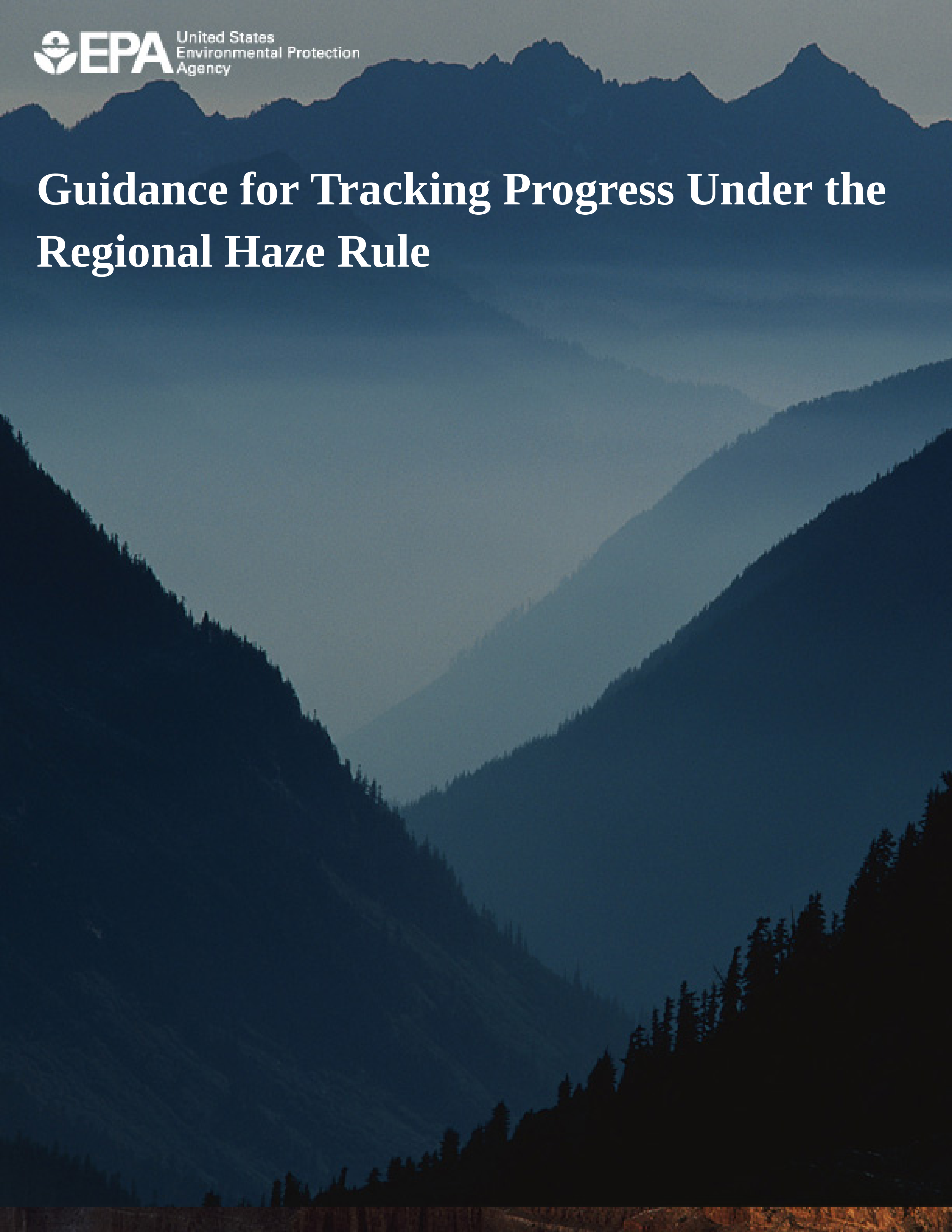

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Guidance for Tracking Progress Under the Regional Haze Rule

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Guidance for Tracking Progress Under the Regional Haze Rule

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Abbreviations and Acronyms

b_{ag} - Light extinction coefficient associated with the absorption by gases

b_{ap} - Light extinction coefficient associated with the absorption by particles

b_{ext} - Total light extinction coefficient

b_{sg} - Light extinction coefficient associated with the scattering by gases

b_{sp} - Light extinction coefficient associated with the scattering by particles

BART - best available retrofit technology

CAA – Clean Air Act

CAAA – 1990 Clean Air Act Amendments

CASTNet - Clean Air Status and Trends Network

CIRA – Cooperative Institute for Research in the Atmosphere, Colorado State University

CM - Coarse mass

dv - Deciview - unit of the haze index

EPA – United States Environmental Protection Agency

f(RH) – Relative humidity adjustment factor

GCVTC – Grand Canyon Visibility Transport Commission

IMPROVE – Interagency Monitoring of Protected Visual Environments

LAC - Light absorbing carbon

$\mathbf{Mm^{-1}}$ - Inverse megameter (10^{-6} m^{-1})

MARAMA - Mid-Atlantic Regional Air Management Association

NAAQS – National Ambient Air Quality Standards

NESCAUM - Northeast States for Coordinated Air Use Management

$\mathbf{NO_2}$ – Nitrogen dioxide

NOAA - National Oceanic and Atmospheric Administration

NPS – United States Department of the Interior, National Park Service

OC - Organic carbon

OMC - Organic carbon mass

OP - Pyrolized organics

PIXE - Proton induced x-ray emission spectroscopy

PM – Particulate matter

$PM_{2.5}$ – Particulate matter with an aerodynamic diameter less than 2.5 microns

PM_{10} – Particulate matter with an aerodynamic diameter less than 10 microns

RH - Relative humidity

RPO - Regional Planning Organization

SIP – State Implementation Plan

STAPPA - State and Territorial Air Pollution Program Administrators

TDMA - Tandem differential mobility analyzers

TIP - Tribal implementation plan

TOR - Thermal optical reflectance

WESTAR - Western States Air Resources Council

Glossary of Terms

Aerosols – Suspensions of tiny liquid and/or solid particles in the air.

Coarse mass – Mass of particulate matter with an aerodynamic diameter greater than 2.5 microns but less than 10 microns.

Deciview (dv) - The unit of measurement of haze, as in the haze index (HI) defined below.

Fine particulate matter – particulate matter with an aerodynamic diameter less than 2.5 microns($PM_{2.5}$).

Fine soil – Particulate matter composed of pollutants from the Earth's soil, with an aerodynamic diameter less than 2.5 microns. The soil mass is calculated from chemical mass measurements of fine aluminum, fine silicon, fine calcium, fine iron, and fine titanium as well as their associated oxides.

Haze index (HI) – A measure of visibility derived from calculated light extinction measurements that is designed so that uniform changes in the haze index correspond to uniform incremental changes in visual perception, across the entire range of conditions from pristine to highly impaired. The haze index [in units of deciviews (*dv*)] is calculated directly from the total light extinction [b_{ext} expressed in inverse megameters (Mm-1)] as follows:

$$HI = 10 \ln (b_{ext}/10)$$

Light absorbing carbon - Carbon particles in the atmosphere that absorb light; also reported as elemental carbon.

Least-impaired days – Data representing a subset of the annual measurements that correspond to the clearest, or least hazy, days of the year.

Light extinction - A measure of how much light is absorbed or scattered as it passes through a medium, such as the atmosphere. The aerosol light extinction refers to the absorption and scattering by aerosols, and the total light extinction refers to the sum of the aerosol light extinction, the absorption of gases (such as NO_2), and the atmospheric light extinction (Rayleigh scattering).

Mandatory Federal Class I areas - Certain national parks (over 6,000 acres), wilderness areas (over 5,000 acres), national memorial parks (over 5,000 acres), and international parks that were in existence as of August 1977. Appendix A lists the mandatory Federal areas.

Most impaired days – Data representing a subset of the annual measurements that correspond to the dirtiest, or haziest, days of the year.

Nitrate – Solid or liquid particulate matter containing ammonium nitrate [NH_4NO_3] or other nitrate salts. Atmospheric nitrate aerosols are often formed from the atmospheric oxidation of oxides of nitrogen (NO_x).

Organic carbon – Aerosols composed of organic compounds, which may result from emissions from incomplete combustion processes, solvent evaporation followed by atmospheric condensation, or the oxidation of some vegetative emissions.

Particulate matter – Material that is carried by liquid or solid aerosol particles with aerodynamic diameters less than 10 microns (in the discussions of this report). The term is used for both the in situ atmospheric suspension and the sample collected by filtration or other means.

Rayleigh scattering – Light scattering of the natural gases in the atmosphere. At an elevation of 1.8 kilometers, the light extinction from Rayleigh scattering is approximately 10 inverse megameters (Mm^{-1}).

Relative humidity – Partial pressure of water vapor at the atmospheric temperature divided by the vapor pressure of water at that temperature, expressed as a percentage.

Sulfate – Solid or liquid particulate matter composed of sulfuric acid [H_2SO_4], ammonium bisulfate [NH_4HSO_4], or ammonium sulfate [$(NH_4)_2SO_4$]. Atmospheric sulfate aerosols are often formed from the atmospheric oxidation of sulfur dioxide.

Total carbon – Sum of the light absorbing carbon and organic carbon.

Visibility impairment – Any humanly perceptible change in visibility (light extinction, visual range, contrast, coloration) from that which would have existed under natural conditions. This change in atmospheric transparency results from added particulate matter or trace gases.

1. INTRODUCTION

1.1 What is regional haze?

Regional haze is visibility impairment caused by the cumulative air pollutant emissions from numerous sources over a wide geographic area. Visibility impairment is caused by particles and gases in the atmosphere. Some particles and gases scatter light while others absorb light. The net effect is called "light extinction." The result of these processes is a reduction of the amount of light from a scene that is returned to the observer, as well as an addition of scattered light to the sight path, creating a hazy condition. To a viewer, haze can be perceived as a reduction in the visual clarity of an object.

The primary cause of regional haze in many parts of the country is light scattering resulting from fine particles (i.e., particulate matter less than 2.5 microns in diameter, referred to as $PM_{2.5}$) in the atmosphere. These fine particles can contain a variety of chemical species including carbonaceous species (i.e., organics and elemental carbon), as well as ammonium nitrate, sulfates, and soil. Additionally, coarse particles between 2.5 and 10 microns in diameter can contribute to light extinction. Each of these components can be naturally occurring or the result of human activity. The natural levels of these species result in some level of visibility impairment in the absence of any human influences and will vary with season, daily meteorology, and geography.

1.2 What is the purpose of this Tracking Progress guidance document for the regional haze program?

This document provides guidance to EPA Regional, State, and Tribal air quality management authorities and the general public, on how EPA intends to exercise its discretion in implementing Clean Air Act provisions and EPA regulations, concerning the tracking of progress under the regional haze program. The guidance is designed to implement national policy on these issues. Sections 169A and 169B of the Clean Air Act (42) U.S.C. § § 7491,7492 and implementing regulations at 40 CFR 51.308 and 51.309 contain legally binding requirements. This document does not substitute for those provisions or regulations, nor is it a regulation itself. Thus, it does not impose binding, enforceable requirements on any party, nor does it assure that EPA may approve all instances of its application, and thus the guidance may not apply to a particular situation based upon the circumstances. The EPA and State decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. Any decisions by EPA regarding a particular State implementation plan (SIP) demonstration will only be made based on the statute and regulations and will only be made following notice and opportunity for public review and comment. Therefore, interested parties are free to raise questions and objections about the appropriateness of the application of this guidance to a particular situation; EPA will, and States should, consider whether or not the recommendations in this guidance are appropriate in that situation. This guidance is a living document and may be revised periodically without public notice. The EPA welcomes public comments on this document at any time and will consider those comments in any future revision of this guidance document.

Readers of this document are cautioned not to regard statements recommending the use of certain procedures or defaults as either precluding other procedures or information or providing guarantees that using these procedures or defaults will result in actions that are fully approvable. As noted above, EPA cannot assure that actions based upon this guidance will be fully approvable in all instances, and all final actions may only be taken following notice and opportunity for public comment.

1.3 Does this guidance document apply to Tribal Class I areas as well as mandatory Federal Class I areas?

Not directly, although the procedures for calculating light extinction and tracking visibility changes over time that are described in this guidance can be used by Tribes that are conducting their own air quality monitoring using the Interagency Monitoring of Protected Visual Environments (IMPROVE) protocol. The CAA and the regional haze rule call for the protection of visibility in 156 “mandatory Federal Class I areas.”[1] Tribes can establish Class I areas for the purposes of the prevention of significant deterioration program, but the CAA does not provide for the inclusion of Tribal areas as mandatory Federal Class I areas subject to section 169A and 169B of the CAA. For this reason, progress goals do not have to be established for Tribal Class I areas.

However, Tribes may find it advantageous for a number of reasons to participate in regional planning organizations (RPO) for regional haze and to develop regional haze Tribal implementation plans (TIPs). Participation in an RPO may allow some Tribes to build capacity

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[1] Areas designated as mandatory Class I areas are those National Parks exceeding 6,000 acres, wilderness areas and national memorial parks exceeding 5,000 areas, and all international parks which were in existence on August 7, 1977. Visibility has been identified as an important value in 156 of these areas. See 40 CFR part 81, subpart D. The extent of a Class I area includes subsequent changes in boundaries, such as park expansions. [CAA section 162 (a)]. States and tribes may designate additional areas as Class I, but the requirements of the visibility program under section 169A of the CAA apply only to "mandatory Class I areas," and do not affect these additional areas. For the purpose of this guidance document, the term “Class I area” will be used interchangeably with “mandatory Federal Class I area.”

and enhance their air quality management capabilities. Under the Tribal Air Rule, Tribal governments may elect to implement air programs in much the same way as States, including development of Tribal implementation plans.[2]

In this way, Tribes can work with other States and Tribes on the development and adoption of specific emissions reduction strategies designed to protect air quality across a broad region including Tribal and State lands.

1.4 What is the statutory and regulatory basis for the regional haze program?

Section 169A of the 1977 Clean Air Act amendments (CAAA) set forth legislative requirements for addressing visibility impairment due to air pollution. It established a national visibility goal to remedy existing impairment and prevent future impairment in 156 National Parks and wilderness areas across the country designated as mandatory Federal Class I areas. It also called for EPA to develop regulations requiring State implementation plans (SIPs) to address visibility. These plans must include a long-term strategy and Best Available Retrofit Technology (BART) on certain existing sources for making “reasonable progress” toward this goal.

The EPA issued initial visibility regulations in 1980[3] that addressed visibility impairment in a mandatory Federal Class I area that is “reasonably attributable” to a single source or small group of sources. The EPA subsequently issued regulations to address regional haze (i.e., visibility impairment caused by emissions from numerous sources located over a broad geographic region), in 1999.[4] The regional haze rule requires States with mandatory Federal Class I areas to develop SIPs that include reasonable progress goals for improving visibility in each mandatory Federal Class I area and emission reduction measures to meet those goals.

1.5 What are the initial milestones of the regional haze program?

After publication of the regional haze rule in 1999, the first step in the implementation process was the upgrade and expansion of the IMPROVE visibility monitoring network to 110 sites nationally. These sites were selected to represent all mandatory Federal Class I areas, except

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[2] See 63 Federal Register 7254 (February 12, 1998), and 40 CFR Part 49.

[3] See 45 Federal Register 80084 (December 2, 1980).

[4] See 64 Federal Register 35713 (July 1, 1999). See also 40 CFR 51.300-309.

for the Bering Sea Wilderness site[5]. The expanded IMPROVE monitoring network was deployed during the 1999-2001 time frame in accordance with Table 1-1.

Representative monitoring data collected from this network will be used to establish baseline conditions (for the 2000-2004 period) for each Class I area and to track progress toward goals established in future SIPs.[6] One can see from Table 1-1 that 101 (or 92%) of the 110 sites are expected to have at least 4 complete years of data for the purpose of determining baseline conditions. Only 9 sites are expected to use 3 years of data to establish baseline conditions.

Table 1-1 Deployment of IMPROVE Sites, 1999-2001

Year	Number of IMPROVE Sites Deployed	Number of Years of Data for Calculating Baseline Conditions (2000-2004)
1999	60	5
2000	41	4
2001	9	3
TOTAL	110	

Most States (and Tribes as appropriate) are expected to submit regional haze SIPs in the 2007-2008 time frame. Nine western States have the option under Section 51.309 of the regional haze rule to implement the recommendations of the Grand Canyon Visibility Transport Commission (GCVTC) within the framework of the regional haze rule, provided they submit initial regional haze SIPs in 2003. Progress reviews are to be conducted every 5 years after SIP submittal, and comprehensive SIP revisions are required in 2018 and every 10 years thereafter.

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[5] Bering Sea Wilderness is too remote for routine measurements of the kind employed by the IMPROVE visibility monitoring network.

[6] 40CFR51.308 (d) (2) (i). Also, as discussed in the preamble to the regional haze rule (64 FR 35728-9, July 1, 1999), representative monitoring data collected from this network will be used to establish baseline conditions (for the 2000-2004 period) for each Class I area and to track progress toward goals established in future SIPs.

1.6 What visibility metric will be used for setting goals and tracking progress?

As stated at 40 CFR 51.308 (d) (1), baseline visibility conditions, progress goals, and changes in visibility must be expressed in terms of deciview (*dv*) units. The deciview is a unit of measurement of haze, implemented in a haze index (*HI*) that is derived from calculated light extinction, and that is designed so that uniform changes in haziness correspond approximately to uniform incremental changes in perception, across the entire range of conditions, from pristine to highly impaired.

The *HI* is expressed by the following formula:

$$HI = 10 \ln(b_{ext}/10)$$

where b_{ext} represents total light extinction expressed in inverse megameters (i.e., $Mm^{-1} = 10^{-6}\ m^{-1}$). See Section 3 of this document for further details on calculating *HI* in *dv* units from IMPROVE monitoring data.

1.7 What key requirements in the regional haze rule relate to progress goals for mandatory Federal Class I areas?

In their initial control strategy SIPs due in 2007-8, States are required to adopt progress goals for improving visibility from baseline conditions (represented by 2000-2004) to 2018 (represented by 2014 to 2018) for each Class I area in the State. A State that does not have any Class I areas will not establish any progress goals in its SIP, but it is required to consult with other States having Class I areas that may be impacted by emissions from the State. A State without any Class I areas will also need to adopt emission reduction strategies to address its contribution to visibility impairment problems in Class I areas located in other States.

Specifically, a State is required to set progress goals for each Class I area in the State that:

- provide for an improvement in visibility for the most impaired (i.e., 20% worst) days over the period of the implementation plan, and
- ensure no degradation in visibility for the least impaired (i.e., 20% best) days over the same period.

In Class I areas with higher levels of visibility impairment, the conditions on the best days may still be several deciviews higher than estimated natural conditions. The EPA expects that for most of these areas, emission reduction strategies to improve visibility conditions on the worst days should also lead to improvements on the best days. States should track progress on the best days as well as the worst days in order to determine if emission reduction strategies lead to an improvement in the overall distribution of visibility conditions. If a degradation in best day conditions is observed over time, States should re-evaluate their emission reduction strategies.

The reasonable progress goals must provide for a rate of improvement sufficient to attain natural conditions by 2064, or justify any alternative to this rate based upon factors listed in 169A (g) (1) of the Clean Air Act and 308 (d) (1) (i) (A) of the regional haze rule. States will determine whether they are meeting their goals by comparing visibility conditions from one five-year average to another (e.g., 2000-2004 to 2013-2017). In order to conduct the analysis for setting progress goals, the State should use this Tracking Progress guidance document for determining 5-year baseline conditions. A separate guidance document addresses methods for estimating Natural Visibility Conditions (i.e., the ultimate goal of the visibility improvement program).

1.8 How does a State determine the rate of progress it must analyze in the progress goal development process?

In developing any progress goal, the State will need to analyze and consider in its set of options the rate of improvement between 2004 (when 2000-2004 baseline conditions are set), and future periods (such as 2018) that, if maintained in subsequent implementation periods, would result in achieving estimated natural conditions by the year 2064. For example, for an eastern Class I area for which the 20% worst visibility baseline condition is 29 *dv* and the estimated natural condition is 11 *dv*, the rate of improvement that the State must analyze for establishing the 2018 progress goal is equal to18 *dv* (i.e., the difference between current and estimated natural conditions) divided by 60 years (i.e., 2004 to 2064), which equals 0.3 *dv* per year. Carried out over 14 years (i.e., 2004 to 2018), this rate of improvement would lead to a reduction in the 20% worst average value by 4.2 *dv*.

For this example, the rate of improvement is calculated as:

$$\frac{\text{Current worst day conditions - estimated natural conditions}}{\text{(2064 - current year)}} = \text{yearly improvement (in dv)}$$

or,

$$\frac{(29dv - 11dv)}{(2064 - 2004)} = \frac{18dv}{60years} = 0.3dv/yr$$

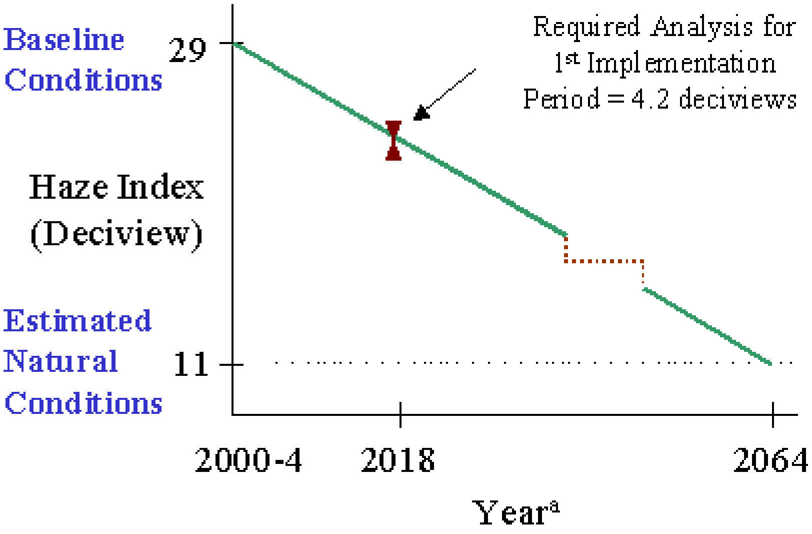

Figure 1-1 Example of method for determining Mandatory Federal Class I area rate of progress to be analyzed in SIP development process ([a] HI values for 2004 are based on 2001-2004 data, etc.)

and, carried out over 14 years, this rate would achieve an improvement on the worst days of:

$$0.3 \text{ dv / year} \times 14 \text{ years} = 4.2 \text{ dv.}$$

The State must demonstrate in the SIP whether it finds that this rate of improvement is reasonable or not, taking into consideration the relevant statutory factors (*see next question*). If it finds that this rate is not reasonable, the State shall evaluate alternative rates of progress and include a demonstration supporting its finding that an alternate rate is reasonable. In order to determine the 2004-2018 progress rate for these analyses, the State will need to calculate 2000-2004 baseline conditions in accordance with this guidance document and use separate EPA guidance for estimating Natural Visibility Conditions.

1.9 What other factors should be considered in developing Class I area progress goals?

Other important issues to be considered in developing Class I area progress goals include the reasonable progress factors in the CAA, consultation with other States, Tribes and Federal land managers, and emission reductions due to other Clean Air Act programs. The reasonable progress factors[7] to consider in developing any progress goal are:

- the costs of compliance;
- the time necessary for compliance;
- the energy and non-air quality environmental impacts of compliance; and
- the remaining useful life of any existing source subject to such requirements.

In this context, non-air quality environmental impacts might include effects on aquatic, terrestrial or materials damaged from acidic deposition, eutrophication of coastal estuaries from nitrogen deposition, changes in the deposition of toxic trace metals or organics that may result from emissions changes. The EPA plans to develop additional guidance on how to address these factors in the goal-setting process.

States with mandatory Federal Class I areas are required to develop Class I area progress goals and consult with other States in developing Class I area progress goals and long-term strategies to meet these goals. If one State is reasonably anticipated to cause or contribute to visibility impairment in a Class I area located in another State, the two States are required to consult with one another on the development of progress goals for the affected Class I area. Furthermore, these States must include strategies in their SIPs that address their respective contributions to the haze in the affected Class I area. A State can take projected emissions reductions from other States into account in setting specific Class I area goals. This consultation process is essential because of the regional nature of the haze problem. The EPA supports the regional planning organization process currently under way to implement the regional haze program. We expect that much of the consultation, strategy development, apportionment demonstrations, and technical documentation needed for SIPs of participating States will be facilitated and developed through the RPO process.

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[7] See CAA section 169A (g).

In developing progress goals, the regional haze rule also requires in paragraph 51.308 (d) (1) (vi) that States must take into account any emission reduction strategies in place or on the way in order to meet other Clean Air Act requirements. For example, emission reduction strategies (e.g., strategies to attain the $PM_{2.5}$ and ozone NAAQS and national mobile source measures such as the Tier II or heavy duty diesel regulations) implemented in the State and/or in regions contributing to visibility impairment in the State's Class I areas should be taken into account by the State, as it develops Class I area progress goals for regional haze. Progress goals for regional haze certainly cannot be any less than the level of visibility improvement expected due to implementation of emission reduction measures for other programs.

1.10 Would EPA accept a progress goal providing for a reduced rate of visibility degradation?

Section 169A (a) (4) and other subsections of the Clean Air Act call for reasonable progress "toward meeting the national goal" of eliminating man-made impairment of visibility. Since any progress goal calling for degradation of visibility, even at a modest rate, would not be progress toward the goal, it is unlikely that EPA could propose to approve any demonstrations that purport to show further visibility degradation as reasonable progress, (e.g., in situations where visibility would be expected to degrade, and such projected degradations would be lessened but not reversed thru proposed emission control strategies).

1.11 What are the regional haze rule requirements for progress reviews and future SIP revisions?

After the initial SIPs are approved, States will conduct formal progress reviews, in the form of a SIP revision, every 5 years from the date of SIP submittal (e.g., in 2013 if the initial SIP is submitted in 2008). Progress will be reviewed for each Class I area by comparing "current" conditions based on the most recent 5 consecutive years of data to the 2000-2004 baseline value to determine whether air quality improvements are consistent with the progress goals established in the SIP. Progress reviews in 2018 and beyond shall also compare the current visibility conditions to visibility conditions 5 years prior, and to the 2000-2004 baseline value. In each 5-year review, the State will also check progress in terms of emissions reductions to determine whether emissions reductions measures contained in the plan have occurred in a timely and effective manner.

