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
Technical Services Program
4300 Cherry Creek Drive South
Denver, Colorado 80246

Table of Contents

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:

1. "*CALMET/CALPUFF BART Protocol for Class I Federal Area Individual Source Attribution Visibility Impairment Modeling Analysis*." Colorado Department of Public Health and Environment. October 24, 2005. http://www.colorado.gov/airquality/documents/Colorado-subject-to-BART-CALPUFFprotocol.pdf

2. "*BART Control Technology Visibility Improvement Modeling Analysis Guidance*." Colorado Department of Public Health and Environment. April 12, 2006. http://www.colorado.gov/airquality/documents/Colorado-BART-Analysis-Modeling-Guidance.pdf

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:
    a. 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.
    b. 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.
    c. 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.
    d. 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."
    e. Postprocessors. The April 15 protocol indicated that the Division might use its 98th percentile processor to streamline the modeling. In fact, the Division's 98^{th} percentile processor was not used because the regulatory version of CALPOST adequately summarizes results.
    f. 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:

- "Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts" (IWAQM, 1998)
- "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_{ext}) considers light extinction by scattering (b_{scat}) and light extinction by absorption (b_{abs}):

$$b_{ext} = b_{scat} + b_{abs}$$

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

- light scattering due to air molecules = Rayleigh scattering = $b_{rayleigh}$
- light scattering due to particles = b_{sp}

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

- light absorption due to gaseous absorption = b_{ag}
- light absorption due to particle absorption = b_{ap}

Particle scattering, b_{sp}, can be expressed by its components:

$$b_{sp} = b_{SO4} + b_{NO3} + b_{OC} + b_{SOIL} + b_{Coarse}$$

where:

- b_{SO4} = scattering coefficient due to sulfates = $3[(NH_4)_2SO_4]f(RH)$
- b_{NO3} = scattering coefficient due to nitrates = $3[NH_4NO_3]f(RH)$
- b_{OC} = scattering coefficient due to organic aerosols = 4[OC]
- b_{SOIL}= scattering coefficient due to fine particles = 1[Soil]
- b_{Coarse}= scattering coefficient due to coarse particles = 0.6[Coarse Mass]

Particle absorption from soot is defined as:

- b_{ap} = absorption due to elemental carbon (soot) = 10[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(RH) term is the relative humidity adjustment factor.

The total atmospheric extinction can be expressed as:

$$b_{ext} = b_{SO4} + b_{NO3} + b_{OC} + b_{SOIL} + b_{Coarse} + b_{ap} + b_{rayleigh}$$

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, Δdv, value is calculated from the source's contribution to extinction, b_{source}, and background extinction, $b_{background}$, as follows:

$$\Delta dv = 10\ \mathit{ln}((b_{background} + b_{source}) / b_{background})$$

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, NOx, and direct particulate matter (PM) emissions (e.g., filterable and condensable PM2.5 and PM10) 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 NOx 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 $\mu g/m^3$.

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.

According to "*Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts*" (IWAQM Phase 2 Report):

> *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[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

[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.

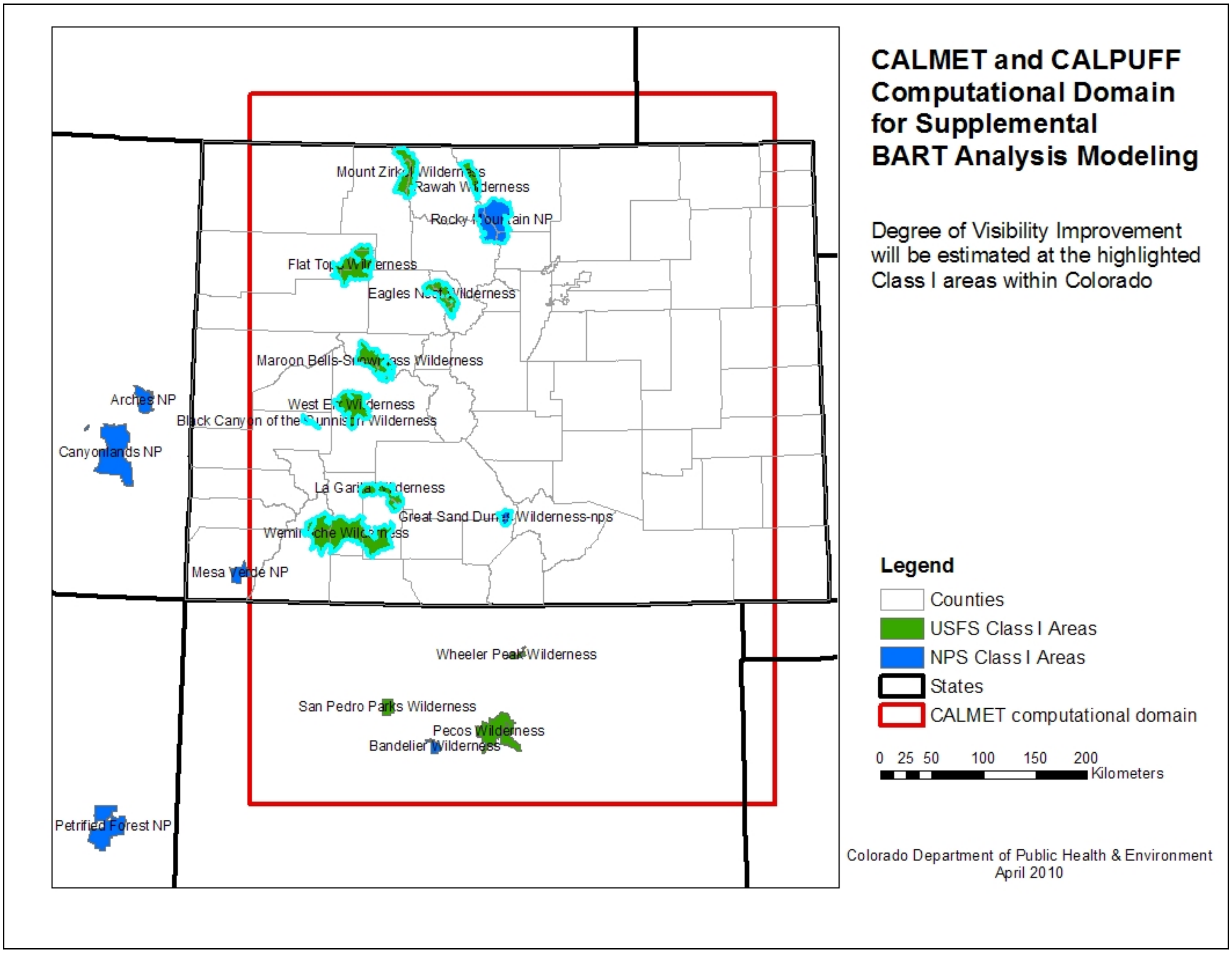

Figure 1. CALMET/CALPUFF modeling domain for 2001 and 2002. For 2003, the southern end of the domain is about 72 km north of the one shown above because of limitations with the CDPHE 2003 MM5 domain. Refer to Figure 2 to view the southern end of the 2003 domain.

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.

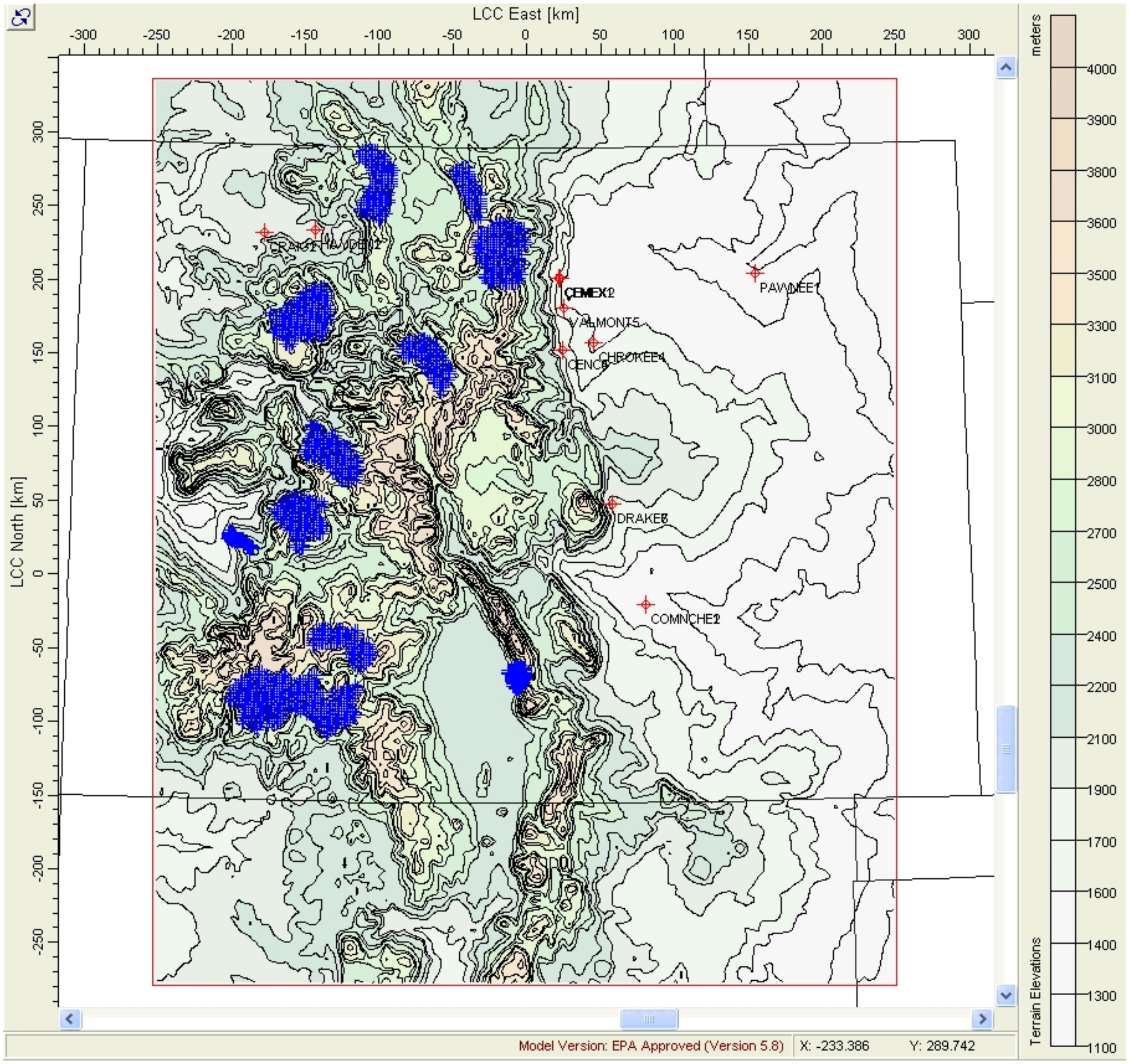

Figure 2. CALMET terrain plus Class I Area receptors (blue) and BART sources. This example image is for the year 2003 configuration.

