ADMS 6 Buildings Validation
Millstone Nuclear Power Plant

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1 Introduction

A series of tracer releases was carried out at the Millstone nuclear power plant[1] located near Niantic on the Connecticut coast [2].

Each release comprised an hour-long continuous emission of SF_6 from a stack at 48.3 m or of Freon-12 from three stacks at 29.1 m. A total of 36 releases of SF_6 and 26 releases of Freon-12 were carried out. Concentrations were measured at 38 receptor locations along three arcs. The experimental set-up is illustrated in **Figure 1**.

Meteorological measurements were made at an on-site tower, at heights of 10 and 43 m. Winds were predominantly on-shore, with generally high speeds. The wind speed exceeded 7 m/s for most hours and reached more than 10 m/s for several of the release periods. The majority of the releases were carried out during stable or neutral conditions.

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

This document compares the results of ADMS 5.2.0.0 with those of ADMS 6.0.0.1 (hereafter referred to as ADMS 5.2 and ADMS 6.0, respectively).

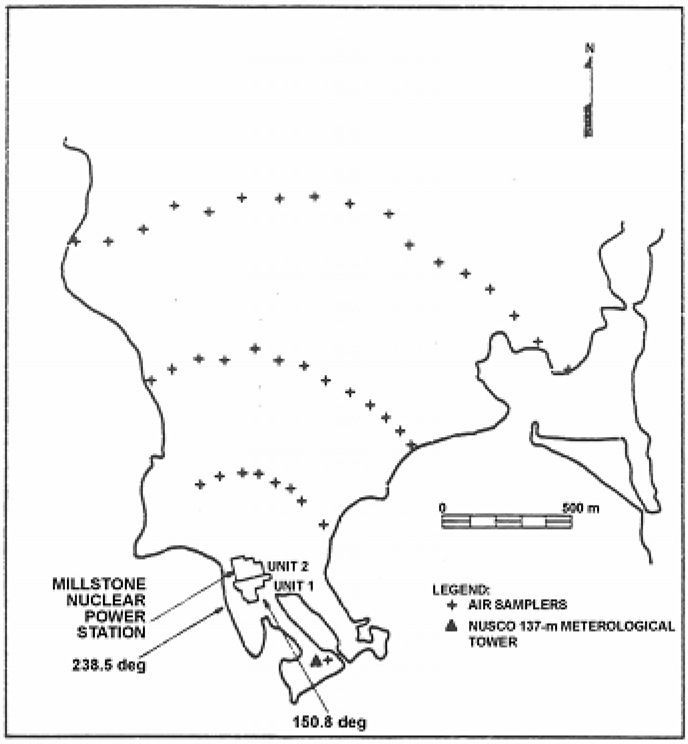


Figure 1 – Millstone experiment site.

Section 2 describes the input data used for the model. The results are presented in Section 3 and discussed in Section 4.

[1] Note that the study description and **Figure 1** have been taken directly from the document [1].

2 Input data

2.1 Study area

The site is located at 41.31°N and the surface roughness is 0.010 m. This relatively low roughness chosen for the model runs was due to the close proximity of the experimental site to the sea, and the fact that the winds were predominantly from the direction of the sea.

2.2 Source parameters

The source parameters are summarised in **Table 1**.

Emission temperatures were different for each of the releases, but were all close to ambient temperature at around 21.9°C. Similarly, release velocities varied for different hours, but were all close to 10 m/s. Note that the 1 g/s emission rate indicates that the observed concentrations supplied in [3] have been normalised by the emission rate.

Source name	Pollutant	Location	h (m)	V (m/s)	T (°C)	D (m)	Q (g/s)
REAC (reactor stack)	SF_6	(0,0)	48.3	varied	varied	2.12	1
TURB1 (turbine stack)	Freon-12	(-77, 32)	29.1	varied	varied	1.40	1
TURB2 (turbine stack)	Freon-12	(-66, -5)	29.1	varied	varied	1.40	1
TURB3 (turbine stack)	Freon-12	(-53, -50)	29.1	varied	varied	1.40	1

Table 1 – Source input parameters. h is the stack height, V the exit velocity, T the exit temperature, D the effective diameter and Q the emission rate.

2.3 Receptors

The receptors were positioned in three arcs at distances of 350, 800 and 1500 metres downwind of the sources, as shown in **Figure 4**.

