Cambridge Environmental Research Consultants Ltd

Validation and Sensitivity Study of ADMS-Urban For London

TOPIC REPORT

Prepared for
DEFRA, National Assembly for Wales, The Scottish Executive, and the Department of the Environment, Northern Ireland

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C E R C

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EXECUTIVE SUMMARY

The high resolution air quality model, ADMS-Urban, has been set up for use with the latest London Emissions Inventory for 1999 emissions and validated against continuous hourly measurements of NO_x, NO_2, O_3 and PM_{10} from AURN sites across London. In addition the sensitivity of predicted concentrations to model input data and set-up parameters has been investigated in detail.

The comparison has confirmed the generally good performance of the model with the annual mean values of NO_2 (overall fractional bias 0.02) and PM_{10} (overall fractional bias 0.048) being especially well predicted, although individual site locations are subject to greater errors (e.g. the overall normalised mean square error for NO_2 is 0.19). The high percentile (peak) values of NO_x and NO_2 show some tendency to overprediction.

The sensitivity study investigated the sensitivity to different model inputs: namely the height of grid sources, surface roughness length, minimum Monin Obukhov length used to limit stable stratification in an urban area, meteorological data sites and emissions. One of the greatest sensitivities was to the choice of meteorological site with, for instance, the overall mean of NO_2 reducing by 6% if London Weather Centre data was used rather than Heathrow. Adjusting the initial grid source height, minimum Monin Obukhov length or surface roughness within a realistic range had little impact on concentration so we can be sure that these parameters are set at reasonable values which apply equally well to future projections of concentrations. Thus the study suggests that, given accurate emission predictions, the model will calculate future concentration to reasonable accuracy.

The overall fractional biases of future projections of annual means NO_2 and PM_{10}, which are not very sensitive to the meteorological year, are likely to be no more than about 5%, although individual sites may show greater error. In terms of the percentage of road segments across London exceeding annual mean objectives for NO_2 and PM_{10}, the uncertainty corresponds to a relatively small range for NO2 (81%:94% for 1999; 50%:73% for 2005 and 25%:44% for 2010), but can result in a larger range for PM_{10} depending on the year (eg, 46%:100% for 2005). High percentiles can be subject to greater error and uncertainty due to meteorological variability.

1. Introduction

This validation and sensitivity study is the first of a series of topic reports prepared as part CERC's contract to model air pollutants in urban areas in the UK. The initial part of the project has focussed on using the Air Dispersion Modelling System ADMS-Urban to model several important pollutants in Greater London: Nitrogen Dioxide (NO_2); Oxides of Nitrogen (NO_x); particles smaller than 10 microns diameter (PM_{10}); and Ozone (O_3). The other two topic reports record how ADMS-Urban was used to produce air quality maps for London (Blair et al., 2003) and a comparison with the results of ERG and NETCEN pollution prediction methodologies (Carruthers et al., 2003).

All of the pollutants are measured at various locations across London, with the number of automatic monitoring network (AURN) sites for which data are available having increased significantly over the last few years. These measurements give a good idea of the current state of air quality in London. However, concentrations are unknown at interim locations and it is not possible to directly project measured concentrations into the future to anticipate changes in air quality, which will accompany expected changes in pollutant emissions profiles.

For this reason air dispersion modelling is necessary to enable maps of air quality to be produced and to allow changes in air quality to be predicted for various scenarios. It is important that the model gives realistic results thus a validation study is necessary, in which air quality predictions are compared with measurements. If the model performs well, this is reasonable assurance that the predictions made for intermediate locations and future years will also be realistic.

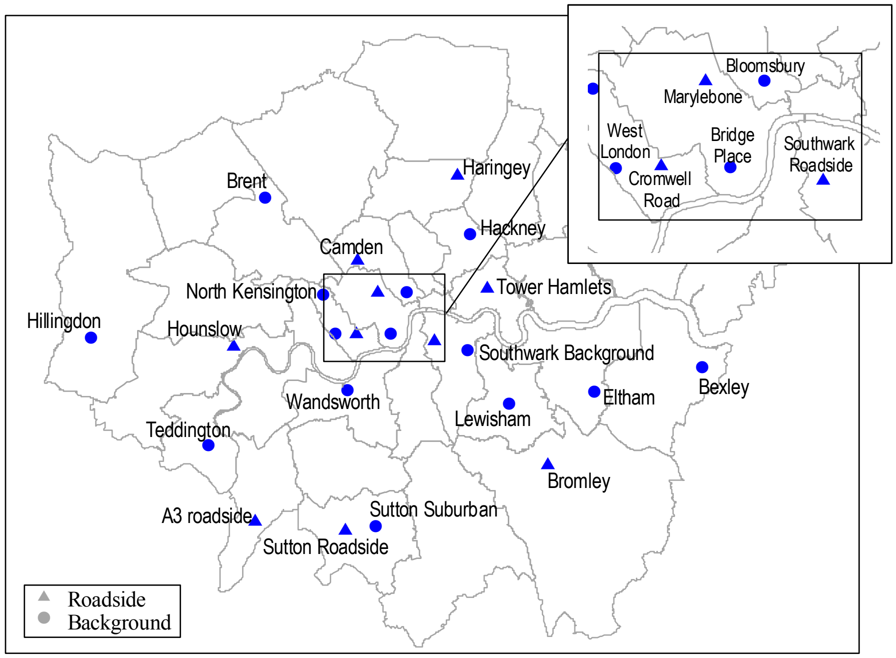
Naturally, there are more uncertainties in predicting future concentrations than in current ones, for example, meteorology is known to affect the air quality causing changes for year to year giving significant "good-case" and "worst-case" conditions for particular pollutants. Assessment of how the air quality is likely to vary in response to these and other variables can be investigated using an appropriate sensitivity study.

This topic report records a validation study and sensitivity study for Greater London modelling using the Air Dispersion Modelling System ADMS-Urban (Carruthers et al., 1998). The year 1999 was used as a base year for the studies, because it is a typical year of meteorological data and measured data are available for up to 24 AURN sites. Their locations are illustrated in Figure 1.1. Data were measured on an hour-by-hour basis and the modelled concentrations of pollutants were predicted for these locations, also on an hour by hour basis, using what was considered to be a representative set of model parameters.

For ease of comparison, the results are presented in ppb for NO_x, NO_2, and ozone, but in $\mu g/m^3$ for PM_{10}, in gravimetric equivalent output.

Sections 2 to 5 present a brief description of ADMS-Urban, a discussion of the emissions data, meteorological data and background calculations. Model validation and model sensitivities are presented in sections 6 and 7.

Figure 1.1 Automatic Monitoring Sites in Greater London



2. ADMS-Urban

The ADMS-Urban air quality model (Carruthers et al., 1998) is a transport and dispersion model based on ADMS 3, the advanced gaussian short range dispersion model for industrial sources (Carruthers et al., 1994). Full technical details on this model are described in the technical specification (CERC, 2000). ADMS has been developed by CERC in collaboration with the University of Surrey and the Met Office and has been extensively validated (e.g. Hanna et al., 1999). It is routinely used for regulatory purposes. ADMS-Urban was developed by CERC from ADMS 3 specifically for air quality calculations across urban areas and was motivated by the Air Quality Strategy. The model is able to calculate pollutant concentrations for the full range of averaging times required by the Air Quality Strategy and EU Directives (i.e. 15 minutes to 1 year).

Additional features of ADMS-Urban include:

- Modification of the line source algorithms so that they can be applied to dispersion from road sources – specifically traffic produced turbulence and street canyons;
- Allowance for a large array of grid sources necessary for large urban areas;
- A trajectory model within which the ADMS algorithms are nested and which allows the temporal variation in meteorology and emissions to impact on the chemical reaction scheme.

The sources are treated as precisely as is possible and necessary. Thus road sources relatively close to the output domain (i.e. within 3km) are characterised by their location, width, street canyon height (where relevant) and traffic/emission characteristics, whilst road sources more distant are aggregated into grids without loss of accuracy. Large point sources are generally treated explicitly whilst smaller point sources and other emissions are all aggregated onto grids.

The model is run using successive hours of meteorological data, background pollution data and emissions data as input. Thus both long term averages, shorter averaging times (as little as one hour) and percentiles can be calculated. Meteorological data from London Heathrow, background data from surrounding rural sites and emissions data from the London Atmospheric Emissions Inventory (LAEI, December 2001) were used. Local explicit sources take account only of the most recent meteorology while other sources are affected by current meteorology and that prevailing over previous hours. Chemical reactions take account of the time history of a parcel of air/pollutant arriving at a particular receptor point and are characterised by the generic reaction set (Azzi et al., 1992; Ventrakan et al., 1994).

Pollution not arising from emissions included in the inventory is estimated from rural measurements (rural background). In addition, in the case of PM_{10}, the local coarse component deriving from construction dust, etc, is also added to the ADMS-Urban dispersion calculation. This procedure is also used in the NETCEN mapping.

ADMS-Urban has within it a number of adjustable global parameters. The most important of these are surface roughness (z_0), minimum Monin Obukhov length L_{MO}(min) for limiting stable stratification in urban areas, and the depth of the grid sources (h_g), i.e. the depth of which the gridded emissions are mixed. In setting the model up for a particular location these parameters may be adjusted within reasonable and justifiable ranges to obtain the best overall comparison with monitoring data. It is this 'best set' of parameters which is used to calculate the modelled concentrations in this report. For instance reasonable estimates of the parameters for London might vary within the following range:

- $0.8 < z_0 < 2.0$m;
- 30m < L_{MO}(min) < 100m;
- 30m < h_g < 100m.

ADMS-Urban has been subject to a large number of validation studies. These have included previous studies in London (Carruthers et al., 1999), validation against monitoring sites and studies in Budapest and North East China.

ADMS-Urban version 1.7 was used for this study.

3. Emissions Data

The Greater London Authority (GLA) released an early version of the London Atmospheric Emissions Inventory in October 2001. This was then replaced in December 2001 by an inventory which used a new set of traffic emission factors. The validation study uses the December inventory and the October inventory is used as one of the scenarios in the sensitivity analysis section of this study. Since then a further inventory was issued in February 2002 which used slightly modified traffic emission factors. Table 3.1 compares the total annual emissions of NO_x, PM_{10} and VOC used in the modelling. It also gives the total annual emissions in the February 2002 inventory, this is just for comparison purposes, as the inventory has not been used in the modelling in this study.