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.

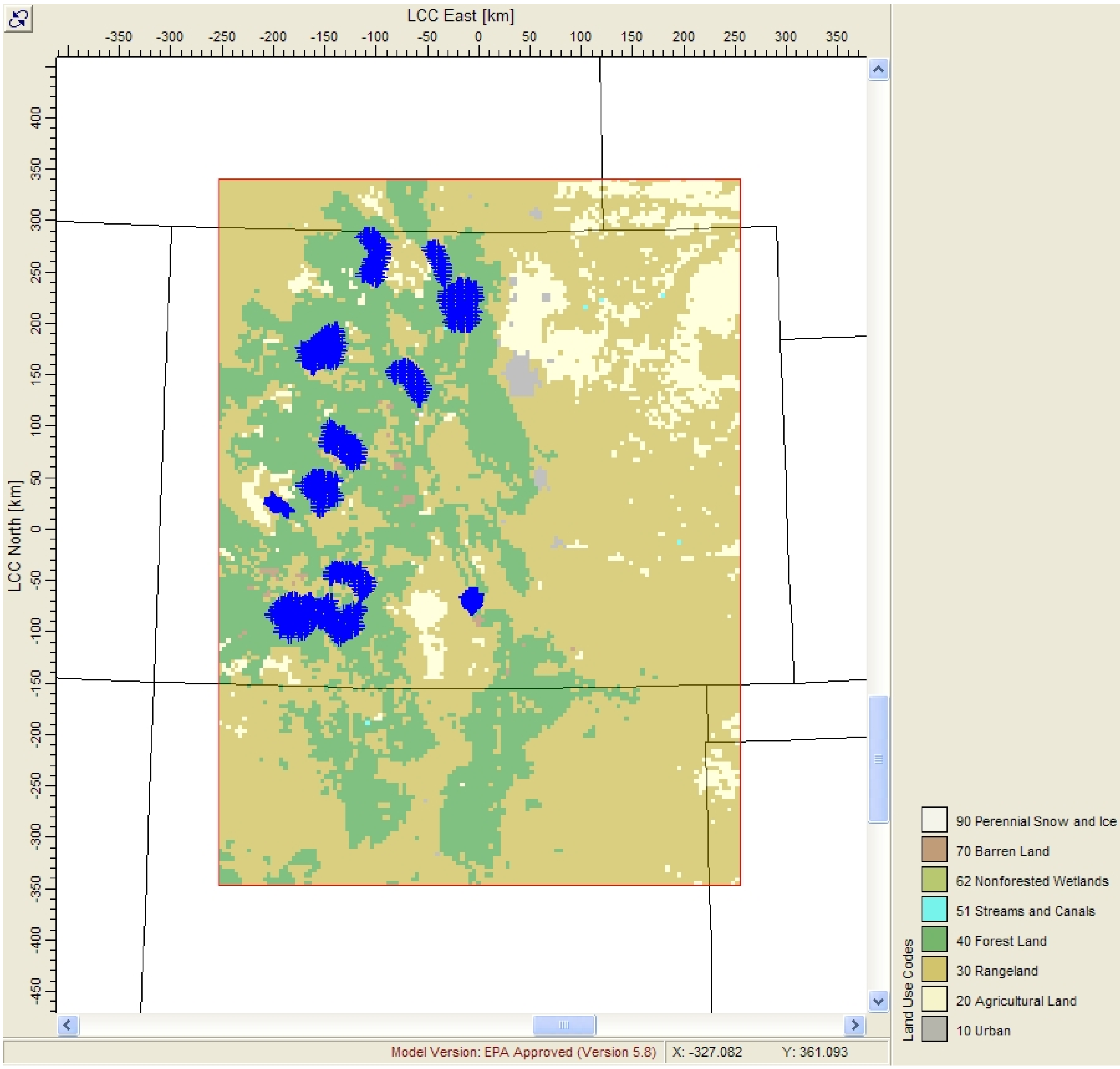

Figure 3. Land Use (example shown is for year 2002).

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.

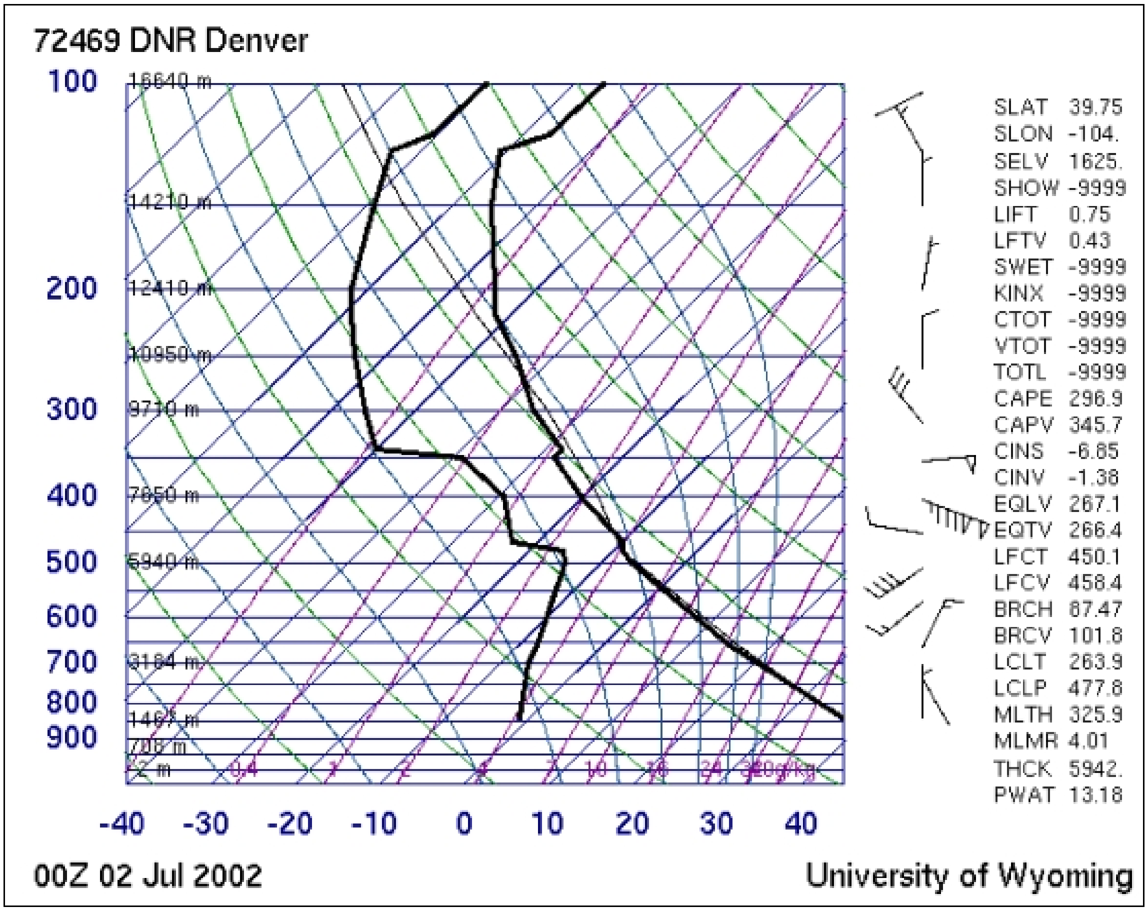

Figure 4. Example Denver summertime sounding.

