Comments on EPA Region 8 and FLM Concerns Regarding BART Exemption Modeling for Montana-Dakota Utilities Company's R.M. Heskett Station Unit 2: August 2009 Update

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Introduction

In 2006, Montana Dakota Utilities Co. (Montana-Dakota) asked ENSR (now AECOM) to review the results of the North Dakota Department of Health (NDDH's) 2005 Best Available Retrofit Technology (BART) CALPUFF modeling analysis of Unit 2 at the R.M. Heskett Station to determine whether there were any aspects of the modeling procedures that should be refined to make the modeling results more accurate. In addition to utilizing annual average background visibility instead of the best 20% days' background visibility in the model, ENSR found two additional areas of refinement.

First, and in accordance with EPA's CALPUFF modeling "Frequently Asked Questions" and EPA guidance on resolving terrain features, ENSR decreased the horizontal grid spacing in the model from 3 km to 1 km. Use of the 1-km grid spacing for modeling the projected visibility impacts of Unit 2 is supported by both the intervening complex terrain and the proximity of R.M. Heskett Station to the Class I areas of concern. The effect of using the finer grid spacing over the three years modeled at the Class I areas ranged from a slight increase in visibility impacts to about a 40% decrease. Since the smaller grid size forces a smaller step change in the CALPUFF model and a better representation of causality effects, the 1-km grid size improved upon independent NDDH CALPUFF evaluations that show an overprediction tendency in the range of 50-70% relative to observed 24-hour concentrations in the Theodore Roosevelt National Park with the use of a 3-km grid spacing.

Second, since the NDDH modeling did not consider speciation of PM_{10} emissions, ENSR introduced a PM_{10} speciation input into the CALPUFF modeling in accordance with technical advice provided by other BART protocols, which had the effect of increasing the predicted impacts because the added species have a larger extinction efficiency than the model default for "soils" used by NDDH.

Application of the available refinements to the CALPUFF BART modeling for Heskett Unit 2 showed a worst-year 98th percentile deciview change from background of 0.421 at Theodore Roosevelt National Park and 0.399 at the Lostwood Wilderness Area. These values are below the 0.5 dv threshold which is used to determine if a BART-eligible source is contributing to regional haze at a Class I area. NDDH therefore concluded that Heskett Unit 2 is not a BART-subject source.

One additional area of refinement that was not available in the CALPUFF modeling system until 2008 was the ability to use the new IMPROVE equation, which is a more accurate method to convert the predicted particulate concentrations into visibility impairment. ENSR's experience with this new method is that it typically reduces the visibility impairment for emissions sources such as power plants in the range of 20-30%. The availability of this method would have further reduced the modeled visibility impact of Heskett Unit 2 over that which was reported to the NDDH in 2006. Therefore, the ENSR-reported visibility impact is overly conservative.

By letter to NDDH dated August 4, 2008, EPA Region 8 expressed concerns regarding the use of 1-km grid spacing in the Heskett Unit 2 BART exemption modeling analysis, although the ENSR modeling report did provide a discussion justifying the grid spacing selection. These comments provide an updated technical justification for the use of finer grid spacing.

Summary Background

In 2005, NDDH conducted CALPUFF modeling for emission sources at several BART-eligible facilities in North Dakota. One of these sources was Unit 2 at the R.M. Heskett Station (Heskett). This unit became operational in 1963 with a capacity of 75 MW, and was retrofitted to a fluidized-bed combustor in 1987.

The NDDH conducted initial CALPUFF modeling to determine whether Unit 2 at Heskett is subject to BART. The NDDH's CALPUFF modeling, which was provided to Montana-Dakota, indicated that baseline emissions impacts would result in a visibility impact of 0.82 deciviews (dv) at the Theodore Roosevelt National Park (TRNP) and 0.58 at the Lostwood Wilderness Area (LWA). These predicted visibility impacts exceed the 0.5 dv threshold for "contributing to impairment" as noted in the United States Environmental Protection Agency's (EPA's) final BART rule published on July 6, 2005 (70 Fed. Reg. 39104). This determination was based upon the use of the 20% best days' background visibility and the use of a 3-km grid spacing in CALMET and CALPUFF.

Subsequent to that modeling exercise, EPA announced a court settlement regarding BART that allows each state to use the annual average background visibility instead of the best 20% days' background visibility. This change occurred because the final July 6, 2005 BART rule stipulated that the annual average background visibility value should be used, while the preamble was inconsistent and mentioned that the 20% best days' background visibility should be used. NDDH elected to adopt a policy to use the annual average option for determining the results of BART exemption modeling analyses. This change alone resulted in a nearly 25% reduction of visibility impacts, adjusting the results at LWA to be below the 0.5 delta-dv threshold. The adjusted results at TRNP were also lower, but still above the 0.5 delta-dv threshold.

