

ADMS 4 Complex Terrain Validation

Hogback Ridge Tracer Experiments

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December 2010

1 Introduction

During October 1982, the United States Environmental Protection Agency (US EPA) carried out a series of eleven tracer gas experiments near Farmington, New Mexico, in the United States [1]. Hogback Ridge is a small hill, with maximum elevation 104 m above the minimum elevation in the area. The terrain is semi-arid, with sparse vegetative cover of desert shrubs and grasses.

Tracer gases (SF₆ and 13B1) were released from points on the side of Hogback Ridge, and 100 samplers were arranged along the nearside of the top of the ridge to collect measurements of these tracer gases.

Among the data available from the US EPA experiments are hourly measured meteorological parameters at various heights on a tower (tower A) located at the base of the ridge, hourly measurements of SF₆ (ppt) at the 100 samplers and location data for the samplers and tracer release points.

Experiments 4, 10 and 12 have been modelled using the air pollution dispersion model ADMS, and the results compared with the measured concentrations of SF₆. These three experiments represent stable (experiment 4) and convective meteorological conditions (experiments 10 and 12).

This document compares the predictions by two versions of ADMS with observed concentrations of SF₆. The two versions are 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).

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 ground cover around Hogback Ridge is desert-like, with sparse vegetative cover of desert shrubs and grasses, so a roughness length of 0.02 m was used in the modelling.

Terrain data for the modelling were obtained from the United States Geological Survey's archive of 1°×1° digital elevation model (DEM) data [2]. A contoured plot of the terrain data used is shown in **Figure 1**. It extends 2.5 km in the east-west direction and 2 km in the north-south direction. The resolution of the data is approximately 80 m.

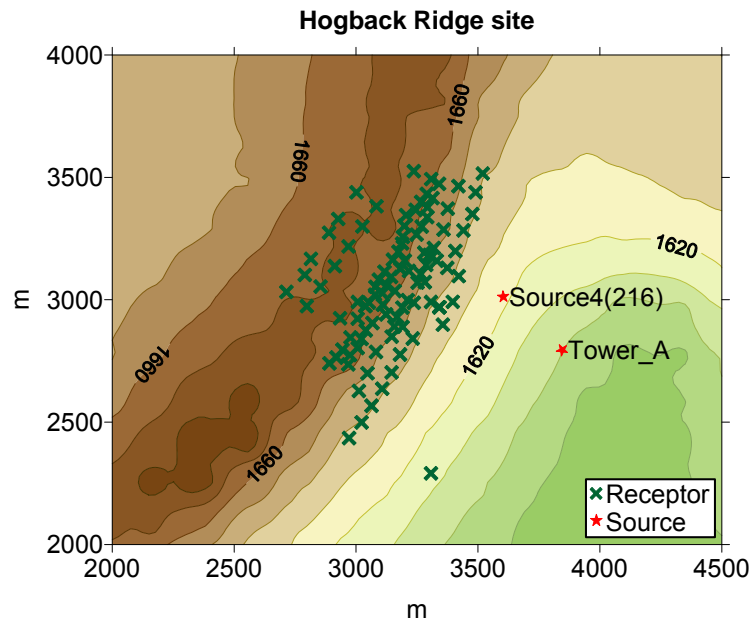


Figure 1 – Modelled area around Hogback Ridge (elevation in metres above mean sea level).

2.2 Source parameters

Table 1 below shows the different source parameters that were used for the three different experiments. All experiments were modelled as passive releases.

The location of the sources is shown in **Figure 1**.

| Experiment | Source name | Pollutant | Stack height (m) | Exit V (m/s) | Exit T (°C) | Diameter (m) | Emission rate (g/s) |
|------------|--------------|-----------------|------------------|--------------|-------------|--------------|---------------------|
| 4 | Source4(216) | SF ₆ | 20 | 0 | 15 | 0.05 | 0.77 |
| 10 | Tower A | SF ₆ | 70 | 0 | 15 | 0.05 | 0.21 |
| 12 | Tower A | SF ₆ | 50 | 0 | 15 | 0.05 | 0.30 |

Table 1 – Source input parameters. T is the temperature, V the velocity.

2.3 Receptors

The monitors were arranged along the ridge (**Figure 1**), at a higher elevation than the sources.

