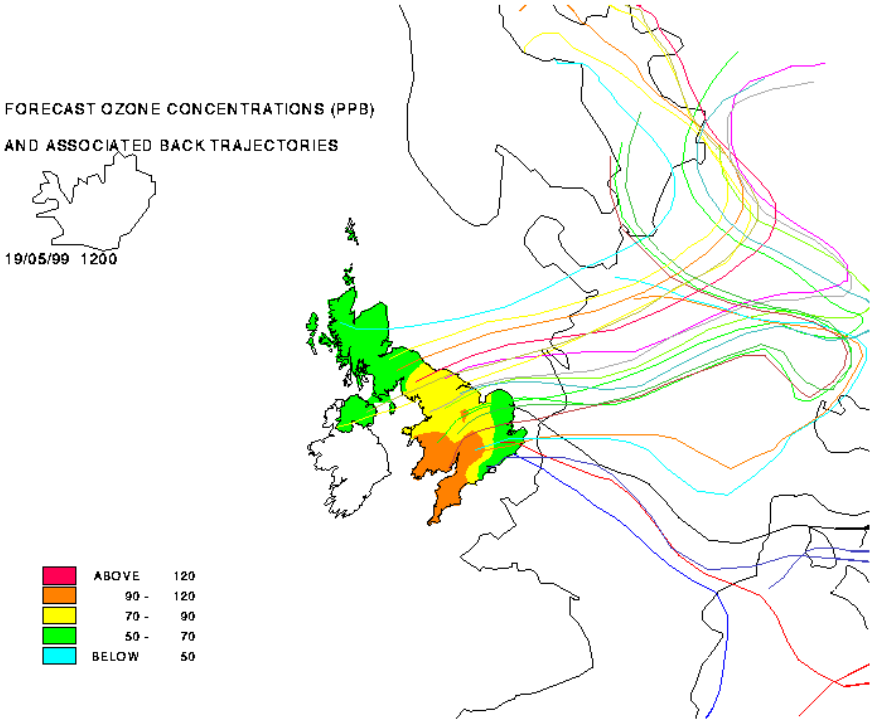
AEAT/ENV/R/0505 /ISSUE2

Air Pollution Forecasting in the United Kingdom: 1998-2000

A report produced for the Department for Environment, Food and Rural Affairs, the Scottish Executive, the National Assembly for Wales and the Department of the Environment in Northern Ireland



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Executive Summary

Daily air pollution forecasts for ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide and particles are issued by AEA Technology Environment, National Environmental Technology Centre. The forecasts are an important part of the Department for Environment, Food and the Rural Affairs and devolved administrations air pollution information systems. An air pollution forecast is important because it allows individuals who may be affected by episodes of high air pollutant concentrations to take preventative measures. Air pollution information is made available to the public by a Data Dissemination Unit through television and radio weather forecasts, teletext, newspapers, a free telephone information service (freephone number 0800 556677) and the World Wide Web.

This is the sixth report on air pollution forecasting in the UK and summarises the achievements and success rates of the air pollution forecasting service from January 1998 to December 2000.

There were a number of changes to the forecasting service during this period:

- In February 1998 a new forecasting region was introduced for East Anglia. This means that for forecasting purposes the UK is now split into ten separate regions.
- In November 1998 forecasts were introduced for different environments – rural, urban background and roadside. Detailed forecasts for each of these environments are available from the Web site. Other media present the “worst case” for each of the forecasting regions. The report presents a number of analyses carried out in order to justify the inclusion of these new forecasts.
- Methods for predicting concentrations of PM_{10} particles continue to be subject to substantial research and review in order to enable us to better capture local and regional impacts on the particle concentrations.
- From April to September 2000 we carried out an evaluation of the NAME air pollution forecasting model, developed by the UK Meteorological Office. The aim of this study was to assess whether the more sophisticated NAME model performed better than the existing BOXURB urban pollution forecasting model. The study concluded that in most cases on average NAME indeed provided improved correlation with measured hourly data. Under the critical low windspeed conditions which result in air pollution episodes, NAME performed much better than BoxUrb which tends to produce false alarms of HIGH concentrations. We therefore recommend that BOXURB be replaced by NAME for operational forecasting.

Contents

1 Introduction

The Department for Environment, Food and Rural Affairs (DEFRA), the Scottish Executive, the National Assembly for Wales and the Department of the Environment in Northern Ireland provide an hourly update on air pollution levels, together with a 24-hour air pollution forecast, which is widely disseminated through the media. An air pollution forecast allows individuals who may be affected by episodes of high air pollutant concentrations to take preventative measures. These can include increasing medication or taking steps to reduce exposure and dose.

Air Pollution Bulletins continue to be made available to the public each day by the Data Dissemination Unit (DDU), via television teletext, newspapers and a free telephone information service (currently 0800 556677). Information on current air pollution and forecasts are also made available on the World Wide Web:

- http://www.aeat.co.uk/netcen/airqual
- http://www.defra.gov.uk/environment/airquality/index.htm

This site also includes a comprehensive Air Quality Archive. Air pollution information is always made available for inclusion in television, and radio weather forecasts and is usually broadcast during periods of HIGH air pollution.

Detailed, region-by-region, forecasts of air pollution for inclusion in these bulletins are provided by AEA Technology Environments', National Environmental Technology Centre (NETCEN). The forecast consists of an air pollution band for each pollutant for the following 24 hours, for each geographical region. At the beginning of 1998 there were 9 geographical regions, but in February the new region of East Anglia was introduced bringing the total to 10 (see Figure 1.1).

Since 19 November 1997 ambient concentrations for O_3, NO_2, SO_2, CO and particles (PM_{10}) have been described according to a new set of air pollution bandings defined by the EPAQS and COMEAP (1997) recommendations and current EC directives. Under the new bandings forecasters are aiming to predict HIGH and VERY HIGH levels of air pollution.

In addition to the public dissemination of the daily air pollution forecast, NETCEN also provides DEFRA with an 'early warning' forecasting service of major air pollution episodes. From summer 2000 this consists of a regular twice-weekly e-mail message to a circulation within DEFRA and other government departments.

Our first report (Stedman and Willis, 1994) described the techniques that are used to forecast air pollution in the UK and presented an analysis of the forecasting success rate for the year from April 1992 to March 1993. Subsequent reports (Stedman and Willis, 1995, Stedman and Willis, 1996, Stedman *et al*, 1997, Stedman *et al*, 1998) presented analyses of the forecasting success rate and discussed modifications to the forecasting system. This report, the sixth on air pollution forecasting in the UK, presents an analysis and discussion of the forecasting success rate for the three-year period from January 1998 to December 2000. The forecasting success rate is discussed in section 4.

From November 1998 forecasts were issued for three separate environments within each region – Rural, Urban Background and Roadside. Section 5 details the analyses which we carried out to assess the feasibility of issuing these new forecasts.

Section 6 looks at the evaluation of new modelling techniques, Section 7 provides an update on the system for near real-time ozone data exchange within North-West Europe, and Section 8 looks at some possible changes to the data dissemination systems which will also affect the forecasting work.

Figure 1.1 National Air Pollution Forecasting Regions, 2000, And The Locations Of Automatic Monitoring Sites

2 Current Air Pollution Bandings

Since November 19th 1997 air pollution levels have been described using the bandings for O_3, NO_2, SO_2, CO and PM_{10} shown in Table 2.1.

Table 2.1: Air Pollution Bandings

	Standard	Information	Alert	
	LOW	MODERATE	HIGH	VERY HIGH
Sulphur Dioxide (ppb, 15 minute mean)	less than 100	100 – 199	200 – 399	400 or more
Ozone (ppb)	Less than 50 (hourly and 8-hourly running mean)	50 - 90 (hourly or 8-hourly mean)	90 – 179 (hourly mean)	180 or more (hourly mean)
Carbon Monoxide (ppb, 8 hour running mean)	Less than 10	10 – 14	15 – 19	20 or more
Nitrogen Dioxide (ppb, hourly mean)	less than 150	150 – 299	300 – 399	400 or more
Fine Particles ($\mu g/m^3$, 24 hour running mean)	less than 50	50 –74	75 - 99	100 or more

This scheme includes bandings for PM_{10} and CO as well as the three pollutants previously forecast (O_3, NO_2 and SO_2). Since the introduction of the new bandings scheme, forecasts for all five pollutants have been issued on a daily basis. For the purposes of this report we have assessed the forecasting success rate for the “Information” threshold between MODERATE and HIGH.

In section 8 and table 8.1 we present details of a proposed 1-10 air pollution index as an alternative to the current air pollution bandings. This index has already been adopted by the BBC and a DEFRA consultation document has been circulated with a view to adopting the approach for UK air quality forecasts.

In the fifth forecasting report (Stedman *et al*, 1998) the number of HIGH or VERY HIGH air pollution episode days for 1997 was compared with the number of POOR or VERY POOR air quality days for 1997. The findings of the comparison were:

- There would be a similar number of ozone episodes as under the old scheme.
- There would be fewer SO_2 episodes.
- There would be virtually no NO_2 episodes.

This comparison exercise will not be repeated here, but the 1998-2000 forecast analysis (see Chapter 4) continues to show that there are very few days with HIGH or VERY HIGH air pollution for SO_2 and none for NO_2. For the new pollutants covered by forecasting, it is clear that there will be a significant number of HIGH air pollution days for PM_{10}, whereas for CO there are not expected to be any HIGH air pollution days. It therefore remains important to continually review and improve the models used for PM_{10} in line with our latest understanding of this pollutant, in order to improve our predictions.

3 Current Air Pollution Forecasting Techniques

A forecast of air pollution for the following 24 hours is prepared each afternoon, for inclusion in the 16:00 air pollution bulletin. A revised forecast is also issued at 11:00 if VERY HIGH air pollution is being measured or is expected. It is also possible to issue new or revised forecasts at any hour of the day.

The air pollution forecasts are based on information from a number of sources. The forecast is prepared with reference to all available information and on the basis of a number of years of 'hands on' experience of UK air pollution monitoring (Stedman and Willis, 1994). Sources of information include:

- On-line measured concentrations from the UK monitoring networks, for all pollutants. Data are averaged for comparison with the relevant bandings (i.e. 15-minute, hourly, 8-hourly or 24-hourly averages).
- Weather forecasts for the following day, provided by the UK Meteorological Office (MO).
- 'Real time' results from the trajectory ozone forecasting model (Stedman and Williams, 1992). The model is run each day during the summer by the MO, taking the output of numerical weather prediction models as its input, with the results automatically transferred to NETCEN via a computer link. This model provides estimates of ozone concentration for one day ahead for 20 sites and for two days ahead for five sites.
- Ozone data from selected monitoring sites in North West Europe are available each day via email. Moves towards the co-ordination of ozone data exchange in North West Europe are discussed in Section 7
- Results from the urban pollutants forecasting box model, BOXURB (Middleton, 1998) also provided by the MO. The NO_x emissions estimates used in this model are provided by the National Atmospheric Emissions Inventory. This model provides estimates of NO_x, NO_2 and PM_{10} concentrations for eleven sites for one-day ahead and meteorological parameters for the same sites for two days ahead.
- Carbon monoxide concentrations can be forecast using the box model by assuming that the dispersion and emission conditions that are likely to lead to elevated CO are similar to those likely to lead to high concentrations of NO_x and NO_2.
- Elevated SO_2 concentrations can result from poor dispersion of low level emission sources and forecasts of such episodes can be based on the box model results and a knowledge of local low level emissions (which are significant in cities such as Belfast). SO_2 episodes due to the impact of plumes from individual major point sources are predicted by reference to meteorological forecasts, and further research is under way to improve the reliability of these forecasts (see section 6)
- Results from a trajectory model adapted to forecast particulate sulphate (Stedman *et al*, 1998) are used in the forecasting of secondary PM_{10}. Primary PM_{10} can be forecast using the results from the urban pollutants forecasting box model.

- From April 2000 onwards the results of the NAME urban air pollution forecasting model (Ryall, D.B. and Maryon, R.H., 1996 and 1998), also provided by the MO, were made available to the NETCEN forecasting team for evaluation and comparison with BOXURB. The main features of NAME are;

  1. A sophisticated Lagrangian particle dispersion model.
  2. Uses up-to-date 3-D meteorology from The Met. Office's Unified Model (UM) (Cullen, 1993).
  3. Uses 1996 emission inventories (NAEI and EMEP) and takes account of daily traffic flows and large point source emissions. The inventories for1998 are now available and currently being tested.
  4. The PM_{10} forecast is comprised of three elements; U.K.-only primary PM_{10}, non-U.K. European primary PM_{10} and the sulphate component of secondary PM_{10}.
  5. The U.K. emissions are modelled using the high-resolution (~11 km) mesoscale meteorology from the UM. The non-U.K. primary PM_{10} and secondary sulphate pollutants are modelled using a coarser met. grid (~60 km) also from the UM.
  6. Twice daily (approximately 4am and 9am) the 0-47 hour U.K.-wide forecasts for NO_x, SO_2 and PM_{10} are updated. CO predictions can also be provided by using a simple relationship between NO_x and CO concentrations.

  The results of the six-month comparison of BOXURB and NAME are discussed in detail in Section 6 and elsewhere (Willis P.G., Manning A.J. 2001) An earlier comparison by the Met. Office based on NO_x only is also available (Manning A.J. 1999).