If progress is not consistent with the visibility and emission reduction goals established in the previous SIP, the State must evaluate the reason for lack of progress and take any appropriate action. If the lack of progress is primarily due to emissions from within the State, then the State must revise its implementation plan within 1 year to include additional measures to make progress. If the lack of progress is primarily due to emissions from other States, then the State must reinitiate the regional planning process to address this problem in the next major SIP revision (e.g., in 2018). If the State finds that international emissions sources are responsible for a substantial increase in emissions in any Class I area or causing a deficiency in visibility progress, the State must submit a technical demonstration to EPA in support of its finding. Similarly, the State should submit a technical demonstration if the State finds that unusual events (e.g., large wildfires), have affected visibility progress during the 5-year period.[8] Given that progress is determined based upon long-term averaging, the EPA believes that it is unlikely that such events will have a significant effect in most cases. See Section 3.10 regarding treatment of outliers and other data associated with unusual events.

States will be required to conduct a comprehensive SIP revision in 2018 and every 10 years thereafter. This process will involve re-evaluating rates of progress for each mandatory Federal Class I area within the State and establishing new visibility improvement goals for these areas. Using the previous example, suppose that the eastern Class I area made only 2 *dv* of the planned 4.2 *dv* of improvement on the worst days (e.g., from 29 to 27 *dv*) by 2018. If the lack of progress is due to planned emission reductions that were not implemented or were ineffective, then the revised SIP must include revised emission reduction measures needed to meet the original progress goal for 2028 illustrated by Figure 1-1.[8] This corresponds to 3 *dv* per 10 years plus the 2.2 *dv* not achieved during the previous implementation period. The revised SIP must also include revised emission reduction measures needed to meet the new Class I area progress goals.

1.12 What are the major analytical tasks involved in addressing specific requirements in the regional haze rule regarding tracking progress?

As noted above, the first step in tracking progress for the regional haze rule is collecting and analyzing filter samples from IMPROVE network sites. In order to identify the 20% most impaired and 20% least impaired days in a particular year, a haze index value (in deciview units) needs to be determined for each 24-hour sample period, and then these values should be sorted from highest to lowest. Averages (in deciviews) for that year can be calculated for HI values associated with the 20% most impaired and 20% least impaired days.

The average HI values for the 20% most impaired and 20% least impaired days in each year should then be averaged for the five consecutive years 2000-2004 to define baseline conditions. Similarly, when checking mid-course progress (e.g., in 2013), or for calculation of current conditions for future SIPs, the annual average values for the 20% most impaired and 20% least impaired days will be averaged for the 5 most recent years of data available, and then those

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[8] 64 Federal Register 35746 (Thursday, July 1, 1999).

values should be compared to the baseline values for that site. For mandatory Federal Class I areas with multiple representative monitors, separate visibility values and progress goals should be established for each site representing the area.

In order to facilitate this tracking process, States having one or more mandatory Federal Class I areas are required by the rule to establish, and update as necessary, three important visibility parameters for the 20% best and 20% worst visibility days at each mandatory Federal Class I area within the State:

- **Baseline conditions** - Baseline conditions represent visibility for the 20% best and worst days for the initial 5-year period of the regional haze program. Baseline conditions are calculated based on monitored data collected during the 2000-2004 period.

- **Current conditions** - Current conditions for the best and worst days are calculated from a 5-year average (in deciviews), based on the most recent 5-year block of monitored data. Calculations of current conditions for each mandatory Federal Class I area are revised every 5 years at the time of each periodic SIP revision and would be used to evaluate:

  (1) the amount of progress made in relation to the reasonable progress goals established for that mandatory Federal Class I area;

  (2) the amount of progress made since the last 5-year progress review, and

  (3) the amount of progress made from the baseline period of the program (2000-2004).

- **Estimate of natural visibility conditions** - The CAA sets a national visibility goal of "remedying existing impairment and preventing future impairment." Following from the national goal, the regional haze rule calls for improvements on the worst days to remedy existing impairment, and no degradation on the best days to prevent future impairment. Thus, the ultimate goal of the regional haze program is "natural conditions,"or the visibility conditions that would be experienced in the absence of human-caused impairment. Under the haze rule, natural conditions need to be estimated for the 20% best and 20% worst days. These estimates should represent long-term averages, analogous to the 5-year averages used to determine baseline conditions and current conditions. A separate guidance document provides a methodology for developing estimates of natural visibility conditions for each Class I area. Potential approaches for refining those estimates are also discussed in that document.

1.13 What air quality monitoring is under way to support tracking progress toward improving visibility conditions under the regional haze rule?

The IMPROVE visibility monitoring program was initiated in two mandatory Federal Class I areas in 1986 and grew to include 30 sites in 1988. The IMPROVE program has been coordinated and funded through a cooperative multi-organizational approach, with participation by EPA, the Federal land managers (Department of Agriculture, U.S. Forest Service; Department of Interior, National Park Service, Fish & Wildlife Service, Bureau of Land Management), National Oceanic and Atmospheric Administration (NOAA), and multi-state organizations such as the Mid-Atlantic Regional Air Management Association (MARAMA), Northeast States for Coordinated Air Use Management (NESCAUM), Western States Air Resources Council (WESTAR), and The State and Territorial Air Pollution Program Administrators (STAPPA). The IMPROVE monitoring protocols include aerosol monitoring of particulate matter mass and its chemical components, optical monitoring of light scattering or overall light extinction, and photographic monitoring. Some but not all sites include on-site monitoring of relative humidity. Through calendar year 1999, the IMPROVE sampling schedule was one 24-hour aerosol sample twice a week, on Wednesdays and Saturdays.

In 1999, EPA provided funding for a significant expansion of the IMPROVE network. Fully deployed, the network includes aerosol monitoring at a total of 110 mandatory Federal Class I area sites. The new sites in the expanded network were selected in order to provide "representative" monitoring for all but one of 156 mandatory Federal Class I areas. New IMPROVE sites began coming on-line in 1999. Most sites were fully deployed by the end of 2000, although a few did not come online until 2001 (see Table 1-1). In the expanded IMPROVE network, one 24-hour sample is collected every 3 days, consistent with the sampling schedule for the Federal Reference Method for the $PM\text{-}_{2.5}$ National Ambient Air Quality Standard (NAAQS). Under this schedule, a total of 122 aerosol samples can be collected for each IMPROVE site each year.

Most of the new IMPROVE sites include aerosol monitoring only. With limited network funds, priority was given to aerosol monitoring with chemical composition analysis of collected particulate matter samples. This allows the States, Tribes and Federal land managers to evaluate changes in visibility impairment and to identify the principal types of emission sources contributing to the visibility impairment there. Figure 1-2 shows the locations of the monitoring sites in the expanded IMPROVE network. It should be noted that some States, Tribes, and Federal Land Managers have funded the operation of additional IMPROVE sites to represent mandatory Federal Class I areas or other areas of the country. At the time of publication of this guideline, there are approximately 50 such additional sites known as IMPROVE protocol sites.

1.14 Why haven't particulate matter monitors been deployed at all mandatory Federal Class I areas?

Because of the broad spatial distributions of regional haze, and in order to use monitoring resources efficiently, EPA determined, in conjunction with State and Federal land managers, that some neighboring mandatory Federal Class I areas could be represented by a single monitoring site.

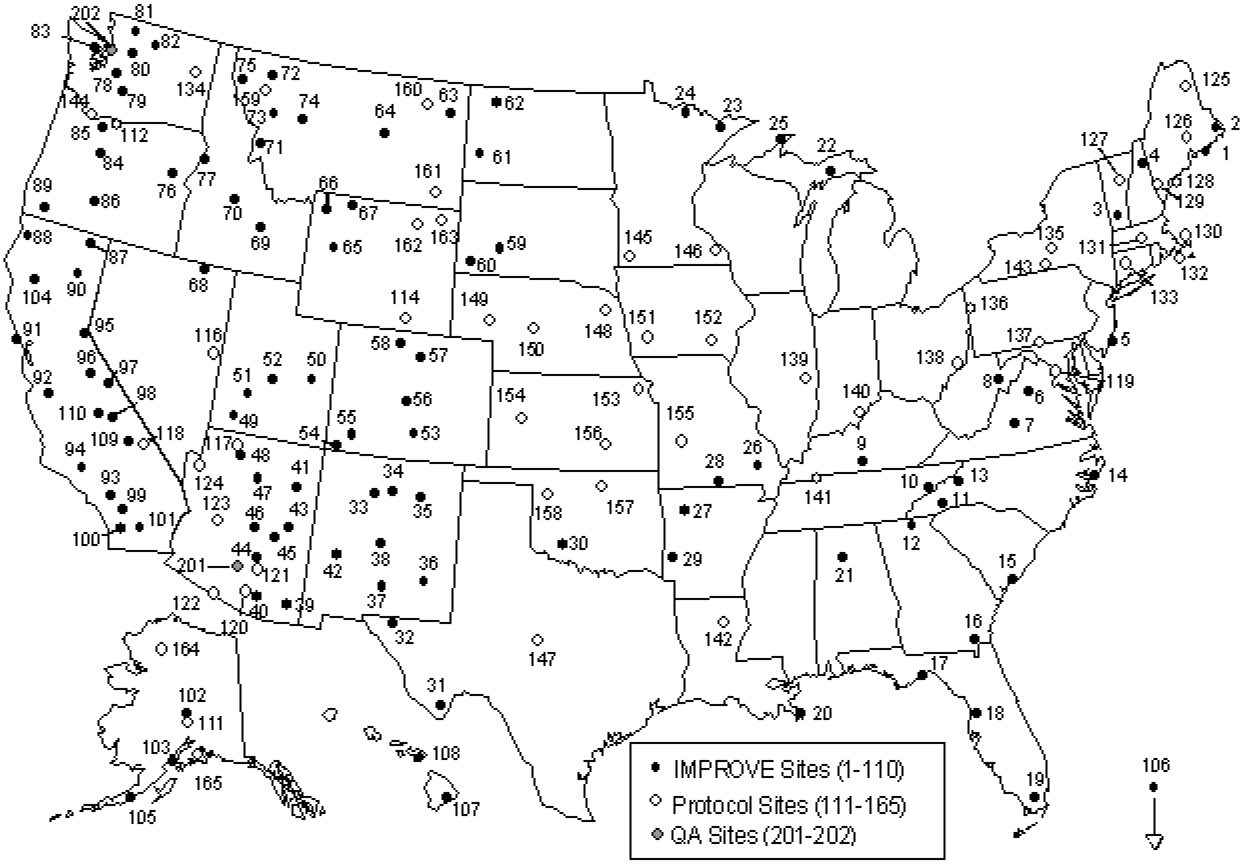

Figure 1-2 Expanded IMPROVE Visibility Monitoring Network
(Site 106 represents the US Virgin Islands)

In addition, one isolated mandatory Federal Class I area (Bering Sea, an uninhabited and infrequently visited island 200 miles from the coast of Alaska), was considered to be so remote from electrical power and people that it would be impractical to collect routine aerosol samples. The EPA consulted with the States in order to design a network that was as representative of all mandatory Federal Class I areas as possible. All mandatory Federal Class I areas (except Bering Sea) are currently covered by at least one IMPROVE monitoring site, and some are covered by additional IMPROVE protocol sites. If changes are made in the sites which cover specific mandatory Federal Class I areas, all the calculations discussed in this document should be performed for each site the State chose in the SIP's monitoring strategy to represent the Class I area.

1.15 Does this guidance pertain to tracking of Class I area changes in visibility by western States submitting regional haze plans under Section 51.309 of the regional haze rule?

Yes, any State with a mandatory Federal Class I area should track changes in visibility according to this guidance, regardless of whether the State has submitted a regional haze implementation plan under Section 51.308 or Section 51.309. Western States (and Tribes as appropriate) that are implementing Section 51.309 to improve air quality at the 16 mandatory Federal Class I areas on the Colorado Plateau, will not be required to set progress goals for these areas for the 2003-2018 period. But they will be required to track progress in these 16 areas every five years according to Section 51.309 (d) (10). Progress reviews and implementation plan revisions are required in 2008, 2013, and 2018. For each mandatory Federal Class I area in the State, the progress review should include an assessment of the following:

- Current visibility conditions (i.e., the most recent 5-year average) for the most impaired and least impaired days;
- The difference between current conditions and baseline conditions (2000-2004) for most impaired and least impaired days;
- The change in visibility conditions over the past 5 years for the most impaired and least impaired days;
- The change in visibility conditions as compared to the State's projection of visibility improvement required in Section 51.309 (d) (2).

1.16 Does this guidance on Tracking Progress address all of the required elements of the 5-year progress reviews required under the regional haze rule?

No, the primary focus of this document is to describe a recommended methodology for calculating total light extinction values for a mandatory Federal Class I area, based on ambient monitoring data. The document also provides basic guidance on the types of visibility assessments needed as part of the 5-year progress reviews. However, the State will need to evaluate both ambient monitoring information and the effectiveness of emission reduction measures in the 5-year progress reviews. The EPA will develop guidance for the full progress review process at a later date.

1.17 What information is provided in the rest of this guidance document?

The remainder of this document provides guidance on procedures to measure regional haze and track progress towards meeting the national visibility goals. Section 2 of this document provides a summary step-by-step description of recommended calculations for tracking progress in regional haze improvement. Section 3 elaborates on that process and presents equations and supporting information needed to perform the calculations. Section 4 discusses the final comparisons used for tracking progress in visibility.

An appendix is included in this document which lists the monthly relative humidity correction factors for each mandatory Federal Class I area. These factors are used for calculating light extinction at each mandatory Federal Class I area.

2. SUMMARY OF TRACKING PROGRESS CALCULATION PROCEDURES

2.1 What is the purpose of this section of the guidance document?

This section of the guidance document describes the process that could be carried out to track progress in improving visibility in mandatory Federal Class I areas, using data from the IMPROVE monitoring sites. The required calculation procedures should be carried out in a nationally consistent manner in order to facilitate inter-comparability among States and national reporting by EPA. The IMPROVE program will perform these calculations for all IMPROVE and IMPROVE protocol monitoring sites and provide the results through the IMPROVE website at:

http://vista.cira.colostate.edu/improve

as a service for those agencies who do not wish to implement the process themselves. The IMPROVE program will ensure that all data and calculations are available in a timely manner, consistent with SIP schedules and will reduce the burden on States which do not wish to perform their own calculations. Data provided to the web site from the IMPROVE monitoring efforts will be used to calculate light extinction and deciview values, 5-year average results, and visibility trends at all IMPROVE sites. This centralized approach will assure consistent treatment of all composite components of $PM_{2.5}$, missing data, data substitution, and averaging, and will reduce the effort needed from Federal, State, Tribes, and other interested parties or agencies doing assessments. The calculations should be done according to the equations and procedures presented in Section 3 of this guidance document, which are also detailed on the IMPROVE web site. All monitoring data will be accessible for review by the responsible agencies so that data flagging or adjustments for special occurrences or other factors can be implemented effectively. However, this service in no way usurps or relieves individual States from their regulatory responsibility to assess the change in visibility in each mandatory Federal Class I area. The aim of this approach is to promote consistency in the calculation procedures while making the process easier for those States, Tribes, and other parties or agencies, who choose to do their own assessments.

2.2 What is the sequence of steps needed to calculate data for tracking progress?

Figure 2-1 summarizes the step-by-step process for assessing visibility trends. The process begins with the transfer of quality-assured, State-reviewed, IMPROVE $PM_{2.5}$ monitoring data to the IMPROVE web site. Then the following sequence of steps will be carried out on data from each IMPROVE site, leading to the data needed for calculation of trends in visibility at each site.

Step 1 - Assemble Composite Components of $PM_{2.5}$

Several of the particle components needed to assess $PM_{2.5}$ light extinction are termed composite components. Such variables may be a composite of multiple measured species, or may be derived from measured species by appropriate conversion factors. Composite components include Fine Soil, which is the sum of several crustal elements; Organic Carbon (OC), which is the sum of four measured OC fractions and the pyrolyzed organics (OP); Light Absorbing Carbon (LAC), which is the sum of three measured elemental carbon (EC) fractions less the OP fraction; Coarse Mass, which is the difference between measured PM_{10} and $PM_{2.5}$ mass; Sulfate, which may be determined based upon either measurements of particulate sulfur or of sulfate ion, with correction for associated ammonium ion; and Nitrate, which is calculated as the mass of ammonium nitrate. The first step in the data process should be to complete these component variables, using a procedure such as that summarized below: **Note:** All of these recommended calculations are performed by the IMPROVE program and are made available on the IMPROVE website.

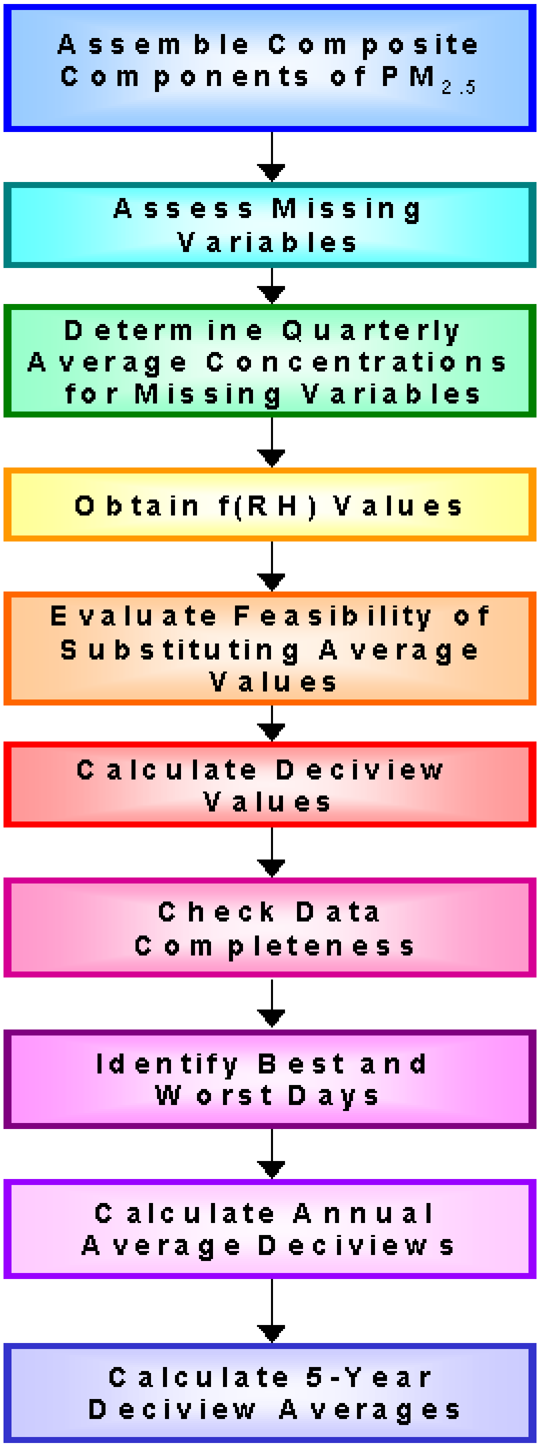

Figure 2-1 Summary of Step-by-Step Process for Tracking Progress Calculations

Fine Soil is calculated by summing the five crustal elements (Al, Si, Ca, Fe, and Ti), accounting for their presence as oxides (e.g., Al_2O_3), and applying adjustment factors to correct for factors such as non-soil potassium, and the presence of other soil components. If any of the five primary crustal elements is below the minimum detection limit, it is assigned a value of half the minimum detection limit. If any of the five crustal elements is missing from the data set, generally all five will be missing because of the analytical method used for these elements. In that case the Fine Soil data are flagged as missing.

Organic Carbon is calculated by summing the five OC fractions after each has been blank corrected. If the resultant sum is negative, a value of zero is assigned for Organic Carbon.

Light Absorbing Carbon is calculated in a similar way, by first summing the three blank corrected elemental carbon fractions, and subtracting the OP fraction. If the result after subtraction is negative, a value of zero is assigned for Light Absorbing Carbon.

Coarse Mass is calculated by subtracting the $PM_{2.5}$ value from the corresponding PM_{10} value. If the result after blank subtraction is negative, a value of zero is assigned for Coarse Mass.

Sulfate is preferably calculated from the particulate sulfur determination. If the sulfur value is below the minimum detection limit, a value of half the minimum detection limit is assigned for sulfate but if that analysis is missing, then the ionic $SO_4^{=}$ determined by ion chromatography is used. The total mass of sulfate present is then calculated assuming it exists in the aerosol as ammonium sulfate $[(NH_4)_2SO_4]$. Nitrate is calculated directly from the measured nitrate ion values, with a factor of 1.29 applied to account for associated ammonium ion. Both Sulfate and Nitrate measurements are blank corrected. If the result is negative for either measurement, a value of zero is assigned for Sulfate or Nitrate accordingly.

Step 2 - Assess Missing Variables

Once the calculations outlined in the first step above have been completed, the entire data set should be reviewed to identify any missing data for the composite components. Those variables for which one or more results are missing should be addressed as in the following steps to fill in the missing data with long-term average values. Days for which no data at all are available are not included in any further calculations.

Step 3 - Determine Quarterly Median Concentrations for Missing Variables

For each variable for which one or more data points were found missing in Step 2, quarterly median values are calculated for the current year and each of the previous 4 years of data. For each calendar quarter (i.e., January-March, April-June, July-September, October-December), the calculated median values for the corresponding complete quarters from the current year and the previous 4 years are then averaged to obtain an average of up to five median values. All data for each variable in the data set are used to calculate the medians, including data that have been set to zero (e.g., for Organic Carbon, Light Absorbing Carbon), and those that are based partly on assigned non-detect values (e.g., Fine Soil). The resulting averages of the quarterly median concentrations are then used in subsequent steps to determine whether missing data can be replaced with the average values.

In this context, a complete quarter is defined as one in which data for a species are available for at least 50% of the sampling days and which has no more than 10 consecutive sampling days with data missing for that species. With a sampling schedule of every third day, this requirement means that no more than one consecutive month of data can be missing. Quarters which do not meet these criteria should not be used to calculate the quarterly average values.

In carrying out this step, care must be taken that the sampling and analytical procedures are uniform throughout the data period being considered. For example, it must be determined that monitors have not been moved, that filter mask sizes have not been changed, etc. Such determinations require a careful review of the history of any siting changes as well as changes in the monitoring procedures for the site. If siting or procedural changes are made, it is important to establish that comparability in the monitoring data has been maintained throughout the changes. Also see Section 4.5.

Step 4 - Obtain *f(RH)* Values

Calculations of light extinction and deciview values require *f(RH)* factors, which adjust the light scattering effect of hygroscopic aerosol species to account for particle growth caused by water vapor in the atmosphere. It is recommended that the *f(RH)* factors used be site-specific and be associated with monthly, rather than, e.g., seasonal or annual time frames. A table of recommended monthly *f(RH)* values for the Class I areas is included as Appendix A of this guidance document. The appropriate *f(RH)* values are used with monitoring data from each IMPROVE site in all visibility calculations.

Step 5 - Evaluate Feasibility of Substituting Average Values

The reason the guidance includes a process for testing the feasibility of substituting average species concentration values for missing values is to maximize the number of sample periods upon which haze trends can be assessed without significantly degrading the haze calculation. The alternative, a rule that valid data for each species must be available for every sample period, both tends to reduce the number of valid haze calculations and in extreme cases can result in the introduction of substantial biases in annual average worst-case calculated haze values. For example in the mid-1990s the eastern United States summertime IMPROVE fine particulate nitrate data were occasionally invalidated as a result of the sampler's nylon filter clogging, typically during periods of high sulfate concentration. Invalidating these sample periods would produce a biased annual average of the worst-case haze conditions since sulfates contribute significantly to the haze in the eastern United States during the summer. However, substitution of an average nitrate value for the missing nitrate would avoid the bias and would not significantly degrade the haze calculation because summer fine particulate nitrate concentrations are minor contributors to haze in the eastern United States. The process described below is an objective approach for determining whether a substitution can be made for missing species data without significantly degrading the calculated haze values.

In this step, light extinction calculations by equation 8 in Section 3 are carried out in two ways for each IMPROVE site having any missing data: (1) using the original data from the past 1 to 5 "complete" years, as defined below in Step 7, and (2) by substituting the appropriate average of the quarterly median concentrations determined in Step 3 for the individual species concentrations in the data set. Comparison of the two sets of results then determines whether the average of quarterly median concentrations can be used to fill in any missing data. This step in the overall process requires several steps in itself, as described below.

First, for a given IMPROVE site, the total light extinction values (b_{ext}, see Section 3) for all days with no missing data are calculated. This calculation is done as described in Section 3 of this guidance document, using the appropriate *f(RH)* factors and the appropriate calculations of the individual composite components. This calculation produces a list of b_{ext} values for that portion of the original data set that had no missing values.

The second step is to recalculate the b_{ext} values for the same sampling days, but with the appropriate average of the quarterly median values for a single species (from Step 3 above), substituted in place of all of the individual values of that species. For example, the average of the quarterly median values of sulfate at a site would be substituted for the corresponding individual sulfate values, for all the days from that site with no missing data. The b_{ext} values are then calculated for the resulting data set. The product of this step is a second set of b_{ext} values, corresponding one-to-one with those calculated from the original values.

Next, these two sets of b_{ext} values are compared for each sample day on a calendar year basis. If the difference between the 2nd b_{ext} value relative to the 1st b_{ext} value is less than 10% for at least 90% of the sample days, then it is acceptable to replace any missing values for that species with the appropriate average of the quarterly medians for that species. If this criterion is not met, then any missing values for that species must remain missing for that calendar year.

The preceding process should be repeated as necessary for each species with any missing data, one at a time, e.g., producing a set of b_{ext} values with the average of the quarterly median sulfate concentration substituted for all individual sulfate values, then another set of b_{ext} values with an average of the quarterly median nitrate concentration substituted for all individual nitrate values, etc. Each such set of b_{ext} values is compared to the original set, to make a judgment about substitution of averages for just one particle species. Note that this process is to be carried out for each composite species for each year, i.e., producing up to 30 tests for each 5-year period, depending on the extent of missing data. It is expected that at any given IMPROVE site, it may be reasonable and appropriate to replace missing data with quarterly medians for some species, but not for others.

In calculating b_{ext} values in this step of the overall process, a value of 10 inverse megameters (i.e., $10/10^6$ m, or 10 Mm^{-1}) for Rayleigh scattering should be used for all sites.

Instances in which data on more than one aerosol component are missing in the same sample are likely to be rare. As a result, the process for dual substitution is not presented at length here. However, substitution of two variables in the same sample could be done, subject to adequate justification and testing, such as in the substitution test described previously. The same acceptance criterion of less than 10% difference in b_{ext} values in 90% of the data should apply. For example, currently, light absorbing carbon and organic carbon data are likely to either be present or missing in the same samples because of the common analysis method for these species. As a result, this substitution test could also be carried out for those two species simultaneously. That is, the quarterly median values for both species could be substituted for their individual values at a site, the b_{ext} values could be calculated, and the comparison made to assess whether simultaneous replacement of missing LAC and OC data with averages is appropriate.

