Supplemental BART Analysis
CALPUFF Protocol
for
Class I Federal Area
Visibility Improvement Modeling Analysis
DRAFT

April 15, 2010
(revised June 25, 2010 and August 19, 2010)

Colorado Department of Public Health and Environment
Air Pollution Control Division
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Colorado Department of Public Health & Environment / Air Pollution Control Division / Technical Services Program April 15, 2010 (revised June 25, 2010 and August 19, 2010)
1. Introduction

This protocol documents the Colorado Department of Public Health and Environment Air Pollution Control Division (Division) CALPUFF modeling analysis for estimating the degree of visibility improvement from potential Best Available Retrofit Technology (BART) control technology options. It describes dispersion modeling and analysis procedures and methods for quantifying the degree of visibility improvement from potential BART control scenarios/strategies. It does not explain how the visibility results are factored into the BART determination process (i.e., 5-step process) or discuss the specific BART scenarios that will analyzed.

This protocol is based on the following two documents:


This protocol follows the procedures above with the following exceptions:

1. General changes were made to reflect the fact that this modeling analysis will be performed by the Division and not by the source operators.
2. CALMET settings are consistent with the August 31, 2009 EPA memo "Clarification on EPA-FLM Recommended Settings for CALMET" with the exception of three CALMET parameters (NZ, ZFACE, and ZIMAX). U.S. EPA Region 8 approved this deviation for CALMET modeling in Colorado via email on October 7, 2009. Details about these parameters and the technical justification are found elsewhere in this protocol.
3. MM5 meteorological fields used in CALMET include the following three years: 2001, 2002, and 2003. Specifically, 36 kilometer (km) resolution meteorological fields are from a national U.S. EPA MM5 modeling analysis for 2001. For 2002, 12km resolution Western Regional Air Partnership (WRAP) MM5 fields are used. For 2003, 4 km resolution kilometer fields from a CDPHE MM5 analysis, performed by Alpine Geophysics, are used. Language in the CALMET section of this protocol has been revised accordingly.
4. Emissions estimation language from the subject-to-BART modeling protocol was replaced with BART analysis modeling language.
5. The most recent regulatory model versions of CALMET, CALPUFF, and CALPOST are used.
6. CALMET processing for all three years has been revised. As compared to the 2005 Division BART modeling, this analysis uses higher resolution MM5 data for 2002 and 2003. As compared to the Division’s 2005 modeling, this analysis uses a larger modeling
domain and a different projection. All of the geophysical processing and meteorological data preprocessing was revised. The CALMET modeling used in this analysis was performed by CH2M Hill for a recent PSD permit application in Colorado. Prior to use for this modeling effort, the CALMET analysis was reviewed and approved by the Division earlier in 2010. This protocol has been updated accordingly to reflect the way the CALMET fields were developed by the permit applicant.

7. **Degree of visibility improvement metrics and associated modeling procedures** have been revised to streamline the reporting process, to improve the clarity of the procedures, and to remove the methods that relied on use of presumptive limits as a starting point.

8. The **June 25, 2010 revision** to this protocol clarifies the modeling procedures. It includes language revisions to better describe model settings and the modeling process. In addition, during the modeling process, there were a few deviations from the April 15, 2010 protocol.

A description of the deviations is presented below:

- **Ozone Stations.** The Division inadvertently included an old ozone station list in the April 15, 2010 draft protocol. The ozone station list in this protocol has been updated to match the stations used in this analysis.

- **Upper Air Stations.** The Division inadvertently retained language from the 2005 protocol in the April 15, 2010 draft protocol that stated the CALMET meteorological modeling would include the Grand Junction upper air station. For this supplemental BART modeling, as indicated in #6, above, the Division used the CALMET.DAT files developed by a recent PSD permit applicant. The CALMET modeling performed by the applicant did not use the Grand Junction upper air station. The Division did not make any changes to the permit applicant’s CALMET modeling for this supplemental BART analysis.

- **Ammonia Background.** The April 15 protocol indicated that an ammonia background of 44 ppb would be used for all sources in northeast Colorado. During the process of setting up modeling runs for CENC (near Golden) and CEMEX (near Lyons), file review showed that the Division’s technical staff had previously approved an ammonia background of 5 ppb for CENC and CEMEX in 2006 during the BART Analysis process. To maintain consistency with previous ammonia background decisions for these two BART-eligible sources, the ammonia background for CEMEX and CENC used in this analysis is 5 ppb, not 44 ppb. The ammonia section of this protocol has been updated accordingly.

- **Degree of Visibility Improvement Metrics.** Per U.S. EPA comments on the April 15, 2010 protocol, a statement has been added to the protocol to reflect the U.S. EPA Region 8 comment that “To show the change in visibility impact between scenarios the most important metric to provide would be the delta-deciview between pre and post control 98th percentile impacts for each scenario in the three modeling years. Also provide the number of days exceeding .5 and 1 deciview.”

- **Postprocessors.** The April 15 protocol indicated that the Division might use its 98th percentile processor to streamline the modeling. In fact, the Division’s 98th percentile processor was not used because the regulatory version of CALPOST adequately summarizes results.

- **Domain maps.** The protocol has been clarified to reflect the fact that the modeling domain for 2003 is slightly smaller than the 2001 and 2002 domains due to the
limited size of the CDPHE 2003 4km MM5 fields. Language describing the domain has been updated to reflect the domains used in this analysis.
g. Section 2 (Emission Estimates) revisions. The opening paragraph of Section 2 and Section 2.2 were revised to clarify the emission estimation process for this analysis.
9. The August 19, 2010 revision to this protocol are limited to Section 2.4. The revised language provides additional detail and clarification regarding the treatment of direct particulate matter.
1.1. Visibility Calculations

The general theory for performing visibility calculations with the CALPUFF modeling system is described in several documents, including:

- “Federal Land Manager’s Air Quality Related Values Workgroup (FLAG): Phase I Report” (FLAG, 2000)
- “A User's Guide for the CALPUFF Dispersion Model” (Scire, 2000)

In general, visibility is characterized either by visual range (the greatest distance that a large object can be seen) or by the light extinction coefficient, which is a measure of the light attenuation per unit distance due to scattering and absorption by gases and particles.

Visibility is impaired when light is scattered in and out of the line of sight and by light absorbed along the line of sight. The light extinction coefficient \( b_{\text{ext}} \) considers light extinction by scattering \( b_{\text{scat}} \) and light extinction by absorption \( b_{\text{abs}} \):

\[
b_{\text{ext}} = b_{\text{scat}} + b_{\text{abs}}
\]

The scattering components of extinction can be represented by these components:

- light scattering due to air molecules = Rayleigh scattering = \( b_{\text{rayleigh}} \)
- light scattering due to particles = \( b_{\text{sp}} \)

The absorption components of extinction can be represented by these components:

- light absorption due to gaseous absorption = \( b_{\text{ag}} \)
- light absorption due to particle absorption = \( b_{\text{ap}} \)

Particle scattering, \( b_{\text{sp}} \), can be expressed by its components:

\[
b_{\text{sp}} = b_{\text{SO}_4} + b_{\text{NO}_3} + b_{\text{OC}} + b_{\text{SOIL}} + b_{\text{Coarse}}
\]

where:

- \( b_{\text{SO}_4} \) = scattering coefficient due to sulfates = \( 3[(\text{NH}_4)_2\text{SO}_4]f(\text{RH}) \)
- \( b_{\text{NO}_3} \) = scattering coefficient due to nitrates = \( 3[\text{NH}_4\text{NO}_3]f(\text{RH}) \)
- \( b_{\text{OC}} \) = scattering coefficient due to organic aerosols = \( 4[\text{OC}] \)
- \( b_{\text{SOIL}} \) = scattering coefficient due to fine particles = \( 1[\text{Soil}] \)
- \( b_{\text{Coarse}} \) = scattering coefficient due to coarse particles = \( 0.6[\text{Coarse Mass}] \)

Particle absorption from soot is defined as:

- \( b_{\text{ap}} \) = absorption due to elemental carbon (soot) = \( 10[\text{EC}] \)

The concentration values (in brackets) are expressed in micrograms per cubic meter. The numeric coefficient at the beginning of each equation is the dry scattering or absorption efficiency in meters-squared per gram. The \( f(\text{RH}) \) term is the relative humidity adjustment factor.
The total atmospheric extinction can be expressed as:

\[ b_{\text{ext}} = b_{\text{SO}_4} + b_{\text{NO}_3} + b_{\text{OC}} + b_{\text{SOIL}} + b_{\text{Coarse}} + b_{\text{ap}} + b_{\text{rayleigh}} \]

In this equation, the sulfate (SO4) and nitrate (NO3) components are referred to as hygroscopic components because the extinction coefficient depends upon relative humidity. The other components are non-hygroscopic.

The variation of the effect of relative humidity on the extinction coefficients for SO4 and NO3 can be determined in several ways. According to the BART guideline, monthly \( f(RH) \) values should be used.

The CALPUFF modeling techniques in this analysis provide ground level concentrations of visibility impairing pollutants. The concentration estimates from CALPUFF are used with the previously shown equations to calculate the extinction coefficient.

As described in the IWAQM Phase 2 Report, the change in visibility is compared against background conditions. The delta-deciview, \( \Delta dv \), value is calculated from the source’s contribution to extinction, \( b_{\text{source}} \), and background extinction, \( b_{\text{background}} \), as follows:

\[ \Delta dv = 10 \ln((b_{\text{background}} + b_{\text{source}}) / b_{\text{background}}) \]
2. Emission Estimates

The Division will perform the visibility change analysis based on 24-hour emission rates, described herein, that are developed for each unit evaluated in this supplemental BART analysis.

2.1. Pre-Control Emission Estimates

Pre-control emission rates are intended to reflect peak 24-hour average emissions that may occur in the future under the source’s current permit. There are several ways the emission rates may be determined.

For each BART-eligible unit at the facility, determine the pre-control peak 24-hour average emission rate for SO$_2$, NO$_x$, and direct particulate matter (PM) emissions (e.g., filterable and condensable PM$_{2.5}$ and PM$_{10}$) for each fuel and operational scenario allowed under the source’s current permit. For simplicity and to reduce the number of modeling scenarios, the Division may determine the peak 24-hour emission rate for each pollutant from all fuel/operational scenarios and combine the peak emission rates to produce a single pre-control emissions scenario. For example, the NO$_x$ emission rate might be from a natural gas-fired scenario while the SO$_2$ emission rate is from a coal-fired scenario. However, if the Division believes it is problematic to combine emissions from different fuel/operational scenarios, individual emission scenarios may be developed for each fuel/operational scenario allowed under the permit.

Historic data (e.g., CEM data) may be used to determine peak 24-hour emission rates. If historic emissions/operational data are used, it should:

1. Reflect operations from the most recent 3 to 5 year period unless a more recent period is more representative due to the recent installation of emission controls or due to other recent permit modifications.
2. Account for “high capacity utilization” during normal operating conditions.
3. Not include periods of start-up, shutdown, and malfunction, although these periods may be included for simplicity.
4. Be a good indicator of anticipated future peak emissions allowed under the current permit.
5. Account for fuel/material flexibility allowed under the source's permit. For example, if the unit is allowed to use more than one fuel, and the fuel resulting in the highest emission rates is not reflected in the historic data, conduct additional analysis to determine the peak 24-hour average emissions. Similarly, if a raw material has variable properties (e.g., variable sulfur content) and the raw material resulting in the highest emission rates was not used during the historic data period, conduct additional analysis.

If historic data are not a good indicator of anticipated future peak emissions allowed under the current permit, use supplemental emission calculations to determine the peak 24-hour average emission rates.
Allowable short-term (≤24-hours) emission rates or federally enforceable short-term emission limits (≤24-hours) may be used instead of CEM data or other historic data. If 24-hour emission limits do not exist, use limits of a shorter averaging period. If limits do not exist, use maximum hourly emissions based on emission factors and design capacity.

2.2. Post-Control Scenario/Strategy Emissions
The Division will determine the post-control emissions based on (1) estimated percent reduction for a particular control scenario using the highest 30-day rolling average emission rate in lb/MMBtu over the 3-year baseline period, or (2) the generally accepted lb/MMBtu emission rate documented for similar sources; depending on the availability of information from the source that specifies the expected post-control emission rate. Refer to section 2.4 for a discussion on PM speciation.

2.3. Documentation and Supporting Data
The Division will document and support the emission rates.

2.4. Treatment of Direct Particulate Matter Emissions and Particle Size Distributions
Direct filterable particulate matter (PM) emissions will be modeled initially with the same method used in the Division's original subject-to-BART CALPUFF modeling. Specifically, all direct filterable PM is modeled in CALPUFF as a single species with a geometric mass mean diameter of 2.5 microns and a geometric standard deviation of five. In CALPOST, the extinction efficiency for direct PM is set equal to 1.0 1/Mm per μg/m³.
3. CALMET, CALPUFF, POSTUTIL, CALPOST Modeling Methodology and Post-Processor Data Processing

This report includes sufficient technical documentation to support the application of CALPUFF at distances up to 300 kilometers. While CALPUFF may be used for source-to-receptor distances less than 50 kilometers at some receptors, depending on the sources modeled, there is a Class I area within the 50 to 300 km range from every BART source in Colorado.


In the context of the Phase 2 recommendation, the focus of the visibility analysis is on haze. These techniques are applicable in the range of thirty to fifty kilometers and beyond from a source. At source-receptor distances less than thirty to fifty kilometers, the techniques for analyzing visual plumes (sometimes referred to as ‘plume blight’) should be applied.

For the few cases where BART source-to-receptors distances are less than 50 kilometers, both the topography and the meteorological fields are complex and the use of CALPUFF appears to be appropriate based on the possibility of recirculation, stagnation, and complex flows. If the CEMEX Lyons plant is modeled, for example, the shortest source-to-receptor distance modeled is about 25 kilometers, but it involves an elevation change of about 3000 ft. In addition, in each case where a source has a source-to-receptor distance of less than 50 kilometers, such as the CEMEX, only a portion of the Class I area is less than 50 km from the source.

3.1. CALMET/CALPUFF Model Selection

The following model versions will be used:

- CALPUFF version 5.8, level 070623
- CALMET version 5.8, level 070623
- POSTUTIL version 1.56, level 070627
- MAKEGEO version 2.29, level 070327
- PMERGE version 5.32, level 070627
- SMERGE version 5.57, level 070627
- CALPOST version 5.6394, level 070622
3.1.1. CALMET

The MM5/CALMET meteorological fields have been generated for 2001, 2002, and 2003. CALMET is based on the Diagnostic Wind Model (Douglas, S. and R. Kessler, 1988). The Diagnostic Wind Model has been significantly enhanced (Scire, 2000). For this particular study, the model uses a Lambert Conformal Projection coordinate system to account for the Earth's curvature.

CALMET uses a two-step approach to calculate wind fields. In the first step, an initial-guess wind field is adjusted for slope flows and terrain blocking effects, for example, to produce a Step 1 wind field. In the second step, an objective analysis is performed to introduce observational data into the Step 1 wind field.

In this application, the initial guess wind fields are based on 36 km resolution MM5\textsuperscript{1} meteorological fields for 2001, 12 km resolution MM5 fields for 2002, and 4 km resolution MM5 fields for 2003. CALMET setting IPROG=14 will be used. Alpine Geophysics performed the CALMM5 extractions to convert the data format from MM5 output into a CALMET MM5.DAT format. The 2001 MM5 data were generated by the U.S. EPA. The 2002 MM5 data were generated by the Western Regional Air Partnership (WRAP). The 2003 MM5 data were generated for CDPHE by Alpine Geophysics.

