ADMS 5 Complex Terrain Validation
Clifty Creek Power Plant

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November 2016

1 Introduction

The Clifty Creek power plant[1] is located in southern Indiana on the north side of the Ohio River (see **Figure 1**). The area immediately north of the facility is characterized by cliffs rising about 115 m above the river and intersected by creek valleys. The tops of the stacks extend about 80 to 100 m above the top of the cliffs on both sides of the river. Three 208 m stacks were modeled in this evaluation.

There were six SO_2 monitors on the surrounding terrain. One was located in the river valley approximately 8 km to the east (upriver) at about the same elevation as the sources. Another was located 3 km south of the facility on Liberty Ridge near the meteorological tower on the south side of the Ohio River and about 110 m above stack base. The remaining four monitors were located on the terrain north and north-east of the facility at about 125 m above the base of the stacks, ranging in distance from four to 15 km.

Meteorological data from this field study covered 1 January 1975 through to 31 December 1975. The on-site meteorological data were recorded on an instrumented meteorological tower 3 km south of the facility (across the river in Kentucky) on Liberty Ridge.

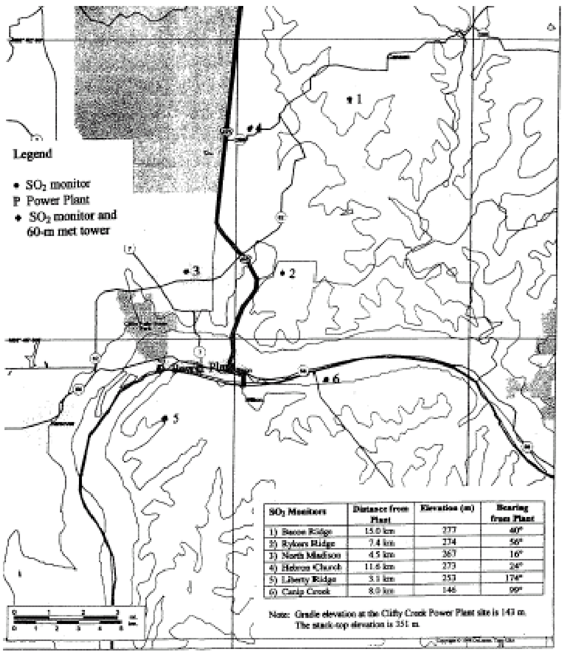

Figure 1 − Monitoring locations in the vicinity of the Clifty Creek power plant.

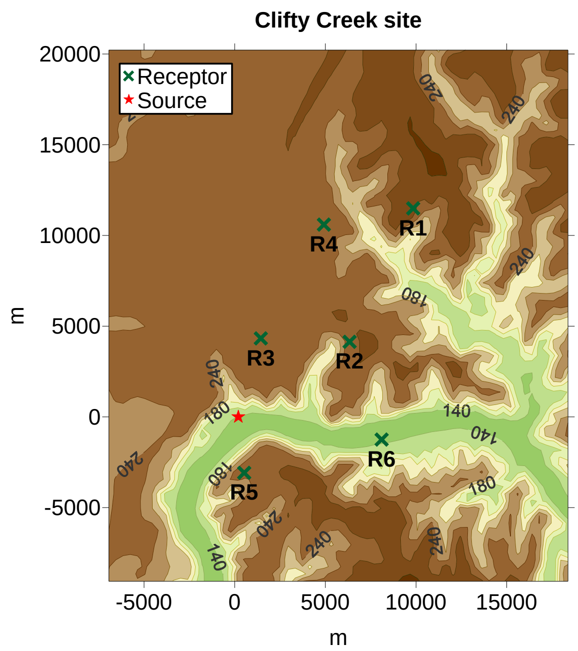

Figure 2 − Modelled area around the Clifty Creek power plant (met. tower close to R5 monitor.)

[1] Note that the study description and **Figure 1** have been taken directly from the document [1].

The input data for the ADMS runs were taken from the AERMOD files downloaded from the United States Environmental Protection Agency website [2]. These data include the observed concentrations that are used for comparison with the ADMS modelled concentrations.

This document compares the results of ADMS 5.1.2.0 (hereafter referred to as ADMS 5.1) with those of ADMS 5.2.0.0 (hereafter referred to as ADMS 5.2).

Section 2 describes the input data used for the model. The results are presented in Section 3 and discussed in Section 4.

2 Input data

2.1 Study area

The study area is located around 38.7°N. The roughness length varies, depending on wind direction and month as shown in **Table 1**.

Terrain data included in the modelling covered a 20 km × 28 km area (**Figure 2**) with terrain data points located every 300-400 m.

Time of the year	Wind sector	
	245-185°	185-245°
January to March	0.20	0.40
April to May	0.30	0.50
June to August	0.40	0.60
September to November	0.30	0.50
December	0.20	0.40

Table 1 – Surface roughness length (m) according to wind sector.

