

ADMS 4 Complex Terrain Validation *Westvaco Corporation*

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1 Introduction

The Westvaco Corporation's pulp and paper mill¹ in rural Luke, Maryland is located in a complex terrain setting in the Potomac River valley [2]. A single 190-m buoyant source was modelled for this evaluation. There were 11 SO₂ monitors surrounding the facility, with eight monitors well above stack top on the high terrain east and south of the mill at a distance of 800-1500 m (**Figure 1**).

Hourly meteorological data (wind, temperature, and turbulence) were collected between December 1980 and November 1981 at three instrumented towers: the 100-m Beryl tower in the river valley about 400 m southwest of the facility, the 30-m Luke Hill tower on a 18 ridge 900 m north-northwest of the facility, and the 100-m Met tower located 900 m east-south-east of the facility on a ridge across the river.

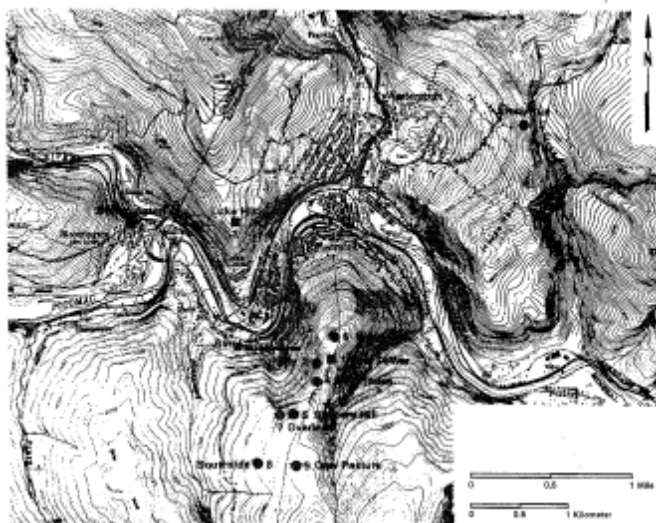


Figure 1 – Locations of SO₂ monitors and meteorological towers in the vicinity of the Westvaco Luke Mill.

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

This document compares the results of ADMS 4.1.0.0 (hereafter referred to as ADMS 4.1) with those of ADMS 4.2.2.0 (hereafter referred to as ADMS 4.2).

¹ Note that the study description and **Figure 1** have been taken directly from the document [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 was located at 39.47°N. The surface roughness used varied between 0.6 and 1.3 m depending on the time of the year.

Terrain data included in the modelling covered a 6 km x 7 km area (as shown in **Figure 2**). Terrain data points were located every 160 m within this area.

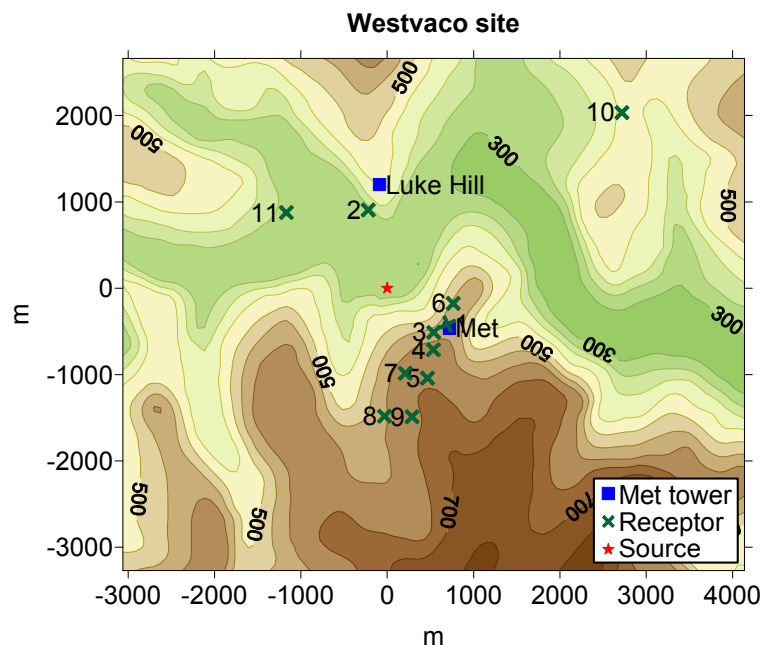


Figure 2 – Modelled terrain area around the Westvaco Corporation.

2.2 Source parameters

The source parameters are summarised in **Table 1**. Each of these sources is modelled separately for different hours. The exit velocity varied from 7.2 to 35.7 m/s, the exit temperature from 92.9 to 129.9°C and the emission rate varied from 42.8 g/s to 635 g/s.

Source name	Pollutant	Location	h (m)	V (m/s)	T (°C)	D (m)	Q rate (g/s)
Stack	SO ₂	(0,0)	189.7	varied	varied	3.36	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.

2.3 Receptors

The receptor network consisted of 11 monitors located as shown in **Figure 2**.

