ADMS 5 Flat Terrain Validation
Kincaid, Indianapolis and Prairie Grass

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1 Introduction

This document presents a summary of ADMS model results compared against three well known field data sets: Prairie Grass, Kincaid and Indianapolis.

ADMS has been developed in the UK and is widely used internationally by industry, consultants and regulatory bodies. ADMS is described as a 'new generation' model. This type of model describes the state of the atmospheric boundary layer using two parameters: boundary layer depth and Monin-Obukhov length. The vertical concentration distribution is Gaussian in neutral and stable atmospheres but is a skewed Gaussian in convective conditions. As with the 'old generation' models a Gaussian distribution is assumed in the crosswind horizontal direction for all stabilities.

ADMS has been extensively validated during its development against field data sets and wind tunnel data sets. Studies have covered a range of meteorological conditions (Carruthers *et al.*, 1994 [3]; Carruthers *et al.*, 1996 [4]; Carruthers *et al.*, 1998 [6]), including a comparison against LIDAR data undertaken for the UK Environment Agency with the emphasis on convective conditions. Advanced model features have also been tested, particularly the buildings module (Carruthers, McKeown *et al.*, 1999 [2]).

The three data sets used here are drawn from those that are openly available and have been generally accepted as containing enough measurements and of sufficient quality for meaningful validation. A series of workshops have been held over the last twenty years on 'Harmonisation of Atmospheric Dispersion Modelling for Regulatory Purposes'. At these 'harmonisation workshops' a Model Validation Kit (MVK) was developed to evaluate models which includes the Kincaid and Indianapolis data sets. The Prairie Grass data set is derived from the files that have been used for the ASTM model evaluation (D6589) [1], with additional input data from United States Environmental Protection Agency Website [8]. The graphs and statistical analysis in this document have been produced by the MyAir Toolkit for Model Evaluation, which is described further in Section 2.1.

ADMS model runs have been carried out by CERC. This document presents the results of ADMS 5.1.2.0 (hereafter referred to as ADMS 5.1) and ADMS 5.2.0.0 (hereafter referred to as ADMS 5.2).

Section 2 presents the method of analysis. Section 3 presents and discusses the results for each of the field experiments: Kincaid (Section 3.2), Indianapolis (Section 0) and Prairie Grass (3.4). Section 4 summarises the associated analyses.

2 Method of analysis

2.1 MyAir Toolkit for Model Evaluation

The MyAir Toolkit for Model Evaluation [9] was developed under the local forecast model evaluation support work package of the EU's 7th Framework, PASODOBLE project. It draws on existing best practice such as the EU Joint Research Council's (JRC) FAIRMODE initiative on model evaluation [10] and the openair project tools [11]. The toolkit can take as input modelled data from regional or local scale models and the same netCDF input files as the FAIRMODE DELTA tool. Observed data are in situ time series data. Missing data are handled if they are indicated by a standard value.

As output, the MyAir Toolkit creates plots of the model performance in predicting concentrations for single or multiple sites and single or multiple pollutants. Results can be classified by the type of monitoring site (e.g. urban background, suburban, roadside, kerbside) and the pollutant. The diagnosis of model performance for individual sites and individual pollutants produces time series plots, scatter plots and analyses with respect to month, day of the week and hour of the day. All the data plotted are also exported to data files to provide an audit trail and make the data available for further analysis and visualisation.

Note that the sign of the bias and fractional bias calculated by the Myair Toolkit is consistent with openair [11] and the DELTA tool [10], but not with the BOOT package [12].

2.2 Arcwise maximum concentration

All the analyses presented in this document are based solely on the maximum observed concentrations for each arc. Concentrations measured at other locations along each arc that are less than the maximum value, are discarded once the maximum has been located.

The maximum observed value is subject to significant inherent uncertainty due to turbulence. This means that if an experiment were repeated under identical conditions, the maximum concentration measured would be different each time. The ensemble mean predicted by the models, which represents the average over a large number of repetitions, is the value compared here with measurements. Therefore, even a 'perfect' ensemble average model would not match prediction with the individual observations.

3 Validation data sets

3.1 Quality indicators

The measured data have been collected on arcs downwind of a source. A quality indicator has been assigned to each hour's measurements according to how well the maximum concentration is defined, as shown in **Table 1**. It has been recommended that data with a quality indicator of 2 or 3 should be used when analysing model behaviour. This has been followed for the Kincaid and Indianapolis data sets. There were too few quality 2 and 3 data points to do this for Prairie Grass, so all points have been included.

If a model is compared with the quality 2 and quality 3 data separately, the results, if displayed on a quantile−quantile plot, should show the quality 2 line lying above the quality 3 line as a lower maximum concentration will be observed. Note that the quantile-quantile plots presented in this document are linear; care should be exercised when comparing these plots with similar ones presented with logarithmic axes.

