ADMS 6 Complex Terrain Validation
Tracy Power Plant

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1 Introduction

The Tracy Power Plant is situated 27 km east of Reno, Nevada, in a region of complex terrain. The power plant is in a valley surrounded by peaks rising to around 950 m above the power plant elevation. During 1984, the United States Environmental Protection Agency carried out a series of 14 experiments between August 6th and 27th, for a total of 128 hours of data collection, mainly during the late evening and early morning hours [1].

The power plant was maintained in warm stand-by status as a tracer gas (SF_6) was released from the 91 m stack on the power plant, and concentrations were measured at 110 receptors (**Figure 1**). The majority of the receptors were positioned on high areas of the terrain, and around 20 were located within the valley. Different combinations of receptors were used for each of the experiments.

Meteorological data were measured at an instrumented 150 m tower located 1.2 km east of the plant. Wind speed, temperature and vertical turbulence parameter data were profile obtained from [2]. The observed data available included hourly average concentrations of SF_6 at each receptor point and meteorological data for each hour of each experiment.

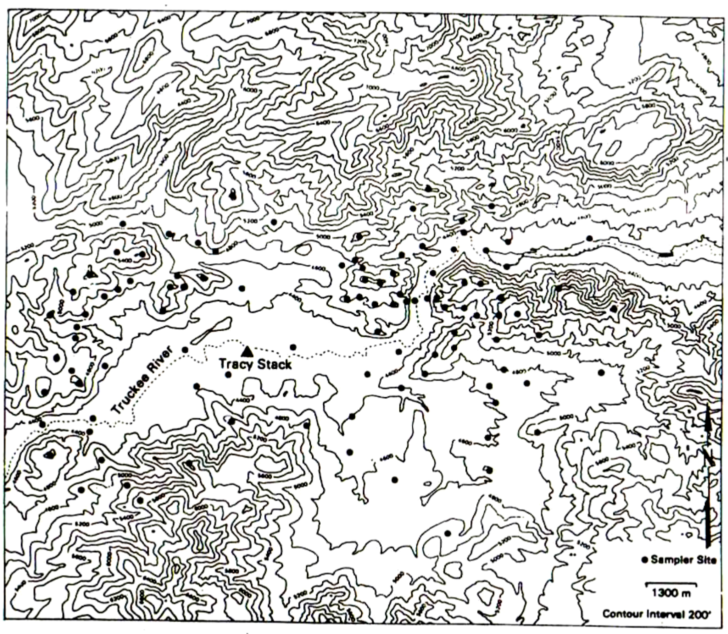


Figure 1 − Deployment of tracer sampling sites for the Tracy power plant study[1].

This document compares the results of ADMS 5.2.0.0 (hereafter referred to as ADMS 5.2) with

[1] **Figure 1** has been directly taken from the document [1].

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 roughness length was 0.1 m, the surface albedo 0.25, the Priestley-Taylor parameter 0.6 and the latitude used in the runs was 40°N. The terrain file was created from Digital Elevation Model (DEM) data and covers a 17 km × 16 km area (as shown in **Figure 2**) with a resolution of approximately 230−240 m.

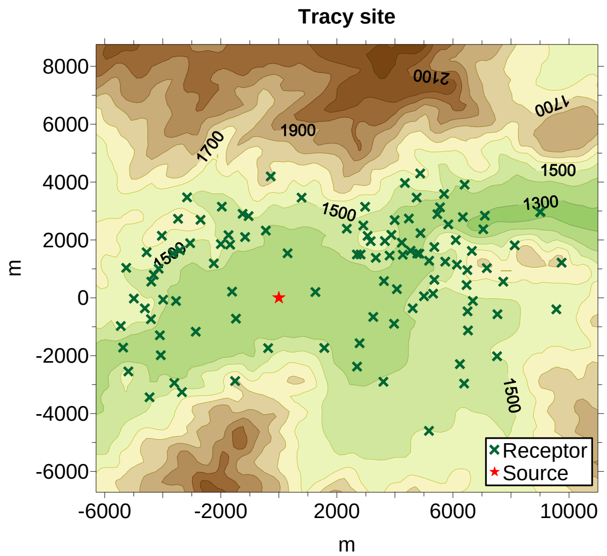


Figure 2 − The terrain surrounding the Tracy power plant, with the source location indicated by a star and receptor locations by green crosses. Heights are given in metres.

