Single Source Modeling to Support Regional Haze BART
Modeling Protocol

March 21, 2006
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Des Plaines, IL

Modeling may be necessary to support a decision by the States about which BART eligible sources "cause or contribute" to visibility impairment and are subject to BART. The threshold used to determine whether a source "contributes" to visibility impairment is 0.5 deciviews, or lower, which is suggested in U.S. Environmental Protection Agency (EPA) guidance (EPA, 2005). For the purposes of this analysis, the threshold used to determine whether a source "contributes" to visibility impairment is 0.5 deciviews. EPA guidance recommends CALPUFF for modeling single source visibility impacts at Class I areas (EPA, 2005).

POLLUTANTS

EPA guidance lists SO2, NOX, and primary particulate matter (PM) as visibility impairing pollutants (EPA, 2005). Emissions of SO2, NOX, and PM must be examined for source contribution to visibility impairment. EPA recommends using the CALPUFF modeling system. EPA guidance recommends the use of judgment to determine whether VOC, ammonia, or primary PM emissions contribute to visibility impairment (EPA, 2005). An additional modeling analysis will be performed to determine whether VOC, ammonia, and primary PM emissions need to be considered.

VISIBILITY IMPAIRMENT MODELING: SUBJECT TO BART

The list of BART-eligible sources in each state will include all 26 applicable source categories (i.e., both EGUs and non-EGUs). For EGUs, EPA states the CAIR rule will result in controls for electric generating units (EGUs) better than those achievable by the BART provision of the Regional Haze rule. Each State will need to make a policy decision to either accept this position or to impose BART controls on their EGUs. Since the CAIR rule regulates SOX and NOX emissions, some consideration for other EGU emissions including primary PM, VOC, and ammonia is necessary. An additional modeling analysis will be performed to determine whether VOC, ammonia, and primary PM emissions from all elevated point sources in the Midwest RPO States contribute to visibility impairment at Class I areas.

For non-EGUs, the options in the BART guideline for determining which sources need not be subject to BART will be considered. The three options are individual source attribution approach (i.e., CALPUFF modeling), use of model plants to exempt individual sources, and cumulative modeling to show that certain elevated point source emissions species do not contribute to visibility degradation at nearby Class I areas. All three options will be used here. Specifically, the following approach will be taken:

(1) Calculate the Q/d value for all sources based on actual emissions and minimum distance to a Class I area. (Note, the Q/d metric was

identified in EPA's proposed rule and is similar to the emissions-distance criteria suggested in the final rule.)

(2) Conduct individual source CALPUFF modeling for those sources with a Q/d value $\geq$ 5. (Note, the CALPUFF modeling conducted in response to EPA's proposed BART rule showed that the emissions-distance criteria associated with less than 0.5 dv visibility impacts on nearby Class I areas was consistent with a Q/d value of < 5.)

(3) Review the results of the new CALPUFF modeling to determine which sources have less than a 0.5 dv impact on nearby Class I areas and which can, therefore, be assumed to be exempt from the BART process.

(4) Also review the results of the new CALPUFF modeling for sources with a Q/d value between 5 and 20 to determine if 5 is an appropriate cut-off for exempting sources from the BART process.

(5) Cumulative modeling will also be performed with CAMx to determine if ammonia, VOC, and direct PM (fine and coarse mass) emissions can be exempt from the BART process.

CUMULATIVE VISBILITY IMPAIRMENT MODELING

A photochemical model (CAMx4) will be applied with the VOC, ammonia, and PM fine and coarse mass emissions "zeroed-out" from all point sources in the Midwest RPO States, both BART-eligible and non-BART-eligible. The "zero-out" run will include EGU and non-EGU point sources. The results of this run will be compared to a base run with these emissions included to determine if these emissions species impair visibility. This type of cumulative modeling is consistent with option 3 under the section on determining which sources are subject to BART (EPA, 2005). The CAMx4 modeling system is applied with the same inputs and parameters as used for the PM2.5 and regional haze SIP. CAMx4 will be applied for the 2002 calendar year at 36 km grid resolution.

SINGLE SOURCE VISIBILITY IMPAIRMENT MODELING: SUBJECT TO BART

The CALPUFF modeling system is used to estimate visibility impairment from single sources. CALPUFF consists of the plume transport model (CALPUFF), meteorological data pre-processors (CALMM5, CALMET), inorganic chemistry parameterization module (POSTUTIL), and post-processor (CALPOST) (Scire et al, 2000a; Scire et al, 2000b). The versions of the CALPUFF modeling system code used for this analysis are shown in Table 1.