2.2 Source parameters

The source parameters are summarised in **Table 2**. The minimum exit velocity for all stacks is just under 25 m/s. The maximum exit velocity for stack 1 is 57 m/s, whereas stacks 2 and 3 have exit velocity peaks of 103.5 and 102.7 m/s. Emissions rates vary from 3-3682 g/s.

Source name	Pollutant	Location	Stack height (m)	Exit V (m/s)	Exit T (°C)	Diameter (m)	Emission rate (g/s)
Stack 1	SO_2	200, 0	207.9	varied	172.22	4.63	varied
Stack 2	SO_2	200, 0	207.9	varied	172.22	4.63	varied
Stack 3	SO_2	200, 0	207.9	varied	172.22	4.63	varied

Table 2 – Source input parameters. T is the temperature, V the velocity.

2.3 Receptors

The receptor network consists of 6 monitors, ranging from 4 to 15 km from the sources. All receptors are modelled as ground level receptors.

Figure 2 shows the receptor network used in the experiment. **Table 3** gives the receptor coordinates in a local coordinate system; for reference, the stacks are located at (200,0).

Receptor name	Location
R1	9842, 11491
R2	6335, 4138
R3	1440, 4326
R4	4918, 10597
R5	524, -3083
R6	8102, -1251

Table 3 – Receptor point locations.

2.4 Meteorological data

One year of hourly sequential data from 1 January 1975 to 31 December 1975 was used. The wind rose is shown in **Figure 3**. **Table 4** gives the detail of the modelled conditions.

Conditions		ADMS 5.1	ADMS 5.2
Hours modelled	Stable conditions	5012 (59%)	5012 (59%)
	Neutral conditions	943 (11%)	943 (11%)
	Unstable conditions	2556 (30%)	2556 (30%)
	Total	*8511 (100%)*	*8511 (100%)*
Hours not modelled	Calm conditions	0	0
	Wind speed at 10 m < 0.75 m/s	248	248
	Inadequate data	1	1
	Total	*249*	*249*

Table 4 – Meteorological conditions. Percentage values are computed with respect to the total number of modelled hours.

The wind speeds vary from 0.27 to 21.1 m/s and the surface temperature from -18.8 to 34.4°C. The height of the recorded wind measurement was 60 m. The wind rose is shown in **Figure 3**.

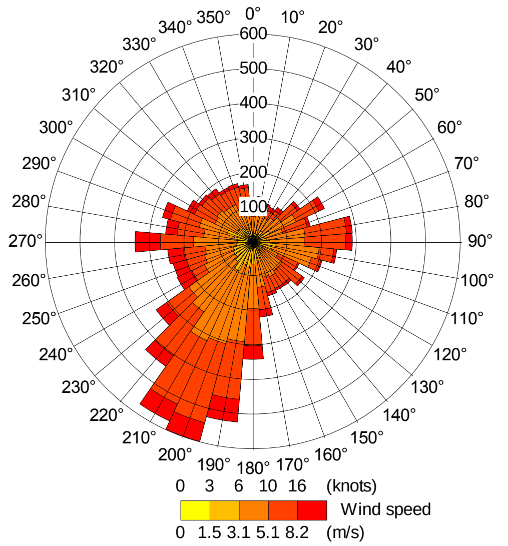

Figure 3 – Wind rose from meteorological data.

3 Results

Scatter plots and quantile-quantile plots of model results against observed data are presented in Section 3.1. Other statistical analysis is presented in Section 3.2. The graphs and statistical analysis have been produced by the MyAir Toolkit for Model Evaluation [4].

3.1 Scatter and quantile-quantile plots

The modelled SO_2 concentrations are compared to observed hourly concentrations (μg/m^3). **Figures 4** and **5** show frequency scatter plots and quantile-quantile plots of results. Note that these quantile-quantile plots are *linear*; care should be exercised when comparing these plots with similar ones presented with *logarithmic* axes.

