ADMS 6 Buildings & Complex Terrain Validation
Martins Creek Steam Electric Station

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1 Introduction

The Martins Creek Steam Electric Station[1] [1] is located in a rural area along the Delaware River on the Pennsylvania/New Jersey border, approximately 30 km north-east of Allentown, PA and 95 km north of Philadelphia, PA.

The area can be characterised by complex terrain rising above the stacks. Sources included multiple tall stacks ranging from 122 to 183 m in height. The seven SO_2 monitors were located on Scotts Mountain which is about 2.5-8 km south-east of the Martins Creek facility.

On-site meteorological data covered the period from 1 May 1992 through 19 May 1993. Hourly temperature, wind speed and wind direction at 10 m were recorded from an instrumented tower located in a flat area approximately 2.5 km west of the plant. In addition, hourly multi-level wind measurements were taken by a SODAR located approximately 3 km south-west of the Martins Creek station.

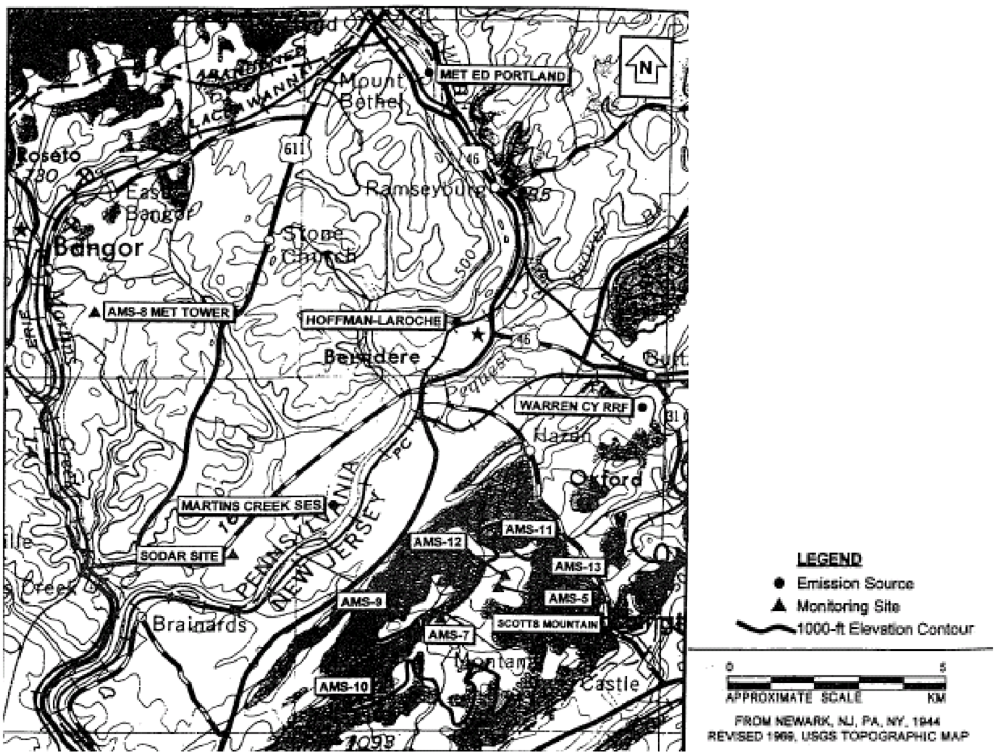

Figure 1 – Locations of monitors, meteorological stations and emissions sources.

[1] Note that the study description has been taken directly from the document [2] and **Figure 1** from the document [3].

The input data for the ADMS runs were taken from the AERMOD files downloaded from the United States Environmental Protection Agency website [4]. These data included the observed concentrations that have been used for comparison with the ADMS modelled concentrations.

This document compares results from ADMS 5.2.0.0 (hereafter referred to as ADMS 5.2) with results from ADMS 6.0.0.1 (hereafter referred to as ADMS 6.0).