In 2006, Montana-Dakota asked ENSR to review the results of NDDH's CALPUFF modeling analysis and to determine whether there were any aspects of the modeling procedures that should be changed or refined to make the modeling results more accurate. ENSR found two areas for such refinement (in addition to the selection of the background metric mentioned above). These included the following:

1) In accordance with EPA's CALPUFF modeling "Frequently Asked Questions" and EPA guidance on resolving terrain features, ENSR decreased the horizontal grid spacing in the model from 3 km to 1 km. The effect of the finer grid spacing over the three years modeled at the various Class I areas (LWA and three units of TRNP) ranged from a slight increase in visibility impacts to about a 40% decrease in some cases.

2) Since the NDDH modeling did not consider speciation of PM_{10} emissions, ENSR introduced a PM_{10} speciation input into the CALPUFF modeling in accordance with technical advice provided by other BART protocols such as the VISTAS BART protocol, available at http://www.vistas-sesarm.org/documents/BARTModelingProtocol_rev3.2_31Aug06.pdf, and PM_{10} speciation guidance from the Federal Land Managers available at a link on the VISTAS web site (http://www.vistas-sesarm.org/BART/calpuff.asp). This change to the model increased the predicted impacts because the added species have a larger extinction efficiency than the "soils" used by NDDH.

The result of the refinements to the CALPUFF BART modeling for Heskett Unit 2 was a worst-year 98th percentile deciview change from background of 0.421 at TRNP and 0.399 at LWA. These values are below the 0.5 dv threshold which is used to determine if a BART-eligible source is contributing to regional haze at a Class I area. NDDH therefore concluded that Heskett Unit 2 is not a BART-subject source.

Since the selection of background visibility and a more conservative treatment of PM_{10} speciation are consistent with NDDH policy, the comments below relate to the selected grid spacing refinement ENSR employed.

It is noteworthy to consider that a third refinement, the use of the new IMPROVE equation, was not available to ENSR in 2006, but is now available as “Method 8” in CALPOST and is recognized now as an approved technique by the Federal Land Managers (see slide 4 of the presentation at http://www.cleanairinfo.com/regionalstatelocalmodelingworkshop/archive/2009/presentations/04%20Weds%20AM/RSL-FLM-05-13-09E.pdf). ENSR’s experience with this more accurate method is an expected substantial decrease in the visibility impairment that is not reflected in the modeling analysis conducted in 2006.

EPA and FLM concerns with the CALPUFF Grid Spacing Issue

NDDH received a letter dated August 4, 2008 from EPA Region 8 in which the agency expressed some concern regarding the process for exempting Heskett Unit 2 from BART. In the letter, EPA stated:

> “We have concerns with ENSR's CALPUFF modeling. They reduce the CALMET/CALPUFF grid size from 3 km to 1 km. EPA has recently seen data indicating that CALPUFF may inappropriately reduce predicted concentrations with such grid size manipulation…Given that ENSR's refined results move Heskett from “subject-to-BART” to “exempt”, a more robust discussion is necessary regarding why NDDH found ENSR's analysis "acceptable," including an explanation of why you think this approach will not lead to underestimates of visibility impacts.”

EPA’s statement that “grid size manipulation” may inappropriately reduce predicted concentrations is inaccurate. The grid size adjustment that ENSR employed follows EPA guidance regarding recommended resolution of terrain features, as noted below, and it improves CALPUFF’s accuracy in addressing terrain feature interactions. The latter point is supported, in particular, by CALPUFF’s developer as well as by Mr. Clint Bowman of the Washington Department of Ecology, each of whom conclude that grid size reductions are technically valid and improve the accuracy of CALPUFF modeling.

EPA Model Clearinghouse Memorandum

On May 15, 2009, EPA’s Model Clearinghouse ruled on the Big Stone Unit 1 BART case (South Dakota) in which the use of a 1-km grid was questioned by EPA Region 8. In a February 24, 2009 letter to the Model Clearinghouse, EPA Region 8 questioned the use of a 1-km grid for a long distance plume travel (400 km) and relatively flat terrain. EPA Region 8 therein stated its support for the use of 1-km and even smaller grid spacing in areas where complex terrain would affect plume dispersion because the “higher resolution at these distances will better characterize terrain effects and local scale meteorology.” However, for the Big Stone case under consideration which lacked complex terrain and which involved multiple-day transport, EPA Region 8 suggested that a 4-km grid spacing for a BART analysis would be supportable.