3.1.1.5. CALMET Surface Stations

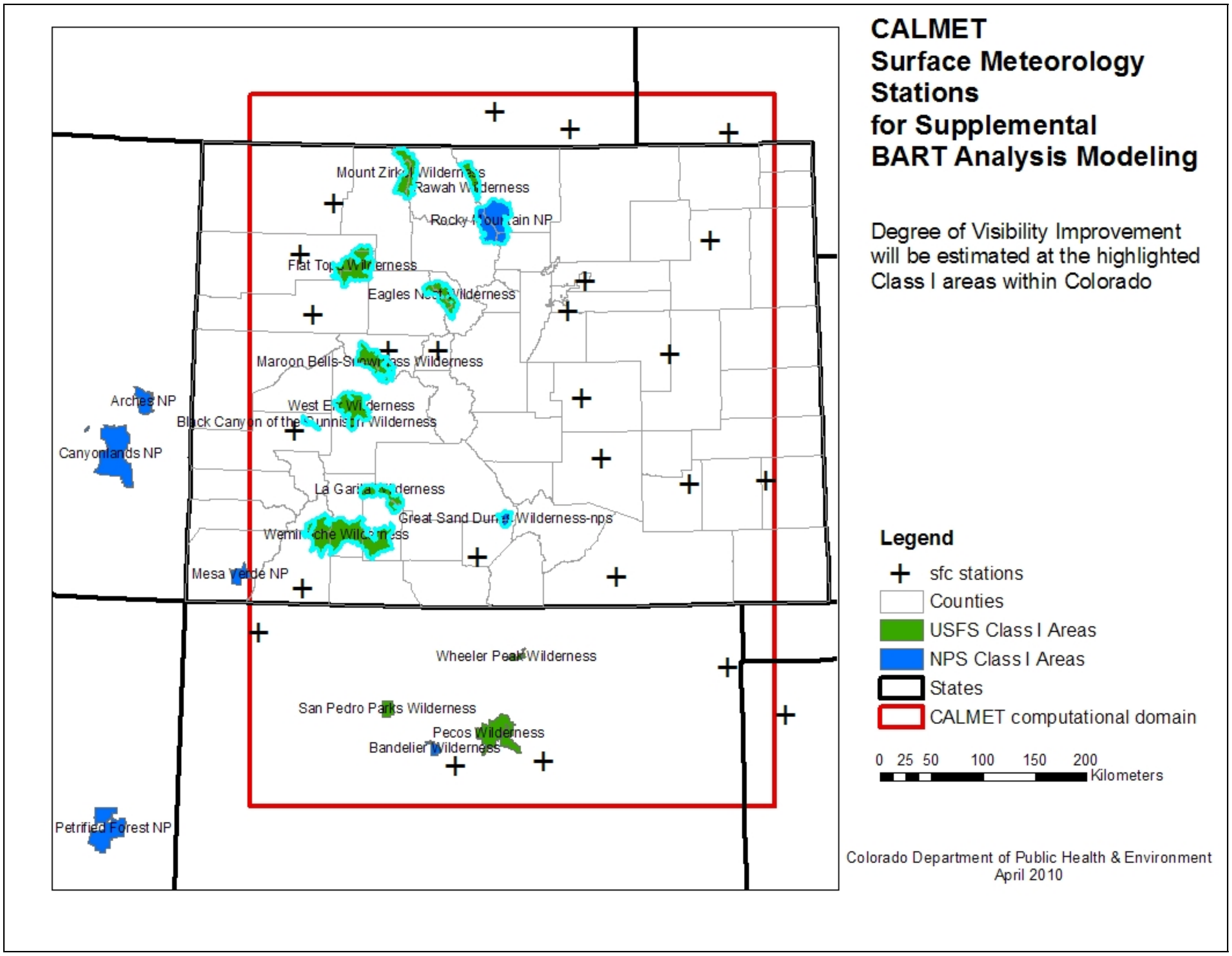

Figure 5. Surface meteorological stations.

3.1.1.6. CALMET Upper Air

The Denver upper air station is included in CALMET.

3.1.1.7. CALMET Precipitation Stations

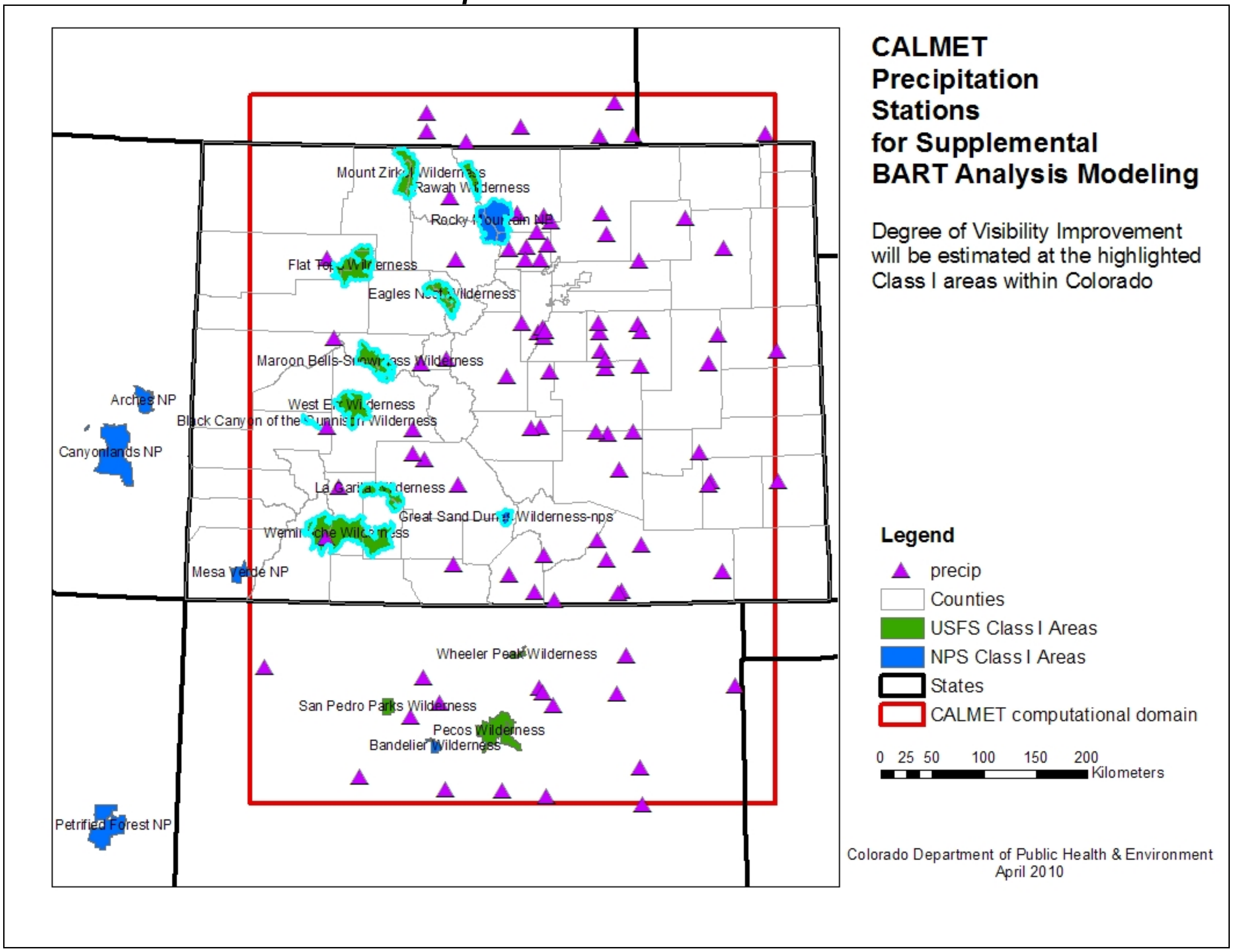

Figure 6. Precipitation stations.

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.

	Receptors				
Class I Area	**start**	**end**	**leading 0's**	**sum**	**CALPOST setting for NCRECP**
Black Canyon of the Gunnison	1	91	0	91	91*1
Eagles Nest	92	304	91	213	91*0, 213*1
Great Sand Dunes	305	498	304	194	304*0, 194*1
La Garita	499	685	498	187	498*0, 187*1
Maroon Bells	686	964	685	279	685*0, 279*1
RMNP	965	1371	964	407	964*0, 407*1
Weminuche	1372	2116	1371	745	1371*0, 745*1
West Elk	2117	2376	2116	260	2116*0, 260*1
Rawah	2377	2492	2376	116	2376*0, 116*1
Flat Tops	2493	2847	2492	355	2492*0, 355*1
Mt Zirkel	2848	3100	2847	253	2847*0, 253*1

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.

```
Number of chemical species (NSPEC)                         Default: 5       ! NSPEC =  7 !
Number of chemical species emitted (NSE)                   Default: 3       ! NSE =    5 !
(AVET)                                                     Default: 60.0    ! AVET = 60. !
(PGTIME)                                                   Default: 60.0    ! PGTIME = 60. !
Vertical distribution used in the near field (MGAUSS)      Default: 1       ! MGAUSS =  1   !
Terrain adjustment method (MCTADJ)                         Default: 3       ! MCTADJ =  3   !
Subgrid-scale complex terrain flag (MCTSG)                 Default: 0       ! MCTSG =   0   !
Near-field puffs modeled as elongated 0 (MSLUG)            Default: 0       ! MSLUG =   0   !
Transitional plume rise modeled?(MTRANS)                   Default: 1       ! MTRANS =  1   !
Stack tip downwash? (MTIP)                                 Default: 1       ! MTIP =    1   !
Vertical wind shear modeled above stack top? (MSHEAR)      Default: 0       ! MSHEAR =  0   !
Puff splitting allowed? (MSPLIT)                           Default: 0       ! MSPLIT =  0   !
Chemical mechanism flag (MCHEM)                            Default: 1       ! MCHEM =   1   !
Aqueous phase transformation flag (MAQCHEM)                Default: 0       ! MAQCHEM =  0  !
Wet removal modeled ? (MWET)                               Default: 1       ! MWET =     1  !
Dry deposition modeled ? (MDRY)                            Default: 1       ! MDRY =     1  !
Method used to compute dispersion coefficients(MDISP)      Default: 3       ! MDISP =    3  !
PG sigma-y,z adj. for roughness?                           Default: 0       ! MROUGH =  0  !
Partial plume penetration of elevated inversion?           Default: 1       ! MPARTL =  1  !
Strength of temperature inversion                          Default: 0       ! MTINV =  0  !
PDF used for dispersion under convective conditions?       Default: 0       ! MPDF =  0  !
Sub-Grid TIBL module used for shore line?                  Default: 0       ! MSGTIBL = 0  !
Boundary conditions (concentration) modeled?               Default: 0       ! MBCON = 0  !
Configure for FOG Model output?                            Default: 0       ! MFOG =  0   !
Do options specified to see if they conform to regulatory values?          ! MREG =  1   !
    1 = Technical options must conform to USEPA Long Range Transport (LRT) guidance
```

Figure 7. CALPUFF parameter summary.

3.1.2.5. Chemical Mechanism

The MESOPUFF II pseudo-first-order chemical reaction mechanism (MCHEM=1) is used for the conversion of SO_2 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 SO_2 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 SO_2 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 HNO_3 formation rate (RNITE3)" is set to 2.0 percent per hour.

According to the 1996 "Mt. Zirkel Wilderness Area Reasonable Attribution Study of Visibility Impairment. Volume II: Results of Data Analysis and Modeling - Final Report,"

> *The CALPUFF chemical module is formulated around linear transformation rates for SO_2 to sulfate and NO_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_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_2 to sulfate. The MESOPUFF-II chemical transformation algorithm includes a surrogate reaction rate to account for aqueous-phase oxidation of SO2 to sulfate as follows:*
>
> $$K_{aq} = 3 \times 10^{-8} \times RH^4 \ (\%/hr) \qquad (B.2\text{-}1)$$
>
> *Thus, at 100% relative humidity (RH), the MESOPUFF-II aqueous-phase surrogate SO_2 oxidation rate will be 3% per hour. Measurements in generating station plumes suggest spatially- and temporally-integrated SO_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 (TNO3 = HNO3 + NO3) is partitioned into each species according to the equilibrium relationship between HNO3 and NO3. 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 NH3 to form ammonium nitrate (NH4NO3), 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/HNO_3 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 SO_2 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, SO_2, 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 SO_2 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 SO_2 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 SO_2 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 SO_2 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.