The BART guideline does not specify the exact number of years of mesoscale meteorological data for use in CALPUFF, but according to 40 CFR 51 Appendix W, at least three years of meteorological data should be used.

3.1.1.1. CALMET Modeling Domain

The CALMET computational modeling domain is shown in Figure 1. It is based on a Lambert Conformal Conic (LCC) projection, as follows:

Latitude and longitude (decimal degrees) of projection origin:

- RLAT0 = 38.4N
- RLON0 = 105.5W

Matching parallels of latitude (decimal degrees) for project:

- XLAT1 = 36.4N
- XLAT2 = 40.5N

Datum:

- DATUM = NAR-C
- (North American 1983 GRS 80 Spheroid, mean for CONUS (NAD83))

The domain includes all Class I areas in Colorado with the exception of Mesa Verde NP. Mesa Verde was excluded because it is more than 300 km from all of the BART-eligible sources in Colorado and because the BART-eligible sources in Colorado would have higher impacts at other Class I areas. In addition, preliminary BART modeling in 2005 indicated that impacts at Mesa Verde would be small enough that its inclusion would not alter decisions based on impacts at other Class I areas that are

\textsuperscript{1} Fifth-Generation NCAR/Penn State Mesoscale Model.
closer to the BART sources. The domain does not include Class I areas in any nearby states because visibility impacts from Colorado’s BART sources are expected to be highest at Class I areas in Colorado. This assumption is based on source-to-receptor distances, professional judgment regarding prevailing air pollutant transport regimes, and recent modeling for a PSD permit in Pueblo. The CALMET domain includes almost the entire state of Colorado. For 2001 and 2002, it is 508 km x 688 km with 4-kilometer CALMET grid cells. For 2003, it is 504 km x 616 km with 4-kilometer CALMET grid cells. The domain for 2003 is smaller due to limitations in the size of the CDPHE 4km MM5 domain for 2003.

Figure 1. CALMET/CALPUFF modeling domain for 2001 and 2002. For 2003, the southern end of the domain is about 72 km north of the one shown above because of limitations with the CDPHE 2003 MM5 domain. Refer to Figure 2 to view the southern end of the 2003 domain.
3.1.1.2. CALMET Performance Evaluation
The MM5 meteorological fields used in this analysis were evaluated historically as part of other projects. The CALMET meteorological fields used in this analysis were developed by CH2M Hill for a recent PSD permit in Colorado. CH2M Hill performed a CALMET performance evaluation and concluded that the meteorological fields performed satisfactorily for the PSD application. The Division also reviewed the performance evaluation and the meteorological fields and concluded that the fields were satisfactory for the PSD permit. After further review, the Division concluded that the CALMET fields, which are consistent with the August 2009 EPA CALMET memo, are satisfactory for this supplemental BART analysis modeling.

3.1.1.3. Geophysical Processing (Terrain, Landuse, Landcover)
Gridded terrain elevations for the modeling domain are derived from 3 arc-second digital elevation models (DEMs) produced by the United States Geological Survey (USGS). The files cover 1-degree by 1-degree blocks of latitude and longitude. USGS 1:250,000 scale DEMs were used. The elevations are in meters relative to mean sea level and have a resolution of about 90 meters, shown in Figure 2. TERREL version 3.684, level 070327 was used.
Figure 2. CALMET terrain plus Class I Area receptors (blue) and BART sources. This example image is for the year 2003 configuration.
The land use data are based on USGS NLCD 1992 data use categories were mapped into the CALMET land use categories, as shown in Figure 3, using CTGPROC version 2.682, level 070430 with internal coordinate transformations by COORDLIB version 1.98, level 060911.

Figure 3. Land Use (example shown is for year 2002).

MAKEGEO version 2.29, level 070327 was used to process the geophysical data to create the GEO.DAT file.
3.1.1.4. CALMET Parameter Settings

U.S. EPA issued a memo regarding CALMET settings dated August 31, 2009 titled "Clarification on EPA-FLM Recommended Settings for CALMET." As shown in the example CALMET file in Appendix C, the CALMET settings in the U.S. EPA memo will be used with the exception of three CALMET parameters (NZ, ZFACE, and ZIMAX). U.S. EPA Region 8 approved this deviation for CALMET modeling in Colorado via email on October 7, 2009.

Parameter Descriptions:
NZ = number of vertical layers
ZFACE = cell face heights in arbitrary vertical grid (ZFACE (NZ+1)) (m)
ZIMAX = maximum overland mixing height (m)

EPA-FLM Recommended Setting:
NZ = 10
ZFACE = 0,20,40,80,160,320, 640, 1200, 2000, 3000, 4000
ZIMAX = 3000 m

CDPHE Setting:
NZ = 11
ZFACE = 0,20,40,80,160,320, 640, 1200, 2000, 3000, 4000, 5000
ZIMAX = 4500 m

Justification:
A ZIMAX setting of 3000 m is too low for some summer days in Colorado. A value of 4500 m is recommended instead of 3000 m. A ZIMAX setting of 4500 meters is based on analyses of soundings for summer ozone events. The analysis suggests mixing heights in the Denver area are often well above the CALMET default and EPA-FLM value of 3000 meters during the summer. For example, on some summer days, ozone levels are elevated all the way to 6000 meters MSL or beyond during some meteorological regimes, including some regimes associated with high ozone episodes. A sounding from the evening of July, 1 2002 (see Figure 4), which is a day the 8-hour ozone standard was exceeded at Rocky Mountain National Park, suggests the mixing height was likely around 6000 meters MSL. The mixing height estimate is based on the relative uniformity of the water vapor mixing ratio below 6000 meters, the temperature profile, the inverted "V" in the sounding, and data from a NOAA ozonesonde from Boulder that shows relatively constant ozone levels with height. Although low mixing heights can occur during the summer and other times of the year, maximum summertime daytime mixing heights in the Denver area often range from about 12,000 feet (3700 m) to 20,000 feet (6000 m) MSL. Since the CALMET ZIMAX setting is above ground level (AGL), not above mean sea level (MSL), the maximum summer daytime mixing height range over the plains would be about 15000 feet (4500 m) AGL. Thus, a ZIMAX setting of 4500 m is appropriate. In order to implement a ZIMAZ of 4500 m, it would be appropriate to add one additional vertical layer with a cell face height at 5000 m.
Figure 4. Example Denver summertime sounding.
3.1.1.5. CALMET Surface Stations

Figure 5. Surface meteorological stations.

3.1.1.6. CALMET Upper Air

The Denver upper air station is included in CALMET.
3.1.1.7. CALMET Precipitation Stations

Figure 6. Precipitation stations.

3.1.1.8. CALMET Parameter Summary

See Appendix C for a sample CALMET input file.
3.1.2. CALPUFF
The use of CALPUFF is recommended in 40 CFR 51 Appendix Y (BART guideline). The primary niche for CALPUFF is as a long-range transport model. It is a multi-layer, non-steady-state puff dispersion model that can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, chemical transformations, vertical wind shear, and deposition (Scire, 2000).

The default technical options in CALPUFF are used, unless specified otherwise in this report.

3.1.2.1. Receptor Network and Class I Federal Areas
The modeling domain will contain all Class I federal areas in Colorado within 300 kilometers of the BART-eligible source. Eleven federal Class I areas are included:
- Flat Tops Wilderness Area
- Rawah Wilderness Area
- Mt Zirkel Wilderness Area
- Weminuche Wilderness Area
- Rocky Mountain National Park
- Maroon Bells-Snowmass Wilderness Area
- La Garita Wilderness Area
- Great Sand Dunes National Park
- West Elk Wilderness Area
- Eagles Nest Wilderness Area
- Black Canyon of the Gunnison National Park

The discrete receptors for the Class I federal areas were generated by the National Park Service (NPS) NPS Convert Class I Areas (NCC) computer program. Receptor elevations provided by the NPS conversion program are used.

All receptors are included in a single CALPUFF simulation for each pre-control or post-control BART scenario. The appropriate receptors for each Class I area were extracted from the CALPUFF or POSTUTIL output files with the NCRECP parameter in CALPOST, which specifies the receptor range to be processed in CALPOST, as shown below.

<table>
<thead>
<tr>
<th>Class I Area</th>
<th>start</th>
<th>end</th>
<th>loading 0’s</th>
<th>CALPOST setting for NCRECP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Canyon of the Gunnison</td>
<td>1</td>
<td>91</td>
<td>0</td>
<td>91*1</td>
</tr>
<tr>
<td>Eagles Nest</td>
<td>52</td>
<td>304</td>
<td>91</td>
<td>213, 91<em>1, 213</em>1</td>
</tr>
<tr>
<td>Great Sand Dunes</td>
<td>375</td>
<td>438</td>
<td>304</td>
<td>154, 304<em>1, 194</em>1</td>
</tr>
<tr>
<td>La Garita</td>
<td>499</td>
<td>595</td>
<td>438</td>
<td>167, 498<em>1, 187</em>1</td>
</tr>
<tr>
<td>Maroon Bells</td>
<td>686</td>
<td>954</td>
<td>835</td>
<td>275, 889<em>1, 273</em>1</td>
</tr>
<tr>
<td>RMNP</td>
<td>966</td>
<td>1371</td>
<td>964</td>
<td>407, 864<em>1, 407</em>1</td>
</tr>
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<td>1371</td>
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<td>283, 2847<em>1, 283</em>1</td>
</tr>
</tbody>
</table>
3.1.2.2. CALPUFF Meteorology
Refer to the CALMET section of the report for details.

3.1.2.3. CALPUFF Modeling Domain
In this case, the CALPUFF and CALMET modeling domains are identical. Based on prevailing transport and modeling analyses done to support the subject-to-BART process, the Division concluded that the modeling domain used during the BART process would be sufficient for BART analysis modeling. In this case, the Division is using a larger CALPUFF domain that the one used in the subject-to-BART modeling. The larger domain retains more mass in the modeling system. Nevertheless, for some of the BART sources closer to the edge of the modeling domain, mass may be lost during some transport regimes. While this is less than ideal, modeling suggests that the periods with highest impacts occur with relatively direct transport from the BART source to the affected Class I areas and this same approach resulted in the inclusion of these BART-eligible sources in the BART process (i.e., the sources like Craig and Hayden near the domain boundary were found to be subject-to-BART based on CALPUFF modeling with a similar domain). Therefore, this modeling domain is sufficient in size to capture impacts on the days likely to be associated with the highest degree of visibility impairment. The modeling configuration provides a reasonable measure of the degree of visibility improvement associated with various BART alternatives.

3.1.2.4. CALPUFF Parameter Summary
Figure 7 summarizes some of the key CALPUFF settings.
3.1.2.5. Chemical Mechanism

The MESOPUFF II pseudo-first-order chemical reaction mechanism (MCHEM=1) is used for the conversion of SO2 to sulfate (SO4) and NOx to nitrate (NO3). Refer to the CALPUFF User’s Guide for a description of the mechanism (Scire, 2000).

In the MESOPUFF II mechanism, the ammonia background concentration affects the equilibrium between nitric acid, ammonia, and ammonium nitrate. The equilibrium constant for the reaction is a non-linear function of temperature and relative humidity (Scire, 2000). Unlike sulfate, the calculated nitrate concentration is limited by the amount of available ammonia, which is preferentially scavenged by sulfate (Scire, 2000). In particular, the amount of ammonia available for the nitric acid, ammonium nitrate, and ammonia reactions is determined by subtracting sulfate from total ammonia.

While the chemical mechanism simulates both the gas phase and aqueous phase conversion of SO2 to sulfate, the aqueous phase method, which is important when the plume interacts with clouds and fog, can significantly underestimate sulfate formation. In this report, as recommended by the IWAQM Phase 2 report, the “nighttime SO2 loss rate (RNITE1)” is set to 0.2 percent per hour. The “nighttime NOx loss rate (RNITE2)” is set to 2.0 percent per hour and the “nighttime HNO3 formation rate (RNITE3)” is set to 2.0 percent per hour.

The CALPUFF chemical module is formulated around linear transformation rates for SO\textsubscript{2} to sulfate and NO\textsubscript{X} to total nitrate. There are two options for specifying these transformation rates:

Option 1: An internal calculation of rates based on local values for several controlling variables (e.g., solar radiation, background ozone, relative humidity, and plume NO\textsubscript{X}) as used in MESOPUFF-II. The parametric transformation rate relationships employed were derived from box model calculations using the mechanism of Atkinson et al. (1982).

Option 2: A user-specified input file of diurnally varying but spatially uniform conversion rates.

Morris et al. (1987) reviewed the MESOPUFF-II mechanism as part of the U.S. EPA Rocky Mountain Acid Deposition Model Assessment study. They found that it provided physically plausible responses to many of the controlling environmental parameters. However, the mechanism had no temperature dependence, which is an important factor in the Rocky Mountain region where there are wide variations in temperature. Furthermore, the MESOPUFF-II transformation scheme was based on box model simulations for conditions more representative of the Eastern U.S. than of the Rocky Mountains.

The largest deficiency in the MESOPUFF-II chemical transformation algorithm is the lack of explicit treatment for in-cloud (aqueous-phase) enhanced oxidation of SO\textsubscript{2} to sulfate. The MESOPUFF-II chemical transformation algorithm includes a surrogate reaction rate to account for aqueous-phase oxidation of SO\textsubscript{2} to sulfate as follows:

$$K_{aq} = 3 \times 10^{-8} \times RH^4 \ (%/hr) \ (B.2-1)$$

Thus, at 100% relative humidity (RH), the MESOPUFF-II aqueous-phase surrogate SO\textsubscript{2} oxidation rate will be 3% per hour. Measurements in generating station plumes suggest spatially- and temporally-integrated SO\textsubscript{2} oxidation rates due to oxidants in clouds to be 10 times this value.

Another issue is the amount of ammonia available for nitrate chemistry. According to a paper by EarthTech (Escoffier-Czaja and Scire, 2002),

"In the CALPUFF model, total nitrate (TNO\textsubscript{3} = HNO\textsubscript{3} + NO\textsubscript{3}) is partitioned into each species according to the equilibrium relationship between HNO\textsubscript{3} and NO\textsubscript{3}. This equilibrium varies as a function of time and space, in response to both the ambient temperature and relative humidity. In addition, the formation of nitrate is subject to the availability of NH\textsubscript{3} to form ammonium nitrate (NH\textsubscript{4}NO\textsubscript{3}), the assumed form of nitrate in the model. In CALPUFF, a continuous plume is simulated as a series of puffs, or discrete plume elements. The total concentration at any point in the model is the sum of the contribution of all nearby puffs from each source."
Because CALPUFF allows the full amount of the specified background concentration of ammonia to be available to each puff for forming nitrate, the same ammonia may be used multiple times in forming nitrate, resulting in an overestimate of nitrate formation. In order to properly account for ammonia consumption, a program called POSTUTIL was introduced into the CALPUFF modeling system in 1999. POSTUTIL allows total nitrate to be repartitioned in a post-processing step to account for the total amount of sulfate scavenging ammonia from all sources (both project and background sources) and the total amount of TNO3 competing for the remaining ammonia. In POSTUTIL, ammonia availability is computed based on receptor concentrations of total sulfate and TNO3, not on a puff-by-puff basis.