In their May 15, 2009 reply, the EPA Model Clearinghouse concurred with EPA Region 8’s position on the grid spacing issue. The Model Clearinghouse noted that the modeling analysis documentation did not adequately justify the need for the finer grid resolution. They also recommended that prognostic meteorological data sets should have adequate evaluation.

The BART modeling for Heskett Unit 2 differs significantly from the Big Stone case because: (a) the Heskett case involves complex terrain with features that require a 1-km grid resolution (not flat terrain); and (b) plume travel distances from Heskett to the Class I areas at issue (LWA and three units at TRNP) are much less than 400 km, such that the plume-terrain interaction is more important to simulate correctly. Because the reduced grid size forces a smaller step change in the model and a better representation of causality effects, the 1-km grid improves on independent NDDH CALPUFF evaluations that show an overprediction tendency in the range of 50-70% relative to observed 24-hour concentrations from use of 3-km grid spacing. In addition, the NDDH has thoroughly researched and studied the Rapid Update Cycle (RUC) prognostic meteorological data being used for the BART analysis. This data set was also used previously for SO_2 increment modeling using CALPUFF and was accepted after a national review of this modeling application.

Appropriate CALMET/CALPUFF Grid Size: Response to Comments

EPA provides guidance for the selection of the CALPUFF grid size in the "Frequently Asked Questions" area on the TRC CALPUFF web site (available at http://www.src.com/calpuff/FAQ-answers.htm#2.1.4). The text of this guidance states the following:

> ***2.1.4 How will I know whether my terrain elevation data is sufficiently resolved (i.e., small enough grid size) for my specific application?***
>
> *In making CALMET and CALPUFF modeling runs, the goal is to find the optimum balance between the desire to make the grid size as large as feasible in order to reduce the run times and file sizes, and the desire to make the grid size small enough that CALMET can characterize the terrain effects on the wind field. The optimum grid spacing for a particular application will depend on the size of the modeling domain and the complexity of the terrain within the domain.*
>
> *There are some obvious checks one can make. For instance, if your application involves some terrain features (hills, valleys, etc.), CALMET needs to have as least 5 (preferably 10) grids to resolve each terrain feature. So if you have a valley of particular interest that is typically 5 km wide, one might like to have a grid spacing of 0.5 to 1-km terrain and land-use data.*
>
> *Graphical analyses may also prove helpful. Consider the following sequence to develop three graphical analyses: 1) contour the gridded data at what you think will be your final resolution, say 2-km; 2) shift the origin of the grid by ½ of the grid scale (left or right, up or down), re-grid the data using twice the original grid scale, and contour the terrain heights, and 3) using the same grid origin as in the second case, re-grid the data using ½ the original grid scale as in the first case, and contour the terrain heights. Compare the three plots to see how terrain features are 'appearing' and 'disappearing', and decide whether you are comfortable with your original grid scale. One could repeat these three steps using a different initial grid scale, but we should also remember that these results are subjective in nature, so try not to over-engineer this analysis. Common sense and experience should prevail.*

The key aspect of this guidance is that CALMET needs to have at least 5 grid elements to adequately resolve terrain features. The terrain features within the TRNP South Unit are depicted in Figures 1 and 2. Figure 1 is included since it better represents the actual terrain features of TRNP, while Figure 2 depicts the actual park boundaries more accurately. Two typical areas are circled in both figures as examples of terrain features that are on the order of 5 km or less in size. This implies that a grid spacing as large as 3 km would excessively smooth out these terrain features. In compliance with the guidance provided by EPA through the TRC website's Frequently Asked Questions, ENSR used a 1-km grid spacing for the CALPUFF modeling to improve the accuracy of the model.

We also note that EPA Region 8 has indicated its support of the use of 1-km grid spacing or even smaller for applications with complex terrain and without long travel distances. In the case of Heskett Unit 2 and Theodore Roosevelt National Park (TRNP), virtually the entire North Unit has elevations above the Unit 2 stack top, and the terrain relief within the park exceeds 220 meters (720 feet). The distance to TRNP is less than 200 km, which is well within a distance that could be covered during nocturnal travel (12 hours at 5 m/s at plume level) in which the plume would stay relatively compact and significantly interact with the complex terrain at TRNP. The use of the 1-km grid spacing for the Heskett Unit 2 analysis therefore supplies higher resolution and better characterize terrain effects and local scale meteorology to improve the objective accuracy of the CALPUFF predictions.

In addition to this guidance, the following e-mail exchange between Robert Paine of ENSR and Joe Scire of TRC (the CALPUFF model developer) further establishes the scientific credibility of using the 1-km rather than the 3-km grid spacing.