Quality	Meaning
0	This value should clearly be disregarded.
1	This value is most probably not the maximum value.
2	A maximum is identified but the true value may be different e.g. the concentration pattern is irregular, there are only 2 or 3 monitors impacted, the plume is near the edge of the arc. Note: arcs where the observed maximum is essentially zero but with evidence that a plume is present aloft are included in this group.
3	A relatively well-defined maximum is observed, which is continuous in space, is away from the edge of the monitoring arc, and is not irregular or isolated.

Table 1 − Quality indicators.

3.2 Kincaid

Experiment

The Kincaid data set contains 171 hours of tracer experiments, which were performed at the Kincaid power plant in Illinois, U.S.A. during 1980-81 (**Figure 1**[1]). The power plant is surrounded by flat farmland with some lakes. The roughness length is approximately 10 cm. During the experiments, SF_6 was released from a stack 187-m tall with a 9-m diameter.

Meteorological data were composed of nearby National Weather Service data, and of temperature, wind speed and wind direction from an instrumented tower (2, 10, 50 and 100 m levels). The meteorological conditions ranged from neutral to convective.

In the ADMS model runs shown here, the boundary layer height was calculated using the model's own meteorological pre-processor.

The emission rate was set to 1 g/s, indicating that the observed concentrations supplied have been normalised by the emission rate.

Statistical analysis

Results are summarised in **Table 2** and **Figure 2** for hours when the observed data were of qualities 2 and 3. **Table 3** and **Figure 3** correspond to results for data of quality 3 only.

A model would be expected to perform better compared with quality 3 data than quality 2 and quality 3 data as the maximum concentration reported is more likely to be near to the true maximum value. ADMS shows some improvement in NMSE and proportion of values within a factor of 2 when modelling quality 3 data than combined qualities 2 and 3.

There is negligible change in the results from ADMS 5.1 to ADMS 5.2.

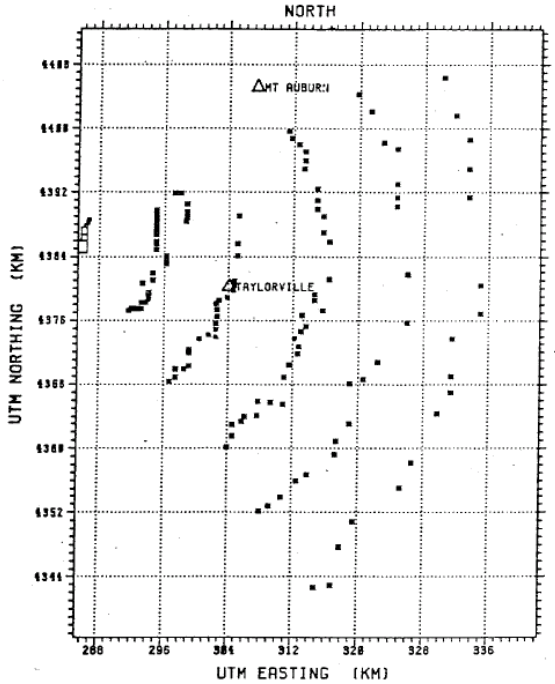


Figure 1 − Example of Kincaid SF_6 tracer sampling array for neutral conditions.

Data	Mean	Sigma	Bias	NMSE	Cor	Fa2	Fb	Fs
Observed	41.0	39.3	0.0	0.0	1.00	1.00	0.00	0.00
ADMS 5.1	41.4	31.2	0.4	0.7	0.51	0.59	0.01	-0.23
ADMS 5.2	41.4	31.2	0.4	0.7	0.51	0.59	0.01	-0.23

Table 2 − Statistics: Kincaid, qualities 2&3. Units for mean, sigma and bias: ns/m^3.

[1] Figure and caption have been taken directly from the document [7].

Data	Mean	Sigma	Bias	NMSE	Cor	Fa2	Fb	Fs
Observed	54.3	40.3	0.0	0.0	1.00	1.00	0.00	0.00
ADMS 5.1	49.5	31.6	-4.9	0.5	0.48	0.68	-0.09	-0.24
ADMS 5.2	49.5	31.6	-4.9	0.5	0.48	0.68	-0.09	-0.24

Table 3 − Statistics: Kincaid, quality 3 only. Units for mean, sigma and bias: ns/m^3.