Table 3.1 shows that the February 2002 inventory is only slightly different to the December 2001 inventory, therefore it is likely that the calculated concentrations using each of these inventories would be very similar. Figure 3.1 shows the total emissions of NO_x and PM_{10} for 1999 as 1×1km gridded emissions, using the December 2001 inventory.

Figure 3.1 GLA December 2001 inventory total Emissions for 1999

(a) 1999 NOx (b) 1999 PM10

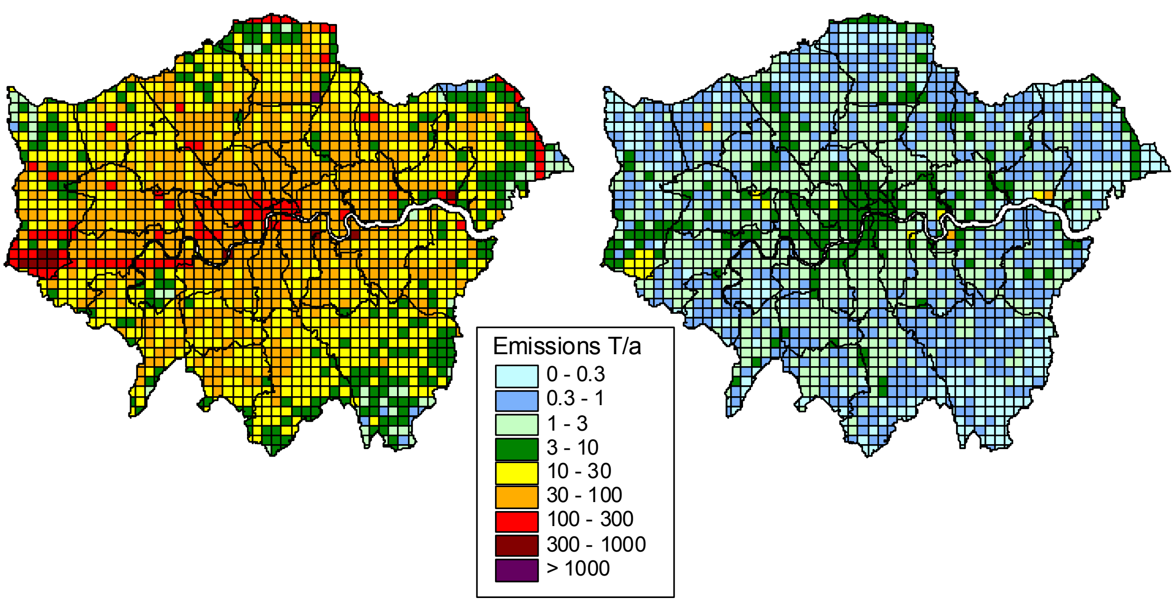


Table 3.1 1999 Emission totals from three versions of the LAEI (Tonnes/year)

	Source Type	October 2001	December 2001	February 2002
NO_x	Road	51,402 (62%)	64,681 (67%)	65,308 (67%)
	Non-road	31,462 (38%)	31,462 (33%)	31,462 (33%)
	Total	**82,864**	**96,143**	**96,770**
VOC	Road	42,144 (42%)	42,144 (42%)	42,144 (42%)
	Non-road	58,999 (58%)	58,999 (58%)	58,999 (58%)
	Total	**101,143**	**101,143**	**101,143**
PM_{10}	Road	3,100 (76%)	3,199 (77%)	3,073 (76%)
	Non-road	968 (24%)	968 (23%)	968 (24%)
	Total	**4,068**	**4,167**	**4,041**

4. Meteorological Data

Hourly sequential meteorological data from Heathrow in 1999 has been used for the majority of the modelling in this study. One of the scenarios employs data gathered at the London Weather Centre in 1999.

Table 4.1 summarises the meteorological data and indicates the number of hours that were suitable for use in the modelling. This excludes hours of calm, hours of variable wind direction and unavailable data. In this validation and sensitivity study only the hours where data were available for Heathrow, London Weather Centre and monitoring data have been used in the modelling.

Figure 4.1 compares the wind roses for the two meteorological sites, in general the wind speed at Heathrow is less than that at LWC, and the wind direction is more variable.

Figure 4.1 Windroses for Meteorological Data from London for 1999

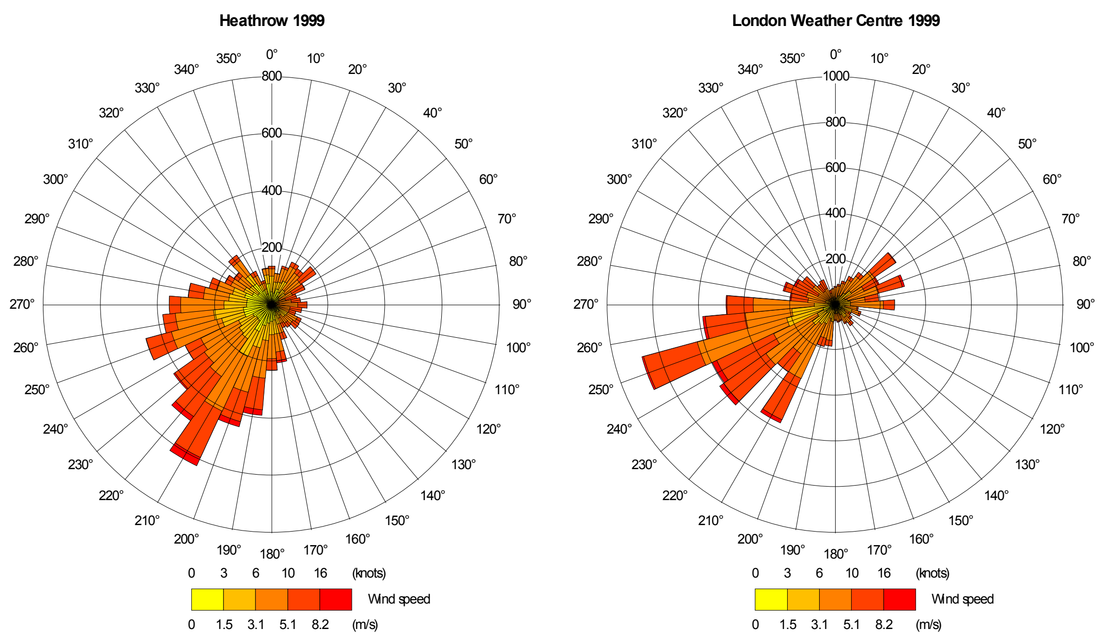


Table 4.1 Summary of 1999 meteorological data

	Heathrow			London Weather Centre		
Data Capture	99.8%			95.9%		
Height	10m			39m		
Roughness length	0.2m			1m		
Location	(507700, 176700)			(530200, 180000)		
Statistics	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Temperature (°C)	11.8	-4.6	32.7	12.5	-1.3	31.9
Wind speed (m/s)	3.1	0.0	12.9	4.0	0.5	12.9
Precipitation (mm/hr)	0.1	0.0	17.8	0.1	0.0	13.8
Cloud cover (oktas)	5.6	0.0	8.0	5.5	0.0	8.0

5. Background Concentration Data

ADMS-Urban requires rural background concentration as input to the system. In the case of NO_x, NO_2 and O_3 monitored concentrations were utilized from Rochester, Harwell, Lullington Heath and Wicken Fen, the monitored concentration used for a particular hour depending upon the wind direction for that hour. The wind direction used was from Heathrow. Figure 5.1 shows the wind direction segments used for each background site. It shows that, for example, if the wind direction for a particular hour is blowing from between 60° and 135° then the background NO_x, NO_2 and O_3 concentrations are taken to be the monitored values for that hour at Rochester. The hour by hour values are summarised in Table 5.1.

In the case of PM_{10} monitored TEOM PM_{10} data from Rochester and Harwell were used. For each hour of the year either the Rochester or Harwell observation was chosen depending upon the wind direction for that hour. Again, the wind direction used was from Heathrow. The Rochester data were used for hours when the wind direction was between 4° and 184° otherwise the Harwell observation was chosen. The TEOM values were then converted to gravimetric units by multiplying by a factor of 1.3. It was assumed that the coarse component was 9.9 $\mu g/m^3$ gravimetric and that 4.9 $\mu g/m^3$ of this was contained within the monitored data, so a further 5 $\mu g/m^3$ was added to the PM_{10} data to give the total background, as follows:

Total 1999 PM_{10} background = (Observed TEOM $\times$ 1.3) + 5

The values are summarised in Table 5.1.

Part of the sensitivity study was modelling with worst case meteorological data. These are generally accepted to be 1996 for PM_{10} and 1997 for NO_x. Background data were similarly calculated for these years and are summarised in Table 5.1

Figure 5.1 Wind direction segments used to calculate background concentrations

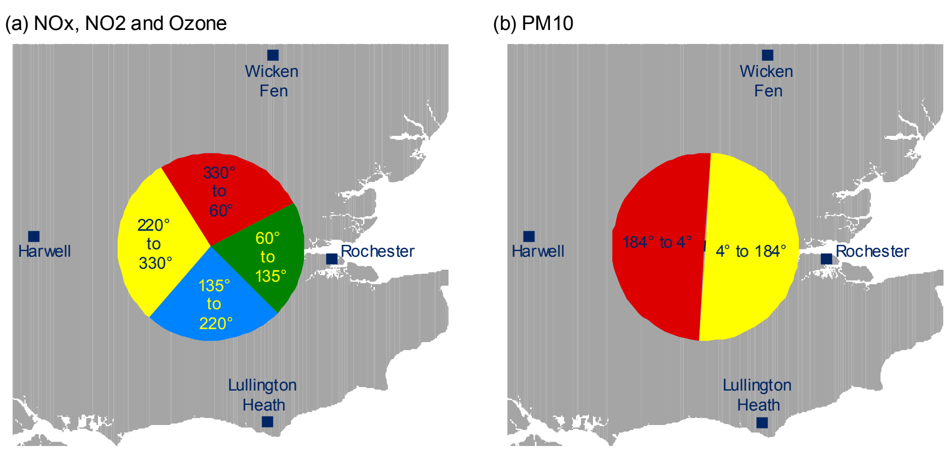


Table 5.2 1999 Background Concentrations for NO_x, NO_2, O_3 and PM_{10}

		1999 met	Worst case met
NO_x (ppb)	Annual Average	10	12
	Maximum hourly average	179	160
	99.8 percentile	91	113
NO2 (ppb)	Annual Average	7	9
	Maximum hourly average	49	43
	99.8 percentile	35	37
O_3 (ppb)	Annual Average	29	27
	Maximum hourly average	111	115
	99.8 percentile	87	86
PM_{10} ($\mu g/m^3$)	Annual Average	23	25
	Maximum hourly average	126	209
	90.4 percentile of 24 hour averages	35	39
	98.1 percentile of 24 hour averages	47	55

6. Model Validation

6.1 Overview

The purpose of model validation is to test the model performance against real data. Pollutant concentrations are predicted for each hour of the year. Predictions are not made for hours with inadequate meteorological data and the corresponding monitored value is disregarded. Two sets of meteorological data have been used, so in order to ensure all the results in this study are comparable to each other, predictions were not made for hours when either set of meteorological data was inadequate. Predictions for the hours where monitored data at the AURN site are missing are also disregarded, thus each predicted value has a one to one relationship with a monitored value.