4 Analysis Of Air Pollution Forecasting Success Rate

4.1 INTRODUCTION

Air pollution in the UK is generally within the LOW or MODERATE air pollution bands. Episodes of HIGH or VERY HIGH air pollution are, however, also experienced. Episodes during the winter are generally associated with periods of poor pollutant dispersion caused by low temperatures and light winds (see for example Bower *et al*, 1994). Air pollution episodes during the summer are often photochemical in nature and are associated with light winds, high temperatures and strong sunlight.

In Tables 4.1 to 4.5 we present the forecasting success rates for ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide and PM_{10} particulate matter. Each table gives an analysis of forecast versus measured HIGH air pollution during the three-year period 1998 to 2000. The air pollution band for each region is the band for the highest concentration recorded at any monitoring site within that region.

The forecasts that are issued tend to err on the side of caution and consequently more occurrences of HIGH air pollution were predicted for some pollutants than were measured. This is because it is considered to be better for public information and health, to predict HIGH and be wrong than to predict MODERATE and fail to warn the public of potentially HIGH air pollution.

In Table 4.6 and Figure 4.1 we present an analysis of forecasting success rate over the eight-year period 1993 to 2000.

4.2 FORECAST ANALYSIS FOR OZONE

Thirty-nine of the forty-nine "region-days" with HIGH ozone air pollution were correctly forecast (see Table 4.1). A cautious approach by the forecasters resulted in this 80% success rate, but also led to a number of HIGH air pollution days being forecast which were not measured. A significant number of these were 'near-misses' where the 90 ppb threshold just failed to be breached. For days that were forecast as HIGH ozone pollution but did not result in measured HIGH values, the measured values often fell into the MODERATE air pollution band.

The frequency of "region-days" with HIGH ozone air pollution during 1998 (10 days) was lower than in 1996 and 1997, and much lower than the photochemically active year of 1995, which had 57 episode days (Stedman and Willis, 1996). 1999 was a more photochemically active summer, with 39 "region-days" with HIGH ozone air pollution, and with the highest number of days with MODERATE ozone air pollution or worse since 1990. In 2000 there were only three "region-days" with HIGH ozone air pollution recorded.

There were no forecasts or measurements of VERY HIGH air pollution for ozone during 1998-2000.

Table 4.1 Forecast Analysis for Ozone, 1998-2000 Summary

	NW England	NE England	Midlands	East Anglia	SW England	SE England	London
HIGH days measured	1	6	6	8	4	8	9
HIGH days forecast	6	10	17	25	26	34	31
Forecast & measured	1	4	5	6	4	7	7
Forecast & not measured	5	6	12	19	22	27	24
not forecast & measured	0	2	1	2	0	1	2

	N Ireland	Scotland	Wales	Total (UK)
HIGH days measured	0	1	6	49
HIGH days forecast	0	0	22	171
forecast & measured	0	0	5	39
forecast & not measured	0	0	17	132
not forecast & measured	0	1	1	10

4.3 FORECAST ANALYSIS FOR NITROGEN DIOXIDE

There were no forecasts or measurements of HIGH or VERY HIGH air pollution for nitrogen dioxide during 1998-2000. There have, in fact, been no such incidents since the air pollution banding system was changed in November 1997.

Table 4.2 Forecast Analysis for Nitrogen Dioxide, 1998-2000 Summary

	NW England	NE England	Midlands	East Anglia	SW England	SE England	London
HIGH days measured	0	0	0	0	0	0	0
HIGH days forecast	0	0	0	0	0	0	0
forecast & measured	0	0	0	0	0	0	0
forecast & not measured	0	0	0	0	0	0	0
not forecast & measured	0	0	0	0	0	0	0

	N Ireland	Scotland	Wales	Total (UK)
HIGH days measured	0	0	0	0
HIGH days forecast	0	0	0	0
forecast & measured	0	0	0	0
forecast & not measured	0	0	0	0
not forecast & measured	0	0	0	0

4.4 FORECAST ANALYSIS FOR CARBON MONOXIDE

There were no forecasts or measurements of HIGH or VERY HIGH air pollution for carbon monoxide during 1998-2000. There have, in fact, been no such incidents since the air pollution banding system for this pollutant was introduced in November 1997.

Table 4.3 Forecast Analysis for Carbon Monoxide, 1998 Summary

	NW England	NE England	Midlands	East Anglia	SW England	SE England	London
HIGH days measured	0	0	0	0	0	0	0
HIGH days forecast	0	0	0	0	0	0	0
forecast & measured	0	0	0	0	0	0	0
forecast & not measured	0	0	0	0	0	0	0
not forecast & measured	0	0	0	0	0	0	0

	N Ireland	Scotland	Wales	Total (UK)
HIGH days measured	0	0	0	0
HIGH days forecast	0	0	0	0
forecast & measured	0	0	0	0
forecast & not measured	0	0	0	0
not forecast & measured	0	0	0	0

4.5 FORECAST ANALYSIS FOR SULPHUR DIOXIDE

Five (17%) out of the thirty “region-days” with HIGH air pollution for sulphur dioxide were correctly forecast (see Table 4.4). There was only one day (September 2nd 1998) when VERY HIGH air pollution was measured. This was at the Nottingham site and a forecast of HIGH air pollution was issued for this region on this day. HIGH sulphur dioxide air pollution was recorded at a number of locations in the Midlands, NorthEast and NorthWest England on September 2nd; this was attributed to unusual meteorological conditions leading to widespread plume grounding. The Environment Agency has issued a detailed report on this episode (Environment Agency, 2000).

Over recent years the proportion of HIGH sulphur dioxide air pollution days measured in Northern Ireland compared to the rest of the UK has reduced significantly. This is due to:

- The reduction in sulphur dioxide concentrations in Belfast.
- The increase in sulphur dioxide monitoring elsewhere in the UK, and
- The reduction in the total number of days with HIGH sulphur dioxide pollution.

Historically, HIGH Belfast sulphur dioxide pollution was fairly easy to forecast using the urban box model, as it generally co-incided with periods of poor atmospheric dispersion conditions. Most other HIGH sulphur dioxide air pollution episodes are due to grounding of plumes from nearby point sources. These are much more difficult to predict, even using the most sophisticated modelling techniques, and further research is underway to improve our success rate in these cases (see Section 6.).

Table 4.4 Forecast Analysis for Sulphur Dioxide, 1998-2000 Summary

	NW England	NE England	Midlands	East Anglia	SW England	SE England	London
HIGH days measured	2	13	4	0	0	1	1
HIGH days forecast	3	6	0	0	0	0	0
forecast & measured	0	3	0	0	0	0	0
forecast & not measured	3	4	0	0	0	0	0
not forecast & measured	2	10	4	0	0	1	1

	N Ireland	Scotland	Wales	Total (UK)
HIGH days measured	9	0	0	30
HIGH days forecast	12	0	0	21
forecast & measured	2	0	0	5
forecast & not measured	10	0	0	17
not forecast & measured	7	0	0	25

4.6 FORECAST ANALYSIS FOR PARTICLES (PM_{10})

Twenty-eight (23%) of the one hundred and twenty-one HIGH air pollution days for particles were forecast correctly (see Table 4.5). There were a number of monitoring sites which were affected by dust from nearby building works during this period. These included Reading (SE England), Marylebone Road (London), Tranmere Wirral (NW England) and Glasgow Kerbside (Scotland). PM_{10} concentrations often reached HIGH or VERY HIGH at these locations with no relationship to prevailing meteorological conditions, thus making the episodes impossible to forecast. Of course the concentrations from such incidents are very localised and not representative of overall regional air pollution levels.

Apart from building works there were also HIGH or VERY HIGH PM_{10} air pollution episodes due to a wide range of pollutant sources;

- Bonfire Night,
- Domestic Heating Emissions (mainly N.Ireland),

- Point source emissions (e.g.September 2nd 1998 as detailed in Section 4.5),
- Motor vehicle emissions – often building up over the course of several days,
- Secondary particulate matter in combination with one or more other PM_{10} emissions sources,
- Natural sources of PM_{10} e.g. Saharan dust or Volcanic Eruptions.

Of these, the motor vehicle and domestic heating related episodes are the least difficult to model and therefore forecast. New modelling approaches should improve the success of modelling the industrial and long-range transport episodes (see Section 6).

Table 4.5 Forecast Analysis for Particles (PM_{10}), 1998-2000 Summary

	NW England	NE England	Midlands	East Anglia	SW England	SE England	London
HIGH days measured	9	14	8	0	2	2	21
HIGH days forecast	5	7	15	0	3	0	16
Forecast & measured	2	3	4	0	2	0	3
Forecast & not measured	3	4	11	0	1	0	13
Not forecast & measured	7	11	4	0	0	2	18

	N Ireland	Scotland	Wales	Total (UK)
HIGH days measured	14	26	25	121
HIGH days forecast	10	9	8	56
forecast & measured	5	3	6	28
forecast & not measured	5	6	2	45
not forecast & measured	9	23	19	93

4.7 COMPARISON WITH PREVIOUS YEARS

Table 4.6 and Figure 4.1 show the forecasting success rate for the whole UK over the last eight years. This is the percentage of episode days which were correctly forecast. During 1997 there is obviously a step change where the new bandings were introduced.

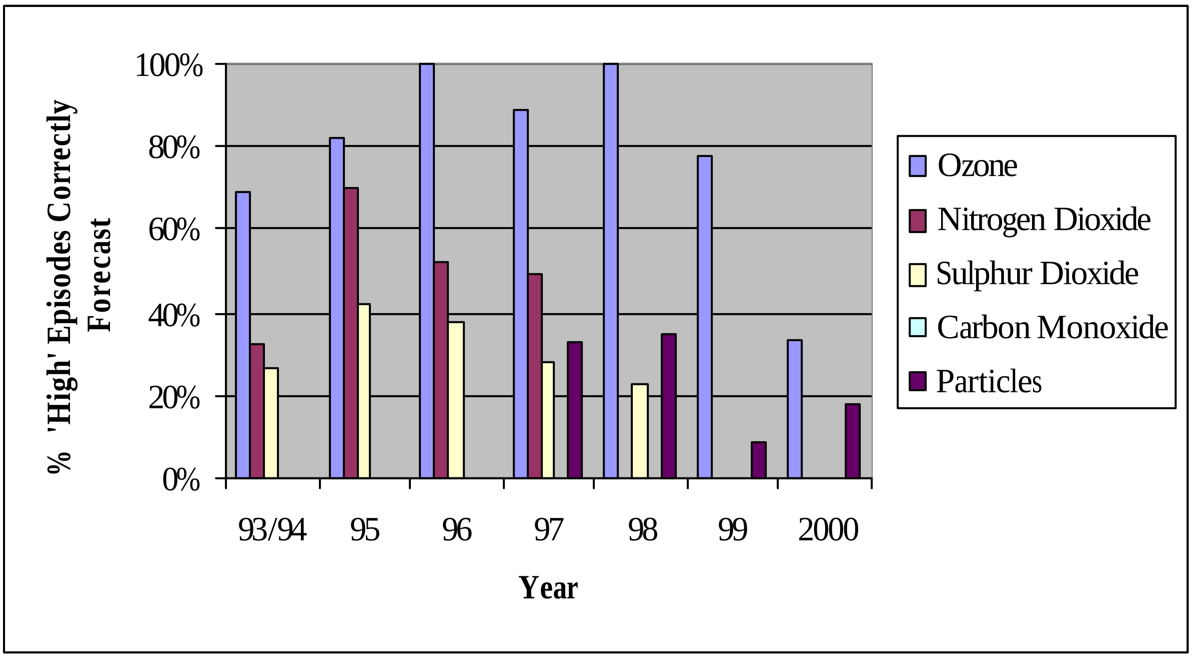
Table 4.6 Forecasting Success Rates for the Whole of the UK

	1993/94	1995	1996	1997	1998	1999	2000
Ozone	69%	82%	100%	89%	100%	78%	33%
Nitrogen Dioxide	32%	70%	52%	49%	*	*	*
Sulphur Dioxide	27%	42%	38%	28%	23%	0%	0%
Carbon Monoxide	-	-	-	-	*	*	*
Particles	-	-	-	33%	34%	9%	18%

* No HIGH or VERY HIGH days recorded.

The success rate for ozone over many years has been consistently high at 75% or above, in 2000 this fell due to the small and unusual nature of the episodes – only one out of three days were correctly forecast. The success rate for sulphur dioxide has dropped again with the fall in the number of incidents - as discussed earlier. For nitrogen dioxide and carbon monoxide there have been no episodes since the introduction of the new Air Pollution bandings. For PM_{10} particles the success rate was 33% and 34% for the first two years of predictions for this pollutant, and then fell due to unusual local sources such as construction work affecting a number of locations. This indicates the difficulties associated with forecasting episodes of this complicated multi-source pollutant.