2.2 Source parameters

The source parameters are summarised in **Table 1**. The exit velocity varied from 6.8 to 23.2 m/s and the exit temperature from 22.2 to 110.0°C. The SF_6 emission rate (Q) varied between 1.2 and 1.5 g/s during the experiments, but an emission rate of 1 g/s was used for all of the modelled hours, so that the output concentrations (C) are normalized (C/Q) for direct comparison with the observed normalised values.

Pollutant	Location	h (m)	V (m/s)	T (°C)	D (m)	Q (g/s)
SF_6	(0,0)	90.95	varied	varied	2.74	1

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

Concentrations were calculated at all 110 receptors used in the tracer experiment (see **Figure 2**). The height of the majority of the receptors was 0.5 m above ground level. Three elevated receptors were positioned at heights of 43 m, 105 m and 145 m on a tower, which was located approximately 1.2 km east of the source.

2.4 Meteorological data

Meteorological data were collected from an instrumented 150 m tower located 1.2 km east of the power plant. Measurements were recorded at 15 heights, ranging from 10 m to 375 m.

The wind speeds and direction data used to create the meteorological file were those corresponding to a height of 100 m, in order to best represent the dispersion conditions at the height of the stack (see the wind rose shown in **Figure 3**). Inspection of **Figures 2** and **3** shows that that most of the wind comes from the south west, up the valley, towards the Tracy power station. The ambient temperatures ranged from 12.2 to 29.6°C.

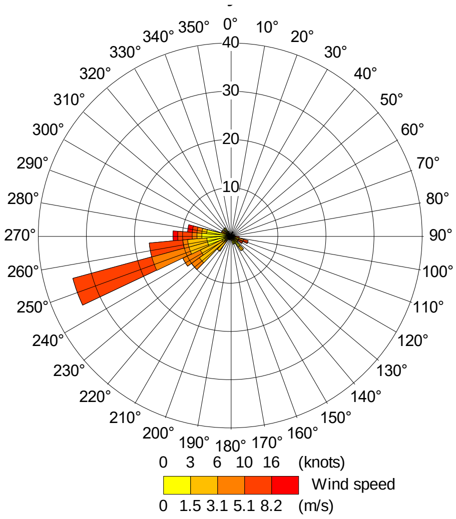


Figure 3 – Wind rose from meteorological data (wind measured at 100 m high).

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**
Stable conditions	99 (77%)	100 (78%)
Neutral conditions	0 (0%)	0 (0%)
Unstable conditions	29 (23%)	28 (22%)
Total	*128 (100%)*	*128 (100%)*

Table 2 – Meteorological conditions.

In the meteorology data file, the boundary layer height was set to 75 m for all night-time hours, and set to missing for daytime hours to force the meteorological processor to estimate it. The value of the minimum wind speed (at a height of 10 m) to be used by the model was set to 0.5 m/s, in order to ensure that the low wind speed conditions were modelled.

In addition to the meteorological file, a profile file was created and used in the model run. It incorporates the wind speed, temperature and vertical turbulence parameter data measured at the 15 heights (10, 50, and every 25 m until 375 m).

3 Results

When comparing the observed and modelled concentrations, SF_6 ambient background values were subtracted from the observed results, assuming that the C/Q value[2] corresponding to the background levels was 0.011 $\mu s/m^3$, which was the smallest value present in the observed data.

In Section 3.1, results are presented as scatter plots and quantile-quantile plots of model results versus observed data. The results for all modelled hours are presented together. The results of other statistical analysis of the data are given in Section 3.2. The graphs and statistical analysis have been produced by the Model Evaluation Toolkit v5.2.

3.1 Scatter and quantile-quantile plots

The scatter plots and quantile-quantile plots are given in **Figures 4** to **8** for all receptors, for the ground-level receptors and for each elevated receptor. Note that these quantile-quantile plots are linear; care should be exercised when comparing these plots with similar ones presented with logarithmic axes.

[2] C = concentration in $\mu g/m^3$, Q = emission rate in g/s.

