Appendix D: Development of Parallel CALPUFF Dispersion Modeling Platforms for Sulfate Source Attribution Studies in the Northeast U.S.

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ABSTRACT

The CALPUFF Lagrangian dispersion model was run on two different, largely independent platforms – developed and implemented by two different groups participating in this study – which were used to simulate sulfate production and transport in the MANE-VU and nearby regions. Most of the techniques and approaches for both platforms (including model versions) were consistent if not identical. The primary difference involved the source, and processing, of meteorological data with CALMET. An additional difference included a different focus for each group on the development of emissions and source parameters. The Vermont Department of Environmental Conservation (VT DEC) developed meteorological inputs for CALPUFF through the use of observation-based inputs (i.e., rawinsonde and surface measurements) from the National Weather Service (NWS) and application of CALMET. VTDEC furthermore developed hourly emissions and exhaust flow data from the Acid Rain Program's continuous emissions monitoring system (CEMS) data files for large electric generating units, and created and utilized these inputs for the CALPUFF modeling, along with emissions data for non-EGU point sources from the 2002 NEI inventory. The Maryland Department of Natural Resources and the Maryland Department of the Environment (DNR/MDE) developed a second CALMET/CALPUFF platform with contractor assistance provided by ERM. Meteorological inputs for CALPUFF on the DNR/MDE platform were developed through the use of MM5 data developed for 2002 by the University of Maryland on a 12-km grid. This MM5 data set was used to update the DNR/MDE modeling which had been conducted for Phase I using a 36-km MM5 data set developed by the CENRAP RPO. DNR/MDE focused on the development of emissions and source parameters through the use of the 2002 NEI. Phase II model results for sulfate ion predications are presented, in an evaluation mode (comparing model predictions with measurements) and an application mode (ranking states and individual EGUs), along with comparison of results between platforms. Additionally, the DNR/MDE modeling included an evaluation of model performance based on nitrate aerosol predictions and measurements.

APPENDIX D: DISPERSION MODEL TECHNIQUES

This appendix deals with Lagrangian models, specifically the CALPUFF modeling system (USEPA, 2006). In contrast to the Eulerian grid models referenced and utilized in other sections of this report, a Lagrangian model simulates atmospheric transport, transformation, and dispersion through the treatment of air pollutant emissions from stacks or area sources as a series of discrete puffs. Each puff is tracked individually by the model until it leaves the modeling domain, and the contribution of each puff to receptor concentrations (or deposition fluxes) is calculated separately and can be used to create individual source impacts, or summed in different ways to create total impacts over source groups based on the users' choices. The CALPUFF modeling system includes numerous related programs used to create inputs for the model and to extract and analyze model outputs. One key related program is CALMET, which is the meteorological processor that creates three-dimensional wind fields for the dispersion model CALPUFF. Another key related program is CALPOST, which performs a number of post-processing functions including the calculation of visibility impacts from model-predicted particulate concentrations (including particulate sulfate, particulate nitrate, and direct emissions of $PM_{2.5}$).

This appendix is devoted to describing two specific applications of the CALPUFF system to the simulation of particulate sulfate concentrations, and corresponding visibility impacts, at a number of receptors in the MANE-VU region.[1] Two different, largely independent platforms – developed and implemented by two different groups participating in this study – were used for the modeled simulations described here. Most of the techniques and approaches for both platforms (including model versions) were consistent if not identical. The primary difference involved the source, and processing, of meteorological data with CALMET. An additional difference included a different focus for each group on the development of emissions and source parameters.

The Vermont Department of Environmental Conservation (VTDEC) developed meteorological inputs for CALPUFF through the use of observation-based inputs (i.e., rawinsonde and surface measurements) from the National Weather Service (NWS) and application of CALMET. VTDEC furthermore developed hourly emissions and exhaust flow data from the Acid Rain Program's continuous emissions monitoring system (CEMS) data files for large electric generating units, and created and utilized these inputs for the CALPUFF modeling, along with emissions data for non-EGU point sources from the 2002 NEI inventory.

The Maryland Department of Natural Resources and the Maryland Department of the Environment (DNR/MDE) developed a second CALMET/CALPUFF platform with contractor assistance provided by ERM. Meteorological inputs for CALPUFF on the DNR/MDE platform were developed through the use of MM5 data developed by the University of Maryland on a 12-km grid. This MM5 data set was used to update the DNR/MDE Phase I modeling, which had been conducted using a 36-km MM5 data set

[1] While CALPUFF is capable of estimating concentrations of particulate nitrate and of primary PM2.5, estimates of these pollutants are not included here (except for an evaluation of nitrate ion predictions compared to measurements with the DNR/MDE platform) due to the importance of sulfate contributions to visibility impairment in the MANE-VU region .

developed by the CENRAP RPO. DNR/MDE focused on the development of emissions and source parameters through the use of the 2002 NEI, incorporating five different source sectors: EGUs, non-EGU point sources, mobile (on-road), mobile (off-road), and general area sources. The hourly data files developed by VTDEC based on CEMS data for large EGUs were used directly with the MM5 platform.

Both platforms were used to model the entire calendar year 2002. In this section, reference is made to Phase I and Phase II of the CALPUFF modeling; generally, Phase I was the initial effort designed to provide reasonably complete estimates of particulate sulfate impacts at a set of receptors in the MANE-VU region based on the two different modeling platforms. These estimates have been configured to provide individual source and cumulative state impacts to provide inter-platform comparisons. The modeling domain has been designed to be consistent with the other modeling approaches included in this report (e.g. REMSAD, CMAQ), so that conclusions regarding the most significant sources and states to sulfate visibility impacts in MANE-VU can be compared. Consistency across a broad range of approaches will add credibility to the conclusions reached in the overall contribution assessment.

The rest of this appendix provides a brief description of the CALPUFF modeling system; describes the application of CALPUFF in this Phase I assessment on both the VTDEC and the DNR/MDE platforms including a description of model input development and data evaluations; provides the results of evaluations of the performance of CALPUFF compared to measured particulate sulfate concentrations; and provides the results of the Phase I contribution assessment modeling based on both platforms.

D.1. The CALPUFF Modeling System Description and Background

The CALPUFF modeling system is included in EPA's Guideline on Air Quality Models (GAQM) as a recommended model for long-range transport, specifically to address the impacts of emissions from Prevention of Significant Deterioration (PSD) sources in Class I areas. CALPUFF has recently seen wide use across the US, providing estimated concentration and visibility impacts in Class I areas for numerous PSD applications for new power plants and other PSD sources. The use of CALPUFF for regional modeling at the scale of this contribution assessment (where transport distances exceed 1000 kilometers in some cases) has not been as wide-spread, and its performance at distances beyond 300 kilometers is subject to some uncertainty. The Interagency Workgroup on Air Quality Modeling (IWAQM) Phase II Report (USEPA, 1998) suggested, based on an analysis of the CAPTEX tracer study, that under-prediction of horizontal dispersion at greater than 300 kilometer transport distances could lead to an over prediction of surface concentrations using CALPUFF. For the present study, this uncertainty is addressed through the emphasis on model performance (compared to measured data) and by the context in which the CALPUFF model results are used. This context is that the CALPUFF results are used to contribute to a weight of evidence assessment that considers the results of many different modeling approaches.

The CALPUFF modeling system was developed by Earth Tech, and is publicly available. Model and support program executables, a graphical user interface, model and support program source code, examples, and users guides are available either through a link provided on EPA's web site www.epa.gov/ttn/scram or directly from Earth Tech at www.src.com/calpuff/calpuff1.htm. Two beta-test versions of CALPUFF have been released since the GAQM version was released on April 17, 2003: one dated July 11, 2003, and one dated July 16, 2004. Additional updates to the modeling system have been released by Earth Tech, most notably the version recommended by the VISTAS RPO for BART modeling and Version 6 that includes the capability to model with sub-hourly time steps (latest updates released on April 14, 2006). The model versions identified as V5.711 030625 and V5.711 040716 are being used in this analysis as opposed to the GAQM version, since they correct bugs found in the GAQM version that affect the use of data files (e.g. the hourly emissions and point source parameter file for incorporating CEMS data) that are important for this analysis. The latest model versions (VISTAS, Version 6) were not available at the time that this work was being performed and were therefore not used.

D.1.1. CALMET

The CALMET meteorological processor is a key component of the CALPUFF modeling system. Its primary purpose is to prepare meteorological inputs for running CALPUFF, consisting nominally of three-dimensional wind fields, two-dimensional gridded derived boundary layer parameter fields (e.g. mixing depth, friction velocity, Monin Obukhov length, etc.), and two-dimensional gridded fields of surface measurements and precipitation rates (for use in calculating wet deposition fluxes).

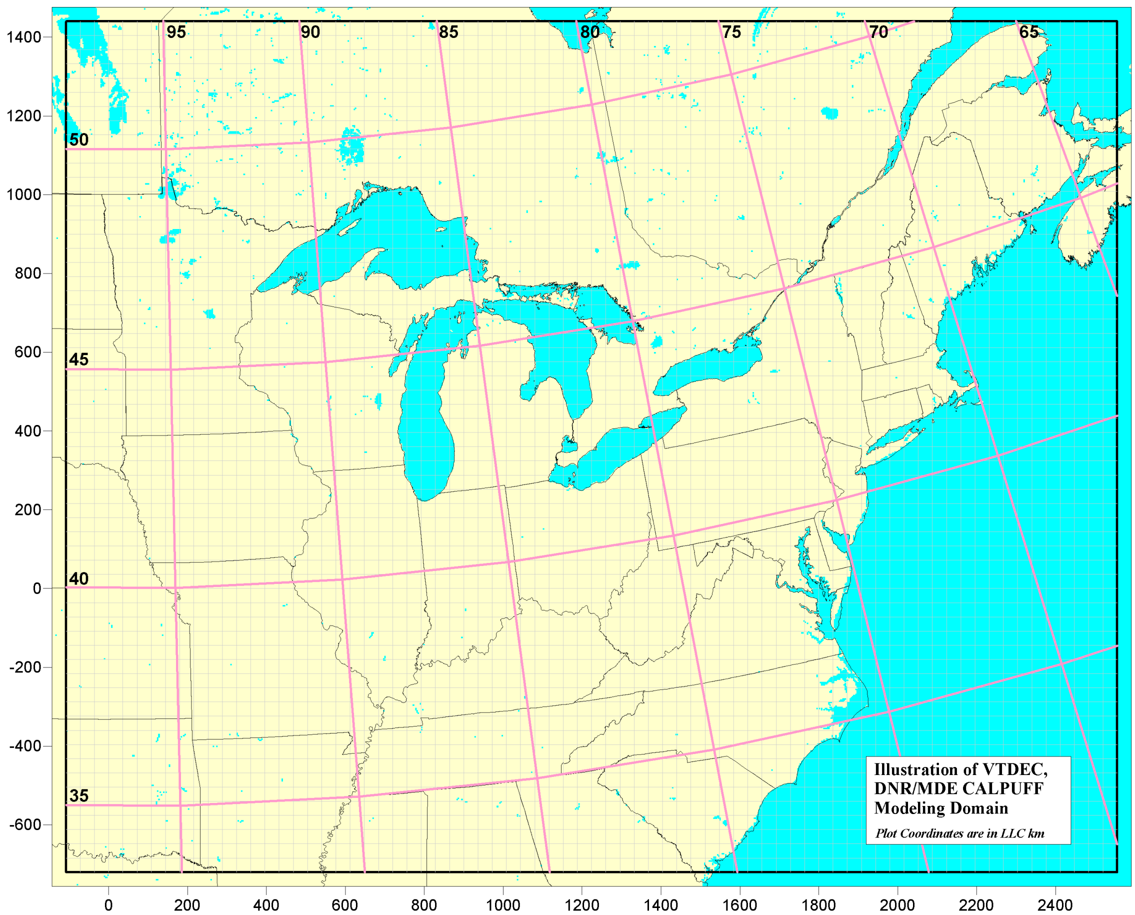
The wind field generated by CALMET is based on a diagnostic wind field model. An initial guess wind field is adjusted for the effects of terrain to produce a step 1 wind field. Observations are then used to adjust the step 1 wind field to produce a final step 2 wind field based on interpolation that is written to the CALMET output data file. The CALMET model differs from the family of prognostic meteorological models, such as the Penn State/NCAR Meteorological Model (MM5), that solve basic conservation equations to generate a modeled atmosphere and which can be used in a forecast mode.

Inputs to CALMET consist of geophysical data (land use, terrain) and observations in the form of surface measurements, precipitation rates, and upper air rawinsonde soundings. The output from MM5 can also be used as input to CALMET. Depending on the relationship of the MM5 grid to the CALMET grid, the MM5 data can be introduced in one of three places: as the initial guess field, as the step 1 wind field, or as pseudo-observations. The latest version of CALMET allows for a “no observations” mode for cases where the prognostic model grid is similar in resolution to the CALMET grid. This option allows for maximum reliance on the prognostic model meteorological fields. The no observations mode can be configured to rely entirely on MM5 data, or to combine surface observations with MM5 data.

The CALMET model contains numerous options regarding both the wind field and micrometeorological parameters. Further descriptions of the development of inputs, the selection of options and application of CALMET, and the evaluation of CALMET inputs and outputs can be found in the appropriate sections below for the observation-based platform (VTDEC) and the MM5-based platform (DNR/MDE).

The domain utilized for both of these platforms is identical, and is based on a Lambert Conformal Conic projection consistent with the RPO projection; namely, an origin of 40.0 degrees N and 97.0 degrees W and matching parallels of latitude at 33.0 and 45.0 degrees N. The vertical extent of the domain is set at approximately 3 km with different resolution depending on the platform. Grid resolution for the VTDEC platform was set at 36 kilometers, which resulted in a grid size of 74 by 61 cells. Grid resolution for the DNR/MDE platform was set at 12 km, which resulted in a grid size of 222 by 180 cells. A depiction of the domain utilized in these analyses is shown in Figure D-1.

Figure D-1. CALPUFF modeling domain.



D.1.2. CALPUFF

For this modeling effort, the focus is on the prediction of sulfate aerosol at a number of receptors in and near the MANE-VU RPO. Visibility impacts are also presented based on the application of the default extinction efficiency coefficient for SO_4 from the CALPOST program. The present visibility calculations are based on monthly-averaged relative humidity coefficients.

CALPUFF initiates the simulation of point source plumes with a calculation of buoyant plume rise. Based on the effective plume height (stack height plus plume rise), transport winds are extracted from the meteorological data file. For near-field effects, the height of the plume in transition to the final plume height is taken into account. The puff release rate is calculated internally, based on the transport speed and the distance to the closest receptor; for the present analysis, source-receptor distances are such that in most cases, the puff release rate is one per hour. As the puff is transported downwind, it grows due to dispersion and wind shear and the trajectory is determined by transport winds at the puff location and height at each time step. The pollutant mass within each puff is initially a function of the emission rate from the original source. The pollutant mass is subject to chemical transformation based on model user choices and removal by both wet and dry processes. Chemical transformation and removal are calculated based on a one-hour time step.

The chemical transformation scheme chosen for this analysis is the "MESOPUFF-II" scheme available with CALPUFF, described in the CALPUFF user's guide as a "pseudo first-order chemical reaction mechanism". This scheme involves five species: SO_2, SO_4, NO_X, HNO_3, and particulate nitrate. CALPUFF calculates the rate of transformation of SO_2 to SO_4, and the rate of transformation of NO_X to NO_3, based on environmental conditions including the ozone concentration, atmospheric stability, solar radiation, relative humidity, and the plume NO_X concentration. For SO_2, the primary subject of this modeling, the following expression is used to calculate the SO_2 to SO_4 transformation rate (equation 2-253 in the CALPUFF user guide):

$$k_1 = 36\,[R]^{0.55}\,[O_3]^{0.71}\,S^{-1.29} + k_{1(aq)}$$
$$k_{1(aq)} = 3 \times 10^{-8} \times [RH]^{4.0}$$

where,

k_1	is the SO_2 to SO_4 transformation rate (percent/hour)
R	is the total solar radiation intensity (kw/m^2)
$[O_3]$	is the background ozone concentration (ppm)
S	is a stability index ranging from 2 (unstable) to 6 (stable)
$k_{1(aq)}$	is a parameterization of the aqueous phase component of the SO_2 conversion rate
RH	is the relative humidity (percent)

At night, the transformation rate defaults to a constant value of 0.2% per hour. At present, CALPUFF does not have a mechanism for estimating aqueous SO_2 transformation that can occur in clouds. Calculations based on these formulas show that the transformation rate can reach about 3 percent per hour at noon on a cloudless day with 100 ppb of ozone.

For NO_X, the transformation rates are calculated by the following (equations 2-254 and 2-255 in the CALPUFF user guide):

$$k_2 = 1206\,[O_3]^{1.5}\,S^{-1.41}\,[NO_X]^{-0.33}$$
$$k_3 = 1261\,[O_3]^{1.45}\,S^{-1.34}\,[NO_X]^{-0.12}$$

where,

k_2	is the NO_X to HNO_3 + RNO_3 transformation rate (percent/hour)
k_3	is the NO_X to HNO_3 (only) transformation rate (percent/hour)
$[O_3]$	is the background ozone concentration (ppm)
S	is a stability index ranging from 2 (unstable) to 6 (stable)
$[NO_X]$	is the plume NO_X concentration (ppm)

In the NO_X transformation scheme, RNO_3 represents organic nitrates and is a sink for NO_X since the transformation is irreversible – RNO_3 does not react further in this scheme, and is not subject to wet or dry deposition. At night, the NO_X transformation rate defaults to a constant value of 2.0% per hour. After HNO_3 (nitric acid) is formed from the oxidation of NO_X, the MESOPUFF-II mechanism estimates the formation of particulate nitrate by the reaction of nitric acid and ammonia. This reaction is reversible and is a function of temperature and relative humidity.

The CALPUFF model does not simulate the interaction of puffs; in other words, each puff does not “know” about the number or characteristics of other puffs from other sources that may be nearby. The puff is informed of the state of the atmosphere during transport through the specification of ozone concentrations (used in the transformation rate equations) and background concentrations of ammonia. Ammonia concentrations are used to calculate the equilibrium between nitric acid and particulate nitrate. For the Phase I and Phase II modeling, both platforms used hourly surface ozone concentrations, derived from AIRS data, as input to CALPUFF to calculate transformation rates.

The availability of ammonia to react with both SO_4 and NO_3 to form fine particulate matter is an issue that requires special consideration. CALPUFF first assumes that ammonia reacts preferentially with sulfate, and that there is always sufficient ammonia to react with all of the sulfate present within a single puff. Once particulate sulfate has been formed, CALPUFF performs a calculation to determine how much ammonia remains and is available for reaction with NO_3 within the puff. Subsequent formation of particulate nitrate is limited by the amount of available ammonia. In situations where significant puff overlap can occur (such as the multi-source modeling conducted here), the individual puff computation can result in the over-prediction of particulate nitrate formation since available ammonia may not be sufficient to react with the total quantity of nitrate due to the combined impacts of many sources. The POSTUTIL program, part of the CALPUFF modeling system, is capable of re-partitioning the nitric acid/particulate nitrate split to address situations that may be ammonia-limited. Its use is recommended in the CALPUFF sections of BART modeling protocols for other RPOS (e.g. VISTAS, CENRAP). The latest version of POSTUTIL (released April 14, 2006) is currently being evaluated for application in MANE-VU.

Both wet and dry deposition fluxes are calculated by CALPUFF, based on a full resistance model for dry deposition and the use of precipitation rate-dependent scavenging coefficients for wet deposition. Pollutant mass is removed from the puff due to deposition at each time step.

CALPUFF has numerous options to control the way in which transformation, deposition, and concentrations are calculated. It also contains a complex terrain module based on the CTDMPLUS treatment of terrain. For the present modeling analyses, most options were set at “default” values, including the MESOPUFF II transformation scheme and the treatment of terrain. Several sensitivity studies were carried out with the VTDEC platform to examine the performance of different approaches to calculating the SO_2 to SO_4 transformation rate, including the use of user-defined diurnal variations. As described further in Section D.2.1.1, the overall effect of different chemistry approaches showed did not appear to be significant enough, or the underlying basis of the approach was not well established enough, to depart from the defaults used for the model runs that are reported in this appendix.

Additional, platform-specific details of the implementation of CALPUFF are contained in the following sections.

D.2. VT DEC CALMET/CALPUFF Platform

CALPUFF_v5.711_030625 BETA version was downloaded and compiled for use on the domain shown in Figure D-1 which contains some or all of 34 states in the eastern U.S and portions of southeastern Canada. The model source code had to be re-compiled using Lahey Fortran 95 after changing parameter settings. These changes allowed large numbers of emission sources to be modeled together, hourly ozone inputs from more than 500 ozone monitoring sites to be used, input of hourly met data from a comprehensively large number of surface met stations (ASOS), and data from more than 1000 precipitation stations to be used. As finally configured for Phase I modeling which was conducted during 2004, the VT CALPUFF platform was able to handle up to 2,000,000 puffs on the domain simultaneously. However, soon after the initiation of modeling runs during Phase I it was found to be counter-productive to model very large sets of sources together in one run due to the run-time involved. It also proved to be impossible for the model to handle the complete set of all sources, even with 2,000,000 puffs allowed on the domain at one time, since during summertime periods when transport across the domain is less rapid than at other times, more than that number of puffs remained on the large domain being used. Consequently, a procedure was developed by which all EGU point sources modeled were modeled as individual sources in separate runs, and groups of smaller point sources, groups of area sources (based on county boundaries or on 20 km sized area source squares), and groups of area sources representing on-road and non-road mobile emission patterns by county were modeled on a state-by-state run basis. The post-processing software (CALSUM) available for use with CALPUFF output was used to combine impacts from all source categories. This procedure was also used in the follow-up Phase II modeling carried out during 2005.

Aside from the 3-dimensional meteorological fields required to run CALPUFF (described in the CALMET discussion above and detailed for the VT application below), the primary inputs needed by CALPUFF are the temporal and spatial emissions data for all air pollutants to be modeled, as well as information related to the stationary point, mobile, and area categories of sources that emit these pollutants. In addition, the transformation, deposition and dispersion parameter settings and flags mentioned above needed to be selected. Discussion of the platform-specific parameters and settings used for these CALPUFF runs is included in section D.2.1 describing the emissions used in the CALPUFF dispersion modeling and section D.2.2 describing data validation and settings used in the CALMET meteorological modeling.

D.2.1. VT DEC Emissions Preparations

This section describes the development of the emissions input information used by VT DEC in both the Phase I and Phase II CALPUFF modeling. The objective of the VT DEC modeling with CALPUFF is specifically to quantify and rank the relative impact on the sulfate component of regional haze attributable to sulfur dioxide emissions from individual large stationary point sources and from collective emissions of sulfur dioxide from individual states at specific receptor locations in the MANE-VU RPO. Achieving this modeling objective was planned as a 2-Phase modeling exercise. The year 2002 was chosen for modeling since it represents a year for which extensive measurement data is available (NESCAUM, 2004), it is within the five-year time period being used to characterize regional haze baseline levels at Class I areas in MANE-VU, and several other contribution assessment techniques are focused on this time period. The ultimate objective involves running CALPUFF with all sulfur dioxide emissions as accurately represented as possible within the domain for the entire year of 2002 and through comparison of ambient measured sulfate (possibly also deposited sulfur) to predicted impacts, to establish that the platform is producing acceptable overall results. Once this “validation” of the modeling system is established, impacts from the individual stationary point sources and from the individual states can be calculated.

Because quality-assured 2002 emissions data for all categories of sulfur dioxide emissions was not yet available in early 2004 when this modeling exercise was initiated, a Phase I modeling objective was established. This objective was to create a working, semi-validated CALPUFF modeling platform using actual 2002 hourly continuous emissions monitoring system (CEMS) data for the large electric generating units (EGUs) in the domain and utilizing 1999 National Emissions Inventory (NEI) data for all other stationary point sources as a surrogate until 2002 NEI data became available. The CEMS data is more time-resolved (hourly average rates) than the NEI data (annual average hourly rate). In the Phase I modeling, only stationary point sources of sulfur dioxide were included in the Vermont CALPUFF runs and, as noted, emissions used were not contemporaneous with the actual year 2002 for all these sources. During Phase II, which began in February 2005, contemporaneous 2002 sulfur dioxide emissions data was used for all source categories, including small stationary point sources, “area sources” and “mobile sources” of sulfur dioxide and nitrogen oxides extracted from the regional planning organization emission inventories developed under the auspices of the RPOs in MANE-VU, MWRPO, and VISTAS. Phase II modeling also involved the utilization of slightly adjusted NWS-based meteorological fields (particularly the first quarter met fields were re-produced with some adjusted assumptions in CALMET).

In addition to more general sensitivity runs exploring model input assumptions applied to the full set of CEMS emission sources on the domain, sensitivity runs were conducted on only a few representative CEMS sources in the initial stages of Phase II modeling by VTDEC. These selected source runs included a sensitivity check on the use of different dispersion settings. The default dispersion setting from the CALPUFF model is utilized when the parameter MDISP is set equal to 3. This causes the PG dispersion coefficients for rural areas (computed using the ISCST multi-segment approximation) and the MP coefficients for urban areas to be used. This was the setting used in Phase I modeling. An additional run was done for a selection of representative CEMS sources using the setting MDISP set equal to 4. This causes the CALPUFF model to calculate dispersion coefficients for rural areas by using the MESOPUFF II equations, and otherwise uses the same MP coefficients for urban portions of the domain. It was found that using MESOPUFF II dispersion coefficients did not show appreciable changes in impacts at the 72 standardized receptor locations identified for model evaluation, therefore subsequent to these initial sensitivity runs, only the setting MDISP=3 was utilized in the Phase II modeling conducted by VTDEC. Other aspects of the sensitivity runs conducted on the entire set of CEMS emission sources are discussed below under the CEMS data section of this report.

D.2.1.1. CEMS Data

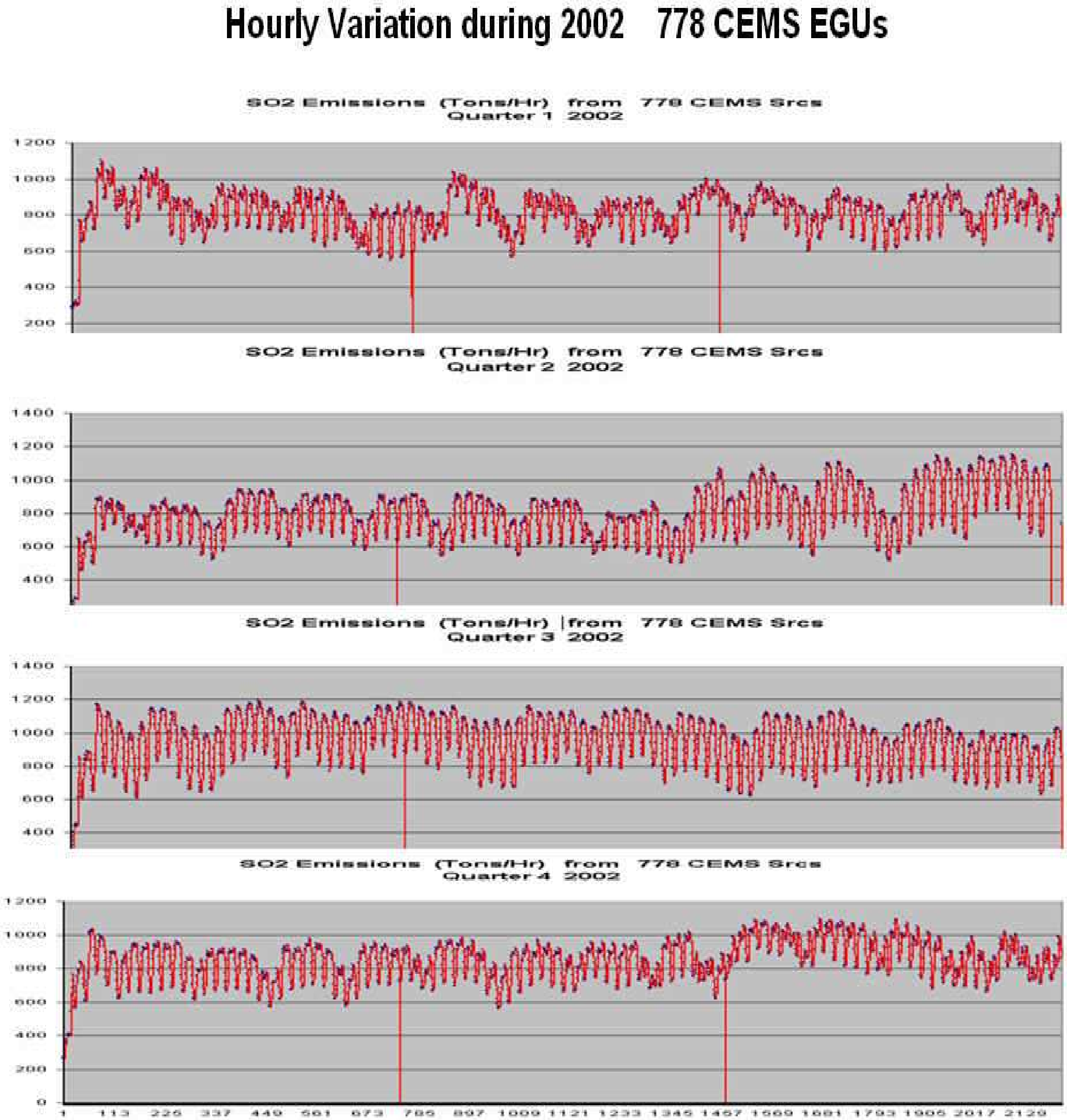
EGUs subject to the reporting requirement for hourly CEMS data for sulfur dioxide contained in Title IV of the Clean Air Act Amendments of 1990 (Acid Rain Program) have been submitting data since 1995. The raw data files submitted to EPA in fulfillment of this requirement on a quarterly basis are routinely made available to the public via the internet. The data files may be found at the following URL:

http://www.epa.gov/airmarkets/emissions/raw/index.html

Submission of the hourly data is in what is called EDR format. The EDR format has undergone some changes over time. For year 2002 data, the format utilized is generally EDR Version 2.1 which was required for all “Acid Rain Program” facilities beginning on April 1, 2000. Some additional CEMS reporting EGUs may not have begun using EDR Version 2.1 until after May 1, 2002 based on requirements for units subject to the NO_X SIP call and NO_X Model Trading Rule, before which EDR Version 1.3 may have been used. The changes and/or additions to requirements between these versions generally do not complicate the extraction of sulfur dioxide hourly data from the database. Differences involved relate primarily to the nitrogen oxides emissions reporting. For extracting emissions data from the Acid Rain CEMS database files, VTDEC created procedures which extracted both the sulfur dioxide and the nitrogen oxides emissions information along with unit and facility stack parameters (as available in the database).

Important constraints exist to running sequential quarterly variable hourly emissions data with the CALPUFF model. The CALPUFF model can accept two forms of input emissions data: (1) constant average hourly data which is input into the model through lines of entry within the “control file” for each stack emission point where each entry has a constant emission rate for all hours during the modeling period (VT chose to run separate runs for each quarter during 2002), and (2) variable hourly data which is input into the model through an entirely separate file structured to allow each hour during the time period to have a different emission rate and a different stack velocity. These separate files for variable hourly emissions will be referred to as “PTEMARB” files after the default name given in the model’s guidance document. VTDEC determined through some sensitivity testing, that in random cases tested, use of an average hourly emission rate for the entire time period modeled does not always produce the same maximum short-term (hourly or 24-hourly) impact at a random receptor than use of variable actual hourly emissions during the time period. For this reason VTDEC decided that it wanted to utilize the variable hourly CEMS data for any stationary point sources for which it was available from the Acid Rain CEMS database. The hourly variability of the set of CEMS EGU sources modeled in Phase I for the year 2002 can be seen in Figure D-2.

Figure D-2. CEMS EGU SO_2 Emission Hourly Variability during 2002



In order for output from multiple sequential modeling periods (4 quarters for example) to be as complete as possible, without ramp up between each of the periods modeled, CALPUFF has a feature which allows preservation of the “state” of all puffs on the entire domain at the end of each modeled period. This allows the model to continue running sequentially, with the initial puff state for the next period the same as the end puff state of the last period’s run. Model output for all hours of the entire year covered by four quarters run separately is usable for evaluation in this mode. However, in order to utilize hourly variable emission inputs with this feature, because the puff “state” depends on puffs associated with each source and each hour, the number of sources with hourly data contained in each PTEMARB file for each of the quarters involved must remain exactly the same. Also, it was found by VTDEC that utilization of the CALPUFF BETA version dated June 25, 2003 was necessary if input of hourly variable CEMS emission rates using a PTEMARB file was desired.

During Phase I, VTDEC first examined the entire listing of EGUs in the CEMS database for each quarter of 2002 to determine a common set of units reporting for all four quarters. We also removed those units which were not located within the domain. An examination of the 2002 CEMS data on the EPA website indicates that for the entire U.S., quarter 1 has 2646 data files, quarter 2 has 3161, quarter 3 has 3340, and quarter 4 has 3017. However, after applying the constraints listed above and limiting selection to those sources which had non-zero SO_2 emissions during at least one hour in each quarter, 778 common units (or combined units as reported) were identified and extracted. During Q/A on the source emission files, the initial procedure used was determined to be somewhat too restrictive in that it missed 8 additional EGUs which had reasonably significant SO_2 emissions in only three or less of the quarters. Hourly variable emission PTEMARB files for these eight additional EGUs were included in the final stages of Phase I modeling. As Phase II modeling was initiated, it became clear that a further error in the extraction routine related to nitrogen oxide emitting EGUs was discovered and the final set of EGUs for which CEMS data was used to develop inputs for Phase II CALPUFF modeling included a total of 869 different electric generating units.

In most cases, the CEMS information being reported by a source applies to a single EGU at a facility associated with a single stack or emission point. In many cases, however, the reported information represents the combined emissions for between one and five EGUs at a facility. In these cases emissions for each unit are reported separately, but some of the stack or emission point information is common. We extracted the reported hourly SO_2 and NO_X emissions data for each of the combined units and created an hourly sum from all the units included in the raw data file. Thus for more than 200 of the 869 modeled points (represented by a stack), the mass emission of pollutants modeled is actually the sum of emissions from a combination of two or more EGUs at a facility.

Information characterizing how the emission occurs at each emission point (stack height, stack diameter, stack exit velocity, stack temperature, and stack base elevation) are necessary inputs required by CALPUFF. The CEMS database generally has data fields allowing calculation of all but the stack temperature. A default stack temperature of 422 degrees K was used for VTDEC modeling during Phase I. This assumed stack temperature was also used for all CEMS points modeled during Phase II. This assumption affects the height of plume transport in the long range transport situations being modeled. In cases where there were missing values in the reported data for stack exit velocity, a default value which was the average of all the reported values in the CEMS database extracted was used (14.67 m/sec based on 3,785,000 values reported in the data for the initial 778 EGUs extracted during Phase I). In cases where stack height or diameter was missing, a two step process was followed. First, a database comprised of Utility ORIS codes and 1990 National Emissions Data with stack parameters was searched to match the ORIS code and extract the information if available. If this did not produce a usable stack height or stack diameter, 150m was used for stack height and 6m was used for stack diameter.

Stack base elevations were determined from the model terrain created by CALMET pre-processors and the lat/lon location of the EGU point which was always available in the CEMS database.

To rank the individual stationary point sources with the largest ambient sulfate impact at receptors, it proved useful to structure modeling input files in a way such that a single source's impacts could be distinguished separately from all others. Post-processing routines available for use with CALPUFF output (CALSUM) allow individual output files to be combined into composite output files providing combined impacts at the receptors. This post-processing works properly if there is compatibility between the model results running all sources together with summing the model results from many individual source runs. For the sulfur chemistry involved, this assumption is entirely reasonable. Although nitrogen chemistry does not prove so amenable to this assumption, there are ways to post-process the results to obtain more realistic partitioning of nitrogen compounds predicted. As previously mentioned, the primary objective of the Vermont modeling study is to evaluate sources of sulfur emissions and their influence on ambient sulfate concentrations at Class I areas, therefore we were not so concerned about the predictions for ambient nitrogen at these receptors. While sulfur will utilize available ammonia preferentially, leaving only excess ammonia available for nitrogen reactions, sensitivity runs using an assumed background ammonia concentration of 1 ppb for all 12 months of year did not show any significant difference in the sulfate modeled when sources were run together versus when they were run individually.

Sensitivity Runs Conducted Prior to Final Phase II Model Runs

Prior to Phase II final runs, a relatively comprehensive sensitivity and validation process was conducted examining several potential variations in CALPUFF input file assumptions about rate of conversion from gaseous sulfur dioxide to particulate sulfate forms. Sensitivity to diurnal variability in percent conversion rates was tested. In addition to these diurnal variability sensitivity runs, a single run was conducted which assumed only domain boundary conditions and no sources internal to the domain. This allowed us to test the sensitivity of results in various portions of the domain to background SO_4 values transported into the domain and temporal changes in these.

Sensitivity runs were only conducted for the CEMS variable hourly emission EGUs modeled individually which were then summed to show combined impacts for the total of all 869 stack points. For Phase I modeling it had been concluded that running individual sources in separate CALPUFF runs and combining the results together using CALSUM processing routines provided by EarthTech (the developers of the CALPUFF system) was appropriate for the ambient sulfate assessment which is the primary objective of this VTDEC modeling work. The additional sensitivity runs conducted during Phase II did not change our conclusion in this regard.

The most comprehensive aspect of the sensitivity runs conducted during Phase II related to how the assumptions estimating rate of chemical conversion from sulfur dioxide gas to sulfate particle form affected the predicted impacts at the receptors. Five different scenarios were utilized. The first scenario (ORIGc) used the standard default assumptions from CALPUFF's January 2000 User's Guide. The default assumes a constant conversion rate at night throughout the entire time period of the run (0.2% per hour) and daytime rates based on MESOPUFF II chemistry. This initial Phase II version of the modeling runs for CEMS sources (ORIGc) was essentially the same as the Phase I run except for the fact that instead of leaving the night-time conversion rate at 0.2% for all four quarters of the year, scenario ORIGc changed the default rate in each quarter. 1st quarter rate was set at 0.1% per hour, 2nd quarter rate at 0.2%, 3rd quarter rate at 0.3%, and 4th quarter rate at 0.2%. Other differences between this base run for Phase II and the Phase I run were the result of an increase in the number of CEMS sources from 778 to 869 and a revised Quarter 1 CALMET wind-field treatment which corrected a bias in the 750 mb wind speeds for the 1st Quarter that was discovered while analyzing Phase I runs.

Four other scenarios were run. Three of these incorporated user-specified SO_2 to SO_4 conversion rates which were input into the model through an external file. These three runs also added an estimate of direct SO_4 emissions for the CEMS sources. A direct sulfate emission rate for each of the EGUs, estimated to be 3% of the total mass of SO_2 emission each hour was incorporated into the input files for each CEMS source. The fourth run involved only the addition of direct SO_4 emissions, with no change to the conversion rate chemistry. The direct SO_4 emission added was thought to be a reasonable estimate based on a number of papers in the literature concerning power plant plume studies using aircraft and theoretical quantification of sulfite (SO_3) and H_2SO_4 in exhaust streams exiting power plant stacks. The 2nd thru 5th sensitivity runs were labeled DIRso4, CHEM2, CHEM3, and finally CHEM4, run in that order. The DIRso4 run was comparable to the ORIGc run except for addition of the direct SO_4 emissions. For the three runs labeled CHEM2, CHEM3, and CHEM4, flags were set to cause CALPUFF to read the appropriate user-supplied CHEM.DAT file which contained diurnal variation in hourly chemical conversion rates which were the same for each day during a quarter but changed by quarter.

In the first of the three user-specified diurnal rate variation scenarios (CHEM2), rates were based on information contained in informal guidance included with the HYSPLIT4 SO_2/SO_4 Chemistry Module developed as part of an experimental package by NOAA Air Resources Laboratory staff (Draxler, 29 August 2003 Readme.txt file which was attached to the downloaded software). The CHEM3 scenario used similar diurnal patterns for rates of conversion as CHEM2 but roughly doubled the rates uniformly. In all three of these scenarios exploring the effect of hourly conversion rate the same assumptions for direct SO_4 emissions were incorporated as were included in the DIRso4 scenario. The last scenario run (CHEM4) used rates of conversion roughly halfway between the CHEM2 and CHEM3 scenarios. Table D-1 below shows the diurnal hourly SO_2 to SO_4 conversion rates in percent per hour for these sensitivity runs.

Table D-1. Transformation Rates of gaseous SO_2 to particulate form SO_4 used in VTDEC Sensitivity Run Scenarios

Diurnal %/Hour Rates of Conversion of SO_2 to SO_4 used in VTDEC CALPUFF Phase II Sensitivity Runs																								
Scenario	**Hr 01**	**Hr 02**	**Hr 03**	**Hr 04**	**Hr 05**	**Hr 06**	**Hr 07**	**Hr 08**	**Hr 09**	**Hr 10**	**Hr 11**	**Hr 12**	**Hr 13**	**Hr 14**	**Hr 15**	**Hr 16**	**Hr 17**	**Hr 18**	**Hr 19**	**Hr 20**	**Hr 21**	**Hr 22**	**Hr 23**	**Hr 24**
Quarter 1																								
ORIGc	**Default CALPUFF setting: MESOPUFF II transformation rates used in Day-time Night-time rate constant 0.1**																							
DIRso4	**Default CALPUFF setting: MESOPUFF II transformation rates used in Day-time Night-time rate constant 0.1**																							
CHEM2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.7	0.8	0.8	0.8	0.7	0.6	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1
CHEM3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.8	1.2	1.4	1.6	1.6	1.6	1.4	1.2	0.8	0.4	0.2	0.2	0.2	0.2	0.2	0.2
CHEM4	.15	.15	.15	.15	.15	.15	.15	0.3	0.6	0.9	1.0	1.2	1.2	1.2	1.0	0.9	0.6	0.3	.15	.15	.15	.15	.15	.15
Quarter 2																								
ORIGc	**Default CALPUFF setting: MESOPUFF II transformation rates used in Day-time Night-time rate constant 0.2**																							
DIRso4	**Default CALPUFF setting: MESOPUFF II transformation rates used in Day-time Night-time rate constant 0.2**																							
CHEM2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.8	1.2	1.6	2.0	2.0	2.0	1.6	1.2	0.8	0.4	0.2	0.2	0.2	0.2	0.2	0.2
CHEM3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.8	1.6	2.4	3.2	4.0	4.0	4.0	3.2	2.4	1.6	0.8	0.4	0.4	0.4	0.4	0.4	0.4
CHEM4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6	1.2	1.8	2.4	3.0	3.0	3.0	2.4	1.8	1.2	0.6	0.3	0.3	0.3	0.3	0.3	0.3
Quarter 3																								
ORIGc	**Default CALPUFF setting: MESOPUFF II transformation rates used in Day-time Night-time rate constant 0.3**																							
DIRso4	**Default CALPUFF setting: MESOPUFF II transformation rates used in Day-time Night-time rate constant 0.3**																							
CHEM2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6	1.3	2.0	2.6	3.0	3.0	3.0	2.6	2.0	1.3	0.6	0.3	0.3	0.3	0.3	0.3	0.3
CHEM3	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.2	2.6	4.0	5.4	7.0	7.0	7.0	5.4	4.0	2.6	1.2	0.6	0.6	0.6	0.6	0.6	0.6
CHEM4	.45	.45	.45	.45	.45	.45	.45	0.9	2.0	3.0	4.0	5.3	5.3	5.3	4.0	3.0	2.0	0.9	.45	.45	.45	.45	.45	.45
Quarter 4																								
ORIGc	**Default CALPUFF setting: MESOPUFF II transformation rates used in Day-time Night-time rate constant 0.2**																							
DIRso4	**Default CALPUFF setting: MESOPUFF II transformation rates used in Day-time Night-time rate constant 0.2**																							
CHEM2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.7	1.0	1.3	1.5	1.5	1.5	1.3	1.0	0.7	0.4	0.2	0.2	0.2	0.2	0.2	0.2
CHEM3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.8	1.4	2.0	2.6	3.0	3.0	3.0	2.6	2.0	1.4	0.8	0.4	0.4	0.4	0.4	0.4	0.4
CHEM4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6	1.0	1.5	2.0	2.3	2.3	2.3	2.0	1.5	1.0	0.6	0.3	0.3	0.3	0.3	0.3	0.3

A PTEMARB input file was created for each quarter of 2002 for each of the 869 CEMS emission points. The emission points are identified by an ID created from the EGU ORIS facility code and a descriptor of the unit or units for which the hourly emission applied. These individual 869 CEMS EGU emission points were run separately for the full year 2002 (it takes 4 minutes per CEMS emission point to complete the full year run on a 3.2 Ghz PC with 1 GB RAM). In testing the sensitivity to the different rates of conversion, each of these EGU input files was run for the complete year of 2002 a total of five times. All other groups of small point sources, area sources, and mobile sources modeled were only run one time using the default (ORIGc) sensitivity conditions. A sixth set of results was independently produced by incorporating transport into the domain using an hourly estimate of sulfate formed external to the domain boundaries. A variable boundary file was produced by examining measurements along the boundaries and wind directions indicated by the CALMET meteorological fields. Results from this "background SO_4" estimate could be added to any of the sensitivity runs for the CEMS sources. As of the writing of this report, final evaluation of these sensitivity runs is still being conducted and there may be further refinement of some of these scenarios in the future. After our initial interpretation of the comparative results obtained for the various sensitivity runs, we concluded that the differences between them was either relatively minor at almost all locations in the domain, or the assumptions used in the sensitivity scenario were not well enough documented to support utilization of those results over the base case (ORIGc) run results.

In Phase II, the Vermont modeling included small points and most "area" and mobile source categories of emissions whereas these were not modeled during Phase I.

In addition to the CEMS point EGU results, the Phase II results include these additional sources of sulfur dioxide, nitrogen oxides, and $PM_{2.5}$ for most of the states in the domain (inventories for these emissions for some source categories in states on the western boundary of the domain were not complete enough by the time the modeling was conducted.). In making a decision as to the appropriateness of the ORIGc assumptions over others tested for the CEMS point EGU sources, an evaluation was conducted to examine how well the model reproduced the 24-hr sulfate measurements at 22 sites in the northeastern quadrant of the domain when run with all the sources included.

As seen in Figure D-3 and Figure D-4, there were some clear differences between some of the sensitivity runs, primarily in the magnitude of impacts predicted at various receptors. However, the regression of modeled 24-hr SO_4 impact against monitored ambient SO_4 at ground level did not show obvious improvement from the base ORIGc scenario when evaluated at the 22 evaluation sites chosen from the northeastern quadrant of the domain, based on either paired 24-hr comparisons individually or the quarterly averages of those paired 24-hr values at each site (Figure D-5 and Figure D-6). As of the date of this report, the analysis has not been completed adequately to cause us to currently determine that anything other than the default (ORIGc) run was any better at reproducing measured SO_4 ion at the discrete receptors overall. Therefore the results of Phase II modeling with the Vermont CALPUFF platform are being presented based on the ORIGc scenario results which were produced using essentially all default settings for the CALPUFF inputs. There is some potential that this decision could be revised as we have more time to carefully examine the huge volume of information that all the Phase II modeling produced.

Figure D-3. Acadia National Park Modeled 24-Hr SO_4 Ion Comparison to Measurements

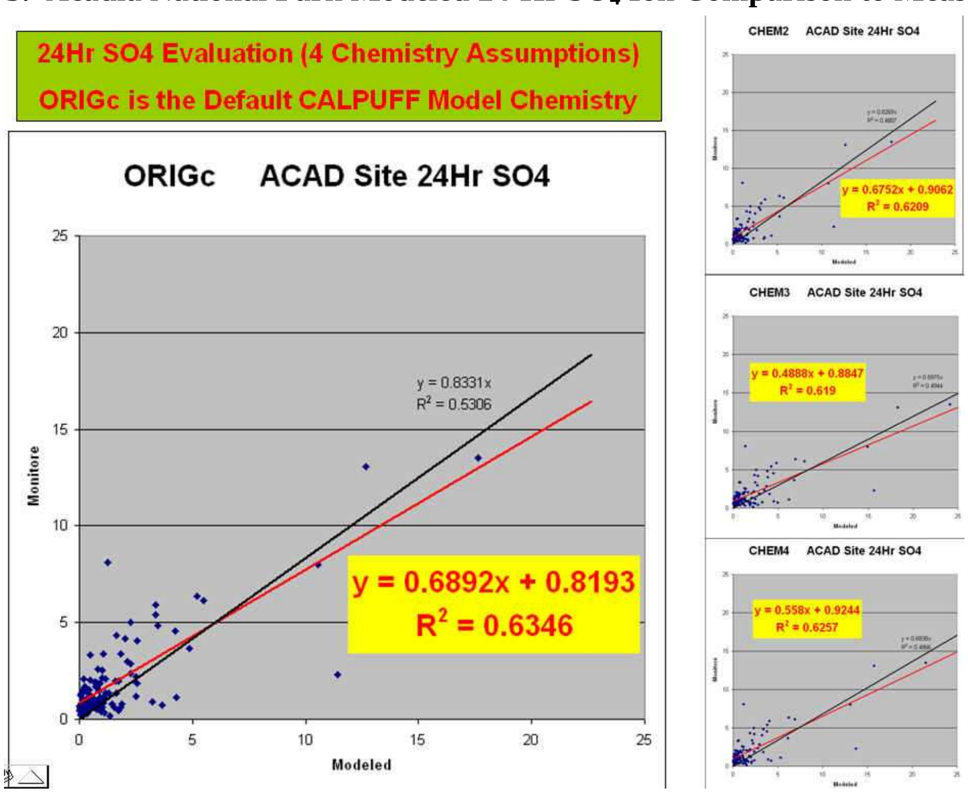


Figure D-4. Lye Brook Wilderness Area Modeled 24-Hr SO_4 Ion Comparison to Measurements

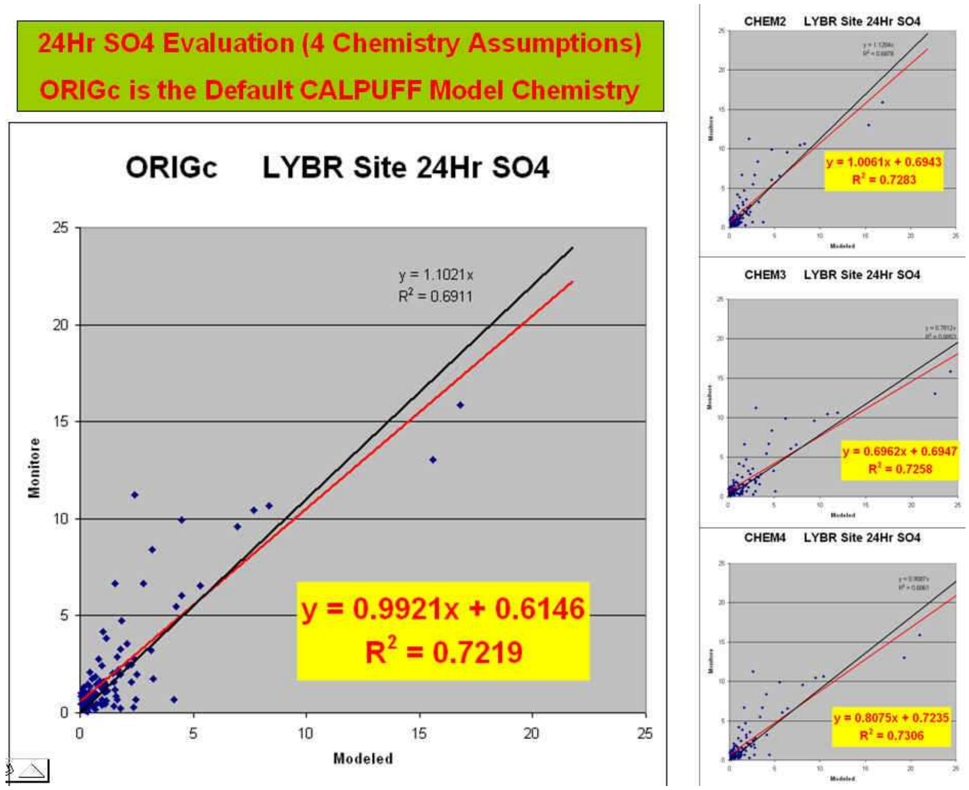


Figure D-5. 22 Northeastern Site Modeled 24-Hr SO_4 Ion Comparison to Measurements

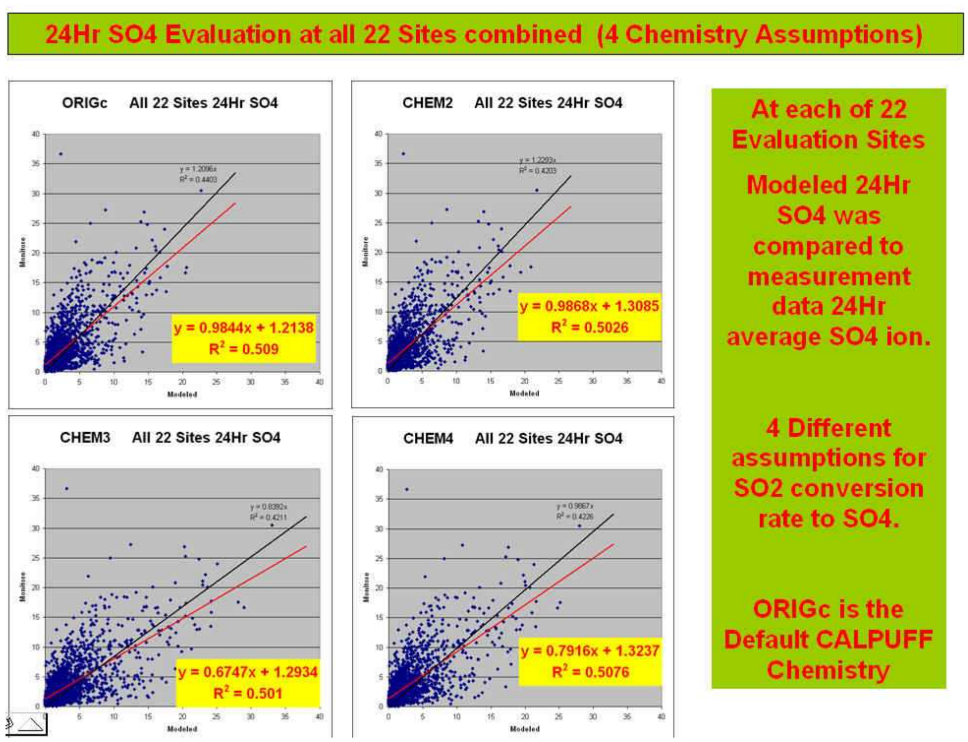
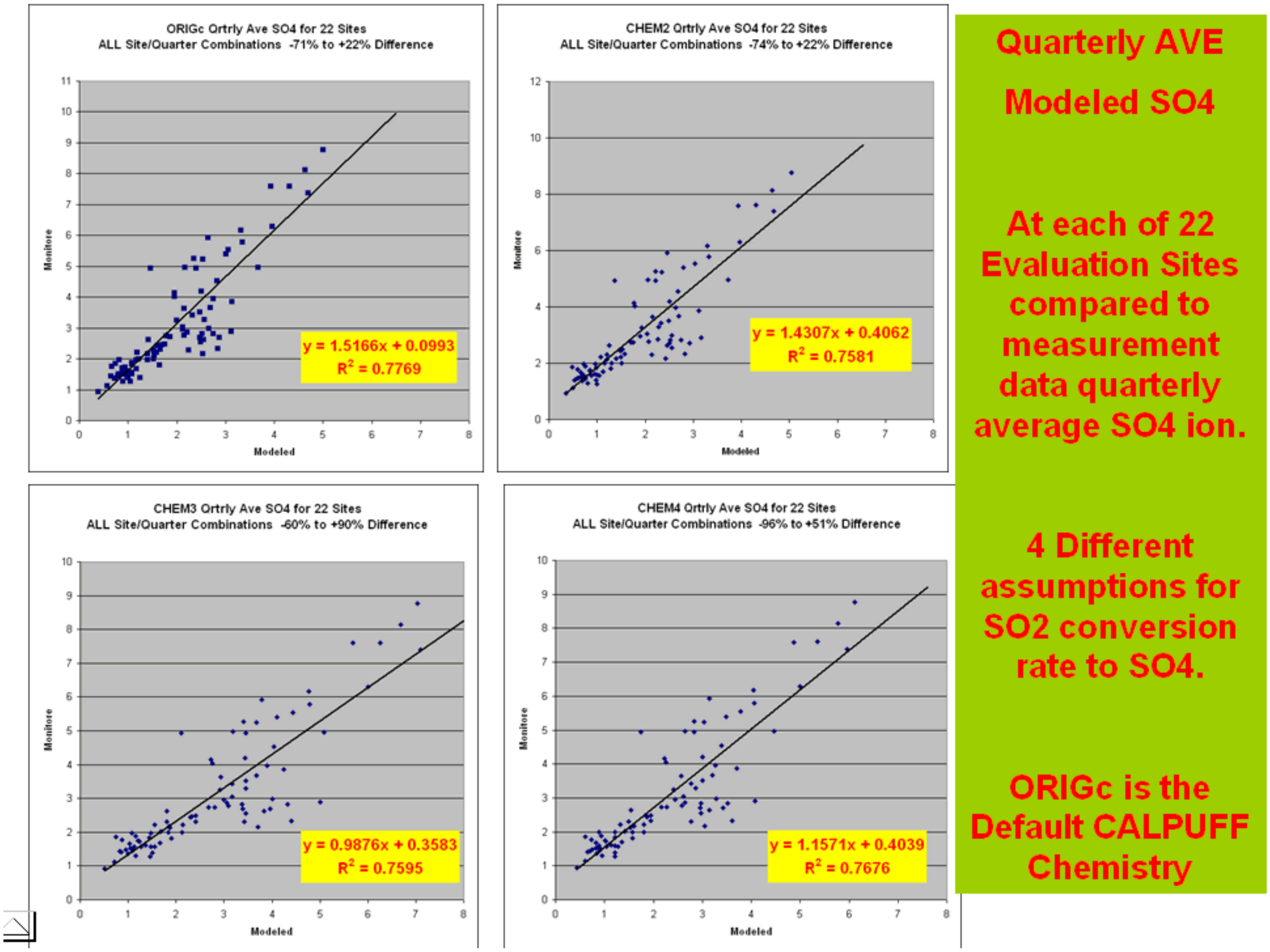


Figure D-6. 22 Northeastern Site Modeled Quarterly Average SO4 Ion Comparison to Measurements



D.2.1.2. RPO Modeling Inventories and NEI Data Used for Non-CEMS Sources

The most complete source of emission data available from states is generally the National Emission Inventory (NEI) which is updated and maintained by EPA on a three-year cycle. The most recent quality-assured data available at the initiation of Phase I modeling was for calendar year 1999. At the end of 2005, year 2002 NEI data was still being reviewed and quality assured. Data incorporated in the NEI for any given year is data that has been submitted to EPA by the individual state regulatory air programs. It routinely includes annual average emissions for sulfur dioxide, nitrogen oxides, and fine particulate matter from both EGUs and non-EGUs located in each state. Data in the NEI may also include emission data for time periods less than annual, such as rates applicable only to several months of the year or typical summer day emissions. The average long-term emission data in NEI includes entries for the same EGUs that are also reporting detailed hourly variable emissions to the EPA maintained CEMS database.

For Phase I CALPUFF point source modeling conducted by VTDEC, the 1999 NEI version 3 (files dated 11/20/03) data was used to supplement CEMS data described above. Data was downloaded from the EPA website in mid-December 2003. A revised version of 1999 NEI version 3 (dated 3/3/04) was posted at some point in 2004, however that updated version was not used in Phase I modeling by VTDEC. The 1999 NEI version 3 data consisted of zipped files with emission data for point sources, area sources, on-road sources, and non-road sources. Phase I modeling by VTDEC was focused on the point source component therefore only the 1999 point source NEI file data was used for the modeling performed by VTDEC during Phase I of the project.

