Guideline Refinements: A More Realistic NAAQS Analysis in AERMOD?

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George J. Schewe[1], CCM, QEP, Anthony J. Schroeder[2], CCM; [1]Trinity Consultants, 1717 Dixie Highway, Suite 900, Covington, KY 41011, [2]Trinity Consultants, 7330 Woodland Drive, Suite 225, Indianapolis, IN 46278

ABSTRACT

The Revision to the Guideline on Air Quality Models (40 CFR 51, Appendix W), proposed by EPA on July 14, 2015 and published in the Federal Register on July 29, 2015 includes several updates that are intended to make dispersion modeling analyses for National Ambient Air Quality Standards (NAAQS) compliance demonstration purposes more "realistic", that is, more like an ambient concentration that is actually measured at a monitor. These updates include changes to guidance with respect to modeling actual emissions instead of allowable emissions for regional inventory sources, increased dependence on background concentrations to represent "nearby" sources, and the proposed promulgation of low wind speed adjustments (ADJ_U* and LOWWIND1, LOWWIND2, or LOWWIND3) as default options for use in regulatory applications. This paper provides a case study in which a stationary source inventory was modeled using AERMOD for an area surrounding two ambient SO_2 monitors for direct comparison with monitored concentrations. SO_2 was selected because it is fairly stable in the atmosphere, because it is a source-oriented pollutant, because it does not have precursors with which to deal, and because it does not have tiered levels of chemical reactivity to consider after release to the atmosphere. The analysis includes use of both actual and allowable emissions as well as differing combinations of the low wind speed options proposed for regulatory default status in the proposed guidelines.

INTRODUCTION

The AERMOD Model[1] was introduced to the regulatory dispersion modeling community in 1995 as part of EPA's proposed updates and later introduced as a regulatory preferred model in 2005 in Section 4.2.2.b of the *Guideline on Air Quality Models* (GAQM)[2] where it states that AERMOD is the recommended model for "a wide range of regulatory applications in all types of terrain". Along with AERMOD are preprocessors also recommended for preparing data sets applicable to running the AERMOD algorithms for transport, dispersion, convective boundary layer turbulence, stable boundary layer, terrain influences, building downwash, and land use. These are AERMAP, AERSURFACE, and AERMET. As per the GAQM, specific default options should be used in the set up and running of AERMOD to have it concur with the EPA-recommended methodologies for using the models. These options range from consideration of elevated terrain to calm wind preprocessing to inclusion of stack-tip effects on an effluent plume.

Over the course of the past 10 years as the science of atmospheric transport and dispersion has improved, as more research studies have revealed deficiencies in model performance, and as the modeling community has increased its cooperative stakeholder activities with the regulatory agencies, a number of new options have been offered and tested in the AERMOD Model. Some of these have become accepted practices and options while others are yet undergoing review and consideration. To reflect these improvements to the science and practice of air dispersion modeling, EPA has recently proposed an update to the GAQM, which will retain AERMOD as a recommended model, but refine some of the methodologies discussed in the current version of the GAQM.[3] Those of interest in this paper that were reviewed include:

- Actual versus allowable emissions for regional sources (Table 8-2 of Section 8.2.2 of the proposed GAQM),
- Increased dependence on background ambient monitoring to represent nearby source impacts (Section 8.3.1.i of the proposed GAQM),
- And low wind speed options to better represent turbulence at wind speeds from about 0.5 to 1.0 m/s (GAQM Preamble, Section IV.A.2. Updates to EPA's AERMOD Modeling System).

The remainder of the paper describes the selection of a data set of sources, two monitors, the modeling performed, and a comparison of the actual emissions impacts to the allowable emissions impacts for a number of LOWWIND options. An analysis of the resulting comparisons is given and observations on model performance improvement and no-improvement is described.

MODELING METHODOLOGY

The methodology for this analysis was to apply the most current version of the AERMOD Model (Version 15181) to all regional sources within a 50 km radius of two monitors located in central Kentucky. This allowed the use of two monitors located in a similar region and also the restriction of using a regional inventory of sources all within the same state to limit any differences between inventories that could arise due to variable collection, reporting, and storage of such data.

