Appendix H.6

BART VOC, NH3, and Primary PM Sensitivity Modeling

DRAFT

BART in the VISTAS Region: Sensitivity to VOC, NH_3 and Primary PM Emissions

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Preface

This report summarizes the results of efforts by several organizations and individuals.

The VOC and NH_3 sensitivity simulations with the CMAQ regional chemical transport model were carried out by the Georgia Institute of Technology. Calculations of the resulting impacts on regional haze (i.e., Δdv, delta-deciviews) were performed by Dr. James Boylan of the State of Georgia Department of Natural Resources.

The PM sensitivity simulations with the CMAQ regional chemical transport model were carried out by Alpine Geophysics. Calculations of the resulting impacts on regional haze were performed at ENVIRON Corporation.

Dr. Ivar Tombach, VISTAS' Technical Advisor, prepared this report from information provided by the above organizations and individuals.

1. Introduction

The U.S. Environmental Protection Agency (US EPA) has established a program for reducing atmospheric haze in mandatory Class I Federal Areas through the application of best available retrofit technology (BART) emission controls to certain large sources.[1] States are to ascertain the appropriate form of BART, if any, for each of these sources.

The BART program addresses emissions of SO_2, NO_x, primary particulate matter (PM), and, at the option of the State, emissions of volatile organic compounds (VOCs) and ammonia (NH_3). PM is inert, while SO_2, NO_x, NH_3 and VOCs are precursors to secondary particulate matter in the forms of ammoniated sulfate ("sulfates"), ammonium nitrate ("nitrates"), and particulate organic matter (POM). The POM consists of organic carbon (OC) and of other species (such as hydrogen, oxygen, and halocarbons) attached to the OC. Sulfates, nitrates, POM, and PM in the atmosphere, as well as NO_2 gas, all contribute to visibility impairment and haze.[2]

The US EPA has established that the controls on the emissions of SO_2 and NO_x that will be implemented under the Clear Air Interstate Rule (CAIR) will constitute BART for major electric generating units (EGUs),[3] so that the State programs need only consider emissions of PM, ammonia, and VOCs from EGU sources. Furthermore, the US EPA guidance for implementing the BART program provides that States have the discretion of deciding whether or not ammonia and VOC emissions are to be considered in their BART programs, based on their evaluations of the contributions of the emissions of these species to haze at Class I areas in their areas of influence.[4] The guidance also provides that one approach a State can use to ascertain whether applying BART will be needed is to evaluate the cumulative haze impacts of current emissions from all BART-eligible sources in the State. If their cumulative impact is less than the "contribution" threshold established by the State (0.5 deciviews for VISTAS states), then source-by-source analysis for BART will not be needed.[5]

In light of these drivers, VISTAS has undertaken sensitivity analyses with the CMAQ regional chemical transport model to ascertain the aggregate contributions of all VISTAS-region BART sources of VOCs, ammonia, and PM to haze in Class I areas. In this analysis, CMAQ simulations of the VISTAS region and surrounding states were carried out with all point sources included and then with selected emissions turned off. Comparisons of the haze impacts under the various emission scenarios indicated the contributions of the specific species emissions.

[1] Federal Register, Vol. 70, No. 128, pp 39104-39172. 6 July 2005.
[2] Although sulfates, nitrates, and POM are in the form of secondary particulate matter, in this report we will use PM to denote only primary particulate matter.
[3] 70FR39138
[4] 40CFR51, Appendix Y, Section II.A, Step 3 (or 70FR39160)
[5] 40CFR51, Appendix Y, Section III.A.3, Option 3 (or 70FR39163)

The following emissions reduction scenarios were modeled with CMAQ and analyzed:

- VOCs
  - 100% reduction in VOC emissions from *all* point sources (not just BART-eligible sources) in the VISTAS States
- NH_3
  - 100 % reduction in ammonia emissions from all BART-eligible point sources in the VISTAS States
- PM
  - 100% reduction in primary PM emissions from *all* EGU point sources in the VISTAS States
  - 100% reduction in primary PM emissions from *all* non-EGU point sources in the VISTAS States.

In all cases, the CMAQ model, including secondary organic aerosol (SOA) chemistry modifications developed for VISTAS,[6] was applied to the VISTAS 12-km grid CMAQ modeling domain, which is shown in Figure 1-1. Note that the domain extends at least one state outside the VISTAS region, in order to include the effects of VISTAS emissions on Class I areas in other RPO regions.