The record structure used for 1999 NEI is NIF version 2. Fortran executable code was developed to extract records from the point source data files based on the file formats specified in NIF version 2. The code was designed to also create text files which placed the NEI data extracted into lines of input formatted to be compatible with CALPUFF control file Input Group 13 format (for large point sources) or Input Group 14 format (aggregated small point sources into area sources). The code repeatedly searched the record files contained in the file "99v3pointascii.zip" which contain stack parameter ("erpoint.txt"), emissions ("empoint.txt"), and facility id ("sipoint.txt") data. The extracted facility and emission point identification information was compared to a target listing of identification codes for EGUs for which variable hourly emissions of sulfur oxides and nitrogen oxides already had been extracted from the CEMS database. Several output files were generated for each of 34 states in the domain. Each output file comprised a subset of emission and stack data formatted in CALPUFF control file input format. The extracted subsets produced during Phase I VTDEC modeling (and later reproduced using RPO databases during Phase II) are described below:

FOR EACH STATE IN THE DOMAIN

1. A subset of NEI sources whose ID matched a CEMS EGU point. Only the $PM_{2.5}$ emissions information was included in the formatted "POINT source" input file, the NEI sulfur oxide and nitrogen oxide emission information was ignored in preference to the CEMS data.

2. A subset of NEI sources with ANNUAL SO_2 emissions greater than 100 Tons for 1999 whose ID did not match any CEMS EGU point. In this case all three pollutant emissions ($PM_{2.5}$, SO_2, and NO_X) were included in the formatted "POINT source" input file.

3. A subset of NEI sources with DAILY SO_2 emissions specifically identified at different rate at the start of the 3rd quarter time period whose ID did not match any CEMS EGU point. In this case all three pollutant emissions ($PM_{2.5}$, SO_2, and NO_X) were included in the formatted "POINT source" input file. When annual CALPUFF run was done, for the 3rd quarter this subset of inputs was substituted for the inputs in subset 2 or subset 4 that were used for the other three quarters in the annual run.

4. A subset of NEI sources with ANNUAL SO_2 emissions greater than 10 Tons for 1999 and located within 100 km of any of 51 receptors identified for the MANE-VU RPO whose ID did not match any CEMS EGU point. In this case all three pollutant emissions ($PM_{2.5}$, SO_2, and NO_X) were included in the formatted "POINT source" input file.

5. A subset of NEI sources with ANNUAL SO_2 emissions less than 100 Tons for 1999 and also not within 100 km of any of the 51 receptors whose ID did not match any CEMS EGU point. In this case all three pollutant emissions ($PM_{2.5}$, SO_2, and NO_X) were aggragated in a formatted "20km x 20km AREA Source" input file appropriate for the location of the point source.

When combined with the 2002 CEMS emission data for SO_2 and NO_X from EGUs, these subsets of emission points derived from the 1999 NEI data represented a reasonable surrogate for all the remaining 2002 non-CEMS point source emissions of SO_2, NO_X, and $PM_{2.5}$ in the domain being modeled. For Phase I CALPUFF runs, each of the state-specific subsets was run in a single run to produce the NEI large point source impacts and the NEI small point source impacts (pseudo area sources) from each state on each of 72 chosen receptors in the domain. The pseudo area sources were run with an assumed initial sigma-z of 5.0 meters and a default emission height of 25.0 meters. In cases where the NEI data permitted the computation of an average stack height for the small sources incorporated into the pseudo area source, the average stack height was used for that area source.

For Phase II modeling, the VTDEC initially intended to utilize the quality assured version of the 2002 NEI. This would have meant that the same software developed to extract non-CEMS source input data from the 1999 NEI could have been used to extract similar data from the 2002 NEI. At the beginning of the Phase II modeling effort (March 2005) there was still no quality assured NEI for 2002; only a draft version was available. In the same time period, each of the regional haze planning organizations (RPOs) had already created draft versions of the RPO inventories that would be used for base-year 2002 CMAQ or other grid-based modeling efforts needed for ozone SIPs (as well as $PM_{2.5}$ and regional haze SIPs) required by states in the eastern U.S. VTDEC decided to re-configure its emission data extraction program codes to be able to access the various RPO emission inventory data files. RPO inventories were accessed from RPO web-sites identified by the MARAMA organization which is coordinating the production of SIP quality emission inventories for states in the MANE-VU and OTC regions and also coordinating exchange of these inventories with other RPOs. Inventories are always being upgraded and changed, so it is likely that the actual inventory files accessed to create modeling inputs used by VTDEC may differ from the latest versions of those inventories. VTDEC believes that the conclusions that can be drawn about sources and relative source and state impacts on visibility in eastern Class I areas due to sulfate aerosol formed secondarily from sulfur dioxide emissions in the domain modeled would not change dramatically should more current non-CEMS RPO source emissions be substituted for modeling inputs used by VTDEC in its Phase II CALPUFF modeling.

Source categories modeled during Phase II were expanded from those modeled during Phase I. In addition to utilizing the expanded set of 869 CEMS EGU hourly source emission inputs, the Phase II VTDEC modeling included all subsets of stationary sources extracted from the RPO inventories in a manner similar to that described above for extraction and identification of non-CEMS point sources modeled under Phase I. On-road and non-road mobile sources and area sources aggregated at the county level were also modeled during Phase II, although in some cases data was not available from particular states in the domain covered by the CALPUFF modeling. Only the largest SO_2 point sources located in portions of Canada within the modeling domain were included. The Canadian sources modeled had to be modeled using reasonable assumptions with regard to stack height and stack exit flow conditions due to inability to obtain this information. The state-by-state emissions of sulfur dioxide, nitrogen oxides, and $PM_{2.5}$ modeled by VTDEC during Phase II are summarized in Table D-2 through Table D-4. Canadian source emissions modeled are summarized on the line labeled CN in these tables.

Table D-2. Summary of SO_2 Emission Inputs for Phase II VT CALPUFF runs

2002 SO2 Emissions Modeled (12,163,466 Tons)

STATE	EGUs using CEMS	RPO Large PT as PT	RPO Small PT 20kmx20km AREA	MOBILE ON-ROAD as CNTY km**2	MOBILE NON-ROAD as CNTY km**2	RPO Area as CNTY km**2
AL	301,262	28,977	31,374	not modeled	4,153	14,725
CT	10,131	1,905	287	1,534	8,149	11,489
DC	1,073	967	20	1,599	1,677	7,940
DE	31,144	5,000	4,043	2,942	18,180	5,744
GA	497,490	18,467	21,107	not modeled	9,074	29,014
IA	125,460	183,377	1,247	not modeled	4,429	not modeled
IL	342,762	142,501	5,329	not modeled	360,917	77,362
IN	720,890	87,818	8,593	not modeled	11,976	98,268
KY	462,012	30,688	34,362	not modeled	80,477	67,317
MA	90,194	11,219	3,416	3,338	9,776	40,421
MD	248,407	34,687	2,634	22,835	121,496	103,098
ME	1,923	20,610	718	2,682	6,620	10,689
MI	319,673	60,963	5,154	not modeled	6,736	23,069
MN	93,895	65,046	5,844	not modeled	5,701	3,990
MS	8	7,914	9,041	not modeled	10,071	176
NC	442,505	54,048	60,887	not modeled	51,775	8,625
NH	41,425	1,923	678	479	3,591	4,416
NJ	46,791	7,820	1,019	5,815	44,682	16,800
NY	216,112	30,184	6,971	9,781	38,960	117,584
OH	1,073,526	59,200	680	not modeled	83,946	22,961
PA	788,130	90,457	22,339	19,417	58,309	112,610
SC	189,252	55,119	60,482	not modeled	21,802	10,134
TN	302,876	84,652	5,607	not modeled	79,963	28,677
VA	224,375	20,362	56,178	not modeled	38,166	35,895
VT	5	874	36	515	25,580	2,322
WI	187,937	61,458	3,367	not modeled	5,616	2,065
WV	489,823	15,775	41,121	not modeled	106,622	71,793
RI	5	0	0	350	5,715	3,795
MO	179,396	not modeled	not modeled	not modeled	not modeled	not modeled
OK	103,734	not modeled	not modeled	not modeled	not modeled	not modeled
KS	125,918	not modeled	not modeled	not modeled	not modeled	not modeled
AR	70,009	not modeled	not modeled	not modeled	not modeled	not modeled
NE	30,536	not modeled	not modeled	not modeled	not modeled	not modeled
TX	39	not modeled	not modeled	not modeled	not modeled	not modeled
SD	11705	not modeled	not modeled	not modeled	not modeled	not modeled
CN	Modeled as PT	592,073	not modeled	not modeled	not modeled	not modeled
	7,770,423	**1,774,084**	**392,534**	**71,287**	**1,224,159**	**930,979**

Table D-3. Summary of NO_X Emission Inputs for Phase II VT CALPUFF runs

2002 Nox Emissions Modeled (18,068,578 Tons)

STATE	EGUs using CEMS	RPO Large PT as PT	RPO Small PT 20kmx20km AREA	MOBILE ON-ROAD as CNTY km**2	MOBILE NON-ROAD as CNTY km**2	RPO Area as CNTY km**2
AL	109,435	17,072	39,769	0	46,530	9,213
CT	5,144	6,141	1,169	63,490	22,916	11,751
DC	402	769	40	52,556	16,453	9,669
DE	9,574	2,067	2,366	72,166	54,509	10,192
GA	139,613	7,729	27,656	not modeled	111,016	18,904
IA	77,015	84,596	122,089	not modeled	41,026	not modeled
IL	167,937	37,988	96,931	not modeled	3,406,188	720,994
IN	241,542	37,336	76,498	not modeled	122,347	44,933
KY	176,107	12,033	38,186	not modeled	618,504	60,897
MA	27,421	15,592	4,543	90,378	50,739	23,217
MD	69,625	22,642	3,351	684,914	255,726	109,333
ME	734	17,905	1,659	39,805	10,671	5,820
MI	109,169	33,434	85,526	not modeled	77,698	23,348
MN	72,834	76,365	105,786	not modeled	59,794	15,136
MS	4,455	3,821	20,316	not modeled	91,412	951
NC	137,313	28,950	56,472	not modeled	590,772	not modeled
NH	6,430	2,261	864	20,687	6,323	6,867
NJ	26,154	17,943	4,177	236,710	103,467	40,161
NY	64,318	33,897	7,130	306,829	131,190	93,606
OH	325,887	9,415	22,666	not modeled	866,257	67,647
PA	174,127	84,165	14,056	607,150	130,801	84,112
SC	79,314	28,244	46,529	not modeled	235,457	14,608
TN	133,278	42,923	73,250	not modeled	747,932	17,289
VA	77,061	25,145	45,621	not modeled	246,970	196,212
VT	228	500	58	11,978	3,785	1,809
WI	87,239	433	36,932	not modeled	63,292	6,807
WV	197,459	15,976	32,954	not modeled	1,418,683	76,908
RI	290	0	0	13,716	4,074	3,185
MO	122,373	not modeled	not modeled	not modeled	not modeled	not modeled
OK	74,219	not modeled	not modeled	not modeled	not modeled	not modeled
KS	84,686	not modeled	not modeled	not modeled	not modeled	not modeled
AR	40,891	not modeled	not modeled	not modeled	not modeled	not modeled
NE	21,978	not modeled	not modeled	not modeled	not modeled	not modeled
TX	2,156	not modeled	not modeled	not modeled	not modeled	not modeled
SD	14,503	not modeled	not modeled	not modeled	not modeled	not modeled
CN	Modeled as PT	147,250	not modeled	not modeled	not modeled	not modeled
	2,880,912	**812,592**	**966,594**	**2,200,379**	**9,534,532**	**1,673,569**

Table D-4. Summary of $PM_{2.5}$ Emission Inputs for Phase II VT CALPUFF runs

2002 PM2.5 Emissions Modeled (3,091,089 Tons)

STATE	EGUs using CEMS	RPO Large PT as PT	RPO Small PT 20kmx20km AREA	MOBILE ON-ROAD as CNTY km**2	MOBILE NON-ROAD as CNTY km**2	RPO Area as CNTY km**2
AL	Modeled as RPO PT	0	13,066	not modeled	3,044	12,873
CT	Modeled as RPO PT	928	678	959	2,705	15,116
DC	Modeled as RPO PT	211	48	900	1,270	8,200
DE	Modeled as RPO PT	207	540	8,998	7,133	15,246
GA	Modeled as RPO PT	0	5,736	not modeled	10,212	25,546
IA	Modeled as RPO PT	0	13,108	not modeled	4,737	not modeled
IL	Modeled as RPO PT	0	1,242	not modeled	354,094	432,882
IN	Modeled as RPO PT	0	12,560	not modeled	12,060	174,177
KY	Modeled as RPO PT	0	4,823	not modeled	38,749	58,087
MA	Modeled as RPO PT	3,540	3,155	8,129	8,080	39,238
MD	Modeled as RPO PT	2,186	4,749	12,701	108,798	235,600
ME	Modeled as RPO PT	10,144	979	10,870	6,161	36,959
MI	Modeled as RPO PT	0	2,701	not modeled	8,056	5,634
MN	Modeled as RPO PT	0	1,159	not modeled	7,019	31,478
MS	Modeled as RPO PT	0	2,666	not modeled	5,495	10,358
NC	Modeled as RPO PT	0	10,736	not modeled	52,353	52,438
NH	Modeled as RPO PT	631	437	349	2,745	11,910
NJ	Modeled as RPO PT	2,396	2,274	3,965	21,792	34,711
NY	Modeled as RPO PT	3,129	3,123	5,642	31,617	120,295
OH	Modeled as RPO PT	166	1,861	not modeled	76,598	29,696
PA	Modeled as RPO PT	12,128	13,938	9,993	55,721	165,612
SC	Modeled as RPO PT	0	13,263	not modeled	18,583	19,289
TN	Modeled as RPO PT	0	27,818	not modeled	52,588	31,248
VA	Modeled as RPO PT	5,567	7,777	not modeled	30,553	118,368
VT	Modeled as RPO PT	309	131	273	2,634	7,621
WI	Modeled as RPO PT	0	40	not modeled	7,364	6,979
WV	Modeled as RPO PT	14,505	3,785	not modeled	106,251	79,642
RI	Modeled as RPO PT	68	116	1,484	417	2,170
MO	not modeled	not modeled	not modeled	not modeled	not modeled	not modeled
OK	not modeled	not modeled	not modeled	not modeled	not modeled	not modeled
KS	not modeled	not modeled	not modeled	not modeled	not modeled	not modeled
AR	not modeled	not modeled	not modeled	not modeled	not modeled	not modeled
NE	not modeled	not modeled	not modeled	not modeled	not modeled	not modeled
TX	not modeled	not modeled	not modeled	not modeled	not modeled	not modeled
SD	not modeled	not modeled	not modeled	not modeled	not modeled	not modeled
CN	not modeled	not modeled	not modeled	not modeled	not modeled	not modeled
	0	**56,115**	**152,509**	**64,263**	**1,036,829**	**1,781,373**

D.2.2. VT DEC Meteorological Preparations

The VT DEC CALPUFF Modeling System uses the 2003 'beta test' version of the CALMET Model on the domain shown in Figure D-1 and described earlier. The vertical grid structure for the VT platform consisted of 8 levels, specified to allow accurate representation of atmospheric conditions in the surface level, transition level, and the free atmosphere.

CALMET runs performed by the VT DEC utilized *National Weather Service meteorological observations only* (i.e. radiosonde measurements for the upper atmospheric representation, Automated Surface Observing Station (ASOS) for the surface, and precipitation observers' measurements). Usage of the meteorological fields computed for this domain are acceptable for transport scenarios which occur above the surface layers, or, as defined by the EPA, long range transport events of greater than 50 kilometers. For these CALMET runs, the geographical processing to produce terrain heights and land use represented in the model was performed per Scire et al. (2000).

D.2.2.1. CALMET model input settings

A progressive model validation procedure (PMVP) – involving repetitive comparison of modeled to measured meteorological quantities as CALMET was run iteratively – was utilized to optimize CALMET model performance. In the following discussion the option settings are divided between 'invariable' settings which were constant throughout (e.g. grid size), and 'variable' settings which are indeterminate until the PMVP is complete. A list of the variable settings is provided below.

The 'Variable' CALMET Settings

The final meteorological fields produced by CALMET for this analysis resulted from comparison of the CALMET output meteorological fields to observations in the progressive model validation procedure. Thus comparison of CALPUFF predicted to monitored concentrations of sulfate was used to select optimal CALMET switch settings. The 'variable' settings primarily control the radial interpolation of meteorological observations as well as the distances at which terrain effects are estimated. The following 'variable' option settings were determined through the progressive model validation procedure discussed in section D.2.2.3:

IEXTRP - Defines extent to which surface wind observations are extrapolated to upper layers.

LVARY - Defines radial interpolation methods of observational inputs, where all observations within a specified radius may be utilized in estimation of wind field at a grid point, or just the nearest observation beyond a specified radial distance from the grid point.

R1,R2 - Defines the relative weighting of the first guess field and observations at each grid point in the domain, where R1 is the distance from an observational station at which the observation and first guess field are equally weighted.

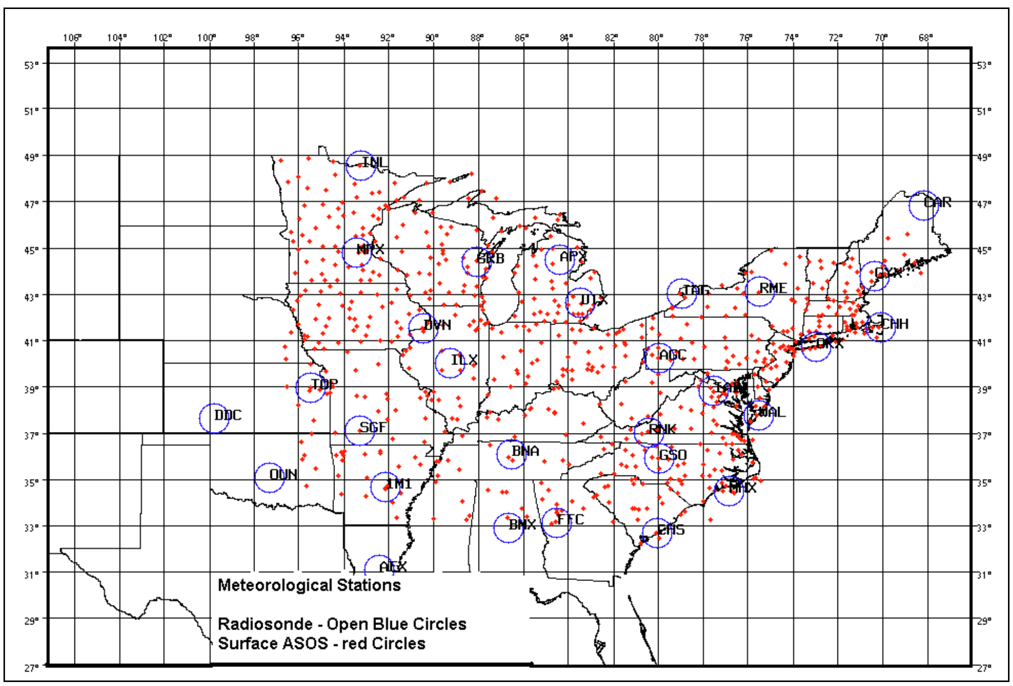
TERRAD – Defines the radius of influence of terrain features in the generation of the first guess field at each grid point within the domain.

D.2.2.2. Production of CALMET Model Inputs

Meteorological data inputs consisted of 684 surface stations, 27 radiosonde stations for upper air representation, 1037 precipitation measurement sites, and 5 overwater (buoy) sites (see Figure D-7).

The surface stations were extracted from the integrated surface hourly observations (ISHO) dataset compiled by the National Climatic Data Center (NCDC). This data set also includes over-water stations, supplementing the 5 buoy site data acquired from a separate database. From all of these sources, 2002 data was extracted and processed in four quarters to allow for reasonable run times. For each meteorological data set, data format conversion and data filling was necessary. The following sections discuss procedures for each data set.

Figure D-7. Surface (ASOS), and Upper Air (Radiosonde), Stations used in the CALMET runs.



Upper Air Radiosonde Data

In order to develop a continuous dataset, a data substitution routine is required in order to fill-in missing radiosonde data. A routine was established to maximized the use of radiosonde data, given that the CALMET model does not always accept radiosonde measurements. If a sounding has a missing level within one of the lowest defined vertical model levels, CALMET will not accept the sounding. To correct this problem, wind or temperature data is taken from the closest level above where data *does* exist and substitutes for the missing datum (usually the lowest 200 meters of the atmosphere). This method is preferable to substituting an entire sounding from a different location. When too much data was missing from a sounding, or the sounding was missing entirely, the surrounding stations were used for substitution.

Surface Meteorological Data

The ISHO surface meteorological observations is a compilation of the automated surface observing stations (ASOS), across North America. Variables that CALMET requires as inputs for the surface level are wind speed, wind direction, ceiling height, opaque sky cover, air temperature, relative humidity, station pressure and precipitation code. Given the parameters available in the ISHO dataset, it was necessary to compute relative humidity. This was done using following the National Weather Service guidance method (NWS, 2006).

Precipitation Data

Because of the large number of precipitation stations and the required format in CALMET input files, preprocessing and preparation of this data set can be time-consuming. For the precipitation data, the flag indicating data validity had to be recoded before the data could be read in by the EarthTech preprocessors.

Geographical Data

Using a set of programs for preprocessing geographical data (available from Earth Tech including terrel, ctgproc, ctgcomp, and makegeo) the land use and terrain elevations for the chosen domain were developed (Shown in Figure D-8 and Figure D-9). From this information CALMET then produces related physical fields that are necessary for the CALPUFF pollutant predictions including surface roughness, albedo, bowen ratio, soil heat flux, and leaf area index. Figure D-10 and Figure D-11 portray fields of friction velocity and the leaf area index for the domain.

Figure D-8. Smoothed Terrain Heights Utilized by VT DEC CALMET.

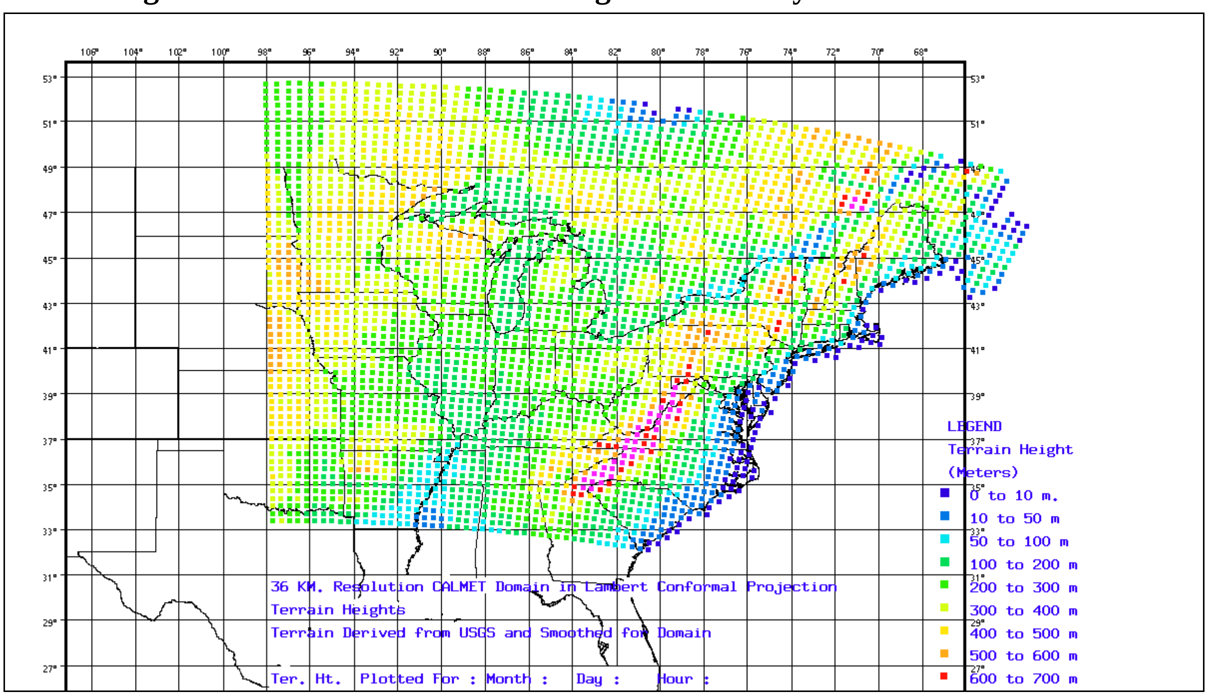


Figure D-9. Land Use Utilized by VT DEC CALMET.

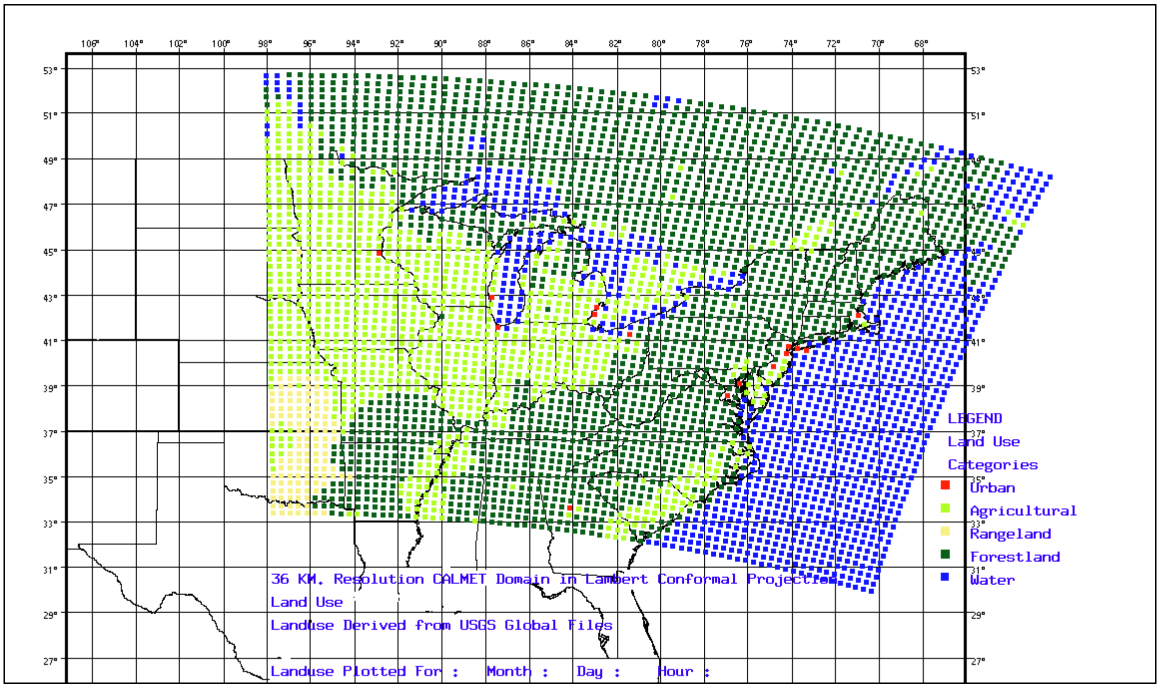


Figure D-10. Friction Velocity Field Produced by VT DEC CALMET.

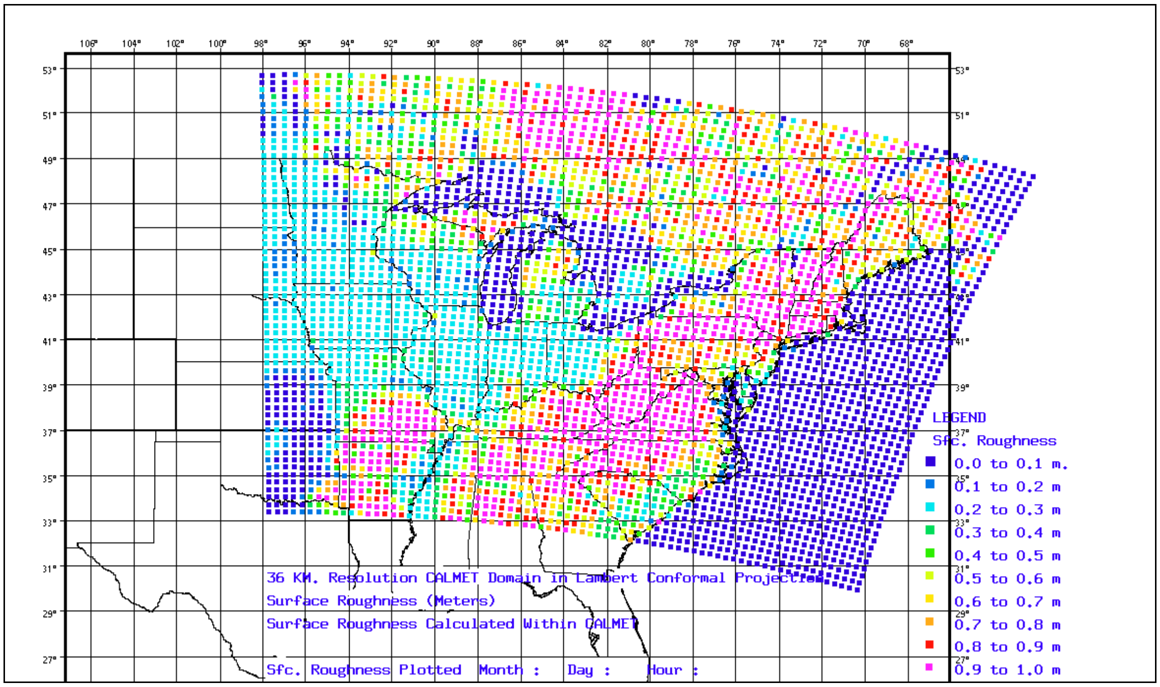
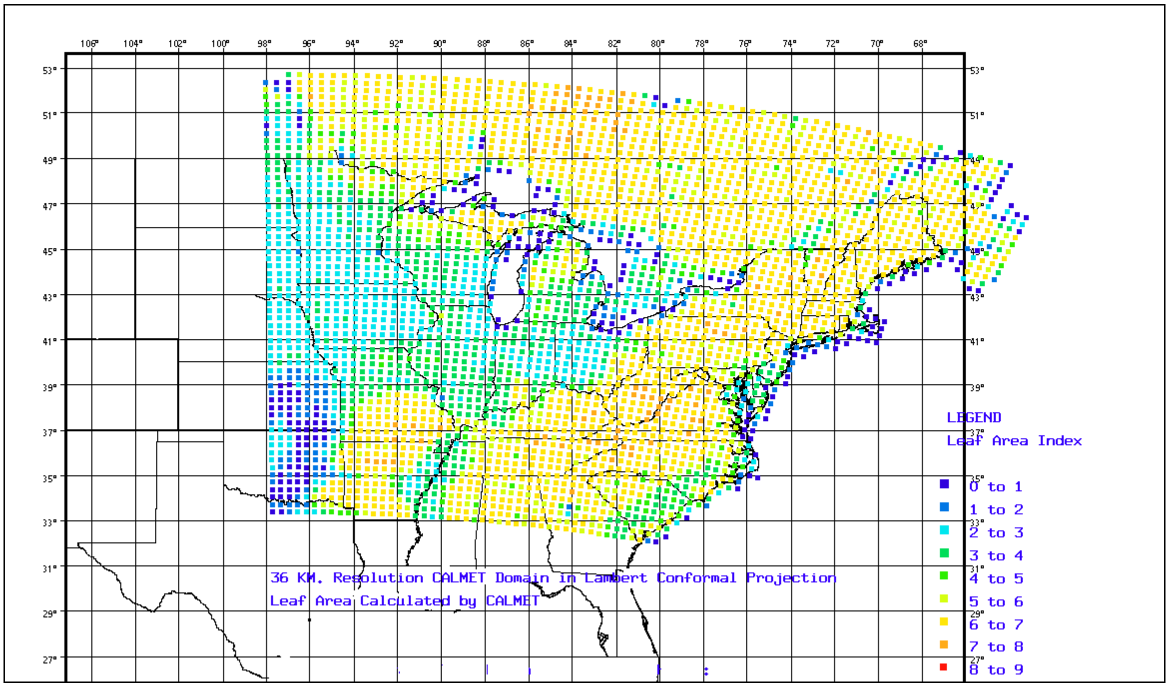


Figure D-11. Indexed Leaf Area Field Produced by VT DEC CALMET.



D.2.2.3. Data Validation

An iterative data validation/optimization process was used to determine the best mode to run CALMET in, and will be used for verification of the accuracy of the final meteorological fields produced to run CALPUFF during Phase II. Phase I data validation procedures involves only comparison of CALMET predicted meteorological fields to observations.

Validation Method Used to Determine Optimum CALMET Parameter Settings

The fundamental physical processes affecting long-range transport of air pollutants related to CALMET option settings are:

- Transport
- Dispersion
- Chemistry (not evaluated for CALMET usage).

With respect to long-range transport, model performance on the order of 200 kilometers or more, is most important. Therefore the CALMET runs must be able to accurately simulate transport above the surface layer. Thus, in order to minimize geographical effects on surface wind flows simulated in the production of the “Step One” windfield in CALMET option settings were intended to minimize CALMET physics and produce wind fields by interpolating measured data from the NWS meteorological observations. A major concern for this application, where a very large domain was employed, was accurate representation of the meteorological fields at the domain edges, such as over water and over Canada.

When utilizing ‘observations only’ (i.e., no prognostic model inputs) mode for CALMET, ‘variable’ option settings must be set uniquely for each application. These option settings primarily involve interpolation of the observations, defining the ‘weighting’ of the observations in relation to the first guess field, and defining the extent to which surface observations may be weighted at levels above the surface. These settings include IEXTRP, LVARY, R1,R2, and TERRAD which were defined previously. The validation procedures consisted of a *visual examination* of these fields for ten day periods during each quarter of the year *prior* to the progressive model validation procedure involving comparison to observations. Visual examination also occurred as a final verification of fields produced to be utilized by CALPUFF. Figure D-12 and Figure D-13 are snapshots of the wind fields examined in movie form for a daytime and nighttime wind field for a summer day.

In the progressive model validation procedure, comparison to observations and quantification of accuracy were performed. Because this evaluation examines wind fields above the surface layer, radiosonde data was utilized. A radiosonde station located at 38.9 North Latitude and 77.5 West Longitude was chosen in a region of the domain where its exclusion would be acceptable because of the density other nearby radiosonde stations. This station then comprised the observational data set for the evaluation. Wind data at 925 millibars pressure level from the radiosonde was compared to CALMET output for level 4, whose center level elevation was 750 meters. The radiosonde was *excluded* from the CALMET runs for which the validation procedures were performed.

Figure D-12. Example noontime wind field at 750 meters for VT DEC CALMET.

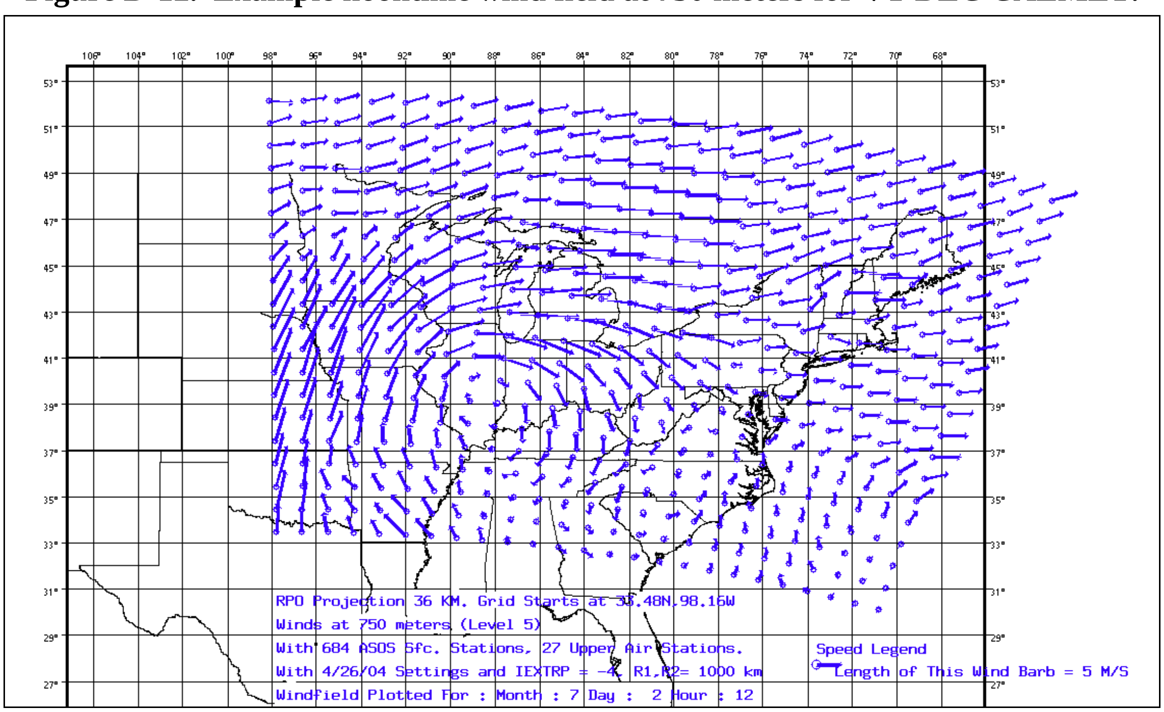
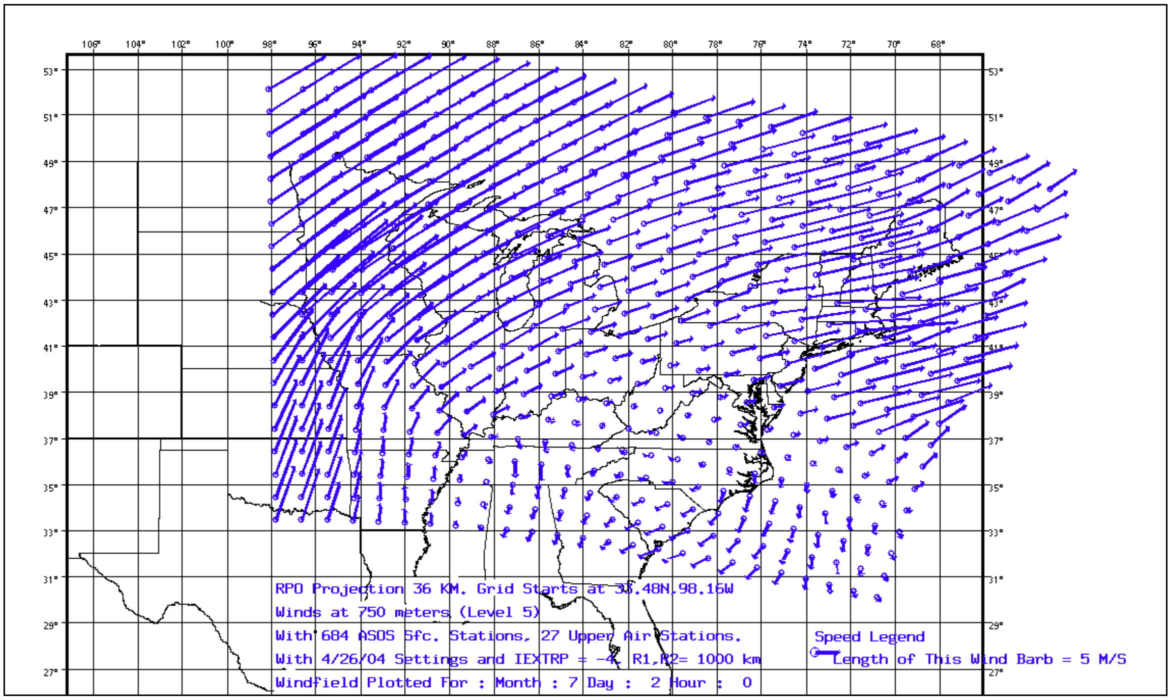


Figure D-13. Example midnight wind field at 750 meters for VT DEC CALMET.



Wind field calculations produced by CALMET were then extracted for the grid point nearest the geographical location of the radiosonde station.

The first method involving comparison of CALMET wind fields to observations was paired in space and time and involves the estimation of 'bias' and 'absolute error' measures for wind speed and direction, where the 'bias' is computed as the average of the difference between modeled and measured values for each data pair accounting for the sign. The 'absolute error' estimates are identical to the bias estimate method, except the sign is not accounted for in the averaging. Table D-5 and Table D-6 give summaries of these results since the option settings mentioned above were varied to ascertain best model performance in this application.

The progressive model validation procedure runs performed in Table D-5 represent the final runs in the procedure. Early in this process it was established that a setting of 100 km for TERRAD and LVARY = T produced best results. In the runs tabulated in Table D-5, the R1 and R2 settings were varied by orders of magnitude over a reasonable range of settings, and also set at the horizontal grid resolution. The IEXTRP setting, which controls the vertical extrapolation of the surface wind to upper layers, was set for the several alternatives governing its effect on wind field production. Note that variation of the Option settings from run to run has significant effect on the four quantities calculated. It was decided that the most important quantities in this procedure, which was validating CALPUFF usage for an annual averaging application of pollutant impacts, were the bias estimates. In Table D-5 the first three runs have comparable values for the composite bias measure, which represents the product of the speed and directional bias. Therefore choice of these sensitive option settings for the final CALMET runs was narrowed to these three alternatives. An unrelated issue regarding domain accuracy was selecting the best representation of the wind field for large areas of the domain with no observations (i.e. Canada). For these areas, it was decided that geographic effects should be minimized and reliance on interpolated observations should occur to the greatest extent possible. The default setting for IEXTRP for the CALMET model version used for this study, is to use similarity theory to perform vertical extrapolation from the surface wind to upper layers (IEXTRP = -4).

Table D-5. A summary of observed to modeled wind fields in the progressive model evaluation procedure for CALMET for summer. Sorted by Composite Bias Measure

Summer or Winter	Radiosonde Location	WD Bias	WD Error	WS Bias	WS Error	Notes Regarding Switch Settings	Composite bias measure
summer	IAD	-1.93	40.6	-0.5	5.44	IEXTRP = 4, R1,R2 = 1000 km	0.97
summer	IAD	-2.01	40.52	-0.51	5.43	IEXTRP = -4, R1,R2 = 1000 km	1.03
summer	IAD	-2.01	40.52	-0.51	5.43	IEXTRP =-4, R1,R2 = 100 km	1.03
summer	IAD	-1.26	40.12	-2.31	4.66	IEXTRP=-4, R1,R2 = 36 km	2.91
summer	IAD	2.82	22.84	-3.26	4.02	IEXTRP =1, R1,R2 = 100 km	9.19
summer	IAD	4.58	24.57	-3.82	4.25	With ETA upper air	17.5
summer	IAD	21.06	44.9	-5.86	6.11	IEXTRP =2, R1,R2 = 1000 km	123.41

Table D-6. A summary of observed to modeled wind fields in the progressive model evaluation procedure for CALMET for all other seasons. Sorted by Wind Direction Bias

Summer or Winter	Radiosonde Location	WD Bias	WD Error	WS Bias	WS Error	Notes Regarding Switch Settings
spring	IAD	-1.57	37.65	0.77	7.2	IEXTRP = -4, R1,R2 = 1000 km
winter	IAD	-3.85	23.88	-0.63	6.46	IEXTRP=4,R1,R2=36 km
winter	IAD	-4.12	16.21	-2.17	4.31	IEXTRP =1, R1,R2 = 1000 km
winter	IAD	4.94	25.52	-4.31	5.7	With ETA upper air
winter	IAD	-5.19	25.95	7.16	10.04	IEXTRP = -4, R1,R2 = 1000 km
winter	IAD	-8.08	23.47	12.16	12.96	IEXTRP=4,R1,R2=1000 km
fall	IAD	8.82	20.81	-4.43	5.74	With ETA upper air
spring	IAD	12.02	24.75	-4.24	5.13	With ETA upper air
winter	IAD	17.47	30.2	-11.81	11.86	IEXTRP =2, R1,R2 = 1000 km

The first priority in determination of the optimized settings was based on the summer season, because the maximum sulfate events occur during the summer. Based on this consideration, and the progressive model validation procedure for summer, the following settings were utilized for the final runs for all of the year except the winter season.

R1, R2 = 1000 km
IEXTRP = -4

LVARY = T
TERRAD = 100 km.

Note that for all results there are significant seasonal variations. In particular, it was noted that the effect of the IEXTRP setting on wind field accuracy during the winter at 750 meters elevation was significant. Therefore it was necessary to decide whether CALMET would be run with the sensitive option settings varied for different seasons, or to utilize option settings fixed over the entire year. There was no guidance on this subject available. Because a significant level of accuracy improvement can be obtained for the winter period by using the IEXTRP setting of 1, it was decided to rely on this non-default setting for the first quarter of the year. Table D-7 is a representation of the progressive model validation procedure for January in which the switch settings for quarter 2 through 4 are compared to the optimum switch settings for the winter period (i.e., with IEXTRP turned off). Table D-8 is a representation of same bias and error measures for January and July with the final switch settings for both winter and summer at 750 meters and 3000 meters elevation.

Table D-7. Progressive Model Validation Procedure for January

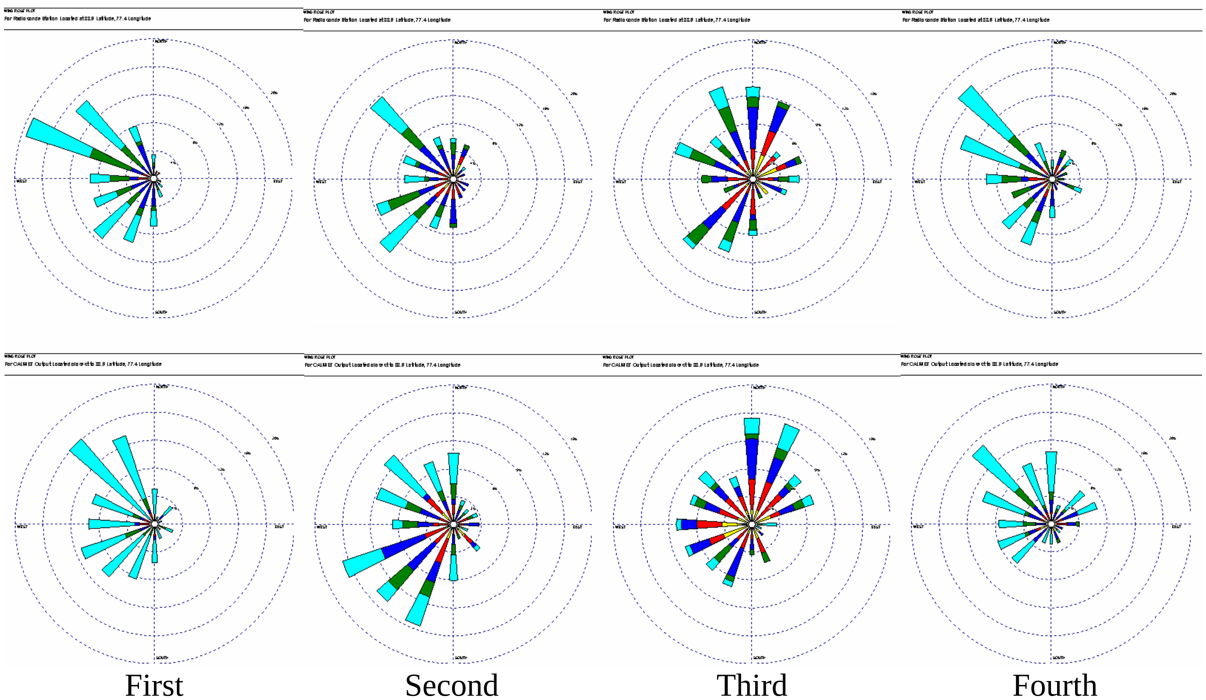
Month of 2002	Calmet Vertical Level (M)	Rad. Pres. Lvl (Mb)	WD Bias	WD Error	WS bias (kts)	WS Error (kts)	composite bias measure	Notes Regarding Switch Settings
January	750	925	-6.8	22.5	8.23	9.4	56.3	iextrp=-4,R1,R2=1000 km,LVARY=T
January	750	925	-1.2	16.7	-0.75	3.92	0.92	iextrp=1,R2=1000km, LVARY=T
January	3000	700	-1.3	11.1	2.51	6.65	3.26	iextrp=-4,R1,R2=1000 km,LVARY=T
January	3000	700	1.84	8.44	0.84	5.2	1.5	iextrp=1,R2=1000km, LVARY=T

Table D-8. Bias and Error measures for January and July

Summer or Winter	Calmet Vertical Level (M)	Rad. Pres. Lvl (Mb)	WD Bias	WD Error	WS bias (kts)	WS Error (kts)	composite bias measure	Notes Regarding Switch Settings
January	3000	700	1.84	8.44	0.84	5.2	1.5	iextrp=1,R2=1000km,LVARY=T
January	750	925	-1.2	16.74	-0.75	3.92	0.92	iextrp=1,R2=1000km,LVARY=T
July	3000	700	3.35	21	1.78	3.9	5.96	iextrp=-4,R1,R2=1000 km,LVARY=T
July	750	925	-2.3	39.5	1.86	7.5	4.28	iextrp=-4,R1,R2=1000 km,LVARY=T

In a *time independent* evaluation, wind roses were produced for each quarter's CALMET run and compared to windroses produced from the radiosonde location. Figure D-14 shows the wind rose plots by season using the final option settings chosen in the analysis described above.

Figure D-14. Comparison of observed(top) and CALMET calculated (bottom) wind roses for four quarters of 2002.



Validation Method Used to Determine Optimum CALMET Parameter Settings for Other physical processes

Other physical processes – including lateral and vertical pollutant dispersion, chemical conversion of SO_2 to sulfate, and mechanisms to reduce airborne concentrations of sulfur compounds, including dry deposition of SO_2 and wet deposition of sulfate – must be properly handled by CALPUFF, and all of these are greatly affected by the meteorological fields CALMET produces.

The choice of calculation method *for lateral pollutant dispersion* is made in the CALPUFF option settings, where several alternatives are available. A sensitivity analysis was performed using the CALPUFF SO_4 fields in comparison to monitored SO_4 values. For Gaussian dispersion methods, *ground level stability estimates* dictate the amount of lateral spread in CALPUFF. Stability, as a function of thermal and mechanical mixing, is calculated within CALMET. Figure D-15 and Figure D-16 show stability fields which were used for visual examination of diurnal variability.

Figure D-15. VT DEC Daytime PGT Stability Classifications During Summer.

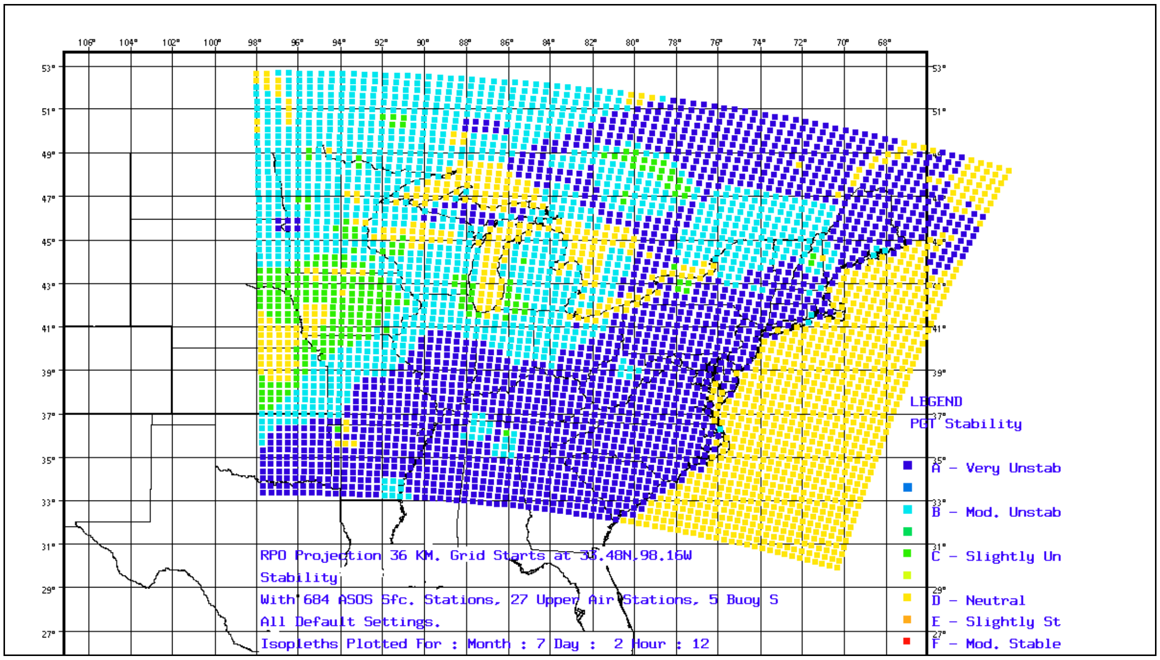
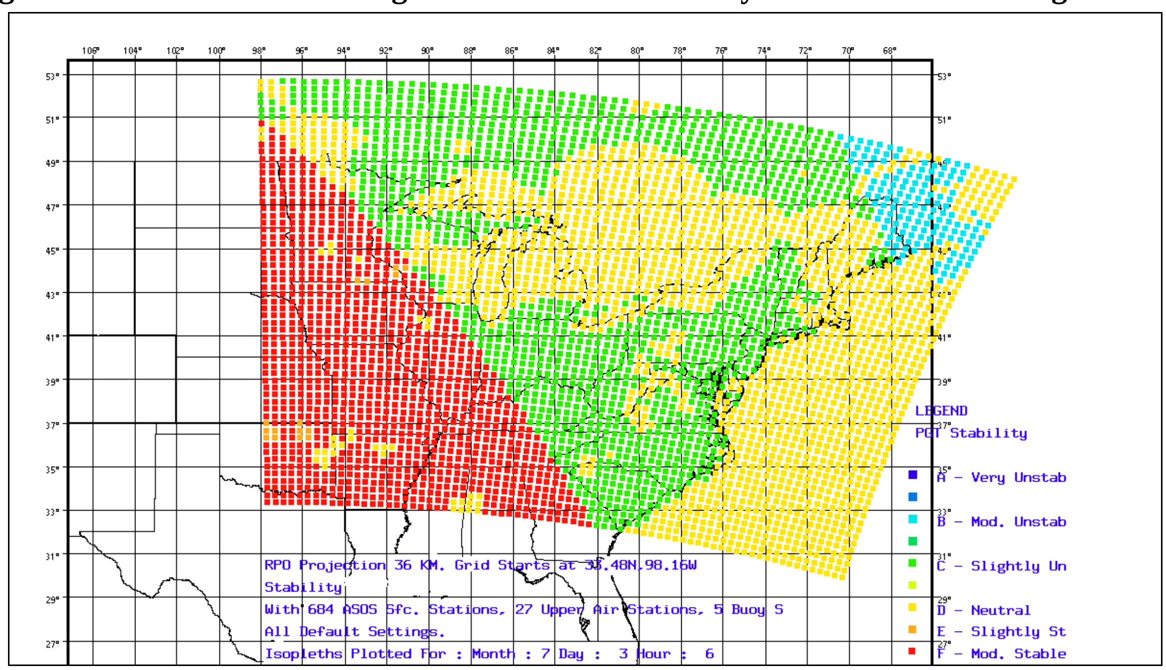


Figure D-16. VT DEC Morning Transition PGT Stability Classifications During Summer.



Vertical Pollutant Dispersion is largely a function of *mixing height*. Mixing heights are estimated by CALMET. Therefore validation procedures were performed to examine the reasonableness of the stability and temperature fields produced by CALMET, since the mixing height calculations are based on these fields, and the mixing heights themselves for reasonableness. This validation, then, consisted of a *visual examination* of the aforementioned fields for ten day periods during each quarter of the year. Figure D-17 and Figure D-18 illustrate examples of mixing height fields during a fair weather period in July.

Figure D-17. Mixing Height Calculations from CALMET for a summer day.

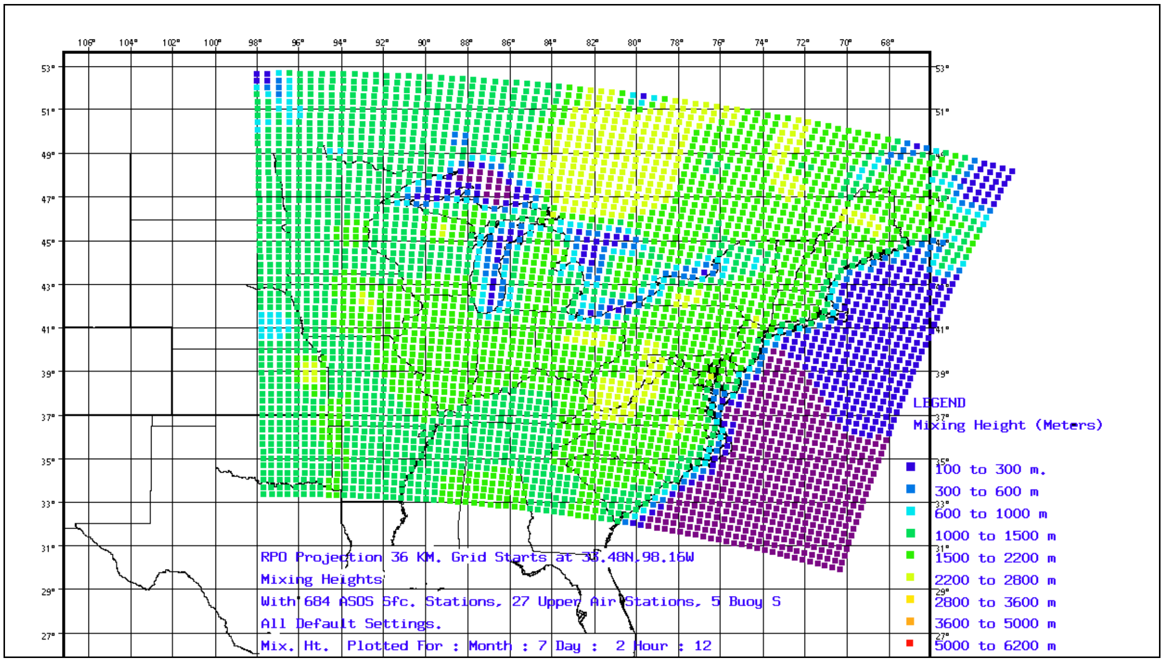
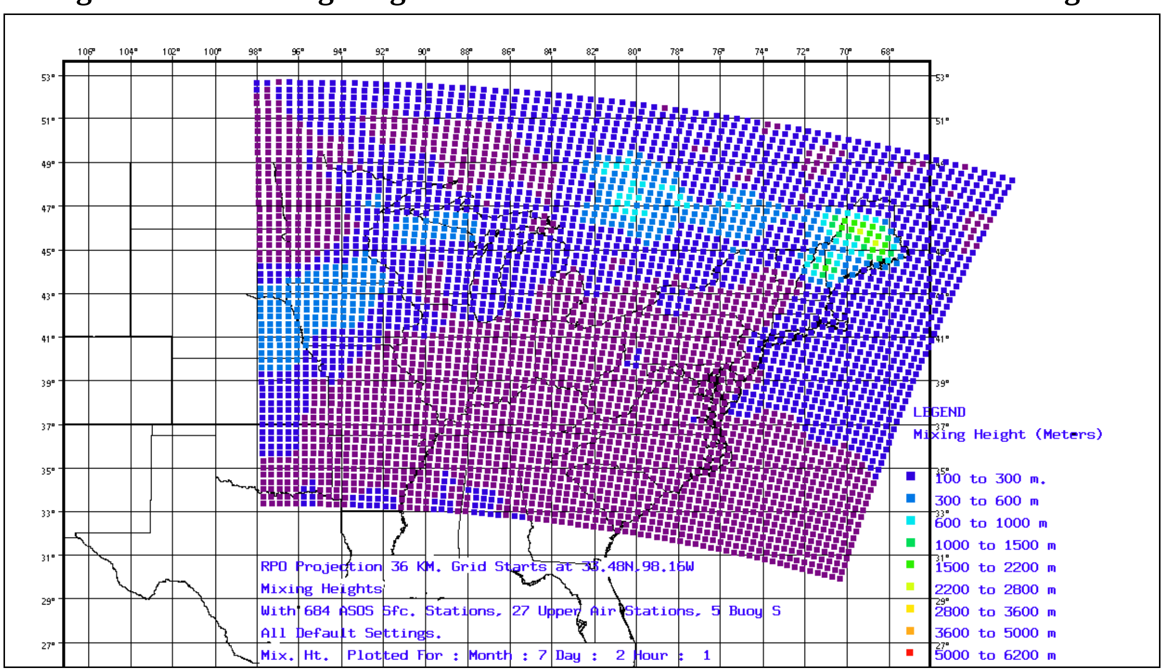


Figure D-18. Mixing Height Calculations from CALMET for a summer night.



