ADMS 5 Complex Terrain Validation
Westvaco Corporation

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November 2016

1 Introduction

The Westvaco Corporation's pulp and paper mill[1] 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 SO_2 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.

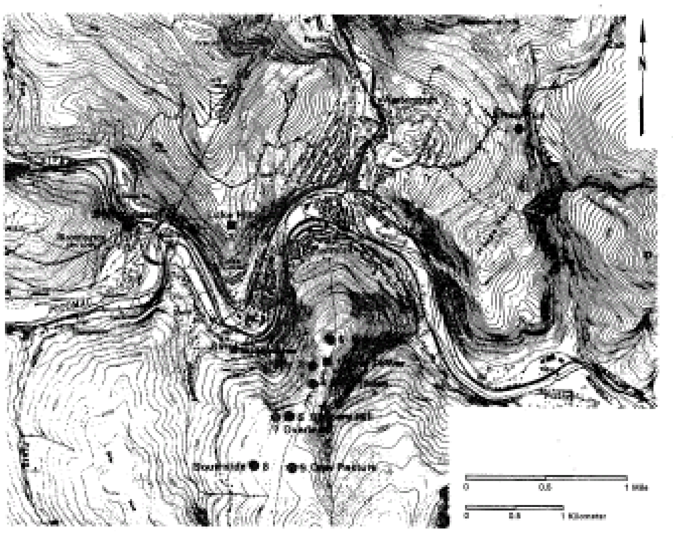

Figure 1 − Locations of SO_2 monitors and meteorological towers in the vicinity of the Westvaco Luke Mill.

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 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).

[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.

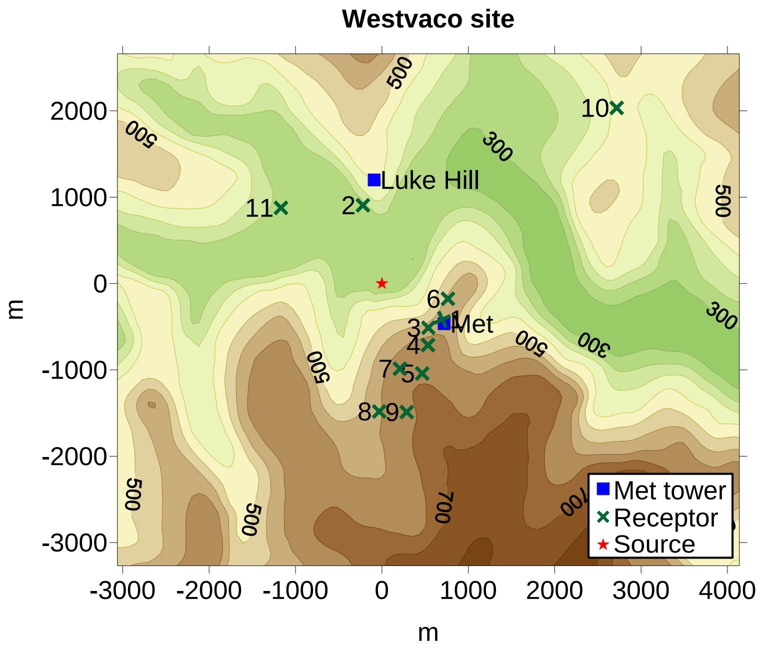

Figure 2 − Modelled terrain area around the Westvaco Corporation.

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**
Hours modelled	Stable conditions	4292 (61%)
	Neutral conditions	428 (6%)
	Unstable conditions	2331 (33%)
	Total	*7051 (100%)*
Hours not modelled	Calm conditions	0
	Wind speed at 10 m < 0.75 m/s	1575
	Inadequate data	134
	Total	*1709*

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.

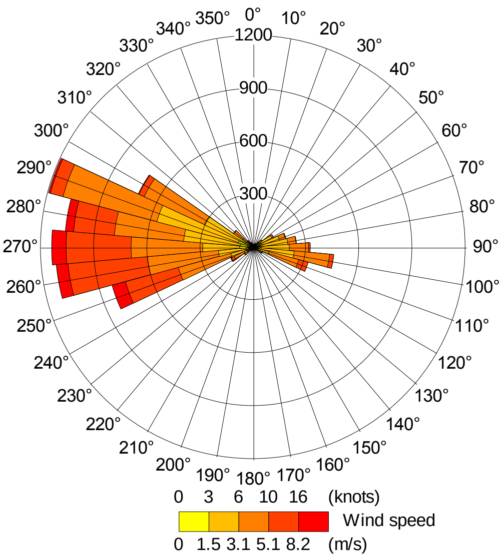

Figure 3 – Wind rose.

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. The graphs and statistical analysis have been produced by the MyAir Toolkit for Model Evaluation [5].

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.