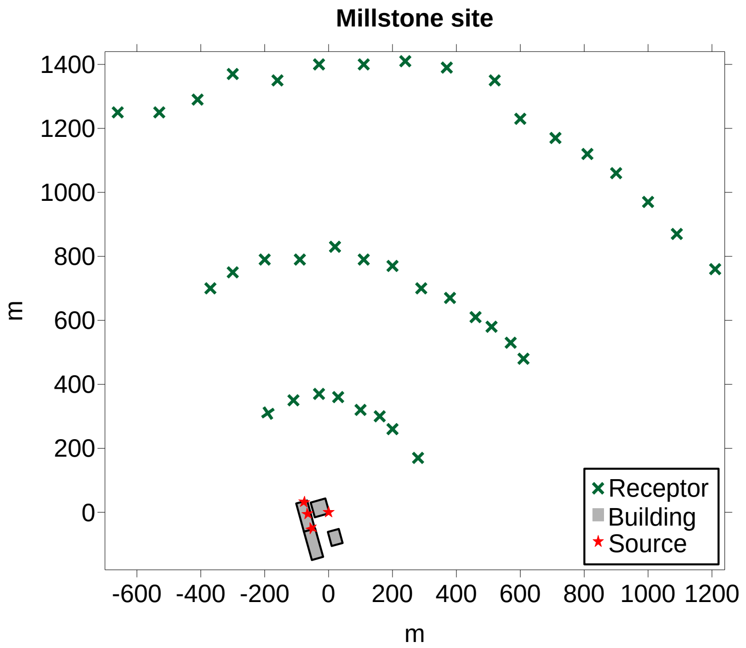


Figure 2 – The receptor network.

2.4 Meteorological data

At 43.3 m, the wind speeds varied from 3.4 to 12.6 m/s, the wind direction from 147 to 232° and the ambient temperature from 8.9 to 17.9°C.

Wind speeds at heights of 10 and 43.3 m were input to the model.

The wind rose at 43.3 m is shown in **Figure 3**.

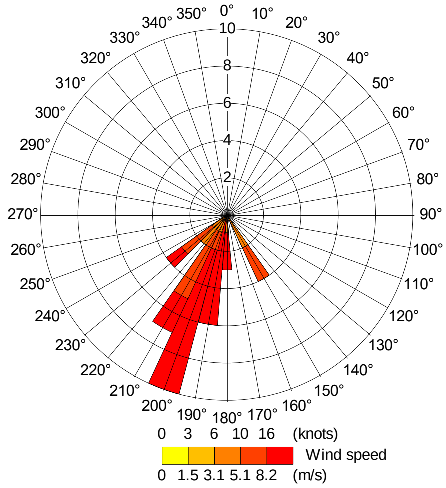


Figure 3 – Wind rose.

The meteorological conditions are presented in **Table 2.** 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	17	20
Neutral conditions	17	14
Unstable conditions	2	2
Total	*36*	*36*

Table 2 – Meteorological conditions.

2.5 Buildings

The building dimensions are given in **Table 3** and their location relative to the modelled stacks are shown in **Figure 4**.

Building name	Length (m)	Width (m)	Height (m)	Angle (°)
Reactor1	47.8	47.8	44.7	344.2
Reactor2	45.6	35.4	41.6	344.8
Turbine1	92.4	36.7	27.6	344.3
Turbine2	91.2	35.4	27.6	344.8

Table 3 – Dimensions of the buildings.

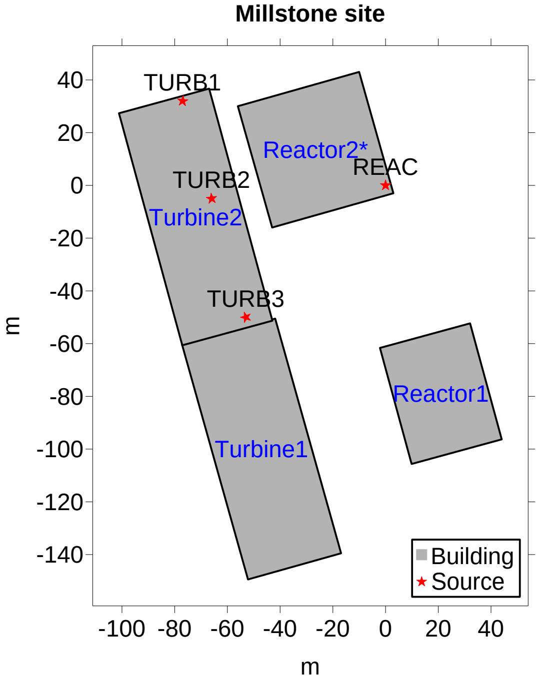


Figure 4 – The building and stack locations.

