ADMS 6 Buildings & Complex Terrain Validation
Baldwin Power Plant

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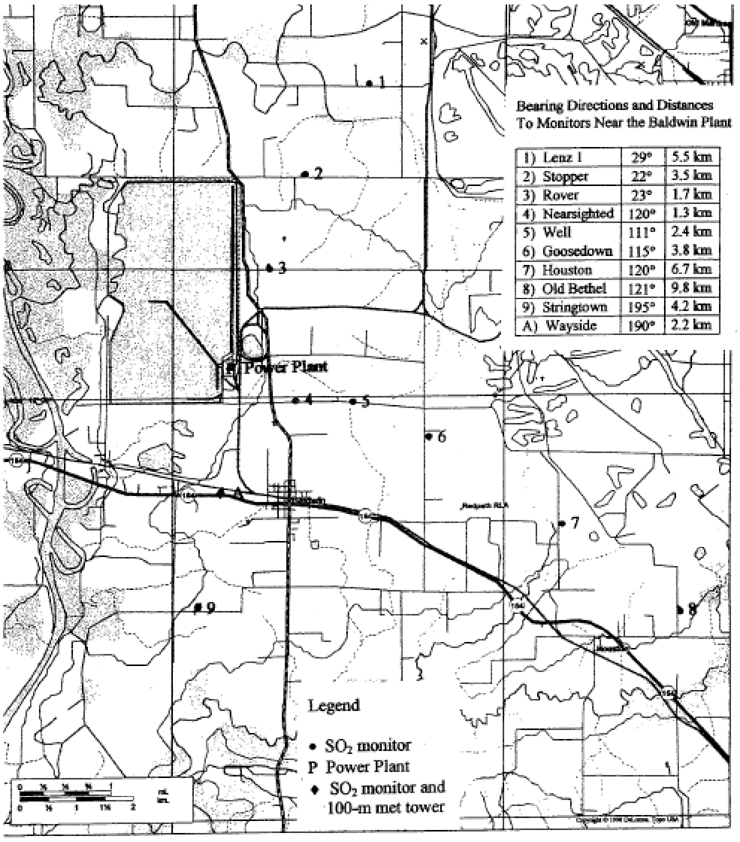
1 Introduction

The Baldwin Power Plant[1] (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 SO_2 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.



Bearing Directions and Distances
To Monitors Near the Baldwin Plant

1) Lenz I	29°	5.5 km
2) Stopper	22°	3.5 km
3) Rover	23°	1.7 km
4) Nearsighted	120°	1.3 km
5) Well	111°	2.4 km
6) Goosedown	115°	3.8 km
7) Houston	120°	6.7 km
8) Old Bethel	121°	9.8 km
9) Stringtown	195°	4.2 km
A) Wayside	190°	2.2 km

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 observed

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

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 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 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 255º-23º) to 0.190 m (June to September, wind direction 23º-255º). 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.

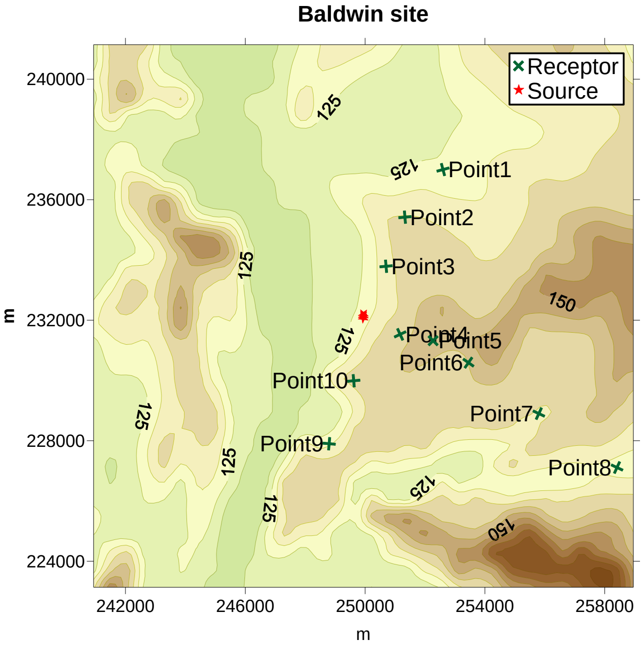

Figure 2 – Modelled terrain area around Baldwin power plant.