2.4 Meteorological Data

The meteorological data used were hourly data from the instruments on tower A, located at the base of the ridge, plus cloud cover data from the archive of International Surface Weather Observations, 1982-1997 [4]. Each experiment was approximately 9 hours long and all hours were modelled although results are only presented for hours where the wind direction was such that the receptor points were downstream of the source. The meteorological data for the complete experiments are presented in **Table 2**.

The values of the Priestley-Taylor parameter were chosen according to the ambient temperature at the hours being presented, the time of year (autumn) and the nature of the terrain around Hogback Ridge (desert). The local time zone at Hogback Ridge is Mountain Daylight Time (MDT), which is 6 hours behind GMT at the time of year at which these experiments were conducted.

| Time (MDT) | Wind speed (m/s) | Wind direction (°) | Ambient T (°C) | Cloud cover (oktas) | Priestley-Taylor parameter | Stability |
|--|------------------|--------------------|----------------|---------------------|----------------------------|-----------|
| Experiment 4, 11th October 1982 (wind measured at 40 m above the terrain) | | | | | | |
| 00:00 | 2.71 | 267.5 | 6.9 | 0 | 0.0 | stable |
| 01:00 | 2.87 | 279.6 | 6.5 | 2 | 0.0 | stable |
| 02:00 | 1.33 | 345.3 | 4.9 | 2 | 0.0 | stable |
| 03:00 | 1.61 | 102.1 | 4.5 | 0 | 0.0 | stable |
| 04:00 | 1.04 | 232.8 | 3.7 | 0 | 0.0 | stable |
| 05:00 | 1.17 | 27.8 | 4.0 | 0 | 0.0 | stable |
| 06:00 | 1.10 | 229.3 | 3.5 | 2 | 0.0 | stable |
| 07:00 | 1.33 | 207.3 | 3.5 | 7 | 0.0 | stable |
| 08:00 | 1.38 | 226.8 | 4.2 | 7 | 0.0 | convec. |
| Experiment 10, 22th October 1982 (wind measured at 60 m above the terrain) | | | | | | |
| 00:00 | 4.92 | 291.9 | 10 | 2 | 0.18 | stable |
| 01:00 | 1.26 | 168.8 | 7.1 | 0 | 0.18 | stable |
| 02:00 | 1.34 | 137.9 | 5.6 | 0 | 0.18 | stable |
| 03:00 | 2.08 | 146.5 | 4.5 | 0 | 0.18 | stable |
| 04:00 | 1.15 | 122.5 | 3 | 0 | 0.18 | stable |
| 05:00 | 1.01 | 160 | 1.9 | 0 | 0.18 | stable |
| 06:00 | 2.5 | 105.7 | 1.5 | 0 | 0.18 | stable |
| 07:00 | 2.58 | 102.9 | 1.4 | 0 | 0.18 | stable |
| 08:00 | 2.08 | 116.4 | 0.9 | 0 | 0.18 | convec. |
| 09:00 | 2.69 | 110.1 | 4.8 | 0 | 0.18 | convec. |
| 10:00 | 2.07 | 121.3 | 8 | 0 | 0.18 | convec. |
| Experiment 12, 24th October 1982 (wind measured at 60 m above the terrain) | | | | | | |
| 00:00 | 2.08 | 85.2 | 12.2 | 7 | 0.16 | stable |
| 01:00 | 1.33 | 187.4 | 10.2 | 7 | 0.16 | stable |
| 02:00 | 2.03 | 169.8 | 7.4 | 2 | 0.16 | stable |
| 03:00 | 1.94 | 149.3 | 7.4 | 2 | 0.16 | stable |
| 04:00 | 2.63 | 119.1 | 6.8 | 2 | 0.16 | stable |
| 05:00 | 2.2 | 67.4 | 6.3 | 2 | 0.16 | stable |
| 06:00 | 2.58 | 77.0 | 6.2 | 2 | 0.16 | stable |
| 07:00 | 3.54 | 90.9 | 6.4 | 2 | 0.16 | stable |
| 08:00 | 3.16 | 112.2 | 5.3 | 2 | 0.16 | convec. |
| 09:00 | 3.02 | 115.3 | 4.9 | 0 | 0.19 | convec. |
| 10:00 | 3.59 | 128.6 | 7.6 | 0 | 0.17 | convec. |
| 11:00 | 3.93 | 130.6 | 11.5 | 0 | 0.16 | convec. |

Table 2 – Meteorological data. The wind direction is given in degrees from north. T is the temperature. The shaded rows indicate the hours for which data are presented.