Examples of the predicted NO_x, NO_2 and PM_{10} values illustrated as a time series compared to the monitored values are given for Bloomsbury, Camden (Swiss Cottage) and Marylebone Road in Figures 6.1 to 6.3. Predicted values are shown as 'negative' for comparison purposes. Data series were produced for all of the AURN sites under consideration.

There are no straightforward techniques for determining whether a model is 'good' or 'bad' because model performance depends on so many different factors. These are connected with model input data, model set-up parameters and the model algorithms. In addition performance depends on the averaging time for the pollutant concentration, the pollutant itself and the location (e.g. roadside or background). Even if all these different effects could be disentangled and an appropriate validation scheme devised there remains the question of what is good or satisfactory and what is bad or unacceptable. In fact, much research has gone into devising acceptable validation techniques. The commonly used 'BOOT statistics' approach derives from that of Hanna and Paine (1989) and employs a series of statistical measures including the mean, correlation, normal mean square error and fractional bias.

An alternative approach could be based on that developed for the ASTM (American Society for Testing of Materials, 2001), however we employ the BOOT statistical approach in this study. Statistical measurements (described in Section 5.2) are presented separately for comparisons made at each site. Although using this approach no single statistical measure is used to assess a model's performance, the range of measures provides alternative ways of presenting information on model performance which, taken together can allow conclusions to be drawn. Examples of the use of this approach are detailed in Carruthers et al. (1997) and Oleson (1995).

It is assumed that the measured concentrations are accurate to within a few percent of the actual concentrations of pollutants in air. Except for ozone, this would be expected to be the case because the concentrations have been measured using continuous monitors. There may be some exceptions to this general rule, such as the Bromley AURN site, which is believed to be unrepresentative due to poor siting of the monitor and has therefore been omitted from this study. The error in ozone concentrations can be greater where the NO_x concentration is high and ozone concentration low.

Figure 6.1 Hourly Average Time Series for NO_x at (a) Bloomsbury, (b) Camden and (c) Marylebone Road

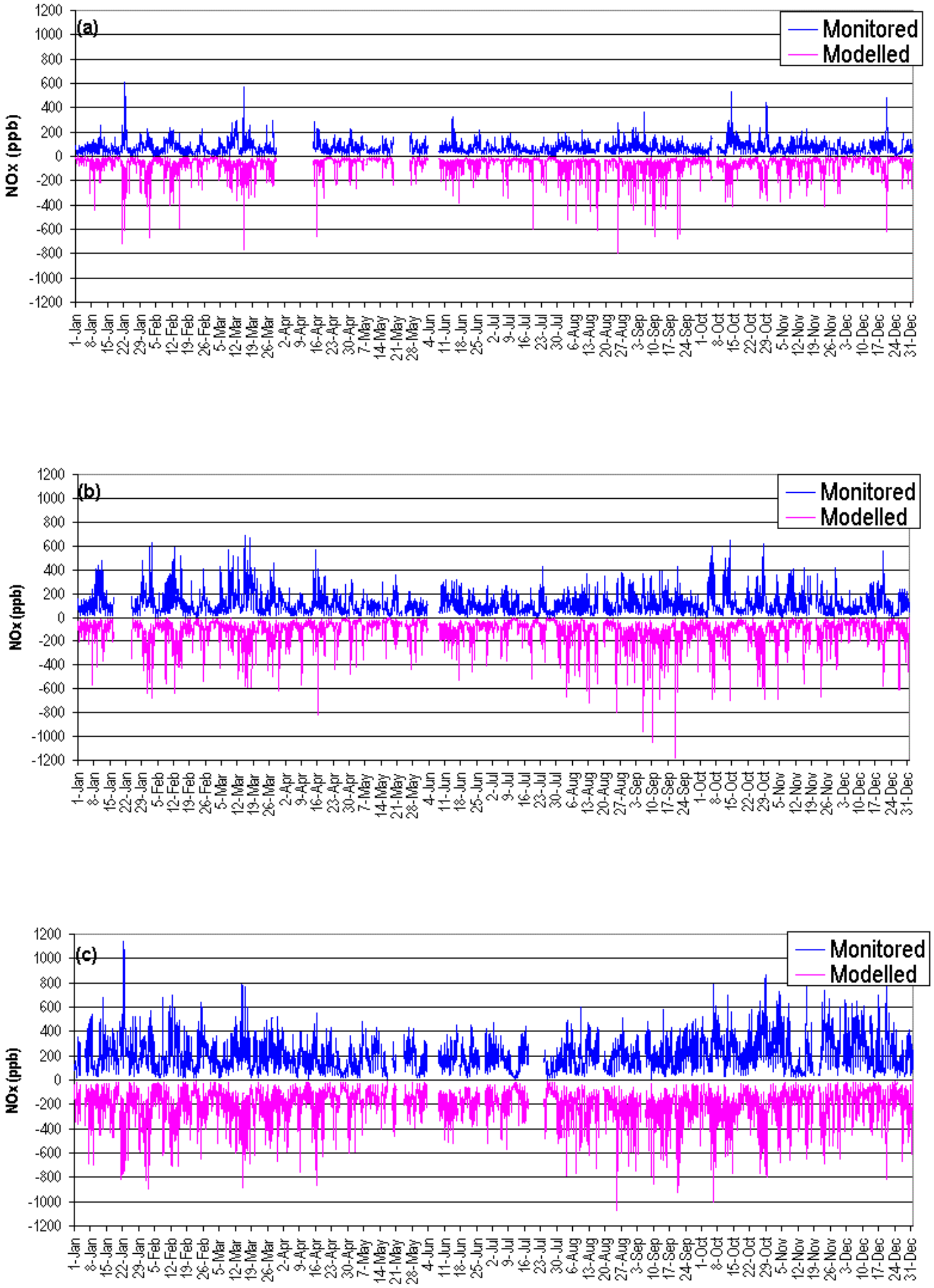


Figure 6.2 Hourly Average Time Series for NO_2 at (a) Bloomsbury, (b) Camden and (c) Marylebone Road

