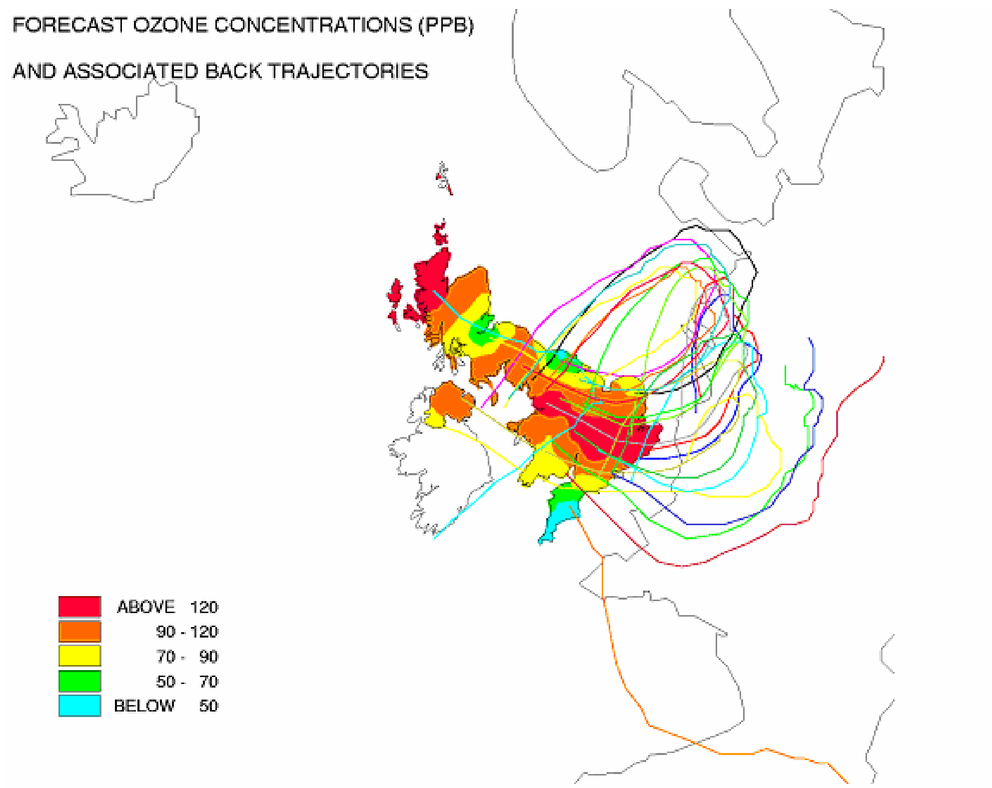
UK Air Quality Forecasting: Annual Report 2006

A report produced for the Department for Environment, Food and Rural Affairs, the Scottish Executive, the Welsh Assembly Government and the Department for the Environment in Northern Ireland



AEAT/ENV/R/2386/Issue 1
March 2007

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AEA Technology plc
AEA Energy & Environment
Building 551.11
Harwell
Didcot
Oxfordshire
OX11 0QJ
UK
+44 (0) 870 190 6441 tel.
+44 (0) 870 190 6608 fax.

Andy.cook@aeat.co.uk

	Name	Date
Authors	Andrew Cook Claire Witham	23/02/2007
Reviewed by	Paul Willis	27/02/2007
Approved by	Jon Bower	01/03/2007

Executive Summary

This report covers the operational activities carried out by AEA Energy & Environment and the Met Office on the UK Air Quality Forecasting Contract for the year 2006. The work is funded by the Department for Environment Food and Rural Affairs, the Scottish Executive, Welsh Assembly Government and the Department of the Environment in Northern Ireland.

During 2006, there was a total of 52 days on which HIGH air pollution was recorded across the UK. Thirty three of these days were due to PM_{10} alone, thirteen were due to ozone alone and one solely due to SO_2. Five HIGH days occurred for coincident PM_{10}/O_3. A total of 117 regional-days were recorded in the HIGH band for zones, 80% of which were due to elevated ozone, together with a further 67 HIGH agglomeration-days, 60% of which were due to elevated ozone.

The forecasting success and accuracy for this year is summarised in Table 1 below. The overall forecasting success rate performance for HIGH episodes has increased by a significant 70 % compared to the previous two years, mainly due to the large number of ozone episodes in 2006 compared to all recent years. Please note that success rates are able to be greater than 100 %, as detailed in section 3.1. The overall accuracy was 20 % above that attained in 2002/2003 and the accuracy for zones has increased by 5% above that attained in 2005. The accuracy in zones has climbed every year since 2002. Again accuracy rates for this year may have been affected by the large number of HIGH ozone exceedences.

Table 1 – forecast success/accuracy for incidents above 'HIGH' and above 'MODERATE' in 2006 (2005 rates in brackets)

Region/Area	*HIGH % success*	*% accuracy*	*MODERATE % success*	*% accuracy*
Zones	**114** (77)	**63** (57)	**143** (172)	**81** (86)
Agglomerations	**109** (10)	**53** (7)	**158** (180)	**69** (69)

During this year, four ad-hoc reports were presented to Defra and the devolved administrations. These reports analysed pollution episodes, as detailed below:

- Initial review of Air Quality aspects of the Buncefield Oil Depot Explosion
- An ad-hoc report detailing HIGH ozone levels during June and July.
- Two ad-hoc reports detailing particulate episodes experienced in May and September.

All episode reports can be found on the National Air Quality Archive (www.airquality.co.uk/archive/reports/list.php).

There were no reported breakdowns over the year and all bulletins were delivered to the Air Quality Communications contractor on time.

We continue to actively research ways of improving the air pollution forecasting system by:

1. Investigating the use of automatic software systems to streamline the activities within the forecasting process, thereby allowing forecasters to spend their time more efficiently in maximising forecast accuracy.
2. Researching the chemistry used in our models, in particular the $NO_x \rightarrow NO_2$ conversion used in NAME and the chemical schemes for secondary PM_{10} and ozone.
3. Improving the NAME model runs which can be used for ad-hoc analysis, in particular with regard to investigating the possible long-range transport of PM_{10}.
4. Improving and updating the emissions inventories used in our models.

Contents

1 Introduction

AEA Energy & Environment and the Met Office are contracted by The Department for Environment, Food and Rural Affairs (Defra), the Scottish Executive, the Welsh Assembly Government and the Department for the Environment in Northern Ireland to provide a 24-hour air pollution forecast which is widely disseminated through the media. The forecast allows individuals who may be affected by episodes of high air pollutant concentrations to take appropriate preventative measures. These can include increasing medication or taking steps to reduce exposure and dose.

A forecast of the following day's air pollution is prepared every day by AEA Energy & Environment. The forecast consists of a prediction of the air pollution descriptor for the worst-case situation in 16 zones and 16 agglomerations over the following 24-hours. Forecasts are disseminated in an number of ways to maximise public accessibility; these include Teletext, the World Wide Web and a Freephone telephone service.

Updates can occur at any time of day, but the most important forecast of the day is the "daily media forecast". This is prepared at 3.00 p.m. for uploading to the Internet and Air Quality Communications contractor before 4.00 p.m. each day. It is then included in subsequent air quality bulletins for the BBC, newspapers and many other interested organisations.

This report covers and analyses the media forecasts issued during the 12 months from January 1st to December 31st 2006. Results from forecasting models are available each day and are used in constructing the forecast. The forecasters issue predictions for rural, urban background and roadside environments but, for the purposes of this report, these have been combined into a single "worst-case" category.

Twice per week, on Tuesdays and Fridays, AEA Energy & Environment also provides a long-range pollution outlook. This takes the form of a short piece of text which is emailed to approximately sixty recipients in the Defra and other government Departments, plus the BBC weather forecasters. The outlook is compiled by examining the outputs from our pollution models, which currently extend to 3 days ahead for Defra and the DAs, and by assessing the long-term weather situation.

We continue to use a comprehensive quality control system in order to ensure that the 5-day forecasts provided by the Met Office to the BBC are consistent with the "daily media forecasts" and long-range pollution outlook provided by Netcen for Defra and the DAs. The BBC requires 5-day air pollution index forecasts for 230 UK towns and cities for use on its BBC Online service. The quality control review is carried out at 3.00 p.m. daily, with the resulting forecast updating onto the BBC Online Web site at 4.00 a.m. the following morning.

2 New developments during this year

2.1 MET OFFICE DEVELOPMENTS

A number of significant developments were carried out over the course of this year:

- During the first quarter of 2006, the Met Office Air Quality Forecast System was fully integrated into the main production processes of the Met Office. This provided greater operational resilience and allowed structured development at all levels: customer support, software, hardware and model enhancement.
- During the second quarter, Met Office system developments included the reintroduction of output of UK air quality maps to a development version of the forecasting model, an example of which is shown in figure 2.1 below. Improvements to the resilience and error notification of the operational air quality system were also made.

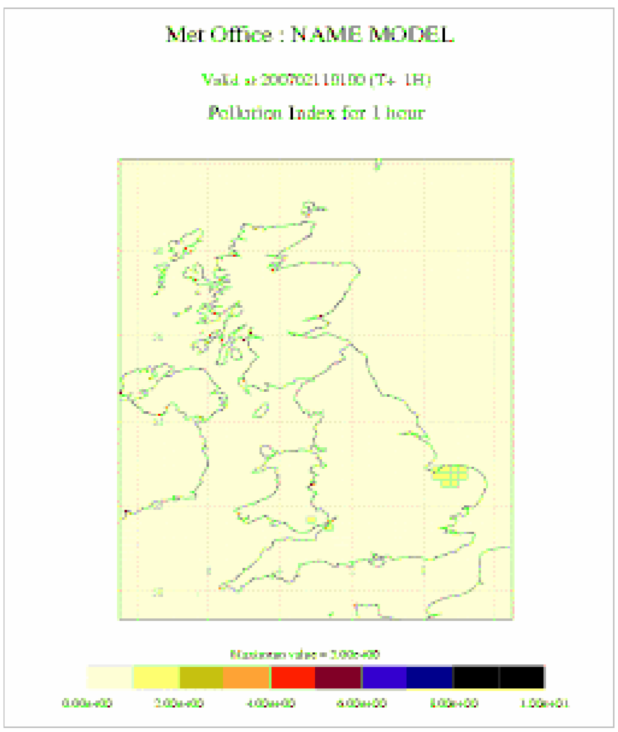

Figure 2.1 – UK air quality map as used in a development version of a forecasting model.

- In the third quarter of 2006 the Met Office upgraded its external FTP servers. This increased the robustness of the data transfer system, and required changes at both the Met Office and AEA Energy & Environment to maintain the delivery of products. To improve the resilience of the forecast system, the Met Office instigated a back-up system by which the model forecast files were transferred to AEA Energy & Environment by FTP in addition to being sent by email.
- The fourth quarter was characterised by ongoing developments of the air quality systems employed.

2.2 AEA ENERGY & ENVIRONMENT DEVELOPMENTS

AEA also made a number of system changes to improve the efficiency of the forecasting team:

- The "AQtoolkit" spreadsheet was updated with five emergency contact telephone numbers for key staff at Defra and the Met Office. This was to prevent any recurrence of the weekend communication difficulties surrounding the Buncefield Oil Depot explosion during quarter 4, 2005.
- Emergency response procedures were reviewed with Defra at a series of meetings, and a seminar was held on the Buncefield oil depot explosion incident. A technical report on monitoring, modelling and emissions inventory work carried out on the Buncefield incident was subsequently published, as detailed in section 4 of this report.
- The Toolkit was also updated with a link to current and archived satellite images of the UK. These were used extensively in the production of reports on two widespread particulate pollution episodes which were experienced across the UK during 2006. An illustration of some of the additions to the links in the "AQtoolkit" are shown below in figure 2.2, including an archive satellite image taken from a website maintained by Dundee University.

