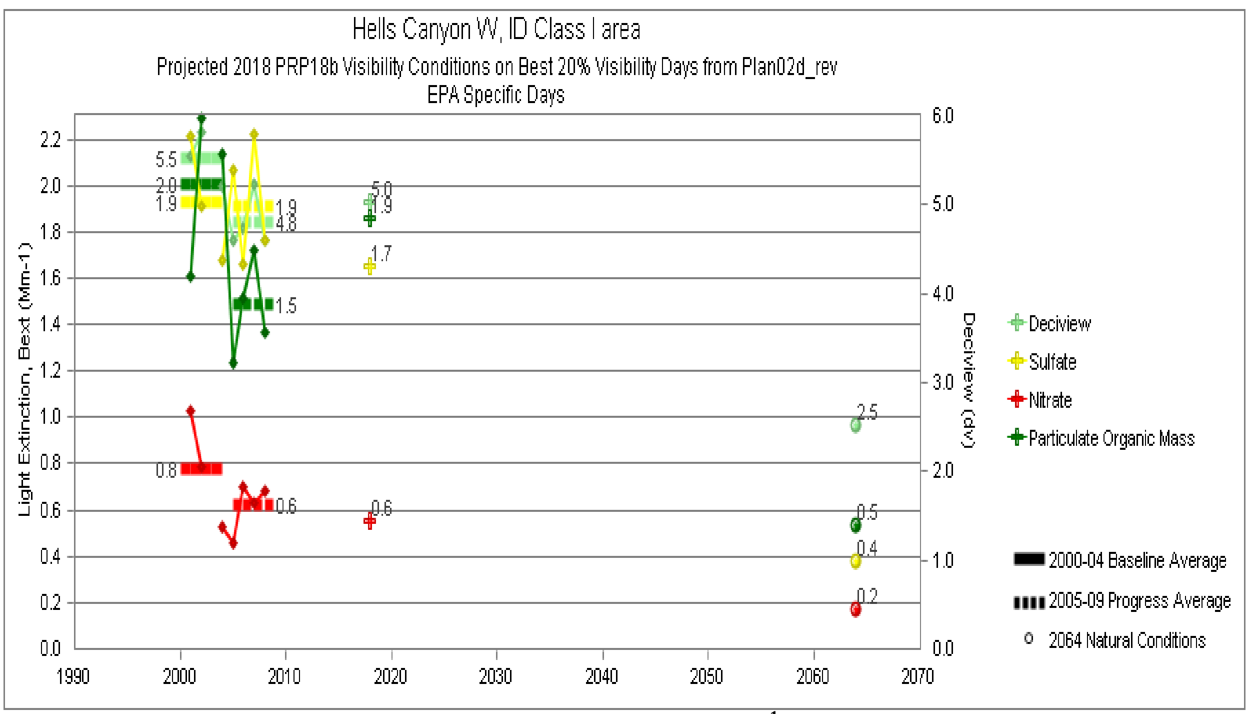


Figure 9.4.4.1b. Deciview and light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate, ammonium nitrate, and particulate organic mass (POM) for the baseline (2000–2004), period 1 (2005–2009), and 2064 natural conditions estimates for the best 20% visibility days at Hell's Canyon WA, OR/ID. Values of b_{ext} for other species, including elemental carbon (EC), soil, coarse mass, and sea salt are listed in the table below the graph (data and graphs obtained at http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