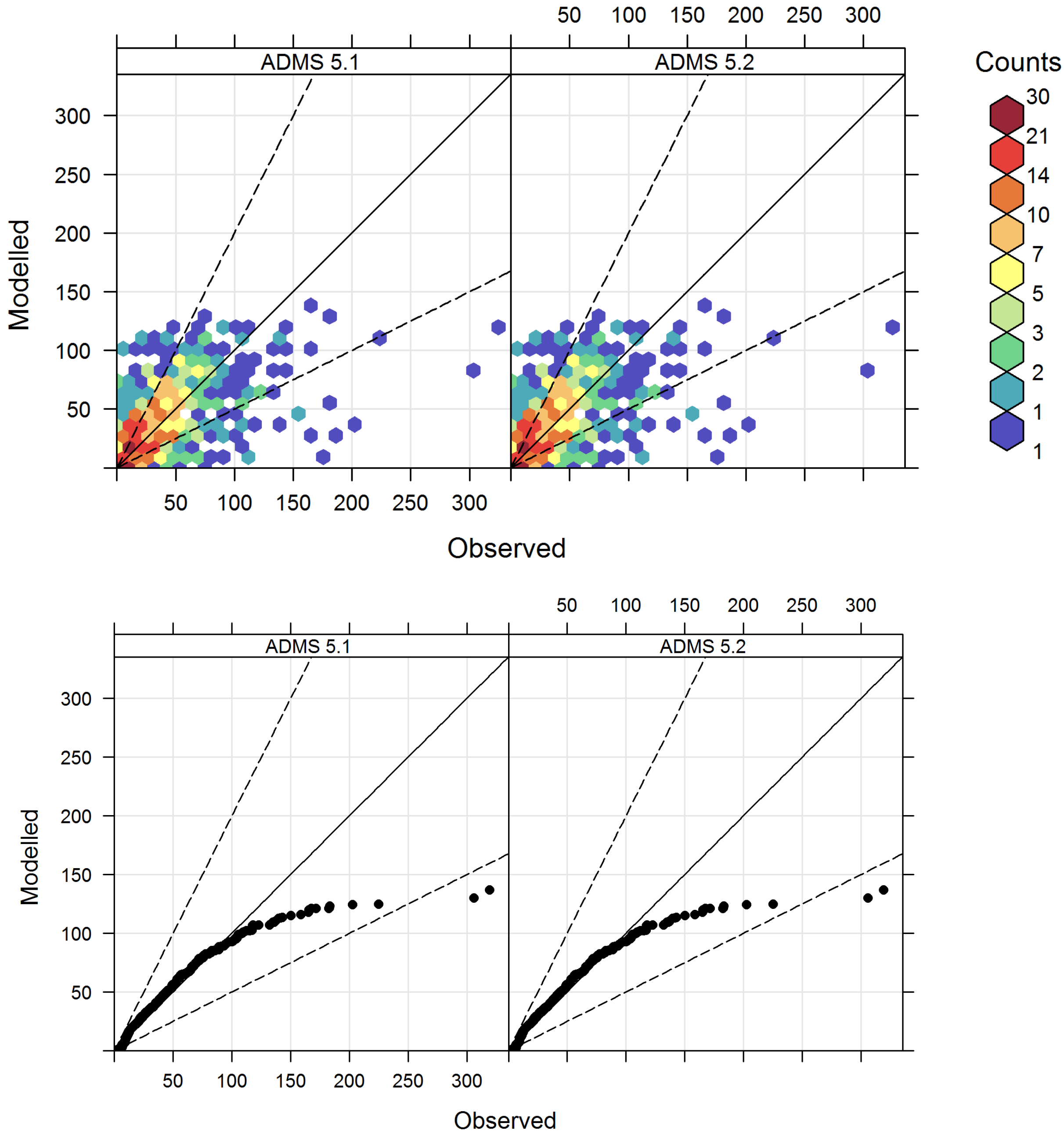


Figure 2 − Kincaid experiment, ADMS, quality 2 & 3 data (units are ns/m^3).