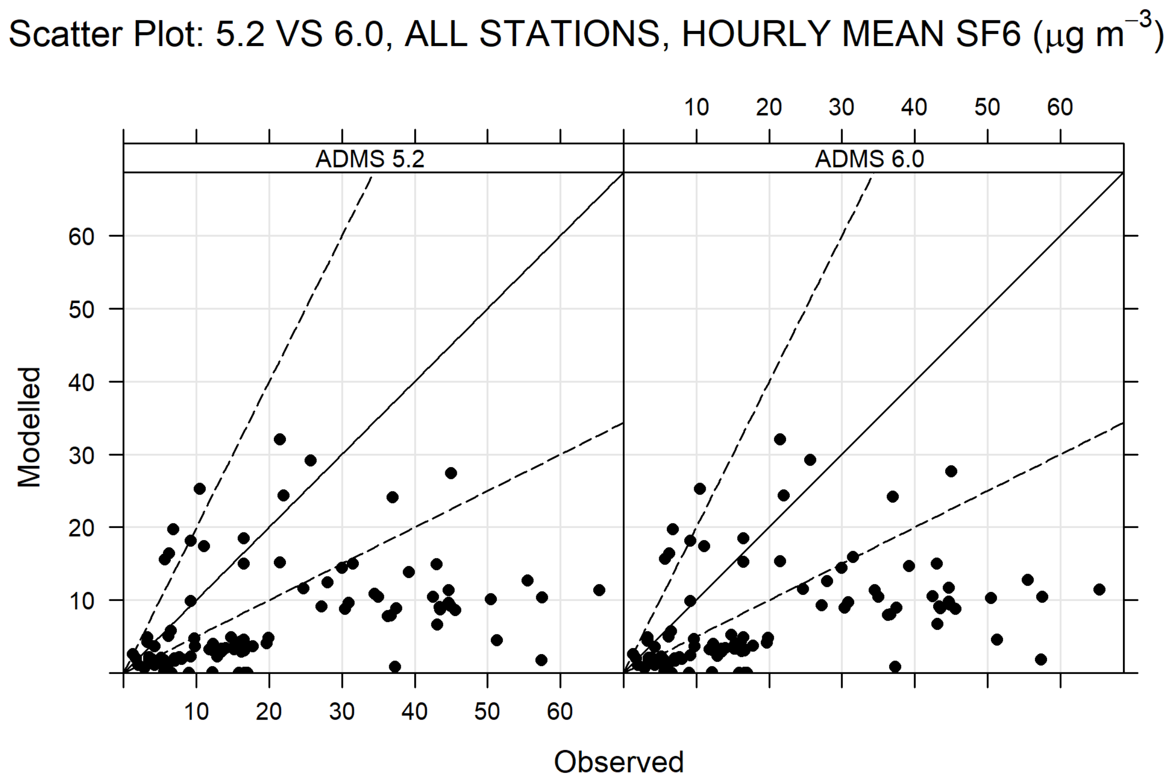
3 Results

For this experiment, arc maximum modelled and observed concentration values are compared.

The data were processed using the Model Evaluation Toolkit v5.2 [4]. Scatter plots and quantile-quantile plots of model results against observed data are presented in Section 3.1 and statistical results are given in Section 0.

3.1 Scatter and quantile-quantile plots

Figure 5 and **Figure 6** show the conventional scatter plots and the quantile-quantile plots respectively of ADMS results for Freon-12 and SF_6. Note that these quantile-quantile plots are linear; care should be exercised when comparing these plots with similar ones presented with logarithmic axes.



