

ADMS 5 Buildings & Complex Terrain Validation *Baldwin Power Plant*

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1 Introduction

The Baldwin Power Plant¹ (Hanna and Chang [3]) was located in a rural, flat terrain setting of southwestern Illinois, USA, and had three identical 184 m stacks aligned approximately north-south with a horizontal spacing of about 100 m. There were 10 SO₂ monitors that surrounded the facility, ranging in distance from 2 to 10 km.

On-site meteorological data were available during the study period of 1 April 1982 through 31 March 1983 and consisted of hourly averaged wind speed, wind direction and temperature measurements taken at 10 m, and wind speed and wind direction at 100 m.

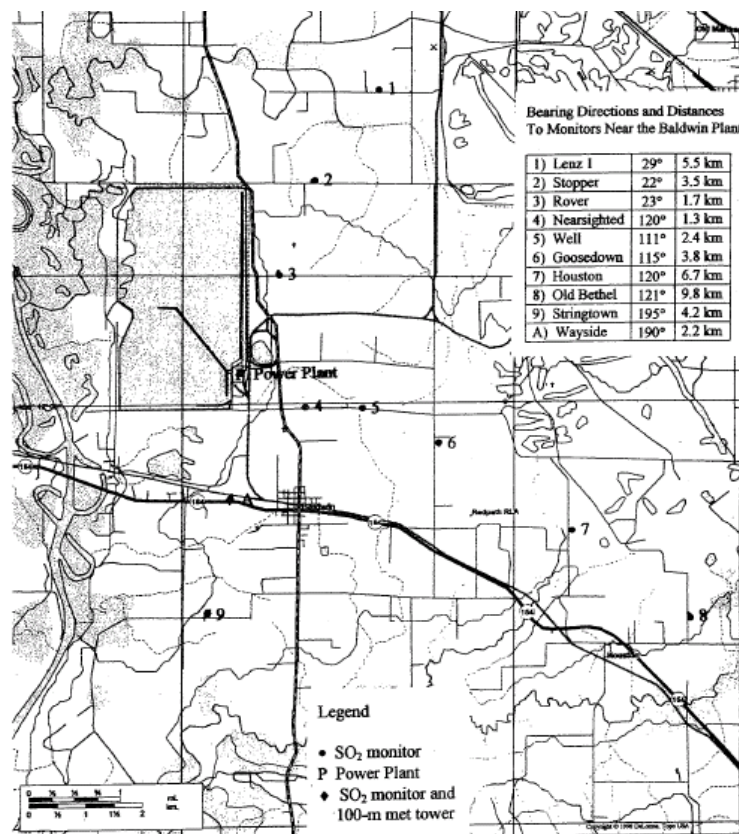


Figure 1 – Monitoring locations in the vicinity of the Baldwin power plant.

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

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

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

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 site is located at 38.2°N. The roughness length was dependent on wind direction and month. Its value ranged from 0.003 m (January to February, wind direction 255°-23°) to 0.190 m (June to September, wind direction 23°-255°). Terrain data included in the modelling covered a 9 km × 9 km area centred on the source locations; terrain data points were located every 140 m within this area. **Figure 2** shows the modelled terrain area.

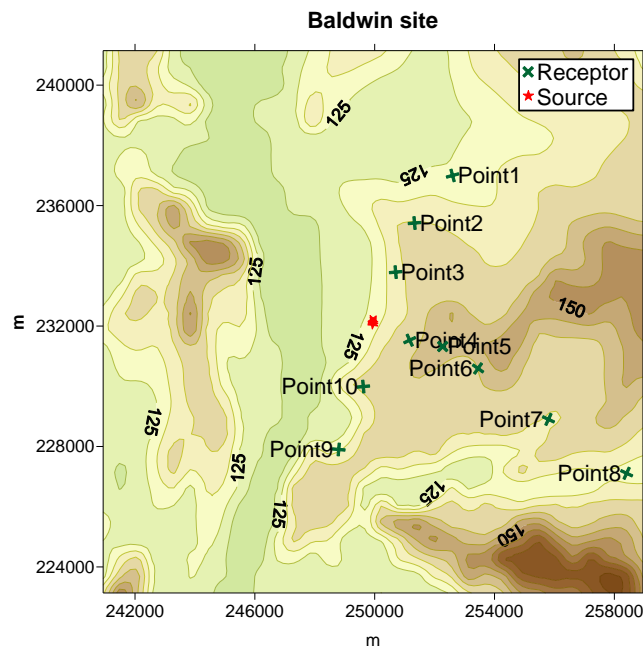


Figure 2 – Modelled terrain area around Baldwin power plant.