Once the suitability of replacing missing data with medians has been assessed as described above, all missing data for those species meeting the acceptance criterion should be replaced with the appropriate quarterly average values, and the b_{ext} values for those samples should then be calculated. Missing data for species not meeting the criterion should be left missing, and no b_{ext} values should be calculated for those samples.

Step 6 - Calculate Deciview Values

In this step the b_{ext} values calculated in Step 5 are converted to deciview values using equation 9 in Section 3. Note that the appropriateness of substituting averages for missing data could just as easily be evaluated in terms of deciview values, instead of the b_{ext} values, since a difference of 10% in b_{ext} is equivalent to a difference of approximately 1 deciview. That is, if the deciview values calculated with substituted averages differ from those of the original data by less than 1 deciview for at least 90% of the samples, then replacement of missing data with annual average values is appropriate. Otherwise, the missing data should remain missing.

Step 7 - Check Data Completeness

In this step the data sets resulting from previous steps are reviewed for completeness. In order for a year of data from a site to be used to track progress in improving visibility, all four quarters of that year should be at least 50% complete, and overall, the year should be 75% complete. That is, complete data (including that filled in by substitution of averages), should be available for at least 50% of the sampling days in each quarter of the year and for 75% of all scheduled sampling days for the year. In addition, there should be no more than 10 missing sampling days in a row at any time during the calendar year. With a sampling schedule of every third day, this requirement means that a site should not be out of operation for any period of more than one consecutive month during the calendar year.

Annual data sets meeting these completeness criteria should be used in subsequent steps to calculate 5-year average visibility results for tracking progress. Every attempt should be made to get 5 years of complete data within each 5-year period, and EPA expects that failure to meet this goal will be rare. However, if maximum data recovery is not achieved, EPA believes that a minimum of 3 years of data meeting these completeness requirements is sufficient to calculate the 5-year averages within each 5-year period. This recommendation for at least 3 years out of 5 is consistent with the policy established in EPA's regulations governing monitoring and analysis of $PM_{2.5}$, which establishes minimum data requirements for $PM_{2.5}$ NAAQS comparisons. Because of the close relationships between visibility impairment and fine particle concentrations, as well as between the regional haze program and efforts to attain national ambient air quality standards, we believe that similar data completeness policies should apply. Due to delays in deployment, some of the 110 IMPROVE monitoring sites will have no more than 3 or 4 years of complete data at the time when baseline conditions are calculated (Table 1-1). The 3 year completeness criterion will allow calculation of baseline conditions at these sites. If 3 years with complete data are not available, estimates for baseline or current conditions should be prepared in consultation with the Environmental Protection Agency's Office of Air Quality Planning and Standards (EPA/OAQPS). In any case, all complete years should be used in these calculations.

Step 8 - Identify Best and Worst Days

In this step, the 20% best and 20% worst visibility days within a year are identified, based on the deciview values. This step is conducted only for those years of data that meet the data completeness requirements stated in Step 7 above.

Step 9 - Calculate Annual Average Deciviews

In this step, an annual average deciview value is calculated for the best 20% of the days in a year and for the worst 20% of the days in the year. This process uses the best and worst days identified in the previous step and should be carried out only for years meeting the data completeness requirements.

Step 10 - Calculate 5-Year Deciview Averages

Once the annual average deciview values are calculated for the 20% best and 20% worst days in each year, those values should be then averaged to produce best and worst average deciview values over the prescribed 5-year periods. As noted above, a minimum of 3 years of complete data should be available before a 5-year average is calculated. If 3 years with complete data are not available, estimates for baseline or current conditions should be prepared in consultation with the EPA/OAQPS. The resulting estimates for the 5-year period then should be used as the basis for tracking progress (Section 4).

2.3 This 10-step process focuses on using complete years of data. What if an incomplete year would obviously have been a particularly bad or good visibility year?

This potential occurrence is an indication of one instance in which it would be appropriate to include data from incomplete years in calculations. For example, suppose that for a given year, in which data completeness overall fell below the recommendation stated above, there were 25 deciview values (out of 122 sampling periods) that were above the average for 20% worst days for the other years in a 5-year period. The inclusion of these results in the calculation of the 5-year averages (i.e., Step 10 above) would necessarily increase the 5-year average for the 20% worst days, regardless of the deciview values for the other 97 sampling episodes in that year. That increase would bring the 5-year average <u>closer to its true value</u> for that 5-year period. Thus it is reasonable to include the highest 20% deciview readings from an incomplete year, if those values increase the 5-year average of the highest 20% of deciviews, relative to that based on complete years only. For similar reasons, it is also appropriate to include the lowest 20% of deciview readings from an incomplete year, if those values decrease the 5-year average for the lowest 20% of deciviews, relative to that based on complete years only. As a result, the highest and lowest deciview readings from incomplete years may be included in tracking progress calculations, provided they meet the criteria outlined above. This inclusion is analogous to the policy represented in provisions of Appendices K, M, and N to 40 CFR 50 regarding particulate matter and makes use of incomplete years to provide more accurate estimates for tracking progress.

In any 5-year period of baseline or current conditions, there should be at most 2 incomplete years of data. One process for using an incomplete year of data is as follows. First, calculate quarterly average deciview values from those years with complete data (i.e., the 3 or more years meeting the data completeness criteria). Second, substitute the appropriate quarterly average deciview values for all sampling days in an incomplete year that have some missing data, or even days with no data at all. The purpose of this substitution is to fill in the middle of the data set from the incomplete year to define the 20% highest and lowest values. Consequently, substituting even for days with no data is appropriate. Third, sort all deciview values within each incomplete year and calculate the averages of the 20% best and 20% worst visibility days. Finally, if the average deciview value of the 20% worst days in the incomplete year is higher than the corresponding average calculated from all the complete years, then include the average from the incomplete year along with those from the complete years and calculate a new 5-year average. Similarly, if the average deciview value of the 20% best days in the incomplete year is lower than the corresponding average calculated from all the complete years, then include the average from the incomplete year along with those from the complete years, and calculate a new 5-year average.

3. METHOD TO CALCULATE THE HAZE INDEX

3.1 What causes haze?

Haze is caused by the presence of particles and gases in the air which either absorb or scatter light. Light reflected from landscape features is scattered and absorbed (attenuated) as it passes through the atmosphere toward the observer, and other light is scattered into the observer's sight path by the intervening atmosphere. The degree to which light is attenuated by these scattering and absorption processes can be expressed in terms of a coefficient of light extinction, b_{ext}. Absorption of light due to gases, b_{ag}, is caused primarily by the presence of nitrogen dioxide (NO_2) in the atmosphere, and absorption due to particles, b_{ap}, is caused primarily by elemental carbon (also called light absorbing carbon). Scattering by gases in the atmosphere, b_{sg}, is described by the Rayleigh scattering theory [van de Hulst, 1957] and is referred to as Rayleigh scattering. The magnitude of Rayleigh scattering varies depending on air density and the wavelength of light. To simplify comparisons of values among sites at a variety of elevations, the IMPROVE program assumes a standard value of 10 Mm^{-1} for Rayleigh scattering in visibility calculations regardless of site elevation. Scattering by particles, b_{sp}, is caused by both fine and coarse aerosol species and is the largest contributor to total light extinction in most rural locations [Malm et al., 1994a]. The sum of these individual coefficients provides the overall light extinction coefficient, b_{ext}, which is used to calculate the haze level.

3.2 How are haze levels calculated?

Tracking of trends for the regional haze rule requires the calculation of haze levels, in deciview units, from measured particle species concentrations representative of each mandatory Federal Class I area. The species concentrations needed are routinely measured by the IMPROVE network at selected mandatory Federal Class I areas across the United States. Under IMPROVE protocols, particle measurements are made every third day on a 24-hour integrated sampling interval, starting at midnight. $PM_{2.5}$ (particulate matter < 2.5 μm aerodynamic diameter) and PM_{10} (particulate matter < 10 μm aerodynamic diameter) mass are measured at all sites, with chemical speciation provided for the $PM_{2.5}$ fraction. The chemical speciation results provide concentration values for the major chemical constituents of $PM_{2.5}$ (i.e., sulfate, nitrate, organic carbon, elemental carbon, and soil). The species concentrations are used along with site-specific correction factors to correct for the effects of relative humidity, and species-specific extinction efficiencies to account for the different degree to which each species causes light extinction, to determine daily overall light extinction values. These total light extinction values (expressed as b_{ext}) are then used to calculate the haze index in terms of deciviews. Figure 3-1 summarizes this process.

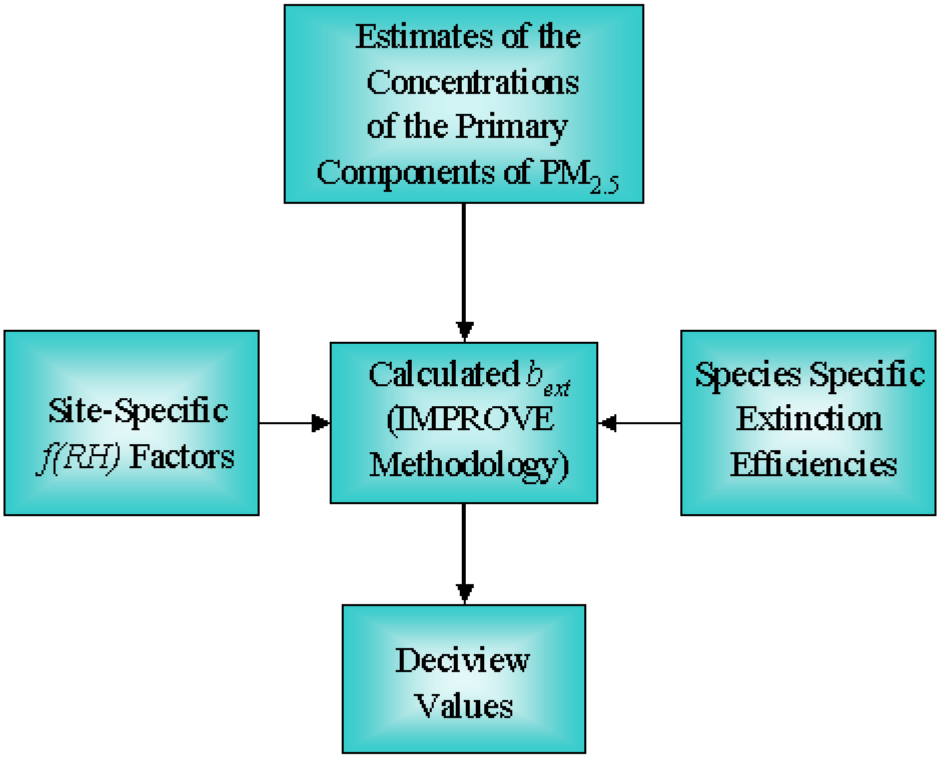

Figure 3-1 Summary of Process to Calculate Haze Index

3.3 How are the monitoring data used for the calculation of b_{ext} obtained?

The IMPROVE network has monitoring sites at 110 locations to monitor conditions representative of the 155 mandatory Federal Class I areas. At each of the sites, an IMPROVE sampler is operated. These samplers each have 4 modules (identified as A, B, C, and D) which are used to collect particulate matter samples for chemical or gravimetric analysis. Modules A, B, and C collect fine particles (0-2.5 µm), and D collects PM_{10} particles (0-10 µm). The Module A Teflon filter is the primary filter for providing the fine particle mass data. Module B, with a denuder before the nylon filter to remove acidic gases, is used primarily for nitrate. Module C collects samples on quartz filters which are analyzed for carbon in eight temperature fractions and used to determine both organic carbon and light absorbing carbon concentrations. At some sites Module C uses a single quartz filter to collect samples whereas other sites use tandem quartz filters for quality assurance purposes.

Sulfate ion concentration is determined by multiplying the concentration of elemental sulfur, as determined from proton induced x-ray emission (PIXE) analysis of the Module A sample, by 3 to account for the oxygen in the sulfate ion. When elemental sulfur data are not available, sulfate measured by ion chromatographic analysis of the Module B sample can be used to determine the dry sulfate concentration.

Fine particle sulfate content originates predominantly from atmospheric oxidation of sulfur dioxide to sulfuric acid, either by aqueous reactions in cloud droplets or through gas-phase photochemistry. If there is inadequate ammonia in the atmosphere to fully neutralize the sulfuric acid, then the resulting aerosols are acidic. Depending on the ammonia available, solutions of varying acidity may be formed, ranging from ammonium sulfate (fully neutralized) to sulfuric acid. If only the sulfate ion is measured, as is the case at nearly every IMPROVE site, then one must assume a form of sulfate (i.e., a degree of neutralization by ammonia) and multiply by an appropriate multiplication factor, for instance, 1.375 * $[SO_4^{2-}]$, if ammonium sulfate is assumed as is the case for the IMPROVE program.

The mass of organic material present can be calculated from the measured $PM_{2.5}$ OC mass, which is determined by thermal optical reflectance (TOR) analysis [Chow, et al., 1993]. An average ambient particulate organic compound is assumed to have a constant fraction of carbon by weight. Organic carbon mass concentration (OMC) is simply:

$$[OMC] = (1.4)[OC] \tag{1}$$

where the factor of 1.4 was selected to adjust the organic carbon mass for other elements assumed to be associated with the organic carbon molecule [White and Roberts, 1977; Japar et al., 1984].

Light absorbing carbon (LAC), sometimes referred to as elemental carbon (EC), is also determined by TOR analysis and is calculated from the sum of elemental carbon fractions minus the pyrolized fraction.

Nitrate ion concentration is determined by ion chromatographic analysis of the sample collected in Module B. Assuming that the nitrate ion is associated with ammonium nitrate aerosol, $[NH_4NO_3]$, the ammonium nitrate mass, [NITRATE], can be estimated from the nitrate ion mass concentration by using a multiplication factor of 1.29, which accounts for the mass ratio of NH_4NO_3 to NO_3^-.

Soil mass concentration, [SOIL], is estimated by summing the mass of those elements predominantly associated with soil, with allowance for oxygen present in the common compounds (e.g., Al_2O_3, SiO_2, CaO, K_2O, FeO, Fe_2O_3, TiO_2) as shown in Equation 2:

$$\begin{aligned}[SOIL] &= 2.2[Al] + 2.49[Si] + 1.63[Ca] \\ &+ 2.42[Fe] + 1.94[Ti]\end{aligned} \tag{2}$$

Since potassium can originate from wood smoke as well as from soil, iron is used as a surrogate for determining [SOIL]. The concentrations of these elements are determined by analysis of the Module A sample by PIXE. In addition, a correction is applied for other compounds such as MgO, Na_2O, and carbonate [Malm, et. al., 1994a].

Coarse particle mass (CM) is estimated gravimetrically by subtracting the gravimetric fine mass ($PM_{2.5}$ from Module A) from total gravimetric mass (PM_{10} from Module D); - i.e., in the IMPROVE program, no additional chemical analyses are carried out on the coarse fraction.

3.4 What are the species mass extinction efficiencies for aerosol components?

$$[CM] = [PM_{10}] - [PM_{2.5}] \tag{3}$$

The goal of tracking progress guidance is to evaluate changes in haze or visibility attributed to various aerosol species. However, as noted by White [1986], attribution of atmospheric extinction to aerosol species is an ill-defined problem. Whereas the sum of mass associated with each aerosol species is roughly equal to gravimetric mass, and therefore fractional contribution of each species to total mass can be calculated, the same is not generally true for extinction. Because two or more species can be mixed together in a variety of ways into a single particle with different optical properties (internally mixed) it is not possible to state, in a general way, the amount of extinction attributed to the individual species. Moreover, a review of the literature reveals that single particle efficiency as it relates to the removal of radiant energy as it passes through the atmosphere is defined in a multiplicity of ways [van de Hulst, 1957; Ouimette and Flagan, 1982; White, 1986; Malm and Kreidenweis, 1997]. Ouimette and Flagan [1982] define an extinction efficiency as the change in extinction associated with the addition or removal of a fraction of a specific species and White [1986] argues that the most meaningful species extinction efficiency is associated with the decrease in total extinction resulting from an incremental removal of that species from the atmosphere. These parameters can be highly dependent on assumptions concerning particle size, mixing characteristics, and chemical and optical properties which are rarely if ever measured. A full discussion of the various concepts is beyond the scope of this guidance.

For tracking progress, a simple and straightforward approach for estimating aerosol species contribution to extinction is outlined. Most routine aerosol monitoring programs and many special study visibility characterization programs were designed to measure bulk aerosol species mass concentrations such as sulfates, nitrates, carbonaceous material, and selected elements [White and Roberts, 1977; Heisler et al., 1980; Malm et al., 1994b; Tombach and Thurston, 1994; Watson et al., 1990; Macias et al., 1981]. They were not designed to determine the microphysical and chemical characteristics of these species. Any particle in the atmosphere scatters and/or absorbs a specific fraction of radiant energy, whether it is externally or internally mixed. When computing total extinction, the microscopic structure of the aerosol (that is, the extent of internal or external mixing) is found to be relatively unimportant, so that the assumption of internally vs. externally mixed particles does not have much impact on the predicted results. This insensitivity to total scattering/extinction has been demonstrated by a number of authors, including Hasan and Dzubay [1983], Sloane [1983], and, more recently, Pilinis et al. [1995], and McMurry et al. [1996].

$$b_{ext} = \sum_i \alpha_i m_i f_i(RH) \tag{4}$$

Therefore, the calculation of light extinction from aerosol species concentrations treats each species contribution separately and merely sums them. This formulation implies no interaction between the various aerosol species with respect to their contributions to extinction. This would be the case if each of the particles were composed of only one species (e.g., sulfate particles separate from nitrate particles which are separate from organic carbon particles, etc.). In general the extinction contribution for each species is modeled as the product of three factors: the dry mass extinction efficiency for that species (α_i), the relative humidity adjustment term that varies as a function of relative humidity for that species ($f_i(RH)$), and the dry concentration of that species (m_i):

> where α_i, the dry mass extinction efficiency, is defined to be the ratio of the total extinction associated with species *i* divided by its mass and the relative humidity adjustment factor, $f_i(RH)$, is defined to be the ratio of scattering by a species at some relative humidity to scattering by that species under dry conditions, i.e., $f_i(RH) = b_{spi}(RH)/b_{spi}(RH=0)$ where i refers to the i^{th} species.

The extinction efficiencies for soil and coarse mass are taken from a literature review by Trijonis and Pitchford [1987]. For soil, the dry extinction efficiency of 1 m^2/g is used, and for coarse mass, a value of 0.6 m^2/g is used. For both nitrate and sulfate, a dry extinction efficiency of 3 m^2/g is based on literature reviews by Trijonis et al. [1990] and by White [1990]. Trijonis' best estimate for sulfates and nitrates is 2.5 m^2/g with an error factor of 2, while White's average low and high estimates for the rural West are 3.0 and 3.7 m^2/g respectively. For organic carbon mass, Trijonis estimates a dry extinction efficiency of 3.75 m^2/g, again with an error factor of 2, and White's low and high average estimates for the rural West are 1.8 and 4.1 m^2/g respectively. Based on these estimates, a dry extinction efficiency of 4 m^2/g is used. More recently, Malm et al. [1996] and Chow et al. [2002] demonstrated that the assumption of the dry specific scattering values yielded good agreement between measured and calculated extinction across the entire IMPROVE monitoring network.

3.5 What effect does relative humidity have on the haze levels?

Some aerosol components are hygroscopic (principally sulfates and nitrates), meaning that particles composed of those materials grow in size by accumulating water from the atmosphere under moist conditions. This causes an enhanced amount of light scattering that is directly related to the atmospheric relative humidity. Implicit to the use of Equation (4) is an assumed linear relationship between aerosol species mass and extinction. However, the relationship between measured light scattering and hygroscopic species mass can be quite nonlinear because of water uptake as a function of relative humidity. A number of authors have attempted to linearize the model, in an empirical way, by multiplying the hygroscopic species by such a factor as 1/(1-RH) to account for the presence of water mass [White and Roberts, 1977; Malm et al., 1989]. However, Malm et al. [1989] and Gebhart and Malm [1989] proposed a different approach. They multiplied the hygroscopic species by a relative humidity scattering enhancement factor, $f(RH)$, that is calculated on a sampling-period-by-sampling-period basis using Mie theory, an assumed size distribution, and laboratory measured aerosol growth curves which illustrate the size of aerosol particles as a function of relative humidity.

Tang [1996] published growth curves showing the ratio of particle diameter to particle diameter at zero relative humidity, D/D_o, as a function of increasing and decreasing relative humidity for a number of inorganic salts. For increasing or decreasing RH, many salts exhibit a hysteresis in the D/D_o vs. RH relationship, with sharp discontinuities at the deliquescence (relative humidity at which the crystal abruptly absorbs water) and crystallization (relative humidity at which particles abruptly lose water and recrystalize) humidities. Because mixtures of ammoniated sulfate compounds with other species have been shown to be hygroscopic below the deliquescent values [Sloane, 1984; Sloane, 1986; Stelson and Seinfeld, 1982; Chow et al., 2002] and because the growth factor and light-scattering efficiency for ambient aerosols has previously been observed to be rather smooth [Sloane, 1984; Sloane, 1986; Sloane, 1983; Wexler and Seinfeld, 1991; Waggoner et al., 1981; Day et al., 2000; Malm et al., 2000a; Malm et al., 2000b; Malm and Day, 2001], it is not known whether the upper or lower limb of the hysteresis curve applies for a particular aerosol sample. Therefore, as a “best estimate” for the sulfate species growth, the curves are smoothed between the deliquescence and crystallization points.

Malm et al. [2000 a, b] and Malm and Day [2001] have demonstrated that in both the East and West, the best estimate growth curves yield good agreement between measured and theoretically predicted *f(RH)* functions and between measured and predicted ambient fine particle scattering. It is recognized that the sulfate *f(RH)* function is quite different for the East than West because of sulfate ammoniation. In the East where sulfates can be quite acidic, average growth of the sulfate aerosol begins at much lower relative humidities (<30%) than in the West. In the Colorado Plateau region of the West, growth does not typically initiate until about 40-50% relative humidity. However, because ammonium mass concentration is not routinely measured in the IMPROVE program, ammonium sulfate is assumed as the form of sulfate and the “smoothed” ammonium sulfate growth curve is used for estimating sulfate *f(RH)* curves. This smooth curve is illustrated in Figure 3-2, which shows the *f(RH)* for ammonium sulfate as a function of relative humidity. The data are listed in Appendix A-1.

The value of *f(RH)* rises very slowly from 1 as the relative humidity increases, only reaching 2 at about 70% relative humidity. However, *f(RH)* is non-linear and increases rapidly as it approaches 100% relative humidity (at which point it is undefined). For example, *f(RH)* is 4 at about 90% relative humidity and increases to 7.5 at about 95% relative humidity. The importance of this effect is illustrated by considering that the same concentration of sulfate aerosol is responsible for 4 times the haze at 95% relative humidity as at 70% relative humidity.

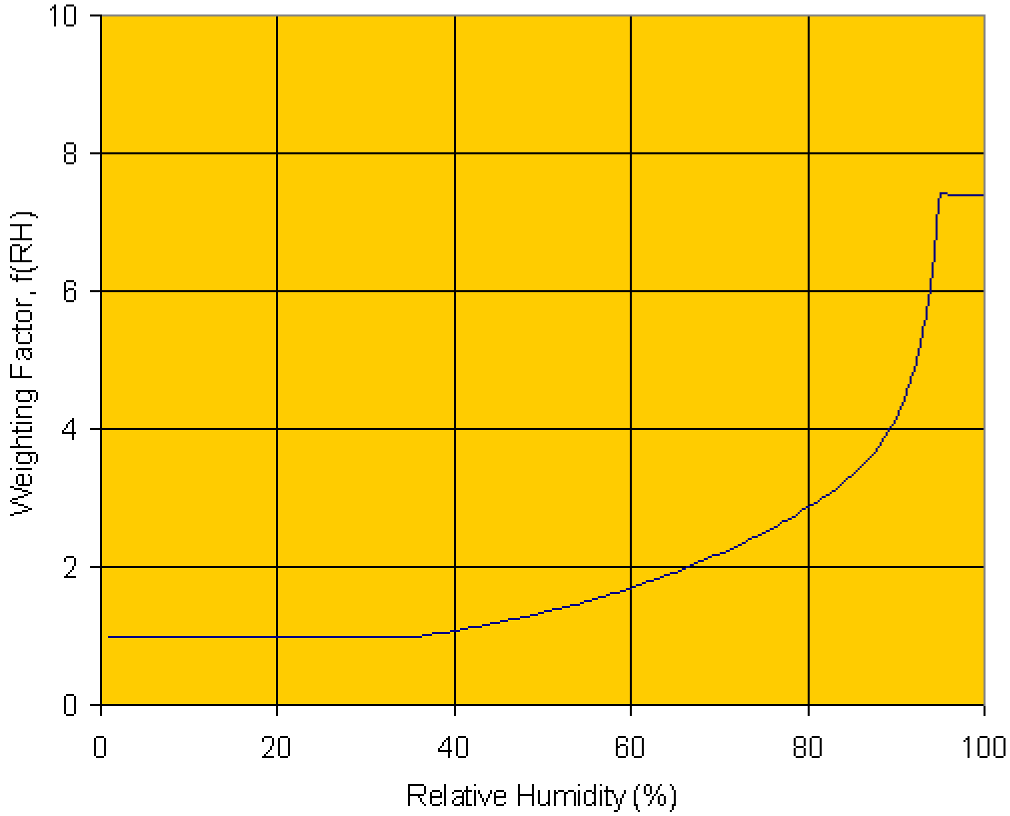

Figure 3-2 Smoothed Ammonium Sulfate *f(RH)* Curve

Various functions for the hygroscopicity of particulate organic compounds have also been proposed. Assumptions must be made about the fraction of organics that are soluble. Models that treat water uptake for non-ideal multicomponent solutions using theoretical and semi-theoretical thermodynamic relationships have been developed and have been applied to both visibility and climate forcing problems [Saxena and Peterson, 1981; Pilinis et al., 1995; Saxena et al., 1986, 1993]. The correct treatment of the hygroscopicity of species in multicomponent mixtures (especially organic species) remains problematic, not only because of the lack of suitable mixture thermodynamic data but also because of the lack of information about other critical mixture properties.

Scientists have experimentally measured growth of ambient particles as a function of relative humidity using tandem differential mobility analyzers (TDMA) in non-urban settings

[Zhang et al., 1993; 1994; Swietlicki et al., 1999]. One study was carried out in Meadview, Arizona (west end of Grand Canyon) over a 31-day period during the summer of 1991, a second at Hopi Point, Arizona (midpoint of Grand Canyon), over a 13-day period during the winter of 1990, and a third at Claremont, California, over an 11-day period during the summer of 1987 [Cai et al., 1993; Zhang et al., 1993, 1994; McMurry and Zhang, 1991]. A TDMA consists of two DMAs operated in series. The first DMA is used to select a size, while the second is used to measure the change in particle size as relative humidity is varied. Usually, a MOUDI size sampler [Marple et al., 1991] is run concurrent with the TDMA to derive estimates of particle composition.