Table 1. CALPUFF Modeling System Versions

	Version	Level
CALPUFF	5.771a	040716
CALPOST	5.51	030709
CALMET	5.53a	040716
CALMM5	2.0	021111
POSTUTIL	1.4	040818

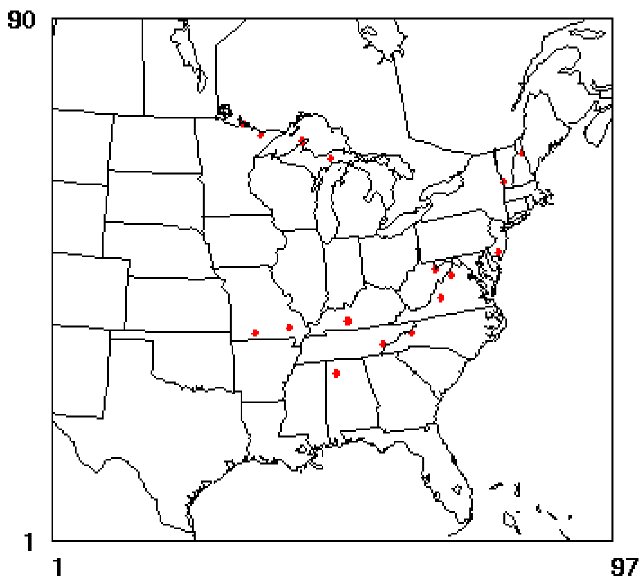
The modeling system is applied consistently with the EPA guidance recommendation of following the guidelines set forth in EPA's Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts (EPA, 2005; EPA, 1998). None of the BART eligible sources in the Midwest Regional Planning Organization are less than 50 km from a

Class I area so modeling analysis in addition to CALPUFF is not applicable. The IWAQM guidance states that less than 5 years of meteorological data may be used if a meteorological model using FDDA is used to supply data.

CALPUFF will be applied to each source for a 3 annual simulations, covering calendar years 2002 to 2004. CALPUFF will be applied using discrete receptor points covering the Class I areas with an approximate resolution of 1 km. POSTUTIL is used to re-partition nitrate into the gas or particulate phase depending on the estimated ammonia availability. This option has been shown to improve model performance (Scire et al, 2001). CALPOST is then applied to the POSTUTIL output for each group of Class I area receptors (shown in Figure 1 and in Table 3). CALPUFF, POSUTIL, and CALPOST are also run for 3 consecutive years for each source for gridded receptors that match the CALMET/CALPUFF domain shown in Figure 1. These runs allow for quality assurance and quality control by plotting the results for visual inspection. The results are checked for reasonableness of stack location, stack parameters, and emission rates. Each source is applied in CALPUFF for 3 years in a discrete receptor mode to meet regulatory requirements and for 3 years in a gridded receptor mode as a quality assurance and control measure.

The CALPUFF/CALMET modeling domain is a Lambert conformal grid projection centered at (97 W, 40 N) with true latitudes at 33 N and 45 N and origin at (-900 km, -1620 km). The horizontal domain consists of 97 36 km cells in the east-west direction and 90 36 km cells in the north-south direction (see Figure 1). The vertical atmosphere up to approximately 15 km is resolved with 16 vertical layers, most of which are in the boundary layer to appropriately resolve the diurnal fluctuations in boundary layer mixing depths.

Figure 1. Model Domain



Landuse and terrain data are extracted from the global datasets, USGS Composite Theme Grid landuse and USGS Digital Elevation Model terrain height, distributed with CALPUFF and match the horizontal grid specifications. Meteorological inputs to CALPUFF are output from a prognostic meteorological model using four-dimensional data assimilation. MM5v3.6 output is used to supply hourly meteorological data to CALPUFF.

Observation data is included in the ETA analysis fields used to initialize MM5 so additional assimilation of observational data in CALMET is redundant to the specific purpose of a prognostic meteorological model, which is to appropriately fill in the data around the surface monitoring network and sparse upper air monitoring network. The MM5 output used to support the BART CALPUFF modeling has extensive model performance evaluation and is used to support regional photochemical modeling applications for the ozone, PM2.5, and regional haze State Implementation Plans (Baker, 2004; Baker, 2005; Johnson, 2003).

Modeling options are set to be consistent with the IWAQM guidance. A few modifications to the suggested parameter settings are discussed in this section. For CALMET, several options were selected to use the MM5 output as input to CALMET rather than observation data; ICLOUD=3, IPROG=14, ITPROG=2, and IEXTRP=-1. Several options are selected in CALPUFF that differ from the IWAQM recommendations: the IDRY and IWET variables are set to 0 since dry and wet deposition flux output is not applicable for this analysis. The IPRTU variable is set to 3 to output specie concentrations in units of ug/m^3 to be consistent with measured regional concentrations.