2.5 Output Data

The model output contained short-term hourly averages of SF₆ concentration with units of µg/m³ at receptor points positioned at the sampler locations.

The conversion from concentration in µg/m³ to concentration in ppt was done using the Ideal Gas Equation:

$$p = \frac{10^3 \rho R^* T}{M} \rightarrow \text{conc}_{ppt} = \text{conc}_{\mu\text{g}/\text{m}^3} \times 10^6 \times \frac{R^* T}{Mp} = \text{conc}_{\mu\text{g}/\text{m}^3} \times 164.8$$

where $p = 1013 \text{ mb} = 101300 \text{ Pa}$, $T = 293.15\text{K}$, $M(\text{SF}_6) = 146 \text{ g/mol}$, and $R^* = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$.

In the original experiments, a different subset of samplers collected measurements each hour, and this is reflected in the modelling by using a different subset of receptor points each hour.

The height above terrain of all but three of the receptor points was 0.5 m; the other three were at 8 m, 14 m and 25 m.

3 Results

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

3.1 Scatter and quantile-quantile plots

Figure 2 shows the scatter plots and quantile-quantile plots of modelled versus observed data for the experiment 4, **Figure 3** shows the same plots for the experiment 10 and **Figure 4** shows the same plots for the experiment 12.

The scatter plots compare concentrations at a fixed location and a fixed time under particular meteorological conditions. This sort of comparison in space and time is likely to be subject to greater variation than, for instance, comparisons of arcwise maxima where the comparison is at a downstream distance, not at a downstream and crosswind location.

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.

Note that the quantile-quantile plots are linear; care should be exercised when comparing these plots with similar ones presented with logarithmic axes.