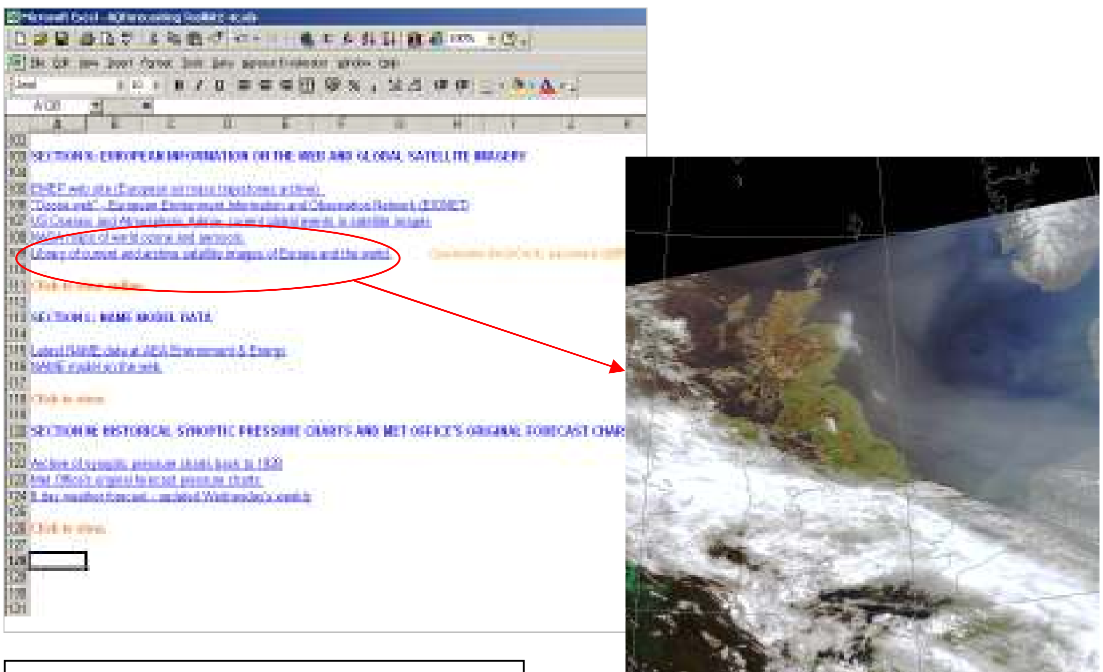

Figure 2.2 – Recent additions of extra links in the AEA "AQtoolkit".

- A technical problem with a delay in the update of the BBC forecast to BBC Online was resolved by liaison with Met Office and BBC forecasting teams. The BBC agreed to carry out more regular update of the BBC Online pages to fit in with the twice-daily air pollution forecasts.
- Two new WAP enabled forecasting mobile phones have been purchased with a view to enabling greater mobility of the web-based forecasting process, particularly outside of normal office hours.

3 Analysis of forecasting success rate

3.1 INTRODUCTION

Analysis of the forecasting performance is carried out for each of the 16 zones and 16 agglomerations used in the daily forecasting service. Further details of these zones and agglomerations are presented in Appendix 2. Forecasting performance is analysed for a single, general pollutant category rather than for each individual pollutant and has been aligned to the forecasting day (a forecasting day runs from the issue time, generally 3 pm). This analysis of forecasting performance is based on provisional data, as used in the daily forecasting process. Any obviously faulty data have been removed.

The analysis treats situations where the forecast index was within ±1 of the measured index as a successful prediction, as this is the target accuracy we aim to obtain in the forecast. Because the calculations of accuracy and success rates are based on a success being ±1 of the measured index, it is possible to record rates in excess of 100% rather than 'true' percentages. Further details of the text descriptions and index code used for the forecasting are given in Appendix 1.

The forecasting success rates for each zone and agglomeration for January - December 2006 are presented in Tables 3.1 (forecasting performance in zones) and 3.2 (forecasting performance in agglomerations) for 'HIGH' days. Table 3.5 provides a summary for each pollutant of the number of days on which HIGH and above pollution was measured, the maximum exceedence concentration and the day and site at which it was recorded. The forecasting performance Tables 3.1 and 3.2 give:

- The number of 'HIGH' days measured in the PROVISIONAL data
- The number of 'HIGH' days forecast
- The number of days with a correct forecast of 'HIGH' air pollution, within an agreement of ±1 index value. A HIGH forecast is recorded as correct if air pollution is measured HIGH and the forecast is within ±1 index value, or it is forecast HIGH and the measurement is within ±1 index value. For example measured index 7 with forecast index 6 counts as correct, as does measured index 6 with forecast index 7.
- The number of days when 'HIGH' air pollution was forecast ('f' in the tables) but not measured ('m') on the following day to within an agreement of 1 index value.
- The number of days when 'HIGH' air pollution was measured ('m') but had not been forecast ('f') to within an agreement of 1 index value.

The two measures of forecasting performance used in this report are the 'success rate' and the 'forecasting accuracy'.

The forecast success rate (%) is calculated as:
- (Number of episodes successfully forecast/total number of episodes measured) x 100

The forecast accuracy (%) is calculated as:
- (Number of episodes successfully forecast/[Number of successful forecasts + number of wrong forecasts]) x 100

3.2 FORECAST ANALYSIS FOR 2006

Table 3.1 - Forecast Analysis for UK Zones 'HIGH' band and above *

ZONES	Central Scotland	East Mids	Eastern	Greater London	Highland	North East	North East Scotland	North Wales	North West & Merseyside	Northern Ireland	Scottish Borders	South East	South Wales	South West	West Midlands	Yorkshire & Humberside	Overall
Measured days	1	9	20	15	2	7	0	6	9	2	0	12	5	7	11	11	117
Forecasted days	3	16	18	19	2	14	2	9	12	2	4	16	13	11	16	14	171
Ok (f and m)	0	13	20	18	2	8	0	8	10	2	2	13	9	9	11	8	133
Wrong (f not m)	3	4	1	3	2	6	2	3	3	0	2	5	4	4	6	6	54
Wrong (m not f)	1	1	5	6	0	1	0	0	0	0	0	2	1	0	1	7	25
Success %	0	144	100	120	100	114	100	133	111	100	100	108	180	129	100	73	114
Accuracy %	0	72	77	67	50	53	0	73	77	100	50	65	64	69	61	38	63

Table 3.2 - Forecast Analysis for UK Agglomerations 'HIGH' band and above *

AGGLOMERATIONS	Belfast UA	Brighton/Worthing /Littlehampton	Bristol UA ^	Cardiff UA	Edinburgh UA	Glasgow UA	Greater Manchester UA	Leicester UA	Liverpool UA
Measured days	2	4	9	4	0	5	3	4	2
Forecasted days	0	11	5^	7	2	2	10	11	6
Ok (f and m)	2	8	5	6	0	1	7	7	3
Wrong (f not m)	0	3	1	2	2	1	4	4	3
Wrong (m not f)	0	0	4	0	0	4	0	0	0
Success %	100	200	56	150	100	20	233	175	150
Accuracy %	100	73	50	75	0	17	64	64	50

AGGLOMERATIONS	Nottingham UA	Portsmouth UA	Sheffield UA	Swansea UA	Tyneside	West Midlands UA	West Yorkshire UA	***Overall***
Measured days	1	8	0	6	0	7	12	67
Forecasted days	9	10	4	7	6	11	7	108
Ok (f and m)	6	9	1	6	1	9	2	73
Wrong (f not m)	3	2	3	1	5	2	5	41
Wrong (m not f)	1	0	0	2	0	2	11	24
Success %	600	113	100	100	100	129	17	109
Accuracy %	60	82	25	67	17	69	11	53

*** All performance statistics are based on provisional data. Obviously incorrect data due to instrumentation faults have been removed from the analyses. ^ number of forecasted days for the Bristol UA from 15/6 onwards due to site move.**

Please refer to the start of section 3 for an explanation of the derivation of the various statistics, figures >100 % may occur.

Table 3.3 - Forecast Analysis for UK Zones 'MODERATE' band and above *

ZONES	Central Scotland	East Mids	Eastern	Greater London	Highland	North East	North East Scotland	North Wales	North West & Merseyside	Northern Ireland	Scottish Borders	South East	South Wales	South West	West Midlands	Yorkshire & Humberside	Overall
Measured days	34	80	170	151	84	60	23	79	100	21	37	101	85	98	101	85	1309
Forecasted days	89	143	158	164	106	122	86	95	106	92	88	150	119	123	145	116	1902
Ok (f and m)	74	132	184	178	120	110	69	109	115	78	80	144	122	119	126	115	1875
Wrong (f not m)	21	19	12	22	10	24	22	12	11	17	15	20	21	20	27	19	292
Wrong (m not f)	7	7	12	19	6	10	4	2	8	2	4	10	8	9	13	13	134
Success %	218	165	108	118	143	183	300	138	115	371	216	143	144	121	125	135	143
Accuracy %	73	84	88	81	88	76	73	89	86	80	81	83	81	80	76	78	81

Table 3.4 - Forecast Analysis for UK Agglomerations 'MODERATE' band and above *

AGGLOMERATIONS	Belfast UA	Brighton/Worthing /Littlehampton	Bristol UA ^	Cardiff UA	Edinburgh UA	Glasgow UA	Greater Manchester UA	Leicester UA	Liverpool UA
Measured days	12	64	26	35	33	54	69	51	34
Forecasted days	66	107	36^	80	69	85	97	102	78
Ok (f and m)	50	97	26	59	66	81	99	77	69
Wrong (f not m)	20	21	17	27	14	22	14	37	14
Wrong (m not f)	0	9	8	6	4	15	8	14	3
Success %	417	152	100	169	200	150	143	151	203
Accuracy %	71	76	51	64	79	69	82	60	80

AGGLOMERATIONS	Nottingham UA	Portsmouth UA	Sheffield UA	Swansea UA	Tyneside	West Midlands UA	West Yorkshire UA	Overall
Measured days	34	75	29	73	28	57	76	750
Forecasted days	85	109	75	102	81	101	95	1332
Ok (f and m)	55	108	52	97	61	86	86	1169
Wrong (f not m)	37	15	30	21	27	23	25	364
Wrong (m not f)	5	10	6	13	7	10	33	151
Success %	162	144	179	133	218	151	113	158
Accuracy %	57	81	59	74	64	72	60	69

*** All performance statistics are based on provisional data. Obviously incorrect data due to instrumentation faults have been removed from the analyses. ^ number of forecasted days for the Bristol UA from 15/6 onwards due to site move.**

Please refer to the start of section 3 for an explanation of the derivation of the various statistics, figures >100 % may occur.

