ADMS 5 Complex Terrain Validation
Lovett Power Plant

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1 Introduction

The Mirant Lovett[1] power plant is located in Tompkins Cove, on the Hudson river in the state of New York, about 30 miles upstream of New York city. Terrain elevations vary significantly over the study area, with altitudes in the river valley close to zero and maximum altitudes close to the receptors of approximately 270 m − see **Figures 1** and **2**.

On-site meteorological data included wind speeds, temperatures and turbulence data at heights of 10, 50 and 100 m.

A long term SO_2 sampling experiment was undertaken during the whole year 1988. The buoyant, continuous SO_2 source was released from a 145 m stack.

Data were collected from 12 monitoring sites located 2 to 3 km from the plant. Hourly, 3 hour, 24 hour and annual average concentrations are available from 9 of them only.

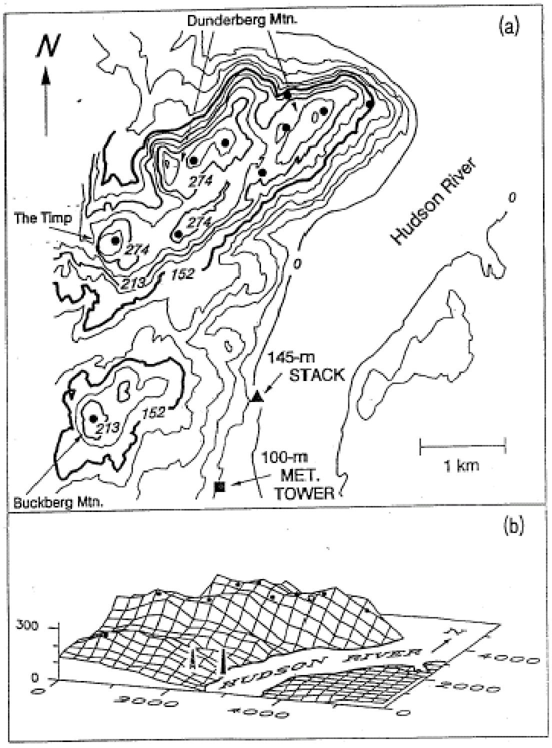

Figure 1 − (a) Monitoring network used in the Lovett study. (b) Receptors, stack and on-site met. station shown with the terrain elevation.

The input data for the ADMS runs were taken from the AERMOD files downloaded from the United States Environmental Protection Agency website [3]. These data includes the observed concentrations that are used for comparison with the ADMS modelled concentrations.

Figure 2 − Top: 360° panorama from Dunderberg Mountain (receptors DD). Bottom: 270° panoramic view from the Timp (location of receptor TIMP3).

[1] Note that the study description and **Figure 1** have been taken from the documents [1] and [2].

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

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 41.3°N and 74.0°W. The roughness length used in the study depends on wind direction and month as shown in **Table 1**.

Time of the year	Wind sector					
	0-35°	35-60°	60-130°	130-175°	175-225°	225-360°
January to March	0.750	0.001	0.300	0.001	0.750	1.500
April to May	0.850	0.001	0.500	0.001	1.000	1.500
June to August	1.000	0.001	0.700	0.001	1.500	1.500
September to November	0.900	0.001	0.500	0.001	1.250	1.500
December	0.750	0.001	0.300	0.001	0.750	1.500

Table 1 − Surface roughness length (m).

Terrain data included in the modelling covered a 17 km × 20 km area (**Figure 3**); terrain data points were located every 260 m within this area. **Figure 2** shows panoramic views from two of the receptors, illustrating the significant changes in elevation over the study area.