Based on their modeling assumptions, Saxena et al. [1995] concluded that at the Grand Canyon, aerosol organic species increased water absorption by inorganic species, while at Claremont the net effect of organics was to diminish water absorption by inorganics. On the other hand, Pitchford and McMurry [1994] showed that on 6 of the 8 sampling days at the Grand Canyon study cited above, if it is assumed that nitrates and sulfates uptake water at the same rate as measured in the laboratory, they alone could account for all of the measured water absorption.

Swietlicki et al.[1999] made TDMA measurements in Northern England and found growth to take place in two modes, one mode being less hygroscopic than the other. They concluded that growth could be attributed to the inorganic content of the aerosol. Cocker et al. [2001] measured hygroscopic properties of Pasadena, California, aerosol and concluded that growth factors increased when forest fires were present. However, they were unable to attribute the growth to any single species because concurrent aerosol speciation was not carried out simultaneously.

McDow et al. [1994] measured water uptake by diesel soot, automobile exhaust, and wood smoke particles. They found all three emission types absorbed water, with the wood smoke sample weight increasing by about 10% as sample relative humidities increased, whereas diesel soot sample weight increased by only 2%-3%.

Chughtai et al. [1999] examined the hydration characteristics of BP2000 (commercially available carbon black), and of carbon produced from n-hexane, diesel fuel, JP8 (aviation fuel), pine needles, Utah coal, and acetylene. They examined water adsorption isotherms between 20% and 85% relative humidity and concluded that the ability of black carbons, produced from a variety of fuel types, to adsorb water generally increased with age and surface oxidation. At high relative humidity (83%), large surface areas determine the adsorption capacity. At lower relative humidity, however, the surface functional groups determine the extent of hydration. Even at 83% relative humidity, the water uptake was less than 10% of total mass for all carbon species other than BP2000. Because of its large surface area, BP2000 absorbed about 40% of its mass in water. Consequently, they concluded that commercial carbon blacks are not acceptable models for fuel-produced carbons.

Field experiments and subsequent data analysis at the Great Smoky Mountains and Grand Canyon National Parks [Malm et al., 1997; Malm and Kreidenweis, 1997; Malm et al., 2000 a, b] and, more generally, data collected in the IMPROVE network [Malm et al., 1996] show that within the uncertainty of the measurements and modeling assumptions, ambient organics in rural areas of the United States are at most only weakly hygroscopic. Therefore, based on the available data, the *f(RH)* for aerosol organics can be reasonably set equal to one.

The additive extinction by chemical species embodied in Equation 4 can be combined with the effect of RH discussed above, to estimate the scattering of light by fine particles. The following equation is used to estimate calculated particle light scattering:

$$\begin{aligned} b_{sp} &= (3) f_{SO4}(RH)[SULFATE] \\ &+ (3) f_{NO3}(RH)[NITRATE] \\ &+ (4) f_{org}(RH)[OMC] \\ &+ (1)[SOIL] \\ &+ (0.6)[CM] \end{aligned} \tag{5}$$

The brackets in Equation 5 indicate the species concentration, 3 m^2/g is the dry specific scattering efficiency for sulfates and nitrates, 4 m^2/g is the dry specific scattering efficiency for organic mass, and 1 m^2/g and 0.6 m^2/g are the respective scattering efficiencies for soil and coarse mass.

3.6 How are the f(RH) values determined?

Average $f_{SO4}(RH)$ values for each sampling period are calculated based on the ambient humidity, using Tang's [1996] ammonium sulfate growth curves. Assuming a lognormal sulfate mass size distribution, with a geometric mass mean diameter of 0.3 µm and a geometric standard deviation, σ_g, of 2.0, the $f_{SO4}(RH)$ values are calculated using D/D_o curves that are smoothed between the crystallization and deliquescent points. The $f_{NO3}(RH)$ associated with nitrates is assumed to be the same as for sulfates, while $f_{org}(RH)$ for organics is set equal to 1.0.

To assess the changes in man-made pollution contributions to visibility impairment, it is appropriate to use relative humidity that is the same for the baseline period and future periods with changed emissions. In other words, it is more appropriate to eliminate the confounding effects of interannual variations in relative humidity, while maintaining typical regional and seasonal humidity patterns.

To that end, the U.S. EPA recently 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 for each mandatory Federal Class I area.[9] The hourly RH measurements from each site were converted to *f(RH)* values using a non-linear weighting factor curve (see Figure 3-2). Values above 95% RH were set equal to the *f(RH)* corresponding to 95% RH.

The results of that work are the values presented in Appendix A. These relative humidity factors have been calculated from available hourly relative humidity data from 292 National Weather Service stations across the 50 States and the District of Columbia as well as from 29 IMPROVE and IMPROVE protocol monitoring sites, 48 Clean Air Status and Trends Network (CASTNet) sites, and 13 additional sites administered by the National Park Service. Using a software tool available from EPA, monthly *f(RH)* values can be calculated for any location in the United States. 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 associated listed for each mandatory Federal Class I area in this way are recommended to be used for all visibility and tracking progress calculations for that Class I area. These values are provided in Table A-2. A supplemental table of 12 monthly-averaged *f(RH)* values for each mandatory Federal Class I area is also provided in Table A-3 for informational purposes.

Appendix B examines within-month correlations that may exist between RH and inorganic aerosol concentrations and the potential effect on the computed haze index. If the correlations are significant, then the use of monthly-average *f(RH)* could systematically over- or under-predict the contribution of sulfate or nitrate to visibility impairment The results in Appendix B show that monthly average *f(RH)* values are appropriate. The difference in computed haze index values resulting from the use of monthly values of *f(RH)* vs. 24 hr values, is within 10% for 20 IMPROVE sites studied.

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[9] U.S. EPA, *Interpolating Relative Humidity Weighting Factors to Calculate Visibility Impairment and the Effects of IMPROVE Monitor Outliers*, prepared by Science Applications International Corporation, Raleigh, NC, EPA Contract No. 68-D-98-113, August 30, 2001.

3.7 How does light absorption contribute to light extinction?

Light absorption by gaseous species, primarily NO_2, is generally negligible in mandatory Federal Class I areas and not included in calculations of light extinction. However, estimating the total light extinction also requires a knowledge of light absorption by particles. Light absorption by particles is primarily due to elemental carbon (also called light-absorbing carbon). Horvath [1993] has reviewed the measurement of light absorption by elemental carbon, while Fuller et al. [1999] has explored theoretically the variability of absorption efficiency as a function of carbon morphology. Estimated mass absorption efficiencies of elemental carbon vary by more than a factor of two, as do direct measurements. Although particle light absorption can be estimated in a variety of ways, there is no one method that is generally accepted by the scientific community. For purposes of this guidance, elemental carbon light absorption is estimated using:

$$b_{ap} = 10\left[LAC\right] \quad \textbf{(6)}$$

were LAC is the concentration of light-absorbing carbon as measured using the Thermal Optical Reflectance (TOR) analysis method [Chow et al., 1993], and 10 is the specific absorption efficiency for LAC, which has been used by a number of scientists [Horvath, 1993].

3.8 How is the total light extinction calculated?

In addition to particle scattering and particle absorption, total light extinction needs to include a term b_{sg}, i.e., for Rayleigh scattering, which is scattering by the gas molecules in the atmosphere. Thus, $b_{ext} = b_{sp} + b_{ap} + b_{sg}$. As indicated in Section 3.7, carbon light absorption is estimated as ten times the concentration of light-absorbing carbon for the purposes of the guidance. A standard value of $10Mm^{-1}$ for Rayleigh scattering is used in visibility calculations regardless of site elevation in keeping with the practice of rounding each constant in the aerosol extinction calculation to one significant digit and to simplify comparisons of values among sites at a variety of elevations.

Combining all of the factors discussed above, the following equation converts particle species concentration data in units of μg/m^3 for a sample period at a monitoring location to total light extinction in units of Mm^{-1}.

$$\begin{aligned} b_{ext} = {} & (3)f(RH)[SULFATE] + \\ & (3)f(RH)[NITRATE] \\ & +(4)[OMC] \\ & +(10)[LAC] \\ & +(1)[SOIL] \\ & +(0.6)[CM] \\ & +10 \end{aligned} \tag{7}$$

Malm et. al. [1996] used this IMPROVE algorithm to successfully reconstruct scattering at nine sites, namely Grand Canyon, Petrified Forest, Guadalupe Mountains, Yellowstone, Rocky Mountain, Glacier, Pinnacles, Bandelier National Parks, and the Bridger Wilderness Area. Additionally, comparisons were made between calculated and measured extinction at Acadia and Shenandoah National Parks for the time period 1988-1991. Those results were reported in the February 1993 IMPROVE report "Spatial and Temporal Patterns and the Chemical Composition of the Haze in the United States," ISSN No. 0737-5352-26. Finally, Chow et al. [2002] has compared measured and calculated scattering at the Great Smoky Mountains National Park for the time period 1994-2000 and found that, on average, nephelometer measured scattering is about 6% larger than calculated scattering, and the RMS error was 23%.

3.9 How are haze index values in deciview units calculated?

Once the light extinction has been calculated for a monitoring site, using Equation 7, the haze index (*HI*) in deciview (*dv*) units can be calculated. The *HI* is a visibility metric based on the light-extinction coefficient that expresses incremental changes in perceived visibility [Pitchford and Malm, 1994]. Because the *HI* expresses a relationship between changes in light extinction and perceived visibility, it can be useful in describing visibility trends. A change in the *HI* of one *dv* is equivalent to about a 10% change in extinction coefficient, which is a small but perceptible scenic change under a wide range of visibility conditions. The *HI* is defined by the following equation:

$$HI = 10\ln(b_{ext}/10) \tag{8}$$

The value of the haze index is near zero dv for a pristine atmosphere (*dv* = 0 for a pure Rayleigh scattering condition) and increases as visibility is degraded.

3.10 Should outliers in the data be excluded?

Each annual estimate of best and worst days should be based on all valid measured aerosol concentrations during the calendar year. This includes high concentrations associated with regional forest fires or other unusual events. An analysis of IMPROVE data[10] collected during 1994-1998 revealed that by excluding outliers (measurements greater than 2 standard deviations from the mean of the 20% worst days) from the calculation of the 5-year mean for the 20% worst visibility days, the mean haze index changed by 0.3% at Great Smoky Mountains and by 2.5% at Great Sand Dunes. Changes at other sites were between these two values. Similarly, changes in the calculated 5-year mean haze index resulting from the exclusion of outliers in the 20% best visibility days (measurements greater than 2 standard deviations from the mean of the 20% best days) were between 0.6% (Point Reyes) and 2.9% (Big Bend). Thus the impact from a small number of days tends to average out when the visibility is examined on a deciview scale over a 5-year period. It is important to include these extreme concentrations in the estimates for 5-year baseline and current visibility conditions because the impact from these events may be part of natural background and is thus reflected in the estimate for the target visibility levels. When an outlier in the data is clearly not representative of the regional haze levels, the result should be flagged and an explanation provided of the cause of the outlier. If a very localized fire (for example, a nearby structural fire) severely impacts the loading of a specific sampler but does not degrade the visibility outside of the immediate vicinity (e.g., within 1 mile), the data should be flagged in all data files and calculations. Such occurrences may not be appropriate for inclusion in visibility trends analysis. On the other hand, events which result in apparent outliers in the data and do have an impact on the regional visibility (e.g., forest fires) should be included in subsequent trends analysis. The data should be flagged and explained, if possible, but should remain in the data set. Any supporting evidence which may be used to help quantify the impact of the episode causing the outlier should be collected, if possible.

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[10] Walsh, K. "OUTLIERS AND THEIR EFFECTS ON AVERAGE VISIBILITY IMPAIRMENT CONDITIONS," EPA Contract 68-D-98-113 with Science Applications International Corporation. March 2001.

4. PROCEDURES FOR COMPARING 5-YEAR PERIODS

4.1 How are the daily deciview values, calculated as described in Section 3, used to track progress in improving visibility?

The daily deciview values from the best and worst days in each year are first selected, then averaged over annual and 5-year periods, and finally those 5-year averages are compared to assess progress. This section of the guidance document describes the procedures for carrying out this process.

4.2 How are the selection and averaging of the best and worst days in each year done?

Once the daily deciview values have been calculated for each sampling day at a site, including those days for which missing data were replaced by appropriate averages, the deciview values for each year are ranked from lowest to highest. Then the lowest 20% of the deciview values for the year (i.e., the best 20% of the days in terms of visibility) are averaged, to produce an annual average deciview value for the best 20% of the days. Similarly, the highest 20% of the deciview values for the year (i.e., the worst 20% of the days in terms of visibility) are averaged, giving the annual average deciview value for the worst 20% of the days. The methods used to calculate %iles are based on those found in Interpretation of the National Ambient Air Quality Standards for Particulate Matter (40 CFR 50, Appendix N). After sorting the values from lowest to highest, the 20th %ile value for year y, is given by

$$P_{0.20,y} = X_i$$

where $P_{0.20,\,y}$ is the 20th %ile for year y, X_i = the i^{th} number in the ordered series of n numbers, and i is the integer part of the product of 0.20 and n.

Similarly, the 80th %ile is given by

$$P_{0.80,y} = X_{[i+1]}$$

where $P_{0.80,\,y}$ is the 80th %ile for year y, $X_{[i+1]}$ = the $(i+1)^{th}$ number in the ordered series of n numbers, and i is the integer part of the product of 0.80 and n.

This process should be repeated for each year of data available. Note that the data completeness recommendations stated earlier in this document may eliminate some years from being included in this calculation. For each complete year of data for a site, the results of this calculation are two values, i.e., the average deciview values for the best and worst days, respectively.

4.3 How are the 5-year deciview averages determined?

The annual average deciview values for the 20% best and 20% worst visibility days in each year are further averaged over the 5-year periods specified in the regional haze rule. For example, the baseline 5-year period is 2000-2004. The annual average deciview values for the 20% best days in each year in that period are averaged together, producing a single average deciview value for the best days. Similarly, the annual average deciview values for the 20% worst days in each year in that period are averaged together, producing a single average deciview value for the worst days. Thus each 5-year period is characterized by two values, i.e., the average deciview values for the best and worst days, respectively. These averages over the 2000-2004 time period are the basis against which improvements in worst day visibility and lack of degradation for the best day visibility are judged. Corresponding averages are to be calculated over successive 5-year periods, i.e., 2005-2009, 2010-2014, etc.

Within any specified 5-year period, there should be at least 3 complete years of data from which annual averages are drawn for this calculation of 5-year averages. The calculation of 5-year averages should include all complete years in that period. If a 5-year period has less than three complete years of data, then estimates should be prepared through consultation with EPA/OAQPS.

4.4 What is the nature of the comparison between 5-year average deciview values?

The comparison should be a simple arithmetic comparison of the current 5-year average deciview values to those from the baseline (i.e., 2000-2004) period. The 5-year average deciview values for the 20% worst days are compared to judge progress in improving visibility, and the 5-year average deciview values for the 20% best days are compared to check whether any degradation of visibility on the best days has occurred. The first such SIP comparison will take place in 2018, with an interim progress check in 2013.

4.5 What if siting or procedural changes are implemented at an IMPROVE site?

If siting or procedural changes that may affect the monitoring data at a site occur, care must be taken to ensure the comparability of the monitoring data before and after the change is implemented. When possible, the monitoring agency should conduct comparative sampling adequate to demonstrate data comparability.

4.6 What if changes are made in the sites selected to cover a mandatory Federal Class I area?

Currently, all mandatory Federal Class I areas are covered by at least one IMPROVE monitoring site. The sites chosen to represent the different mandatory Federal Class I areas were chosen in consultation between EPA and the States. If a different site or additional sites are selected to represent a given mandatory Federal Class I area, the calculations presented in this document for trends assessment must be performed using the data from the newly selected monitoring site(s).

4.7 Are trends in the individual species important, as well as the overall trend in visibility?

Though the regional haze regulation calls for tracking of calculated haze expressed in deciview units, the implementation of the haze regulation can only be accomplished by reducing the concentrations of the particulate species that are responsible for the man-made portion of the worst haze days. Towards that end it is especially helpful to also track trends for all of the particle species that contribute to haze. Apportioning the haze to the various particle species contributors is an important first step to assessing which pollutants offer the best haze reduction opportunities for emissions controls. In the long-term, tracking trends of species contributions to haze provides information that can be useful in determining whether implemented emission controls are having the expected effects. Ultimately as the man-made contributions to specific particle species are reduced below those from natural source, natural haze level estimates can be refined.

The contribution to haze by each particle species cannot be determined in terms of the haze index expressed in deciview units, which because of its logarithmic nature cannot appropriately be broken into components. The best approach to assign haze contribution to particle species is by their share of the light extinction expressed in units of inverse megameters (Mm^{-1}) as defined by the individual terms in equation 8. The IMPROVE web site reports the species contribution to light extinction for each site and sample period as well as annual trends at each site for the worst, best, and middle haze days.

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APPENDIX A

Monthly Site-Specific *f(RH)* Values for Each Mandatory Federal Class I Area

APPENDIX A
Origin of Relative Humidity and f(RH) Values

In terms of visibility reduction caused by fine particles, it is appropriate to treat relative humidity differently for different objectives. If the objective is the most reliable short-term estimate of visibility, then the measured or estimated relative humidity for the specific time and location of the aerosol speciation data is most appropriate. On the other hand, if the objective is to assess the long-term changes in man-made visibility impairment, it is appropriate to use relative humidity that is the same for the baseline period and future periods. In other words, it is more appropriate to eliminate the confounding effects of varying relative humidity, if the purpose is to track the visibility effects of air pollution emissions over extended time periods.

A number of approaches were considered to prevent variations in the relative humidity adjustment factor from confounding efforts to track progress related to emission controls. The simplest approach would use the same typical or overall average adjustment factor for all Class I areas at all times. However, this would enhance the contributions of hygroscopic particle species in dry locations and during typically dry seasons above what they truly should be, while reducing their contributions in moist locations and seasons. Such distortions of the contributions to haze by hygroscopic particle species are unnecessary if a set of Class I area-specific adjustment factors are used that reflect seasonal changes in relative humidity.

A second approach would be to review relative humidity data over a long period of time to derive climatological estimates for relative humidity adjustment factors. These climatological estimates would then be used to estimate visibility extinction coefficients. These estimates are more likely to reflect “typical” relative humidity at the different mandatory Federal Class I areas during different times of year and, thus, are more likely to be more appropriate for establishing trends in visibility at the mandatory Federal Class I areas.

Recently, the U.S. EPA sponsored a project to examine measured hourly relative humidity data over a 10-year period within the United States, to derive month-specific climatological mean humidity correction factors for each mandatory Federal Class I area.[1] The results of that work are presented in the table below. These relative humidity factors have been calculated from available hourly relative humidity data from 292 National Weather Service

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[1] U.S. EPA, Interpolating Relative Humidity Weighting Factors to Calculate Visibility Impairment and the Effects of IMPROVE Monitor Outliers, prepared by Science Applications International Corporation, Raleigh, NC, EPA Contract No. 68-D-98-113, August 30, 2001.

stations across the 50 States and the District of Columbia as well as from 29 IMPROVE and IMPROVE protocol monitor sites, 48 CASTNet sites, and 13 additional sites administered by the National Park Service.

The hourly RH measurements from each site were converted to *f(RH)* values using a non-linear weighting factor curve, based on a modified ammonium sulfate growth curve. Values above 95% RH were set equal to the *f(RH)* corresponding to 95% RH. For days in which at least 16 hours of valid RH data were available, daily averages were determined from these hourly *f(RH)* values at each site. Monthly averages were then calculated from the daily *f(RH)* averages at each site.

The monthly average *f(RH)* values were interpolated at 1/4-degree increments using the inverse distance weighting technique (with a distance interpolation exponent of 1):

$$f(RH)_g = \frac{\sum f(RH)_w / x_{wg}}{\sum 1 / x_{wg}}$$

where the monthly $f(RH)_g$ of the grid cell is calculated from $f(RH)_w$ at the weather station, and the horizontal distance between the grid cell center and the weather station, x_{wg}, summed over all the weather stations within a 250-mile radius with valid *f(RH)* values for that month.

In most regions there is a seasonal cycle of relative humidity which is accounted for by this process of appropriate *f(RH)* values for each month of the year from the daily-averaged values. Thus, the 12 monthly-averaged *f(RH)* values determined in this way for each Class I area should be used for all aerosol speciation data or model predictions for that location. However, a more complicated approach has also been investigated, as described below.

The regional haze regulation requires separate tracking of visibility changes for the worst 20% and best 20% of visibility days. If there is a significant correlation in any month at any site between daily relative humidity and the sulfate or nitrate concentrations, then use of the monthly-averaged *f(RH)* will systematically over- or under-predict the contribution to visibility impairment of the aerosol species. Fortunately, this concern can be tested at a number of locations in all regions of the country using the IMPROVE database. If the use of monthly-averaged values were found to cause large systematic biases in any region of the country, the Class I areas in those regions would require two *f(RH)* values for each month. One value would be the average *f(RH)* associated with relative humidity conditions that correspond to the worst 20% and the other value associated with relative humidity conditions that correspond to the best 20% of the light extinction values. Therefore, there is the potential that some Class I area locations could require up to 24 *f(RH)* values for use in calculating extinction for aerosol data.

The U.S. National Park Service has tested this possibility by examining data for each of the 12 months from 20 mandatory Federal Class I areas where relative humidity measurements are made. In nearly all cases, no statistically significant correlations were found between measured concentrations of SO_4^{2-}, NO_3^- and $[SO_4^{2-} + NO_3^-]$ vs. daily values of relative humidity in a large majority of months. Furthermore, deciview calculations were made using day-specific vs. climatological values for the relative humidity adjustment factor for each of 10 years in 15 mandatory Federal Class I areas. In 14 of the 15 areas, little if any difference was observed in the year-to-year calculations for the mean deciview values for the 20% worst and 20% best days, nor was there any difference in the trends. Some difference in the mean deciview value for the worst 20% days was observed in one mandatory Federal Class I area. However, the overall trend in the mean worst and best deciview values for this site was similar using the two types of $f(rh)$ values. These results suggest there is a relatively weak correlation between hygroscopic components of PM and relative humidity and that the choice of a "climatological" vs. "day-specific" method for computing $f(RH)$ has little apparent effect on observed trends in visibility. Consequently, the simpler climatological approach is used in regional haze calculations.

Table A-1 Values for f(RH) Determined from the Growth of Ammonium Sulfate

RH	f(RH)	RH	f(RH)	RH	f(RH)
1	1.00	34	1.00	67	2.03
2	1.00	35	1.00	68	2.08
3	1.00	36	1.00	69	2.14
4	1.00	37	1.02	70	2.19
5	1.00	38	1.04	71	2.25
6	1.00	39	1.06	72	2.31
7	1.00	40	1.08	73	2.37
8	1.00	41	1.10	74	2.43
9	1.00	42	1.13	75	2.50
10	1.00	43	1.15	76	2.56
11	1.00	44	1.18	77	2.63
12	1.00	45	1.20	78	2.70
13	1.00	46	1.23	79	2.78
14	1.00	47	1.26	80	2.86
15	1.00	48	1.28	81	2.94
16	1.00	49	1.31	82	3.03
17	1.00	50	1.34	83	3.12
18	1.00	51	1.37	84	3.22
19	1.00	52	1.41	85	3.33
20	1.00	53	1.44	86	3.45
21	1.00	54	1.47	87	3.58
22	1.00	55	1.51	88	3.74
23	1.00	56	1.54	89	3.93
24	1.00	57	1.58	90	4.16
25	1.00	58	1.62	91	4.45
26	1.00	59	1.66	92	4.84
27	1.00	60	1.70	93	5.37
28	1.00	61	1.74	94	6.16
29	1.00	62	1.79	95	7.40
30	1.00	63	1.83	96	9.59
31	1.00	64	1.88	97	14.1
32	1.00	65	1.93	98	26.4
33	1.00	66	1.98		