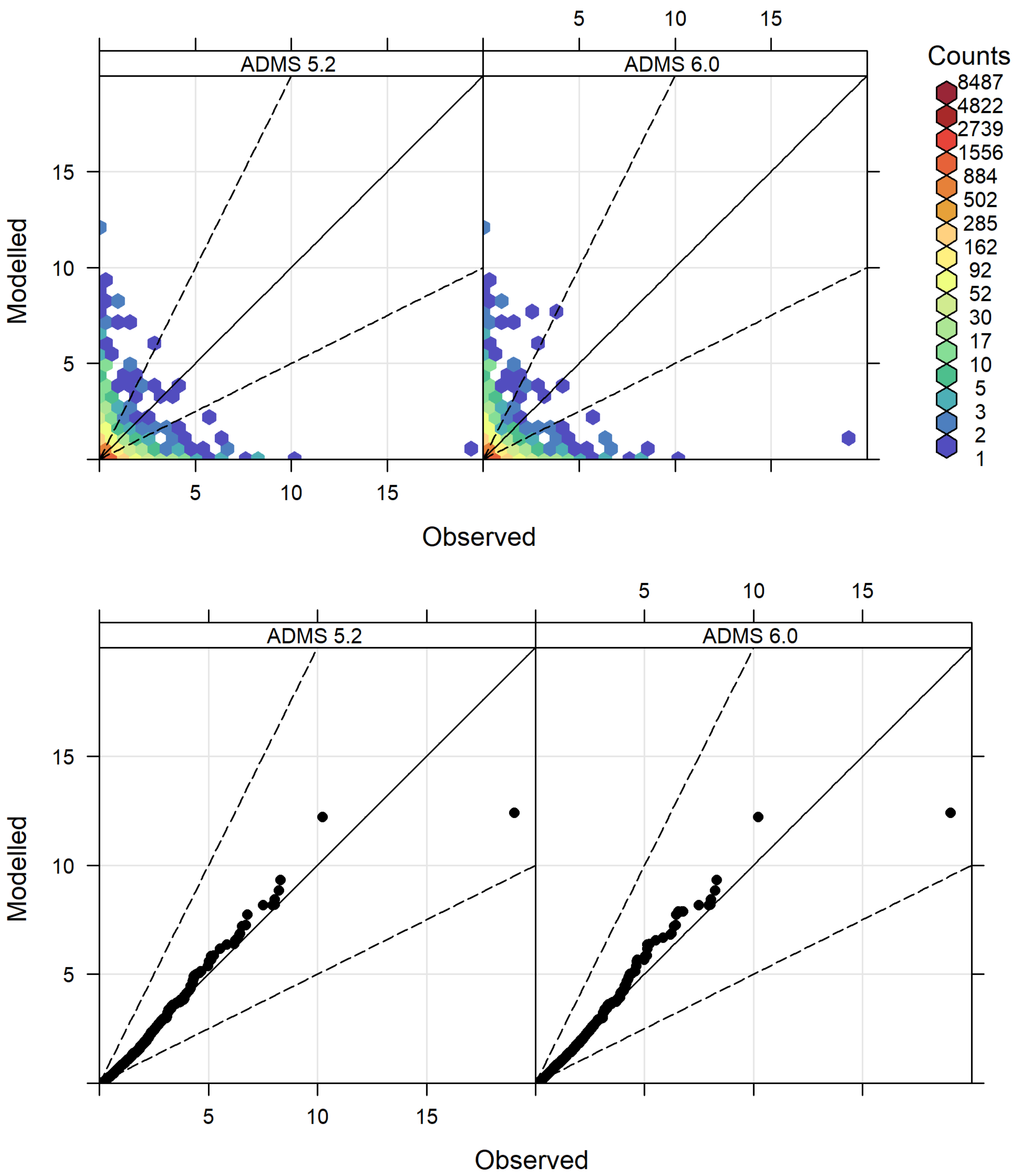


Figure 4 − Scatter plots and quantile-quantile plots of ADMS results against observed data for all receptors (us/m³).