Figure 4.1 Forecasting Success Rates for the Whole of the UK



4.8 DISCUSSION OF INACCURATE FORECASTS IN THE YEAR 2000 DUE TO 'NEAR MISSES OR LOCALISED POLLUTANT EMISSIONS

It is difficult to carry out a quantitative analysis of all failed forecasts due to a number of uncertainties:

1. It may not be possible to validate a forecast of HIGH air pollution which has been issued in good faith, based on expert judgement and model predictions. Due to analyser breakdown or simply no monitoring equipment in a given region and location type, the data may simply not be available.
2. It may not be possible to accurately assess the reason for a HIGH pollution episode. For example there may be a contribution from local construction work coupled with generally elevated pollutant levels. Often, unless a local site operator is in the vicinity of the site during the episode, then there will be insufficient information to confirm the source one way or another.
3. Forecast accuracy can be perceived to be low on a day-to-day basis due to faulty monitoring data. In some cases the forecaster can even be fooled into thinking that a genuine localised episode may be in progress, and hence manually intervene to issue a prediction of higher air pollution than model results may be indicating. Once data have been ratified the forecast accuracy can be recalculated but then it is not always simple to discover exactly where faulty data have been removed from the data sets.

As more detailed information is available for the latest year we will for the remainder of this section consider the inaccuracies in the HIGH ozone and PM_{10} forecasts for the year 2000. We will do this by taking a judgmental rather than purely statistical approach to the issue.

There were no HIGH pollution episodes of NO_2 or CO in the year 2000 to analyse so these pollutants are not examined here. Also, all the SO_2 episodes which were measured in the year 2000 could be attributed to point source emissions. These SO_2 episodes could not be predicted using the BoxUrb model which was in use at the time. An alternative model for SO_2 which can predict these episodes is considered in section 6.1 of this report.

The inaccurate forecasts issued for ozone and PM_{10} in the year 2000 are listed in Table 4.7 below.

Table 4.7 Inaccurate HIGH forecasts issued for ozone and PM_{10} in the year 2000

Pollutant	Forecast Inaccuracy	NW England	NE England	Midlands	East Anglia	SW England	SE England	London
Ozone	Forecast & not measured	0	2	2	2	1	5	5
	Not forecast & measured	0	2	0	0	0	0	0
PM_{10}	Forecast & not measured	0	0	1	0	0	0	2
	Not forecast & measured	5	0	1	0	0	1	4

Pollutant	Forecast Inaccuracy	N Ireland	Scotland	Wales	Total (UK)
Ozone	Forecast & not measured	0	0	1	18
	Not forecast & measured	0	0	0	2
PM_{10}	Forecast & not measured	0	0	1	4
	Not forecast & measured	3	4	7	25

The analysis clearly shows that there are two separate problems here. For ozone the forecasters tend to predict episodes which do not occur, whilst for PM_{10} many episodes occur which have not been forecast.

Generally this is because of the nature of the pollutants:

- Ozone pollution gradually builds up over a several days, so the forecasters are often confident that the trend will continue the trend and result in a transition from MODERATE to HIGH pollution.
- General levels of PM_{10} may be forecast to be LOW, but the forecasters can be caught out by a sudden increase in PM_{10} from an unexpected source. This can change the measured concentration to HIGH almost immediately.

Looking at the Year 2000 figures in detail we find the following:

- The two HIGH ozone episodes which were not forecast were at Rotherham (June 18th) and Middlesborough (July 21st). On both these occasions the monitors recorded 15 – 20 ppb higher than neighbouring stations. As the measurements appear to be genuine, it's possible that local industrial emission may have in some way enhanced the ozone local ozone climate on these days, a feature which is not fully understood and cannot be modelled at the moment.

- The eighteen false HIGH ozone forecasts were issued over the periods July 20th to 22nd and August 23rd to 24th. On each of these days MODERATE ozone levels were recorded, but the concentrations did not increase further due to more cloud cover over the UK than expected. The forecasts could not really be described as “near-misses” as the measured concentrations did not approach within 10% of the HIGH band.
- Of the twenty-five HIGH PM_{10} episodes which were missed, only one (London, January 26th), was an incident which should have been forecast by modelling. PM_{10} concentrations were elevated over much of the UK but increased in London more rapidly than the forecasters expected. The other twenty four incidents were all due to unusual local or long-range incidents. Examples are Volcanic ash / Saharan dust across the whole of the UK on March 2nd to 3rd, construction work near the Tranmere, Reading, Glasgow and London Marylebone Road sites, local industry near Port Talbot and a bonfire within 5 metres of a monitoring station. This accounts for 96% of the missed incidents.
- Three of the four false HIGH PM_{10} episodes were when then forecasters failed to predict the end of the widespread episode at the end of January correctly. Measured concentrations fell to MODERATE levels more quickly than expected. The false HIGH in Wales was when the forecasters attempted to predict the worsening of a localised episode at Port Talbot, but measured concentrations did not increase beyond MODERATE levels.

In summary, 10% of the inaccurate ozone HIGH episodes in the year 2000 can be explained by localised affects, whilst the other 90% were due to poor model treatment of cloud cover and/or inaccurate meteorological forecasts. Proposed improvements to the ozone forecasts by including cloud cover in the model are discussed further in Section 6.2 of this report. For PM_{10}, 86% of the inaccurate HIGH forecasts could be explained by localised affects, whilst the other 14% were due to poor pollutant modelling and/or inaccurate meteorological forecasts.

Our experience leads us to believe that there is probably currently a 50:50 split between errors due to poor modelling and errors due to poor weather forecasts. The model errors can be fairly well quantified and improved by using analysis (i.e. based on measurements) met. data to look at historical episodes. The comparison between two different models in Section 6.1 of this report shows the kind of analysis which can be done. The errors in the meteorological forecasts are more difficult to quantify as under episode conditions of low windpeed and extremes of temperature, small errors in the meteorological parameters can make large differences in the predicted pollutant concentrations.

The year 2000 can be taken to be typical of an overall low pollution year. In higher pollution years it may be that a lower percentage of the inaccurate forecasts are due to localised pollutant emissions.

5 Analyses to assess the feasibility of issuing forecasts for Roadside, Urban Background and Rural Environments.

In summer 1998 the forecasting team considered that there may now be enough UK air pollution monitoring sites to enable the preparation and validation of daily forecasts for different environments within each forecasting region. In order to assess the feasibility of this a number of analyses were carried out.

5.1 AVAILABILITY OF UK AIR POLLUTION MONITORING DATA

Table 5.1 shows the availability of monitoring data by pollutant and environment in the UK. Whilst it is clear that there are not sufficient monitoring points to validate forecasts for each pollutant in each environment of every region, it was felt that there was sufficient coverage to enable meaningful forecasts to be issued

Table 5.1 Availability of monitoring sites for specified pollutants by UK region and environment during 1998

	Rural and Remote					Kerbside and Roadside					Urban Non-Roadside				
	O3	NO2	CO	SO2	PM10	O3	NO2	CO	SO2	PM10	O3	NO2	CO	SO2	PM10
London	X	X	X	X	X	O	O	O	O	O	O	O	O	O	O
SE England	O	O	X	O	O	X	O	O	X	X	O	O	O	O	O
SW England	O	X	X	X	X	O	O	O	O	X	O	O	O	O	O
East Anglia	O	O	X	O	X	X	O	X	X	X	O	O	O	O	O
Midlands	X	X	X	X	X	X	O	O	O	X	O	O	O	O	O
NW England	O	X	X	X	X	O	O	O	O	O	O	O	O	O	O
NE England	O	O	X	O	X	X	O	X	X	X	O	O	O	O	O
Wales	O	O	X	O	O	X	X	X	X	X	O	O	O	O	O
Scotland	O	X	X	X	X	X	O	O	X	O	O	O	O	O	O
N Ireland	O	X	X	X	O	X	X	X	X	X	O	O	O	O	O

O – Regions containing monitoring site producing available data
X – Regions with no available monitoring sites

5.2 WHAT LEVELS OF POLLUTANTS CAN BE EXPECTED WITHIN THE DIFFERENT REGIONS AND ENVIRONMENTS?

In order to assess the types of forecasts which would be likely to be issued for each region and environment, an extensive analysis of monitoring data for the 1994 to 1997 period was carried out. The results are presented in Table 5.2 and the summary of our findings was as follows:

- NO_2 is always LOW at rural sites.
- There have been no instances of HIGH NO_2 since 1994 (Manchester).
- There have been no instances of HIGH ozone at roadside sites since monitoring began.
- There have been no measurements of VERY HIGH ozone since the 1970's.
- There have been no instances of VERY HIGH PM_{10} at any rural site since monitoring began.
- There have been no instances of HIGH CO over the last 4 years.

The tables show on how many days there were incidents of LOW, MODERATE, HIGH or VERY HIGH air pollution recorded in each year, for each pollutant and environment type. The analysis was carried out such that any given day can have more than one pollution band reported within it. Hence LOW pollution is usually reported on all 365 days of the year. Exceptions to this are when there are only a small number of sites within each category. Faulty analysers or new sites starting part-way through a year may then result in less than 365 days with valid data in a year and hence less than 365 days with LOW pollution levels reported.

Table 5.2 Number of days on which the listed banding was attained for each type of site and pollutant during 1994 to 1997.

NUMBER OF DAYS ACROSS NETWORK

1994		LOW	MODERATE	HIGH	VERY HIGH
RURAL AND REMOTE	O3	365	95	12	0
	NO2	364	0	0	0
	CO	N.M.	N.M.	N.M.	0
	SO2	365	6	2	0
	PM10	N.M.	N.M.	N.M.	0
KERBSIDE	O3	N.M.	N.M.	N.M.	0
	NO2	352	1	0	0
	CO	361	1	0	0
	SO2	346	4	1	0
	PM10	N.M.	N.M.	N.M.	0
URBAN	O3	365	31	5	0
	NO2	365	13	2	0
	CO	365	3	0	0
	SO2	365	114	31	5
	PM10	365	149	41	9

NUMBER OF DAYS ACROSS NETWORK

1996		LOW	MODERATE	HIGH	VERY HIGH
RURAL AND REMOTE	O3	366	72	10	0
	NO2	366	0	0	0
	CO	N.M.	N.M.	N.M.	0
	SO2	366	19	1	0
	PM10	306	23	5	0
KERBSIDE	O3	183	5	0	0
	NO2	364	3	0	0
	CO	364	1	0	0
	SO2	363	10	0	0
	PM10	274	43	5	4
URBAN	O3	366	38	6	0
	NO2	366	2	0	0
	CO	366	0	0	0
	SO2	366	99	23	3
	PM10	365	110	32	8

NUMBER OF DAYS ACROSS NETWORK

1995		LOW	MODERATE	HIGH	VERY HIGH
RURAL AND REMOTE	O3	365	77	25	0
	NO2	365	0	0	0
	CO	N.M.	N.M.	N.M.	0
	SO2	365	4	1	0
	PM10	N.M.	N.M.	N.M.	0
KERBSIDE	O3	N.M.	N.M.	N.M.	0
	NO2	344	4	0	0
	CO	335	0	0	0
	SO2	358	6	2	0
	PM10	N.M.	N.M.	N.M.	0
URBAN	O3	365	48	12	0
	NO2	365	6	0	0
	CO	365	5	0	0
	SO2	365	115	31	7
	PM10	365	96	23	8

NUMBER OF DAYS ACROSS NETWORK

1997		LOW	MODERATE	HIGH	VERY HIGH
RURAL AND REMOTE	O3	365	75	9	0
	NO2	365	0	0	0
	CO	N.M.	N.M.	N.M.	0
	SO2	365	7	1	0
	PM10	365	7	1	0
KERBSIDE	O3	363	15	0	0
	NO2	365	9	0	0
	CO	365	5	0	0
	SO2	365	10	0	0
	PM10	363	114	19	4
URBAN	O3	365	57	6	0
	NO2	365	10	0	0
	CO	365	0	0	0
	SO2	365	84	12	1
	PM10	365	155	40	13

N.M. – The listed pollutant was not measured at the type of site specified

5.3 TOOLS AVAILABLE FOR FORECASTING AIR QUALITY

Based on the analysis presented in Section 5.2, we then assessed the availability of tools for forecasting the likely air pollutant levels at each of the different environment types. Table 5.3 presents a review of the situation in summer 1998.

Table 5.3 Tools used for forecasting air pollution by pollutant and environment

	Rural	Urban	Roadside
O_3	Trajectory model. LOW, MODERATE or HIGH can be forecast.	Trajectory model + expert judgement (for NO_x scavenging and day-of-week effects) needed for LOW, MODERATE and HIGH forecasts.	Trajectory model + expert judgement for LOW and MODERATE forecasts. Predictions tend not to be meaningful due to effects of locally emitted NO
NO_2	Always LOW	Winter – Box Model + expert judgement for LOW, MODERATE (and HIGH).	Winter – Box model + expert judgement (including roadside enhancement) for LOW, MODERATE (and HIGH).
		Summer – Box model and Trajectory model (ozone titration) for LOW (and MODERATE)	Summer – Trajectory, Box models + Expert Judgement (including roadside enhancement) for LOW (and MODERATE).
SO_2	Depends on location of sources. Expert judgement together with meteorological forecasts needed to predict LOW, MODERATE, HIGH (or VERY HIGH).	Winter – Box model for domestic coal burning areas. Otherwise expert judgement as for Rural SO_2. LOW, MODERATE, HIGH or VERY HIGH forecasts.	Winter – As for urban SO_2 with up to 10 ppb additional for roadside.
		Summer – Expert judgement as for Rural SO_2.	Summer – As for urban SO_2 with up to 10 ppb additional for roadside.
CO	Not measured but always LOW.	Box model for LOW (and MODERATE).	Box Model + expert judgement for LOW (and MODERATE).
PM_{10}	Trajectory Model for LOW, MODERATE and HIGH.	Trajectory & Box Models for LOW, MODERATE, HIGH and VERY HIGH.	Trajectory & Box models + Expert Judgement (roadside enhancement) for LOW, MODERATE, HIGH and VERY HIGH.
	( ) Pollution bandings in brackets are highly unlikely		

This review indicated that although tools were available for forecasting each of the pollutant and environment types, there were weaknesses in some areas which needed addressing:

- Firstly, the forecasting of SO_2 episodes resulting from point-source emissions. This needed the addition of a dispersion model to enhance the forecast capability. Section 6 gives details of the NAME model evaluation.
- Secondly, we needed to attempt to quantify the "roadside enhancement" which would need to be added to urban background NO_2, CO and PM_{10} forecasts. These analyses are presented in sections 5.4 – 5.6 below.