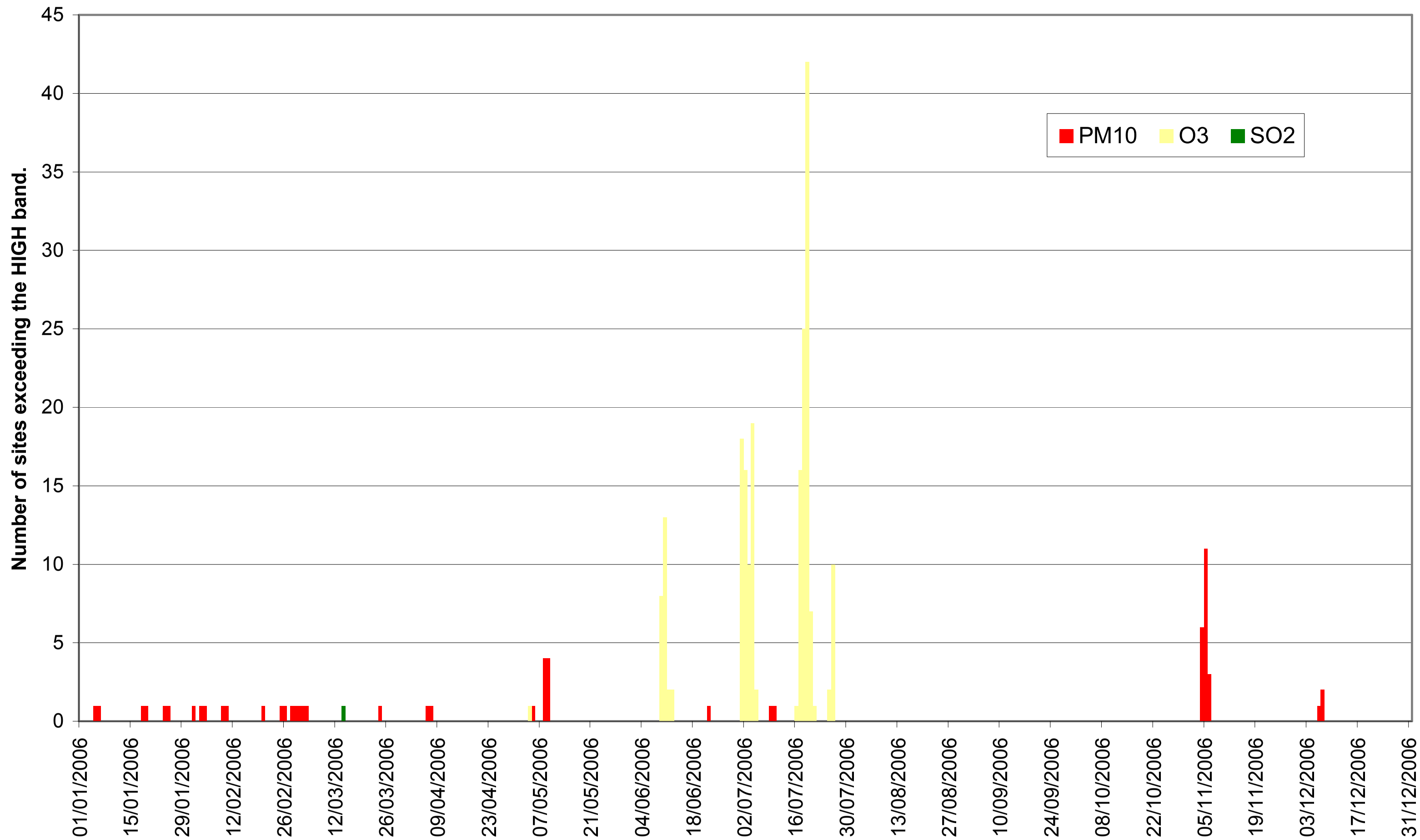

Figure 3.1 Number of stations with air pollution levels of HIGH and above for days throughout 2006.

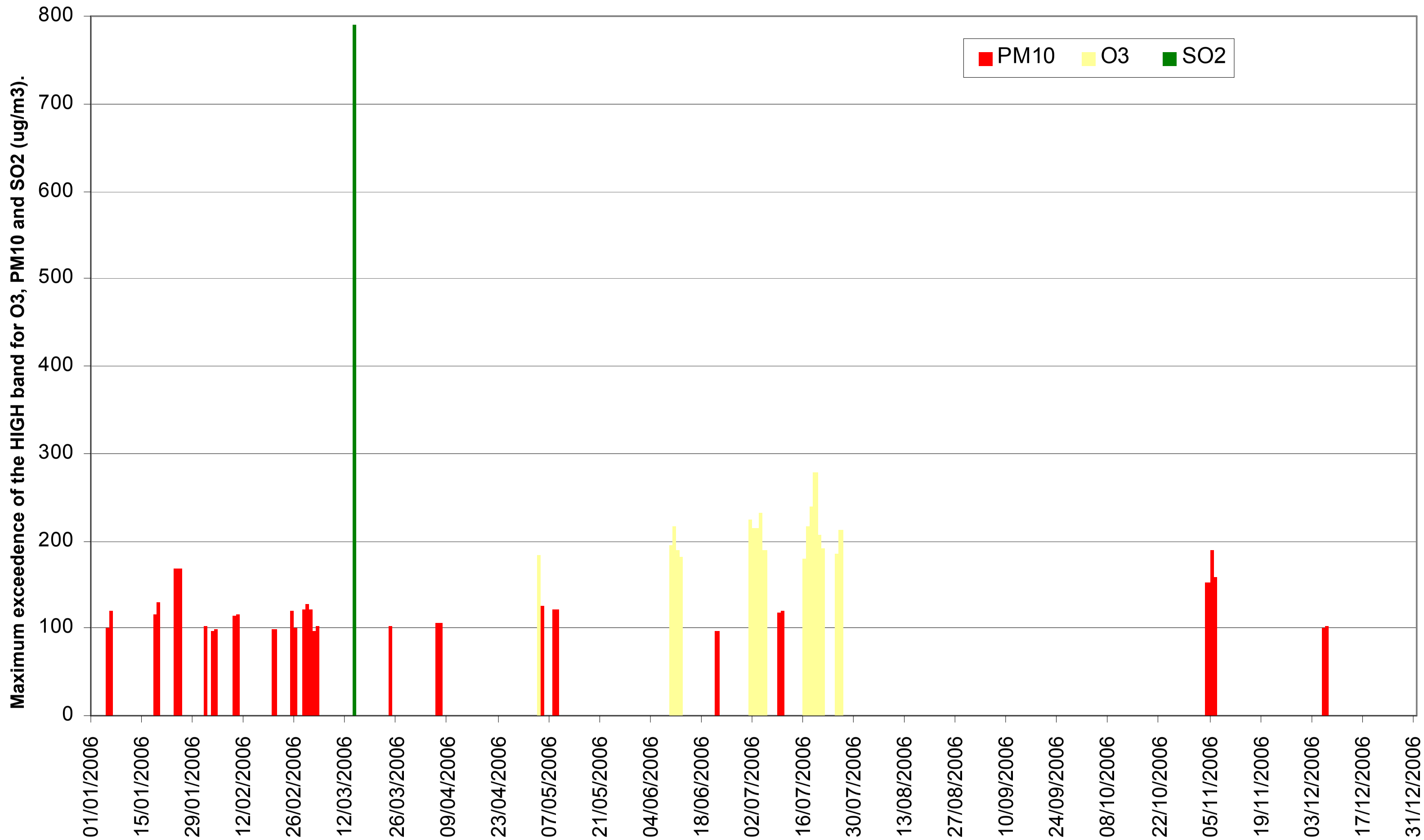

Figure 3.2 Maximum exceedence when air pollution levels were HIGH and above for days throughout 2006.

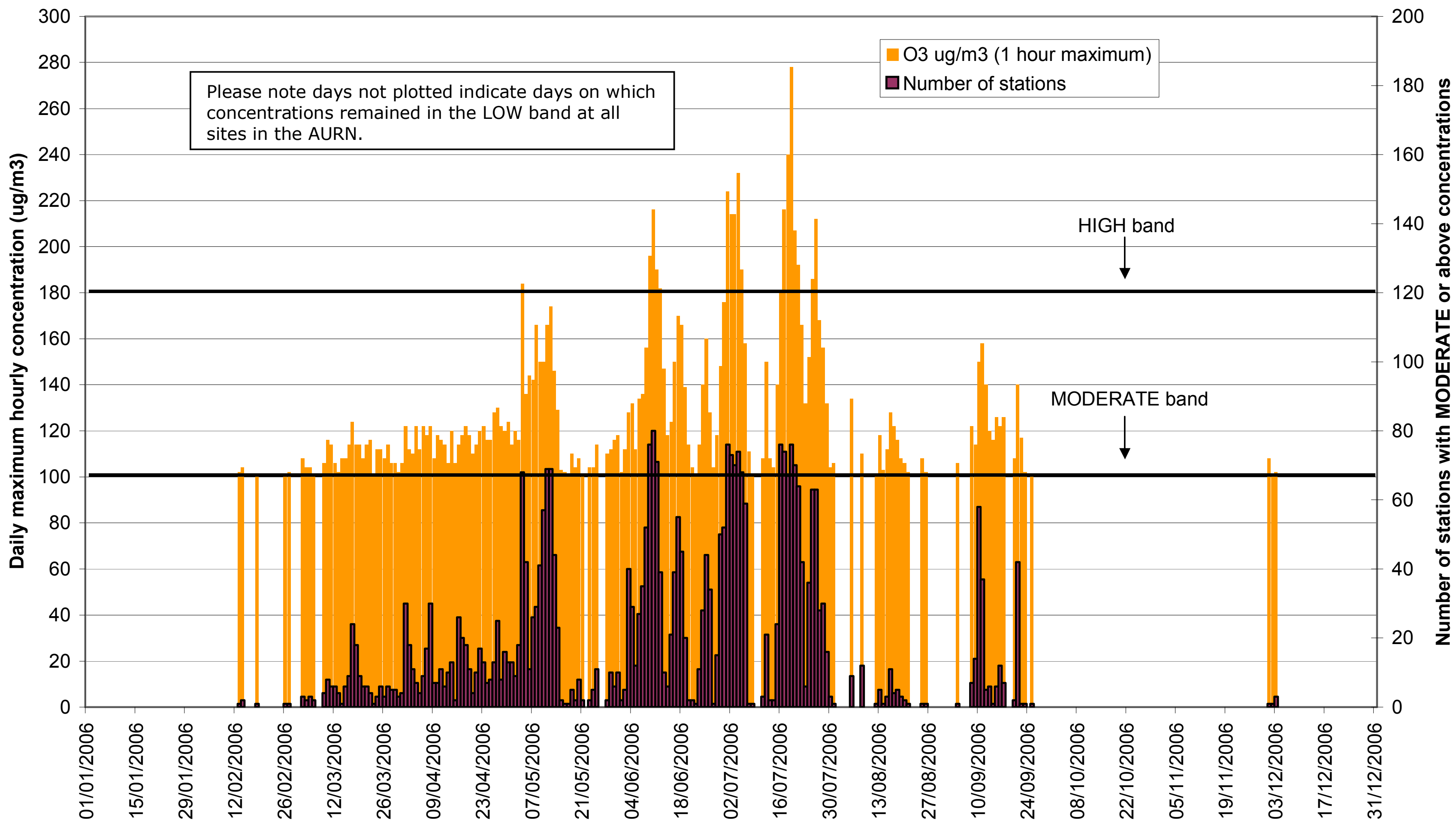

Figure 3.3 Daily maximum hourly ozone concentration across AURN Network with total number of stations measuring moderate or above levels of ozone over 2006.