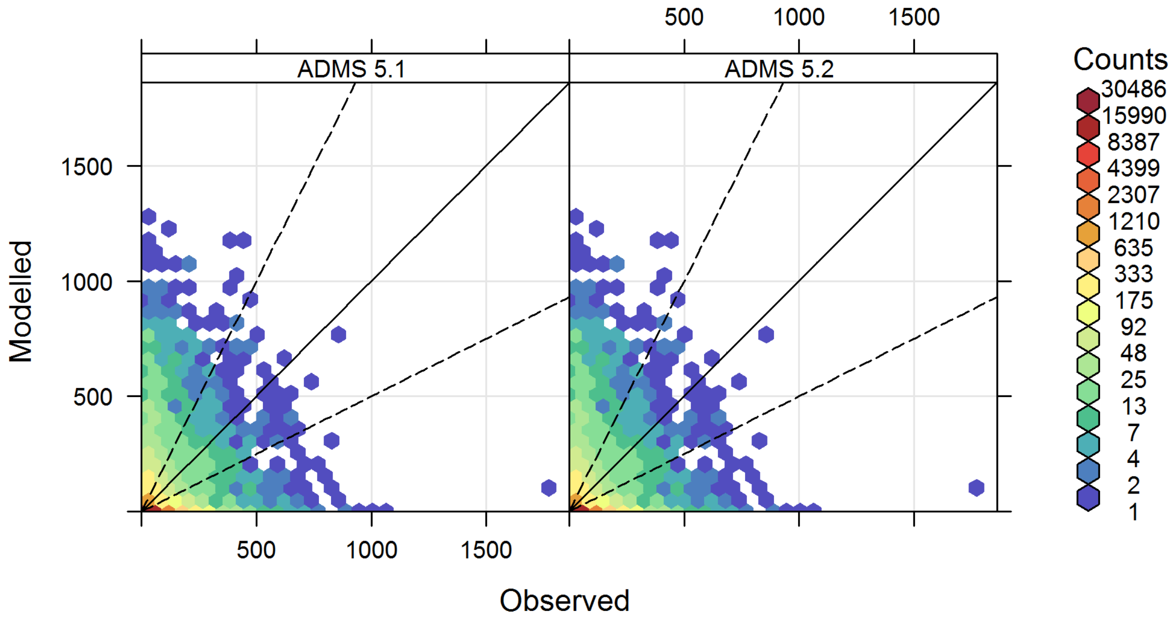

Figure 4 – Scatter plots of ADMS results against observed data for all receptors (μg/m³).

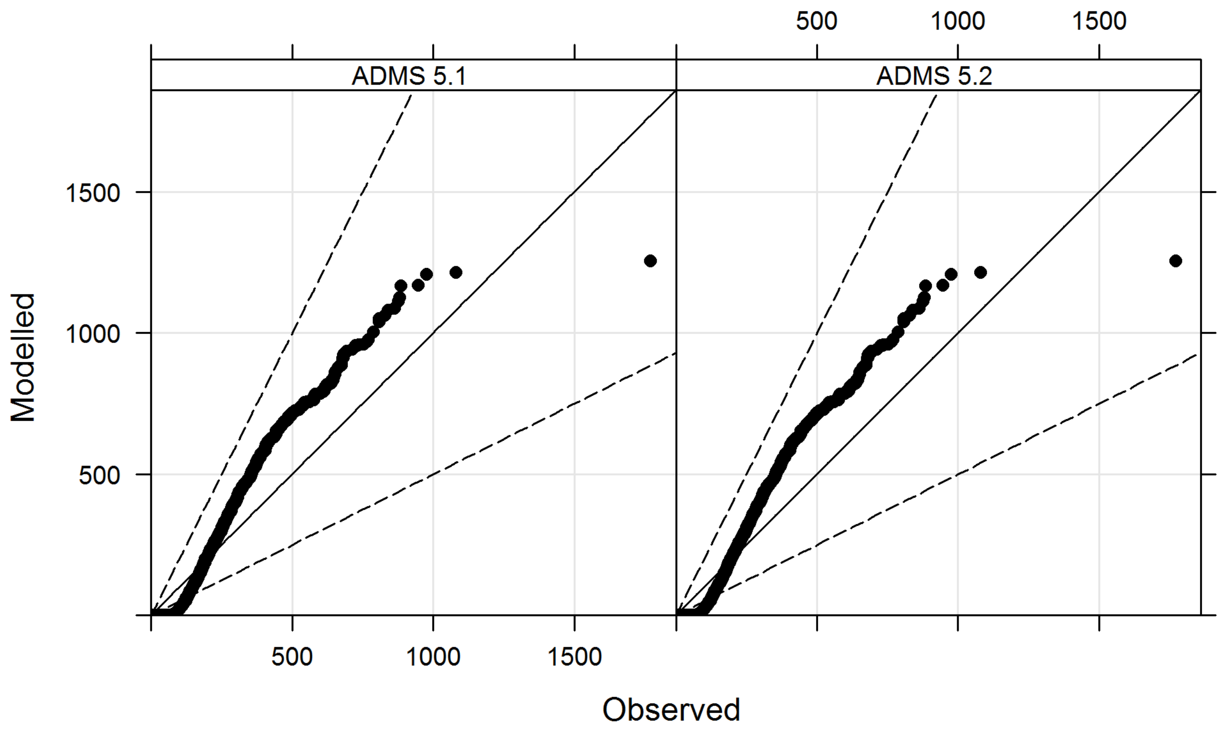

Figure 5 – Quantile-quantile plots of ADMS results against observed data for all receptors (µg/m³).

