ADMS 6 Buildings Validation
Bowline Point Site

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1 Introduction

The Bowline Point[1] site is located in the Hudson River valley in New York State (**Figure 1**). There are two stacks of height 86.9 m, close to the western shore of the river. The emissions from the stacks were buoyant and varied hour by hour, and very close to the stacks there was a complex of buildings. The site itself was rural and the terrain was relatively flat, although there was an urban area to the west of the site, and some significant hills to the south-west.

There were four monitoring sites; their distances from the stacks ranged from 250 to 850 m. Two of the monitors were to the south-east of the site; the others were to the north and west.

Hourly meteorological data were obtained from a 100 m mast on the site for the whole year 1981. The prevailing wind was from the north-west.

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 included the observed concentrations that have been used for comparison with the ADMS modelled concentrations.

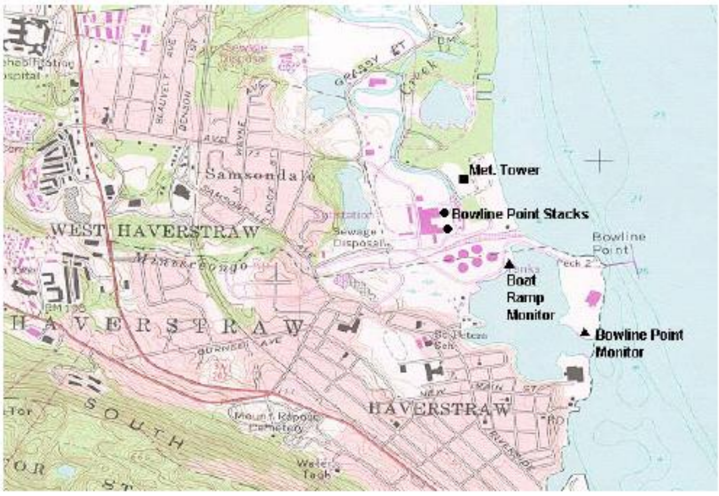

Figure 1 – Bowline Point study area.

This document compares the results of ADMS 6.0.0.1 (hereafter referred to as ADMS 6.0) 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 0.

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

2 Input data

This study involves the modelling of two stacks in close proximity to a number of buildings. Study details are given in Sections 2.1 to 2.5 below.

2.1 Study area

The latitude of the site is 41.2°N and the surface roughness was taken to be 0.03 m.

2.2 Source parameters

The source parameters are summarised in **Table 1**. For the first stack (second stack), the exit velocity varied between 7.9 and 27.9 m/s (8.6 and 30.9 m/s), the exit temperature between 84.9 and 126.9°C (89.0 and 136.1°C) and the emission rate between 0 and 449.3 g/s (0 and 431.3 g/s).

Source name	Pollutant	Location	Stack height (m)	Exit V (m/s)	Exit T (°C)	Diameter (m)	Emission rate (g/s)
Stack1	SO_2	(7.78, -44.13)	86.87	varied	varied	5.72	varied
Stack2	SO_2	(-7.78, 44.13)	86.87	varied	varied	5.72	varied

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

2.3 Receptors

There were four monitoring sites located around the stacks as shown in **Figure 2**.

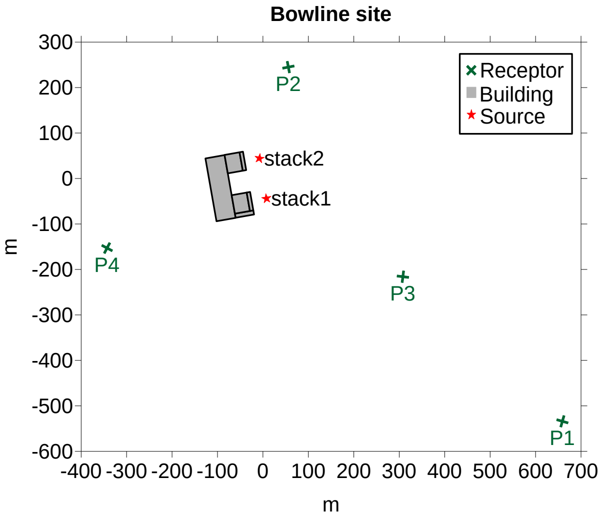

Figure 2 – Locations of buildings and stacks.

2.4 Meteorological data

The experiment used 1 year of hourly sequential data from the 1 January 1981 to 31 December 1981. Hourly meteorological data were obtained from a 100 m mast on the site. **Table 2** gives details of the modelled meteorological conditions.