Ammonia-limiting methods are used for repartitioning nitric acid and nitrate on a receptor-by-receptor and hour-by-hour basis to account for over prediction due to overlapping puffs in CALPUFF. Specifically, the use of the MNIRATE=1 option in POSTUTIL is acceptable. At this time, other ammonia-limiting methods, including iterative techniques that use observational data to resolve backward the thermodynamic equilibrium equation between NO3/HNO3 for each hour to minimize available ammonia, are not acceptable. Generally, for regulatory CALPUFF modeling in Colorado, techniques that assume the atmosphere is always ammonia poor are not acceptable, particularly in eastern Colorado.
3.1.2.6. Chemical Mechanism – Ammonia Sensitivity Tests

In 2005, to better understand the response of the modeling system to background ammonia when a single point source with significant emissions of SO2 and NOx is modeled, the Division performed sensitivity tests for a source in northeast Colorado and a source in northwest Colorado using the 2002 MM5/CALMET meteorology. These tests have not been revised for this supplemental BART modeling, but they are provided here for informational purposes. In the test case, SO2, NOx, and filterable PM10 emissions were modeled. The ammonia background value was varied from 0 to 100 ppb. In the northeast Colorado test case, the SO2 emission rate is about 3 times higher than the NOx emission rate. In the northwest Colorado test case, the modeled NOx emission rate is about 4.4 times higher than the SO2 rate.

In both cases, when the background ammonia concentration is zero, the model produces no nitrate, as expected; however, it produces sulfate.

For the northeast Colorado sensitivity test (see Figure 8), where the modeled SO2 emission rate is significantly higher than the NOx emission rate, the change in visibility (delta-deciview) is not very sensitive to the background ammonia concentration across the range from 1.0 ppb to 100.0 ppb because of the high SO2 emission rates relative to NOx and the way sulfate is produced in the MESOPUFF II chemical mechanism. Visibility impacts drop significantly when the ammonia background is less than 1.0 ppb, but even at 0.0 ppb of ammonia, sulfate impacts remain relative high.

![Figure 8. Sensitivity of CALPUFF visibility impacts (delta-deciview) to ammonia backgrounds from 0 ppb to 100 ppb from a source with high SO2 emissions relative to NOx.](image-url)
For the northeast Colorado case, on days with the highest visibility impacts, the relative contribution of nitrate and sulfate vary (see Figure 9 and Figure 10), but most of the modeled visibility impairment is due to sulfate. When comparing these figures, be aware the relative rank for some days is different. For example, day 85 is the 2nd worst day for the 0.1 ppb ammonia case, but it’s the 3rd worst day for the 100 ppb case. On the day with the highest impact (day 84), the contribution from sulfate is 98.8% for the 0.1 ppb ammonia case and 72.7% for the 100 ppb ammonia case. For the 8th high delta-deciview value, the contribution from sulfate is 86.3% for the 0.1 ppb case and 67.9% for the 100 ppb case.

Figure 9. Contribution of sulfate and nitrate to the modeled change in deciviews, assuming a background ammonia of 0.1 ppb in CALPUFF.
Figure 10. Contribution of sulfate and nitrate to the modeled change in deciviews, assuming a background ammonia of 100 ppb.

For the northwest Colorado sensitivity test (see Figure 11), where the modeled NOx emission rate is significantly higher than the SO2 emission rate, the change in visibility (delta-deciview) is not sensitive to the background ammonia concentration across the range from 10 ppb to 100 ppb. While there is a moderate drop in impacts when ammonia is dropped from 10 ppb to 1.0 ppb, the model is very sensitive to ammonia when the background ammonia level is less than 1.0 ppb.
Figure 11. Sensitivity of CALPUFF visibility impacts (delta-deciview) to ammonia backgrounds from 0 ppb to 100 ppb from a source with high NOx emissions relative to SO2.
For the northwest Colorado test case, according to CALPUFF as implemented here, impairment is primarily due to nitrate (see Figure 12 and Figure 13), but the contribution due to nitrate varies significantly depending on the assumed ammonia background level. For the 100 ppb background case, the nitrate contribution is greater than 90% for the top 20 days. However, for the 0.1 ppb case, the nitrate contribution varies from 43% to 81% for the top 20 days.

Figure 12. Contribution of sulfate and nitrate to the modeled change in deciviews, assuming a background ammonia of 0.1 ppb in CALPUFF.

Figure 13. Contribution of sulfate and nitrate to the modeled change in deciviews, assuming a background ammonia of 100 ppb in CALPUFF.

Caution should be used when extrapolating the results of these tests to other CALPUFF applications.
Since the MESOPUFF II chemical mechanism used in this analysis depends on several parameters, including ozone and ammonia background concentrations, the methods for determining the background ozone and ammonia concentration fields are discussed in more detail in the next two sections.

### 3.1.2.7. Ammonia Assumptions - Discussion

In CALPUFF, as used in this application, the background ammonia concentration is temporally and spatially uniform. It is likely that some portions of the modeling domain are ammonia poor and some are ammonia rich. Thus, setting a domain-wide background is problematic. As discussed in the previous section, when modeling a single large source with high SO$_2$ emission rates relative to NOx, the assumed background ammonia concentration is not a critical parameter for determining visibility impacts.

According to the IWAQM Phase 2 Report,

> A further complication is that the formation of particulate nitrate is dependent on the ambient concentration of ammonia, which preferentially reacts with sulfate. The ambient ammonia concentration is an input to the model. Accurate specification of this parameter is critical to the accurate estimation of particulate nitrate concentrations. Based on a review of available data, Langford et al. (1992) suggest that typical (within a factor of 2) background values of ammonia are: 10 ppb for grasslands, 0.5 ppb for forest, and 1 ppb for arid lands at 20°C. Langford et al. (1992) provide strong evidence that background levels of ammonia show strong dependence with ambient temperature (variations of a factor of 3 or 4) and a strong dependence on the soil pH. However, given all the uncertainties in ammonia data, IWAQM recommends use of the background levels provided above, unless specific data are available for the modeling domain that would discredit the values cited. It should be noted, however, that in areas where there are high ambient levels of sulfate, values such as 10 ppb might overestimate the formation of particulate nitrate from a given source, for these polluted conditions. Furthermore, areas in the vicinity of strong point sources of ammonia, such as feedlots or other agricultural areas, may experience locally high levels of background ammonia.

The Northern Front Range is assumed to be ammonia rich. “Sulfate along the Northern Front Range is completely neutralized by available ammonium and is present in the form of ammonium sulfate.... The Northern Front Range is ammonia rich. There was sufficient ammonia, on most days during winter, to completely neutralize available nitric acid (NFRAQS, 1998).”

For northeast Colorado, a background ammonia concentration of 30.4 µg/m$^3$ (about 44 ppb) or less appears to be reasonable based on measurements for this modeling study. According to monitoring conducted for NFRAQS,

- “With respect to gaseous measurements, only ammonia was acquired at all nine sites with the denuder difference method at the Brighton and Welby sites and...”
with the filter-pack method (i.e., impregnated cellulose-fiber filters behind Teflon-membrane filters) at the other sites. Average ammonia concentrations were 30.4 ± 53.4 µg/m³ at the core sites and 10.3 ± 12.6 µg/m³ at the satellite sites. The large standard deviation is mainly due to elevated ammonia concentrations found at the Evans site. Maximum 24-hour ammonia concentrations were 187.0 ± 5.4 µg/m³ at the Evans core site on 01/17/97 and 66.7 ± 3.5 µg/m³ at the Masters site on 01/20/97. Figure 6.3-5 shows that during the mid-January episode, 24-hour ammonia concentrations varied by orders of magnitude at the nine NFRAQS sites.

• "For the 6- and 12-hour samples, Figure 6.4-3 [not included in this report] ammonia concentrations were rather consistent throughout the day, with apparent site-to-site and season-to-season variation. Average ammonia concentrations at the Brighton site were double those at the Welby site during Winter 97. Summertime ammonia concentrations were ~1 to 2 µg/m³ higher than the wintertime at the Welby site. Since ammonia concentrations closely reflect the vicinity of the sampling area, site-to-site variations were more pronounced than seasonal or diurnal variations. This is evidenced by the graph in Figure 6.4-4 [not included in this report], which shows ammonia concentrations were factors of 10 to 20 higher at the Evans site than at most of the other sites during Winter 97. Elevated concentrations exceeded 50 µg/m³ on 20% of the days at the Evans site. Twenty-four hour ammonia concentrations at the Masters and Longmont sites were also factors of 5 to 10 higher than at the other sites."

For other areas like northwest Colorado, an annual background ammonia concentration of about 1 ppb or less is probably more reasonable, based on ammonia measurements from the Mt. Zirkel Visibility Study.

In the Aerosol Evolution Model (AEM) simulations done for the Mt Zirkel Study for a specific period, "base case background air concentrations for ammonia were assumed to be 0.5 µg/m³ and 30 ppbv for ozone, consistent with measured values at the Hayden VOR site." An ammonia concentration of 0.5 µg/m³ is about 0.7 ppb.

In the CALPUFF modeling section of the Mt Zirkel Study report, “The CALPUFF default value for background ammonia concentrations of 10 ppb was also considered far too high as a representative area-average. Measurements from the Buffalo Pass and Gilpin Creek sites were used to adjust ammonia concentration to episode and site-mean values."

Based on a review of CALUUFF files used for the Mt. Zirkel Study, for the August simulations, the assumed ammonia background (BCKNH3) was 1.6 ppb; for the October simulation, the assumed background was 0.5 ppb; and for the September simulation, the assumed background was 0.8 ppb.
3.1.2.8. Ammonia Assumptions
To help provide consistency with the Division’s original BART modeling, the Division has not determined if more recent ammonia measurements would change the assumptions below. The assumptions below are assumed to be reasonable for purposes of comparing control technologies.

Based on information in the previous section, for sources located in northeast Colorado (e.g., Pawnee) and along the South Platte River, a domain-wide ammonia background value of 44 ppb is used. For CENC near Golden and CEMEX near Lyons, a background of 5 ppb is used, as justified by the source operators and approved by the Division in 2006 during the original BART Analysis process. For sources located in northwest Colorado (e.g., Craig and Hayden), a background ammonia concentration of 1.0 ppb is used. For sources located in Colorado Springs (e.g., Drake), southeastern Colorado along the Arkansas River (e.g., Comanche), a background value of 10 ppb is used.

3.1.2.9. Ozone Assumptions
According to the IWAQM Phase 2 Report, CALPUFF provides two options for providing the ozone background data: (1) a single, typical background value appropriate for the modeling region, or (2) hourly ozone data from one or more ozone monitoring stations. The second and preferred option requires the creation of the OZONE.DAT file containing the necessary data. For the Demonstration Assessment, the domain was large (700 km by 1000 km) such that the second option was necessary. The IWAQM does not anticipate such large domains as being the typical application. Rather, it is anticipated that the more typical application will involve domains of order 400 km by 400 km or smaller. But even for smaller domains, the ability to provide at least monthly background values of ozone is deemed desirable. The problem in developing time (and perhaps spatial) varying background ozone values is having access to representative background ozone data. Ozone data are available from EPA’s Aerometric Information Retrieval System (AIRS); however, AIRS data must be used with caution. Many ozone sites are located in urban and suburban centers and are not representative of oxidant levels experienced by plumes undergoing long range transport.

In this study, the following ozone stations were used:
- Welby
- Rocky Mountain National Park
- Greeley
- Highland
- S. Boulder Creek
- Carriage
- Chatfield
- USAF Academy
Arvada
Welch
Rocky Flats North
NREL
Ignacio (S. Ute)
Hwy. 550 (S. Ute)
Ft. Collins S. Mason-CSU
Mesa Verde
Bloomfield-Hyw. Dept. Yard
USBR-Shiprock Substation (Farmington)

3.1.3. CALPOST Settings and Visibility Post-Processing

To maintain consistency with previous BART modeling in Colorado, to expedite this analysis, and as approved by EPA Region 8, the old IMPROVE equation is used for this CALPUFF analysis. As of the date of this report, the regulatory version of CALPUFF relies on the old IMPROVE equation.

The CALPUFF results are post-processed with the regulatory version of CALPOST and POSTUTIL.

For the Division’s original subject-to-BART modeling analysis, all PM10 was assumed to have an extinction efficiency of 1.0 since the contribution of direct PM10 emissions was expected to be relatively small compared to visibility impairment caused by SO2 and NOX emissions. This same approach is used for this supplemental BART analysis modeling. However, if it is reasonable to believe that the inclusion of condensable and filterable PM10 emissions and speciation would change the outcome of a BART analysis decision, the Division may consider including these factors. If speciated PM emissions are modeled, the following species are considered: fine particulates (PMF), coarse particulates (PMC), elemental carbon (EC), organic carbon (SOA), and sulfate (SO4) along with appropriate particle size and deposition parameters for the source type and emission control technology.

To calculate background light extinction, MVISBK = 6 is used. That is, monthly RH adjustment factors are applied directly to the background and modeled sulfate and nitrate concentrations, as recommended by the BART guideline. The RHMAX parameter, which is the maximum relative humidity factor used in the particle growth equation for visibility processing, is not used when method 6 is selected. Similarly, the relative humidity adjustment factor (f(RH)) curves in CALPOST (e.g., IWAQM growth curve and the 1996 IMPROVE curve) are not used when MVISBK is equal to 6.

EPA allows use of either the 20% best visibility days or annual average to calculate natural background for purposes of BART. In 2005, prior to the Utility Air Regulatory Group (UARG) settlement, the Division based natural background on the 20% best visibility days, as recommended by the BART guideline preamble:
Finally, these BART guidelines use the natural visibility baseline for the 20 percent best visibility days for comparison to the "cause or contribute" applicability thresholds. We believe this estimated baseline is likely to be reasonably conservative and consistent with the goal of natural conditions (70 FR 39125).

This assumption was revisited in 2006 after the UARG settlement. The Division decided to continue using 20% best days for BART natural background. For this supplemental modeling analysis, 20% best days for natural background is used.

The method for estimating natural background is presented in section 3.1.3.1. Specifically, for hygroscopic components, BKSO4 in CALPOST is set to 0.0893 for all months. For non-hygroscopic components, BKSOIL should be set to 1.620 for all months. The BKSO4 and BKSOIL values have been computed specifically for the Colorado Class I areas used in this analysis.

The extinction due to Rayleigh scattering (i.e., the scattering of light by natural particles much smaller than the wavelength of the light) is set to 10 Mm⁻¹ (BEXTRAY = 10.0).

As part of the protocol development process, previous analyses performed by the Division were reviewed regarding comparison’s between the natural background assumptions used in this analysis (see next section) and newer methods such as those presented in the draft FLAG 2008 report. For Rocky Mountain National Park, the approach specified in this analysis uses a natural background that has a monthly background extinction of about 12 Mm⁻¹ whereas the FLAG 2008 “20% best days” value is about 14 Mm⁻¹ and the FLAG 2008 “annual average best days” value is about 10 Mm⁻¹. A directionally similar trend exists for the other Class I areas in Colorado. That is, the Division’s “20% best days” natural background assumption is between the FLAG 2008 recommendations.

Consequently, as mentioned earlier, to help maintain consistency with previous BART modeling and to streamline this supplemental BART analysis process, the Division retained its original approach, as described in the next section.

3.1.3.1. Natural Conditions - Determining Hygroscopic And Non-Hygroscopic Values For the Best 20% Visibility Days

3.1.3.1.1. Natural Background - Objective

The spreadsheet shown in Figure 14 was created to determine the hygroscopic (3[BKSO4]) and non-hygroscopic (equivalent to [BKSOIL]) portions of natural background for the best 20% visibility days (Best Days) at all Class I areas in Colorado’s BART modeling. These concentrations, [BKSO4] and [BKSOIL], are used in CALPOST with monthly relative humidity adjustment factors (f(RH)) to determine monthly natural background visibility that would, on average, represent the average natural background visibility for the best 20% days in EPA's “Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program” (EPA, 2003).
3.1.3.1.2. **Natural Background - Discussion**

“Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program” (EPA, 2003), section 2.4, describes the calculation of the annual average background extinction (in 1/Mm) for a Class I area using the area's annual $f(RH)$ and average natural concentrations based on the area's geographic location (east versus west). Annual average background extinction values (in 1/Mm) are converted to annual average Haze Index (HI) values (in deciview or dv). Then, the average HI value for the 20% best visibility days (Best Days (dv)) is estimated from 10th percentile of the annual average HI value for a Class I area assuming normal distribution. Thus, no average natural concentrations are provided for determining extinction for the 20% best visibility days.