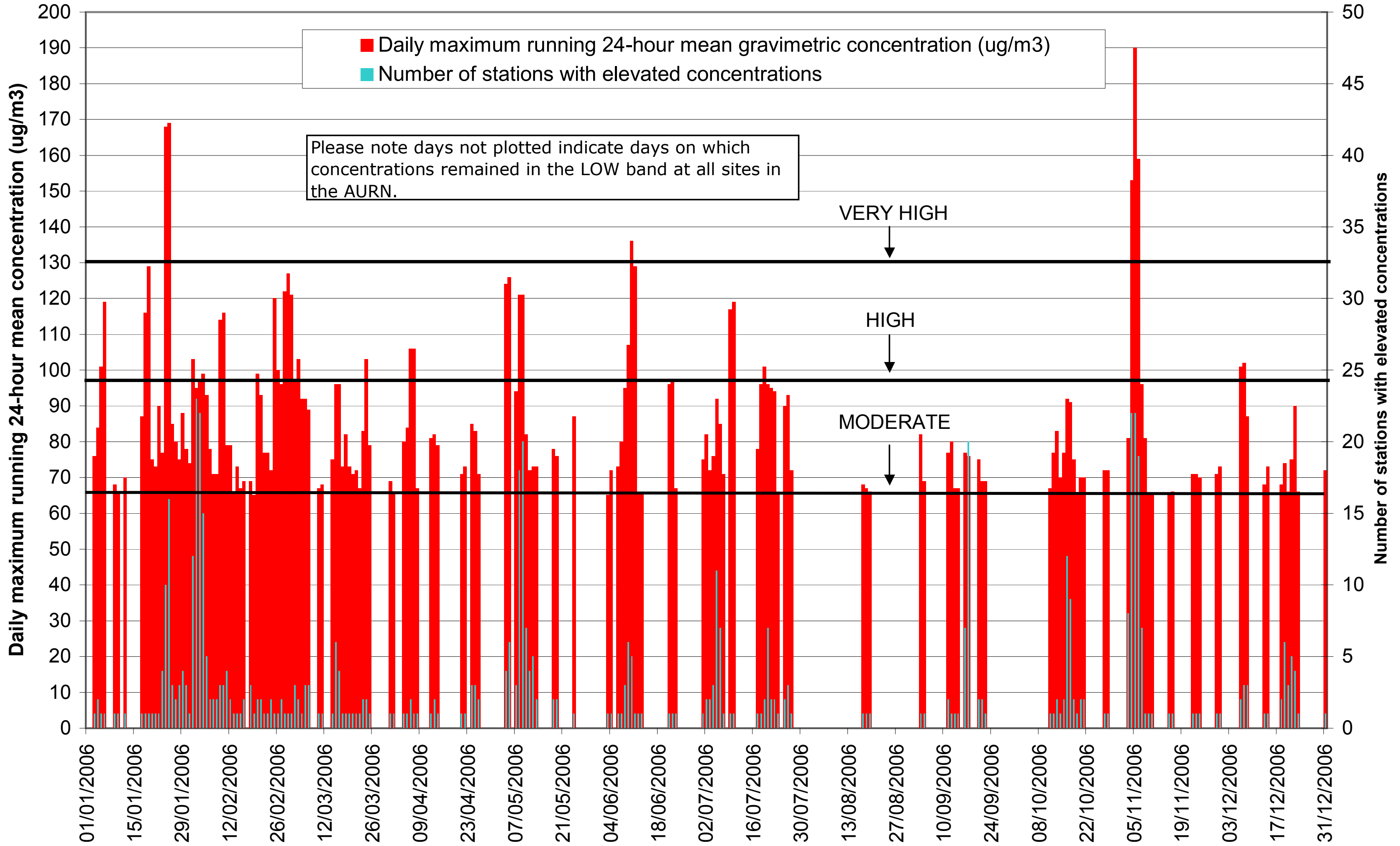

Figure 3.4 Daily maximum running 24-hour mean PM_{10} concentration across AURN Network with total number of stations measuring moderate or above levels over 2006

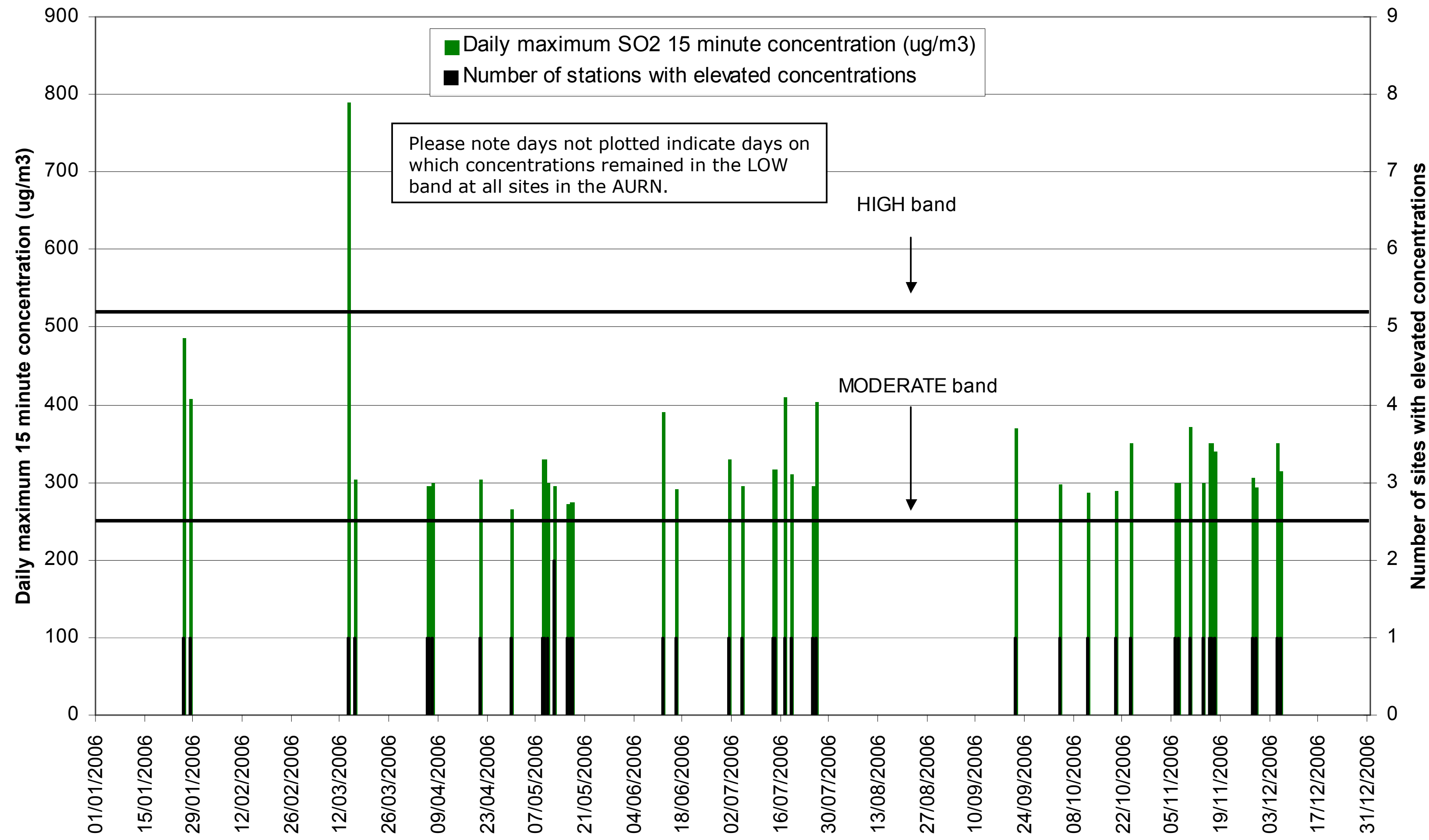

Figure 3.5 Maximum 15 minute average concentrations of SO_2 across AURN Network with total number of stations measuring moderate or above levels over 2006

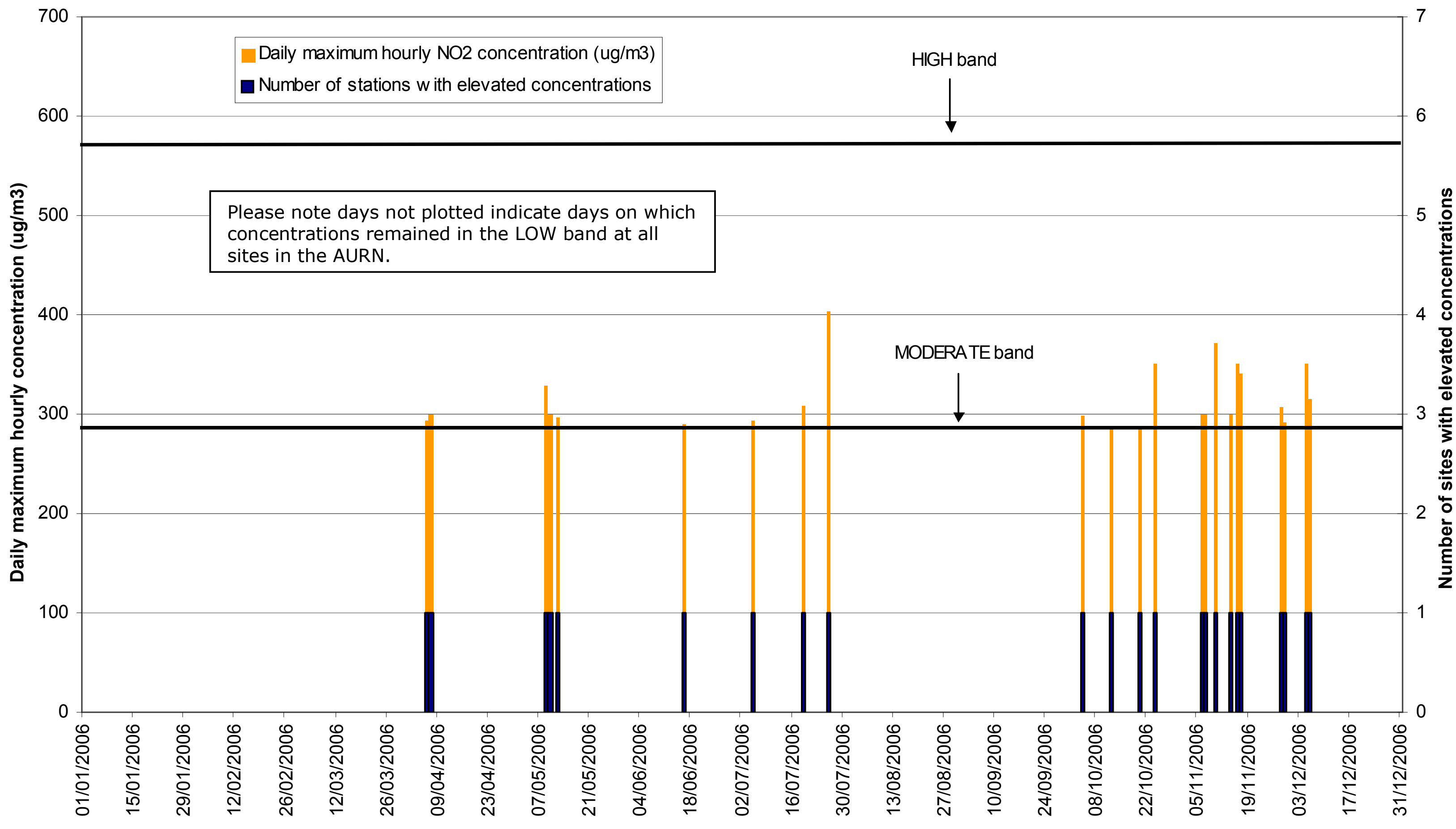

Figure 3.6 Daily Maximum hourly average of NO_2 across AURN Network with total number of stations measuring moderate or above levels over 2006