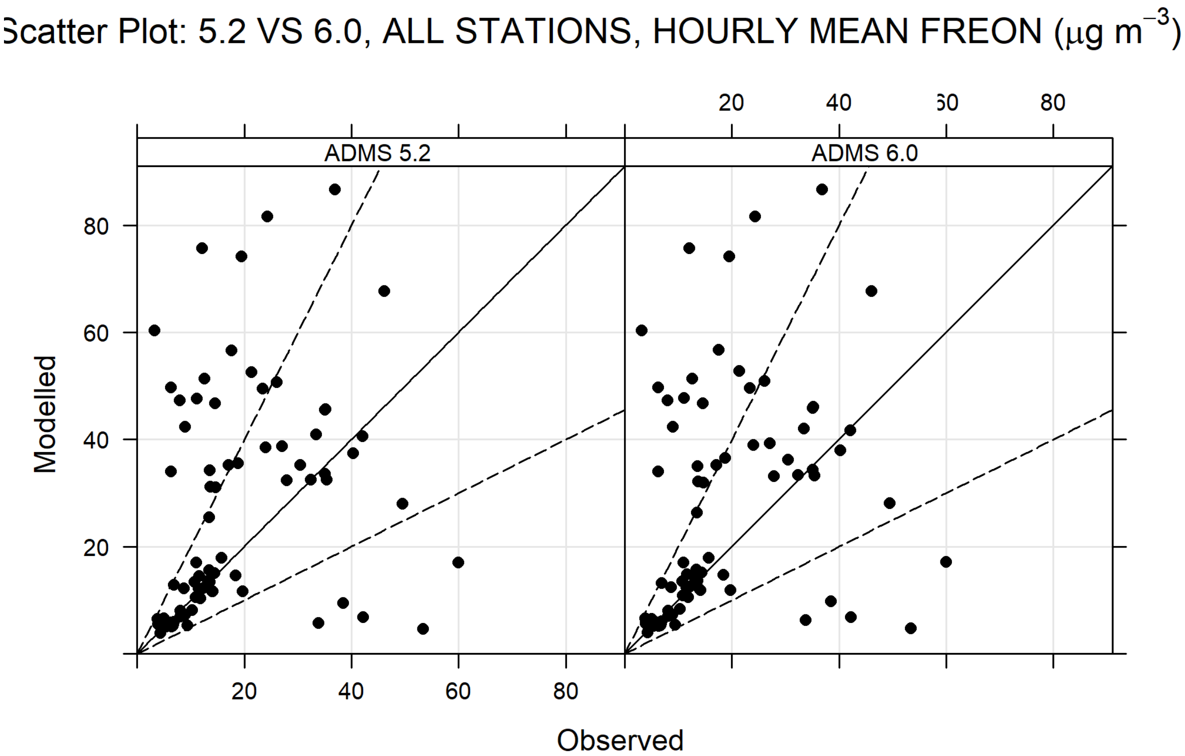


Figure 5 – Scatter plots of ADMS results against observed concentrations (µs/m³).