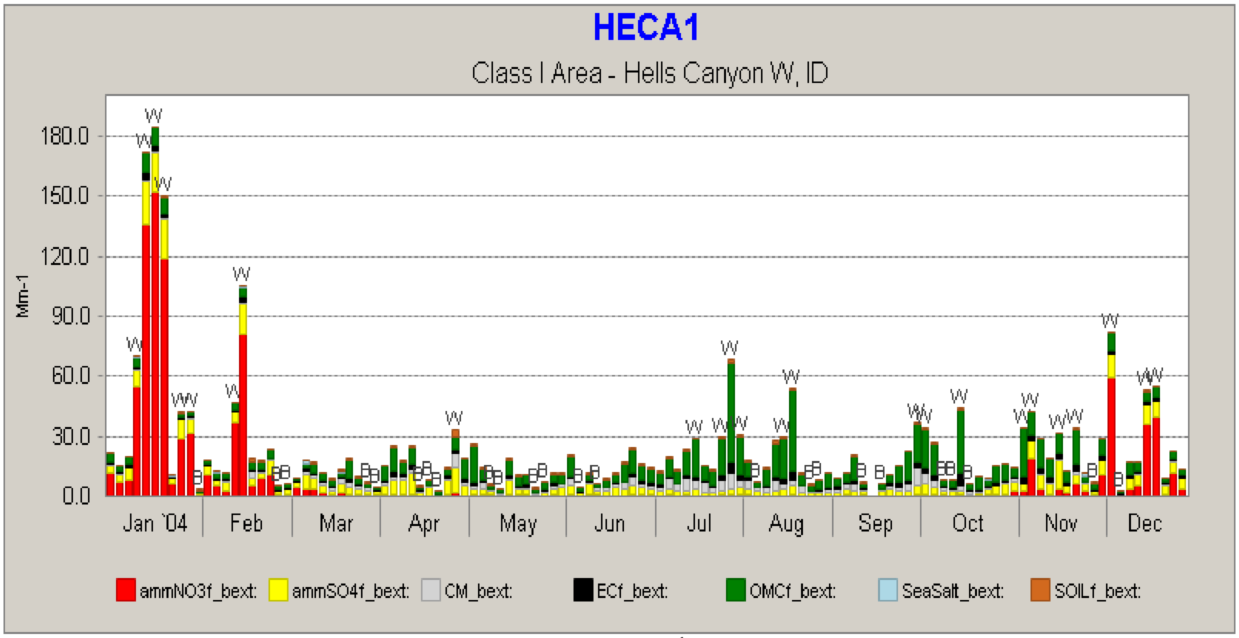


Figure 9.4.4.2a. Daily light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate (ammSO4f_bext), ammonium nitrate (ammNO3f_bext), particulate organic matter (OMCf_bext), coarse mass (CM_bext), elemental carbon (EC_bext), soil (soil_bext), and sea salt (seasalt_bext) for 2004 Hells Canyon, ID (HECA1). Worst 20% days are marked with a "W" above the bar for that day, and similarly, best 20% days are marked with a "B" (from http://views.cira.colostate.edu/web/Composition/).

