Draft Final Modeling Protocol

CALMET/CALPUFF Protocol for BART Exemption Screening Analysis for Class I Areas in the Western United States

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FOREWORD

This document is a draft final Modeling Protocol that discusses the procedures to be used by the Western Regional Air Partnership (WRAP) Regional Modeling Center (RMC) for developing MM5 databases to support CALMET/CALPUFF modeling and for conducting BART screening exemption modeling using the CALMET/CALPUFF modeling system for six WRAP region States: Alaska; Arizona; New Mexico; Nevada; Utah; and South Dakota. Processed MM5 data will also be provided to Montana who will conduct their own CALMET/CALPUFF BART modeling.

This Modeling Protocol is based on the BART CALPUFF Modeling Protocol prepared by the Colorado Department of Public Health and Environment (CDPHE) Air Pollution Control Division (APCD) (CDPHE, 2005). We would like to thank Chuck Machovec and others at the CDPHE/APCD for allowing us to use their Modeling Protocol as a starting point for the WRAP RMC Modeling Protocol.

In addition to addressing different States, potential BART-eligible sources and Class I areas, there are several other differences between the proposed CALMET/CALPUFF modeling approach in this Modeling Protocol versus those proposed by the CDPHE (CDPHE, 2005) and other WRAP States (e.g., NDDOH, 2005). For example, we are proposing to use the three years of 2001, 2002 and 2003 for which 36 km MM5 data are available, whereas the CDPHE used the three years of 1996, 2001 and 2002. One major change in this revised draft Modeling Protocol compared to previous draft Modeling Protocols prepared by the WRAP RMC is we are now using meteorological observations along with the MM5 data as input to the CALMET/CALPUFF modeling system. In previous draft Modeling Protocols we proposed to operate CALMET using just the MM5 data without observed meteorological observations (i.e., the NOOBS mode). Comments received from EPA and Federal Land Managers (FLMs) noted that running CALMET/CALPUFF with meteorological observations was preferred and more conservative. Thus, meteorological observations were acquired and processed for input into CALMET for the WRAP RMC BART screening exemption modeling.

The resultant CALMET/CALPUFF modeling databases developed under this work effort will be made available to the affected States. If the States or others wish to use or enhance the databases (e.g., high grid resolution, addition of more meteorological observations, etc.), they may obtain the databases from the States.

1. Introduction

Federal law requires Best Available Retrofit Technology (BART) for any BART-eligible source that ''emits any air pollutant which may reasonably be anticipated to cause or contribute to any impairment of visibility" in any mandatory Class I federal area. Pursuant to federal regulations, states have the option of exempting a BART-eligible source from the BART requirements based on dispersion modeling demonstrating that the source cannot reasonably be anticipated to cause or contribute to visibility impairment in a Class I area.

According to 40 CFR Part 51, Appendix Y (EPA BART Guidelines; EPA, 2005), a BART-eligible source is considered to "contribute" to visibility impairment in a Class I area if the modeled 98th percentile change in deciviews is equal to or greater than the "contribution threshold." Any BART-eligible source determined to cause or contribute to visibility impairment in any Class I area is subject to BART. The EPA BART Guidelines suggest a contribution threshold of 0.5 change in deciview be used.

The WRAP RMC is processing 36 km MM5 data for the three years of 2001, 2002 and 2003 to support CALMET/CALPUFF modeling for six WRAP region States in the contiguous United States: Arizona; Montana; New Mexico; Nevada; Utah; and South Dakota. The processing of MM5 data to support CALMET/CALPUFF modeling for these six WRAP region States is discussed in Section 2. The WRAP RMC will conduct BART screening modeling for five of these States using the CALMET/CALPUFF modeling system and the 2001, 2002 and 2003 MM5 using procedures discussed in Section 3. The RMC will also conduct CALMET/CALPUFF BART screening modeling for sources in Alaska using a 2002 MM5 and CALMET/CALPUFF databases that is discussed in Section 4.

The WRAP RMC will apply CALPUFF with three years of meteorological data (one year for Alaska) and report on the 24-hour change in visibility (delta-deciview, Δdv) from potential BART-eligible sources at mandatory Federal Class I areas in and near each of the States modeled. The maximum and 98th percentile estimated 24-hour change in visibility (Δdv) will be summarized for each potential BART-eligible source and each Class I area under study. Spreadsheets of 24-hout average change in deciview from each potential BART-eligible source and each Class I area will be provided to the States in question who will determine which potential BART-eligible sources in their States are subject to BART.

The WRAP RMC will use this protocol for the initial subject-to-BART modeling for the States indicated above. However, it is up to the States themselves to make the subject to BART determination. Additional modeling performed by the States or source operators may supersede the screening results from the WRAP RMC. Subsequent modeling should use modeling techniques consistent with the EPA BART Guidelines (EPA, 2005). The CALMET/CALPUFF modeling databases developed by the WRAP RMC will be provided to the affected States if desired.

1.1. Emissions Used

According to the EPA BART Guidelines: "*The emissions estimates used in the models are intended to reflect steady-state operating conditions during periods of high capacity utilization. We do not generally recommend that emissions reflecting periods of start-up, shutdown, and malfunction be used, as such emission rates could produce higher than normal effects than would be typical of most facilities. We recommend that States use the 24 hour average actual emission rate from the highest emitting day of the meteorological period modeled, unless this rate reflects periods start-up, shutdown, or malfunction.*" (EPA, 2005)

Short-term emission rates (≤24-hours) should be modeled since visibility impacts are calculated for a 24-hour averaging period. SO_2, NOx, and PM10 (including condensible and filterable direct PM10) should be modeled from all BART-eligible units at the facility. States will provide the WRAP RMC with the source characteristics and emission rates to be used in the BART screening analysis. Source characteristics that must be included are:

- Stack Location (e.g., latitude/longitude, UTM, etc.)
- Stack Height (e.g., m or ft)
- Stack Diameter (e.g. m or ft)
- Exit Velocity (e.g., m/s or ft/s) or Flow Rate (e.g., m^3/s or ft^3/s)

Emission rates that must be included include the following (e.g., gm/s, tons/day. tons/year):

- SO2
- NOx (as NO2)
- Primary PM10

In addition, the PM10 emissions should be broken down by PM species as follows:

- SO4 (Sulfate, included primary H_2SO_4)
- NO3 (Nitrate)
- EC (Elemental Carbon)
- OC (Organic Carbon)
- PMF (Other $PM_{2.5}$ or Soil)
- PMC (Coarse PM, $PM_{2.5-10}$)

However, in reality most States provided PM emission estimates for their potential BART-eligible sources as total PM_{10} without speciation. In this case we will model the PM_{10} as $PM_{2.5}$ and summarize the PM contribution to light extinction for the highest visibility impairment days and it will be up to the States to justify performing the BART exemption screening analysis without speciating the PM emissions (see Section 1.2 for extinction characteristics of the different components of PM).

Maximum actual 24-hour emission rates may not be generally available for all sources. It is up to the States to provide the WRAP RMC with the emission rates they wish the RMC to use. The CDPHE provided the following guidance in their BART Modeling Protocol on what emission rates the CDPHE felt was acceptable for CALPUFF BART exemption modeling (CDPHE, 2005):

- Short-term (≤24-hours) allowable emission rates (e.g., emission rates calculated using the maximum rated capacity of the source).
- Federally enforceable short-term limits (≤24-hours).
- Peak 24-hour actual emission rates (or calculated emission rates) from the most recent 3 to 5 years of operation that account for "high capacity utilization" during normal

operating conditions and fuel/material flexibility allowed under the source's permit. In situations where a unit is allowed to use more than one fuel, the fuel resulting in the highest emission rates should be used for the modeling, even if that fuel has not been used in the last 3 to 5 years.

If short-term rates are not available, emissions rates based on averaging periods longer than 24-hours are acceptable only in cases where the modeling shows that the source has impacts equal to or greater than the contribution threshold (CDPHE, 2005).

The WRAP region States reviewing the visibility impacts will make their own opinion on the interpretation of the visibility modeling results in the case emission rates with longer averaging times than 24-hours are used. As noted above, if the visibility impact at a Class I area exceeds the 0.5 dv using longer averaging time emissions, then the 0.5 dv threshold would also be exceeded using the maximum 24-hour average emissions. If on the other hand, the visibility impacts due to the source at all Class I areas and all days are substantially below the 0.5 dv threshold, the State may be able to justify the determination that the source does not contribute significantly to visibility impairment at any Class I area.

1.2.   Visibility Calculations

The CALPUFF modeling of the potential BART-eligible sources at Class I areas will potentially produce estimated 24-hour concentrations of SO_4, NO_3, EC, OC, PMF and PMC concentrations at a set of receptors that cover the Class I area. These concentration estimates need to be converted to light extinction. 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)
- IMPROVE documents such as "Spatial and Seasonal Patterns and Temporal Variability of Haze and its constituents in the United State" (Malm et al., 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}

Modeled concentrations are converted to light extinction using the IMPROVE reconstructed mass extinction equation. This equation accounts for both light scattering and light absorption due to particles. The current IMPROVE reconstructed mass extinction equation does not account for light absorption due to gases. The IMPROVE Steering Committee has recently endorsed a new IMPROVE equation that includes light absorption due to gases, but EPA BART Guidelines and this Modeling Protocol will use the current IMPROVE equation.

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 = $1[Soil] = 1[PMF]$
- b_{Coarse} = scattering coefficient due to coarse particles = $0.6[Coarse\ Mass]$ = $0.6[PMC]$

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 (also called the extinction coefficient). Sulfate (SO_4) and nitrate (NO_3) are assumed to be completely neutralized by ammonium (NH_4). Both SO_4 and NO_3 are assumed to by hygroscopic and take up water under conditions of higher moisture, which affects their scattering properties. This is accounted for by the f(RH) term that is the relative humidity adjustment factor.

The total atmospheric extinction (b_{ext}) 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 assumed to be non-hygroscopic.

The variation of the effect of relative humidity on the extinction coefficients for SO_4 and NO3 can be determined in several ways. According to the EPA BART Guidelines, monthly f(RH) values should be used (EPA, 2003a,b).

The CALPUFF modeling techniques in this protocol will 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:

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

Here the background extinction ($b_{background}$) is supposed to represent Natural Conditions (i.e., no man made impairment). The EPA BART Guidelines references that Natural Conditions be based on EPA's "Guidance for Estimating Natural Conditions under the Regional Haze Rule" (EPA, 2003a). This guidelines lists three sets of Natural Conditions corresponding to Annual Average, Best 20% Days and Worst 20% Days. EPA initially stated that the Natural Visibility Conditions corresponding to the Best 20% Days should be used for BART modeling (EPA, 2005). However, the use of the B20% Natural Conditions was challenged by the Utility Air Regulatory Group (UARG) and now EPA will allow States to use the Annual Average Natural Conditions in their subject to BART assessment (Paise, 2006a,b). For the WRAP RMC CALPUFF BART exemption screening modeling, changes in visibility at Class I area will be calculated using all three types of EPA default Natural Conditions (B20%, Annual Average and W20%) so that the States can understand the sensitivity of the results to this assumption and it is up to the States to select what Natural Conditions they believe are appropriate for their subject to BART determinations.

2. Extraction of MM5 Data For CALMET/CALPUFF Modeling

Three years of 36 km MM5 data from 2001, 2002 and 2003 will be processed for the CALMET/CALPUFF modeling system and six States in the western U.S.: Arizona; Montana; New Mexico; Nevada; Utah; and South Dakota. The MM5 data were carried out by different groups as follows:

> 2001 36 km MM5 data developed by Alpine Geophysics, LLC for the EPA and was used in the CAIR and CAMR modeling (McNalley, 2003);

> 2002 36 km MM5 data developed by the WRAP RMC for the WRAP regional modeling (Kemball-Cook et al., 2004); and

> 2003 36 km MM5 data developed by the Midwest RPO (MRPO/LADCO) for their regional modeling (Baker, 2004a,b).

The 2002 36km MM5 data have been more extensively analyzed and tested for optimal configuration by the RMC for performance in the WRAP region. The 2001 and 2003 MM5 datasets have not been similarly evaluated in as detailed fashion for their accuracy and performance in the WRAP region.

In addition, a separate 2002 MM5 database developed by the WRAP RMC will be used for the Alaska BART CALPUFF modeling analysis (see Section 4).

Table 2-1 summarizes the model options used in the MM5 simulations that are being used in the CALMET/CALPUFF BART screening modeling. For the 2001, 2002 and 2003 continental US MM5 simulations the same 36 km Lambert Conformal Projection grid was used. Whereas, due to the much higher latitudes, the Alaska simulations used a Polar Stereographic grid projection. The Pleim-Xiu LSM module was used for the continental U.S. simulations, where for the 2002 and 2003 runs the MM5 simulations were conducted in 5½ day segments with a cold start and 12 hours of spin up time, but for the 2001 run each MM5 run segment soil moisture was initialized off of the previous run segment (but not soil temperature which was found to lead to a cold bias in the runs). During the summer the Alaska MM5 simulations used the OSU/Noah LSM module. However the winter Alaska MM5 simulations was run with the "sea ice" turned on which does not support the OSU LSM so the simpler 5-layer LSM was used.