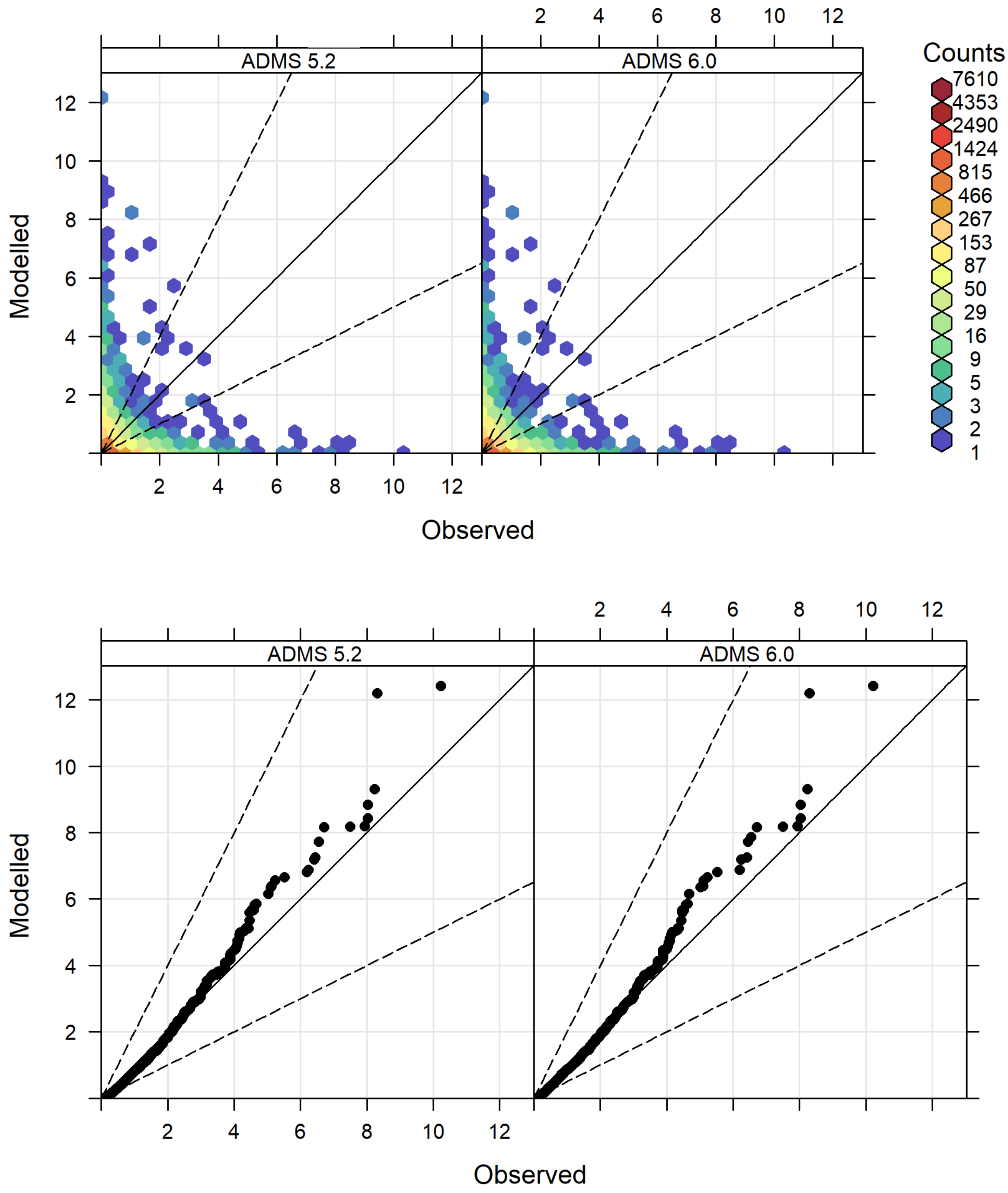


Figure 5 − Scatter plots and quantile-quantile plots of ADMS results against for the ground-level receptors (us/m³).