Study Area

The study area selected for this study was centered at the approximate halfway point between two ambient monitors both collecting ambient SO_2 data in the area in and around Lexington, Kentucky. The monitor sites included the ambient monitor located at 650 Newtown Pike in Lexington, Kentucky (Site No. 21-067-0012) and that located at 260 Wilson Drive in Nicholasville, Kentucky (Site No. 21-113-0001). Figure 1 shows the location of the two monitors as well as the area surrounding the two monitors and a 50 km radius circle as the area of regional inventory sources to model. To obtain all sources in the study area, actual emissions, potential to emit (PTE), and source release information was obtained from the KyEIS 2014 inventory which is a compilation of information reported by sources to the Kentucky Division of Air Quality (KDAQ). The state-wide inventory was filtered using Excel to identify those sources located within 50 km of the center point between the two monitors.

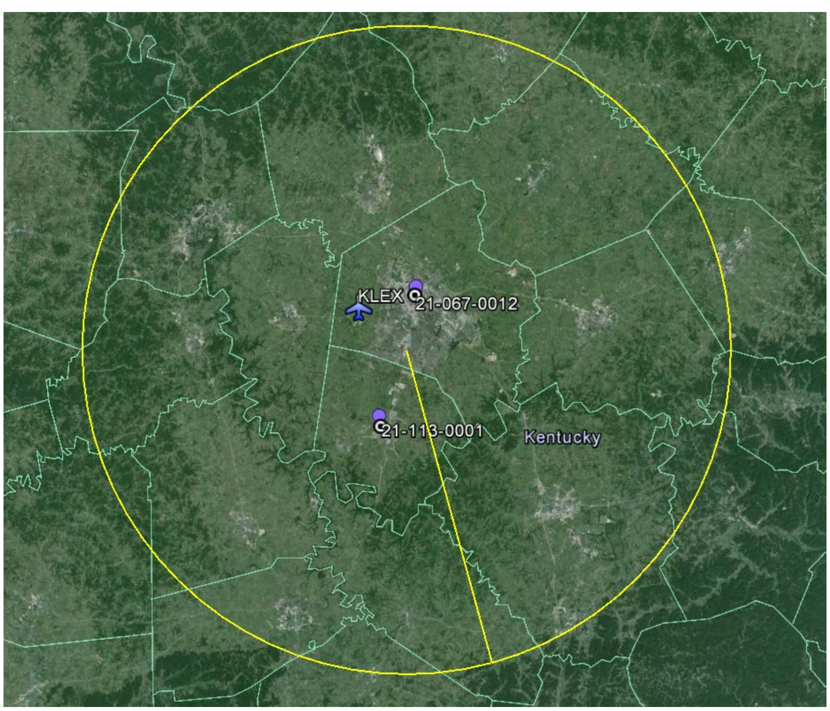
In this area, 213 individual sources with emissions greater than 0.01 tpy actual emissions of SO_2 were modeled for a total of 2,501.6 tpy total in the study domain (one source was 1,031.5 tpy alone but was located over 20 km from the two ambient monitors). When considering all sources in the study area with PTE emission rates greater than 0.01 tpy, 883 sources were included in the modeling with a total of 28,665.6 tpy. Several of these sources had PTEs greater than 1,000 tpy, but examination of actuals showed many of this group reported far lower actual emissions for 2014 than the values reported for PTE. This difference between the PTE and actuals was generally thought to be significant in terms of model performance even prior to performing the modeling.

For all sources in the modeling, no buildings or structures were included given the regional nature of the modeling. Also, the actual and PTE emissions were all reported in tons per year which were averaged over the number of hours in a year to obtain the hourly emission rates.

Model Receptors

For the modeling a small grid of five (5) receptors at each of the two monitor locations was defined for use in AERMOD. One receptor was defined at the monitor location and an additional receptor was defined 100 meters in each of the four cardinal directions (north, south, east, and west) from the monitor location. The purpose of this configuration was to reduce the impact of slight differences in wind direction between the meteorological data set used in AERMOD and the actual wind directions transporting SO_2 from emission sources to the monitor location.[4] Receptor elevations and hill height scales were defined using AERMAP (version 11103) along with terrain elevations from USGS 1-arcsecond NED data.