Table 2-1. MM5 model options for the MM5 simulations to be used in the WRAP BART screening modeling.

Model Option	Continental US			Alaska 2002	
	2001	**2002**	**2003**	**Summer**	**Winter**
Source					
Coordinate System	Lambert	Lambert	Lambert	Polar	Polar
Grid Resolution	36 km	36 km	36 km	15 km	15 km
Land Surface Module	Pleim-Xiu[1]	Pleim-Xiu	Pleim-Xiu	OSU/Noah	5-Layer
Planetary Boundary Layer	ACM	ACM	ACM	ETA	ETA
Radiation	RRTM	RRTM	RRTM	RRTM	RRTM
Moist Physics	Reisner II	Reisner I	Reisner I	Reisner II	Reisner II
Cumulus	KF 1	BM	KF 1	Grell	Grell
Shallow Convection	None	None	None	None	None
Sea Ice	No	No	No	No	Yes
Analysis Nudging					
Surface	None	U/V	None	None	None
Aloft	U/V/T/Q	U/V/T/Q	U/V/T/Q	U/V/T/Q	U/V/T/Q
Observation Nudging					
Surface	None	U/V	None	U/V	U/V

[1] The 2001 Pleim-Xiu LSM simulation used continuous moisture, whereas 2002 and 2003 used cold starts with 12 hours initialization.

The processed MM5 data for CALPUFF modeling produce quite large files. Thus, we wish to define smaller domains for each of the States that need the data in order for the file sizes and data transfers to be more manageable. The MM5 data must completely cover the CALMET/CALPUFF modeling domains. They need to include the State of interest, plus Class I areas in nearby States with sufficient buffer between the Class I areas and the boundaries (e.g., 50 km) to assure that CALPUFF puffs are not eliminated due to the centerline leaving the domain while the puff is still having a significant visibility impacts at a Class I area. Based on the States that require MM5 processing assistance, we have identified the following four MM5 extraction domains:

    Arizona-New Mexico
    Nevada-Utah
    Montana
    South Dakota

MM5 Windowed Domains

Figure 2-1 displays the four windowed domains where MM5 data will be processed for CALMET/CALPUFF modeling. Also displayed in Figure 2-1 are the locations of the States (source regions) and Class I area (receptor regions) in the western U.S.

Arizona-New Mexico

The Arizona-New Mexico MM5 window domain is centered on the two States (Figure 2-1). It extends west to include the Sequoia and Kings Canyon National Parks and Dome Land Wilderness in the north as well as several Southern California Class I areas. The northern boundary of the Arizona-New Mexico MM5 window domain is sufficiently north to include Class I areas in southern Utah and Colorado with a 50 km buffer. The eastern boundary was extended to include all of New Mexico; originally it was extended as far east to include the Wichita Mountains Class I area in Oklahoma but comments received from the FLMs were that this was unnecessary. We also considered pushing the southern boundary sufficiently far to include Big Bend National Park, however any BART source impact at Big Bend would likely have much higher impacts at the closer southern New Mexico and Arizona Class I areas (e.g., Guadalupe and Carlsbad Caverns). Consequently, the southern boundary was terminated north of Big Bend National Park.

Nevada-Utah

The Nevada-Utah MM5 window domain includes the two States and extends to the: (1) southwest to include the Southern California Class I areas; (2) northwest to include the northeastern California and some south-central Oregon Class I areas; (3) north to include the Sawtooth Wilderness Area; (4) northeast to include Wind River and Eton Class I areas in Wyoming; and (5) to the east and southeast to include Class I areas in the Colorado Rocky Mountains and San Pedro Parks Class I area in New Mexico.

Montana

The Montana MM5 window domain includes all of Montana and all Class I areas in Idaho and some in eastern Washington and Oregon. The Southern boundary is sufficient south to include all of the Wyoming Class I areas. The eastern boundary was placed so that the Theodore Roosevelt, North Dakota and Wind Cave and Badlands, South Dakota Class I areas could be included. The State of Montana also provided the definitions of their CALPUFF modeling domain that stretched west-east from longitude –177 to –103 degrees and south-north from latitude 44 to 49.5 degrees. The Montana MM5 window domain was made sufficient large to encompass these dimensions.

South Dakota

The South Dakota MM5 window domain had to be made fairly large due to distance between the State and Class I areas in nearby States. The western boundary was sufficiently west to include eastern Montana and western Wyoming Class I areas. Southern Boundary stretched down to include the Mount Zirkel Colorado Class I area. And the northern and eastern boundaries were defined so that the Voyageurs and Boundary Waters, Minnesota Class I areas could be included.
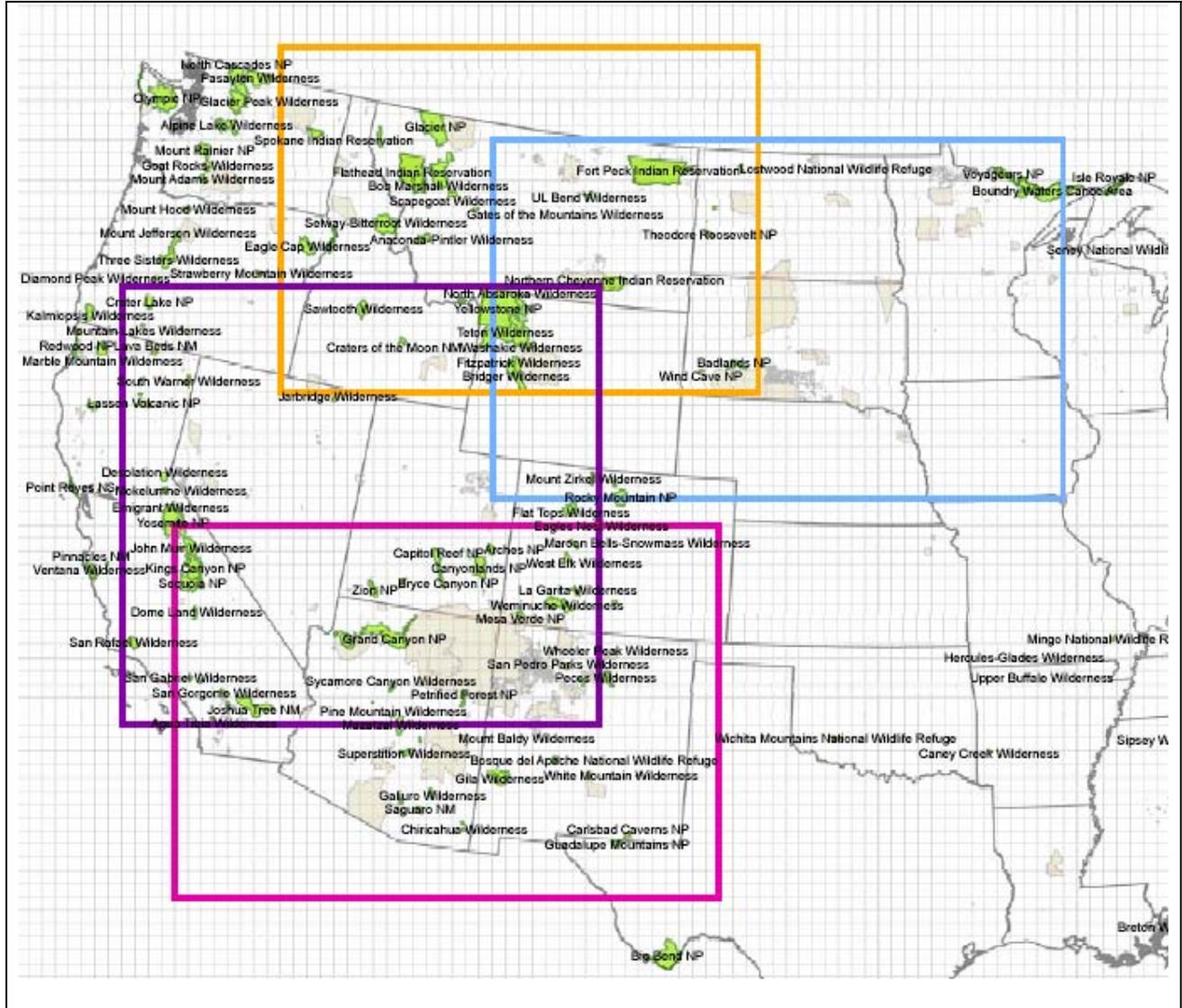
Figure 2-1. Relationship of four MM5 extraction window domains for State CALPUFF modeling (AZ, MT, NM, NV, SD and UT) and Class I areas.

3. CALMET/CALPUFF Modeling Methodology

For the WRAP RMC BART exemption screening modeling, we will follow the EPA BART Guidelines (EPA, 2005) and the applicable CALMET/CALPUFF modeling guidance (e.g., IWAQM, 1998; FLAG, 2000; EPA, 2003c) including EPA's recent March 16, 2006 memorandum: "Dispersion Coefficients for Regulatory Air Quality Modeling in CALPUFF" (Atkinson and Fox, 2006). This memorandum was written by the EPA Office of Air Quality and Planning Standards (OAQPS) Model Clearing House Director in response to questions from EPA Region 4 on what constitutes the regulatory version of CALPUFF and recommended CALPUFF options for BART modeling in their region. Consequently, the CALMET/CALPUFF modeling recommendations in the EPA memorandum (Atkinson and Fox, 2006) are followed in this Modeling Protocol, with the following exceptions (more details on these exceptions are provided in Sections 3.1.1.6 and 3.1.2.4):

- We propose to use the latest version of CALPUFF (Version 6 dated April 2006) rather than the "EPA Approved Version";
- A maximum mixing height of 4,500 m AGL will be specified rather than the EPA recommended default maximum mixing height value of 3,000 m AGL;
- The modeling domains will be based on a Lambert Conformal Conic (LCC) projection consistent with the RPO modeling rather than the EPA default;
- Compatible values for the CALMET IEXTRP and RMIN2 parameters will be used;
- The number of emitted and modeled species will depend on the level of detail on emissions provided by the States rather than the EPA default 3 and 5 species, respectively; and
- A background ammonia value of 1 ppb will be used in the CALPUFF modeling (0–1 ppb for Alaska) rather then the 10 ppb EPA default.
- Water land use will be specified and no spatial averaging of temperatures will be performed (IAVET=0).

The WRAP RMC will perform an initial subject-to-BART screening analysis modeling using the procedures in this Modeling Protocol and provide the results to the affected States. However, the WRAP RMC initial modeling may be superseded by additional modeling performed by the States or source operators.

Relevant guidance suggests that the CALPUFF model is generally applicable at distances from 50 km to 300 km downwind and may be used for distance less than 50 km when complex flows exist on a case by case basis (IWAQM, 1998; FLAG 2000; EPA, 2003c). Class I areas in the west generally are located in complex terrain resulting in complex flows. Consequently, the BART screening modeling conducted by the RMC will include results for potential BART-eligible sources that reside within 50 km of a Class I area. The WRAP RMC BART screening modeling may also apply CALPUFF to downwind distances greater than 300 km. When providing results to the States, the downwind distance between the BART source and the Class I area will be included, and a recommendation from the RMC as to the utility of applying the results for Class I areas less than 50 km and greater than 300 km from the source. The individual States will need to make their own regulatory assessment of the applicability of the model results at those distances less than 50 km and greater than 300 km.

3.1. CALMET/CALPUFF Model Selection

The March 16, 2006 memorandum from the EPA/OAQPS Model Clearing House is very clear on which is the regulatory version of the model: "The regulatory version of CALPUFF, along with specific regulatory options, resides on the Earth Tech website, described as the 'EPA-Approved Version'." (Atkinson and Fox, 2006). This version was originally proposed for the BART screening analysis. However, discussions with the FLMs and others revealed that this version of the model contained errors and that a newer version should be used. Consequently, we propose to use the latest (as of April, 2006) version of the CALPUFF modeling system (available at www.src.com):

- CALMET Version 6.211 Level 060414
- CALPUFF Version 6.112 Level 060412

3.1.1. CALMET

CALMET will be applied for separate State domains using a 4 km grid and 11 vertical layers (see Figure 3-1). A Lambert Conformal Conic (LCC) map projection will be used that is the same as used in the WRAP MM5 and CMAQ/CAMx modeling. Terrain and land use data will be provided at 4 km grid resolution, whereas the MM5 data will be provided at a 36 km grid resolution.

The 36 km MM5 meteorological fields for 2001, 2002 and 2003 have been processed into the format used by CALMET. CALMET is based on the Diagnostic Wind Model (Douglas and Kessler, 1988) that was originally developed as part of the EPA Rocky Mountain Acid Deposition Model Assessment Project (Morris et al., 1987) and later adapted for the UAM Modeling System (Morris and Myers, 1990).