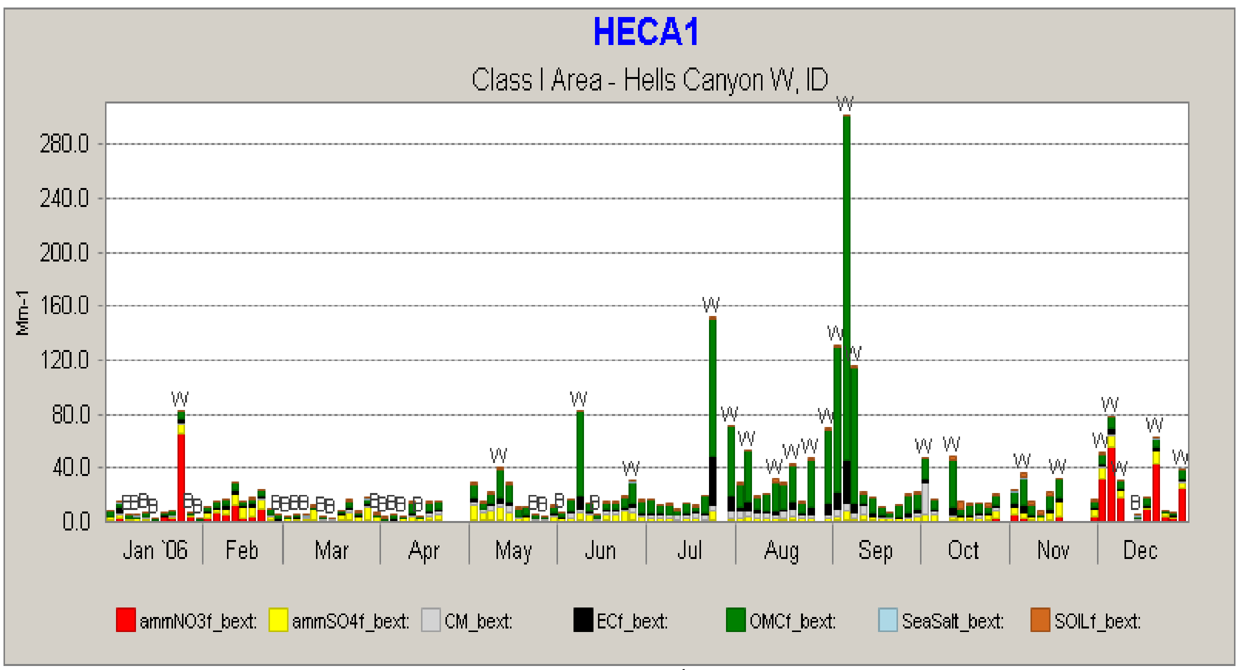


Figure 9.4.4.2b. Daily light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate (ammSO4f_bext), ammonium nitrate (ammNO3f_bext), particulate organic matter (OMCf_bext), coarse mass (CM_bext), elemental carbon (EC_bext), soil (soil_bext), and sea salt (seasalt_bext) for 2006 Hells Canyon, ID (HECA1). Worst 20% days are marked with a "W" above the bar for that day, and similarly, best 20% days are marked with a "B" (from http://views.cira.colostate.edu/web/Composition/).

Table 9.4.4.1. Monitored, estimated, and projected 2018 visibility conditions and emissions changes for the worst 20% visibility days from WRAP regional analyses for Hell's Canyon Wilderness Area, OR/ID (HECA1) (from http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

Class I Area Visibility Summary: Hells Canyon W, OR/ID Class I area
Visibility Conditions: Worst 20% Days
Model Relative Response Factor Calculation Method: Specific Days (EPA)
Emissions Scenarios for Projected 2018 Emissions & Visibility Changes: WRAP 2000-04 Baseline (plan02d_rev) & 2018 PRPb (prp18b)

	Monitored		**Estimated**		**Projected**			
	2000-04 Baseline Conditions (Mm-1)	2005-09 1st Progress Period Conditions (Mm-1)	2064 Natural Conditions (Mm-1)	2018 Uniform Rate of Progress Target (Mm-1)[1]	2018 Projected Visibility Conditions (Mm-1)	Baseline to 2018 Change In Statewide Emissions (tons / %)	Baseline to 2018 Change in Upwind Weighted Emissions[2] (%)	Baseline to 2018 Change in Anthropogenic Upwind Weighted Emissions[2] (%)
Sulfate	8.37	6.8	1.14	6.35	7.89	-20,912 -40%	-29%	-38%
Nitrate	28.47	13.5	2.67	19.69	20.34	-96,079 -37%	-22%	-30%
Organic Carbon	15.6	31.4	3.69	12.12	14.01	-3,120 -3%	-12%	-31%
Elemental Carbon	3.06	5.3	0.37	2.37	2.18	-3,043 -11%	-21%	-44%
Fine Soil	0.66	0.8	0.92	0.72	0.73	-909 -3%	10%	15%
Coarse Material[3]	1.93	1.9	3.4	2.26	Not Applicable	31,039 47%	12%	27%
Sea Salt[3]	0.05	0.1	0.05	0.05		Not Applicable		
Total Light Extinction	69.14	60.9	23.24	53.48	58.13			
Deciview	18.55	18.1	8.32	16.17	16.99			

Table 9.4.4.2. Monitored, estimated, and projected 2018 visibility conditions and emissions changes for the best 20% visibility days from WRAP regional analyses for Hell's Canyon Wilderness Area, OR/ID (HECA1) (from http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

Class I Area Visibility Summary: Hells Canyon W, OR/ID Class I area
Visibility Conditions: Best 20% Days
Model Relative Response Factor Calculation Method: Specific Days (EPA)
Emissions Scenarios for Projected 2018 Emissions & Visibility Changes: WRAP 2000-04 Baseline (plan02d_rev) & 2018 PRPb (prp18b)