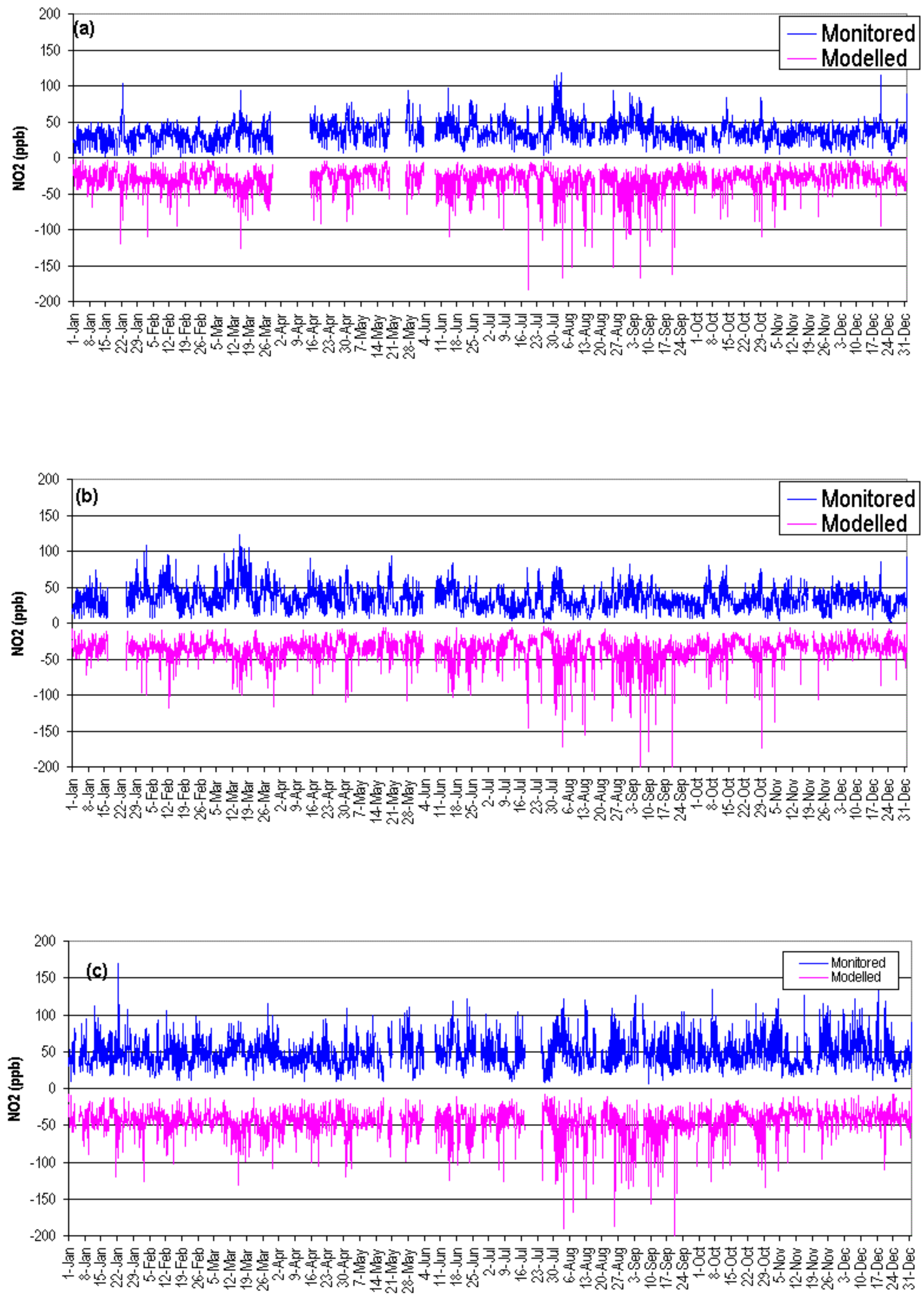
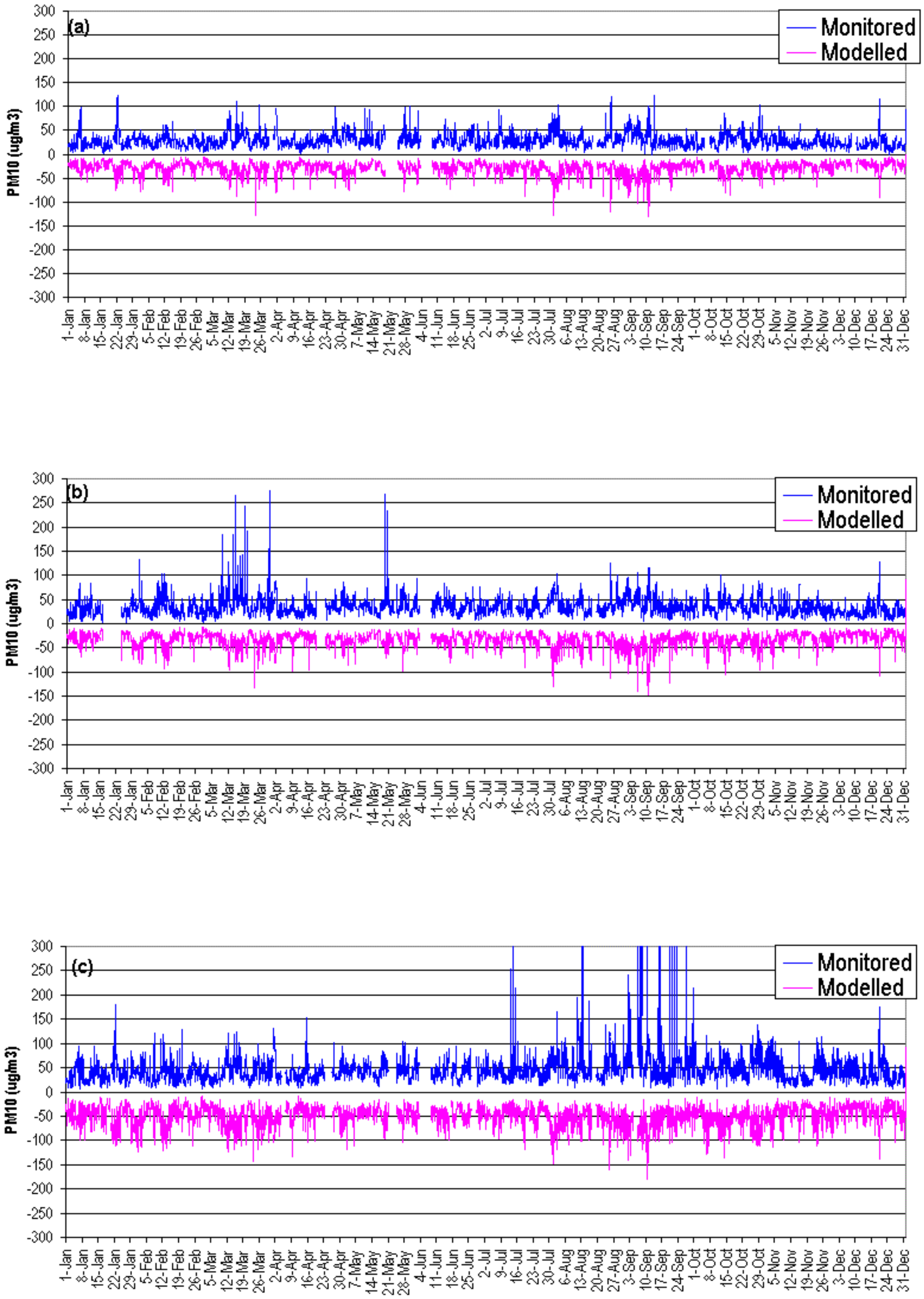


Figure 6.3 Hourly Average Time Series for PM_{10} at (a) Bloomsbury, (b) Camden and (c) Marylebone Road



6.2 Statistical Measures Calculated by the BOOT Statistical Package

The data format was hour-by-hour values for the measured (observed) concentrations (X_{o_i}, t = 1,2….n) and predicted concentrations (X_{p_i}, t = 1,2….n), where t is the time in hours. The following statistical measures were applied to the data sets.

- The **mean** or the annual averages $\overline{X_o}$ and $\overline{X_p}$.

- Any **percentiles** of interest because they represent the number of exceedences in the air quality standards.

- **Standard deviation**, – The standard deviation is a measure of the scatter of observed and predicted concentrations:

$$\sigma_o = (\overline{X_o^2} - \overline{X_o}^2)^{1/2},\ \sigma_p = (\overline{X_p^2} - \overline{X_p}^2)^{1/2}.$$

- **Normalised mean square error (NMSE)** – a normalised overall measure of the error in hour-by-hour comparisons between measured and predicted concentrations.

$$\text{NMSE} = \frac{\overline{(X_o - X_p)^2}}{\overline{X_o X_p}}$$

- **Correlation (R)** – The correlation coefficient describes the relationship between two sets of data. It is calculated from the covariance of the data sets, which is the average of the products of deviations for each data point pair. An exact data match would give a correlation of 1.

$$R = \frac{\overline{(X_o - \overline{X_o})(X_p - \overline{X_p})}}{\sigma_o \sigma_p}$$

- **FA2** – this is the fraction of predicted concentrations within a factor of two of the equivalent measured values. If all predictions were with a factor of two of measurements the fraction would be 1.

$$\text{FA2} = \sum_{i=1}^{N} \theta(X_p/X_o - 0.5)\theta(2.0 - X_p/X_o)/N$$

(Where θ is the step function, = 1 for positive arguments; = 0 for negative arguments).

- **Fractional bias (FB)** – a measure of how the calculated mean differs from the observed mean, sometimes referred to as normalised bias. A value of zero indicates no difference, **positive values** indicate an **underestimate** in calculated concentrations and **negative values** indicate an **overestimate**.

$$FB = \frac{\overline{X_o} - \overline{X_p}}{\left(\overline{X_o} + \overline{X_p}\right)/2}$$

6.3 Base Case

A base scenario was used to predict pollutant concentrations at the locations of the London AURN sites. The December 2001 LAEI was used and the base model parameters are given in Table 6.1 The results of this modelling were compared with the concentrations measured at the London AURN sites during 1999.

Table 6.1 Base model parameters

Parameter	Value (m)
Surface roughness	1
Minimum Monin-Obukhov length	75
Initial traffic pollution mixing height	2
Area source grid depth	75
Meteorological data	Heathrow 1999, roughness at met site 0.2m

6.4 Validation - Comparisons between measured concentrations

Tables 6.2 to 6.5 present statistics of comparisons between measured concentrations and ADMS-Urban calculations. Statistics have been calculated based on hourly comparisons for each site, first for the roadside sites, then the background and other sites. Finally, sets of overall statistics have been calculated for roadside, background and all sites. Figures 6.4 to 6.9 present the statistics diagrammatically.

As discussed in Section 6.1, interpretation of the statistical analysis is not straightforward, however, it can be concluded that when all of the statistics are taken into account there is a good agreement between the predicted and measured data for each of the pollutants. This is shown by low values of normalised mean square error and fractional bias and high values for the correlation and fraction of points with a factor of 2 (hour by hour comparisons). This is true both for the individual site statistics and overall statistics. Specific points to note are as follows:

- Annual mean NO_x tends to be slightly underpredicted compared to measured values at roadside sites. However, there is some overprediction for the high (99.8) percentiles at both roadside and background sites.

- Overall, NO_2 values are well predicted with a very low fractional bias (0.02) and very close agreement between annual mean concentrations. Hour by hour comparisons of concentrations show somewhat greater error than shown by normalised mean square error (0.22). The 99.8 percentile values tend to be higher than the measured values as a result of some overprediction of peak values of NO_x.

- Ozone is in general slightly underpredicted with an overall fractional bias of 0.18. However, there are questions about the accuracy of ozone measurements at roadside sites.

- Overall, the predicted PM_{10} values show a good agreement with the measured values as shown by the low overall fractional bias (-0.05). The higher (98.1) percentile values show a slight tendency to underpredict the measured values. This is likely to result from the assumption that the coarse component of PM_{10} is constant.

Table 6.2 1999 Monitored and calculated NO_x concentrations (ppb)

	Annual average		99.8th percentile of hourly average		Standard deviation		NMSE (objective 0)	Correlation (objective 1)	FA2 (objective 1)	Normalised bias (objective 0)
	Monitored	Calculated	Monitored	Calculated	Monitored	Calculated				
A3	134	120	598	534	101	90	0.35	0.71	0.80	0.11
Camden	110	107	556	638	86	94	0.65	0.53	0.73	0.02
Cromwell Road	134	136	503	611	77	105	0.54	0.44	0.64	-0.01
Haringey	71	60	499	455	60	62	0.78	0.57	0.69	0.18
Hounslow	100	69	565	465	83	76	0.71	0.69	0.57	0.37
Marylebone Road	204	201	784	772	131	131	0.38	0.54	0.76	0.02
Southwark roadside	119	97	524	547	72	81	0.34	0.71	0.79	0.21
Sutton roadside	61	40	330	413	51	52	1.17	0.54	0.47	0.42
Tower Hamlets	126	101	543	593	89	83	0.49	0.63	0.75	0.22
Roadside mean	**115**	**99**	**529**	**561**	**94**	**99**	**0.59**	**0.66**	**0.69**	**0.13**
Bexley	36	41	369	499	43	62	1.91	0.55	0.71	-0.13
Bloomsbury	71	62	421	536	49	65	0.70	0.57	0.67	0.13
Brent	35	40	366	402	47	50	1.56	0.54	0.71	-0.14
Bridge Place	55	57	351	465	44	64	0.79	0.63	0.78	-0.04
Eltham suburban	34	45	367	555	41	69	2.30	0.55	0.74	-0.28
Hackney	71	59	540	468	66	62	0.90	0.56	0.70	0.18
Hillingdon	87	108	482	750	77	106	0.65	0.70	0.77	-0.21
Lewisham	73	61	434	471	61	63	0.77	0.58	0.69	0.17
North Kensington	43	53	403	422	49	55	1.01	0.61	0.78	-0.20
Southwark urban centre	62	52	391	501	50	66	0.88	0.62	0.61	0.18
Sutton suburban	34	35	348	381	42	48	1.45	0.57	0.72	-0.04
Teddington	27	32	223	338	31	45	1.61	0.59	0.80	-0.16
Wandsworth	74	67	402	440	63	63	0.67	0.59	0.67	0.10
West London	52	48	380	445	45	52	0.74	0.62	0.76	0.10
Background mean	**54**	**54**	**391**	**477**	**54**	**63**	**1.02**	**0.60**	**0.72**	**0.01**
Overall statistic	**78**	**72**	**449**	**512**	**79**	**83**	**0.79**	**0.67**	**0.70**	**0.09**