2.4 Meteorological data

The experiment used 1 year of hourly sequential data from the 1 December 1980 to 30 November 1981.

Table 2 gives the detail of the modelled meteorological conditions.

Conditions		ADMS 4.1	ADMS 4.2
Hours modelled	Stable conditions	4283(61%)	4283(61%)
	Neutral conditions	428 (6%)	428 (6%)
	Unstable conditions	2329 (33%)	2329 (33%)
	<i>Total</i>	<i>7040 (100%)</i>	<i>7040 (100%)</i>
Hours not modelled	Calm conditions	0	0
	Wind speed at 10 m < 0.75 m/s	1586	1586
	Inadequate data	134	134
	<i>Total</i>	<i>1720</i>	<i>1720</i>

Table 2 – Meteorological conditions. Percentage values are computed with respect to the total number of modelled hours.

The wind speeds varied from 0.3 to 14.7 m/s and the wind direction was either westerly or easterly for the majority of the study duration (see the wind rose shown in **Figure 3**). The height of the recorded wind is 30 m. The ambient temperature varied from -19.7 to 29.5°C.

The model has used a profile of wind speeds and temperature with readings at 30, 50 and 100 m; it was based on recorded wind speeds at the Luke Hill (30 m) and ‘Met’ (50 and 100 m) instrumented towers (see location on **Figure 2**). A correction factor is applied to wind speed data at the met. sites to account for the difference in location; this factor ranges from 60 % at 10 m to 33 % at 100 m.

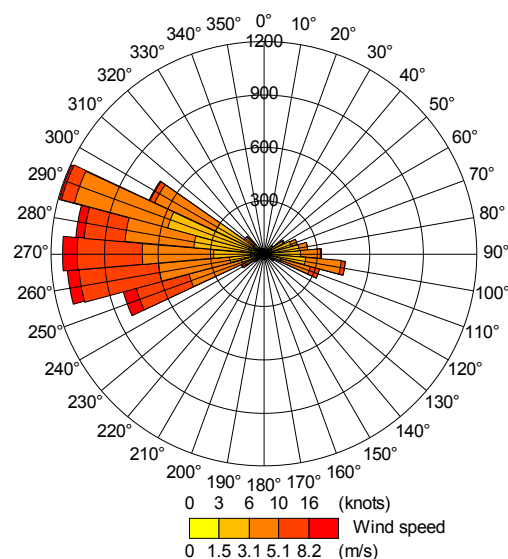


Figure 3 – Wind rose.

3 Results

Scatter plots and quantile-quantile plots of model results against observed data are presented in Section 3.1. The statistical analysis of the data is also provided in Section 3.2.

3.1 Scatter and quantile-quantile plots

Figure 4 shows the scatter plots and quantile-quantile plots of results for hourly mean concentrations. Note that these quantile-quantile plots are *linear*; care should be exercised when comparing these plots with similar ones presented with *logarithmic* axes.