CALMET/DWM uses a two-step approach to calculate wind fields. In the first step, an initial-guess wind field is adjusted for diagnostic wind effects of terrain, such as channeling, blocking and deflection and slope flows, to produce a Step 1 wind field. In Step 2, an objective analysis is performed to introduce observational data into the Step 1 wind field. For the WRAP RMC BART screening modeling, CALMET is being operated using hourly three-dimensional 36 km MM5 meteorological and observed surface meteorological and precipitation data. In earlier versions of this Modeling Protocol we have proposed to run CALMET using the no observations (NOOBS) mode. However, EPA/FLMs have noted that running CALMET/CALPUFF in the NOBS mode is less conservative that when meteorological observations are also used. The reasons why CALMET/CALPUFF run in the NOOBS model produces less conservative concentrations (i.e., lower) estimates than when observations are specified has been traced to the calculation of PGT stability Class. When surface meteorological observations are specified, PGT Stability Class is calculated using sky cover, solar intensity and wind speed, whereas in the NOOBS mode an alternative algorithms is used that estimates a more unstable atmosphere and therefore enhanced dispersion and lower concentration estimates. Using the NOOBS mode to operate CALMET/CALPUFF does not necessarily mean it is less accurate than when surface meteorological observations are used, just that it produces lower concentration estimates and is therefore less conservative. In fact, the IWAQM (1998) testing of the CALMET/CALPUFF modeling system against real-world observed atmospheric tracer measurements found it

overestimated downwind measured concentrations beyond 200-300 km by a factor of 3-4 due to inadequate spread (dispersion) of the plume, suggesting that enhanced dispersion may be more accurate.

For the BART screening analysis, initial guess wind fields based on hourly 36-kilometer MM5 meteorological fields for 2001, 2002 and 2003 (i.e., IPROG=14) will be used. These initial guess wind fields are adjusted to account for the effects of 4 km terrain and land use data on the wind fields in Step 1 of CALMET/DWM. Note that although surface meteorological and precipitation observations are specified as input to CALMET, no observed upper-air meteorological observations will be used as they are redundant to the MM5 data and may introduce spurious artifacts in the wind fields. In the application of the MM5, the twice daily upper-air meteorological observations are used as input with the MM5 model estimates nudged to the observations as part of the Four Dimensional Data Assimilation (FDDA). This results in higher temporal (hourly vs. 12-hour) and spatial (36 km vs. ~300 km) resolution upper-air meteorology in the MM5 field that is dynamically balanced than contained in the upper-air observations. Therefore the use of the upper-air observations with CALMET is not needed and in fact will upset the dynamic balance of the meteorological fields potentially producing spurious vertical velocities.

The EPA BART Guidelines do not state the exact number of years of mesoscale meteorological data for use in CALPUFF, but according to EPA air quality modeling guidelines (EPA, 2003c, 40 CFR 51 Appendix W) and discussed by FLAG (2000), at least three years of meteorological data should be used. Five years of meteorological data is preferable, but when mesoscale meteorological data are used (i.e., MM5) three years of modeling is acceptable.

3.1.1.1. CALMET Modeling Domains

The WRAP RMC has developed seven CALMET/CALPUFF modeling domains in the contiguous U.S. that focus on the following States and nearby Class I areas: Arizona, Montana, New Mexico, Nevada, South Dakota and Utah (Figure 3-1). In addition, there is an Alaska CALMET/CALPUFF modeling that is discussed in Section 4. At this time the RMC does not plan on performing CALMET/CALPUFF modeling for Montana. Montana has requested the 2001, 2002 and 2003 processed MM5 data and will conduct their own CALPUFF modeling.

All of the CALMET/CALPUFF modeling domains are based on the same Lambert Conformal Conic (LCC) map projection as used in the RPO's MM5 and CMAQ modeling:
- X-Center = 97° Longitude
- Y-Center = 40° Latitude
- Alpha = 33° Latitude
- Beta = 45° Latitude

Using the RPO LCC map projection, each of the CALMET/CALPUFF modeling domains shown in Figure 3-1 are defined using the parameters in Table 3-1. Shown in these figures are the Class I areas, potential BART-eligible sources (when available) and the locations of the surface meteorological observation sites.

Table 3-1. Definition of State CALMET/CALPUFF modeling domains using the RPO LCC projections based on an origin at (-97°, 40°) and true latitudes at 33° and 45°.

State	SW and NE Corners (m LCP)		Number of 4 km Grids		No. Class I Receptors
	Southwest	Northeast	x-direction	y-direction	
Arizona	(-1944, -900)	(-792, 0)	288	225	12,156
Montana	(-1656, 360)	(-360, 1296)	324	234	10,575
New Mexico	(-1368, -900)	(-504, -36)	216	216	4,471
Nevada CALMET	(-2088, -576)	(-1296, 648)	198	306	10,254
NV CALPUFF N	(-2088, -200)	(-1460, 500)	157	175	4900
NV CALPUFF S	(-2000, -576)	(-1300, 420)	175	249	8183
S. Dakota	(-1080, 216)	(468, 1044)	387	207	5,786
Utah	(-1620, -540)	(-792, 648)	207	297	11,365

These domains are quite large and many of the source-receptor distances will exceed 300 km. Thus, when the RMC provides the modeling results to the States, the distance between the potential BART-eligible source and the Class I area should be considered in their interpretation of whether a visibility impact is significant. Also, the proposed modeling domains contain many receptors in the Class I areas (roughly 4,000-12,000). This may result in CALPUFF simulations with excessive computational requirements. Consequently, we will discuss the following issues with each State that would reduce the computational requirements of the CALPUFF simulations:

- Reductions in the size of the CALPUFF computational domains displayed in Figure 3-1.
- Reduction in the number of receptors covering the Class I areas (e.g., reduction in the density or elimination of receptors over 300 km from the sources of interest).

For the Nevada CALMET/CALPUFF modeling, CALMET modeling for 2001, 2002 and 2003 will be conducted for the entire 198 x 306 4 km domain depicted in Figure 3-1d-1. The Nevada BART sources are clustered either near Reno in the northern or Las Vegas in the southern parts of the State. Consequently, we will run two separate CALPUFF modeling domains, a northern and southern domain that are shown in Figure 3-1d-2 and Figure 3-1d-3, respectively.

Figure 3-1a. Proposed CALMET/CALPUFF modeling domain, Class I area receptors (green) and observed surface meteorological sites for Arizona.
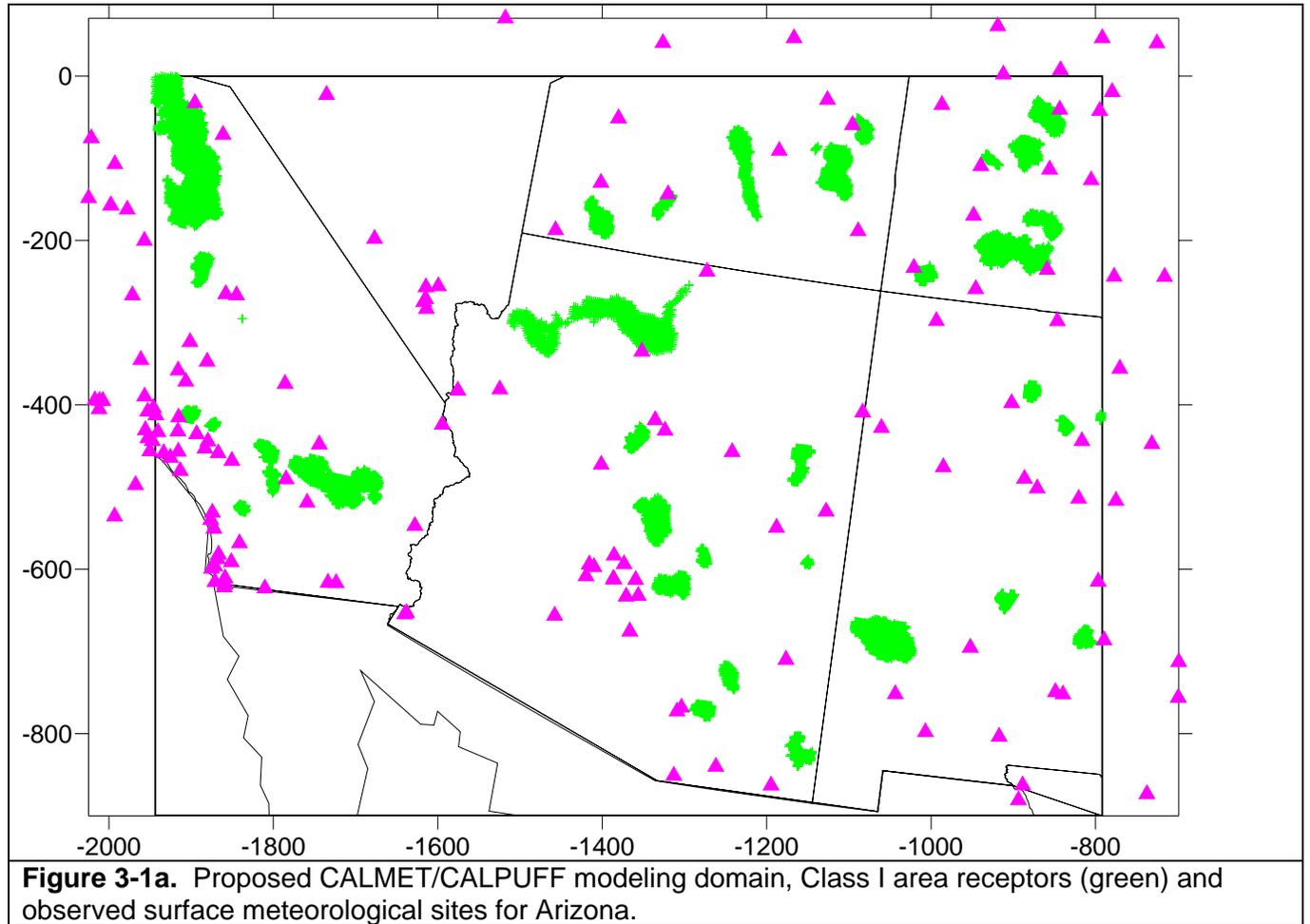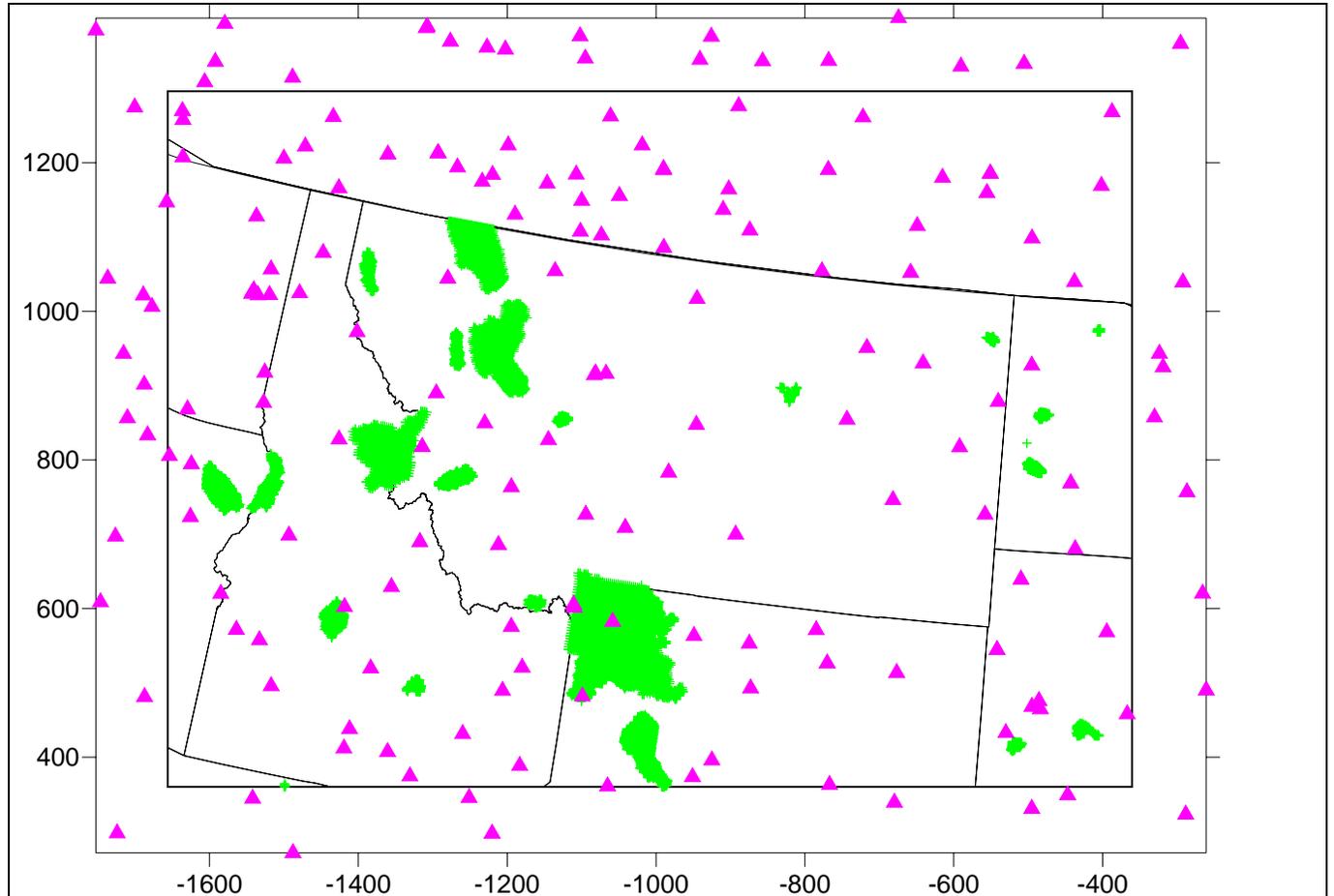
Figure 3-1b. Proposed CALMET/CALPUFF modeling domain, Class I area receptors (green) and observed surface monitoring sites (purple triangles) for Montana (RMC currently does not have any plans for modeling Montana BART sources).
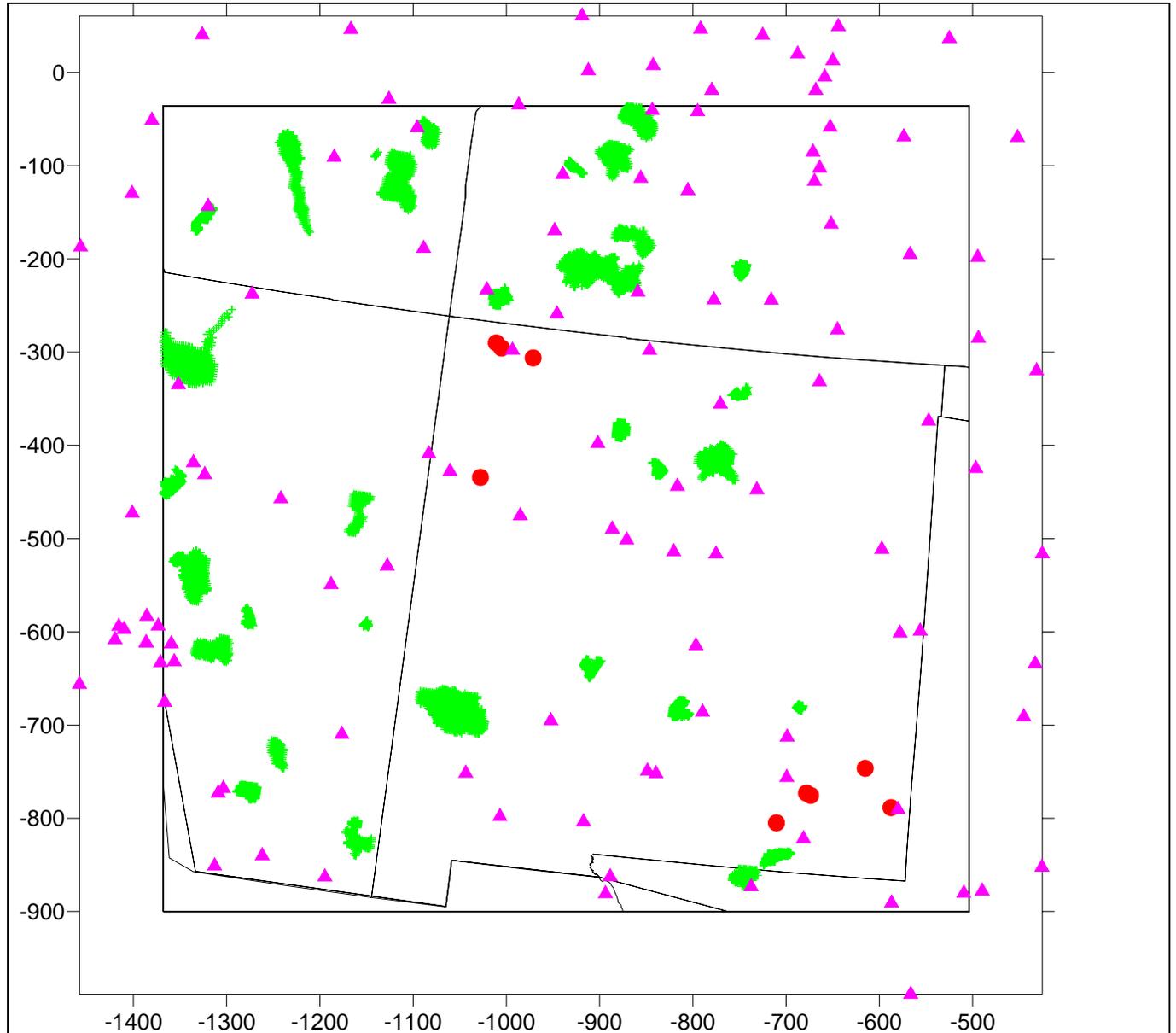
Figure 3-1c. Proposed CALMET/CALPUFF modeling domain, Class I area receptors (green), observed surface meteorological sites (purple triangles) and potential BART-eligible source locations (red circles) for New Mexico.