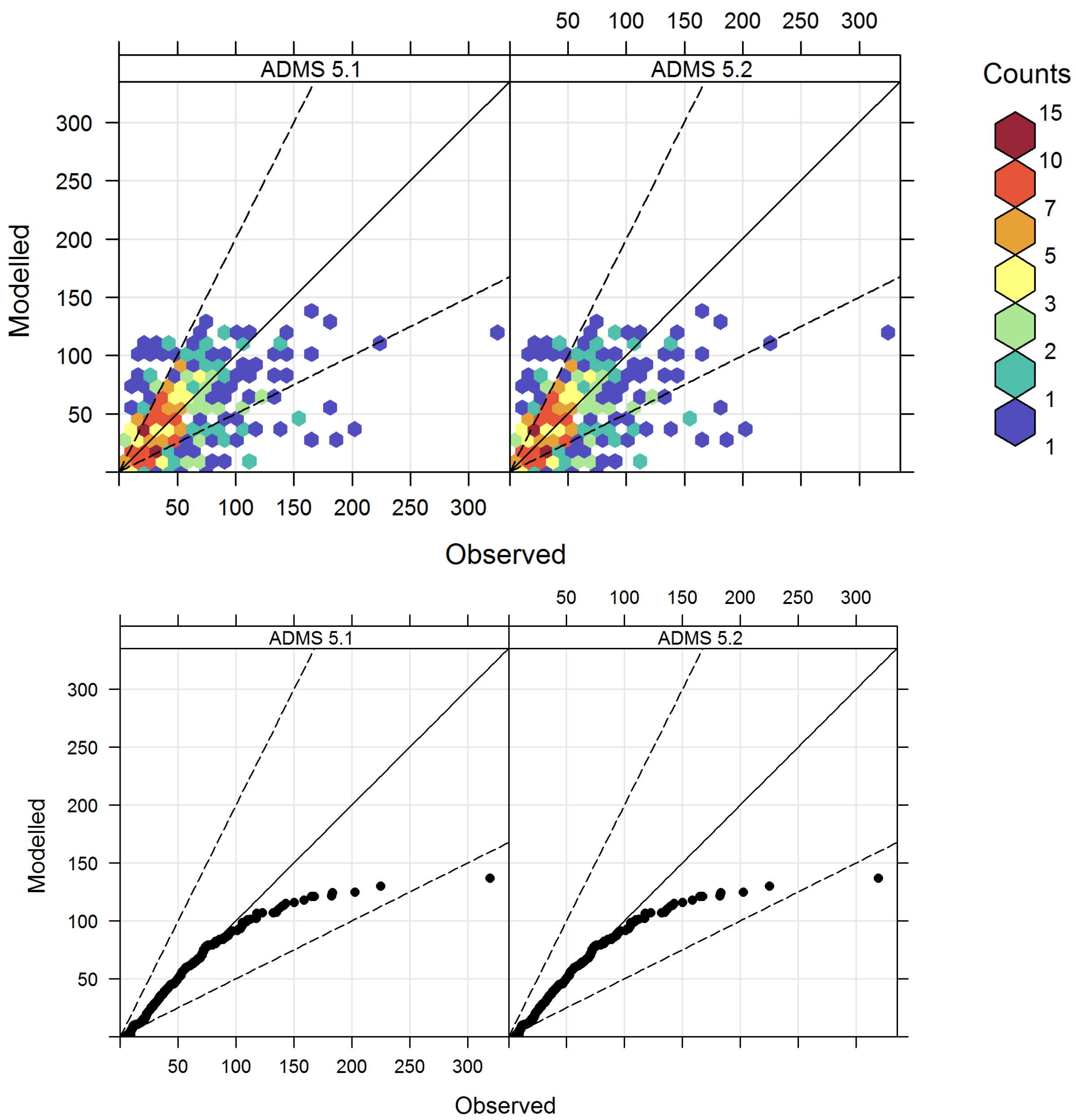


Figure 3 − Kincaid experiment, ADMS, quality 3 data (units are ns/m^3).

3.3 Indianapolis

Experiment

The Indianapolis dataset contains the results of 170 hours of SF_6 tracer experiments carried out for EPRI (Electric Power Research Institute) in 1985 at the Perry-K power plant on the outskirts of Indianapolis (**Figure 4**[2]).

The stack of the Perry-K power plant is 83.8-m tall with a diameter of 4.72 m. The site is situated on the south-west edge of Indianapolis, in a mixed industrial/commercial/urban area with many buildings within one or two kilometres. The individual buildings were shown not to influence the plume, which tended to rise 100 m or more above the stack top most of the time, so building effects are not included explicitly in the modelling runs.

Tracer concentrations were recorded hourly from arrays of up to 160 receptors on arcs at distances ranging from 0.25 to 12 km from the stack, which were moved according to the prevailing wind direction.

Meteorological data were composed of data collected by different instrumented towers: 94-m tower (located on a bank building) providing sigma-theta, wind speed and wind direction, other 10-m towers (located in rural and suburban areas) providing wind speed, temperature difference between 2 and 10 m high, and other surface data. Meteorological conditions covered a range of stability classes and wind speeds throughout the experimental period, which covered daytime and night-time.

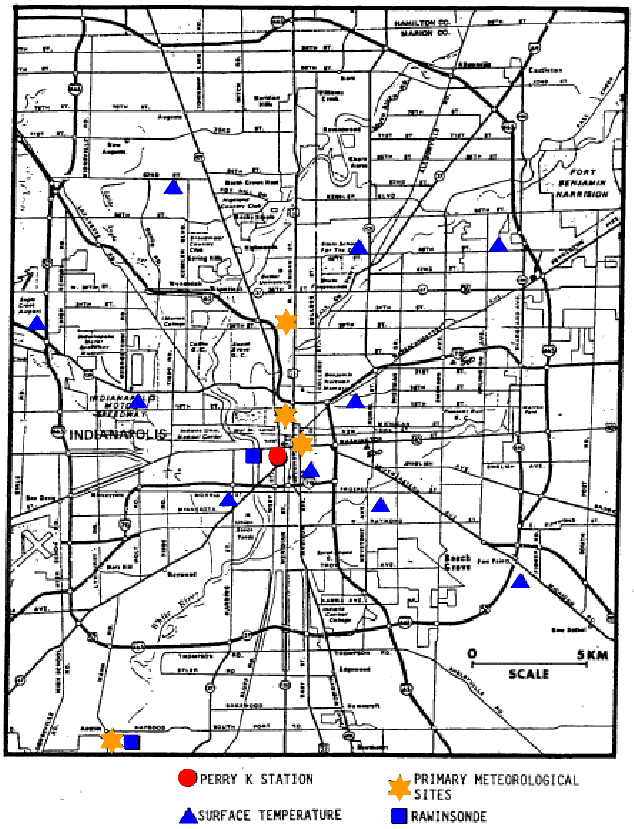


Figure 4 − Location of meteorological sensors deployed in Indianapolis for the SF_6 tracer study.