Chemical Conversion of SO_2 to H_2SO_4 in CALPUFF is strongly dependent on surface *temperature* and *relative humidity fields* produced by CALMET. Therefore these fields were subject to a *visual examination* for ten day periods during each quarter of the year, where CALMET was run in different modes to effect their estimation. Part of the temperature field evaluation involved inspection of the predicted fields when ISURFT, which defines which surface observational site input to CALMET is used to produce the first guess temperature field, was varied, Figure D-19 and Figure D-20 illustrate examples of the final surface temperature fields during a fair weather period in July.

Figure D-19. Surface Temperature from CALMET for a summer day.

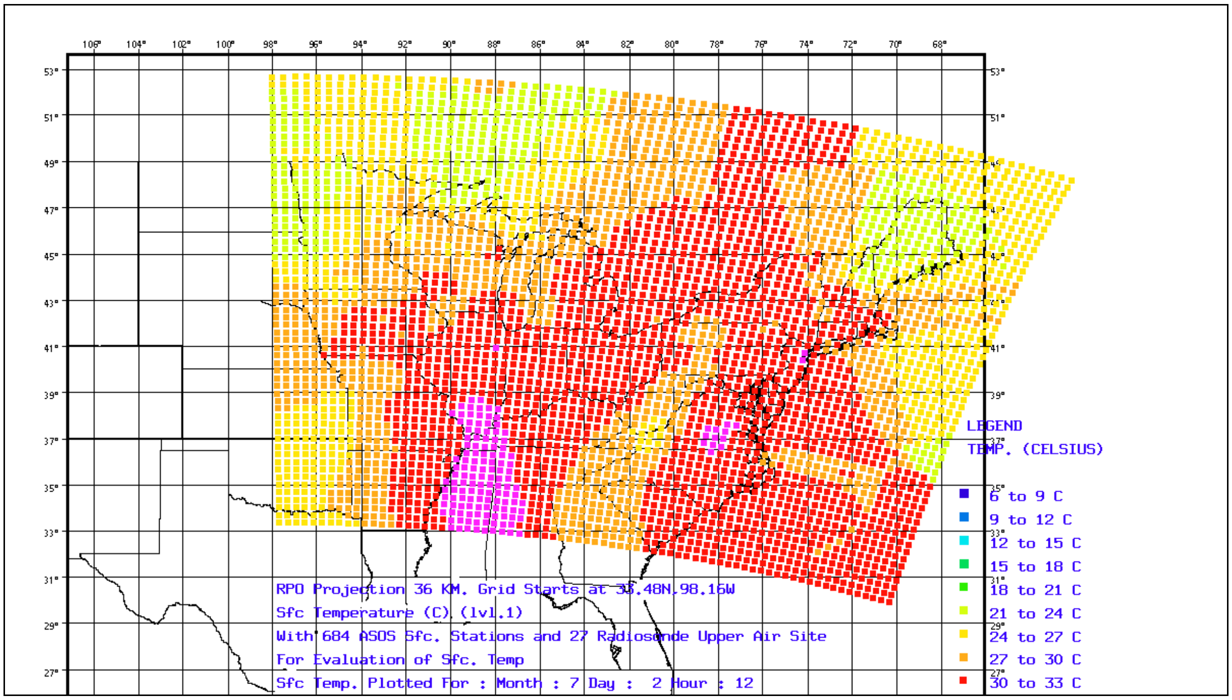
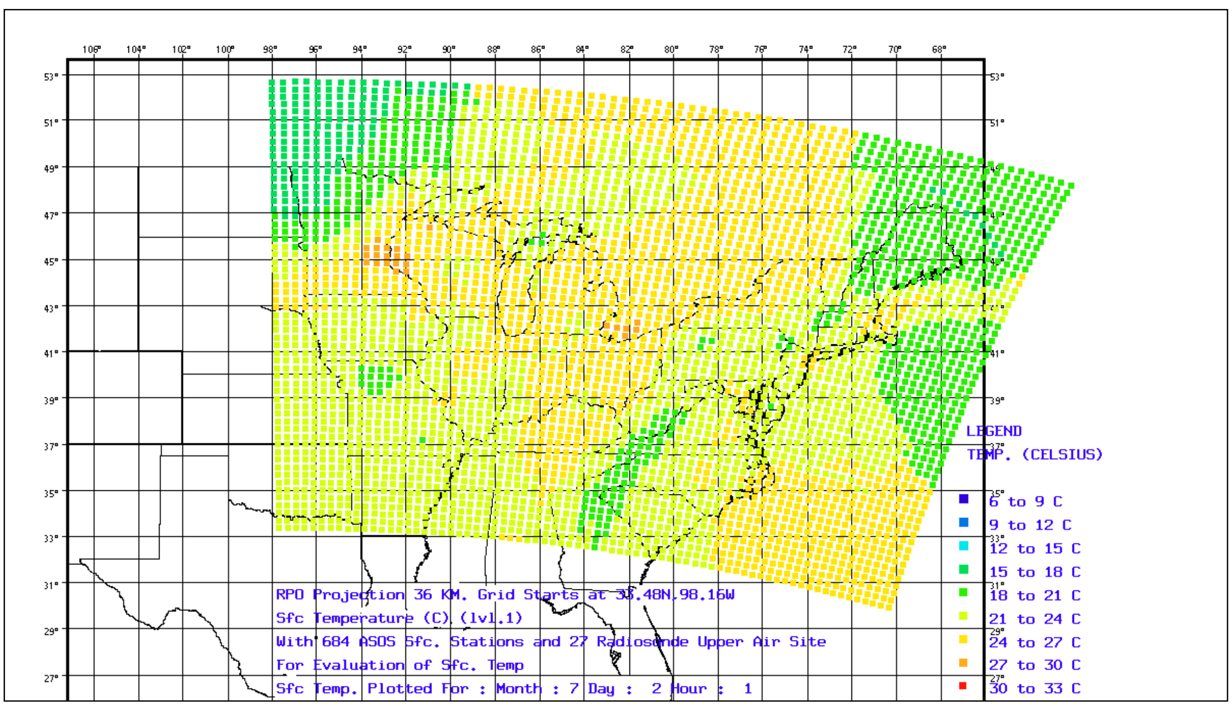


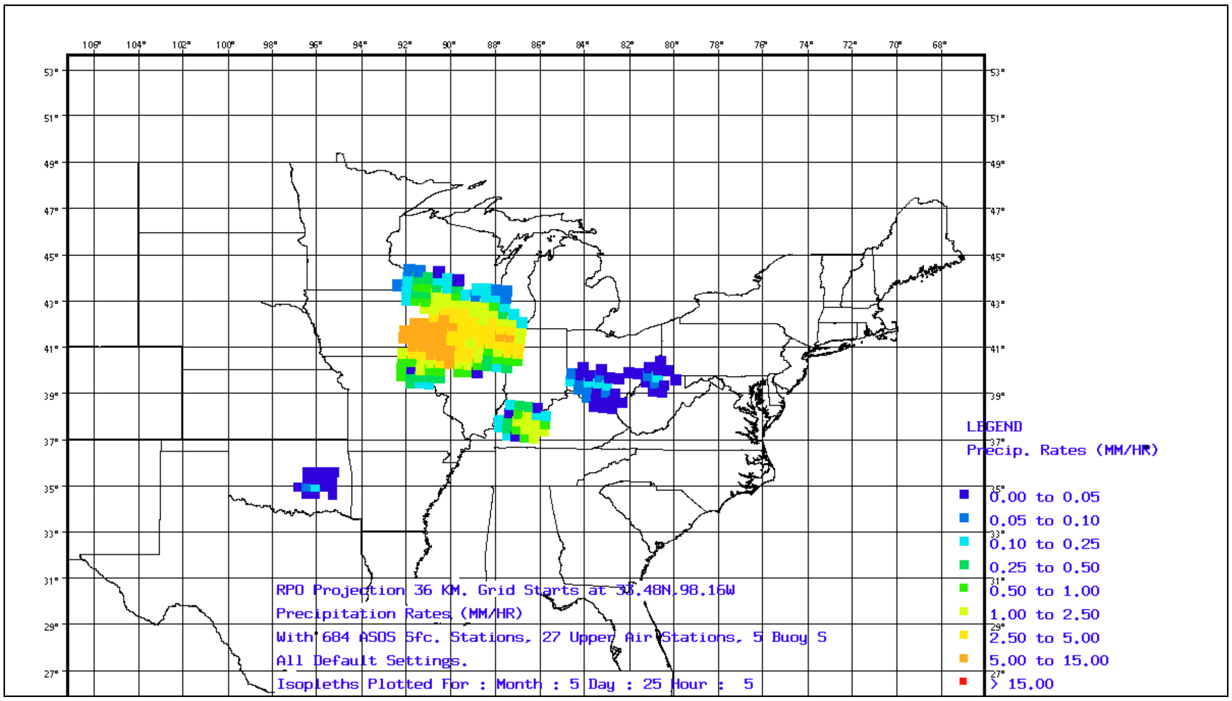
Figure D-20. Surface Temperature from CALMET for a summer night.



Dry Deposition estimates by CALPUFF are sensitive to the original geographical representation of certain variables for the domain (eg leaf area). See Figure D-11 for a plot of the leaf area index values. Parameters in equations for dry deposition rates may also be altered in CALPUFF. CALPUFF runs will be performed in Phase II of this effort to assess effect of different dry deposition algorithms.

Wet deposition is primarily influenced by representation of precipitation fields, as well as parameters in equations for dry deposition rates within CALPUFF. Therefore, for wet deposition handling by CALMET, precipitation fields were examined for reasonableness. Some modifications will be performed in CALPUFF runs in Phase II. for wet deposition, as well as additional CALMET reruns.altering initial production of the precipitation fields. Figure D-21 illustrates an example of a precipitation field for one hour. Fields were compared to National Weather Service maps to verify accurate representation of precipitation events.

Figure D-21. Example of a Precipitation Field Snapshot produced by CALMET.



D.2.3. CALPUFF Phase II Modeling Results Using NWS-derived Wind Fields

We note again that these Phase II VTDEC CALPUFF results for year 2002 are based on emissions reported in the CEMS raw data files and data from RPO emission inventories which include only sulfur dioxide, nitrogen oxides, and $PM_{2.5}$. The sulfate component of visibility affecting aerosol is the only model output component that has been evaluated against measurement data. Direct emissions of $PM_{2.5}$ from all source categories modeled (including the CEMS EGU point sources) were estimated using data from the RPO modeling inventories available in the October 2005 time period. However, we have not evaluated the model results for all regional haze affecting species that the

EGUs, other point sources, and area/mobile sources may be emitting. Direct emissions of $PM_{2.5}$ or VOC may affect visibility at Class I areas. An estimate of direct $PM_{2.5}$ emissions from some of the sources has been included in the CALPUFF runs completed under Phase II of the project, but there was no attempt to evaluate direct $PM_{2.5}$ visibility impacts or to incorporate any organics effects on visibility in the CALPUFF modeling which Vermont has conducted thru Phase II. As of the end of 2005, it has not been possible to spend the time to do a complete analysis of all the outputs generated by the modeling. The ambient sulfate component of impacts affecting haze has been examined in some detail for a number of the Class I areas in the northeastern portion of the domain.

CALPUFF was run on the VT DEC platform for each quarter sequentially, using the restart option of the CALPUFF switch settings. Ramp-up was confined to several days at the beginning of January 2002. Six chemical species were specified to be modeled. In the Vermont CALPUFF modeling presented in these Phase II results, only three of these species were emitted, these being SO_2, NO_X, and $PM_{2.5}$. Calculation of ambient concentration for SO_4, HNO_3, and NO_3 was also performed in addition to that for the emitted species. In some of the sensitivity runs tested during Phase II, direct emissions of SO_4 from the CEMS EGUs were also estimated as 3% of the hourly SO_2 emission rate, but these emissions were not included in the reported Phase II results. Phase II modeling evaluation was limited to the sulfate ion concentration output. Because the nitrogen chemistry in the model is dependant on partitioning of the chemical transformation products properly under available ammonia conditions, the direct concentration and deposition results for nitrogen compounds obtained in Phase II modeling would need to be post-processed in a more complex way using a utility called POST-UTIL. Post-processing with POST-UTIL has not yet been carried out with the Phase II results. The option to post-process results obtained for $PM_{2.5}$, nitrogen compounds and overall visibility impacts remains available

During Phase I, CALPUFF was also run selectively using a dense set of gridded receptors (117 x 117 @ 18 km spacing) for short periods of time with all point sources and for annual periods with small groups of sources. These output results were used to visually observe the time series of hourly predictions being produced by the model. This process proved helpful in identifying time periods when episodic levels of sulfate were predicted in the MANE-VU region and for which monitoring patterns could also be matched in time. Modeling on sets of gridded receptors was not conducted during Phase II modeling.

Phase II CALPUFF Results compared to observations

VTDEC modeled predictions for SO_4 ion concentration at 72 discrete receptors in the eastern U.S. produced during Phase II CALPUFF modeling were available for comparison to SO_4 ion measurements available at these same locations. Modeled emissions from the comprehensive set of SO_2 source categories which have been identified in Table D-2 through Table D-4 in Section D.2.1.2.are estimated to represent at least 95% of the SO_2 emissions which occurred in the domain during calendar year 2002. A comparison of predicted impacts from the modeling with actual measurements of SO_4 ion at these receptors was done for both quarterly average impacts and for 24-hour average impacts during the entire year, based on predictions and measurements paired in space and time.

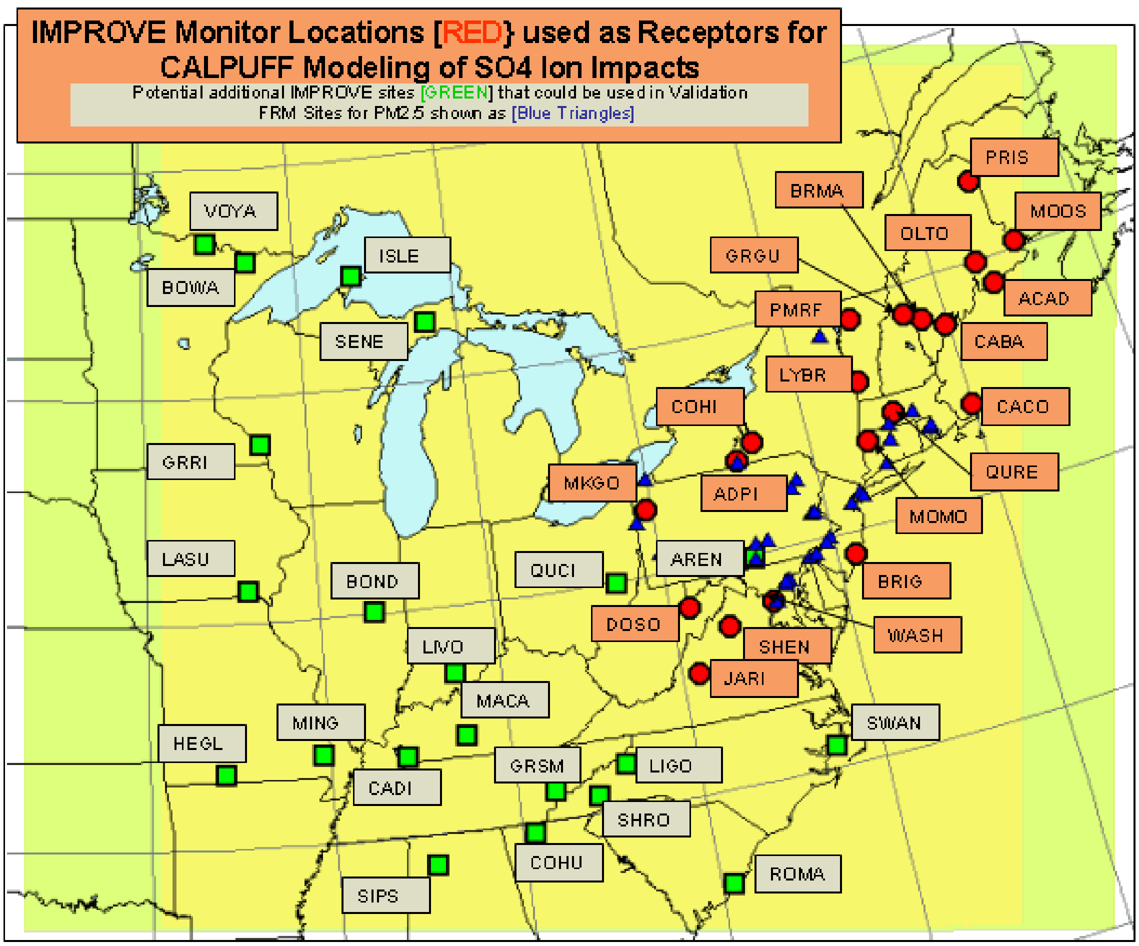
During Phase I we had identified the entire set of pertinent calendar year 2002 measurements from within the domain for use in performing a validation of the CALPUFF model platform for the most significant regional haze affecting component (SO_4 ion) in the northeast. These measurements comprise a very substantial dataset that is spatially and temporally dense for this purpose. Both ambient concentration measurements and deposition measurements may eventually be utilized to perform this validation on Phase II modeling results. The discussion to follow focuses only on a comparison of Phase II CALPUFF modeled ambient SO_4 ion to measurements of ambient SO_4 ion. 24-hr fine particulate matter ($PM_{2.5}$) measurements for the modeled time period are available at many locations (in some cases on a daily basis) in the domain covered by the modeling. However, because Phase II VTDEC CALPUFF modeling results have not yet been post-processed to accurately represent secondary nitrate particulate matter impacts at the receptors, it did not seem productive to do comparisons between modeled and measured $PM_{2.5}$ until the Phase II results can be post-processed to account for nitrogen partitioning more appropriately.

SO_4 Ion Measurements used for Model Validation

The modeling domain includes 41 monitoring locations which utilize IMPROVE-type monitors. These operate on a one-in-three day schedule (every third day) which is the same for each of the monitor locations. Each 24-hr ambient air sample collected has been analyzed for a large number of compounds and elemental concentrations, including SO_4 ion. This network of monitors operated throughout 2002 and measurements obtained at all 41 of these sites were available for comparison to VTDEC CALPUFF modeled predictions of SO_4 ion at these specific discrete receptor locations. 22 of these IMPROVE-type measurement sites are in the northeastern quadrant of the domain, that portion most frequently upwind of other portions. One of the sites (WASH) is located in the urban area of Washington D.C. so although it is being used in the model validation, it is a site somewhat different than the rural sites used and measurements may include the influence of locally important sources not appropriately accounted for in the modeling. Two of these 22 sites (AREN & QUCI) were not included in the initial Phase I validation process. The remaining 19 sites in the other three quadrants are close to boundaries of the domain from which direction the prevailing air flow over the domain frequently occurs (south and west). Information about emission sources outside the domain in those directions was not accounted for in a completely satisfactory way during the Phase II modeling. A sensitivity test run which attempted to account for transport of sulfate aerosol across these boundaries did show a definite ability to improve the results close to the western and southern boundaries of the domain. In the evaluation described below, the 19 IMPROVE-type monitoring sites outside the northeast quadrant were not considered as primary sites for model validation, but comparisons for them were also produced.

Figure D-22 shows the locations of all ambient SO_4 ion concentration monitoring sites available for model validation purposes. The RED circles shown are the 20 IMPROVE-type monitoring sites used in the preliminary validation of SO_4 ion predicted during Phase I modeling. These primary receptor sites plus the AREN and QUCI (green squares) sites were used to validate SO_4 ion predictions using Phase II model results. BLUE triangles show 31 FRM sites which could be used in the future with Phase II modeling results for $PM_{2.5}$ validation. The remaining GREEN squares show the 19 additional IMPROVE-type monitor locations outside the northeast quadrant, some of which may be considered for expanded SO_4 ion and NO_3 ion comparison. It would be very useful to conduct further validation analysis if there is future enhancement of Phase II results by incorporating improved transport representation of ambient SO_4 and NO_3 ion concentrations being carried into the domain across its western, southern, and northern boundaries. All of these sites could be considered for use when an evaluation of the particulate matter and nitrate components of visibility affecting aerosol can more appropriately be performed following post-processing to properly partition the nitrogen compound results.

Figure D-22. Ambient SO_4 ion concentration monitors



Model Validation Results (Quarterly Averages of Coincident 24HrAve)

Table D-9 shows a comparison of average long-term (quarterly) SO_4 ion impacts obtained during Phase II modeling showing predicted values at the 22 IMPROVE site locations versus the monitored average values when only the dates with monitored SO_4 ion were included in both sets of average value calculations.

This table indicates that in the configuration being run for Phase II the model is under-predicting the long-term (quarterly average) impacts for SO_4 Ion by at least 30% for 22 of the 88 site/quarter combinations in the northeastern portion of the domain. Most of these under-predictions occurred during the first two quarters of the year. This seems to indicate that, based on the patterns and magnitudes of under-prediction seen, the overall conversion of SO_2 to SO_4 during transport and/or the deposition and removal during transport may not be optimized appropriately in the model during these seasons. In the winter (1st quarter) most of the sites under-predicted are located in the extreme northeastern portion of the domain, the furthest from the primary known large sources of SO_2. However during the spring (2nd quarter) many of the sites under-predicted are located closer to the primary source regions for SO_2.

Table D-9. Phase II Evaluation of Average SO_4 ion CALPUFF Predictions

COMPARISON of IMPROVE Monitored Ave Qrtrly SO4 vs CALPUFF Modeled Ave Qrtrly SO4
Coincident 24-Hr periods paired in Space & Time used for averaging

SO4 Ion Values in ug/m3 DIFF given is Modeled minus Monitored

	QUARTER 1 Ave SO4 Ion				QUARTER 2 Ave SO4				QUARTER 3 Ave SO4				QUARTER 4 Ave SO4			
Site	Monitor	Model	DIFF	%DIFF	Monitor	Model	DIFF	%DIFF	Monitor	Model	DIFF	%DIFF	Monitor	Model	DIFF	%DIFF
ACAD	1.53	1.19	-0.34	-22.27	1.57	1.83	0.26	16.46	2.54	3.08	0.54	21.17	1.56	1.86	0.30	19.19
ADPI	2.47	1.63	-0.84	-33.87	4.04	2.78	-1.26	-31.16	5.55	6.47	0.91	16.46	2.44	2.79	0.36	14.70
AREN	2.96	2.22	-0.73	-24.82	5.93	3.08	-2.86	-48.12	7.18	6.65	-0.54	-7.49	3.25	3.23	-0.02	-0.61
BRIG	2.13	1.56	-0.57	-26.87	4.54	2.87	-1.68	-36.92	4.86	6.05	1.19	24.52	2.78	2.90	0.12	4.35
BRMA	1.67	1.12	-0.55	-32.65	1.44	1.07	-0.37	-25.80	3.21	2.23	-0.98	-30.58	1.45	1.43	-0.02	-1.62
CABA	1.89	1.22	-0.67	-35.54	1.74	1.78	0.03	1.99	2.53	2.75	0.22	8.87	1.61	1.76	0.15	9.31
CACO	1.82	1.92	0.10	5.35	1.99	2.12	0.12	6.26	2.65	4.05	1.39	52.44	2.00	2.29	0.30	14.84
COHI	2.48	1.73	-0.75	-30.36	4.15	2.89	-1.26	-30.38	5.17	5.95	0.79	15.24	2.32	2.80	0.47	20.28
DOSO	2.33	3.74	1.41	60.19	5.26	2.96	-2.30	-43.76	4.81	4.95	0.13	2.79	2.16	3.76	1.60	74.36
GRGU	1.52	1.10	-0.42	-27.81	1.77	1.32	-0.44	-25.01	3.27	1.99	-1.28	-39.23	1.37	1.34	-0.03	-2.15
JARI	2.73	2.52	-0.21	-7.61	4.94	1.99	-2.95	-59.72	7.68	6.65	-1.04	-13.47	2.98	3.60	0.62	20.81
LYBR	1.39	1.31	-0.08	-5.85	1.83	1.91	0.08	4.13	3.13	2.91	-0.22	-7.00	1.27	1.60	0.33	26.25
MKGO	2.83	2.74	-0.09	-3.27	4.94	3.42	-1.52	-30.69	5.67	7.63	1.96	34.46	2.74	3.78	1.05	38.31
MOMO	2.30	1.63	-0.67	-29.08	2.63	2.36	-0.27	-10.28	3.56	4.92	1.36	38.35	2.22	2.04	-0.17	-7.82
MOOS	1.47	1.03	-0.44	-30.02	1.29	1.83	0.53	41.20	2.45	2.60	0.15	6.21	1.58	1.72	0.14	8.89
OLTO	1.86	0.77	-1.09	-58.76	0.93	0.56	-0.36	-39.29	2.86	2.17	-0.70	-24.28	1.52	1.38	-0.14	-9.42
PMRF	1.58	1.00	-0.58	-36.57	1.98	1.46	-0.52	-26.31	3.80	2.70	-1.10	-28.86	1.72	1.83	0.11	6.32
PRIS	1.41	0.75	-0.66	-46.81	1.13	0.95	-0.18	-16.29	2.08	1.29	-0.80	-38.27	1.69	1.81	0.12	6.81
QUCI	2.90	3.60	0.70	24.13	5.24	2.82	-2.41	-46.11	6.77	9.96	3.19	47.11	3.04	3.71	0.66	21.87
QURE	1.98	1.46	-0.51	-25.92	2.21	2.14	-0.07	-3.16	3.38	3.96	0.58	17.21	2.01	1.84	-0.17	-8.49
SHEN	2.30	2.87	0.57	24.84	4.97	2.11	-2.86	-57.60	7.17	6.52	-0.66	-9.16	2.63	3.51	0.87	33.13
WASH	3.29	2.75	-0.54	-16.49	5.40	2.85	-2.55	-47.17	8.55	8.52	-0.02	-0.28	3.96	3.88	-0.07	-1.83

Model was OVER-Predicting the quarterly average by more than 30% primarily during 3rd and 4th quarters 9 of 88 Averages
Model was UNDER-Predicting the quarterly average by more than 30% primarily during 1st and 2nd quarters 22 of 88 Averages
Maximum OVER-PREDICTIONS are found for IMPROVE site within the most significant known SO2 source region

Figure D-23 and Figure D-24 represent a graphic depiction of the tendency for the model to under-predict ambient SO_4, especially during the 1st and 2nd quarters. In the first of these figures D-23 the set of 22 sites is repeated in the same sequence for each of the four quarters of the year while in the following Figure D-24 the site/quarter average values are ordered from highest monitored quarterly value to lowest (left to right). From Figure D-24 it seems appropriate to conclude that model over-prediction is most likely to occur at locations measuring mid-range quarterly average SO_4 ion values (i.e. not the highest quarterly averages nor the lowest for the northeastern part of domain). At these same mid-range measurement value locations, the model also appears to be least likely to under-predict.

Figure D-23. Quarter-by-Quarter Under-prediction & Over-prediction at 22 Sites

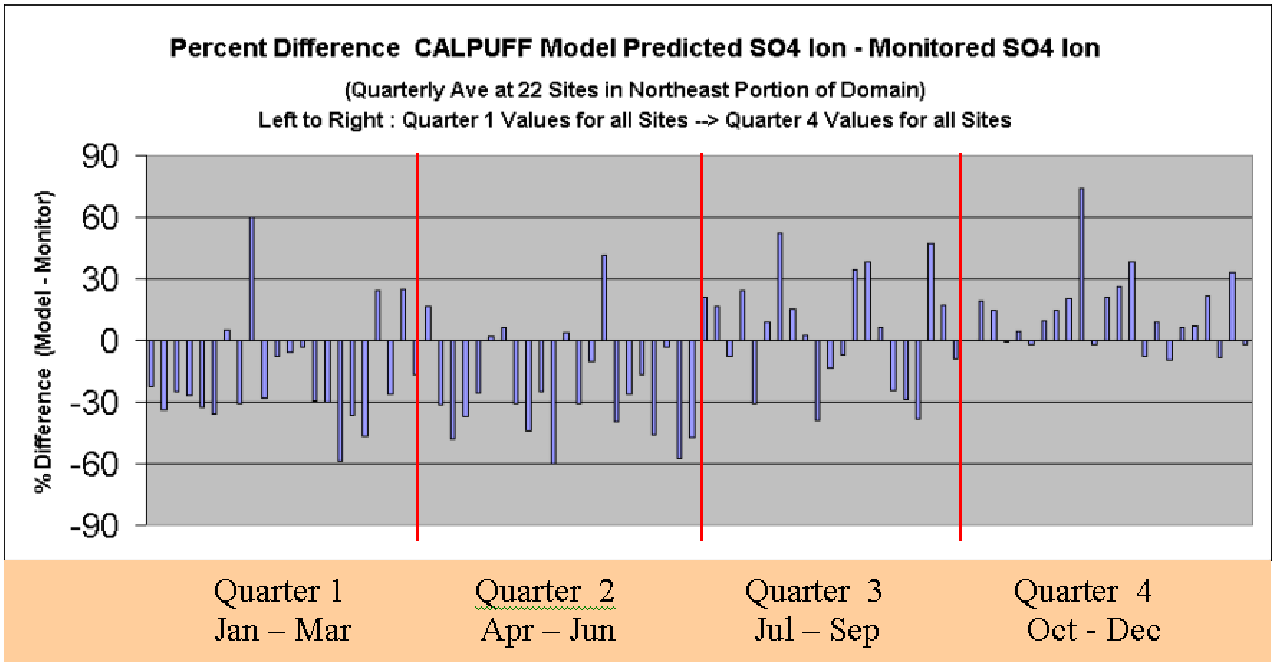
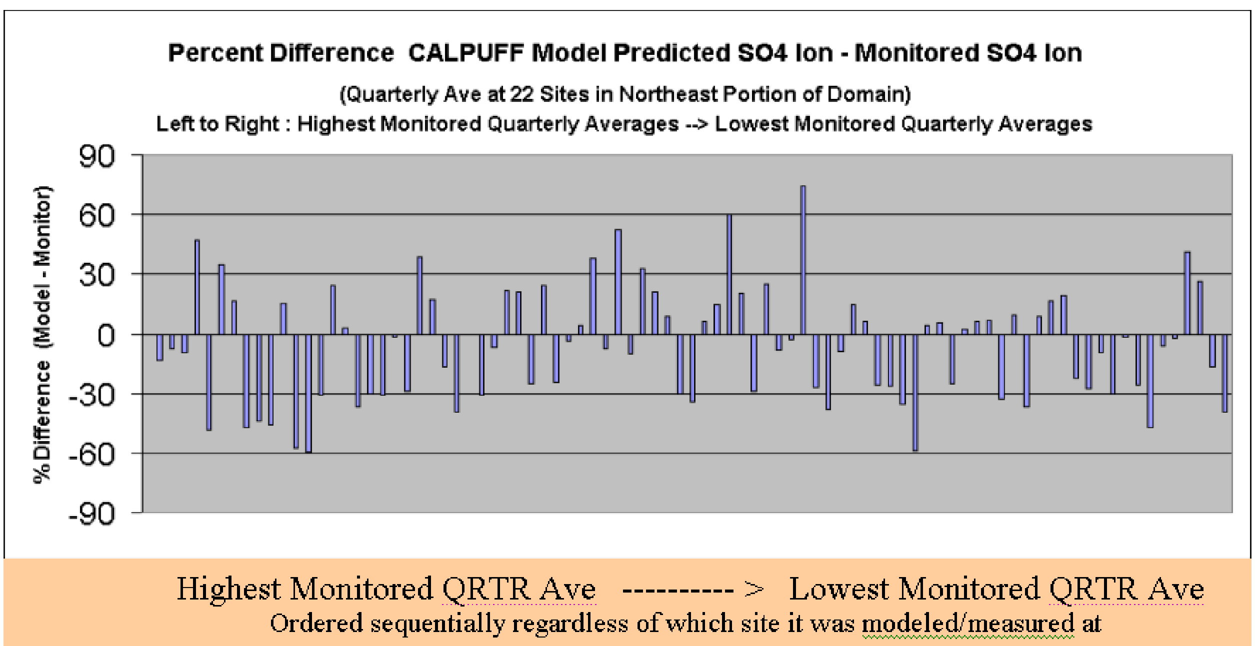
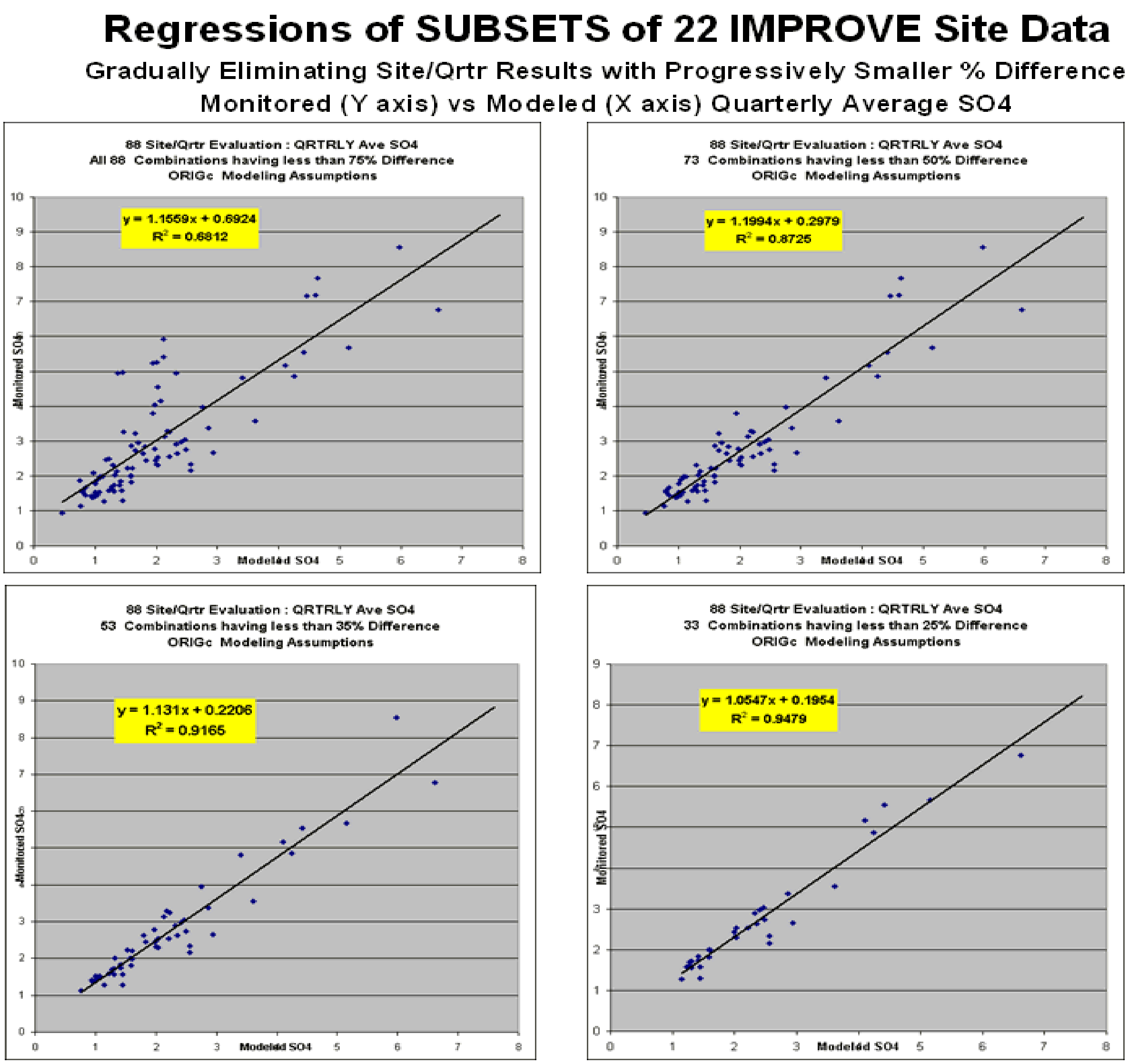


Figure D-24. Under-prediction & Over-prediction at 22 Sites relative to Measured Quarterly Values



Examining the quarterly average SO_4 ion predictions at these 22 sites in yet another way is also informative as to the potential for the regional modeling platform to produce very robust results at subsets of the receptors being used in the validation. Figure D-25 indicates that by gradually removing the outlier site/quarter averages from the regression of receptor measurements vs modeled predictions, very close agreement of the model to measurement at a more limited set of receptors may be demonstrated. Figure D-25 is included in this report to simply illustrate that there may be a subset of receptors (either spatially consistent with model settings or appropriately located relative to most significant SO_2 emission regions) for which model performance is greatly improved.

Figure D-25. Regression of Modeled vs Monitored Quarter-by-Quarter SO_4 Ion at 22 Sites: Gradually Removing Outliers



If, rather than only the 22 upwind northeastern sites, 40 of the available IMPROVE sites are used in this type of analysis of the long-term predictive ability of the VTDEC modeling platform, results are surprisingly good even though several of these sites are located near the extreme south-western or north-western portions of the domain modeled. By including these sites, which are most likely not seeing enough modeled SO_4 ion transport from outside domain boundaries, it was not expected that model performance would be very good. When average quarterly modeled impacts were regressed against measurement at these 40 sites it is clear that some sites are not at all well predicted. However, if those quarters which produced the greatest percent difference in predicted vs measured quarterly averages are sequentially removed, predictive agreement for the site/quarter combinations which remain improves significantly. The following Figure D-26, Figure D-27, and Figure D-28 show the relationship when 7, 27, and 57 of the greatest percent difference outliers are removed.

Figure D-26. Modeled vs Monitored Quarter-by-Quarter SO_4 Ion at 40 Sites: Quarterly %Differences Ordered with best 150 Site/Quarter Values Regressed

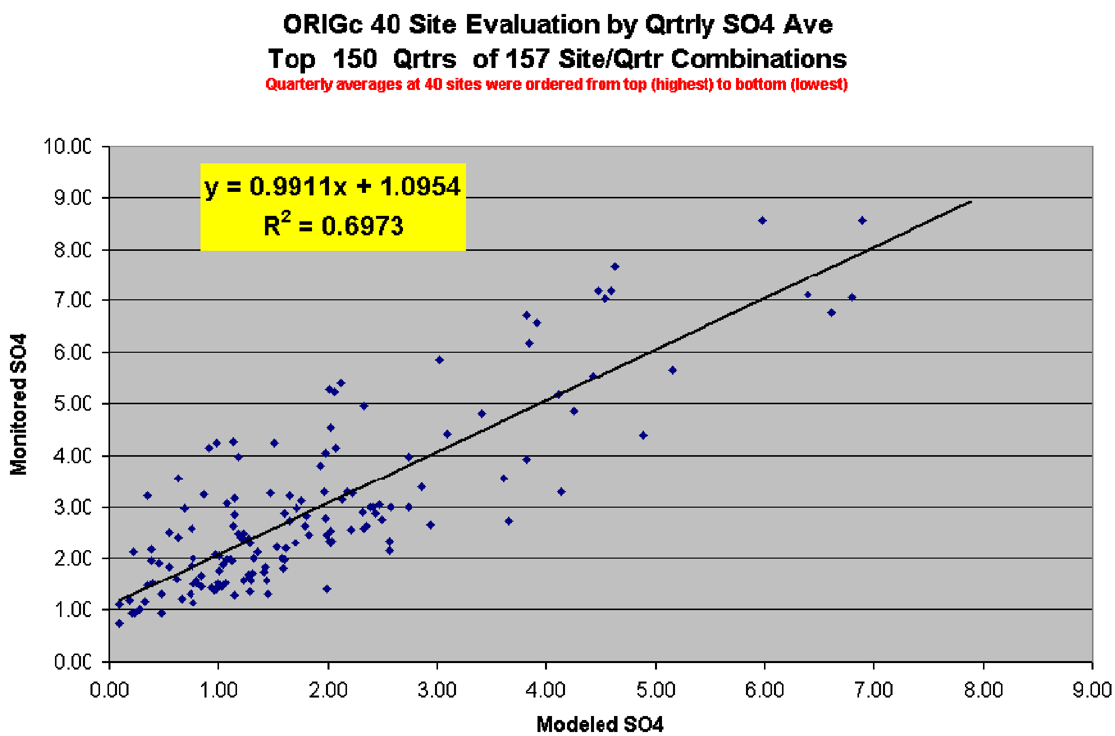


Figure D-27. Modeled vs Monitored Quarter-by-Quarter SO_4 Ion at 40 Sites: Quarterly %Differences Ordered with best 140 Site/Quarter Values Regressed

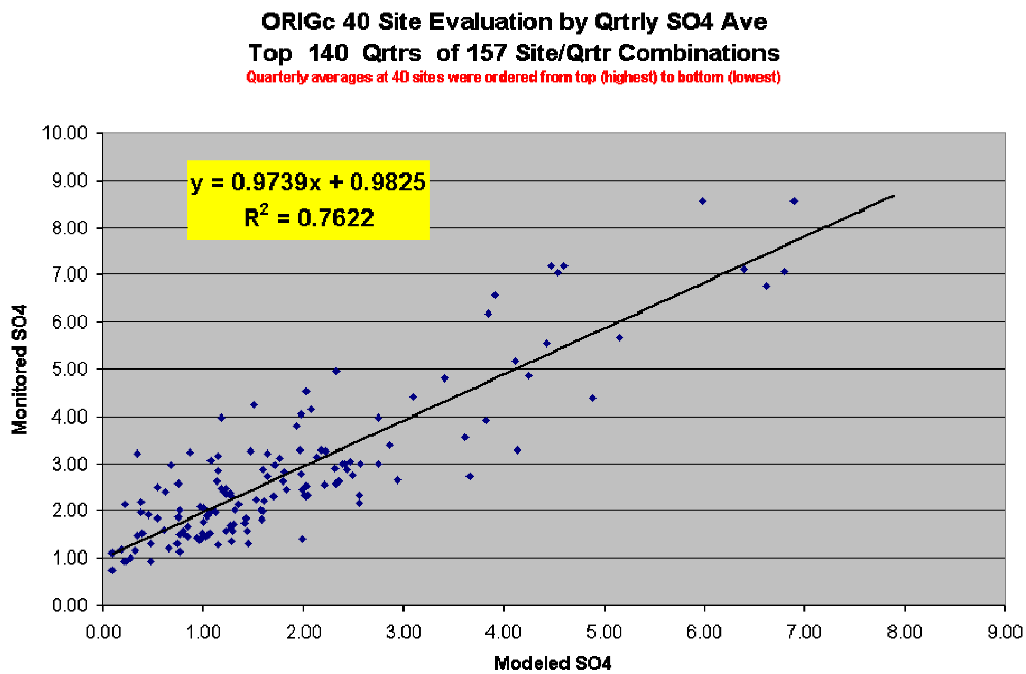
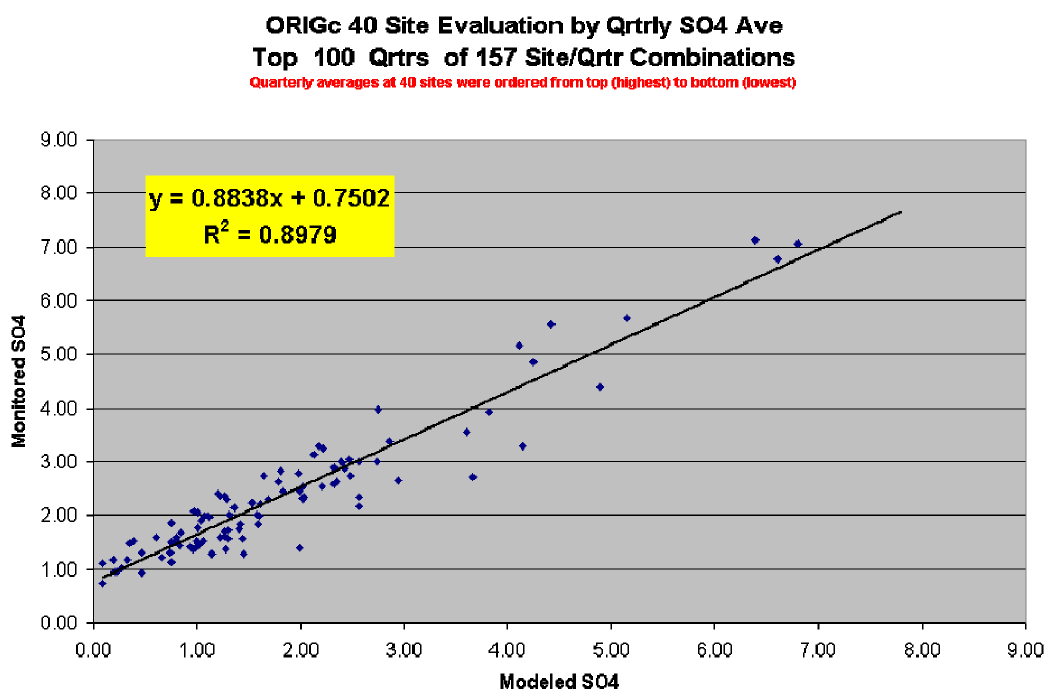


Figure D-28. Modeled vs Monitored Quarter-by-Quarter SO_4 Ion at 40 Sites: Quarterly %Differences Ordered with best 100 Site/Quarter Values Regressed



Model Validation Results (24 Hour Averages of Hourly Predictions)

Quarterly average validation of the VTDEC CALPUFF platform for 22 sites (and even the set of 40 sites) was quite encouraging in that regression models relating the modeled to measured quarterly averages generally show that the average over-prediction or under-prediction balances out on that time scale at sites in the domain. Comparisons of 24-hr ambient SO_4 Ion concentrations monitored and modeled at the 22 IMPROVE sites were also produced for the full year of 2002 modeling. The modeled predictions and the monitored 24-hr measurements were paired in both space and time for these comparisons. When we examined the 24-hr predictions versus the measurements the results are not quite so encouraging as they are for quarterly averages. For an averaging period of 24 hours, the model does not appear well able to match the variability of SO_4 ion formation that is taking place over the spatial scale of the domain. There is more scatter in the data than desired, although the overall linear model does not seriously over or under predict on average. Figure D-29 shows the relationship between monitored and modeled 24-hr SO_4 ion for the 22 northeastern IMPROVE sites generally upwind of the major source regions of SO_2.

Figure D-29. Modeled vs Monitored 24-Hr Average SO_4 Ion at 22 Sites

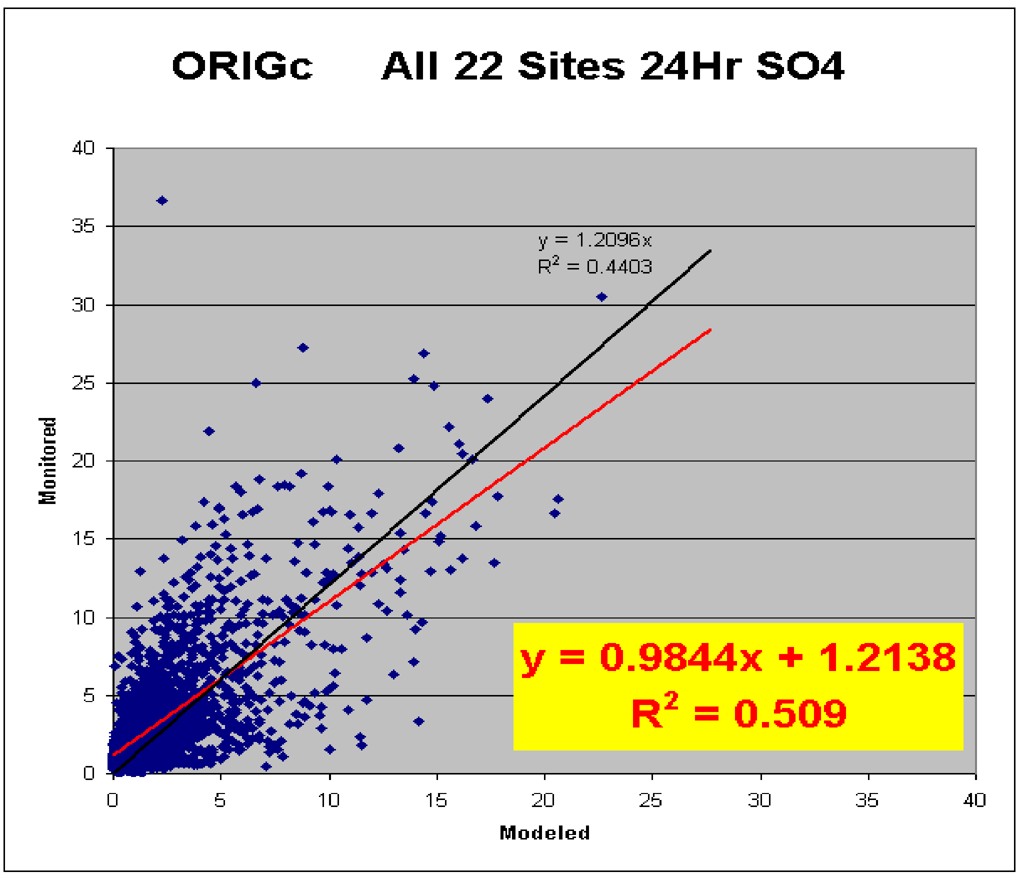
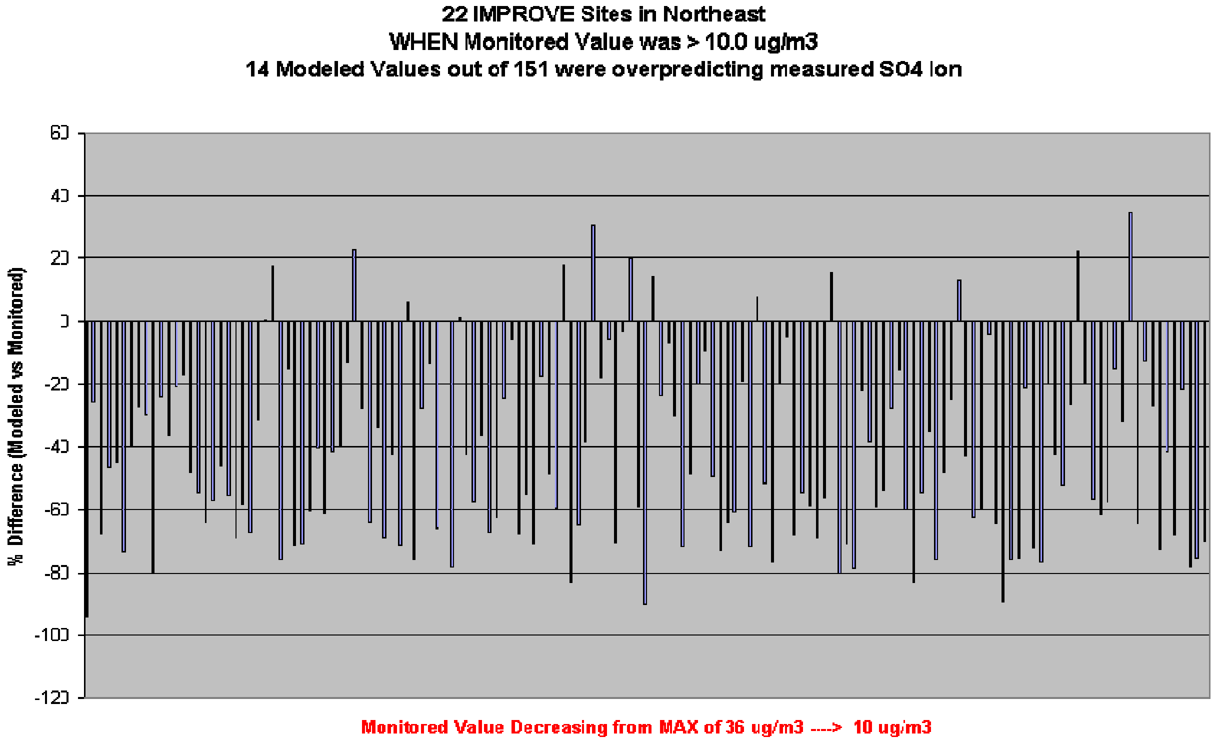


Figure D-30 shows further evidence that the model is generally under-predicting SO_4 ion for the highest actual monitored values measured across the northeast portion of the domain. As a percent of under or over-prediction, the plot indicates that for these 22 mostly downwind receptor sites, for dates when the highest SO_4 ion was measured (24Hr SO_4 ion measurements in the range of 10 $\mu g/m^3$ to 36 $\mu g/m^3$ occurred 151 times at the 22 IMPROVE sites during 2002) **only 14 dates were over-predicted**. The performance of the model in predicting 24-hr SO_4 ion appears to be biased toward under-prediction for those sites generally directly downwind of the major source regions. Given that a very large percentage of the SO_2 emissions have been incorporated in the modeling, this implies that model predictions represent a lower limit to the influence of these sources on the receptor areas.

Figure D-30. Percent Difference between Modeled and Monitored 24Hr Avg of SO_4 Ion



Looking at the performance of the model for smaller subsets of receptor sites allows us to identify how well the model platform is representing the combined processes of transport, chemical conversion, removal, and dispersion to predict SO_4 ion concentration at sites similar to each other in some characteristic way, but different from other subsets. Figure D-31a-c show model performance summaries of the variability and success or lack of success the model had in predicting 24-hr SO_4 ion in the distribution of values modeled for the year 2002 meteorology. The three subsets of sites are characteristically different from each other mostly by their location in the domain, representing either coastal New England, interior New England, or locations closer to the western boundary of the MANE-VU region

In these three figures, the smoother blue line is the monitored 24-hr SO_4 ion and the variable red line shows the corresponding modeled value, where the distribution of monitored values for the subset of sites is ordered from highest to lowest going from left to right on the figure.

Figure D-31a. Four Coastal New England IMPROVE Sites

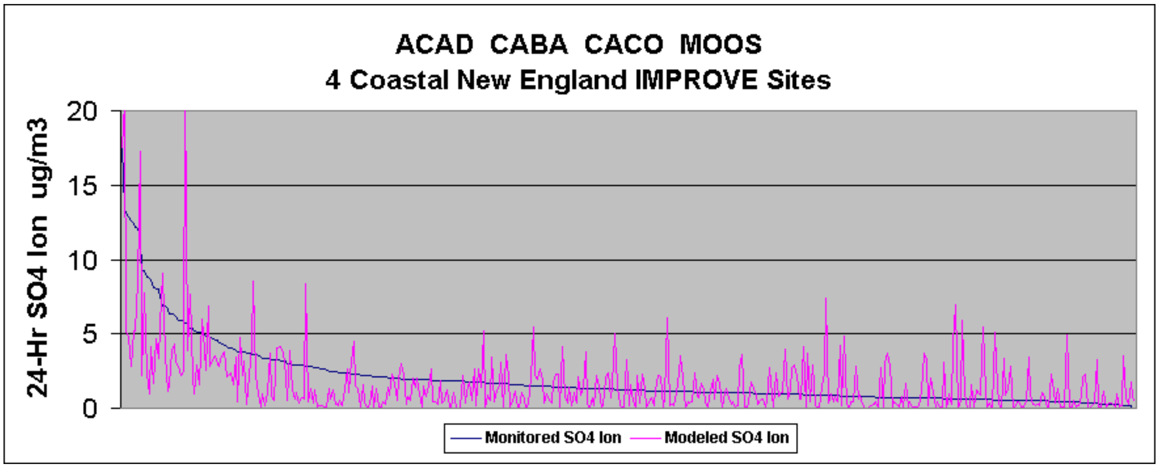


Figure D-31b. Four IMPROVE Sites in Western Portion of MANE-VU

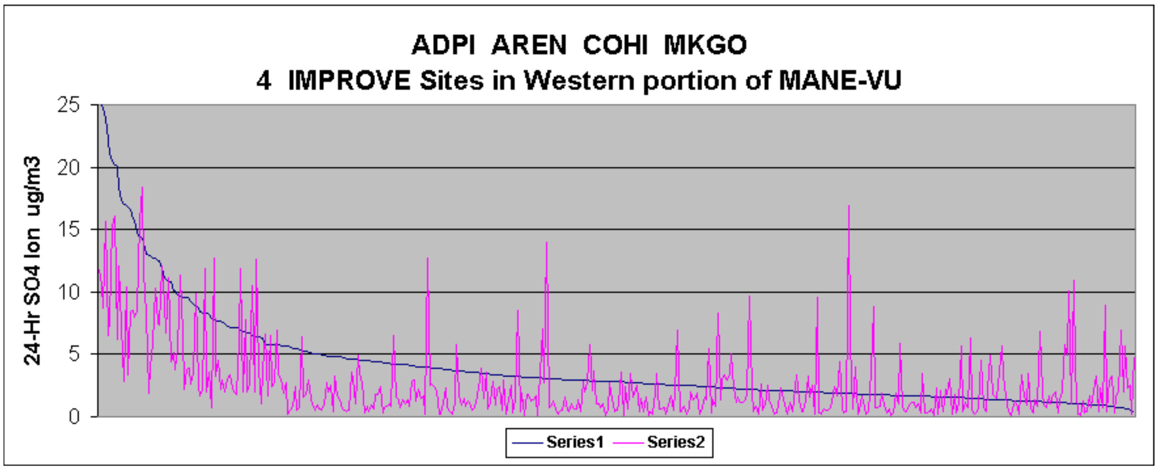
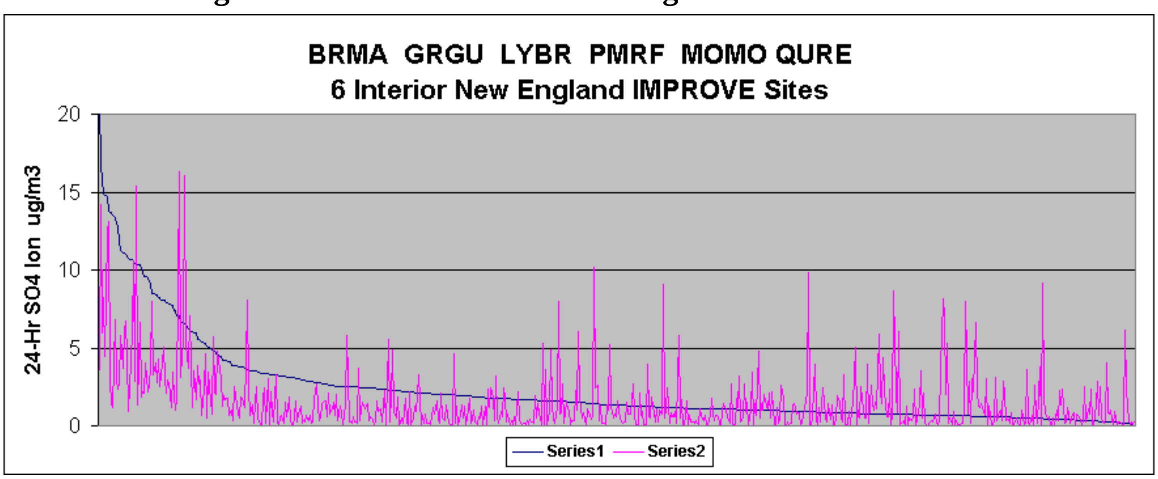


Figure D-31c. Six Interior New England IMPROVE Sites



Note: **BLUE LINE shows the monitored 24-hr SO4 ion** and the **RED LINE shows the corresponding modeled value**, where the distribution of monitored values for the subset of sites is ordered from **HIGHEST → LOWEST** going from left to right on the figure.

For all three of these subsets it is still clear that for the highest values monitored (especially those greater than about 5.0 ug/m3) at each of the sites in that subset, there is under-prediction of the 24-hr ambient SO_4 ion. This under-prediction appears to be least in the subset comprised of coastal Maine and Massachusetts sites which are furthest from the primary SO_2 emitting source regions in the domain. For sites on the western edge of the MANE-VU region which is closer to the primary SO_2 emitting sources contributing to domain wide precursors of SO_4 ion the magnitude of the under-prediction appears to increase in absolute value. Under-prediction at sites in interior New England appears to fall between that seen for the other two subsets. For all the sites in the northeastern portion of the domain (generally downwind of the most significant SO_2 emission areas) it is clear that the model is not producing enough SO_4 ion for the meteorological and emission representations used in the model during periods of highest measured SO_4 ion. This could mean that the chemistry is not adequately being modeled or that missing emissions are coming into play. Based on a relatively good understanding of the sources of SO_2 precursor emissions, and the belief that the inventories of emissions used in the Phase II modeling were very good representations of the actual emissions pattern during 2002, these results seem to indicate that a more robust chemical conversion rate from gaseous SO_2 to aerosol form SO_4 ion needs to be incorporated in the model, perhaps through better representation of the aqueous phase chemistry which is currently not accounted for well in CALPUFF.