In order to keep the computational requirements manageable, simulations were not done for a full year. Rather, two periods were analyzed – a winter period and a summer period. The exact dates of these periods differed for the three analyses.

Details of the analyses and their results appear in the following chapters, with VOCs addressed in Chapter 2, ammonia in Chapter 3, and PM in Chapter 4. The conclusions derived from this work are summarized in Chapter 5.

[6] The SOA chemistry modifications are described in "Model sensitivity evaluation for organic carbon using two multi-pollutant air quality models that simulate regional haze in the southeastern United States" by Ralph E Morris, Bonyoung Koo, Alex Guenther, Greg Yarwood, Dennis McNally, T.W. Tesche, Gail Tonnesen, James Boylan, and Patricia Brewer. *Atmospheric Environment*, Volume 40, August 2006, pages 4960-4972.

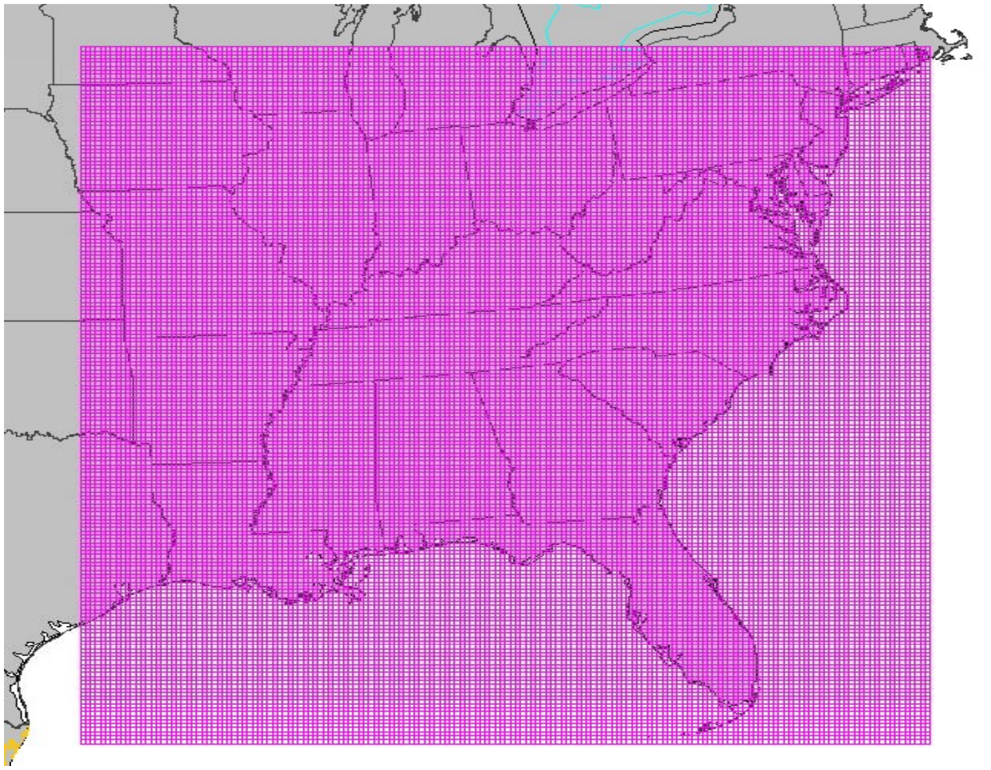

Figure 1-1. The VISTAS 12-km CMAQ modeling domain (gridded area).

2. VOC Analyses

The VOC sensitivity simulations were carried out using version 4.4 of the CMAQ model, including the VISTAS secondary organic aerosol (SOA) chemistry modifications. Two periods were modeled – a "summer" period of 1 June to 10 July 2002 and a "winter" period of 19 November to 19 December 2002.

The emissions starting point for the simulations was the VISTAS 2009 OTW BaseD emissions inventory.[7] The contribution of point source VOC emissions at each Class I area in the VISTAS region and in adjacent States was then ascertained by turning off *all* point source VOC emissions in the VISTAS states and comparing the CMAQ-modeled result with the initial simulation with all emissions.