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 site is located at 40.79°N. The roughness length was dependent on wind direction and month. The value ranged from 0.1 (December to March, wind direction 260-179º) to 0.6 (June to August, wind direction 180-259º).

Terrain data included in the modelling covered a 20 km x 20 km area centred on the source locations. Terrain data points were located every 625 m within this area. **Figure 2** shows the modelled terrain area.

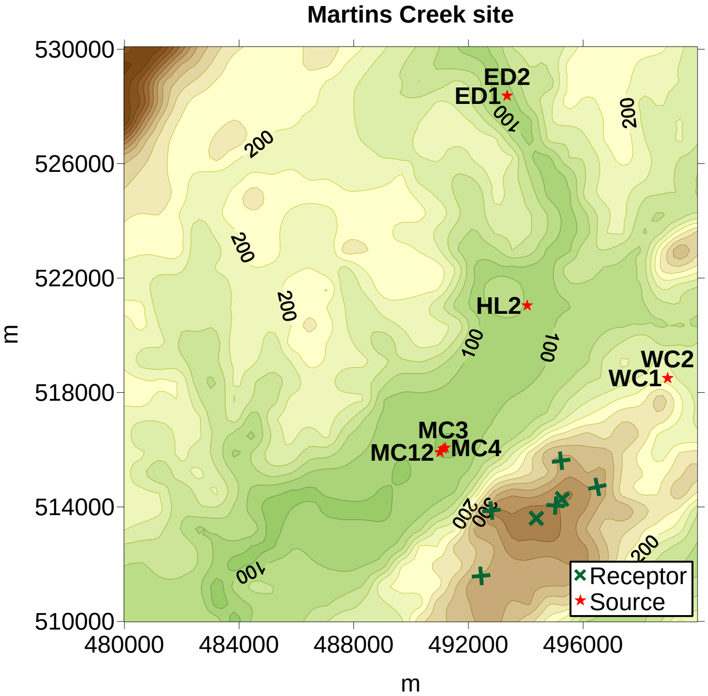

Figure 2 – Modelled terrain area around Martin Creek steam electric station site.

2.2 Source parameters

The source parameters are summarised in **Table 1**.

Exit velocities varied from 0.2-45.5 m/s. Exit temperatures varied 0.5-194.5ºC and emissions rates varied from 0-1321.9 g/s.

Source name	Pollutant	Location	Stack height (m)	Exit V (m/s)	Exit T (°C)	Diameter (m)	Emission rate (g/s)
MC12	SO_2	491010, 515910	182.9	varied	varied	5.30	varied
MC3	SO_2	491123, 516030	182.9	varied	varied	6.90	varied
MC4	SO_2	491190, 516068	182.9	varied	varied	6.90	varied
ED1	SO_2	493350, 528370	121.9	varied	varied	3.10	varied
ED2	SO_2	493350, 528370	121.9	varied	varied	3.60	varied
HL2	SO_2	494050, 521040	67.0	varied	varied	2.70	varied
WC1	SO_2	498950, 518500	64.9	varied	varied	1.87	varied
WC2	SO_2	498950, 518500	64.9	varied	varied	1.87	varied

Table 1 − Source input parameters. T is the temperature, V the velocity.

2.3 Receptors

Receptor name	Location
Point1	495041, 514049
Point2	494369, 513602
Point3	492801, 513876
Point4	492440, 511592
Point5	495232, 515616
Point6	495266, 514282
Point7	496497, 514701

Table 2 – Receptor point locations.

The receptor network consists of 7 points, ranging from 2 to 10 km from the sources. All receptors were modelled as ground level receptors. **Figure 2** shows the receptor network used in the experiment and **Table 2** summarises their locations.