5.4 ENHANCEMENT OF NO_2 CONCENTRATIONS AT KERBSIDE LOCATIONS

This analysis was carried out for two locations where there were kerbside monitors and urban centre monitors within reasonable proximity, in this case London Marylebone Road and Bloomsbury, and Glasgow Kerbside and Glasgow Centre. The measured concentration of NO_2 at the urban centre location was plotted as a timeseries and compared against a similar plot of the kerbside minus background concentration.

Figures 5.1 and 5.2 show the results of the analysis. On average the "best-fit" line shows that there is a 20-30 ppb enhancement of NO2 concentrations at the kerbside location compared to the background site. It appears, however, that during episode conditions when the concentrations at background sites are elevated, the difference between the two types of sites is reduced. i.e. if MODERATE levels of NO_2 pollution are expected then concentrations will be similar at both urban centre and kerbside locations.

Figure 5.1 "Roadside enhancement" of NO_2 in London

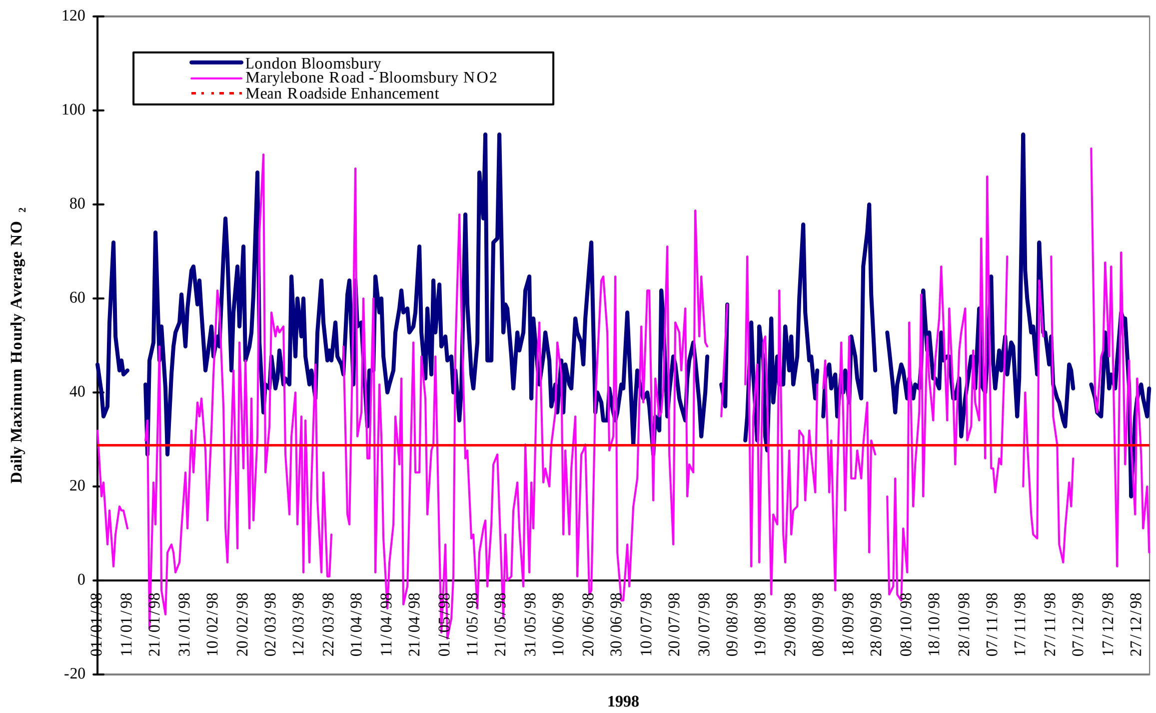
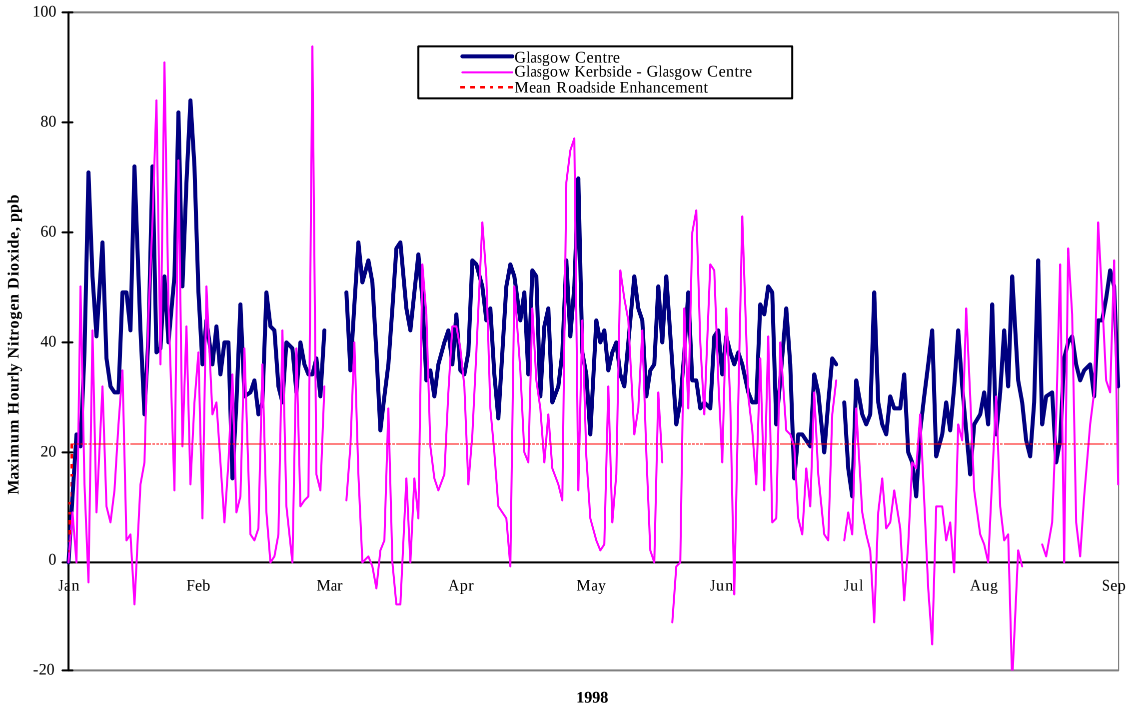


Figure 5.2 “Roadside enhancement” of NO_2 in Glasgow

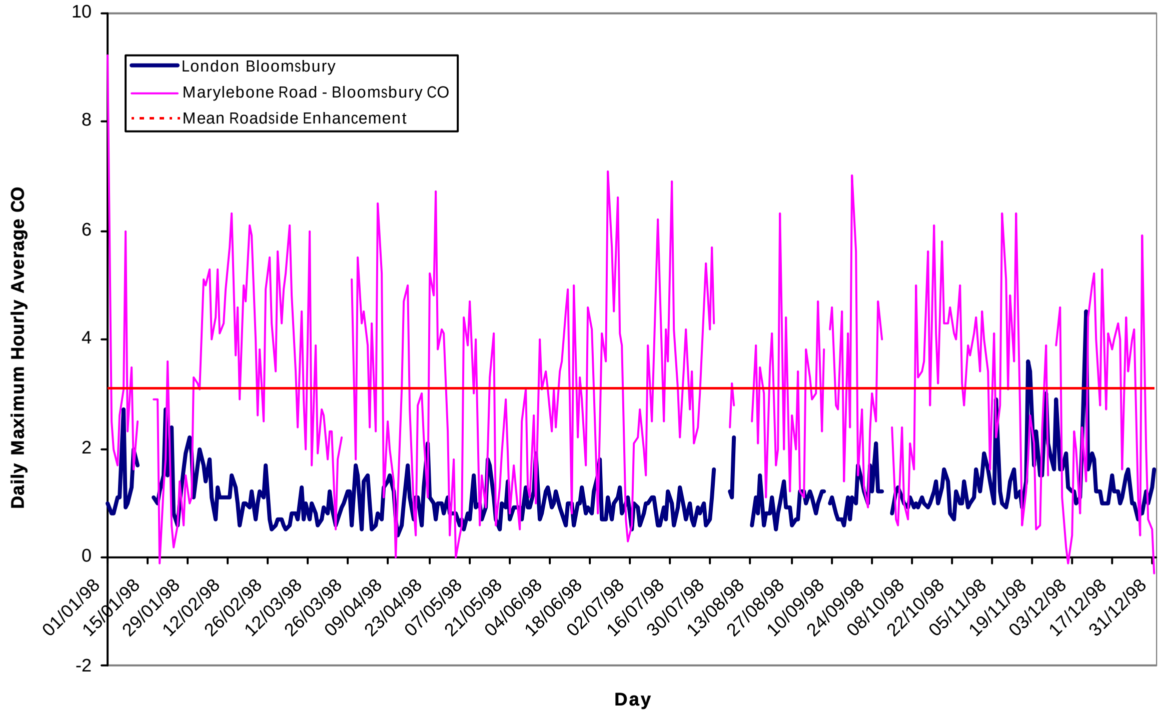


5.5 ENHANCEMENT OF CO CONCENTRATIONS AT KERBSIDE LOCATIONS

This analysis was carried out for a location where there were kerbside monitors and urban centre monitors within reasonable proximity, in this case London Marylebone Road and Bloomsbury. The measured concentration of CO at the urban centre location was plotted as a timeseries and compared against a similar plot of the kerbside minus background concentration.

Figure 5.3 shows the results of the analysis. On average the “best-fit” line shows that there is a 3ppm enhancement of CO concentrations at the kerbside location compared to urban background. During periods of elevated pollutant concentrations this difference appears to become smaller. Most of the time the air pollution band in both locations will therefore still remain in the ‘Low’ category.

Figure 5.3 "Roadside enhancement" of CO in London



5.6 ENHANCEMENT OF PM_{10} CONCENTRATIONS AT KERBSIDE LOCATIONS

Trends in the concentrations of PM_{10} at urban and kerbside locations are often highly similar see Figures 5.4 and 5.5. The measured concentrations of PM_{10} at the Marylebone Road and London Bloomsbury, and Glasgow Kerbside and Glasgow Centre sites have been analysed for 1998. The plots show the difference between the nearby kerbside and background sites, plotted alongside the background data for comparison.

For most of the time the value of the 'enhancement' at the kerbside site is within 5 $\mu g\ /m^3$ of zero. There are however, a number of times when the value of the enhancement is significantly above zero. At Marylebone Road the enhancement occasionally increases to 20 $\mu g\ /m^3$, but on average the roadside site is around 10 $\mu g\ /m^3$ higher than the background site. At the Glasgow kerbside site the situation is similar with an average enhancement of around 10 $\mu g\ /m^3$, however, there are occasional extreme excursions leading to an enhancement of 50 $\mu g\ /m^3$ or more. These peaks are believed to be due to construction work in the vicinity of the Glasgow Kerbside monitoring location.