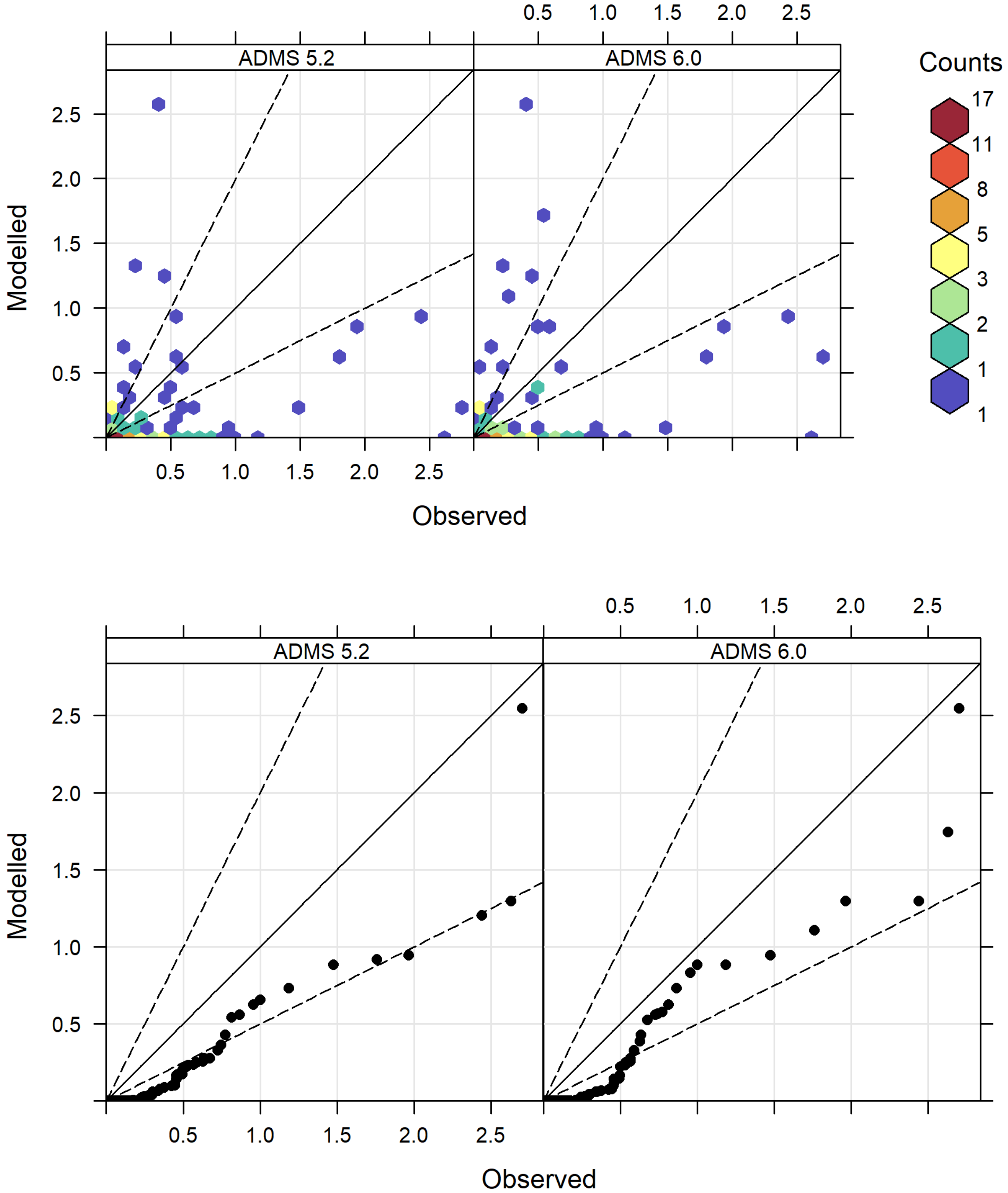
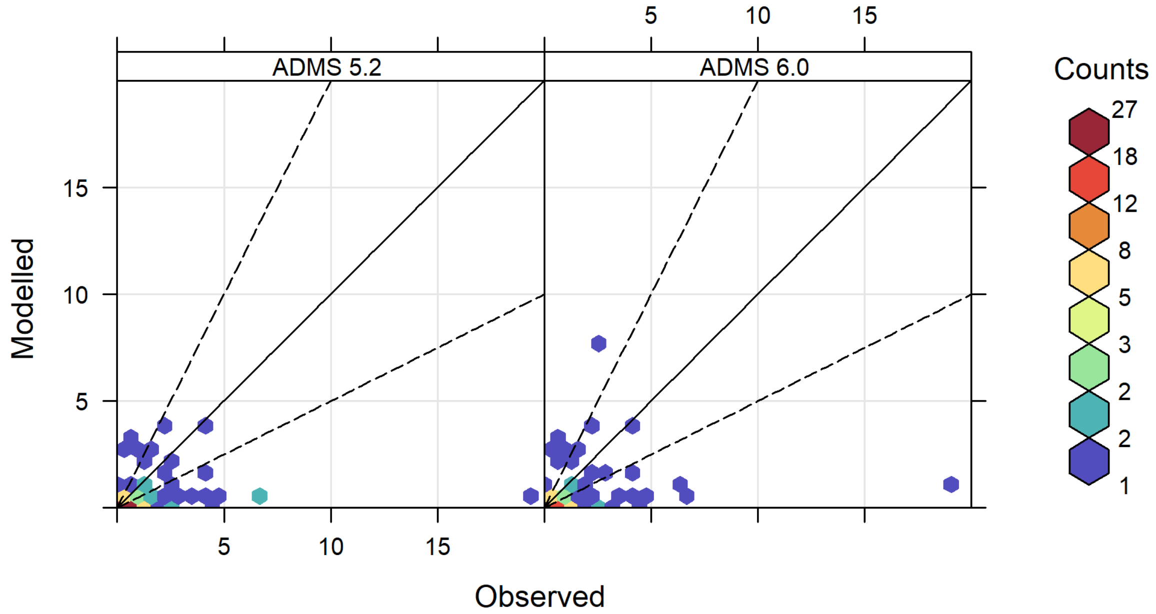