Results are presented here from ADMS model runs compared with observed data of qualities 2&3 and quality 3 only, as the night-time observations were unexpectedly very high given the height of the stack and the stable meteorological conditions reported. The concentrations have been normalised by the emission rate.

The following assumptions have been used in the ADMS modelling:

(i) The region surrounding the site is an urban area, which may be considered to have a surface roughness of 3 m.

(ii) In stable conditions, the minimum Monin-Obukhov length (L_{MO}) was set to 100 m, to account for the 'urban heat island' effect.

Statistical analysis

Results are summarised in **Table 4** and **Figure 5** for hours when the observed

[2] Figure and caption directly taken from document [7].

data were of quality 2 and 3. **Table 5** and **Figure 6** correspond to results for data of quality 3 only. There is negligible difference in the results from ADMS version 5.1 and ADMS version 5.2.

The statistical analysis on the quality 2 and 3 data, **Table 4**, shows that ADMS predicts a mean value and standard deviation very close to the observed, the correlation is 30 % and the fraction within a factor of 2 is equal to 0.43.

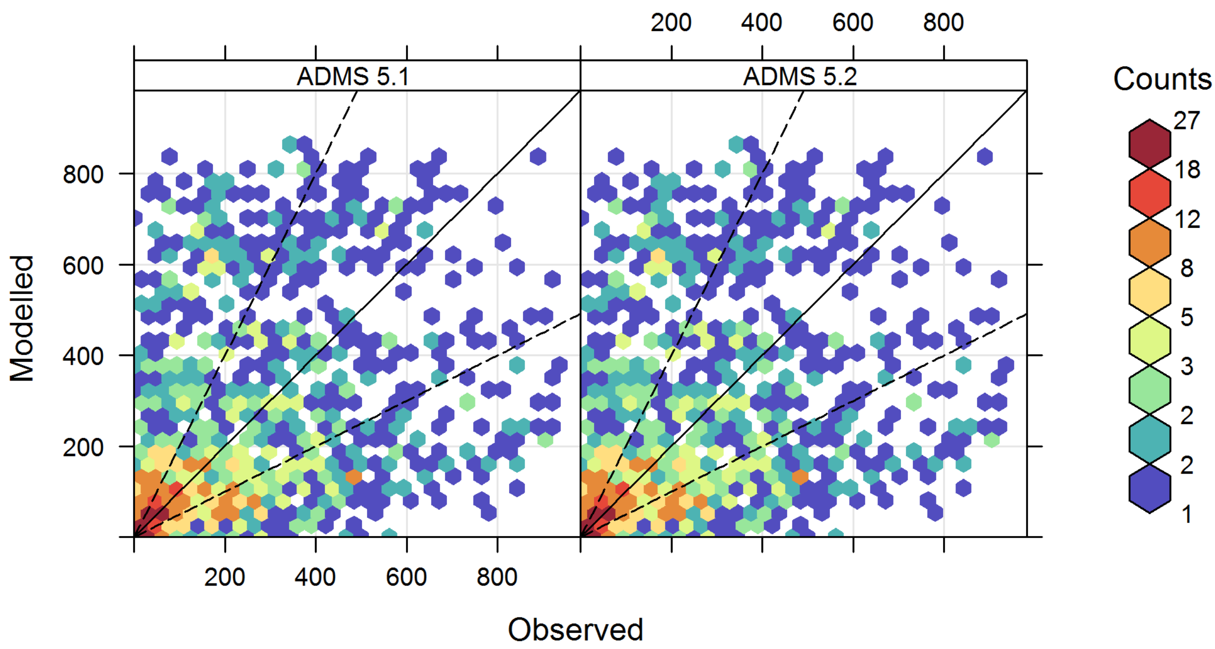
In **Table 5** the results are shown for the quality 3 results only. The mean is again well predicted by ADMS, while the fraction within a factor of 2 improves as does the normalised mean square error.

Data	Mean	Sigma	Bias	NMSE	Cor	Fa2	Fb	Fs
observed	257.8	221.6	0.0	0.0	1.00	1.00	0.00	0.00
ADMS 5.1	260.2	226.4	2.5	1.0	0.30	0.43	0.01	0.02
ADMS 5.2	260.2	226.4	2.5	1.0	0.30	0.43	0.01	0.02

Table 4 − Statistics: Indianapolis, qualities 2&3. Units for mean, sigma and bias: are ns/m^3.

Data	Mean	Sigma	Bias	NMSE	Cor	Fa2	Fb	Fs
observed	351.5	221.4	0.0	0.0	1.00	1.00	0.00	0.00
ADMS 5.1	347.5	237.0	-4.1	0.6	0.26	0.55	-0.01	0.07
ADMS 5.2	347.5	237.0	-4.1	0.6	0.26	0.55	-0.01	0.07

Table 5 − Statistics: Indianapolis, quality 3 only. Units for mean, sigma and bias are ns/m^3.