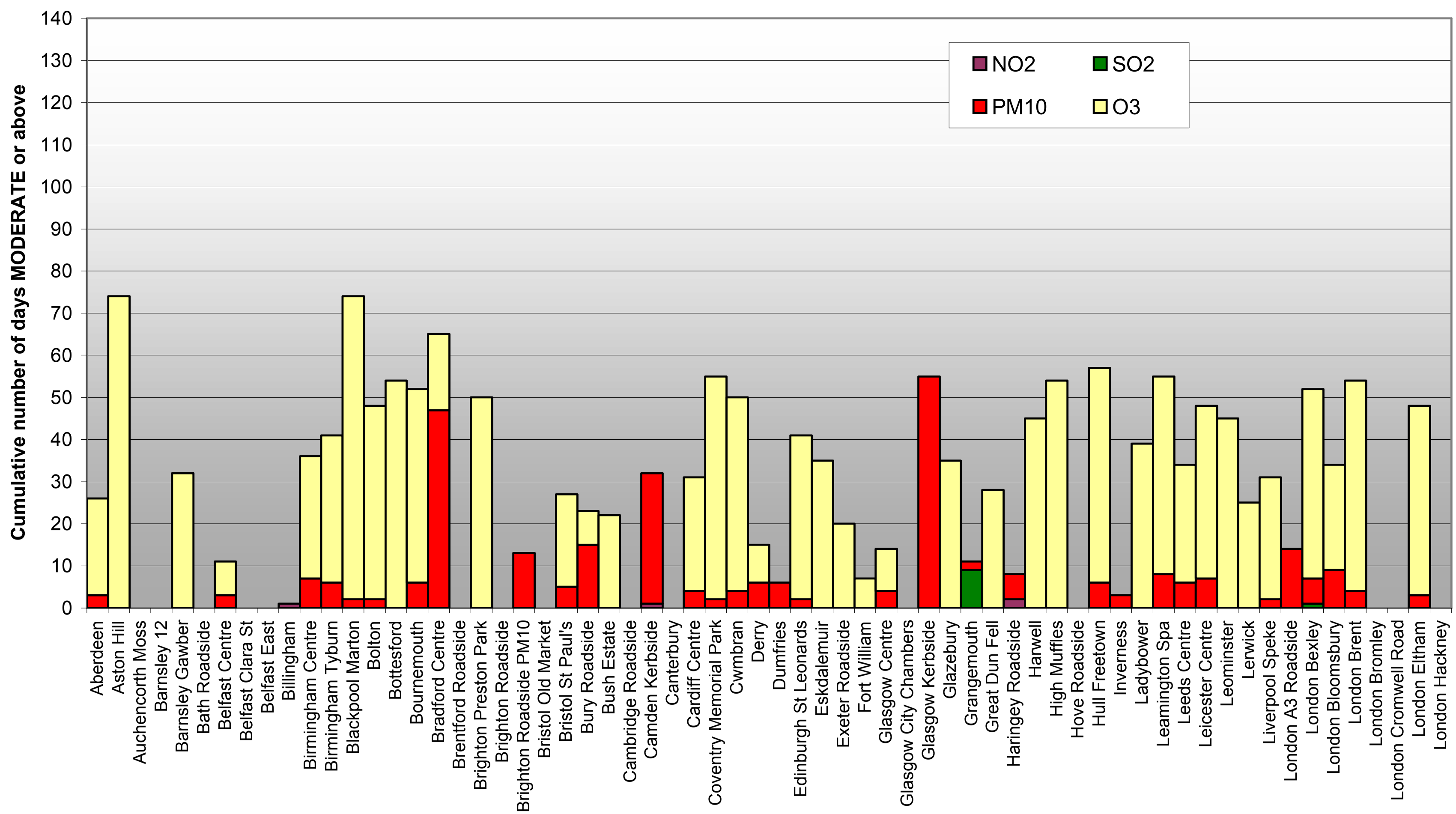

Figure 3.7a Number of days moderate and above for each AURN Network station over 2006 – provisional data

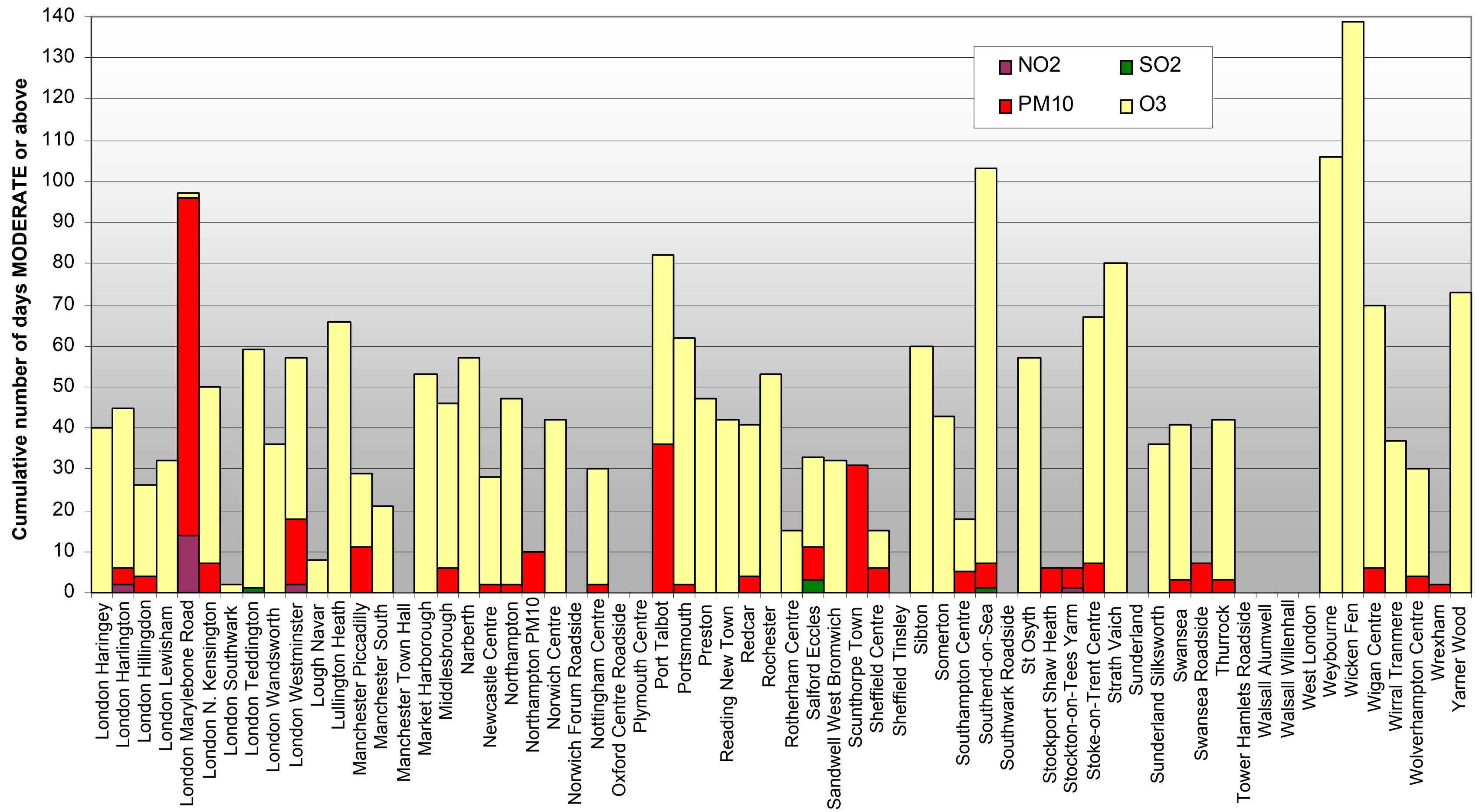

Figure 3.7b Number of days moderate and above for each AURN Network station over 2006 – provisional data

Table 3.3 – Summary of HIGH episodes year 2006

Pollutant	*No. of HIGH days*	*No. of MODE RATE days ^*	*Maximum concentration* (Index)*	*Site with max concentration*	*Zone or Agglomeration*	*Date of max conc.*	*Forecast success HIGH days (%)**** [no. incidents, zone or agglomoration days] **
Ozone	18	163	278 (Index 8)	Wicken Fen	Eastern UA	19/7	94 % [141]
PM_{10}	38	145	190 gravimetric ug/m^3 (Index 10)	Bristol St Paul's	Bristol UA	5/11	16 % [55]
NO_2	0	23	403 (Index 5)	Marylebone Road	London UA	26/7	[0]
SO_2	1	36	790 (Index 8)	Grangemouth	Central Scotland	14/3	0 % [1]
CO	0	0	3.4 (Index 1)	Hackney	London UA	7/11	[0]

** Maximum concentration relate to 8 hourly running mean or hourly mean for ozone, 24 hour running mean for PM_{10}, hourly mean for NO_2, 15 minute mean for SO_2 and 8 hour running mean for CO. Units ug/m3 throughout, except CO units mg/m3.*
*** the number of incidents is the total of the number of HIGH days in all zones and agglomorations (ie a HIGH day on the same day in many zones or agglomerations is counted as many incidents, not just one)*
**** The success rates for the number of HIGH days in table 3.5 have been calculated using calendar days (ie midnight to midnight) and therefore may not necessarily agree with the success rates calculated within the forecast analysis tables 3.1 and 3.2, which are calculated based on media forecast days starting generally at 3 pm each day.*
^ a MODERATE day is not counted on any HIGH day.

General trends

As seen in figures 3.1 to 3.6 PM_{10} levels were consistently in the Defra HIGH band during the first half of the year, but on fewer occasions in the second half. The most notable periods of HIGH pollution were during cold weather at the end of January, an episode of long-range pollution transport in May 2006 (see below for further details), and during the weekend of the Bonfire Night celebrations in November. PM_{10} episodes are often localised events, and for HIGH incidents, which tend to dominate in agglomerations where road traffic pollution, industry and construction are abundant, the success rate is normally low. This year it was 16% for 55 zone or agglomeration HIGH pollution-day incidents. This is to be expected since sources of PM_{10} are by their nature complex and often unpredictable. Despite improvements to the UK modeling, forecasting of PM_{10} pollution episodes continues to remain difficult.

Ozone entered the HIGH band 17 times during June and July 2006 due mainly to the exceptionally warm weather conditions. The success rate for forecasting HIGH band ozone-related episodes continues to be comparatively high (at 94% success based on zone or agglomeration day-incidents). This is partly because forecasters can see ozone levels progressively increasing over several days of hot, sunny weather and partly due to the accuracy of ozone models used in the forecasting process. Unsuccessful forecasts of ozone are therefore rarely the result of measured HIGH levels that are not forecast, but more often due to HIGH forecast levels that do not occur when an episode ends before the forecaster expects. Due to their regional nature ozone episodes inherently tend to be monitored at more locations than episodes for other pollutants (figures 3.3 and 3.4).

One sulphur dioxide 15-minute average reading entered the HIGH band during the year, measured at an urban industrial-designated site located near an oil refinery in Scotland.

Particulate matter

HIGH concentrations were measured periodically throughout 2006 at localized locations.

It is likely that these elevated PM_{10} levels were attributable to several factors including:

- Local emissions from industrial or construction sources.
- Poor dispersion due to low wind speeds, including recirculation of air over the UK and possible formation of secondary particulates from UK emissions.
- Easterly winds bringing secondary pollution across from Europe during warm settled weather (some days during the warm period over June and July).

Three incidents of widespread PM_{10} pollution were also recorded during the year.

The first occurred in early May when particulate-laden air, which was later modeled to have been sourced from western Russia and to have passed over parts of northern Europe, arrived over the UK between the 7th and the 12th May. The particulate-laden air met a weather front lying over the UK which slowly changed position over a period of several days, affecting which parts of the UK experienced the particles at ground level. Sites in Scotland and the north of England experienced the most intense effect over the first two days, with sites towards the south of the UK experiencing a diminishing effect as the weather front broke up over the remaining days. Twelve MODERATE exceedences were judged to have been the direct result of the particulate-laden air which was thought to have been primarily smoke from deforestation activities in western Russia. A later optical analysis of the episode dust revealed that a combustion process had been the source of the particles and was not due to a simultaneous pollen release seen in Europe and the UK. The episode had been cited as a possibility in an AEA Energy & Environment air quality forecasting team forecast bulletin several days in advance of the event and the majority of the episode was forecast successfully in the numerical form.

The second event occurred on 17th September when eighteen sites measured MODERATE levels. This was caused by polluted air, of European origin, becoming trapped behind a cloud front which had remained relatively stationary over the UK during the weekend of Saturday 16th and Sunday 17th September.

The third and final event happened on Monday 16th October when twelve sites entered the MODERATE band. Forecasted air trajectories over that period were predominantly westerly, although satellite imagery showed that a haze had built up over the North Sea on the 13th and had passed over to areas of the UK from the 14th to the 16th, until finally dispersing by the 18th.

Ad-hoc reports will be shortly available on the Air Quality Archive website detailing the first two of these long-range pollution episodes.