Figure 1. Modeling Domain Centered Around Lexington-Nicholasville, Kentucky



Meteorological Data

Two sets of meteorological data were generated for this study, one with no ADJ_U* and one with the beta ADJ_U* enabled. the non-regulatory beta ADJ_U* option which adjusts some of the AERMET output turbulence parameters which are adjusted under low wind speed, stable atmospheric conditions.[3] For both data sets, one year (2014) of hourly meteorological data from the Lexington Bluegrass Regional Airport (KLEX, WBAN 03849) surface observation station and Nashville, Tennessee (KBNA, WBAN 13897) upper air station were processed using the latest version of AERMET (15181). The 1-minute ASOS wind data was also included in the preparation of the meteorological data sets using the AERMINUTE (version 15272) meteorological data preprocessor. All regulatory default options were used in AERMET. A minimum threshold wind speed of 0.5 m/s was implemented using the THRESH_1MIN keyword incorporated into AERMET. All hours with wind speeds below this value are treated as "calm" in AERMOD.

Background Concentrations

The Lexington and Nicholasville monitors are located in and near urban areas with regional sources located in all directions. As such these monitors represent concentrations from both industrial sources as well as impacts due to natural sources and smaller anthropogenic sources. Because not all sources in the domain were modeled (i.e., smaller sources were excluded) a rural background was considered. Of the monitors in Kentucky, the most representative monitor for background was in Mammoth Cave National Park (MCNP; Monitor No. 21-061-0501). Based on the 2012-2014 data collected at the Mammoth Cave monitor, this 1-hour average design value concentration was 26.2 $\mu g/m^3$, which is the 3-year average of the 99th percentile of the yearly distribution of 1-hour daily maximum SO_2 concentrations.

AERMOD Scenarios Processed

The AERMOD Model was used to model several scenarios to consider the modeled impacts based on actual versus PTE emissions as well as to consider the use of the beta options for low wind speeds with and without the ADJ_U*. Table 1 shows the various scenarios considered in the modeling.

Table 1. Modeling Scenarios Considered in Modeling

AERMET Options	**Low Wind Speed Beta Options**			
All default	No LOWWIND	LOWWIND1	LOWWIND2	LOWWIND3
With ADJ_U*	No LOWWIND	LOWWIND1	LOWWIND2	LOWWIND3

RESULTS

Modeling was performed for both actual emissions and PTE emissions for all of the scenarios described in Table 1. With no background concentrations added to the results the modeling of actual emissions under predicted concentrations at the monitors. But by adding in the MCNP background, the actual emissions scenarios estimated the concentrations at both monitors quite well. Table 2 shows the estimated concentrations for the actual emissions scenarios with and without ambient background concentrations of SO_2 included. As can be seen in the table, when background concentrations were included, the model demonstration was a good representation of the measured concentrations at the Lexington monitor with some underestimation at the Nicholasville monitor. Table 3 shows the ratios of the modeled to monitored concentrations. Slight improvement is noted when the LOWWIND and ADJ_U* options are included but these improvements are only adjusting the modeled component of the total design concentration and not the background which accounted for over 75 percent of the total concentration. So the fact that the model seems to give comparable results for all low wind speed options may be misleading. Figures 2 and 3 show these comparisons in graphical format showing the inequalities between model and monitors for both the default meteorology as well as that with ADJ_U*.

Table 2. Comparison of Modeled Versus Monitored 1-Hour SO_2 Concentrations – Actual Emissions

Scenario	Monitor Location			
	LEXINGTON 21-067-0012	LEXINGTON 21-067-0012 +MCNP	Nicholasville 21-113-0001	Nicholasville 21-113-0001 +MCNP
Monitor	34.0	34.0	39.2	39.2
Default AERMOD	9.2	35.3	4.5	30.6
LOWWIND1	7.7	33.8	5.4	31.5
LOWWIND2	7.5	33.6	4.1	30.2
LOWWIND3	6.8	32.9	4.1	30.2
ADJ_U*	4.8	30.9	4.5	30.6
ADJ_U* LOWWIND1	5.5	31.6	5.4	31.5
ADJ_U* LOWWIND2	4.3	30.4	4.1	30.2
ADJ_U* LOWWIND3	4.1	30.2	4.1	30.2