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	3982 (57%)	3952* (57%)
	Neutral conditions	544 (8%)	532* (8%)
	Unstable conditions	2482 (35%)	2493* (36%)
	Total	*7008 (100%)*	*6977 (100%)*
Hours not modelled	Calm conditions	0	0
	Wind speed at 10 m < 0.75 m/s	1286	1317*
	Inadequate data	466	466
	Total	*1752*	*1783*

Table 2 – Meteorological conditions.

*There has been a change to the meteorological processor in ADMS 6.0, in which the solar elevation angle is calculated at the middle of the hour rather than the end of it. This can lead to different stability estimates for daytime hours. As the height of recorded wind is at 100 m, the wind speed as calculated at 10 m can also change as different stability regimes use different wind speed profiles.

The wind speed varied between 0.4 and 19 m/s and the wind direction between 0 and 360° (the prevailing wind was from the north-west). The ambient temperature varied between -19.2 and 33.9°C. The height of the recorded wind used was 100 m. The wind rose is shown in **Figure 3**.

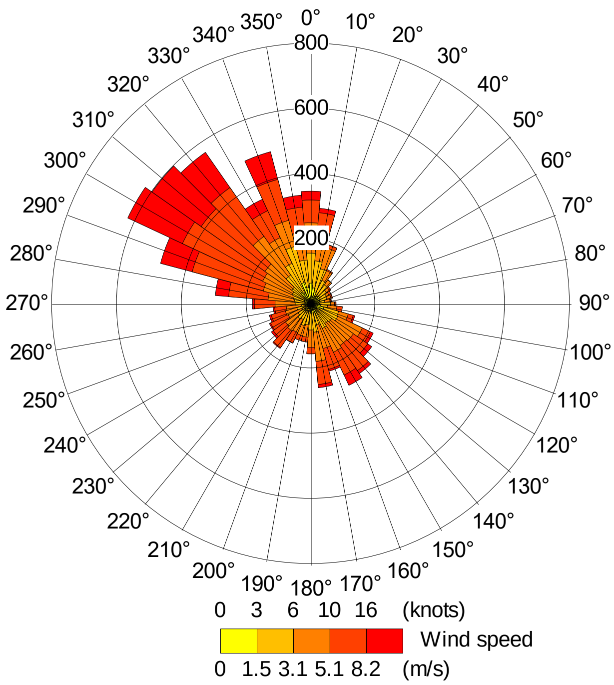

Figure 3 – Wind rose.

2.5 Buildings

The building dimensions are given in **Table 3**. **Figure 4** shows the locations of the buildings.

Building name	Length (m)	Width (m)	Height (m)
WHOUSE1A	140.21	42.82	29.57
WHOUSE1B	9.15	41.2	29.57
WHOUSE2	41.2	33.53	65.23
WHOUSE3	41.2	7.62	38.4
WHOUSE4	41.2	33.53	65.23
WHOUSE5	41.2	7.62	38.4

Table 3 – Dimensions of the buildings.

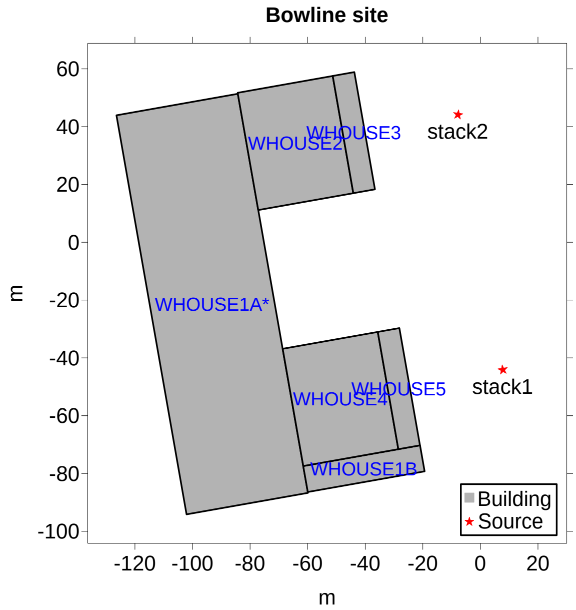

Figure 4 – Stack and building locations.

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 [4].

3.1 Scatter and quantile-quantile plots

Figure 5 shows the scatter plots and the quantile-quantile plots of modelled versus observed hourly average concentrations.

Note that these quantile-quantile plots are *linear*; care should be exercised when comparing these plots with similar ones presented with *logarithmic* axes.