From: Scire, Joseph [mailto:JScire@TRCSOLUTIONS.com]

Sent: Wednesday, January 10, 2007 2:32 PM

To: Paine, Bob

Subject: RE: issue of finer grid spacing in CALMET

Bob,

Generally, if CALMET is using a smaller grid spacing than MM5, it should be able to pick up terrain effects that MM5 does not see, and therefore improve the quality of the wind fields. The grid resolution of MM5 should not limit what is used in CALMET. This was tested in the Wyoming project and it was shown that the winds using CALMET at finer resolution produced the channeling that MM5 missed.

Also, another advantage of finer grid resolution in CALMET is the ability to characterize the land use data in a more detailed way.

Joe

Figure 1: Terrain Features within Theodore Roosevelt National Park, South Unit

Note: the southern boundary depicted on this figure may not be accurate, but the purpose of this map is to show the terrain features within the park.

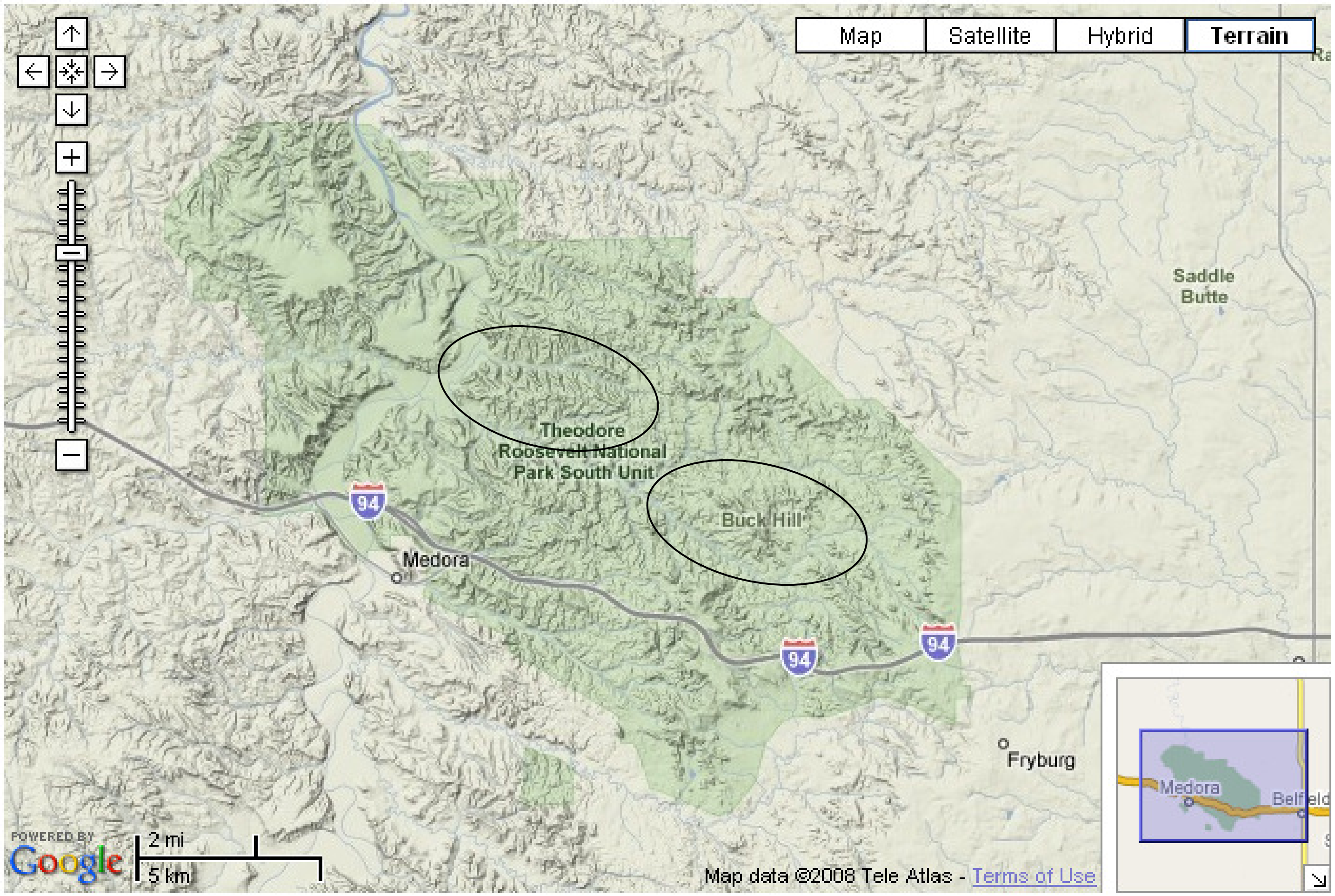
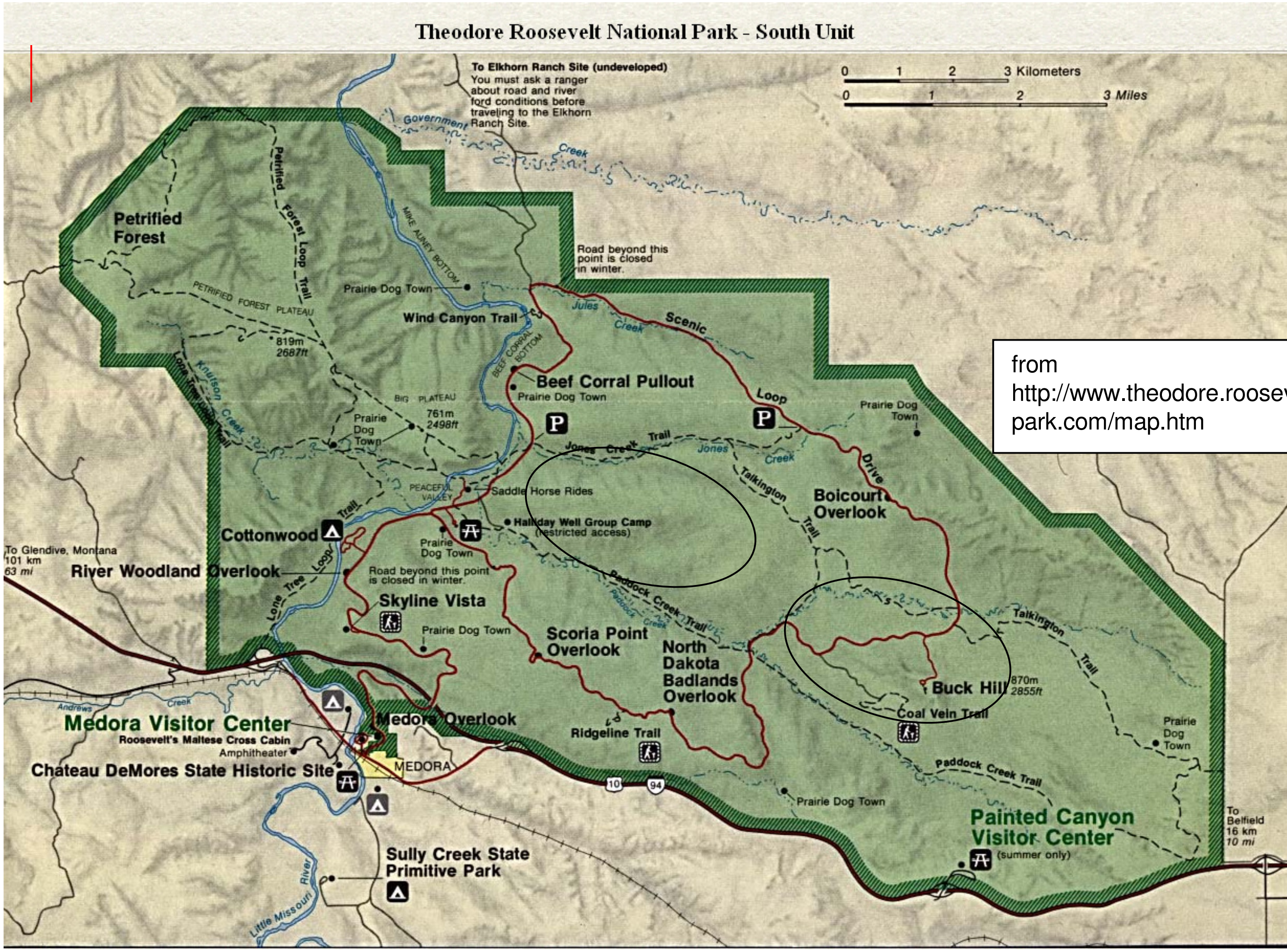