Apportioning the Contribution of States and Individual EGU Sources of SO_2

Based on a reasonable conclusion that the VTDEC CALPUFF modeling platform appears to be performing well enough to be used at least in a relative sense, the following Figure D-32a and Figure D-32b summarize the contribution to annual ambient SO_4 ion at all of the Class I areas in the northeastern portion of the domain due to modeled SO_2 emissions originating in the four RPOs and portions of Canada located either entirely or partially in the domain.

Figure D-32a. Contribution to SO_4 Ion at ACAD LYBR BRIG SHEN

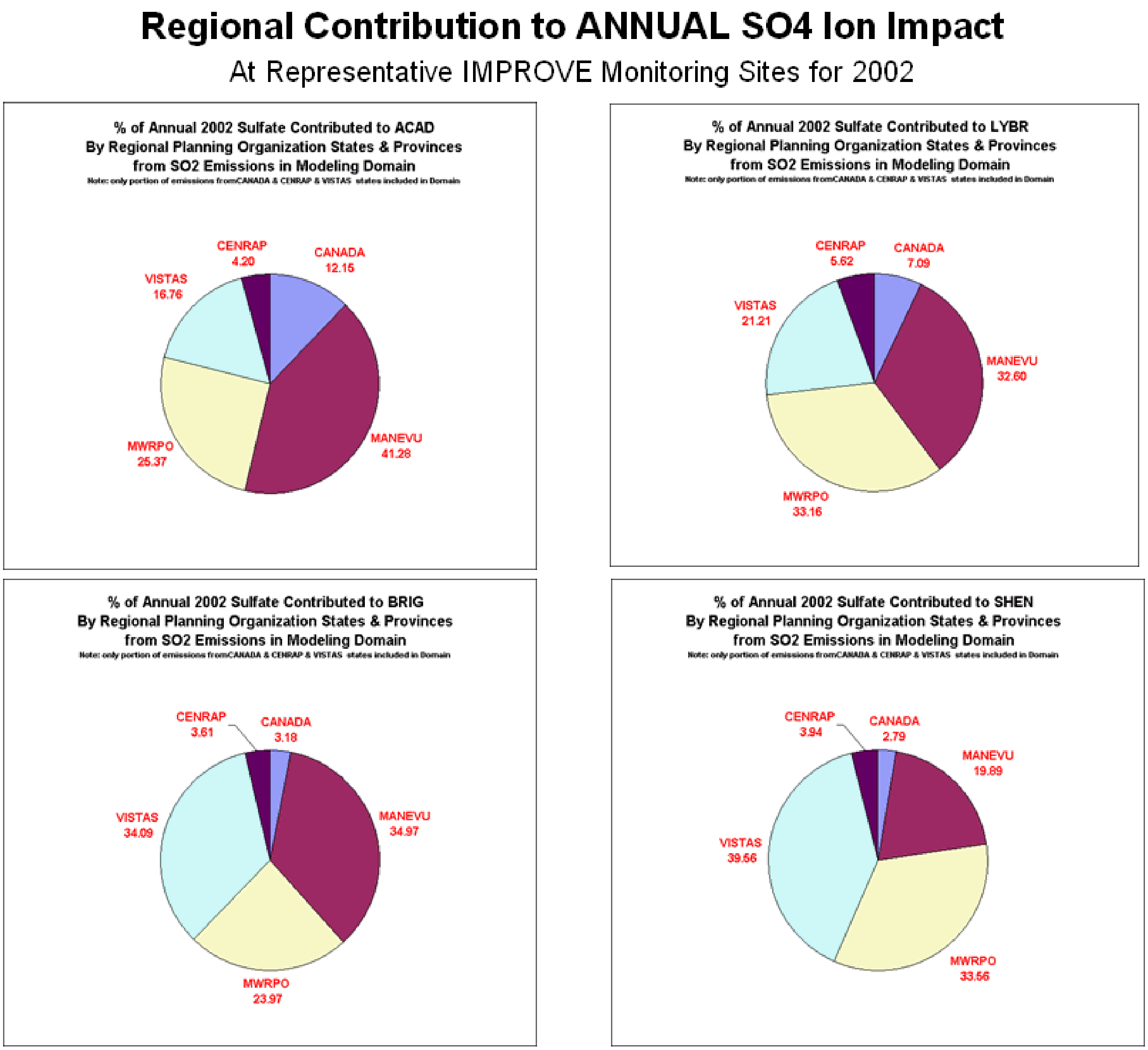
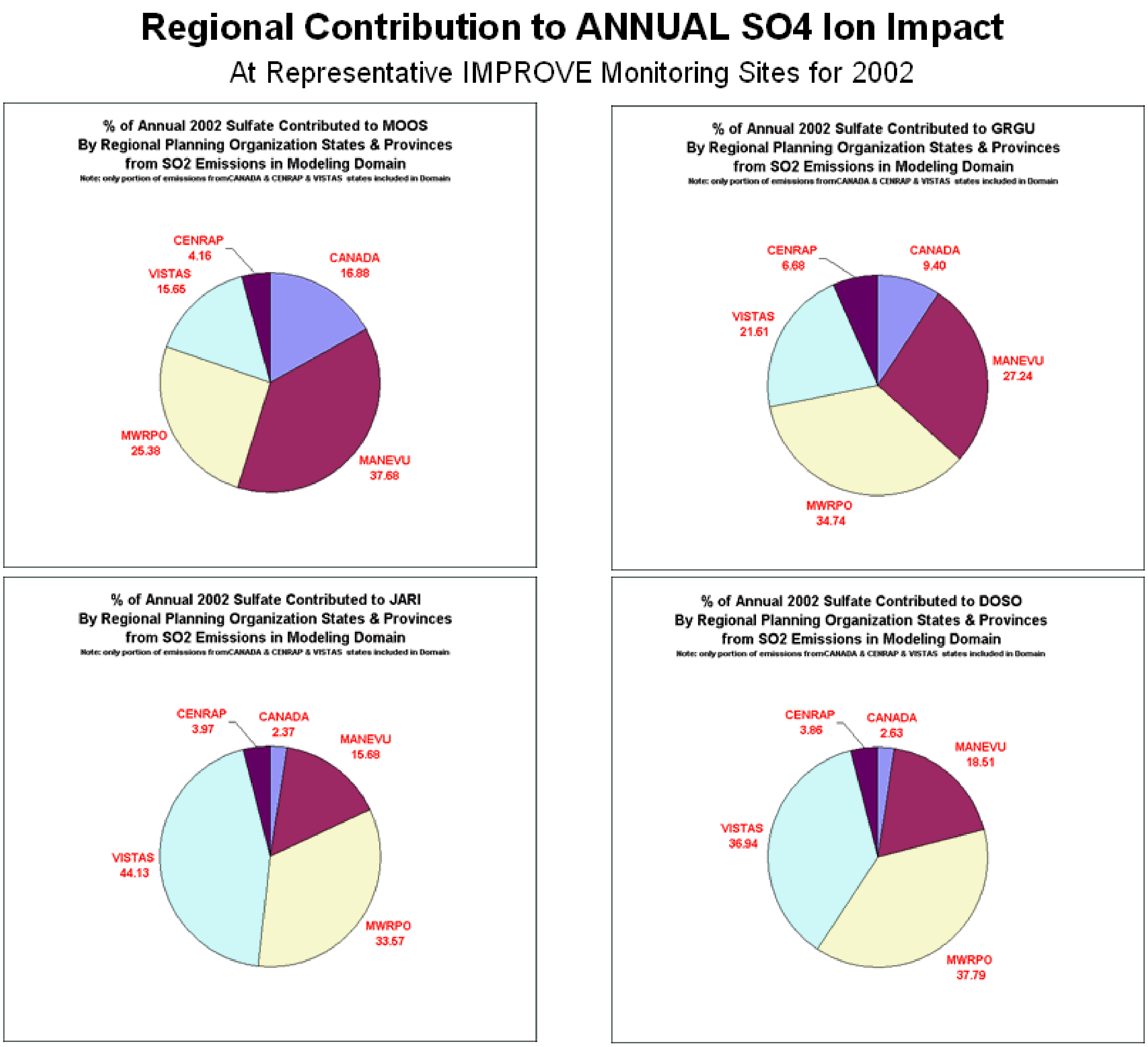


Figure D-32b. Contribution to SO_4 Ion at MOOS GRGU JARI DOSO



State-by-State Results Summary: VTDEC NWS-Based Meteorology

Figure D-33(a-d, for different Class I areas) shows the contribution from individual states and from Canada to the SO_4 Ion concentrations predicted for 2002 at four of the Class I areas in the northeastern portion of the domain modeled.

Figure D-33a. State by State Contributions to Ambient SO_4 Ion at Acadia National Park

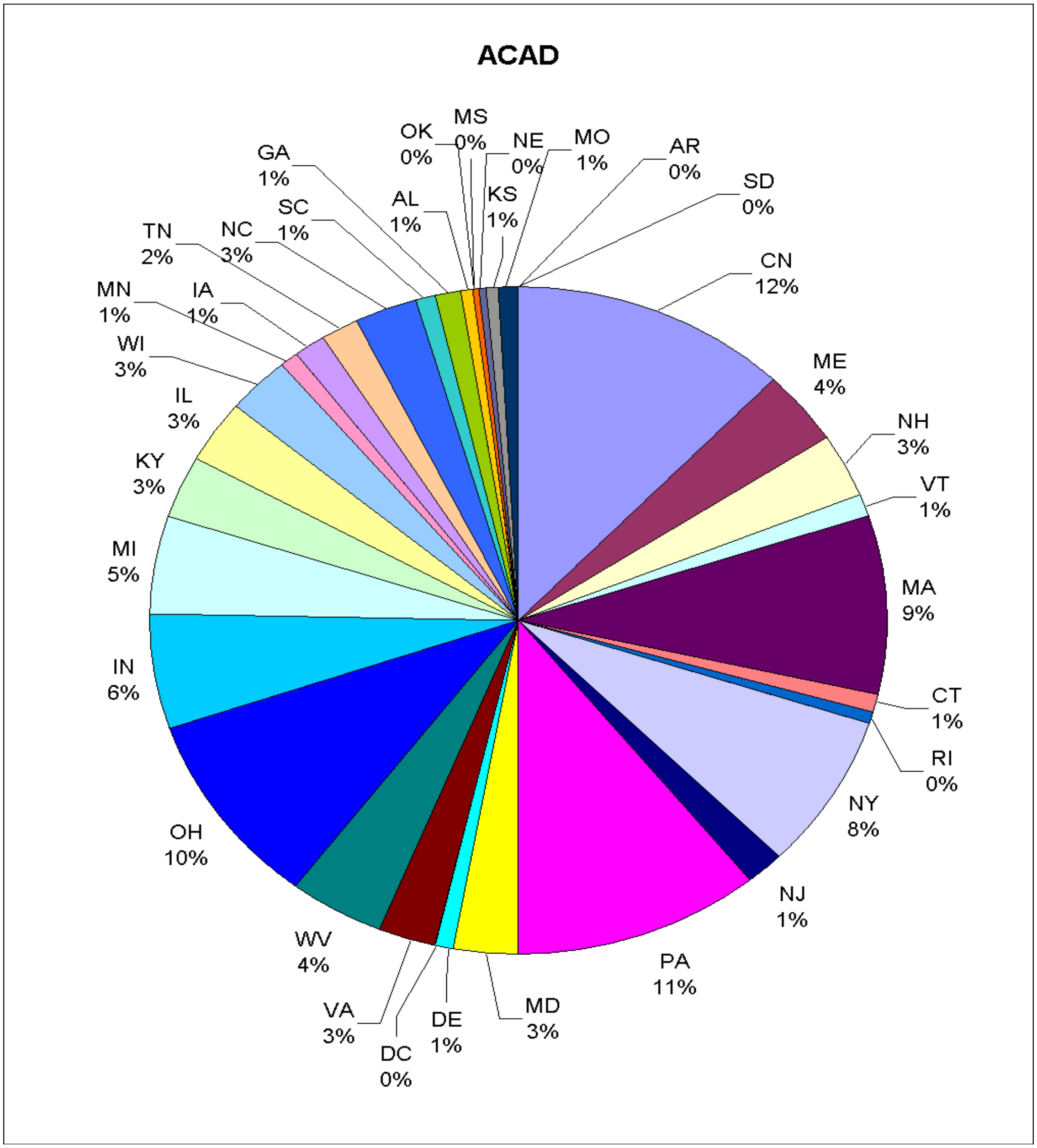


Figure D-33b State by State Contributions to Ambient SO_4 Ion at Lye Brook Wilderness Area

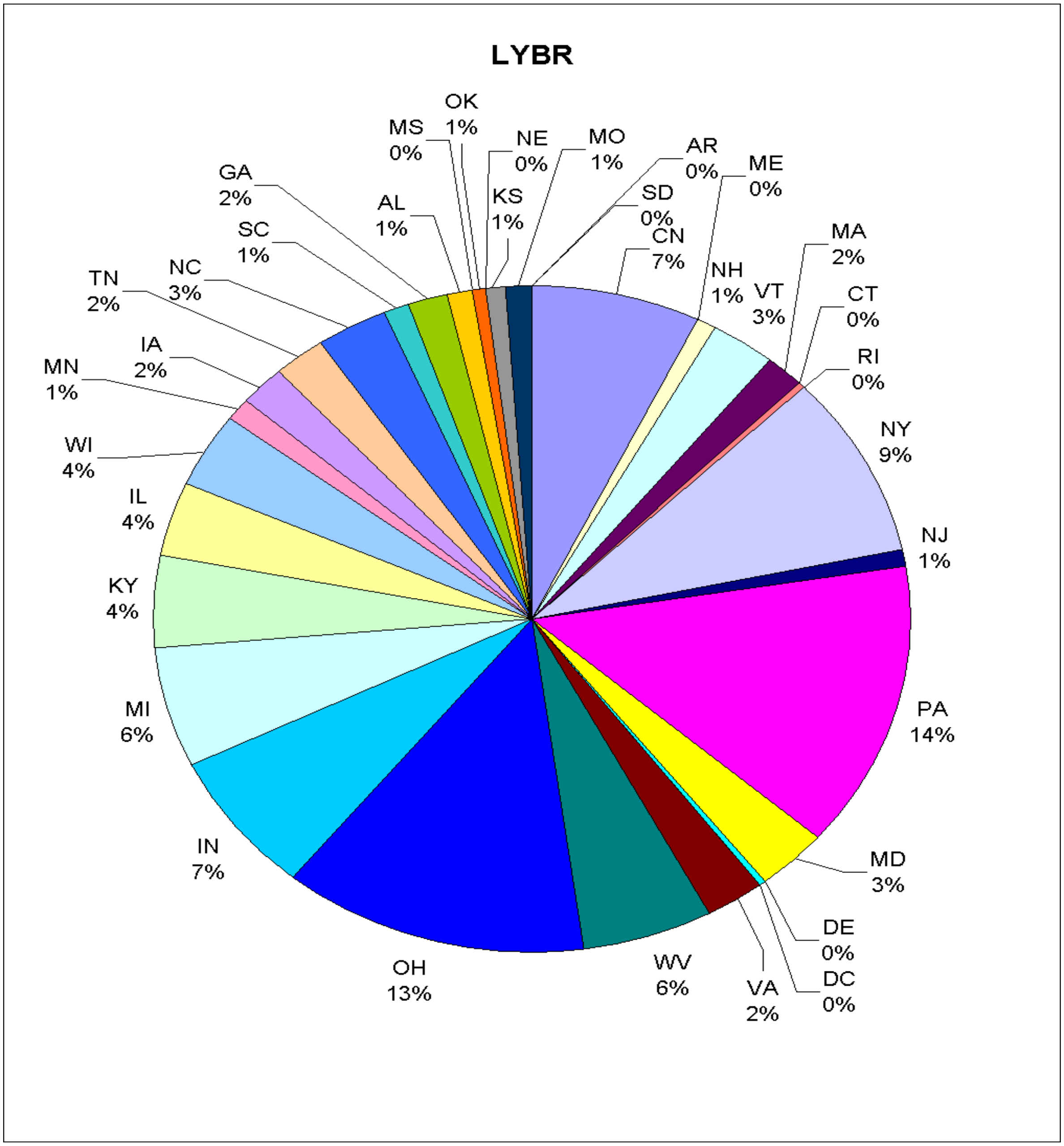


Figure D-33c. State by State Contributions to Ambient SO_4 Ion at Brigantine National Wildlife Refuge

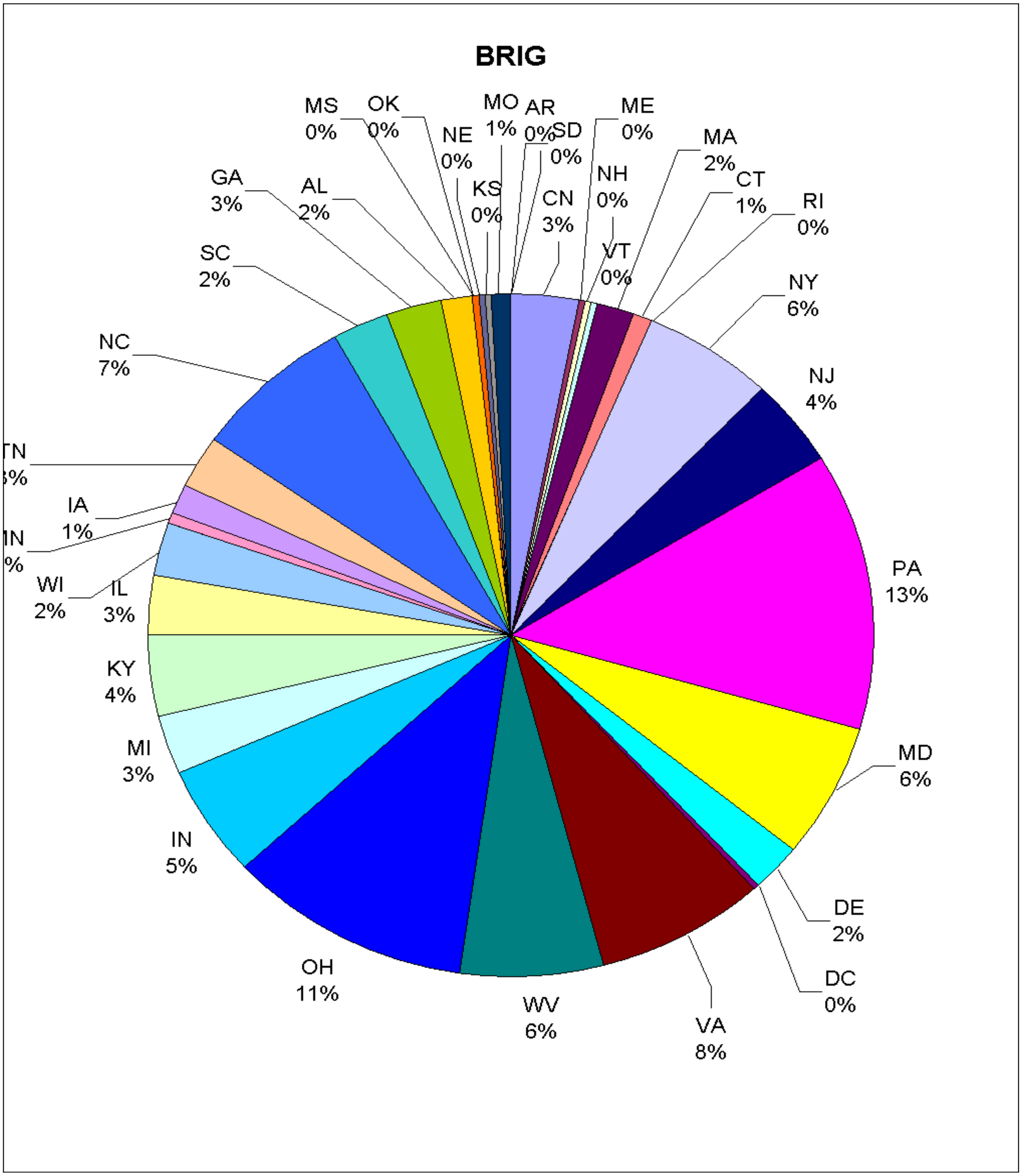


Figure D-33d. State by State Contributions to Ambient SO_4 Ion at Shenandoah National Park

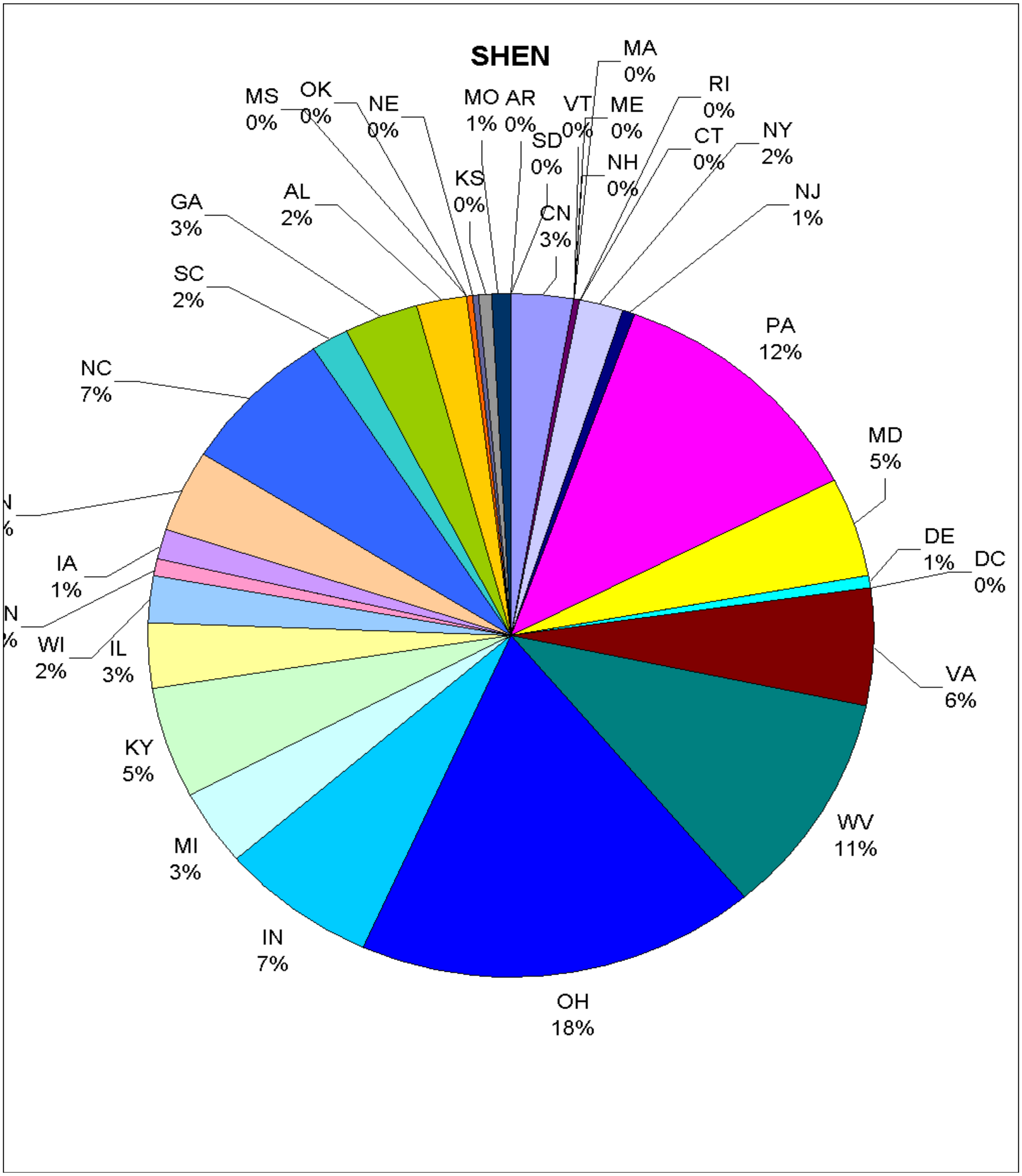


Table D-10(a-d, for different Class I areas) provides a summary of individual EGU impacts. These tables represent the 100 highest predicted 24-hr average sulfate ion concentrations at each site. Additional information shown includes the unit identification code from the CEMS data base, the State where the unit is located, the date of the 24-hr prediction, the predicted annual average sulfate ion concentration for the unit (and the rank of the annual average concentration), total tons of SO_2 emitted in 2002, the stack height, and the distance from the source to the Class I area.

Table D-10a. VT DEC CALPUFF MODELING RESULTS

Acadia National Park								
RANK	CEMS SOURCE	STATE	24-Hr Max SO4 Ion Impact (~µg/m^3)	24Hr Date	Annual SO_4 Ion Impact (~µg/m^3)	2002 SO_2 (Tons)	Modeled StkHt (Meters)	Distance (Kms)
1	D028404	OH	0.541	08/14/02	0.01364	87723.73	245.4	1207.2
2	D031361	PA	0.498	08/13/02	0.01677	87357.00	243.8	992.3
3	D031362	PA	0.473	08/13/02	0.01176	62791.27	243.8	992.3
4	D031222	PA	0.429	08/13/02	0.01050	55167.46	243.8	990.5
5	D031492	PA	0.394	07/23/02	0.01102	50232.01	347.2	776.2
6	D031221	PA	0.394	08/13/02	0.00887	45713.85	243.8	990.5
7	D02876C01	OH	0.392	08/15/02	0.00793	72528.72	243.8	1294.7
8	D031491	PA	0.368	08/13/02	0.01220	60188.24	347.2	776.2
9	D028281	OH	0.336	08/14/02	0.00650	37274.20	251.5	1111.4
10	D03179C01	PA	0.319	08/14/02	0.01128	79564.81	150.0	1080.3
11	D03406C10	TN	0.311	10/03/02	0.00696	104430.60	150.0	1875.4
12	D080421	NC	0.299	08/16/02	0.00472	57768.69	182.9	1337.1
13	D03948C02	WV	0.294	08/14/02	0.00823	55355.96	167.6	1146.4
14	D016193	MA	0.270	07/23/02	0.01060	19307.64	107.3	378.9
15	D080422	NC	0.270	08/16/02	0.00388	45255.73	182.9	1337.1
16	D028667	OH	0.268	08/14/02	0.00670	33571.62	259.1	1095.9
17	D023642	NH	0.259	08/13/02	0.01541	19435.42	159.7	291.3
18	D037976	VA	0.239	08/16/02	0.00540	40533.88	127.7	1086.1
19	D02872C04	OH	0.235	08/14/02	0.00877	83060.23	150.0	1223.3
20	D0283612	OH	0.220	08/14/02	0.00777	41395.14	182.9	1161.8
21	D082261	PA	0.217	08/13/02	0.00683	40231.91	228.6	1033.1
22	D039432	WV	0.215	08/14/02	0.00620	45808.91	167.6	1088.3
23	D039431	WV	0.209	08/14/02	0.00564	42347.54	167.6	1088.3
24	D01733C12	MI	0.207	08/14/02	0.00799	46039.95	137.2	1249.4
25	D016264	MA	0.199	09/20/02	0.00345	2877.66	152.4	294.1
26	D01733C34	MI	0.199	01/31/02	0.00769	39326.85	152.4	1249.4
27	D015992	MA	0.194	05/31/02	0.00353	8971.48	151.8	341.6
28	D028327	OH	0.190	08/15/02	0.00600	46949.57	243.8	1482.6
29	D00988U4	IN	0.189	01/31/02	0.00570	45022.27	122.8	1488.3
30	D01353C02	KY	0.189	08/15/02	0.00477	41507.88	243.8	1375.6
31	D03131CS1	PA	0.188	08/13/02	0.00476	22323.74	150.0	901.2
32	D01010C05	IN	0.182	10/03/02	0.00836	60693.13	122.8	1662.7
33	D039353	WV	0.181	08/15/02	0.00527	42174.31	274.9	1299.5
34	D031403	PA	0.177	08/13/02	0.00600	38766.62	269.1	837.4
35	D03298WL1	SC	0.177	08/16/02	0.00114	25147.74	121.9	1614.4
36	D015991	MA	0.176	07/29/02	0.00756	13002.46	151.8	341.6
37	D02712C03	NC	0.176	08/16/02	0.00327	30749.26	150.0	1260.2
38	D028306	OH	0.175	01/30/02	0.00358	30438.59	137.2	1451.0
39	D027274	NC	0.174	08/16/02	0.00183	27284.07	85.3	1447.9

Acadia National Park								
RANK	**CEMS SOURCE**	**STATE**	**24-Hr Max SO4 Ion Impact (~µg/m^3)**	**24Hr Date**	**Annual SO_4 Ion Impact (~µg/m^3)**	**2002 SO_2 (Tons)**	**Modeled StkHt (Meters)**	**Distance (Kms)**
40	D027273	NC	0.173	08/16/02	0.00176	26305.45	85.3	1447.9
41	D027122	NC	0.170	08/16/02	0.00303	29310.41	121.9	1260.2
42	D03935C02	WV	0.170	05/29/02	0.00677	63009.75	274.3	1299.5
43	D03809CS0	VA	0.169	08/16/02	0.00417	21200.55	98.8	1048.1
44	D06166C02	IN	0.168	10/03/02	0.00554	51662.69	304.8	1715.4
45	D027215	NC	0.167	08/16/02	0.00145	19128.20	152.4	1527.9
46	D03140C12	PA	0.166	07/23/02	0.00514	29709.17	259.1	837.4
47	D01571CE2	MD	0.164	07/23/02	0.00711	48522.41	335.3	950.7
48	D06113C03	IN	0.162	08/15/02	0.00828	71118.81	150.0	1748.0
49	D062641	WV	0.161	08/15/02	0.00514	42719.38	335.3	1276.8
50	D015731	MD	0.156	08/16/02	0.00521	36790.12	213.4	983.0
51	D02554C03	NY	0.155	09/11/02	0.00748	30124.51	150.0	916.5
52	D038093	VA	0.154	08/16/02	0.00140	10467.61	149.0	1048.1
53	D015732	MD	0.153	08/16/02	0.00435	30760.70	213.4	983.0
54	D02866C01	OH	0.153	08/14/02	0.00419	24627.17	153.6	1095.9
55	D0099070	IN	0.151	10/03/02	0.00411	29774.44	172.2	1559.5
56	D02864C01	OH	0.146	08/14/02	0.00473	35161.71	259.1	1141.4
57	D023641	NH	0.145	04/17/02	0.00766	9347.83	131.7	291.3
58	D062491	SC	0.145	08/16/02	0.00093	17919.56	123.1	1550.3
59	D06250C05	NC	0.144	08/16/02	0.00273	27370.73	243.8	1245.7
60	D067054	IN	0.139	10/03/02	0.00442	40082.21	152.4	1738.5
61	D027133	NC	0.139	08/16/02	0.00116	14460.20	167.6	1391.2
62	D03947C03	WV	0.137	08/14/02	0.00489	38540.84	150.0	1145.8
63	D031782	PA	0.133	08/13/02	0.00339	16468.79	307.2	988.8
64	D02549C01	NY	0.132	08/14/02	0.00671	25320.03	150.0	869.6
65	D028502	OH	0.132	08/15/02	0.00328	28672.85	213.4	1425.8
66	D016192	MA	0.131	09/20/02	0.00757	8881.31	107.3	378.9
67	D028501	OH	0.131	08/15/02	0.00354	30770.84	213.4	1425.8
68	D03297WT1	SC	0.131	08/16/02	0.00089	17670.72	91.4	1577.2
69	D02866C02	OH	0.130	08/14/02	0.00429	25999.24	153.6	1095.9
70	D06113C04	IN	0.129	01/31/02	0.00348	27823.32	213.4	1748.0
71	D01356C02	KY	0.129	01/30/02	0.00343	25622.89	225.9	1519.4
72	D02712C04	NC	0.128	08/16/02	0.00227	22941.29	150.0	1260.2
73	D02840C02	OH	0.128	08/14/02	0.00333	22770.56	172.2	1207.2
74	D080021	NH	0.126	08/14/02	0.00461	5028.40	133.2	247.0
75	D000475	AL	0.125	10/03/02	0.00110	27218.75	152.4	1975.2
76	D025945	NY	0.125	08/15/02	0.00084	1746.53	213.4	668.5
77	D028504	OH	0.124	08/15/02	0.00327	27318.93	213.4	1425.8
78	D016263	MA	0.122	09/20/02	0.00494	4966.05	132.6	294.1
79	D01572C23	MD	0.121	08/13/02	0.00464	32159.23	121.9	950.3
80	D016191	MA	0.118	09/20/02	0.00763	9244.07	107.3	378.9
81	D023781	NJ	0.118	03/14/02	0.00351	9737.90	144.8	770.2
82	D028665	OH	0.117	08/14/02	0.00330	19778.82	304.8	1095.9

Acadia National Park								
RANK	**CEMS SOURCE**	**STATE**	**24-Hr Max SO4 Ion Impact (~µg/m^3)**	**24Hr Date**	**Annual SO_4 Ion Impact (~µg/m^3)**	**2002 SO_2 (Tons)**	**Modeled StkHt (Meters)**	**Distance (Kms)**
83	D03297WT2	SC	0.117	08/16/02	0.00075	17199.39	91.4	1577.2
84	D00709C02	GA	0.115	08/16/02	0.00090	47548.54	121.9	1788.7
85	D02866M6A	OH	0.115	08/14/02	0.00335	19546.42	304.8	1095.9
86	D028375	OH	0.113	07/03/02	0.00712	35937.73	182.9	1111.1
87	D03407C15	TN	0.113	08/16/02	0.00213	37274.48	152.4	1660.6
88	D037975	VA	0.113	08/16/02	0.00265	19602.10	61.0	1086.1
89	D07253C01	OH	0.112	08/15/02	0.00369	30949.43	213.4	1224.2
90	D033194	SC	0.111	08/16/02	0.00056	11838.20	91.4	1591.7
91	D017437	MI	0.110	09/12/02	0.00359	15804.84	182.9	1154.7
92	D028725	OH	0.110	08/14/02	0.00355	30052.41	252.1	1223.3
93	D060191	OH	0.109	08/15/02	0.00244	21495.65	174.6	1452.5
94	D038034	VA	0.109	08/15/02	0.00211	10806.45	61.0	1078.6
95	D007034LR	GA	0.106	08/16/02	0.00128	40973.96	304.8	1818.2
96	D00861C01	IL	0.105	07/24/02	0.00540	42318.01	152.4	1838.3
97	D024032	NJ	0.105	03/09/02	0.00582	18768.40	152.1	621.5
98	D03407C69	TN	0.105	10/03/02	0.00223	38610.70	150.0	1660.6
99	D007033LR	GA	0.104	08/16/02	0.00118	43029.15	304.8	1818.2
100	D013783	KY	0.102	05/26/02	0.00309	46660.04	243.8	1749.3

Table D-10b. VT DEC CALPUFF MODELING RESULTS

Brigantine National Wildlife Refuge								
RANK	**CEMS SOURCE**	**STATE**	**24-Hr Max SO_4 Ion Impact (~µg/m^3)**	**24Hr Date**	**Annual SO_4 Ion Impact (~µg/m^3)**	**2002 SO_2 (Tons)**	**Modeled StkHt (Meters)**	**Distance (Kms)**
1	D03935C02	WV	0.580	06/26/02	0.02133	63009.75	274.3	643.2
2	D028404	OH	0.560	06/11/02	0.02024	87723.73	245.4	636.0
3	D037976	VA	0.511	06/27/02	0.02723	40533.88	127.7	343.0
4	D01571CE2	MD	0.504	08/14/02	0.02772	48522.41	335.3	217.5
5	D080421	NC	0.454	08/14/02	0.01933	57768.69	182.9	603.1
6	D02872C04	OH	0.453	07/20/02	0.01933	83060.23	150.0	616.7
7	D031491	PA	0.435	03/15/02	0.02096	60188.24	347.2	258.4
8	D03179C01	PA	0.424	07/19/02	0.02476	79564.81	150.0	468.3
9	D02876C01	OH	0.396	06/26/02	0.01982	72528.72	243.8	660.6
10	D080422	NC	0.389	08/14/02	0.01531	45255.73	182.9	603.1
11	D039353	WV	0.386	06/26/02	0.01527	42174.31	274.9	643.2
12	D015731	MD	0.380	07/03/02	0.02099	36790.12	213.4	249.5
13	D015732	MD	0.372	07/03/02	0.01753	30760.70	213.4	249.5
14	D031361	PA	0.371	07/16/02	0.02671	87357.00	243.8	435.1
15	D023781	NJ	0.367	07/02/02	0.01627	9737.90	144.8	25.0
16	D038034	VA	0.363	08/13/02	0.01059	10806.45	61.0	338.7
17	D03809CS0	VA	0.362	08/13/02	0.01787	21200.55	98.8	303.9
18	D062641	WV	0.354	06/26/02	0.01298	42719.38	335.3	643.2
19	D031362	PA	0.352	07/16/02	0.02101	62791.27	243.8	435.1
20	D031492	PA	0.338	07/04/02	0.01719	50232.01	347.2	258.4
21	D005944	DE	0.318	08/05/02	0.00987	7383.72	121.9	118.5
22	D028327	OH	0.315	06/26/02	0.00920	46949.57	243.8	886.4
23	D027122	NC	0.308	08/13/02	0.01213	29310.41	121.9	520.7
24	D02712C03	NC	0.307	08/13/02	0.01365	30749.26	150.0	520.7
25	D03954CS0	WV	0.291	01/22/02	0.00613	20111.54	225.9	413.0
26	D01353C02	KY	0.289	06/26/02	0.01479	41507.88	243.8	718.2
27	D037975	VA	0.289	06/27/02	0.01494	19602.10	61.0	343.0
28	D01010C05	IN	0.282	06/26/02	0.00842	60693.13	122.8	1106.0
29	D038093	VA	0.273	08/13/02	0.00839	10467.61	149.0	303.9
30	D028281	OH	0.268	07/19/02	0.01137	37274.20	251.5	533.3
31	D039432	WV	0.268	07/20/02	0.01378	45808.91	167.6	466.6
32	D039431	WV	0.264	07/20/02	0.01305	42347.54	167.6	466.6
33	D03406C10	TN	0.258	07/30/02	0.01199	104430.60	150.0	1214.5
34	D00988U4	IN	0.256	07/20/02	0.00843	45022.27	122.8	891.4
35	D06250C05	NC	0.253	08/13/02	0.01148	27370.73	243.8	505.3
36	D03948C02	WV	0.244	07/20/02	0.01490	55355.96	167.6	543.4
37	D03298WL1	SC	0.236	08/15/02	0.00499	25147.74	121.9	870.8
38	D031221	PA	0.228	07/16/02	0.01247	45713.85	243.8	420.4
39	D027215	NC	0.225	08/15/02	0.00515	19128.20	152.4	795.8
40	D028306	OH	0.225	06/26/02	0.00555	30438.59	137.2	844.8

Brigantine National Wildlife Refuge								
RANK	**CEMS SOURCE**	**STATE**	**24-Hr Max SO_4 Ion Impact (~µg/m^3)**	**24Hr Date**	**Annual SO_4 Ion Impact (~µg/m^3)**	**2002 SO_2 (Tons)**	**Modeled StkHt (Meters)**	**Distance (Kms)**
41	D028667	OH	0.224	07/19/02	0.01036	33571.62	259.1	536.7
42	D082261	PA	0.224	07/19/02	0.01106	40231.91	228.6	467.9
43	D06113C03	IN	0.221	06/26/02	0.00955	71118.81	150.0	1152.2
44	D005943	DE	0.215	08/05/02	0.00681	4681.50	117.3	118.5
45	D01572C23	MD	0.213	07/03/02	0.01459	32159.23	121.9	259.4
46	D031403	PA	0.213	09/05/02	0.01465	38766.62	269.1	203.1
47	D02712C04	NC	0.210	06/12/02	0.00998	22941.29	150.0	520.7
48	D027273	NC	0.210	08/15/02	0.00660	26305.45	85.3	713.7
49	D028502	OH	0.210	06/26/02	0.00672	28672.85	213.4	798.7
50	D024032	NJ	0.209	08/03/02	0.00984	18768.40	152.1	145.4
51	D027274	NC	0.207	08/15/02	0.00688	27284.07	85.3	713.7
52	D028504	OH	0.206	06/26/02	0.00648	27318.93	213.4	798.7
53	D028501	OH	0.204	06/26/02	0.00695	30770.84	213.4	798.7
54	D005935	DE	0.201	08/05/02	0.00316	2135.69	83.8	121.1
55	D038033	VA	0.201	08/13/02	0.00843	9493.00	61.0	338.7
56	D016193	MA	0.199	03/20/02	0.00664	19307.64	107.3	369.7
57	D07253C01	OH	0.194	06/11/02	0.00877	30949.43	213.4	604.0
58	D007034LR	GA	0.188	03/08/02	0.00678	40973.96	304.8	1099.1
59	D027121	NC	0.187	08/13/02	0.00519	12020.17	121.9	520.7
60	D02832C06	OH	0.186	06/26/02	0.00489	23673.32	213.4	886.4
61	D03297WT1	SC	0.186	08/15/02	0.00392	17670.72	91.4	832.3
62	D028503	OH	0.184	06/26/02	0.00636	27943.53	213.4	798.7
63	D02864C01	OH	0.181	06/11/02	0.00947	35161.71	259.1	542.5
64	D007033LR	GA	0.180	03/08/02	0.00690	43029.15	304.8	1099.1
65	D00861C01	IL	0.180	06/26/02	0.00553	42318.01	152.4	1279.5
66	D03407C15	TN	0.178	08/14/02	0.00792	37274.48	152.4	965.0
67	D06170CS1	WI	0.175	07/20/02	0.00533	32737.32	182.9	1172.4
68	D010012	IN	0.174	06/26/02	0.00427	25992.39	152.4	1103.3
69	D03140C12	PA	0.174	09/05/02	0.01169	29709.17	259.1	203.1
70	D0099070	IN	0.168	06/26/02	0.00472	29774.44	172.2	1000.8
71	D081021	OH	0.166	06/26/02	0.00493	18190.75	253.0	659.3
72	D060191	OH	0.166	06/26/02	0.00472	21495.65	174.6	840.5
73	D03297WT2	SC	0.166	08/15/02	0.00351	17199.39	91.4	832.3
74	D005942	DE	0.165	08/05/02	0.00524	3759.93	152.4	118.5
75	D00709C02	GA	0.163	05/14/02	0.00616	47548.54	121.9	1050.5
76	D01733C34	MI	0.163	07/19/02	0.00804	39326.85	152.4	792.7
77	D060312	OH	0.162	06/26/02	0.00496	19500.08	274.3	779.6
78	D081022	OH	0.161	06/26/02	0.00404	12322.44	253.0	659.3
79	D0393851	WV	0.161	06/26/02	0.00402	12936.25	183.8	642.4
80	D01733C12	MI	0.160	07/19/02	0.00823	46039.95	137.2	792.7
81	D06166C02	IN	0.158	06/26/02	0.00742	51662.69	304.8	1098.7
82	D062491	SC	0.158	08/15/02	0.00407	17919.56	123.1	807.9
83	D06113C04	IN	0.156	06/26/02	0.00443	27823.32	213.4	1152.2

Brigantine National Wildlife Refuge								
RANK	**CEMS SOURCE**	**STATE**	**24-Hr Max SO_4 Ion Impact (~µg/m^3)**	**24Hr Date**	**Annual SO_4 Ion Impact (~µg/m^3)**	**2002 SO_2 (Tons)**	**Modeled StkHt (Meters)**	**Distance (Kms)**
84	D013783	KY	0.156	06/26/02	0.00630	46660.04	243.8	1112.4
85	D019151	MN	0.155	12/17/02	0.00329	21855.00	239.0	1620.5
86	D007031LR	GA	0.153	03/08/02	0.00619	38486.16	304.8	1099.1
87	D033194	SC	0.153	08/15/02	0.00215	11838.20	91.4	847.5
88	D01356C02	KY	0.151	06/26/02	0.00505	25622.89	225.9	911.1
89	D0283612	OH	0.151	07/19/02	0.00841	41395.14	182.9	677.8
90	D037974	VA	0.150	06/27/02	0.00687	9293.00	61.0	343.0
91	D03407C69	TN	0.149	08/14/02	0.00828	38610.70	150.0	965.0
92	D031222	PA	0.148	08/20/02	0.01496	55167.46	243.8	420.4
93	D000265	AL	0.147	02/01/02	0.00515	53015.27	228.6	1271.8
94	D03938C04	WV	0.145	06/26/02	0.00672	26427.11	121.9	642.4
95	D005941	DE	0.144	08/05/02	0.00488	3742.48	152.4	118.5
96	D02866C01	OH	0.141	07/19/02	0.00679	24627.17	153.6	536.7
97	D027093	NC	0.139	08/15/02	0.00375	9389.76	91.4	553.7
98	D03936C02	WV	0.138	06/26/02	0.00557	15466.69	304.8	616.2
99	D01355C03	KY	0.136	09/05/02	0.00736	38069.95	150.0	905.3
100	D033193	SC	0.136	08/15/02	0.00221	11045.11	91.4	847.5

Table D-10c VT DEC CALPUFF MODELING RESULTS

Lye Brook Wilderness								
RANK	**CEMS SOURCE**	**STATE**	**24-Hr Max SO_4 Ion Impact (~µg/m^3)**	**24Hr Date**	**Annual SO_4 Ion Impact (~µg/m^3)**	**2002 SO_2 (Tons)**	**Modeled StkHt (Meters)**	**Distance (Kms)**
1	D031361	PA	0.764	06/24/02	0.02622	87357.00	243.8	580.4
2	D031362	PA	0.689	06/24/02	0.01933	62791.27	243.8	580.4
3	D028404	OH	0.680	08/13/02	0.02024	87723.73	245.4	794.3
4	D03179C01	PA	0.598	08/13/02	0.01709	79564.81	150.0	671.2
5	D031492	PA	0.576	06/23/02	0.01598	50232.01	347.2	371.2
6	D031491	PA	0.557	06/23/02	0.01699	60188.24	347.2	371.2
7	D03948C02	WV	0.543	08/13/02	0.01175	55355.96	167.6	735.3
8	D028281	OH	0.539	08/13/02	0.00996	37274.20	251.5	699.1
9	D082261	PA	0.470	06/24/02	0.01067	40231.91	228.6	621.0
10	D02876C01	OH	0.463	08/14/02	0.01137	72528.72	243.8	884.6
11	D031222	PA	0.444	08/13/02	0.01239	55167.46	243.8	579.5
12	D039432	WV	0.409	08/13/02	0.00903	45808.91	167.6	680.2
13	D039431	WV	0.405	08/13/02	0.00834	42347.54	167.6	680.2
14	D031221	PA	0.402	08/13/02	0.01137	45713.85	243.8	579.5
15	D02872C04	OH	0.377	08/13/02	0.01413	83060.23	150.0	811.6
16	D028667	OH	0.370	08/13/02	0.00976	33571.62	259.1	683.1
17	D01010C05	IN	0.321	07/03/02	0.00817	60693.13	122.8	1251.9
18	D031403	PA	0.312	06/23/02	0.00871	38766.62	269.1	448.1
19	D00988U4	IN	0.311	07/03/02	0.00834	45022.27	122.8	1075.3
20	D028327	OH	0.282	08/14/02	0.00891	46949.57	243.8	1069.6
21	D03935C02	WV	0.282	03/17/02	0.00972	63009.75	274.3	892.6
22	D01733C12	MI	0.267	07/10/02	0.01042	46039.95	137.2	845.4
23	D03140C12	PA	0.262	06/23/02	0.00757	29709.17	259.1	448.1
24	D02864C01	OH	0.257	08/13/02	0.00705	35161.71	259.1	730.1
25	D03947C03	WV	0.255	08/13/02	0.00720	38540.84	150.0	734.6
26	D039353	WV	0.238	05/28/02	0.00757	42174.31	274.9	892.6
27	D01733C34	MI	0.227	07/10/02	0.00991	39326.85	152.4	845.4
28	D01571CE2	MD	0.205	07/23/02	0.00922	48522.41	335.3	590.0
29	D01353C02	KY	0.200	08/14/02	0.00784	41507.88	243.8	967.9
30	D02866C01	OH	0.199	08/13/02	0.00604	24627.17	153.6	683.1
31	D060041	WV	0.197	08/13/02	0.00493	21561.93	304.8	785.8
32	D01572C23	MD	0.194	07/23/02	0.00676	32159.23	121.9	566.1
33	D07253C01	OH	0.193	08/13/02	0.00571	30949.43	213.4	813.5
34	D080421	NC	0.190	08/15/02	0.00587	57768.69	182.9	961.3
35	D0283612	OH	0.189	07/23/02	0.00906	41395.14	182.9	752.6
36	D028725	OH	0.188	08/13/02	0.00522	30052.41	252.1	811.6
37	D0099070	IN	0.184	06/12/02	0.00449	29774.44	172.2	1148.0
38	D015731	MD	0.181	07/15/02	0.00690	36790.12	213.4	620.2
39	D015732	MD	0.180	07/15/02	0.00604	30760.70	213.4	620.2
40	D062641	WV	0.177	08/14/02	0.00728	42719.38	335.3	867.0

Lye Brook Wilderness								
RANK	**CEMS SOURCE**	**STATE**	**24-Hr Max SO_4 Ion Impact (~µg/m^3)**	**24Hr Date**	**Annual SO_4 Ion Impact (~µg/m^3)**	**2002 SO_2 (Tons)**	**Modeled StkHt (Meters)**	**Distance (Kms)**
41	D06113C03	IN	0.172	03/07/02	0.00924	71118.81	150.0	1335.3
42	D013783	KY	0.172	06/13/02	0.00615	46660.04	243.8	1337.1
43	D03406C10	TN	0.171	10/03/02	0.00820	104430.60	150.0	1464.8
44	D024032	NJ	0.170	03/16/02	0.00341	18768.40	152.1	276.9
45	D028501	OH	0.170	08/14/02	0.00466	30770.84	213.4	1014.1
46	D028502	OH	0.170	08/14/02	0.00444	28672.85	213.4	1014.1
47	D01008C01	IN	0.169	06/13/02	0.00383	24087.17	228.6	1193.7
48	D016061	MA	0.168	06/21/02	0.00197	5249.48	112.8	105.0
49	D080422	NC	0.168	08/15/02	0.00476	45255.73	182.9	961.3
50	D02866C02	OH	0.168	08/13/02	0.00590	25999.24	153.6	683.1
51	D02554C03	NY	0.167	09/11/02	0.00835	30124.51	150.0	510.9
52	D01355C03	KY	0.165	06/27/02	0.00509	38069.95	150.0	1139.9
53	D028665	OH	0.160	08/13/02	0.00494	19778.82	304.8	683.1
54	D028504	OH	0.160	08/14/02	0.00477	27318.93	213.4	1014.1
55	D01008C02	IN	0.154	06/13/02	0.00388	23827.97	307.2	1193.7
56	D028282	OH	0.154	08/13/02	0.00433	20579.94	251.5	699.1
57	D06166C02	IN	0.150	06/27/02	0.00761	51662.69	304.8	1302.5
58	D02866M6A	OH	0.150	08/13/02	0.00476	19546.42	304.8	683.1
59	D01356C02	KY	0.149	06/13/02	0.00521	25622.89	225.9	1106.5
60	D060191	OH	0.146	08/14/02	0.00386	21495.65	174.6	1039.9
61	D017459A	MI	0.144	07/10/02	0.00487	18324.29	171.3	826.8
62	D00861C01	IL	0.139	07/03/02	0.00541	42318.01	152.4	1428.1
63	D02840C02	OH	0.139	08/13/02	0.00495	22770.56	172.2	794.3
64	D02832C06	OH	0.137	08/14/02	0.00466	23673.32	213.4	1069.6
65	D03131CS1	PA	0.137	06/24/02	0.00619	22323.74	150.0	489.3
66	D037976	VA	0.135	08/16/02	0.00536	40533.88	127.7	731.9
67	D03954CS0	WV	0.133	11/22/02	0.00249	20111.54	225.9	672.2
68	D007032LR	GA	0.129	10/03/02	0.00226	37255.59	304.8	1424.5
69	D028306	OH	0.129	07/03/02	0.00521	30438.59	137.2	1038.2
70	D028375	OH	0.128	06/12/02	0.00811	35937.73	182.9	702.1
71	D00709C02	GA	0.125	08/16/02	0.00175	47548.54	121.9	1411.5
72	D02549C01	NY	0.125	07/03/02	0.00781	25320.03	150.0	470.3
73	D067054	IN	0.123	08/14/02	0.00528	40082.21	152.4	1325.6
74	D000265	AL	0.121	10/03/02	0.00201	53015.27	228.6	1592.6
75	D007031LR	GA	0.121	10/03/02	0.00242	38486.16	304.8	1424.5
76	D03407C15	TN	0.121	08/15/02	0.00320	37274.48	152.4	1258.5
77	D00988C03	IN	0.119	08/14/02	0.00303	15946.48	85.3	1075.3
78	D02712C03	NC	0.119	08/16/02	0.00345	30749.26	150.0	893.4
79	D039423	WV	0.119	08/13/02	0.00218	10126.02	68.6	675.6
80	D028283	OH	0.118	06/24/02	0.00253	15372.27	274.3	700.2
81	D031782	PA	0.118	08/13/02	0.00460	16468.79	307.2	576.1
82	D027274	NC	0.117	08/15/02	0.00261	27284.07	85.3	1070.2
83	D06113C04	IN	0.116	07/03/02	0.00426	27823.32	213.4	1335.3

Lye Brook Wilderness								
RANK	**CEMS SOURCE**	**STATE**	**24-Hr Max SO_4 Ion Impact (~µg/m^3)**	**24Hr Date**	**Annual SO_4 Ion Impact (~µg/m^3)**	**2002 SO_2 (Tons)**	**Modeled StkHt (Meters)**	**Distance (Kms)**
84	D027273	NC	0.116	08/15/02	0.00253	26305.45	85.3	1070.2
85	D027215	NC	0.116	08/15/02	0.00204	19128.20	152.4	1146.7
86	D02963C10	OK	0.114	12/16/02	0.00278	34232.90	182.9	2050.3
87	D023642	NH	0.112	07/26/02	0.00371	19435.42	159.7	134.1
88	D080062	NY	0.112	06/22/02	0.00086	2839.86	79.2	187.9
89	D007034LR	GA	0.110	08/15/02	0.00278	40973.96	304.8	1424.5
90	D060312	OH	0.110	08/14/02	0.00303	19500.08	274.3	995.4
91	D03407C69	TN	0.110	08/15/02	0.00344	38610.70	150.0	1258.5
92	D060042	WV	0.110	03/17/02	0.00388	20531.62	304.8	785.8
93	D080061	NY	0.109	06/22/02	0.00103	3816.50	79.2	187.9
94	D007033LR	GA	0.107	08/15/02	0.00238	43029.15	304.8	1424.5
95	D081021	OH	0.107	03/17/02	0.00281	18190.75	253.0	882.6
96	D01702C09	MI	0.106	06/27/02	0.00154	4565.21	91.4	864.7
97	D0393851	WV	0.106	08/14/02	0.00225	12936.25	183.8	867.0
98	D060412	KY	0.104	08/14/02	0.00347	20472.77	245.7	1019.3
99	D006022	MD	0.103	07/23/02	0.00426	19263.13	211.8	523.1
100	D006021	MD	0.102	06/24/02	0.00436	19995.88	211.8	523.1

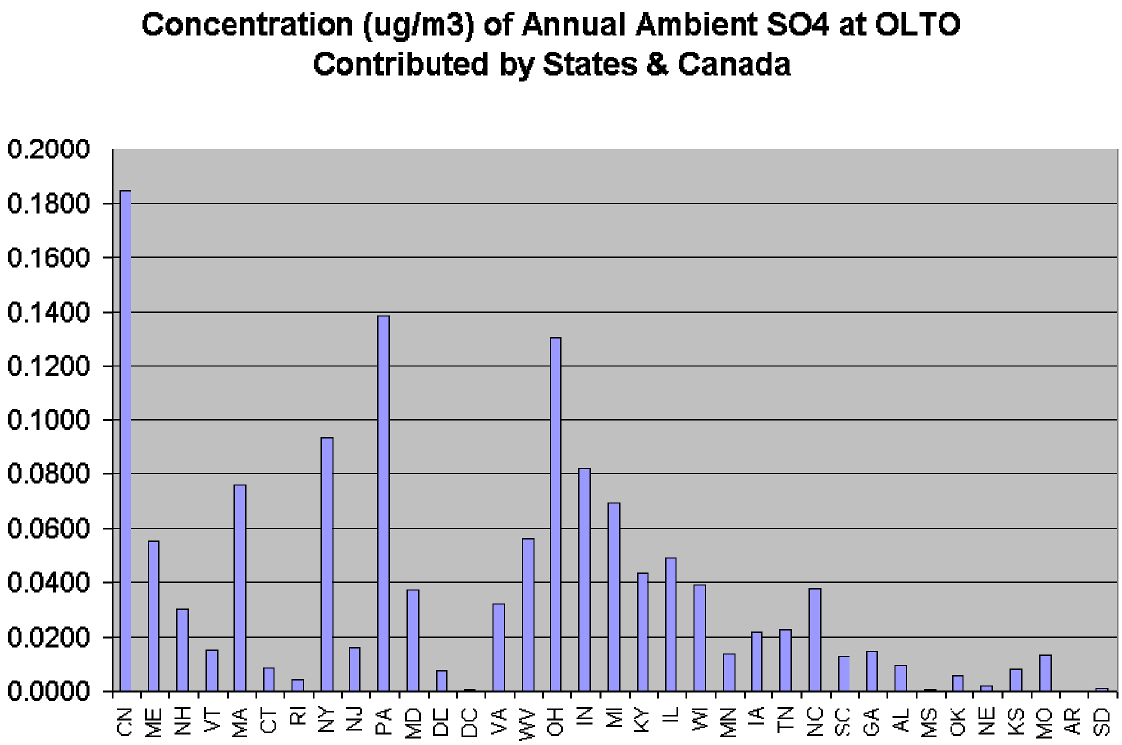
Table D-10d. VT DEC CALPUFF MODELING RESULTS

Shenandoah National Park								
RANK	CEMS SOURCE	STATE	24-Hr Max SO_4 Ion Impact (~µg/m^3)	24Hr Date	Annual SO_4 Ion Impact (~µg/m^3)	2002 SO_2 (Tons)	Modeled StkHt (Meters)	Distance (Kms)
1	D03179C01	PA	1.281	07/04/02	0.04605	79564.81	150.0	194.9
2	D028404	OH	0.950	07/16/02	0.03373	87723.73	245.4	347.2
3	D03954CS0	WV	0.868	10/14/02	0.01228	20111.54	225.9	103.7
4	D02872C04	OH	0.757	12/13/02	0.04278	83060.23	150.0	302.6
5	D01353C02	KY	0.711	06/26/02	0.01905	41507.88	243.8	365.1
6	D02876C01	OH	0.684	07/19/02	0.03050	72528.72	243.8	321.6
7	D01571CE2	MD	0.658	06/21/02	0.02057	48522.41	335.3	151.3
8	D03948C02	WV	0.635	07/16/02	0.02926	55355.96	167.6	250.0
9	D039353	WV	0.631	06/11/02	0.02051	42174.31	274.9	293.3
10	D03935C02	WV	0.609	06/26/02	0.02967	63009.75	274.3	293.3
11	D039432	WV	0.581	01/02/02	0.02901	45808.91	167.6	182.0
12	D060041	WV	0.577	03/15/02	0.01345	21561.93	304.8	249.8
13	D039431	WV	0.576	07/04/02	0.02634	42347.54	167.6	182.0
14	D060042	WV	0.556	03/15/02	0.01311	20531.62	304.8	249.8
15	D028281	OH	0.517	07/04/02	0.01871	37274.20	251.5	269.0
16	D031361	PA	0.498	09/19/02	0.03253	87357.00	243.8	250.4
17	D028667	OH	0.464	07/04/02	0.01554	33571.62	259.1	290.5
18	D031222	PA	0.462	09/19/02	0.02149	55167.46	243.8	231.7
19	D031221	PA	0.459	09/19/02	0.01982	45713.85	243.8	231.7
20	D01010C05	IN	0.455	07/19/02	0.01123	60693.13	122.8	779.6
21	D015731	MD	0.446	06/21/02	0.01614	36790.12	213.4	127.6
22	D080421	NC	0.443	02/01/02	0.02574	57768.69	182.9	286.2
23	D02864C01	OH	0.443	01/21/02	0.01917	35161.71	259.1	253.5
24	D015732	MD	0.442	06/21/02	0.01401	30760.70	213.4	127.6
25	D03407C15	TN	0.435	08/13/02	0.01102	37274.48	152.4	609.5
26	D03947C03	WV	0.424	03/15/02	0.02157	38540.84	150.0	251.3
27	D037976	VA	0.422	10/01/02	0.01934	40533.88	127.7	155.9
28	D031362	PA	0.419	09/19/02	0.02489	62791.27	243.8	250.4
29	D07253C01	OH	0.417	03/15/02	0.01732	30949.43	213.4	281.3
30	D031491	PA	0.415	08/31/02	0.01328	60188.24	347.2	319.0
31	D03406C10	TN	0.413	07/29/02	0.01808	104430.60	150.0	856.8
32	D062641	WV	0.412	06/11/02	0.02153	42719.38	335.3	306.0
33	D031492	PA	0.407	08/31/02	0.01222	50232.01	347.2	319.0
34	D080422	NC	0.382	06/25/02	0.02137	45255.73	182.9	286.2
35	D006022	MD	0.375	08/28/02	0.00817	19263.13	211.8	178.7
36	D006021	MD	0.364	08/28/02	0.00902	19995.88	211.8	178.7
37	D03407C69	TN	0.360	08/13/02	0.01147	38610.70	150.0	609.5
38	D0283612	OH	0.342	10/24/02	0.01406	41395.14	182.9	449.9
39	D06113C03	IN	0.339	07/20/02	0.01362	71118.81	150.0	809.1
40	D082261	PA	0.337	01/21/02	0.01687	40231.91	228.6	251.1