Table 3. Comparison of Ratio of Modeled to Monitored 1-Hour SO_2 Concentrations – Actual Emissions

Scenario	Ratio of Modeled to Monitored Concentration			
	LEXINGTON 21-067-0012	LEXINGTON 21-067-0012 +MCNP	Nicholasville 21-113-0001	Nicholasville 21-113-0001 +MCNP
Default	0.27	1.04	0.12	0.78
LW1	0.23	0.99	0.14	0.80
LW2	0.22	0.99	0.10	0.77
LW3	0.20	0.97	0.10	0.77
ADJ_U*	0.14	0.91	0.11	0.78
ADJ_U* LW1	0.16	0.93	0.14	0.80
ADJ_U* LW2	0.13	0.90	0.10	0.77
ADJ_U* LW3	0.12	0.89	0.10	0.77

Figure 2. Comparison of Actual Emissions Modeled Versus Monitored Concentrations Using Default AERMET

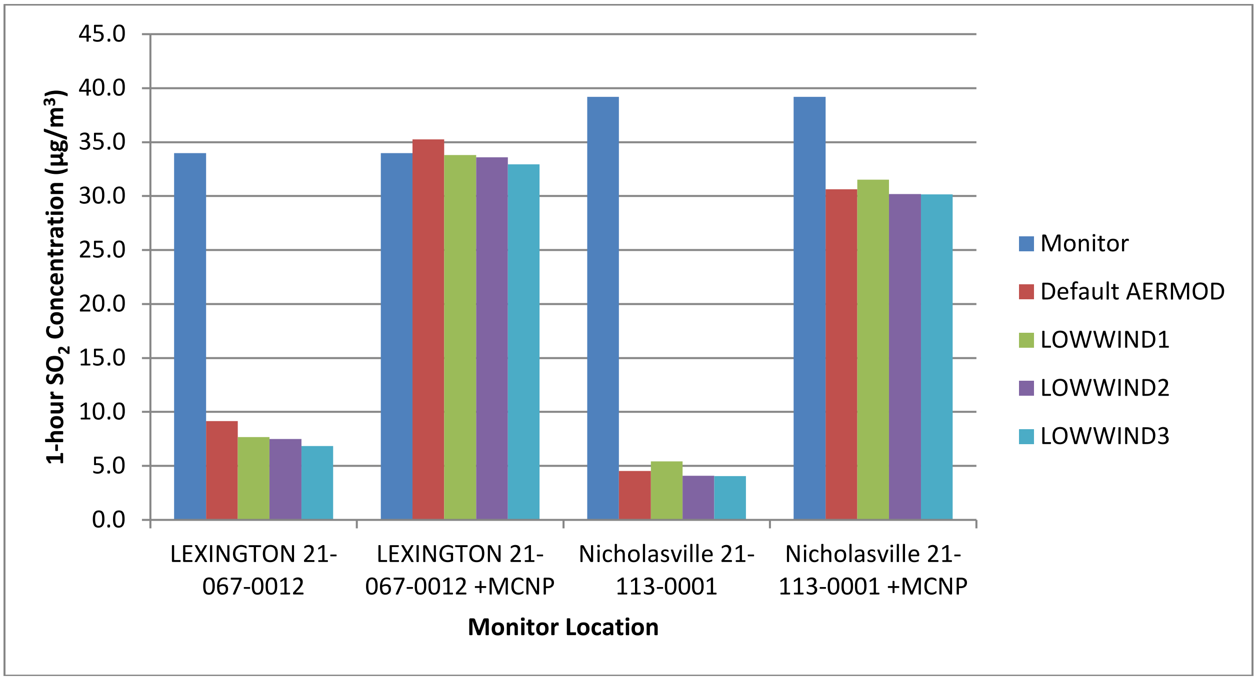
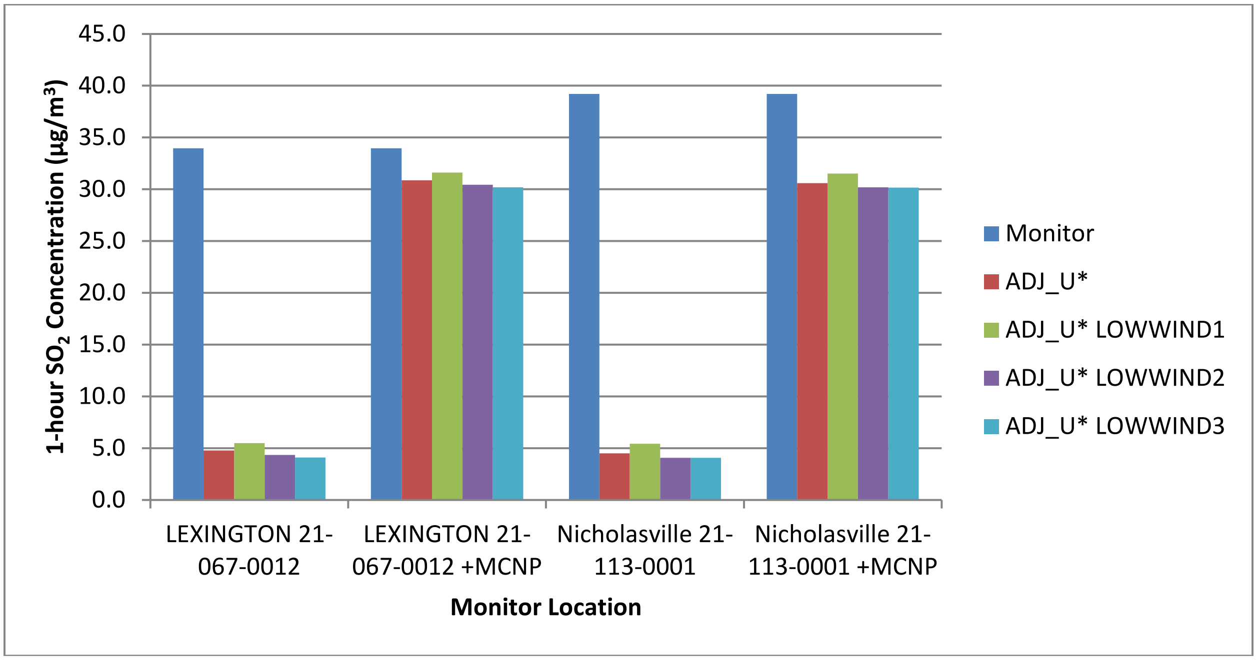