Figure 3-1d-1. Proposed CALMET/CALPUFF modeling domain and Class I area receptors (green) and observed surface meteorological sites (purple triangles) for Nevada.
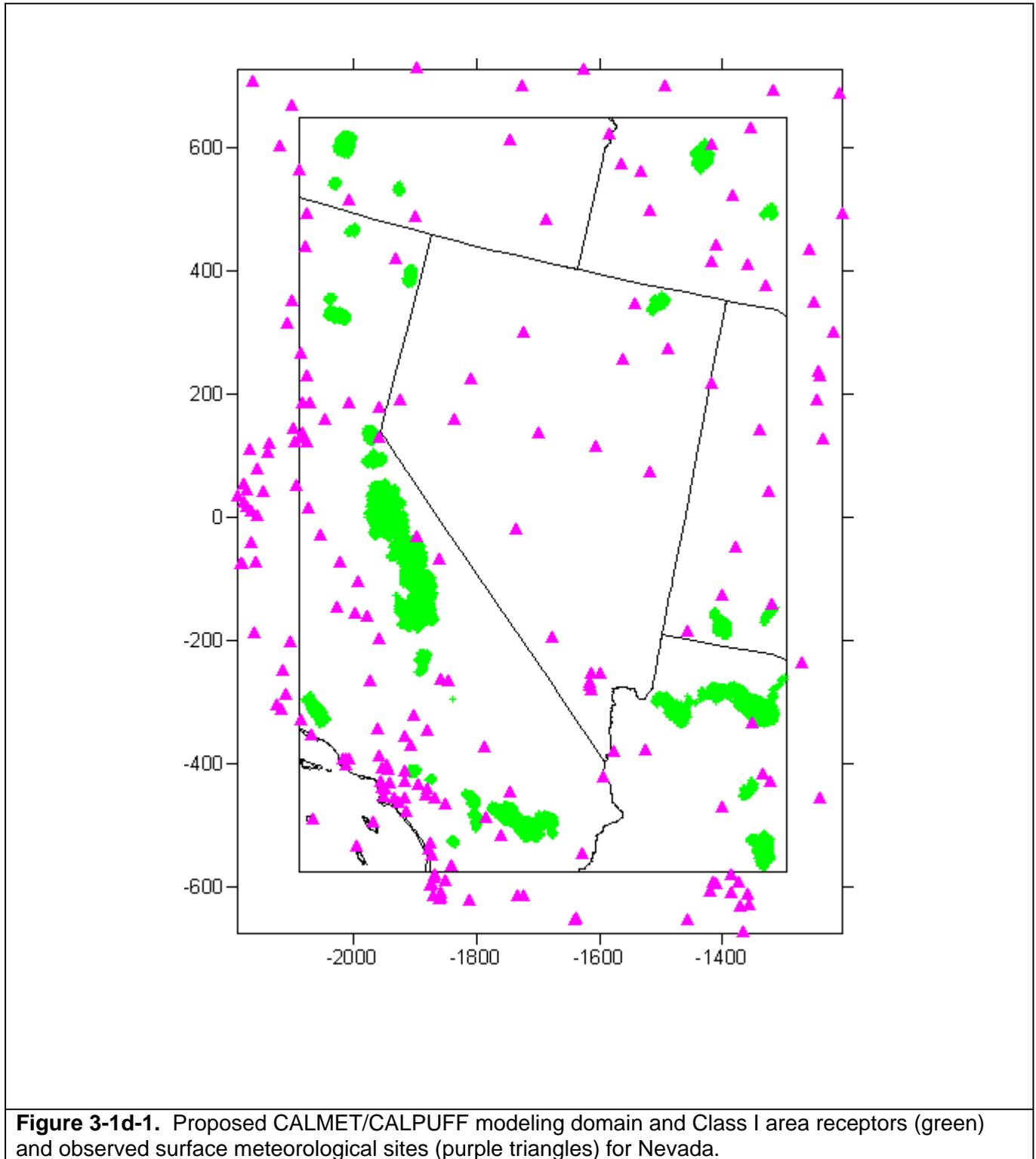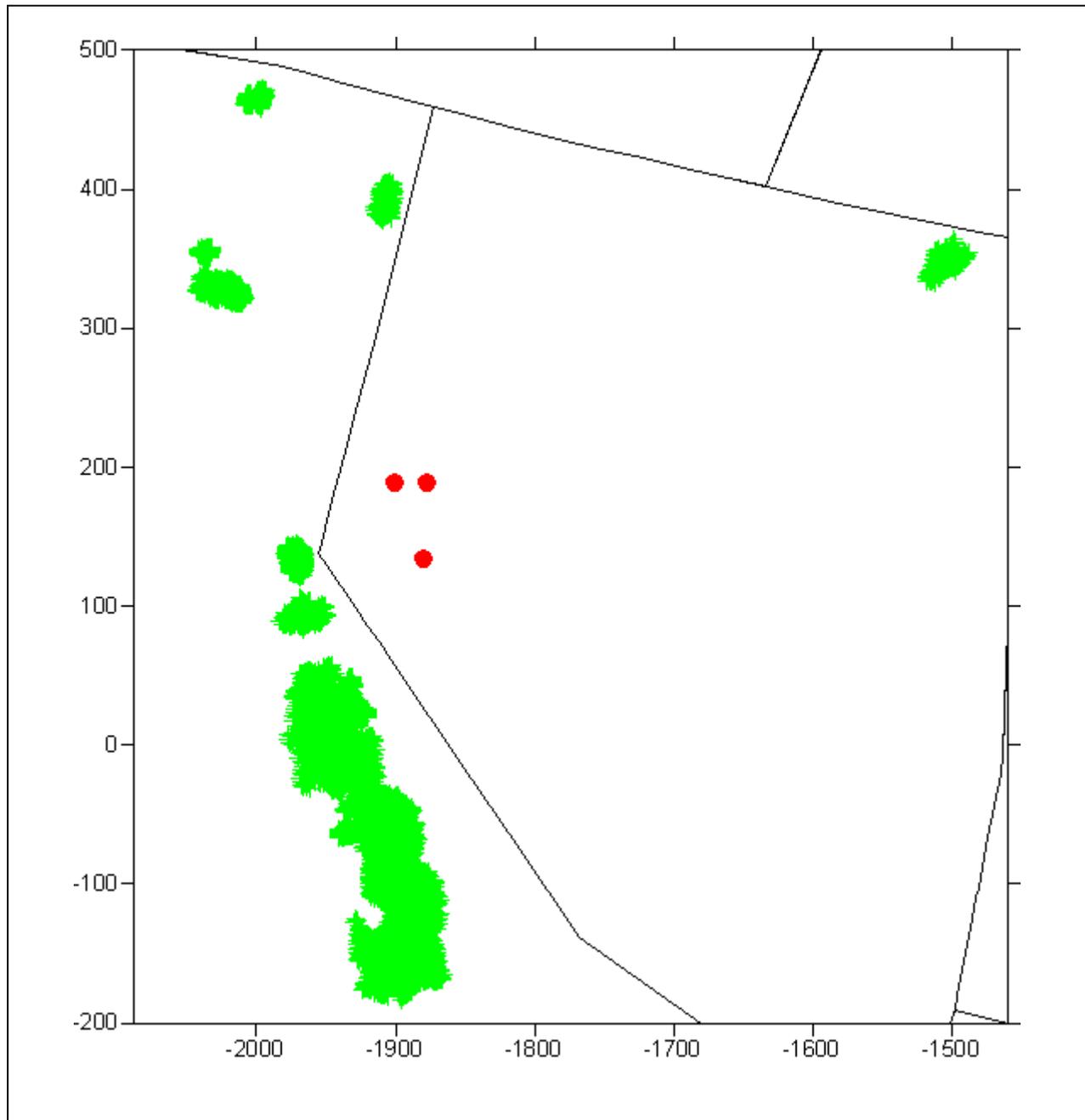
Figure 3-1d-2. Proposed CALPUFF modeling domain for northern potential BART-eligible sources (red circles) near Reno and Class I area receptors (green).
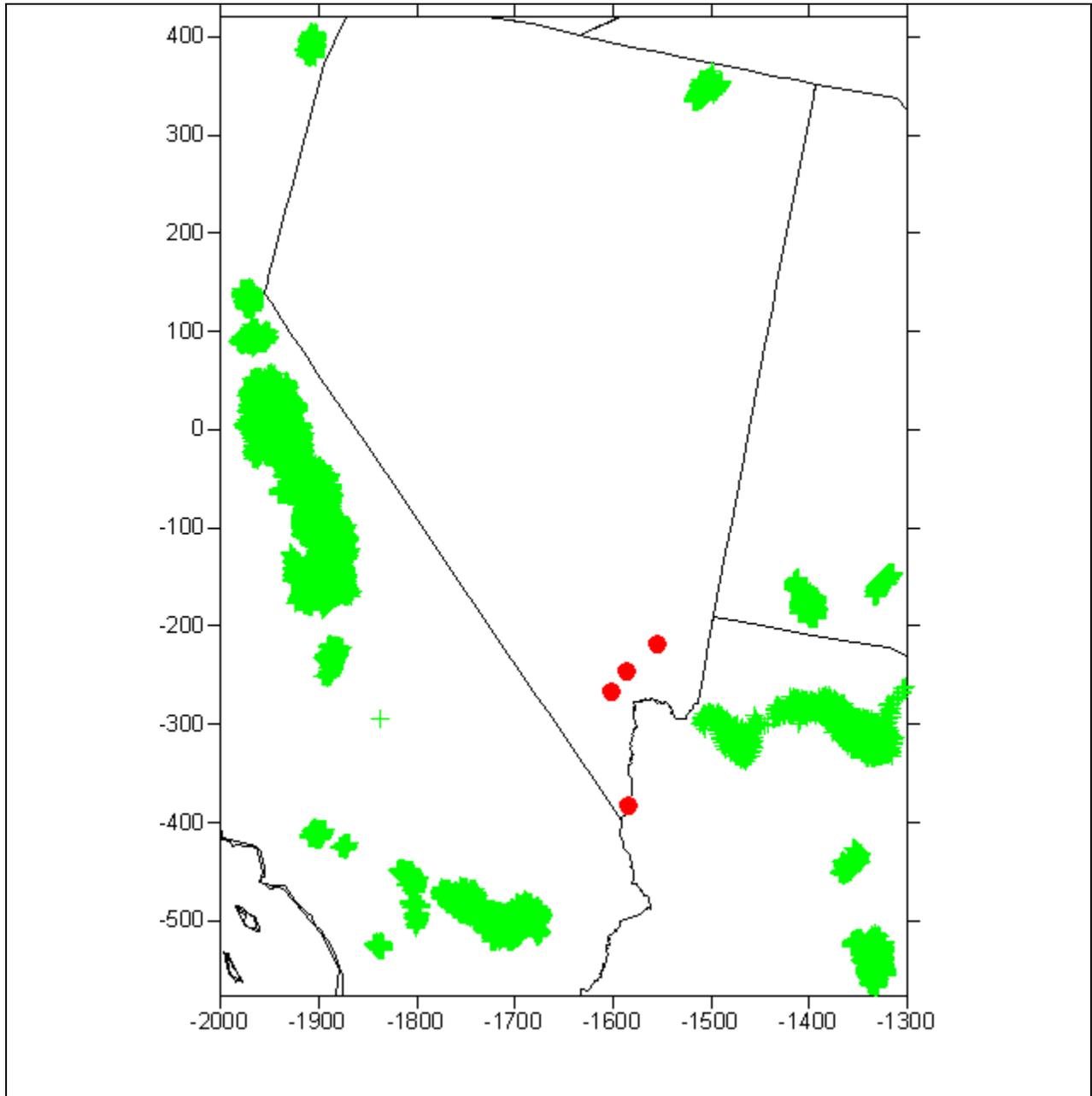
Figure 3-1d-3. Proposed CALPUFF modeling domain for southern potential BART-eligible sources (red circles) near Las Vegas and Class I area receptors (green).