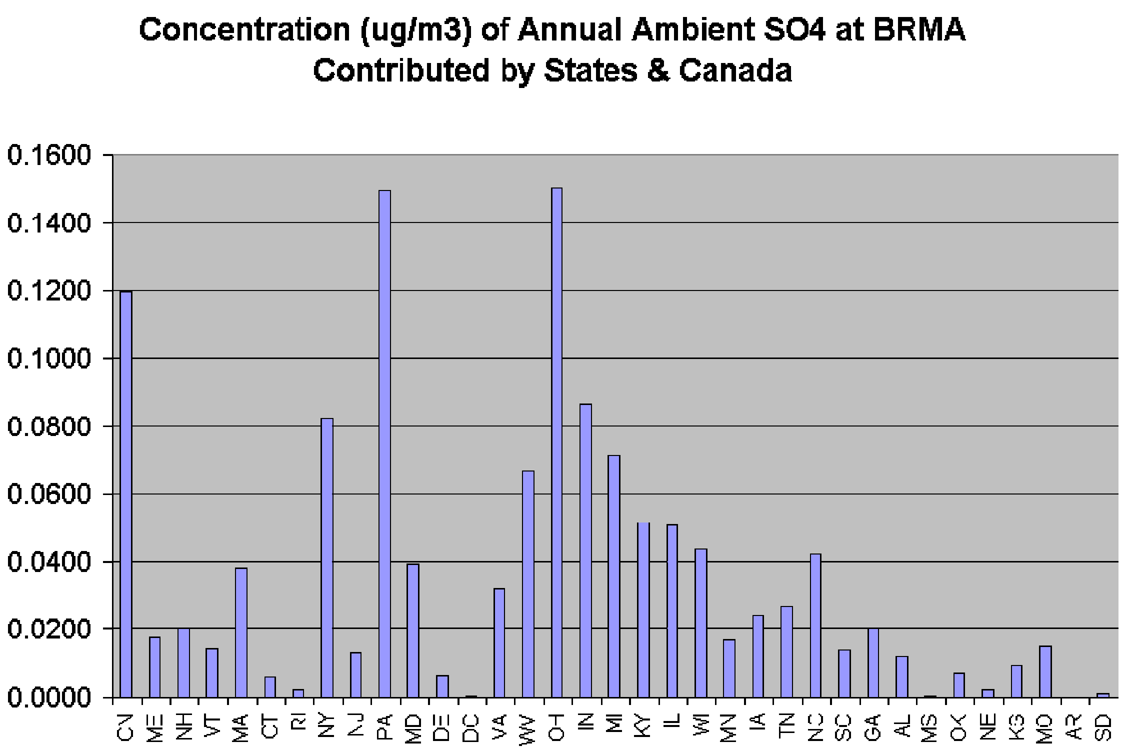
Shenandoah National Park								
RANK	CEMS SOURCE	STATE	24-Hr Max SO_4 Ion Impact (~µg/m^3)	24Hr Date	Annual SO_4 Ion Impact (~µg/m^3)	2002 SO_2 (Tons)	Modeled StkHt (Meters)	Distance (Kms)
41	D02866C01	OH	0.336	07/04/02	0.01060	24627.17	153.6	290.5
42	D028504	OH	0.336	07/20/02	0.00920	27318.93	213.4	454.7
43	D01572C23	MD	0.335	08/28/02	0.01845	32159.23	121.9	112.8
44	D00988U4	IN	0.329	07/19/02	0.01314	45022.27	122.8	556.8
45	D031403	PA	0.327	08/28/02	0.01494	38766.62	269.1	229.4
46	D028375	OH	0.316	12/13/02	0.01332	35937.73	182.9	433.0
47	D027122	NC	0.315	02/01/02	0.01298	29310.41	121.9	232.4
48	D02712C04	NC	0.303	02/01/02	0.01066	22941.29	150.0	232.4
49	D007034LR	GA	0.300	08/14/02	0.00905	40973.96	304.8	755.7
50	D037975	VA	0.300	02/01/02	0.01047	19602.10	61.0	155.9
51	D038044	VA	0.298	09/09/02	0.00720	10441.80	46.9	99.8
52	D007033LR	GA	0.294	08/14/02	0.00911	43029.15	304.8	755.7
53	D03936C02	WV	0.288	08/13/02	0.00872	15466.69	304.8	261.3
54	D039543	WV	0.286	02/08/02	0.00284	2919.63	181.7	103.7
55	D028725	OH	0.285	10/04/02	0.01477	30052.41	252.1	302.6
56	D02866C02	OH	0.281	07/04/02	0.01109	25999.24	153.6	290.5
57	D028502	OH	0.280	07/19/02	0.00960	28672.85	213.4	454.7
58	D01733C34	MI	0.277	07/05/02	0.01049	39326.85	152.4	557.5
59	D06250C05	NC	0.276	02/01/02	0.01214	27370.73	243.8	224.3
60	D015543	MD	0.272	08/28/02	0.00525	10075.06	109.7	178.6
61	D039462	WV	0.266	03/15/02	0.00676	10320.05	65.8	263.5
62	D028501	OH	0.262	07/19/02	0.00950	30770.84	213.4	454.7
63	D028665	OH	0.261	07/04/02	0.00863	19778.82	304.8	290.5
64	D03396M1A	TN	0.261	08/13/02	0.00641	20011.21	228.6	574.6
65	D00050C16	AL	0.260	08/14/02	0.00645	24955.19	304.8	764.0
66	D02712C03	NC	0.259	02/01/02	0.01483	30749.26	150.0	232.4
67	D00709C02	GA	0.255	08/14/02	0.00677	47548.54	121.9	734.0
68	D027274	NC	0.254	06/26/02	0.01018	27284.07	85.3	393.3
69	D007032LR	GA	0.251	08/14/02	0.00777	37255.59	304.8	755.7
70	D028283	OH	0.249	07/04/02	0.00681	15372.27	274.3	268.7
71	D027273	NC	0.246	06/26/02	0.01031	26305.45	85.3	393.3
72	D028503	OH	0.246	07/19/02	0.00883	27943.53	213.4	454.7
73	D01733C12	MI	0.243	07/05/02	0.01091	46039.95	137.2	557.5
74	D03140C12	PA	0.242	10/14/02	0.01188	29709.17	259.1	229.4
75	D015522	MD	0.241	09/10/02	0.00574	14261.70	107.6	199.0
76	D007031LR	GA	0.238	08/14/02	0.00805	38486.16	304.8	755.7
77	D028327	OH	0.238	06/26/02	0.01296	46949.57	243.8	552.4
78	D01384CS1	KY	0.237	08/13/02	0.00670	21817.18	61.0	563.9
79	D081021	OH	0.234	02/08/02	0.00899	18190.75	253.0	320.8
80	D03938C04	WV	0.234	07/19/02	0.01213	26427.11	121.9	304.8
81	D010012	IN	0.232	07/19/02	0.00565	25992.39	152.4	783.8
82	D01355C03	KY	0.231	06/26/02	0.00952	38069.95	150.0	551.9
83	D028282	OH	0.230	07/04/02	0.01013	20579.94	251.5	269.0

Shenandoah National Park								
RANK	CEMS SOURCE	STATE	24-Hr Max SO_4 Ion Impact (~µg/m^3)	24Hr Date	Annual SO_4 Ion Impact (~µg/m^3)	2002 SO_2 (Tons)	Modeled StkHt (Meters)	Distance (Kms)
84	D06166C02	IN	0.229	07/20/02	0.01037	51662.69	304.8	749.9
85	D03809CS0	VA	0.220	10/05/02	0.00728	21200.55	98.8	225.0
86	D015521	MD	0.213	08/28/02	0.00610	17766.58	107.6	199.0
87	D060312	OH	0.213	07/19/02	0.00690	19500.08	274.3	436.3
88	D00710C01	GA	0.205	08/14/02	0.00553	27865.05	213.4	749.5
89	D000265	AL	0.203	08/14/02	0.00628	53015.27	228.6	927.1
90	D000508	AL	0.203	07/28/02	0.00279	9823.53	152.4	763.5
91	D02840C02	OH	0.202	07/04/02	0.00932	22770.56	172.2	347.2
92	D010011	IN	0.196	07/19/02	0.00550	28850.75	152.4	783.8
93	D027215	NC	0.196	06/12/02	0.00675	19128.20	152.4	469.2
94	D039423	WV	0.195	03/15/02	0.00738	10126.02	68.6	148.5
95	D017437	MI	0.194	08/26/02	0.00442	15804.84	182.9	578.5
96	D017436	MI	0.194	08/26/02	0.00361	11172.85	129.5	578.5
97	D027121	NC	0.192	02/01/02	0.00490	12020.17	121.9	232.4
98	D02866M6A	OH	0.184	07/04/02	0.00811	19546.42	304.8	290.5
99	D02549C01	NY	0.179	10/18/02	0.00542	25320.03	150.0	493.8
100	D028306	OH	0.179	07/19/02	0.00742	30438.59	137.2	508.1

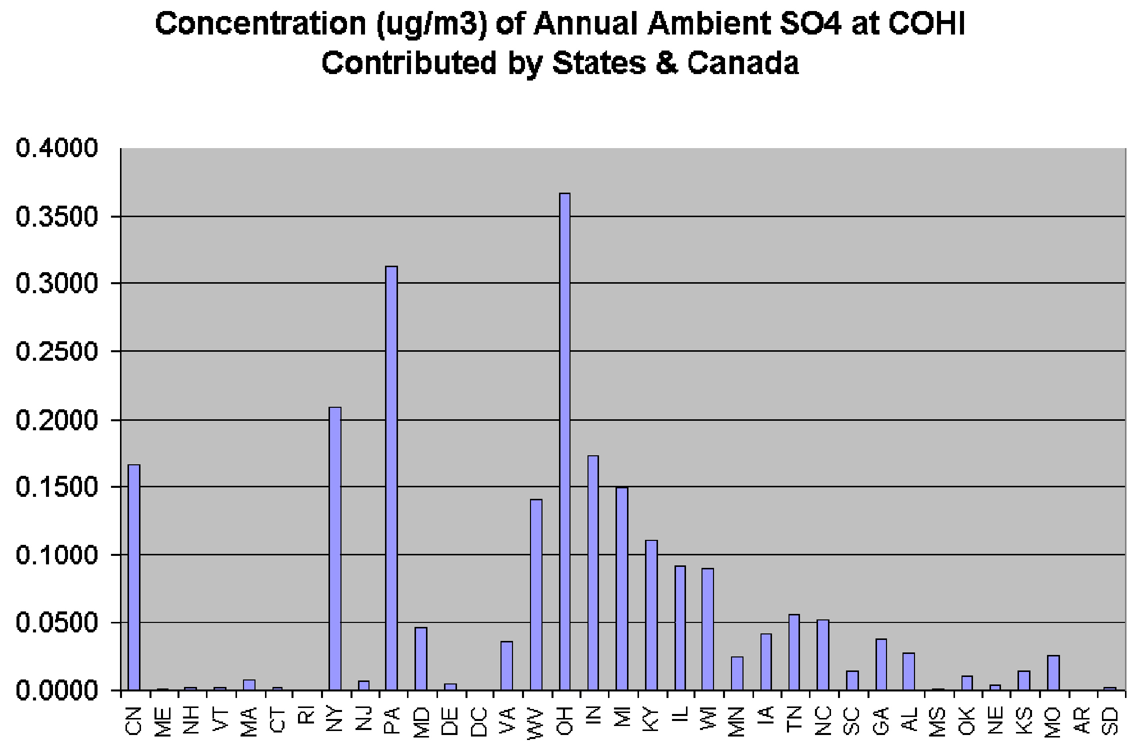
Figure D-34a-v. State-by-State Apportionment of Annual SO4 Ion at all 22 IMPROVE-type Monitoring Sites in the Northeastern Portion of Domain



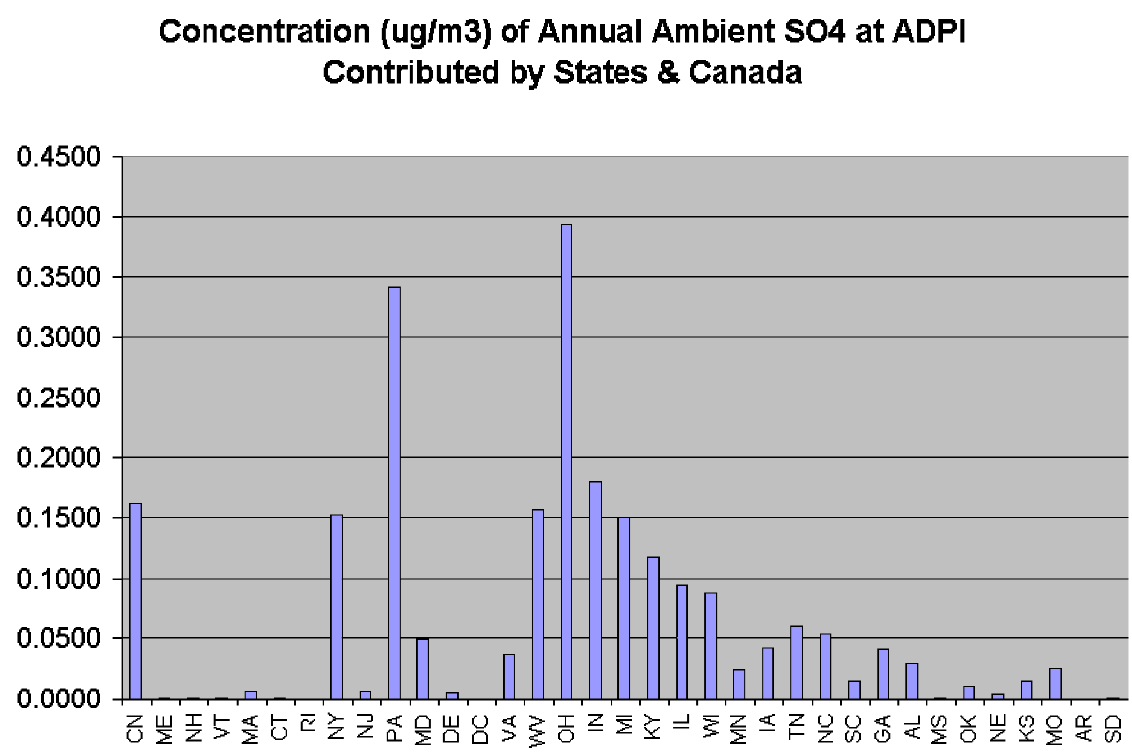
a.



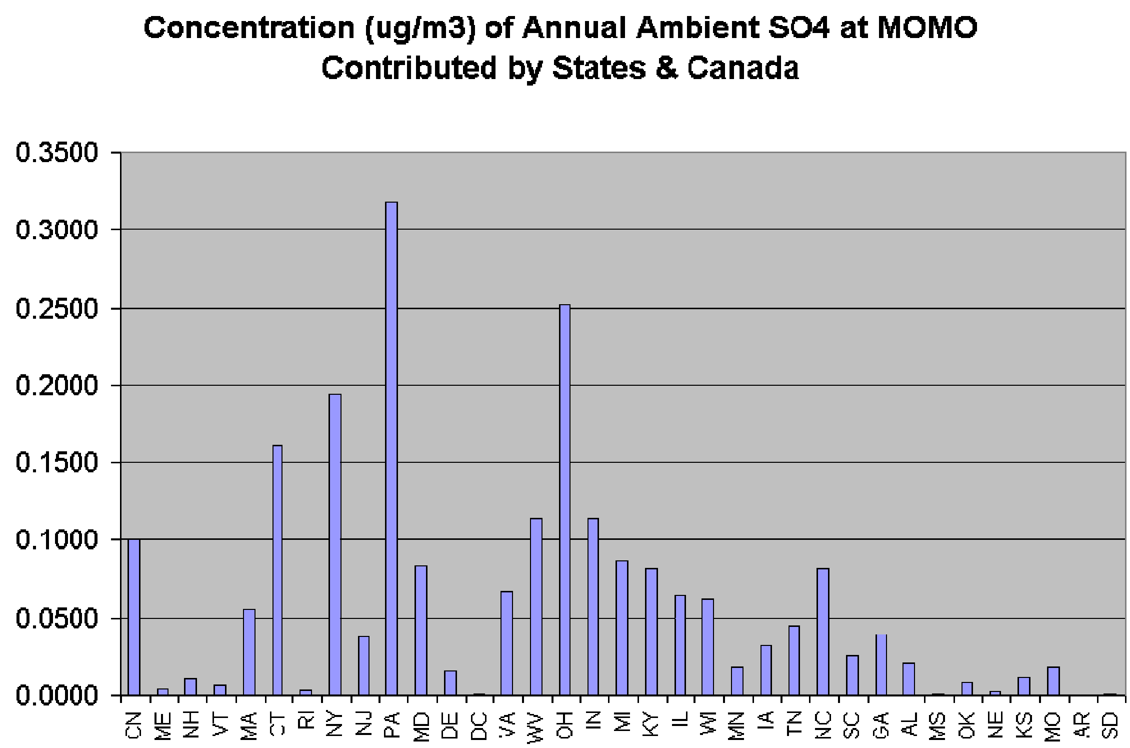
b.


Concentration (ug/m3) of Annual Ambient SO4 at COHI
Contributed by States & Canada
0.4000
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

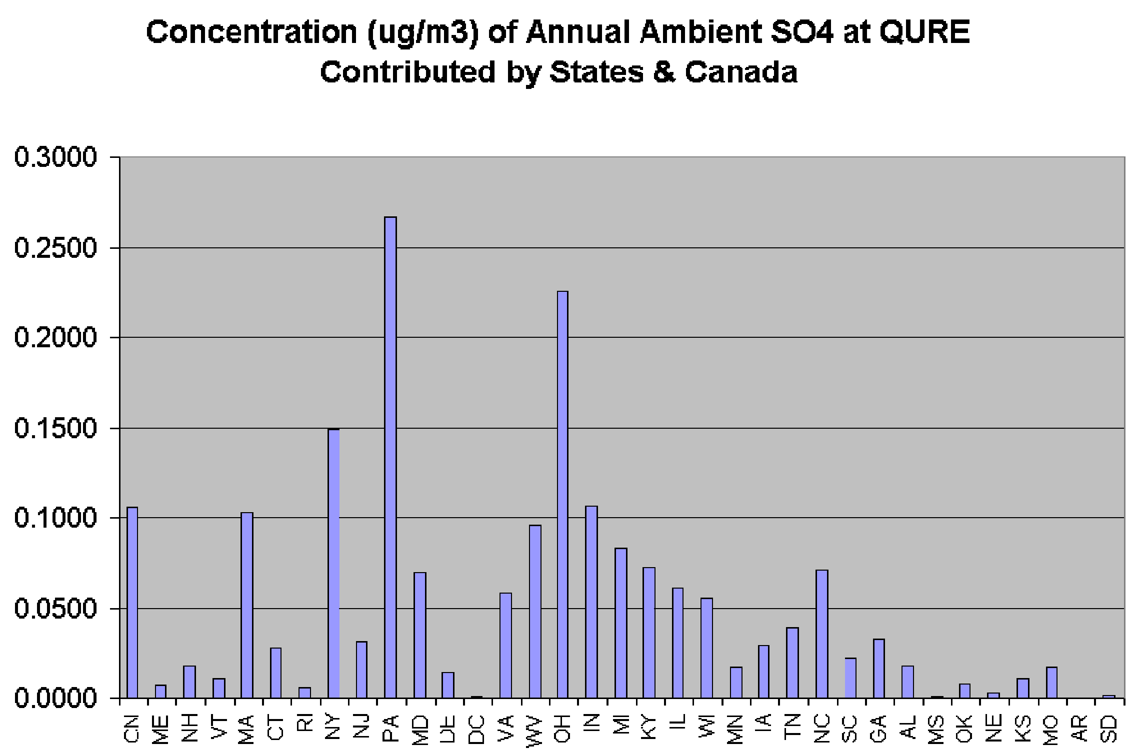
c.


Concentration (ug/m3) of Annual Ambient SO4 at ADPI
Contributed by States & Canada
0.4500
0.4000
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

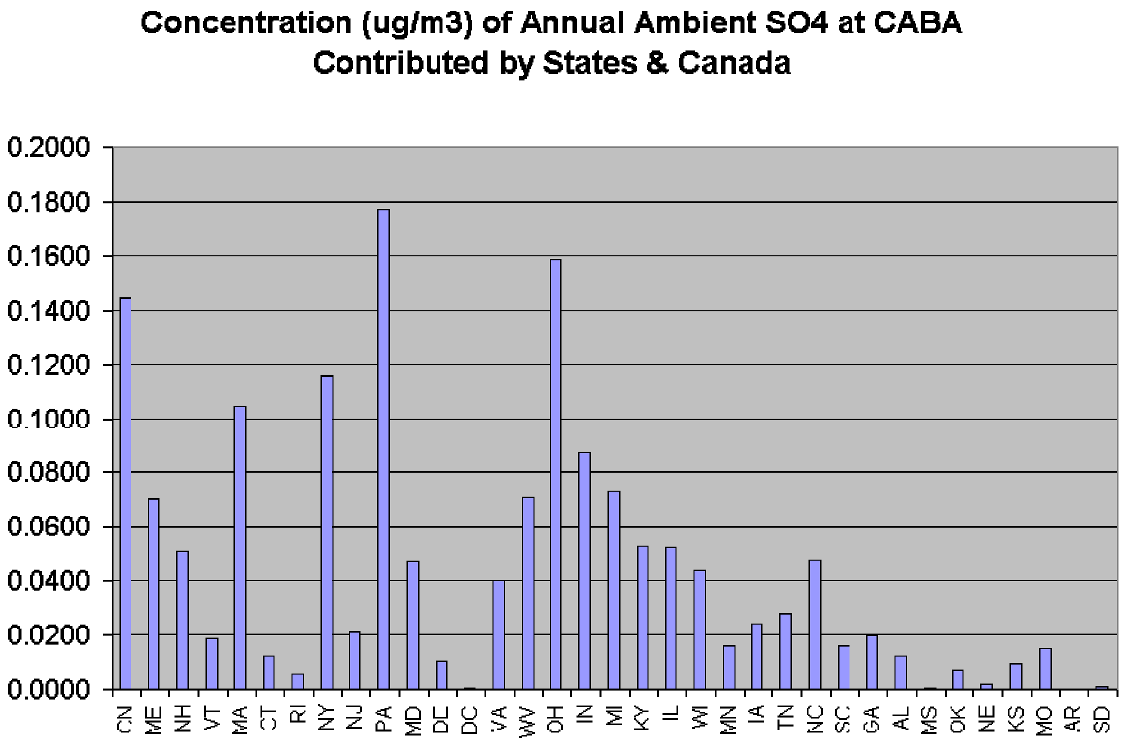
d.


Concentration (ug/m3) of Annual Ambient SO4 at MOMO
Contributed by States & Canada
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

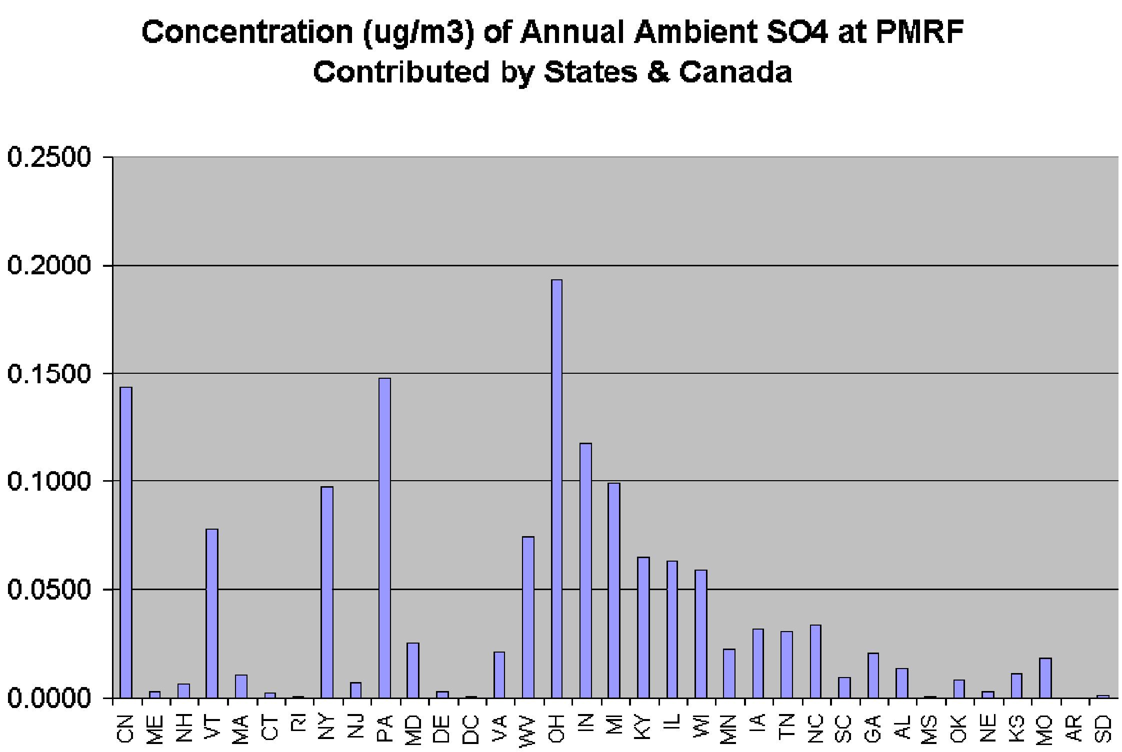
e.


Concentration (ug/m3) of Annual Ambient SO4 at QURE
Contributed by States & Canada
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

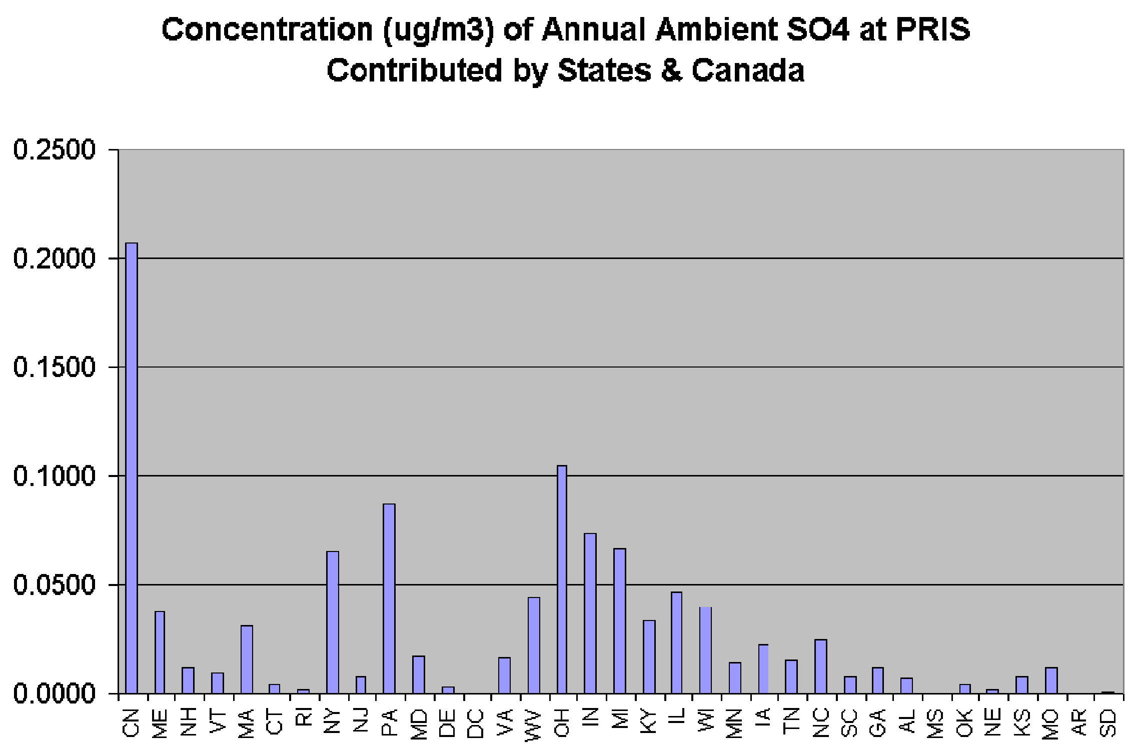
f.


Concentration (ug/m3) of Annual Ambient SO4 at CABA
Contributed by States & Canada
0.2000
0.1800
0.1600
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DC DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

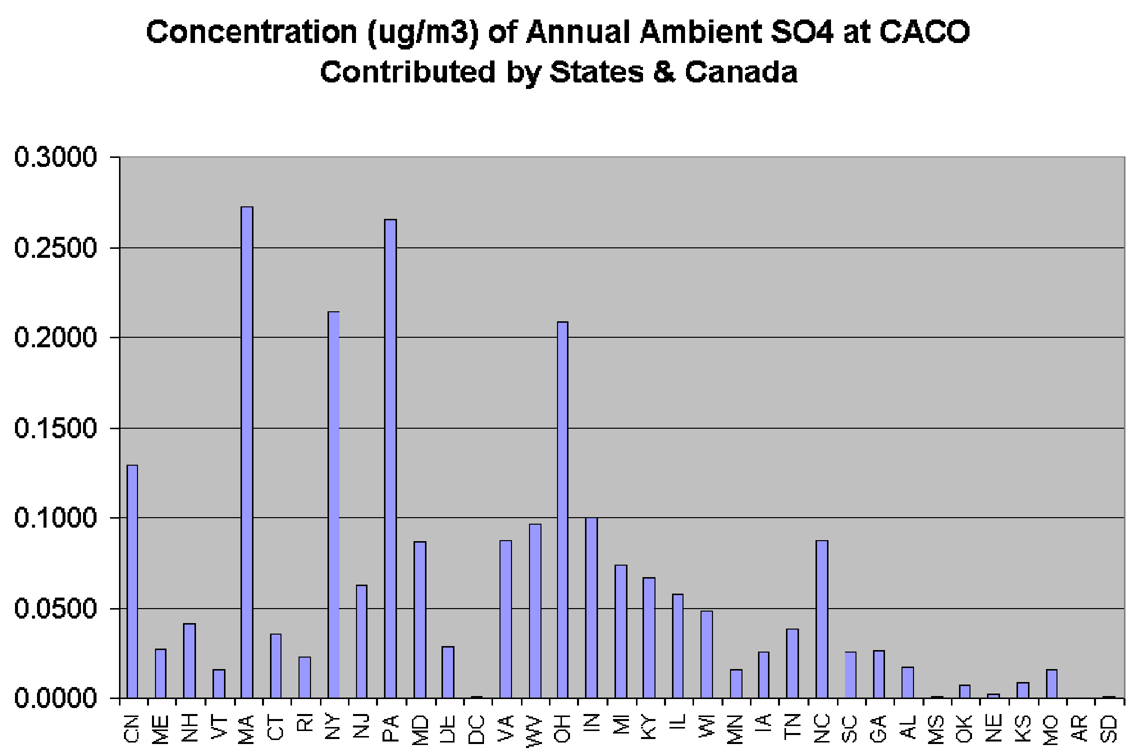
g.


Concentration (ug/m3) of Annual Ambient SO4 at PMRF
Contributed by States & Canada
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

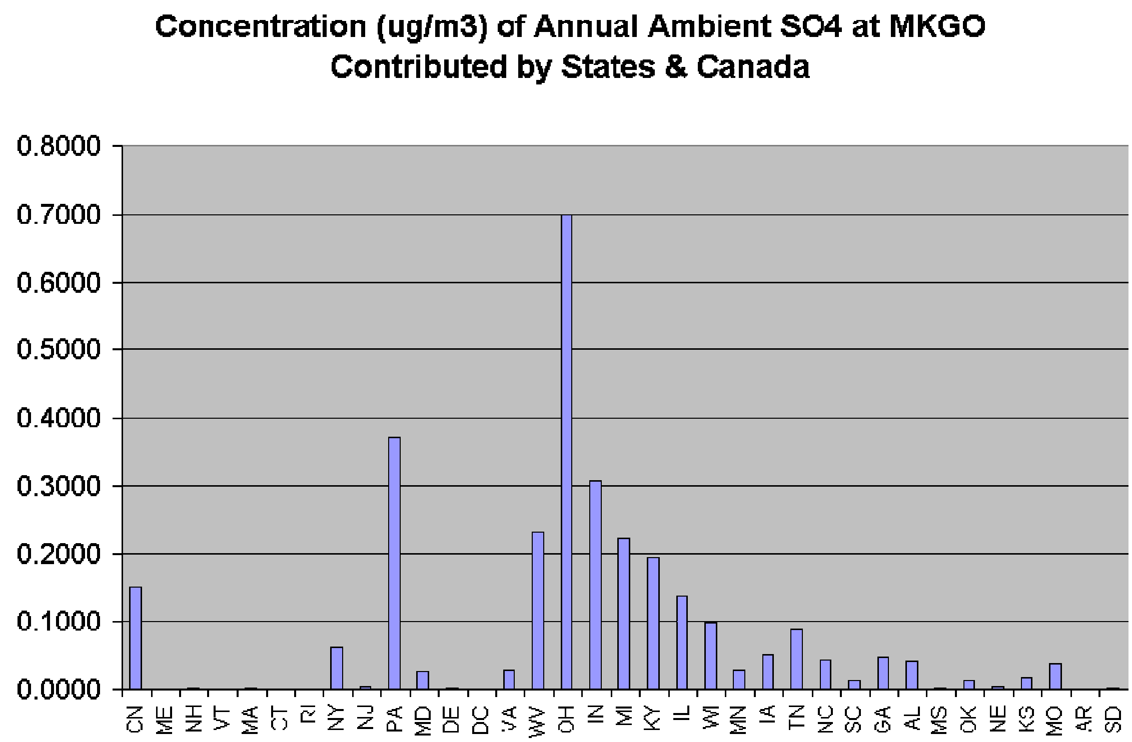
h.


Concentration (ug/m3) of Annual Ambient SO4 at PRIS
Contributed by States & Canada
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

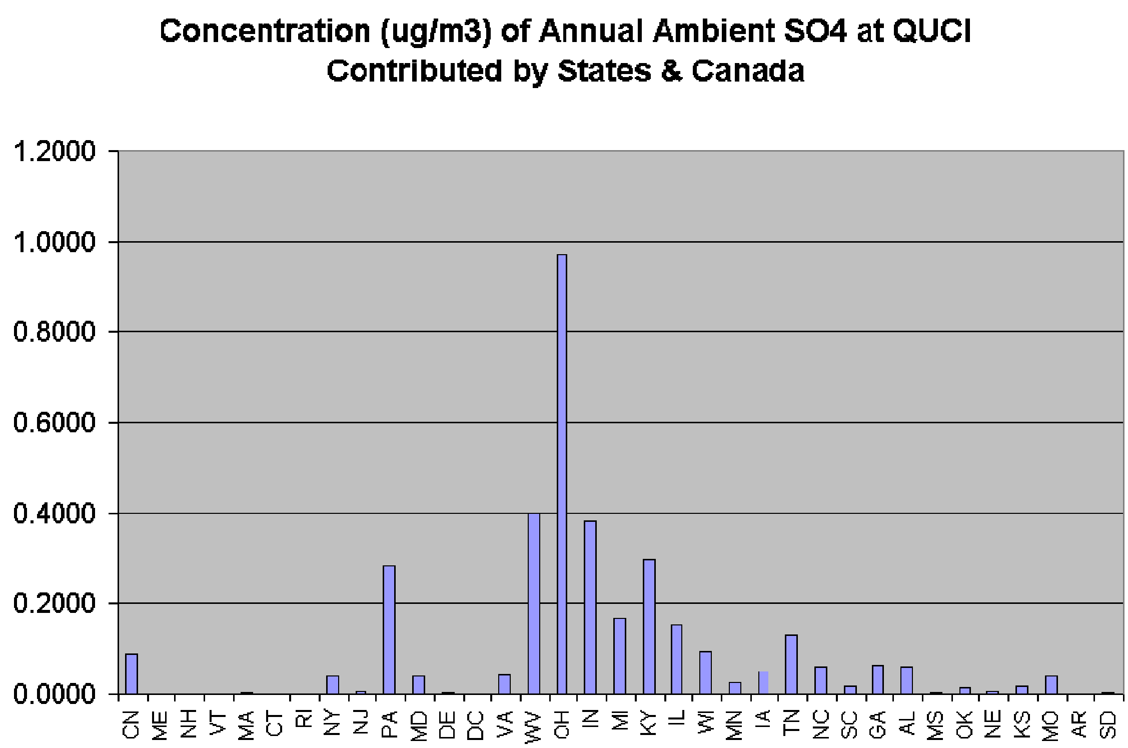
i.


Concentration (ug/m3) of Annual Ambient SO4 at CACO
Contributed by States & Canada
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

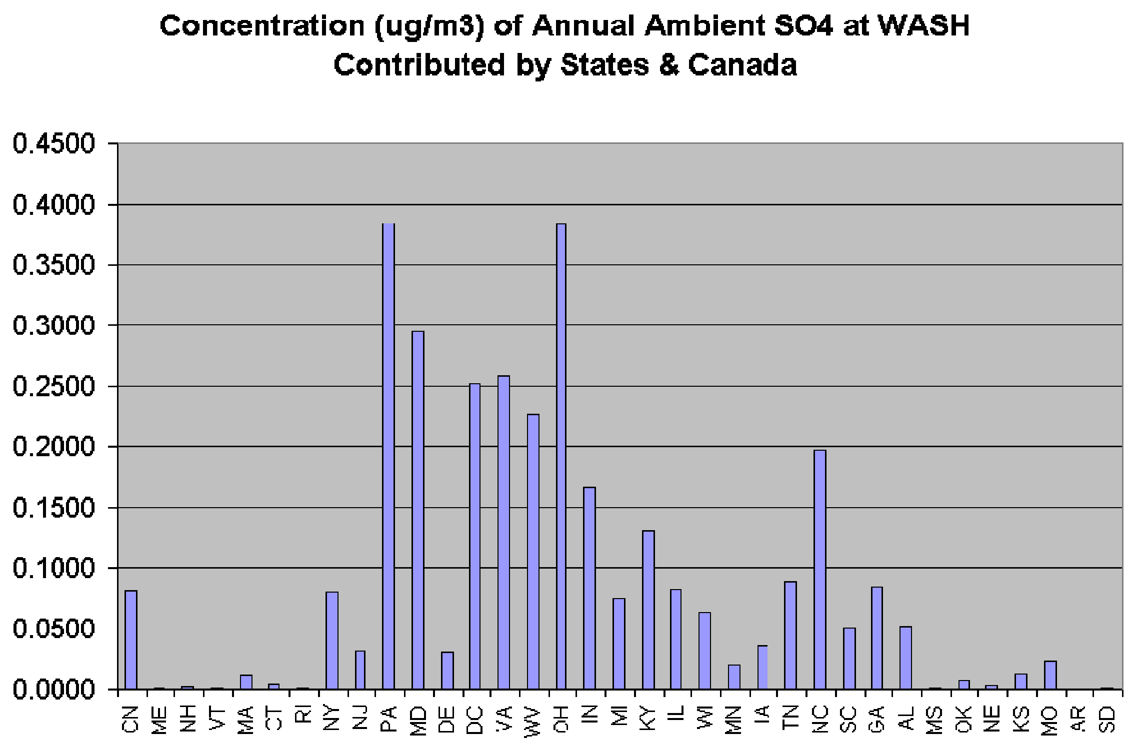
j.


Concentration (ug/m3) of Annual Ambient SO4 at MKGO
Contributed by States & Canada
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

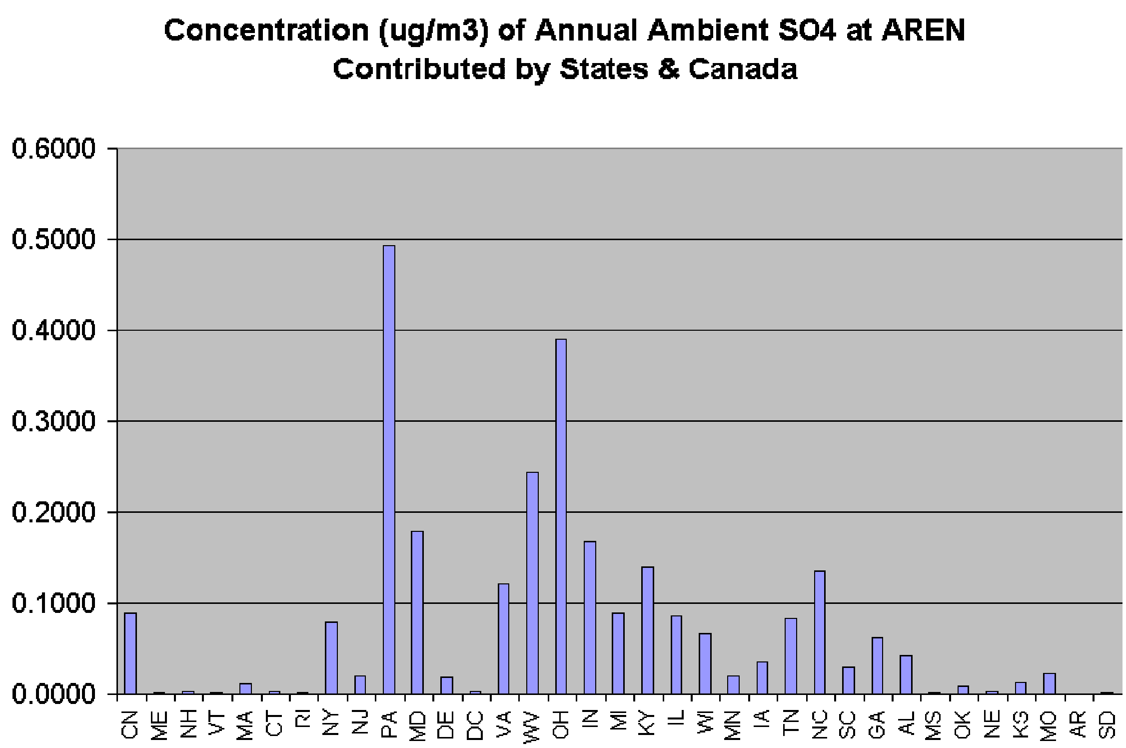
k.


Concentration (ug/m3) of Annual Ambient SO4 at QUCI
Contributed by States & Canada
1.2000
1.0000
0.8000
0.6000
0.4000
0.2000
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

l.

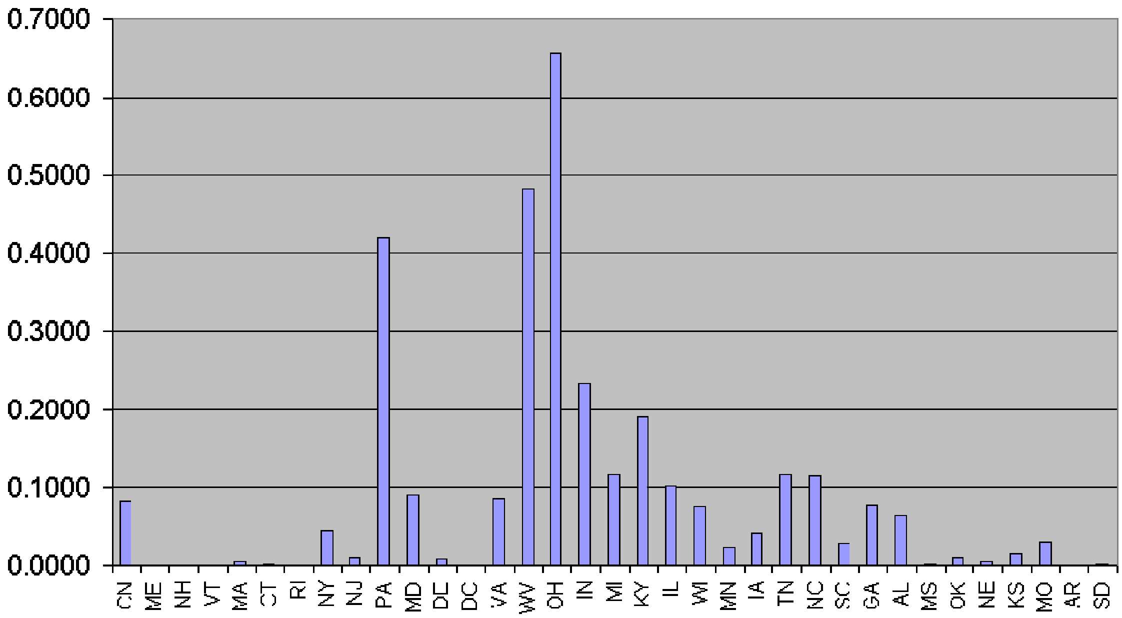

Concentration (ug/m3) of Annual Ambient SO4 at WASH
Contributed by States & Canada
0.4500
0.4000
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

m.


Concentration (ug/m3) of Annual Ambient SO4 at AREN
Contributed by States & Canada
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

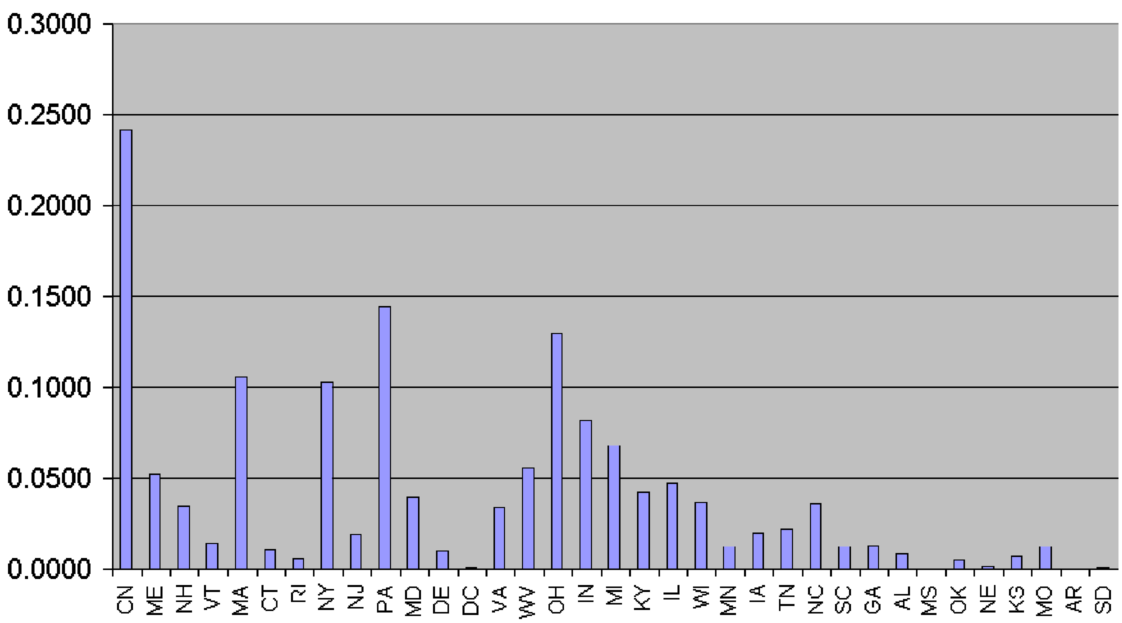
n.

Concentration (ug/m3) of Annual Ambient SO4 at DOSO Contributed by States & Canada

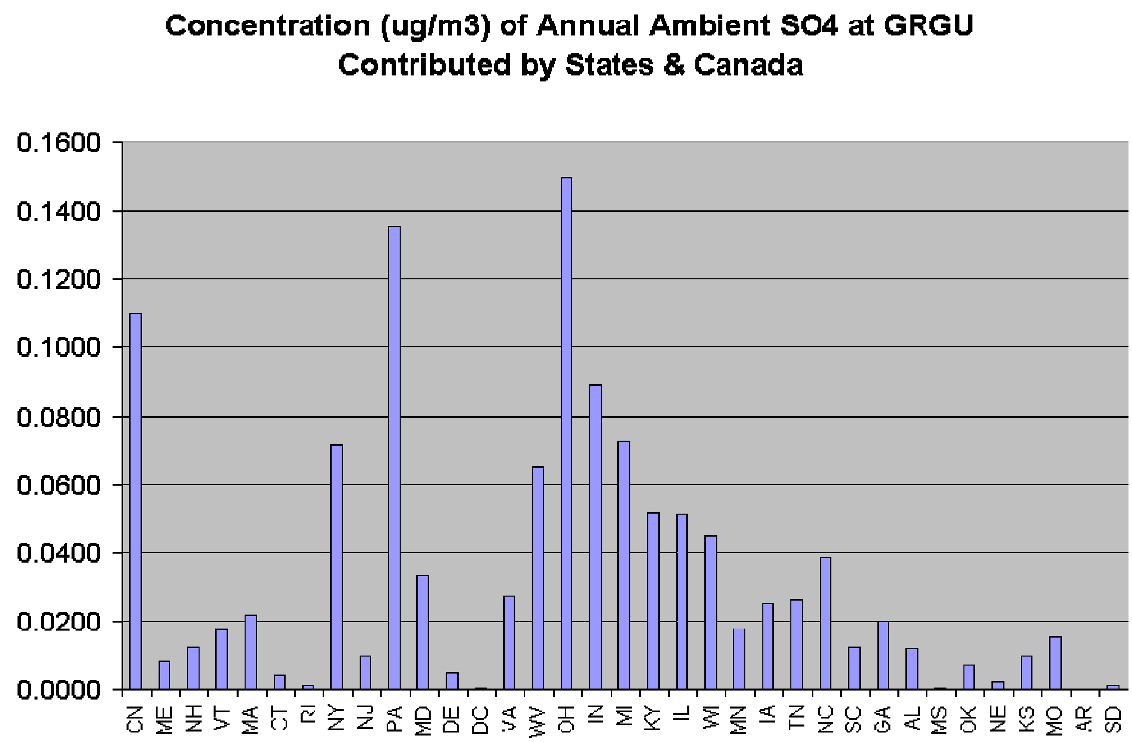


o.

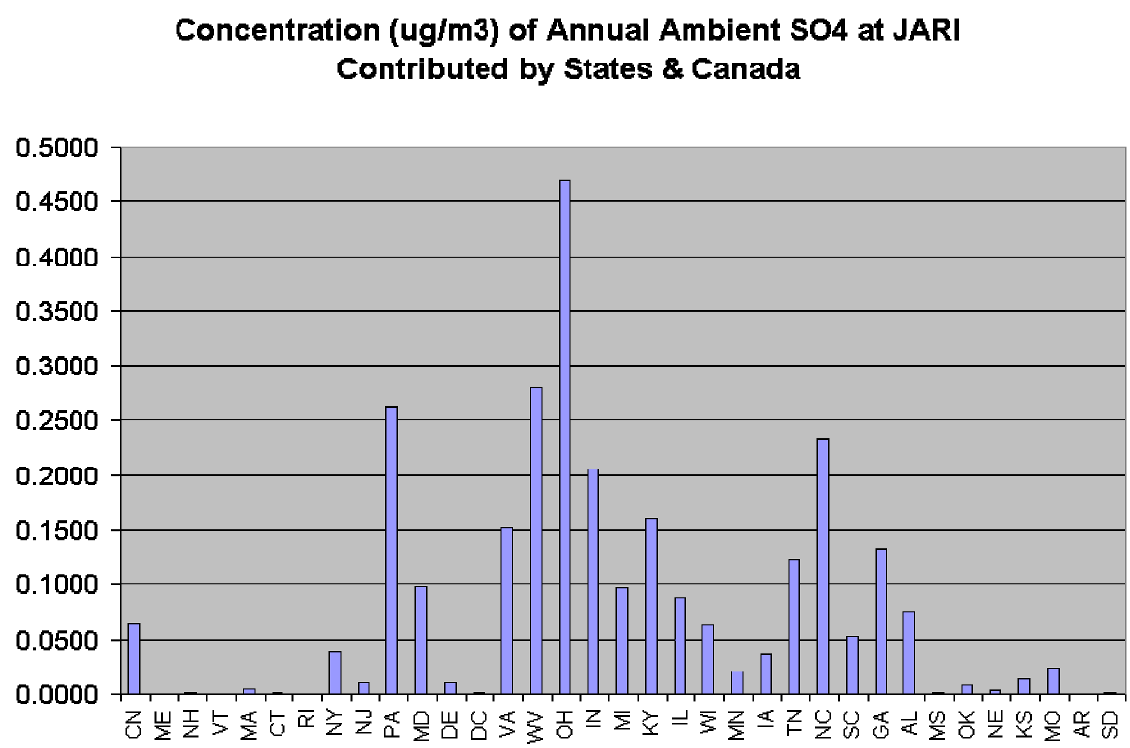
Concentration (ug/m3) of Annual Ambient SO4 at MOOS Contributed by States & Canada



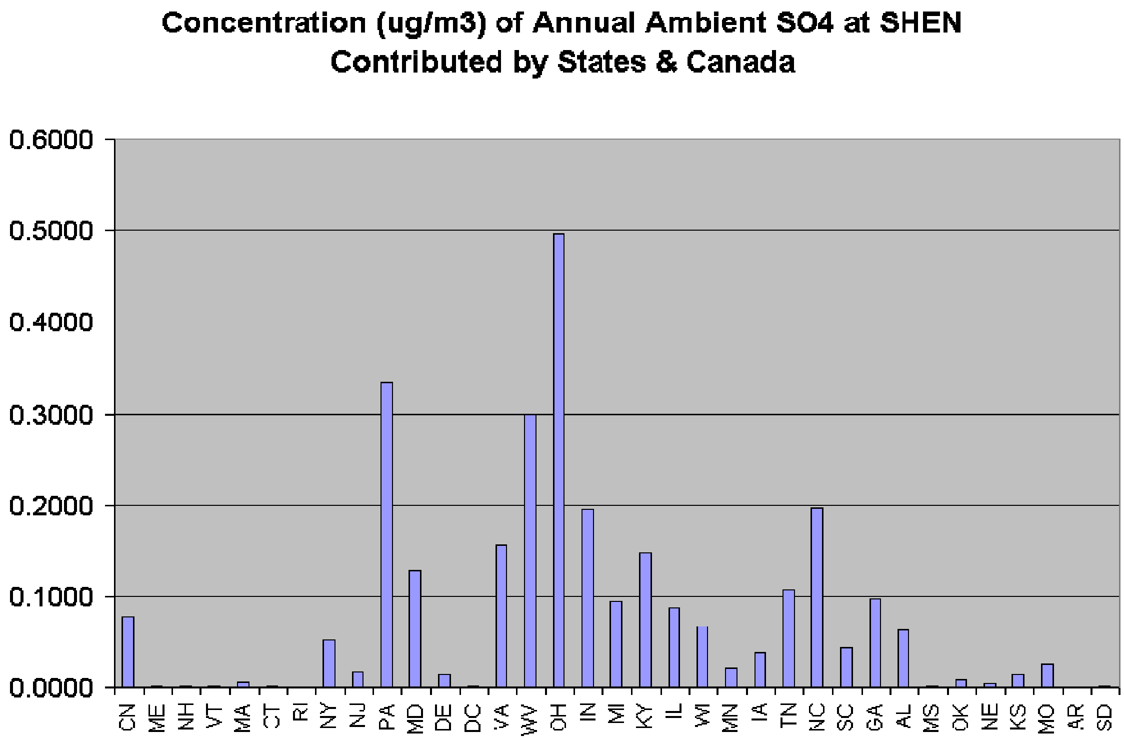
p.


Concentration (ug/m3) of Annual Ambient SO4 at GRGU
Contributed by States & Canada
0.1600
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

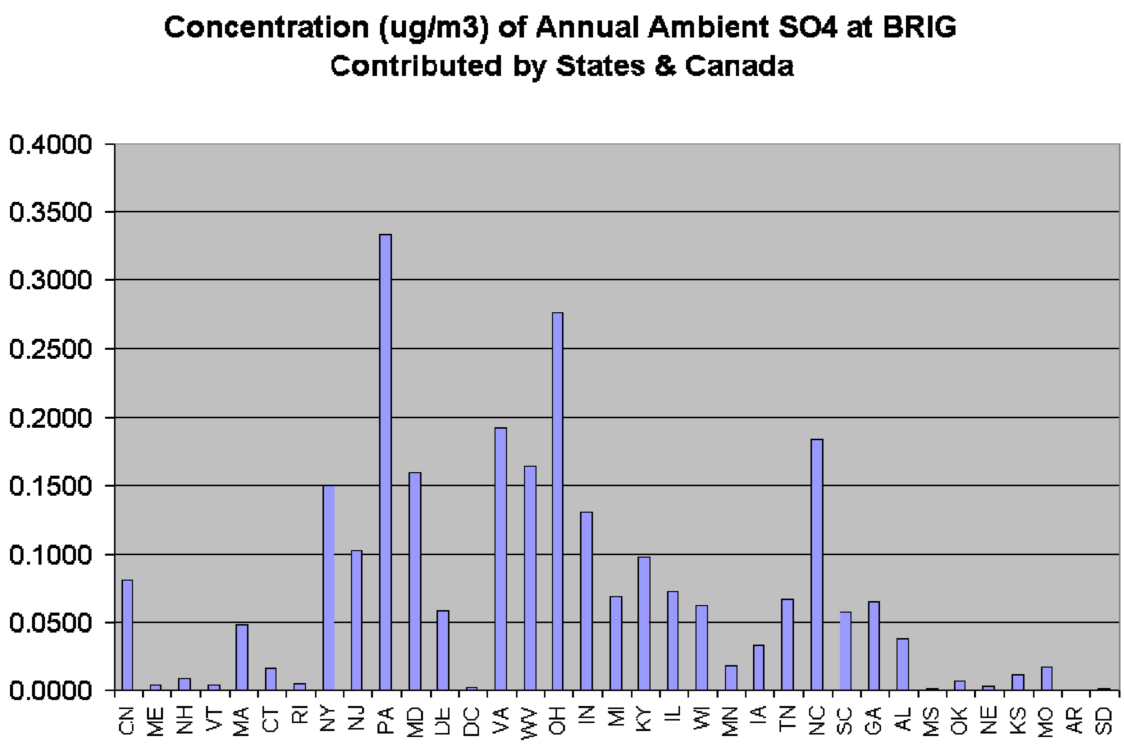
q.