The models currently employed do not predict, accurately the episodes described above. As a result expert judgement is applied to model results to more accurately predict episodes of PM_{10} due to this enhancement at kerbside locations. On average this enhancement is around 10 μg $/m^3$

Figure 5.4 “Roadside enhancement” of PM_{10} in London

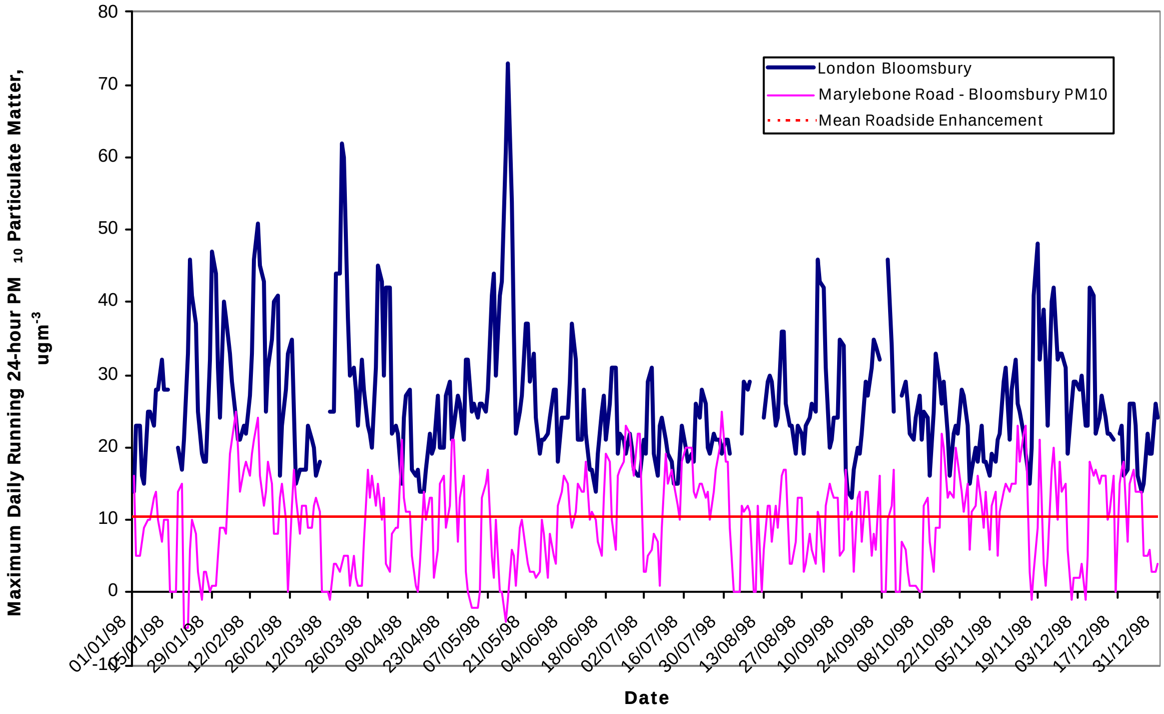
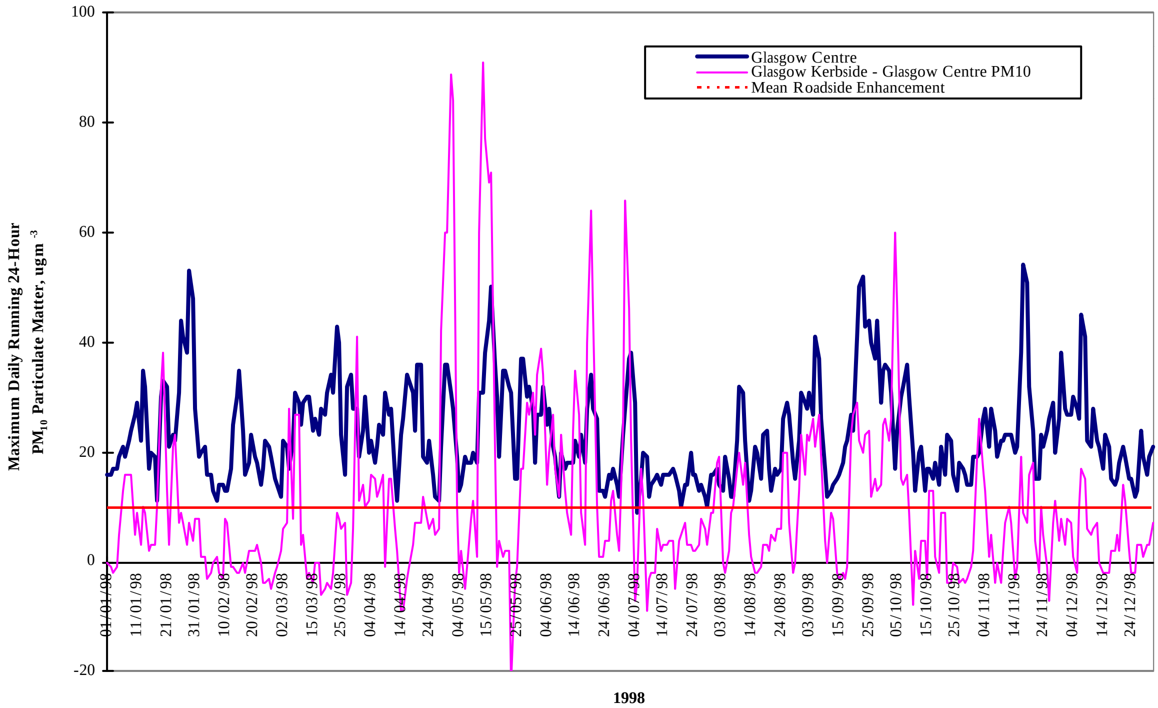


Figure 5.5 “Roadside enhancement” of PM_{10} in Glasgow



6 New and Improved Modelling Techniques for Forecasting

As the UK pollution climate changes, and more sophisticated computer software and hardware become available, it is necessary to continually update the tools which are used by the forecasters. This includes both the investigation of new modelling techniques and improvement of existing ones.

6.1 A SIX MONTH EVALUATION OF THE NAME MODEL FOR AIR POLLUTION FORECASTING

As detailed in both sections 4 and 5, the decline of sulphur dioxide episodes due to emissions from domestic coal burning or “area sources” has meant an increase in the proportion of sulphur dioxide episodes due to emissions from “point-sources”. The simple urban box model is not capable of modelling such episodes and hence we decided to evaluate the NAME dispersion model to assess whether it provided improved predictions. For the purpose of this study, which was from April to September 2000, the three pollutants NO_x, SO_2 and PM_{10} were assessed.

The NAME model is owned by the Met. Office and has the following features:

- A sophisticated Lagrangian particle dispersion model.
- Uses up-to-date 3-D meteorology from The Met. Office’s Unified Model (UM) (Cullen, 1993).
- Uses 1996 emission inventories (NAEI and EMEP) and takes account of daily traffic flows and large point source emissions. The inventories for1998 are now available and currently being tested.
- The PM_{10} forecast is comprised of three elements; U.K.-only primary PM_{10}, non-U.K. European primary PM_{10} and the sulphate component of secondary PM_{10}.
- The U.K. emissions are modelled using the high-resolution (~11 km) mesoscale meteorology from the UM. The non-U.K. primary PM_{10} and secondary sulphate pollutants are modelled using a coarser met. grid (~60 km) also from the UM.

A system was set up so that twice daily (approximately 4am and 9am) the 0-47 hour U.K.-wide forecasts for NO_x, SO_2 and PM_{10} were updated and made available to NETCEN both by e-mail and on a Web site. CO predictions were also provided towards the end of the study by using a simple relationship between NO_x and CO concentrations. The forecasters assessed both the accuracy of the model prediction, and the reliability of the provision of the results.

Table 6.1 shows the format of the tabular model output which was e-mailed to NETCEN twice daily. For each of the pollutants hour-by-hour predictions are made for eighteen different urban centre locations. Eleven of these locations were the same as the BoxUrb output so that a direct comparison between the models could be made, whilst the remainder were to show that the model performed well compared to measured data at a range of other locations.

Table 6.1 Tabular NAME model output for selected sites.

Air Quality Forecast data (NAME version 4.61)

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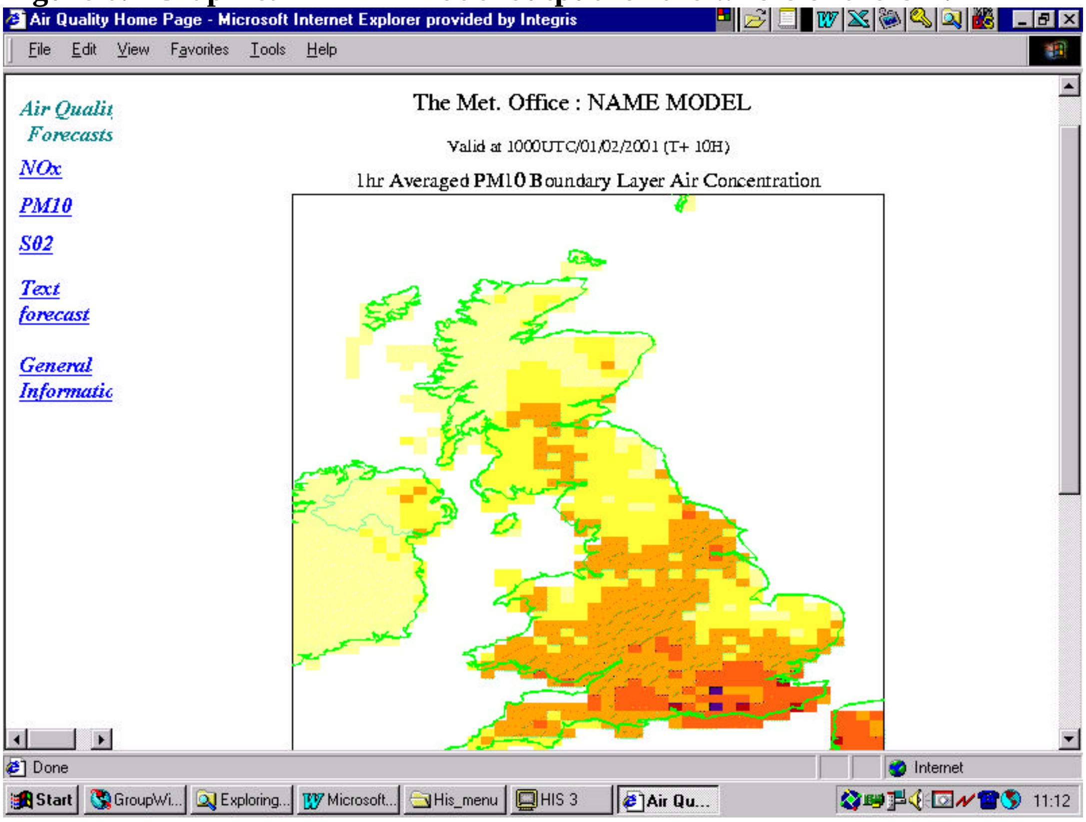
NO2 POLLUTION FORECAST (in parts per billion)
F/c time: 00:00 01/02/2001 Actual time: Thu Feb 1 10:09:52 2001

Hr	Begin	LOND	BIRM	GLAS	MANC	BELF	CARD	NEWC	LEED	BRIS	SOUT	NORW	ABER	EDIN	DERR	MIDD	HULL	LIVE	SHEF	NOTT	PLYM
		Location																			
00	020201	24	7	6	4	9	3	20	8	1	14	26	19	6	1	16	17	14	10	6	2
01	020201	17	4	10	5	6	4	10	9	1	7	28	14	7	1	13	15	12	6	11	0
02	020201	6	3	10	9	9	13	11	10	2	9	27	19	11	0	9	12	14	9	6	2
03	020201	13	3	10	8	5	9	6	8	1	4	23	19	7	1	10	11	16	5	6	2
04	020201	8	7	9	9	8	7	8	8	3	8	13	21	6	0	10	14	13	9	6	3
05	020201	5	11	9	17	7	8	10	13	9	15	7	19	11	1	9	9	6	7	8	2
06	020201	13	16	17	29	10	10	12	15	16	12	2	20	16	2	8	12	16	9	15	2
07	020201	29	28	29	38	14	16	22	27	21	17	9	21	27	1	18	13	26	19	18	8
08	020201	35	27	28	44	17	16	28	28	19	14	8	25	24	0	24	12	30	21	31	13
09	020201	33	24	17	44	13	13	22	23	16	15	3	23	16	0	23	16	21	17	30	7
10	020201	37	23	20	43	12	11	17	20	15	13	2	19	15	1	26	20	19	18	22	4
11	020201	42	12	18	30	12	5	17	14	9	6	7	21	16	0	27	18	15	10	17	2
12	020201	43	13	17	23	13	6	16	11	12	8	4	18	15	1	30	25	14	8	15	1
13	020201	43	16	18	28	9	10	24	16	5	10	7	19	16	0	31	29	15	18	21	1
14	020201	43	17	15	30	13	7	25	20	5	12	9	18	13	0	30	30	10	24	23	1
15	020201	43	19	14	32	10	9	31	21	6	10	11	15	16	0	36	32	15	24	28	3
16	020201	45	28	24	35	15	13	35	28	7	18	14	19	18	0	35	30	26	24	28	9
17	020201	46	30	30	38	21	21	37	33	20	17	23	17	15	1	33	33	34	24	30	15
18	020201	44	28	29	42	15	18	37	35	17	15	23	17	17	1	30	37	34	22	29	8
19	020201	41	28	27	39	11	17	32	31	15	11	22	13	13	0	30	38	33	27	29	3
20	020201	37	24	25	41	9	23	17	24	14	12	23	8	12	0	29	34	34	32	30	11
21	020201	32	25	24	37	4	15	9	22	13	14	23	7	10	1	21	35	35	31	29	6
22	020201	34	21	20	35	7	16	15	23	7	17	20	4	9	0	21	34	34	28	30	6
23	020201	39	17	9	32	9	9	19	24	8	22	20	3	5	1	16	33	29	28	25	3

The tabular output from NAME is in fact a set of timeseries extracted from the UK maps which are automatically generated each day. In order to get a feel for the overall UK pattern of pollutants which were predicted by NAME, these maps were made available by the Met. Office on a Web site for the NETCEN forecasters on a daily basis. The maps were animated to show "movies" of how the predicted pollution behaved over the 24-hour period. Figure 6.1 shows a still from a recent PM_{10} map downloaded from the Web site.