3.2 Statistics

Table 5 compares the modelled and observed maximum 1-hour, 3-hour and 24-hour average concentrations at the receptor points. **Table 6** compares the corresponding robust highest concentrations, where this statistic is defined by:

$$\text{robust highest concentration} = \chi(n) + (\chi - \chi(n))\ln\left(\frac{3n-1}{2}\right),$$

where n is the number of values used to characterise the upper end of the concentration distribution, χ is the average of the $n-1$ largest values, and $\chi(n)$ is the n^{th} largest value; n is taken to be 26, as in Perry et *al*. [3].

Statistics	Data	Concentrations (µg/m³)						Mean M/O ratio
		P1	P2	P3	P4	P5	P6	
1-hour maximum	Observed	887	809	1772	976	692	1081	-
	ADMS 5.1	720	1204	1195	966	1079	1256	1.11
	ADMS 5.2	720	1204	1195	966	1079	1256	1.11
3-hour maximum	Observed	579	536	857	613	384	632	-
	ADMS 5.1	567	857	935	734	600	792	1.28
	ADMS 5.2	567	857	935	734	600	792	1.28
24-hour maximum	Observed	267	195	338	165	153	178	-
	ADMS 5.1	165	159	266	217	149	113	0.86
	ADMS 5.2	165	159	266	217	149	113	0.86

Table 5 – Observed (O) and modelled (M) maximum concentrations (ug/m³) per receptor point, and the mean ratio of modelled/observed values for each statistic.

Statistics	Data	Robust Highest Concentrations (µg/m³)						Mean M/O ratio
		P1	P2	P3	P4	P5	P6	
1-hour RHC	Observed	892	926	1334	973	523	856	-
	ADMS 5.1	855	1142	1274	1020	1272	1235	1.35
	ADMS 5.2	855	1142	1274	1020	1272	1235	1.35
3-hour RHC	Observed	667	589	782	605	390	623	-
	ADMS 5.1	590	912	973	729	649	608	1.25
	ADMS 5.2	590	912	973	729	649	608	1.25
24-hour RHC	Observed	245	196	203	188	146	166	-
	ADMS 5.1	140	170	259	217	121	118	0.90
	ADMS 5.2	140	170	259	217	121	118	0.90

Table 6 – Observed (O) and modelled (M) robust highest concentrations (RHC) per receptor point, and the mean ratio of modelled/observed RHC for each statistic (number of points = 26).

4 Discussion

The scatter and quantile-quantile plots (**Figures 4** and **5**) show good agreement between modelled and observed concentrations for both ADMS 5.1 and ADMS 5.2. The scatter plots compare predicted and measured concentrations at a particular location at a particular time, i.e. an (x,t) pairing. The quantile-quantile plots compare the distribution of predicted and measured concentrations during the period having abandoned the (x,t) pairing. Predicting the distribution of concentrations accurately is relevant to calculations for permitting purposes, where the comparison with air quality limits is more important than accurately predicting a time series of concentrations at each location. The latter is a harder task.

The pollutant monitored for this study is SO_2. There are a number of issues with using SO_2 as a tracer, which include:

- The detection limits of monitors are usually of the order of 16 µg/m³, and concentrations below these are set to one-half of the limit. This leads to considerable inaccuracy when modelled concentrations are low.
- SO_2 is released from other sources. If estimates of these background concentrations are not available, then the model will underestimate concentrations, particularly long-term averages.

Comparisons between modelled and observed annual average concentrations are not presented in this report due to the issues with monitor detection limits and background data.

The predictions of maximum concentrations and robust highest concentrations presented in **Tables 5** and **6** show good model performance considering the complexity of the domain modelled.

Consideration of the scatter and quantile-quantile plots show that concentrations predicted by ADMS 5.2 are very similar to those predicted by ADMS 5.1.

5 References

[1] Paine, R.J, Lee, R.F, Brode, R, Wilson, R.B, Cimorelli, A.J., Perry, S.G., Weil, J.C., Venkatram, A, and Peters, W., 1998: Model Evaluation Results for AERMOD (draft). United States Environmental Protection Agency.

[2] United States Environmental Protection Agency website, Model Evaluation Databases. http://www.epa.gov/scram001/dispersion_prefrec.htm

[3] Perry, S. G., Cimorelli, A. J., Paine, R.J., Brode, R.W., Weil, J.C., Venkatram, A., Wilson, R.B., Lee, R.F, & Peters, W.D. 2005 AERMOD: A Dispersion Model for Industrial Source Applications. Part II: Model Performance against 17 Field Study Databases. *J. Appl. Met.* **44**, pp 694-708.

[4] Stidworthy A, Carruthers D, Stocker J, Balis D, Katragkou E, and Kukkonen J, 2013: *MyAir Toolkit for Model Evaluation*. 15th International Conference on Harmonisation, Madrid, Spain, May 2013.