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. 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	5231 (60%)	5241 (61%)
	Neutral conditions	547 (7%)	529 (6%)
	Unstable conditions	2878 (33%)	2885 (33%)
	Total	*8656 (100%)*	*8655 (100%)*
Hours not modelled	Calm conditions	0	0
	Wind speed at 10 m < 0.75 m/s	104	105
	Inadequate data	0	0
	Total	*104*	*105*

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**.

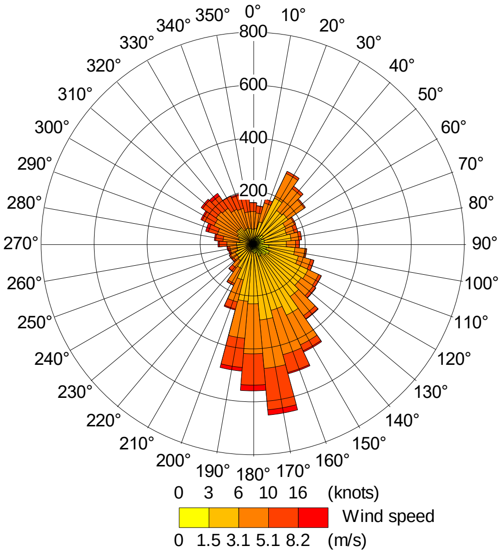

Figure 3 – Wind rose.

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.

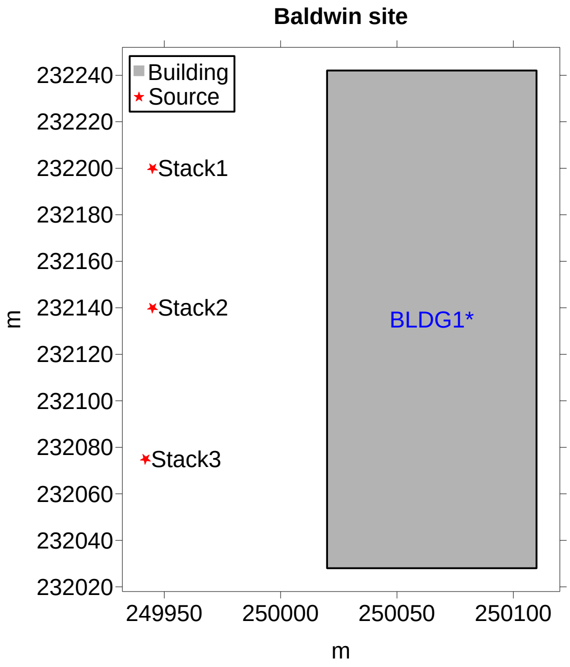

Figure 4 − The building and stack locations.

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 Model Evaluation Toolkit v5.2 [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.