For background extinction computation methods 2, 3, and 6 in CALPOST, background extinction is calculated with user-supplied monthly concentrations of SO$_4$, NO$_3$, PM coarse, organic carbon, soil, and elemental carbon species. In practice, concentrations for only 2 species, SO$_4$ ([BKSO4]) and soil ([BKSOIL]), are supplied in the CALPOST input file to represent hygroscopic and non-hygroscopic portions of background extinction, respectively.

To determine background extinction for the BART analysis with CALPOST, average natural concentrations that represent average natural background visibility for the best 20% days need to be determined.

3.1.3.1.3. **Natural Background - Method**

Following EPA's approach of using regional average natural concentrations and the concept of using simplified inputs in CALPOST, the same hygroscopic ([BKSO4]$_{best20}$) and non-hygroscopic ([BKSOIL]$_{best20}$) values would be used in CALPOST for all Class I areas in Colorado's BART modeling.

The spreadsheet calculates an average background (dv) based on monthly background extinction (1/Mm) for each Class I area in Colorado's BART modeling using the following equations:

1. Monthly background extinction in 1/Mm ($b_{ext\_month}$) = 3[BKSO4]$_{best20}$f(RH) + [BKSOIL]$_{best20}$ + Rayleigh
2. Annual average background extinction in 1/Mm ($b_{ext\_annual\_ave}$) = ($b_{ext\_Jan}$ + $b_{ext\_Feb}$ + \ldots + $b_{ext\_Dec}$)/12
3. Calculated Best Days in dv = 10ln($b_{ext\_annual\_ave}$/10)

EPA guidance provides $f(RH)$ values based on the centroid of the Class I area (see Appendix B - Monthly $f(RH)$ Values) and a Best Days (dv) value for each of the Class I areas (see Appendix A - Natural Background Values).

The hygroscopic ([BKSO4]) and non-hygroscopic ([BKSOIL]) values determined yielded the lowest sum of the absolute differences between the published Best Days (dv) and calculated Best Days (dv) for all Class I areas in the analysis.
Minimize $\sum_{n=1}^{11} |(\text{published Best Days})_n - (\text{calculated Best Days})_n|$

where: $n = \text{number of Class I areas in analysis}$

The "hygro ($3[BKSO4]$)" and "non-hygro ($[BKSOIL]$)" values of 0.268 and 1.620 were calculated in Microsoft Excel using the "solver add-in" tool for optimization and equation solving (Figure 14). As can be seen from the “difference” values in Figure 14, the annual 20% best visibility days background concentrations for each Class I area calculated with this method are within 0.01 deciviews or less of the annual 20% best visibility days background values recommended by EPA. For CALPOST, the hygroscopic component of extinction is divided by 3 (the extinction coefficient of sulfate and nitrate) and input as BKSO4 (i.e., $BKSO4 = 0.268/3 = 0.0893$). The non-hygrosopic component is used directly (i.e., $BKSOIL = 1.620$).

<table>
<thead>
<tr>
<th>hygro ($3[BKSO4]$)</th>
<th>0.268</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-hygro ($[BKSOIL]$)</td>
<td>1.620</td>
</tr>
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</table>

Figure 14. Spreadsheet showing the "hygro ($3[BKSO4]$)" (0.268) and "non-hygro ($[BKSOIL]$)" (1.620) values calculated in Microsoft Excel using the "solver add-in" tool for optimization and equation solving.
3.1.3.2. CALPOST and POSTUTIL Parameters

Two post-processing examples are provided. In example #1, fine particulate emissions are speciated into PMF, PMC, EC, SOA, and SO4 and explicitly included as species in CALPUFF. Emission rates for each species are included in CALPUFF. Figure 15 summarizes some of the key CALPOST settings. The monthly f(RH) values (RHFAC), which are different for each Class I area, are from Appendix B – Monthly f(RH) Values.

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<th>Modeled species to be included in computing the light extinction</th>
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<td>Include NITRATE? (LYNO3) -- Default: T</td>
</tr>
<tr>
<td>Include ORGANIC CARBON? (LYOC) -- Default: T</td>
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<tr>
<td>Include COARSE PARTICLES? (LYPMC) -- Default: T</td>
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<td>Include FINE PARTICLES? (LYPMF) -- Default: T</td>
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<tr>
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<td>Species name used for particulates in MODEL DAT file</td>
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<td>FINE (SPECMPF) -- Default: PMF</td>
</tr>
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<td>PM FINE (EPPM) -- Default: 1.0</td>
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<tr>
<td>Method used for background light extinction</td>
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<td>(MWSBK) -- Default: 2</td>
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</table>

(RHFAC) — No default | RHFAC = 2.4, 2.2, 2.1, 2.1, 1.7, 1.7, 1.5, 1.6, 1.6, 2.0, 1.9, 1.7, 2.1, 2.3 |

(EESO4) — No default | EESO4 = 0.0893, 0.0893, 0.0893, 0.0893, 0.0893 |

(EENO3) — No default | EENO3 = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0 |

(EEOC) — No default | EEOC = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0 |

(EESOIL) — No default | EESOIL = 1.520, 1.520, 1.520, 1.520, 1.520, 1.520, 1.520, 1.520, 1.520 |

(EEC) — No default | EEC = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0 |

Extinction due to Rayleigh scattering is added (1/Mm)

(BEKTRAY) -- Default: 10.0 | BEKTRAY = 10.0 |

Figure 15. CALPOST - key parameters (example #1 setup).
In example #1, POSTUTIL is used to compute the partition for the total concentration fields with MNITRATE=1 and the appropriate ammonia background concentration. The ammonia background concentration, BCKNH3, in POSTUTIL is the same as the background value presented in section 3.1.2.8. In POSTUTIL, the input species include SO2, SO4, NOX, HNO3, NO3, SOA, PMF, PMC, and EC and the output species include SO4, HNO3, NO3, SOA, PMF, PMC, and EC. Key POSTUTIL parameters are shown in Figure 16.

```
Number of species to process from CALPUFF runs (NSPECINP) -- No default  ! NSPECINP = 9 !
Number of species to write to output file (NSPECOUT) -- No default  ! NSPECOUT = 7 !
Number of species to compute from those modeled (must be no greater than NSPECOUT) (NSPECOMP) -- No default  ! NSPECOMP = 0 !
Number of CALPUFF data files that will be scaled (must be no greater than NFILES) (NSCALED)  Default: 0  ! NSCALED = 0 !
Recompute the HNO3/NO3 partition for concentrations? (MNITRATE)  Default: 0  ! MNITRATE = 1 !

The following NSPECINP species will be processed:
! ASPECI =  SO4  !  END!
! ASPECI =  SO2  !  END!
! ASPECI =  NOx  !  END!
! ASPECI =  NO3  !  END!
! ASPECI =  HNO3  !  END!
! ASPECI =  PMF  !  END!
! ASPECI =  PMC  !  END!
! ASPECI =  EC  !  END!
! ASPECI =  SOA  !  END!

The following NSPECOUT species will be written:
! ASPECO =  SO4  !  END!
! ASPECO =  NO3  !  END!
! ASPECO =  HNO3  !  END!
! ASPECO =  PMF  !  END!
! ASPECO =  PMC  !  END!
! ASPECO =  EC  !  END!
! ASPECO =  SOA  !  END!
```

Figure 16. POSTUTIL - key parameters for cases with nitrate partitioning and speciated PM10 concentrations (example #1 setup).
In example #2, PM10 is included as a species in CALPUFF and ammonia limiting is performed with POSTUTIL. The example #2 CALPOST setup is the same as shown in example #1 (see Figure 15) except LVPMC=F, since there are is no coarse PM, and SPECPMF=SOIL because the PM10 emissions from CALPUFF are reallocated to the species SOIL and EC in the first of two POSTUTIL runs. The first POSTUTIL setup for example #2 (see Figure 17) is intended to provide a post-processing opportunity to divide the PM10 concentrations into SOIL and EC components; however, in the setup example shown in Figure 17, all of the PM10 is allocated to SOIL and none is allocated to EC.

![Figure 17. POSTUTIL setup for simulations where PM10 is divided into SOIL and EC species (example #2 setup).](image-url)

<table>
<thead>
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<th>Number of species to process from CALPUFF runs</th>
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<td>Number of species to write to output file</td>
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</tr>
<tr>
<td>(NSPECMPF) -- No default ! NSPECMPF = 2 !</td>
</tr>
<tr>
<td>Recompute the HNO3/N03 partition for concentrations?</td>
</tr>
<tr>
<td>(MNITRATE) Default: 0 ! MNITRATE = 0 !</td>
</tr>
<tr>
<td>The following NSPECINP species will be processed:</td>
</tr>
<tr>
<td>! ASPECI = SO4 !</td>
</tr>
<tr>
<td>! ASPECI = NO3 !</td>
</tr>
<tr>
<td>! ASPECI = HNO3 !</td>
</tr>
<tr>
<td>! ASPECI = PM10 !</td>
</tr>
<tr>
<td>! ASPECI = SOA !</td>
</tr>
<tr>
<td>The following NSPECOUT species will be written:</td>
</tr>
<tr>
<td>! ASPECO = SO4 !</td>
</tr>
<tr>
<td>! ASPECO = NO3 !</td>
</tr>
<tr>
<td>! ASPECO = HNO3 !</td>
</tr>
<tr>
<td>! ASPECO = EC !</td>
</tr>
<tr>
<td>! ASPECO = SOIL !</td>
</tr>
<tr>
<td>! ASPECO = SOA !</td>
</tr>
<tr>
<td>The following NSPECMPF species will be computed by scaling and summing one or more of the processed input species. Identify the name(s) of the computed species and provide the scaling factors for each of the NSPECINP input species (NSPECMPF groups of NSPECINP+1 lines each):</td>
</tr>
<tr>
<td>! CSPECMP = EC !</td>
</tr>
<tr>
<td>! SO4 = 0.0 !</td>
</tr>
<tr>
<td>! NO3 = 0.0 !</td>
</tr>
<tr>
<td>! PM10 = 0.00 !</td>
</tr>
<tr>
<td>! SOA = 0.0 !</td>
</tr>
<tr>
<td>! END!</td>
</tr>
<tr>
<td>! CSPECMP = SOIL !</td>
</tr>
<tr>
<td>! SO4 = 0.0 !</td>
</tr>
<tr>
<td>! NO3 = 0.0 !</td>
</tr>
<tr>
<td>! PM10 = 1.0 !</td>
</tr>
<tr>
<td>! SOA = 0.0 !</td>
</tr>
<tr>
<td>! END!</td>
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</table>
In the second POSTUTIL setup for example #2, POSTUTIL is used to compute the partition for the total concentration fields with MNITRATE=1 and the appropriate ammonia background concentration. The ammonia background concentration, BCKNH3, in POSTUTIL is the same as the background value presented in section 3.1.2.8. In this POSTUTIL setup, the input species include SO4, NO3, HNO3, EC, SOIL, and SOA and the output species include SO4, NO3, HNO3, EC, SOIL, and SOA. Key POSTUTIL parameters are shown in Figure 16.

| Number of species to process from CALPUFF runs (NSPECINP) — No default | NSPECINP = 6 |
| Number of species to write to output file (NSPECOUT) — No default | NSPECOUT = 6 |
| Number of species to compute from those modeled (must be no greater than NSPECOUT) (NSPECOMP) — No default | NSPECOMP = 0 |
| Recompute the HNO3/NO3 partition for concentrations? (MNITRATE) Default: 0 | MNITRATE = 1 |

The following NSPECINP species will be processed:

| ! ASPECI = | SO4 | !END! |
| ! ASPECI = | NO3 | !END! |
| ! ASPECI = | HNO3 | !END! |
| ! ASPECI = | EC | !END! |
| ! ASPECI = | SOIL | !END! |
| ! ASPECI = | SOA | !END! |

The following NSPECOUT species will be written:

| ! ASPECO = | SO4 | !END! |
| ! ASPECO = | NO3 | !END! |
| ! ASPECO = | HNO3 | !END! |
| ! ASPECO = | EC | !END! |
| ! ASPECO = | SOIL | !END! |
| ! ASPECO = | SOA | !END! |

Figure 18. POSTUTIL setup for simulations where ammonia limiting is performed using the output file generated from the POSTUTIL setup in Figure 17 (example #2 setup).
4. BART Analysis Modeling Process

The Division’s modeling approach models all pollutants (i.e., direct PM, SO₂, and NOₓ) from all BART-eligible units at a source in each CALPUFF run. The Division is not modeling unit-by-unit and pollutant-by-pollutant impacts because looking at results from individual units and pollutants can, in some cases, provide misleading results.

Judicious selection of “pre-control” and “post-control” scenarios is used to isolate specific units or pollutants.

For example:

1. Consider a source with one unit where a decision has already been made on SO₂ BART and only NOₓ BART controls are under evaluation. In this case, it would be appropriate to compare the following two scenarios:
   - Scenario #1 = Model pre-control emissions for NOₓ, pre-control emissions direct PM, and post-control (BART) emissions for SO₂.
   - Scenario #2 = keep everything constant from Scenario #1 but model a NOₓ BART control scenario.

   Impacts from the two scenarios above would then be compared to provide “degree of visibility improvement” results for the specified NOₓ control.

2. The situation becomes more complicated when a source has more than one unit. However, the same isolation method would be used. For example, consider a source with 3 units:
   - Scenario #1
     - Pre-control emissions for NOₓ and direct PM; SO₂ BART post-control emissions on unit 1
     - Pre-control emissions for NOₓ and direct PM; SO2 BART post-control emissions on unit 2
     - Pre-control emissions for NOₓ, direct PM, and SO₂ on unit 3
   - Scenario #2 = keep everything constant from Scenario #1 but add a NOₓ control for unit 2.

   Impacts from the two scenarios above would isolate the degree of visibility improvement from the addition of NOₓ controls to unit 2.

A matrix of BART scenarios is established and the effects of BART controls are estimated for individual pollutants and individual units by using the isolation technique above. In addition, the cumulative impact for a given source from the total BART control strategy (e.g., SO₂ controls and NOₓ controls), as compared to pre-control emissions, is evaluated as appropriate.

The BART modeling process is summarized in the following steps:
Step A.
Model the pre-control emission rates for SO₂, NOx, and direct PM emissions (e.g., filterable and condensable PM2.5 and PM10) from all BART-eligible units at the source. This scenario becomes the pre-control “base case.”

Step B.
Model as many pre- and post-control scenarios as necessary to isolate the desired units, pollutants, and BART scenarios. (Note: For each control scenario,strategy evaluated, model SO₂, NOx, and direct PM emissions together from all BART-eligible units at the facility.)

Step C.
As appropriate to complete the BART analysis, compare the pre-control (step A) with post-control (step B) results and/or compare various permutations to isolate specific units and specific pollutants.