2.2 Source parameters

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

Source name	Pollutant	Location	h (m)	V (m/s)	T (°C)	D (m)	Q (g/s)
stack1	SO ₂	249945, 232200	184.4	varied	varied	5.94	varied
stack2	SO ₂	249945, 232140	184.4	varied	varied	5.94	varied
stack3	SO ₂	249942, 232075	184.4	varied	varied	5.94	varied

Table 1 – Source input parameters. h is the stack height, V the exit velocity, T the exit temperature, D the diameter and Q the emission rate.

Exit velocities varied from 0 to 40.2 m/s, exit temperatures varied from 20 to 156°C and emissions rates varied from 0 to 4200 g/s.

2.3 Receptors

The receptor network consisted of 10 points, ranging from 2 to 10 km from the sources. All receptors were modelled as ground level receptors.

Figure 2 shows the receptor network in the experiment and **Table 2** summarises their locations.

Receptor name	Location
Point1	252600, 237000
Point2	251330, 235420
Point3	250700, 233790
Point4	251170, 231530
Point5	252270, 231320
Point6	253450, 230590
Point7	255800, 228900
Point8	258410, 227110
Point9	248800, 227900
Point10	249620, 229990

Table 2 – Receptor point locations for Baldwin power plant site.

2.4 Meteorological data

The experiment used 1 year of hourly sequential data from the 1 April 1982 to 31 March 1983 measured at an on-site meteorological mast.

Table 3 gives the detail of the modelled meteorological conditions.

Conditions		ADMS 5.1	ADMS 5.2
Hours modelled	Stable conditions	5231 (60%)	5231 (60%)
	Neutral conditions	547 (7%)	547 (7%)
	Unstable conditions	2878 (33%)	2878 (33%)
	<i>Total</i>	<i>8656 (100%)</i>	<i>8656 (100%)</i>
Hours not modelled	Calm conditions	0	0
	Wind speed at 10 m < 0.75 m/s	104	104
	Inadequate data	0	0
	<i>Total</i>	<i>104</i>	<i>104</i>

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

The wind speeds at 10 m varied from 0.3 to 13.6 m/s and the ambient temperature from -11.1 to 36.1°C. The model also used the temperature and wind speed at 100 m entered via a meteorological profile file.

The 10-m wind rose is shown in **Figure 3**.

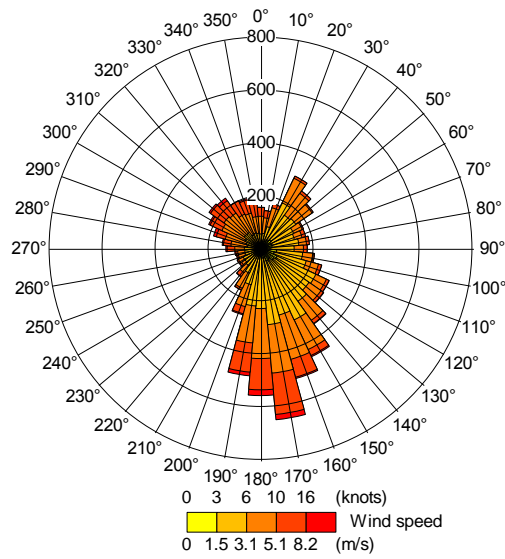


Figure 3 – Wind rose.

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 (°)
BLDG1	214	90	81.9	0

Table 4 – Dimensions of the building.