Figure 6.1 Graphical NAME model output for the whole of the UK.



Over the six-month period the provision of the model results to NETCEN was generally reliable. There were a number of “teething problems” with the system which resulted in a some missing days. A more robust system is now in place, with the same level of support as the operational weather forecasting models.

Whilst the model results were examined and compared each day by the forecasters during “normal operations” it was not until the end of the six-months that a full statistical comparison of the NAME, BOXURB and measured data was carried out. The results of this work are published in full elsewhere (Willis P.G., Manning A.J. 2001), but a summary is presented here.

In tables 6.2 to 6.6 we present the results of a simple linear regression analysis of the six months’ of modelled data against the six months’ of measured data. Figure 6.2 shows an example of a scatter plot – this represents graphically the data which were analysed to produce each entry in the tables. For NO_x we actually had two versions of the BOXURB model, the new version includes some ozone chemistry which is not used in the old version. In the table we have listed the slope of the best-fit line in each case, and χ, a measure of the standard error or scatter of the data. The nearer the slope is to 1, and the smaller the value of χ, then the better the model is performing.

The NAMEB and BOXURB comparisons are based on the model runs provided each day from the 00z meteorological forecasts. The NAMEA model runs are based on the 12z meteorological forecasts.

Table 6.2 Comparison of BOXURB, NAME and measured data for NO_x

Daily Max NO_x	BOXURB_OLD		BOXURB_NEW		NAME_A		NAME_B	
Site	Slope	χ	Slope	χ	Slope	χ	Slope	χ
London Bloomsbury	0.54	33.79	0.48	29.61	1.85	126.99	1.76	100.20
Birmingham Centre	1.14	50.21	1.87	83.85	1.02	39.21	1.03	37.78
Glasgow Centre	0.40	37.42	0.69	94.50	0.47	37.77	0.48	35.64
Manchester Piccadilly	0.91	63.28	1.66	142.31	1.01	46.49	0.97	46.44
Belfast Centre	0.16	10.97	0.45	40.08	0.45	23.08	0.47	29.76
Cardiff Centre	0.37	16.71	1.09	64.22	0.66	19.94	0.68	20.81
Newcastle Centre	0.63	40.89	0.85	73.90	0.79	35.88	0.78	38.90
Leeds Centre	0.42	26.48	1.36	121.08	0.78	45.08	0.73	35.69
Bristol Centre	0.22	23.06	0.75	106.45	0.27	20.05	0.25	22.65
Southampton Centre	0.32	22.28	0.74	71.10	0.44	25.24	0.44	23.75
Norwich Centre	0.18	7.41	0.59	41.06	0.58	17.50	0.67	16.47

Table 6.3 Comparison of BOXURB, NAME and measured data for NO_2

Daily Max NO_2	BOXURB_OLD		BOXURB_NEW		NAME_A		NAME_B	
Site	Slope	χ	Slope	χ	Slope	χ	Slope	χ
London Bloomsbury	0.51	8.39	0.58	13.79	0.86	17.41	0.83	11.15
Birmingham Centre	0.88	9.98	1.48	42.50	0.86	8.97	0.87	8.61
Glasgow Centre	0.59	10.99	0.82	21.92	0.70	11.23	0.71	10.77
Manchester Piccadilly	0.82	10.45	1.47	54.68	0.94	9.37	0.94	9.64
Belfast Centre	0.23	5.77	0.49	14.04	0.61	7.47	0.64	7.78
Cardiff Centre	0.39	7.29	0.80	17.31	0.71	6.89	0.72	6.90
Newcastle Centre	0.73	9.82	0.95	18.97	0.93	8.09	0.95	7.90
Leeds Centre	0.56	9.37	1.16	35.70	0.82	10.74	0.84	9.00
Bristol Centre	0.37	8.74	0.80	29.26	0.46	8.35	0.46	8.25
Southampton Centre	0.39	8.69	0.75	20.24	0.61	7.71	0.62	7.36
Norwich Centre	0.23	4.44	0.68	24.61	0.71	7.37	0.70	8.09

Table 6.4 Comparison of NAME and measured data for SO_2

Daily Max SO_2	NAME_A		NAME_B	
Site	Slope	χ	Slope	χ
London Bloomsbury	1.10	16.14	1.06	15.50
Birmingham Centre	1.07	11.48	1.29	13.69
Glasgow Centre	1.09	9.03	1.16	7.98
Manchester Piccadilly	2.33	19.80	2.40	19.03
Belfast Centre	1.38	18.32	1.33	23.24
Cardiff Centre	0.97	9.41	1.00	12.90
Newcastle Centre	1.27	16.89	1.38	13.99
Leeds Centre	2.61	24.83	1.87	25.45
Bristol Centre	0.82	6.52	0.97	7.93
Southampton Centre	1.71	12.35	1.83	13.53
Norwich Centre	0.52	7.77	0.56	5.47

Table 6.5 Comparison of BOXURB, NAME and measured data for PM_{10}

Daily Max running 24 hour mean PM_{10}	BOXURB_NEW		NAME_A		NAME_B	
Site	Slope	χ	Slope	χ	Slope	χ
London Bloomsbury	0.69	6.47	0.67	8.22	0.65	7.31
Birmingham Centre	1.06	14.28	0.53	4.79	0.53	5.80
Glasgow Centre	0.53	12.05	0.18	4.68	0.19	4.51
Manchester Piccadilly	0.88	16.57	0.48	6.23	0.48	5.84
Belfast Centre	0.58	5.88	0.51	5.76	0.53	6.00
Cardiff Centre	0.67	8.23	0.41	4.70	0.40	5.03
Newcastle Centre	1.11	9.08	0.58	4.50	0.61	4.67
Leeds Centre	1.03	13.57	0.52	5.38	0.52	5.40
Bristol Centre	0.84	11.25	0.37	3.83	0.37	4.24
Southampton Centre	0.82	7.47	0.45	4.53	0.46	4.49
Norwich Centre	0.59	5.29	0.46	3.88	0.47	4.42

Table 6.6 Comparison of BOXURB (+secondary PM_{10} trajectory modelling), NAME and measured data for PM_{10}

Daily Max running 24 hour mean PM_{10}	BOXURB + Secondary from sulphate.		BOXURB + Secondary From Total PM_{10}.		NAME_A		NAME_B	
Site	Slope	χ	Slope	χ	Slope	χ	Slope	χ
London Bloomsbury	1.01	12.45	1.03	10.74	0.67	8.16	0.64	7.38
Birmingham Centre	1.39	16.16	1.42	16.21	0.53	4.76	0.52	5.86
Belfast Centre	0.79	13.84	0.78	9.94	0.51	5.97	0.53	5.96
Cardiff Centre	0.98	15.06	0.97	12.48	0.42	4.75	0.41	5.03
Southampton Centre	1.04	10.59	1.08	10.11	0.44	4.35	0.45	4.43

The analysis indicates that in most cases NAME performs better than BOXURB. For NO_2 the slope is much better and scatter reduced slightly, whilst for PM_{10} the scatter is much reduced and the poor slope agreement for NAME is easily explained (see below). The figures do vary considerably from one urban location to another however, and for some of the locations the errors are still large. It's interesting that for all the models the agreement for NO_2 is much better than for NO_x. In one way this is surprising, since NO_2 is a secondary pollutant and should therefore more complicated to model. However, NO_2 concentrations will vary much less than NO_x and the scatter on the regression will therefore be much lower. For SO_2 the slopes and scatter are most variable, and except by using approximate scaling of NO_x at Belfast and Barnsley this pollutant could not be forecast using BoxUrb. The scatter is mainly due to a large proportion of the emissions being from point sources. In order to model such sources accurately you need a detailed emissions inventory with known operating cycles for the emitting processes, and very accurate meteorological forecasts. Although we are using the best available data, it is inevitable that there are still large uncertainties in these factors. Also, during this period there were no incidents of MODERATE or worse SO_2 pollution on which to test the model. The results using analysis meteorological data are presented in the full report (Willis P.G., Manning A.J. 2001) and show improved agreement, indicating that the accuracy of the pollution model is of course affected greatly by inaccuracies in the meteorological forecasts. However, for the purposes of operational UK air pollution forecasting all the errors need to be assessed together.

The differences between the NAMEA and NAMEB results will be simply due to differences in the meteorological forecasts from the 12z and 00z model runs. In theory NAMEB should provide better modelling of the morning rush-hour pollution as it has more up-to-date meteorological forecast data. NAMEA should provide better modelling of the afternoon pollution. In practice this cannot be seen from the results of the analysis.

Figures 6.2 – 6.4 show some example time series graphs which illustrate well the comparison of BOXURB, NAMEB and measurement data for selected pollutants and sites. The plots confirm the findings of the statistical analysis above, mainly that the NAME model follows the measured data better than BOXURB, and that unlike BoxUrb, NAME does not produce false alarms under low windspeed conditions. For PM_{10} particles the plot shows that the NAME model clearly under-reads measurements by a significant amount, whilst following the pollutant profile quite well. This is probably due to some of the secondary PM_{10} chemistry still being missing from the NAME model. Also, the coarse fraction is incorporated into BoxUrb as an arbitrary constant 10 μgm^{-3} offset, whereas there is no attempt to model this by NAME, it has to be added on as a post-processing factor by the forecasters.