Figure 6 − Scatter plots and quantile-quantile plots of ADMS results against observed data for the 43 m receptor (us/m³).



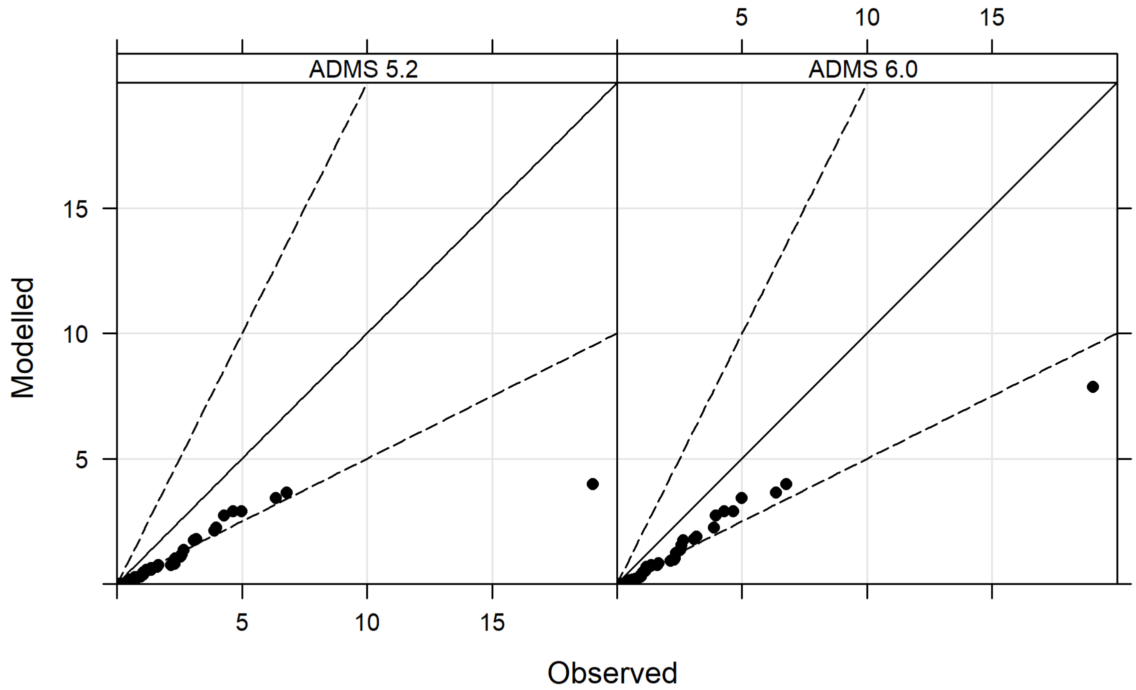
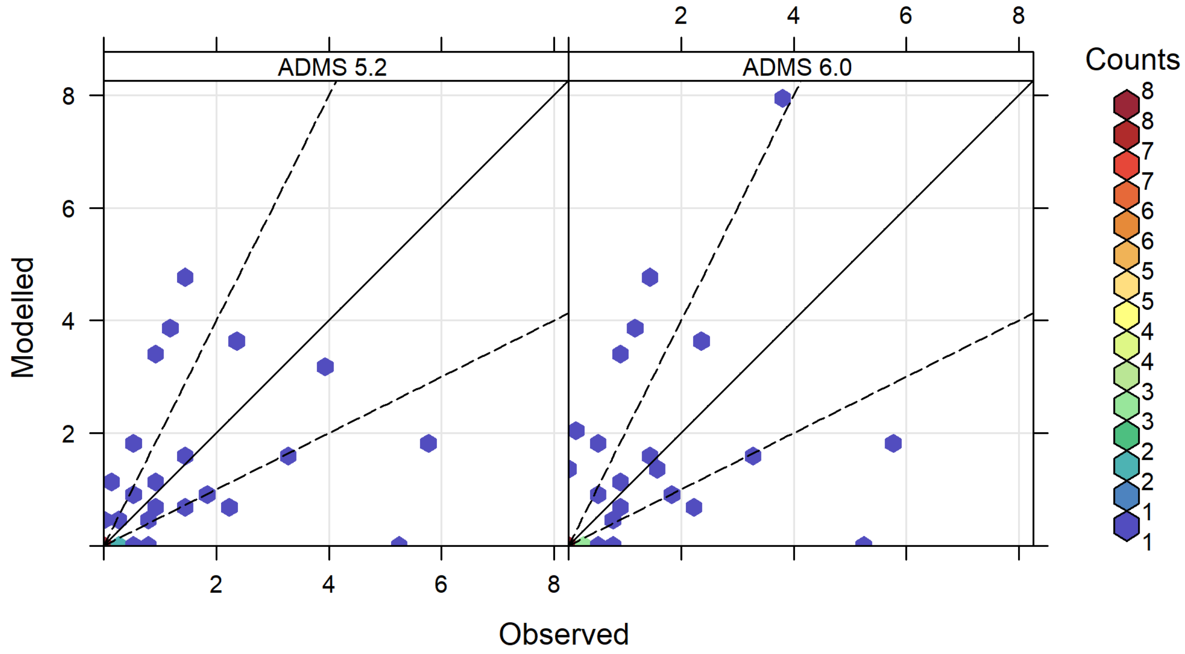