Figure 3. Comparison of Actual Emissions Modeled Versus Monitored Concentrations Using ADJ_U* AERMET



Modeling was also performed for PTE emissions for all of the scenarios described in Table 1. With no background concentrations added in to the results the modeling of the PTE emissions far exceeded the measured concentrations at the monitors. When adding the MCNP background concentration, the over prediction of the total design concentration compared with the measured concentration was increased. Table 4 shows the estimated concentrations for the PTE emissions scenarios with and without ambient background concentrations of SO_2 included. As can be seen in the table, concentrations are over predicted by up to an order of magnitude both with and without consideration of a background concentration. Table 5 shows the ratios of the modeled to monitored concentrations. Over predictions by AERMOD ranging from a factor of 3.62 to 13.34 are seen with lesser over prediction for the ADJ_U* and LOWWIND scenarios. Figures 4 and 5 show these comparisons in a bar graph format to demonstrate the inequalities between model and monitors.

Table 4. Comparison of Modeled Versus Monitored 1-Hour SO_2 Concentrations – PTE Emissions

Scenario	Monitor Location			
	LEXINGTON 21-067-0012	LEXINGTON 21-067-0012 +MCNP	Nicholasville 21-113-0001	Nicholasville 21-113-0001 +MCNP
Monitor	34.0	34.0	39.2	39.2
Default AERMOD	427.1	453.2	381.1	407.2
LOWWIND1	379.5	405.6	291.1	317.2
LOWWIND2	280.3	306.4	272.9	299.0
LOWWIND3	291.4	317.5	275.4	301.5
ADJ_U*	257.9	284.0	181.3	207.4
ADJ_U* LOWWIND1	265.5	291.6	116.4	142.5
ADJ_U* LOWWIND2	252.2	278.3	143.7	169.8
ADJ_U* LOWWIND3	246.2	272.3	142.1	168.2

Table 5. Comparison of Ratio of Modeled to Monitored 1-Hour SO_2 Concentrations – PTE Emissions

Scenario	Ratio of Modeled to Monitored Concentration			
	LEXINGTON 21-067-0012	LEXINGTON 21-067-0012 +MCNP	Nicholasville 21-113-0001	Nicholasville 21-113-0001 +MCNP
Default	12.57	13.34	9.72	10.39
LW1	11.17	11.94	7.42	8.09
LW2	8.25	9.02	6.96	7.63
LW3	8.58	9.34	7.03	7.69
ADJ_U*	7.59	8.36	4.63	5.29
ADJ_U* LW1	7.81	8.58	2.97	3.64
ADJ_U* LW2	7.42	8.19	3.67	4.33
ADJ_U* LW3	7.25	8.01	3.62	4.29

Figure 4. Comparison of PTE Emissions Modeled Vs. Monitored Concentrations Using Default AERMET

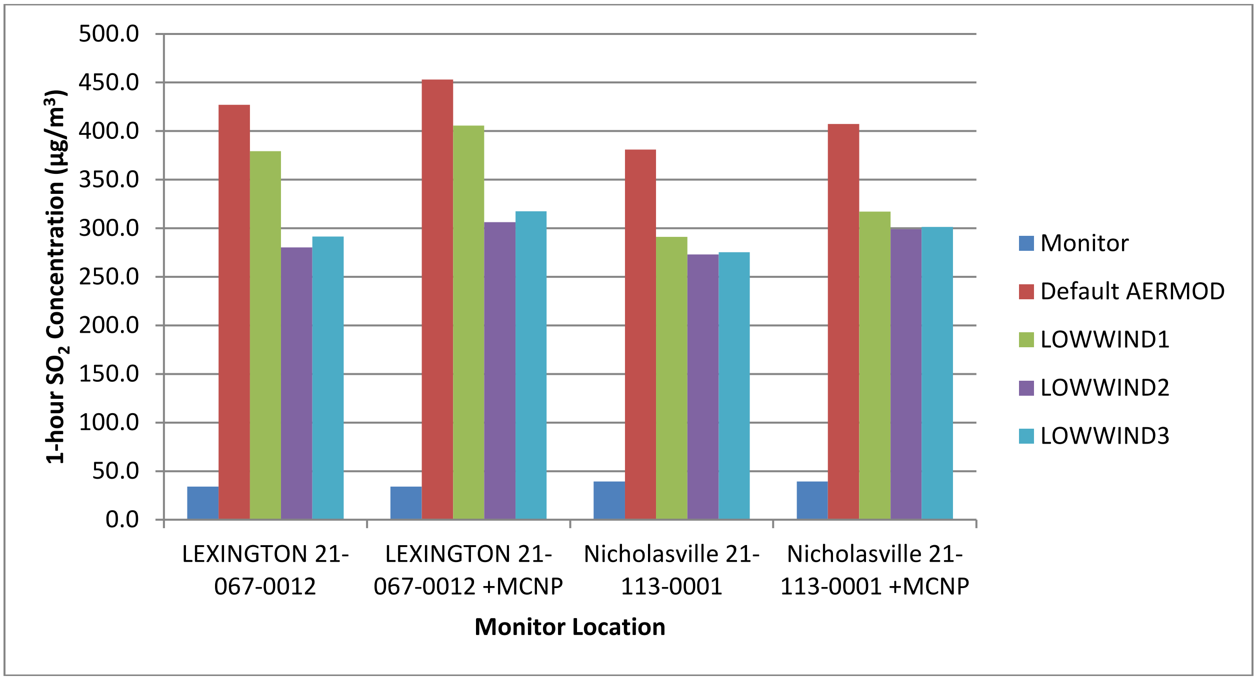
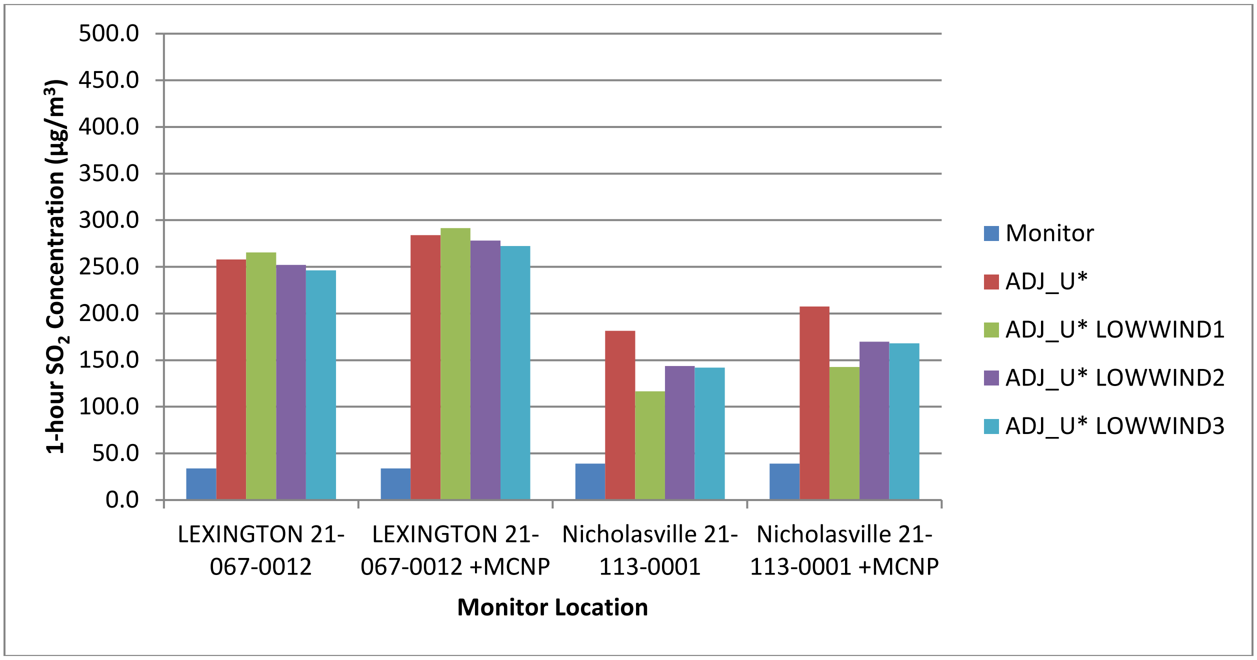