Figure 3-1e. Proposed CALMET/CALPUFF modeling domain and Class I area receptors (green), observed surface meteorological sites (purple triangles) and potential BART-eligible source locations (red circles) for South Dakota.
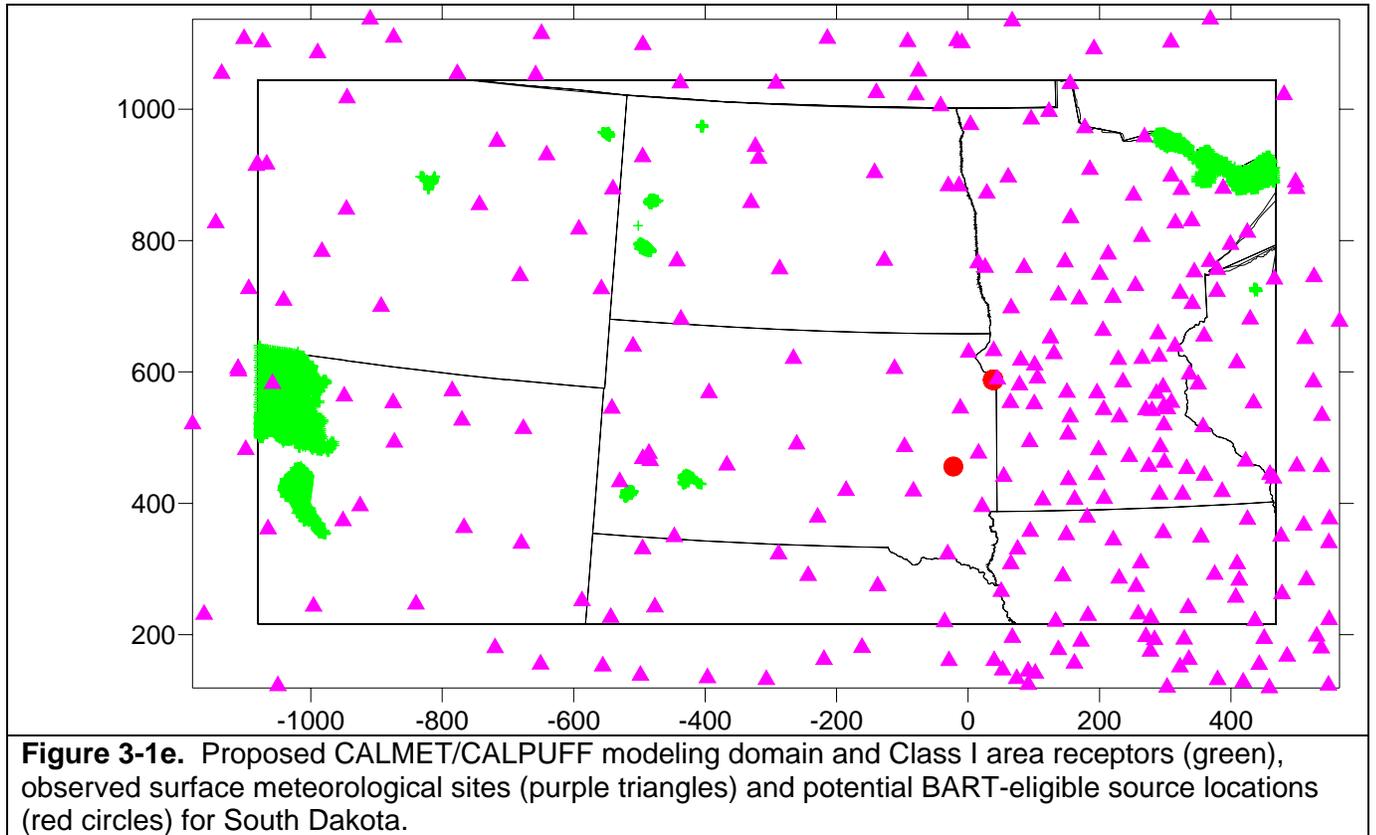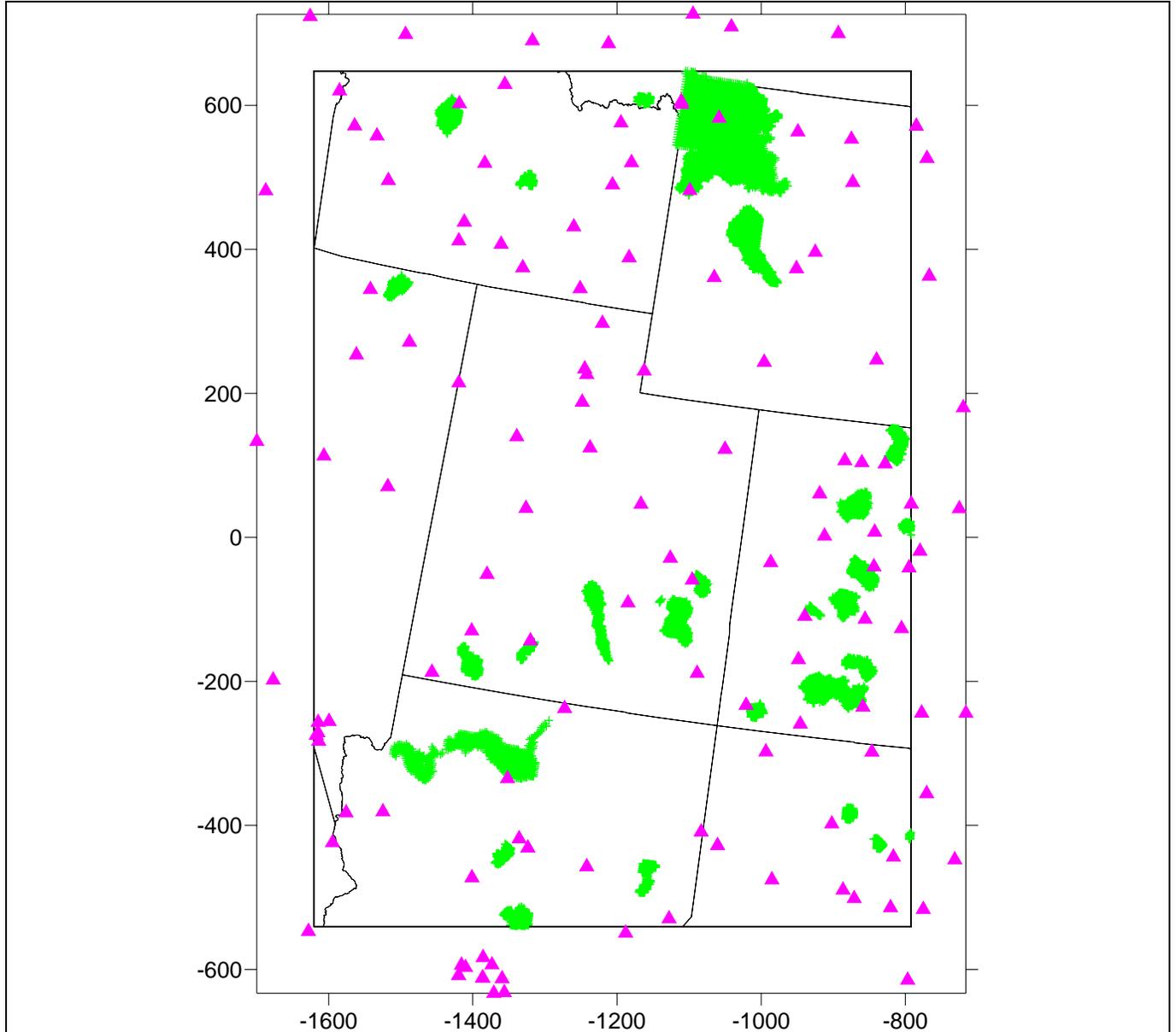
Figure 3-1f. Proposed CALMET/CALPUFF modeling domain and Class I area receptors (green) and observed surface meteorological sites (purple triangles) for Utah.

3.1.1.2. CALMET Performance Evaluation

The CALMET meteorological fields will be spot checked for reasonableness using visualization and animation tools, but no comprehensive evaluation will be undertaken. The main inputs to CALMET are the hourly 36 km MM5 data, surface meteorological and precipitation measurements, terrain data and land use data. The 36 km MM5 fields have been evaluated previously (McNally, 2003; Kemball-Cook et al., 2005; Baker, 2004a,b) and the terrain and land use inputs will be evaluated by comparison spatial plots of the inputs against topographic and land use maps.

3.1.1.3. Terrain

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. These data will be processed to generate 4 km average terrain heights that will be input into CALMET. Additional terrain databases will be used to define terrain heights in the Canada and Mexico portions of the modeling domains as needed.

3.1.1.4. Land Use

The land use data is based on the Composite Theme Grid format (CTG) using Level I USGS land use categories were "mapped into the 14 primary CALMET land use categories described in Figure 3-2.