Concentration (ug/m3) of Annual Ambient SO4 at JARI
Contributed by States & Canada
0.5000
0.4500
0.4000
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

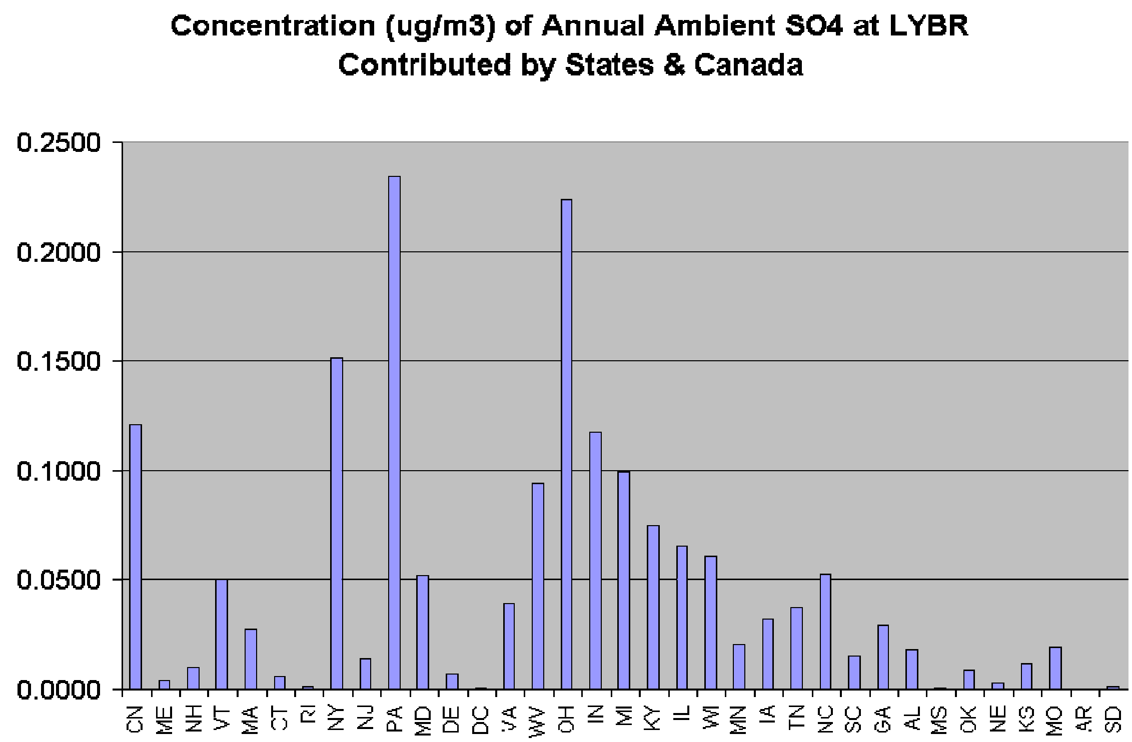
r.


Concentration (ug/m3) of Annual Ambient SO4 at SHEN
Contributed by States & Canada
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

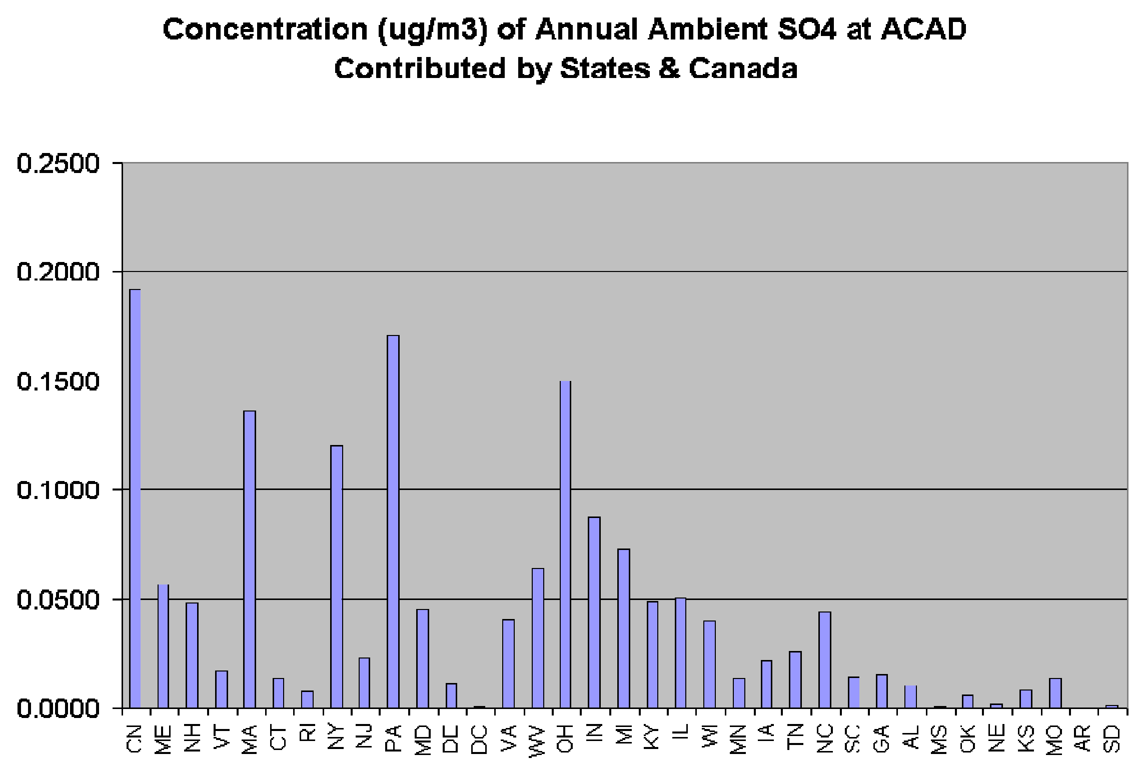
s.


Concentration (ug/m3) of Annual Ambient SO4 at BRIG
Contributed by States & Canada
0.4000
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

t.


Concentration (ug/m3) of Annual Ambient SO4 at LYBR
Contributed by States & Canada
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

u.


Concentration (ug/m3) of Annual Ambient SO4 at ACAD
Contributed by States & Canada
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
CN ME NH VT MA CT RI NY NJ PA MD DE DC VA WV OH IN MI KY IL WI MN IA TN NC SC GA AL MS OK NE KS MO AR SD

v.

State-by-State Apportionment of Annual SO_4 Ion Impact by Source Type at Selected Class I Areas

Table D-11(a-d) provides a different type of summary. Impacts from EGUs in the 2002 data base were summed by state, and then sorted by annual impact. Predicted annual average sulfate ion concentrations from the other source sectors were added to this table, and SO_2 emissions totals for the source categories and states shown were added for comparison. The last part of this table shows the relative contribution of each state and source sector to the total predicted sulfate ion concentration.

Table D-11a. VT DEC CALPUFF Modeling Results
Acadia National Park
Phase II Modeling States --- Ranked by Annual Impact

STATE	Annual SO_4 Ion (~ µg/m^3) CEMS PT	Non-CEMS PT	Small PT	On-Road	Non-Road	Area	TOTAL	CEMS PT % of Total
CN	0.00000	0.19135	0.00000	0.00000	0.00000	0.00000	0.19135	0.00
PA	0.13834	0.01618	0.00343	0.00073	0.00247	0.00942	0.17057	81.10
OH	0.14017	0.00805	0.00008	0.00000	0.00101	0.00027	0.14957	93.72
MA	0.06530	0.00967	0.00307	0.00179	0.00642	0.04970	0.13595	48.03
NY	0.05771	0.00976	0.00205	0.00202	0.00708	0.04140	0.12003	48.08
IN	0.07575	0.00957	0.00071	0.00000	0.00011	0.00087	0.08701	87.06
MI	0.06114	0.00769	0.00065	0.00000	0.00071	0.00240	0.07261	84.20
WV	0.05834	0.00203	0.00326	0.00000	0.00035	0.00021	0.06418	90.90
ME	0.00318	0.02323	0.00111	0.00287	0.00782	0.01875	0.05696	5.58
IL	0.03422	0.01525	0.00049	0.00000	0.00034	0.00007	0.05037	67.94
KY	0.04106	0.00272	0.00264	0.00000	0.00113	0.00116	0.04871	84.29
NH	0.03864	0.00143	0.00076	0.00028	0.00195	0.00484	0.04790	80.67
MD	0.03978	0.00166	0.00027	0.00029	0.00101	0.00206	0.04508	88.24
NC	0.03420	0.00412	0.00398	0.00000	0.00119	0.00018	0.04367	78.31
VA	0.03185	0.00173	0.00646	0.00000	0.00034	0.00034	0.04071	78.24
WI	0.01521	0.01936	0.00024	0.00000	0.00032	0.00013	0.03525	43.15
TN	0.01922	0.00430	0.00022	0.00000	0.00172	0.00068	0.02613	73.56
NJ	0.01304	0.00219	0.00029	0.00060	0.00407	0.00297	0.02315	56.33
IA	0.00970	0.01209	0.00008	0.00000	0.00007	0.00000	0.02194	44.21
VT	0.00000	0.00041	0.00002	0.00027	0.01507	0.00154	0.01731	0.00
GA	0.01418	0.00041	0.00041	0.00000	0.00012	0.00039	0.01551	91.42
MO	0.01401	0.00000	0.00000	0.00000	0.00000	0.00000	0.01401	0.00
CT	0.00413	0.00105	0.00012	0.00054	0.00267	0.00525	0.01376	30.01
MN	0.00887	0.00394	0.00035	0.00000	0.00030	0.00019	0.01365	64.98
SC	0.00919	0.00158	0.00143	0.00000	0.00061	0.00036	0.01318	69.73
DE	0.00871	0.00107	0.00090	0.00007	0.00042	0.00032	0.01148	75.87
AL	0.00862	0.00066	0.00059	0.00000	0.00006	0.00023	0.01016	84.84
KS	0.00806	0.00000	0.00000	0.00000	0.00000	0.00000	0.00806	100.00
RI	0.00000	0.00000	0.00000	0.00020	0.00349	0.00375	0.00744	0.00
OK	0.00590	0.00000	0.00000	0.00000	0.00000	0.00000	0.00590	100.00
AR	0.00391	0.00000	0.00000	0.00000	0.00000	0.00000	0.00391	100.00
NE	0.00169	0.00000	0.00000	0.00000	0.00000	0.00000	0.00169	100.00
SD	0.00088	0.00000	0.00000	0.00000	0.00000	0.00000	0.00088	100.00
DC	0.00011	0.00011	0.00000	0.00001	0.00001	0.00015	0.00039	28.21
MS	0.00000	0.00008	0.00010	0.00000	0.00016	0.00000	0.00034	0.00
TX	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00
TOTALS	**0.96511**	**0.35169**	**0.03371**	**0.00967**	**0.06102**	**0.14763**	**1.56881**	

Notes: 52 Canadian Point Sources > 250 Tons/Yr SO_2 Emission during 2002 (from Canadian NPRI) and sources that were within the RPO Modeling Domain were modeled.

Table D-11b. VT DEC CALPUFF Modeling Results
Brigantine National Wildlife Refuge
Phase II Modeling --- States Ranked by Annual Impact

STATE	Annual SO_4 Ion (~ μg/m^3) CEMS PT	Non-CEMS PT	Small PT	On-Road	Non-Road	Area	TOTAL	CEMS PT % of Total
PA	0.25376	0.03810	0.00785	0.00219	0.00623	0.02549	0.33363	76.06031
OH	0.26112	0.01284	0.00011	0.00000	0.00131	0.00035	0.27573	94.70134
VA	0.14417	0.00794	0.03678	0.00000	0.00172	0.00182	0.19244	74.91686
NC	0.14144	0.01819	0.01783	0.00000	0.00521	0.00079	0.18347	77.09162
WV	0.14990	0.00419	0.00756	0.00000	0.00100	0.00059	0.16325	91.82236
MD	0.13513	0.00584	0.00146	0.00136	0.00560	0.00949	0.15888	85.05161
NY	0.06578	0.01034	0.00169	0.00283	0.01051	0.05856	0.14971	43.93828
IN	0.11649	0.01166	0.00087	0.00000	0.00013	0.00101	0.13015	89.50442
NJ	0.04258	0.00661	0.00149	0.00374	0.03034	0.01767	0.10243	41.56985
KY	0.08456	0.00486	0.00489	0.00000	0.00168	0.00217	0.09815	86.15385
CN	0.00000	0.08067	0.00000	0.00000	0.00000	0.00000	0.08067	0.00000
IL	0.05214	0.01864	0.00060	0.00000	0.00044	0.00009	0.07190	72.51739
MI	0.05793	0.00708	0.00062	0.00000	0.00065	0.00219	0.06846	84.61876
TN	0.04767	0.01324	0.00059	0.00000	0.00343	0.00149	0.06642	71.77055
GA	0.05755	0.00218	0.00220	0.00000	0.00073	0.00222	0.06488	88.70222
DE	0.03951	0.00510	0.00596	0.00066	0.00407	0.00259	0.05788	68.26192
SC	0.03615	0.00724	0.00663	0.00000	0.00270	0.00150	0.05422	66.67281
WI	0.02161	0.03084	0.00038	0.00000	0.00050	0.00020	0.05353	40.36989
MA	0.02400	0.00376	0.00111	0.00066	0.00214	0.01629	0.04796	50.04170
AL	0.03165	0.00283	0.00265	0.00000	0.00024	0.00089	0.03825	82.74510
IA	0.01564	0.01746	0.00012	0.00000	0.00010	0.00000	0.03332	46.93878
MN	0.01195	0.00509	0.00049	0.00000	0.00044	0.00029	0.01825	65.47945
MO	0.01786	0.00000	0.00000	0.00000	0.00000	0.00000	0.01786	100.00000
CT	0.00405	0.00120	0.00014	0.00065	0.00279	0.00644	0.01526	26.53997
KS	0.01130	0.00000	0.00000	0.00000	0.00000	0.00000	0.01130	100.00000
NH	0.00643	0.00026	0.00011	0.00004	0.00029	0.00083	0.00796	80.77889
OK	0.00676	0.00000	0.00000	0.00000	0.00000	0.00000	0.00676	100.00000
AR	0.00474	0.00000	0.00000	0.00000	0.00000	0.00000	0.00474	100.00000
RI	0.00000	0.00000	0.00000	0.00012	0.00194	0.00212	0.00418	0.00000
ME	0.00038	0.00166	0.00006	0.00013	0.00034	0.00111	0.00370	10.27027
VT	0.00000	0.00015	0.00000	0.00007	0.00289	0.00037	0.00348	0.00000
NE	0.00306	0.00000	0.00000	0.00000	0.00000	0.00000	0.00306	100.00000
DC	0.00094	0.00041	0.00001	0.00005	0.00006	0.00064	0.00211	44.54976
SD	0.00107	0.00000	0.00000	0.00000	0.00000	0.00000	0.00107	100.00000
MS	0.00000	0.00029	0.00034	0.00000	0.00028	0.00000	0.00091	0.00000
TX	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
TOTALS	**1.84732**	**0.31867**	**0.10254**	**0.01250**	**0.08776**	**0.15720**	**2.52597**	

Notes: 52 Canadian Point Sources > 250 Tons/Yr SO_2 Emission during 2002 (from Canadian NPRI) and sources that were within the RPO Modeling Domain were modeled.

Table D-11c. VT DEC CALPUFF Modeling Results
Lye Brook Wilderness
Phase II Modeling -- States Ranked by Annual Impact

STATE	Annual SO_4 Ion (~ µg/m^3) CEMS PT	Non-CEMS PT	Small PT	On-Road	Non-Road	Area	TOTAL	CEMS PT % of Total
PA	0.19176	0.02092	0.00462	0.00097	0.00349	0.01239	0.23416	81.89
OH	0.21083	0.01114	0.00010	0.00000	0.00129	0.00034	0.22370	94.25
NY	0.06369	0.02643	0.00243	0.00280	0.01110	0.04466	0.15110	42.15
CN	0.00000	0.12108	0.00000	0.00000	0.00000	0.00000	0.12108	0.00
IN	0.10387	0.01112	0.00083	0.00000	0.00012	0.00100	0.11695	88.82
MI	0.08405	0.01042	0.00089	0.00000	0.00094	0.00315	0.09945	84.51
WV	0.08523	0.00305	0.00480	0.00000	0.00053	0.00032	0.09393	90.74
KY	0.06466	0.00378	0.00373	0.00000	0.00149	0.00161	0.07528	85.89
IL	0.04731	0.01678	0.00054	0.00000	0.00041	0.00008	0.06512	72.65
WI	0.02285	0.02897	0.00037	0.00000	0.00048	0.00019	0.05286	43.23
NC	0.04239	0.00443	0.00438	0.00000	0.00133	0.00023	0.05276	80.34
MD	0.04519	0.00223	0.00030	0.00037	0.00118	0.00249	0.05176	87.31
VT	0.00000	0.00060	0.00001	0.00103	0.03579	0.01306	0.05050	0.00
VA	0.02949	0.00256	0.00627	0.00000	0.00040	0.00038	0.03910	75.42
TN	0.02807	0.00620	0.00031	0.00000	0.00229	0.00093	0.03780	74.26
IA	0.01505	0.01735	0.00012	0.00000	0.00009	0.00000	0.03261	46.15
GA	0.02700	0.00077	0.00078	0.00000	0.00026	0.00080	0.02960	91.22
MA	0.01055	0.00323	0.00079	0.00061	0.00166	0.01018	0.02702	39.05
MN	0.01304	0.00567	0.00052	0.00000	0.00044	0.00029	0.01996	65.33
MO	0.01911	0.00000	0.00000	0.00000	0.00000	0.00000	0.01911	100.00
AL	0.01506	0.00121	0.00112	0.00000	0.00011	0.00043	0.01793	83.99
NJ	0.00707	0.00154	0.00020	0.00040	0.00268	0.00204	0.01394	50.72
SC	0.00882	0.00191	0.00183	0.00000	0.00078	0.00051	0.01384	63.73
KS	0.01153	0.00000	0.00000	0.00000	0.00000	0.00000	0.01153	100.00
NH	0.00716	0.00052	0.00013	0.00007	0.00060	0.00134	0.00982	72.91
OK	0.00858	0.00000	0.00000	0.00000	0.00000	0.00000	0.00858	0.00
DE	0.00448	0.00096	0.00070	0.00006	0.00034	0.00026	0.00680	65.88
CT	0.00149	0.00039	0.00005	0.00026	0.00106	0.00244	0.00569	26.19
AR	0.00533	0.00000	0.00000	0.00000	0.00000	0.00000	0.00533	100.00
ME	0.00012	0.00188	0.00007	0.00015	0.00037	0.00122	0.00382	3.14
NE	0.00273	0.00000	0.00000	0.00000	0.00000	0.00000	0.00273	0.00
SD	0.00137	0.00000	0.00000	0.00000	0.00000	0.00000	0.00137	100.00
RI	0.00000	0.00000	0.00000	0.00004	0.00057	0.00069	0.00129	0.00
MS	0.00000	0.00019	0.00021	0.00000	0.00022	0.00000	0.00063	0.00
DC	0.00011	0.00015	0.00000	0.00002	0.00002	0.00022	0.00052	21.15
TX	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00
TOTALS	**1.17799**	**0.30548**	**0.03610**	**0.00678**	**0.07004**	**0.10125**	**1.69767**	

Notes: 52 Canadian Point Sources > 250 Tons/Yr SO_2 Emission during 2002 (from Canadian NPRI) and sources that were within the RPO Modeling Domain were modeled.

Table D-11b. VT DEC CALPUFF Modeling Results
Shenandoah National Park (10/26/04v)
Phase II Modeling -- States Ranked by Annual Impact

STATE	Annual SO_4 Ion (~ µg/m^3)							CEMS PT % of Total
	CEMS PT	Non-CEMS PT	Small PT	On-Road	Non-Road	Area	TOTAL	
OH	0.46778	0.02542	0.00017	0.00000	0.00209	0.00057	0.49604	94.30
PA	0.27738	0.03016	0.00523	0.00129	0.00405	0.01608	0.33420	83.00
WV	0.26914	0.01024	0.01566	0.00000	0.00280	0.00170	0.29953	89.85
NC	0.16692	0.01270	0.01235	0.00000	0.00420	0.00081	0.19698	84.74
IN	0.17820	0.01454	0.00103	0.00000	0.00016	0.00129	0.19523	91.28
VA	0.11024	0.01697	0.02286	0.00000	0.00221	0.00244	0.15472	71.25
KY	0.12733	0.00670	0.00676	0.00000	0.00247	0.00327	0.14653	86.90
MD	0.10452	0.01074	0.00090	0.00110	0.00338	0.00732	0.12796	81.68
TN	0.07812	0.01981	0.00086	0.00000	0.00499	0.00235	0.10614	73.60
GA	0.08786	0.00277	0.00286	0.00000	0.00099	0.00299	0.09747	90.14
MI	0.08299	0.00747	0.00075	0.00000	0.00083	0.00280	0.09484	87.51
IL	0.06458	0.02152	0.00071	0.00000	0.00050	0.00010	0.08740	73.89
CN	0.00000	0.07814	0.00000	0.00000	0.00000	0.00000	0.07814	0.00
AL	0.05209	0.00437	0.00405	0.00000	0.00038	0.00145	0.06233	83.57
WI	0.02589	0.03066	0.00039	0.00000	0.00052	0.00021	0.05765	44.91
NY	0.03504	0.00207	0.00063	0.00060	0.00219	0.01132	0.05185	67.58
SC	0.02424	0.00587	0.00583	0.00000	0.00248	0.00163	0.04005	60.52
IA	0.01915	0.01799	0.00013	0.00000	0.00010	0.00000	0.03737	51.24
MO	0.02552	0.00000	0.00000	0.00000	0.00000	0.00000	0.02552	100.00
MN	0.01477	0.00498	0.00048	0.00000	0.00044	0.00029	0.02096	70.47
NJ	0.01022	0.00165	0.00017	0.00033	0.00260	0.00166	0.01663	61.46
DE	0.01005	0.00142	0.00149	0.00009	0.00059	0.00044	0.01408	71.38
KS	0.01372	0.00000	0.00000	0.00000	0.00000	0.00000	0.01372	100.00
OK	0.00803	0.00000	0.00000	0.00000	0.00000	0.00000	0.00803	100.00
AR	0.00735	0.00000	0.00000	0.00000	0.00000	0.00000	0.00735	100.00
MA	0.00355	0.00043	0.00011	0.00008	0.00022	0.00166	0.00604	58.77
NE	0.00379	0.00000	0.00000	0.00000	0.00000	0.00000	0.00379	100.00
CT	0.00053	0.00013	0.00002	0.00007	0.00028	0.00074	0.00177	29.94
DC	0.00036	0.00042	0.00001	0.00006	0.00006	0.00069	0.00161	22.36
MS	0.00000	0.00043	0.00048	0.00000	0.00039	0.00001	0.00131	0.00
NH	0.00095	0.00004	0.00001	0.00001	0.00004	0.00012	0.00117	81.20
SD	0.00112	0.00000	0.00000	0.00000	0.00000	0.00000	0.00112	100.00
ME	0.00003	0.00035	0.00001	0.00003	0.00007	0.00019	0.00068	4.41
VT	0.00000	0.00003	0.00000	0.00001	0.00054	0.00007	0.00065	0.00
RI	0.00000	0.00000	0.00000	0.00001	0.00015	0.00019	0.00035	0.00
TX	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00
TOTALS	**2.27146**	**0.32802**	**0.08395**	**0.00368**	**0.03972**	**0.06239**	**2.78921**	

Notes: 52 Canadian Point Sources > 250 Tons/Yr SO_2 Emission during 2002 (from Canadian NPRI) and sources that were within the RPO Modeling Domain were modeled.

D.3. The MDNR/MDE CALMET/CALPUFF Platform

D.3.1. CALMET: Meteorological Inputs and Processing

As described for the VTDEC CALMET platform, several different types of inputs are needed to create the meteorological data file for CALPUFF: geophysical, surface, precipitation, and upper air winds and temperatures. The inputs as they were prepared and used to develop the MD CALMET data are described in the following sections.

D.3.1.1. Geophysical Data

The geophysical data required by CALMET consists of information about land use and terrain elevations. A data file is prepared with this information through the use of several preprocessors. TERREL is used to read raw terrain data and to calculate the average elevation for each cell. CTGCOMP and CTGPROC compress and then process land use data, respectively, and create a file containing the fractional land use in each model cell for 38 categories. MAKEGEO combines the output from TERREL and CTGPROC to create a single geophysical data file for CALMET input, referred to as the GEO.DAT file. The GEO.DAT file contains values for each grid cell of the predominant land use category (14 categories), terrain elevation, surface parameters (roughness length, albedo, Bowen ratio, soil heat flux parameter, and leaf area index), and anthropogenic heat flux (kept as a category but for practical purposes, negligible compared to other sources of heat flux). Fractional land use based on the original 38 categories are used by MAKEGEO to estimate weighted values of the surface parameters for inclusion in the geophysical data file. The modeling domain used in this analysis extends well into Canada. High resolution land use and terrain files were obtained from USGS and used for the U.S.; less highly resolved global files were used to define land use and terrain characteristics for the part of the domain located in Canada.

D.3.1.2. Surface Data

The primary source of surface data for input to CALMET (winds, temperature, relative humidity, pressure, cloud cover and ceiling height) was the Integrated Surface Hourly (ISH) data set. ISH data consists of worldwide surface weather observations from about 12,000 stations, collected for sources such as the Automated Weather Network (AWN), Global Telecommunications System (GTS), Automated Surface Observing System (ASOS), and data keyed from paper forms. The ISH data for 2002 was obtained from the National Climatic Data Center (NCDC) on two cd-roms, one for the U.S. and one for Canada. The availability of hourly observations depends on the station type, location and instrumentation. Since the publicly available CALMET processors do not accept the ISH format, software was developed to read the raw data, test data quality codes, generate summaries of data availability, test for outliers, and create a surface data file (SURF.DAT) for input to CALMET. Although CALMET contains routines for handling missing values, a minimum data capture of 50% for winds was imposed to accept a station for inclusion in the SURF.DAT file. The software also performed other functions normally done with the standard processors, including making adjustments for time zone of the surface station. Surface stations located within 200 kilometers of the modeling domain were included, to improve CALMET processing in cells close to the domain boundary. A total of 959 ISH surface stations were incorporated into the surface data file.

The Clean Air Status and Trends Network (CASTNET) program includes stations throughout the U.S. (and one site in Ontario, Canada) that measure weekly concentrations of sulfate, nitrate, and ammonium aerosols, and sulfur dioxide and nitric acid. The stations also record hourly meteorological parameters including winds, relative humidity, temperature, and precipitation. Location of the CASTNET sites at relatively rural and in many cases elevated locations provide a good complement to the set of ISH stations. Data from 55 CASTNET sites were incorporated into the CALMET surface data file.

D.3.1.3. Precipitation

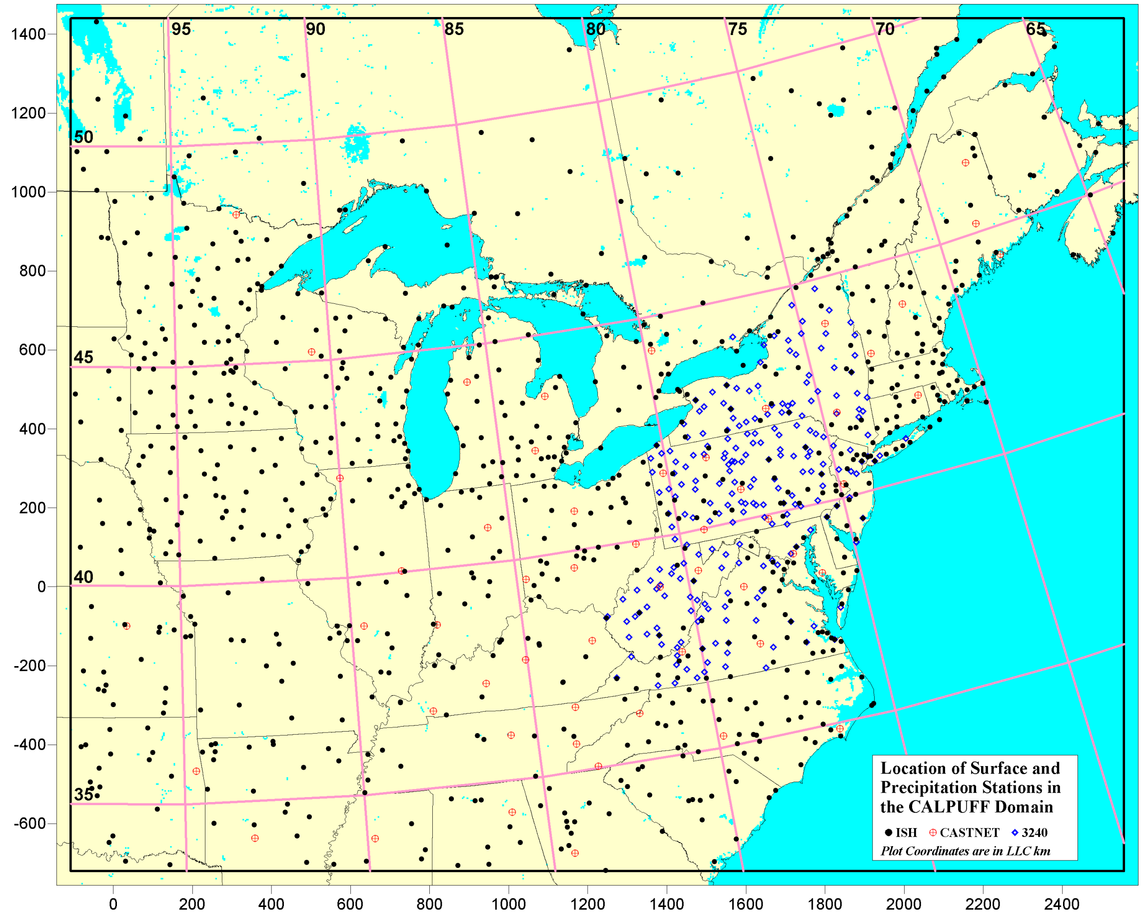
Hourly precipitation is an important input to CALPUFF: it utilizes precipitation intensity and type to estimate wet deposition of both particulate and gaseous species. Removal by wet deposition (as well as removal by dry deposition) is an important process in modeling on this scale, even when the main focus is on ambient concentrations. CALMET utilizes interpolation routines to create gridded precipitation fields in the meteorological data file for CALPUFF; no physical processes are modeled to fill in the gaps between measurement stations.

Hourly precipitation quantities were obtained from the ISH stations within, and up to 200 kilometers of the edge of the domain. As with the surface data processing, software was developed to read the raw data, test data quality codes, generate summaries of data availability, test for outliers, and create a precipitation data file (PRECIP.DAT) for input to CALMET. Many of the ISH stations in Canada reported precipitation data as accumulations over six hours instead of hourly. Rather than reject these data, the software was programmed to divide the six-hour total by three and assign the resulting value to hours 2, 3, and 4 of the period. Additional hourly precipitation data were obtained from coop stations (in the "3240" format) for states from Virginia to New York. Finally, precipitation data from CASTNET sites were analyzed and incorporated. Data from a total of 748 ISH stations, 227 3240 coop stations, and 55 CASTNET sites passed data quality checks and were included in the precipitation data file.

A further observation was that many of the stations that were analyzed reported annual total precipitation in a range that appeared reasonable for the station location, but reported missing data for a significant portion of the year. Although CALMET has routines for handling missing hourly precipitation data, experimentation with the interpolation routines revealed that erroneous gridded fields could be produced in regions where significant numbers of stations reported high percentages of missing data. A selective process was used to identify stations with reasonable annual totals and a large amount of missing data, and data that was coded as "missing" at these stations was filled with zero values. The resulting gridded precipitation field appeared to almost eliminate areas where this anomaly initially occurred.

Figure D-35 shows the location of the ISH, 3240, and CASNET measurement sites that were used for both surface and precipitation data input to CALMET.

Figure D-35. Location of the ISH, 3240, and CASNET measurement sites that were used for both surface and precipitation data input to CALMET.



D.3.1.4. CENRAP 2002 MM5

The modeling conducted in Phase I utilized a continental scale, 36-kilometer, full year meteorological data set for calendar year 2002 created by the Iowa DNR for the Central Regional Air Planning Association (CENRAP) RPO. The Penn State/NCAR Meteorological Model (MM5) version 3.5 was used in this effort. Development of the data set is described in the protocol, available at www.iowadnr.com/air/prof/progdev/regionmod.html. CALMET has the option to utilize prognostic model (e.g., MM5) output as input to CALMET. CALMET has the capability to account for local scale effects created by terrain, and can be used to "refine" the prognostic model outputs through the use of a much finer grid. In the present case, the domain has been designed to be consistent with the projection and the location of the MM5 grid, including the 36-kilometer grid spacing. The objective of CALMET processing in Phase I, therefore, was to maximize reliance on the MM5 wind fields. The only introduction of additional observational data for the creation of the CALMET meteorological data set was to utilize the surface and precipitation data developed as described above in place of the MM5 surface and precipitation data.

The MM5 data for 2002 were provided to DNR/MDE on two external, 300-GB drives. In order to be used as input to CALMET, processing was required that extracted data for the CALMET domain and re-formatted the data for input to CALMET. This is normally accomplished with the CALMM5 processor, part of the CALPUFF modeling system. The CALMM5 processor was not publicly available at the time, however, was programmed to process MM5 version 2 inputs, and modifications were required to process version 3+ data. Utility programs were obtained from the MM5 Community Model home page to aid in this process. Numerous tests were run both during and after processing to ensure that data were being read correctly. For a small number of time periods during the 2002 calendar year, data were not readable from the original files and substitutions were made to fill in the entire calendar year.

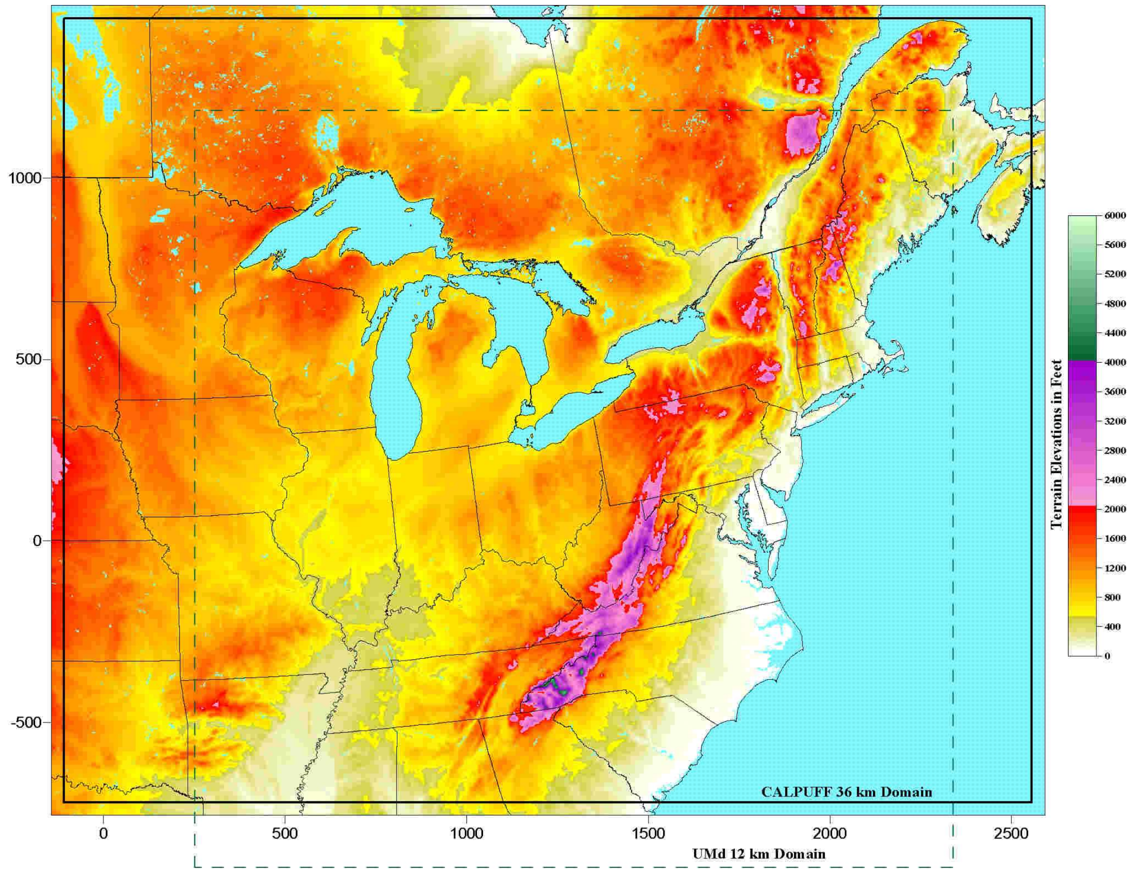
Twenty-four MM5 files were created for input to CALMET, each consisting of one-half months'data (e.g., January 1-15 and 16-31). This setup was necessary due to the 4GB file size limit for PCs. Further information on the development of the original MM5 data can be found in the protocol (see the link above); further information on the MM5 model can be found at the MM5 Community model home page at www.mmm.ucar.edu/mm5.

D.3.1.5. University of Maryland 12 km MM5

The University of Maryland created a continental scale, 36-kilometer, full year meteorological data set for calendar year 2002 and a 12-kilometer, full year meteorological data set for a smaller domain covering most of the CALPUFF domain. The extent of the 12-kilometer UMd domain is shown in Figure D-36. The Phase II modeling used the UMd MM5 data on a 12-kilometer grid. As seen in Figure D-36, The 12-kilometer data did not completely cover the CALPUFF domain in border areas to the west, north and east. In order to maintain the domain that is consistent with the Phase I modeling, these border areas were handled by utilizing the UMd 36-kilometer grid and creating pseudo-12-kilometer MM5 data by duplicating the 36-kilometer data for surrounding cells.

Slightly different processing steps were taken with the 12-kilometer MM5 data. A more recent version of CALMM5 was used that is designed to read version 3+ MM5 files. The files generated by CALMM5 for input to CALMET occupied approximately 1GB per day. Since it was not practical to generate and archive the CALMET-ready files, CALMM5 was used to generate MM5 files on a daily basis for each month. After the daily files for each full month were created, CALMET was run and the files were over-written for the next month processed.

Figure D-36. Extent of 12-km MM5 Domain



D.3.1.6. CALMET Options and Execution

The CALMET model inputs were developed as described above, and the CALMET processor was used to create 12 meteorological data files, one for each month, for input to CALPUFF (the original CENRAP processing created a total of 24 files, based on a half month each) . Running CALMET requires the selection of many processing options; some of these, including sensitivity studies as to the effect of different options on the creation of wind fields from rawinsonde data, are described in the section of this report on the Vermont DEC platform. In keeping with the goal of maximizing reliance on MM5 wind fields, options were selected for use on this platform that minimized wind field modifications by CALMET (with the exception of surface and precipitation data). Key parameter option choices were as follows:

"NOOBS" was set to a value of 2, which instructs CALMET to use MM5 data for wind fields, including surface winds. The only external data that was incorporated into the CALMET files was the hourly precipitation values developed from ish, CASTNE, and 3240 files;
"IWFCOD" was set to a value of 0, which results in excluding any diagnostic wind field processing;
"IPROG" was set to a value of 13, which causes CALMET to treat MM5 winds as the Step 1 windfield;

Eleven vertical layers were specified; the "face heights" of the layers (ZFACE) were set at 0, 20, 80, 220, 380, 620, 980, 1420, 1860, 2300, 2740, and 3180 meters. These values were chosen to reflect the vertical layers in MM5 up to about 3 kilometers; however, above about 400 meters the CALMET layers were deeper than the MM5 layers.

Evaluations of the meteorological data used by, and created by, CALMET can be found in the next section. These evaluations include a comparison of MM5 12-kilometer winds to profiler-measured winds, comparison of MM5 12-kilometer winds to the 36-kilometer CENRAP winds, and domain-wide summaries of winds and other derived parameters calculated by CALMET.

D.3.2. Evaluation of Meteorological Fields

The process of evaluating the three-dimensional, time-varying winds and other meteorological fields produced by CALMET is an important but difficult step. Comparison to observations can be problematical, since in many cases observations were used to generate the CALMET meteorology; furthermore, the CALMET modeled meteorology is much more detailed both in space (e.g., every 12 kilometers in this application, and 11 vertical layers) and time (every hour) than observational data sets. For the present analysis, the evaluation focused on three components: comparison of wind fields with available measured data from wind profilers; comparison of predicted weekly precipitation totals for locations that represent the location of NADP measurement stations; and finally, examination of the patterns of derived boundary layer parameters that are important inputs to CALPUFF. These evaluations are described in the following sections.

D.3.2.1. Wind Fields: Comparison to Profiler Data

The NOAA Profiler Network web site provides information about, and data access to, NOAA's own profiler network and also participating Cooperative Agency Profiler (CAP) sites (see http://www.profiler.noaa.gov/jsp/capSiteLocations.jsp). The site information at this link was examined for sites with data availability during the summer of 2002. Three sites were selected to use for the CALMET/MM5 comparisons: Fort Meade, MD (FMEMD, sponsored by MDE); New Brunswick, New Jersey (RUTNJ, sponsored by Rutgers University and the New Jersey Department of Environmental Protection (NJDEP)); and Stow, Massachusetts (STWMA, sponsored by the Massachusetts Department of Environmental Protection, Air Assessment Branch).

Data from these three sites was downloaded and processed to extract winds for three months in 2002 (June through August). The wind profiles were further processed by linearly interpolating measured levels to a set of elevations above ground that were selected to provide a common vertical profile for comparison. Wind profiles were also extracted from the CALMET files created with MM5 data (MDNR/MDE platform) and with NWS inputs (VTDEC platform), and linearly interpolated to the common vertical levels.

Wind profile comparisons were made in three different ways. First, plots were created that illustrate the geographic surroundings of each of the profiler sites and that also display wind roses representing the three different wind profiles (Profiler, CALMET-MM5 and CALMET-NWS) at 100, 500, 1000, and 3000 meters above ground. The wind roses were developed based on three months (June-August) of data from 2002. These plots are shown in Figure D-37 through Figure D-39 for the Fort Meade, Rutgers, and Stowe sites respectively. Although there are some similarities between the three profiles at all levels, generally the MM5-based wind roses appear to more closely match the profiler-based wind roses at the upper levels, while the NWS-based wind roses appear to more closely match the profiler-based wind roses at the lower levels. One limitation of these plots is that, especially at the upper levels, data capture on the profilers is somewhat limited (ranging from 33% to 54% at the three sites, as shown on the figures), while the meteorological models have wind estimates at all levels 100% of the time.

Wind profile comparisons were also made by calculating statistics that express the degree of bias between different sets of profiles for the three months June-August 2002. The statistics were developed by calculating the difference in wind direction and speed at each level, for each hour with available data, for three combinations: MM5 vs. Profiler, MM5 vs. NWS, and NWS vs. Profiler. The bias for speed and wind direction are presented in Table D-12. In general, the MM5-based winds compared more favorably against the profiler winds for this time period, for the three profiler locations.

Figure D-37. Comparison of wind roses based on observed profiler data, MM5-based CALMET (MD) and NWS observation-based CALMET (VT) for Fort Meade, MD.

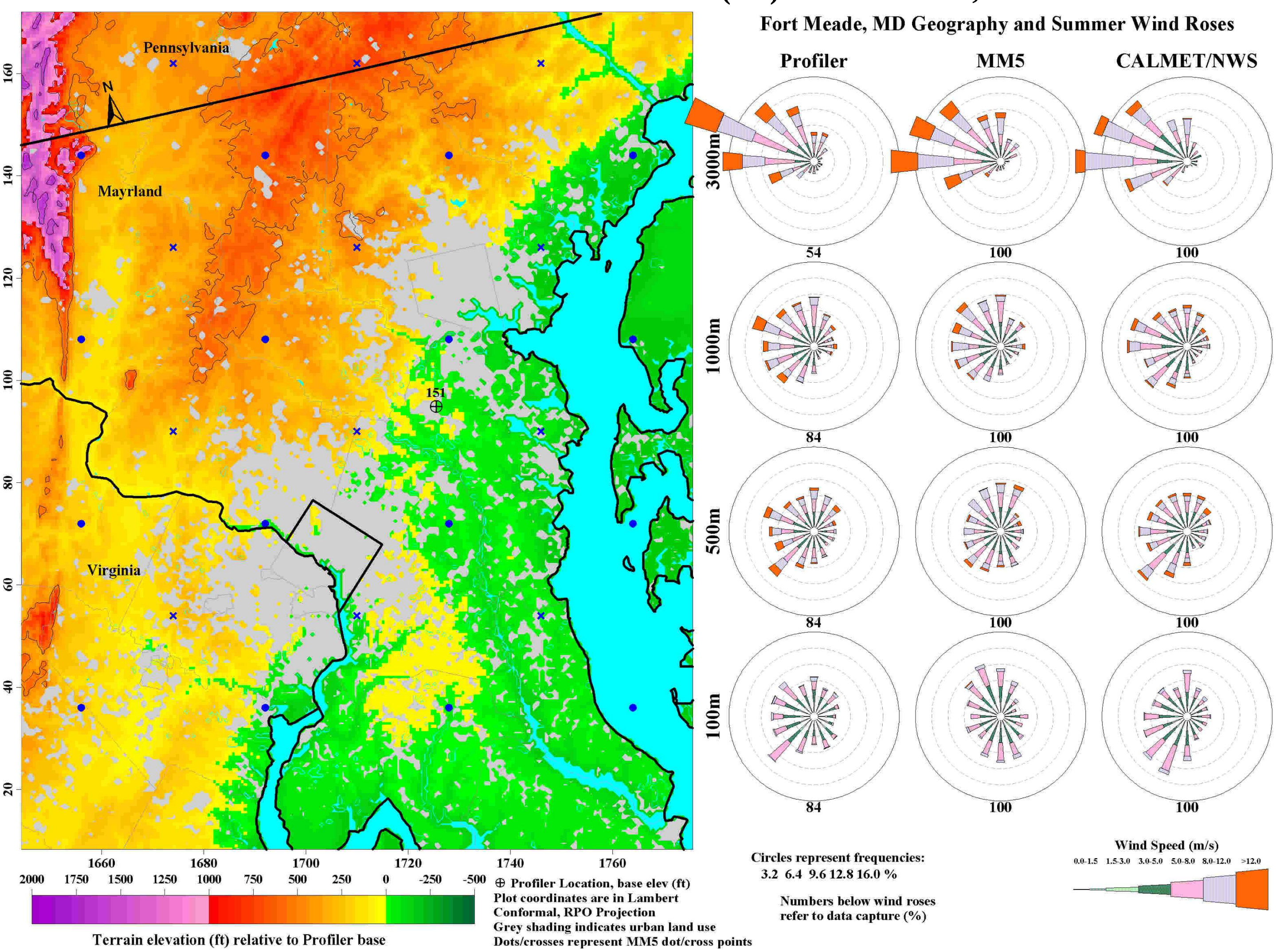


Figure D-38. Comparison of wind roses based on observed profiler data, MM5-based CALMET (MD) and NWS observation-based CALMET (VT) for Rutgers, NJ.

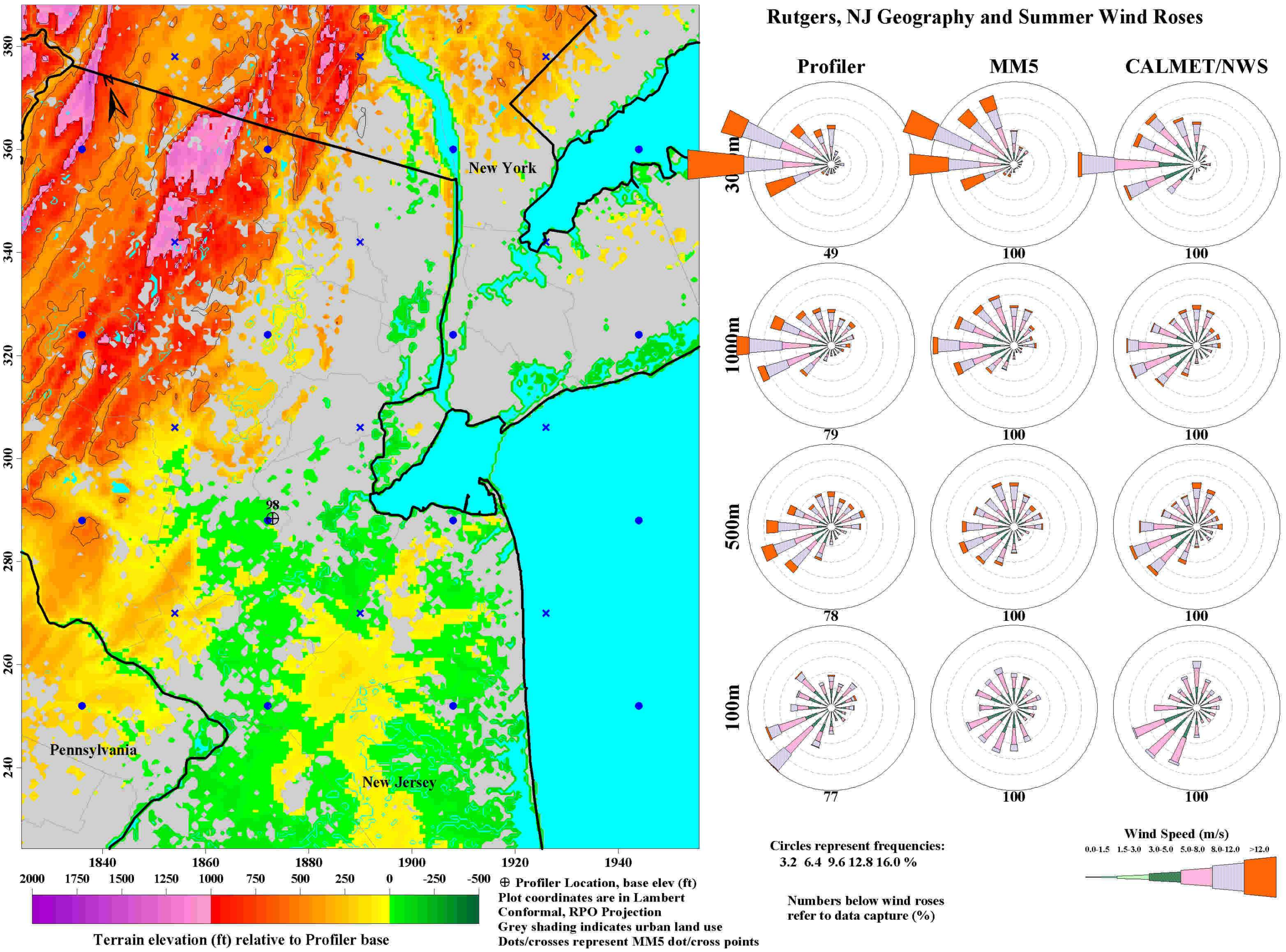


Figure D-39. Comparison of wind roses based on observed profiler data, MM5-based CALMET (MD) and NWS observation-based CALMET (VT) for Stowe, MA.

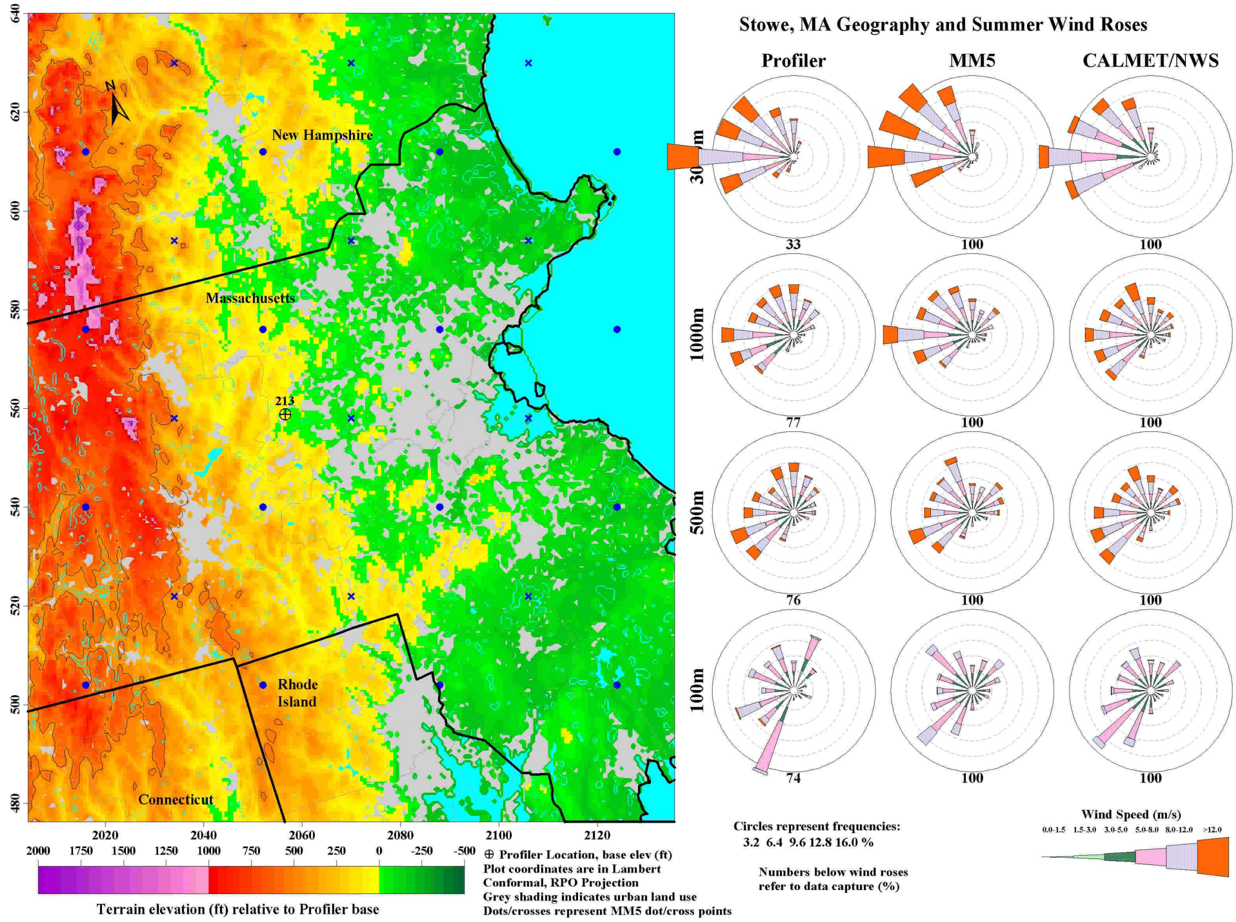


Table D-12. Wind Speed and Direction Bias at Three Profiler Sites.

Site	Elevation (m)	Wind Speed Bias (m/s)			Wind Direction Bias (degrees)		
		mm5_pro	mm5_nws	nws_pro	mm5_pro	mm5_nws	nws_pro
Fort Meade	100	0.23	0.02	0.15	3.44	8.51	-4.29
Fort Meade	500	-0.88	-0.19	-0.78	-6.42	1.55	-3.58
Fort Meade	1000	-0.75	0.07	-0.88	-5.31	10.35	-11.08
Fort Meade	3000	-0.71	1.11	-1.67	-1.99	1.64	-8.28
Rutgers	100	-0.14	0.20	-0.40	-6.19	6.86	-13.32
Rutgers	500	-0.77	0.23	-1.03	-3.38	8.37	-10.16
Rutgers	1000	-0.86	0.48	-1.37	0.38	21.81	-19.87
Rutgers	3000	-0.57	3.08	-3.25	3.56	17.83	-19.89
Stowe	100	0.39	0.15	0.34	1.89	7.75	-6.27
Stowe	500	-0.15	-0.70	0.56	8.94	7.44	1.79
Stowe	1000	-0.23	-0.63	0.52	8.53	12.93	-1.06
Stowe	3000	-0.23	2.72	-2.93	6.45	17.27	-7.93

Comparison codes:

mm5_pro: MM5-based CALMET winds vs. profiler winds
mm5_nws: MM5-based CALMET winds vs. NWS-based CALMET winds
nws_pro: NWS-based CALMET winds vs. profiler winds

Two time periods in the summer of 2002, namely, July 4-12 and August 7-15, were used to develop a third type of comparison between wind profiles. These comparisons were based on visualizations of the vertical profiles of wind speed and direction, and are presented in Figure D-40a-c for the July time period and in Figure D-41a-c for the August time period. These figures show a representation of the vertical winds from 100 to 3000 meters above ground, and use arrow symbols to represent wind vectors and a color scale to represent wind speed. Generally, the MM5-based wind profiles appear to provide a better representation of the measured profiles.

One point that is clear from these comparisons is that fine details of wind fields are difficult to represent accurately at each point in space and time, although the broad patterns appear to be reasonably well simulated, especially with the MM5-based profiles. It is instructive to recall that these comparisons represent only three locations in a much larger domain.

Figure D-40a. Comparison of vertical components of wind fields from observed profiler data, MM5-based CALMET (MD) and NWS observation-based CALMET (VT) for Ft. Meade, MD during July, 2002.

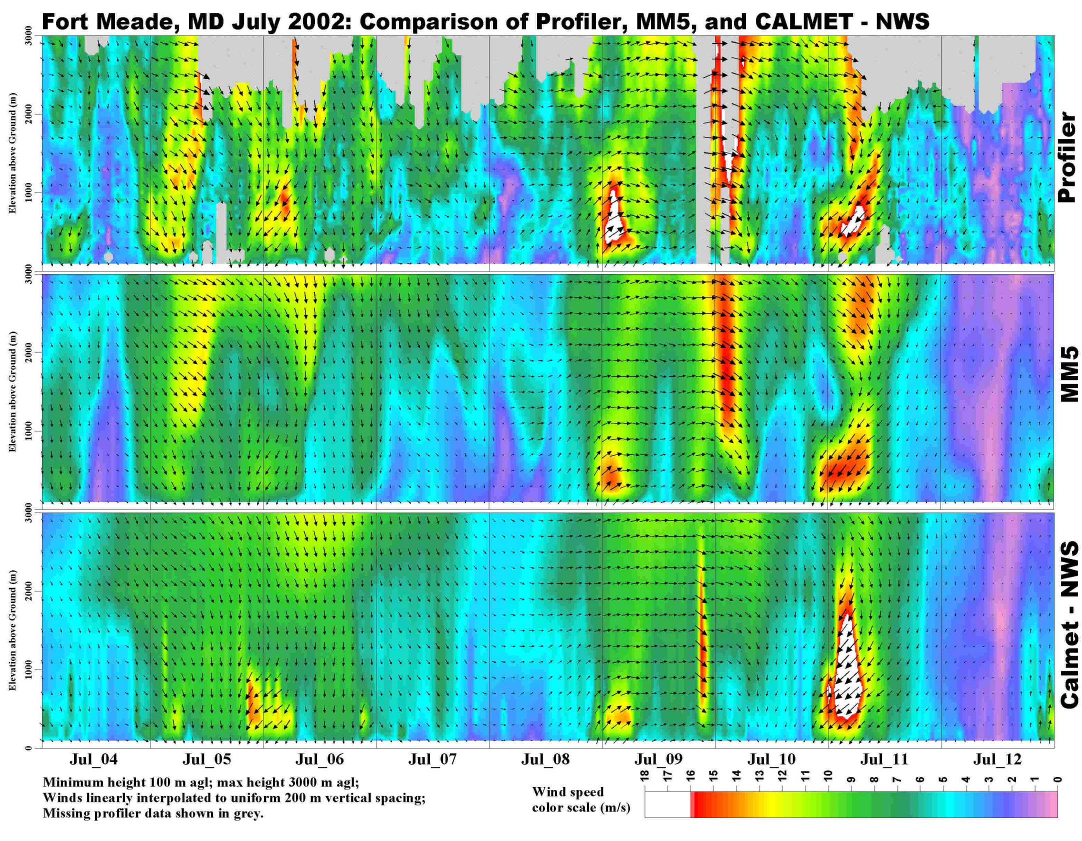


Figure D-40b. Comparison of vertical components of wind fields from observed profiler data, MM5-based CALMET (MD) and NWS observation-based CALMET (VT) for Rutgers, NJ during July, 2002.