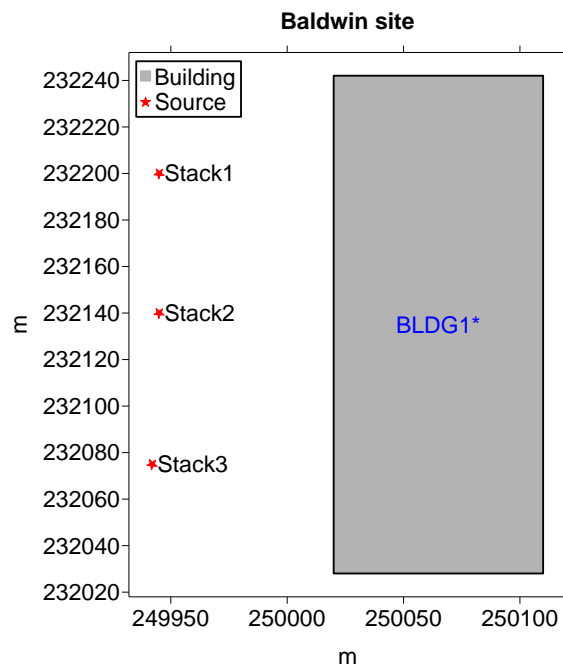


Figure 4 – The building and stack locations.

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 MyAir Toolkit for Model Evaluation [6].

3.1 Scatter and quantile-quantile plots

Figure 5 shows frequency scatter plots and 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.