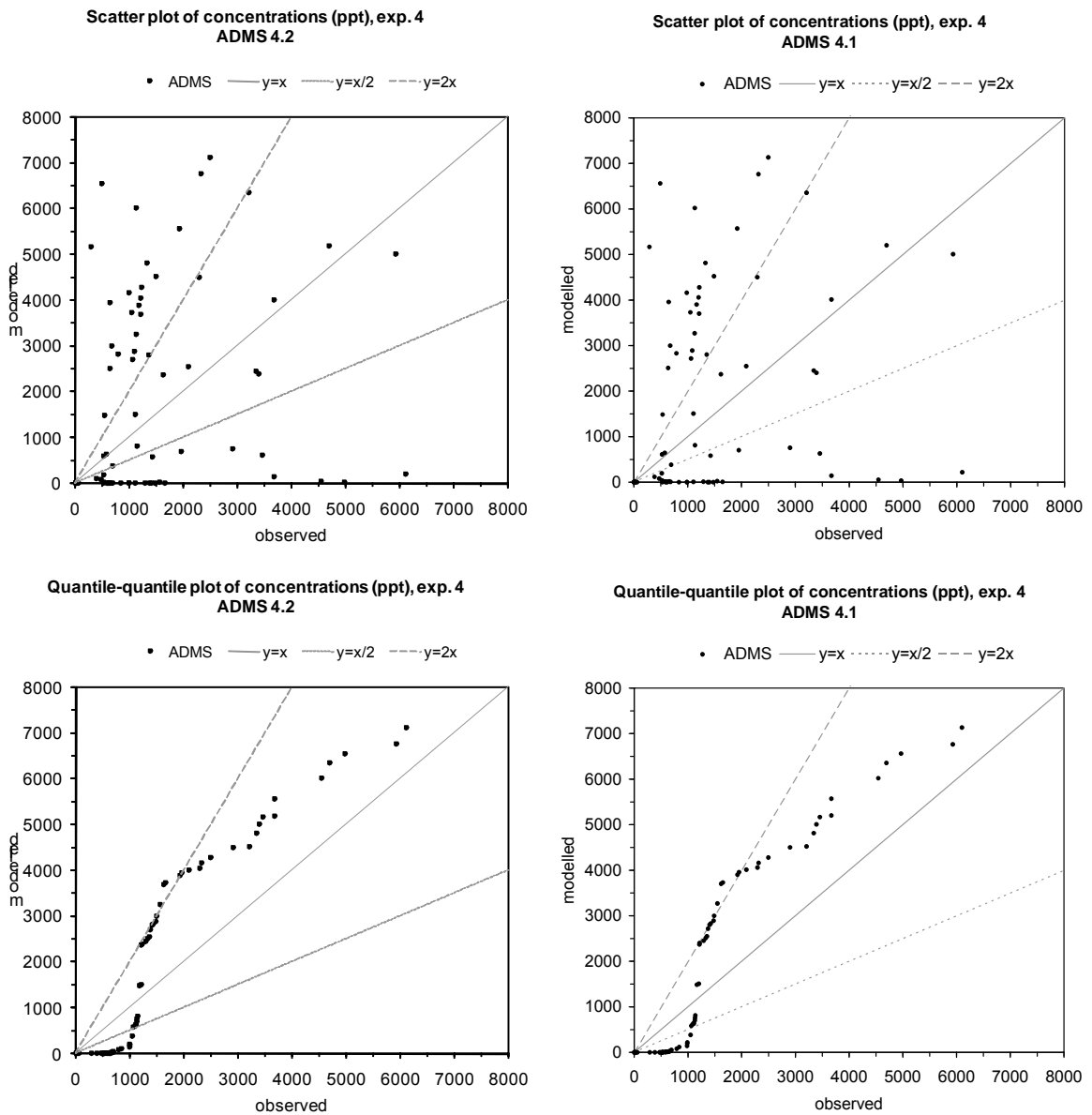


Figure 2 – Scatter plots and quantile-quantile plots of modelled SF₆ concentration against observed data for **experiment 4**.