Figure 6.2 London NO_2 Forecast vs. Measured Data

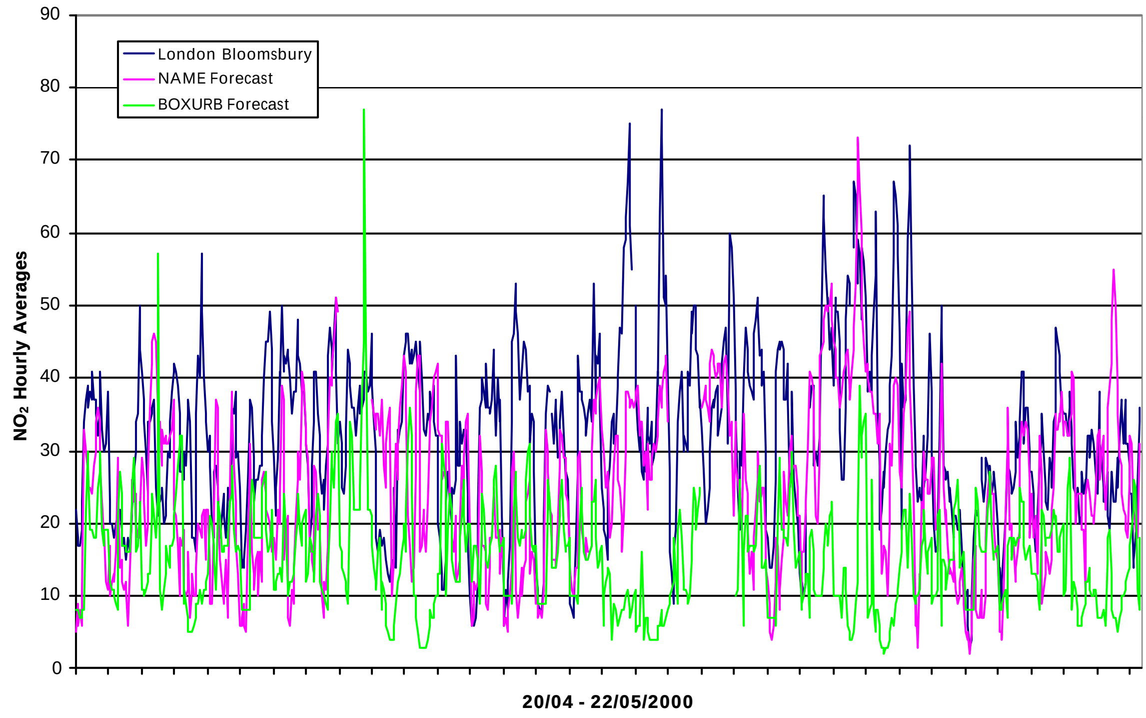


Figure 6.3 Birmingham SO_2 Forecast vs. Measured Data

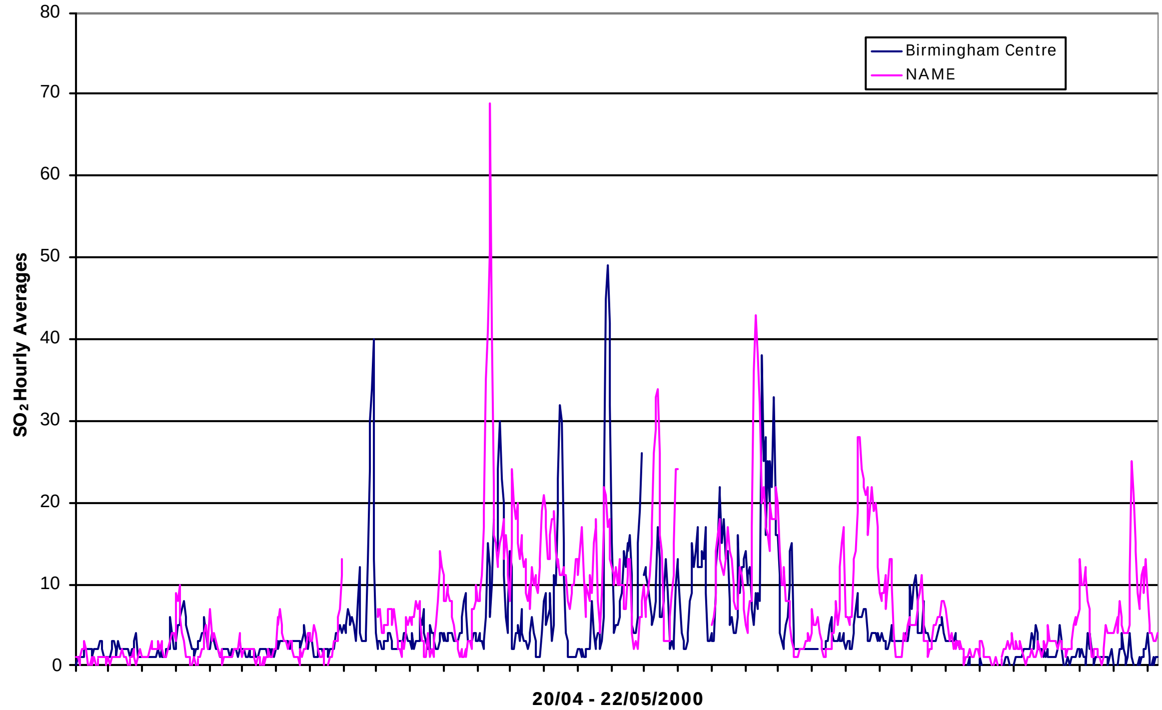
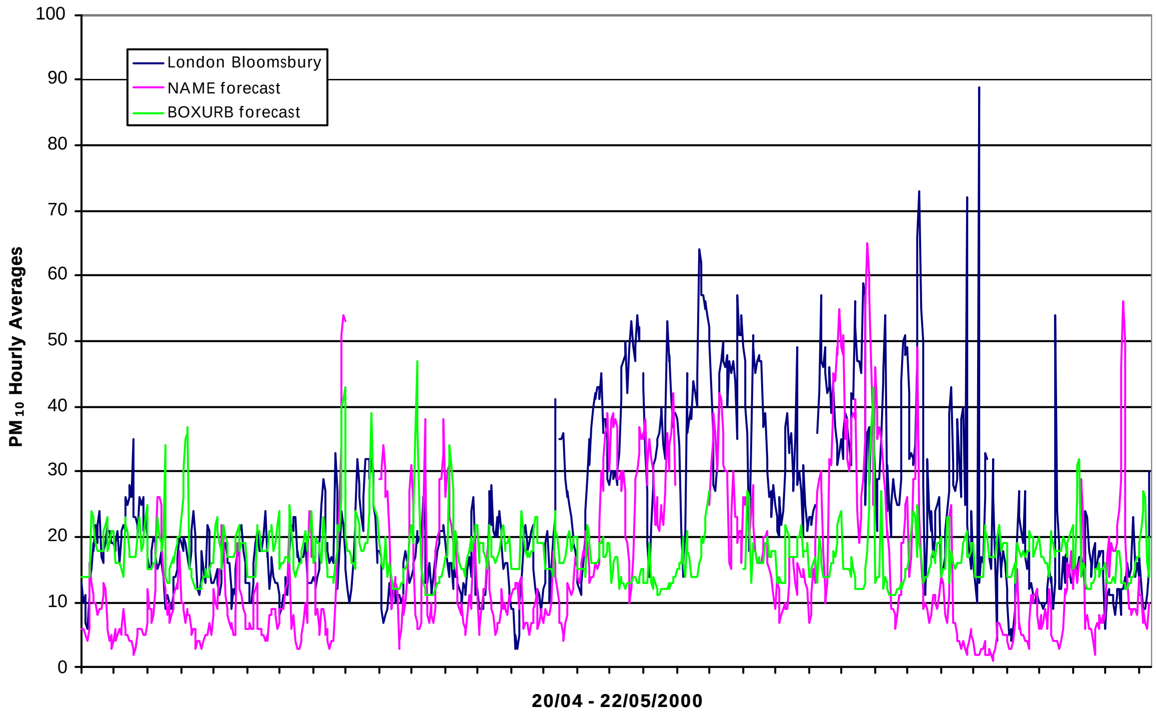


Figure 6.4 London PM_{10} Forecast vs. Measured Data



In summary, we conclude that NAME performs better than BOXURB because:

- Simple linear regression between modelled and measured data shows that in many cases the scatter on the best-fit line is less for NAME than BOXURB.
- When we plot the time series of modelled and measured data we can clearly see why this is, NAME clearly follows the profile of the measurement data much better than BoxUrb.
- **The main advantage of NAME over BoxUrb is that it does not produce false alarms under low windspeed conditions. These are the conditions under which the accurate prediction of pollutant concentrations is most crucial.**

Some improvements to NAME are currently being researched in order to improve the agreement:

- In many cases the slope of the NAME vs. measured data regression is not close to unity, this can easily be corrected for by calibrating the model or post-processing the data.
- For PM_{10} we are aware that only primary UK, primary European and secondary sulphate particulate are currently modelled. As re-suspended dust, secondary nitrate and numerous other sources will also make significant contributions under certain conditions, we are continuing to carry out research to improve this part of the model. Again, calibration or post-processing of model data will improve the agreement.

6.2 IMPROVEMENTS TO THE OZONE TRAJECTORY MODEL

This model currently tends to over-predict episodes, we are working to update the following which should improve the situation:

- Incorporate the latest NAEI and EMEP emissions inventories.
- Include some day-of-the-week factors based on recent modelling work carried out by Jenkin *et al*, 2000
- Investigate the inclusion of other parameters such as "cloud-cover" along the trajectories to improve the model performance. Cloud cover data will improve the model by restricting the chemistry under cloudy conditions. At the moment full sunlight is assumed along the full trajectory path, and whilst this is often the case during summer ozone episodes, it can lead to over-predictions. This is especially the case when the weather pattern is breaking down and low pressure with associated cloud cover is gradually pushing out a stable high pressure situation.

These modifications should be fully implemented, validated and reported during the summer 2001 ozone season.

Again, as for NAME, as long as you are aware of the limitations of your model you can also calibrate or post-process the results to give better agreement.

7 Near "Real-Time" Ozone Data Exchange Within North-West Europe

Following a report on ozone forecasting and data exchange in Northwest Europe, a pilot study was set up by NETCEN to evaluate a "real-time" data exchange system. This enables information on the previous days' maximum hourly mean ozone measurements for selected locations to be available to air pollution forecasters in nine European countries on a daily basis. There were originally five European countries participating in the study, and this has now expanded to a total of nine, the latest addition being the Czech Republic.
The availability of data on a European scale gives access to information that can be used for forecasting more accurately the likelihood of episodes in the UK. We are currently trying to encourage other European countries, and in particular France who are our nearest neighbours, to join this informal data exchange scheme.

The data are reported on the web at http://www.aeat.co.uk/netcen/airqual/forecast/smogwarners/ as shown in Figure 7.1. The Web site has a colour coded map of the concentrations at each site, and A text version of the data is also e-mailed directly to the participants on a daily basis, an example of this is given in Table 7.1.

Figure 7.1 – Web site for European daily maximum ozone concentrations.

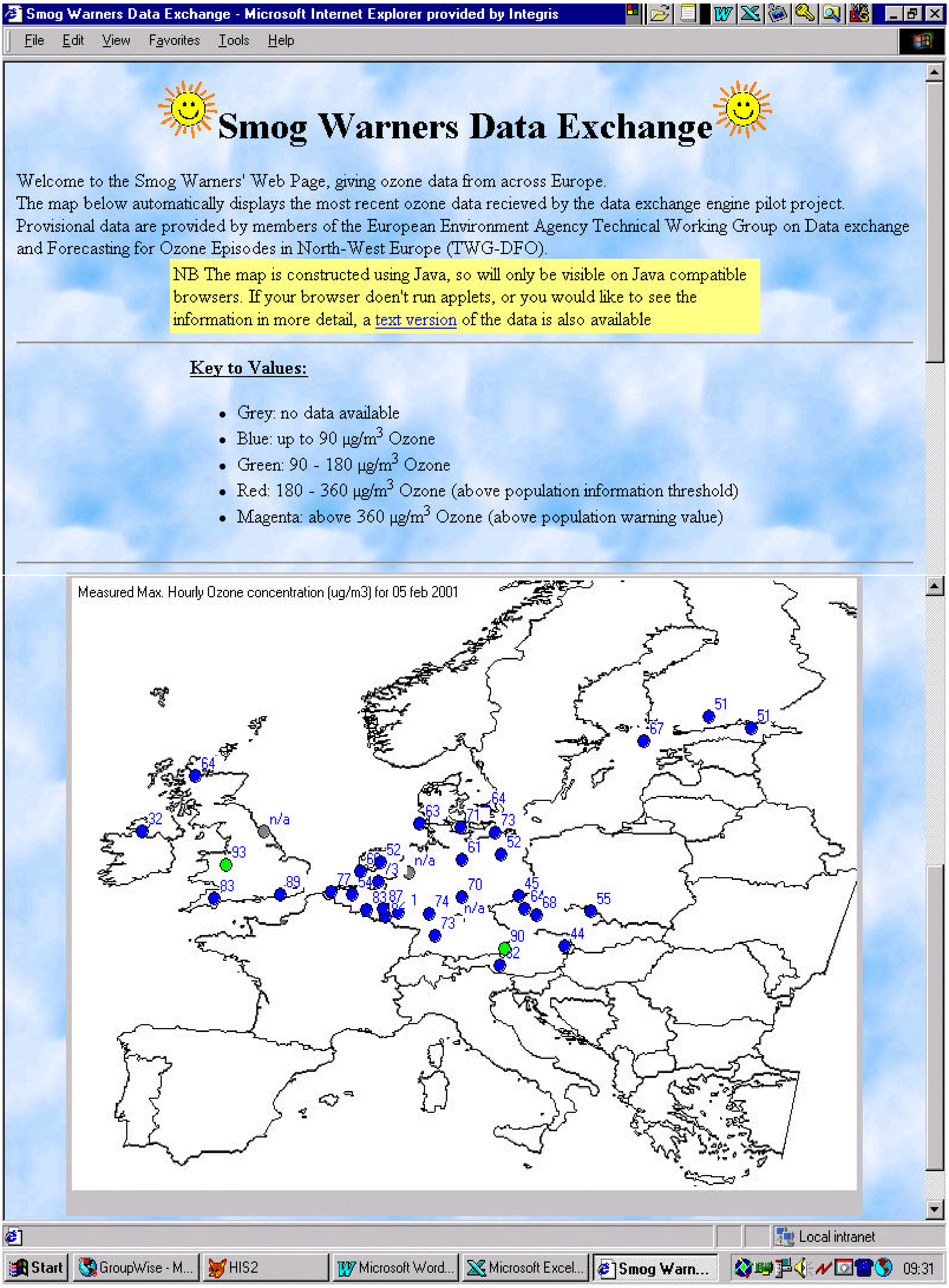


Table 7.1 Daily Exchange of European Ozone monitoring data

Visit the Smogwarners data Exchange web site at
http://www.aeat.co.uk/netcen/airqual/forecast/smogwarners/