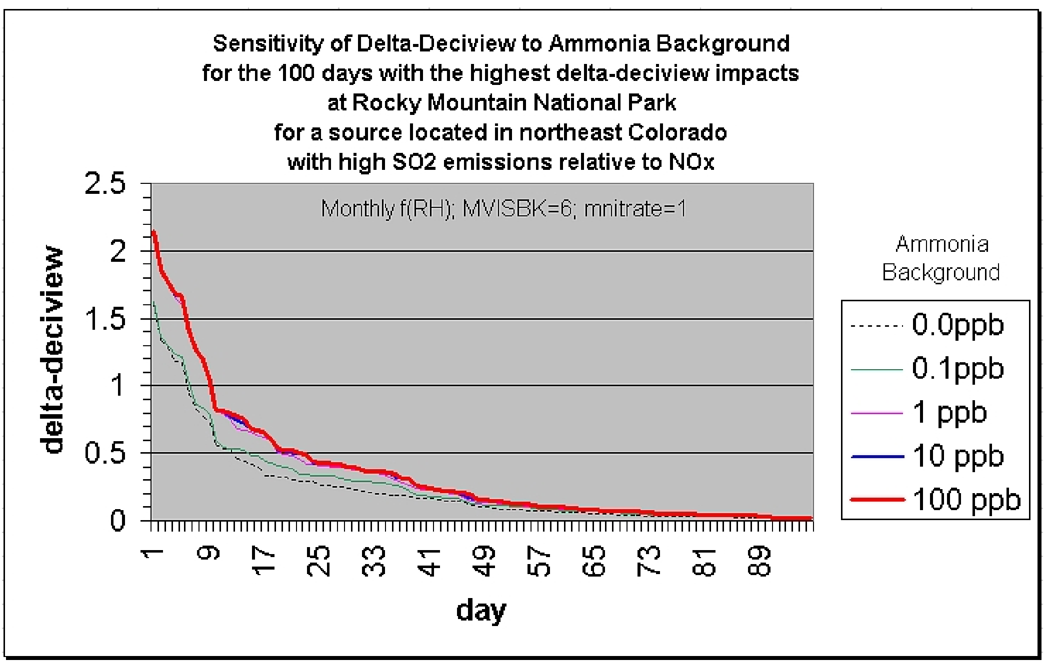

Figure 8. Sensitivity of CALPUFF visibility impacts (delta-deciview) to ammonia backgrounds from 0 ppb to 100 ppb from a source with high SO_2 emissions relative to NOx.

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.

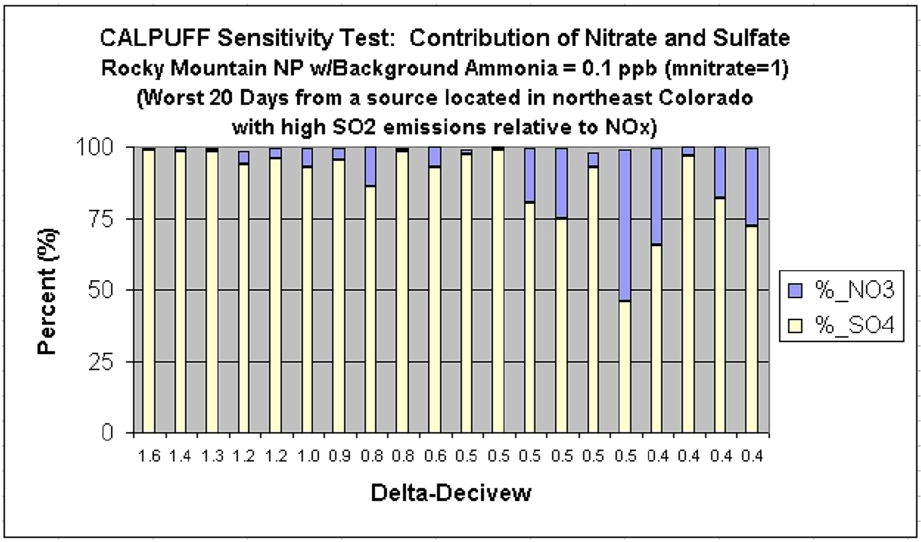

Figure 9. Contribution of sulfate and nitrate to the modeled change in deciviews, assuming a background ammonia of 0.1 ppb in CALPUFF.

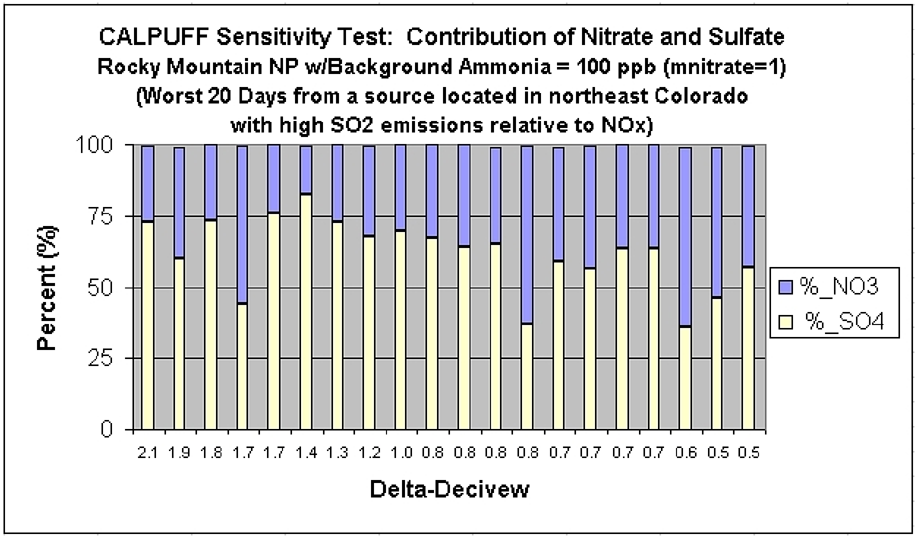

Figure 10. Contribution of sulfate and nitrate to the modeled change in deciviews, assuming a background ammonia of 100 ppb.

For the northwest Colorado sensitivity test (see Figure 11), where the modeled NOx emission rate is significantly higher than the SO_2 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.

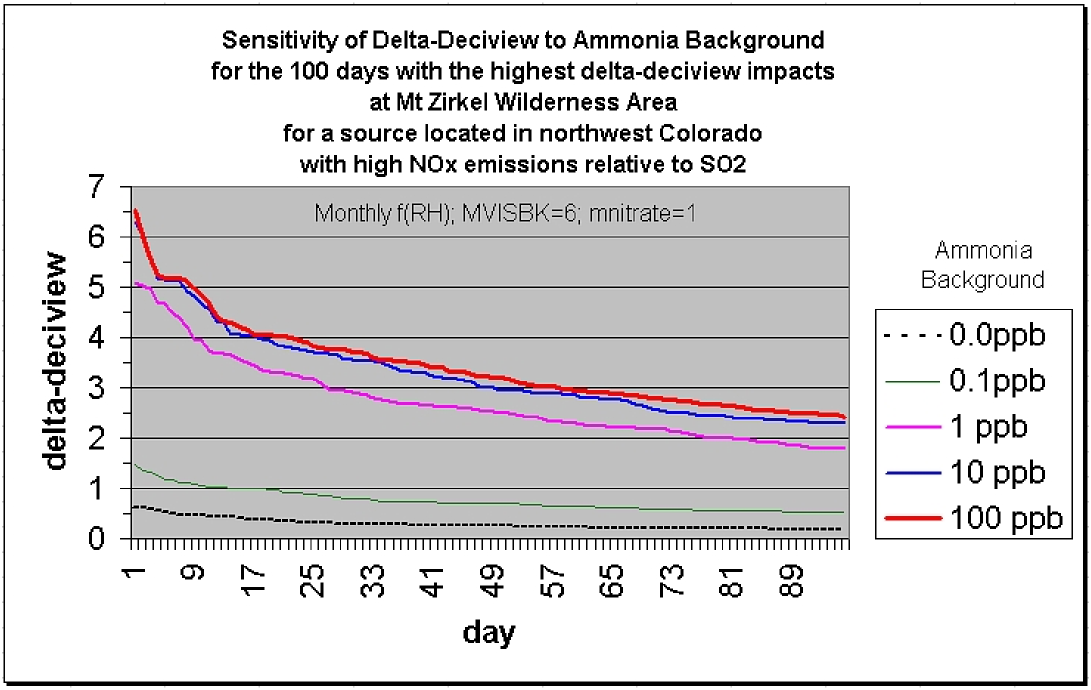

Figure 11. Sensitivity of CALPUFF visibility impacts (delta-deciview) to ammonia backgrounds from 0 ppb to 100 ppb from a source with high NOx emissions relative to SO_2.

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.

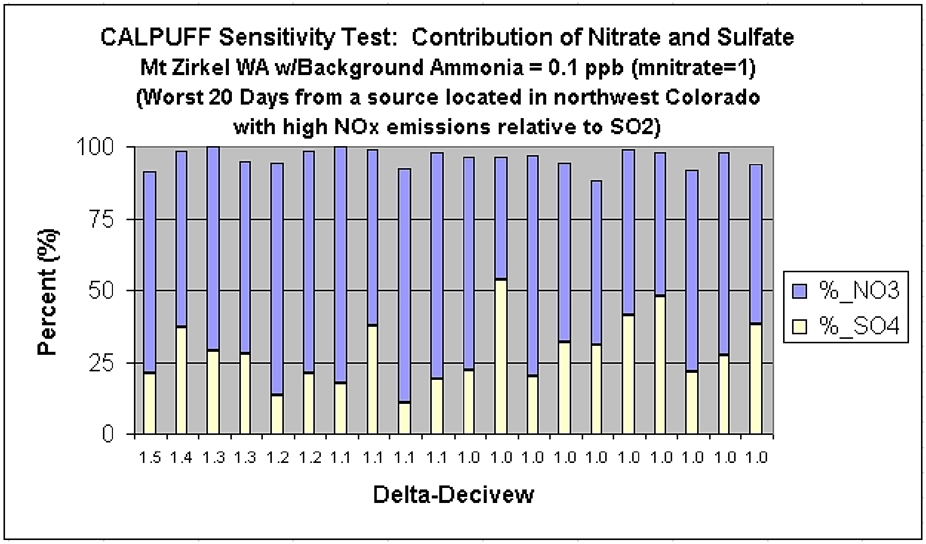

Figure 12. Contribution of sulfate and nitrate to the modeled change in deciviews, assuming a background ammonia of 0.1 ppb in CALPUFF.