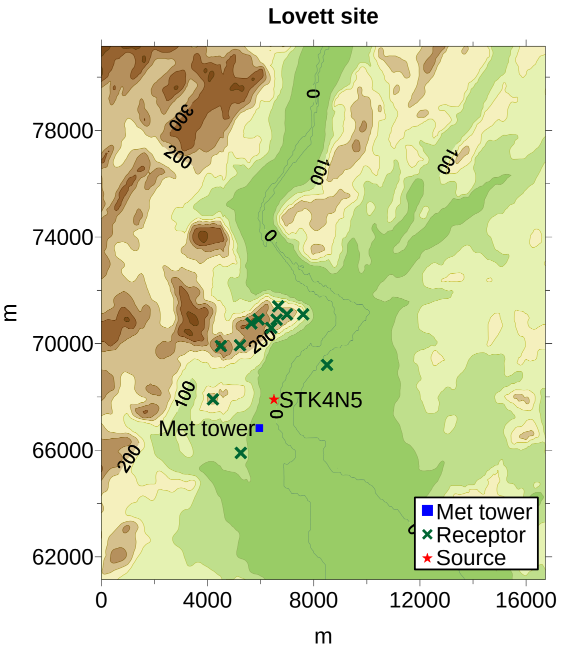

Figure 3 − Modelled Lovett plant site.

2.2 Source parameters

The source parameters are summarised in **Table 2**. The gas exit velocity and temperature range between 4 and 39 m/s and between 69 and 163°C respectively. The SO_2 emission rate ranges between 1 and 396 g/s. Note that for over 13% of year, the emission rate from the source was zero.

Source name	Pollutant	Location	h (m)	V (m/s)	T (°C)	D (m)	Q (g/s)
STK4N5	SO_2	6500, 67900	145	varied	varied	4.5	varied

Table 2 − Source input parameters. h is the stack height, V the exit velocity, T the exit temperature, D the diameter and Q the emission rate.

2.3 Receptors

The receptor network consists of 9 monitors, ranging from 2 to 3 km from the sources. All receptors are modelled as ground level receptors. During the experiment, background measurements were apparently taken from a further 3 sites, but these data are unavailable and therefore no account of background concentrations has been taken in the results presented in Section 3. **Figure 4** shows the receptor network and **Table 3** gives their spatial coordinates.

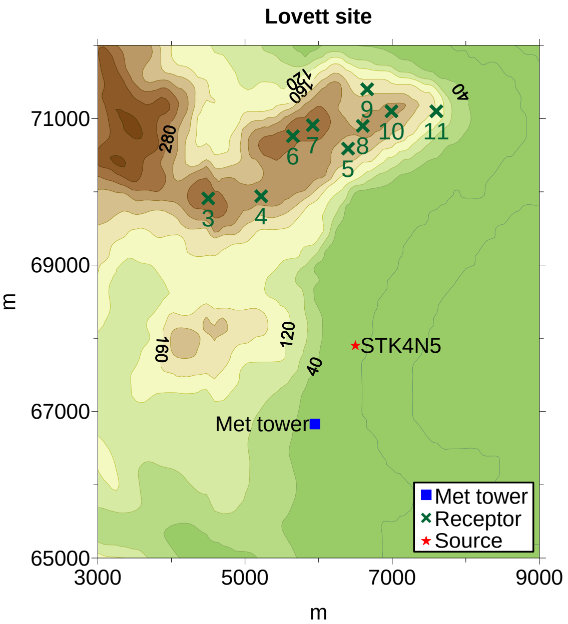

Figure 4 − Enlarged view of the modelled area, showing the receptor locations on Dunderberg Mountain and the Timp.

Output point			X (m)	Y (m)
3	TIMP3	The Timp	4500	69910
4	DD4	Dunderberg Mtn	5220	69940
5	DD5	Dunderberg Mtn	6400	70590
6	DD6	Dunderberg Mtn	5650	70760
7	DD7	Dunderberg Mtn	5920	70910
8	DD8	Dunderberg Mtn	6600	70900
9	DD9	Dunderberg Mtn	6660	71400
10	DD10	Dunderberg Mtn	6990	71100
11	DD11	Dunderberg Mtn	7600	71100

Table 3 − Receptor point locations.

2.4 Meteorological data

One year of hourly sequential data from 1 January 1988 to 31 December 1988 was used. On-site wind speed, temperature, and vertical and horizontal turbulence data were available at heights of 10, 50 and 100 m above ground level. Cloud cover information was available from a meteorological station in Albany, NY.