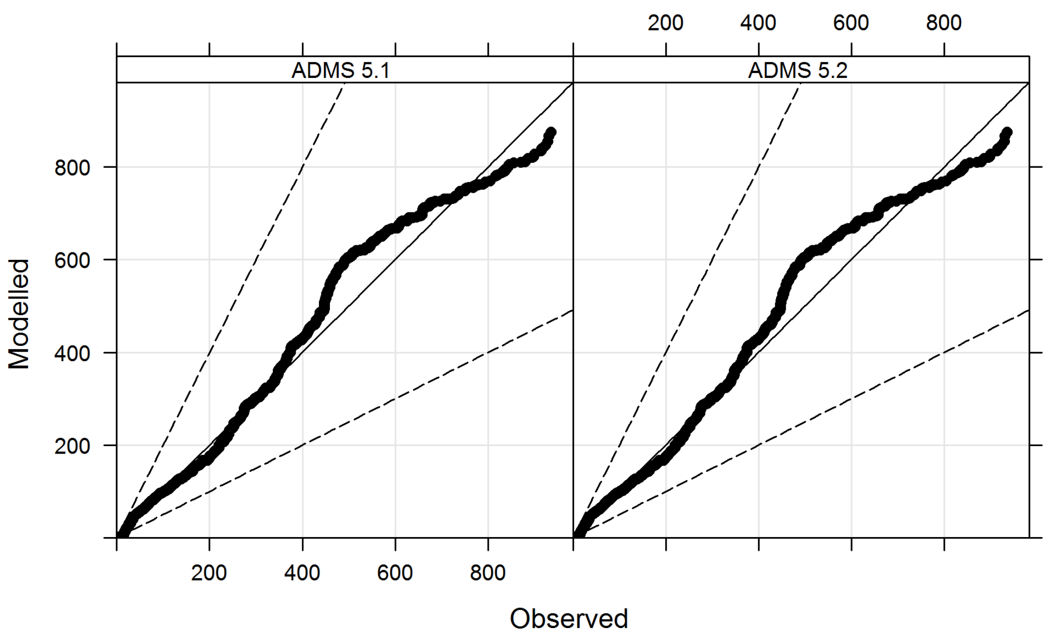
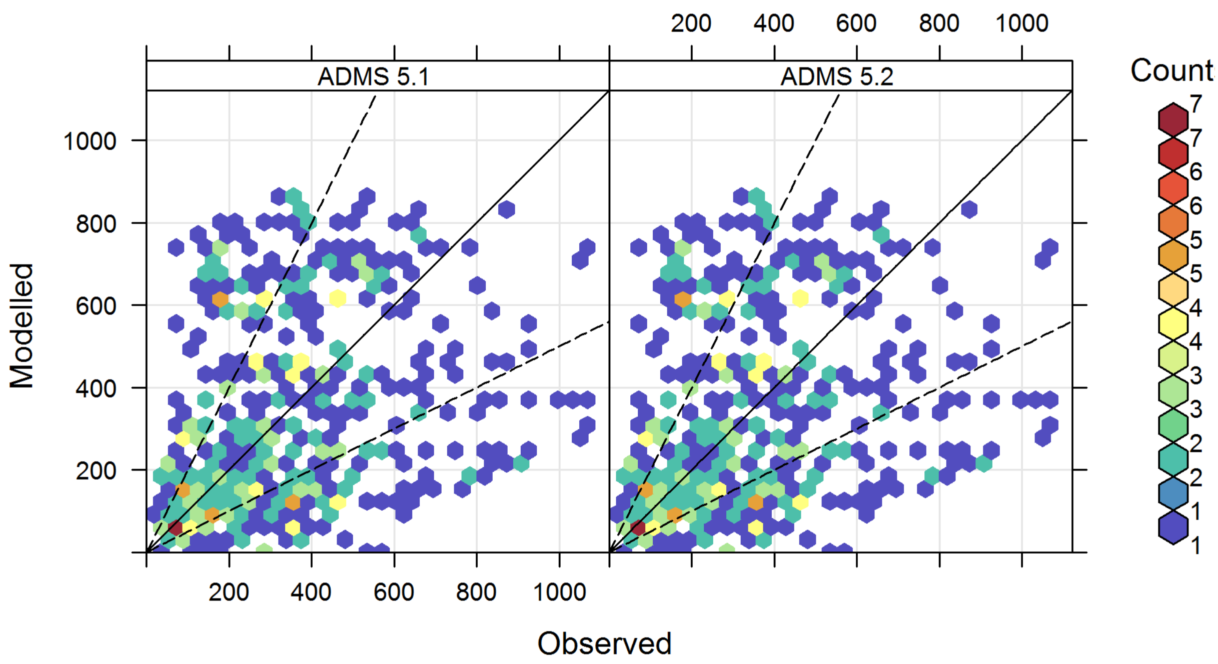


Figure 5 − Indianapolis experiment, ADMS, quality 2 & 3 data (units are ns/m^3).