Figure 7 − Scatter plots and quantile-quantile plots of ADMS results against observed data for the 104 m receptor (us/m³).



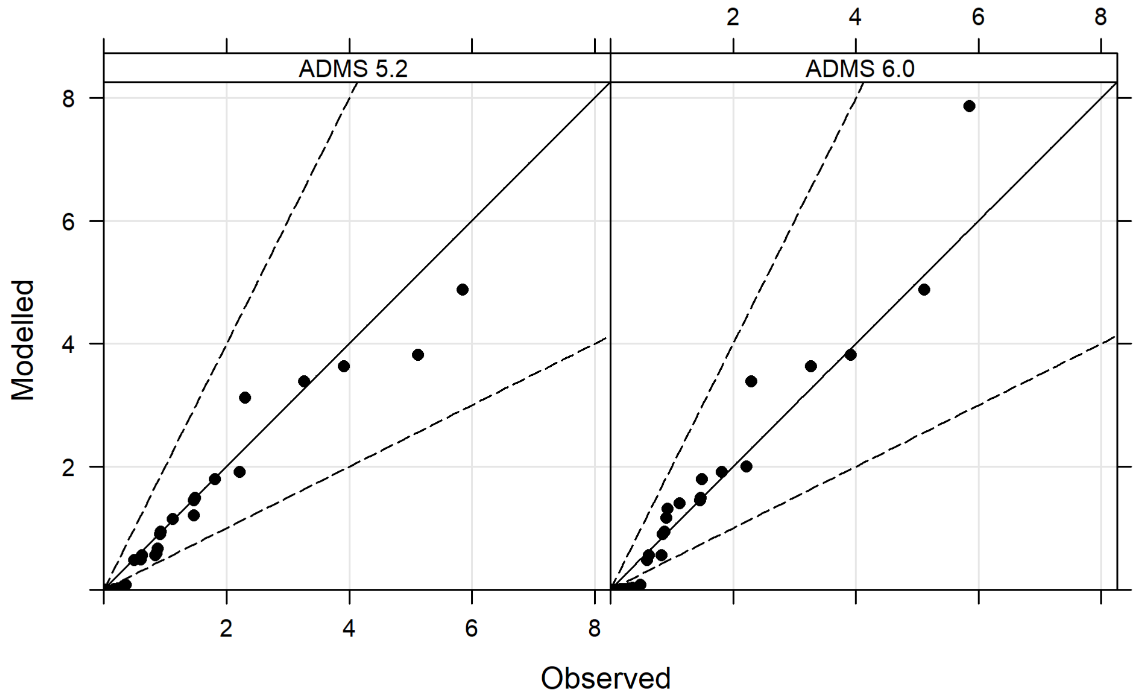


Figure 8 − Scatter plots and quantile-quantile plots of ADMS results against observed data for the 145 m receptor (us/m³).