The results of this sensitivity analysis are shown in Figure 2-1, which displays the largest haze impact in deciviews, Δdv, found over the two simulation periods at each Class I area. The Δdv changes shown represent the contributions of all VOC emissions relative to assumed natural haze levels based on EPA-default annual average natural concentrations for the East and monthly-varying "climatologically representative" relative humidity at each Class I area. All of the impacts are below the BART contribution threshold of 0.5 dv, although the contribution of all VOC point sources to Swanquarter (SWAN) haze is nearly 0.5 dv.

Figure 2-1 overstates the impacts of VOC emissions from BART-eligible sources alone, however. Because BART-eligible sources typically account for only a small fraction of the total point source VOC emissions in each State, as shown in Table 2-1, the impacts of BART-eligible sources alone will be less that those shown in Figure 2-1. For example, averaged over the entire VISTAS region, only 9% of the point source VOC emissions are from BART-eligible sources. Consequently, to estimate the contributions to haze from BART eligible sources alone, the impacts on light extinction (b_{ext}) due to all VOC point sources in each VISTAS State were scaled by the factors listed in Table 2-1 and the results were again expressed as Δdv.

[7] OTW = On the way, i.e., including controls on the books in 2002, plus CAIR. (CAIR is now also on the books.)

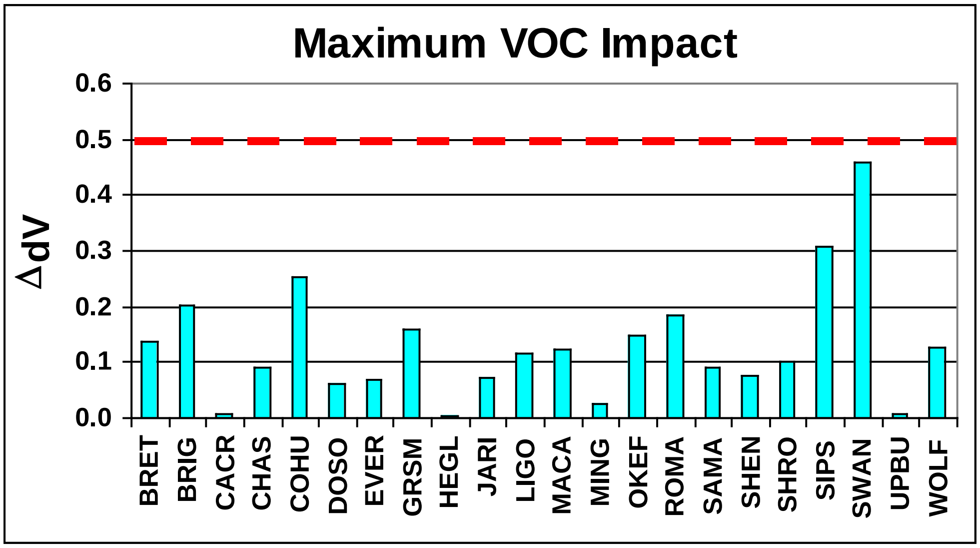

Figure 2-1. Maximum contributions of all VISTAS-region VOC point sources to haze in Class I areas during the CMAQ-modeled periods.

Table 2-1. Fractions of point-source VOC emissions in VISTAS States that are due to BART-eligible sources.

State	**Fraction of point-source VOC emissions due to BART-eligible sources**
AL	0.13
FL	0.11
GA	0.14
KY	0.08
MS	0.14
NC	0. 06
SC	0.09
TN	0.05
VA	0.05
WV	0.23
VISTAS (total)	**0.09**

Two approaches, which bracket the range of possible conditions, were used for this scaling. In the first approach, the assumption was made that most of the POM at any Class I area originates from VOC emissions within the State within which the Class I area is located. In that case, the modeled impact on light extinction at that Class I area was multiplied by the factor in Table 2-1 for that State, and the result was converted to deciviews to produce an estimate of the impact of BART-eligible VOC point sources to haze in that Class I area.

The result of such calculations is shown in Figure 2-2 (which has the same scale as Figure 2-1). The figure shows that none of the Class I areas is impacted by more than 0.05 dv because of VOCs from BART-eligible sources, so all impacts are less than a tenth of US EPA's recommended BART contribution threshold of 0.5 dv.