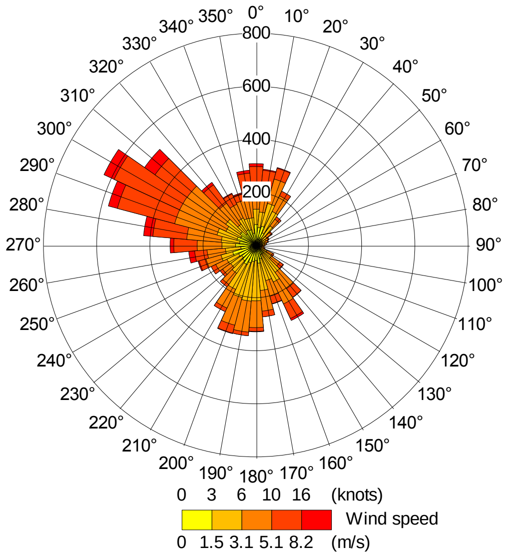

Figure 5 − Wind rose.

Conditions		ADMS 5.1	ADMS 5.2
Hours modelled	Stable conditions	5117 (63%)	5117 (63%)
	Neutral conditions	486 (6%)	486 (6%)
	Unstable conditions	2571 (31%)	2571 (31%)
	Total	*8174 (100%)*	*8174 (100%)*
Hours not modelled	Calm conditions	0	0
	Wind speed at 10 m < 0.50 m/s	495	495
	Inadequate data	115	115
	Total	*610*	*610*

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

The prevailing wind at 100 m was from north-west, which disperses the tracer from the stack away from the receptor points. As the mean wind speed at 10 m is 1.2 m/s, with a maximum of 6.6 m/s, the power plant appears well sheltered from the prevailing wind by the hills to the north and west. The wind rose is shown in **Figure 5** for the wind at 100 m in height.

There is a wide annual variation in temperature with a minimum of -18.5°C and a maximum of 35.6°C.

The model also used a profile of the wind speed and temperature at 10, 50 and 100 m.

Table 4 gives the detail of the modelled meteorological conditions.

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 [5].

3.1 Scatter and quantile-quantile plots

The modelled SO_2 concentrations are compared to observed hourly concentrations (µg/m^3). **Figure 6** shows the scatter plots and the 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.