There could be a large number of combinations if every unit, every pollutant, and every potential BART control is isolated with the steps above. Consequently, the Division may not conduct an exhaustive set of modeling analyses that examine every possible combination of potential BART controls if it is clear that the evaluation of certain combinations of controls are solely academic exercises. The Division will exercise reasonable professional judgment when deciding how many modeling analyses are necessary to characterize the degree of visibility improvement from the realistically viable BART scenarios. In addition, the actual number of modeling analyses depends on how the modeling results are factored into the BART determination process. In cases where the weight given to modeling is relatively low compared to the weight given to other factors, a limited number of modeling analyses may be adequate to satisfactorily complete the BART analysis process.

5. Reporting of Results for the Degree of Visibility Change

The metrics discussed in this section are intended to help provide a common framework for quantifying the degree of change from control scenarios/strategies. The BART analysis should discuss the recommended metrics in this section (plus others, as appropriate) and how the results have been factored into the BART determination process.

For this analysis, the magnitude (e.g., 98th percentile delta-deciview impact) and frequency (e.g., days per year with impacts above 0.5 dv and 1.0 dv) for the pre-control and post-control scenario under evaluated are presented.
5.1. 1st-High and 98th Percentile Metrics
The BART guideline provided specific guidance on the use of 98th percentile values for the subject-to-BART modeling:

"...you should compare your “contribution” threshold against the 98th percentile of values. If the 98th percentile value from your modeling is less than your contribution threshold, then you may conclude that the source does not contribute to visibility impairment and is not subject to BART. (70 FR 39162)"

The BART guideline did not recommend the use of a specific set of metrics for determining the degree of visibility improvement from BART.

As explained in more detail later, to determine the degree of visibility improvement from various BART scenarios, the Division will report the 98th percentile value, as well as the number of days over 0.5 dv and the number of days over 1.0 dv.

For a 365-day simulation, the 98th percentile value is the 8th highest modeled delta-deciview value from the list of ranked delta-deciview values. That is, the top 7 days are ignored, even though the values being ignored may be at different receptors.

The use of the 8th high value for a given year to represent the 98th percentile value, as recommended by U.S. EPA, is consistent with the values that would be generated from the equations in 40 CFR 50 Appendix N - “Interpretation of the National Ambient Air Quality Standards for PM2.5” – for determining 98th percentile values for PM2.5 monitoring.

5.2. Metrics for Characterizing the Change in Visibility Impacts
According to U.S. EPA Region 8, “to show the change in visibility impact between scenarios the most important metric to provide would be the delta-deciview between pre and post control 98th percentile impacts for each scenario in the three modeling years. Also provide the number of days exceeding .5 and 1 deciview.”

In addition to the approach recommended by U.S. EPA, the Division may use other metrics, if appropriate, to describe the expected degree of visibility change from each BART scenario.

5.3. Postprocessor for Generating Metrics
The Division’s BART postprocessor from 2005 and 2006, which was described in the April 15, 2010 draft protocol, was not used because the newer versions of CALPOST provide results in a more convenient format than older versions of the postprocessor.
6. References


Appendix A – Natural Background Values
## Appendix B
**Default Natural $b_{nv}$, $dv$, and 10th and 90th Percentile $dv$ Values at All Mandatory Federal Class I Areas**

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## Appendix B

### Default Natural $b_{\text{av}}$, $dv$, and 10th and 90th Percentile $dv$ Values at All Mandatory Federal Class I Areas

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## Appendix B
Default Natural $b_{en}$, $dv$, and 10th and 90th Percentile $dv$ Values at All Mandatory Federal Class I Areas

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Appendix B

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\[B - 5\]
### Appendix B

Default Natural $b_{sr}, dv$, and 10th and 90th Percentile $dv$ Values at All Mandatory Federal Class I Areas

<table>
<thead>
<tr>
<th>Mandatory Federal Class I Area</th>
<th>State</th>
<th>Lat.</th>
<th>Lon.</th>
<th>best (Mm-1)</th>
<th>Ann. Avg. (dv)</th>
<th>Best Days (dv) $^{(a)}$</th>
<th>Worst Days (dv) $^{(b)}$</th>
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(a) Values for the best and worst days are estimated from a statistical approach described in Section 2.6 of this document.

(b) $ff(RH)$ values for Virgin Islands National Park were not calculated because of the limited RH data available. As such no estimates for Natural Visibility Conditions are presented at this time.
Appendix B – Monthly $f(RH)$ Values
### Guidance for Tracking Progress Under the Regional Haze Rule

#### 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 | Site ID | Month | Jan (7th) | Feb (7th) | Mar (7th) | Apr (7th) | May (7th) | Jun (7th) | Jul (7th) | Aug (7th) | Sep (7th) | Oct (7th) | Nov (7th) | Dec (7th) |
|--------------|-----------|---------|-------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Acredas      | Acredas   | 1       | CACD1 | 44.37     | 86.26     | 2.3       | 2.9       | 2.8       | 3.4       | 3.1       | 3.0       | 3.4       | 3.8       | 4.0       | 3.8       | 3.6       |
| Aguas Tibis  | Aguas Tibis | 100    | GTB1  | 33.41     | 116.59    | 2.4       | 2.4       | 2.4       | 2.4       | 2.2       | 2.3       | 2.5       | 2.3       | 2.1       | 2.2       |
| Alpinos Lakes| Alpinos Lakes | 80    | BAHA| 47.42     | 121.47    | 4.3       | 3.8       | 3.6       | 3.6       | 3.2       | 3.6       | 3.1       | 3.3       | 3.6       | 4.6       |
| Amapache     | Amapache | 71     | SULAA | 45.68     | 113.42    | 3.3       | 2.9       | 2.6       | 2.4       | 2.4       | 2.3       | 2.0       | 1.9       | 2.1       | 2.6       | 3.3       |
| Amapache     | Amapache | 110    | KAJ1  | 37.65     | 119.26    | 2.0       | 2.7       | 2.7       | 2.1       | 1.9       | 1.7       | 1.6       | 1.6       | 1.8       | 2.2       | 2.7       |
| Amapache     | Amapache | 50     | CNAV1 | 38.84     | 100.58    | 2.3       | 2.3       | 1.8       | 1.6       | 1.6       | 1.3       | 1.4       | 1.5       | 1.6       | 1.6       | 2.0       | 2.3       |
| Bajo            | Bajo | 59     | BAD1  | 43.74     | 101.94    | 2.6       | 2.7       | 2.6       | 2.4       | 2.8       | 2.7       | 2.6       | 2.4       | 2.2       | 2.3       | 2.7       | 2.7       |
| Bandera       | Bandera | 33     | BAND1 | 32.76     | 109.27    | 2.2       | 2.1       | 1.6       | 1.6       | 1.6       | 1.4       | 1.7       | 2.1       | 1.9       | 1.7       | 2.0       | 2.2       |
| Baringa        | Baringa | 18     | BRE1  | 40.45     | 172.76    | 2.8       | 2.8       | 2.4       | 2.4       | 2.3       | 2.3       | 2.3       | 2.3       | 2.3       | 2.3       | 2.3       | 2.3       |

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Guidance for Tracking Progress Under the Regional Haze Rule

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/Area | Site Name                  | MAP ID | Code | Site Lat | Lon  | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|------------|----------------------------|--------|------|----------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Dome Land  | Dome Land                  | 165    | DOME 1 CA 39.70 | 119.19 | 2.5 | 2.3 | 2.2 | 2.1 | 2.0 | 2.0 | 1.9 | 1.9 | 1.8 |
| Eagle Cap  | Eagle Cap                  | 76     | STAY 1 OR 45.10 | 117.20 | 3.8 | 3.2 | 2.8 | 2.1 | 2.0 | 2.0 | 1.9 | 1.6 | 1.6 |
| English Neck| English Neck               | 86     | WKR 1 CO 38.66 | 108.24 | 3.2 | 2.8 | 2.5 | 2.5 | 2.4 | 2.3 | 2.2 | 2.1 | 2.1 |
| Everglades | Everglades                | 19     | EVER 1 FL 23.36 | 80.55 | 3.0 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.3 | 2.2 | 2.1 |
| Flat Tops  | Flat Tops                  | 85     | BOW 1 WI 43.95 | 97.55 | 3.0 | 2.7 | 2.5 | 2.4 | 2.4 | 2.3 | 2.2 | 2.2 | 2.1 |
| Gatlin     | Gatlin                     | 39     | GATL 1 AZ 32.88 | 110.32 | 2.0 | 1.5 | 1.5 | 1.3 | 1.2 | 1.1 | 1.0 | 1.0 | 1.0 |
| Gates of the Mountains | Gates of the Mountains | 74     | GATL 1 MT 40.55 | 116.51 | 2.5 | 2.5 | 2.4 | 2.3 | 2.3 | 2.2 | 2.1 | 2.1 | 2.1 |
| Gateshead Mountains | Gateshead Mountains | 85     | CRA 1 OR 42.40 | 120.55 | 4.0 | 3.4 | 3.1 | 2.8 | 2.7 | 2.6 | 2.3 | 2.3 | 2.1 |
| Gila       | Gila                       | 42     | GLA 1 NM 33.33 | 108.28 | 2.1 | 1.9 | 1.8 | 1.6 | 1.5 | 1.5 | 1.4 | 1.3 | 1.3 |
| Glendora   | Glendora                   | 72     | GLA 1 CA 40.53 | 116.00 | 2.0 | 2.0 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Glendora Peak| Glendora Peak            | 81     | NOA 1 WA 43.21 | 121.51 | 3.5 | 3.4 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 |
| Great Falls| Great Falls                | 79     | WTR 1 WA 46.54 | 112.40 | 4.5 | 3.0 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 |
| Grand Canyon| Grand Canyon            | 48     | GRC 2 AZ 36.67 | 118.08 | 3.4 | 3.3 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Grand Teton| Grand Teton               | 85     | YELL 2 WY 43.85 | 120.73 | 3.0 | 2.9 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| Great Gulf | Great Gulf                | 4      | GUG 1 NJ 44.31 | 72.22 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |
| Great Smoky Mountains | Great Smoky Mountains | 10     | GRS 1 TN 35.83 | 88.94 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 |
| Guadalupe Mountains | Guadalupe Mountains | 37     | GUM 2 TX 31.53 | 105.00 | 3.0 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Hailstone  | Hailstone                 | 18     | HAIL 1 HI 21.38 | 156.28 | 2.7 | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Hawaii Volcanoes | Hawaii Volcanoes       | 157    | HAV 1 HI 18.43 | 155.27 | 3.1 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Helena     | Helena                     | 77     | HEC 1 OR 45.24 | 116.54 | 3.7 | 3.6 | 3.5 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 |
| Hercules - Glade| Hercules - Glade  | 28     | HER 1 CA 36.69 | 120.90 | 3.2 | 3.0 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Hoover     | Hoover                     | 67     | HOO 1 TX 36.15 | 114.60 | 3.1 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Isla Royale| Isla Royale               | 25     | ISLA 1 MI 47.69 | 88.83 | 3.1 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| James River| James River               | 7      | JAR 1 VA 37.62 | 79.48 | 2.8 | 2.6 | 2.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| Janesville | Janesville                | 65     | JAR 1 NV 41.89 | 116.43 | 3.0 | 3.0 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| John Muir  | John Muir                 | 110    | KASI 1 CA 38.30 | 116.86 | 3.0 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Joshua Tree| Joshua Tree               | 161    | JOS 1 CA 34.03 | 116.18 | 2.4 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| Joyce Kilmer - Stickrock| Joyce Kilmer - Stickrock| 16    | GRSM 1 TN 35.43 | 84.06 | 3.3 | 3.1 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Kalispell  | Kalispell                 | 110    | KASI 1 MT 37.28 | 116.18 | 3.0 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| Kalispell | Kalispell                 | 85     | KASI 1 MT 42.37 | 123.93 | 4.5 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 |
| Kings Canyon| Kings Canyon          | 98     | SEQ 1 CA 26.25 | 116.00 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| La Grange | La Grange                 | 55     | WREM 1 CO 37.66 | 106.81 | 2.3 | 2.2 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 |
| Lassen Volcanic| Lassen Volcanic  | 90     | LASV 1 CA 40.84 | 121.97 | 3.8 | 3.2 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 |
### Guidance for Tracking Progress Under the Regional Haze Rule

#### 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 / Area          | Site Name          | Map ID | Code | Site Lat. | Site Long. | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|-----------------------|-------------------|--------|------|-----------|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Lava Beds             | Lava Beds         | 67     | LABE | CA        | 41.71      | 121.34 | 4.0 | 3.4 | 3.1 | 2.7 | 2.6 | 2.4 | 2.3 | 2.4 | 2.7 | 3.5 | 3.8 |
| Llullota Gorge        | Llullota Gorge    | 13     | LG01 | NC        | 35.86      | 81.99  | 3.0 | 3.0 | 3.0 | 2.7 | 3.3 | 3.9 | 4.1 | 4.6 | 4.4 | 3.7 | 3.2 | 3.4 |
| Lassen Park           | Lassen Park       | 60     | LASS | NV        | 40.82      | 119.38 | 3.6 | 3.9 | 2.9 | 2.9 | 2.3 | 2.3 | 2.3 | 2.7 | 2.4 | 2.3 | 3.3 |
| Lye Brook             | Lye Brook         | 3      | LBY1 | VT        | 43.17      | 73.12  | 3.7 | 2.8 | 2.6 | 2.6 | 2.8 | 2.6 | 3.0 | 3.3 | 3.6 | 3.7 | 3.3 | 2.9 | 2.3 |
| Mammoth Cave          | Mammoth Cave      | 6      | MACA | KY        | 37.22      | 116.07 | 3.4 | 3.1 | 2.9 | 2.6 | 3.2 | 3.5 | 3.7 | 3.9 | 3.4 | 3.2 | 3.5 |
| Martin Mountain       | Trinity            | 164    | TRIN | CA        | 41.52      | 123.21 | 4.4 | 3.8 | 3.7 | 3.3 | 3.4 | 3.2 | 3.2 | 3.7 | 3.4 | 4.1 | 4.2 |
| Murray Lakes - Snowmass | White River     | 68     | WHR1 | CO        | 39.15      | 106.82 | 2.2 | 2.1 | 2.0 | 2.0 | 2.4 | 2.0 | 1.7 | 1.7 | 2.2 | 2.1 | 1.8 |
| Moneda                 | Ralston             | 45     | RAL1 | 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 | 2.1 |
| Medicine Lake         | Medicine Lake      | 53     | MLDA | MT        | 46.50      | 104.26 | 3.0 | 2.6 | 2.9 | 2.3 | 2.6 | 2.2 | 2.2 | 2.0 | 2.4 | 3.3 | 3.2 |
| Mesa Verde            | Mesa Verde         | 54     | MEVE | CO        | 37.20      | 108.49 | 2.3 | 2.3 | 1.9 | 1.5 | 1.5 | 1.3 | 1.6 | 2.0 | 1.9 | 1.7 | 2.1 |
| Mingo                 | Mingo              | 28     | MING | MO        | 38.08      | 90.20  | 3.3 | 3.0 | 2.8 | 2.6 | 3.0 | 3.3 | 3.3 | 3.5 | 3.5 | 3.3 | 3.1 |
| Mount Massive - Miners | Monico         | 73     | MONT | UT        | 47.40      | 113.05 | 3.6 | 3.1 | 2.7 | 2.5 | 2.6 | 2.5 | 2.5 | 2.2 | 2.5 | 2.6 | 3.5 |
| Mount Rainier         | Mount Rainier      | 78     | MORA | WA        | 46.75      | 122.12 | 4.4 | 4.0 | 3.6 | 4.7 | 3.1 | 3.7 | 3.3 | 3.8 | 3.4 | 4.1 | 4.7 |
| Mount Washington       | Mount Washington   | 54     | MUSA | WA        | 46.30      | 117.07 | 4.4 | 3.6 | 3.7 | 3.1 | 3.1 | 3.0 | 2.9 | 3.0 | 3.8 | 4.6 | 4.6 |
| Mount Zirkel          | Mount Zirkel       | 53     | MZIK | CO        | 40.55      | 106.70 | 2.2 | 2.2 | 2.2 | 2.1 | 2.2 | 2.1 | 1.9 | 1.7 | 2.0 | 1.9 | 2.1 |
| Mount Elbert          | Mount Elbert       | 54     | MELB | CO        | 40.55      | 106.70 | 2.2 | 2.2 | 2.2 | 2.1 | 2.2 | 2.1 | 1.9 | 1.7 | 2.0 | 1.9 | 2.1 |
| Mount Massive - Miners | Monico         | 73     | MONT | UT        | 47.40      | 113.05 | 3.6 | 3.1 | 2.7 | 2.5 | 2.6 | 2.5 | 2.5 | 2.2 | 2.5 | 2.6 | 3.5 |
| Mount Massive - Miners | Monico         | 73     | MONT | UT        | 47.40      | 113.05 | 3.6 | 3.1 | 2.7 | 2.5 | 2.6 | 2.5 | 2.5 | 2.2 | 2.5 | 2.6 | 3.5 |
| Mount Rainier         | Mount Rainier      | 78     | MORA | WA        | 46.75      | 122.12 | 4.4 | 4.0 | 3.6 | 4.7 | 3.1 | 3.7 | 3.3 | 3.8 | 3.4 | 4.1 | 4.7 |
| Mount Washington       | Mount Washington   | 54     | MUSA | WA        | 46.30      | 117.07 | 4.4 | 3.6 | 3.7 | 3.1 | 3.1 | 3.0 | 2.9 | 3.0 | 3.8 | 4.6 | 4.6 |
| Mount Zirkel          | Mount Zirkel       | 53     | MZIK | CO        | 40.55      | 106.70 | 2.2 | 2.2 | 2.2 | 2.1 | 2.2 | 2.1 | 1.9 | 1.7 | 2.0 | 1.9 | 2.1 |
| Ozone                 | Ozone              | 53     | OLZ1 | CO        | 40.55      | 106.70 | 2.2 | 2.2 | 2.2 | 2.1 | 2.2 | 2.1 | 1.9 | 1.7 | 2.0 | 1.9 | 2.1 |
| Ozone                 | Ozone              | 53     | OLZ1 | CO        | 40.55      | 106.70 | 2.2 | 2.2 | 2.2 | 2.1 | 2.2 | 2.1 | 1.9 | 1.7 | 2.0 | 1.9 | 2.1 |
| Ozone                 | Ozone              | 53     | OLZ1 | CO        | 40.55      | 106.70 | 2.2 | 2.2 | 2.2 | 2.1 | 2.2 | 2.1 | 1.9 | 1.7 | 2.0 | 1.9 | 2.1 |
| Ozone                 | Ozone              | 53     | OLZ1 | CO        | 40.55      | 106.70 | 2.2 | 2.2 | 2.2 | 2.1 | 2.2 | 2.1 | 1.9 | 1.7 | 2.0 | 1.9 | 2.1 |
### Guidance for Tracking Progress Under the Regional Haze Rule