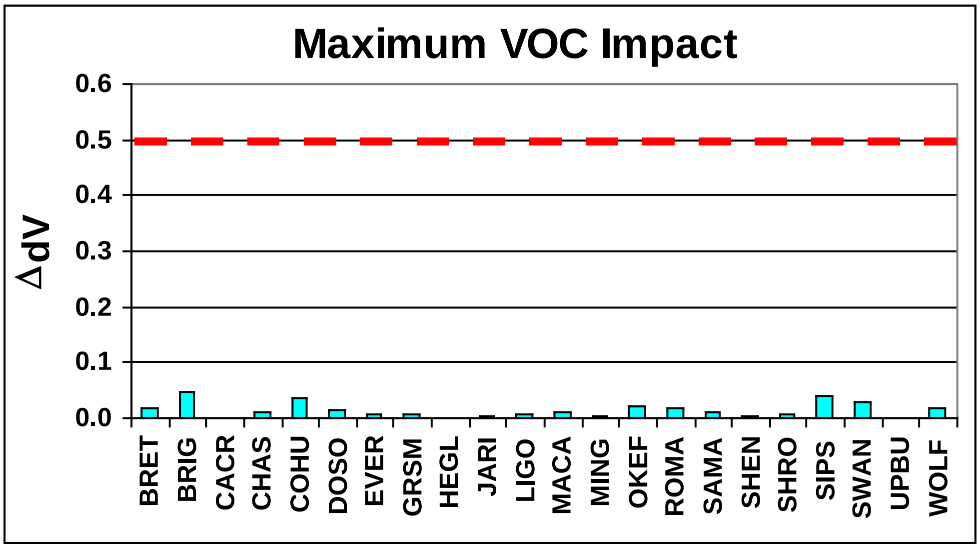

Figure 2-2. Estimated maximum contributions of BART-eligible VISTAS-region VOC point sources to haze in Class I areas during the modeled periods, based on state-by-state scaling of CMAQ simulated impacts from all VOC point sources.

For the second approach, the assumption was made that the POM at any Class I area originates from VOC emissions from many States, and therefore the ratio of BART-eligible VOC point source extinction impacts to all VOC point source extinction impacts is best represented by the VISTAS-average ratio of 0.09 in Table 2-1. In this case, therefore, the CMAQ-modeled impact on light extinction at every Class I area was multiplied by the 0.09 factor and the result was converted to deciviews.

The result of such calculations is shown in Figure 2-3. Although there are some small differences between Figures 2-2 and 2-3, we see again that none of the Class I areas is impacted by more than 0.05 dv, a tenth of US EPA's BART contribution threshold.

In reality, the contributions to haze at a Class I area are likely to lie between the results developed under the two approaches. Since both approaches yield estimates of cumulative impacts from BART-eligible VOC sources that are less than 0.05 dv, and therefore are substantially less than the 0.5 dv threshold, we conclude from this analysis that VOC emissions from individual BART-eligible sources will have minimal impact on visibility I Class I areas. VISTAS has therefore decided that effects of the VOC emissions from BART-eligible sources do not need to be modeled.

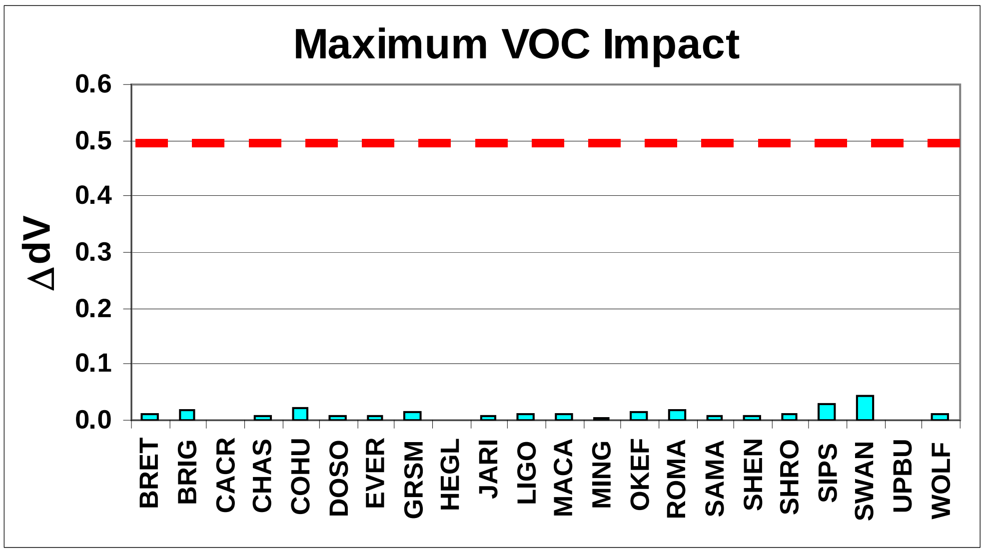

Figure 2-3. Estimated maximum contributions of BART-eligible VISTAS-region VOC point sources to haze in Class I areas during the modeled periods, based on VISTAS region-average scaling of CMAQ simulated impacts from all VOC point sources.