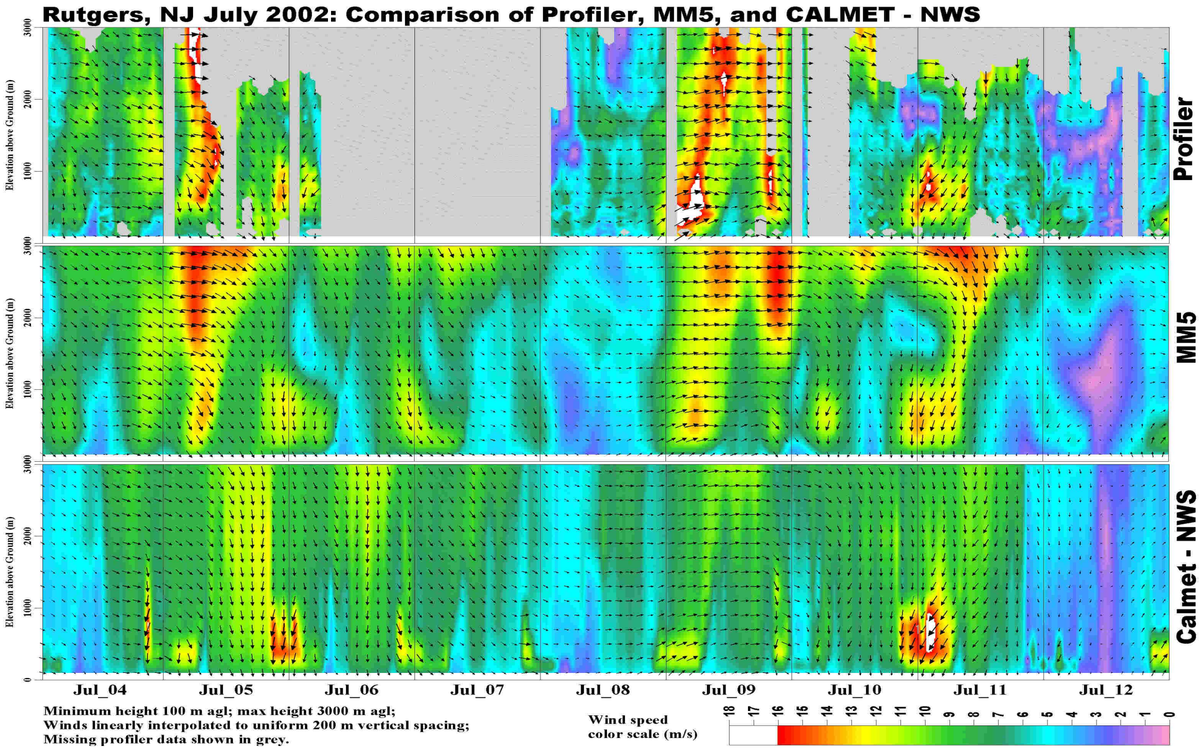


Figure D-40c. Comparison of vertical components of wind fields from observed profiler data, MM5-based CALMET (MD) and NWS observation-based CALMET (VT) for Stowe, MA during July, 2002.

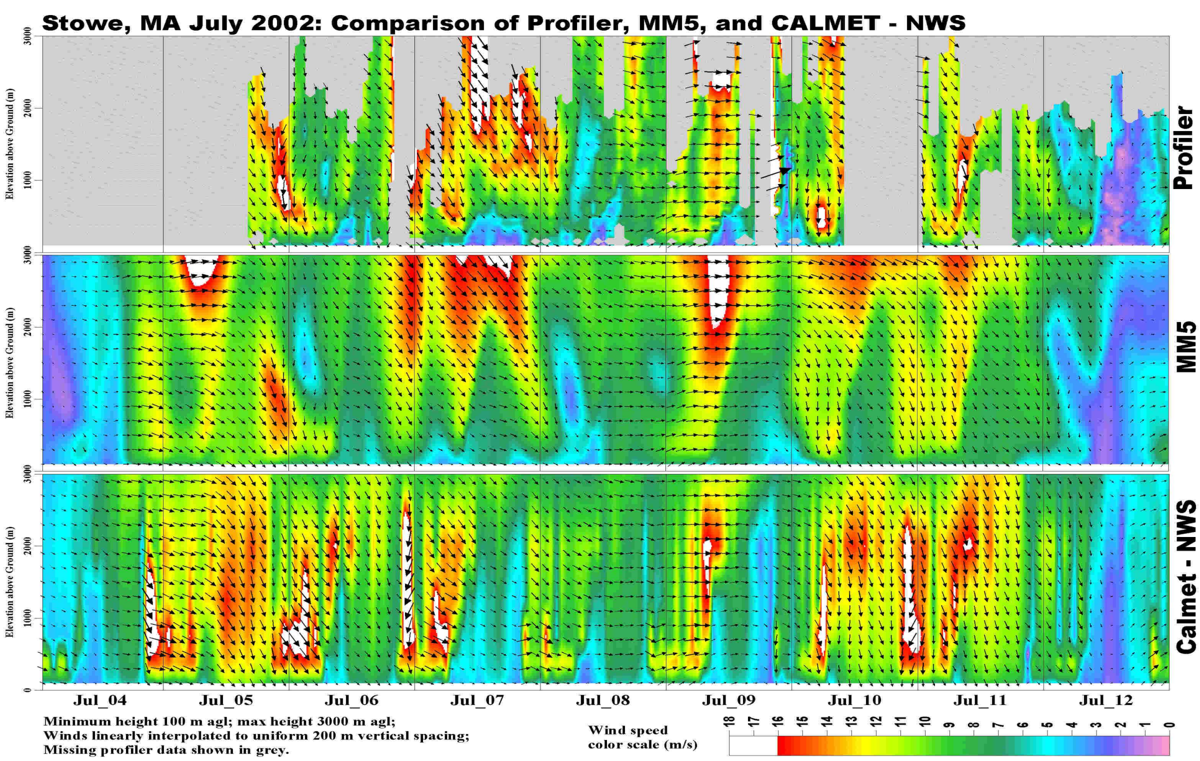


Figure D-41a. Comparison of vertical components of wind fields from observed profiler data, MM5-based CALMET (MD) and NWS observation-based CALMET (VT) for Ft. Meade, MD during August 2002.

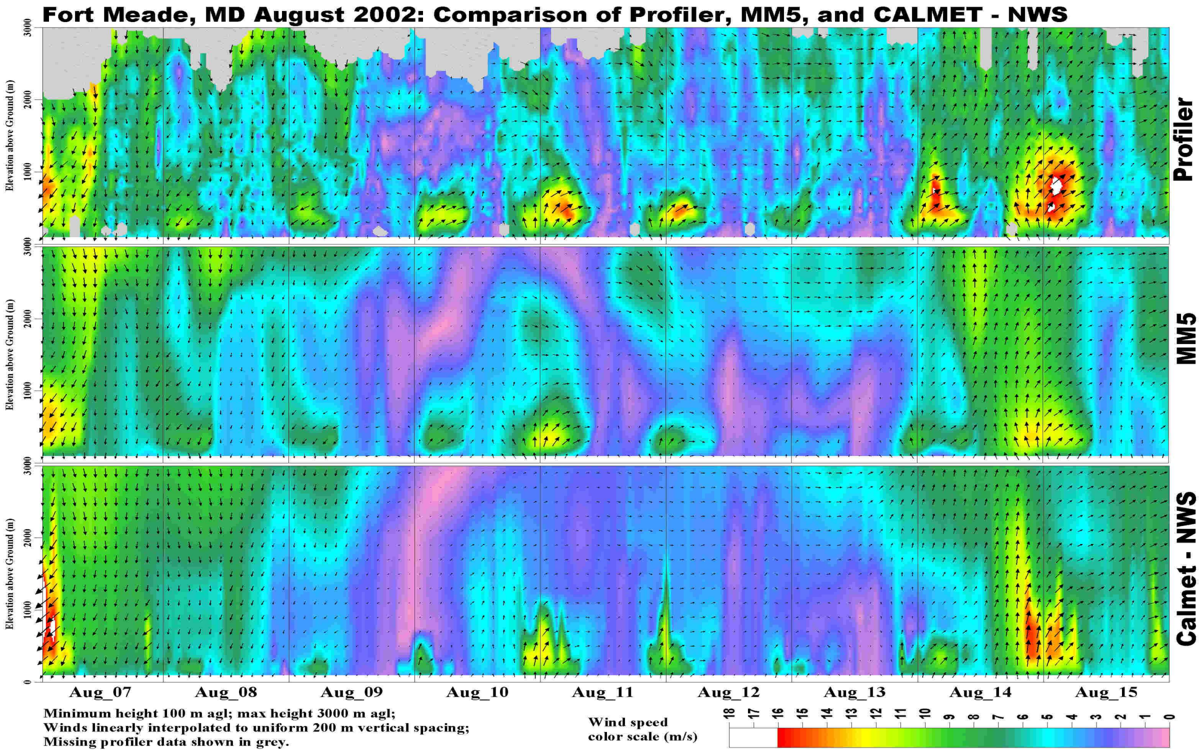


Figure D-41b. Comparison of vertical components of wind fields from observed profiler data, MM5-based CALMET (MD) and NWS observation-based CALMET (VT) for Rutgers, NJ during August 2002.

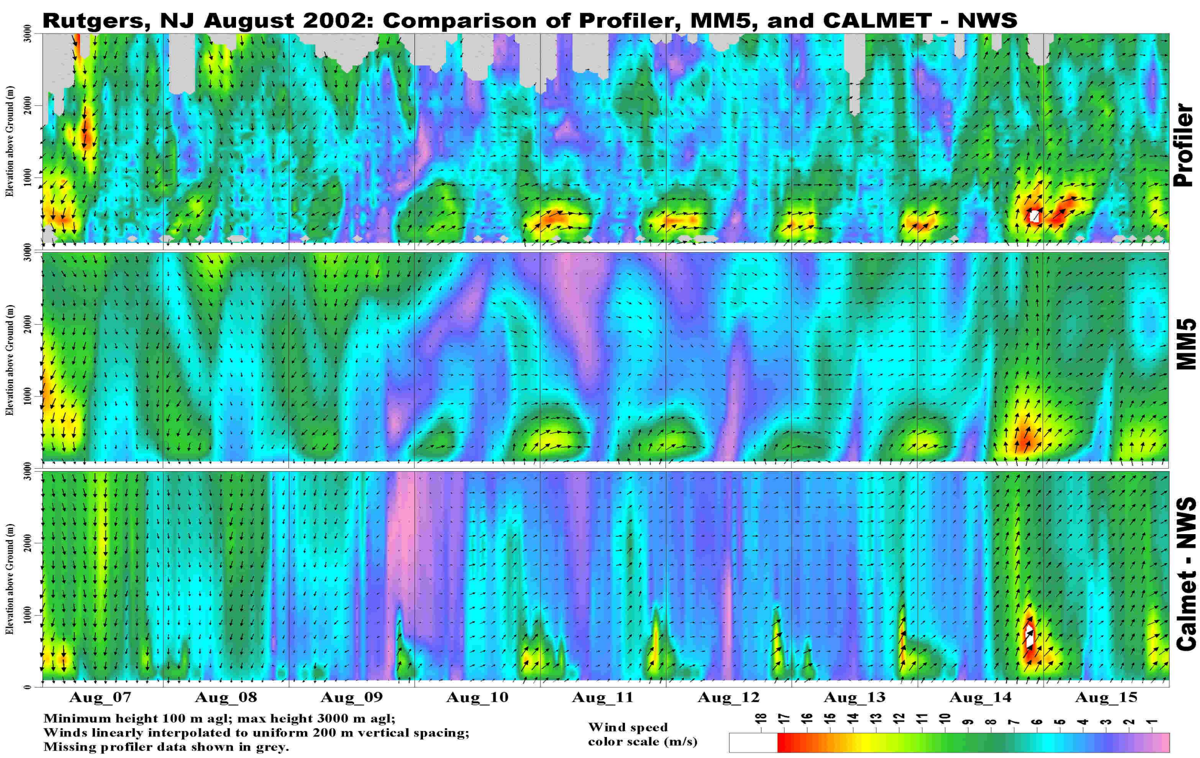
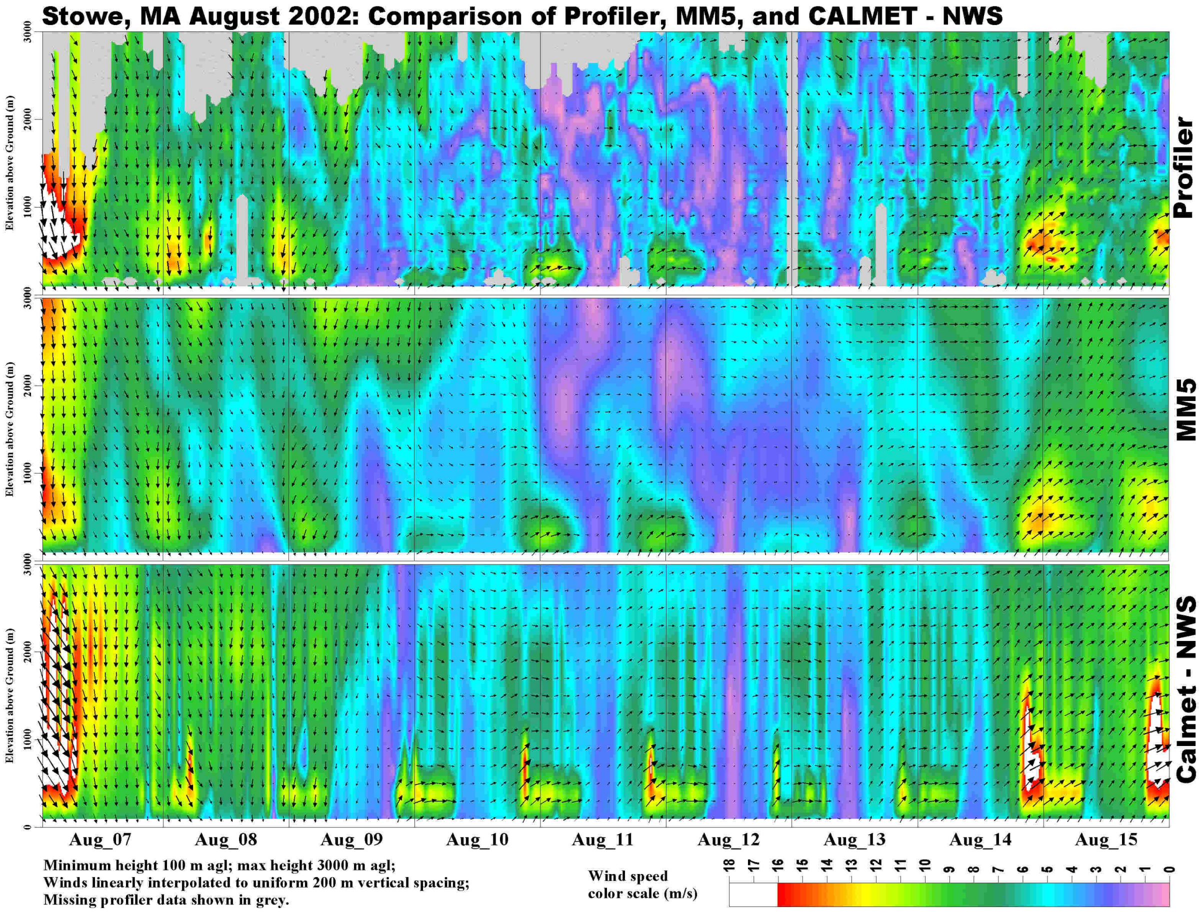


Figure D-41c. Comparison of vertical components of wind fields from observed profiler data, MM5-based CALMET (MD) and NWS observation-based CALMET (VT) for Stowe, MA during August 2002.

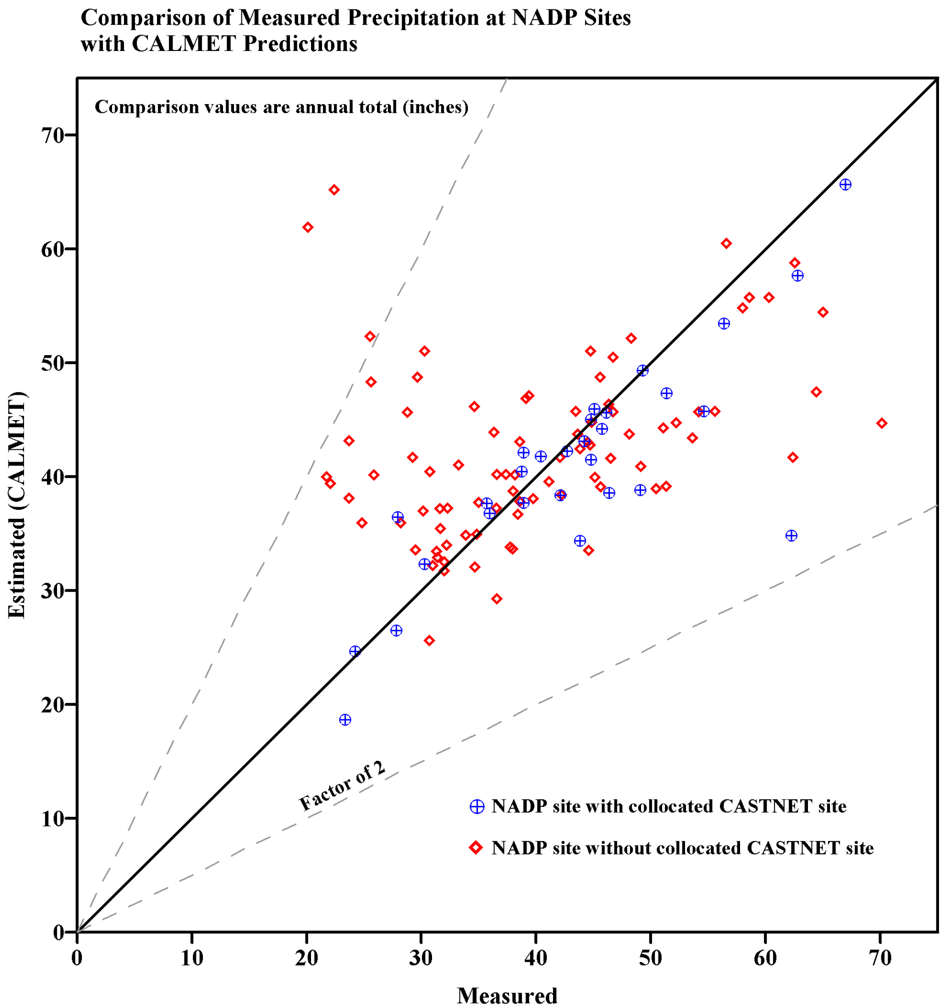


D.3.2.2. Precipitation

The hourly gridded precipitation fields were developed as discussed previously. In order to evaluate the gridding carried out by CALMET, the annual average precipitation at National Acid Deposition Program (NADP) sites in the domain were compared to the annual average precipitation predicted by CALMET in the model cell where the NADP site is located. In some cases, a CASTNET site is co-located with the NADP site. In these cases, the hourly data recorded at the CASTNET site was used in the gridding process and the comparison is less meaningful than comparisons at locations where measurement stations were more distant from the grid cell (NADP sites record precipitation as weekly totals, not hourly values, and so these data were not input to CALMET).

Figure D-42 displays the results of the comparison of gridded vs. measured annual precipitation within the domain. Points representing NADP sites with collocated CASTNET stations are shown separately from NADP sites with no collocated CASTNET station. The CALMET predictions for cells with NADP sites that have collocated CASTNET stations are, as expected, closer to observations than other cells. Even though most predictions are within a factor of two of the observations, these

Figure D-42. Comparison of gridded vs. measured annual precipitation within the CALPUFF domain



differences should be considered when comparing CALPUFF predictions of wet deposition at NADP stations.

D.3.2.3. Other Evaluations

Additional evaluations of the meteorological fields produced by CALMET were carried out. This set of evaluations was not based on comparisons to observations; rather, data summaries were prepared that allowed for an evaluation of ranges and averages of parameters (including derived boundary layer parameters) and of interrelationships between these parameters and other features such as land use and terrain. Table D-13 illustrates the relationship of the derived parameters of friction velocity, convective velocity scale, and heat flux with land use type by month. Table D-14 displays the maximum daily and average night-time mixing depths by land use type and by month; and Table D-15 illustrates the relationship of average wind speed with height, season, and land use type.

Table D-13. Derived Boundary Layer Parameters

	Land Use	# Cells	Overall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Parameter Friction Velocity m/s (ustar)	All Land	29546	0.39	0.37	0.45	0.46	0.45	0.46	0.38	0.34	0.34	0.35	0.35	0.38	0.41
	Urban	199	0.37	0.38	0.44	0.45	0.42	0.41	0.34	0.32	0.31	0.31	0.33	0.39	0.39
	Agriculture	12465	0.37	0.38	0.45	0.45	0.44	0.41	0.34	0.30	0.30	0.30	0.31	0.36	0.38
	Forest	16882	0.41	0.37	0.46	0.47	0.46	0.49	0.40	0.37	0.37	0.39	0.37	0.39	0.43
	Water	9919	0.22	0.26	0.27	0.24	0.21	0.21	0.17	0.16	0.15	0.18	0.20	0.25	0.29
	Other	495	0.33	0.31	0.36	0.40	0.38	0.39	0.36	0.30	0.31	0.30	0.29	0.30	0.31
	All LU Cats	39960	0.35	0.34	0.41	0.41	0.39	0.39	0.33	0.29	0.29	0.31	0.31	0.35	0.38
Convective Velocity m/s (wstar)	All Land	29546	0.59	0.27	0.39	0.53	0.70	0.84	0.92	0.92	0.81	0.64	0.46	0.32	0.24
	Urban	199	0.58	0.29	0.41	0.52	0.68	0.79	0.88	0.89	0.78	0.63	0.45	0.33	0.26
	Agriculture	12465	0.60	0.29	0.41	0.54	0.70	0.83	0.93	0.92	0.81	0.66	0.47	0.34	0.26
	Forest	16882	0.58	0.25	0.37	0.53	0.70	0.84	0.92	0.92	0.81	0.62	0.45	0.30	0.22
	Water	9919	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other	495	0.55	0.27	0.38	0.50	0.63	0.76	0.86	0.85	0.77	0.62	0.43	0.31	0.24
	All LU Cats	39960	0.44	0.20	0.29	0.40	0.52	0.63	0.69	0.69	0.61	0.48	0.34	0.24	0.18
Heat Flux w/m2	All Land	29546	201.9	92.9	133.9	185.6	244.2	291.2	321.6	320.1	281.1	218.5	145.5	103.5	80.9
	Urban	199	210.1	102.0	146.3	191.6	250.9	294.3	327.5	327.5	288.1	230.5	153.5	113.3	91.9
	Agriculture	12465	210.0	102.6	143.7	193.1	248.1	294.0	329.3	326.9	287.8	230.8	154.9	114.5	90.6
	Forest	16882	195.9	85.6	126.6	180.0	241.2	289.2	315.9	315.0	276.0	209.3	138.6	95.3	73.7
	Water	9919	210.2	101.4	138.4	194.8	253.4	299.2	324.2	324.4	288.6	234.0	165.8	106.5	87.4
	Other	495	210.2	104.7	148.2	196.0	246.3	293.4	329.3	320.0	287.9	228.6	154.9	116.7	93.1
	All LU Cats	39960	204.1	95.1	135.2	188.0	246.5	293.2	322.3	321.2	283.0	222.5	150.7	104.4	82.7

Table D-14. Mixing Depths

Land Use	# Cells	Overall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average of maximum daily mix height														
All Land	29546	1415	2204	785	965	1267	1430	1697	1746	1786	1657	1362	1119	896
Urban	199	1334	2037	847	1001	1209	1366	1526	1596	1652	1562	1234	1024	910
Agriculture	12465	1417	2193	801	981	1235	1413	1666	1786	1811	1662	1422	1081	890
Forest	16882	1414	2215	772	953	1291	1444	1722	1718	1770	1654	1320	1149	900
Water	9919	600	1089	688	641	649	559	582	471	458	435	475	534	619
Other	495	1348	2104	756	896	1147	1282	1490	1656	1787	1691	1433	1039	839
All LU Cats	39960	1212	1926	760	884	1112	1212	1418	1429	1456	1354	1143	973	827
Average of night-time mix heights														
All Land	29546	759	418	588	736	893	1093	1159	1131	993	774	578	482	447
Urban	199	720	445	608	706	856	972	1056	1056	925	701	535	489	444
Agriculture	12465	756	436	606	729	889	1071	1175	1132	984	782	556	473	425
Forest	16882	763	405	574	742	897	1110	1149	1132	1001	769	595	488	463
Water	9919	383	426	456	423	384	389	325	309	287	321	352	421	472
Other	495	713	390	524	672	802	981	1108	1120	1020	794	538	425	368
All LU Cats	39960	665	420	554	658	766	917	951	927	818	662	521	466	452

Table D-15. Domain-wide wind speed averages

By elevation above ground and land use (m/s)							
Elevation (m)	**All_Land**	**Urban**	**Agriculture**	**Forest**	**Water**	**Other**	**All_LU_Cats**
10	3.07	3.05	3.38	2.84	5.68	3.54	3.72
50	4.72	4.63	4.96	4.55	6.49	5.18	5.17
150	6.15	5.95	6.34	6.02	7.35	6.61	6.46
300	7.37	7.14	7.51	7.28	8.00	7.78	7.54
500	8.17	7.95	8.21	8.13	8.40	8.47	8.23
800	8.72	8.52	8.64	8.79	8.67	8.83	8.71
1200	9.38	9.16	9.15	9.56	9.13	9.11	9.32
1640	10.25	10.11	9.90	10.51	9.97	9.54	10.17
2080	11.27	11.27	10.84	11.59	11.01	10.24	11.19
2520	12.35	12.48	11.86	12.71	12.10	11.11	12.28
2960	13.48	13.69	12.94	13.88	13.21	12.07	13.40
By season and land use (surface speeds; m/s)							
Season	**All_Land**	**Urban**	**Agriculture**	**Forest**	**Water**	**Other**	**All_LU_Cats**
Annual	3.07	3.05	3.38	2.84	5.68	3.54	3.72
Winter	3.42	3.48	3.94	3.04	6.78	3.80	4.26
Spring	3.37	3.27	3.72	3.10	5.52	4.01	3.91
Summer	2.57	2.46	2.64	2.52	4.48	3.10	3.05
Fall	2.94	3.01	3.24	2.72	6.00	3.25	3.70

D.3.3. CALPUFF: Development and Evaluation of Model Inputs

The CALPUFF model requires the development of several different types of inputs. Meteorological data files (12 files for the full year) based on MM5 upper air wind fields were developed using CALMET and associated processors as described in Sections D.3.1 and D.3.2. For this analysis, hourly ozone concentrations were required based on CALPUFF option selections. Development of the ozone data file, and source and emissions data processing and inputs, are described below.

For the MM5 platform, a total of 22 receptor locations were selected and modeled.. These receptors correspond to the location of 11 Clean Air Status and Trends Network (CASTNET) sites, 7 IMPROVE monitor sites, and 5 sites that have collocated CASTNET and IMPROVE measurement station. The locations of these receptors are shown in Figure D-43, and Table D-16 provides further identification of the receptor sites.

Figure D-43. Location of Receptors Modeled with the DNR/MDE MM5 Platform

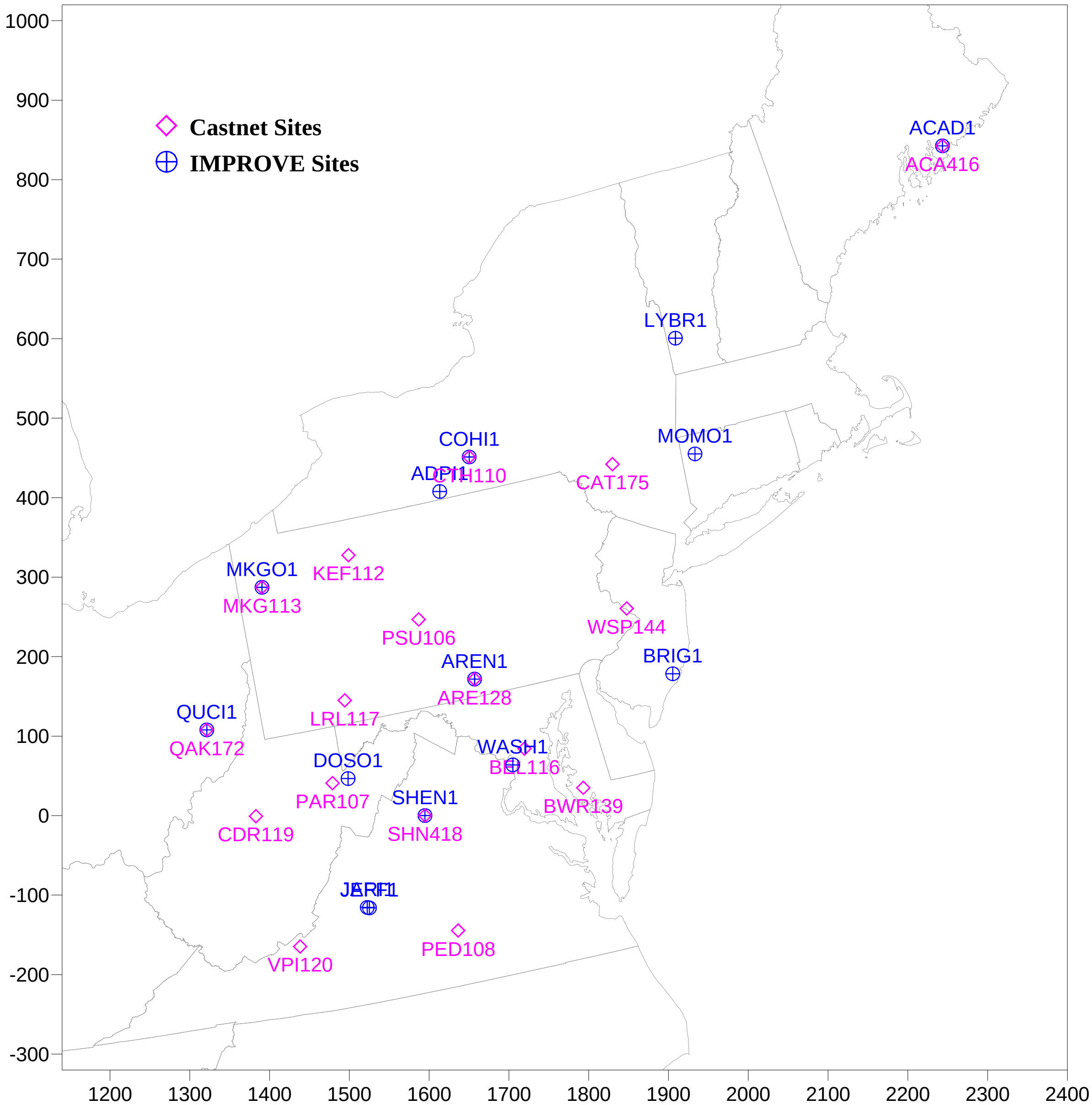


Table D-16. Identification of Receptors Modeled with DNR/MDE MM5 Platform

Site	State	CASTNET ID	IMPROVE ID
Arendtsville	PA	ARE128	AREN1
Kane Experimental Forest	PA	KEF112	-
Horton's Station	VA	VPI120	-
Prince Edward	VA	PED108	-
Shenandoah National Park-Big Meadows	VA	SHN418	SHEN1
Cedar Creek State Park	WV	CDR119	-
Parsons	WV	PAR107	-
Beltsville	MD	BEL116	-
Blackwater NWR	MD	BWR139	-
Claryville	NY	CAT175	-
Connecticut Hill	NY	CTH110	COHI1
Laurel Hill	PA	LRL117	-
M.K. Goddard	PA	MKG113	MKGO1
Penn State	PA	PSU106	-
Quaker City	OH	QAK172	QUCI1
Wash. Crossing	NJ	WSP144	-
Addison Pinnacle	NY	-	ADPI1
Brigantine National Wildlife Refuge	NJ	-	BRIG1
Dolly Sods /Otter Creek Wilderness	WV	-	DOSO1
James River Face	VA	-	JARI1
Mohawk Mt.	CT	-	MOMO1
Washington D.C.	DC	-	WASH1

D.3.3.1. Ozone Data

Hourly ozone data sets for calendar year 2002 were downloaded from EPA's Technology Transfer Network Air Quality System (http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm). Approximately 1,500 stations within the modeling domain had at least some data available for 2002. These data were read and processed were downloaded for calendar year 2002. Processing consisted of identifying the model grid location of each station, averaging hourly concentrations for each hour for all stations located within one grid cell, and creating the CALPUFF hourly ozone file based on the averages within the grid cells (i.e., grid cell centers were essentially identified as pseudo-ozone stations). This process resulted in a data file that included 1,077 such pseudo-ozone stations for use in the modeling.

D.3.3.2. NEI 2002

The National Emissions Inventory (NEI) for criteria pollutants, 1999 version 3 (as of March, 2004) was used to develop emissions and source characteristics for EGUs, for non-EGU point sources, and general area, non-road mobile, and onroad mobile sources for the Phase I modeling effort. As stated in the Phase I report, use of the 1999 inventory was considered temporary until the 2002 inventory was available. The final 2002 inventory was released by EPA in February, 2006 and there have been several updates including the latest in April, 2006. At the time when the work for this modeling was being conducted, a final 2002 inventory was not available; therefore, individual RPO inventories were obtained from web postings and processed for modeling with CALPUFF. The VISTAS (Base F) and Midwest (Base J) RPO inventories were downloaded from http://www.rpodata.org/. The MANE-VU Version 2 inventory was downloaded from ftp://manevu.org. Emissions of SO_2, NO_X, and PM were extracted from three inventories for the non-EGU point, area, and nonroad mobile source categories. The VISTAS and Midwest RPO inventories did not have emissions calculated for onroad mobile sources, so for these states emissions for this category were obtained from the 2002 draft NEI dated February 2005; onroad mobile source emissions were available from the MANE-VU Version 2 inventory, and these were processed and used in the modeling. For states outside of the MANE-VU, VISTAS, and Midwest RPO, emissions were obtained from the 2002 draft NEI dated February 2005 For EGU sources, the VTDEC hourly CEMS file was utilized in the MM5 platform modeling, so that at least for this source category, the emissions and stack parameter inputs were identical between the two platforms.

Emissions from mobile (onroad and nonroad) and area sources are reported in the NEI and in the RPO inventories on a county total basis, and each county was modeled as a single area source with some exceptions. Some counties with low emissions and that were distant (greater than 200 kilometers) from any of the model receptors were combined and modeled as large state-wide area source instead of being modeled as individual counties. This process of developing input files for CALPUFF resulted in a slightly different total number of sources modeled: 1,104 mobile/onroad sources; 684 mobile/nonroad sources, and 617 area sources.

The RPO and draft 2002 NEI point source inventories were also used to extract emissions and stack information to develop model inputs for industrial (non-EGU) facilities. The distinction between EGU and non-EGU sources was made based on the listed SIC code in the inventory; a small number of obvious mistakes in the listed SIC code were made to ensure that no EGUs were in this category.

Stack parameters and emission rates were extracted from the NEI point source text files. Thes files contained entries for a large number of individual release points, far more than could be modeled individually with CALPUFF. For this modeling effort, a single stack was selected for each facility (generally, the stack with the highest total of SO_2 plus NO_X emissions). Further processing was undertaken to reduce the number of sources to model, based on the total annual facility SO_2 + NO_X emissions and the closest distance to any of the modeled receptors. Facilities with emissions greater than specified distance-dependent thresholds were modeled as individual stacks; emissions from all other facilities were added to county-wide “industrial cateogry” sources. Most of these counties were modeled as area sources; some with low total emissions were combined into state-wide area sources. This process resulted in a modeling inventory of 545 stacks and 349 county-wide area sources.

D.3.3.3. CEMS Data

The VTDEC "PTEMARB" files, based on the CEMS data and including hourly stack parameters and SO_2 and NO_X emissions, were used with the DNR/MDE MM5 modeling platform. The individual files were combined into three files covering the entire year for approximately one-third of the total number of sources in each file. For the EGU category, therefore, the only differences in model predictions are related to meteorology. CALPUFF was modified to allow for writing predicted values from each source modeled to a separate external output file. In this way, the impacts of individual sources were retained as well as the total impacts.

D.3.3.4. Emissions Summary

Table D-17 and Table D-18 provide a summary of the 2002 emissions of SO_2 and NO_X, respectively, that were modeled with the DNR/MDE platform.

Table D-17. Summary of SO_2 Emissions from 2002 NEI and CEMS

FIPS	STATE	TOTAL	CEM PT (2002)	Non-EGU Point TOTAL	AREA	ONROAD	NONROAD
39	OH	1,417,975	1,074,480	277,438	32,334	12,641	21,082
42	PA	974,532	786,467	82,098	80,590	8,459	16,918
18	IN	925,837	741,918	86,664	74,252	8,525	14,477
13	GA*	605,137	497,931	23,919	59,137	9,640	14,510
21	KY	594,149	462,425	31,619	74,928	5,736	19,442
54	WV	565,597	489,511	52,809	16,299	2,345	4,633
37	NC	548,019	440,989	55,828	24,199	9,923	17,080
17	IL	496,469	322,682	124,606	23,526	7,392	18,263
26	MI	473,952	319,958	59,184	61,528	13,476	19,806
36	NY	469,507	193,088	85,653	154,343	14,594	29,188
47	TN	465,533	303,145	88,087	47,762	8,670	17,869
1	AL*	371,342	301,530	28,233	30,208	4,024	7,347
29	MO	333,707	173,391	95,453	44,523	8,154	12,186
24	MD	331,351	269,265	34,162	27,402	7,505	15,010
51	VA	329,896	224,577	58,181	25,054	6,653	15,431
55	WI	295,847	188,108	72,176	17,743	6,439	11,382
45	SC	278,838	189,419	52,390	22,420	5,088	9,520
19	IA	271,742	125,575	102,956	31,323	3,714	8,174
25	MA	267,251	63,543	106,056	72,015	8,546	17,092
27	MN	169,783	93,980	29,110	27,955	6,332	12,406
20	KS*	163,660	124,451	15,989	11,751	2,948	8,521
40	OK*	161,220	103,827	30,471	13,255	4,923	8,744
5	AR*	159,937	70,056	47,868	27,853	3,677	10,483
34	NJ	151,617	46,833	9,874	44,403	16,836	33,671
10	DE	92,718	30,138	40,979	9,593	4,003	8,005
33	NH	52,497	41,463	2,519	7,649	289	578
31	NE*	52,200	30,564	0	14,188	1,643	5,805
38	ND*	48,675	0	16,958	28,727	411	2,579
23	ME	37,891	1,170	20,713	14,760	806	1,612
9	CT	36,142	10,137	2,234	16,959	2,271	4,541
46	SD*	33,256	11,716	647	17,588	635	2,670
28	MS*	23,053	0	10,073	5,791	1,701	5,488
44	RI	7,384	6	956	5,304	373	745
50	VT	6,780	6	874	4,811	363	726
11	DC	4,445	1,074	616	1,903	284	568
48	TX*	2,952	40	0	1,285	524	1,103
TOTAL		**11,220,887**	**7,733,461**	**1,747,389**	**1,173,361**	**199,543**	**397,655**
Percent			**68.9%**	**15.6%**	**10.5%**	**1.8%**	**3.5%**

Emissions by source category in tons per year
States are sorted by total emissions
* indicates a stat that was only partially inculded in the domain

Table D-18. Summary of NO_X Emissions from 2002 NEI and CEMS

FIPS	STATE	TOTAL	CEM PT (2002)	Non-EGU Point TOTAL	AREA	ONROAD	NONROAD
39	OH	1,655,416	326,181	126,123	456,215	327,821	419,076
26	MI	1,325,288	109,102	60,242	435,058	324,986	395,900
17	IL	1,296,175	164,341	75,575	421,454	260,786	374,019
47	TN*	1,237,292	133,398	72,466	385,111	279,034	367,283
37	NC*	1,229,497	137,215	50,794	403,521	278,341	359,626
18	IN	1,122,064	245,511	71,973	309,277	216,202	279,101
13	GA	1,098,553	139,740	31,580	348,219	259,890	319,124
51	VA	953,642	77,132	58,751	326,623	216,498	274,638
21	KY	926,067	176,267	36,481	310,825	150,649	251,845
29	MO	900,576	120,322	24,949	288,952	215,990	250,364
27	MN	841,563	72,900	64,497	296,037	171,628	236,501
42	PA*	827,834	170,989	81,573	258,658	105,538	211,076
36	NY*	800,498	52,839	45,232	336,224	122,568	245,135
55	WI*	781,618	87,320	41,296	249,565	175,864	227,573
45	SC	669,276	79,289	39,762	211,882	145,793	192,550
40	OK	618,634	74,190	36,520	205,560	129,920	172,444
19	IA	539,457	77,087	42,584	173,081	102,693	144,012
1	AL	526,963	109,534	38,449	148,947	96,005	134,028
5	AR	526,790	40,719	21,984	200,413	99,530	164,144
54	WV	495,954	195,221	45,472	105,013	57,920	92,328
20	KS	477,806	84,221	14,422	156,534	79,248	143,381
25	MA	438,255	20,562	48,242	166,595	67,619	135,237
34	NJ*	398,923	24,791	18,298	158,296	65,846	131,692
24	MD	279,131	74,828	21,633	84,673	34,499	68,997
31	NE	260,450	21,998	0	102,934	44,427	91,091
28	MS	237,014	0	31,083	80,804	46,043	79,084
9	CT	144,756	4,145	6,578	61,226	24,269	48,538
46	SD	111,342	14,516	463	41,508	17,897	36,958
10	DE*	99,250	8,082	7,080	35,200	16,296	32,593
38	ND	87,990	0	1,657	41,648	11,669	33,016
23	ME*	66,201	414	17,362	23,951	8,296	16,592
33	NH	64,602	6,436	1,768	29,135	9,088	18,175
48	TX*	57,386	2,158	0	21,040	13,849	20,339
44	RI*	29,478	290	590	13,765	4,944	9,889
50	VT	23,801	229	386	11,192	3,998	7,996
11	DC	16,452	403	476	7,212	2,787	5,574
TOTAL		**21,165,984**	**2,852,370**	**1,236,336**	**6,906,348**	**4,188,431**	**5,989,919**
Percent			**13.5%**	**5.8%**	**32.6%**	**19.8%**	**28.3%**

Emissions by source category in tons per year
States are sorted by total emissions
* indicates a stat that was only partially inculded in the domain

D.3.4. Phase I CALPUFF Results Using MM5-Derived Wind Fields

CALPUFF modeling was conducted utilizing the meteorological, source, ozone, and receptor inputs developed as described previously. Modeled concentrations of sulfate and nitrate ion were extracted from output files and summarized. Comparisons of total predicted sulfate and nitrate ion concentrations to measurements at the 22 modeled CASTET and IMPROVE stations, and summaries of model predictions by source and by state, are discussed in the following sections.

D.3.4.1. Evaluation of CALPUFF Sulfate and Nitrate Predictions

Tables D19(a-c) display the results of CALPUFF modeling with MM5 meteorological inputs, compared to observations at CASTNET and IMPROVE locations. Table D19(a) displays a comparison of predicted and observed sulfate ion concentrations. There is a distinct tendency to under predict annual average sulfate ion concentrations at nearly all of the sites modeled, with slight overprediction at Acadia and Lye Brook. The maximum predicted 24-hr sulfate ion concentrations display a wider range of predicted to observed ratios, ranging from a low of 0.58 at Dolly Sods to 1.87 at Acadia. Table D-19(b) displays similar comparisons with nitrate aerosol ion concentrations at IMPROVE and CASTNET sites. Both annual average and 24-hr maximum nitrate aerosol ion concentrations are over-predicted substantially. Table D-19(c) displays model comparisons for total nitrate ion at CASTNET sites, where the total nitrate ion is calculated as the sum of nitric acid and nitrate aerosol. CALPUFF still overpredicts, but not as substantially as with the nitrate aerosol ion alone (IMPROVE sites do not report nitric acid, therefore comparisons of total nitrate ion could not be made at IMPROVE sites). The CALPUFF algorithms, as described in Section D.1.2, partition available nitrate between nitric acid and nitrate aerosol as a function of temperature, relative humidity, and available ammonia. The results shown in Tables 19(b) and 19(c) show that the nitrate partitioning is clearly biased towards forming too much nitrate aerosol, and that this may be due to limitations on available ammonia that are not simulated directly by CALPUFF. The POSTUTIL program, also discussed in Section D.1.2, can be applied to effectively correct for limited ammonia availability; however, the results shown here do not reflect the application of POSTUTIL. The nitrate ion predictions based on using this modeling platform should therefore be considered to be conservative estimates.

Table D-19a. Summary of Model Performance for Sulfate Ion: MM5 Meteorology

Annual Averages (ug/m3) CASTNET and IMPROVE Sites						
				Source Category Contributions		
Location	Total Modeled	Observed	Predicted/ Obs Ratio	EGU CEMS	Industry Point	Mobile/ Area
Arendtsville	3.81	5.00	0.76	3.03	0.51	0.28
Shenandoah National Park-Big Meadows	3.66	4.61	0.79	2.99	0.46	0.22
Connecticut Hill	2.81	3.76	0.75	2.16	0.42	0.24
M.K. Goddard	3.30	4.29	0.77	2.61	0.47	0.22
Quaker City	4.06	4.90	0.83	3.28	0.57	0.21
Addison Pinnacle	2.80	3.90	0.72	2.17	0.41	0.22
Brigantine National Wildlife Refuge	3.50	4.06	0.86	2.63	0.51	0.38
Dolly Sods	3.33	4.23	0.79	2.75	0.42	0.18
James River Face	3.16	4.84	0.65	2.54	0.44	0.19
Mohawk Mt.	2.88	2.88	1.00	2.09	0.43	0.37
Washington D.C.	4.07	5.27	0.77	3.22	0.52	0.35
Acadia NP	2.19	1.86	1.18	1.48	0.44	0.28
Lye Brook Wilderness	2.27	2.17	1.05	1.66	0.36	0.25
Kane Experimental Forest	3.08	4.25	0.72	2.44	0.43	0.20
Horton's Station	2.86	4.69	0.61	2.26	0.44	0.17
Prince Edward	3.58	4.48	0.80	2.92	0.45	0.22
Cedar Creek State Park	3.48	4.36	0.80	2.84	0.47	0.19
Parsons	3.23	4.72	0.68	2.65	0.41	0.17
Beltsville	4.04	4.73	0.85	3.20	0.53	0.33
Blackwater NWR	3.82	4.53	0.84	2.98	0.52	0.32
Claryville	2.66	3.31	0.80	2.02	0.38	0.26
Laurel Hill	3.84	5.08	0.76	3.17	0.47	0.22
Penn State	3.60	4.74	0.76	2.90	0.46	0.25
Wash. Crossing	3.51	4.18	0.84	2.61	0.50	0.41

24-hr Maxima (ug/m3) IMPROVE Sites Only						
				Source Category Contributions		
Location	Total Modeled	Observed	Predicted/ Obs Ratio	EGU CEMS	Industry Point	Mobile/ Area
Arendtsville	23.01	24.97	0.92	19.28	3.07	0.66
Shenandoah National Park-Big Meadows	20.54	19.20	1.07	16.68	2.42	1.44
Connecticut Hill	21.76	22.17	0.98	16.76	3.20	1.80
M.K. Goddard	18.00	25.22	0.71	16.30	1.28	0.42
Quaker City	22.04	18.82	1.17	18.05	3.35	0.65
Addison Pinnacle	18.96	24.83	0.76	14.30	2.87	1.79
Brigantine National Wildlife Refuge	21.16	26.87	0.79	18.04	2.36	0.76
Dolly Sods	21.23	36.61	0.58	17.15	3.07	1.01
James River Face	23.15	16.95	1.37	18.95	2.83	1.37
Mohawk Mt.	17.51	14.86	1.18	14.49	2.14	0.88
Washington D.C.	24.59	25.31	0.97	20.90	2.71	0.98
Acadia NP	25.23	13.51	1.87	18.04	3.84	3.34
Lye Brook Wilderness	17.37	15.87	1.09	11.74	3.91	1.72

Table D-19b. Summary of Model Performance for Nitrate Aerosol Ion: MM5 Meteorology

Annual Averages (ug/m3) CASTNET and IMPROVE Sites						
				Source Category Contributions		
Location	Total Modeled	Observed	Predicted/ Obs Ratio	EGU CEMS	Industry Point	Mobile/ Area
Arendtsville	3.01	1.51	1.99	0.89	0.37	1.75
Shenandoah National Park-Big Meadows	2.95	0.71	4.15	1.02	0.32	1.61
Connecticut Hill	2.31	0.94	2.45	0.71	0.26	1.33
M.K. Goddard	3.06	1.28	2.39	0.87	0.32	1.88
Quaker City	3.35	0.98	3.41	0.96	0.42	1.97
Addison Pinnacle	2.29	0.91	2.53	0.74	0.27	1.29
Brigantine National Wildlife Refuge	2.71	0.92	2.94	0.70	0.31	1.71
Dolly Sods	2.39	0.44	5.47	0.99	0.28	1.12
James River Face	2.60	0.62	4.20	0.78	0.30	1.52
Mohawk Mt.	2.77	0.65	4.26	0.67	0.31	1.79
Washington D.C.	3.16	1.39	2.28	0.87	0.32	1.97
Acadia NP	1.77	0.36	4.94	0.45	0.26	1.07
Lye Brook Wilderness	2.02	0.48	4.19	0.54	0.24	1.25
Kane Experimental Forest	2.54	0.58	4.36	0.87	0.29	1.38
Horton's Station	2.41	0.34	7.01	0.77	0.28	1.36
Prince Edward	2.66	0.33	8.17	0.78	0.33	1.55
Cedar Creek State Park	2.67	0.28	9.52	0.88	0.36	1.44
Parsons	2.27	0.49	4.61	0.88	0.27	1.12
Beltsville	3.00	0.71	4.23	0.85	0.33	1.82
Blackwater NWR	2.53	1.12	2.26	0.79	0.30	1.45
Claryville	2.17	0.47	4.65	0.66	0.24	1.26
Laurel Hill	2.79	0.40	7.03	1.06	0.33	1.41
Penn State	2.76	1.18	2.33	0.88	0.33	1.55
Wash. Crossing	3.16	1.22	2.59	0.72	0.35	2.10
24-hr Maxima (ug/m3) IMPROVE Sites Only						
				Source Category Contributions		
Location	Total Modeled	Observed	Predicted/ Obs Ratio	EGU CEMS	Industry Point	Mobile/ Area
Arendtsville	16.93	10.59	1.60	6.45	1.81	8.66
Shenandoah National Park-Big Meadows	19.14	3.10	6.18	7.25	2.48	9.42
Connecticut Hill	23.94	5.61	4.27	8.92	2.36	12.66
M.K. Goddard	13.36	5.83	2.29	3.12	1.11	9.13
Quaker City	16.66	5.27	3.16	7.87	2.40	6.39
Addison Pinnacle	21.72	4.85	4.48	7.46	2.06	12.20
Brigantine National Wildlife Refuge	13.93	5.70	2.44	4.01	1.65	8.27
Dolly Sods	15.64	1.78	8.81	5.04	1.65	8.96
James River Face	16.86	3.26	5.17	6.59	2.00	8.27
Mohawk Mt.	17.80	3.86	4.61	4.86	1.68	11.26
Washington D.C.	22.15	7.44	2.98	2.98	0.97	18.20
Acadia NP	22.76	2.56	8.89	6.61	2.93	13.22
Lye Brook Wilderness	16.99	3.68	4.62	6.26	1.92	8.81

Table D-19c. Summary of Model Performance for Total Nitrate Ion: MM5 Meteorology

Annual Averages (ug/m3) CASTNET Sites Only						
				Source Category Contributions		
Location	Total Modeled	Observed	Predicted/ Obs Ratio	EGU CEMS	Industry Point	Mobile/ Area
Kane Experimental Forest	3.17	2.35	1.35	1.13	0.39	1.66
Horton's Station	3.25	2.68	1.21	1.02	0.46	1.78
Prince Edward	3.97	1.92	2.07	1.21	0.49	2.27
Cedar Creek State Park	3.60	1.69	2.13	1.28	0.50	1.83
Parsons	2.93	1.83	1.60	1.20	0.35	1.38
Beltsville	4.74	2.96	1.60	1.37	0.51	2.86
Blackwater NWR	3.79	3.55	1.07	1.17	0.45	2.17
Claryville	2.65	2.58	1.03	0.81	0.30	1.55
Laurel Hill	3.73	2.25	1.66	1.50	0.43	1.80
Penn State	3.57	3.31	1.08	1.22	0.42	1.93
Wash. Crossing	4.71	3.74	1.26	1.05	0.52	3.14

D.3.4.2. Results Summary: MM5-Based Meteorology

Table D-20(a-d, for different Class I areas) provides a summary of individual EGU impacts. These tables represent the 100 highest predicted 24-hr average sulfate ion concentrations at each site. Additional information shown includes the unit identification code from the CEMS data base, the State where the unit is located, the date of the 24-hr prediction, the predicted annual average sulfate ion concentration for the unit (and the rank of the annual average concentration), total tons of SO_2 emitted in 2002, the stack height, and the distance from the source to the Class I area.

Table D-21(a-d, for different Class I areas) provides a different type of summary. Impacts from EGUs in the 2002 data base were summed by state, and then sorted by annual impact. Predicted annual average sulfate ion concentrations from the other source sectors were added to this table, and SO_2 emissions totals for the source categories and states shown were added for comparison. The last part of this table shows the relative contribution of each state and source sector to the total predicted sulfate ion concentration.

Table D-20 and Table D-21 provide an overall summary of the modeling with MM5 meteorology. This summary can be used to compare with results from other platforms to evaluate commonalities and differences.