	Monitored		**Estimated**		**Projected**			
	2000-04 Baseline Conditions (Mm-1)	2005-09 1st Progress Period Conditions (Mm-1)	2064 Natural Conditions (Mm-1)	2018 Uniform Rate of Progress Target (Mm-1)[1]	2018 Projected Visibility Conditions (Mm-1)	Baseline to 2018 Change in Statewide Emissions (tons / %)	Baseline to 2018 Change in Upwind Weighted Emissions[2] (%)	Baseline to 2018 Change in Anthropogenic Upwind Weighted Emissions[2] (%)
Sulfate	1.93	1.9	0.38	Not Applicable	1.65	-20,912 -40%	-36%	-42%
Nitrate	0.78	0.6	0.17	Not Applicable	0.55	-96,079 -37%	-28%	-35%
Organic Carbon	2.01	1.5	0.54	Not Applicable	1.86	-3,120 -3%	-12%	-25%
Elemental Carbon	0.58	0.4	0.08	Not Applicable	0.43	-3,043 -11%	-23%	-41%
Fine Soil	0.25	0.2	0.14	Not Applicable	0.24	-909 -3%	3%	4%
Coarse Material[3]	0.8	0.5	0.48	Not Applicable	Not Applicable	31,039 47%	10%	25%
Sea Salt[3]	0.08	0.1	0.07	Not Applicable		Not Applicable		
Total Light Extinction	17.45	5.3	12.87	Not Applicable	16.62			
Deciview	5.52	4.8	2.52	Not Applicable	5.04			

1) 2018 Uniform Rate of Progress Target for Best 20% Days is not defined.
2) Results based on Weighted Emissions Potential analysis using the 2000-04 Baseline (plan02d_rev) & 2018 PRPb (prp18b) emissions scenarios.
3) Visibility projections not available due to model performance issues.

9.4.5 Agua Tibia Wilderness, California

Agua Tibia Wilderness (AGTI1) is southeast of Los Angeles and is one of seven CIAs in southern California. While visibility is more significantly impaired at AGTI1 compared to many other CIAs in the West (see Appendix G), data from AGTI1 show an apparent success story as virtually all haze components show improvement beyond the URP in period 1 (see Figures 9.4.5.1a and 9.4.5.1b for the 20% worst and 20% best visibility days, respectively). Data from AGTI1 are generally representative of data from the other southern California IMPROVE sites, and do not appear to have been significantly affected by fire-related activity (see daily b_{ext} from 2002 and 2008 in Figures 9.4.5.2a and 9.4.5.2b, respectively). Emissions reductions by the State of California, local air districts, and federal programs to achieve air quality health standards are providing co-benefits for visibility improvement at the Agua Tibia Wilderness. Improvements in b_{ext} for ammonium nitrate are particularly notable. Data are summarized in Table 9.4.5.1 and Table 9.4.5.2 for the 20% worst and 20% best visibility days, respectively.