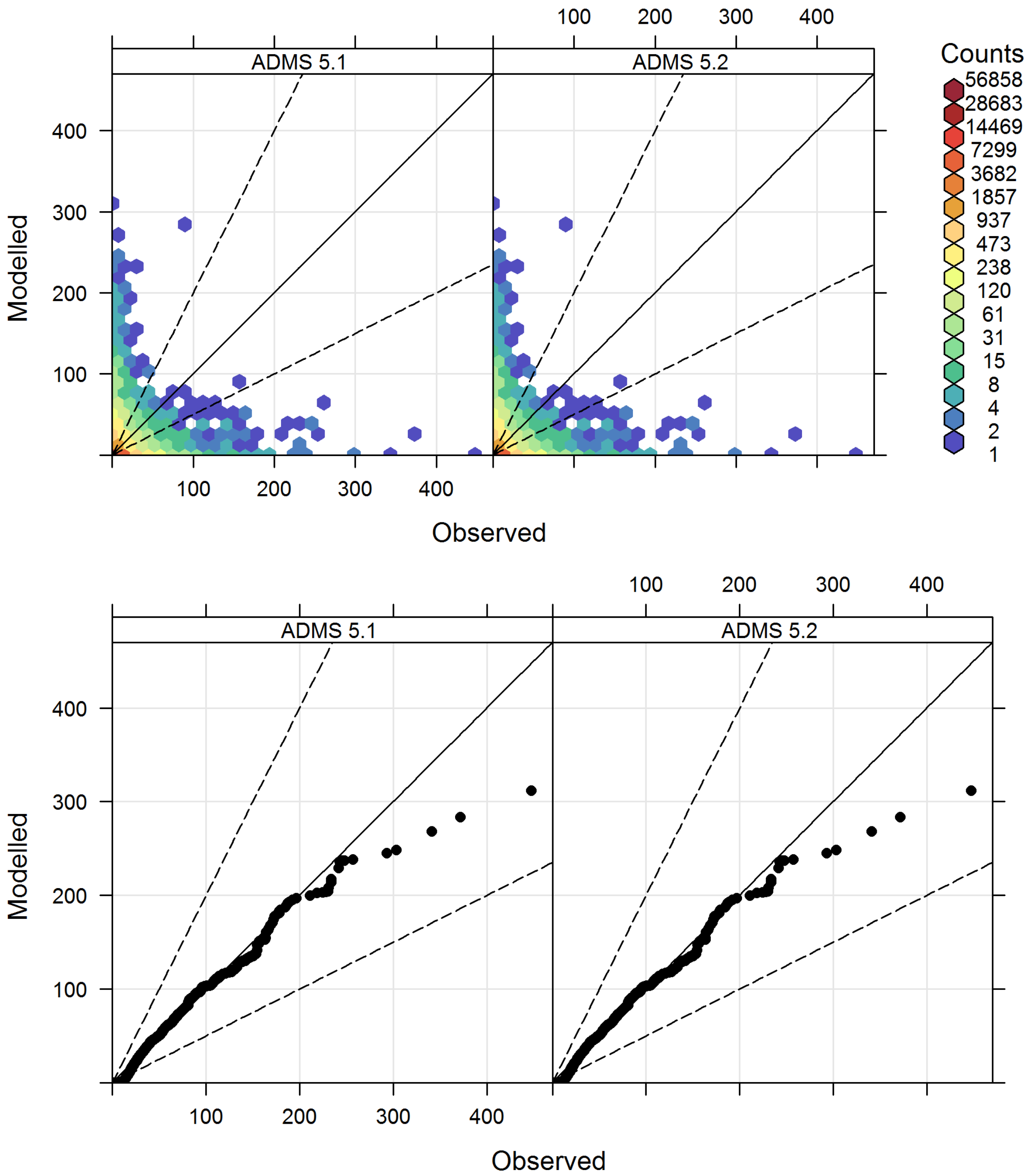

Figure 6 – Frequency scatter plots and quantile-quantile plots of ADMS results against observed concentrations (µg/m^3).

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:

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

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*. [4].

Statistics	Data	Maximum Concentrations (µg/m³)									Mean M/O ratio
		P3	P4	P5	P6	P7	P8	P9	P10	P11	
1-hour maximum	Observed	231	257	151	448	372	157	230	193	155	-
	ADMS 5.1	115	101	131	237	312	174	238	229	181	0.85
	ADMS 5.2	115	101	131	237	312	174	238	229	181	0.85
3-hour maximum	Observed	146	137	66	184	136	109	102	103	83	-
	ADMS 5.1	61	67	67	179	168	141	185	164	98	1.11
	ADMS 5.2	61	67	67	179	168	141	185	164	98	1.11
24-hour maximum	Observed	76	22	21	40	47	21	22	29	19	-
	ADMS 5.1	25	17	43	90	107	59	63	34	24	1.76
	ADMS 5.2	25	17	43	90	107	59	63	34	24	1.76

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
		P3	P4	P5	P6	P7	P8	P9	P10	P11	
1-hour RHC	Observed	287	235	119	408	255	171	237	181	108	-
	ADMS 5.1	116	108	158	293	374	204	242	208	177	1.04
	ADMS 5.2	116	108	158	293	374	204	242	208	177	1.04
3-hour RHC	Observed	174	138	74	217	141	107	105	112	58	-
	ADMS 5.1	65	68	75	162	188	99	149	123	106	1.03
	ADMS 5.2	65	68	75	162	188	99	149	123	106	1.03
24-hour RHC	Observed	51	27	23	42	47	23	23	28	23	-
	ADMS 5.1	18	17	23	41	46	34	40	33	16	1.01
	ADMS 5.2	18	17	23	41	46	34	40	33	16	1.01

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 6**) show relatively 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.

The issue with missing background pollutant data can be investigated by inspecting monitored concentration values when all sources are downwind of the receptors. When this is done, it is clear that there are significant levels of background SO_2 present during this study. 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.

The graphs and tables presented in Section 3 show generally good prediction of the observed concentrations by ADMS. In particular, the high concentrations are well-predicted – see for example the 1-hour maximum values presented in **Table 5**, and the RHC values presented in **Table 6**.

Inspection of the data also shows that the receptors for which there is best agreement between modelled and observed concentrations are those on the near side hill relative to the stack, and not around the sides or behind the hill i.e. in regions where the flow is not separated. Once the flow has separated, it is very complex and difficult to model.

Consideration of the scatter and quantile-quantile plots show that the concentration distribution predicted by ADMS 5.2 is very similar to that 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, 2003: *AERMOD, Latest Features and Evaluation Results*. EPA-454/R-03-003.

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

[4] 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.

[5] 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.