Figure 2: Terrain Features within Theodore Roosevelt National Park, South Unit (alternative map)



from
http://www.theodore.roosevelt.national-park.com/map.htm

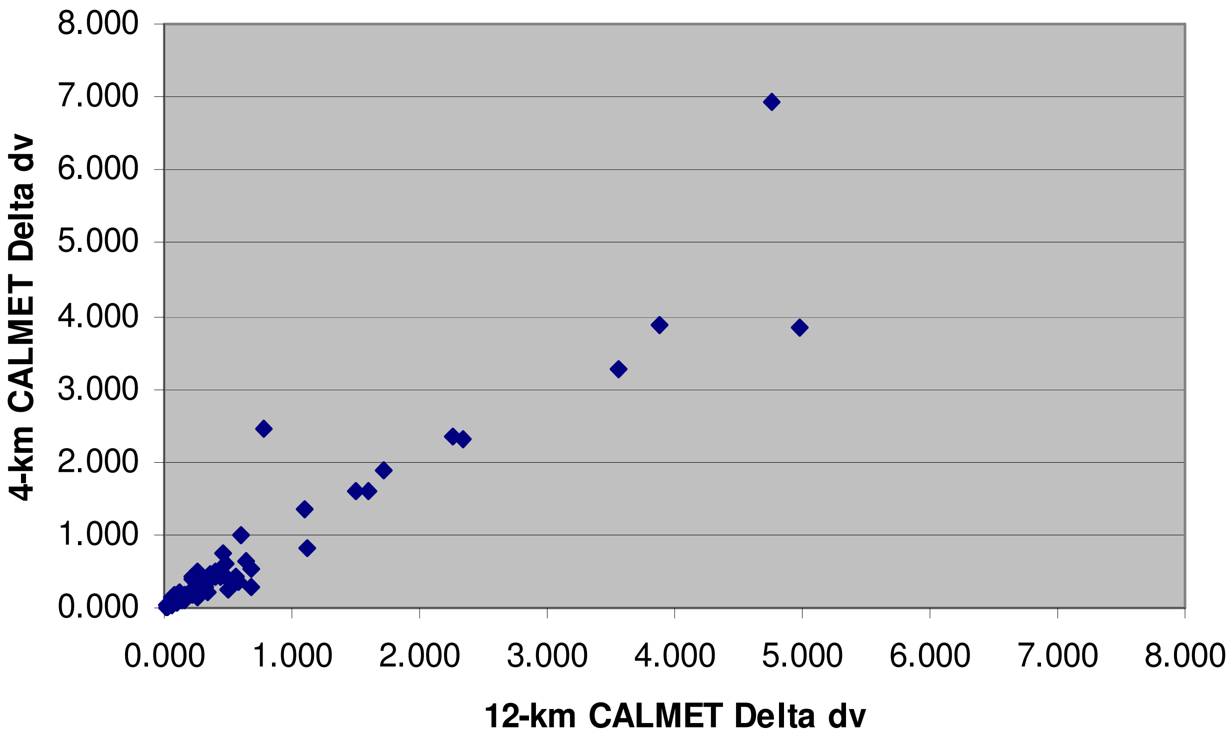
CALPUFF Modeling Bias Introduced by Smaller Grid Size?

Recently, the FLMs have suspected that lower CALPUFF predictions are routinely generated by smaller grid spacing. We surmise that this is why it is referred to in the August 4, 2008 EPA Region 8 letter to NDDH as a “grid size manipulation”. ENSR recently discussed this issue with Tim Allen of the Fish & Wildlife Service. According to Mr. Allen, his discussions in 2008 with Joe Scire indicated that the use of a finer grid spacing was neutrally biased in providing either lower or higher CALPUFF impacts.

A similar communication from Joe Scire on this issue, dated September 25, 2008, indicates that the smaller grid size would generally not be expected to introduce a routine bias in the modeling results for a large sample of modeling applications. Excerpts from Scire’s communication are provided below.

> *In CALPUFF, when using finer resolution, the model will provide a better representation of the terrain (higher peaks, lower valleys more closely representing the actual terrain), land use (higher resolution of land use variability), coastlines (a better representation of the actual land-water variation), wind flow adjustments caused by terrain (i.e., terrain channeling and slope flows) and other things too. A smaller grid size forces a smaller time step in the model and this can give a better representation of causality effects in the model.*
>
> *Regarding the issue that finer resolution always gives lower modeling predictions, this is clearly not the case. A summary of VISTAS modeling results for 26 sources at 90 source-Class I area combinations conducted previously by TRC shows this [see Figure 3]. Of the 90 cases, 47 cases showed higher max impact results with the finer grid resolution and 43 cases showed higher impacts with the coarse grid resolution. Given this result, using a fine resolution for selected Class I areas and coarse resolution for others (i.e., picking whichever produces the lower results) would probably not be deemed acceptable, since it is hard to argue the finer resolution result is better only in the cases when it produces lower impacts.*
>
> *In any given situation there may be valid reasons why the changes might be skewed more in one direction or the other, but the conclusion that finer grid resolution always decreases concentrations is not correct. As one example, coarse resolution that raises the valley floor in the model and lowers the peaks might make the flow at plume height completely different than a higher resolution run that lowers the stack base ground elevation and increases the peak elevations which may result in the plume being within the valley walls and thus subject to channeling effects. The higher resolution simulation might channel the plume into a Class I area, resulting in higher impacts, or transport it away from a Class I area and produce lower impacts (depending on where the source and Class I area are located). I’ve seen examples of both types of situations. In both cases, it could be argued the finer resolution results are more appropriate, whether they are higher or lower. But the details of the situation determine the nature of the response in the model and it will not always be the same.*