2.4 Meteorological data

The experiment used just over one year of hourly sequential data from 1st May 1992 to 19th May 1993. **Table 3** gives the detail of the modelled meteorological conditions. The wind speeds at 90 m varied from 0.1 to 13.6 m/s and the ambient temperature varied from -17 to 32°C. The criteria for the stability categories are as follows, where H is the boundary layer height and L_{MO} is the Monin-Obukhov length, as calculated by the model's meteorological processor:

Stable: $H/L_{MO} > 1$

Neutral: $-0.3 \leq H/L_{MO} \leq 1$

Convective: $H/L_{MO} < -0.3$

Conditions		ADMS 5.2	ADMS 6.0
Hours modelled	Stable conditions	4450 (60%)	4449 (60%)
	Neutral conditions	325 (4%)	320 (4%)
	Unstable conditions	2603 (35%)	2592 (35%)
	Total	*7378 (100%)*	*7361 (100%)*
Hours not modelled	Calm conditions	0	0
	Wind speed at 10 m < 0.75 m/s	1209	1226
	Inadequate data	629	629
	Total	*1838*	*1855*

Table 3 – Meteorological conditions. Percentage values are computed with respect to the total number of modelled hours.

The wind rose is shown in **Figure 3**. The model also used the recorded wind at 10, 90, and every 30 m until 420 m above ground level, and the temperature at 10 m.

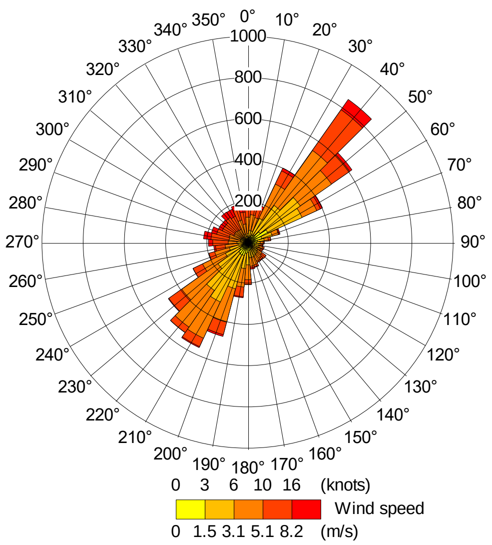

Figure 3 – Wind rose

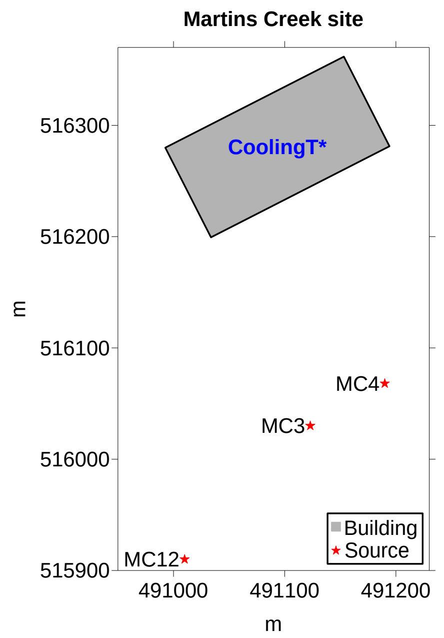

Figure 4 – The building location

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2.5 Buildings

The building dimensions are given in **Table 4**.

The building location relative to the modelled stacks is shown in **Figure 4**.

Building name	Length (m)	Width (m)	Height (m)	Angle (°)
CoolingT	180.2	90.4	90.0	63

Table 4 – Dimensions of the building.

3 Results

Scatter plots and quantile-quantile plots of model results against observed data are presented in Section 3.1. Other statistical analysis of the data is presented in Section 3.2. The graphs and statistical analysis have been produced by the Model Evaluation Toolkit v5.2 [6].

3.1 Scatter and quantile-quantile plots

The modelled SO_2 concentrations are compared to observed hourly concentrations (ug/m^3). **Figure 5** shows the 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.