Table D-20a. Individual Unit Sulfate Ion Impact Summary: MM5 Meteorology

Acadia National Park

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
1	D023642	NH	0.693	28_Jan_028	0.0272	2	19,452.6	159.7	291.4
2	D023641	NH	0.672	29_Jan_029	0.0157	12	9,356.2	131.7	291.4
3	D028404	OH	0.663	29_Jan_029	0.0210	3	87,801.2	245.4	1207.3
4	D016193	MA	0.569	12_Aug_224	0.0194	4	19,324.8	107.3	378.9
5	D015991	MD	0.546	03_Aug_215	0.0162	11	13,014.0	151.8	341.6
6	D02872C04	OH	0.494	29_Jan_029	0.0178	8	83,133.5	150.0	1223.4
7	D015992	MD	0.476	03_Aug_215	0.0106	20	8,979.5	151.8	341.6
8	D031361	PA	0.452	16_Mar_075	0.0278	1	87,434.3	243.8	992.3
9	D031222	PA	0.424	07_Mar_066	0.0184	7	55,216.4	243.8	990.5
10	D03406C10	TN	0.414	29_Jan_029	0.0090	33	104,522.6	150.0	1875.4
11	D031221	PA	0.401	07_Mar_066	0.0139	13	45,754.3	243.8	990.5
12	D000265	AL	0.399	29_Jan_029	0.0024	174	53,062.0	228.6	1988.9
13	D080421	NC	0.396	16_Mar_075	0.0084	41	57,819.7	182.9	1337.1
14	D00988U4	IN	0.388	30_Jan_030	0.0071	50	45,062.0	122.8	1488.3
15	D031492	PA	0.385	12_Aug_224	0.0172	10	50,276.3	347.2	776.2
16	D03179C01	PA	0.384	16_Mar_075	0.0175	9	79,635.0	150.0	1080.3
17	D03935C02	WV	0.369	16_Mar_075	0.0090	32	63,065.5	274.3	1299.6
18	D031362	PA	0.364	12_Aug_224	0.0185	6	62,846.8	243.8	992.3
19	D031491	PA	0.363	15_Jul_196	0.0193	5	60,241.6	347.2	776.2
20	D028504	OH	0.354	29_Jan_029	0.0056	69	27,343.1	213.4	1425.9
21	D01355C03	KY	0.349	29_Jan_029	0.0059	62	38,103.8	150.0	1550.8
22	D01384CS1	KY	0.343	29_Jan_029	0.0035	121	21,836.6	61.0	1591.4
23	D080422	NC	0.335	16_Mar_075	0.0065	54	45,295.8	182.9	1337.1
24	D028502	OH	0.331	29_Jan_029	0.0046	85	28,698.3	213.4	1425.9
25	D082261	PA	0.312	29_Jan_029	0.0113	18	40,267.5	228.6	1033.2
26	D028503	OH	0.311	29_Jan_029	0.0053	74	27,968.3	213.4	1425.9
27	D01733C34	MI	0.305	30_Jan_030	0.0096	25	39,361.7	152.4	1249.5
28	D00861C01	IL	0.302	30_Jan_030	0.0078	45	42,355.4	152.4	1838.3
29	D028281	OH	0.299	29_Jan_029	0.0120	16	37,307.2	251.5	1111.5
30	D06113C03	IN	0.296	30_Jan_030	0.0090	30	71,181.7	150.0	1748.1
31	D031403	PA	0.294	01_Oct_274	0.0098	24	38,800.9	269.1	837.5
32	D016264	MA	0.291	12_Aug_224	0.0084	40	2,880.2	152.4	294.2
33	D02554C03	NY	0.281	18_Jan_018	0.0091	29	30,151.1	150.0	916.6
34	D067054	IN	0.275	30_Jan_030	0.0050	78	40,117.7	152.4	1738.6
35	D016192	MA	0.270	28_May_148	0.0121	15	8,889.3	107.3	378.9
36	D028501	OH	0.269	29_Jan_029	0.0052	76	30,798.1	213.4	1425.9
37	D016191	MA	0.261	28_May_148	0.0130	14	9,252.3	107.3	378.9
38	D01353C02	KY	0.260	16_Mar_075	0.0057	67	41,544.5	243.8	1375.7
39	D03405C34	TN	0.259	16_Mar_075	0.0023	176	19,368.2	150.0	1519.9
40	D02876C01	OH	0.259	18_Jan_018	0.0111	19	72,592.9	243.8	1294.7
41	D039353	WV	0.255	16_Mar_075	0.0058	66	42,211.5	274.9	1299.6

Acadia National Park

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
42	D01571CE2	MD	0.252	13_Mar_072	0.0106	21	48,565.5	335.3	950.8
43	D01010C05	IN	0.244	30_Jan_030	0.0098	23	60,746.6	122.8	1662.8
44	D06113C04	IN	0.242	30_Jan_030	0.0042	98	27,847.9	213.4	1748.1
45	D080021	NH	0.238	08_Sep_251	0.0084	39	5,032.9	133.2	247.1
46	D028306	OH	0.237	30_Jan_030	0.0054	73	30,465.5	137.2	1451.1
47	D03775C02	VA	0.234	16_Mar_075	0.0022	184	16,673.8	307.2	1428.4
48	D03407C69	TN	0.228	16_Mar_075	0.0036	119	38,645.0	150.0	1660.7
49	D01733C12	MI	0.221	29_Dec_363	0.0091	27	46,080.6	137.2	1249.5
50	D039432	WV	0.221	16_Mar_075	0.0091	28	45,849.5	167.6	1088.4
51	D039431	WV	0.220	16_Mar_075	0.0086	36	42,385.1	167.6	1088.4
52	D03140C12	PA	0.217	01_Oct_274	0.0082	43	29,735.6	259.1	837.5
53	D060412	KY	0.214	29_Jan_029	0.0039	108	20,491.0	245.7	1431.4
54	D03131CS1	PA	0.213	12_Aug_224	0.0090	31	22,343.5	150.0	901.2
55	D0283612	OH	0.212	30_Jan_030	0.0105	22	41,431.8	182.9	1161.9
56	D02712C03	NC	0.211	16_Mar_075	0.0050	80	30,776.4	150.0	1260.3
57	D028667	OH	0.210	07_Mar_066	0.0093	26	33,601.3	259.1	1096.0
58	D03948C02	WV	0.203	18_Jan_018	0.0120	17	55,404.9	167.6	1146.5
59	D015732	MD	0.200	13_Mar_072	0.0058	65	30,788.0	213.4	983.0
60	D06250C05	NC	0.198	16_Mar_075	0.0045	90	27,395.0	243.8	1245.7
61	D060411	KY	0.194	29_Jan_029	0.0036	118	18,374.6	245.4	1431.4
62	D06166C02	IN	0.193	30_Jan_030	0.0075	49	51,708.4	304.8	1715.4
63	D024032	NJ	0.189	28_Jul_209	0.0088	34	18,785.1	152.1	621.5
64	D03407C15	TN	0.186	16_Mar_075	0.0032	128	37,307.5	152.4	1660.7
65	D028327	OH	0.179	30_Jan_030	0.0077	47	46,991.1	243.8	1482.6
66	D037976	VA	0.178	13_Mar_072	0.0080	44	40,569.8	127.7	1086.1
67	D015731	MD	0.177	13_Mar_072	0.0078	46	36,822.7	213.4	983.0
68	D03954CS0	WV	0.174	21_Nov_325	0.0036	116	20,129.5	225.9	1073.0
69	D007034LR	GA	0.172	29_Jan_029	0.0036	117	41,010.3	304.8	1818.3
70	D02864C01	OH	0.172	18_Jan_018	0.0077	48	35,193.0	259.1	1141.5
71	D007033LR	GA	0.170	29_Jan_029	0.0034	126	43,067.2	304.8	1818.3
72	D007032LR	GA	0.166	29_Jan_029	0.0029	140	37,288.5	304.8	1818.3
73	D01572C23	MD	0.163	16_Mar_075	0.0058	64	32,187.7	121.9	950.3
74	D028725	OH	0.160	29_Jan_029	0.0059	61	30,079.1	252.1	1223.4
75	D062641	WV	0.160	16_Mar_075	0.0067	53	42,757.1	335.3	1276.9
76	D013783	KY	0.157	06_Jan_006	0.0043	95	46,701.2	243.8	1749.4
77	D031782	PA	0.156	28_Jan_028	0.0059	63	16,483.5	307.2	988.9
78	D015074	ME	0.154	14_Aug_226	0.0030	136	1,170.0	128.3	166.6
79	D007031LR	GA	0.152	29_Jan_029	0.0030	137	38,520.3	304.8	1818.3
80	D00026CAN	AL	0.152	29_Jan_029	0.0012	287	33,723.4	150.0	1988.6
81	D00026CBN	AL	0.150	29_Jan_029	0.0012	300	35,099.1	121.9	1988.6
82	D027122	NC	0.147	16_Feb_047	0.0041	103	29,336.5	121.9	1260.3
83	D060182	KY	0.143	30_Jan_030	0.0025	160	12,083.1	198.1	1497.4
84	D02840C02	OH	0.143	18_Jan_018	0.0062	58	22,790.7	172.2	1207.3
85	D016261	MA	0.142	18_Jun_169	0.0067	52	3,430.0	132.6	294.2

Acadia National Park

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
86	D03947C03	WV	0.141	07_Mar_066	0.0087	35	38,575.0	150.0	1145.8
87	D06170CS1	WI	0.141	29_Dec_363	0.0046	88	32,766.4	182.9	1591.1
88	D02712C04	NC	0.139	16_Mar_075	0.0035	123	22,961.7	150.0	1260.3
89	D027274	NC	0.137	16_Mar_075	0.0030	138	27,308.3	85.3	1448.0
90	D006021	MD	0.137	16_Mar_075	0.0046	87	20,013.7	211.8	892.8
91	D016263	MA	0.137	21_Jun_172	0.0085	38	4,970.6	132.6	294.2
92	D06705C02	IN	0.137	30_Jan_030	0.0033	127	27,895.4	121.9	1738.6
93	D01356C02	KY	0.137	30_Jan_030	0.0044	93	25,645.7	225.9	1519.5
94	D016138	MA	0.134	18_Jun_169	0.0065	55	4,376.3	73.8	374.2
95	D010012	IN	0.133	29_Dec_363	0.0041	102	26,015.5	152.4	1645.3
96	D03809CS0	VA	0.133	15_Sep_258	0.0041	101	21,219.4	98.8	1048.1
97	D02866C01	OH	0.132	29_Jan_029	0.0062	59	24,649.0	153.6	1096.0
98	D027215	NC	0.132	10_Nov_314	0.0021	196	19,145.2	152.4	1527.9
99	D006022	MD	0.132	13_Mar_072	0.0045	89	19,280.3	211.8	892.8
100	D027273	NC	0.131	16_Mar_075	0.0025	161	26,328.9	85.3	1448.0

Note: Top 100 Based on ranking of maximum 24-hr Sulfate Ion Impact

Table D-20b. Individual Unit Sulfate Ion Impact Summary: MM5 Meteorology

Brigantine National Wildlife Refuge

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
1	D01571CE2	MD	0.920	23_Jun_174	0.0386	3	48,565.5	335.3	217.5
2	D023781	NJ	0.687	26_Aug_238	0.0219	22	9,746.6	144.8	25.1
3	D02876C01	OH	0.685	12_Aug_224	0.0348	5	72,592.9	243.8	660.7
4	D031361	PA	0.567	18_Jul_199	0.0451	1	87,434.3	243.8	435.2
5	D03179C01	PA	0.566	24_Jun_175	0.0429	2	79,635.0	150.0	468.3
6	D028404	OH	0.546	18_Jul_199	0.0383	4	87,801.2	245.4	636.0
7	D037976	VA	0.531	25_Nov_329	0.0320	8	40,569.8	127.7	343.0
8	D031362	PA	0.526	18_Jul_199	0.0339	7	62,846.8	243.8	435.2
9	D031403	PA	0.481	15_Jul_196	0.0256	15	38,800.9	269.1	203.1
10	D015732	MD	0.476	12_Aug_224	0.0267	12	30,788.0	213.4	249.5
11	D013783	KY	0.447	25_Mar_084	0.0110	61	46,701.2	243.8	1112.4
12	D01010C05	IN	0.445	19_Jul_200	0.0124	56	60,746.6	122.8	1106.0
13	D02872C04	OH	0.431	14_Mar_073	0.0340	6	83,133.5	150.0	616.7
14	D06113C03	IN	0.423	04_Feb_035	0.0128	47	71,181.7	150.0	1152.3
15	D01353C02	KY	0.408	12_Aug_224	0.0167	35	41,544.5	243.8	718.2
16	D015731	MD	0.406	12_Aug_224	0.0309	9	36,822.7	213.4	249.5
17	D03948C02	WV	0.402	13_Aug_225	0.0264	14	55,404.9	167.6	543.4
18	D080421	NC	0.400	02_Oct_275	0.0243	18	57,819.7	182.9	603.2
19	D03809CS0	VA	0.388	25_Nov_329	0.0199	25	21,219.4	98.8	304.0
20	D039431	WV	0.380	13_Aug_225	0.0234	19	42,385.1	167.6	466.6

Brigantine National Wildlife Refuge

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
21	D031492	PA	0.376	06_Dec_340	0.0255	16	50,276.3	347.2	258.5
22	D039432	WV	0.369	13_Aug_225	0.0253	17	45,849.5	167.6	466.6
23	D081021	OH	0.368	01_Mar_060	0.0097	75	18,207.0	253.0	659.4
24	D03954CS0	WV	0.366	21_Jan_021	0.0093	76	20,129.5	225.9	413.0
25	D024032	NJ	0.358	30_Aug_242	0.0126	51	18,785.1	152.1	145.4
26	D031221	PA	0.357	15_Jul_196	0.0221	21	45,754.3	243.8	420.4
27	D03406C10	TN	0.351	25_Nov_329	0.0169	34	104,522.6	150.0	1214.5
28	D039353	WV	0.351	09_Jul_190	0.0199	26	42,211.5	274.9	643.2
29	D006022	MD	0.347	28_Jul_209	0.0164	37	19,280.3	211.8	181.5
30	D06166C02	IN	0.347	29_Dec_363	0.0126	52	51,708.4	304.8	1098.7
31	D028281	OH	0.343	24_Jun_175	0.0186	29	37,307.2	251.5	533.3
32	D080422	NC	0.338	02_Oct_275	0.0196	27	45,295.8	182.9	603.2
33	D082261	PA	0.338	18_Jul_199	0.0188	28	40,267.5	228.6	468.0
34	D067054	IN	0.332	29_Dec_363	0.0078	91	40,117.7	152.4	1124.2
35	D031491	PA	0.332	06_Dec_340	0.0298	10	60,241.6	347.2	258.5
36	D031132	PA	0.330	26_Aug_238	0.0125	53	14,293.8	121.9	168.4
37	D031222	PA	0.326	19_Mar_078	0.0280	11	55,216.4	243.8	420.4
38	D006021	MD	0.326	28_Jul_209	0.0170	33	20,013.7	211.8	181.5
39	D028501	OH	0.318	13_Aug_225	0.0116	59	30,798.1	213.4	798.8
40	D028502	OH	0.309	13_Aug_225	0.0106	67	28,698.3	213.4	798.8
41	D02549C01	NY	0.305	26_Nov_330	0.0092	78	25,342.5	150.0	538.0
42	D028667	OH	0.304	18_Jul_199	0.0163	38	33,601.3	259.1	536.7
43	D03935C02	WV	0.296	12_Aug_224	0.0265	13	63,065.5	274.3	643.2
44	D037975	VA	0.282	25_Nov_329	0.0165	36	19,619.6	61.0	343.0
45	D028504	OH	0.282	13_Aug_225	0.0103	69	27,343.1	213.4	798.8
46	D010012	IN	0.281	19_Jul_200	0.0067	110	26,015.5	152.4	1103.4
47	D01572C23	MD	0.275	24_Jun_175	0.0223	20	32,187.7	121.9	259.4
48	D0283612	OH	0.270	18_Jul_199	0.0130	46	41,431.8	182.9	677.8
49	D03140C12	PA	0.270	18_Aug_230	0.0205	23	29,735.6	259.1	203.1
50	D062641	WV	0.263	12_Aug_224	0.0203	24	42,757.1	335.3	643.3
51	D01355C03	KY	0.247	11_Jun_162	0.0123	57	38,103.8	150.0	905.4
52	D00988U4	IN	0.242	31_Jan_031	0.0132	45	45,062.0	122.8	891.5
53	D010011	IN	0.241	19_Jul_200	0.0064	117	28,876.3	152.4	1103.4
54	D027122	NC	0.241	31_Dec_365	0.0134	44	29,336.5	121.9	520.7
55	D03947C03	WV	0.233	13_Aug_225	0.0181	31	38,575.0	150.0	543.8
56	D028375	OH	0.231	19_Mar_078	0.0114	60	35,969.5	182.9	638.9
57	D02712C03	NC	0.230	31_Dec_365	0.0148	40	30,776.4	150.0	520.7
58	D07253C01	OH	0.228	13_Aug_225	0.0136	42	30,976.8	213.4	604.1
59	D028327	OH	0.221	28_Dec_362	0.0145	41	46,991.1	243.8	886.5
60	D024082	NJ	0.220	27_Aug_239	0.0087	84	5,674.9	99.1	82.6
61	D02864C01	OH	0.220	13_Aug_225	0.0173	32	35,193.0	259.1	542.5
62	D02554C03	NY	0.218	04_Jul_185	0.0124	54	30,151.1	150.0	528.6
63	D015521	MD	0.215	03_Sep_246	0.0185	30	17,782.4	107.6	164.4
64	D038093	VA	0.213	07_Feb_038	0.0090	81	10,476.9	149.1	304.0

Brigantine National Wildlife Refuge

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
65	D016193	MA	0.213	21_Jul_202	0.0070	107	19,324.8	107.3	369.6
66	D060041	WV	0.211	13_Aug_225	0.0109	64	21,581.2	304.8	570.6
67	D060312	OH	0.211	13_Aug_225	0.0078	92	19,517.4	274.3	779.6
68	D015522	MD	0.209	03_Sep_246	0.0158	39	14,274.4	107.6	164.4
69	D005944	DE	0.208	23_Jun_174	0.0124	55	7,390.4	121.9	118.5
70	D028306	OH	0.207	31_Jan_031	0.0091	79	30,465.5	137.2	844.8
71	D03148C12	PA	0.203	26_Aug_238	0.0127	48	17,214.2	228.6	157.0
72	D028503	OH	0.201	29_Dec_363	0.0101	71	27,968.3	213.4	798.8
73	D01008C01	IN	0.198	29_Dec_363	0.0067	109	24,108.5	228.6	988.8
74	D007033LR	GA	0.195	26_May_146	0.0076	98	43,067.2	304.8	1099.1
75	D06705C02	IN	0.195	29_Dec_363	0.0051	135	27,895.4	121.9	1124.2
76	D000265	AL	0.195	02_Oct_275	0.0046	151	53,062.0	228.6	1271.8
77	D015543	MD	0.195	28_Jul_209	0.0099	72	10,084.1	109.7	181.6
78	D028725	OH	0.194	13_Aug_225	0.0134	43	30,079.1	252.1	616.7
79	D03131CS1	PA	0.194	06_Dec_340	0.0126	50	22,343.5	150.0	376.3
80	D01733C12	MI	0.191	28_Oct_301	0.0126	49	46,080.6	137.2	792.8
81	D013644	KY	0.191	29_Dec_363	0.0024	255	7,184.7	182.9	999.8
82	D031131	PA	0.190	26_Aug_238	0.0076	96	9,674.3	121.9	168.4
83	D027274	NC	0.189	28_Jan_028	0.0083	87	27,308.3	85.3	713.8
84	D005943	DE	0.188	23_Jun_174	0.0091	80	4,685.7	117.4	118.5
85	D03403C34	TN	0.186	29_Dec_363	0.0056	130	20,314.4	183.8	1035.6
86	D007034LR	GA	0.186	14_Mar_073	0.0075	99	41,010.3	304.8	1099.1
87	D027215	NC	0.184	14_Aug_226	0.0057	127	19,145.2	152.4	795.9
88	D060042	WV	0.184	13_Aug_225	0.0103	68	20,549.8	304.8	570.6
89	D007032LR	GA	0.184	29_Jan_029	0.0065	113	37,288.5	304.8	1099.1
90	D005935	DE	0.184	04_Aug_216	0.0045	157	2,137.6	83.8	121.2
91	D060412	KY	0.182	13_Aug_225	0.0077	94	20,491.0	245.7	808.2
92	D02866C02	OH	0.182	23_Oct_296	0.0109	65	26,022.4	153.6	536.7
93	D02866C01	OH	0.182	18_Jul_199	0.0109	63	24,649.0	153.6	536.7
94	D03298WL1	SC	0.174	27_May_147	0.0040	172	25,170.1	121.9	870.9
95	D024081	NJ	0.173	30_Aug_242	0.0093	77	8,075.5	99.1	82.6
96	D025163	NY	0.172	27_Aug_239	0.0042	166	7,359.0	182.9	186.4
97	D06113C04	IN	0.171	29_Dec_363	0.0050	139	27,847.9	213.4	1152.3
98	D01008C02	IN	0.170	29_Dec_363	0.0067	111	23,849.1	307.2	988.8
99	D023642	NH	0.168	31_Jan_031	0.0050	140	19,452.6	159.7	476.3
100	D0099070	IN	0.167	28_Dec_362	0.0071	106	29,800.8	172.2	1000.8

Note: Top 100 Based on ranking of maximum 24-hr Sulfate Ion Impact

Table D-20c. Individual Unit Sulfate Ion Impact Summary: MM5 Meteorology

Lye Brook Wilderness Area

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
1	D031491	PA	0.744	14_Jul_195	0.0254	3	60,241.6	347.2	371.2
2	D028404	OH	0.719	12_Aug_224	0.0268	2	87,801.2	245.4	794.3
3	D031492	PA	0.708	14_Jul_195	0.0222	8	50,276.3	347.2	371.2
4	D03406C10	TN	0.663	30_Jan_030	0.0137	17	104,522.6	150.0	1464.9
5	D03179C01	PA	0.584	01_Oct_274	0.0253	4	79,635.0	150.0	671.2
6	D031361	PA	0.519	22_Jun_173	0.0363	1	87,434.3	243.8	580.4
7	D00988U4	IN	0.495	30_Jan_030	0.0100	36	45,062.0	122.8	1075.4
8	D031362	PA	0.441	22_Jun_173	0.0237	5	62,846.8	243.8	580.4
9	D03948C02	WV	0.419	12_Aug_224	0.0168	10	55,404.9	167.6	735.3
10	D080421	NC	0.398	15_Mar_074	0.0107	30	57,819.7	182.9	961.3
11	D03935C02	WV	0.391	01_Oct_274	0.0123	21	63,065.5	274.3	892.6
12	D028306	OH	0.377	29_Jan_029	0.0085	42	30,465.5	137.2	1038.2
13	D031222	PA	0.365	11_Aug_223	0.0229	7	55,216.4	243.8	579.5
14	D039432	WV	0.349	01_Oct_274	0.0139	15	45,849.5	167.6	680.3
15	D080422	NC	0.341	15_Mar_074	0.0086	41	45,295.8	182.9	961.3
16	D039431	WV	0.341	01_Oct_274	0.0128	19	42,385.1	167.6	680.3
17	D031221	PA	0.340	11_Aug_223	0.0192	9	45,754.3	243.8	579.5
18	D031403	PA	0.323	14_Jul_195	0.0124	20	38,800.9	269.1	448.1
19	D02872C04	OH	0.320	06_Jan_006	0.0236	6	83,133.5	150.0	811.7
20	D01571CE2	MD	0.309	26_Feb_057	0.0134	18	48,565.5	335.3	590.0
21	D02712C03	NC	0.304	15_Mar_074	0.0063	68	30,776.4	150.0	893.4
22	D06113C03	IN	0.301	29_Dec_363	0.0115	24	71,181.7	150.0	1335.3
23	D03954CS0	WV	0.289	01_Oct_274	0.0056	77	20,129.5	225.9	672.3
24	D028281	OH	0.288	12_Aug_224	0.0142	13	37,307.2	251.5	699.2
25	D03140C12	PA	0.280	14_Jul_195	0.0103	33	29,735.6	259.1	448.1
26	D01733C34	MI	0.278	30_Jan_030	0.0101	35	39,361.7	152.4	845.4
27	D02554C03	NY	0.270	09_Sep_252	0.0140	14	30,151.1	150.0	511.0
28	D023642	NH	0.269	22_Nov_326	0.0074	53	19,452.6	159.7	134.0
29	D0283612	OH	0.258	30_Jan_030	0.0145	12	41,431.8	182.9	752.7
30	D02876C01	OH	0.251	28_Jan_028	0.0138	16	72,592.9	243.8	884.7
31	D01010C05	IN	0.237	22_Jan_022	0.0108	29	60,746.6	122.8	1251.9
32	D03131CS1	PA	0.237	11_Aug_223	0.0107	31	22,343.5	150.0	489.3
33	D06166C02	IN	0.234	22_Jan_022	0.0093	38	51,708.4	304.8	1302.5
34	D037976	VA	0.233	19_Dec_353	0.0091	39	40,569.8	127.7	732.0
35	D028375	OH	0.230	28_Dec_362	0.0121	23	35,969.5	182.9	702.1
36	D082261	PA	0.230	24_Jan_024	0.0149	11	40,267.5	228.6	621.1
37	D06250C05	NC	0.230	15_Mar_074	0.0054	81	27,395.0	243.8	880.6
38	D000265	AL	0.226	29_Jan_029	0.0032	139	53,062.0	228.6	1592.7
39	D060182	KY	0.221	29_Jan_029	0.0035	129	12,083.1	198.1	1084.4
40	D024032	NJ	0.220	19_Sep_262	0.0054	80	18,785.1	152.1	276.9
41	D028667	OH	0.212	12_Aug_224	0.0122	22	33,601.3	259.1	683.1
42	D02549C01	NY	0.210	05_Aug_217	0.0113	26	25,342.5	150.0	470.4
43	D02832C06	OH	0.207	30_Jan_030	0.0058	75	23,694.3	213.4	1069.6

Lye Brook Wilderness Area

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
44	D067054	IN	0.204	30_Jan_030	0.0061	70	40,117.7	152.4	1325.6
45	D01733C12	MI	0.196	22_Jul_203	0.0114	25	46,080.6	137.2	845.4
46	D00861C01	IL	0.194	07_Feb_038	0.0078	50	42,355.4	152.4	1428.1
47	D02712C04	NC	0.193	15_Mar_074	0.0044	103	22,961.7	150.0	893.4
48	D028327	OH	0.191	26_Jun_177	0.0101	34	46,991.1	243.8	1069.6
49	D02864C01	OH	0.189	12_Aug_224	0.0106	32	35,193.0	259.1	730.1
50	D01356C02	KY	0.185	29_Jan_029	0.0064	65	25,645.7	225.9	1106.6
51	D015732	MD	0.175	19_Dec_353	0.0073	54	30,788.0	213.4	620.3
52	D00983C01	IN	0.174	30_Jan_030	0.0047	90	19,922.4	150.0	1136.0
53	D00047C14	AL	0.171	29_Jan_029	0.0024	180	22,492.0	107.3	1568.0
54	D00983C02	IN	0.169	30_Jan_030	0.0046	96	18,130.8	153.6	1136.0
55	D013783	KY	0.168	06_Jan_006	0.0066	62	46,701.2	243.8	1337.1
56	D015731	MD	0.167	19_Dec_353	0.0098	37	36,822.7	213.4	620.3
57	D03947C03	WV	0.165	24_Jan_024	0.0113	27	38,575.0	150.0	734.6
58	D01384CS1	KY	0.165	28_Jan_028	0.0036	128	21,836.6	61.0	1183.6
59	D081021	OH	0.162	02_Mar_061	0.0040	113	18,207.0	253.0	882.6
60	D007034LR	GA	0.161	28_Jan_028	0.0041	110	41,010.3	304.8	1424.5
61	D007032LR	GA	0.159	28_Jan_028	0.0035	131	37,288.5	304.8	1424.5
62	D03809CS0	VA	0.158	15_Jan_015	0.0049	88	21,219.4	98.8	714.3
63	D007033LR	GA	0.156	28_Jan_028	0.0043	106	43,067.2	304.8	1424.5
64	D039353	WV	0.154	26_Jun_177	0.0077	51	42,211.5	274.9	892.6
65	D015991	MD	0.154	08_Mar_067	0.0029	151	13,014.0	151.8	262.7
66	D027274	NC	0.154	15_Mar_074	0.0040	115	27,308.3	85.3	1070.3
67	D03407C15	TN	0.153	09_Nov_313	0.0044	101	37,307.5	152.4	1258.5
68	D01355C03	KY	0.153	26_Jun_177	0.0072	55	38,103.8	150.0	1139.9
69	D01572C23	MD	0.152	15_Mar_074	0.0081	49	32,187.7	121.9	566.1
70	D02963C10	OK	0.150	29_Dec_363	0.0038	120	34,263.2	182.9	2050.3
71	D024804	NY	0.148	19_Sep_262	0.0045	97	7,719.9	72.5	187.7
72	D00008CAN	AL	0.148	29_Jan_029	0.0014	295	17,650.8	150.0	1673.7
73	D06113C04	IN	0.148	22_Jan_022	0.0047	91	27,847.9	213.4	1335.3
74	D015992	MD	0.147	08_Mar_067	0.0020	226	8,979.5	151.8	262.7
75	D027273	NC	0.147	15_Mar_074	0.0038	122	26,328.9	85.3	1070.3
76	D017459A	MI	0.145	09_Jul_190	0.0046	93	18,340.6	171.3	826.9
77	D062641	WV	0.144	01_Oct_274	0.0089	40	42,757.1	335.3	867.0
78	D02526C03	NY	0.144	20_Nov_324	0.0109	28	14,929.0	150.0	259.0
79	D016193	MA	0.144	18_Mar_077	0.0037	127	19,324.8	107.3	224.3
80	D025276	NY	0.142	13_Aug_225	0.0084	43	12,650.2	69.2	291.4
81	D02840C02	OH	0.142	12_Aug_224	0.0071	58	22,790.7	172.2	794.3
82	D03407C69	TN	0.141	09_Nov_313	0.0049	89	38,645.0	150.0	1258.5
83	D060041	WV	0.140	12_Aug_224	0.0072	56	21,581.2	304.8	785.8
84	D03148C12	PA	0.139	20_Sep_263	0.0068	59	17,214.2	228.6	307.7
85	D01353C02	KY	0.139	14_Aug_226	0.0074	52	41,544.5	243.8	967.9
86	D037975	VA	0.138	19_Dec_353	0.0046	94	19,619.6	61.0	732.0
87	D013782	KY	0.137	29_Jan_029	0.0035	130	20,244.8	182.9	1337.1

Lye Brook Wilderness Area

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
88	D028504	OH	0.136	29_Jan_029	0.0063	67	27,343.1	213.4	1014.1
89	D00709C02	GA	0.135	10_Nov_314	0.0025	177	47,590.6	121.9	1411.5
90	D028725	OH	0.134	13_Aug_225	0.0081	48	30,079.1	252.1	811.7
91	D02642CS2	NY	0.132	26_Nov_330	0.0081	47	14,086.2	150.0	364.1
92	D02866C01	OH	0.131	12_Aug_224	0.0082	46	24,649.0	153.6	683.1
93	D031132	PA	0.129	19_Dec_353	0.0063	66	14,293.8	121.9	295.3
94	D027122	NC	0.127	15_Aug_227	0.0053	84	29,336.5	121.9	893.4
95	D06170CS1	WI	0.126	18_Jul_199	0.0066	63	32,766.4	182.9	1201.2
96	D06705C02	IN	0.124	30_Jan_030	0.0040	112	27,895.4	121.9	1325.6
97	D027215	NC	0.124	15_Aug_227	0.0020	221	19,145.2	152.4	1146.7
98	D028502	OH	0.120	29_Jan_029	0.0055	79	28,698.3	213.4	1014.1
99	D02549C02	NY	0.120	06_Dec_340	0.0053	83	12,317.4	150.0	470.4
100	D01008C01	IN	0.119	26_Jun_177	0.0040	116	24,108.5	228.6	1193.7

Note: Top 100 Based on ranking of maximum 24-hr Sulfate Ion Impact

Table D-20d. Individual Unit Sulfate Ion Impact Summary: MM5 Meteorology

Shenandoah National Park

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
1	D039432	WV	1.505	02_Jan_002	0.0491	6	45,849.5	167.6	181.9
2	D02876C01	OH	1.100	12_Aug_224	0.0587	3	72,592.9	243.8	321.5
3	D080421	NC	1.077	21_Nov_325	0.0391	12	57,819.7	182.9	286.1
4	D080422	NC	1.020	21_Nov_325	0.0324	16	45,295.8	182.9	286.1
5	D03948C02	WV	0.896	25_Jun_176	0.0450	8	55,404.9	167.6	250.0
6	D03935C02	WV	0.785	14_Mar_073	0.0555	4	63,065.5	274.3	293.2
7	D028404	OH	0.764	19_Mar_078	0.0382	13	87,801.2	245.4	347.2
8	D02872C04	OH	0.738	23_Oct_296	0.0643	2	83,133.5	150.0	302.5
9	D062641	WV	0.734	27_Dec_361	0.0409	10	42,757.1	335.3	305.9
10	D03179C01	PA	0.688	31_Jan_031	0.0687	1	79,635.0	150.0	194.9
11	D028281	OH	0.685	17_Sep_260	0.0305	19	37,307.2	251.5	269.0
12	D03938C04	WV	0.681	14_Mar_073	0.0229	26	26,450.6	121.9	304.7
13	D031361	PA	0.671	03_Jan_003	0.0533	5	87,434.3	243.8	250.4
14	D031221	PA	0.640	04_Dec_338	0.0332	15	45,754.3	243.8	231.7
15	D031362	PA	0.635	03_Jan_003	0.0425	9	62,846.8	243.8	250.4
16	D015732	MD	0.630	24_Dec_358	0.0197	34	30,788.0	213.4	127.6
17	D015731	MD	0.623	24_Dec_358	0.0227	27	36,822.7	213.4	127.6
18	D02864C01	OH	0.623	25_Jun_176	0.0289	20	35,193.0	259.1	253.4
19	D031492	PA	0.590	02_Aug_214	0.0206	31	50,276.3	347.2	319.1
20	D039353	WV	0.580	14_Mar_073	0.0398	11	42,211.5	274.9	293.2
21	D031222	PA	0.579	04_Dec_338	0.0376	14	55,216.4	243.8	231.7

Shenandoah National Park

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m³	24Hr Date	Annual ~ µg/m³	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
22	D031491	PA	0.544	02_Aug_214	0.0224	29	60,241.6	347.2	319.1
23	D028667	OH	0.543	17_Sep_260	0.0220	30	33,601.3	259.1	290.5
24	D01572C23	MD	0.541	01_Sep_244	0.0254	24	32,187.7	121.9	112.9
25	D03406C10	TN	0.533	23_Aug_235	0.0257	23	104,522.6	150.0	856.7
26	D01353C02	KY	0.531	13_Aug_225	0.0272	21	41,544.5	243.8	365.0
27	D01571CE2	MD	0.508	05_Dec_339	0.0244	25	48,565.5	335.3	151.3
28	D039431	WV	0.507	25_Jun_176	0.0469	7	42,385.1	167.6	181.9
29	D03947C03	WV	0.505	25_Jun_176	0.0320	18	38,575.0	150.0	251.3
30	D007034LR	GA	0.479	25_Mar_084	0.0113	75	41,010.3	304.8	755.6
31	D082261	PA	0.474	12_Dec_346	0.0321	17	40,267.5	228.6	251.1
32	D03954CS0	WV	0.458	20_Jan_020	0.0192	36	20,129.5	225.9	103.7
33	D027122	NC	0.451	30_Dec_364	0.0176	39	29,336.5	121.9	232.4
34	D01355C03	KY	0.447	10_Jun_161	0.0175	41	38,103.8	150.0	551.8
35	D081021	OH	0.439	14_Mar_073	0.0170	45	18,207.0	253.0	320.7
36	D028327	OH	0.429	23_Oct_296	0.0195	35	46,991.1	243.8	552.3
37	D007033LR	GA	0.426	25_Mar_084	0.0107	77	43,067.2	304.8	755.6
38	D013783	KY	0.394	03_Sep_246	0.0130	65	46,701.2	243.8	758.2
39	D007032LR	GA	0.391	25_Mar_084	0.0101	82	37,288.5	304.8	755.6
40	D03407C15	TN	0.386	11_Aug_223	0.0125	68	37,307.5	152.4	609.4
41	D02712C03	NC	0.386	20_Sep_263	0.0187	38	30,776.4	150.0	232.4
42	D01733C12	MI	0.378	16_Jul_197	0.0152	55	46,080.6	137.2	557.4
43	D028501	OH	0.378	12_Aug_224	0.0170	44	30,798.1	213.4	454.6
44	D028502	OH	0.377	12_Aug_224	0.0166	47	28,698.3	213.4	454.6
45	D06166C02	IN	0.372	12_Aug_224	0.0159	52	51,708.4	304.8	749.9
46	D028282	OH	0.366	17_Sep_260	0.0166	48	20,598.2	251.5	269.0
47	D01733C34	MI	0.354	16_Jul_197	0.0123	70	39,361.7	152.4	557.4
48	D015521	MD	0.349	05_Dec_339	0.0068	111	17,782.4	107.6	199.1
49	D03407C69	TN	0.347	11_Aug_223	0.0127	66	38,645.0	150.0	609.4
50	D0283612	OH	0.347	16_Jul_197	0.0192	37	41,431.8	182.9	449.9
51	D031403	PA	0.343	31_Jan_031	0.0175	42	38,800.9	269.1	229.5
52	D01008C01	IN	0.343	12_Aug_224	0.0093	89	24,108.5	228.6	642.0
53	D038093	VA	0.342	26_Mar_085	0.0036	183	10,476.9	149.1	225.0
54	D00988U4	IN	0.340	18_Jul_199	0.0175	40	45,062.0	122.8	556.8
55	D07253C01	OH	0.335	23_Oct_296	0.0258	22	30,976.8	213.4	281.3
56	D03140C12	PA	0.335	31_Jan_031	0.0142	58	29,735.6	259.1	229.5
57	D006022	MD	0.335	27_Aug_239	0.0076	101	19,280.3	211.8	178.8
58	D028375	OH	0.330	26_Nov_330	0.0162	51	35,969.5	182.9	433.0
59	D028725	OH	0.328	23_Oct_296	0.0226	28	30,079.1	252.1	302.5
60	D006021	MD	0.323	27_Aug_239	0.0089	94	20,013.7	211.8	178.8
61	D028504	OH	0.319	12_Aug_224	0.0154	54	27,343.1	213.4	454.6
62	D02866C01	OH	0.305	26_Nov_330	0.0164	49	24,649.0	153.6	290.5
63	D01008C02	IN	0.305	12_Aug_224	0.0092	90	23,849.1	307.2	642.0

Shenandoah National Park

RANK	CEMS Unit	STATE	24-HR Max Impact ~ µg/m^3	24Hr Date	Annual ~ µg/m^3	Annual Rank	2002 SO_2 Tons	Modeled StkHt Meters	Distance Kms
64	D037976	VA	0.303	18_Sep_261	0.0167	46	40,569.8	127.7	156.0
65	D027274	NC	0.301	31_Dec_365	0.0142	59	27,308.3	85.3	393.2
66	D02866C02	OH	0.301	26_Nov_330	0.0174	43	26,022.4	153.6	290.5
67	D06250C05	NC	0.295	26_Mar_085	0.0146	56	27,395.0	243.8	224.3
68	D01010C05	IN	0.293	03_Nov_307	0.0131	64	60,746.6	122.8	779.6
69	D060041	WV	0.289	10_Jun_161	0.0205	33	21,581.2	304.8	249.8
70	D067054	IN	0.288	12_Aug_224	0.0085	97	40,117.7	152.4	775.6
71	D060312	OH	0.278	12_Aug_224	0.0122	71	19,517.4	274.3	436.2
72	D06113C03	IN	0.275	01_May_121	0.0132	63	71,181.7	150.0	809.0
73	D02712C04	NC	0.274	30_Dec_364	0.0138	61	22,961.7	150.0	232.4
74	D03396M1A	TN	0.268	11_Aug_223	0.0075	103	20,029.0	228.6	574.5
75	D060521	GA	0.268	25_Mar_084	0.0061	127	39,071.2	304.8	817.9
76	D060042	WV	0.267	10_Jun_161	0.0206	32	20,549.8	304.8	249.8
77	D027215	NC	0.256	26_May_146	0.0069	109	19,145.2	152.4	469.1
78	D027273	NC	0.254	31_Dec_365	0.0140	60	26,328.9	85.3	393.2
79	D02963C10	OK	0.254	29_Dec_363	0.0030	206	34,263.2	182.9	1530.7
80	D02866M6A	OH	0.248	17_Sep_260	0.0137	62	19,563.8	304.8	290.5
81	D015543	MD	0.247	05_Dec_339	0.0058	133	10,084.1	109.7	178.7
82	D000265	AL	0.245	02_Oct_275	0.0067	112	53,062.0	228.6	927.0
83	D037964	VA	0.245	30_Dec_364	0.0094	88	8,098.0	61.0	90.9
84	D03936C02	WV	0.243	13_Aug_225	0.0162	50	15,480.4	304.8	261.2
85	D01356C02	KY	0.243	09_Jul_190	0.0107	76	25,645.7	225.9	570.4
86	D037975	VA	0.243	10_Feb_041	0.0084	98	19,619.6	61.0	156.0
87	D060522	GA	0.238	25_Mar_084	0.0046	150	34,085.1	304.8	817.9
88	D00709C02	GA	0.236	25_Mar_084	0.0076	102	47,590.6	121.9	734.0
89	D038044	VA	0.231	21_Apr_111	0.0072	107	10,451.1	46.9	99.9
90	D00050C16	AL	0.230	11_Aug_223	0.0065	121	24,977.3	304.8	763.9
91	D02840C02	OH	0.225	19_Mar_078	0.0124	69	22,790.7	172.2	347.2
92	D02554C03	NY	0.225	07_Jan_007	0.0106	78	30,151.1	150.0	445.6
93	D03405C12	TN	0.221	28_Jan_028	0.0081	100	14,994.6	150.0	463.0
94	D028665	OH	0.219	17_Sep_260	0.0144	57	19,796.4	304.8	290.5
95	D027121	NC	0.216	30_Dec_364	0.0066	116	12,030.9	121.9	232.4
96	D081022	OH	0.213	14_Mar_073	0.0095	87	12,333.4	253.0	320.7
97	D0393851	WV	0.211	27_Dec_361	0.0104	80	12,947.7	183.8	304.7
98	D028503	OH	0.209	06_Feb_037	0.0159	53	27,968.3	213.4	454.6
99	D028306	OH	0.202	19_Mar_078	0.0126	67	30,465.5	137.2	508.1
100	D03775C02	VA	0.197	14_Mar_073	0.0115	74	16,673.8	307.2	373.2

Note: Top 100 Based on ranking of maximum 24-hr Sulfate Ion Impact

Table D-21a. State Total Annual Average Sulfate Ion Impact Summary: MM5 Meteorology, Acadia

STATE	SO_4 Ion Impact (Annual Average) CEM PT (2002)	Non-CEM PT (2002)	Area/ Mobile (2002)	TOTAL	Percent of Total Modeled CEM PT (2002)	Non-CEM PT (2002)	Area/ Mobile (2002)	TOTAL
MA	0.2248	0.0457	0.0055	0.2759	10.36%	2.10%	0.25%	12.71%
OH	0.0865	0.0086	0.0016	0.0966	3.98%	0.40%	0.07%	4.45%
PA	0.2354	0.0214	0.0156	0.2725	10.85%	0.99%	0.72%	12.55%
NY	0.0554	0.0057	0.0019	0.0630	2.55%	0.26%	0.09%	2.90%
IN	0.1089	0.0119	0.0099	0.1307	5.02%	0.55%	0.46%	6.02%
WV	0.0632	0.0038	0.0069	0.0740	2.91%	0.18%	0.32%	3.41%
MI	0.0389	0.0081	0.0029	0.0499	1.79%	0.37%	0.14%	2.30%
NH	0.0780	0.0062	0.0040	0.0882	3.59%	0.29%	0.18%	4.06%
KY	0.0286	0.0076	0.0031	0.0393	1.32%	0.35%	0.14%	1.81%
IL	0.0656	0.0095	0.0093	0.0844	3.02%	0.44%	0.43%	3.89%
NC	0.0259	0.0009	0.0019	0.0287	1.19%	0.04%	0.09%	1.32%
MD	0.0486	0.0172	0.0034	0.0693	2.24%	0.79%	0.16%	3.19%
ME	0.0736	0.0363	0.0578	0.1677	3.39%	1.67%	2.66%	7.73%
VA	0.0139	0.0009	0.0011	0.0159	0.64%	0.04%	0.05%	0.73%
TN	0.0254	0.0085	0.0019	0.0358	1.17%	0.39%	0.09%	1.65%
MO	0.0134	0.0036	0.0012	0.0182	0.62%	0.17%	0.05%	0.84%
WI	0.0215	0.0115	0.0041	0.0371	0.99%	0.53%	0.19%	1.71%
NJ	0.0149	0.0120	0.0030	0.0299	0.69%	0.55%	0.14%	1.38%
IA	0.0093	0.0109	0.0018	0.0219	0.43%	0.50%	0.08%	1.01%
GA*	0.0187	0.0033	0.0133	0.0354	0.86%	0.15%	0.61%	1.63%
DE	0.0107	0.0022	0.0023	0.0151	0.49%	0.10%	0.10%	0.70%
SC	0.0054	0.0020	0.0010	0.0083	0.25%	0.09%	0.05%	0.38%
KS*	0.0071	0.0015	0.0006	0.0092	0.33%	0.07%	0.03%	0.42%
AL*	0.0137	0.0012	0.0010	0.0159	0.63%	0.06%	0.05%	0.73%
CT	0.0860	0.1544	0.0773	0.3176	3.96%	7.11%	3.56%	14.64%
MN	0.0028	0	0.0009	0.0037	0.13%	0%	0.04%	0.17%
OK*	0	0.0009	0.0012	0.0021	0%	0.04%	0.06%	0.10%
AR*	0.0012	2.8E-05	0.0009	0.0022	0.06%	0.00%	0.04%	0.10%
RI	0	0.0002	0.0002	0.0004	0%	0.01%	0.01%	0.02%
NE*	0.0074	0.0011	0.0072	0.0156	0.34%	0.05%	0.33%	0.72%
VT	0.0666	0.0020	0.0065	0.0750	3.07%	0.09%	0.30%	3.46%
SD*	0.0001	0.0001	0.0003	0.0005	0.00%	0.01%	0.01%	0.02%
ND*	0.0030	0.0356	0.0236	0.0622	0.14%	1.64%	1.09%	2.87%
DC	5.9E-06	0.0007	0.0043	0.0050	0.00%	0.03%	0.20%	0.23%
MS*	4.0E-06	0.0004	0.0026	0.0030	0.00%	0.02%	0.12%	0.14%
TX*	1.1E-05	0	2.3E-05	3.5E-05	0.00%	0%	0.00%	0.00%
Total	**1.454**	**0.436**	**0.280**	**2.170**	**67.0%**	**20.1%**	**12.9%**	**100.0%**

Note: States sorted by annual average SO_4 Ion Impact (2002 CEMs)

* indicates a state that was only partially included in the domain

Table D-21b. State Total Annual Average Sulfate Ion Impact Summary: MM5 Meteorology, Brigantine

STATE	SO_4 Ion Impact (Annual Average)				Percent of Total Modeled			
	CEM PT (2002)	Non-CEM PT (2002)	Area/ Mobile (2002)	TOTAL	CEM PT (2002)	Non-CEM PT (2002)	Area/ Mobile (2002)	TOTAL
PA	0.4297	0.0836	0.0088	0.5221	12.31%	2.40%	0.25%	14.96%
OH	0.2340	0.0202	0.0046	0.2588	6.70%	0.58%	0.13%	7.42%
WV	0.4407	0.0553	0.0461	0.5421	12.63%	1.58%	1.32%	15.53%
MD	0.1609	0.0160	0.0054	0.1823	4.61%	0.46%	0.16%	5.22%
VA	0.1632	0.0162	0.0128	0.1921	4.67%	0.46%	0.37%	5.50%
IN	0.1285	0.0076	0.0135	0.1496	3.68%	0.22%	0.39%	4.29%
NY	0.1577	0.0331	0.0119	0.2027	4.52%	0.95%	0.34%	5.81%
NC	0.2191	0.0228	0.0210	0.2630	6.28%	0.65%	0.60%	7.54%
NJ	0.0630	0.0188	0.0061	0.0879	1.81%	0.54%	0.18%	2.52%
KY	0.0810	0.0110	0.0120	0.1040	2.32%	0.32%	0.34%	2.98%
DE	0.0672	0.0024	0.0057	0.0753	1.93%	0.07%	0.16%	2.16%
MI	0.0535	0.0190	0.0043	0.0768	1.53%	0.54%	0.12%	2.20%
TN	0.0810	0.0307	0.0779	0.1896	2.32%	0.88%	2.23%	5.43%
MA	0.0304	0.0017	0.0020	0.0341	0.87%	0.05%	0.06%	0.98%
IL	0.0315	0.0106	0.0026	0.0447	0.90%	0.30%	0.07%	1.28%
GA*	0.0341	0.0101	0.0032	0.0475	0.98%	0.29%	0.09%	1.36%
SC	0.0202	0.0108	0.0036	0.0346	0.58%	0.31%	0.10%	0.99%
WI	0.0152	0.0137	0.0032	0.0321	0.44%	0.39%	0.09%	0.92%
MO	0.0524	0.0549	0.0138	0.1211	1.50%	1.57%	0.39%	3.47%
AL*	0.0625	0.0124	0.0805	0.1553	1.79%	0.35%	2.31%	4.45%
IA	0.0114	0.0025	0.0027	0.0166	0.33%	0.07%	0.08%	0.48%
MN	0.0088	0.0032	0.0017	0.0137	0.25%	0.09%	0.05%	0.39%
AR*	0.0077	0.0014	0.0007	0.0098	0.22%	0.04%	0.02%	0.28%
KS*	0.0107	0.0009	0.0008	0.0124	0.31%	0.03%	0.02%	0.35%
CT	0.0234	0.0406	0.0168	0.0808	0.67%	1.16%	0.48%	2.31%
NH	0.0025	0	0.0009	0.0035	0.07%	0%	0.03%	0.10%
OK*	0	0.0011	0.0015	0.0026	0%	0.03%	0.04%	0.07%
NE*	0.0012	3.4E-05	0.0012	0.0024	0.03%	0.00%	0.03%	0.07%
DC	0	0.0006	0.0005	0.0012	0%	0.02%	0.01%	0.03%
ME	0.0044	0.0009	0.0063	0.0116	0.12%	0.03%	0.18%	0.33%
ND*	0.0100	0.0003	0.0010	0.0113	0.29%	0.01%	0.03%	0.32%
SD*	0.0012	0.0005	0.0013	0.0030	0.04%	0.01%	0.04%	0.09%
RI	0.0002	0.0017	0.0011	0.0030	0.01%	0.05%	0.03%	0.09%
MS*	2.1E-06	0.0003	0.0016	0.0019	0.00%	0.01%	0.05%	0.05%
VT	1.5E-06	0.0001	0.0006	0.0008	0.00%	0.00%	0.02%	0.02%
TX*	2.5E-07	0	2.9E-05	3.0E-05	0.00%	0%	0.00%	0.00%
Total	**2.607**	**0.505**	**0.378**	**3.490**	**74.7%**	**14.5%**	**10.8%**	**100.0%**

Note: States sorted by annual average SO_4 Ion Impact (2002 CEMs)
* indicates a state that was only partially included in the domain

Table D-21c. State Total Annual Average Sulfate Ion Impact Summary: MM5 Meteorology, Lye Brook

STATE	SO_4 Ion Impact (Annual Average)				Percent of Total Modeled			
	CEM PT (2002)	Non-CEM PT (2002)	Area/ Mobile (2002)	TOTAL	CEM PT (2002)	Non-CEM PT (2002)	Area/ Mobile (2002)	TOTAL
OH	0.2963	0.0649	0.0078	0.3690	13.05%	2.86%	0.34%	16.25%
PA	0.1232	0.0121	0.0023	0.1375	5.43%	0.53%	0.10%	6.06%
NY	0.3050	0.0288	0.0219	0.3558	13.43%	1.27%	0.96%	15.67%
IN	0.0680	0.0058	0.0022	0.0760	2.99%	0.26%	0.10%	3.35%
WV	0.1369	0.0148	0.0128	0.1645	6.03%	0.65%	0.56%	7.24%
MI	0.0820	0.0047	0.0099	0.0967	3.61%	0.21%	0.44%	4.26%
KY	0.0454	0.0104	0.0037	0.0596	2.00%	0.46%	0.16%	2.62%
IL	0.0686	0.0088	0.0052	0.0826	3.02%	0.39%	0.23%	3.64%
MD	0.0407	0.0098	0.0042	0.0546	1.79%	0.43%	0.19%	2.41%
NC	0.0798	0.0121	0.0120	0.1039	3.51%	0.53%	0.53%	4.58%
MA	0.0351	0.0012	0.0029	0.0392	1.55%	0.05%	0.13%	1.73%
VA	0.0550	0.0208	0.0047	0.0805	2.42%	0.92%	0.21%	3.54%
TN	0.0985	0.0613	0.0842	0.2440	4.34%	2.70%	3.71%	10.75%
WI	0.0209	0.0013	0.0015	0.0238	0.92%	0.06%	0.07%	1.05%
MO	0.0351	0.0116	0.0028	0.0495	1.54%	0.51%	0.13%	2.18%
GA*	0.0133	0.0040	0.0014	0.0187	0.59%	0.18%	0.06%	0.82%
IA	0.0253	0.0140	0.0052	0.0445	1.11%	0.62%	0.23%	1.96%
NJ	0.0184	0.0158	0.0041	0.0383	0.81%	0.69%	0.18%	1.69%
AL*	0.0076	0.0123	0.0020	0.0219	0.33%	0.54%	0.09%	0.97%
DE	0.0128	0.0029	0.0115	0.0272	0.57%	0.13%	0.51%	1.20%
MN	0.0147	0.0031	0.0035	0.0213	0.65%	0.14%	0.15%	0.94%
KS*	0.0072	0.0029	0.0015	0.0116	0.32%	0.13%	0.07%	0.51%
SC	0.0097	0.0020	0.0009	0.0127	0.43%	0.09%	0.04%	0.56%
NH	0.0167	0.0016	0.0013	0.0195	0.73%	0.07%	0.06%	0.86%
OK*	0.0161	0.0291	0.0203	0.0655	0.71%	1.28%	0.89%	2.88%
AR*	0.0032	0	0.0012	0.0044	0.14%	0%	0.05%	0.19%
VT	0	0.0014	0.0020	0.0035	0%	0.06%	0.09%	0.15%
CT	0.0017	4.3E-05	0.0014	0.0031	0.07%	0.00%	0.06%	0.14%
NE*	0	0.0006	0.0004	0.0011	0%	0.03%	0.02%	0.05%
ME	0.0024	0.0006	0.0045	0.0075	0.11%	0.03%	0.20%	0.33%
ND*	0.0137	0.0008	0.0023	0.0167	0.60%	0.04%	0.10%	0.74%
SD*	0.0001	0.0002	0.0004	0.0006	0.00%	0.01%	0.02%	0.03%
RI	0.0003	0.0024	0.0018	0.0044	0.01%	0.10%	0.08%	0.19%
MS*	1.4E-06	0.0002	0.0010	0.0012	0.00%	0.01%	0.04%	0.05%
DC	4.0E-06	0.0017	0.0083	0.0100	0.00%	0.07%	0.36%	0.44%
TX*	8.4E-06	0	3.2E-05	4.0E-05	0.00%	0%	0.00%	0.00%
Total	**1.654**	**0.364**	**0.253**	**2.271**	**72.8%**	**16.0%**	**11.1%**	**100.0%**

Note: States sorted by annual average SO_4 Ion Impact (2002 CEMs)
* indicates a state that was only partially included in the domain

Table D-21d. State Total Annual Average Sulfate Ion Impact Summary: MM5 Meteorology, Shenandoah National Park

STATE	SO_4 Ion Impact (Annual Average)				Percent of Total Modeled			
	CEM PT (2002)	Non-CEM PT (2002)	Area/ Mobile (2002)	TOTAL	CEM PT (2002)	Non-CEM PT (2002)	Area/ Mobile (2002)	TOTAL
OH	0.6483	0.1088	0.0114	0.7685	17.70%	2.97%	0.31%	20.99%
WV	0.4657	0.0402	0.0111	0.5170	12.72%	1.10%	0.30%	14.12%
PA	0.4517	0.0318	0.0247	0.5082	12.33%	0.87%	0.68%	13.88%
NC	0.2257	0.0148	0.0062	0.2467	6.16%	0.40%	0.17%	6.74%
IN	0.1907	0.0181	0.0155	0.2243	5.21%	0.49%	0.42%	6.13%
KY	0.1741	0.0106	0.0184	0.2031	4.75%	0.29%	0.50%	5.55%
VA	0.1124	0.0469	0.0263	0.1856	3.07%	1.28%	0.72%	5.07%
MD	0.1365	0.0373	0.0109	0.1847	3.73%	1.02%	0.30%	5.04%
TN	0.0929	0.0304	0.0086	0.1319	2.54%	0.83%	0.24%	3.60%
MI	0.0860	0.0100	0.0125	0.1085	2.35%	0.27%	0.34%	2.96%
GA*	0.0963	0.0032	0.0079	0.1073	2.63%	0.09%	0.21%	2.93%
IL	0.0561	0.0189	0.0045	0.0794	1.53%	0.52%	0.12%	2.17%
NY	0.0468	0.0141	0.0167	0.0776	1.28%	0.39%	0.46%	2.12%
AL*	0.0504	0.0029	0.0034	0.0567	1.38%	0.08%	0.09%	1.55%
WI	0.0289	0.0096	0.0026	0.0410	0.79%	0.26%	0.07%	1.12%
SC	0.0232	0.0093	0.0035	0.0359	0.63%	0.25%	0.09%	0.98%
MO	0.0180	0.0104	0.0034	0.0318	0.49%	0.28%	0.09%	0.87%
IA	0.0152	0.0130	0.0036	0.0318	0.42%	0.35%	0.10%	0.87%
DE	0.0086	0.0136	0.0021	0.0243	0.24%	0.37%	0.06%	0.66%
NJ	0.0119	0.0022	0.0071	0.0212	0.33%	0.06%	0.19%	0.58%
MN	0.0109	0.0023	0.0028	0.0160	0.30%	0.06%	0.08%	0.44%
AR*	0.0087	0.0035	0.0019	0.0141	0.24%	0.10%	0.05%	0.39%
OK*	0.0081	0.0016	0.0009	0.0105	0.22%	0.04%	0.02%	0.29%
KS*	0.0091	0.0007	0.0006	0.0104	0.25%	0.02%	0.02%	0.28%
MA	0.0029	0.0047	0.0023	0.0098	0.08%	0.13%	0.06%	0.27%
NE*	0.0023	0	0.0009	0.0032	0.06%	0%	0.02%	0.09%
ND*	0	0.0011	0.0016	0.0027	0%	0.03%	0.04%	0.07%
SD*	0.0011	4.0E-05	0.0014	0.0025	0.03%	0.00%	0.04%	0.07%
MS*	0	0.0010	0.0007	0.0017	0%	0.03%	0.02%	0.05%
CT	0.0007	0.0001	0.0009	0.0017	0.02%	0.00%	0.02%	0.05%
NH	0.0013	0.0001	0.0002	0.0016	0.04%	0.00%	0.00%	0.04%
DC	0.0001	0.0003	0.0009	0.0013	0.00%	0.01%	0.03%	0.04%
ME	2.8E-05	0.0003	0.0002	0.0006	0.00%	0.01%	0.01%	0.02%
RI	3.1E-07	2.9E-05	0.0002	0.0002	0.00%	0.00%	0.00%	0.01%
VT	3.6E-07	2.6E-05	0.0001	0.0002	0.00%	0.00%	0.00%	0.00%
TX*	1.7E-07	0	3.2E-05	3.2E-05	0.00%	0%	0.00%	0.00%
Total	**2.985**	**0.462**	**0.216**	**3.662**	**81.5%**	**12.6%**	**5.9%**	**100.0%**

Note: States sorted by annual average SO_4 Ion Impact (2002 CEMs)
* indicates a state that was only partially included in the domain

D.4. CALPUFF Phase I Modeling Results Overview

Previous sections have described in some detail the results of CALPUFF modeling of sulfate ion impacts at receptor locations, including IMPROVE and CASNET sites, in the northeast U.S. These results have been presented and discussed for two different modeling platforms, namely, the VTDEC/rawinsonde platform and the DNR-MDE/MM5 platform. A limited number of comparisons were provided comparing nitrate ion predictions to measurements at both IMPROVE and CASTNET sites.

Table D-22 and Table D-23 address the comparability between the results created by the two platforms. Table D-22 displays the rank of each state included in the modeling, based on annual averages, for the two platforms, and also shows the difference in the ranking. These differences show fairly close comparability between the two platforms, with only a small number of exceptions. Differences in ranking for the states with the highest total impacts are smaller than differences for states that have smaller total impacts.

Table D-23 shows how the two platforms compare on the basis of 24-hr maximum predicted sulfate ion concentrations. This table is divided into three parts, representing comparability of the top 10, top 50, and top 100 EGUs respectively. The average concentration at each Class I area for these three groups is displayed, along with the number of "common" units between the two platforms, i.e. the number of units within the group that is in that group for both platforms. For the top 10 units, a significant percentage (from 3 at Acadia to 7 at Lye Brook) are identified by both platforms. For the top 50 and 100 units, comparability is much better: 32 out of 50 at Lye Brook to 36 out of 50 at Brigantine, and 70 out of 100 at Brigantine to 85 out of 100 at Shenandoah. This comparability is an improvement over the same metrics presented in the Phase I report. Overall, reasonably good comparability has been demonstrated between the two platforms.

Several conclusions can be drawn from this Phase II CALPUFF modeling.

- The meteorological data for both platforms appears to be well-represented, based on comparisons that were made to profiler and other available data for comparison. Sensitivity tests conducted by VTDEC of selected choices aided in choosing the best options within CALMET.
- The results for both platforms showed an ability to predict the highest 24-hour sulfate ion concentrations reasonably well, although an examination of the top 24-hour rankings by VTDEC indicated that underprediction occurred for many days out of the year. Annual averages were underpredicted by both platforms. In contrast to the Phase I results, the DNR-MD/MM5 platform predicted generally higher sulfate concentrations than the VTDEC platform. The DNR-MDE/MM5 results showed a tendency to predict high sulfate concentrations in the wintertime, which is not consistent with observations.
- Sensitivity tests conducted by VTDEC suggested that the default chemistry transformation scheme in CALPUFF may not produce enough sulfate, and the lack of a complete aqueous phase transformation within the CALPUFF scheme may contribute to the underprediction.

- Particulate nitrate ion concentrations predicted by the DNR-MDE/MM5 platform overpredicted measured concentrations substantially. When total nitrate (particulate nitrate plus nitric acid) predicted concentrations are compared to measurements at CASTNET sites, some overprediction is still evident but to a much lesser degree than for particulate nitrate. This result indicates the importance of applying an ammonia-limiting technique, such as implemented in the POSTUTIL program, if particulate nitrate is an important factor in visibility impacts.
- The two model platforms show good comparability for sulfate ion predictions, which indicates a degree of robustness in CALPUFF's ability to simulate this important component of visibility impairment in the northeast U.S.
- Although some issues (sulfate transformation, wintertime sulfate, ammonia-limiting conditions) need to be investigated further, CALPUFF has shown a reasonably good capability to reproduce sulfate ion concentrations in the northeast U.S. This evaluation of the model using two different meteorological platforms and comparing predictions to observations should provide further support for its use in assessing visibility impacts in the MANE-VU region, particularly when used to complement the use of other modeling and analysis tools.

Table D-22. CALPUFF Overall Modeling Summary

State	Rawinsonde-Based Meteorology				MM5-Based Meteorology				Differences in Ranking			
	Shen	Brig	Acad	LyeB	Shen	Brig	Acad	LyeB	Shen	Brig	Acad	LyeB
OH	1	2	2	1	1	2	2	2	0	0	0	-1
WV	2	3	6	5	3	5	7	6	-1	-2	-1	-1
PA	3	1	3	2	2	1	1	1	1	0	2	1
NC	4	8	11	10	4	4	13	10	0	4	-2	0
IN	5	6	5	4	5	8	5	4	0	-2	0	0
KY	6	10	9	7	7	10	10	7	-1	0	-1	0
VA	7	5	14	12	6	3	14	13	1	2	0	-1
MD	8	4	12	9	8	6	12	11	0	-2	0	-2
TN	9	13	15	13	9	13	16	14	0	0	-1	-1
MI	10	12	7	6	11	12	6	5	-1	0	1	1
GA*	11	16	20	16	10	14	20	16	1	2	0	0
IL	12	15	10	8	12	11	9	8	0	4	1	0
NY	13	7	4	3	15	7	4	3	-2	0	0	0
AL*	14	20	24	19	13	19	26	20	1	1	-2	-1
WI	15	18	17	14	14	17	15	9	1	1	2	5
SC	16	17	22	23	16	16	24	22	0	1	-2	1
MO	17	19	16	15	18	22	21	19	-1	-3	-5	-4
IA	18	21	19	17	17	20	18	15	1	1	1	2
DE	19	11	21	20	21	15	25	26	-2	-4	-4	-6

State	Rawinsonde-Based Meteorology				MM5-Based Meteorology				Differences in Ranking			
	Shen	Brig	Acad	LyeB	Shen	Brig	Acad	LyeB	Shen	Brig	Acad	LyeB
NJ	20	9	18	18	20	9	17	21	0	0	1	-3
MN	21	22	26	21	19	21	23	18	2	1	3	3
AR*	22	23	28	26	24	27	30	28	-2	-4	-2	-2
OK*	23	27	27	25	23	26	29	25	0	1	-2	0
KS*	24	24	23	22	22	24	27	23	2	0	-4	-1
MA	25	14	1	11	25	18	3	17	0	-4	-2	-6
NE*	26	28	30	29	26	31	31	30	0	-3	-1	-1
SD*	27	31	32	31	31	33	32	31	-4	-2	0	0
MS*	28	33	34	33	29	34	34	33	-1	-1	0	0
CT	29	25	25	28	27	23	22	27	2	2	3	1
NH	30	26	8	24	30	25	11	24	0	1	-3	0
DC	31	29	33	34	28	32	33	34	3	-3	0	0
ME	32	30	13	30	32	29	8	29	0	1	5	1
RI	33	32	29	32	34	28	28	32	-1	4	1	0
VT	34	34	31	27	33	30	19	12	1	4	12	15
TX*	35	35	35	35	35	35	35	35	0	0	0	0

Note: State Ranking: Annual Average SO_4 Ion Concentration

Table D-23. CALPUFF Overall Modeling Summary

Top 10

	NWS	MM5	Number in Common
Shenandoah	0.778	0.931	6
Brigantine	0.471	0.598	5
Acadia	0.414	0.540	3
Lye Brook	0.588	0.569	7

Top 50

	NWS	MM5	Number in Common
Shenandoah	0.483	0.578	35
Brigantine	0.318	0.397	36
Acadia	0.245	0.350	32
Lye Brook	0.310	0.324	32

Top 100

	NWS	MM5	Number in Common
Shenandoah	0.361	0.424	85
Brigantine	0.242	0.299	70
Acadia	0.185	0.257	78
Lye Brook	0.218	0.235	76

Note: Averages of EGU 2002 CEMS (24-hr SO_4 Ion Concentrations)

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