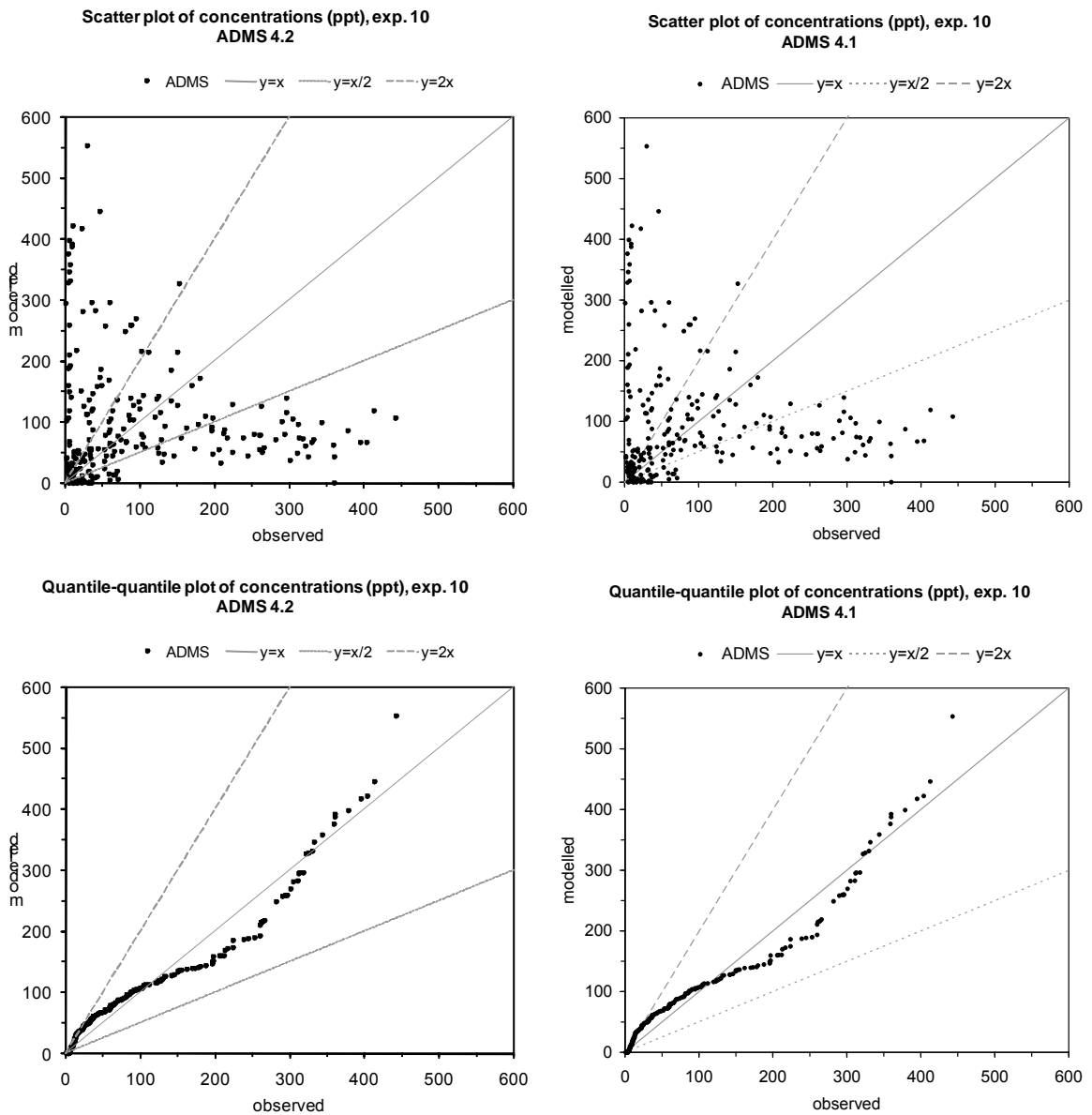


Figure 3 – Scatter plots and quantile-quantile plots of modelled SF₆ concentration against observed data for **experiment 10.**