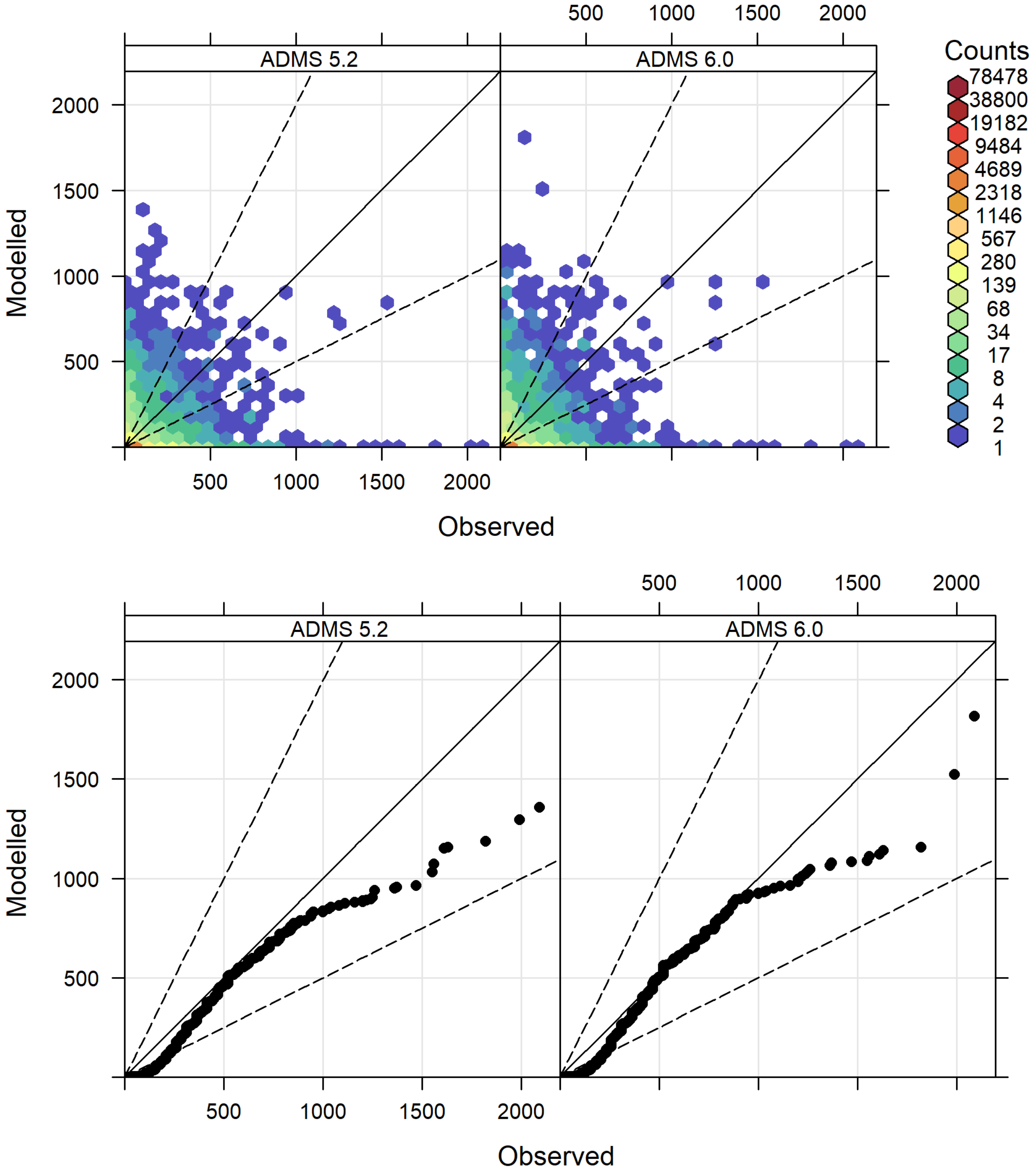

Figure 5 − Scatter plots and quantile-quantile plots of ADMS results against observed data (ug/m³).

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 5.2	1150	939	658	719	1032	1294	1358	1186	737	657	0.65
	ADMS 6.0	1088	1065	586	743	936	1109	1815	1524	1155	615	0.71
3-hour max.	Observed	688	1007	755	1031	966	688	961	755	1037	1055	-
	ADMS 5.2	683	572	298	592	595	692	846	713	638	400	0.70
	ADMS 6.0	579	504	272	615	611	596	647	885	685	379	0.67
24-hour max.	Observed	114	145	108	158	152	163	204	152	260	163	-
	ADMS 5.2	185	91	69	105	100	131	135	107	113	87	0.74
	ADMS 6.0	155	83	54	110	102	124	130	108	113	81	0.68

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.

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 5.2	1304	2709	1191	2138	3168	3457	3703	2230	3110	1853	1.96
	ADMS 6.0	1284	2766	1209	2149	3054	3468	4302	2870	3465	1878	2.08
3-hour RHC	Observed	677	630	503	722	741	763	920	622	874	785	-
	ADMS 5.2	682	558	277	369	536	766	713	610	503	387	0.75
	ADMS 6.0	675	565	278	348	476	733	698	665	597	406	0.76
24-hour RHC	Observed	146	127	88	168	193	212	213	148	180	173	-
	ADMS 5.2	141	104	43	66	93	150	158	120	105	79	0.64
	ADMS 6.0	134	102	46	60	94	157	170	141	121	81	0.67

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 16μg/m^3, 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 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.

Consideration of the scatter and quantile-quantile plots show that the concentration distributions predicted by ADMS 5.2 and ADMS 6.0 are similar, though ADMS 6.0 seems to behave better at the high end of the quantile-quantile plots. The statistics presented in **Tables 5** and **6** also show that for this study ADMS 5.2 and ADMS 6.0 give broadly similar results, with ADMS 6.0 performing slightly better for the robust highest concentrations and the 1-hour maximum concentrations, but slightly worse for the 3-hour and 24-hour maximum concentrations. 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 sources compared with the building.

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. 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.