Bonfire night weekend celebrations also yielded an exceptional number of MODERATE and HIGH band exceedences this year in comparison to previous years. Figure 3.8 below shows a comparison of exceedences with earlier years from 2000 onwards.

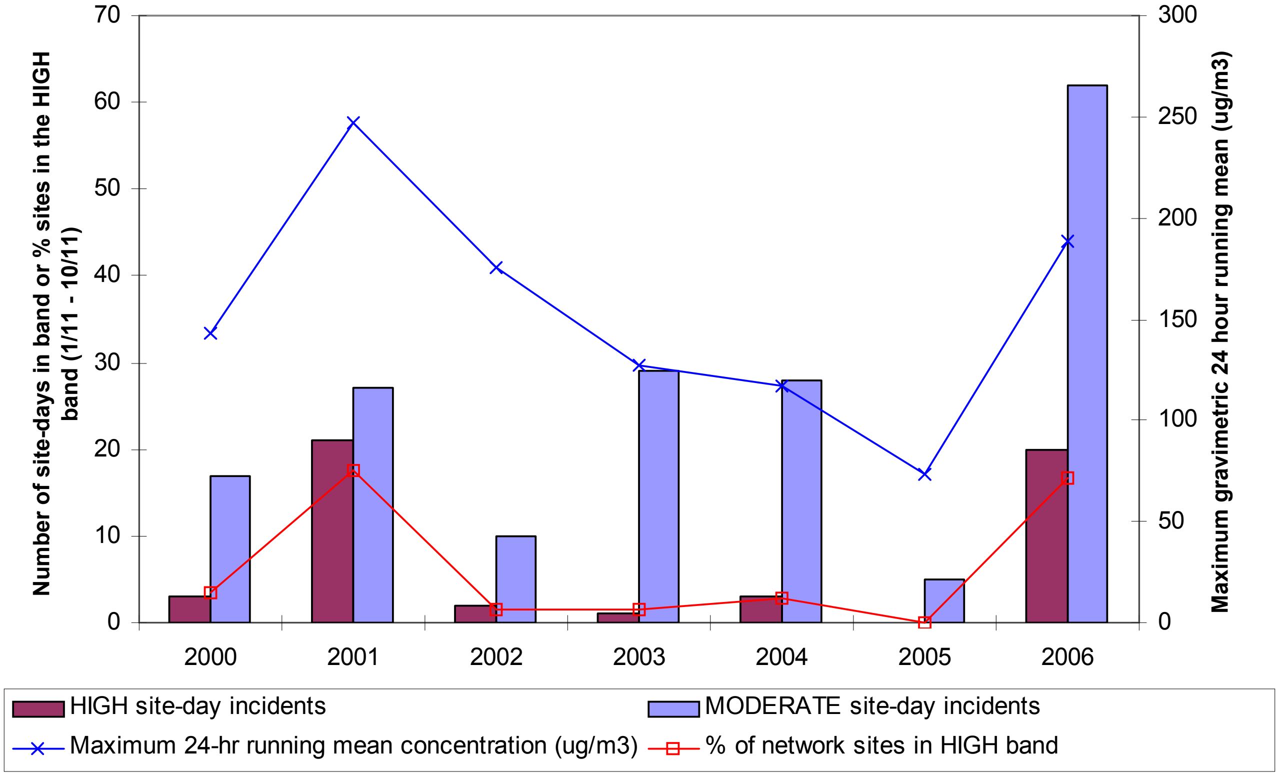

Figure 3.8: Number of sites exceeding the MODERATE and HIGH bands over 1st November to 10th November annually from the year 2000 onwards with additional descriptive statistics.

Overnight freezing conditions and a very light breeze, as a result of high pressure air towards the south of the UK, are likely to have been the cause of the exceptional number of exceedences, many of which were measured towards the south of the UK. The 5th November was a Sunday this year which meant that municipal bonfires and firework displays would have been held over a single weekend, opposed to the split normally associated with a mid-week November 5th, this is also likely to have contributed to the build up of elevated localised levels.

Figure 3.9 shows the overall number of PM_{10} exceedences annually from the year 2000 onwards, indicating that this year has been the second highest for elevated particulate levels in recent years.

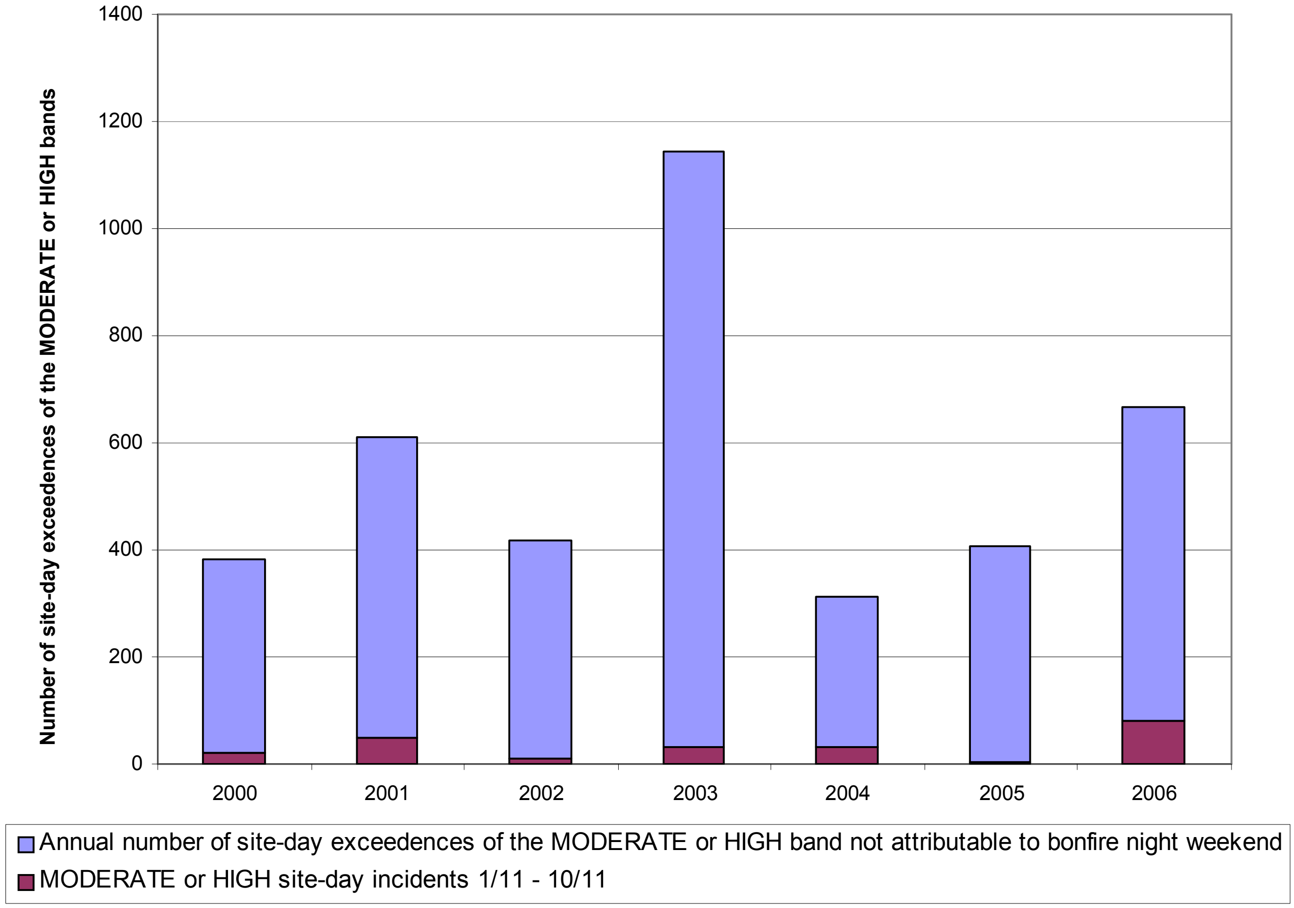

Figure 3.9: Annual number of site-day exceedences of the MODERATE or HIGH band for 2000 – 2006.

Ozone

Seventeen HIGH band days for ozone were recorded throughout June and July during a period of persistent and exceptionally warm weather.

Figure 3.10 below shows that 2006 has been the highest year yet recorded for elevated ozone levels in terms of overall site-day incidents of the HIGH band. Other descriptive statistics suggest that 2006 has been very similar to 2003 for ozone exceedences. Following the warm spell in June and July the wind direction generally turned westerly for August and the remainder of the summer, hence no further HIGH exceedences were measured in 2006.

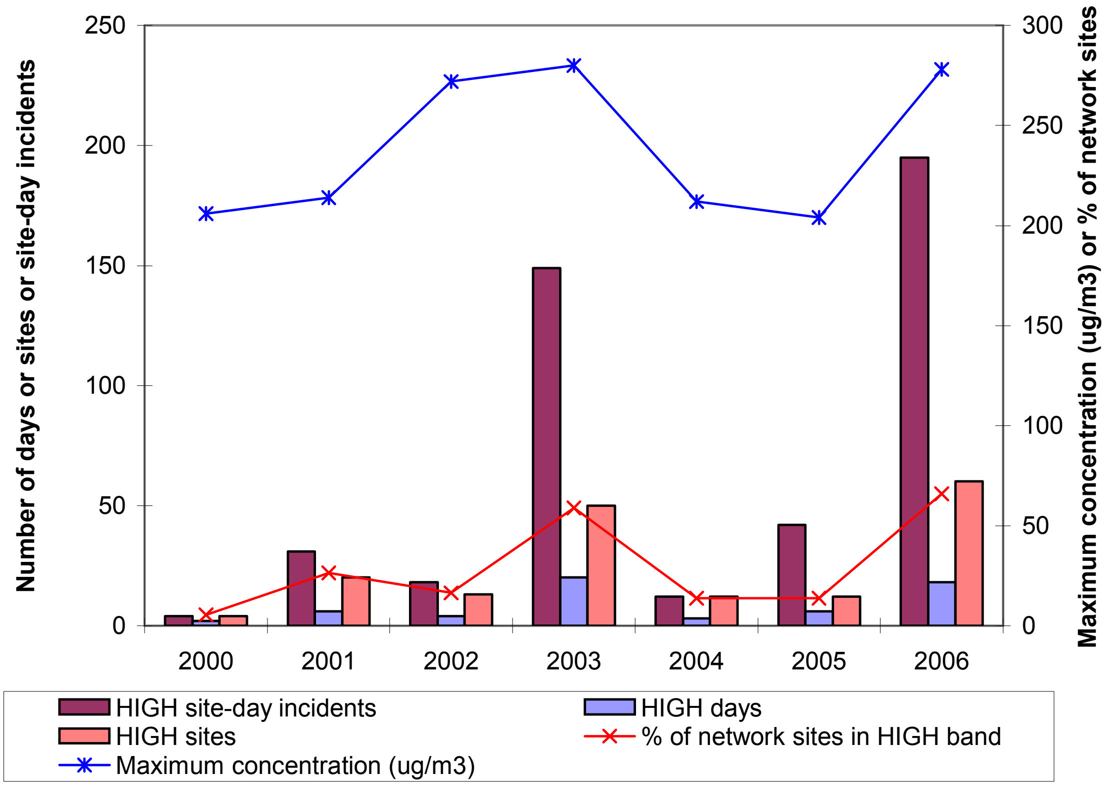

Figure 3.10: UK ozone episodes summarized for years 2000 onwards.

94 % of the 141 HIGH zone or agglomeration pollution-day incidents for ozone were forecast successfully.

An ad-hoc report is available on the Air Quality Archive website detailing the summer episodes, reference: Air Pollution Forecasting: Ozone Pollution Episode Report (June to July 2006) by Jaume Targa, AEA/ENV/R/2168.