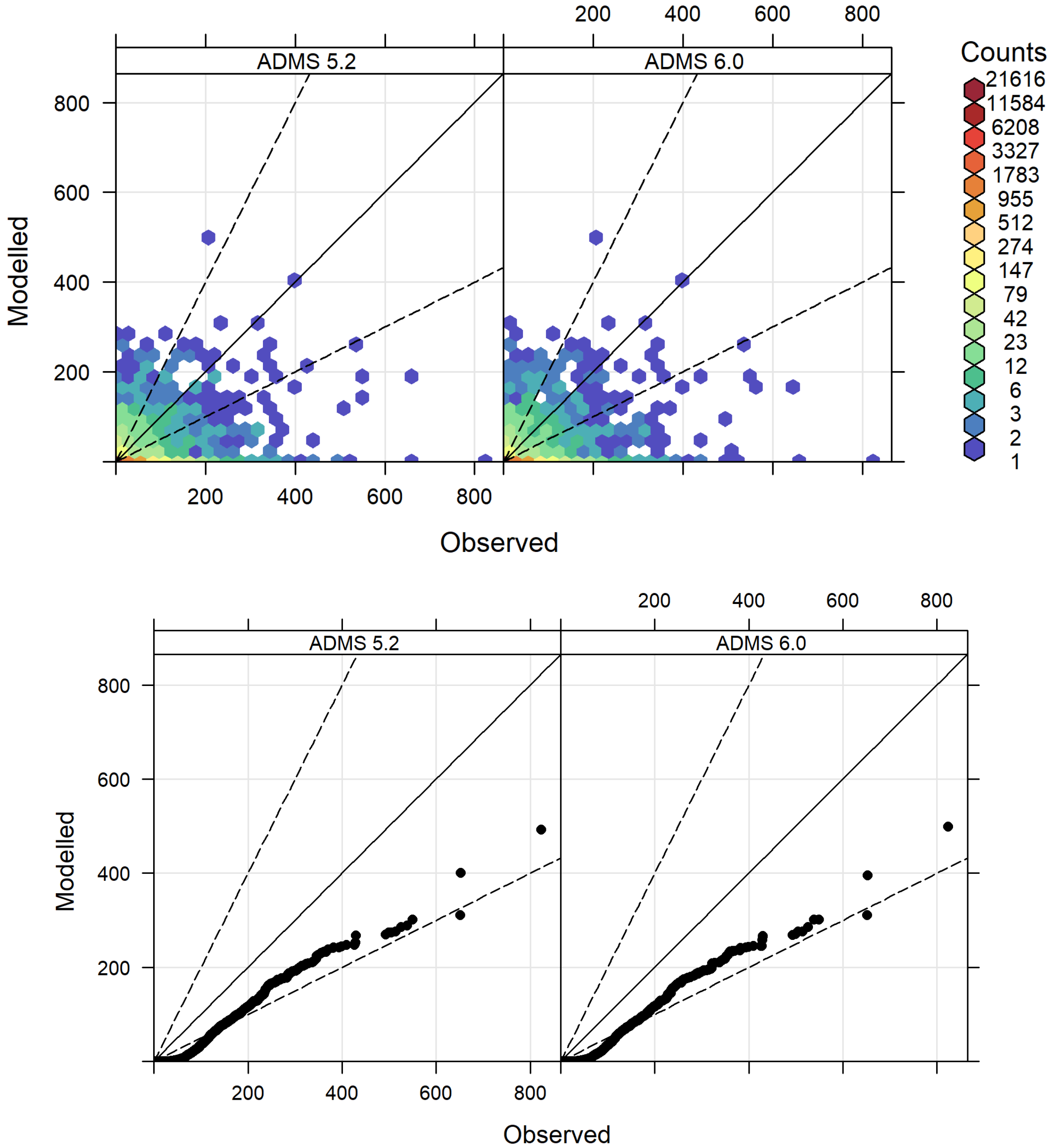

Figure 5 − Scatter and quantile-quantile plots of modelled against observed 1 hour average concentrations (ug/m^3).

3.2 Statistics

Table 4 compares the modelled and observed maximum 1-hour, 3-hour and 24-hour average concentrations at the receptor points. **Table 5** 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.* [5].