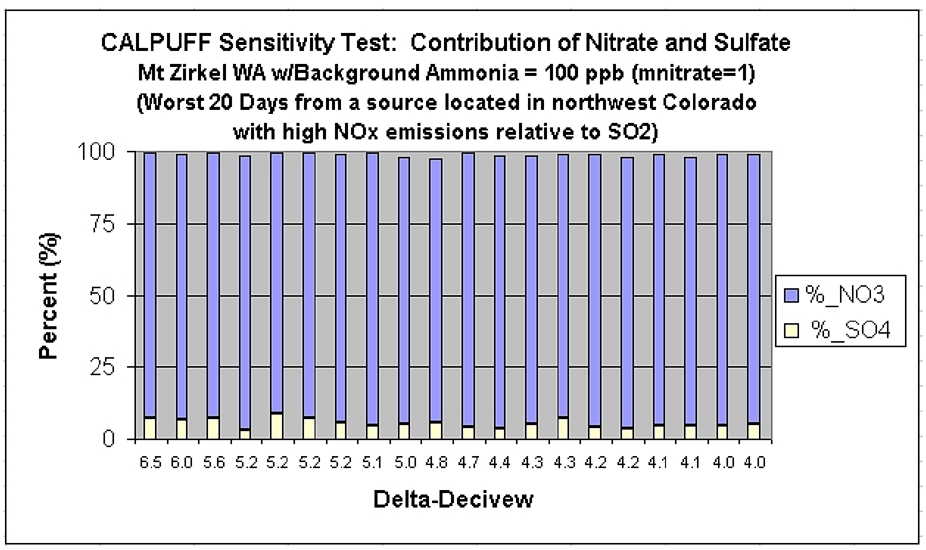

Figure 13. Contribution of sulfate and nitrate to the modeled change in deciviews, assuming a background ammonia of 100 ppb in CALPUFF.

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 $\mu g/m^3$ (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/m^3 and 30 ppb$_v$ for ozone, consistent with measured values at the Hayden VOR site*." An ammonia concentration of 0.5µg/m^3 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 CALUFF 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 a extinction efficiency of 1.0 since the contribution of direct PM10 emissions was expected to be relatively small compared to visibility impairment caused by SO_2 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 SO4, NO3, PM coarse, organic carbon, soil, and elemental carbon species. In practice, concentrations for only 2 species, SO4 ([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 ($3[BKSO4]_{best20}$) 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 ($bext_{month}$) = $3[BKSO4]_{best20}f(RH) + [BKSOIL]_{best20}$ + Rayleigh
2. Annual average background extinction in 1/Mm ($bext_{annual\_ave}$) = ($bext_{Jan} + bext_{Feb} + \ldots + bext_{Dec}$)/12
3. Calculated Best Days in dv = $10\ln(bext_{annual\_ave}/10)$

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 (3[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:

$$\text{Minimize} \sum_{n=1}^{11} \left| (\text{published Best Days})_n - (\text{calculated Best Days})_n \right|$$

where: n = 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-hygroscopic component is used directly (i.e., BKSOIL = 1.620).

hygro (3[BKSO4])	**0.268**
non-hygro ([BKSOIL])	**1.620**

	f(RH)											Background Extinction (1/Mm)										
Month	BC	EN	FT	GSD	LG	MB	MZ	RW	RM	WEM	WELK	BC	EN	FT	GSD	LG	MB	MZ	RW	RM	WEM	WELK
1	2.4	2.2	2.3	2.4	2.3	2.2	2.2	2.1	1.7	2.4	2.3	12.3	12.2	12.2	12.3	12.2	12.2	12.2	12.2	12.1	12.3	12.2
2	2.2	2.2	2.2	2.3	2.2	2.1	2.2	2.1	1.9	2.2	2.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.1	12.2	12.2
3	1.9	2.0	2.0	2.0	1.9	2.0	2.0	2.0	1.9	1.9	1.9	12.1	12.2	12.2	12.2	12.1	12.2	12.2	12.2	12.1	12.1	12.1
4	1.9	2.0	2.0	1.9	1.8	2.0	2.1	2.1	2.1	1.7	1.9	12.1	12.2	12.2	12.1	12.1	12.2	12.2	12.2	12.2	12.1	12.1
5	1.9	2.1	2.0	1.9	1.8	2.1	2.2	2.3	2.3	1.7	1.9	12.1	12.2	12.2	12.1	12.1	12.2	12.2	12.2	12.2	12.1	12.1
6	1.6	1.9	1.8	1.8	1.6	1.7	1.9	2.0	2.0	1.5	1.7	12.0	12.1	12.1	12.1	12.0	12.1	12.1	12.2	12.2	12.0	12.1
7	1.7	1.8	1.7	1.9	1.7	1.9	1.7	1.8	1.8	1.6	1.8	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.0	12.1
8	1.9	2.0	1.9	2.3	2.1	2.2	1.9	2.0	2.0	2.0	2.1	12.1	12.2	12.1	12.2	12.2	12.2	12.1	12.2	12.2	12.2	12.2
9	2.0	2.0	1.9	2.2	2.0	2.1	2.0	2.0	1.9	1.9	2.0	12.2	12.2	12.1	12.2	12.2	12.2	12.2	12.2	12.1	12.1	12.2
10	1.8	1.9	1.8	1.9	1.8	1.8	1.9	1.9	1.8	1.7	1.8	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
11	2.1	2.1	2.2	2.4	2.2	2.1	2.1	2.1	1.8	2.1	2.1	12.2	12.2	12.2	12.3	12.2	12.2	12.2	12.2	12.1	12.2	12.2
12	2.3	2.1	2.2	2.4	2.3	2.1	2.1	2.0	1.7	2.3	2.2	12.2	12.2	12.2	12.3	12.2	12.2	12.2	12.2	12.1	12.2	12.2
											Annual Ave (dv)	1.95	1.96	1.95	1.98	1.95	1.96	1.96	1.96	1.93	1.93	1.95
											Target Annual Best Days (dv)	1.94	1.96	1.95	1.98	1.94	1.95	1.96	1.96	1.93	1.94	1.95
											Difference	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00
											Sum of Differences	0.039										

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.

```
Modeled species to be included in computing the light extinction
     Include SULFATE?          (LVSO4) -- Default: T   ! LVSO4  = T  !
     Include NITRATE?          (LVNO3) -- Default: T   ! LVNO3  = T  !
     Include ORGANIC CARBON?   (LVOC)  -- Default: T   ! LVOC   = T  !
     Include COARSE PARTICLES? (LVPMC) -- Default: T   ! LVPMC  = T  !
     Include FINE PARTICLES?   (LVPMF) -- Default: T   ! LVPMF  = T  !
     Include ELEMENTAL CARBON? (LVEC)  -- Default: T   ! LVEC   = T  !
Species name used for particulates in MODEL.DAT file
                   COARSE    (SPECPMC) -- Default: PMC ! SPECPMC = PMC !
                   FINE      (SPECPMF) -- Default: PMF ! SPECPMF = PMF !
MODELED particulate species:
               PM  COARSE      (EEPMC) -- Default: 0.6 ! EEPMC  = 0.6 !
               PM  FINE        (EEPMF) -- Default: 1.0 ! EEPMF  = 1.0 !
BACKGROUND particulate species:
               PM  COARSE    (EEPMCBK) -- Default: 0.6 ! EEPMCBK = 0.6 !
Other species:
              AMMONIUM SULFATE (EESO4) -- Default: 3.0 ! EESO4  = 3.0 !
              AMMONIUM NITRATE (EENO3) -- Default: 3.0 ! EENO3  = 3.0 !
              ORGANIC CARBON   (EEOC)  -- Default: 4.0 ! EEOC   = 4.0 !
              SOIL             (EESOIL)-- Default: 1.0 ! EESOIL = 1.0 !
              ELEMENTAL CARBON (EEEC)  -- Default: 10. ! EEEC   = 10.0 !
Method used for background light extinction
                              (MVISBK) -- Default: 2   ! MVISBK =  6  !

(RHFAC)  -- No default     ! RHFAC = 2.4,2.2,1.9,1.7,
                                     1.7,1.5,1.6,2.0,
                                     1.9,1.7,2.1,2.3 !
(BKSO4)  -- No default     ! BKSO4 = 0.0893, 0.0893, 0.0893, 0.0893,
                                     0.0893, 0.0893, 0.0893, 0.0893,
                                     0.0893, 0.0893, 0.0893, 0.0893 !
(BKNO3)  -- No default     ! BKNO3 = 0.0, 0.0, 0.0, 0.0,
                                     0.0, 0.0, 0.0, 0.0,
                                     0.0, 0.0, 0.0, 0.0 !
(BKPMC)  -- No default     ! BKPMC = 0.0, 0.0, 0.0, 0.0,
                                     0.0, 0.0, 0.0, 0.0,
                                     0.0, 0.0, 0.0, 0.0 !
(BKOC)   -- No default     ! BKOC  = 0.0, 0.0, 0.0, 0.0,
                                     0.0, 0.0, 0.0, 0.0,
                                     0.0, 0.0, 0.0, 0.0 !
(BKSOIL) -- No default     ! BKSOIL= 1.620, 1.620, 1.620, 1.620,
                                     1.620, 1.620, 1.620, 1.620,
                                     1.620, 1.620, 1.620, 1.620 !
(BKEC)   -- No default     ! BKEC  = 0.0, 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)
                             (BEXTRAY) -- Default: 10.0 ! BEXTRAY = 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 POSTUIL, 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)
                              (NSPECCMP) -- No default    ! NSPECCMP = 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.

```
Number of species to process from CALPUFF runs
                              (NSPECINP) -- No default    ! NSPECINP = 5 !
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)
                              (NSPECCMP) -- No default    ! NSPECCMP = 2 !
Recompute the HNO3/NO3 partition for concentrations?
      (MNITRATE)                      Default: 0        ! MNITRATE  =  0  !
The following NSPECINP species will be processed:
 ! ASPECI =          SO4 !         !END!
 ! ASPECI =          NO3 !         !END!
 ! ASPECI =         HNO3 !         !END!
 ! ASPECI =         PM10 !         !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!