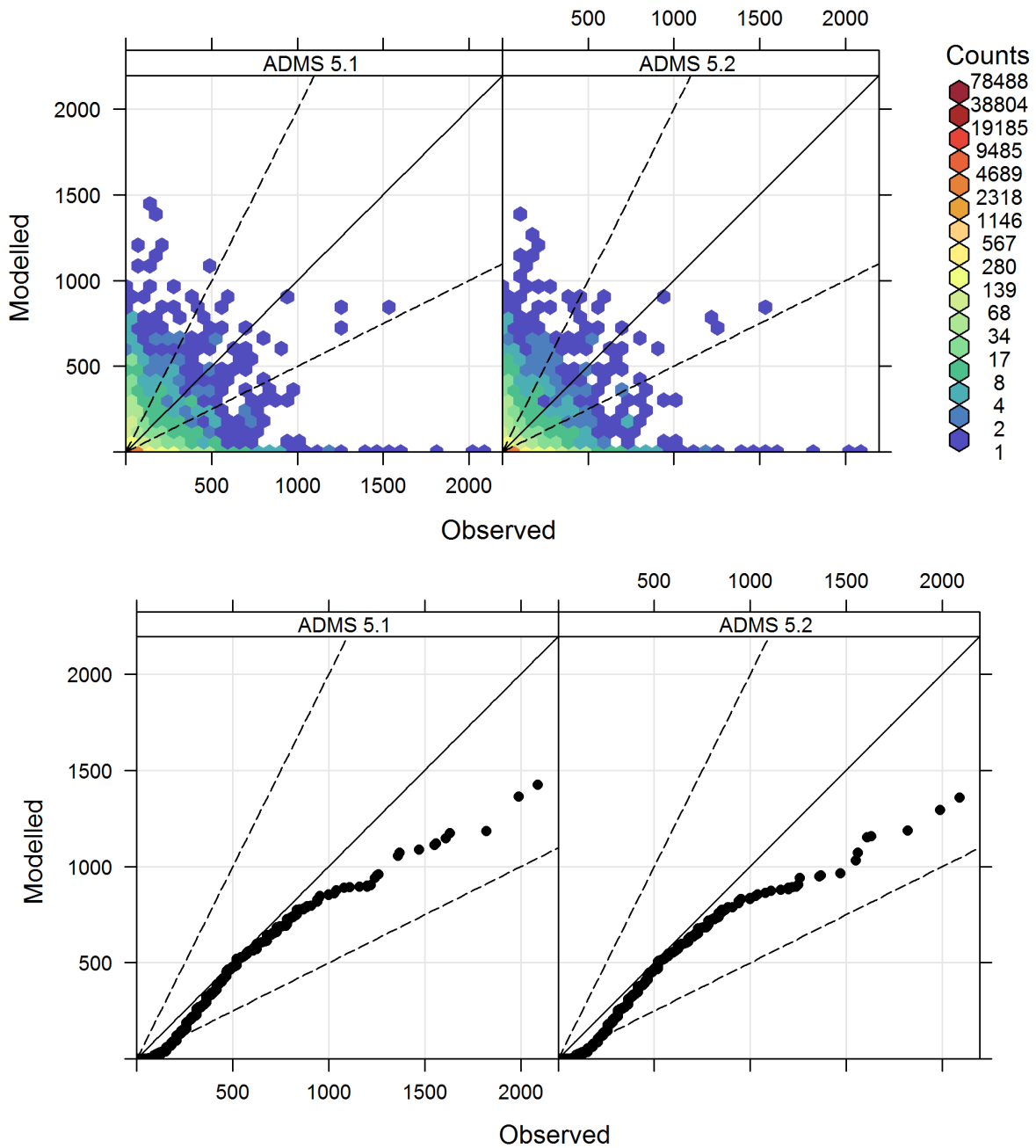


Figure 5 – Scatter plots and quantile-quantile plots of ADMS results against observed data (ug/m³).

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.* [5].

Statistic	Data	Maximum concentrations (ug/m ³)										Mean M/O ratio
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	
1-hour max.	Observed	1370	1630	1560	1990	1610	1200	1550	1250	2090	1470	-
	ADMS 5.1	1148	1072	658	767	1122	1367	1423	1185	737	657	0.68
	ADMS 5.2	1150	939	658	719	1032	1294	1358	1186	737	657	0.65
3-hour max.	Observed	688	1007	755	1031	966	688	961	755	1037	1055	-
	ADMS 5.1	685	577	298	643	602	734	851	712	639	400	0.71
	ADMS 5.2	683	572	298	592	595	692	846	713	638	400	0.70
24-hour max.	Observed	114	145	108	158	152	163	204	152	260	163	-
	ADMS 5.1	183	91	69	116	113	134	136	107	113	87	0.75
	ADMS 5.2	185	91	69	105	100	131	135	107	113	87	0.74

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.

Statistic	Data	Robust highest concentrations (ug/m ³)										Mean M/O ratio
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	
1-hour RHC	Observed	1088	1166	927	1281	1308	1235	1660	1075	1491	1202	-
	ADMS 5.1	1311	948	530	757	1258	1206	1276	1079	1016	731	0.82
	ADMS 5.2	1304	929	513	652	1060	1171	1242	1103	1024	730	0.79
3-hour RHC	Observed	677	630	503	722	741	763	920	622	874	785	-
	ADMS 5.1	684	559	290	425	585	791	712	513	507	389	0.76
	ADMS 5.2	682	548	273	369	526	766	713	553	503	387	0.74
24-hour RHC	Observed	144	128	87	169	199	210	214	146	174	166	-
	ADMS 5.1	143	107	48	81	118	153	150	113	103	80	0.67
	ADMS 5.2	141	104	44	65	101	149	152	121	102	78	0.65

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 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 SO₂. There are a number of issues with using SO₂ as a tracer, which include:

- The detection limits of monitors are usually of the order of 16µg/m³, and concentrations below these are set to one-half of the limit. This leads to considerable inaccuracy when modelled concentrations are low.
- SO₂ 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 SO₂ 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 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 5 fluctuations module may be used to estimate the likelihood of concentrations greater than or less than the ensemble mean, although currently it is not possible to run the fluctuations module in conjunction with the buildings module in ADMS.

Consideration of the scatter and quantile-quantile plots show that the concentration distributions predicted by ADMS 5.1 and ADMS 5.2 are similar. The statistics presented in **Tables 5** and **6** also show that for this study ADMS 5.2 and ADMS 5.1 give broadly similar results. In general ADMS 5.2 is giving slightly lower predictions of high concentrations than ADMS 5.1.

The ADMS 5 buildings module has been made more consistent between different building effects regions for ADMS 5.2, which may increase or decrease concentrations in some cases depending on the source, building and output point locations and characteristics. In addition the effects of building wake turbulence on plumes outside the wake have been improved.

5 References

- [1] United States Environmental Protection Agency, 2003: AERMOD, Latest Features and Evaluation Results. EPA-454/R-03-003.
- [2] 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.
- [3] Hanna, S.R. and J.C. Chang, 1993: Hybrid Plume Dispersion Model (HPDM) Improvements and Testing at Three Field Sites. *Atmos. Envir.*, **27A**, 1491-1508.
- [4] United States Environmental Protection Agency website, Model Evaluation Databases. http://www.epa.gov/scram001/dispersion_prefrec.htm
- [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.