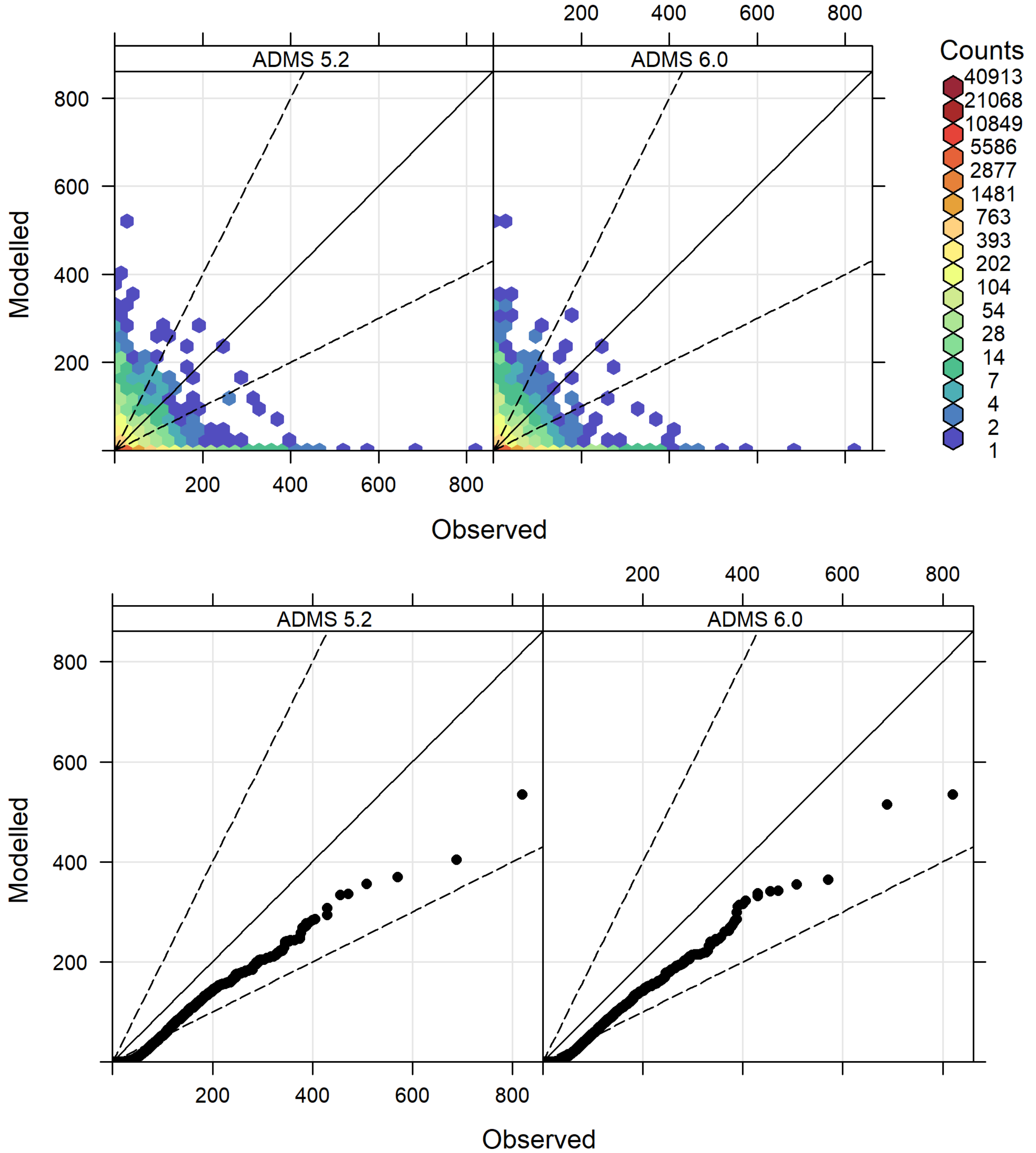

Figure 5 − Scatter plots and quantile-quantile plots of ADMS results against observed concentrations (ug/m^3).