The following NSPECCMP 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 (NSPECCMP groups of NSPECINP+1 lines each):

 ! CSPECCMP =     EC !
 !     SO4  =     0.0      !
 !     NO3  =     0.0      !
 !    PM10  =     0.00  !
 !     SOA  =     0.0      !
 !END!

 ! CSPECCMP =     SOIL !
 !     SO4  =     0.0      !
 !     NO3  =     0.0      !
 !    PM10  =     1.0  !
 !     SOA  =     0.0      !
 !END!
```

Figure 17. POSTUTIL setup for simulations where PM10 is divided into SOIL and EC species (example #2 setup).

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 POSTUIL 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)
                             (NSPECCMP) -- No default    ! NSPECCMP = 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, SO_2, 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 SO_2 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 SO_2.
    - 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; SO_2 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 SO_2 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., SO_2 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 SO_2, 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 SO_2, 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., 98^{th} 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

Escoffier-Czaja, Christelle and J. Scire, 2002. "The Effects of Ammonia Limitation on Nitrate Aerosol Formation and Visibility Impacts in Class I Areas." Earth Tech, Inc., Extended abstract. *12th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association*, Norfolk, VA, Amer. Meteor. Soc, J5.13.

Douglas, S. and R. Kessler, 1988. User's Guide to the Diagnostic Wind Model (Version 1.0). Systems Applications, Inc., San Rafael, CA.

"Federal Land Manager's Air Quality Related Values Workgroup (FLAG): Phase I Report," U.S. Forest Service, National Park Service, U.S. Fish and Wildlife Service, December 2000.

"Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule." EPA-454/B-03-005. September 2003.

"Guidance for Tracking Progress Under the Regional Haze Rule." U.S. EPA, EPA-454/B-03-004. September 2003.

"Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts." EPA-454/R-98-019, December 1998.

"Mt. Zirkel Wilderness Area Reasonable Attribution Study of Visibility Impairment. Volume II: Results of Data Analysis and Modeling - Final Report." Prepared by John G. Watson, et al, Prepared for Colorado Department of Public Health and Environment, 1996.

"Northern Front Range Air Quality Study Final Report." Prepared for Colorado State University, Prepared by John G. Watson, Eric Fujita, Judith C. Chow Barbara Zielinska (Desert Research Institute), L. Willard Richards (Sonoma Technology, Inc.), William Neff (NOAA), David Dietrich (Air Resource Specialists, Inc.), 1998.

Scire J.S., D.G. Strimaitis, R.J. Yamartino. "A User's Guide for the CALPUFF Dispersion Model." Earth Tech, Concord, MA, January 2000.

Scire J.S., F. Robe, F.E.. Fernau, R.J. Yamartino. "A User's Guide for the CALMET Meteorological Model." Earth Tech, Concord, MA, January 2000.

Appendix A – Natural Background Values

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

Mandatory Federal Class I Area	State	Lat.	Lon.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) [a]	Worst Days (dv) [a]
Acadia NP	ME	44.35	-68.24	21.40	7.61	3.77	11.45
Agua Tibia Wilderness	CA	33.42	-116.99	15.86	4.61	2.05	7.17
Alpine Lake Wilderness	WA	47.55	-121.16	16.99	5.30	2.74	7.86
Anaconda-Pintler Wilderness	MT	45.95	-113.5	16.03	4.72	2.16	7.28
Arches NP	UT	38.73	-109.58	15.58	4.43	1.87	6.99
Badlands NP	SD	43.81	-102.36	16.06	4.74	2.18	7.30
Bandelier NM	NM	35.79	-106.34	15.62	4.46	1.90	7.02
Bering Sea	AK	60.46	-172.75				
Big Bend NP	TX	29.33	-103.31	15.48	4.37	1.81	6.93
Black Canyon of the Gunnison NM	CO	38.57	-107.75	15.68	4.50	1.94	7.06
Bob Marshall Wilderness	MT	47.68	-113.23	16.17	4.80	2.24	7.36
Bosque del Apache	NM	33.79	-106.85	15.54	4.41	1.85	6.97
Boundary Waters Canoe Area	MN	48.06	-91.43	20.89	7.37	3.53	11.21
Breton	LA	29.87	-88.82	21.57	7.69	3.85	11.53
Bridger Wilderness	WY	42.99	-109.49	15.71	4.52	1.96	7.08
Brigantine	NJ	39.49	-74.39	21.05	7.44	3.60	11.28
Bryce Canyon NP	UT	37.57	-112.17	15.58	4.43	1.87	6.99
Cabinet Mountains Wilderness	MT	48.18	-115.68	16.27	4.87	2.31	7.43
Caney Creek Wilderness	AR	34.41	-94.08	21.14	7.49	3.65	11.33
Canyonlands NP	UT	38.23	-109.91	15.60	4.45	1.89	7.01
Cape Romain	SC	32.99	-79.49	21.22	7.52	3.68	11.36
Capitol Reef NP	UT	38.06	-111.15	15.63	4.47	1.91	7.03
Caribou Wilderness	CA	40.49	-121.21	16.05	4.73	2.17	7.29
Carlsbad Caverns NP	NM	32.12	-104.59	15.61	4.46	1.90	7.02
Chassahowitzka	FL	28.69	-82.66	21.46	7.63	3.79	11.47
Chiricahua NM	AZ	32.01	-109.34	15.47	4.36	1.80	6.92
Chiricahua Wilderness	AZ	31.86	-109.28	15.45	4.35	1.79	6.91
Cohutta Wilderness	GA	34.93	-84.57	21.39	7.60	3.76	11.44
Crater Lake NP	OR	42.92	-122.13	16.74	5.15	2.59	7.71
Craters of the Moon NM	ID	43.39	-113.54	15.80	4.57	2.01	7.13
Cucamonga Wilderness	CA	34.24	-117.59	15.85	4.61	2.05	7.17
Denali Preserve NP	AK	63.31	-151.19	16.27	4.86	2.30	7.42
Desolation Wilderness	CA	38.9	-120.17	15.80	4.57	2.01	7.13
Diamond Peak Wilderness	OR	43.53	-122.1	16.84	5.21	2.65	7.77
Dolly Sods Wilderness	WV	39	-79.37	21.13	7.48	3.64	11.32
Dome Land Wilderness	CA	35.84	-118.23	15.70	4.51	1.95	7.07
Eagle Cap Wilderness	OR	45.22	-117.37	16.12	4.78	2.22	7.34

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

Mandatory Federal Class I Area	State	Lat.	Lon.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) [a]	Worst Days (dv) [a]
Eagles Nest Wilderness	CO	39.67	-106.29	15.72	4.52	1.96	7.08
Emigrant Wilderness	CA	38.18	-119.77	15.81	4.58	2.02	7.14
Everglades NP	FL	25.35	-80.98	20.77	7.31	3.47	11.15
Fitzpatrick Wilderness	WY	43.24	-109.6	15.73	4.53	1.97	7.09
Flat Tops Wilderness	CO	39.95	-107.3	15.70	4.51	1.95	7.07
Galiuro Wilderness	AZ	32.6	-110.39	15.40	4.32	1.76	6.88
Gates of the Mountains Wilderness	MT	46.86	-111.82	15.93	4.66	2.10	7.22
Gearhart Mountain Wilderness	OR	42.51	-120.86	16.33	4.90	2.34	7.46
Gila Wilderness	NM	33.21	-108.47	15.51	4.39	1.83	6.95
Glacier NP	MT	48.64	-113.84	16.48	5.00	2.44	7.56
Glacier Peak Wilderness	WA	48.21	-121	16.88	5.24	2.68	7.80
Goat Rocks Wilderness	WA	46.52	-121.47	16.93	5.26	2.70	7.82
Grand Canyon NP	AZ	36.3	-112.79	15.51	4.39	1.83	6.95
Grand Teton NP	WY	43.82	-110.71	15.74	4.53	1.97	7.09
Great Gulf Wilderness	NH	44.3	-71.28	21.10	7.47	3.63	11.31
Great Sand Dunes NM	CO	37.77	-105.57	15.74	4.54	1.98	7.10
Great Smoky Mountains NP	TN	35.6	-83.52	21.39	7.60	3.76	11.44
Guadalupe Mountains NP	TX	31.91	-104.85	15.64	4.47	1.91	7.03
Haleakala NP	HI	20.71	-156.16	16.02	4.71	2.15	7.27
Hawaii Volcanoes NP	HI	19.41	-155.34	16.33	4.91	2.35	7.47
Hells Canyon Wilderness	OR	45.54	-116.59	16.09	4.76	2.20	7.32
Hercules-Glades Wilderness	MO	36.68	-92.9	21.03	7.43	3.59	11.27
Hoover Wilderness	CA	38.11	-119.37	15.78	4.56	2.00	7.12
Isle Royale NP	MI	48.01	-88.83	20.91	7.38	3.54	11.22
James River Face Wilderness	VA	37.59	-79.44	20.96	7.40	3.56	11.24
Jarbidge Wilderness	NV	41.77	-115.35	15.75	4.54	1.98	7.10
John Muir Wilderness	CA	36.97	-118.88	15.80	4.58	2.02	7.14
Joshua Tree NM	CA	33.92	-115.88	15.72	4.52	1.96	7.08
Joyce-Kilmer-Slickrock Wilderness	TN	35.44	-83.99	21.40	7.61	3.77	11.45
Kaiser Wilderness	CA	37.28	-119.17	15.80	4.57	2.01	7.13
Kalmiopsis Wilderness	OR	42.26	-123.92	16.74	5.15	2.59	7.71
Kings Canyon NP	CA	36.92	-118.61	15.79	4.57	2.01	7.13
La Garita Wilderness	CO	37.95	-106.83	15.69	4.50	1.94	7.06
Lassen Volcanic NP	CA	40.49	-121.41	16.08	4.75	2.19	7.31
Lava Beds NM	CA	41.76	-121.52	16.37	4.93	2.37	7.49
Linville Gorge Wilderness	NC	35.88	-81.9	21.36	7.59	3.75	11.43
Lostwood	ND	48.59	-102.46	16.11	4.77	2.21	7.33

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

Mandatory Federal Class I Area	State	Lat.	Lon.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) [a]	Worst Days (dv) [a]
Lye Brook Wilderness	VT	43.13	-73.02	20.99	7.41	3.57	11.25
Mammoth Cave NP	KY	37.2	-86.15	21.58	7.69	3.85	11.53
Marble Mountain Wilderness	CA	41.51	-123.21	16.65	5.10	2.54	7.66
Maroon Bells-Snowmass Wilderness	CO	39.1	-107.02	15.70	4.51	1.95	7.07
Mazatzal Wilderness	AZ	34.13	-111.56	15.44	4.35	1.79	6.91
Medicine Lake	MT	48.49	-104.35	16.07	4.74	2.18	7.30
Mesa Verde NP	CO	37.25	-108.45	15.73	4.53	1.97	7.09
Minarets Wilderness	CA	37.74	-119.19	15.78	4.56	2.00	7.12
Mingo	MO	37	-90.19	21.03	7.43	3.59	11.27
Mission Mountains Wilderness	MT	47.48	-113.87	16.21	4.83	2.27	7.39
Mokelumne Wilderness	CA	38.57	-120.06	15.80	4.58	2.02	7.14
Moosehorn	ME	45.09	-67.29	21.22	7.52	3.68	11.36
Mount Adams Wilderness	WA	46.2	-121.49	16.86	5.22	2.66	7.78
Mount Baldy Wilderness	AZ	33.95	-109.54	15.51	4.39	1.83	6.95
Mount Hood Wilderness	OR	45.37	-121.73	16.83	5.21	2.65	7.77
Mount Jefferson Wilderness	OR	44.61	-121.84	16.91	5.25	2.69	7.81