Figure 3: Comparison of Maximum Visibility Impact Predictions for Two CALPUFF Grid Sizes



In another study of the effects of grid spacing on CALPUFF results, Mr. Clint Bowman of the Washington Department of Ecology conducted a sensitivity study and presented it at EPA's 2008 modeling workshop. Bowman tested grid spacing ranging from 100 m to 12 km. He found that smaller grid size could lead to somewhat lower modeled impacts. His basic points were as follows:

- the primary effect of the finer grid spacing is to improve the terrain resolution, and this will improve the model accuracy;
- the finer grid spacing does not materially alter the peak impact location or time period;
- large grid spacing leads to artifacts in wind fields which will degrade model accuracy, while the accurate depiction of terrain-induced drainage flow is more realistic with small grid spacing; and
- the effect of slightly lower modeled impacts for a more accurate model setup with a smaller grid size is not confined to CALPUFF, but it is common to other models as well.

As ENSR has noted in various technical presentations, the issue of how grid spacing affects terrain resolution is important because there are model receptors on real terrain features (i.e., sharp peaks) that are not known to CALMET if the terrain is overly smoothed out with a coarse grid treatment. In the case of grid spacing less than the EPA recommendations noted above, the actual terrain height is provided to CALPUFF in the receptor information, but a lower hill height is presented to CALMET for the same area for purposes of wind flow adjustments. This can result in an incorrect depiction of the wind flow because it responds to the terrain information provided to CALMET. Therefore, with a smoothed version of the terrain, CALPUFF could inaccurately simulate artificial plume impacts for ground-level receptors that appear to be "flagpole" receptors relative to the terrain presented to CALMET if a coarse grid is used.

NDDH CALPUFF Evaluation

As part of the modeling analyses conducted by the NDDH on the SO_2 PSD increment question for Class I areas in North Dakota, the NDDH compared CALPUFF and available monitors with 2002 hourly emissions data from major EGUs, including Heskett Unit 2. The TRNP monitor available in 2002 was at the North Unit, for which a terrain map is shown in Figure 4. Terrain features of a size similar to that of the South Unit are present in the North Unit, justifying a grid spacing of 1 km as a more appropriate choice rather than 3 km.

The NDDH documentation of the CALPUFF model evaluation results are provided at http://www.ndhealth.gov/AQ/Dockets/Responses%20to%20Recuring%20PSD%20Issues/Responses%20to%20Recurring%20PSD%20Issues%20-%20Part%205.pdf, which involves a report of recurring issues involving the PSD increment modeling in PSD Class I areas. The NDDH analysis used more than one meteorological database, but the use of the Rapid Update Cycle (RUC) data is most closely related to the BART modeling. The results of the comparison of modeled to monitored (with a nominal background of 1.5 µg/m^3 added; Figure 23 of the NDDH report) are reproduced in Figure 5.

The relevant results, taken from the solid blue line labeled “RUC + 1.5”, indicate that the CALPUFF model as applied by the NDDH (which used a 3-km grid spacing) generally overpredicts the observed concentrations in a range of 50-70% for the peak few values. Since that margin is comparable to or exceeds the reduction in impacts obtained from reducing the grid size from 3 km to 1 km, we conclude that the smaller grid spacing would result in a better performing and more accurate CALPUFF model that still shows an overprediction tendency.

Conclusions

The initial BART modeling for Heskett Unit 2 was conducted by NDDH and it showed visibility impacts above the BART exemption threshold of 0.5 delta-dv. The EPA settlement with regard to the use of the annual average background resulted in one of the model refinements ENSR subsequently employed upon evaluation of the NDDH CALPUFF modeling. Further refinements that resulted in adjustments toward both higher and lower concentrations were applied by ENSR in two areas: (1) a finer grid spacing; and (2) the use of PM_{10} speciation, which NDDH did not use and which increased predicted visibility impacts. ENSR was not able to use a third refinement that later became available in 2008 (the new IMPROVE equation) which ENSR expects from nationwide modeling experience would have further reduced the predicted visibility impact of Heskett Unit 2.

Use of the finer grid spacing is technically justified by both the intervening complex terrain and the proximity of R.M. Heskett Station to the Class I areas. The finer 1-km grid spacing resulted in a change in impacts ranging from a slight increase to a reduction of about 40% from the 3-km spacing results. It also improved upon independent NDDH CALPUFF evaluations showing an overprediction tendency in the range of 50-70% relative to observed 24-hour concentrations with the use of 3-km grid spacing. It is evident that the use of a finer grid provides better CALPUFF accuracy and performance, still with an overall slight overprediction tendency.