Table 6.3 1999 Monitored and calculated NO_2 concentrations (ppb)

	Annual average		99.8th percentile of hourly average		Standard deviation		NMSE (objective 0)	Correlation (objective 1)	FA2 (objective 1)	Normalised bias (objective 0)
	Monitored	Calculated	Monitored	Calculated	Monitored	Calculated				
A3	31	35	94	104	13	14	0.18	0.53	0.90	-0.14
Camden	34	37	94	127	15	16	0.20	0.49	0.89	-0.07
Cromwell Road	49	40	103	123	17	16	0.19	0.45	0.91	0.20
Haringey	27	29	78	108	12	14	0.18	0.60	0.92	-0.08
Hounslow	31	28	77	95	13	14	0.16	0.65	0.87	0.11
Marylebone Road	48	45	120	131	18	17	0.14	0.52	0.95	0.05
Southwark roadside	39	35	93	111	15	13	0.12	0.65	0.95	0.11
Sutton roadside	23	21	65	89	13	14	0.28	0.61	0.78	0.06
Tower Hamlets	37	37	95	121	14	15	0.15	0.52	0.93	0.00
Roadside mean	**35**	**33**	**90**	**114**	**17**	**16**	**0.19**	**0.60**	**0.89**	**0.04**
Bexley	19	21	61	122	11	15	0.37	0.61	0.81	-0.09
Bloomsbury	35	30	99	115	14	14	0.21	0.53	0.88	0.17
Brent	20	23	68	98	12	14	0.32	0.62	0.82	-0.17
Bridge Place	33	28	81	108	13	14	0.19	0.61	0.90	0.18
Eltham suburban	19	22	65	121	11	15	0.39	0.61	0.84	-0.17
Hackney	31	29	99	104	14	14	0.20	0.58	0.90	0.09
Hillingdon	26	33	71	116	12	15	0.20	0.67	0.86	-0.23
Lewisham	28	29	69	110	11	13	0.18	0.53	0.92	-0.02
North Kensington	24	27	73	98	13	14	0.21	0.63	0.89	-0.11
Southwark urban centre	29	26	77	115	12	15	0.20	0.63	0.88	0.14
Sutton suburban	18	20	58	87	11	13	0.30	0.63	0.84	-0.09
Teddington	17	18	59	83	12	13	0.29	0.70	0.85	-0.06
Wandsworth	27	31	78	101	14	13	0.25	0.46	0.80	-0.12
West London	29	25	75	96	12	13	0.18	0.63	0.91	0.13
Background mean	**25**	**26**	**74**	**105**	**14**	**14**	**0.24**	**0.61**	**0.86**	**-0.01**
Overall statistic	**29**	**29**	**81**	**109**	**16**	**16**	**0.22**	**0.63**	**0.87**	**0.02**

Table 6.4 1999 Monitored and calculated O_3 concentrations (ppb)

	Annual average		Standard deviation		NMSE (objective 0)	Correlation (objective 1)	FA2 (objective 1)	Normalised bias (objective 0)
	Monitored	Calculated	Monitored	Calculated				
Marylebone Road	6.6	2.7	7.1	4.6	2.49	0.63	0.25	0.83
Roadside Mean	**6.6**	**2.7**	**7.1**	**4.6**	**2.49**	**0.63**	**0.25**	**0.83**
Bexley	20	18	14	15	0.24	0.81	0.64	0.12
Bloomsbury	12	11	11	12	0.43	0.78	0.53	0.05
Brent	20	16	15	14	0.27	0.85	0.65	0.23
Bridge Place	17	13	13	13	0.35	0.81	0.57	0.25
Eltham	20	17	15	14	0.24	0.84	0.67	0.18
Hackney	15	12	13	12	0.38	0.82	0.61	0.25
Hillingdon	13	8	12	10	0.70	0.81	0.42	0.44
Lewisham	11	11	10	12	0.52	0.75	0.51	-0.07
North Kensington	18	13	15	13	0.39	0.84	0.59	0.33
Southwark urban centre	15	14	13	14	0.26	0.84	0.62	0.06
Sutton suburban	18	18	14	14	0.23	0.81	0.74	-0.01
Teddington	22	20	15	15	0.18	0.83	0.72	0.09
Wandsworth	13	10	12	11	0.61	0.75	0.49	0.30
Background mean	**16**	**14**	**14**	**13**	**0.33**	**0.82**	**0.59**	**0.16**
Overall statistic	**16**	**13**	**14**	**13**	**0.35**	**0.82**	**0.57**	**0.18**

Table 6.5 1999 Monitored and calculated PM_{10} concentrations ($\mu g/m^3$)

	Annual average		90.4^{th} percentile of 24 hr average		98.1^{th} percentile of 24 hr average		Standard deviation		NMSE (objective 0)	Correlation (objective 1)	FA2 (objective 1)	Normalised bias (objective 0)
	Monitored	Calculated	Monitored	Calculated	Monitored	Calculated	Monitored	Calculated				
A3	30	31	46	44	59	59	16	13	0.15	0.71	0.90	-0.06
Camden	34	33	50	47	68	62	18	15	0.19	0.61	0.93	0.03
Haringey	28	29	42	41	59	53	15	12	0.13	0.71	0.95	-0.01
Marylebone Road	46	49	67	68	109	83	42	20	0.71	0.36	0.90	-0.06
Sutton roadside	26	26	40	39	48	51	14	12	0.21	0.60	0.94	-0.02
Roadside mean	**33**	**34**	**49**	**47**	**69**	**62**	**25**	**17**	**0.4**	**0.55**	**0.92**	**-0.03**
Bexley	25	26	42	38	61	48	16	12	0.22	0.68	0.89	-0.04
Bloomsbury	28	29	42	41	59	54	14	13	0.14	0.69	0.94	-0.01
Brent	23	26	38	38	46	52	14	12	0.21	0.65	0.90	-0.13
Eltham	23	27	35	38	47	48	12	12	0.19	0.67	0.92	-0.16
Hillingdon	27	29	42	41	58	59	17	13	0.22	0.65	0.88	-0.08
North Kensington	27	27	42	39	59	53	15	12	0.14	0.73	0.95	0.00
Background mean	**26**	**27**	**40**	**39**	**55**	**52**	**15**	**12**	**0.19**	**0.67**	**0.91**	**-0.07**
Overall statistic	**29**	**30**	**44**	**43**	**61**	**57**	**20**	**15**	**0.31**	**0.60**	**0.92**	**-0.05**

Figure 6.4 Comparison of 1999 Measured and Predicted Annual Average, Percentile and Standard Deviation Data Pairs for NO_x, NO_2 and O_3

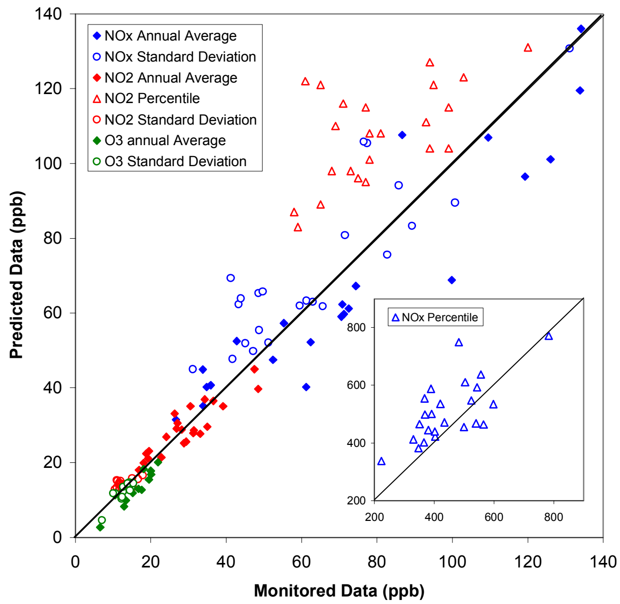


Figure 6.5 Comparison of 1999 Measured and Predicted Annual Average, Percentile and Standard Deviation Data Pairs for PM_{10}

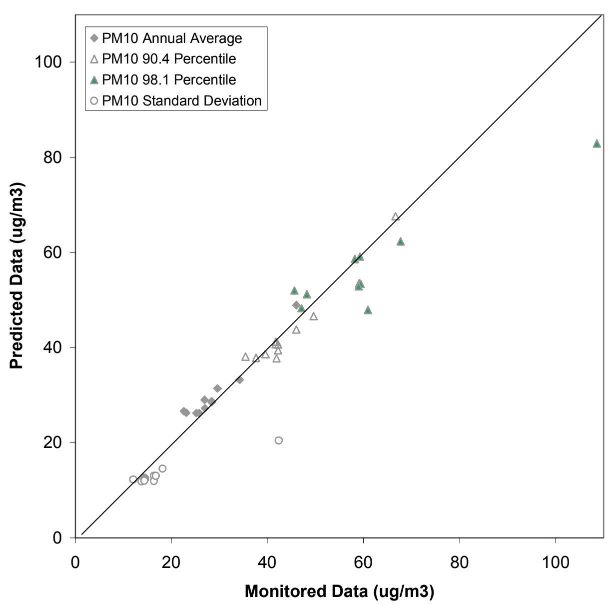


Figure 6.6 1999 Normalised Mean Square Error (NMSE) Values (Exact Match 0)