Mount Rainier NP	WA	46.86	-121.72	17.05	5.34	2.78	7.90
Mount Washington Wilderness	OR	44.3	-121.88	17.03	5.33	2.77	7.89
Mount Zirkel Wilderness	CO	40.75	-106.68	15.71	4.52	1.96	7.08
Mountain Lakes Wilderness	OR	42.33	-122.11	16.50	5.01	2.45	7.57
North Absaroka Wilderness	WY	44.74	-109.8	15.74	4.53	1.97	7.09
North Cascades NP	WA	48.83	-121.35	16.86	5.22	2.66	7.78
Okefenokee	GA	30.82	-82.33	21.41	7.61	3.77	11.45
Olympic NP	WA	47.77	-123.74	17.02	5.32	2.76	7.88
Otter Creek Wilderness	WV	38.99	-79.65	21.14	7.49	3.65	11.33
Pasayten Wilderness	WA	48.89	-120.44	16.84	5.21	2.65	7.77
Pecos Wilderness	NM	35.9	-105.62	15.65	4.48	1.92	7.04
Petrified Forest NP	AZ	34.99	-109.79	15.54	4.41	1.85	6.97
Pine Mountain Wilderness	AZ	34.31	-111.8	15.47	4.36	1.80	6.92
Pinnacles NM	CA	36.48	-121.19	16.12	4.78	2.22	7.34
Point Reyes NS	CA	38.06	-122.9	16.20	4.83	2.27	7.39
Presidential Range-Dry River Wilderness	NH	44.2	-71.34	21.15	7.49	3.65	11.33
Rainbow Lake Wilderness	WI	46.42	-91.31	20.99	7.42	3.58	11.26
Rawah Wilderness	CO	40.69	-105.95	15.72	4.52	1.96	7.08
Red Rock Lakes	MT	44.64	-111.78	15.81	4.58	2.02	7.14
Redwood NP	CA	41.44	-124.03	16.90	5.25	2.69	7.81
Rocky Mountain NP	CO	40.35	-105.7	15.67	4.49	1.93	7.05

B - 4

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

Mandatory Federal Class I Area	State	Lat.	Lon.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) [a]	Worst Days (dv) [a]
Roosevelt Campobello International Park	ME	44.85	-66.94	21.22	7.52	3.68	11.36
Saguaro NM	AZ	32.17	-110.61	15.35	4.28	1.72	6.84
Salt Creek	NM	33.6	-104.41	15.58	4.43	1.87	6.99
San Gabriel Wilderness	CA	34.27	-117.94	15.86	4.61	2.05	7.17
San Gorgonio Wilderness	CA	34.12	-116.84	15.74	4.54	1.98	7.10
San Jacinto Wilderness	CA	33.75	-116.64	15.78	4.56	2.00	7.12
San Pedro Parks Wilderness	NM	36.11	-106.81	15.63	4.47	1.91	7.03
San Rafael Wilderness	CA	34.76	-119.81	16.03	4.72	2.16	7.28
Sawtooth Wilderness	ID	43.99	-115.06	15.82	4.59	2.03	7.15
Scapegoat Wilderness	MT	47.16	-112.74	16.05	4.73	2.17	7.29
Selway-Bitterroot Wilderness	ID	46.12	-114.86	16.09	4.76	2.20	7.32
Seney	MI	46.25	-86.09	21.23	7.53	3.69	11.37
Sequoia NP	CA	36.51	-118.56	15.79	4.57	2.01	7.13
Shenandoah NP	VA	38.47	-78.49	20.98	7.41	3.57	11.25
Shining Rock Wilderness	NC	35.38	-82.85	21.40	7.61	3.77	11.45
Sierra Ancha Wilderness	AZ	33.85	-110.9	15.46	4.36	1.80	6.92
Simeonof	AK	54.91	-159.28	17.21	5.43	2.87	7.99
Sipsey Wilderness	AL	34.32	-87.44	21.28	7.55	3.71	11.39
South Warner Wilderness	CA	41.31	-120.2	16.09	4.76	2.20	7.32
St. Marks	FL	30.11	-84.15	21.54	7.67	3.83	11.51
Strawberry Mountain Wilderness	OR	44.29	-118.74	16.37	4.93	2.37	7.49
Superstition Wilderness	AZ	33.5	-111.27	15.40	4.32	1.76	6.88
Swanquarter	NC	35.39	-76.39	20.91	7.38	3.54	11.22
Sycamore Canyon Wilderness	AZ	35.01	-112.09	15.53	4.40	1.84	6.96
Teton Wilderness	WY	44.04	-110.17	15.74	4.53	1.97	7.09
Theodore Roosevelt NP	ND	46.96	-103.46	16.08	4.75	2.19	7.31
Thousand Lakes Wilderness	CA	40.7	-121.58	16.10	4.76	2.20	7.32
Three Sisters Wilderness	OR	44.04	-121.91	17.01	5.31	2.75	7.87
Tuxedni	AK	60.14	-152.61	16.58	5.06	2.50	7.62
UL Bend	MT	47.54	-107.89	15.87	4.62	2.06	7.18
Upper Buffalo Wilderness	AR	36.17	-92.41	21.04	7.44	3.60	11.28
Ventana Wilderness	CA	36.21	-121.6	16.09	4.76	2.20	7.32
Virgin Islands NP **(b)**	VI	18.35	-64.74				
Voyageurs NP	MN	48.47	-92.8	20.64	7.25	3.41	11.09
Washakie Wilderness	WY	44.1	-109.57	15.73	4.53	1.97	7.09
Weminuche Wilderness	CO	37.61	-107.25	15.68	4.50	1.94	7.06
West Elk Wilderness	CO	38.75	-107.21	15.71	4.51	1.95	7.07

B - 5

Appendix B
Default Natural b_{ext}, *dv*, and 10[th] and 90[th] Percentile *dv* Values at All Mandatory Federal Class I Areas

Mandatory Federal Class I Area	State	Lat.	Lon.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) [a]	Worst Days (dv) [a]
Wheeler Peak Wilderness	NM	36.57	-105.4	15.70	4.51	1.95	7.07
White Mountain Wilderness	NM	33.48	-105.85	15.56	4.42	1.86	6.98
Wichita Mountains	OK	34.75	-98.65	20.60	7.23	3.39	11.07
Wind Cave NP	SD	43.58	-103.47	15.97	4.68	2.12	7.24
Wolf Island	GA	31.33	-81.3	21.33	7.58	3.74	11.42
Yellowstone NP	WY	44.63	-110.51	15.77	4.56	2.00	7.12
Yolla Bolly Middle Eel Wilderness	CA	40.09	-122.96	16.25	4.85	2.29	7.41
Yosemite NP	CA	37.85	-119.54	15.81	4.58	2.02	7.14
Zion NP	UT	37.32	-113.04	15.56	4.42	1.86	6.98

(a) Values for the best and worst days are estimated from a statistical approach described in Section 2.6 of this document.
(b) *f(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.

B - 6

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

A - 11

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

A - 12

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

A - 13

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

A - 14

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

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

A - 15

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!
-------------------------------------------------------------------------------
-
```

```
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.PRT      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

                         !END!
```

```
-------------------------------------------------------------------------------

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
        ! ZFACE = 0.,20.,40.,80.,160.,320.,640.,1200.,2000.,3000.,4000.,5000. !
!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.FRD, 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   (ISTEPPG)          Default: 1      ! ISTEPPG =  1   !

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

RADIUS OF INFLUENCE PARAMETERS

   Use varying radius of influence       Default: F      ! 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 (RMAX1)          No default      ! RMAX1 = 100. !
                                         Units: km
   Maximum radius of influence over land
   aloft (RMAX2)                         No default      ! RMAX2 = 200. !
                                         Units: km
   Maximum radius of influence over water
   (RMAX3)                               No default      ! RMAX3 = 200. !
                                         Units: km


OTHER WIND FIELD INPUT PARAMETERS

   Minimum radius of influence used in
   the wind field interpolation (RMIN)   Default: 0.1    ! RMIN = 0.1 !
                                         Units: km
   Radius of influence of terrain
   features (TERRAD)                     No default      ! TERRAD = 15. !

                                         Units: km
   Relative weighting of the first
   guess field and observations in the
   SURFACE layer (R1)                    No default      ! R1 = 50. !
   (R1 is the distance from an           Units: km
   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 (R2)                     No default      ! R2 = 100. !
   (R2 is applied in the upper layers    Units: km
   in the same manner as R1 is used in
   the surface layer).

   Relative weighting parameter of the
   prognostic wind field data (RPROG)    No default      ! RPROG = 0. !
   (Used only if IPROG = 1)              Units: km
   ------------------------

   Maximum acceptable divergence in the
   divergence minimization procedure
```

```
       (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     No defaults
             for each variable               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. !


    DIAGNOSTIC MODULE DATA INPUT OPTIONS
```

```
      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  !
*DEN*
         (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: (1/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)                    Default: 1      ! ILEVZI =  1  !
       (must be between 1 and NZ)


    CONVECTIVE MIXING HEIGHT OPTIONS:
       Method to compute the convective
       mixing height(IMIHXH)                 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
```

```
   (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.        Default: 0.001  ! DPTMIN = 0.001 !
   (DPTMIN)                             Units: deg. K/m
   Depth of layer above current conv.
   mixing height through which lapse    Default: 200.   ! DZZI = 200. !
   rate is computed (DZZI)              Units: meters

   Minimum overland mixing height       Default:  50.   ! ZIMIN = 50. !
   (ZIMIN)                              Units: meters
   Maximum overland mixing height       Default: 3000.  ! ZIMAX = 4500. !
   (ZIMAX)                              Units: meters
   Minimum overwater mixing height      Default:   50.  ! ZIMINW = 50. !
   (ZIMINW) -- (Not used if observed    Units: meters
   overwater mixing hts. are used)
   Maximum overwater mixing height      Default: 3000.  ! ZIMAXW = 4500. !
   (ZIMAXW) -- (Not used if observed    Units: meters
   overwater mixing hts. are used)