Sulphur Dioxide

One HIGH day was measured during 2006 at the Grangemouth site in central Scotland on March 14th. A single 15 minute average reached index 8. This was likely to have been the result of emissions from the nearby oil refinery combined with local meteorological conditions. Thirty six MODERATE days were measured in 2006, most of these were at the Grangemouth site and other industrial locations in the network, but a number were also recorded in London during the hot summer weather. A more thorough analysis of the concentrations measured during the summer heatwave can be found in section 8 of the report "Air Pollution Forecasting: Ozone pollution episode report (June–July 2006)" which can be found at http://www.airquality.co.uk/archive/reports/list.php.

Nitrogen Dioxide

Twenty three MODERATE days were measured throughout the year. The majority of these were experienced at the kerbside London Marylebone site with the remainder from other London roadside sites and other network kerbside and roadside locations. These would all have been expected to have been as a result of traffic emissions and meteorological conditions unfavourable for atmospheric dispersion.

3.3 COMPARISON WITH YEARS 2003 ONWARDS

FORECASTING SUCCESS RATE

Figure 3.11 below shows the forecasting success rates for the whole of the UK for years 2002 to 2006. This is the percentage of HIGH days that were correctly forecast.

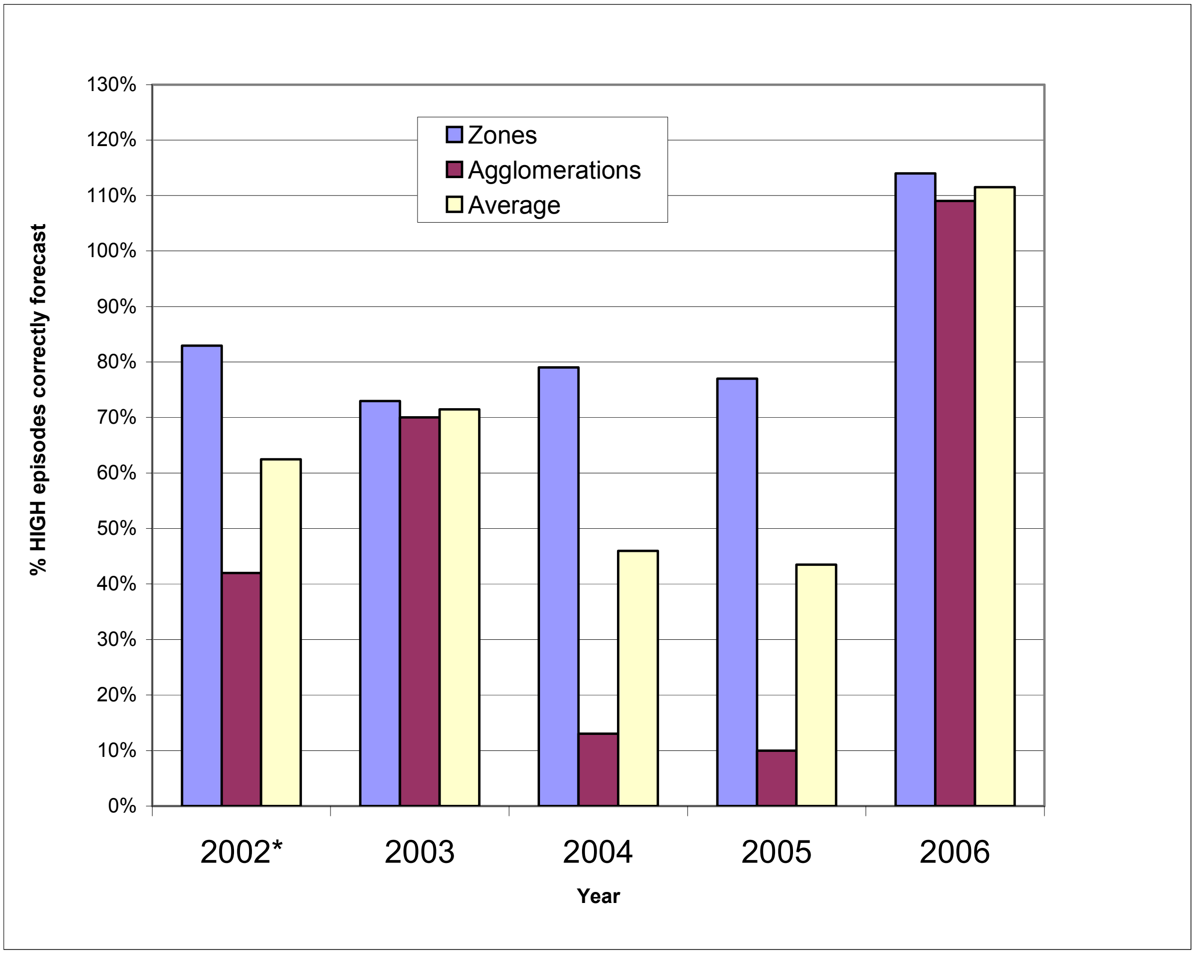

Figure 3.11 - Forecasting Success Rates for the whole of the UK, 2003-2006
*** 2002 was a partial year for forecasting analysis calculations.**

The forecasting success rate for zones has improved by around 35 % and has improved significantly in agglomerations (by approximately 100 %), bringing the average success rate up by 70 % to an overall 112 %. Please note success rates greater than 100% are possible, as detailed in section 3.1. Normally, there is a notable difference in performance in zones and agglomerations as the figure above illustrates, although they tend to be closer during years of significant ozone episodes. Of the 67 HIGH measurements experienced in agglomerations 11 were due local building works and 2 as a result of localised industrial activity (therefore at least 20 % of the HIGHs could not have been reasonably predicted). Zones tend to be characterised by ozone episodes because they include smaller conurbations and large rural areas where ozone is the dominant air pollutant. Agglomerations, which conversely cover large urban and industrial areas, tend to be characterised by local particulate episodes and higher road traffic pollution which results in NO_x scavenging of ozone. The forecasting system currently predicts ozone episodes with a greater degree of success and accuracy than PM_{10}. In 2006 the zones and agglomerations success rates were more similar due to the exceptionally large number of ozone episodes (very successfully predicted) in this heat-wave year.

In terms of MODERATE forecasts, which by far represent the majority of forecasts issued, even greater success rates were achieved, as have always been seen historically, with a 143 % success rate for zones and 158 % success for agglomerations (success rates are able to exceed 100% as an agreement of within one index band is used for the analysis).

LOCALISED INFLUENCES

In addition to the problems of interpreting and forecasting the weather patterns, there are also occasional difficulties in forecasting accurately in areas where local effects on pollution are significant and unpredictable. The following are examples of such sites that reported HIGH concentrations during 2006:

- Scunthorpe is surrounded by local heavy industry, which often results in unpredictable elevated concentrations of PM_{10}.
- Port Talbot monitoring station is located to the NE of the Corus Steelworks. As a result, emissions from the works are known to contribute to local PM_{10} concentrations when winds are southwesterly.
- Glasgow Kerbside regularly reports elevated PM_{10} concentrations as a result of its kerbside location. In addition, there is a taxi rank nearby and vehicles with idling engines for long periods may contribute to local levels.
- Bradford continued to experience a large amount of nearby building works for the first half of the year.
- Building work related activities occurred over a short period near the Leamington Spa site.

OVERALL CONTRIBUTION FROM UK AND EUROPE IN SUMMER, FROM 2000 ONWARDS

Figure 3.12 shows the number of network days measured above various thresholds for ozone over the summers of the last seven years. The total number of days in the MODERATE band or above was very similar, albeit slightly higher, than that seen in 2003. However, the summer of 2003 yielded a slightly higher number of days at HIGH or above and also days above the EC alert threshold, set at 240 ug/m^3 for an hourly average.

Figure 3.13 shows the percentage contribution of air masses reaching the UK from either Europe or recirculated air from the UK itself / incident Atlantic air, for days of ozone at MODERATE or above during the summers of 2000 onwards. The data for this chart was derived by “per-region” analysis of simple 96-hour forecast air mass back-trajectory plots for all MODERATE days from April to the end of September. The chart indicates that a larger number of MODERATE or above network-days were measured as a result of UK-only air compared to European air, at a similar ratio experienced in years 2001 and 2002. A higher contribution from European sources was seen in 2006 compared to the previous year, due in part to mixed air trajectory directions during the warmest period in the summer of 2005.

During the HIGH ozone episodes and long-range transport PM_{10} episodes of 2006 air trajectories were predominantly easterly and therefore European. One hundred and ninety five site-days were measured for the HIGH band during the summer, suggesting that measurements often went HIGH during European air trajectories, perhaps the reason why a greater number of MODERATEs were measured as a result of UK-only contributions. Figure 3.14 shows a similar air mass source contribution plot for the HIGH band or above. The data presented indicates that 2006 was an average year for European air contributing to HIGH ozone exceedences based on analysis of 1-day ahead air mass back-trajectory forecasts. It is thought unlikely that HIGH band exceedences could be measured as a result of air masses from exclusively non-European sources, therefore the 40% contribution to the HIGH band from non-European air masses is likely to represent days of mixed air mass origin or inaccuaries in the 1 day ahead forecast trajectories issued.

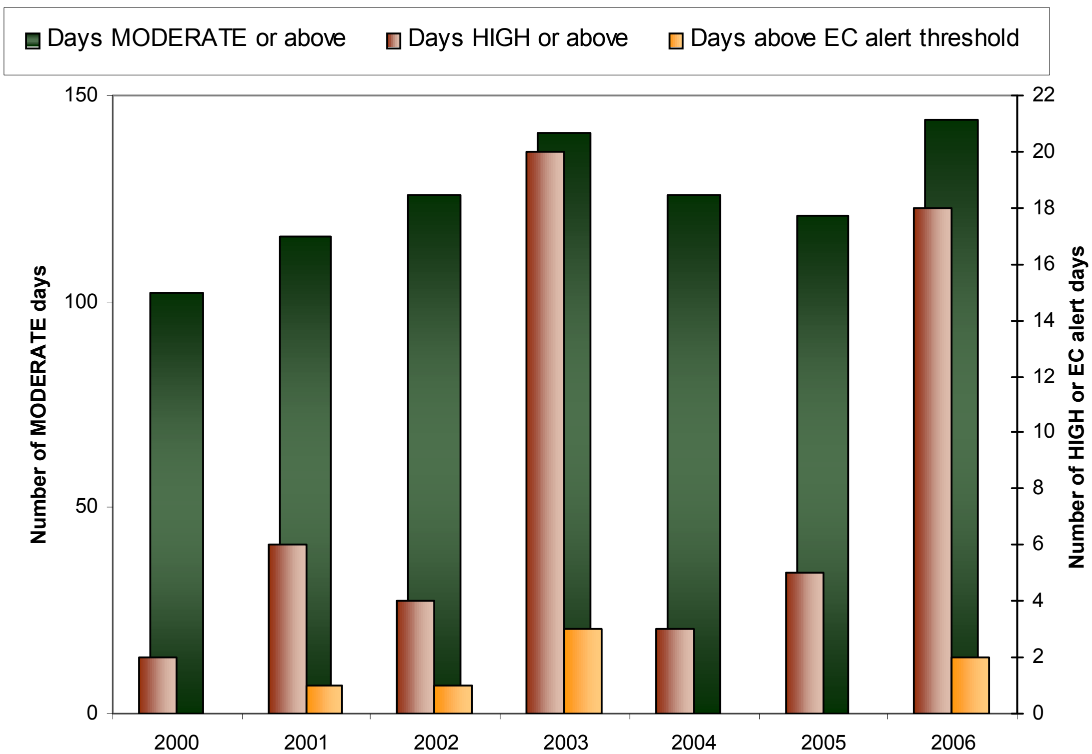

Figure 3.12 –Total network days exceeding various thresholds for ozone over the summers of 2000 onwards.