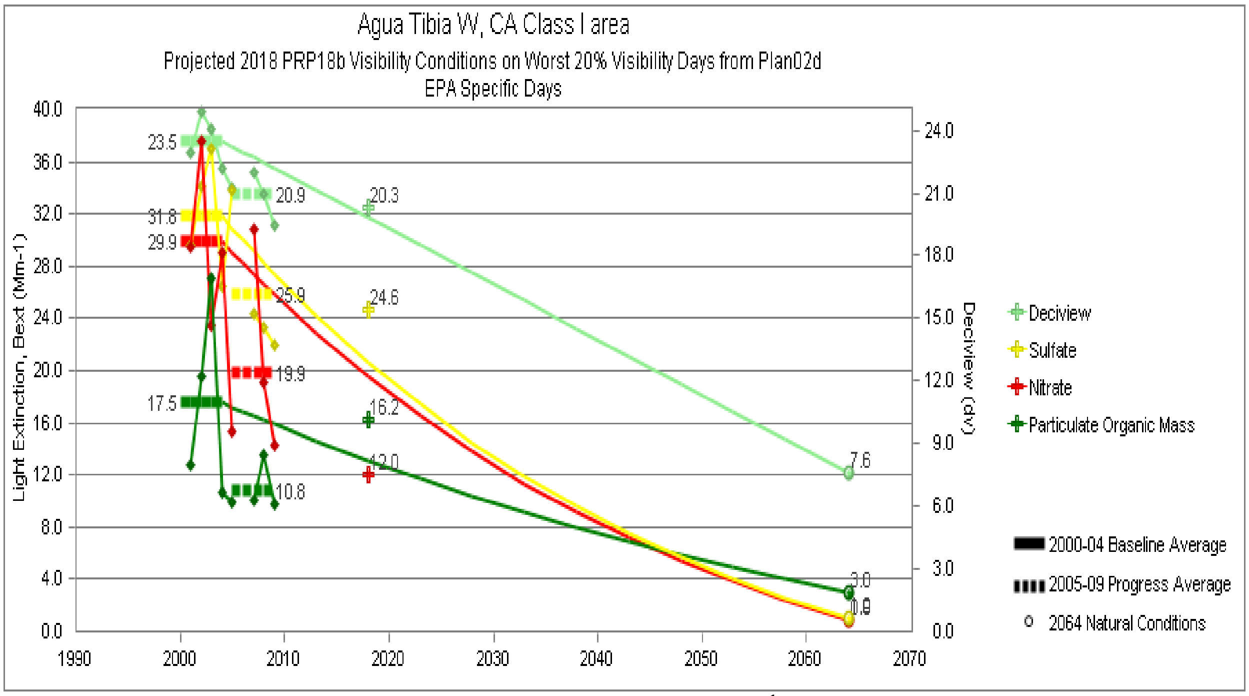


Figure 9.4.5.2a. Deciview and light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate, ammonium nitrate, and particulate organic mass (POM) for the baseline (2000–2004), period 1 (2005–2009), and 2064 natural conditions estimates for the worst 20% visibility days at Agua Tibia Wilderness, CA. Values of b_{ext} for other species, including elemental carbon (EC), soil, coarse mass, and sea salt are listed in the table below the graph (data and graphs obtained at http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