Statistics	Data	Maximum concentrations (ug/m^3)				Mean M/O ratio	
		P1	P2	P3	P4	all P	P1 & P3
1-hour maximum	Observed	824	343	514	85	-	-
	ADMS 5.2	274	98	492	216	1.03	0.64
	ADMS 6.0	270	98	499	217	1.04	0.65
3-hour maximum	Observed	433	203	388	73	-	-
	ADMS 5.2	251	34	276	176	0.97	0.64
	ADMS 6.0	251	34	276	199	1.05	0.65
24-hour maximum	Observed	224	74	185	64	-	-
	ADMS 5.2	82	6	80	45	0.40	0.40
	ADMS 6.0	79	6	77	51	0.41	0.38

Table 4 – 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 (ug/m^3)				Mean M/O ratio	
		P1	P2	P3	P4	all P	P1 & P3
1-hour RHC	Observed	743	281	596	84	-	-
	ADMS 5.2	317	42	521	198	0.95	0.65
	ADMS 6.0	303	39	529	214	1.00	0.65
3-hour RHC	Observed	449	160	397	84	-	-
	ADMS 5.2	308	15	251	80	0.59	0.66
	ADMS 6.0	296	14	251	84	0.60	0.65
24-hour RHC	Observed	223	49	193	107	-	-
	ADMS 5.2	102	3	49	17	0.23	0.36
	ADMS 6.0	107	3	47	16	0.23	0.36

Table 5 – 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 reasonably 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.

As the prevailing wind was from the north-west, there are few useful concentration measurements at receptors P2 and P4, so the results at receptors P1 and P3 are more robust, and have been presented separately.

In order to avoid spurious results from very small numbers of valid hours in a longer averaging time a threshold of 50% valid hours was applied in the Model Evaluation Toolkit when processing the ADMS output for 3 and 24 hour averages. There has been a slight change in how the Model Evaluation Toolkit applies this threshold in the version used to process data for this report, which leads to slight differences between the data for ADMS 5.2 presented here and in the previous validation document comparing ADMS 5.1 to ADMS 5.2. The data presented in this study (i.e. ADMS 5.2 and ADMS 6.0) use the same version of the Toolkit and so are consistent with each other.

The predictions of maximum concentrations and robust highest concentrations presented in **Tables 4** and **5** show reasonable model performance considering the complexity of the domain modelled. At the more robust monitoring stations, P1 and P3, the model has a tendency to predict slightly 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 the maximum and robust highest concentrations predicted by ADMS 5.2 and ADMS 6.0 are typically small with varying sign (some positive, some negative). The model behaviour in the case when the user-selected main building is deemed inappropriate for a given met. line has changed between ADMS 5.2 and ADMS 6, and this is affecting some modelled hours in this study. Furthermore, 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 also 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 source compared with the buildings.

4.1 Background pollutant data issues

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. **Figure 6** shows the concentration at two monitoring sites (P1 and P3) as a function of wind direction. This figure indicates that there is some concentration at the monitors *even when the wind is not blowing from the power plant*.

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.

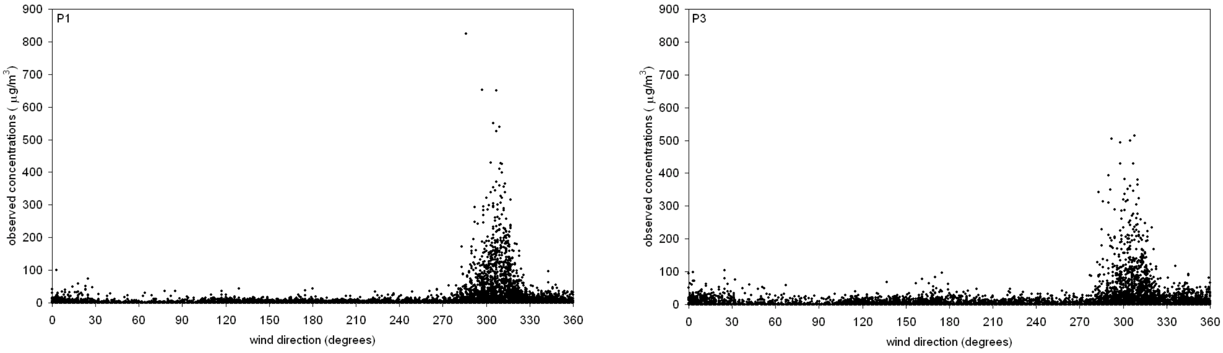

Figure 6 – Observed concentrations at receptors P1 and P3 (both south-east of the stacks), plotted against the wind direction. Note that the concentration is non zero for all wind directions.

4.2 Buildings

In the ADMS modelling, all buildings were included. The heights of buildings 1A, 1B, 3 and 5 are all approximately half of the stack height or less, and these buildings are therefore unlikely to have a large effect on the dispersion of such buoyant releases as those from Stack1 and Stack2. As the prevailing wind is from the north-west, building 2 has a more significant impact than building 4.

5 References

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

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

[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.