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   !
```

```
      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  !

   Radius of influence for temperature
   interpolation (TRADKM)                Default: 500.     ! TRADKM = 500.
!
                                         Units: km

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

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

   Default temperature gradient          Default: -.0098   ! TGDEFB = -
0.0098 !
   below the mixing height over          Units: K/m
   water (TGDEFB)

   Default temperature gradient          Default: -.0045   ! TGDEFA = -
0.0045 !
   above the mixing height over          Units: K/m
   water (TGDEFA)

   Beginning (JWAT1) and ending (JWAT2)
   land use categories for temperature                    ! JWAT1 =  55  !
   interpolation over water -- Make                       ! JWAT2 =  55  !
   bigger than largest land use to disable

  PRECIP INTERPOLATION PARAMETERS

   Method of interpolation (NFLAGP)      Default: 2       ! NFLAGP =  2  !
```

```
        (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          Units: km
         nearest stns w & w/out
         precip when NFLAGP = 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)


             1     2
         Name   ID            X coord.   Y coord.   Time   Anem.
                               (km)       (km)      zone   Ht.(m)
       ----------------------------------------------------------
! SS1  ='AKO '    24698       193.159     198.973    7    10  !
! SS2  ='ALS '    24620       -32.336    -106.860    7    10  !
! SS3  ='APA '    24666        55.922     130.041    7    10  !
! SS4  ='ASE '    24676      -118.091      92.190    7    10  !
! SS5  ='CAG '    25700      -171.322     234.404    7    10  !
! SS6  ='CAO '    23600       210.283    -214.114    7    10  !
! SS7  ='COS '    24660        68.475      45.993    7    10  !
! SS8  ='CYS '    25640        58.198     306.332    7    10  !
! SS9  ='DEN '    25650        72.093     159.306    7    10  !
! SS10 ='DHT '    22636       266.176    -259.412    7    10  !
! SS11 ='DRO '    24625      -200.668    -136.973    7    10  !
! SS12 ='EOO '    24674      -203.468     185.599    7    10  !
! SS13 ='FMN '    23658      -243.657    -180.141    7    10  !
! SS14 ='LAA '    24636       246.555     -32.844    7    10  !
! SS15 ='LAR '    25645       -14.616     323.319    7    10  !
! SS16 ='LHX '    24635       173.058     -36.818    7    10  !
! SS17 ='LIC '    24665       154.047      89.075    7    10  !
! SS18 ='LVS '    23677        32.391    -304.593    7    10  !
! SS19 ='LXV '    24673       -70.429      92.179    7    10  !
! SS20 ='MTJ '    24765      -208.969      14.367    7    10  !
! SS21 ='PUB '    24640        87.574     -11.726    7    10  !
! SS22 ='RIL '    25717      -191.319     127.284    7    10  !
! SS23 ='SAF '    23656       -53.382    -308.617    7    10  !
! SS24 ='SNY '    25610       211.364     302.733    7    10  !
! SS25 ='TAD '    24645       102.806    -125.906    7    10  !

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

      2
        Six digit integer for station ID
```

```
!END!


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

INPUT GROUP: 8 -- Upper air meteorological station parameters
--------------

     UPPER AIR STATION VARIABLES
     (One record per station --  1  records in all)

             1     2
         Name    ID      X coord.   Y coord.  Time zone
                           (km)       (km)
        ----------------------------------------------
! US1  ='DEN '   23062     59.101    152.186    7  !
-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Five digit integer for station ID

!END!


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

INPUT GROUP: 9 -- Precipitation station parameters
--------------

     PRECIPITATION STATION VARIABLES
     (One record per station --  91  records in all)
     (NOT INCLUDED IF NPSTA = 0)

            1          2
         Name   Station    X coord.  Y coord.
                  Code       (km)      (km)
         ------------------------------------

! PS1  ='WY01'   481675      85.74    299.06      !
! PS2  ='WY02'   483050     -81.49    303.46      !
! PS3  ='WY03'   484930     -42.89    294.26      !
! PS4  ='WY04'   485420      10.07    308.59      !
! PS5  ='WY05'   487200     100.45    331.46      !
! PS6  ='WY06'   487240     118.50    300.60      !
! PS7  ='WY07'   487995     -81.29    322.34      !
! PS8  ='NM01'   290041     -68.41   -250.45      !
! PS9  ='NM02'   290407      27.86   -236.26      !
! PS10 ='NM03'   291887     216.54   -233.47      !
! PS11 ='NM04'   291982     -63.65   -334.85      !
! PS12 ='NM05'   292030     126.63   -349.69      !
! PS13 ='NM06'   292241     -97.39   -264.59      !
! PS14 ='NM07'   292700      30.57   -240.69      !
```

```
! 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    111.01   -204.49       !
! PS20 ='NM13'   297638    125.17   -313.06       !
! PS21 ='NM14'   298085     -8.19   -336.20       !
! PS22 ='NM15'   298501    102.51   -241.22       !
! PS23 ='NM16'   299031   -146.20   -322.71       !
! PS24 ='NE01'   257827    245.44    301.36       !
! PS25 ='CO01'   050109    205.46    190.22       !
! PS26 ='CO02'   050130     -1.77   -126.46       !
! PS27 ='CO03'   050183     15.34    191.98       !
! PS28 ='CO04'   050263     -3.46     66.56       !
! PS29 ='CO05'   050372    -86.44     79.24       !
! PS30 ='CO06'   050843     28.16    179.81       !
! PS31 ='CO07'   051179    122.18    116.33       !
! PS32 ='CO08'   051401     86.31     91.44       !
! PS33 ='CO09'   051443   -177.73     17.50       !
! PS34 ='CO10'   051539    192.94    -35.41       !
! PS35 ='CO11'   051547     86.12    109.20       !
! PS36 ='CO12'   051713    -83.95    -13.98       !
! PS37 ='CO13'   051778     93.29     10.53       !
! PS38 ='CO14'   051959    -94.98     14.98       !
! PS39 ='CO15'   052162    126.59    109.74       !
! PS40 ='CO16'   052211     84.30    118.05       !
! PS41 ='CO17'   052220     84.30    118.05       !
! PS42 ='CO18'   052354     25.52    206.44       !
! PS43 ='CO19'   052790     26.70    108.77       !
! PS44 ='CO20'   052965     28.75     16.69       !
! PS45 ='CO21'   053005     38.23    216.49       !
! PS46 ='CO22'   053007     31.41    222.01       !
! PS47 ='CO23'   053386     30.98    113.23       !
! PS48 ='CO24'   053500     -1.70    189.75       !
! PS49 ='CO25'   053553     91.89    204.72       !
! PS50 ='CO26'   053579     91.69     73.75       !
! PS51 ='CO27'   053584     91.60     81.51       !
! PS52 ='CO28'   053662    -94.38     -8.32       !
! PS53 ='CO29'   054155    123.78    178.51       !
! PS54 ='CO30'   054172    191.07     78.84       !
! PS55 ='CO31'   054293     31.88    104.35       !
! PS56 ='CO32'   054388    257.89    -35.82       !
! PS57 ='CO33'   054538    204.78   -122.78       !
! PS58 ='CO34'   054720    191.26    -38.78       !
! PS59 ='CO35'   054742     19.17     15.55       !
! PS60 ='CO36'   054877     11.18    117.61       !
! PS61 ='CO37'   055121     34.93    194.27       !
! PS62 ='CO38'   055352     81.93     12.62       !
! PS63 ='CO39'   055484   -177.53    180.65       !
! PS64 ='CO40'   055706    -54.91   -116.29       !
! PS65 ='CO41'   055765     32.72    109.91       !
! PS66 ='CO42'   055881     14.51    179.77       !
! PS67 ='CO43'   055922    169.01    219.33       !
! PS68 ='CO44'   055982    -59.29    239.94       !
! PS69 ='CO45'   056023     87.41    224.66       !
! PS70 ='CO46'   056136    181.79     -7.93       !
```

```
! PS71 ='CO47'   056203    -166.75    -41.54      !
! PS72 ='CO48'   056740     105.09    -24.83      !
! PS73 ='CO49'   057031    -170.64    103.90      !
! PS74 ='CO50'   057296       5.94    224.17      !
! PS75 ='CO51'   057320      83.01    -92.76      !
! PS76 ='CO52'   057337     -50.88    -38.67      !
! PS77 ='CO53'   057428      23.10   -143.07      !
! PS78 ='CO54'   057519     257.30     90.70      !
! PS79 ='CO55'   057560     199.88    106.81      !
! PS80 ='CO56'   057572      31.85   -107.54      !
! PS81 ='CO57'   057664     125.39     76.43      !
! PS82 ='CO58'   058064     -62.20     83.45      !
! PS83 ='CO59'   058204    -178.35    -90.12      !
! PS84 ='CO60'   058220      41.80   -150.76      !
! PS85 ='CO61'   058429     107.51   -142.40      !
! PS86 ='CO62'   058436     103.98   -144.66      !
! PS87 ='CO63'   058781      92.05   -111.52      !
! PS88 ='CO64'   058997     126.35    -96.64      !
! PS89 ='CO65'   059096     -52.91    179.94      !
! PS90 ='CO66'   059210      37.21     71.09      !
! PS91 ='CO67'   059285     117.67     13.06      !

-------------------
      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!
```