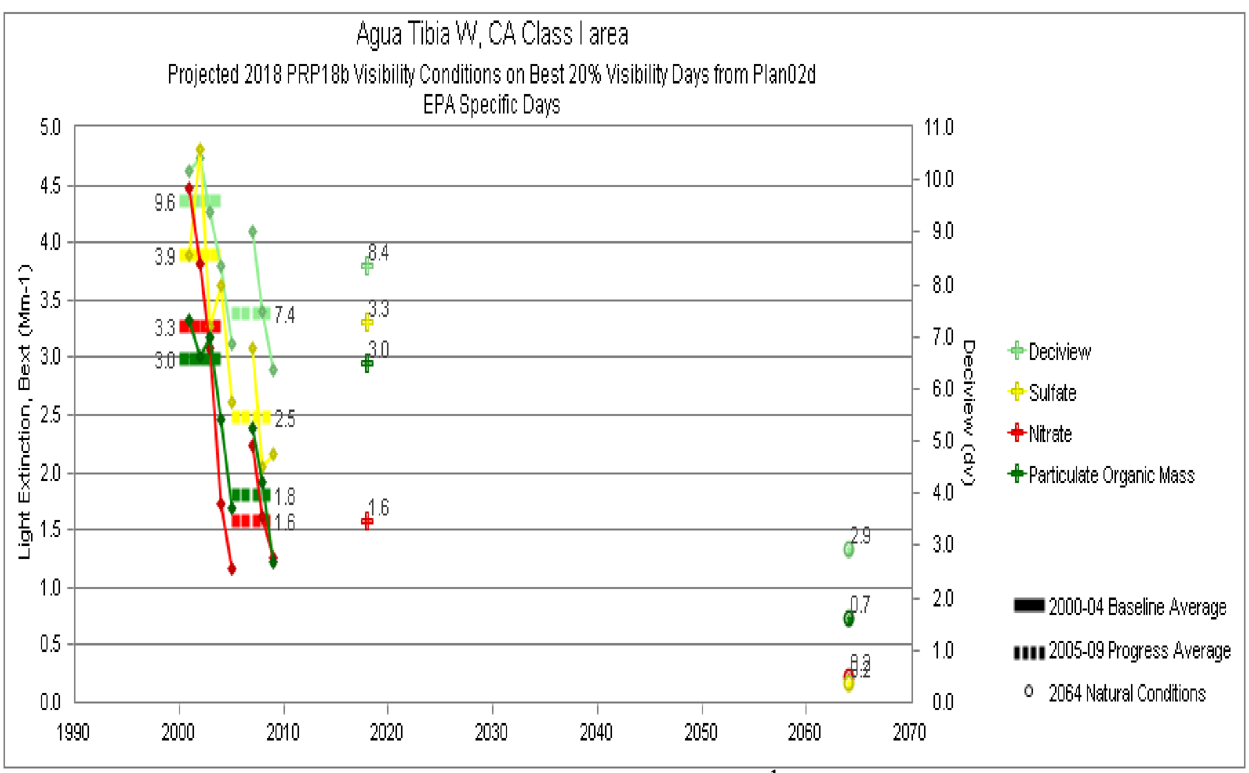


Figure 9.4.5.2b. Deciview and light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate, ammonium nitrate, and particulate organic mass (POM) for the baseline (2000–2004), period 1 (2005–2009), and 2064 natural conditions estimates for the best 20% visibility days at Agua Tibia Wilderness, CA. Values of b_{ext} for other species, including elemental carbon (EC), soil, coarse mass, and sea salt are listed in the table below the graph (data and graphs obtained at http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

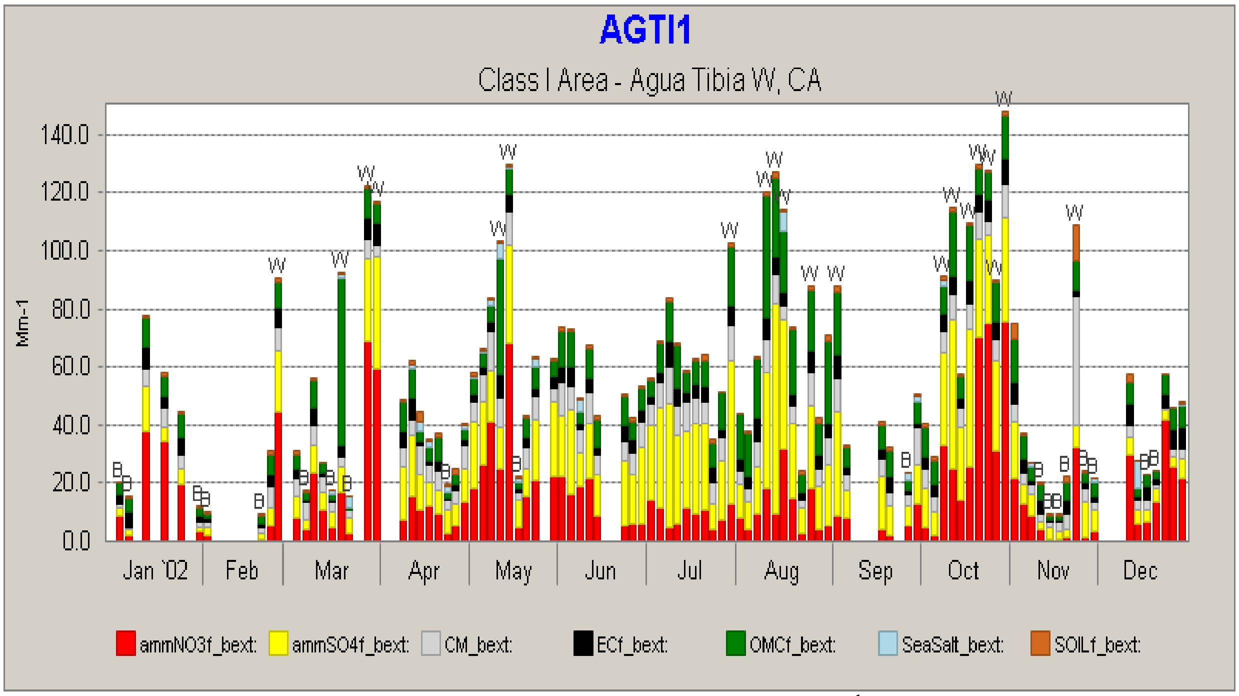


Figure 9.4.5.3a. Class I Area — Daily light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate (ammSO4f_bext), ammonium nitrate (ammNO3f_bext), particulate organic matter (OMCf_bext), coarse mass (CM_bext), elemental carbon (EC_bext), soil (soil_bext), and sea salt (seasalt_bext) for 2002 at Agua Tibia Wilderness, CA (AGTI1). Worst 20% days are marked with a "W" above the bar for that day, and similarly, best 20% days are marked with a "B" (from http://views.cira.colostate.edu/web/Composition/).