Table A-2
Recommended Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area,

Class I Area	Site Name		Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Acadia	Acadia	1	ACAD1	ME	44.38	-68.37	3.2	2.8	2.8	3.2	3.2	3.3	3.7	3.7	3.9	3.5	3.4	3.5
Agua Tibia	Agua Tibia	100	AGTI1	CA	33.38	-116.87	2.4	2.3	2.4	2.2	2.2	2.2	2.2	2.3	2.3	2.2	2.1	2.2
Alpine Lakes	Snoqualmie Pass	80	SNPA1	WA	47.38	-121.37	5.3	5.0	3.7	3.6	4.2	3.1	3.5	3.4	3.8	4.9	5.5	5.3
Anaconda - Pintler	Sula	71	SULA1	MT	45.88	-114.12	3.4	3.0	2.6	2.3	2.3	2.2	1.9	1.8	2.0	2.5	3.3	3.4
Ansel Adams	Kaiser	110	KAIS1	CA	37.13	-119.12	3.0	2.7	2.5	2.1	2.0	1.7	1.7	1.7	1.8	1.9	2.3	2.7
Arches	Canyonlands	50	CANY1	UT	38.38	-109.87	2.6	2.3	1.8	1.6	1.5	1.2	1.3	1.5	1.5	1.6	2.0	2.3
Badlands	Badlands	59	BADL1	SD	43.63	-101.87	2.8	2.8	2.8	2.6	2.8	2.7	2.4	2.4	2.3	2.3	2.9	2.8
Bandelier	Bandelier	33	BAND1	NM	35.88	-106.37	2.3	2.1	1.8	1.6	1.6	1.4	1.7	2.0	1.9	1.7	2.0	2.3
Bering Sea (a)																		
Big Bend	Big Bend	31	BIBE1	TX	29.38	-103.12	1.8	1.7	1.5	1.4	1.5	1.5	1.6	1.8	1.9	1.7	1.7	1.7
Black Canyon of the Gunnison	Weminuche	55	WEMI1	CO	37.63	-107.87	2.5	2.3	2.0	1.7	1.7	1.5	1.7	2.0	1.9	1.7	2.2	2.4
Bob Marshall	Monture	73	MONT1	MT	47.13	-113.12	3.3	2.9	2.6	2.4	2.4	2.4	2.1	2.0	2.3	2.7	3.2	3.3
Bosque del Apache	Bosque del Apache	38	BOAP1	NM	33.88	-106.87	2.2	2.0	1.6	1.4	1.4	1.3	1.7	1.9	1.9	1.6	1.8	2.2
Boundary Waters Canoe Area	Boundary Waters	23	BOWA1	MN	47.88	-91.62	2.9	2.6	2.6	2.3	2.5	2.8	3.0	3.1	3.2	2.7	3.1	3.1
Breton	Breton	20	BRET1	LA	29.13	-89.12	3.5	3.3	3.3	3.3	3.4	3.6	3.8	3.8	3.6	3.4	3.4	3.5
Bridger	Bridger	65	BRID1	WY	42.88	-109.87	2.5	2.3	2.3	2.1	2.1	1.8	1.5	1.5	1.8	2.0	2.5	2.4
Brigantine	Brigantine	5	BRIG1	NJ	39.38	-74.37	2.9	2.6	2.7	2.6	2.9	3.0	3.2	3.4	3.4	3.2	2.8	2.9
Bryce Canyon	Bryce Canyon	49	BRCA1	UT	37.63	-112.12	2.6	2.4	2.0	1.6	1.5	1.3	1.3	1.5	1.5	1.6	2.0	2.4
Cabinet Mountains	Cabinet Mountains	75	CABI1	MT	47.88	-115.62	3.7	3.2	2.8	2.5	2.5	2.4	2.1	2.1	2.4	2.9	3.6	3.8
Caney Creek	Caney Creek	29	CACR1	AR	34.38	-94.12	3.3	3.0	2.7	2.8	3.2	3.2	3.0	3.0	3.2	3.2	3.1	3.3
Canyonlands	Canyonlands	50	CANY1	UT	38.38	-109.87	2.6	2.3	1.8	1.6	1.5	1.2	1.3	1.5	1.5	1.6	2.0	2.3
Cape Romain	Cape Romain	15	ROMA1	SC	32.88	-79.62	3.2	2.9	2.8	2.7	2.9	3.3	3.3	3.6	3.5	3.4	3.1	3.1
Capitol Reef	Capitol Reef	52	CAPI1	UT	38.38	-111.37	2.7	2.5	2.0	1.7	1.6	1.4	1.4	1.6	1.6	1.7	2.1	2.5
Caribou	Lassen Volcanic	90	LAVO1	CA	40.63	-121.62	3.7	3.1	2.8	2.4	2.3	2.1	2.0	2.0	2.1	2.3	3.1	3.5
Carlsbad Caverns	Guadalupe Mountains	32	GUMO1	TX	31.88	-104.87	2.4	2.0	1.6	1.4	1.6	1.5	1.9	2.2	2.4	1.7	1.9	2.3
Chassahowitzka	Chassahowitzka	18	CHAS1	FL	28.63	-82.62	3.5	3.2	3.1	3.0	3.0	3.5	3.5	3.7	3.7	3.5	3.4	3.6
Chiricahua NM	Chiricahua	39	CHIR1	AZ	32.13	-109.37	2.0	1.9	1.6	1.2	1.2	1.1	1.7	2.0	1.7	1.5	1.6	2.1
Chiricahua W	Chiricahua	39	CHIR1	AZ	32.13	-109.37	2.0	1.9	1.6	1.2	1.2	1.1	1.7	2.0	1.7	1.5	1.6	2.1
Cohutta	Cohutta	12	COHU1	GA	34.88	-84.62	3.4	3.1	2.9	2.7	3.2	3.6	3.6	3.7	3.7	3.5	3.2	3.4
Crater Lake	Crater Lake	86	CRLA1	OR	42.88	-122.12	4.6	4.0	3.7	3.5	3.2	2.9	2.6	2.7	2.9	3.6	4.6	4.7
Craters of the Moon	Craters of the Moon	69	CRMO1	ID	43.38	-113.62	3.1	2.7	2.3	2.0	2.0	1.8	1.4	1.4	1.6	2.0	2.7	3.0
Cucamonga	San Gabriel	93	SAGA1	CA	34.38	-118.12	2.6	2.5	2.5	2.2	2.2	2.1	2.2	2.2	2.3	2.2	2.2	2.3
Denali	Denali	102	DENA1	AK	63.75	-148.75	2.5	2.3	2.1	1.9	1.8	2.1	2.5	2.9	2.8	3.0	2.9	3.0

Table A-2
Recommended Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area,

Class I Area	Site Name		Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Desolation	Bliss	95	BLIS1	CA	38.88	-120.12	3.2	2.8	2.5	2.0	1.9	1.6	1.5	1.5	1.7	1.8	2.4	3.0
Diamond Peak	Crater Lake	86	CRLA1	OR	42.88	-122.12	4.6	4.0	3.7	3.5	3.2	2.9	2.6	2.7	2.9	3.6	4.6	4.7
Dolly Sods	Dolly Sods	8	DOSO1	WV	39.13	-79.37	3.0	2.7	2.7	2.5	3.5	3.1	3.2	3.5	3.5	3.1	2.8	3.1
Dome Land	Dome Land	109	DOME1	CA	35.63	-118.12	2.6	2.3	2.2	1.9	1.9	1.8	1.8	1.8	1.9	1.9	2.0	2.2
Eagle Cap	Starkey	76	STAR1	OR	45.13	-118.62	4.3	3.8	3.2	2.9	2.7	2.4	2.0	2.1	2.4	3.3	4.2	4.5
Eagles Nest	White River	56	WHRI1	CO	39.13	-106.87	2.2	2.2	2.0	2.0	2.0	1.7	1.8	2.1	2.1	1.8	2.1	2.1
Emigrant	Yosemite	96	YOSE1	CA	37.63	-119.62	3.0	2.9	2.7	2.2	2.1	1.7	1.5	1.5	1.6	1.8	2.3	2.7
Everglades	Everglades	19	EVER1	FL	25.38	-80.62	2.6	2.5	2.5	2.3	2.3	2.6	2.5	2.8	2.9	2.7	2.5	2.6
Fitzpatrick	Bridger	65	BRID1	WY	42.88	-109.87	2.5	2.3	2.3	2.1	2.1	1.8	1.5	1.5	1.8	2.0	2.5	2.4
Flat Tops	White River	56	WHRI1	CO	39.13	-106.87	2.2	2.2	2.0	2.0	2.0	1.7	1.8	2.1	2.1	1.8	2.1	2.1
Galiuro	Chiricahua	39	CHIR1	AZ	32.13	-109.37	2.0	1.9	1.6	1.2	1.2	1.1	1.7	2.0	1.7	1.5	1.6	2.1
Gates of the Mountains	Gates of the Mountains	74	GAMO1	MT	46.88	-111.62	2.8	2.5	2.4	2.3	2.3	2.2	2.0	1.9	2.1	2.4	2.7	2.7
Gearhart Mountain	Crater Lake	86	CRLA1	OR	42.88	-122.12	4.6	4.0	3.7	3.5	3.2	2.9	2.6	2.7	2.9	3.6	4.6	4.7
Gila	Gila Cliffs	42	GICL1	NM	33.13	-108.12	2.1	1.9	1.6	1.3	1.3	1.2	1.9	1.9	1.8	1.6	1.8	2.2
Glacier	Glacier	72	GLAC1	MT	48.63	-114.12	3.9	3.4	3.1	2.9	3.0	3.0	2.5	2.5	3.0	3.3	3.7	3.8
Glacier Peak	North Cascades	81	NOCA1	WA	48.63	-121.12	4.5	4.1	3.6	3.4	3.3	3.0	2.9	3.1	3.5	4.2	4.7	4.7
Goat Rocks	White Pass	79	WHPA1	WA	46.63	-121.37	4.8	4.2	3.8	3.6	3.4	3.1	2.9	3.0	3.5	4.3	4.9	5.0
Grand Canyon	Grand Canyon, Hance	48	GRCA2	AZ	35.88	-111.87	2.5	2.4	2.0	1.6	1.4	1.2	1.4	1.7	1.7	1.7	2.0	2.3
Grand Teton	Yellowstone	66	YELL2	WY	44.63	-110.37	2.5	2.3	2.2	2.1	2.1	1.9	1.7	1.6	1.8	2.1	2.4	2.5
Great Gulf	Great Gulf	4	GRGU1	NH	44.38	-71.12	2.8	2.6	2.6	2.8	2.9	3.0	3.3	3.5	3.6	3.2	3.0	2.9
Great Sand Dunes	Great Sand Dunes	53	GRSA1	CO	37.63	-105.62	2.4	2.3	2.0	1.9	1.9	1.7	1.9	2.3	2.2	1.9	2.3	2.4
Great Smoky Mountains	Great Smoky Mountains	10	GRSM1	TN	35.63	-83.87	3.6	3.0	3.0	2.8	3.2	3.6	3.6	3.6	3.7	3.4	3.3	3.5
Guadalupe Mountains	Guadalupe Mountains	32	GUMO1	TX	31.88	-104.87	2.4	2.0	1.6	1.4	1.6	1.5	1.9	2.2	2.4	1.7	1.9	2.3
Haleakala	Haleakala	108	HALE1	HI	20.75	-156.25	2.7	2.6	2.5	2.5	2.4	2.3	2.4	2.4	2.3	2.5	2.7	2.6
Hawaii Volcanoes	Hawaii Volcanoes	107	HAVO1	HI	19.25	-155.25	3.0	2.9	2.9	2.9	2.9	2.9	3.0	3.0	3.0	3.0	3.3	3.0
Hells Canyon	Hells Canyon	77	HECA1	OR	44.88	-116.87	3.7	3.1	2.4	2.1	2.0	1.8	1.5	1.4	1.6	2.2	3.4	3.8
Hercules - Glade	Hercules - Glade	28	HEGL1	MO	36.63	-92.87	3.2	2.9	2.6	2.6	3.0	3.0	3.0	3.0	3.2	2.9	3.0	3.2
Hoover	Hoover	97	HOOV1	CA	38.13	-119.12	3.1	2.7	2.5	2.0	1.9	1.6	1.5	1.5	1.6	1.8	2.3	2.8
Isle Royale	Isle Royale	25	ISLE1	MI	47.38	-88.12	3.1	2.6	2.7	2.5	2.4	2.9	3.2	3.4	3.5	2.9	3.3	3.3
James River Face	James River Face	7	JARI1	VA	37.63	-79.62	2.9	2.7	2.6	2.4	2.9	3.1	3.2	3.3	3.4	3.0	2.7	3.0
Jarbidge	Jarbidge	68	JARB1	NV	41.88	-115.37	2.9	2.6	2.1	2.1	2.2	2.0	1.6	1.4	1.4	1.6	2.4	2.8
John Muir	Kaiser	110	KAIS1	CA	37.13	-119.12	3.0	2.7	2.5	2.1	2.0	1.7	1.7	1.7	1.8	1.9	2.3	2.7
Joshua Tree	Joshua Tree	101	JOSH1	CA	34.13	-116.37	2.4	2.3	2.3	2.0	2.0	1.9	1.5	2.0	2.0	2.0	1.9	2.1

Table A-2

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Class I Area	Site Name		Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Joyce Kilmer - Slickrock	Great Smoky Mountains	10	GRSM1	TN	35.63	-83.87	3.6	3.0	3.0	2.8	3.2	3.6	3.6	3.6	3.7	3.4	3.3	3.5
Kaiser	Kaiser	110	KAIS1	CA	37.13	-119.12	3.0	2.7	2.5	2.1	2.0	1.7	1.7	1.7	1.8	1.9	2.3	2.7
Kalmiopsis	Kalmiopsis	89	KALM1	OR	42.63	-124.12	4.5	3.9	3.7	3.5	3.3	3.1	2.9	3.0	3.1	3.6	4.4	4.4
Kings Canyon	Sequoia	98	SEQU1	CA	36.38	-118.87	2.9	2.6	2.5	2.2	2.1	1.8	1.7	1.7	1.8	1.9	2.3	2.5
La Garita	Weminuche	55	WEMI1	CO	37.63	-107.87	2.5	2.3	2.0	1.7	1.7	1.5	1.7	2.0	1.9	1.7	2.2	2.4
Lassen Volcanic	Lassen Volcanic	90	LAVO1	CA	40.63	-121.62	3.7	3.1	2.8	2.4	2.3	2.1	2.0	2.0	2.1	2.3	3.1	3.5
Lava Beds	Lava Beds	87	LABE1	CA	41.63	-121.62	4.0	3.4	3.1	2.8	2.6	2.4	2.2	2.2	2.4	2.8	3.6	4.0
Linville Gorge	Linville Gorge	13	LIGO1	NC	35.88	-81.87	3.2	3.0	2.9	2.7	3.2	3.6	3.6	3.9	3.9	3.4	3.1	3.2
Lostwood	Lostwood	62	LOST1	ND	48.63	-102.37	3.0	2.9	3.0	2.3	2.2	2.5	2.5	2.3	2.2	2.4	3.2	3.2
Lye Brook	Lye Brook	3	LYBR1	VT	43.13	-73.12	2.8	2.6	2.7	2.6	2.8	2.9	3.1	3.3	3.4	3.2	2.9	2.9
Mammoth Cave	Mammoth Cave	9	MACA1	KY	37.13	-86.12	3.3	3.0	2.9	3.0	4.1	4.7	4.6	3.5	3.5	3.2	3.1	3.4
Marble Mountain	Trinity	104	TRIN1	CA	40.88	-122.87	4.0	3.4	3.2	2.9	2.8	2.6	2.5	2.6	2.7	2.9	3.6	3.9
Maroon Bells - Snowmass	White River	56	WHRI1	CO	39.13	-106.87	2.2	2.2	2.0	2.0	2.0	1.7	1.8	2.1	2.1	1.8	2.1	2.1
Mazatzal	Ike's Backbone	46	IKBA1	AZ	34.38	-111.62	2.2	2.0	1.8	1.4	1.3	1.2	1.4	1.7	1.6	1.5	1.8	2.1
Medicine Lake	Medicine Lake	63	MELA1	MT	48.38	-104.37	3.0	2.9	2.9	2.2	2.2	2.4	2.4	2.1	2.2	2.3	3.1	3.1
Mesa Verde	Mesa Verde	54	MEVE1	CO	37.13	-108.37	2.8	2.6	2.2	1.7	1.7	1.3	1.7	2.0	1.9	1.8	2.2	2.6
Mingo	Mingo	26	MING1	MO	36.88	-90.12	3.2	2.9	2.7	2.6	2.9	3.0	3.1	3.1	3.2	2.9	3.0	3.2
Mission Mountains	Monture	73	MONT1	MT	47.13	-113.12	3.3	2.9	2.6	2.4	2.4	2.4	2.1	2.0	2.3	2.7	3.2	3.3
Mokelumne	Bliss	95	BLIS1	CA	38.88	-120.12	3.2	2.8	2.5	2.0	1.9	1.6	1.5	1.5	1.7	1.8	2.4	3.0
Moosehorn	Moosehorn	2	MOOS1	ME	45.13	-67.37	3.0	2.7	2.7	2.9	2.9	3.1	3.5	3.6	3.8	3.3	3.2	3.2
Mount Adams	White Pass	79	WHPA1	WA	46.63	-121.37	4.8	4.2	3.8	3.6	3.4	3.1	2.9	3.0	3.5	4.3	4.9	5.0
Mount Baldy	Mount Baldy	43	BALD1	AZ	34.13	-109.37	2.2	2.1	1.7	1.4	1.3	1.2	1.6	1.9	1.7	1.6	1.9	2.3
Mount Hood	Mount Hood	85	MOHO1	OR	45.38	-121.87	4.6	4.1	3.7	3.6	3.2	3.0	2.7	2.8	3.2	4.1	4.8	4.8
Mount Jefferson	Three Sisters	84	THSI1	OR	44.38	-122.12	5.3	4.6	4.4	4.3	3.8	3.4	2.7	2.7	3.1	4.3	5.2	5.3
Mount Rainier	Mount Rainier	78	MORA1	WA	46.88	-122.12	5.3	4.7	4.4	4.3	3.9	3.7	3.4	3.6	4.2	5.1	5.5	5.6
Mount Washington	Three Sisters	84	THSI1	OR	44.38	-122.12	5.3	4.6	4.4	4.3	3.8	3.4	2.7	2.7	3.1	4.3	5.2	5.3
Mount Zirkel	Mount Zirkel	58	MOZI1	CO	40.63	-106.62	2.2	2.2	2.0	2.1	2.2	1.8	1.7	1.8	2.0	1.9	2.1	2.1
Mountain Lakes	Crater Lake	86	CRLA1	OR	42.88	-122.12	4.6	4.0	3.7	3.5	3.2	2.9	2.6	2.7	2.9	3.6	4.6	4.7
North Absaroka	North Absoraka	67	NOAB1	WY	44.63	-109.37	2.4	2.2	2.2	2.1	2.1	1.9	1.6	1.5	1.8	2.0	2.3	2.4
North Cascades	North Cascades	81	NOCA1	WA	48.63	-121.12	4.5	4.1	3.6	3.4	3.3	3.0	2.9	3.1	3.5	4.2	4.7	4.7
Okefenokee	Okefenokee	16	OKEF1	GA	30.63	-82.12	3.3	3.0	3.2	3.0	3.2	3.8	3.4	3.6	3.6	3.4	3.3	3.4
Olympic	Olympic	83	OLYM1	WA	48.13	-122.87	4.2	3.9	3.6	3.5	2.9	3.2	2.7	3.3	3.8	4.3	4.5	4.4
Otter Creek	Dolly Sods	8	DOSO1	WV	39.13	-79.37	3.0	2.7	2.7	2.5	3.5	3.1	3.2	3.5	3.5	3.1	2.8	3.1

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Class I Area	Site Name		Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Pasayten	Pasayten	82	PASA1	WA	48.38	-119.87	4.6	4.1	3.5	3.3	3.2	2.9	2.8	2.9	3.4	4.1	4.7	4.8
Pecos	Wheeler Peak	35	WHPE1	NM	36.63	-105.37	2.4	2.2	1.9	1.8	1.8	1.6	1.8	2.1	2.1	1.8	2.2	2.4
Petrified Forest	Petrified Forest	41	PEFO1	AZ	35.13	-109.87	2.4	2.1	1.7	1.4	1.3	1.2	1.5	1.8	1.6	1.6	2.0	2.3
Pine Mountain	Ike's Backbone	46	IKBA1	AZ	34.38	-111.62	2.2	2.0	1.8	1.4	1.3	1.2	1.4	1.7	1.6	1.5	1.8	2.1
Pinnacles	Pinnacles	92	PINN1	CA	36.38	-121.12	3.4	3.4	3.5	2.6	2.4	2.2	2.1	2.2	2.2	2.4	2.4	2.9
Point Reyes	Point Reyes	91	PORE1	CA	38.13	-122.87	3.6	3.2	3.1	2.6	2.5	2.3	2.4	2.4	2.5	2.5	2.9	3.3
Presidential Range - Dry River	Great Gulf	4	GRGU1	NH	44.38	-71.12	2.8	2.6	2.6	2.8	2.9	3.0	3.3	3.5	3.6	3.2	3.0	2.9
Rawah	Mount Zirkel	58	MOZI1	CO	40.63	-106.62	2.2	2.2	2.0	2.1	2.2	1.8	1.7	1.8	2.0	1.9	2.1	2.1
Red Rock Lakes	Yellowstone	66	YELL2	WY	44.63	-110.37	2.5	2.3	2.2	2.1	2.1	1.9	1.7	1.6	1.8	2.1	2.4	2.5
Redwood	Redwood	88	REDW1	CA	41.63	-124.12	3.8	3.6	3.8	3.6	3.8	3.9	4.2	4.2	3.7	3.4	3.6	3.4
Rocky Mountain	Rocky Mountain	57	ROMO1	CO	40.38	-105.62	1.9	2.0	2.0	2.1	2.3	2.0	1.9	1.9	2.0	1.8	2.0	1.9
Roosevelt Campobello	Moosehorn	2	MOOS1	ME	45.13	-67.37	3.0	2.7	2.7	2.9	2.9	3.1	3.5	3.6	3.8	3.3	3.2	3.2
Saguaro	Saguaro	40	SAGU1	AZ	32.13	-110.62	1.8	1.6	1.4	1.1	1.1	1.0	1.4	1.7	1.5	1.4	1.5	2.0
Saint Marks	Saint Marks	17	SAMA1	FL	30.13	-84.12	3.5	3.3	3.2	3.1	3.2	3.6	3.8	3.8	3.7	3.5	3.4	3.6
Salt Creek	Salt Creek	36	SACR1	NM	33.38	-104.37	2.2	1.9	1.5	1.5	1.6	1.5	1.7	1.9	2.0	1.7	1.8	2.0
San Gabriel	San Gabriel	93	SAGA1	CA	34.38	-118.12	2.6	2.5	2.5	2.2	2.2	2.1	2.2	2.2	2.3	2.2	2.2	2.3
San Gorgonio	San Gorgonio	99	SAGO1	CA	34.13	-116.87	2.5	2.6	2.4	2.1	2.1	1.8	1.7	1.8	1.9	1.8	1.9	2.1
San Jacinto	San Gorgonio	99	SAGO1	CA	34.13	-116.87	2.5	2.6	2.4	2.1	2.1	1.8	1.7	1.8	1.9	1.8	1.9	2.1
San Pedro Parks	San Pedro Parks	34	SAPE1	NM	36.13	-106.87	2.4	2.2	1.9	1.6	1.6	1.4	1.7	2.0	1.9	1.7	2.1	2.3
San Rafael	San Rafael	94	RAFA1	CA	34.63	-120.12	3.0	2.8	2.8	2.5	2.5	2.4	2.5	2.6	2.7	2.6	2.4	2.6
Sawtooth	Sawtooth	70	SAWT1	ID	44.13	-114.87	3.3	2.8	2.3	2.0	2.0	1.8	1.4	1.4	1.5	2.0	2.9	3.3
Scapegoat	Monture	73	MONT1	MT	47.13	-113.12	3.3	2.9	2.6	2.4	2.4	2.4	2.1	2.0	2.3	2.7	3.2	3.3
Selway - Bitterroot	Sula	71	SULA1	MT	45.88	-114.12	3.4	3.0	2.6	2.3	2.3	2.2	1.9	1.8	2.0	2.5	3.3	3.4
Seney	Seney	22	SENE1	MI	46.38	-85.87	3.3	2.8	2.9	2.7	2.6	3.0	3.3	3.6	3.7	3.3	3.5	3.4
Sequoia	Sequoia	98	SEQU1	CA	36.38	-118.87	2.9	2.6	2.5	2.2	2.1	1.8	1.7	1.7	1.8	1.9	2.3	2.5
Shenandoah	Shenandoah	6	SHEN1	VA	38.63	-78.37	2.9	2.6	2.7	2.4	2.9	3.1	3.2	3.5	3.5	3.0	2.7	2.9
Shining Rock	Shining Rock	11	SHRO1	NC	35.38	-82.87	3.3	3.0	2.9	2.7	3.2	3.6	3.6	3.9	3.9	3.5	3.2	3.3
Sierra Ancha	Sierra Ancha	45	SIAN1	AZ	34.13	-110.87	2.2	2.0	1.7	1.4	1.3	1.1	1.5	1.8	1.6	1.5	1.8	2.2
Simeonof	Simeonof	105	SIME1	AK	55.25	-160.75	4.2	4.2	3.8	4.0	4.2	4.6	5.0	5.2	4.5	3.7	3.9	4.2
Sipsey	Sipsey	21	SIPS1	AL	34.38	-87.37	3.3	3.0	2.8	2.7	3.1	3.4	3.5	3.5	3.5	3.3	3.1	3.3
South Warner	Lava Beds	87	LABE1	CA	41.63	-121.62	4.0	3.4	3.1	2.8	2.6	2.4	2.2	2.2	2.4	2.8	3.6	4.0
Strawberry Mountain	Starkey	76	STAR1	OR	45.13	-118.62	4.3	3.8	3.2	2.9	2.7	2.4	2.0	2.1	2.4	3.3	4.2	4.5
Superstition	Tonto	44	TONT1	AZ	33.63	-111.12	2.1	1.9	1.6	1.3	1.2	1.1	1.4	1.7	1.6	1.5	1.7	2.1

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Swanquarter	Swanquarter	14	SWAN1	NC	35.38	-76.12	2.9	2.7	2.6	2.4	2.7	3.0	3.1	3.2	3.1	3.0	2.7	2.9
Sycamore Canyon	Sycamore Canyon	47	SYCA1	AZ	35.13	-111.87	2.4	2.4	2.0	1.6	1.5	1.2	1.5	2.0	1.9	1.8	2.0	2.3
Teton	Yellowstone	66	YELL2	WY	44.63	-110.37	2.5	2.3	2.2	2.1	2.1	1.9	1.7	1.6	1.8	2.1	2.4	2.5
Theodore Roosevelt	Theodore Roosevelt	61	THRO1	ND	46.88	-103.37	2.9	2.8	2.8	2.4	2.4	2.5	2.4	2.2	2.2	2.3	3.0	3.0
Thousand Lakes	Lassen Volcanic	90	LAVO1	CA	40.63	-121.62	3.7	3.1	2.8	2.4	2.3	2.1	2.0	2.0	2.1	2.3	3.1	3.5
Three Sisters	Three Sisters	84	THSI1	OR	44.38	-122.12	5.3	4.6	4.4	4.3	3.8	3.4	2.7	2.7	3.1	4.3	5.2	5.3
Tuxedni	Tuxedni	103	TUXE1	AK	59.75	-152.75	3.6	3.4	2.9	2.8	2.8	2.9	3.6	3.9	3.8	3.4	3.5	3.7
UL Bend	UL Bend	64	ULBE1	MT	47.63	-108.62	2.6	2.4	2.4	2.3	2.2	2.1	1.9	1.8	1.9	2.2	2.6	2.6
Upper Buffalo	Upper Buffalo	27	UPBU1	AR	35.88	-93.12	3.2	2.9	2.6	2.7	3.1	3.1	3.0	3.0	3.2	3.0	3.0	3.2
Ventana	Pinnacles	92	PINN1	CA	36.38	-121.12	3.4	3.4	3.5	2.6	2.4	2.2	2.1	2.2	2.2	2.4	2.4	2.9
Virgin Islands (b)	Virgin Islands	106	VIIS1	VI	18.75	-155.75												
Voyageurs	Voyageurs	24	VOYA2	MN	48.38	-92.87	2.7	2.4	2.3	2.2	2.2	2.8	2.5	2.7	2.9	2.5	2.8	2.7
Washakie	North Absoraka	67	NOAB1	WY	44.63	-109.37	2.4	2.2	2.2	2.1	2.1	1.9	1.6	1.5	1.8	2.0	2.3	2.4
Weminuche	Weminuche	55	WEMI1	CO	37.63	-107.87	2.5	2.3	2.0	1.7	1.7	1.5	1.7	2.0	1.9	1.7	2.2	2.4
West Elk	White River	56	WHRI1	CO	39.13	-106.87	2.2	2.2	2.0	2.0	2.0	1.7	1.8	2.1	2.1	1.8	2.1	2.1
Wheeler Peak	Wheeler Peak	35	WHPE1	NM	36.63	-105.37	2.4	2.2	1.9	1.8	1.8	1.6	1.8	2.1	2.1	1.8	2.2	2.4
White Mountain	White Mountain	37	WHIT1	NM	33.38	-105.62	2.2	1.9	1.6	1.5	1.5	1.4	1.7	1.9	2.0	1.7	1.8	2.1
Wichita Mountains	Wichita Mountains	30	WIMO1	OK	34.63	-98.62	2.8	2.6	2.4	2.4	2.7	2.5	2.2	2.4	2.7	2.5	2.6	2.8
Wind Cave	Wind Cave	60	WICA1	SD	43.63	-103.37	2.5	2.5	2.5	2.5	2.6	2.5	2.2	2.2	2.1	2.2	2.6	2.5
Wolf Island	Okefenokee	16	OKEF1	GA	30.63	-82.12	3.3	3.0	3.2	3.0	3.2	3.8	3.4	3.6	3.6	3.4	3.3	3.4
Yellowstone	Yellowstone	66	YELL2	WY	44.63	-110.37	2.5	2.3	2.2	2.1	2.1	1.9	1.7	1.6	1.8	2.1	2.4	2.5
Yolla Bolly - Middle Eel	Trinity	104	TRIN1	CA	40.88	-122.87	4.0	3.4	3.2	2.9	2.8	2.6	2.5	2.6	2.7	2.9	3.6	3.9
Yosemite	Yosemite	96	YOSE1	CA	37.63	-119.62	3.0	2.9	2.7	2.2	2.1	1.7	1.5	1.5	1.6	1.8	2.3	2.7

a: No particulate matter sampling or visibility monitoring is conducted in the Bering Sea Wilderness.
b**:** *f(RH)* values for Virgin Islands National Park were not calculated because of the limited RH data available.