Default CALMET Land Use Categories and Associated Geophysical Parameters
Based on the U.S. Geological Survey Land Use Classification System
(14-Category System)

Land Use Type	Description	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux Parameter	Anthropogenic Heat Flux (W/m²)	Leaf Area Index
10	Urban or Built-up Land	1.0	0.18	1.5	.25	0.0	0.2
20	Agricultural Land - Unirrigated	0.25	0.15	1.0	.15	0.0	3.0
-20*	Agricultural Land - Irrigated	0.25	0.15	0.5	.15	0.0	3.0
30	Rangeland	0.05	0.25	1.0	.15	0.0	0.5
40	Forest Land	1.0	0.10	1.0	.15	0.0	7.0
51	Small Water Body	0.001	0.10	0.0	1.0	0.0	0.0
54	Bays and Estuaries	0.001	0.10	0.0	1.0	0.0	0.0
55	Large Water Body	0.001	0.10	0.0	1.0	0.0	0.0
60	Wetland	1.0	0.10	0.5	.25	0.0	2.0
61	Forested Wetland	1.0	0.1	0.5	0.25	0.0	2.0
62	Nonforested Wetland	0.2	0.1	0.1	0.25	0.0	1.0
70	Barren Land	0.05	0.30	1.0	.15	0.0	0.05
80	Tundra	.20	0.30	0.5	.15	0.0	0.0
90	Perennial Snow or Ice	.20	0.70	0.5	.15	0.0	0.0

* Negative values indicate "irrigated" land use

Figure 3-2. Land use categories table from CALMET User's Guide.

3.1.1.5. CALMET ZFACE and ZIMAX Settings

Eleven vertical layers will be used with vertical cell face (ZFACE) heights at: 0, 20, 100, 200, 350, 500, 750, 1000, 2000, 3000, 4000, and 5000 meters.

ZIMAX was set to 4500 meters based on the CDPHE analyses of soundings for summer ozone events in the Denver area (CDPHE, 2005). The CDPHE analysis suggests mixing heights in the Denver area are often well above the CALMET default 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. We suspect that, like in Denver, mixing heights in excess of the 3,000 m AGL CALMET default maximum would occur in the western States. Note that this is one area where we are deviating from EPA's March 16, 2006 memorandum on CALMET/CALPUFF regulatory settings.

3.1.1.6. CALMET Options and Comparison with Regulatory Default Settings

Table 3-2 compares the proposed CALMET options and settings with those recommended by EPA for the regulatory application of the CALMET model (Atkinson and Fox, 2006). The RMC BART screening analysis CALMET parameters conforms with all of EPA's recommendations for regulatory application of the CALPUFF modeling system, with the following exceptions:

- The WRAP CALMET/CALPUFF modeling domains will be based on the same Inter-RPO Lambert Conformal Conic (LCC) projection as used in the WRAP MM5 and CMAQ modeling rather than the EPA default LCC projection.
- Proposed maximum mixing height (Z1MAX) of 4,500 m AGL versus EPA regulatory default of 3,000 m AGL. A 3,000 m AGL maximum mixing height might be appropriate in the eastern U.S., however in the western U.S. in the summer mixing heights may exceed this value. In their BART Modeling Protocol, the CDPHE presents compelling evidence that mixing heights exceed 3,000 m AGL in Denver during the summer. We would expect other areas in the west to also have higher mixing heights so we have adopted the 4,500 m AGL values as used by CDPHE (CDPHE, 2005);
- The EPA default assumes no MM5 data will be used (IPROG=0). In the RMC BART screening analysis MM5 data will be used as an initial guess field (IPROG=14).
- The EPA default assumes values for IEXTRP (-4) and RMIN2 (4) that are incompatible with each other, thus we will use values that are consistent with each other (1 and 4, respectively). Because we are using hourly 36 km MM5 data to define the upper–level winds, the extrapolation of the surface wind data aloft as recommended by EPA (IEXTRP= −4) is not needed and in fact would upset the dynamic balance of the aloft winds producing spurious vertical velocities.
- We are setting IAVET to 0 to turn off spatially averaging of the temperature interpolation since the MM5 temperatures with already be fairly smooth.
- We are setting the beginning and ending water land use categories to 51 and 55, respectively (see Figure 3−2), rather than EPA default (999) that assumes no water landuse categories.

Table 3-2. CALMET options and comparison of proposed values with EPA regulatory default settings as given by Atkinson and Fox (2006), deviations from EPA recommended defaults are indicated by **bold text**.

Variable	Description	EPA Default	Our Values
GEO.DAT	Name of Geophysical data file	GEO.DAT	GEO.DAT
SURF.DAT	Name of Surface data file	SURF.DAT	SURF.DAT
PRECIP.DAT	Name of Precipitation data file	PRECIP.DAT	PRECIP.DAT
NUSTA	Number of upper air data sites	User Defined	0
UPN.DAT	Names of NUSTA upper air data files	UPN.DAT	NA
IBYR	Beginning year	User Defines	User Defines
IBMO	Beginning month	User Defines	User Defines
IBDY	Beginning day	User Defines	User Defines
IBHR	Beginning hour	User Defines	User Defines
IBTZ	Base time zone	User Defines	User Defines
IRLG	Number of hours to simulate	User Defines	User Defines
IRTYPE	Output file type to create (must be 1 for CALPUFF)	1	1
LCALGRD	Are w-components and temperature needed?	T	T
NX	Number of east-west grid cells	User Defines	Table 3-1
NY	Number of north-south grid cells	User Defines	Table 3-1
DGRIDKM	Grid spacing	User Defines	Table 3-1
XORIGKM	Southwest grid cell X coordinate	User Defines	Table 3-1
YORIGKM	Southwest grid cell Y coordinate	User Defines	Table 3-1
XLATO	Southwest grid cell latitude	User Defines	Table 3-1
YLONO	Southwest grid cell longitude	User Defines	Table 3-1
IUTMZN	UTM Zone	User Defines	NA
LLCONF	When using Lambert Conformal map coordinates, rotate winds from true north to map north?	F	F
XLAT1	Latitude of 1st standard parallel	**30**	**33**
XLAT2	Latitude of 2nd standard parallel	**60**	**45**
RLON0	Longitude used if LLCONF = T	**90**	**97**
RLAT0	Latitude used if LLCONF = T	**40**	**40**
NZ	Number of vertical Layers	User Defines	11
ZFACE	Vertical cell face heights (NZ+1 values)	User Defines	0,20,100,200,350,500,750,1000,2000,3000,4000, and 5000
LSAVE	Save met. Data fields in an unformatted file?	T	T
IFORMO	Format of unformatted file (1 for CALPUFF)	1	1
NSSTA	Number of stations in SURF.DAT file	User Defines	Domain dependent, see Figure 3-1 for locations
NPSTA	Number of stations in PRECIP.DAT	User Defines	Domain dependent, see Figure 3-1 for locations
ICLOUD	Is cloud data to be input as gridded fields? 0=No)	0	0
IFORMS	Format of surface data (2 = formatted)	2	2
IFORMP	Format of precipitation data (2= formatted)	2	2
IFORMC	Format of cloud data (2= formatted)	2	2

Variable	Description	EPA Default	Our Values
IWFCOD	Generate winds by diagnostic wind module? (1 = Yes)	1	1
IFRADJ	Adjust winds using Froude number effects? (1= Yes)	1	1
IKINE	Adjust winds using Kinematic effects? (1 = Yes)	0	0
IOBR	Use O'Brien procedure for vertical winds? (0 = No)	0	0
ISLOPE	Compute slope flows? (1 = Yes)	1	1
IEXTRP	Extrapolate surface winds to upper layers? (-4 = use similarity theory and ignore layer 1 of upper air station data)	**-4**	**1**
ICALM	Extrapolate surface calms to upper layers? (0 = No)	0	0
BIAS	Surface/upper-air weighting factors (NZ values)	NZ*0	NZ*0
IPROG	Using prognostic or MM-FDDA data? (0 = No)	0	14
LVARY	Use varying radius to develop surface winds?	F	F
RMAX1	Max surface over-land extrapolation radius (km)	User Defines	50.
RMAX2	Max aloft over-land extrapolations radius (km)	User Defines	100.
RMAX3	Maximum over-water extrapolation radius (km)	User Defines	100.
RMIN	Minimum extrapolation radius (km)	0.1	0.1
RMIN2	Distance (km) around an upper air site where vertical extrapolation is excluded (Set to –1 if IEXTRP = $\pm$4)	4	4
TERRAD	Radius of influence of terrain features (km)	User Defines	10.
R1	Relative weight at surface of Step 1 field and obs	User Defines	100.
R2	Relative weight aloft of Step 1 field and obs	User Defines	200.
DIVLIM	Maximum acceptable divergence	5.E-6	5.E-6
NITER	Max number of passes in divergence minimization	50	50
NSMTH	Number of passes in smoothing (NZ values)	2,4*(NZ-1)	2,4*(NZ-1)
NINTR2	Max number of stations for interpolations (NA values)	99	99
CRITFN	Critical Froude number	1	1
ALPHA	Empirical factor triggering kinematic effects	0.1	0.1
IDIOPT1	Compute temperatures from observations (0 = True)	0	0
ISURFT	Surface station to use for surface temperature (between 1 and NSSTA)	User Defines	1
IDIOPT2	Compute domain-average lapse rates? (0 = True)	0	0

Variable	Description	EPA Default	Our Values
IUPT	Station for lapse rates (between 1 and NUSTA)	User Defines	1
ZUPT	Depth of domain-average lapse rate (m)	200	200
IDIOPT3	Compute internally initial guess winds? (0 = True)	0	0
IUPWND	Upper air station for domain winds (-1 = 1/r**2 interpolation of all stations)	-1	-1
ZUPWND	Bottom and top of layer for 1st guess winds (m)	1,1000	1,1000
IDIOPT4	Read surface winds from SURF.DAT? (0 = True)	0	0
IDIOPT5	Read aloft winds from UPn.DAT? (0 = True)	0	0
CONSTB	Neutral mixing height B constant	1.41	1.41
CONSTE	Convective mixing height E constant	0.15	0.15
CONSTN	Stable mixing height N constant	2400	2400
CONSTW	Over-water mixing height W constant	0.16	0.16
FCORIOL	Absolute value of Carioles parameter	1.E-4	1.E-4
IAVEZI	Spatial averaging of mixing heights? (1 = True)	1	1
MNMDAV	Max averaging radius (number of grid cells)	1	1
HAFANG	Half-angle for looking upwind (degrees)	30	30
ILEVZI	Layer to use in upwind averaging (between 1 and NZ)	1	1
DPTMIN	Minimum capping potential temperature lapse rate	0.001	0.001
DZZI	Depth for computing capping lapse rate (m)	200	200
ZIMIN	Minimum over-land mixing height (m)	50	50
ZIMAX	Maximum over-land mixing height (m)	3000	4500
ZIMINW	Minimum over-water mixing height (m)	50	50
ZIMAXW	Maximum over-water mixing height (m)	3000	4500
IRAD	Form of temperature interpolation (1 = 1/r)	1	1
TRADKM	Radius of temperature interpolation (km)	500	500
NUMTS	Max number of stations in temperature interpolations	5	5
IAVET	Conduct spatial averaging of temperature? (1 = True)	**1**	**0**
TGDEFB	Default over-water mixed layer lapse rate (K/m)	-0.0098	-0.0098
TGDEFA	Default over-water capping lapse rate (K/m)	-0.0045	-0.0045
JWAT1	Beginning landuse type defining	**999**	**51**

Variable	Description	EPA Default	Our Values
	water		
JWAT2	Ending landuse type defining water	**999**	**55**
NFLAGP	Method for precipitation interpolation (2= 1/r**2)	2	2
SIGMAP	Precip radius for interpolations (km)	100	100
CUTP	Minimum cut off precip rate (mm/hr)	0.01	0.01
SSn	NSSTA input records for surface stations	User Defines	Figure 3-1
Usn	NUSTA input records for upper-air stations	User Defines	NA
PSn	NPSTA input records for precipitations stations	User Defines	Figure 3-1

3.1.2. CALPUFF

The CALPUFF model will be applied following EPA guidance and recommendations (EPA, 2003c; Atkinson and Fox, 2006) and other recommendations (IWAQM, 1998; FLAG, 2000).

3.1.2.1. Receptor Network and Class I Federal Areas

The NPS recommended receptor networks for Class I areas will be used in the analysis. The locations of these receptors for each of the CALMET/CALPUFF modeling domains are shown in Figure 3-1. Because of the large size of the CALPUFF modeling domains, the high density of the NPS receptors in the Class I areas and the many Class I areas in the west, there may be a need to reduce the number of receptors to a more manageable number. For example, the proposed Utah CALPUFF modeling domain (Figure 3-1f) includes 11,365 receptors. As the CALPUFF run times depend on the number of sources and receptors, then specifying too many receptors results in excessive run times. For PSD/NSR modeling Class I area receptors are typically limited to within 300 km of the source. The RMC will work with the WRAP Modeling Forum and affected States to determine ways to reduce the total number of receptors without sacrificing the identification of the maximum visibility impacts from potential BART eligible sources at Class I areas.

3.1.2.2. CALPUFF Meteorology

The CALPUFF meteorology will be based on CALMET as described in Section 3.1.1.

3.1.2.3. CALPUFF Modeling Domain

The CALPUFF modeling domains are mostly assumed to be identical to the CALMET modeling domains and are shown in Figure 3-1. Although if run times are excessive the relevant States will be consulted about potential reductions in the size of the CALPUFF computational domain. The State of Nevada requested that two separate CALPUFF computational grids be used, one

associated with northern (Figure 3-1d-2) and one associated with southern Nevada sources (Figure 3-1d-3).