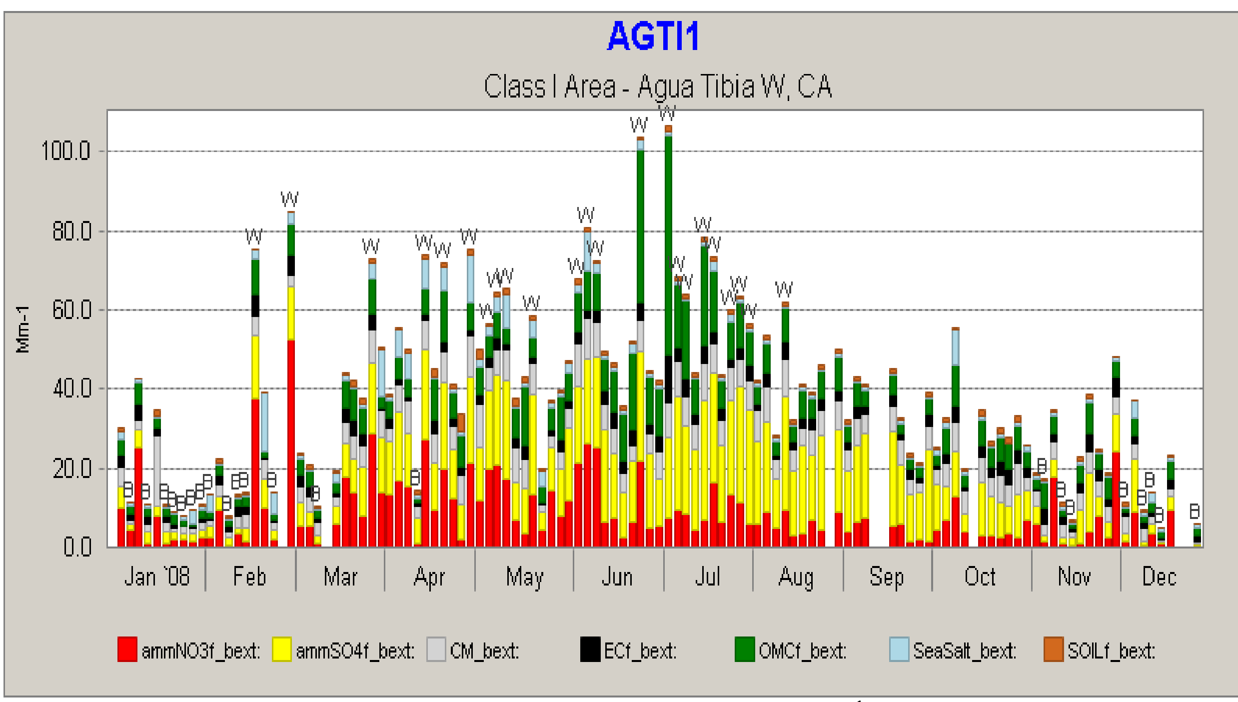


Figure 9.4.5.3b. Class I Area — Daily light extinction coefficients (b_{ext}, Mm^{-1}) for ammonium sulfate (ammSO4f_bext), ammonium nitrate (ammNO3f_bext), particulate organic matter (OMCf_bext), coarse mass (CM_bext), elemental carbon (EC_bext), soil (soil_bext), and sea salt (seasalt_bext) for 2008 at Agua Tibia Wilderness, CA (AGTI1). Worst 20% days are marked with a "W" above the bar for that day, and similarly, best 20% days are marked with a "B" (from http://views.cira.colostate.edu/web/Composition/).