Table A-3 Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area, Based on the Centroid of the Area (Supplemental Information)

Class I Area	Site Name	Map ID	Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Acadia	Acadia	1	ACAD1	ME	44.37	68.26	3.3	2.9	2.8	3.4	3.1	3.0	3.4	3.8	4.0	3.8	3.6	3.5
Agua Tibia	Agua Tibia	100	AGTI1	CA	33.41	116.98	2.4	2.4	2.4	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.1	2.2
Alpine Lakes	Snoqualmie Pass	80	SNPA1	WA	47.42	121.42	4.3	3.8	3.5	3.9	2.9	3.2	2.9	3.1	3.3	3.9	4.5	4.5
Anaconda - Pintler	Sula	71	SULA1	MT	45.98	113.42	3.3	2.9	2.5	2.4	2.4	2.3	2.0	1.9	2.1	2.5	3.2	3.3
Ansel Adams	Kaiser	110	KAIS1	CA	37.65	119.20	3.0	2.7	2.4	2.1	1.9	1.7	1.6	1.6	1.6	1.8	2.3	2.7
Arches	Canyonlands	50	CANY1	UT	38.64	109.58	2.6	2.3	1.8	1.6	1.6	1.3	1.4	1.5	1.6	1.6	2.0	2.3
Badlands	Badlands	59	BADL1	SD	43.74	101.94	2.6	2.7	2.6	2.4	2.8	2.7	2.5	2.4	2.2	2.3	2.7	2.7
Bandelier	Bandelier	33	BAND1	NM	35.78	106.27	2.2	2.1	1.8	1.6	1.6	1.4	1.7	2.1	1.9	1.7	2.0	2.2
Bering Sea (a)					60.45	172.79												
Big Bend	Big Bend	31	BIBE1	TX	29.31	103.19	2.0	1.9	1.6	1.5	1.6	1.6	1.7	2.0	2.1	1.9	1.8	1.9
Black Canyon of the Gunnison	Weminuche	55	WEMI1	CO	38.58	107.70	2.4	2.2	1.9	1.9	1.9	1.6	1.7	1.9	2.0	1.8	2.1	2.3
Bob Marshall	Monture	73	MONT1	MT	47.75	113.38	3.6	3.1	2.8	2.6	2.7	2.7	2.3	2.2	2.6	2.9	3.5	3.5
Bosque del Apache	Bosque del Apache	38	BOAP1	NM	33.79	106.83	2.1	1.9	1.6	1.4	1.4	1.3	1.8	2.0	1.9	1.6	1.8	2.2
Boundary Waters Canoe Area	Boundary Waters	23	BOWA1	MN	47.95	91.50	3.0	2.6	2.7	2.4	2.3	2.9	3.1	3.4	3.5	2.8	3.2	3.2
Breton	Breton	20	BRET1	LA	29.73	88.88	3.7	3.5	3.7	3.6	3.8	4.0	4.3	4.3	4.2	3.7	3.7	3.7
Bridger	Bridger	65	BRID1	WY	42.98	109.76	2.5	2.4	2.3	2.2	2.1	1.8	1.5	1.5	1.7	2.0	2.4	2.4
Brigantine	Brigantine	5	BRIG1	NJ	39.46	74.45	2.8	2.6	2.7	2.6	3.0	3.2	3.4	3.7	3.6	3.3	2.9	2.8
Bryce Canyon	Bryce Canyon	49	BRCA1	UT	37.62	112.17	2.6	2.4	1.9	1.6	1.5	1.3	1.3	1.5	1.5	1.6	2.0	2.4
Cabinet Mountains	Cabinet Mountains	75	CABI1	MT	48.21	115.71	3.8	3.3	2.9	2.6	2.7	2.7	2.3	2.2	2.6	3.0	3.7	3.9
Caney Creek	Caney Creek	29	CACR1	AR	34.41	94.08	3.4	3.1	2.9	3.0	3.6	3.6	3.4	3.4	3.6	3.5	3.4	3.5
Canyonlands	Canyonlands	50	CANY1	UT	38.46	109.82	2.6	2.3	1.7	1.6	1.5	1.2	1.3	1.5	1.6	1.6	2.0	2.3
Cape Romain	Cape Romain	15	ROMA1	SC	32.94	79.66	3.3	3.0	2.9	2.8	3.2	3.7	3.6	4.1	4.0	3.7	3.4	3.2
Capitol Reef	Capitol Reef	52	CAPI1	UT	38.36	111.05	2.7	2.4	2.0	1.7	1.6	1.4	1.4	1.6	1.6	1.7	2.1	2.5
Caribou	Lassen Volcanic	90	LAVO1	CA	40.50	121.18	3.7	3.1	2.8	2.5	2.4	2.2	2.1	2.1	2.2	2.4	3.0	3.4
Carlsbad Caverns	Guadalupe Mountains	32	GUMO1	TX	32.14	104.48	2.1	2.0	1.6	1.5	1.6	1.6	1.8	2.1	2.2	1.8	1.9	2.1
Chassahowitzka	Chassahowitzka	18	CHAS1	FL	28.75	82.55	3.8	3.5	3.4	3.2	3.3	3.9	3.9	4.2	4.1	3.9	3.7	3.9
Chiricahua NM	Chiricahua	39	CHIR1	AZ	32.01	109.39	2.0	2.0	1.6	1.3	1.3	1.1	1.8	2.1	1.8	1.5	1.6	2.2
Chiricahua W	Chiricahua	39	CHIR1	AZ	31.84	109.27	2.0	1.9	1.6	1.2	1.3	1.1	1.8	2.1	1.8	1.5	1.6	2.2
Cohutta	Cohutta	12	COHU1	GA	34.92	84.58	3.3	3.1	3.0	2.8	3.4	3.8	4.0	4.2	4.2	3.8	3.4	3.5
Crater Lake	Crater Lake	86	CRLA1	OR	42.90	122.13	4.6	3.9	3.7	3.4	3.2	3.0	2.8	2.9	3.1	3.6	4.6	4.6
Craters of the Moon	Craters of the Moon	69	CRMO1	ID	43.47	113.55	3.1	2.7	2.3	2.0	2.0	1.8	1.4	1.4	1.6	2.0	2.8	3.0
Cucamonga	San Gabriel	93	SAGA1	CA	34.25	117.57	2.5	2.4	2.4	2.2	2.1	2.1	2.1	2.2	2.2	2.2	2.1	2.2
Denali	Denali	102	DENA1	AK	63.72	148.97	2.5	2.3	2.1	1.9	1.9	2.2	2.5	3.0	2.8	2.9	3.0	3.1
Desolation	Bliss	95	BLIS1	CA	38.98	120.12	3.2	2.8	2.4	2.0	1.8	1.6	1.5	1.6	1.7	1.9	2.4	3.0
Diamond Peak	Crater Lake	86	CRLA1	OR	43.53	122.10	4.5	4.0	3.6	3.7	3.2	3.1	2.9	2.9	3.1	3.7	4.6	4.6
Dolly Sods	Dolly Sods	8	DOSO1	WV	39.11	79.43	3.0	2.8	2.8	2.6	3.1	3.4	3.5	3.9	3.9	3.3	3.0	3.1

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Class I Area	Site Name	Map ID	Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Dome Land	Dome Land	109	DOME1	CA	35.70	118.19	2.5	2.3	2.2	1.9	1.8	1.8	1.8	1.8	1.8	1.9	2.0	2.2
Eagle Cap	Starkey	76	STAR1	OR	45.10	117.29	3.8	3.2	2.5	2.1	2.0	1.9	1.6	1.6	1.6	2.3	3.4	4.0
Eagles Nest	White River	56	WHRI1	CO	39.69	106.25	2.2	2.2	2.0	2.0	2.1	1.9	1.8	2.0	2.0	1.9	2.1	2.1
Emigrant	Yosemite	96	YOSE1	CA	38.20	119.75	3.2	2.8	2.5	2.1	1.9	1.7	1.5	1.6	1.6	1.9	2.4	2.9
Everglades	Everglades	19	EVER1	FL	25.39	80.68	2.7	2.6	2.6	2.4	2.4	2.7	2.6	2.9	3.0	2.8	2.6	2.7
Fitzpatrick	Bridger	65	BRID1	WY	43.27	109.57	2.5	2.3	2.2	2.1	2.1	1.8	1.5	1.5	1.7	2.0	2.4	2.4
Flat Tops	White River	56	WHRI1	CO	39.97	107.25	2.3	2.2	2.0	2.0	2.0	1.8	1.7	1.9	1.9	1.8	2.2	2.2
Galiuro	Chiricahua	39	CHIR1	AZ	32.56	110.32	2.0	1.8	1.5	1.2	1.2	1.1	1.5	1.8	1.6	1.5	1.6	2.1
Gates of the Mountains	Gates of the Mountains	74	GAMO1	MT	46.87	111.81	2.9	2.6	2.4	2.3	2.3	2.3	2.0	1.9	2.1	2.4	2.8	2.8
Gearhart Mountain	Crater Lake	86	CRLA1	OR	42.49	120.85	4.0	3.4	3.1	2.8	2.7	2.5	2.3	2.3	2.4	2.8	3.7	3.8
Gila	Gila Cliffs	42	GICL1	NM	33.22	108.25	2.1	1.9	1.6	1.3	1.4	1.2	2.1	2.0	1.8	1.6	1.8	2.2
Glacier	Glacier	72	GLAC1	MT	48.51	114.00	4.0	3.5	3.2	3.1	3.2	3.4	2.8	2.6	3.2	3.5	3.8	3.9
Glacier Peak	North Cascades	81	NOCA1	WA	48.21	121.04	4.2	3.7	3.4	3.8	2.9	3.2	2.9	3.1	3.3	3.9	4.4	4.4
Goat Rocks	White Pass	79	WHPA1	WA	46.54	121.48	4.3	3.8	3.4	4.2	2.8	3.4	3.0	3.2	3.1	3.8	4.4	4.6
Grand Canyon	Grand Canyon, Hance	48	GRCA2	AZ	35.97	111.98	2.4	2.3	1.9	1.5	1.4	1.2	1.4	1.7	1.6	1.6	1.9	2.3
Grand Teton	Yellowstone	66	YELL2	WY	43.68	110.73	2.6	2.4	2.2	2.1	2.1	1.8	1.5	1.5	1.7	2.0	2.4	2.6
Great Gulf	Great Gulf	4	GRGU1	NH	44.31	71.22	2.8	2.6	2.6	2.8	2.9	3.2	3.5	3.8	4.0	3.4	3.1	2.9
Great Sand Dunes	Great Sand Dunes	53	GRSA1	CO	37.73	105.52	2.4	2.3	2.0	1.9	1.9	1.8	1.9	2.3	2.2	1.9	2.4	2.4
Great Smoky Mountains	Great Smoky Mountains	10	GRSM1	TN	35.63	83.94	3.3	3.0	2.9	2.7	3.2	3.9	3.8	4.0	4.2	3.8	3.3	3.4
Guadalupe Mountains	Guadalupe Mountains	32	GUMO1	TX	31.83	104.80	2.0	2.0	1.6	1.5	1.6	1.5	1.9	2.2	2.2	1.8	1.9	2.2
Haleakala	Haleakala	108	HALE1	HI	20.81	156.28	2.7	2.6	2.6	2.5	2.4	2.3	2.5	2.4	2.4	2.5	2.8	2.7
Hawaii Volcanoes	Hawaii Volcanoes	107	HAVO1	HI	19.43	155.27	3.2	2.9	3.0	3.0	3.0	2.9	3.1	3.2	3.2	3.2	3.7	3.2
Hells Canyon	Hells Canyon	77	HECA1	OR	45.34	116.57	3.7	3.1	2.5	2.2	2.1	2.0	1.6	1.6	1.8	2.4	3.5	3.9
Hercules - Glade	Hercules - Glade	28	HEGL1	MO	36.69	92.90	3.2	2.9	2.7	2.7	3.3	3.3	3.3	3.3	3.4	3.1	3.1	3.3
Hoover	Hoover	97	HOOV1	CA	38.14	119.45	3.1	2.8	2.5	2.1	1.9	1.6	1.5	1.5	1.6	1.8	2.3	2.8
Isle Royale	Isle Royale	25	ISLE1	MI	47.99	88.83	3.1	2.5	2.7	2.4	2.2	2.6	3.0	3.2	3.8	2.7	3.3	3.3
James River Face	James River Face	7	JARI1	VA	37.62	79.48	2.8	2.6	2.7	2.4	3.0	3.3	3.4	3.7	3.6	3.2	2.8	3.0
Jarbidge	Jarbidge	68	JARB1	NV	41.89	115.43	3.0	2.6	2.1	2.1	2.2	2.2	1.6	1.4	1.4	1.6	2.4	2.8
John Muir	Kaiser	110	KAIS1	CA	37.39	118.84	2.9	2.6	2.4	2.1	1.9	1.7	1.7	1.7	1.7	1.9	2.2	2.6
Joshua Tree	Joshua Tree	101	JOSH1	CA	34.03	116.18	2.4	2.3	2.2	2.0	2.0	1.9	2.0	2.0	2.0	2.0	1.9	2.0
Joyce Kilmer - Slickrock	Great Smoky Mountains	10	GRSM1	TN	35.43	84.00	3.3	3.1	2.9	2.7	3.3	3.8	4.0	4.2	4.2	3.8	3.3	3.5
Kaiser	Kaiser	110	KAIS1	CA	37.28	119.18	3.0	2.7	2.5	2.1	1.9	1.7	1.6	1.7	1.7	1.9	2.3	2.7
Kalmiopsis	Kalmiopsis	89	KALM1	OR	42.27	123.93	4.5	3.9	3.8	3.5	3.5	3.3	3.2	3.2	3.3	3.6	4.4	4.3
Kings Canyon	Sequoia	98	SEQU1	CA	36.82	118.76	2.8	2.6	2.4	2.1	1.9	1.8	1.7	1.7	1.8	1.9	2.3	2.5
La Garita	Weminuche	55	WEMI1	CO	37.96	106.81	2.3	2.2	1.9	1.8	1.8	1.6	1.7	2.1	2.0	1.8	2.2	2.3
Lassen Volcanic	Lassen Volcanic	90	LAVO1	CA	40.54	121.57	3.8	3.2	2.9	2.5	2.4	2.2	2.1	2.1	2.2	2.4	3.1	3.5

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Class I Area	Site Name	Map ID	Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Lava Beds	Lava Beds	87	LABE1	CA	41.71	121.34	4.0	3.4	3.1	2.7	2.6	2.4	2.3	2.3	2.4	2.7	3.5	3.8
Linville Gorge	Linville Gorge	13	LIGO1	NC	35.89	81.89	3.3	3.0	3.0	2.7	3.3	3.9	4.1	4.5	4.4	3.7	3.2	3.4
Lostwood	Lostwood	62	LOST1	ND	48.60	102.48	3.0	2.9	2.9	2.3	2.3	2.6	2.7	2.4	2.3	2.4	3.2	3.2
Lye Brook	Lye Brook	3	LYBR1	VT	43.15	73.12	2.7	2.6	2.6	2.6	2.8	3.0	3.3	3.6	3.7	3.3	2.9	2.8
Mammoth Cave	Mammoth Cave	9	MACA1	KY	37.22	86.07	3.4	3.1	2.9	2.6	3.2	3.5	3.7	3.9	3.9	3.4	3.2	3.5
Marble Mountain	Trinity	104	TRIN1	CA	41.52	123.21	4.4	3.8	3.7	3.3	3.4	3.2	3.2	3.2	3.2	3.4	4.1	4.2
Maroon Bells - Snowmass	White River	56	WHRI1	CO	39.15	106.82	2.2	2.1	2.0	2.0	2.1	1.7	1.9	2.2	2.1	1.8	2.1	2.1
Mazatzal	Ike's Backbone	46	IKBA1	AZ	33.92	111.43	2.1	1.9	1.7	1.3	1.3	1.1	1.5	1.7	1.6	1.5	1.7	2.1
Medicine Lake	Medicine Lake	63	MELA1	MT	48.50	104.29	3.0	2.9	2.9	2.3	2.2	2.5	2.5	2.2	2.2	2.4	3.2	3.2
Mesa Verde	Mesa Verde	54	MEVE1	CO	37.20	108.49	2.5	2.3	1.9	1.5	1.5	1.3	1.6	2.0	1.9	1.7	2.1	2.3
Mingo	Mingo	26	MING1	MO	36.98	90.20	3.3	3.0	2.8	2.6	3.0	3.2	3.3	3.5	3.5	3.1	3.1	3.3
Mission Mountains	Monture	73	MONT1	MT	47.40	113.85	3.6	3.1	2.7	2.5	2.6	2.6	2.3	2.2	2.5	2.9	3.5	3.6
Mokelumne	Bliss	95	BLIS1	CA	38.58	120.03	3.2	2.8	2.4	2.0	1.9	1.6	1.5	1.6	1.7	1.9	2.4	2.9
Moosehorn	Moosehorn	2	MOOS1	ME	45.12	67.26	3.0	2.7	2.7	3.0	3.0	3.1	3.4	3.8	3.9	3.5	3.2	3.2
Mount Adams	White Pass	79	WHPA1	WA	46.19	121.50	4.3	3.8	3.4	4.4	2.9	3.5	3.1	3.3	3.1	3.9	4.5	4.6
Mount Baldy	Mount Baldy	43	BALD1	AZ	34.12	109.57	2.2	2.0	1.7	1.4	1.3	1.2	1.6	1.9	1.7	1.6	1.8	2.2
Mount Hood	Mount Hood	85	MOHO1	OR	45.38	121.69	4.3	3.8	3.5	3.9	3.0	3.2	2.9	3.0	3.1	3.9	4.5	4.6
Mount Jefferson	Three Sisters	84	THSI1	OR	44.55	121.83	4.4	3.9	3.6	3.7	3.1	3.1	2.9	2.9	3.0	3.8	4.6	4.5
Mount Rainier	Mount Rainier	78	MORA1	WA	46.76	122.12	4.4	4.0	3.6	4.7	3.1	3.7	3.3	3.5	3.4	4.1	4.7	4.7
Mount Washington	Three Sisters	84	THSI1	OR	44.30	121.87	4.4	3.9	3.6	3.7	3.1	3.1	3.0	2.9	3.0	3.8	4.6	4.6
Mount Zirkel	Mount Zirkel	58	MOZI1	CO	40.55	106.70	2.2	2.2	2.0	2.1	2.2	1.9	1.7	1.9	2.0	1.9	2.1	2.1
Mountain Lakes	Crater Lake	86	CRLA1	OR	42.34	122.11	4.3	3.6	3.3	3.0	2.9	2.6	2.5	2.5	2.6	3.1	4.1	4.3
North Absaroka	North Absoraka	67	NOAB1	WY	44.77	109.78	2.4	2.3	2.2	2.2	2.1	1.9	1.7	1.6	1.8	2.0	2.4	2.4
North Cascades	North Cascades	81	NOCA1	WA	48.54	121.44	4.1	3.7	3.4	3.7	2.9	3.2	2.9	3.2	3.5	3.9	4.4	4.4
Okefenokee	Okefenokee	16	OKEF1	GA	30.74	82.13	3.5	3.2	3.1	3.0	3.6	3.7	3.7	4.1	4.0	3.8	3.5	3.6
Olympic	Olympic	83	OLYM1	WA	47.32	123.35	4.5	4.1	3.8	4.1	3.2	3.5	3.1	3.5	3.7	4.4	4.8	4.8
Otter Creek	Dolly Sods	8	DOSO1	WV	39.00	79.65	3.0	2.8	2.8	2.6	3.2	3.5	3.7	4.1	4.0	3.3	3.0	3.1
Pasayten	Pasayten	82	PASA1	WA	48.85	120.52	4.2	3.7	3.4	3.7	2.9	3.2	2.9	3.2	3.3	3.9	4.4	4.5
Pecos	Wheeler Peak	35	WHPE1	NM	35.93	105.64	2.3	2.1	1.8	1.7	1.7	1.5	1.8	2.1	2.0	1.7	2.0	2.2
Petrified Forest	Petrified Forest	41	PEFO1	AZ	35.08	109.77	2.4	2.2	1.7	1.4	1.3	1.2	1.5	1.8	1.7	1.6	1.9	2.3
Pine Mountain	Ike's Backbone	46	IKBA1	AZ	34.31	111.80	2.2	2.0	1.7	1.4	1.3	1.1	1.4	1.8	1.6	1.5	1.7	2.1
Pinnacles	Pinnacles	92	PINN1	CA	36.49	121.16	3.2	2.8	2.6	2.4	2.3	2.0	2.0	2.1	2.1	2.3	2.5	2.9
Point Reyes	Point Reyes	91	PORE1	CA	38.12	122.90	3.6	3.3	3.1	2.7	2.5	2.3	2.5	2.6	2.6	2.7	2.9	3.3
Presidential Range - Dry River	Great Gulf	4	GRGU1	NH	44.21	71.35	2.8	2.6	2.6	2.8	3.0	3.4	3.7	4.0	4.3	3.5	3.1	3.0
Rawah	Mount Zirkel	58	MOZI1	CO	40.70	105.94	2.1	2.1	2.0	2.1	2.3	2.0	1.8	2.0	2.0	1.9	2.1	2.0
Red Rock Lakes	Yellowstone	66	YELL2	WY	44.67	111.70	2.7	2.5	2.3	2.1	2.1	1.9	1.7	1.6	1.8	2.1	2.6	2.7

Table A-3 Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area, Based on the Centroid of the Area (Supplemental Information)

Class I Area	Site Name	Map ID	Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Redwood	Redwood	88	REDW1	CA	41.56	124.08	4.4	3.9	4.6	3.9	4.5	4.7	4.9	4.7	4.3	3.7	3.8	3.4
Rocky Mountain	Rocky Mountain	57	ROMO1	CO	40.28	105.55	1.7	1.9	1.9	2.1	2.3	2.0	1.8	2.0	1.9	1.8	1.8	1.7
Roosevelt Campobello	Moosehorn	2	MOOS1	ME	44.88	66.95	3.0	2.7	2.7	3.0	3.0	3.1	3.4	3.8	3.9	3.5	3.3	3.2
Saguaro	Saguaro	40	SAGU1	AZ	32.25	110.73	1.8	1.6	1.4	1.1	1.1	1.1	1.4	1.8	1.6	1.4	1.6	2.1
Saint Marks	Saint Marks	17	SAMA1	FL	30.12	84.08	3.7	3.4	3.4	3.4	3.5	4.0	4.1	4.4	4.2	3.8	3.7	3.8
Salt Creek	Salt Creek	36	SACR1	NM	33.61	104.37	2.1	1.9	1.5	1.5	1.7	1.6	1.8	2.0	2.1	1.8	1.8	2.1
San Gabriel	San Gabriel	93	SAGA1	CA	34.27	117.94	2.5	2.5	2.4	2.2	2.2	2.1	2.2	2.2	2.2	2.3	2.1	2.2
San Gorgonio	San Gorgonio	99	SAGO1	CA	34.18	116.90	2.7	2.8	2.6	2.3	2.2	1.9	1.8	1.9	1.9	1.9	1.9	2.2
San Jacinto	San Gorgonio	99	SAGO1	CA	33.75	116.65	2.5	2.4	2.4	2.2	2.1	2.0	2.1	2.1	2.1	2.1	2.0	2.1
San Pedro Parks	San Pedro Parks	34	SAPE1	NM	36.11	106.81	2.3	2.1	1.8	1.6	1.6	1.4	1.7	2.0	1.9	1.7	2.1	2.2
San Rafael	San Rafael	94	RAFA1	CA	34.78	119.83	2.8	2.7	2.7	2.4	2.3	2.3	2.5	2.5	2.4	2.5	2.3	2.5
Sawtooth	Sawtooth	70	SAWT1	ID	44.18	114.93	3.3	2.9	2.3	2.0	2.0	1.8	1.4	1.4	1.5	2.0	2.9	3.3
Scapegoat	Monture	73	MONT1	MT	47.17	112.73	3.2	2.8	2.6	2.4	2.5	2.4	2.1	2.0	2.3	2.6	3.1	3.1
Selway - Bitterroot	Sula	71	SULA1	MT	45.86	114.00	3.5	3.0	2.6	2.3	2.4	2.3	1.9	1.9	2.1	2.6	3.3	3.5
Seney	Seney	22	SENE1	MI	46.26	86.03	3.3	2.8	2.9	2.7	2.6	3.1	3.6	4.0	4.1	3.4	3.6	3.5
Sequoia	Sequoia	98	SEQU1	CA	36.50	118.82	2.5	2.4	2.4	2.2	1.9	1.8	1.7	1.6	1.8	1.9	2.3	2.3
Shenandoah	Shenandoah	6	SHEN1	VA	38.52	78.44	3.1	2.8	2.8	2.5	3.1	3.4	3.5	3.9	3.9	3.2	3.0	3.1
Shining Rock	Shining Rock	11	SHRO1	NC	35.39	82.78	3.3	3.0	2.9	2.7	3.4	3.9	4.1	4.5	4.4	3.8	3.3	3.4
Sierra Ancha	Sierra Ancha	45	SIAN1	AZ	33.82	110.88	2.1	2.0	1.7	1.3	1.3	1.1	1.5	1.8	1.6	1.5	1.7	2.1
Simeonof	Simeonof	105	SIME1	AK	54.92	159.28	4.3	4.1	3.6	3.9	3.9	4.3	5.0	5.2	4.5	3.8	4.0	4.3
Sipsey	Sipsey	21	SIPS1	AL	34.34	87.34	3.4	3.1	2.9	2.8	3.3	3.7	3.9	3.9	3.9	3.6	3.3	3.4
South Warner	Lava Beds	87	LABE1	CA	41.33	120.20	3.6	3.1	2.7	2.4	2.3	2.1	1.9	1.9	2.0	2.3	3.1	3.4
Strawberry Mountain	Starkey	76	STAR1	OR	44.30	118.73	3.9	3.3	2.8	2.9	2.3	2.4	2.0	2.0	1.9	2.6	3.7	4.1
Superstition	Tonto	44	TONT1	AZ	33.63	111.10	2.1	1.9	1.6	1.3	1.3	1.1	1.5	1.7	1.6	1.5	1.7	2.1
Swanquarter	Swanquarter	14	SWAN1	NC	35.31	76.28	2.9	2.7	2.6	2.5	2.9	3.2	3.4	3.5	3.4	3.1	2.8	2.9
Sycamore Canyon	Sycamore Canyon	47	SYCA1	AZ	34.03	116.18	2.4	2.3	2.2	2.0	2.0	1.9	2.0	2.0	2.0	2.0	1.9	2.0
Teton	Yellowstone	66	YELL2	WY	44.09	110.18	2.5	2.4	2.2	2.1	2.1	1.9	1.6	1.5	1.7	2.0	2.4	2.5
Theodore Roosevelt	Theodore Roosevelt	61	THRO1	ND	47.30	104.00	2.9	2.8	2.8	2.3	2.3	2.5	2.4	2.2	2.2	2.3	3.0	3.0
Thousand Lakes	Lassen Volcanic	90	LAVO1	CA	40.70	121.58	3.8	3.2	2.9	2.5	2.4	2.2	2.1	2.1	2.2	2.4	3.1	3.5
Three Sisters	Three Sisters	84	THSI1	OR	44.29	122.04	4.5	4.0	3.6	3.7	3.1	3.1	3.0	2.9	3.0	3.8	4.6	4.6
Tuxedni	Tuxedni	103	TUXE1	AK	60.15	152.60	3.5	3.3	2.9	2.7	2.7	2.9	3.6	4.0	3.9	3.5	3.5	3.7
UL Bend	UL Bend	64	ULBE1	MT	47.55	107.87	2.7	2.5	2.5	2.3	2.2	2.2	2.0	1.8	1.9	2.2	2.7	2.7
Upper Buffalo	Upper Buffalo	27	UPBU1	AR	35.83	93.21	3.3	3.0	2.7	2.8	3.4	3.4	3.4	3.4	3.6	3.3	3.2	3.3
Ventana	Pinnacles	92	PINN1	CA	36.22	121.59	3.2	2.9	2.8	2.4	2.3	2.1	2.2	2.3	2.2	2.4	2.5	2.9
Virgin Islands (b)	Virgin Islands	106	VIIS1	VI	18.33	64.79												
Voyageurs	Voyageurs	24	VOYA2	MN	48.59	93.17	2.8	2.4	2.4	2.3	2.3	3.1	2.7	3.0	3.2	2.6	2.9	2.8