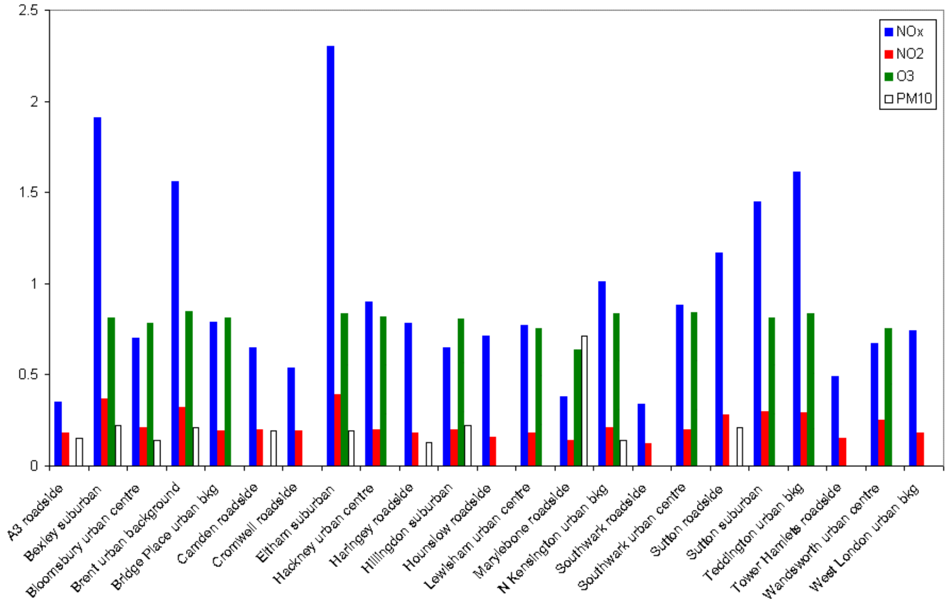


Figure 6.7 1999 Correlation Values (Exact Match 1)

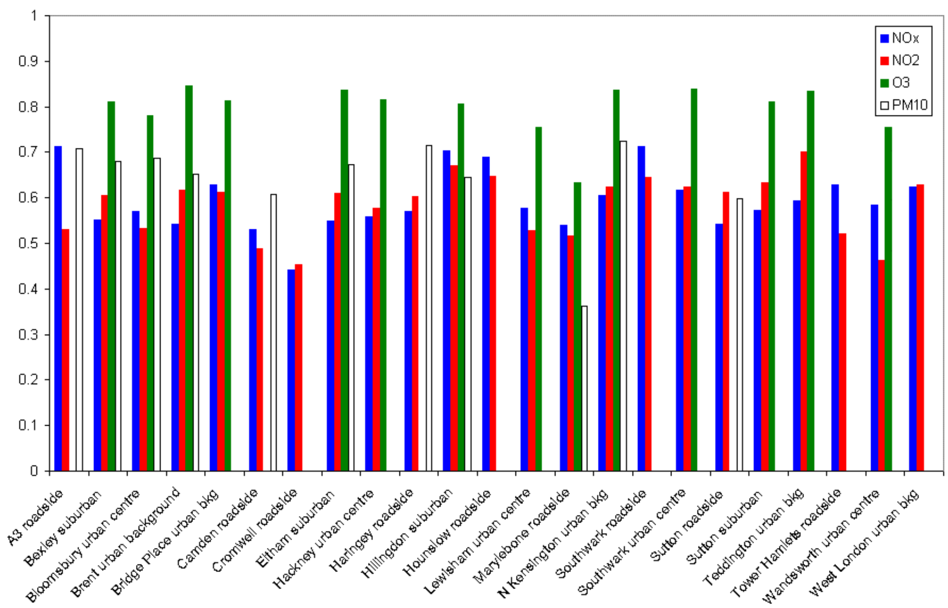


Figure 6.8 1999 FA2 Values (Exact Match 1)

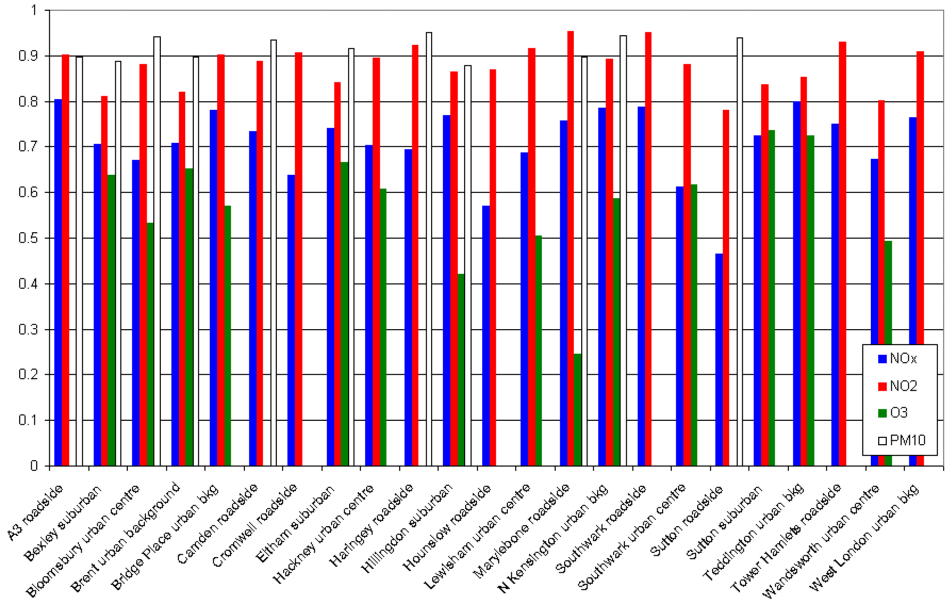
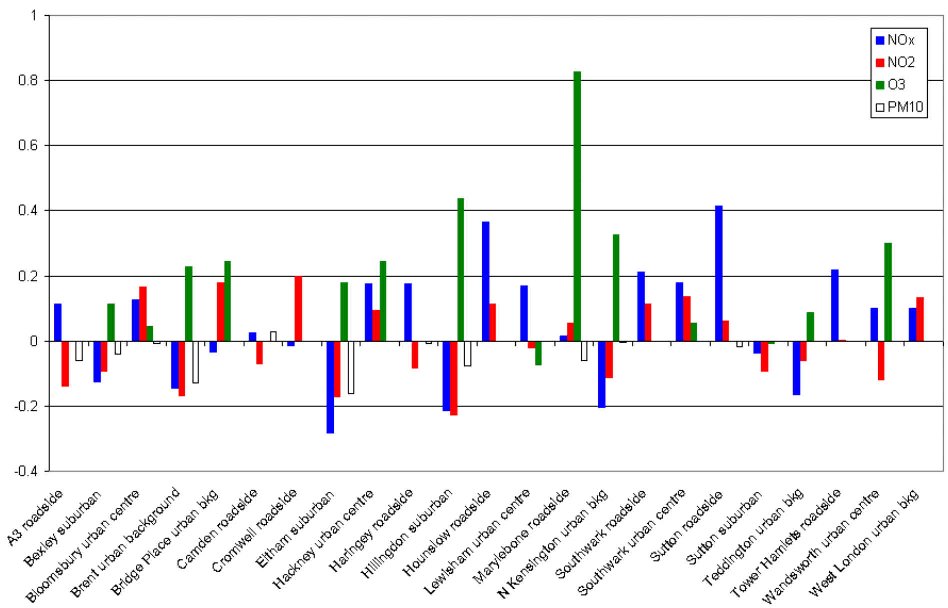


Figure 6.9 1999 Fractional Bias Values (Exact Match 0)



7. Sensitivity Study

Concentrations of NO_x, NO_2, ozone and PM_{10} have been calculated at each site for six scenarios plus the base scenario using 1999 emissions. Calculated concentrations have been compared to one another and to the monitored concentrations during 1999.

7.1 Modelled Scenarios

The majority of the calculations use the GLA December 2001 London emissions inventory for 1999, which was calculated using the consultation traffic emission factors issued in October 2001. However, a comparison has been made using the GLA October 2001 inventory for 1999 issued using the original traffic emission factors.

The base model parameters used in the modelling were shown in Table 6.1. Table 7.1 shows the scenarios considered in the sensitivity modelling. These include changes in the global parameters of the model (grid source depth, minimum Monin Obukhov length to limit urban stability and surface roughness) to account for the uncertainty in these parameters, the impact of using data from the London Weather Centre rather than Heathrow, the impact of the earlier emissions inventory and finally the impact of the meteorological year.

Tables 7.2 to 7.9 summarise the calculated concentrations for each scenario. These include the BOOT statistical analysis of all sites and mean values, separately calculated for roadside, background and all sites.

In the tables of statistics it would not be sensible to compare scenario 6 with the monitored concentrations as it uses a different meteorological year; it has been modelled to give an indication of the effect yearly variation in meteorology can have upon concentrations. Therefore only the average calculated concentrations and the standard deviation of concentrations have been shown for this scenario.

Table 7.1 Sensitivity scenarios (base case values in brackets)

Scenario	Parameter Changed	New Parameter Value
1	Grid source depth	50m (75m)
2	Minimum Monin-Obukhov length	50m (75m)
3	Met data, roughness at met site	London Weather Centre 1999, roughness at met site 1m
4	Emissions Inventory	GLA October 2001 emissions
5	Surface roughness (m)	1.5 (1m)
6	Meteorological year (1999 emissions with 1996/97 meteorology)	1997 Heathrow met data for NO_x, NO_2 and O_3 calculations. 1996 Heathrow met data for PM_{10} calculations. Plus appropriate background data.