Table 9.4.5.1. Monitored, estimated, and projected 2018 visibility conditions and emissions changes for the worst 20% visibility days from WRAP regional analyses for Agua Tibia Wilderness, CA (AGTI1) (from http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

Class I Area Visibility Summary: Agua Tibia W, CA Class I area **Visibility Conditions:** Worst 20% Days **Model Relative Response Factor Calculation Method:** Specific Days (EPA) **Emissions Scenarios for Projected 2018 Emissions & Visibility Changes:** WRAP 2000-04 Baseline (plan02d) & 2018 PRPb (prp18b)								
	Monitored		**Estimated**		**Projected**			
	2000-04 Baseline Conditions (Mm-1)	2005-09 1st Progress Period Conditions (Mm-1)	2064 Natural Conditions (Mm-1)	2018 Uniform Rate of Progress Target (Mm-1)[1]	2018 Projected Visibility Conditions (Mm-1)	Baseline to 2018 Change in Statewide Emissions (tons / %)	Baseline to 2018 Change in Upwind Weighted Emissions[2] (%)	Baseline to 2018 Change in Anthropogenic Upwind Weighted Emissions[2] (%)
Sulfate	31.82	25.9	0.99	20.62	24.64	-6,243 -8%	-26%	-30%
Nitrate	29.91	19.9	0.94	19.50	11.98	-591,119 -45%	-49%	-51%
Organic Carbon	17.55	10.8	2.98	13.11	16.22	-10,792 -7%	-5%	-14%
Elemental Carbon	6.37	4.6	0.26	4.68	3.57	-12,961 -28%	-28%	-49%
Fine Soil	1.25	0.9	0.83	1.15	1.28	250 0%	3%	3%
Coarse Material[3]	8.64	7.5	2.98	7.13	Not Applicable	29,666 13%	13%	16%
Sea Salt[3]	0.82	1.8	1.68	1.01		Not Applicable		
Total Light Extinction	107.36	71.4	21.66	73.56	78.15			
Deciview	23.5	20.9	7.64	19.80	20.3			

Table 9.4.5.2. Monitored, estimated, and projected 2018 visibility conditions and emissions changes for the best 20% visibility days from WRAP regional analyses for Agua Tibia Wilderness, CA (AGTI1) (from http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx).

Class I Area Visibility Summary: Agua Tibia W, CA Class I area
Visibility Conditions: Best 20% Days
Model Relative Response Factor Calculation Method: Specific Days (EPA)
Emissions Scenarios for Projected 2018 Emissions & Visibility Changes: WRAP 2000-04 Baseline (plan02d) & 2018 PRPb (prp18b)

	Monitored		**Estimated**		**Projected**			
	2000-04 Baseline Conditions (Mm-1)	2005-09 1st Progress Period Conditions (Mm-1)	2064 Natural Conditions (Mm-1)	2018 Uniform Rate of Progress Target (Mm-1)[1]	2018 Projected Visibility Conditions (Mm-1)	Baseline to 2018 Change in Statewide Emissions (tons / %)	Baseline to 2018 Change in Upwind Weighted Emissions[2] (%)	Baseline to 2018 Change in Anthropogenic Upwind Weighted Emissions[2] (%)
Sulfate	3.9	2.5	0.17	Not Applicable	3.3	-6,243 -8%	-32%	-36%
Nitrate	3.27	1.6	0.22	Not Applicable	1.57	-591,119 -45%	-48%	-50%
Organic Carbon	2.99	1.8	0.74	Not Applicable	2.95	-10,792 -7%	-4%	-12%
Elemental Carbon	1.87	1.2	0.11	Not Applicable	1.01	-12,961 -28%	-27%	-48%
Fine Soil	0.47	0.4	0.26	Not Applicable	0.5	250 0%	4%	5%
Coarse Material[3]	2.41	2.4	0.72	Not Applicable	Not Applicable	29,666 13%	14%	17%
Sea Salt[3]	0.79	0.6	0.2	Not Applicable		Not Applicable		
Total Light Extinction	26.70	10.4	13.42	Not Applicable	23.51			
Deciview	9.58	7.4	2.92	Not Applicable	8.37			

1) 2018 Uniform Rate of Progress Target for Best 20% Days is not defined.
2) Results based on Weighted Emissions Potential analysis using the 2000-04 Baseline (plan02d) & 2018 PRPb (prp18b) emissions scenarios.
3) Visibility projections not available due to model performance issues.

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