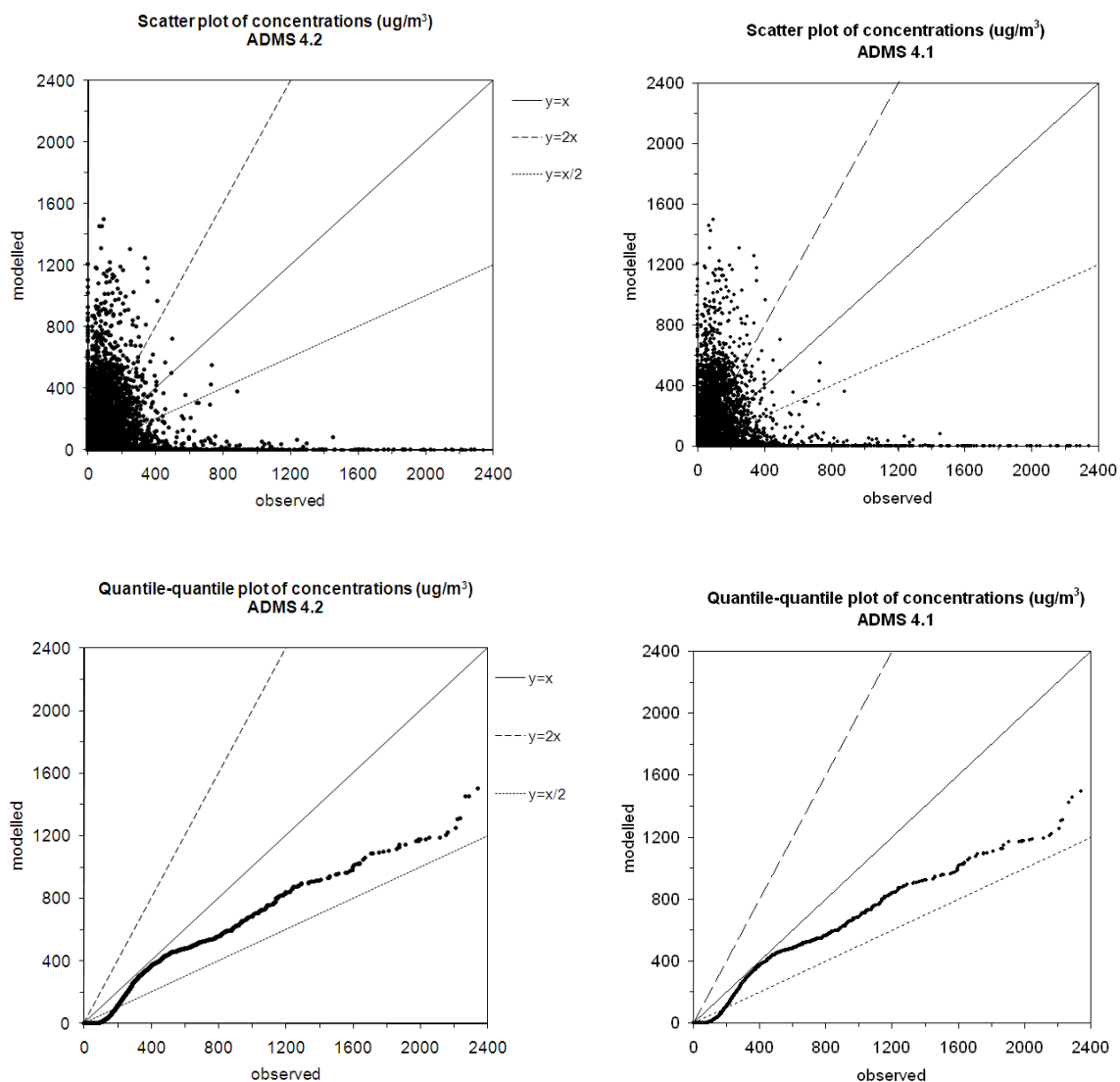


Figure 4 – Scatter plots and quantile-quantile plots of ADMS results against observed data ($\mu\text{g}/\text{m}^3$).

3.2 Statistics

Table 3 compares the modelled and observed maximum 1-hour, 3-hour and 24-hour average concentrations at the receptor points. **Table 4** 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	Concentrations (ug/m ³)											Mean M/O ratio
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	
1-hour maximum	observed	1909	496	1601	2290	2341	2269	2234	2210	1859	468	533	-
	ADMS 4.2	1311	721	1187	762	800	1501	402	338	326	255	676	0.59
	ADMS 4.1	1311	705	1187	762	800	1495	402	337	326	260	676	0.59
3-hour maximum	observed	1418	241	1136	1195	1634	1380	1947	1361	1239	293	380	-
	ADMS 4.2	929	361	629	385	350	1186	164	154	121	148	273	0.51
	ADMS 4.1	929	353	629	393	350	1192	158	150	116	150	273	0.51
24-hour maximum	observed	360	80	282	286	403	332	689	327	285	114	167	-
	ADMS 4.2	403	36	344	176	61	529	51	36	33	38	63	0.56
	ADMS 4.1	403	35	347	177	61	533	49	35	32	37	63	0.56

Table 3 – 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	P5	P6	P7	P8	P9	P10	P11	
1-hour RHC	observed	2192	490	2014	1893	2588	2499	2434	2286	2341	460	585	-
	ADMS 4.2	1448	393	1287	867	790	1658	593	397	454	259	576	0.52
	ADMS 4.1	1448	363	1295	843	776	1659	604	393	472	257	577	0.51
3-hour RHC	observed	1546	274	1224	1224	1284	1355	1427	1066	1016	316	298	-
	ADMS 4.2	1009	219	838	560	349	1084	236	121	158	192	319	0.53
	ADMS 4.1	988	203	848	563	342	1088	227	117	153	189	311	0.51
24-hour RHC	observed	253	89	221	221	289	369	379	247	248	95	108	-
	ADMS 4.2	314	18	232	112	49	514	35	19	24	38	76	0.54
	ADMS 4.1	322	15	234	113	47	503	33	18	23	37	69	0.53

Table 4 – 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 4**) show relatively good agreement between modelled and observed concentrations for both ADMS 4.2 and ADMS 4.1. 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 3** and **4** 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 4.2 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 concentrations predicted by ADMS 4.1 and ADMS 4.2 are very similar. The statistics presented in **Tables 3** and **4** indicate that for this study there is only a small difference in concentrations predicted by ADMS 4.2 and ADMS 4.1, with the results for ADMS 4.2 being very slightly better than those for ADMS 4.1.

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] Strimaitis, D. G., R. J. Paine, B. A. Egan and R. J. Yamartino, 1987: *EPA Complex Terrain Model Development: Final Report*. Contract No. 68-02-3421, United States Environmental Protection Agency, Research Triangle Park, North Carolina.
- [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.