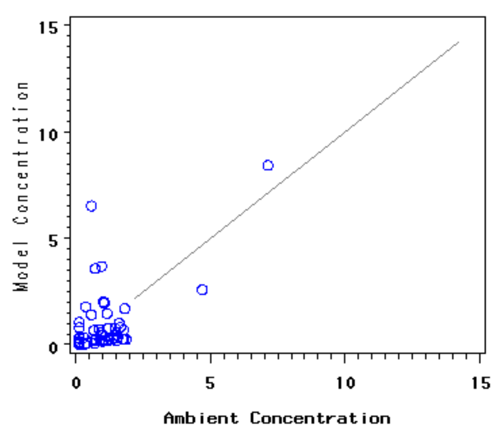
CALPUFF requires the input of ozone (O3) and ammonia (NH3) concentrations as a monthly background value applicable for the entire modeling domain. Seasonal domain averaged concentrations of each will be obtained from an annual 2002 calendar year CAMx4 simulation. These values are shown in Table 2.

Table 2. Domain Seasonal Average Concentrations (ppb)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
O3 (ppb)	31	31	31	37	37	37	33	33	33	27	27	27
NH3 (ppb)	.3	.3	.3	.5	.5	.5	.5	.5	.5	.5	.5	.5

CAMx4 prediction of ammonia at the rural Illinois site in Bondville shows good agreement between model predictions and ambient observations. A scatter plot showing the prediction-observation pairs over the entire calendar year of 2004 is shown in Figure 2.

Figure 2. CAMx4 model and ambient ammonia Predictions at Bondville, Illinois



SOURCE SPECIFIC INPUTS: EMISSIONS and STACK PARAMETERS

States will use the 24-hr maximum emissions rate between 2002 and 2004. If this data is not available, then a short term “allowable” or “potential” emission rate of emissions between 2002-2004 will be used. If neither of these types of emission rates is available, then the highest actual annual emissions divided by hours of operation of NOX, SOX, and primary PM between 2002 and 2004 will be applied in CALPUFF.

EPA recommends the States should determine the specific stacks that BART process emissions will exit and use stack information specific to those stacks (EPA, 2005b).

CLASS I AREA RECEPTORS

The receptors used to determine visibility impacts are taken from the National Park Service’s Class I area receptor index (NPS, 2005). The receptors “should be located in the nearest Class I area with sufficient density to identify likely visibility effects” according to the BART modeling guidance (EPA, 2005). The spatial resolution of the discrete receptors is not changed in any way from the NPS files. Table 3 shows the list of Class I areas and the total number of discrete receptors covering the Class I area used as the receptor field in CALPUFF.

Table 3. Class I Receptor areas and total discrete rectors

Boundary Waters Canoe Area	MN	856
Brigantine National Wildlife Refuge	NJ	16
Dolly Sods /Otter Creek Wilderness	WV	187
Great Gulf Wilderness	NH	38
Great Smoky Mountains National Park	TN	736
Hercules-Glades	MO	80
Isle Royale National Park	MI	966
James River Face	VA	52
Linville Gorge	NC	66
Lye Brook Wilderness	VT	103
Mammoth Cave National Park	KY	302
Mingo	MO	47
Seney	MI	173
Shenandoah National Park	VA	298
Sipsy Wilderness	AL	148
Voyageurs National Park	MN	366

CALPUFF OUTPUT: POST PROCESSING and INTERPRETATION

The light extinction equation will use the monthly average relative humidity (RH) rather than the daily average humidity as detailed in the BART modeling guidance (EPA, 1998; FLAG, 2000). This necessitates using the CALPOST background light extinction option 6, which computes light extinction from speciated PM measurements with a monthly RH adjustment factor. These Class I area centroid specific monthly RH adjustment factors are taken from Table A-3 of the EPA’s “Regional Haze: Estimating Natural Visibility Conditions under the Regional Haze Rule: Guidance Document.” (EPA, 2003).

The daily visibility metric for each receptor is expressed as the change in deciviews compared to natural visibility conditions as outlined in the IWAQM guidance (EPA, 1998). Natural visibility conditions, the 20% best days, for Class I areas used in this analysis are found in Appendix B of EPA's Guidance for Estimating Natural Visibility Conditions under the Regional Haze Rule (EPA, 2003). The 20% best days for each Class I area are listed in Appendix B in deciviews and not as chemically speciated constituents of the light extinction equation, which are needed for CALPOST option 6. Annual background concentrations for the eastern United States are given in the Guidance for Estimating Natural Visibility Conditions in Table 2-1 (EPA, 2003). These values are scaled back to lower concentrations until the Class I area specific natural visibility metric is produced (North Dakota Department of Health, 2005). This scaling procedure is done for each Class I area and uses an annual average fRH calculated from the 12 monthly site specific fRH values mentioned in the first paragraph of this section (EPA, 2003).