#### 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)

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*Colorado Department of Public Health & Environment / Air Pollution Control Division / Technical Services Program April 15, 2010 (revised June 25, 2010 and August 19, 2010)*
### Guidance for Tracking Progress Under the Regional Haze Rule

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)

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<td>3.1</td>
<td>2.8</td>
<td>2.7</td>
<td>2.6</td>
<td>2.4</td>
<td>2.5</td>
<td>2.5</td>
<td>2.7</td>
<td>3.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Yosemite</td>
<td>Yosemite</td>
<td>60</td>
<td>CA</td>
<td>37.71</td>
<td>119.70</td>
<td>3.3</td>
<td>3.0</td>
<td>2.8</td>
<td>2.3</td>
<td>2.1</td>
<td>1.8</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.6</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Zion</td>
<td>Zion</td>
<td>51</td>
<td>UT</td>
<td>37.26</td>
<td>112.01</td>
<td>2.7</td>
<td>2.4</td>
<td>2.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.3</td>
<td>1.2</td>
<td>1.4</td>
<td>1.4</td>
<td>1.6</td>
<td>2.0</td>
<td>2.4</td>
</tr>
</tbody>
</table>

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 C – Sample CALMET File
Sample CALMET file
------------------------ Run title (3 lines) ------------------------------------------

CALMET MODEL CONTROL FILE
--------------------------

INPUT GROUP: 0 -- Input and Output File Names

Subgroup (a)
-------------

Default Name | Type | File Name
--------------|------|--------------
GEO.DAT       | input | ! GEODAT= geo4km.DAT !
SURF.DAT      | input | ! SRFDAT= surf01.DAT !
CLOUD.DAT     | input | * CLDDAT=      *
PRECIP.DAT    | input | ! PRCDAT= PRECIP01.DAT !
WT.DAT        | input | * WTDAT=      *
CALMET.LST    | output | ! METLST= APR01.LST !
CALMET.DAT    | output | ! METDAT= APR01.DAT !
PACOUT.DAT    | output | * PACDAT=      *

All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
T = lower case ! LCFILES = T !
F = UPPER CASE

NUMBER OF UPPER AIR & OVERWATER STATIONS:

Number of upper air stations (NUSTA) No default ! NUSTA = 1 !
Number of overwater met stations
(NOWSTA) No default ! NOWSTA = 0 !

NUMBER OF PROGNOSTIC and IGF-CALMET FILEs:

Number of MM4/MM5/3D.DAT files
(NM3D) No default ! NM3D = 1 !

Number of IGF-CALMET.DAT files
(NIGF) No default ! NIGF = 0 !

!END!

Subgroup (b)
-------------

Upper air files (one per station)
---------------------------------

Default Name | Type | File Name
--------------|------|--------------
UP1.DAT       | input | 1 ! UPDAT= UPden01.DAT! !END!


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Subgroup (c)
-----------------------------------------
Overwater station files (one per station)
-----------------------------------------
Default Name  Type       File Name
------------  ----       ---------
-------------------------------------------------------------------------------

Subgroup (d)
-------------
MM4/MM5/3D.DAT files (consecutive or overlapping)
-------------------------------------------
Default Name  Type       File Name
------------  ----       ---------
MM51.DAT     input     1 ! M3DDAT= APR01.MM5 ! !END!
-------------------------------------------------------------------------------

Subgroup (e)
-------------
IGF-CALMET.DAT files (consecutive or overlapping)
-----------------------------------------------
Default Name  Type       File Name
------------  ----       ---------
IGFn.DAT     input     1 * IGFDAT=CALMET0.DAT * *END*
-------------------------------------------------------------------------------

Subgroup (f)
-------------
Other file names
-------------
Default Name  Type       File Name
------------  ----       ---------
DIAG.DAT     input      * DIADAT=                  *
PROG.DAT     input      * PRGDAT=                  *
TEST.FRT     output     * TSTPRT=                  *
TEST.OUT     output     * TSTOUT=                  *
TEST.KIN     output     * TSTKIN=                  *
TEST.FRD     output     * TSTFRD=                  *
TEST.SLP     output     * TSTSLP=                  *
DCST.GRD     output     * DCSTGD=                  *
-------------------------------------------------------------------------------

NOTES: (1) File/path names can be up to 70 characters in length
(2) Subgroups (a) and (f) must have ONE 'END' (surrounded by delimiters) at the end of the group
(3) Subgroups (b) through (e) are included ONLY if the corresponding number of files (NUSTA, NOWSTA, NM3D, NIGF) is not 0, and each must have an 'END' (surround by delimiters) at the end of EACH LINE
INPUT GROUP: 1 -- General run control parameters
----------

Starting date: Year (IBYR) -- No default ! IBYR= 2001 !
Month (IBMO) -- No default ! IBMO= 4 !
Day (IBDY) -- No default ! IBDY= 1 !
Hour (IBHR) -- No default ! IBHR= 0 !

Note: IBHR is the time at the END of the first hour of the simulation
(IBHR=1, the first hour of a day, runs from 00:00 to 01:00)

Base time zone (IBTZ) -- No default ! IBTZ= 7 !
PST = 08, MST = 07
CST = 06, EST = 05

Length of run (hours) (IRLG) -- No default ! IRLG= 720 !

Run type (IRTYPE) -- Default: 1 ! IRTYPE= 1 !
0 = Computes wind fields only
1 = Computes wind fields and micrometeorological variables
   (u*, w*, L, zi, etc.)
(IRTYPE must be 1 to run CALPUFF or CALGRID)

Compute special data fields required
by CALGRID (i.e., 3-D fields of W wind
components and temperature)
in additional to regular Default: T ! LCALGRD = T !
fields ? (LCALGRD)
(LCALGRD must be T to run CALGRID)

Flag to stop run after
SETUP phase (ITEST) Default: 2 ! ITEST= 2 !
(Used to allow checking
of the model inputs, files, etc.)
ITEST = 1 - STOPS program after SETUP phase
ITEST = 2 - Continues with execution of
   COMPUTATIONAL phase after SETUP

Test options specified to see if
they conform to regulatory
values? (MREG) No Default ! MREG = 1 !
0 = NO checks are made
1 = Technical options must conform to USEPA guidance
   IMIXH -1 Maul-Carson convective mixing height
   over land; OCD mixing height overwater
   ICOARE 0 OCD deltaT method for overwater fluxes
   THRESHL 0.0 Threshold buoyancy flux over land needed
   to sustain convective mixing height growth

!END!
INPUT GROUP: 2 -- Map Projection and Grid control parameters

Projection for all (X,Y):

Map projection
(PMAP) Default: UTM ! PMAP = LCC !

  UTM : Universal Transverse Mercator
  TTM : Tangential Transverse Mercator
  LCC : Lambert Conformal Conic
  PS : Polar Stereographic
  EM : Equatorial Mercator
  LAZA : Lambert Azimuthal Equal Area

False Easting and Northing (km) at the projection origin
(Used only if PMAP= TTM, LCC, or LAZA)
(FEAST) Default=0.0 ! FEAST = 0.000 !
(FNORTH) Default=0.0 ! FNORTH = 0.000 !

UTM zone (1 to 60)
(Used only if PMAP=UTM)
(IUTMZN) No Default ! IUTMZN = -999 !

Hemisphere for UTM projection?
(Used only if PMAP=UTM)
(UTMHEM) Default: N ! UTMHEM = N !
  N : Northern hemisphere projection
  S : Southern hemisphere projection

Latitude and Longitude (decimal degrees) of projection origin
(Used only if PMAP= TTM, LCC, PS, EM, or LAZA)
(RLAT0) No Default ! RLAT0 = 38.4N !
(RLON0) No Default ! RLON0 = 105.5W !

  TTM : RLON0 identifies central (true N/S) meridian of projection
       RLAT0 selected for convenience
  LCC : RLON0 identifies central (true N/S) meridian of projection
       RLAT0 selected for convenience
  PS : RLON0 identifies central (grid N/S) meridian of projection
       RLAT0 selected for convenience
  EM : RLON0 identifies central meridian of projection
       RLAT0 is REPLACED by 0.0N (Equator)
  LAZA: RLON0 identifies longitude of tangent-point of mapping plane
       RLAT0 identifies latitude of tangent-point of mapping plane

Matching parallel(s) of latitude (decimal degrees) for projection
(Used only if PMAP= LCC or PS)
(XLAT1) No Default ! XLAT1 = 36.4N !
(XLAT2) No Default ! XLAT2 = 40.5N !
LCC : Projection cone slices through Earth's surface at XLAT1 and XLAT2

PS : Projection plane slices through Earth at XLAT1
(XLAT2 is not used)

Note: Latitudes and longitudes should be positive, and include a
letter N,S,E, or W indicating north or south latitude, and
east or west longitude. For example,
35.9 N Latitude = 35.9N
118.7 E Longitude = 118.7E

Datum-region

The Datum-Region for the coordinates is identified by a character
string. Many mapping products currently available use the model of the
Earth known as the World Geodetic System 1984 (WGS-84). Other local
models may be in use, and their selection in CALMET will make its output
consistent with local mapping products. The list of Datum-Regions with
official transformation parameters is provided by the National Imagery and
Mapping Agency (NIMA).

NIMA Datum - Regions (Examples)

----

WGS-84  WGS-84 Reference Ellipsoid and Geoid, Global coverage (WGS84)
NAS-C  NORTH AMERICAN 1927 Clarke 1866 Spheroid, MEAN FOR CONUS (NAD27)
NAR-C  NORTH AMERICAN 1983 GRS 80 Spheroid, MEAN FOR CONUS (NAD83)
NWS-84  NWS 6370KM Radius, Sphere
ESR-S  ESRI REFERENCE 6371KM Radius, Sphere

Datum-region for output coordinates
(DATUM)  Default: WGS-84  ! DATUM = NAR-C !

Horizontal grid definition:

Rectangular grid defined for projection PMAP,
with X the Easting and Y the Northing coordinate

No. X grid cells (NX)  No default  ! NX = 127 !
No. Y grid cells (NY)  No default  ! NY = 172 !

Grid spacing (DGRIDKM)  No default  ! DGRIDKM = 4. !
Units: km

Reference grid coordinate of
SOUTHWEST corner of grid cell (1,1)

X coordinate (XORIGKM)  No default  ! XORIGKM = -253.0 !
Y coordinate (YORIGKM)  No default  ! YORIGKM = -348.0 !
Units: km
Vertical grid definition:
-----------------------------------

No. of vertical layers (NZ) No default ! NZ = 11 !

Cell face heights in arbitrary vertical grid (ZFACE(NZ+1)) No defaults
Units: m
!END!

-------------------------------------------------------------------------

INPUT GROUP: 3 -- Output Options
-------

DISK OUTPUT OPTION

Save met. fields in an unformatted output file ? (LSAVE) Default: T ! LSAVE = T !
(F = Do not save, T = Save)

Type of unformatted output file: (IFORMO) Default: 1 ! IFORMO = 1 !
1 = CALPUFF/CALGRID type file (CALMET.DAT)
2 = MESOPUFF-II type file (PACOUT.DAT)

LINE PRINTER OUTPUT OPTIONS:

Print met. fields ? (LPRINT) Default: F ! LPRINT = F !
(F = Do not print, T = Print)
(NOTE: parameters below control which met. variables are printed)

Print interval (IPRINF) in hours Default: 1 ! IPRINF = 1 !
(Meteorological fields are printed every 1 hours)

Specify which layers of U, V wind component to print (IUVOUT(NZ)) -- NOTE: NZ values must be entered
(0=Do not print, 1=Print)
(used only if LPRINT=T) Defaults: NZ*0
! IUVOUT = 11*0 !
-----------------------------------

Specify which levels of the W wind component to print
(NOTE: W defined at TOP cell face -- 10 values)
(IWOUT(NZ)) -- NOTE: NZ values must be entered
(0=Do not print, 1=Print) (used only if LPRINT=T & LCALGRD=T) 
-----------------------------------
Defaults: NZ*0

! IWOUT = 11*0 !

Specify which levels of the 3-D temperature field to print (ITOUT(NZ)) -- NOTE: NZ values must be entered (0=Do not print, 1=Print) (used only if LPRINT=T & LCALGRD=T) 
-----------------------------------
Defaults: NZ*0

! ITOUT = 11*0 !