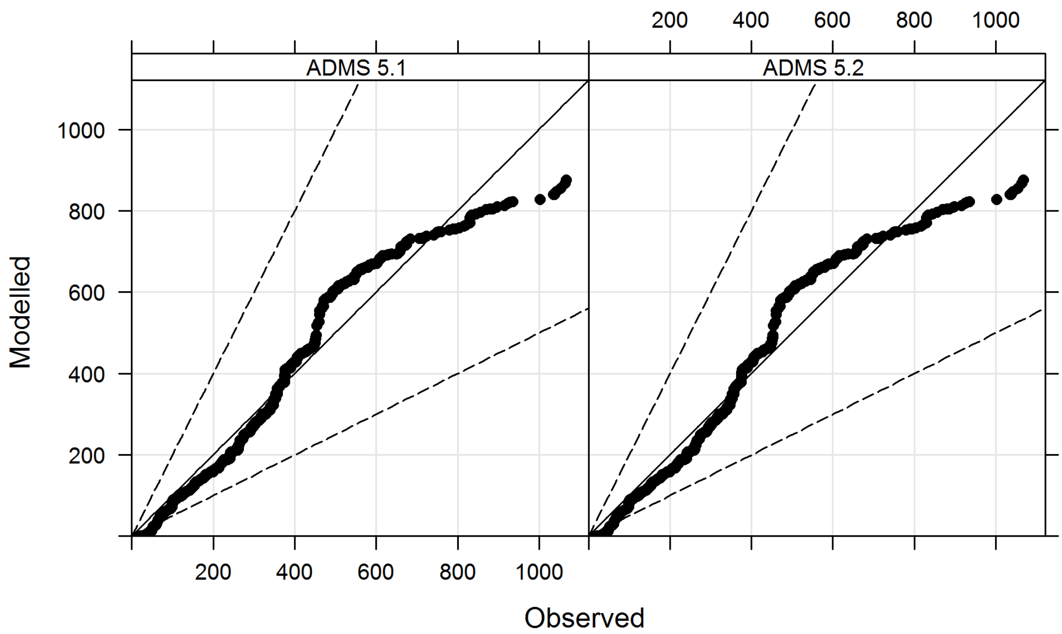


Figure 6 − Indianapolis experiment, ADMS, quality 3 data (units are ns/m^3).

3.4 Prairie Grass

Experiment

Project Prairie Grass, designed by Air Force Cambridge Research Center personnel, was carried out in north central Nebraska in the summer of 1956 (**Figure 7**). The site was located on virtually flat land covered with natural prairie grasses. The roughness length was 6 mm. Small amounts of SO_2 tracer were released over 10 minute periods from near ground level (approximately 0.5 m above ground). In ADMS the release was modelled as a point source with zero exit velocity. Concentration measurements were made at a height of 1.5 m along arcs at five downwind distances: 50, 100, 200, 400 and 800 m. The emission rate was set to 1 g/s, indicating that the observed concentrations have been normalised by the emission rate.

About half of the 68 trials were conducted during unstable (convective) daytime conditions and the rest were held at night with temperature inversions present (stable conditions). Extensive meteorological measurements, including wind speed and turbulence data at more than one height, were taken on-site during the trials.

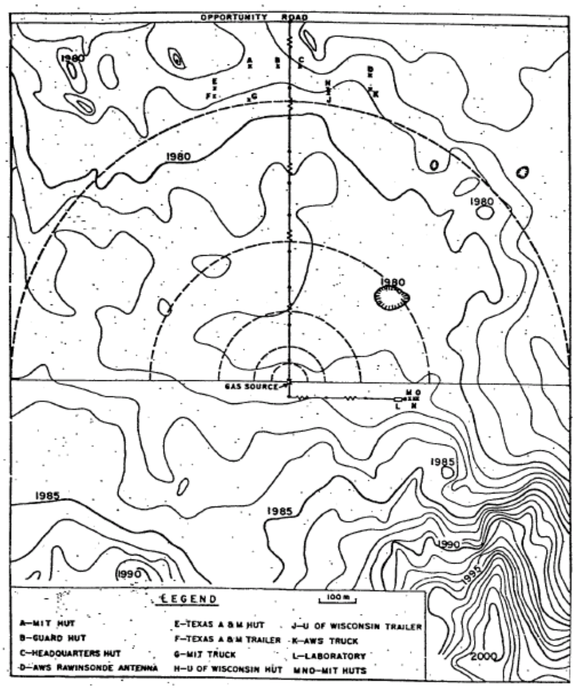


Figure 7 − Layout of the Prairie Grass SO_2 tracer experiment.

Statistical analysis

The results of the Prairie Grass modelling by ADMS are presented in **Table 6** and **Figure 8**. Data of all qualities were included in the analysis, as there were so few data of qualities 2 and 3. The differences in concentrations predicted by ADMS 5.1 and ADMS 5.2 are negligible.