Table 7.2 Annual Average NO_x concentration (ppb)

	1999 monitored	Base Scenario	Scenario 1 Grid height	Scenario 2 L_{MO}	Scenario 3 Met site	Scenario 4 Inventory	Scenario 5 Z_0	Scenario 6 Met year
A3	134	119	120	128	104	103	117	124
Camden	110	107	108	117	80	92	103	110
Cromwell Road	134	136	138	146	114	115	137	145
Haringey	71	60	61	67	43	53	56	63
Hounslow	100	69	69	77	54	61	64	72
Marylebone Road	204	201	203	214	178	167	199	204
Southwark roadside	119	96	97	105	81	82	95	108
Sutton roadside	61	40	41	45	28	36	38	46
Tower Hamlets	126	101	102	111	84	87	97	102
Roadside mean	**118**	**103**	**104**	**112**	**85**	**88**	**101**	**108**
Bexley	36	41	41	47	26	36	38	38
Bloomsbury	71	62	66	70	45	55	58	65
Brent	35	40	41	46	30	36	38	44
Bridge Place	55	57	59	65	40	51	54	58
Eltham suburban	34	45	45	52	28	40	42	42
Hackney	70	59	60	67	42	52	56	62
Hillingdon	87	108	109	118	86	93	100	101
Lewisham	73	61	62	69	42	53	57	63
North Kensington	43	53	55	60	39	47	49	56
Southwark urban centre	62	52	54	59	34	47	49	52
Sutton suburban	34	35	36	40	23	32	33	38
Teddington	27	31	32	36	22	29	30	34
Wandsworth	74	67	68	75	51	58	63	71
West London	52	47	49	54	35	43	45	51
Background mean	**54**	**54**	**56**	**61**	**39**	**48**	**51**	**55**
Overall mean	**79**	**72**	**73**	**79**	**56**	**62**	**69**	**75**
% error	-	-9%	-8%	1%	-29%	-26%	-14%	4%*
Standard Deviation	78.9	83.3	84.0	93.6	57.5	71.9	80.31	83.26
NMSE	0	0.79	0.78	0.84	0.81	0.85	0.82	-
Correlation	1	0.669	0.669	0.661	0.720	0.662	0.659	-
FA2	1	0.698	0.706	0.687	0.707	0.665	0.7	-
Fractional Bias	0	0.089	0.074	-0.011	0.329	0.227	0.134	-

* percentage difference from base case rather than the monitored value

Table 7.3 99.8th percentile of hourly average NO_x concentration (ppb)

	1999 monitored	Base Scenario	Scenario 1 Grid height	Scenario 2 L_{MO}	Scenario 3 Met site	Scenario 4 Inventory	Scenario 5 Z_0	Scenario 6 Met year
A3	598	534	535	595	392	469	551	592
Camden	556	638	641	713	385	559	640	647
Cromwell Road	503	611	614	658	443	541	712	602
Haringey	499	455	458	526	240	403	474	486
Hounslow	565	464	465	511	293	411	486	533
Marylebone Road	784	772	781	859	581	668	754	780
Southwark roadside	524	547	548	629	309	490	539	533
Sutton roadside	330	413	415	435	211	368	437	408
Tower Hamlets	543	593	594	653	373	508	674	572
Roadside mean	**545**	**559**	**561**	**620**	**359**	**491**	**585**	**573**
Bexley	369	498	499	594	194	440	532	433
Bloomsbury	421	536	540	540	253	477	578	464
Brent	366	402	402	456	210	360	411	405
Bridge Place	351	465	467	480	246	410	515	450
Eltham suburban	367	555	555	651	200	488	622	457
Hackney	540	468	468	523	251	411	502	449
Hillingdon	482	750	760	889	443	670	657	735
Lewisham	434	471	472	533	212	417	507	404
North Kensington	403	422	424	458	246	377	450	404
Southwark urban centre	391	501	502	539	213	441	554	438
Sutton suburban	348	381	382	426	177	345	391	349
Teddington	223	338	338	383	200	314	364	351
Wandsworth	402	440	441	492	266	398	474	454
West London	380	445	446	445	225	400	477	391
Background mean	**391**	**477**	**478**	**529**	**238**	**425**	**502**	**442**
Overall Mean	**448**	**512**	**514**	**569**	**285**	**454**	**537**	**493**
% error	-	14%	15%	27%	-36%	1%	20%	10%*

* percentage difference from base case rather than the monitored value

Table 7.4 Annual Average NO_2 concentration (ppb)

	1999 monitored	Base Scenario	Scenario 1 Grid height	Scenario 2 L_{MO}	Scenario 3 Met site	Scenario 4 Inventory	Scenario 5 Z_0	Scenario 6 Met year
A3	31	35	35	36	35	33	35	36
Camden	34	37	37	38	35	35	37	37
Cromwell Road	48	40	40	41	39	38	40	41
Haringey	27	29	29	30	27	28	29	30
Hounslow	31	28	28	29	28	27	27	29
Marylebone Road	47	45	45	46	43	43	45	45
Southwark roadside	39	35	35	36	35	33	35	37
Sutton roadside	23	21	22	22	19	20	21	23
Tower Hamlets	37	36	37	37	36	35	36	37
Roadside mean	**35**	**34**	**34**	**35**	**33**	**32**	**34**	**35**
Bexley	19	21	21	22	18	20	21	20
Bloomsbury	35	30	31	30	28	28	29	30
Brent	20	23	23	24	21	22	23	24
Bridge Place	33	28	28	29	25	26	27	28
Eltham suburban	19	22	23	23	20	21	22	22
Hackney	31	29	29	29	26	27	29	29
Hillingdon	26	33	33	34	31	31	33	33
Lewisham	28	29	29	30	26	27	28	29
North Kensington	24	27	28	28	25	26	27	28
Southwark urban centre	29	26	26	27	23	24	25	26
Sutton suburban	18	20	20	21	17	19	19	21
Teddington	17	18	18	19	16	17	18	19
Wandsworth	27	31	31	31	29	29	30	31
West London	29	25	26	26	23	24	25	26
Background mean	**25**	**26**	**26**	**27**	**23**	**24**	**25**	**26**
Overall mean	**29**	**29**	**29**	**30**	**27**	**27**	**29**	**29**
% error	-	-2%	-1%	1%	-8%	-8%	-3%	2%*
Standard Deviation	15.6	15.8	15.7	16.3	13.4	15.3	15.9	15.7
NMSE	0	0.22	0.21	0.22	0.18	0.23	0.23	-
Correlation	1	0.631	0.632	0.627	0.685	0.628	0.621	-
FA2	1	0.874	0.877	0.871	0.883	0.862	0.873	-
Fractional Bias	0	0.02	0.008	-0.01	0.077	0.075	0.028	-

* percentage difference from base case rather than the monitored value

Table 7.5 99.8th percentile of hourly average NO_2 concentration (ppb)

	1999 monitored	Base Scenario	Scenario 1 Grid height	Scenario 2 L_{MO}	Scenario 3 Met site	Scenario 4 Inventory	Scenario 5 Z_o	Scenario 6 Met year
A3	94	104	104	105	94	101	108	104
Camden	94	127	128	131	95	122	129	126
Cromwell Road	103	123	124	128	100	118	135	123
Haringey	78	108	108	112	74	105	111	113
Hounslow	77	95	95	100	78	92	99	93
Marylebone Road	120	131	131	134	112	128	134	133
Southwark roadside	93	111	112	114	95	106	115	107
Sutton roadside	65	89	89	92	62	87	93	91
Tower Hamlets	95	121	122	125	95	117	128	122
Roadside mean	**91**	**112**	**113**	**116**	**89**	**108**	**117**	**112**
Bexley	61	122	122	127	64	116	137	100
Bloomsbury	99	115	116	119	76	112	123	109
Brent	68	98	98	103	71	95	106	93
Bridge Place	81	108	109	116	71	106	118	96
Eltham suburban	65	121	121	128	61	115	135	95
Hackney	99	104	104	109	74	101	110	113
Hillingdon	71	116	116	123	90	111	121	102
Lewisham	69	110	110	117	62	107	114	91
North Kensington	73	98	98	100	77	95	101	93
Southwark urban centre	77	115	115	118	66	112	122	99
Sutton suburban	58	87	87	92	53	83	89	85
Teddington	59	83	83	88	63	81	85	81
Wandsworth	78	101	101	105	75	97	106	95
West London	75	96	97	97	73	94	102	91
Background mean	**74**	**105**	**106**	**110**	**69**	**102**	**112**	**96**
Overall mean	**81**	**109**	**109**	**113**	**77**	**105**	**115**	**102**
% error	-	35%	35%	40%	-4%	30%	42%	6%*

* percentage difference from base case rather than the monitored value

Table 7.6 Annual Average O_3 concentration (ppb)

	1999 monitored	Base Scenario	Scenario 1 Grid height	Scenario 2 L_{MO}	Scenario 3 Met site	Scenario 4 Inventory	Scenario 5 Z_0	Scenario 6 Met year
Marylebone Road	7	3	3	3	2	3	3	3
Roadside mean	**7**	**3**	**3**	**3**	**2**	**3**	**3**	**3**
Bexley	20	18	18	17	19	19	18	18
Bloomsbury	12	11	11	11	12	12	11	10
Brent	19	15	15	15	17	16	16	15
Bridge Place	17	13	13	13	14	14	13	12
Eltham	20	17	17	16	18	18	17	16
Hackney	15	12	12	12	12	13	12	11
Hillingdon	13	8	8	8	8	9	8	8
Lewisham	10	11	11	11	12	13	12	10
North Kensington	18	13	12	12	13	14	13	12
Southwark urban centre	15	14	14	14	15	15	14	14
Sutton suburban	18	18	18	18	20	19	19	21
Teddington	22	20	20	19	21	21	20	18
Wandsworth	13	10	10	10	10	11	10	9
Background mean	**16**	**14**	**14**	**14**	**15**	**15**	**14**	**13**
Overall mean	**16**	**13**	**13**	**13**	**14**	**14**	**13**	**12**
% error	-	-17%	-18%	-19%	-12%	-10%	-15%	-5%*
Standard Deviation	13.6	13.3	13.2	13.3	12.5	13.6	13.2	13.4
NMSE	0	0.35	0.36	0.37	0.33	0.31	0.35	-
Correlation	1	0.819	0.82	0.82	0.806	0.819	0.815	-
FA2	1	0.569	0.564	0.551	0.611	0.595	0.575	-
Fractional Bias	0	0.178	0.198	0.208	0.131	0.1	0.164	-

* percentage difference from base case rather than the monitored value

Table 7.7 Calculated annual average PM_{10} concentrations ($\mu g/m^3$)