Specify which meteorological fields to print (used only if LPRINT=T) Defaults: 0 (all variables)

-----------------------------------
Variable       Print ?
(0 = do not print, 1 = print)
--------        ------------------
!  STABILITY  = 0           ! - PGT stability class
!  USTAR      = 0           ! - Friction velocity
!  MONIN      = 0           ! - Monin-Obukhov length
!  MIXHT      = 0           ! - Mixing height
!  WSTAR      = 0           ! - Convective velocity scale
!  PRECIP     = 0           ! - Precipitation rate
!  SENSHEAT   = 0           ! - Sensible heat flux
!  CONVZI     = 0           ! - Convective mixing ht.

Testing and debug print options for micrometeorological module

Print input meteorological data and internal variables (LDB) Default: F ! LDB = F !
(F = Do not print, T = print) (NOTE: this option produces large amounts of output)

First time step for which debug data are printed (NN1) Default: 1 ! NN1 = 1 !

Last time step for which debug data are printed (NN2) Default: 1 ! NN2 = 1 !

Print distance to land internal variables (LDBCST) Default: F ! LDBCST = F !
(F = Do not print, T = print) (Output in .GRD file DCST.GRD, defined in input group 0)

Testing and debug print options for wind field module
(all of the following print options control output to
wind field module's output files: TEST.PRT, TEST.OUT, TEST.KIN, TEST.FRQ, and TEST.SLP)

Control variable for writing the test/debug wind fields to disk files (IOUTD)
(0=Do not write, 1=write) Default: 0 ! IOUTD = 0 !

Number of levels, starting at the surface, to print (NZPRN2) Default: 1 ! NZPRN2 = 0 !

Print the INTERPOLATED wind components ? (IPR0) (0=no, 1=yes) Default: 0 ! IPR0 = 0 !

Print the TERRAIN ADJUSTED surface wind components ? (IPR1) (0=no, 1=yes) Default: 0 ! IPR1 = 0 !

Print the SMOOTHED wind components and the INITIAL DIVERGENCE fields ? (IPR2) (0=no, 1=yes) Default: 0 ! IPR2 = 0 !

Print the FINAL wind speed and direction fields ? (IPR3) (0=no, 1=yes) Default: 0 ! IPR3 = 0 !

Print the FINAL DIVERGENCE fields ? (IPR4) (0=no, 1=yes) Default: 0 ! IPR4 = 0 !

Print the winds after KINEMATIC effects are added ? (IPR5) (0=no, 1=yes) Default: 0 ! IPR5 = 0 !

Print the winds after the FROUDE NUMBER adjustment is made ? (IPR6) (0=no, 1=yes) Default: 0 ! IPR6 = 0 !

Print the winds after SLOPE FLOWS are added ? (IPR7) (0=no, 1=yes) Default: 0 ! IPR7 = 0 !

Print the FINAL wind field components ? (IPR8) (0=no, 1=yes) Default: 0 ! IPR8 = 0 !

!END!

INPUT GROUP: 4 -- Meteorological data options
------------

NO OBSERVATION MODE (NOOBS) Default: 0 ! NOOBS = 0 !
0 = Use surface, overwater, and upper air stations
1 = Use surface and overwater stations (no upper air observations)
Use MM4/MM5/3D for upper air data
2 = No surface, overwater, or upper air observations
Use MM4/MM5/3D for surface, overwater, and upper air data

**NUMBER OF SURFACE & PRECIP. METEOROLOGICAL STATIONS**

Number of surface stations \( (NSSTA) \) No default \( ! NSSTA = 25 \) !

Number of precipitation stations
\( (NPSTA=-1: \) flag for use of MM5/3D precip data) \( (NPSTA) \) No default \( ! NPSTA = 91 \) !

**CLOUD DATA OPTIONS**

Gridded cloud fields:

\( (ICLOUD) \) Default: 0 \( ! ICLOUD = 0 \)!

\( ICLOUD = 0 \) - Gridded clouds not used
\( ICLOUD = 1 \) - Gridded CLOUD.DAT generated as OUTPUT
\( ICLOUD = 2 \) - Gridded CLOUD.DAT read as INPUT
\( ICLOUD = 3 \) - Gridded cloud cover computed from prognostic fields

**FILE FORMATS**

Surface meteorological data file format

\( (IFORMS) \) Default: 2 \( ! IFORMS = 2 \)!

(1 = unformatted (e.g., SMERGE output))
(2 = formatted (free-formatted user input))

Precipitation data file format

\( (IFORMP) \) Default: 2 \( ! IFORMP = 2 \)!

(1 = unformatted (e.g., PMERGE output))
(2 = formatted (free-formatted user input))

Cloud data file format

\( (IFORMC) \) Default: 2 \( ! IFORMC = 2 \)!

(1 = unformatted - CALMET unformatted output)
(2 = formatted - free-formatted CALMET output or user input)

!END!

---

**INPUT GROUP: 5 -- Wind Field Options and Parameters**

**WIND FIELD MODEL OPTIONS**

Model selection variable \( (IWFCOD) \) Default: 1 \( ! IWFCOD = 1 \)!

0 = Objective analysis only
1 = Diagnostic wind module

Compute Froude number adjustment effects ? \( (IFRADJ) \) Default: 1 \( ! IFRADJ = 1 \)!

(0 = NO, 1 = YES)

Compute kinematic effects ? \( (IKINE) \) Default: 0 \( ! IKINE = 0 \)!

(0 = NO, 1 = YES)
Use O'Brien procedure for adjustment of the vertical velocity? (IOBR) Default: 0 ! IOBR = 0 !
(0 = NO, 1 = YES)

Compute slope flow effects? (ISLOPE) Default: 1 ! ISLOPE = 1 !
(0 = NO, 1 = YES)

Extrapolate surface wind observations to upper layers? (IEXTRP) Default: -4 ! IEXTRP = -4 !
(1 = no extrapolation is done, 2 = power law extrapolation used, 3 = user input multiplicative factors for layers 2 - NZ used (see FEXTRP array), 4 = similarity theory used, -1, -2, -3, -4 = same as above except layer 1 data at upper air stations are ignored)

Extrapolate surface winds even if calm? (ICALM) Default: 0 ! ICALM = 0 !
(0 = NO, 1 = YES)

Layer-dependent biases modifying the weights of surface and upper air stations (BIAS(NZ))
-1<=BIAS<=1
Negative BIAS reduces the weight of upper air stations (e.g. BIAS=-0.1 reduces the weight of upper air stations by 10%; BIAS= -1, reduces their weight by 100 %)
Positive BIAS reduces the weight of surface stations (e.g. BIAS= 0.2 reduces the weight of surface stations by 20%; BIAS=1 reduces their weight by 100%)
Zero BIAS leaves weights unchanged (1/R**2 interpolation)
Default: NZ*0 ! BIAS = 11*0 !

Minimum distance from nearest upper air station to surface station for which extrapolation of surface winds at surface station will be allowed
(RMIN2: Set to -1 for IEXTRP = 4 or other situations where all surface stations should be extrapolated)
Default: 4. ! RMIN2 = -1 !

Use gridded prognostic wind field model output fields as input to the diagnostic wind field model (IPROG) Default: 0 ! IPROG = 14 !
(0 = No, [IWFCOD = 0 or 1]
1 = Yes, use CSUMM prog. winds as Step 1 field, [IWFCOD = 0]
2 = Yes, use CSUMM prog. winds as initial guess field [IWFCOD = 1]
3 = Yes, use winds from MM4.DAT file as Step 1 field [IWFCOD = 0]
4 = Yes, use winds from MM4.DAT file as initial guess field [IWFCOD = 1]
5 = Yes, use winds from MM4.DAT file as observations [IWFCOD = 1]
13 = Yes, use winds from MM5/3D.DAT file as Step 1 field [IWFCOD = 0]
14 = Yes, use winds from MM5/3D.DAT file as initial guess field [IWFCOD = 1]
15 = Yes, use winds from MM5/3D.DAT file as observations [IWFCOD = 1]
Timestep (hours) of the prognostic model input data \( (\text{ISTEPPG}) \) Default: 1 \( ! \) \( \text{ISTEPPG} = 1 ! \)

Use coarse CALMET fields as initial guess fields \( (\text{IGFMET}) \)
(overwrites IGF based on prognostic wind fields if any)
Default: 0 \( ! \) \( \text{IGFMET} = 0 ! \)

**RADIUS OF INFLUENCE PARAMETERS**

Use varying radius of influence Default: \( F ! \) \( \text{LVARY} = F ! \)
(if no stations are found within RMAX1, RMAX2, or RMAX3, then the closest station will be used)

Maximum radius of influence over land in the surface layer \( (\text{RMAX1}) \) No default \( ! \) \( \text{RMAX1} = 100. ! \)
Units: km

Maximum radius of influence over land aloft \( (\text{RMAX2}) \) No default \( ! \) \( \text{RMAX2} = 200. ! \)
Units: km

Maximum radius of influence over water \( (\text{RMAX3}) \) No default \( ! \) \( \text{RMAX3} = 200. ! \)
Units: km

**OTHER WIND FIELD INPUT PARAMETERS**

Minimum radius of influence used in the wind field interpolation \( (\text{RMIN}) \) Default: 0.1 \( ! \) \( \text{RMIN} = 0.1 ! \)
Units: km

Radius of influence of terrain features \( (\text{TERRAD}) \) No default \( ! \) \( \text{TERRAD} = 15. ! \)
Units: km

Relative weighting of the first guess field and observations in the SURFACE layer \( (\text{R1}) \) No default \( ! \) \( \text{R1} = 50. ! \)
Units: km

(R1 is the distance from an observational station at which the observation and first guess field are equally weighted)

Relative weighting of the first guess field and observations in the layers ALOFT \( (\text{R2}) \) No default \( ! \) \( \text{R2} = 100. ! \)
Units: km

(R2 is applied in the upper layers in the same manner as R1 is used in the surface layer).

Relative weighting parameter of the prognostic wind field data \( (\text{RPROG}) \) No default \( ! \) \( \text{RPROG} = 0. ! \)
(Used only if IPROG = 1)

Maximum acceptable divergence in the divergence minimization procedure

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(DIVLIM) Default: 5.E-6 ! DIVLIM= 5.0E-06

Maximum number of iterations in the divergence min. procedure (NITER) Default: 50 ! NITER = 50 !

Number of passes in the smoothing procedure (NSMTH(NZ))
NOTE: NZ values must be entered
Default: 2, (mxnz-1)*4 ! NSMTH = 2, 10*4 !

Maximum number of stations used in each layer for the interpolation of data to a grid point (NINTR2(NZ))
NOTE: NZ values must be entered Default: 99. ! NINTR2 = 11*99

Critical Froude number (CRITFN) Default: 1.0 ! CRITFN = 1. !

Empirical factor controlling the influence of kinematic effects (ALPHA) Default: 0.1 ! ALPHA = 0.1 !

Multiplicative scaling factor for extrapolation of surface observations to upper layers (FEXTR2(NZ)) Default: NZ*0.0
! FEXTR2 = 11*0. !
(Used only if IEXTRP = 3 or -3)

BARRIER INFORMATION

Number of barriers to interpolation of the wind fields (NBAR) Default: 0 ! NBAR = 0 !

Level (1 to NZ) up to which barriers apply (KBAR) Default: NZ ! KBAR = 11 !

THE FOLLOWING 4 VARIABLES ARE INCLUDED ONLY IF NBAR > 0
NOTE: NBAR values must be entered for each variable No defaults Units: km

X coordinate of BEGINNING of each barrier (XBBAR(NBAR)) ! XBBAR = 0. !
Y coordinate of BEGINNING of each barrier (YBBAR(NBAR)) ! YBBAR = 0. !

X coordinate of ENDING of each barrier (XEBAR(NBAR)) ! XEBAR = 0. !
Y coordinate of ENDING of each barrier (YEBAR(NBAR)) ! YEBAR = 0. !
Supplemental BART Analysis CALPUFF Protocol for Class I Federal Area Visibility Improvement Modeling (DRAFT)

Surface temperature (IDIOPT1)  Default: 0  ! IDIOPT1 = 0 !
0 = Compute internally from
   hourly surface observations
1 = Read preprocessed values from
   a data file (DIAG.DAT)

Surface met. station to use for
the surface temperature (ISURFT)  No default  ! ISURFT = 9 !
(Must be a value from 1 to NSSTA)
(Used only if IDIOPT1 = 0)
--------------------------

Domain-averaged temperature lapse
rate (IDIOPT2)  Default: 0  ! IDIOPT2 = 0 !
0 = Compute internally from
   twice-daily upper air observations
1 = Read hourly preprocessed values
   from a data file (DIAG.DAT)

Upper air station to use for
the domain-scale lapse rate (IUPT)  No default  ! IUPT = 1 !
(Must be a value from 1 to NUSTA)
(Used only if IDIOPT2 = 0)
--------------------------

Depth through which the domain-scale
lapse rate is computed (ZUPT)  Default: 200.  ! ZUPT = 200. !
(Used only if IDIOPT2 = 0)  Units: meters
--------------------------

Domain-averaged wind components
(IDIOPT3)  Default: 0  ! IDIOPT3 = 0 !
0 = Compute internally from
   twice-daily upper air observations
1 = Read hourly preprocessed values
   a data file (DIAG.DAT)

Upper air station to use for
the domain-scale winds (IUPWND)  Default: -1  ! IUPWND = -1 !
(Must be a value from -1 to NUSTA)
(Used only if IDIOPT3 = 0)
--------------------------

Bottom and top of layer through
which the domain-scale winds
are computed
(ZUPWND(1), ZUPWND(2))  Defaults: 1., 1000.  ! ZUPWND= 1., 1000.
(Used only if IDIOPT3 = 0)  Units: meters
--------------------------

Observed surface wind components
for wind field module (IDIOPT4)  Default: 0  ! IDIOPT4 = 0 !
0 = Read WS, WD from a surface
   data file (SURF.DAT)
1 = Read hourly preprocessed U, V from
a data file (DIAG.DAT)

Observed upper air wind components
for wind field module (IDIOPT5) Default: 0 ! IDIOPT5 = 0 !
0 = Read WS, WD from an upper
air data file (UP1.DAT, UP2.DAT, etc.)
1 = Read hourly preprocessed U, V from
a data file (DIAG.DAT)

LAKE BREEZE INFORMATION

Use Lake Breeze Module (LLBREZE)
Default: F ! LLBREZE = F !

Number of lake breeze regions (NBOX) ! NBOX = 0 !
X Grid line 1 defining the region of interest
! XG1 = 0. !
X Grid line 2 defining the region of interest
! XG2 = 0. !
Y Grid line 1 defining the region of interest
! YG1 = 0. !
Y Grid line 2 defining the region of interest
! YG2 = 0. !
X Point defining the coastline (Straight line)
(XBCST) (KM) Default: none ! XBCST = 0. !
Y Point defining the coastline (Straight line)
(YBCST) (KM) Default: none ! YBCST = 0. !
X Point defining the coastline (Straight line)
(XECST) (KM) Default: none ! XECST = 0. !
Y Point defining the coastline (Straight line)
(YECST) (KM) Default: none ! YECST = 0. !

Number of stations in the region Default: none ! NLB = 0 !
(Surface stations + upper air stations)
Station ID's in the region (METBXID(NLB))
(Surface stations first, then upper air stations)
! METBXID = 0 !

!END!

------------------------------------------------------------------------------------------------------------------

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters
---------

EMPIRICAL MIXING HEIGHT CONSTANTS
Neutral, mechanical equation

(CONSTB)

Default: 1.41  ! CONSTB = 1.41 !

Convective mixing ht. equation

(CONSTE)

Default: 0.15  ! CONSTE = 0.15 !

Stable mixing ht. equation

(CONSTN)

Default: 2400.  ! CONSTN = 2400.!