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:

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

where n is the number of values used to characterise the upper end of the concentration distribution, $\bar{\chi}$ 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*. [5].

Statistics	Data	Maximum Concentrations (ug/m^3)							Mean M/O ratio
		P1	P2	P3	P4	P5	P6	P7	
1-hour maximum	Observed	375	571	820	689	430	383	456	-
	ADMS 5.2	355	293	369	404	277	333	534	0.74
	ADMS 6.0	364	299	355	279	514	342	534	0.80
3-hour maximum	Observed	349	571	398	689	307	283	456	-
	ADMS 5.2	176	246	185	222	157	246	534	0.61
	ADMS 6.0	176	249	200	222	173	246	534	0.62
24-hour maximum	Observed	88	89	192	88	88	93	63	-
	ADMS 5.2	53	65	52	44	42	47	58	0.57
	ADMS 6.0	50	59	46	43	45	51	60	0.57

Table 5 - Observed (O) and modelled (M) maximum concentrations (ug/m^3) per receptor point, and the mean ratio of modelled/observed values for each statistic.

Statistics	Data	Robust Highest Concentrations (ug/m^3)							Mean M/O ratio
		P1	P2	P3	P4	P5	P6	P7	
1-hour RHC	Observed	443	410	638	432	474	387	471	-
	ADMS 5.2	360	349	370	351	301	325	328	0.75
	ADMS 6.0	371	344	376	309	349	368	399	0.79
3-hour RHC	Observed	269	262	476	398	328	281	339	-
	ADMS 5.2	215	210	186	186	203	229	243	0.66
	ADMS 6.0	214	204	212	179	222	221	271	0.68
24-hour RHC	Observed	68	69	177	74	75	74	64	-
	ADMS 5.2	47	46	46	50	43	48	51	0.62
	ADMS 6.0	48	48	49	49	41	51	50	0.62

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 (**Figure 5**) show relatively good agreement between modelled and observed concentrations. 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.

According to the AERMOD source files [4], the observed concentrations have been adjusted to account for background concentrations of SO_2. The method used to make this adjustment is not known. However, the number of non-zero observations for which the model is predicting zero concentrations would indicate that there may be some background concentrations still unaccounted for. 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 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 and **6** show good model performance considering the complexity of the domain modelled. The model has a tendency to predict lower maximum concentrations than those observed. However, this apparent underestimate of observed maximum concentrations is a usual feature of a model that has been developed to represent the ensemble mean i.e. a model that neglects turbulent fluctuations. The ADMS fluctuations module may be used to estimate the likelihood of concentrations greater than or less than the ensemble mean. It is now possible to run the fluctuations module in conjunction with the buildings module in ADMS 6.0; this was not possible in ADMS 5.2.

The differences between ADMS 5.2 and ADMS 6.0 are generally small. ADMS 6.0 performs slightly better than ADMS 5.2 at the top end of the quantile-quantile plots and the mean modelled to observed ratios are also either better than or equal to ADMS 5.2 in all cases. There has been a change to the meteorological processor, in which the solar elevation angle is calculated at the middle of the hour rather than the end of it, which is having some effect in daylight hours. The ADMS 6.0 buildings code developments relating to how plumes that directly impact a building are modelled as well as how the ground-level plume downwind of the recirculation region is modelled are unlikely to have a large effect in this study due to the relative height of the buildings-affected sources compared with the building.

5 References

[1] TRC, 1994: Air Quality Model Performance Evaluation and Comparison Study for Martins Creek Steam Electric Station. TRC Project No. 14715-R61. TRC Environmental Corporation, Windsor, CT.

[2] United States Environmental Protection Agency, 2003: AERMOD, Latest Features and Evaluation Results. EPA-454/R-03-003.

[3] 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.

[4] United States Environmental Protection Agency website, *Model* Evaluation Databases. https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models

[5] 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.

[6] 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.