3.1.2.4. *CALPUFF Parameter Summary and Comparison with Regulatory Defaults*

The CALPUFF options were selected to follow EPA's recommended settings for regulatory modeling (Atkinson and Fox, 2006) as shown in Table 3-3. Differences from these recommendations are as follows:

- The number of species modeled and emitted will depend on the emissions data provided by the States for the BART sources. If just SO_2 and NOx emissions are provided, 5 species will be modeled (SO_2, SO4, NOx, NHNO3 and NO3) as recommended by EPA. For States that also provide total PM10 emissions 6 species will be modeled. Potentially States could provide PM emissions split into SO4, NO3, EC, OC, PMF and PMC in which case 9 species will be modeled.
- MRESTART will be 2 for first run segment of the year and 3 for subsequent run segments.
- The background ammonia for the CALPUFF runs will be 1 ppb that is believed to be a more representative value for the western U.S. than the 10 ppb EPA default. Note that we are still reviewing what background ammonia value should be used when post-processing the results to calculate ammonia limiting where site and monthly specific values are being considered.

Table 3-3. CALPUFF options and comparison of EPA regulatory modeling default values with proposed values for the RMC BART screening analysis, bold text indicates deviations from EPA recommendations.

Variable	Description	EPA Default	Our Values
METDAT	CALMET input data filename	CALMET.DAT	CALMET.DAT
PUFLST	Filename for general output from CALPUFF	CALPUFF.LST	CALPUFF.LST
CONDAT	Filename for output concentration data	CONC.DAT	CONC.DAT
DFDAT	Filename for output dry deposition fluxes	DFLX.DAT	DFLX.DAT
WFDAT	Filename for output wet deposition fluxes	WFLX.DAT	WFLX.DAT
VISDAT	Filename for output relative humidities (for visibility)	VISB.DAT	VISB.DAT
METRUN	Do we run all periods (1) or a subset (0)?	0	0
IBYR	Beginning year	User Defined	User Defined
IBMO	Beginning month	User Defined	User Defined
IBDY	Beginning day	User Defined	User Defined
IBHR	Beginning hour	User Defined	User Defined
IRLG	Length of runs (hours)	User Defined	User Defined
NSPEC	Number of species modeled (for MESOPUFF II chemistry)	**5**	**5-9**
NSE	Number of species emitted	**3**	**2-9**
MRESTART	Restart options (0 = no restart), allows splitting runs into smaller segments	**0**	**2 or 3**
METFM	Format of input meteorology (1 = CALMET)	1	1
AVET	Averaging time lateral dispersion parameters (minutes)	60	60
MGAUSS	Near-field vertical distribution (1 =	1	1

Variable	Description	EPA Default	Our Values
	Gaussian)		
MCTADJ	Terrain adjustments to plume path (3 = Plume path)	3	3
MCTSG	Do we have subgrid hills? (0 = No), allows CTDM-like treatment for subgrid scale hills	0	0
MSLUG	Near-field puff treatment (0 = No slugs)	0	0
MTRANS	Model transitional plume rise? (1 = Yes)	1	1
MTIP	Treat stack tip downwash? (1 = Yes)	1	1
MSHEAR	Treat vertical wind shear? (0 = No)	0	0
MSPLIT	Allow puffs to split? (0 = No)	0	0
MCHEM	MESOPUFF-II Chemistry? (1 = Yes)	1	1
MWET	Model wet deposition? (1 = Yes)	1	1
MDRY	Model dry deposition? (1 = Yes)	1	1
MDISP	Method for dispersion coefficients (3 = PG & MP)	3	3
MTURBVW	Turbulence characterization? (Only if MDISP = 1 or 5)	3	3
MDISP2	Backup coefficients (Only if MDISP = 1 or 5)	3	3
MROUGH	Adjust PG for surface roughness? (0 = No)	0	0
MPARTL	Model partial plume penetration? (0 = No)	1	1
MTINV	Elevated inversion strength (0 = compute from data)	0	0
MPDF	Use PDF for convective dispersion? (0 = No)	0	0
MSGTIBL	Use TIBL module? (0 = No) allows treatment of subgrid scale coastal areas	0	0
MREG	Regulatory default checks? (1 = Yes)	1	1
CSPECn	Names of species modeled (for MESOPUFF II, must be SO2, SO4, NOx, HN03, NO3)	User Defined	5
Specie Names	Manner species will be modeled	User Defined	SO2, SO4, NOX, NO3, HNO3, PM25 (depends on emissions data provide by States)
Specie Groups	Grouping of species, if any.	User Defined	
NX	Number of east-west grids of input meteorology	User Defined	Table 3-1
NY	Number of north-south grids of input meteorology	User Defined	Table 3-1
NZ	Number of vertical layers of input meteorology	User Defined	11
DGRIDKM	Meteorology grid spacing (km)	User Defined	4
ZFACE	Vertical cell face heights of input meteorology	User Defined	Table 3-2
XORIGKM	Southwest corner (east-west) of input meteorology	User Defined	Table 3-1
YORIGIM	Southwest corner (north-south) of input meteorology	User Defined	Table 3-1
IUTMZN	UTM zone	User Defined	NA
XLAT	Latitude of center of meteorology domain	User Defined	Table 3-1
XLONG	Longitude of center of meteorology	User Defined	Table 3-1

Variable	Description	EPA Default	Our Values
	domain		
XBTZ	Base time zone of input meteorology	User Defined	MST
IBCOMP	Southwest of Xindex of computational domain	User Defined	Table 3-1
JBCOMP	Southwest of Y-index of computational domain	User Defined	Table 3-1
IECOMP	Northeast of Xindex of computational domain	User Defined	Table 3-1
JECOMP	Northeast of Y- index of computational domain	User Defined	Table 3-1
LSAMP	Use gridded receptors (T -= Yes)	F	F
IBSAMP	Southwest of Xindex of receptor grid	User Defined	NA
JBSAMP	Southwest of Y-index of receptor grid	User Defined	NA
IESAMP	Northeast of Xindex of receptor grid	User Defined	NA
JESAMP	Northeast of Y-index of receptor grid	User Defined	NA
MESHDN	Gridded receptor spacing = DGRIDKM/MESHDN	1	NA
ICON	Output concentrations? (1 = Yes)	1	1
IDRY	Output dry deposition flux? (1 = Yes)	1	1
IWET	Output wet deposition flux? (1 = Yes)	1	1
IVIS	Output RH for visibility calculations (1 = Yes)	1	1
LCOMPRS	Use compression option in output? (T = Yes)	T	T
ICPRT	Print concentrations? (0 = No)	0	0
IDPRT	Print dry deposition fluxes (0 = No)	0	0
IWPRT	Print wet deposition fluxes (0 = No)	0	0
ICFRQ	Concentration print interval (1 = hourly)	1	1
IDFRQ	Dry deposition flux print interval (1 = hourly)	1	1
IWFRQ	Wet deposition flux print interval (1 = hourly)	1	1
IPRTU	Print output units (1 = g/m**3; g/m**2/s)	1	1
IMESG	Status messages to screen? (1 = Yes)	1	1
Output Species	Where to output various species	User Defined	Default
LDEBUG	Turn on debug tracking? (F = No)	F	F
Dry Gas Dep	Chemical parameters of gaseous deposition species	User Defined	Default
Dry Part. Dep	Chemical parameters of particulate deposition species	User Defined	Default
RCUTR	Reference cuticle resistance (s/cm)	30.	30.
RGR	Reference ground resistance (s/cm)	10.	10.
REACTR	Reference reactivity	8	8
NINT	Number of particle-size intervals	9	9
IVEG	Vegetative state (1 = active and unstressed)	1	1
Wet Dep	Wet deposition parameters	User Defined	TBD
MOZ	Ozone background? (1 = read from ozone.dat)	1	1
BCKO3	Ozone default (ppb) (Use only for missing data)	80	80
BCKNH3	Ammonia background (ppb)	**10**	**1**
RNITE1	Nighttime SO2 loss rate (%/hr)	0.2	0.2
RNITE2	Nighttime NOx loss rate (%/hr)	2	2
RNITE3	Nighttime HNO3 loss rate (%/hr)	2	2

Variable	Description	EPA Default	Our Values
SYTDEP	Horizontal size (m) to switch to time dependence	550.	550.
MHFTSZ	Use Heffter for vertical dispersion? (0 = No)	0	0
JSUP	PG Stability class above mixed layer	5	5
CONK1	Stable dispersion constant (Eq. 2.7-3)	0.01	0.01
CONK2	Neutral dispersion constant (Eq. 2.7-4)	0.1	0.1
TBD	Transition for downwash algorithms (0.5 = ISC)	0.5	0.5
IURB1	Beginning urban landuse type	10	10
IURB2	Ending urban landuse type	19	19

3.1.2.5.   Chemical Mechanism

The MESOPUFF II pseudo-first-order chemical reaction mechanism (MCHEM=1) will be used for the conversion of SO_2 to sulfate (SO4) and NOx to nitrate (NO3) as recommended by EPA (Atkinson and Fox, 2006).

3.1.2.6.   Ammonia Assumptions

Ammonia is not simulated by CALPUFF, but rather a background value is specified. Ammonia is important because the level of particulate nitrate (NO3) can depend on the amount of ammonia present. The partitioning of total nitrate between gaseous HNO3 and particulate NO3 depends on the amount of ammonia present and other parameters (e.g., SO4, temperature and RH). In the CALPUFF simulation, one value for background ammonia is assumed across the region and each puff uses the full background value in its equilibrium calculation even though puffs may be overlapping thereby "double counting" the background ammonia value. However, in post-processing the results, you may specific hourly values at receptors and recalculate the HNO3/NO3 equilibrium partitioning on the total concentration due to all overlapping puffs at a receptor.

The IWAQM Phase II report contains the following recommendations for background ammonia "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" (IWAQM, 1998). The CDPHE performed analysis for Colorado and concluded that for sources located in northeast Colorado and along the South Platte River, a domain-wide ammonia background value of 44 ppb is used. For sources located in northwest Colorado, a background ammonia concentration of 1.0 ppb is used. For sources located in southeastern Colorado and for sources located along the Arkansas River, a background value of 10 ppb is used.

In a CALPUFF 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 single domain-wide background is problematic. There is no one value that is likely valid across the modeling domains in Figure 3-1 or even across the different seasons at one particulate location. Although the domain-wide background ammonia value specified in the CALPUFF run is important because it determines how much of the total nitrate is gaseous (HNO3) versus particles (NO3) and therefore affects the dry and wet deposition rates,

the specification of the background ammonia in the post-processing step to partition the total nitrate from overlapping puffs at the Class I areas into HNO3 and NO3 is even more important. Thus, based on the fact that western Class I areas tend to be either more arid or forest land than grassland we proposed to initially use a 1 ppb background ammonia value for the CALPUFF runs. We will then revisit the background ammonia values for the Class I areas for the post-processing step and provide the CALPUFF output to the States so they can investigate alternative background ammonia values if desired.

3.1.2.7. *Ozone Assumptions*

Hourly ozone concentrations from the EPA AIRS and CASTNet networks will be processed and provided as input to the CALPUFF modeling for the three years of modeling.

3.1.3. CALPOST Settings and Visibility Post-Processing

The CALPUFF results will be post-processed using the CALPOST and POSTUTIL or their functional equivalents. The CDPHE had to modify these programs to output the correct values needed for BART analysis. The WRAP RMC may also need to make modifications or perform the post-processing using different tools to obtain the metrics needed for a BART analysis.

To calculate background light extinction, MVISBK should be set to 6. That is, monthly RH adjustment factors (EPA, 2003b) are applied directly to the background and modeled sulfate and nitrate concentrations, as recommended by the EPA BART Guidelines (EPA, 2005). 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. The monthly f(RH) values recommended by EPA would be used (EPA, 2003a,b).

EPA lists three types of Natural Conditions (natural background) in their guidance document, Annual Average, Best 20% (B20%) Days and Worst 20% (W20%) Days (EPA, 2003a). The EPA BART Guidance recommends that the Natural Conditions corresponding to the Best 20% Days be used (EPA, 2005). However, UARG challenged this assumption and EPA has determined that Annual Average Natural Conditions can be used for BART determinations (Paise, 2006a,b). In this analysis, the visibility impacts will be calculated using all three sets of Natural Conditions (Annual Average, B20% and W20%) and provided to the States.