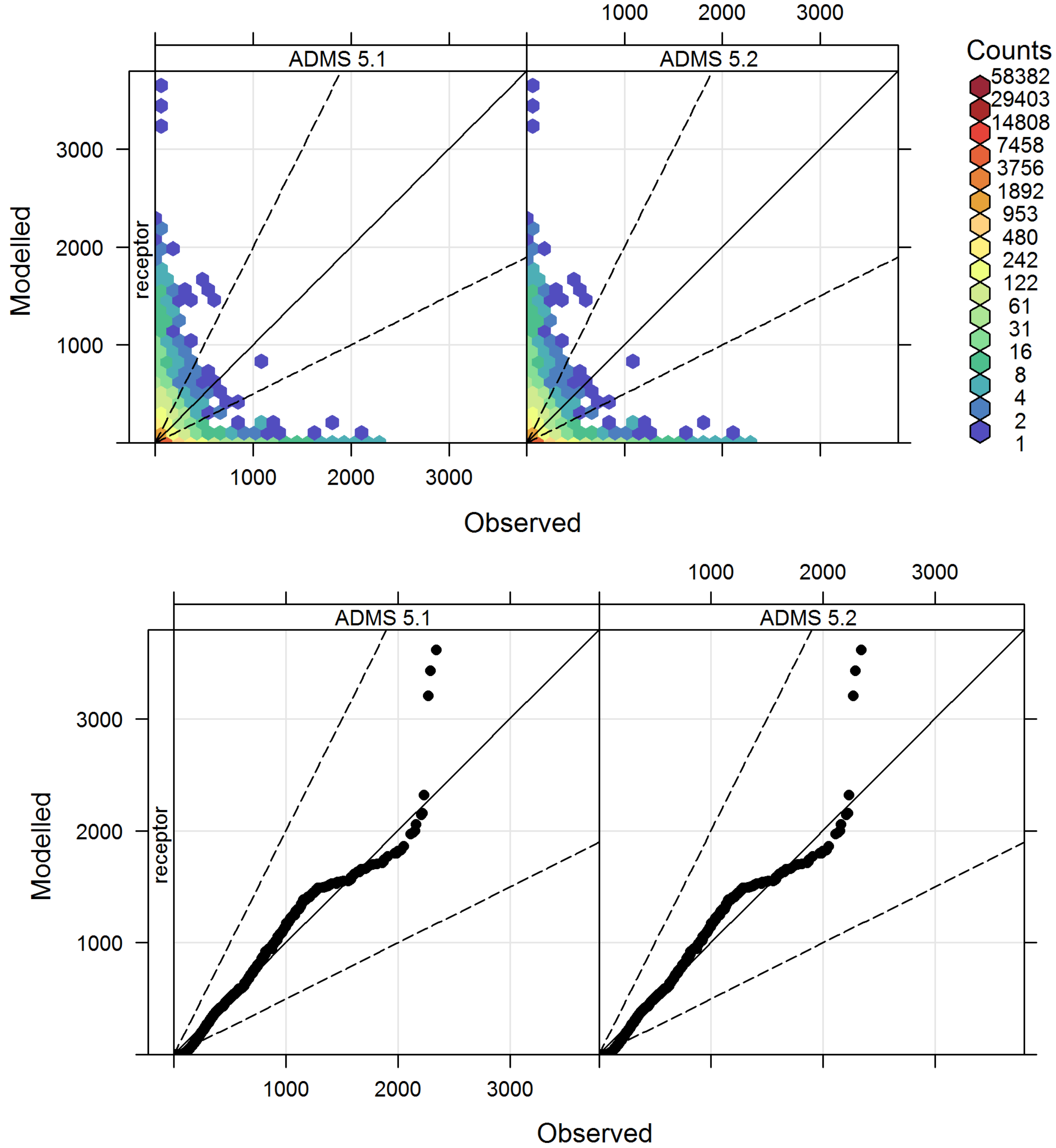

Figure 4 − Scatter plots and quantile-quantile plots of ADMS results against observed data (ug/m³).

3.2 Statistics

Table 3 compares 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/m³)											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 5.1	3202	629	3613	1346	1175	3427	947	856	670	173	460	0.93
	ADMS 5.2	3202	629	3613	1346	1175	3427	947	856	670	173	460	0.93
3-hour maximum	Observed	1418	241	1136	1195	1634	1609	1947	1361	1239	293	402	-
	ADMS 5.1	2169	232	1204	482	1175	1999	947	315	670	172	200	0.75
	ADMS 5.2	2169	232	1204	482	1175	1999	947	315	670	172	200	0.75
24-hour maximum	Observed	554	87	695	371	410	392	1090	581	288	118	171	-
	ADMS 5.1	574	35	287	159	133	1148	96	93	62	36	69	0.61
	ADMS 5.2	574	35	287	159	133	1148	96	93	62	36	69	0.61

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/m³)											Mean M/O ratio
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	
1-hour RHC	Observed	2192	490	2014	1893	2588	2663	2434	2286	2341	460	585	-
	ADMS 5.1	2972	372	2229	990	886	2426	780	559	748	219	382	0.64
	ADMS 5.2	2972	372	2229	990	886	2426	780	559	748	219	382	0.64
3-hour RHC	Observed	1560	273	1138	1229	1452	1546	1480	1183	1179	316	345	-
	ADMS 5.1	1494	148	1141	725	706	1959	539	269	472	186	235	0.65
	ADMS 5.2	1494	148	1141	725	706	1959	539	269	472	186	235	0.65
24-hour RHC	Observed	485	98	465	332	341	478	461	355	291	117	130	-
	ADMS 5.1	393	26	265	152	91	744	62	42	59	38	66	0.47
	ADMS 5.2	393	26	265	152	91	744	62	42	59	38	66	0.47

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 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 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.

Consideration of the scatter and quantile-quantile plots shows that the concentrations predicted by ADMS 5.2 are the same as those from ADMS 5.1 for this study. The statistics presented in **Tables 3** and **4** indicate that for this study ADMS 5.2 predicts the same maximum concentrations as 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] 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.

[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.