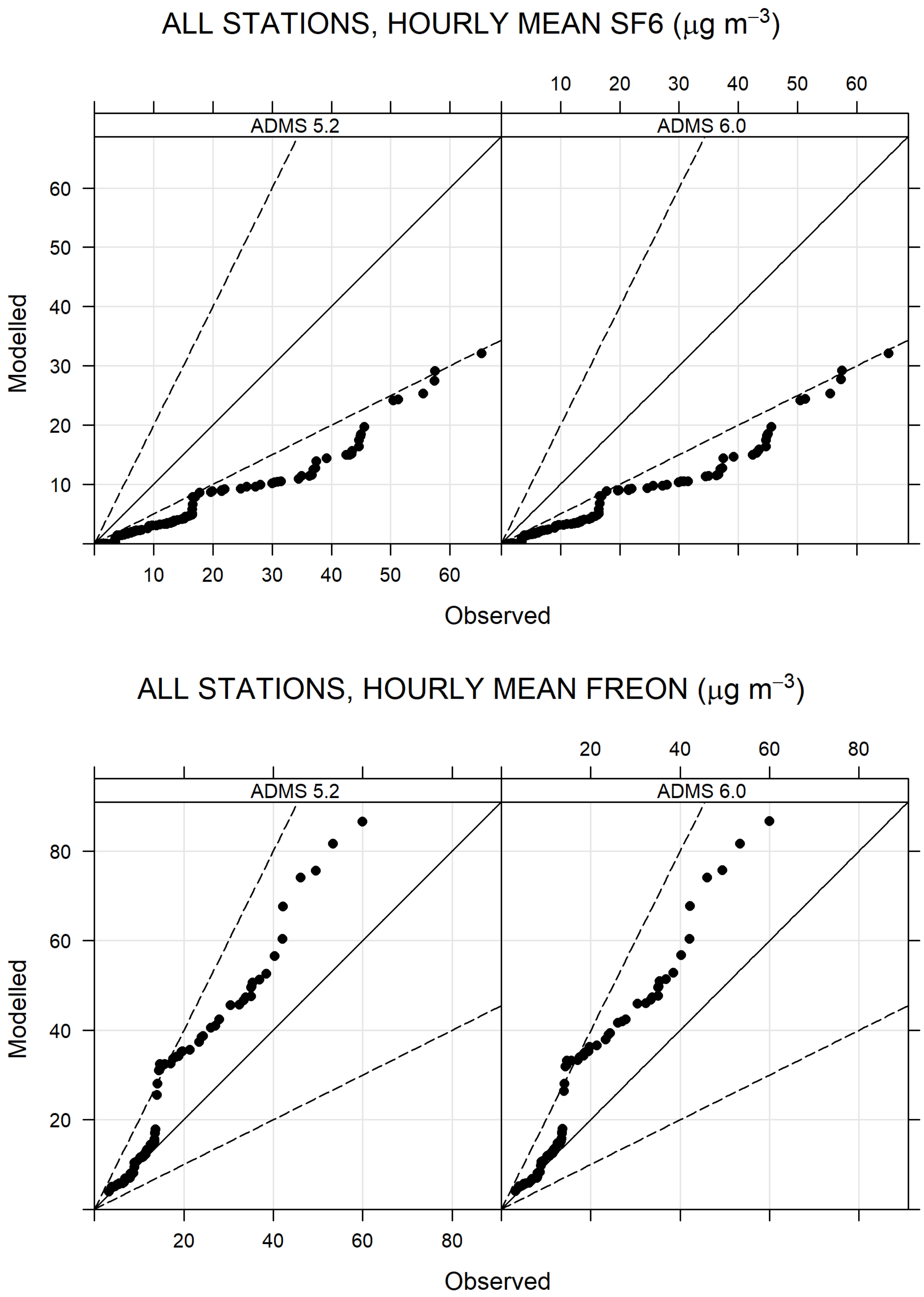


Figure 6 – Quantile-quantile plots of ADMS results against observed concentrations (μs/m³).

3.2 Statistics

The Model Evaluation Toolkit 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 two (Fa2), fractional bias (Fb) and fractional standard deviation (Fs).

Table 4 shows the statistical results for both pollutants. **Tables 5** and **6** show the statistical results for the Freon-12 and SF_6 releases, respectively.

Data	Mean	Sigma	Bias	NMSE	Cor	Fa2	Fb	Fs
Observed	18.58	14.81	0.00	0.00	1.000	1.000	0.000	0.000
ADMS 5.2	14.98	17.48	-3.60	1.50	0.231	0.398	-0.215	0.165
ADMS 6.0	15.13	17.55	-3.45	1.48	0.234	0.409	-0.205	0.170

Table 4 – Statistics for both pollutants together over all arcs.

Data	Mean	Sigma	Bias	NMSE	Cor	Fa2	Fb	Fs
Observed	18.17	13.30	0.00	0.00	1.000	1.000	0.000	0.000
ADMS 5.2	26.22	21.05	8.05	1.07	0.314	0.692	0.363	0.451
ADMS 6.0	26.48	21.09	8.31	1.06	0.318	0.692	0.372	0.453

Table 5 – Statistics for Freon-12 over all arcs.

Data	Mean	Sigma	Bias	NMSE	Cor	Fa2	Fb	Fs
Observed	18.88	15.80	0.00	0.00	1.000	1.000	0.000	0.000
ADMS 5.2	6.87	7.00	-12.01	2.72	0.410	0.185	-0.933	-0.772
ADMS 6.0	6.94	7.03	-11.94	2.66	0.416	0.204	-0.925	-0.768

Table 6 – Statistics for SF_6 over all arcs.

4 Discussion

It is of interest to note that there is significantly different behaviour in the results between the Freon-12 and SF_6 observed values. As this behaviour is also seen in the AERMOD modelling of this experiment (see for example Figures 10 and 11 in [1]), it is likely that there may be some systematic difference in the quantification of the observed data for the different pollutants used in the experiments.

There is generally good agreement between ADMS modelled and observed concentration values. The model tends to underestimate observed SF_6 concentrations and overestimate observed Freon-12 concentrations.

The differences between ADMS 5.2 and ADMS 6.0 are generally small. Over both pollutants, the statistics are generally slightly better with ADMS 6.0. 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. The ground-level plume emanating from recirculation region is now also modelled as a line source rather than a point source, with an initial concentration that is better matched to the uniform concentration of the entrained part of the plume within the well-mixed recirculation region; this is also affecting results slightly. The development relating to how plumes that directly impact a building are modelled does not affect this study as each source is directly above its main building.

5 References

[1] United States Environmental Protection Agency, 2003: *AERMOD, Latest Features and Evaluation Results*. EPA-454/R-03-003.

[2] Bowers, J.F. and A.J. Anderson, 1981: *An Evaluation Study for the Industrial Source Complex (ISC) Dispersion Model*. Report EPA-450/4-81-002. NTIS #PB81-176539. United States Environmental Protection Agency Office of Air Quality Planning and Standards.

[3] United States Environmental Protection Agency website, *Model Evaluation Databases*. https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models

[4] 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.

[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.