Table A-3 Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area, Based on the Centroid of the Area (Supplemental Information)

Class I Area	Site Name	Map ID	Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Washakie	North Absoraka	67	NOAB1	WY	43.95	109.59	2.5	2.3	2.2	2.1	2.1	1.8	1.6	1.5	1.8	2.0	2.4	2.5
Weminuche	Weminuche	55	WEMI1	CO	37.65	107.80	2.4	2.2	1.9	1.7	1.7	1.5	1.6	2.0	1.9	1.7	2.1	2.3
West Elk	White River	56	WHRI1	CO	38.69	107.19	2.3	2.2	1.9	1.9	1.9	1.7	1.8	2.1	2.0	1.8	2.1	2.2
Wheeler Peak	Wheeler Peak	35	WHPE1	NM	36.57	105.42	2.3	2.2	1.9	1.8	1.8	1.6	1.8	2.2	2.1	1.8	2.2	2.3
White Mountain	White Mountain	37	WHIT1	NM	33.49	105.83	2.1	1.9	1.6	1.5	1.5	1.4	1.8	2.0	2.0	1.7	1.8	2.1
Wichita Mountains	Wichita Mountains	30	WIMO1	OK	34.74	98.59	2.7	2.6	2.4	2.4	3.0	2.7	2.3	2.5	2.9	2.6	2.7	2.8
Wind Cave	Wind Cave	60	WICA1	SD	43.55	103.48	2.5	2.5	2.5	2.5	2.7	2.5	2.3	2.3	2.2	2.2	2.6	2.6
Wolf Island	Okefenokee	16	OKEF1	GA	31.31	81.30	3.4	3.1	3.1	3.0	3.3	3.7	3.7	4.1	4.0	3.7	3.5	3.5
Yellowstone	Yellowstone	66	YELL2	WY	44.55	110.40	2.5	2.4	2.3	2.2	2.2	1.9	1.7	1.6	1.8	2.1	2.5	2.5
Yolla Bolly - Middle Eel	Trinity	104	TRIN1	CA	40.11	122.96	4.0	3.4	3.1	2.8	2.7	2.5	2.4	2.5	2.6	2.7	3.3	3.6
Yosemite	Yosemite	96	YOSE1	CA	37.71	119.70	3.3	3.0	2.8	2.3	2.1	1.8	1.5	1.5	1.5	1.8	2.4	2.8
Zion	Zion	51	ZION1	UT	37.25	113.01	2.7	2.4	2.0	1.6	1.5	1.3	1.2	1.4	1.4	1.6	2.0	2.4

a: No particulate matter sampling or visibility monitoring is conducted in the Bering Sea Wilderness.

b: *f(RH)* values for Virgin Islands National Park were not calculated because of the limited RH data available.

APPENDIX B

Analysis of the Effect of Correlation Between *f(RH)* and SO_4 and *f(RH)* and NO_3 on Deciview Calculations using *f(RH)*

The regional haze regulation requires separate tracking of visibility changes for the worst 20% and best 20% visibility days. If there is a significant correlation in any month at any site between daily relative humidity and the sulfate or nitrate concentrations, then use of the monthly-averaged *f(RH)* will systematically over- or under-predict the contribution to visibility impairment of the aerosol species.

This Appendix presents an analysis of potential biases associated with correlations between relative humidity and inorganic hygroscopic aerosol species using data collected at 20 mandatory Federal Class I areas where relative humidity measurements were made. The effect of any correlation that may exist between SO_4 and/or NO_3 and *f(RH)* appears to induce small errors that are, on average, within 10% of the true value for every site included in the study. Generally those sites in the West are slightly overestimated by using average *f(RH)* values while those in the East are underestimated. The type of average *f(RH)* value used (monthly, yearly, average of top 20% extinction days, average of bottom 20% extinction days) can have a significant impact on the amount of error induced in the calculation of a yearly deciview index based on the highest 20% (respectively, lowest 20%) extinction days. In most instances, the use of a yearly or monthly average *f(RH)* resulted in similar percentage errors and both procedures resulted in less error than using average *f(RH)* values derived from the worst or best 20% days. Therefore, the simpler climatological approach is used in regional haze calculations.

We assessed the effect of the correlation between daily *f(RH)* and SO4 and/or NO3 mass concentrations. This is prompted by the observation that, in reconstructing extinction from aerosol mass concentrations, often an average value is used for *f(RH)* due to the unavailability of on-site relative humidity measurements from which *f(RH)* values can be calculated. The equation for reconstructed extinction is an additive linear combination of contributions from various aerosol species. The contribution to estimated atmospheric extinction due to SO_4 and NO_3 (interpreted as ammonium sulfate and nitrate) occurs in the form $ef(RH)*SO_4$ and $ef(RH)*NO_3$, where e is an average mass scattering efficiency. Calculating average extinctions over a given time period results in averaging of the products $ef(RH)*SO_4$ and $ef(RH)*NO_3$. However, when an average *f(RH)* is used in place of a daily *f(RH)*, the contribution to extinction due to SO_4 and/or NO_3 is estimated by the product of the separate averages of *f(RH)* and SO_4, and, likewise, separate averages of *f(RH)* and NO_3. Let us denote the errors introduced due to such substitution of averages by dSO_4 and dNO_3, respectively.

That is,

$$dSO_4 = \text{average}\, f(RH) * \text{average } SO_4 - \text{average } [f(RH) * SO_4] \qquad (1)$$

and

$$dNO_3 = \text{average}\, f(RH) * \text{average } NO_3 - \text{average } [f(RH) * NO_3]. \qquad (2)$$

These errors will be zero if, and only if, the sample Pearson correlation between *f(RH)* and SO_4, respectively *f(RH)* and NO_3, is zero.

More generally, suppose *n* pairs of observations, say $(x_1, y_1), (x_2, y_2),\ldots, (x_n, y_n)$ are available on the variable pair *(x, y)*. If the sample Pearson correlation coefficient *r* between *X* and *Y* is zero, it follows that the average of the product *X*Y* is equal to the product of the separate averages of *X* and *Y*. Namely,

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\left(\sum_{i=1}^{n}(x_i - \bar{x})^2\right)\left(\sum_{i=1}^{n}(y_i - \bar{y})^2\right)}} = 0 \qquad \text{implies} \qquad \frac{1}{n}\sum_{i=1}^{n} x_i y_i = \bar{x}\bar{y}. \qquad (3)$$

An examination of the sample correlation between SO_4 and *f(RH)*, as well as NO_3 and *f(RH)*, for various site/year combinations in the IMPROVE database reveals the presence of statistically significant correlations between SO_4 and/or NO_3 and *f(RH)*, in some instances, implying that the differences dSO_4 and dNO_3, defined in equations (1) and (2) respectively, are not zero. Therefore, to understand the practical implications of the presence of correlations between *f(RH)* and SO_4/NO_3, one needs to examine the magnitudes of dSO_4 and dNO_3 relative to the target quantities [average(*f(RH)**SO_4)] and [average(*f(RH)**NO_3)]. We have made this assessment using IMPROVE data for sites/years for which daily *f(RH)* data is available. In addition to examining dSO_4 and dNO_3 individually, we have also examined the combined error

$$dSO_4 + dNO_3 = \text{average}\, f(RH) * (\text{average of } SO_4 + NO_3) - \text{average } [f(RH) * (SO_4 + NO_3)]. \qquad (4)$$

In our calculations we used the following input quantities and data completeness criteria:

- *f(RH)* is computed from hourly RH observations. Hourly *f(RH)* factors are derived from Tang's smoothed ammonium sulfate growth curves. For RH values greater than 95%, the *f(RH)* value is flagged as missing. Finally, the daily average of the hourly *f(RH)* observations is obtained. Note the daily average *f(RH)* is set to missing on days for which there are fewer than 16 hourly *f(RH)* observations.

- SO_4 is interpreted as ammonium sulfate and NO_3 as ammonium nitrate in units of ng/m^3.

- $f(RH)_{Monthly}$: Monthly average *f(RH)* for each month was computed for any given site by averaging $f(RH)_{Daily}$ for that month across all years for which data were available for the site under consideration.

- $f(RH)_{Yearly}$ = Yearly average *f(RH)* for any given year and site was calculated by averaging all daily *f(RH)* values for the site for the given year. Days for which *f(RH)* was "missing" were not included in the calculation of this average.

The use of two different averages was considered:

(1) $f(RH)_{monthly}$ and (2) $f(RH)_{yearly}$.

The following %age errors were calculated:

(a) (Figure 1)

$pSO_{4\,yearly}$ = The error dSO_4, expressed as a %age, when $f(RH)_{yearly}$ is used in place of $f(RH)_{daily}$

$$= \frac{average[f(RH)_{yearly} * SO_4] - average[f(RH)_{daily} SO_4]}{average[f(RH)_{daily} * SO_4]} \times 100$$

(b) (Figure 2)

$pSO_{4\ monthly}$ = The error dSO_4, expressed as a %age, when $f(RH)_{monthly}$ is used in place of $f(RH)_{daily}$

$$= \frac{average[f(RH)_{monthly} * SO_4] - average[f(RH)_{daily} SO_4]}{average[f(RH)_{daily} * SO_4]} \times 100$$

(c) (Figure 3)

$pNO_{3\ yearly}$ = The error dNO_3, expressed as a %age, when $f(RH)_{yearly}$ is used in place of $f(RH)_{daily}$

$$= \frac{average[f(RH)_{yearly} * NO_3] - average[f(RH)_{daily} NO_3]}{average[f(RH)_{daily} * NO_3]} \times 100$$

(d) (Figure 4)

$pNO_{3\ monthly}$ = The error dNO_3, expressed as a %age, when $f(RH)_{monthly}$ is used in place of $f(RH)_{daily}$

$$= \frac{average[f(RH)_{monthly} * NO_3] - average[f(RH)_{daily} NO_3]}{average[f(RH)_{daily} * NO_3]} \times 100$$

(e) (Figure 5)

$pSO_4NO_{3\ yearly}$ = The error (dSO_4+dNO_3), expressed as a %age, when $f(RH)_{yearly}$ is used in place of $f(RH)_{daily}$

$$= \frac{average[f(RH)_{yearly} * (SO_4 + NO_3)] - average[f(RH)_{daily}(SO_4 + NO_3)]}{average[f(RH)_{daily} * (SO_4 + NO_3)]} \times 100$$

(f) (Figure 6)

$pSO_4NO_{3\ monthly}$ = The error (dSO_4+dNO_3), expressed as a %age, when $f(RH)_{monthly}$ is used in place of $f(RH)_{daily}$

$$= \frac{average[f(RH)_{monthly}*(SO_4+NO_3)] - average[f(RH)_{daily}(SO_4+NO_3)]}{average[f(RH)_{daily}*(SO_4+NO_3)]} \times 100$$

The results are displayed graphically in Figures 1 through 6. In each figure, box-and-whisker plots of the annual visibility indices are displayed for each site. The number of years of data used in any given box-and-whisker plot ranges from 3 to 11 years, depending on the site, based on data completeness for the site. Each box-and-whisker plot has a rectangular part called the box. Lines extending out from the top and bottom edges of the box are called whiskers. The box represents the middle 50% of the distribution of the yearly indices and the position of the horizontal line between the top and bottom edges of the box represents the position of the median value. The red dot on the box-and-whisker plot indicates the position of the mean value for the %age error. The value below the label for each site shown along the horizontal axis is the average "true" $f(RH)_{daily}SO_4$ in ng/m^3 for that site across the years of data included the study. The vertical lines (whiskers) are drawn from the box to the most extreme point within 1.5 interquartile ranges (an interquartile range is the distance between the 25th and the 75th sample %iles). Any value more extreme than this is considered a potential outlier and marked with a plot symbol. Identification of such data values is done to assist the data analyst in carrying out exploratory data analyses and gaining a better understanding of the data and does not imply that there is something wrong with such data values. Often reasons can be found that help explain the "extremeness" of potential outliers.

An examination of Figures 1 through 6 shows that, in general, the average and/or median error is typically below ±10%. Generally those sites in the West are overestimated by using average *f(RH)* values while those in the East are underestimated.

Effect of f(RH) value on Yearly Visibility Index

A second study was carried out to examine the effect on yearly visibility indices of different choices of *f(RH)* values that may be substituted for $f(RH)_{daily}$. Five candidates were considered for such substitution:

- $f(RH)_{daily}$ = daily *f(RH)* value
- $f(RH)_{monthly}$ = monthly average *f(RH)* values computed as explained earlier
- $f(RH)_{yearly}$ = yearly average *f(RH)* values computed as explained earlier.
- $f(RH)_{high20}$ = average of $f(RH)_{daily}$ values computed from the highest 20% extinction days for a given year. These highest 20% extinction days were determined by computing reconstructed extinction using $f(RH)_{daily}$ values, then sorting these extinctions and identifying the highest 20% extinction days.
- $f(RH)_{low20}$ = average of $f(RH)_{daily}$ values computed from the lowest 20% extinction days for a given year. These lowest 20% extinction days were determined by computing reconstructed extinction using $f(RH)_{daily}$ values, then sorting these extinctions and identifying the lowest 20% extinction days.

A sampling day was included in the analysis only when $f(RH)_{daily}$ and all of the aerosol concentrations needed to calculate the reconstructed extinction were available for that day. Such a day is referred to here as a "complete day." Recall that $f(RH)_{daily}$ is available for a day only if at least 16 of the hourly *f(RH)* averages were available for that day in the IMPROVE database. For any given site, years with fewer than 50 "complete days" were not considered in this study. Note that extinction is computed here in inverse kilometers (1/km).

The following quantities were computed for the highest 20% extinction days.

- Sorting was done based on reconstructed daily extinction computed using $f(RH)_{daily}$. The average extinction and deciview for the highest 20% of days were computed. These are denoted by $ext_{high,daily}$ and $dv_{high,daily}$, respectively.

- Sorting was done based on reconstructed daily extinction computed using $f(RH)_{monthly}$. The average extinction and deciview for the highest 20% of days were computed. These are denoted by $ext_{high,monthly}$ and $dv_{high,monthly}$, respectively.

- Sorting was done based on reconstructed daily extinction computed using $f(RH)_{yearly}$. The average extinction and deciview for the highest 20% of days were computed. These are denoted by $ext_{high,yearly}$ and $dv_{high,yearly}$, respectively.

- Sorting was done based on reconstructed daily extinction computed using $f(RH)_{high20}$. The average extinction and deciview for the highest 20% of days were computed. These are denoted by ext_{high20} and dv_{high20}, respectively.

The following quantities were computed for the lowest 20% extinction days:

- Sorting was done based on reconstructed daily extinction computed using $f(RH)_{daily}$. The average extinction and deciview for the lowest 20% of days were computed. These are denoted by $ext_{low,daily}$ and $dv_{low,daily}$, respectively.

- Sorting was done based on reconstructed daily extinction computed using $f(RH)_{monthly}$. The average extinction and deciview for the highest 20% of days were computed. These are denoted by $ext_{low,monthly}$ and $dv_{low,monthly}$, respectively.

- Sorting was done based on reconstructed daily extinction computed using $f(RH)_{yearly}$. The average extinction and deciview for the highest 20% of days were computed. These are denoted by $ext_{low,yearly}$ and $dv_{low,yearly}$, respectively.

- Sorting was done based on reconstructed daily extinction computed using $f(RH)_{high20}$. The average extinction and deciview for the highest 20% of days were computed. These are denoted by ext_{low20} and dv_{low20}, respectively.

As mentioned earlier, only “complete days,” i.e., days for which data were available for each and every component of the equation for reconstructing extinction, were used in the above calculations.

The extinction index (respectively, deciview index) based on $f(RH)_{daily}$ was taken as the "true" or "correct" value. Relative errors, in %, for the other three methods ($f(RH)_{yearly}$, $f(RH)_{monthly}$, and one of $f(RH)_{high20}$ and $f(RH)_{low20}$, depending on whether the highest 20% extinction days or the lowest 20% extinction days are of interest) of computing reconstructed extinction were calculated as follows:

$$\%\ \text{error for a method} = \frac{\text{index computed by the method} - \text{index computed using } f(RH)_{daily}}{\text{index computed using } f(RH)_{daily}} \times 100 \qquad (11)$$

Visual summaries of these %age errors are provided in Figures 7 and 8 for extinction and Figures 9 and 10 for deciview. We observed that, for extinction or deciview representing the lowest 20% extinction days, the index computed with $f(RH)_{low20}$ tends to underestimate the true index, whereas the indices computed with $f(RH)_{monthly}$ or $f(RH)_{yearly}$ tend to overestimate it. For extinction or deciview representing the highest 20% extinction days, the index computed with $f(RH)_{high20}$ tends to overestimate the true index, whereas the indices computed with $f(RH)_{monthly}$ or $f(RH)_{yearly}$ tend to underestimate it.

Conclusions:

(a) The effect of any correlation that may exist between SO_4 and/or NO_3 and $f(RH)$ appears to induce errors that are, on average, within 10% of the true value for every site included in the study. Positive %age errors indicate that the true index is overestimated by the method under consideration. That is, the method results in a positive bias. This will occur when the corresponding correlation coefficient is negative. Likewise, negative %age errors indicate a negative bias. This situation will occur when the corresponding correlation coefficient is positive. These implications follow from the definition of these %age errors.

(b) The type of average $f(RH)$ value used (monthly, yearly, average of top 20% extinction days, average of bottom 20% extinction days) can have a significant impact on the amount of error induced in the calculation of a yearly deciview index based on the highest 20% (respectively, lowest 20%) extinction days. In most instances, the use of a yearly or monthly average $f(RH)$ resulted in similar %age errors and both procedures resulted in less error than using average $f(RH)$ values derived from the worst or best 20% days. Therefore, the simpler climatological approach is used in regional haze calculations.

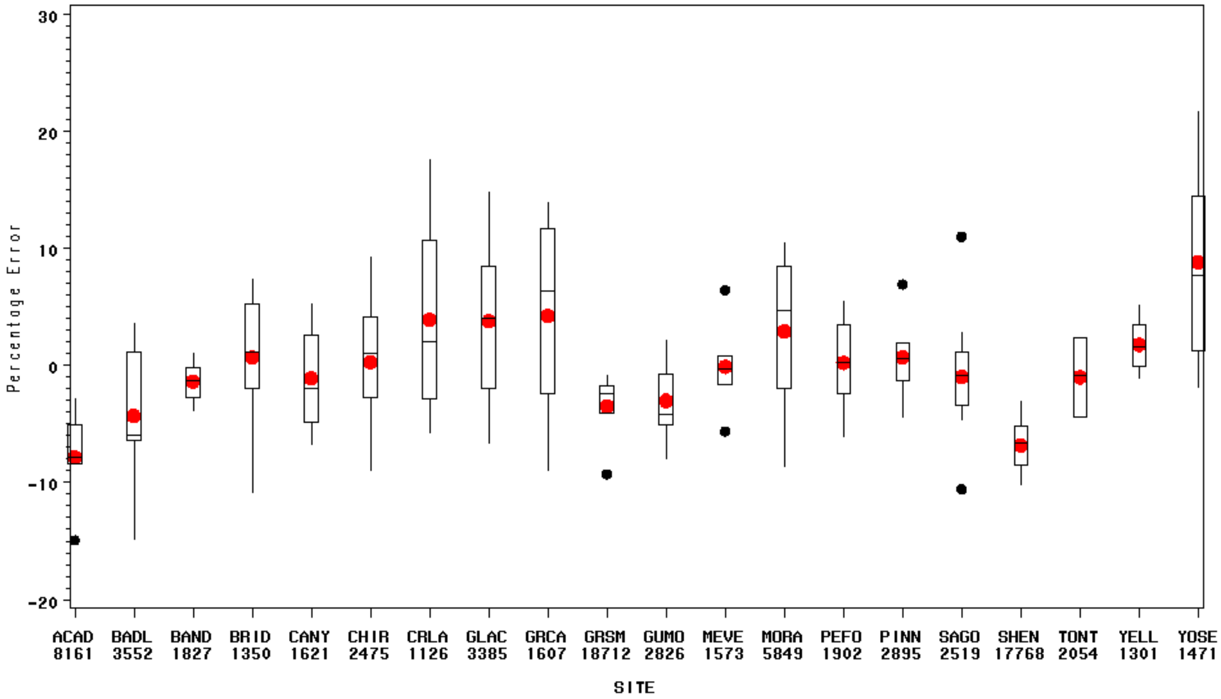

Figure B-1 Boxplots of yearly %age errors $pSO4_{yearly}$ for 20 selected IMPROVE sites. The red dot indicates the mean of the %age errors for a site computed based on years of data for that site included in the study. The value shown below the site name along the horizontal axis is the mean of average[$f(RH)_{daily}$ *SO4] (ng/m^3) for that site, averaged across years. An explanation of how to interpret the box-and-whisker plot is given in the body of the paper.

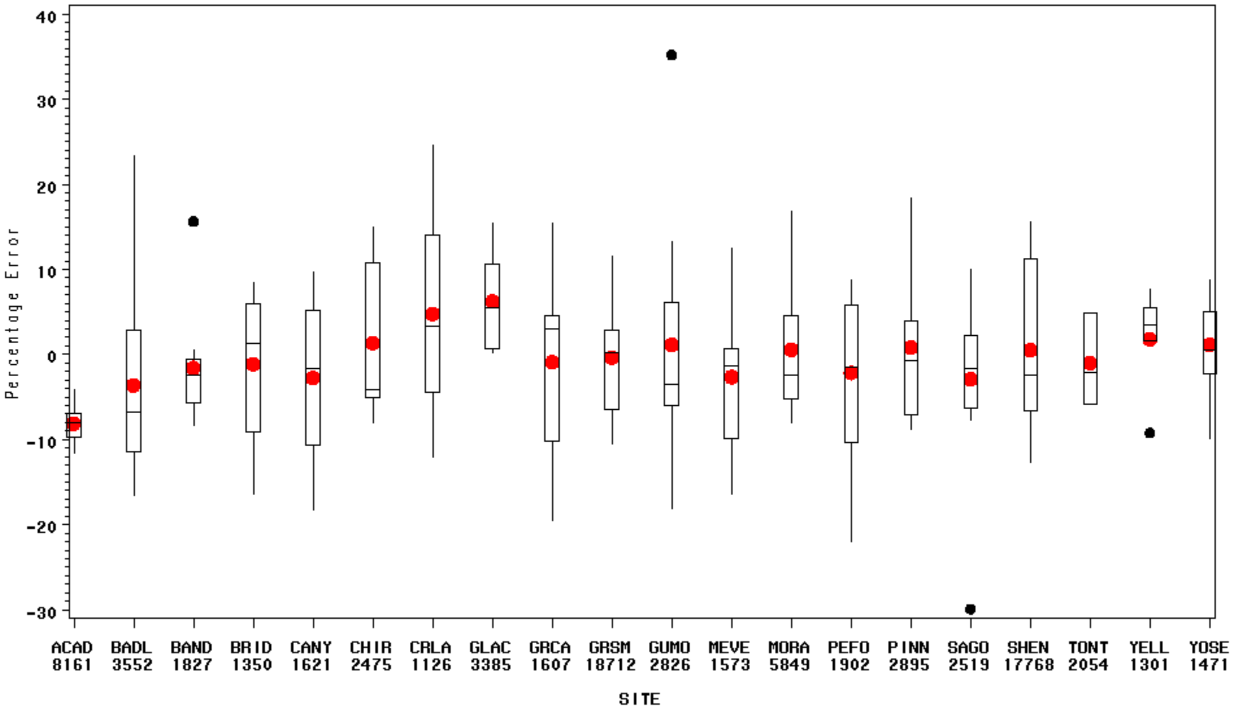

Figure B-2 Boxplots of $pSO4_{monthly}$ for 20 selected IMPROVE sites. The red dot indicates the mean of the %age errors for a site computed based on years of data for that site included in the study. The value shown below the site name along the horizontal axis is the mean of average[$f(RH)_{daily}$*SO4] (ng/m^3) for that site, averaged across years. An explanation of how to interpret the box-and-whisker plot is given in the body of the paper.