Figure 5. Comparison of PTE Emissions Modeled Vs. Monitored Concentrations Using U*_ADJ AERMET



CONCLUSIONS

The impacts of certain proposed changes to the Guideline of Air Quality Models were explored in this case study. The case study presented here demonstrates that NAAQS compliance demonstrations using PTE emissions from nearby sources can dramatically over predict ground level concentrations at monitor locations. While the use of actual emission rates in NAAQS compliance demonstrations alone was shown to under estimate ground level concentrations at the monitor locations, the selection and application of a representative background concentration along with the modeled results showed much better agreement with actual monitored concentrations. This case study supports EPA's proposal to use actual emissions data for existing regional inventory sources in regulatory modeling analyses. It also highlights the importance of selecting a representative background concentrations for use in NAAQS demonstrations when actual emissions are modeled because the background concentration becomes a larger percentage of the total design concentration against which NAAQS compliance is assessed.

The study also showed that the ADJ_U* and LOWWIND beta options have an impact on modeled results. In this study, the application of the ADJ_U* and LOWWIND options resulted in lower model output concentrations compared with the use of current regulatory default options in AERMOD. However, the impact of the beta options in this case was much smaller than impact of the use of actual emissions as an impact to AERMOD rather than PTE.

REFERENCES

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KEYWORDS

AERMOD, NAAQS, Low Wind, SO_2, Regional Inventories