Overwater mixing ht. equation

(CONSTW)

Default: 0.16  ! CONSTW = 0.16 !

Absolute value of Coriolis parameter (FCORIOL)

Default: 1.E-4  ! FCORIOL = 1.0E-04!

Units: (l/s)

SPATIAL AVERAGING OF MIXING HEIGHTS

Conduct spatial averaging

(IAVEZI)  (0=no, 1=yes)

Default: 1  ! IAVEZI = 1 !

Max. search radius in averaging process (MNMDAV)

Default: 1  ! MNMDAV = 1 !

Units: Grid cells

Half-angle of upwind looking cone for averaging (HAFANG)

Default: 30.  ! HAFANG = 30. !

Units: deg.

Layer of winds used in upwind averaging (ILEVZI)

(must be between 1 and NZ)

Default: 1  ! ILEVZI = 1 !

CONVECTIVE MIXING HEIGHT OPTIONS:

Method to compute the convective mixing height (IMIXH)

Default: 1  ! IMIXH = -1 !

1: Maul-Carson for land and water cells
-1: Maul-Carson for land cells only - OCD mixing height overwater
2: Batchvarova and Gryning for land and water cells
-2: Batchvarova and Gryning for land cells only
   OCD mixing height overwater

Threshold buoyancy flux required to sustain convective mixing height growth

overland (THRESHL)  Default: 0.05  ! THRESHL = 0. !

(expressed as a heat flux units: W/m3 per meter of boundary layer)

Threshold buoyancy flux required to sustain convective mixing height growth

overwater (THRESHW)  Default: 0.05  ! THRESHW = 0.05 !

(expressed as a heat flux units: W/m3 per meter of boundary layer)

Option for overwater lapse rates used in convective mixing height growth
Supplemental BART Analysis CALPUFF Protocol for Class I Federal Area Visibility Improvement Modeling (DRAFT)

(ITWPROG) Default: 0 ! ITWPROG = 0 !
0 : use SEA.DAT lapse rates and deltaT (or assume neutral conditions if missing)
1 : use prognostic lapse rates (only if IPROG>2) and SEA.DAT deltaT (or neutral if missing)
2 : use prognostic lapse rates and prognostic delta T (only if iprog>12 and 3D.DAT version # 2.0 or higher)

Land Use category ocean in 3D.DAT datasets
(ILUOC3D) Default: 16 ! ILUOC3D = 16 !
Note: if 3D.DAT from MM5 version 3.0, iluoc3d = 16
if MM4.DAT, typically iluoc3d = 7

OTHER MIXING HEIGHT VARIABLES

Minimum potential temperature lapse rate in the stable layer above the current convective mixing ht. (DPTMIN) Default: 0.001 ! DPTMIN = 0.001 !
Units: deg. K/m

Depth of layer above current conv. mixing height through which lapse rate is computed (DZZI) Default: 200. ! DZZI = 200. !
Units: meters

Minimum overland mixing height (ZIMIN) Default: 50. ! ZIMIN = 50. !
Units: meters

Maximum overland mixing height (ZIMAX) Default: 3000. ! ZIMAX = 4500. !
Units: meters

Minimum overwater mixing height (ZIMINW) -- (Not used if observed overwater mixing hts. are used) Default: 50. ! ZIMINW = 50. !
Units: meters

Maximum overwater mixing height (ZIMAXW) -- (Not used if observed overwater mixing hts. are used) Default: 3000. ! ZIMAXW = 4500. !
Units: meters

OVERWATER SURFACE FLUXES METHOD and PARAMETERS
(ICOARE) Default: 10 ! ICOARE = 0 !
0: original deltaT method (OCD)
10: COARE with no wave parameterization (jwave=0, Charnock)
11: COARE with wave option jwave=1 (Oost et al.) and default wave properties
-11: COARE with wave option jwave=1 (Oost et al.) and observed wave properties (must be in SEA.DAT files)
12: COARE with wave option 2 (Taylor and Yelland) and default wave properties
-12: COARE with wave option 2 (Taylor and Yelland) and observed wave properties (must be in SEA.DAT files)

Coastal/Shallow water length scale (DSHELF) (for modified z0 in shallow water)
(COARE fluxes only) Default: 0. ! DSHELF = 0. !
units: km

COARE warm layer computation (IWARM) ! IWARM = 0 !
Supplemental BART Analysis CALPUFF Protocol for Class I Federal Area Visibility Improvement Modeling (DRAFT)

1: on - 0: off (must be off if SST measured with IR radiometer) Default: 0

COARE cool skin layer computation (ICOOL) ! ICOOL = 0 !
1: on - 0: off (must be off if SST measured with IR radiometer) Default: 0

TEMPERATURE PARAMETERS

3D temperature from observations or from prognostic data? (ITPROG) Default: 0 ! ITPROG = 0 !

0 = Use Surface and upper air stations (only if NOOBS = 0)
1 = Use Surface stations (no upper air observations)
Use MM5/3D for upper air data (only if NOOBS = 0,1)
2 = No surface or upper air observations
Use MM5/3D for surface and upper air data (only if NOOBS = 0,1,2)

Interpolation type
(1 = 1/R ; 2 = 1/R**2) Default: 1 ! IRAD = 1 !

Units: km

Maximum Number of stations to include in temperature interpolation (NUMTS) Default: 5 ! NUMTS = 5 !

Conduct spatial averaging of temperatures (IAVET) (0=no, 1=yes) Default: 1 ! IAVET = 1 !
(will use mixing ht MNMDAV,HAFANG so make sure they are correct)

Default temperature gradient below the mixing height over water (TGDEFB)
Default: -.0098 ! TGDEFB = -
Units: K/m

Default temperature gradient above the mixing height over water (TGDEFA)
Default: -.0045 ! TGDEFA = -
Units: K/m

Beginning (JWAT1) and ending (JWAT2) land use categories for temperature interpolation over water -- Make bigger than largest land use to disable

PRECIP INTERPOLATION PARAMETERS

Method of interpolation (NFLAGP) Default: 2 ! NFLAGP = 2 !
Supplemental BART Analysis CALPUFF Protocol for Class I Federal Area Visibility Improvement Modeling (DRAFT)

(1=1/R, 2=1/R**2, 3=EXP/R**2)

Radius of Influence (SIGMAP) Default: 100.0 ! SIGMAP = 100. !
(0.0 => use half dist. btwn nearest stns w & w/out precip when NPLAGP = 3)

Minimum Precip. Rate Cutoff (CUTP) Default: 0.01 ! CUTP = 0.01 !
(values < CUTP = 0.0 mm/hr) Units: mm/hr

!END!

INPUT GROUP: 7 -- Surface meteorological station parameters

SURFACE STATION VARIABLES
(One record per station -- 25 records in all)

<table>
<thead>
<tr>
<th>Name</th>
<th>ID</th>
<th>X coord. (km)</th>
<th>Y coord. (km)</th>
<th>Time zone</th>
<th>Anem. Ht. (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS1</td>
<td>'AKO'</td>
<td>24698</td>
<td>193.159</td>
<td>198.973</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS2</td>
<td>'ALS'</td>
<td>24620</td>
<td>-32.336</td>
<td>-106.860</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS3</td>
<td>'APA'</td>
<td>24666</td>
<td>55.922</td>
<td>130.041</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS4</td>
<td>'ASE'</td>
<td>24676</td>
<td>-118.091</td>
<td>92.190</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS5</td>
<td>'CAG'</td>
<td>25700</td>
<td>-171.322</td>
<td>234.404</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS6</td>
<td>'CAO'</td>
<td>23600</td>
<td>210.283</td>
<td>-214.114</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS7</td>
<td>'COS'</td>
<td>24660</td>
<td>68.475</td>
<td>45.993</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS8</td>
<td>'CYS'</td>
<td>25640</td>
<td>58.198</td>
<td>306.332</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS9</td>
<td>'DEN'</td>
<td>25650</td>
<td>72.093</td>
<td>159.306</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS10</td>
<td>'DHT'</td>
<td>22636</td>
<td>266.176</td>
<td>-259.412</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS11</td>
<td>'DRO'</td>
<td>24625</td>
<td>-200.668</td>
<td>-136.973</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS12</td>
<td>'EEO'</td>
<td>24674</td>
<td>-203.468</td>
<td>185.599</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS13</td>
<td>'FMN'</td>
<td>23658</td>
<td>-243.657</td>
<td>-180.141</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS14</td>
<td>'LAH'</td>
<td>24636</td>
<td>246.555</td>
<td>-32.844</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS15</td>
<td>'LAR'</td>
<td>25645</td>
<td>-14.616</td>
<td>323.319</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS16</td>
<td>'LHX'</td>
<td>24635</td>
<td>173.058</td>
<td>-36.818</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS17</td>
<td>'LIC'</td>
<td>24665</td>
<td>154.047</td>
<td>89.075</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS18</td>
<td>'LVS'</td>
<td>23677</td>
<td>32.391</td>
<td>-304.593</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS19</td>
<td>'LXV'</td>
<td>24673</td>
<td>-70.429</td>
<td>92.179</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS20</td>
<td>'MTJ'</td>
<td>24765</td>
<td>-208.969</td>
<td>14.367</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS21</td>
<td>'PUB'</td>
<td>24640</td>
<td>87.574</td>
<td>-11.726</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS22</td>
<td>'RIL'</td>
<td>25717</td>
<td>-191.319</td>
<td>127.284</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS23</td>
<td>'SAF'</td>
<td>23656</td>
<td>-53.382</td>
<td>-308.617</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS24</td>
<td>'SNY'</td>
<td>25610</td>
<td>211.364</td>
<td>302.733</td>
<td>7 10 !</td>
</tr>
<tr>
<td>SS25</td>
<td>'TAD'</td>
<td>24645</td>
<td>102.806</td>
<td>-125.906</td>
<td>7 10 !</td>
</tr>
</tbody>
</table>

1
Four character string for station name
(MUST START IN COLUMN 9)

2
Six digit integer for station ID

Colorado Department of Public Health & Environment / Air Pollution Control Division / Technical Services Program
April 15, 2010 (revised June 25, 2010 and August 19, 2010)
INPUT GROUP: 8 -- Upper air meteorological station parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>ID</th>
<th>X coord. (km)</th>
<th>Y coord. (km)</th>
<th>Time zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>US1</td>
<td>'DEN'</td>
<td>23062</td>
<td>59.101</td>
<td>152.186</td>
</tr>
</tbody>
</table>

Four character string for station name
(MUST START IN COLUMN 9)

Five digit integer for station ID

---

INPUT GROUP: 9 -- Precipitation station parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Station Code</th>
<th>X coord. (km)</th>
<th>Y coord. (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS1</td>
<td>'WY01'</td>
<td>481675</td>
<td>85.74</td>
</tr>
<tr>
<td>PS2</td>
<td>'WY02'</td>
<td>483050</td>
<td>-81.49</td>
</tr>
<tr>
<td>PS3</td>
<td>'WY03'</td>
<td>484930</td>
<td>-42.89</td>
</tr>
<tr>
<td>PS4</td>
<td>'WY04'</td>
<td>485420</td>
<td>10.07</td>
</tr>
<tr>
<td>PS5</td>
<td>'WY05'</td>
<td>487200</td>
<td>100.45</td>
</tr>
<tr>
<td>PS6</td>
<td>'WY06'</td>
<td>487240</td>
<td>118.50</td>
</tr>
<tr>
<td>PS7</td>
<td>'WY07'</td>
<td>487995</td>
<td>-81.29</td>
</tr>
<tr>
<td>PS8</td>
<td>'NM01'</td>
<td>290041</td>
<td>-68.41</td>
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<tr>
<td>PS9</td>
<td>'NM02'</td>
<td>290407</td>
<td>27.86</td>
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<tr>
<td>PS10</td>
<td>'NM03'</td>
<td>291887</td>
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<td>'NM04'</td>
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<td>'NM06'</td>
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<tr>
<td>PS14</td>
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<td>30.57</td>
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</table>
Supplemental BART Analysis CALPUFF Protocol for Class I Federal Area Visibility Improvement Modeling (DRAFT)

PS15 = 'NM08' 292837  -84.37 -225.89  
PS16 = 'NM09' 293142  -237.62 -216.24  
PS17 = 'NM10' 294862   34.58 -341.69  
PS18 = 'NM11' 296275   41.42 -252.85  
PS19 = 'NM12' 297279   125.17 -313.06  
PS20 = 'NM13' 298085  -8.19  -336.20  
PS21 = 'NM14' 298501   102.51 -241.22  
PS22 = 'NM15' 299031  -146.20 -322.71  
PS23 = 'NE01' 257827   245.44   301.36  
PS24 = 'CO01' 050109    205.46   190.22  
PS25 = 'CO02' 050130    -1.77  -126.46  
PS26 = 'CO03' 050183    15.34   191.98  
PS27 = 'CO04' 050263    -3.46    66.56  
PS28 = 'CO05' 050372   -86.44    79.24  
PS29 = 'CO06' 050843    28.16   179.81  
PS30 = 'CO07' 051179   122.18   116.33  
PS31 = 'CO08' 051401   86.31    91.44  
PS32 = 'CO09' 051443  -177.73   17.50  
PS33 = 'CO10' 051539   192.94  -35.41  
PS34 = 'CO11' 051547    86.12   109.20  
PS35 = 'CO12' 051713  -83.95  -13.98  
PS36 = 'CO13' 051778    93.29    10.53  
PS37 = 'CO14' 051959  -94.98   14.98  
PS38 = 'CO15' 052162  126.59   109.74  
PS39 = 'CO16' 052211   84.30   118.05  
PS40 = 'CO17' 052220   84.30   118.05  
PS41 = 'CO18' 052354   25.52   206.44  
PS42 = 'CO19' 052790   26.70   108.77  
PS43 = 'CO20' 052965   28.75    16.69  
PS44 = 'CO21' 053005   38.23   216.49  
PS45 = 'CO22' 053007   31.41   222.01  
PS46 = 'CO23' 053386   30.98   113.23  
PS47 = 'CO24' 053500  -1.70   189.75  
PS48 = 'CO25' 053553   91.89   204.72  
PS49 = 'CO26' 053579   91.69    73.75  
PS50 = 'CO27' 053584   91.60   81.51  
PS51 = 'CO28' 053662  -94.38   -8.32  
PS52 = 'CO29' 054155  123.78   178.51  
PS53 = 'CO30' 054172  191.07    78.84  
PS54 = 'CO31' 054293   31.88   104.35  
PS55 = 'CO32' 054388  257.89  -35.82  
PS56 = 'CO33' 054538  204.78  -122.78  
PS57 = 'CO34' 054720  191.26  -38.78  
PS58 = 'CO35' 054742   19.17   15.55  
PS59 = 'CO36' 054877   11.18   117.61  
PS60 = 'CO37' 055121   34.93   194.27  
PS61 = 'CO38' 055352   81.93   12.62  
PS62 = 'CO39' 055484  -177.53   180.65  
PS63 = 'CO40' 055706  -54.91  -116.29  
PS64 = 'CO41' 055765   32.72   109.91  
PS65 = 'CO42' 055881   14.51   179.77  
PS66 = 'CO43' 055922  169.01   219.33  
PS67 = 'CO44' 055982  -59.29   239.94  
PS68 = 'CO45' 056023   87.41   224.66  
PS69 = 'CO46' 056136  181.79   -7.93  

Colorado Department of Public Health & Environment / Air Pollution Control Division / Technical Services Program
April 15, 2010 (revised June 25, 2010 and August 19, 2010)
81
1
Four character string for station name
(MUST START IN COLUMN 9)

2
Six digit station code composed of state
code (first 2 digits) and station ID (last
4 digits)

!END!