3. Ammonia Analyses

The NH_3 sensitivity simulations were carried out using version 4.5 of the CMAQ model, including VISTAS secondary organic aerosol (SOA) chemistry modifications developed. Two periods were modeled – a "summer" period of 1 June to 10 July 2002 and a "winter" period of 19 November to 19 December 2002.

The emissions starting point for the simulations was the VISTAS 2009 OTW BaseF4 emissions inventory. The sensitivity of regional haze at each Class I area in the VISTAS region and in adjacent States to NH_3 emissions was then ascertained by turning off NH_3 emissions from all BART-eligible sources in the VISTAS states and comparing the CMAQ-modeled result with the initial simulation with all emissions.

The results of this sensitivity analysis are shown in Figure 3-1, which displays the largest haze impact in deciviews, Δdv, found over the two simulation periods at each Class I area. The Δdv changes shown represent the haze contributions of all BART source NH_3 emissions relative to assumed natural haze levels based on EPA-default annual average natural concentrations for the East and monthly-varying "climatologically representative" relative humidity at each Class I area.

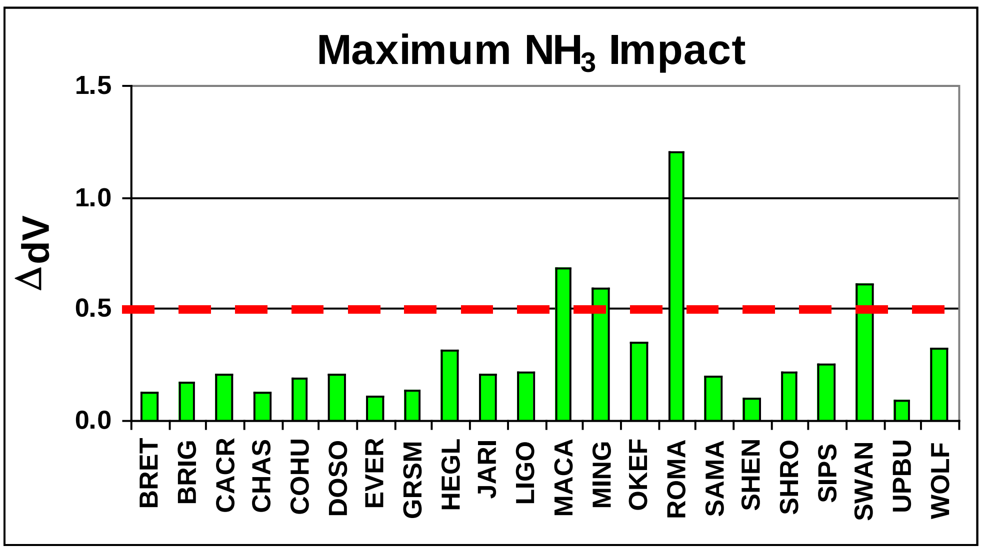

Figure 3-1. Maximum contributions of all BART-eligible NH_3 point sources in the VISTAS region to haze in Class I areas during the CMAQ-modeled periods.

Figure 3-1 shows that, during the two simulation periods, the NH_3 emissions all BART-eligible sources contributed more than 0.5 dv to haziness at four Class I areas – Mammoth Cave National Park (MACA), Kentucky; Mingo Wilderness (MING), Missouri; Cape Romain Wilderness (ROMA), South Carolina, and Swanquarter Wilderness (SWAN), North Carolina. The largest impact under 0.5 dv was at Okefenokee Wilderness(OKEF), Georgia. All other modeled Class I areas had impacts well under 0.5 dv.

The majority of the NH_3 emissions in the VISTAS region are from four large BART-eligible sources, as tabulated in Table 3-1.