The statistical analysis suggests ADMS significantly under-estimates the mean concentration, predicting approximately 70 % of the observed mean. The correlation of all models is reasonable, and 65 % of the ADMS 1 hour averages are within a factor of 2 of the observations.

Data	Mean	Sigma	Bias	NMSE	Cor	Fa2	Fb	Fs
observed	2.23	3.90	0.00	0.00	1.00	1.00	0.00	0.00
ADMS 5.1	1.57	3.34	-0.66	2.96	0.63	0.65	-0.35	-0.15
ADMS 5.2	1.57	3.34	-0.66	2.96	0.63	0.65	-0.35	-0.15

Table 6 − Statistics: Prairie Grass, all qualities. Units for mean, sigma and bias are ms/m^3.

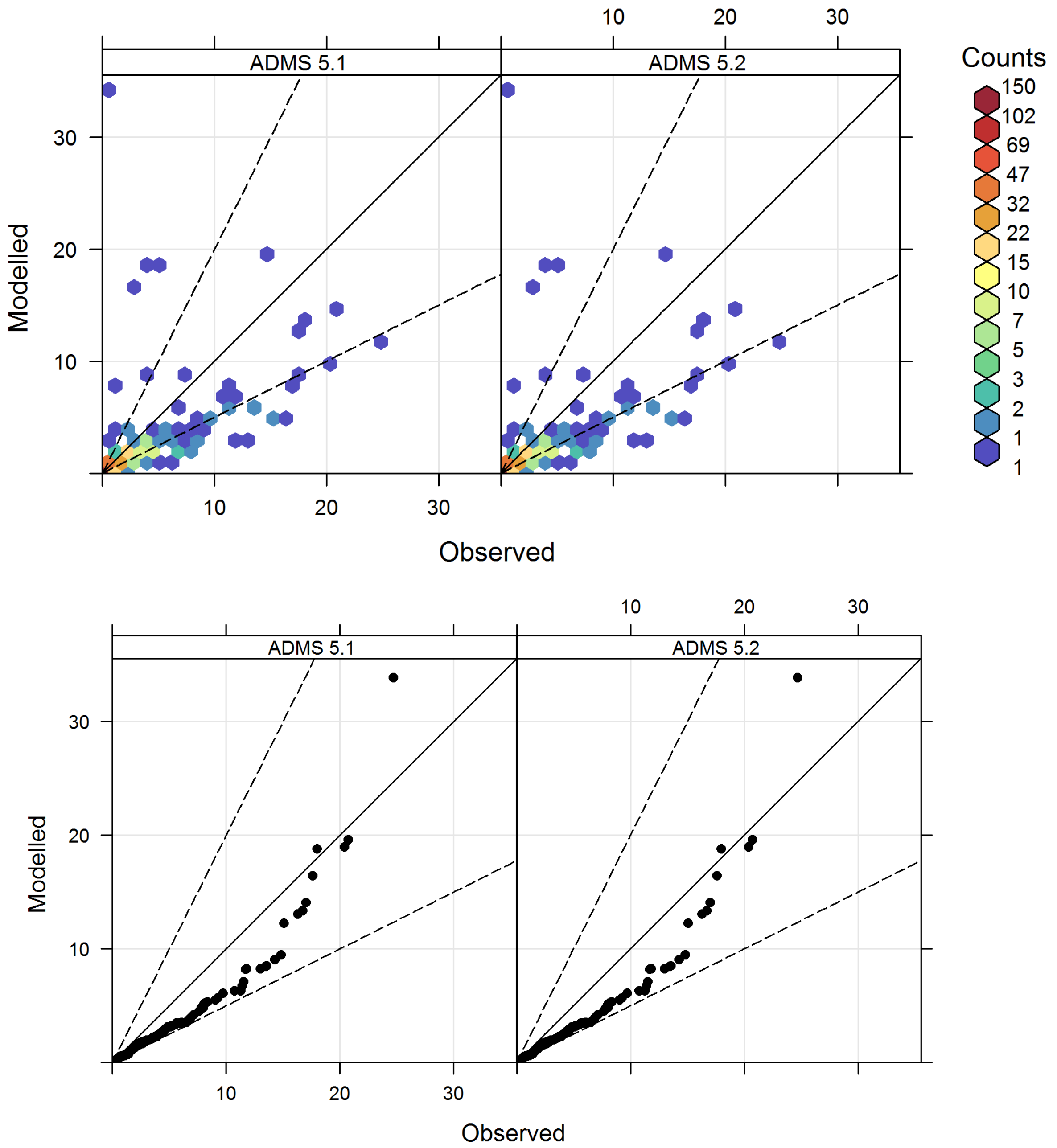


Figure 8 − Prairie Grass experiment, ADMS, all data (units are ms/m^3).

4 Summary

The three data sets used in this validation study cover a range of source elevation and meteorological conditions. The model results have been compared with observations and analysed using the arcwise maximum method. The MyAir Toolkit has been used to analyse the observed and modelled data through graphs and statistics. No single statistical measure gives a complete picture of model performance, but the range of statistical measures and the plots give a fair impression of performance.

References

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