For all of the reasons stated above, the concerns of the EPA and FLMs regarding the ENSR CALPUFF BART analysis have been addressed. The use of the 1-km grid will provide improved accuracy for the CALPUFF predictions. The BART exemption analysis shows that the Heskett Unit 2 regional haze impact would be below the BART contribution threshold of 0.5 delta-dv at TRNP and LWA even with the use of the old IMPROVE equation.

Figure 4: Terrain Features within Theodore Roosevelt National Park, North Unit

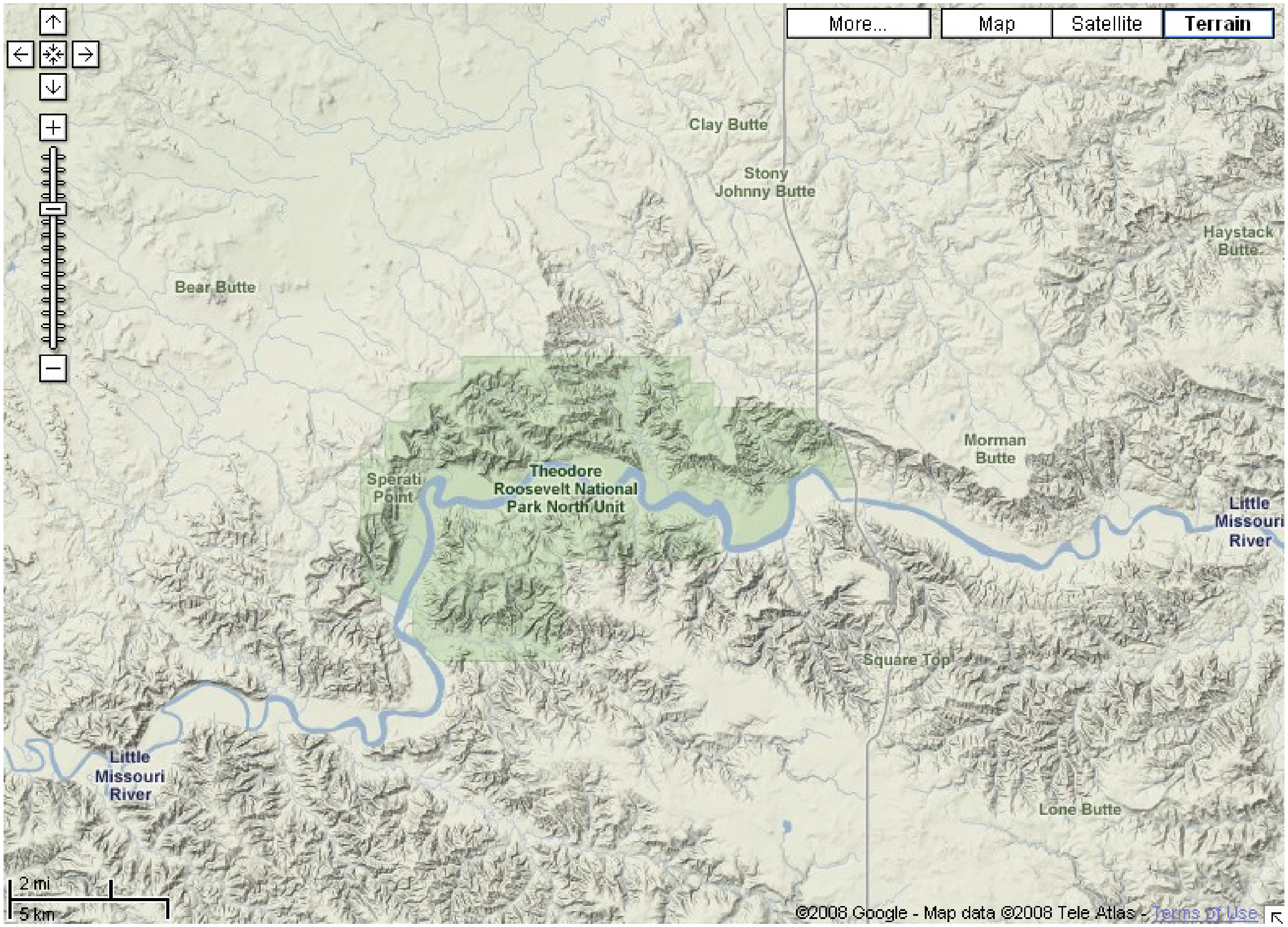


Figure 5: Normalized CALPUFF Bias from Normalized Rank-Order Pairs of SO_2 24-hour Concentrations at TRNP North Unit