Table 3-1. Major BART NH_3 Sources in the VISTAS Region

Facility	State	NH_3 Emissions (tpy)	Distance to Nearest Class 1 Area (km)
Meadwestvaco Corp.	SC	174	30
PCS Phosphate	NC	206	31
PCS Nitrogen	TN	1252	180
PCS Nitrogen	GA	1765	220

Analysis of the modeled spatial and temporal distributions of ammonia concentrations led to these four large sources as the probable principal contributors to the Class I area impacts described above. The principal NH_3 contributor to Cape Romain haze appears to be the Meadwestvaco Corp. plant in South Carolina, located 30 km from that Class I area. The principal NH_3 contributor to Swanquarter haze is the PCS Phosphate plant in North Carolina, which is located 31 km from that Class I area.

At the other Class I areas the connection is not quite as clear because the major NH_3 sources are more distant – roughly 200 km from the nearest Class I area -- but their emissions are some 6 to 9 times greater than those of the two plants mentioned above. It appears likely that the modeled haze impact at both Mammoth Cave and Mingo derives from NH_3 emissions from the PCS Nitrogen plant in Tennessee, and the impact at Okefenokee is attributable to the NH_3 emissions from the PCS Nitrogen plant in Georgia.

The relevant States have the option of asking the few sources mentioned above to evaluate their NH_3 impacts, in order to establish whether they should carry out a full BART analysis that covers conditions throughout the year. VISTAS has concluded that there is no need for any other sources to model their NH_3 impacts.

4. PM Analyses

The sensitivity simulations for primary PM were carried out by Alpine Geophysics using version 4.5 of the CMAQ model, again including the VISTAS secondary organic aerosol (SOA) chemistry modifications. All components of primary PM – primary sulfates, primary nitrates, primary OC, EC, soils, and coarse matter – were simulated.

Two periods were modeled: the first quarter of 2002 (1 January – 31 March 2002), to represent winter conditions, and the 3rd quarter of 2002 (1 July-30 September 2002), to represent summer conditions.

The emissions starting point for the PM simulations was the VISTAS 2002 BaseF4 emissions inventory. The contributions of all EGU PM emissions and of all non-EGU emissions to haze at each Class I area in the VISTAS region and in adjacent States were then ascertained separately by turning off all EGU point sources and all non-EGU point sources, respectively, and comparing the CMAQ-modeled impact results with those of the initial simulation with all emissions.

Results for the winter and summer modeling periods were evaluated separately. Figure 4-1 shows the results for the winter period. Both the highest Δdv and the 3rd highest Δdv (approximating the 98th percentile) impacts are plotted for both EGU and non-EGU point sources. The reference against which impacts were calculated is the light extinction associated with the default annual-average natural background concentration. Figure 4-2 is the corresponding plot for the summer period.

Both figures show many impacts of PM emissions from the aggregates of all EGU sources and all non-EGU sources that exceed the 0.5-dv contribution threshold. The EGU impact is smaller than the non-EGU impact, and the impacts in winter tend to be greater than those in summer.

Since not all of the sources modeled are BART-eligible, the impact of BART-eligible sources alone will be less that that displayed in Figures 4-1 and 4-2. However, most of the worst case impacts in those figures exceed the 0.5 dv contribution threshold by wide margins, and so it is likely that impacts of BART eligible sources will also often exceed that threshold.

Consequently, VISTAS has decided that all BART-eligible sources should model PM emissions.