3.2 Statistics

Statistics calculated include mean, standard deviation (Sigma), bias, normalised mean square error (NMSE), correlation (Cor), fraction of results where the modelled and observed concentrations agree to within a factor of two (Fa2), fractional bias (Fb) and fractional standard deviation (Fs). **Table 3** shows the results of statistical analysis for all receptors, for the ground-level receptors and for each elevated receptor, respectively.

Experiment	Data	Mean	Sigma	Bias	NMSE	Cor	Fa2	Fb	Fs
all receptors	Observed	0.23	0.58	0.00	0.00	1.000	1.000	0.000	0.000
	ADMS 5.2	0.16	0.56	-0.07	16.46	0.110	0.078	-0.387	-0.032
	ADMS 6.0	0.16	0.58	-0.07	15.75	0.121	0.081	-0.330	-0.001
ground-level receptors	Observed	0.22	0.53	0.00	0.00	1.000	1.000	0.000	0.000
	ADMS 5.2	0.15	0.55	-0.07	16.57	0.088	0.076	-0.368	0.047
	ADMS 6.0	0.16	0.56	-0.06	15.90	0.091	0.079	-0.317	0.063
43 m receptor	Observed	0.39	0.53	0.00	0.00	1.000	1.000	0.000	0.000
	ADMS 5.2	0.17	0.36	-0.22	5.75	0.237	0.121	-0.801	-0.391
	ADMS 6.0	0.19	0.41	-0.19	5.08	0.245	0.131	-0.665	-0.257
104 m receptor	Observed	1.29	2.35	0.00	0.00	1.000	1.000	0.000	0.000
	ADMS 5.2	0.52	0.89	-0.78	9.25	0.177	0.169	-0.859	-0.905
	ADMS 6.0	0.61	1.18	-0.69	8.04	0.195	0.157	-0.723	-0.663
145 m receptor	Observed	1.17	1.47	0.00	0.00	1.000	1.000	0.000	0.000
	ADMS 5.2	1.03	1.32	-0.13	2.10	0.357	0.313	-0.122	-0.106
	ADMS 6.0	1.24	1.76	0.07	2.14	0.415	0.281	0.058	0.176

Table 3 – Model evaluation statistics.

4 Discussion

It should be noted that prediction of hour-by-hour concentrations at a point is difficult, being very sensitive to the precise wind direction during the hour. In addition, the monitored concentration is subject to stochastic variation, while the model predictions are of the ensemble mean. ADMS has a fluctuations module that accounts for these variations, but this has not been employed in the current results. For this study, there are many ground-level receptors, but only one receptor at each of the elevated heights, so the analysis at the elevated heights is always for a single location and the expected accuracy of the model is lower.

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.

Consideration of the scatter and quantile-quantile plots show that concentrations predicted by ADMS 5.2 and ADMS 6.0 are similar, though ADMS 6.0 shows a noticeable improvement at the 43 m receptor. The statistics show that ADMS 6.0 tends to predict means that are slightly closer to the observed and also gives a slight improvement in correlation values for the individual receptors. 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.

5 References

[1] United States Environmental Protection Agency, 1986: *Description of a Computer Data Base from the Full Scale Plume Study Tracy Power Plant, Nevada.* Atmospheric Sciences Research Laboratory, United States Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

[2] United States Environmental Protection Agency website, *Model Evaluation Databases*. http://www.epa.gov/scram001/dispersion_prefrec.htm

[3] 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.

[4] Stidworthy A, Carruthers D, Stocker J, Balis D, Katragkou E, and Kukkonen J, 2013: *MyAir Toolkit for Model Evaluation*. 15^{th} International Conference on Harmonisation, Madrid, Spain, May 2013.

[5] Thunis P., E. Georgieva, S. Galmarini, 2010: *A procedure for air quality models benchmarking*. https://fairmode.jrc.ec.europa.eu/document/fairmode/WG1/WG2_SG4_benchmarking_V2.pdf

[6] David Carslaw and Karl Ropkins (2011). *openair: Open-source tools for the analysis of air pollution data*. R package version 0.4-7. http://www.openair-project.org/

[7] Chang, J. and Hanna, S, 2004: *Air quality model performance evaluation*. Meteorol. Atmos. Phys. **87**, 167-196.