Country	Station Name	Yesterday's maximum conc @ time (ug/m^3)	Example from this morning conc @ time (ug/m^3)	Lat	Long	Alt (m)
AT	Data last updated	08:00 on 29-jan-01	timezone GMT		1-hour averages	
AT	Illmitz	82 @1200,28jan	21 @0800,29jan	47d46mN	16d46mE	117
AT	Vorhegg	74 @0300,28jan	71 @0800,29jan	46d40mN	12d58mE	1020
AT	St. Koloman	93 @0600,28jan	75 @0800,29jan	47d39mN	13d14mE	1005
B	Data last updated	07:24 on 29-Jan-01	timezone GMT		1-hour averages	
B	Roeselare	56 @1500,28jan	7 @0800,29jan	50d57mN	03d09mE	16
B	Ukkel	not available	2 @0800,29jan	50d48mN	04d22mE	100
B	Offagne	not available	not available	49d53mN	05d12mE	430
CZ	Data last updated	08:10 on 29-jan-01	timezone GMT		1-hour averages	
CZ	Prague-Libus	70 @1400,28jan	3 @0600,29jan	50d00mN	14d27mE	301
CZ	Usti n.L.-Kockov	70 @1400,28jan	14 @0600,29jan	50d41mN	14d03mE	367
CZ	Ostrava-Fifejdy	73 @1400,28jan	8 @0600,29jan	49d50mN	18d16mE	220
CZ	Kosetice	84 @1300,28jan	32 @0600,29jan	49d34mN	15d05mE	535
D	Data last updated	08:15 on 29-Jan-01	timezone GMT		1-hour averages	
D	Ansbach UBA	not available	not available	49d15mN	10d34mE	481
D	Deuselbach	71 @2000,28Jan	50 @0500,29Jan	49d46mN	07d03mE	480
D	Fuerth/Odenwald	76 @1400,28Jan	53 @0500,29Jan	49d39mN	08d49mE	483
D	Gittrup	not available	not available	52d03mN	07d40mE	43
D	Neuglobsow	39 @0500,28Jan	21 @0500,29Jan	53d09mN	13d02mE	65
D	Schmuecke	72 @2000,28Jan	55 @0500,29Jan	50d39mN	10d46mE	937
D	Schwaebische Alb	84 @1300,28Jan	47 @0500,29Jan	48d21mN	09d13mE	799
D	Waldhof	53 @0200,28Jan	29 @0500,29Jan	52d48mN	10d45mE	72
D	Westerland	44 @0700,28Jan	not available	54d55mN	08d19mE	12
D	Zingst	29 @1500,28Jan	33 @0500,29Jan	54d26mN	12d42mE	1
DK	Data last updated	9:13 on 29-jan-01	timezone GMT		1-hour averages	
DK	Lille Valby	56 @ 600,28jan	16 @ 900,29jan	55d41mN	12d 8mE	10
DK	Keldsnor	56 @2400,28jan	46 @ 900,29jan	54d44mN	10d43mE	10
FI	Data last updated	07:45 on 29-jan-10	timezone GMT		1-hour averages	
FI	Uto	66 @2000,28jan	not available	59d46mN	21d22mE	7
FI	Virolahti	56 @2100,28jan	not available	60d31mN	27d40mE	4
FI	Evo	52 @1100,28jan	not available	61d12mN	25d08mE	132
GB	Data last updated	09:50 on 29-jan-01	timezone GMT		1-hour averages	
GB	Strath Vaich	79 @0300,28jan	61 @0900,29jan	57d44mN	04d46mW	270
GB	High Muffles	53 @1300,28jan	32 @0900,29jan	54d30mN	00d48mW	267
GB	Lough Navar	70 @1400,28jan	not available	54d27mN	07d52mW	130
GB	Aston Hill	83 @0300,28jan	81 @0900,29jan	52d30mN	03d02mW	370
GB	Lullington Heath	72 @1400,28jan	13 @0900,29jan	50d48mN	00d11mE	120
GB	Yarner wood	62 @1300,28jan	60 @0900,29jan	50d36mN	03d43mW	119
L	Data last updated	06:00 on 29-Jan-01	timezone GMT		1-hour averages	
L	Elvange	65 @1900,28Jan	38 @0600,29Jan	49d31mN	06d19mE	303
L	Mt.St.Nicolas(Vianden)	69 @1800,28Jan	37 @0600,29Jan	49d57mN	06d11mE	515
NL	Data last updated	09:30 on 29-Jan-01	timezone GMT		1-hour averages	
NL	Vredepeel-Vredeweg	45 @1300,28jan	1 @0800,29jan	51d32mN	05d51mE	0
NL	Zegveld-Oude Meije	60 @1500,28jan	0 @0800,29jan	52d08mN	04d50mE	0
NL	Barsbeek-De Veenen	64 @1300,28jan	6 @0800,29jan	52d39mN	06d01mE	0

8 Possible Changes to the UK Data Dissemination Systems which will Affect Forecasting

DEFRA are currently consulting on proposed changes to the UK air pollution bulletins. This will have a significant impact on the way UK air pollution forecasts are prepared.

8.1 FORECAST OF AIR POLLUTION INDEX

NETCEN developed the 1-10 air pollution index which is presented in Table 8.1. This is based on the current banding system but with the LOW, MODERATE and HIGH bands for each pollutant split into three smaller increments. VERY HIGH pollution is index 10. The BBC have already adopted this system for the five-day air pollution forecasts presented on their Web site (Figure 8.1), but the wider implementation will depend on the outcome of the consultation period.

Figure 8.1 – BBC Weather Web site showing Air Pollution Index for London

Table 8.1 – Proposed U.K. Air Pollution Index

Old Banding	New Index	Ozone 8-hourly/ hourly mean		Nitrogen Dioxide Hourly Mean		Sulphur Dioxide 15-Minute Mean		Carbon Monoxide 8-Hour Mean		PM_{10} Particles 24-Hour Mean
		μgm^{-3}	ppb	μgm^{-3}	ppb	μgm^{-3}	ppb	mgm^{-3}	ppm	μgm^{-3}
LOW										
	1	0-32	0-16	0-95	0-49	0-88	0-32	0-3.8	0.0-3.2	0-16
	2	33-66	17-32	96-190	50-99	89-176	33-66	3.9-7.6	3.3-6.6	17-32
	3	67-99	33-49	191-286	100-149	177-265	67-99	7.7-11.5	6.7-9.9	33-49
MODERATE										
	4	100-126	50-62	287-381	150-199	266-354	100-132	11.6-13.4	10.0-11.5	50-57
	5	127-152	63-76	382–477	200-249	355-442	133-166	13.5-15.4	11.6-13.2	58-66
	6	153-179	77-89	478-572	250-299	443-531	167-199	15.5-17.3	13.3-14.9	67-74
HIGH										
	7	180-239	90-119	573-635	300-332	532-708	200-266	17.4-19.2	15.0-16.5	75-82
	8	240-299	120-149	636-700	333-366	709-886	267-332	19.3-21.2	16.6-18.2	83-91
	9	300-359	150-179	701-763	367-399	887-1063	333-399	21.3-23.1	18.3-19.9	92-99
VERY HIGH										
	10	≥ 360 μgm^{-3}	≥ 180 ppb	≥ 764 μgm^{-3}	≥ 400 ppb	≥1064 μgm^{-3}	≥ 400 ppb	≥ 23.2 mgm^{-3}	≥ 20 ppm	≥ 100 μgm^{-3}

Old Banding	New Index	Health Descriptor
LOW		
	1	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants
	2	
	3	
MODERATE		
	4	Mild effects unlikely to require action may be noticed amongst sensitive individuals
	5	
	6	
HIGH		
	7	Significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their "reliever inhaler is likely to reverse the effects on the lung.
	8	
	9	
VERY HIGH		
	10	The effects on sensitive individuals described for "High" levels of pollution may worsen.

8.2 INCREASED NUMBER OF FORECASTING REGIONS

There is increasing pressure from the public to provide more detailed or “local” air pollution forecasts. To a certain extent this is unachievable at a national level, as it is impossible to quantify all of the local effects which can result in micro-scale changes to the pollution climate. It may be more appropriate to continue to predict a worst-case scenario for a number of regions.

However, the number of regions could be increased to correspond with either the Met. Office weather forecasting regions, or the EC Daughter Directive Zones and Agglomerations. In the case of the former we have already assessed which monitoring sites would fall into which locations and this is presented in Table 8.2. If the latter approach were to be taken then further analysis of the implications would be required.

Table 8.2 Current Air Pollution Forecast Regions compared to current Weather Forecast Regions and EC Daughter Directive Zones and Agglomerations

Measurement Site	Old Region	Weather Region	Zone/Agglomeration
Cambridge Roadside	East Anglia	Eastern Counties	Eastern
Norwich Centre	East Anglia	Eastern Counties	Eastern
Norwich Roadside	East Anglia	Eastern Counties	Eastern
Sibton	East Anglia	Eastern Counties	Eastern
Wicken Fen	East Anglia	Eastern Counties	Eastern
Camden Roadside	London	London	Greater London
Haringey Roadside	London	London	Greater London
Hounslow Roadside	London	London	Greater London
London A3 Roadside	London	London	Greater London
London Bexley	London	London	Greater London
London Bloomsbury	London	London	Greater London
London Brent	London	London	Greater London
London Bromley	London	London	Greater London
London Cromwell Road 2	London	London	Greater London
London Eltham	London	London	Greater London
London Hackney	London	London	Greater London
London Haringey	London	London	Greater London
London Hillingdon	London	London	Greater London
London Lewisham	London	London	Greater London
London Marylebone Road	London	London	Greater London
London N. Kensington	London	London	Greater London
London Southwark	London	London	Greater London
London Sutton	London	London	Greater London
London Teddington	London	London	Greater London
London Wandsworth	London	London	Greater London
Southwark Roadside	London	London	Greater London
Sutton Roadside	London	London	Greater London
Tower Hamlets Roadside	London	London	Greater London
West London	London	London	Greater London
Birmingham Centre	Midlands	Midlands	West Midlands Urban Area
Birmingham East	Midlands	Midlands	West Midlands Urban Area
Bottesford	Midlands	Midlands	Yorkshire & Humberside
Coventry Memorial Park	Midlands	Midlands	Coventry/Bedworth
Leamington Spa	Midlands	Midlands	West Midlands
Leicester Centre	Midlands	Midlands	Leicester Urban Area
Northampton	Midlands	Eastern Counties	East Midlands
Nottingham Centre	Midlands	Midlands	Nottingham Urban Area
Oxford Centre	Midlands	SE England	South East
Sandwell West Bromwich	Midlands	Midlands	West Midlands Urban Area
Stoke-on-Trent Centre	Midlands	Midlands	The Potteries
Walsall Alumwell	Midlands	Midlands	West Midlands Urban Area
Walsall Willenhall	Midlands	Midlands	West Midlands Urban Area
Wolverhampton Centre	Midlands	Midlands	West Midlands Urban Area

Belfast Centre	N Ireland	N Ireland	Belfast Urban Area
Belfast Clara St	N Ireland	N Ireland	Belfast Urban Area
Belfast East	N Ireland	N Ireland	Belfast Urban Area
Derry	N Ireland	N Ireland	Northern Ireland
Lough Navar	N Ireland	N Ireland	Northern Ireland
Barnsley 12	NE England	Yorks and Lincs	Yorkshire & Humberside
Barnsley Gawber	NE England	Yorks and Lincs	Yorkshire & Humberside
Billingham	NE England	N England	Teesside Urban Area
Bradford Centre	NE England	Yorks and Lincs	West Yorkshire Urban Area
High Muffles	NE England	Yorks and Lincs	Yorkshire & Humberside
Hull Centre	NE England	Yorks and Lincs	Kingston upon Hull
Ladybower	NE England	Midlands	Yorkshire & Humberside
Leeds Centre	NE England	Yorks and Lincs	West Yorkshire Urban Area
Middlesbrough	NE England	N England	Teesside Urban Area
Newcastle Centre	NE England	N England	Tyneside
Redcar	NE England	N England	Teesside Urban Area
Rotherham Centre	NE England	Yorks and Lincs	Sheffield Urban Area
Scunthorpe	NE England	Yorks and Lincs	Yorkshire & Humberside
Sheffield Centre	NE England	Yorks and Lincs	Sheffield Urban Area
Sheffield Tinsley	NE England	Yorks and Lincs	Sheffield Urban Area
Stockton-on-Tees Yarm	NE England	N England	North East
Sunderland	NE England	N England	North East
Blackpool	NW England	NW England	Blackpool Urban Area
Bolton	NW England	NW England	Greater Manchester Urban Area
Bury Roadside	NW England	NW England	Greater Manchester Urban Area
Glazebury	NW England	NW England	North West & Merseyside
Great Dun Fell	NW England	N England	North West & Merseyside
Liverpool Centre	NW England	NW England	Liverpool Urban Area
Manchester Piccadilly	NW England	NW England	Greater Manchester Urban Area
Manchester South	NW England	NW England	Greater Manchester Urban Area
Manchester Town Hall	NW England	NW England	Greater Manchester Urban Area
Preston	NW England	NW England	Preston Urban Area
Salford Eccles	NW England	NW England	Greater Manchester Urban Area
Stockport	NW England	NW England	Greater Manchester Urban Area
Wirral Tranmere	NW England	NW England	West Midlands Urban Area
Aberdeen	Scotland	N Scotland	North East Scotland
Bush Estate	Scotland	S Scotland	Central Scotland
Edinburgh Centre	Scotland	S Scotland	Edinburgh Urban Area
Eskdalemuir	Scotland	S Scotland	Scottish Borders
Glasgow Centre	Scotland	S Scotland	Glasgow Urban Area
Glasgow City Chambers	Scotland	S Scotland	Glasgow Urban Area
Glasgow Kerbside	Scotland	S Scotland	Glasgow Urban Area
Grangemouth	Scotland	S Scotland	Central Scotland
Strath Vaich	Scotland	N Scotland	Highland
Brighton Roadside	SE England	Central S England	Greater London
Canterbury	SE England	SE England	South East
Harwell	SE England	SE England	South East
Hove Roadside	SE England	Central S England	Greater London
Lullington Heath	SE England	Central S England	South East
Portsmouth	SE England	Central S England	South East
Reading	SE England	SE England	Reading/Wokingham Urban Area
Rochester	SE England	SE England	South East
Southampton Centre	SE England	Central S England	Southampton Urban Area
Southend-on-Sea	SE England	Eastern Counties	Southend Urban Area
Thurrock	SE England	Eastern Counties	Eastern
Bath Roadside	SW England	West Country	South West
Bristol Centre	SW England	West Country	Bristol Urban Area
Bristol Old Market	SW England	West Country	Bristol Urban Area
Exeter Roadside	SW England	Devon & Cornwall	South West
Plymouth Centre	SW England	Devon & Cornwall	South West
Somerton	SW England	West Country	South West
Yarner Wood	SW England	Devon & Cornwall	South West
Aston Hill	Wales	Wales	North Wales
Cardiff Centre	Wales	Wales	Cardiff Urban Area
Narberth	Wales	Wales	South Wales
Port Talbot	Wales	Wales	Swansea Urban Area
Swansea	Wales	Wales	Swansea Urban Area

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