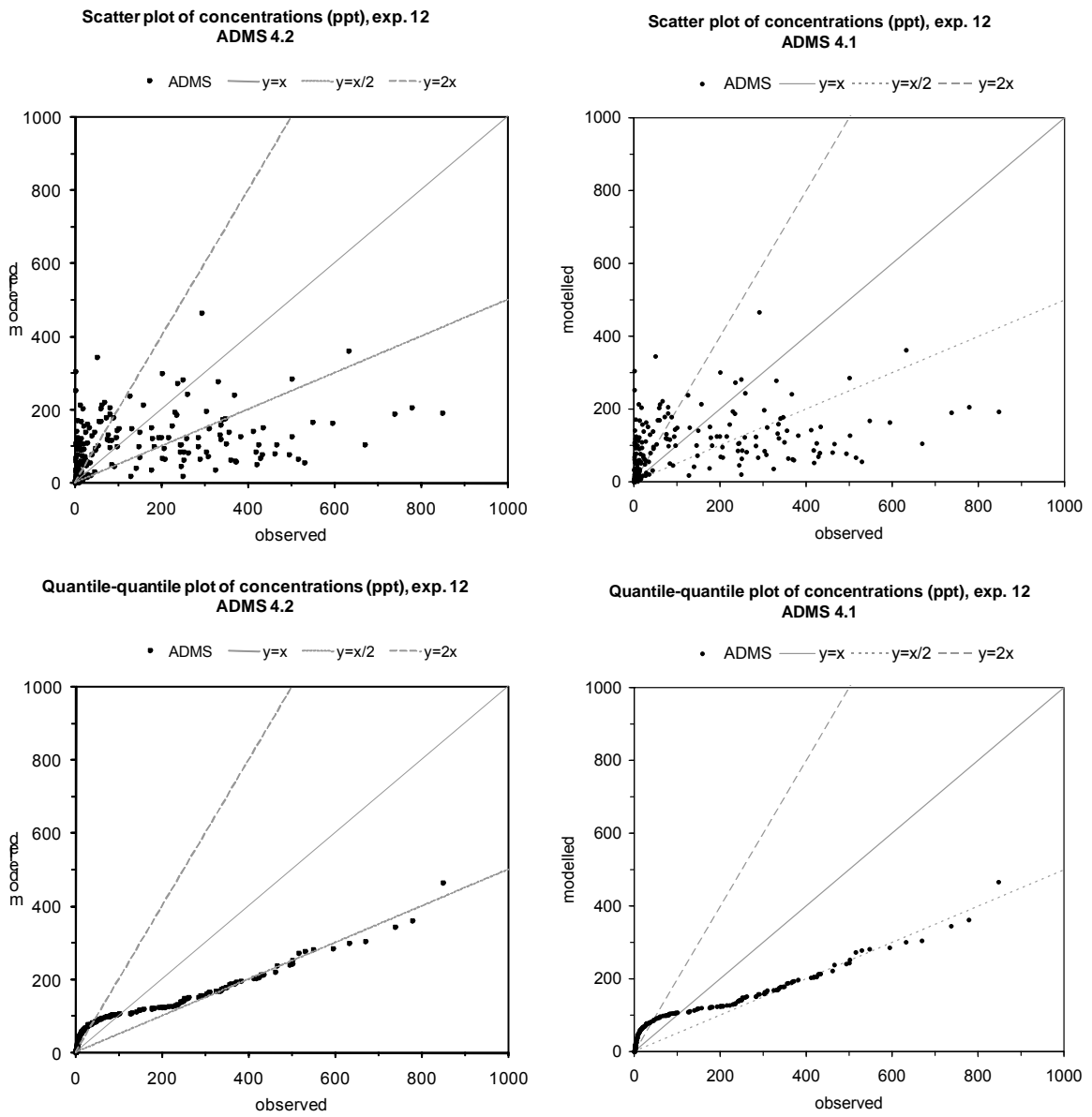


Figure 4 – Scatter plots and quantile-quantile plots of modelled SF₆ concentration against observed data for experiment 12.

3.2 Statistics

The BOOT package produces statistics of the data that are useful in assessing model performance. 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 2 (fa2), fractional bias (fb) and fractional standard deviation (fs). **Tables 3 to 5** summarise the statistics of the comparison of modelled against observed concentration data.

| Data | Mean | Sigma | Bias | NMSE | Cor | Fa2 | Fb | Fs |
|----------|---------|---------|---------|------|-------|-------|--------|--------|
| Observed | 1467.62 | 1371.41 | 0.00 | 0.00 | 1.000 | 1.000 | 0.000 | 0.000 |
| ADMS 4.1 | 1867.85 | 2167.21 | -400.22 | 1.93 | 0.244 | 0.203 | -0.240 | -0.450 |
| ADMS 4.2 | 1867.85 | 2167.21 | -400.22 | 1.93 | 0.244 | 0.203 | -0.240 | -0.450 |

Table 3 – BOOT statistics for **experiment 4** (74 pairs of data points).

| Data | Mean | Sigma | Bias | NMSE | Cor | Fa2 | Fb | Fs |
|----------|-------|--------|-------|------|--------|-------|--------|-------|
| Observed | 92.64 | 105.40 | 0.00 | 0.00 | 1.000 | 1.000 | 0.000 | 0.000 |
| ADMS 4.1 | 95.71 | 98.22 | -3.08 | 2.46 | -0.052 | 0.331 | -0.033 | 0.071 |
| ADMS 4.2 | 95.71 | 98.22 | -3.08 | 2.46 | -0.052 | 0.331 | -0.033 | 0.071 |

Table 4 – BOOT statistics for **experiment 10** (239 pairs of data points).

| Data | Mean | Sigma | Bias | NMSE | Cor | Fa2 | Fb | Fs |
|----------|--------|--------|-------|------|-------|-------|-------|-------|
| Observed | 119.47 | 171.92 | 0.00 | 0.00 | 1.000 | 1.000 | 0.000 | 0.000 |
| ADMS 4.1 | 83.36 | 80.75 | 36.11 | 2.48 | 0.458 | 0.257 | 0.356 | 0.722 |
| ADMS 4.2 | 83.36 | 80.75 | 36.11 | 2.48 | 0.458 | 0.257 | 0.356 | 0.722 |

Table 5 – BOOT statistics for **experiment 12** (238 pairs of data points).

4 Discussion

The scatter and quantile-quantile plots show generally good agreement between modelled and observed concentration data. As mentioned in Section 3.1, comparisons at a fixed location and a fixed time such as those presented are likely to be subject to greater variation than, for instance, comparisons of arcwise maxima, where the comparison is at a downstream distance, not at a downstream and crosswind location. The differences between ADMS 4.1 and ADMS 4.2 in scatter and quantile-quantile plots are negligible.

The tables giving the BOOT statistics in Section 3.2 also show generally good agreement between modelled and observed concentrations, with the model neither consistently over- or under-estimating observed values. The differences between ADMS 4.1 and ADMS 4.2 in BOOT statistical results are negligible.

5 References

- [1] United States Environmental Protection Agency, 1985: *Description of a Computer Data Base from Small Hill Impaction Study No.2, Hogback Ridge, New Mexico*. United States

Environmental Protection Agency Complex Terrain Model Development, Atmospheric Sciences Research Laboratory, EPA/600/3-86/002.

- [2] <ftp://edcftp.cr.usgs.gov/pub/data/DEM/250>
- [3] <http://www.nadn.navy.mil/Users/oceano/pguth/website/microdem.htm>
- [4] United States Department of Commerce (N.O.A.A.) and United States Department of Air Force (A.F.C.C.C.), 1998: *International Surface Weather Observations, 1982-1997*.