	1999 monitored	Base Scenario	Scenario 1 Grid height	Scenario 2 L_{MO}	Scenario 3 Met site	Scenario 4 Inventory	Scenario 5 Z_0	Scenario 6 Met year
A3	30	31	31	32	30	32	31	31
Camden	34	33	33	34	31	33	33	33
Haringey	28	29	29	29	27	29	28	29
Marylebone Road	46	49	49	50	46	48	49	46
Sutton roadside	26	26	26	27	25	26	26	28
Roadside mean	**33**	**34**	**34**	**34**	**32**	**34**	**33**	**33**
Bexley	25	26	26	27	25	26	26	27
Bloomsbury	28	29	29	29	27	28	28	29
Brent	23	26	26	27	25	26	26	27
Eltham	23	27	27	27	25	27	26	27
Hillingdon	27	29	29	30	28	29	29	29
North Kensington	27	27	27	28	26	27	27	28
Background mean	**26**	**27**	**27**	**28**	**26**	**27**	**27**	**28**
Overall mean	**29**	**30**	**30**	**31**	**29**	**30**	**30**	**30**
% error	-	4%	5%	6%	0%	4%	3%	1%*
Standard Deviation	20.25	14.84	14.84	15.42	13.61	14.66	14.63	14.64
NMSE	0	0.31	0.31	0.31	0.31	0.31	0.31	-
Correlation	1	0.604	0.604	0.597	0.613	0.602	0.607	-
FA2	1	0.917	0.917	0.911	0.923	0.917	0.918	-
Fractional Bias	0	-0.046	-0.049	-0.068	0.005	-0.042	-0.036	-

* percentage difference from base case rather than the monitored value

Table 7.8 Calculated 90th percentile of daily average PM_{10} concentration ($\mu g/m^3$)

	1999 monitored	Base Scenario	Scenario 1 Grid height	Scenario 2 L_{MO}	Scenario 3 Met site	Scenario 4 Inventory	Scenario 5 Z_0	Scenario 6 Met year
A3	46	43	44	44	43	44	43	46
Camden	49	46	47	48	42	47	46	47
Haringey	42	40	41	41	39	40	40	44
Marylebone Road	65	67	67	70	63	66	66	66
Sutton roadside	39	38	38	39	38	38	37	42
Roadside mean	**48**	**47**	**47**	**48**	**45**	**47**	**46**	**49**
Bexley	41	37	37	39	36	37	37	41
Bloomsbury	42	40	41	42	39	40	40	44
Brent	37	38	38	38	37	38	38	42
Eltham	35	38	51	52	37	51	51	41
Hillingdon	41	41	41	42	40	41	40	45
North Kensington	42	39	39	40	38	39	38	43
Background mean	**40**	**39**	**41**	**42**	**38**	**41**	**41**	**43**
Overall mean	**44**	**43**	**44**	**45**	**41**	**44**	**43**	**46**
% error	-	-3%	1%	3%	-6%	0%	-1%	7%*

* percentage difference from base case rather than the monitored value

Table 7.9 Calculated 98.1th percentile of daily average PM_{10} concentration ($\mu g/m^3$)

	1999 monitored	Base Scenario	Scenario 1 Grid height	Scenario 2 L_{MO}	Scenario 3 Mat site	Scenario 4 Inventory	Scenario 5 Z_0	Scenario 6 Met year
A3	59	59	59	60	55	59	59	67
Camden	68	62	63	65	58	63	61	69
Haringey	59	53	54	55	51	54	53	62
Marylebone Road	109	83	83	86	79	81	81	87
Sutton roadside	48	51	51	52	49	51	51	61
Roadside mean	**69**	**62**	**62**	**63**	**58**	**62**	**61**	**69**
Bexley	61	48	48	48	48	48	48	59
Bloomsbury	59	54	54	55	52	53	53	65
Brent	46	52	52	53	49	52	52	59
Eltham	47	48	48	50	48	48	48	61
Hillingdon	58	59	59	59	54	58	58	63
North Kensington	59	53	53	55	51	53	52	61
Background mean	**55**	**52**	**52**	**53**	**50**	**52**	**52**	**61**
Overall mean	**61**	**57**	**57**	**58**	**54**	**56**	**56**	**65**
% error	-	-8%	-7%	-5%	-12%	-8%	-8%	15%*

* percentage difference from base case rather than the monitored value

7.2 Summary of Results

The results of the sensitivity study are summarised in Table 7.10, which is a compilation of the differences between the overall mean of background and predicted concentrations. This is '% error' in the tables.

Table 7.10 Summary of errors (%) of observed overall mean concentrations

	Base scenario	Scenario 1 Grid height	Scenario 2 L_{MO}	Scenario 3 Met site	Scenario 4 Inventory	Scenario 5 Z_0	Scenario 6 Met year*
Annual average NO_x	-9	-8	1	-29	-26	-14	4
99.8^{th} percentile of hourly average NO_x	14	15	27	-36	1	20	10
Annual average NO_2	-2	-1	1	-8	-8	-3	2
99.8^{th} percentile of hourly average NO_2	35	35	40	-4	30	42	6
Annual average O_3	-17	-18	-19	-12	-10	-15	5
Annual average PM_{10}	4	5	6	0	4	3	1
90^{th} percentile of 24 hour average PM_{10}	-3	1	3	-6	0	-1	7
98.1^{th} percentile of 24 hour average PM_{10}	-8	-7	-5	-12	-8	-8	15

* percentage difference from base case rather than the monitored value

Examination of tables 7.2 to 7.9 and the summary table shows that replacing Heathrow meteorological data with data from the London Weather Centre (LWC) (Scenario 3) results in one of the largest changes to concentrations. There is a substantial reduction in calculated concentrations of NO_x and NO_2, and corresponding increase in ozone concentrations.

Use of the October inventory (scenario 4) also leads to reduced calculated concentrations, as this inventory used traffic emission factors which gave lower total emissions of NO_x and PM_{10}. Increasing the surface roughness (scenario 5) also decreases the calculated concentrations, as the higher roughness results in more effective mixing of pollutants

The base scenario and scenarios 1 and 2 show the best agreement with monitored data. Decreasing the grid source depth to 50m (scenario 1), increases all calculated concentrations (except ozone), as the initial mixing height of the pollution is reduced.

Decreasing the minimum Monin-Obukhov length to 50m effectively reduces the mixing rate, and therefore also leads to increased calculated concentrations compared to the base scenario.

7.3 Uncertainty

Annual average concentration maps have been produced with ADMS-Urban using the base case scenarios for 1999, 2005 and 2010. In addition maps for PM_{10} have been produced using the accepted worst case meteorological year for this pollutant, 1996. The maps and the methodology used to produce them are presented in the map report

(Blair et al., 2003). The effect of uncertainty on the area of London exceeding certain threshold values was also presented in the map report for the annual average maps.

Uncertainty in the modelled annual average calculation leads to uncertainty in the number of road lengths exceeding annual mean standards for NO_2 and PM_{10} maps. In order to give an indication of the extent of this uncertainty, the maps were analysed to determine the length of roads predicted to exceed certain threshold values for the predicted value ± 5%. Spatial variations in concentration are predicted along and across road segments therefore average concentrations are calculated along each road segment. The total road length is 3,656 km.

The results are presented in Table 7.11 in terms of percentage of total road length exceeding a range of threshold values, which in the case of NO_2 and PM_{10}, include the 2004, 2005 and 2010 annual average air quality objectives. The values given in brackets are for the worst case meteorological conditions.

It can be seen that the estimated 5% uncertainty in concentration has limited impact on the percentage of road length exceeding the NO_2 annual mean standard (40 μg/m^3). For PM_{10} in some cases, notably the London 2010 standard (23 μg/m^3) in 2004 and the EU 2010 standard (20 μg/m^3) in 2010, the uncertainty greatly impacts on the number of roads exceeding the standard.

Table 7.11 The percentage of road length exceeding concentration thresholds for the modelled concentration (C_m) and for C_m±5% (estimated overall uncertainty in annual average NO_2 and PM_{10} concentrations = 5%), the range of percentages represents the uncertainty. Predictions using worst case meteorological conditions given in brackets.

	1999			2004/5			2010		
Threshold (μg/m^3)	C_m -5%	C_m	C_m +5%	C_m -5%	C_m	C_m +5%	C_m -5%	C_m	C_m +5%
NO_x > 30	100	100	100	100	100	100	100	100	100
NO_x > 40	100	100	100	100	100	100	96	98	99
NO_x > 50	100	100	100	95	97	99	76	183	88
NO_x > 60	97	98	99	81	87	90	48	55	63
NO_2 > 20	100	100	100	100	100	100	100	100	100
NO_2 > 30	99	100	100	96	98	99	82	89	94
NO_2 > 40	**81**	**89**	**94**	**50**	**62**	**73**	**25**	**35**	**44**
NO_2 > 50	30	42	54	11	17	24	3	6	10
PM_{10} > 20	**100**	**100**	**100**	**100**	**100**	**100**	**26 (100)**	**91 (100)**	**100 (100)**
PM_{10} > 23	**100**	**100**	**100**	**46**	**98**	**100**	**1 (86)**	**2 (100)**	**9 (100)**
PM_{10} > 25	69	99	100	8	21	66	0 (3)	0 (24)	1 (100)
PM_{10} > 30	5	10	20	0	1	2	0	0	0 (0.1)
PM_{10} > 40	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PM_{10} > 50	0	0	0	0	0	0	0	0	0

8. Discussion

The comparison of ADMS-Urban with pollutant concentrations measured at the London AURN sites in 1999 has confirmed the generally good performance of the model with the annual mean values of NO_2 (overall fractional bias 0.02) and PM_{10} (overall fractional bias 0.048) being especially well predicted. The high percentile (peak) values of NO_x and NO_2 show some tendency to overprediction; the particular meteorological situations causing this will be the subject of further investigation.

The sensitivity study showed the sensitivity to different model inputs: one of the greatest sensitivities is to the choice of meteorological site with, for instance, the overall mean of NO_2 being 6% lower if London Weather Centre data was used rather than Heathrow. Adjusting the initial grid source height, minimum Monin Obukhov length or surface roughness within a realistic range had little impact on concentration so we can be sure that these parameters are set at reasonable values which apply equally well to future projections of concentrations. Thus given accurate emission predictions the model will calculate future concentrations to reasonable accuracy. The overall fractional biases of annual mean NO_2 and PM_{10}, which are not very sensitive to the meteorological year, are likely to be no more than about 5%, although individual sites may show greater error. This results in limited uncertainty in the extent of exceedences of the NO_2 annual mean standard, but a far greater impact on road segments exceeding the London 2010 PM_{10} standard (23 $\mu g/m^3$) in 2004. High percentiles can be subject to greater error and uncertainty due to complex meteorological effects and chemical processes.

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