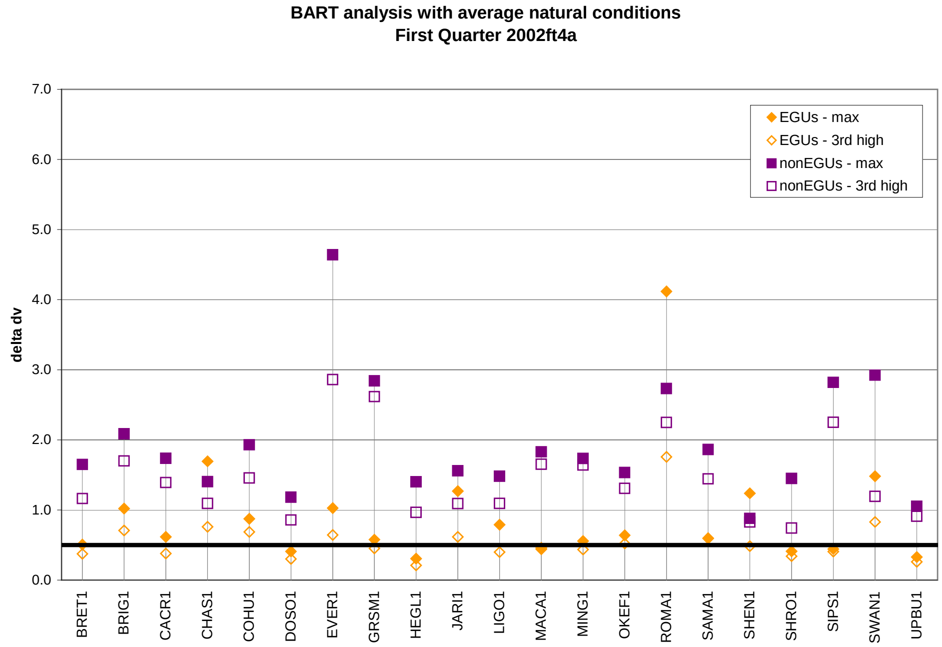

Figure 4-1. Maximum and 98th percentile contributions of all VISTAS-region EGU and non-EGU PM point sources to haze in Class I areas during the winter, based on CMAQ simulations. The solid line marks the 0.5 dv contribution threshold.

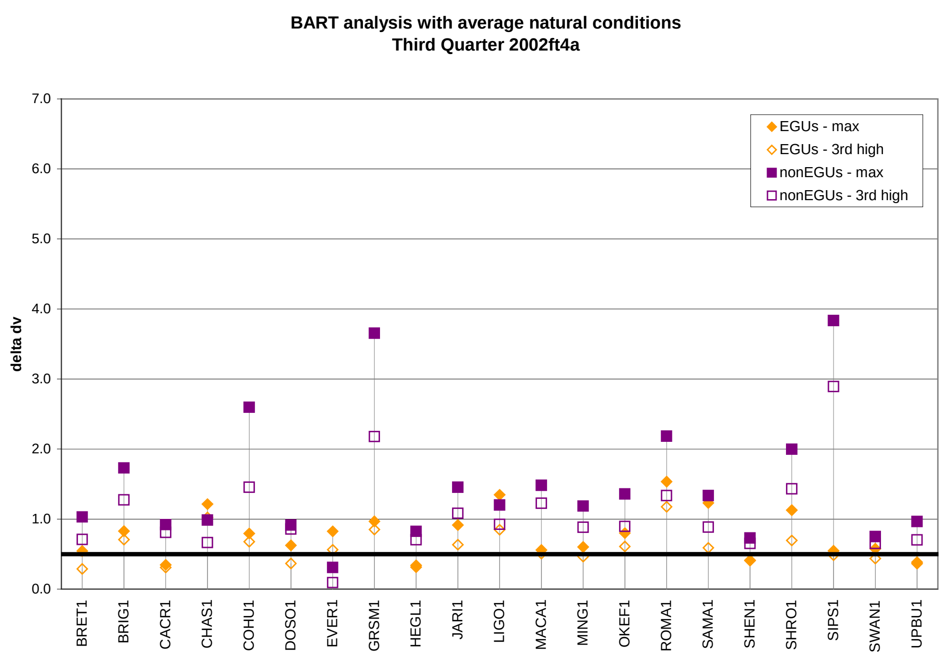

Figure 4-2. Maximum and 98th percentile contributions of all VISTAS-region EGU and non-EGU PM point sources to haze in Class I areas during the summer, based on CMAQ simulations. The solid line marks the 0.5 dv contribution threshold.

5. Conclusions

The analyses described in the preceding chapters lead to different conclusions concerning the necessity of addressing VOC, ammonia, and PM in BART analyses.

VOCs. The cumulative haze impacts from VOC emissions from all BART-eligible sources in the VISTAS region were found to be so small that there is no need to evaluate the VOC impacts of individual sources in BART analyses.

Ammonia. Haze impacts from NH_3 emissions from BART-eligible sources were greater than 0.5 dv at four Class I areas and approached 0.5 dv at another Class I area. Because there are relatively few large NH_3 sources, these impacts likely derive from those sources. (The sources are listed in Table 3-1.) Consequently, modeling of the impacts of NH_3 emissions from these sources throughout the year is appropriate, at the discretion of the State. Modeling of impacts by the remaining NH_3 sources is not needed.

PM. The cumulative haze impacts from primary PM emissions from all EGU sources and from all non-EGU sources were both found to often exceed the 0.5 dv contribution threshold by wide margins. Although the total of PM emissions from BART-eligible sources alone will be somewhat less, the evaluation of individual source PM impacts is warranted for BART analyses.