The annual average Class I area specific natural conditions are given in deciviews, so they must be converted to light extinction.

$$\text{Natural conditions (1/Mm)} = 10*\exp(\text{natural conditions in deciviews}/10)$$

Second, the chemically speciated natural background concentrations for the eastern United States are scaled to equal the site specific natural background light extinction value.

$$\text{Natural conditions in 1/Mm} = 3*fRH*[\text{ammonium sulfate}]*X + 3*fRH*[\text{ammonium nitrate}]*X + 4*[OC]*X + 10*[EC]*X + 1*[SOIL]*X + 0.6*[CM]*X + [\beta_{(Raleigh)}]$$

The bracketed concentrations are expressed as ug/m3. The fRH values represent annual average fRH calculated from the 12 monthly site specific fRH values mentioned in the first paragraph of this section (EPA, 2003). Solving for X gives the dimensionless scaling factor which is applied to each of the chemically speciated natural background concentrations given for the eastern United States. The natural background values and scaling factors used for each Class I area are shown in Table 4.

Table 4. Scaled natural background values by Class I area

Class I Area	Nat. Back. deciview	Nat. Back. 1/Mm	Scaling Factor	Annual average fRH	Amm. Sulfate	Amm. Nitrate	Organic Carbon	Elemental Carbon	Soil	Coarse Mass
BOWA	3.53	14.233	0.39	2.93	0.089	0.038	0.539	0.008	0.192	1.155
BRIG	3.60	14.333	0.39	3.05	0.090	0.039	0.546	0.008	0.195	1.169
DOSO	3.64	14.391	0.39	3.20	0.090	0.039	0.546	0.008	0.195	1.169
GRGU	3.63	14.376	0.39	3.13	0.090	0.039	0.547	0.008	0.195	1.172
GRSM	3.76	14.564	0.40	3.46	0.091	0.040	0.555	0.008	0.198	1.188
HEGL	3.59	14.319	0.39	3.13	0.089	0.039	0.540	0.008	0.193	1.157
ISLE	3.54	14.248	0.39	2.90	0.089	0.039	0.542	0.008	0.194	1.161
JARI	3.56	14.276	0.39	3.04	0.089	0.038	0.539	0.008	0.192	1.155
LIGO	3.75	14.550	0.39	3.54	0.090	0.039	0.549	0.008	0.196	1.176
LYBR	3.57	14.290	0.39	2.99	0.089	0.039	0.543	0.008	0.194	1.164
MACA	3.85	14.696	0.41	3.36	0.095	0.041	0.575	0.008	0.206	1.233
MING	3.59	14.319	0.39	3.14	0.089	0.039	0.539	0.008	0.193	1.156
SENE	3.69	14.463	0.39	3.30	0.090	0.039	0.550	0.008	0.196	1.178
SHEN	3.57	14.290	0.38	3.19	0.088	0.038	0.533	0.008	0.191	1.143
SIPS	3.71	14.492	0.39	3.43	0.090	0.039	0.547	0.008	0.195	1.172
VOYA	3.41	14.064	0.38	2.71	0.087	0.038	0.528	0.008	0.188	1.131

The visibility degradation beyond natural conditions expressed in deciviews is kept for each Class I area and ranked over the length of the modeling simulation. The criteria used to determine if a source is “contributing” to visibility impairment is the 98^{th} percentile that is equal to .5 deciviews for MRPO States using a maximum 24-hour emission rate and the peak value that is equal to .5 deciviews for MRPO States using an actual 24-hour emission rate. The 98^{th} percentile is interpreted as any source with more than 21 days of visibility impairment over the 3 year modeling period or 7 days of visibility impairment in any one of the 3 years modeled is “contributing” to visibility impairment. The peak value is interpreted as any source with more than 1 day of visibility impairment over the 3 year modeling period is “contributing” to visibility impairment.

The gridded receptor run will be post processed through CALPOST for plotting purposes. The plots show the number of days at each receptor that have 24-hr average 1% degradation in light extinction (1/Mm) over background conditions. This is approximate, but not equal, to 0.5 deciview degradation over background conditions. These plots allow for a qualitative visual inspection of the extent impact over the region.

VISIBILITY IMPROVEMENT DETERMINATION

Once a source is considered subject to BART the visibility improvement determination requires additional single source modeling. CALPUFF will be used to determine the visibility improvement at Class I area receptors from the potential BART control technology applied to the source. Post-control emission rates are calculated as a percentage of the pre-control emission rates (EPA, 2005).

The post-control CALPUFF simulation will be compared to the pre-control CALPUFF simulation by the change in the value of the highest degradation in visibility over natural conditions between the pre-control and post-control simulations (EPA, 2005). Further information on the sources and control levels to be used in this additional modeling will be provided later.

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