4. ALASKA CALPUFF BART Modeling

The Alaska CALPUFF modeling will follow the general procedures outlined for the other WRAP States described in Section 3, only it will be based on Alaska MM5 modeling conducted by WRAP for the 2002 calendar year (Kemball-Cook et al., 2005). The WRAP RMC performed MM5 meteorological modeling of Alaska for 2002 on a 45/15 km nested grid. Numerous sensitivity tests were conducted to determine the best physics options and other parameters (e.g., time of year when sea ice forms and melts) to optimized model performance. The Alaska MM5 modeling is described in the report "Alaska MM5 Modeling for the 2002 Annual Period to Support Visibility Modeling" by Kemball-Cook and co-workers (2005) and can be found at:

  http://pah.cert.ucr.edu/aqm/308/docs/alaska/Alaska_MM5_DraftReport_Sept05.pdf

Figure 4-1 displays the locations of the potential BART-eligible sources in Alaska along with the Denali (central Alaska), Tuxedni (Cook Inlet), Simenof (Aleutian Islands) and Bearing Sea (far west) Class I areas. Both the Simenof (> 700 km) and Bearing Sea (> 1000 km) lie far away from the potential BART-eligible sources in Alaska, so will not be considered in the analysis.

Figure 4-1. Locations of potential BART-eligible sources (red dots) and Class I areas (green regions) in Alaska.
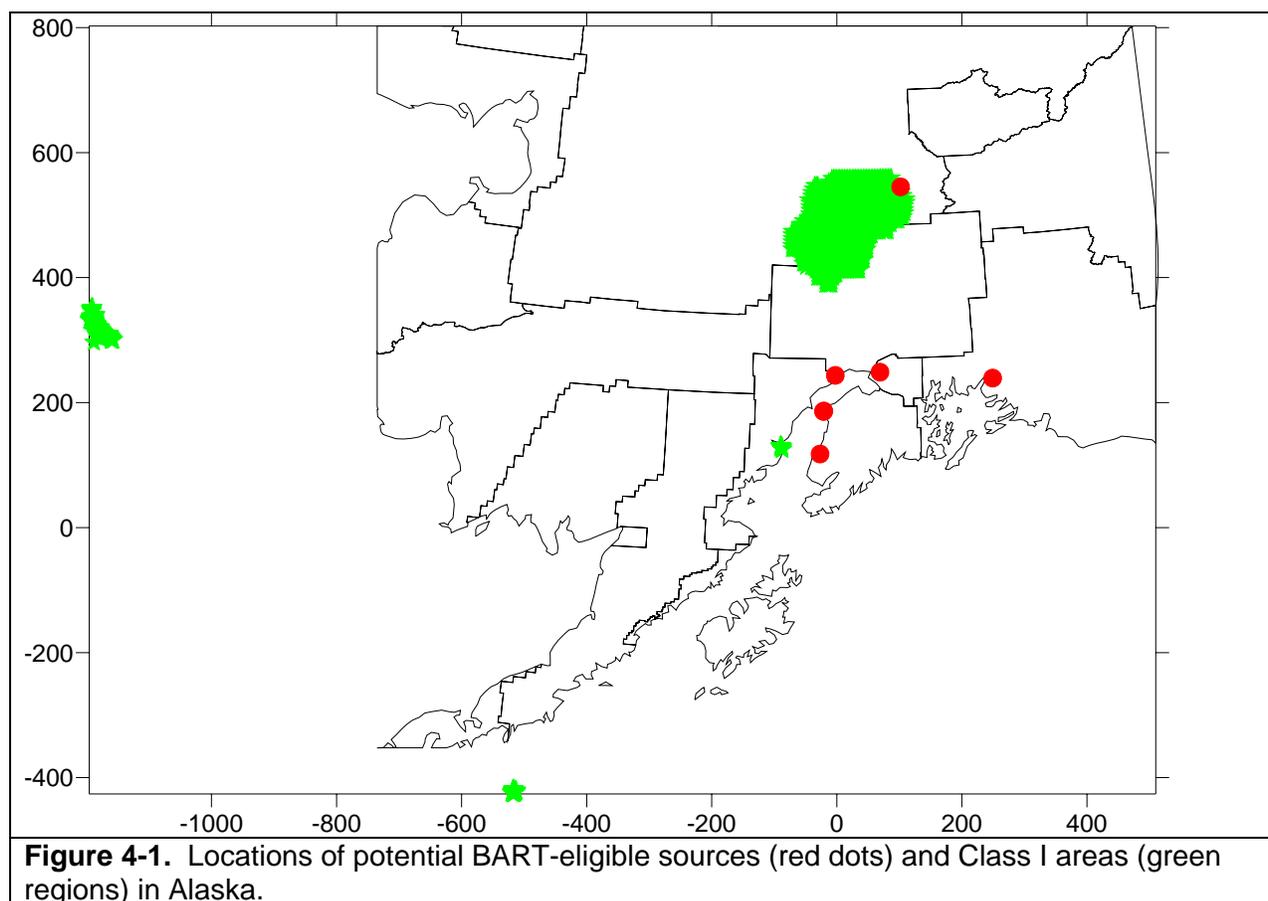
The early versions of the WRAP draft modeling protocol for BART modeling in Alaska proposed to model most of Alaska using a 5 km grid and no observations (NOOBS mode). However, when the Alaska Department of Environmental Protection (ADEQ) provided their list of potential BART-eligible sources it was noted that most of them are located in the Anchorage-Valdez area in southern Alaska, with one located just northeast of Denali National Park (Figure 4-1). Concerns were raised that operating CALMET using 5 km resolution with the 15 km MM5 data in the NOOBS mode would not adequately capture the airflows around the Cook Inlet that would be important in simulating the potential visibility impacts at Tuxedni Wildlife Refuge from BART sources located in southern Alaska. Consequently, the ADEQ sponsored the acquisition and reformatting of surface meteorological observations for input into CALMET and the year 2002 and the Alaska BART modeling domain was redefined with a 2 km resolution grid.

4.1. CALMET Modeling

Although the MM5 modeling was performed on a polar stereographic domain at 45/15 km resolution, since the CALMET/CALPUFF domain did not go as far north we were able to use a Lambert Conformal Conic (LCC) projection at 2 km resolution using the domain definition provided in Table 4-1.

Table 4-1. Definition of the CALMET/CALPUFF Alaska BART modeling domain using a Lambert Conformal Conic (LCC) map projection.

Longitude Origin	-151 degrees
Latitude Origin	59 degrees
1st Standard Parallel	30 degrees
2nd Standard Parallel	60 degrees
X-Origin Offset	-200 km
Y-Origin Offset	0 km
Horizontal Grid Resolution	2 km
Number of Grids	275 x 325
Domain Extent	550 km x 650 km

CALMET will be run using the 15 km resolution 2002 MM5 data (Kemball-Cook et al., 2005), surface meteorological observations from five sites and terrain and landuse data. The locations of the five surface meteorological sites are shown in Table 4-2. Precipitation data will be based on the MM5 15 km resolution output. Similar CALMET options will be used for the Alaska CALMET modeling as discussed in Chapter 3 (i.e., Table 3-2), only using the MM5 precipitation instead of observed precipitation.

Table 4-2. Locations of the 5 surface meteorological sites used in the Alaska BART CALMET/CALPUFF modeling.

Site	ID	LCC-X (km)	LCC-Y(km)
EDF	26401	64.614	250.825
PANC	26451	53.916	245.081
VWS	26442	251.006	244.575
ENA	26523	-12.782	175.868
HOM	25507	-27.103	72.100

Figure 4-2. Alaska BART CALMET/CALPUFF modeling domain showing the potential BART-eligible sources (red dots) and Denali and Tuxedni Class I area receptors.
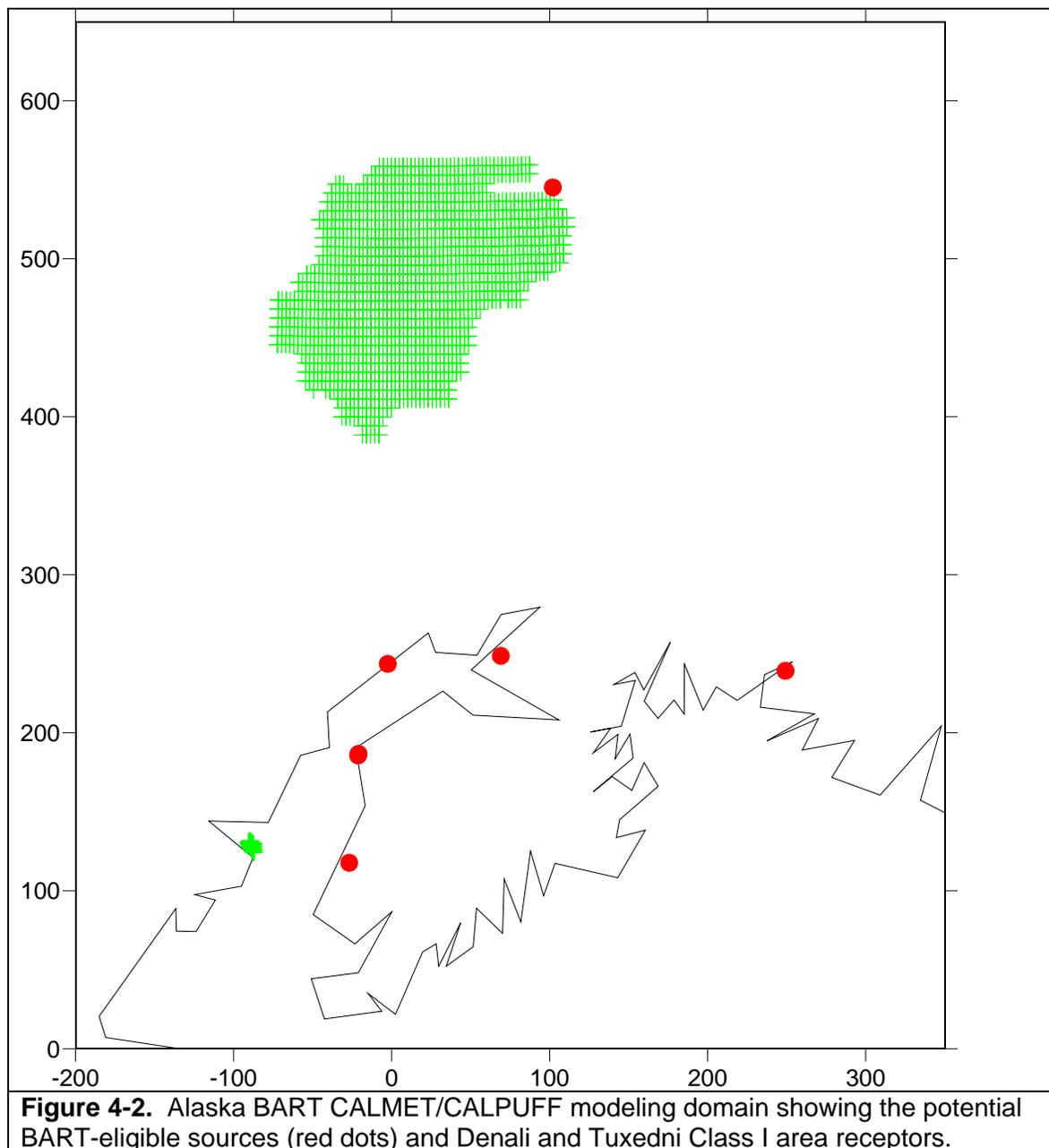
4.2. CALPUFF Modeling

The Alaska BART CALPUFF model will be operated with similar regulatory default settings as discussed in Section 3 (Table 3-3). One major difference is the background ammonia value. The IWAQM (1998) recommendations for background ammonia are representative for the lower 48 states and may not be appropriate for Alaska where lower values are expected to occur. Also, the regulatory default background ozone value when no measurements are available (80 ppb) is also too high for Alaska. Thus, initial background ammonia and ozone values of 0.1 ppb and 40 ppb will be used for the Alaska BART CALPUFF modeling. The specifications of the background ammonia and default background ozone values are undergoing review.

5. Results

For each modeling day, the CALPUFF modeling results would be processed to extract maximum 24-hour visibility impact at any receptor in a Class I area due to a potential BART-eligible source. These maximum 24-hour visibility impacts would be expressed as changes in deciview using three levels of Natural Conditions (Annual Average and Best 20% and Worst 20% Days). For each potential BART-eligible source, Class I area and modeling day (2001, 2002 and 2003), the maximum 24-hour visibility impact would be provided to the States who would make the subject to BART determination. Spread sheets of daily change in deciview impacts would be provided to each State for each of the State's potential BART-eligible source. The maximum and 98th percentile change in deciview would also be provided in summary form to the States.

The CALMET and CALPUFF modeling databases will also be provided to the States if desired. Information on the status of the WRAP BART CALMET/CALPUFF modeling will be posted on the WRAP RMC Website:

http://pah.cert.ucr.edu/aqm/308/bart.shtml

The CALMET MM5 inputs are quite large (several hundred Gb of data) and will be provided on IDE disks that will be distributed to the States as desired for copy. The rest of the CALMET/CALPUFF modeling inputs will be provided on the WRAP RMC Website at the link provided above. CALMET output will not be distributed; rather all CALMET inputs and scripts will be made available so that the CALMET output can be recreated. CALPOST (or similar post-processing program) output will be available on the WRAP RMC Website and depending on their size CALPUFF modeling output will be either available through the Website, ftp transfer or IDE disk transfer.

Note that the WRAP RMC will conduct the BART screening CALPUFF/CALMET modeling on Linux computing platforms. If states wish to use a windows platform then they will have to make the conversion.

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