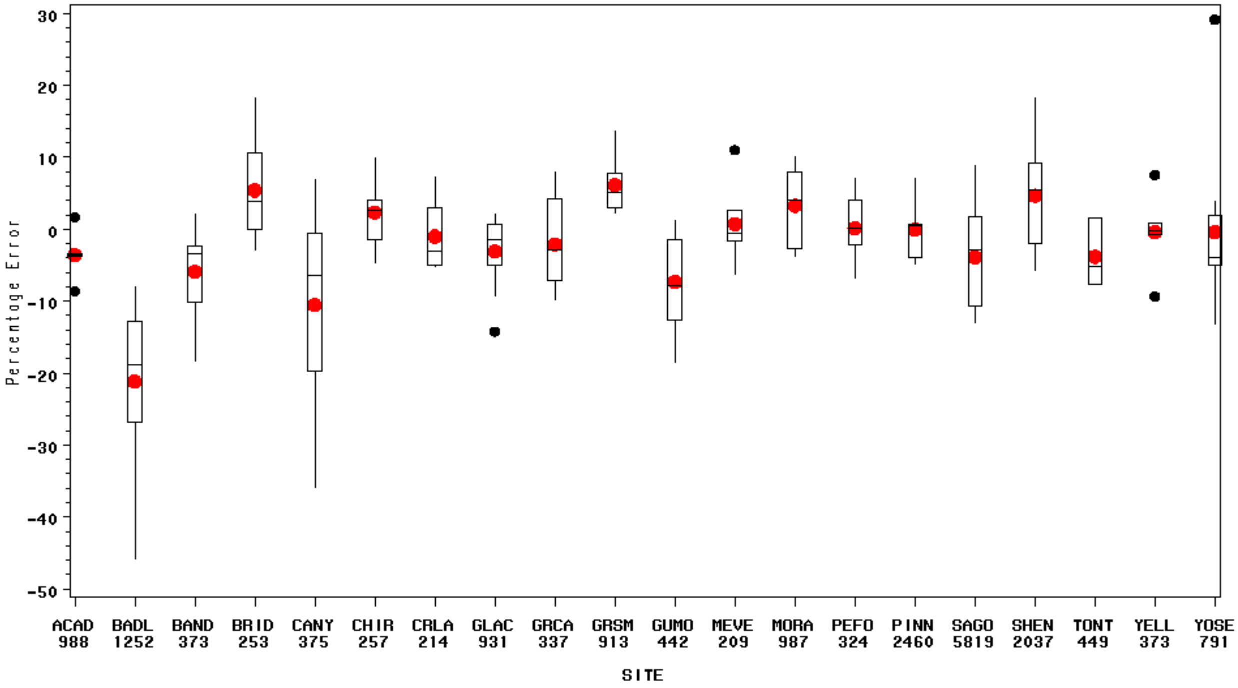

Figure B-3 Boxplots of $pNO3_{yearly}$ for 20 selected IMPROVE sites. The red dot indicates the mean of the %age errors for a site computed based on years of data for that site included in the study. The value shown below the site name along the horizontal axis is the mean of average[$f(RH)_{daily}$*NO3] (ng/m^3) for that site, averaged across years. An explanation of how to interpret the box-and-whisker plot is given in the body of the paper.

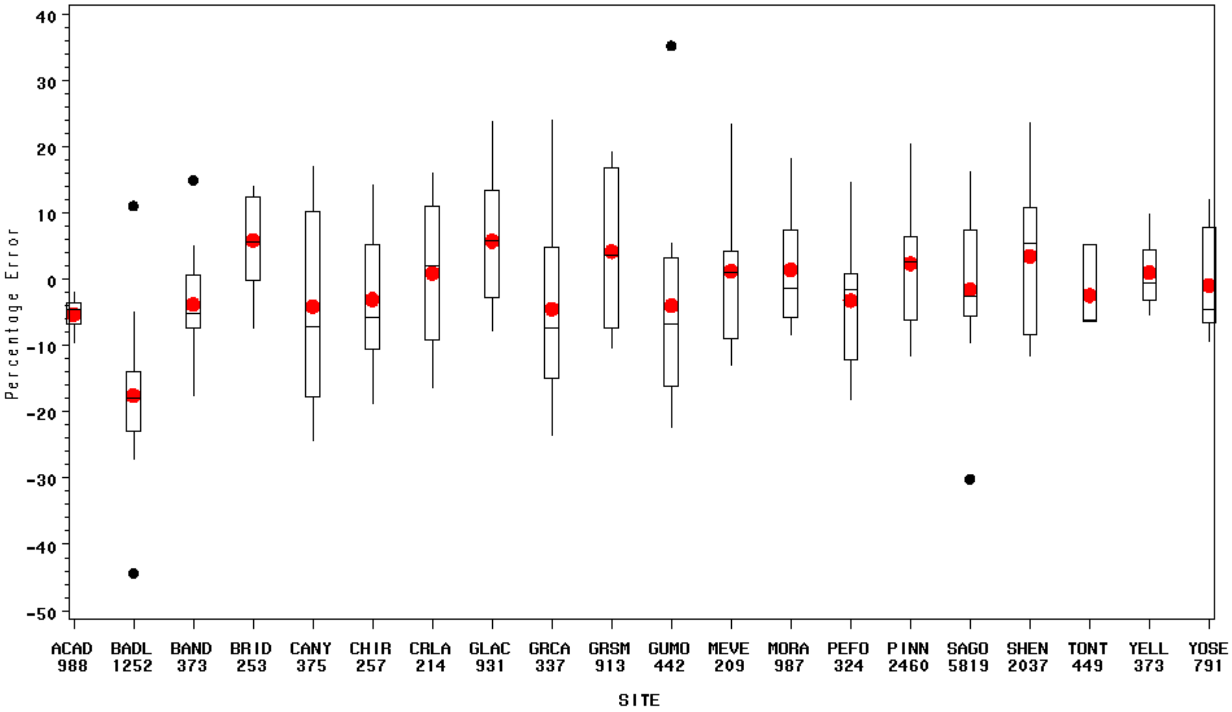

Figure B-4 Boxplots of $pNO3_{monthly}$ for 20 selected IMPROVE sites. The red dot indicates the mean of the %age errors for a site computed based on years of data for that site included in the study. The value shown below the site name along the horizontal axis is the mean of average[$f(RH)_{daily}$*NO3] (ng/m^3) for that site, averaged across years. An explanation of how to interpret the box-and-whisker plot is given in the body of the paper.

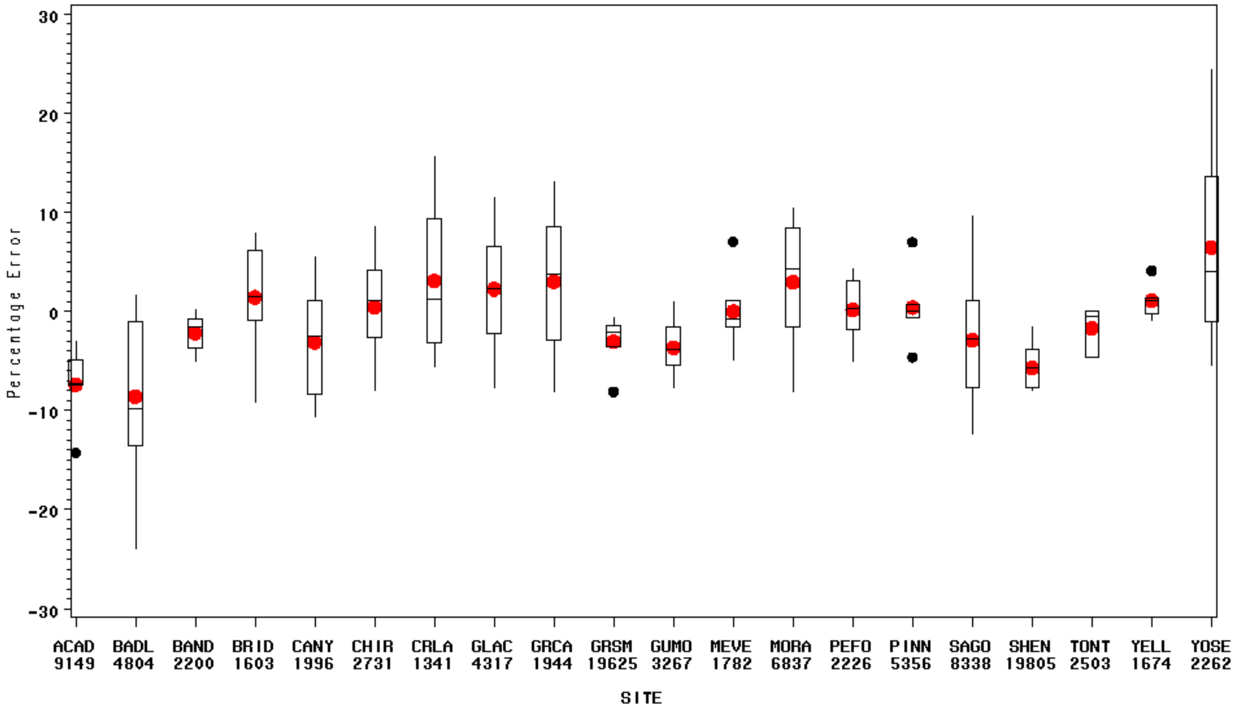

Figure B-5 Boxplots of $pSO4NO3_{yearly}$ for 20 selected IMPROVE sites. The red dot indicates the mean of the %age errors for a site computed based on years of data for that site included in the study. The value shown below the site name along the horizontal axis is the mean of average[$f(RH)_{daily}$*(SO4+NO3)] (ng/m^3) for that site, averaged across years. An explanation of how to interpret the box-and-whisker plot is given in the body of the paper.

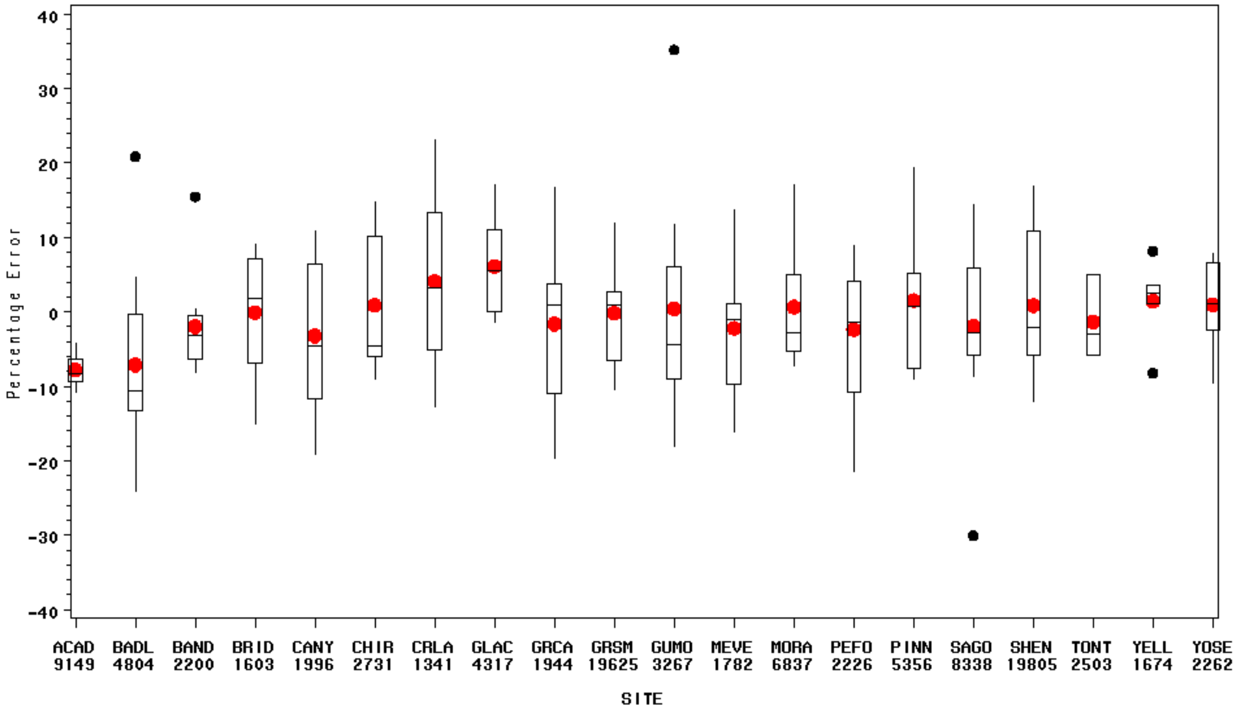

Figure B-6 Boxplots of pSO4NO3$_{monthly}$ for 20 selected IMPROVE sites. The red dot indicates the mean of the %age errors for a site computed based on years of data for that site included in the study. The value shown below the site name along the horizontal axis is the mean of average[f(RH)$_{daily}$*(SO4+NO3)] (ng/m^3) for that site, averaged across years. An explanation of how to interpret the box-and-whisker plot is given in the body of the paper.

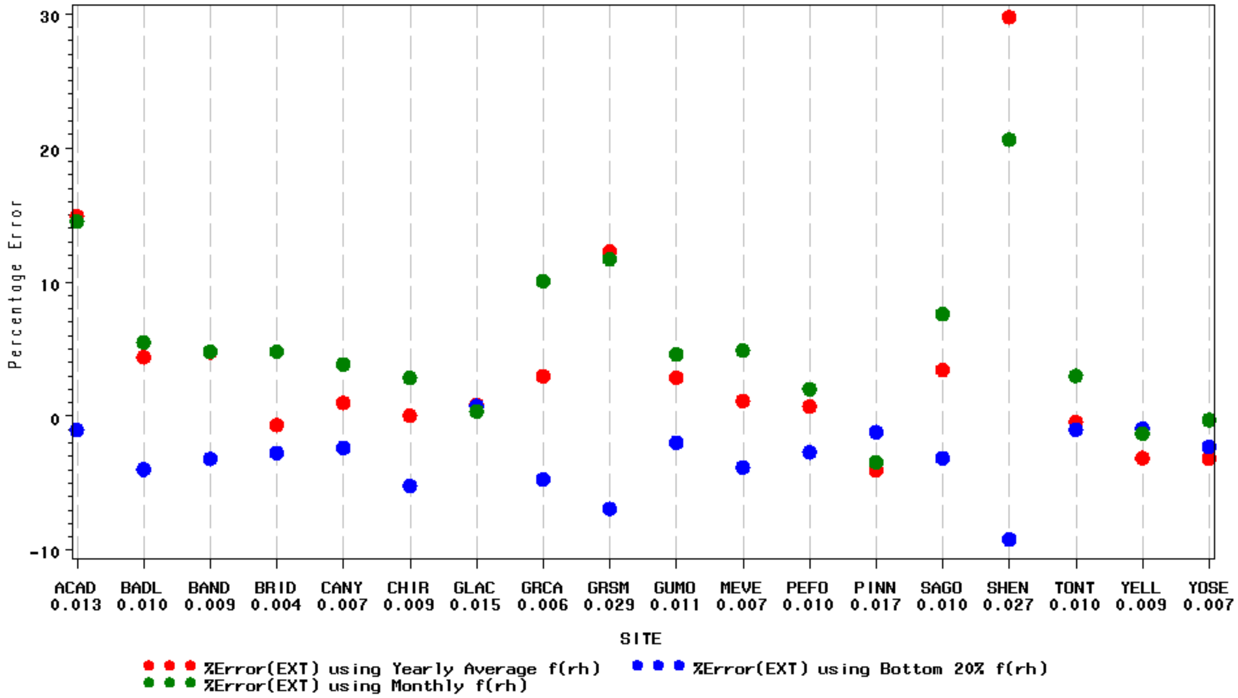

Figure B-7 Comparison of %age errors in average extinction for **LOWEST 20%** extinction days. These values are computed using f(RH)$_{yearly}$ (red points), f(RH)$_{monthly}$ (green points), and f(RH)$_{low20}$ (blue points). For any given site, these values were computed by averaging the %age errors across those years for the site that were included in the study. The value shown below a site name along the horizontal axis is the mean across years of the yearly average lowest 20% extinction values for that site calculated using f(RH)$_{daily}$.

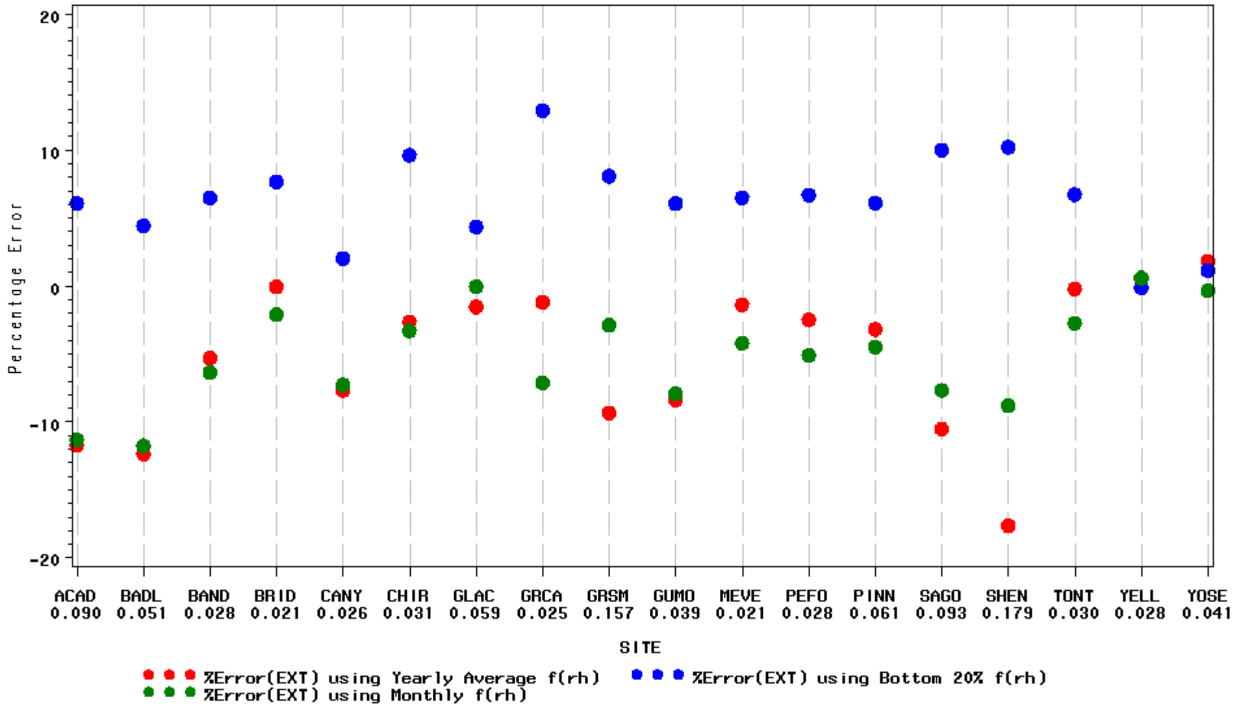

Figure B-8 Comparison of %age errors in average extinction for **HIGHEST 20%** extinction days. These values are computed using $f(RH)_{yearly}$ (red points), $f(RH)_{monthly}$ (green points), and $f(RH)_{high20}$ (blue points). For any given site, these values were computed by averaging the %age errors across those years for the site that were included in the study. The value shown below a site name along the horizontal axis is the mean across years of the yearly average highest 20% extinction values for that site calculated using $f(RH)_{daily}$.

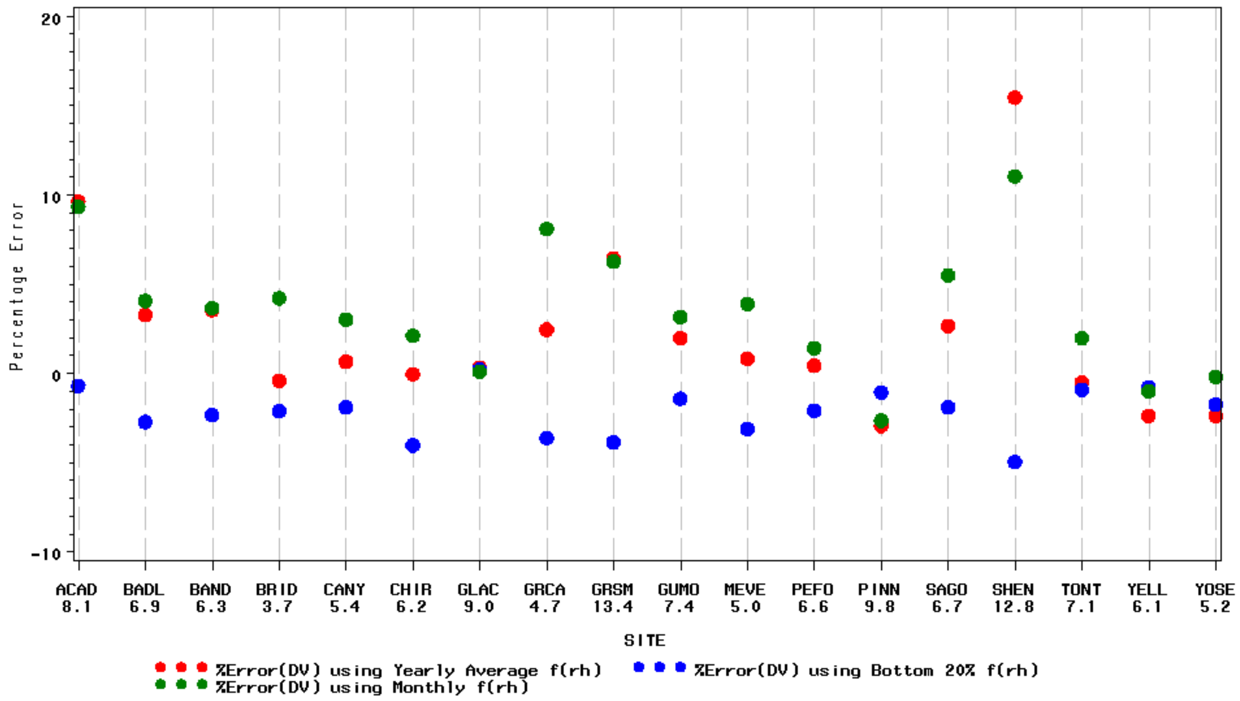

Figure 9. Comparison of %age errors in average deciview for **LOWEST 20%** extinction days. These values are computed using $f(RH)_{yearly}$ (red points), $f(RH)_{monthly}$ (green points), and $f(RH)_{low20}$ (blue points). For any given site, these values were computed by averaging the %age errors across those years for the site that were included in the study. The value shown below a site name along the horizontal axis is the mean across years of the yearly average lowest 20% deciview values for that site calculated using $f(RH)_{daily}$.

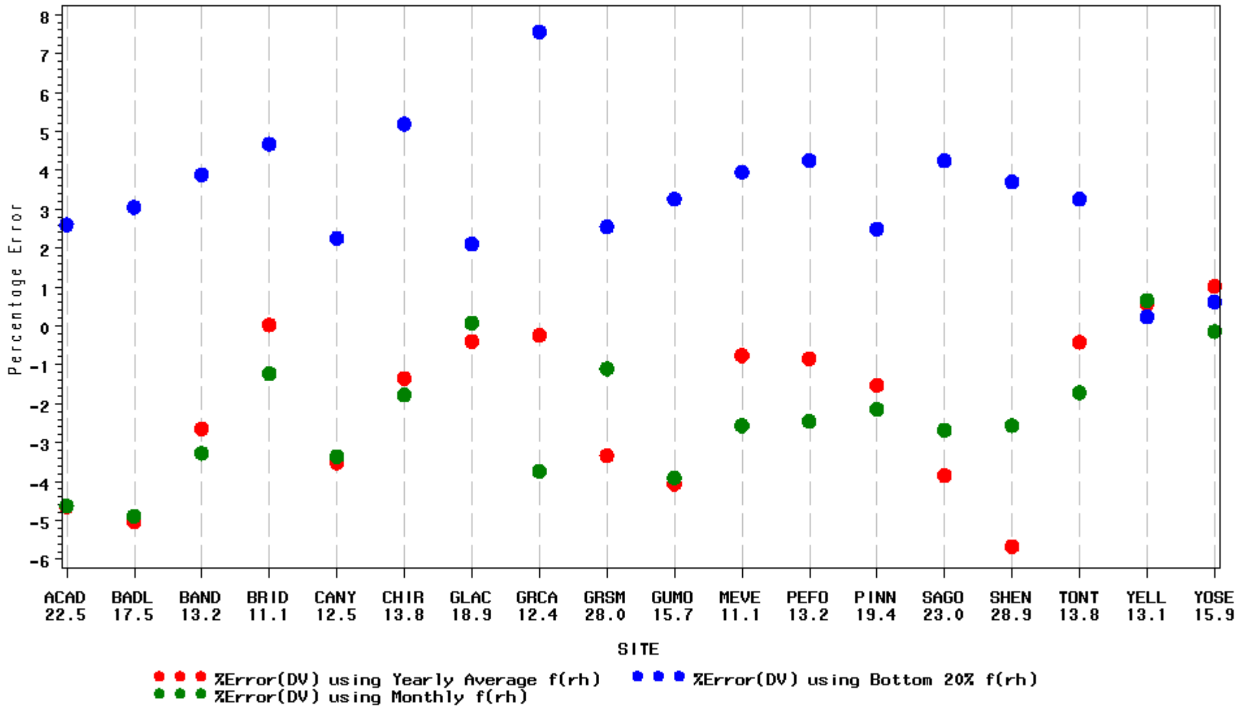

Figure B-10 Comparison of %age errors in average deciview for **HIGHEST 20%** extinction days. These values are computed using $f(RH)_{yearly}$ (red points), $f(RH)_{monthly}$ (green points), and $f(RH)_{high20}$ (blue points). For any given site, these values were computed by averaging the %age errors across those years for the site that were included in the study. The value shown below a site name along the horizontal axis is the mean across years of the yearly average highest 20% deciview values for that site calculated using $f(RH)_{daily}$.

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16. ABSTRACT

The purpose of this document is to provide guidance to the States in implementing the regional haze program under the Clean Air Act. As part of the program, this document provides guidance to EPA Regioal, State, and Tribal air quality management authorities and the general public, on how EPA intends to exercise its discretion in implementing Clean Air Act provisions and EPA regulations, concerning the tracking of progress under the regional haze program.

17. KEY WORDS AND DOCUMENT ANALYSIS

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