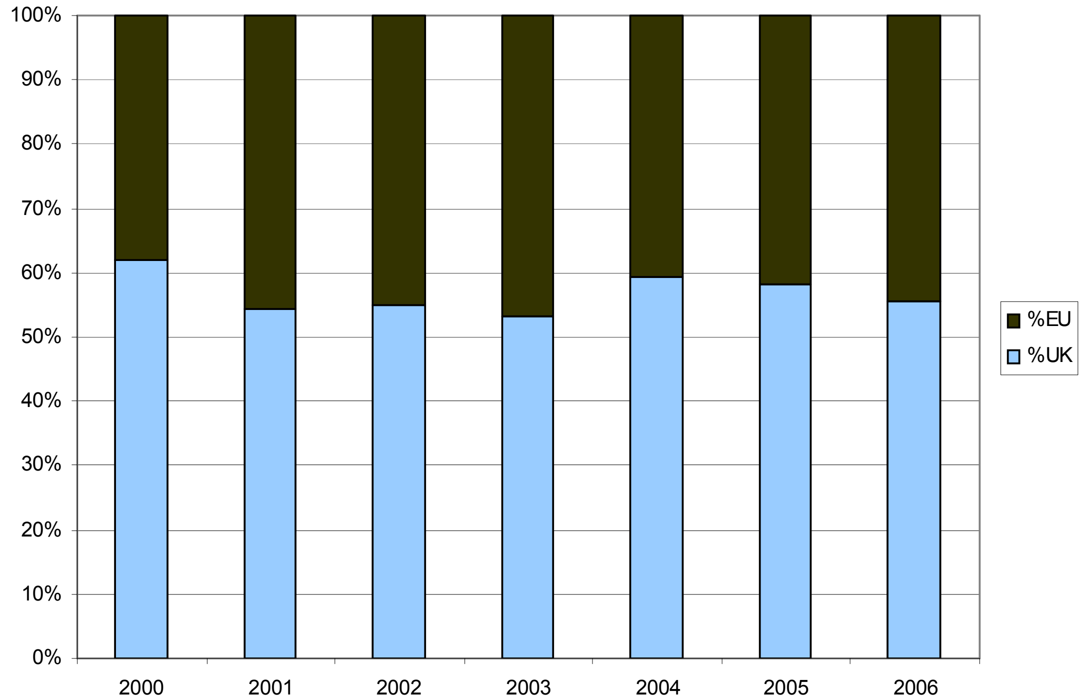

Figure 3.13 – source contributions for MODERATE or above exceedences of ozone over summers from 2000 onwards.

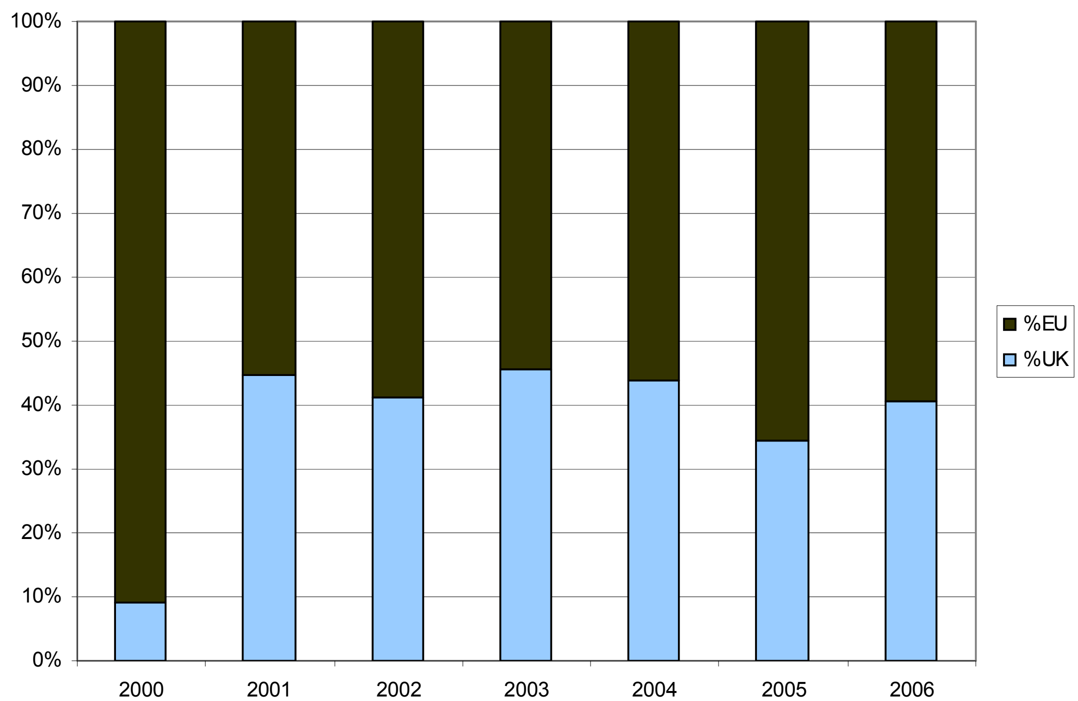

Figure 3.14 – source contributions for HIGH or above exceedences of ozone over the summers of 2000 onwards.

Figure 3.15 shows the number of HIGH or above days per region of the UK due to ozone over the summers of 2000 onwards. The highest number of HIGH days was measured in the Eastern region for 2006, a total of 15 days. During the episodic summer of 2003 the South East was the most affected region of the UK and measured an identical number of HIGH region-days as the Eastern region in 2006. This figure also shows that the HIGH band episodes were more uniformly widespread over the UK in 2006 compared with the summer of 2003. The 2003 episodes appear to have been more confined to the south east of England in comparison. Normally the south east reaches the warmest daytime temperatures for the whole of UK during the summer and is often the first region, along with the Eastern region, to experience polluted air from Europe on easterly breezes. Scotland and Northern Ireland also both measured a HIGH day on the 19th July 2006, the most pronounced day for ozone exceedences.

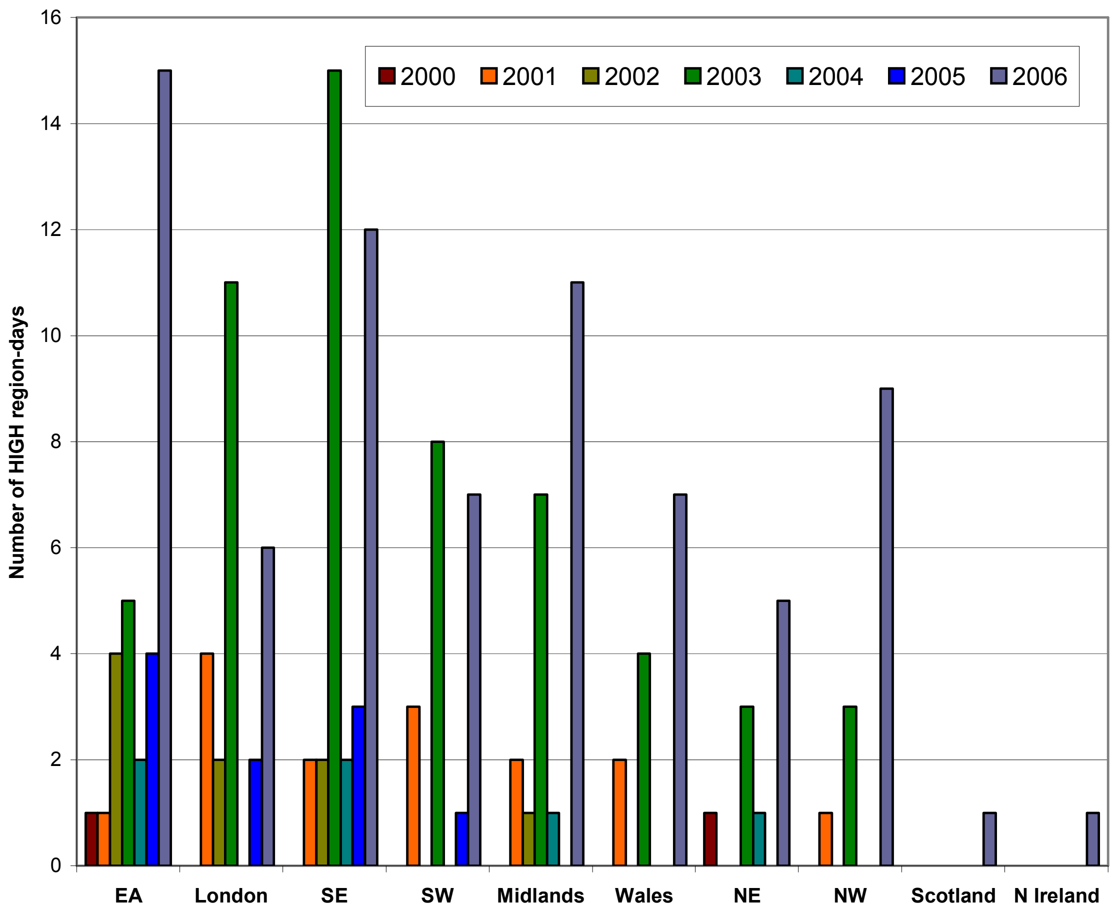

Figure 3.15 – HIGH band exceedences for ozone from the year 2000 onwards by region.

4 Seminar on the Buncefield Oil Depot Explosion

The Fifth Annual Air Pollution Forecasting Seminar - hosted by Netcen on behalf of Defra and the Devolved Administrations – was held on Thursday 22nd June 2006 at Culham Science Centre, near Abingdon in Oxfordshire. More than 70 delegates and speakers attended. The seminar this year provided a forum for organisations involved in the Buncefield incident to present the results of their work.

Buncefield was the largest industrial fire in Europe for over 50 years. Estimations using the National Atmospheric Emissions Inventory have shown that the fire released 5% or more of annual UK air emissions of some pollutants – PM_{10}, $PM_{2.5}$ and benzo(a)pyrene. Emissions of other pollutants such as NO_2, CO and NMVOC were lower at < 0.1% of total annual emissions. The emergency response team of the Chemical Hazards and Poisons Division of HPA was quickly in action following the explosion, which took place at around 6 a.m. on Sunday 11th December 2005. The team worked with local and regional services and the NHS to form the Health Advisory Team (HAT) that advised multi-agency GOLD command. The team quickly received modelling input from the Met Office and the Environment Agency and requested environmental monitoring. Local, portable indicative air quality monitoring by Netcen showed high concentrations of particulate matter and unburnt hydrocarbons close to the fire. The Netcen team could see the plume rising overhead but could not detect increased concentrations downwind, where the plume appeared to be close to the ground. Concentrations of pollutants measured in nearby residential areas were low. There was much discussion of the difficulties in deploying emergency-response air quality monitoring equipment quickly to the scene of such an incident.

Data from UK national air monitoring networks were analysed in detail but, to-date, these show no evidence of significant ground level air quality impacts from the Buncefield plume. Likewise, similar analysis of national monitoring data from Northern France also showed no evidence of any major ground-level impacts. Additional data available from the local and regional monitoring networks co-ordinated by King's College Environmental Research Group has shown some small and short-term (15-minute) PM_{10} peaks at a few sites in Hertfordshire, North London, Surrey and Sussex. Modelling by the Met Office using the advanced NAME III system confirms that the air arriving at these sites at the times of the peaks could have come from the Buncefield area. Despite these sporadic transient events, comparison of ground-level air quality data with health-based air quality standards shows that pollution levels remained "low" or just into the "moderate" category at all national and regional monitoring locations in the southeast, for the duration of the incident. Airborne air quality measurements of the plume by the Met Office instrumented FAAM aircraft showed that the plume was mainly composed of black soot. Carbon Monoxide (CO) and Oxides of Nitrogen (NO_x) were detected but not in large quantities. Concentrations of toxic PAHs and Dioxins measured in the plume were small. The Met Office undertook detailed modelling of the plume both before and after the event. This involved large uncertainties, especially in the early stages when the composition and amount of fuel burning was not known accurately. Observations by civilian aircraft helped to fine-tune the Met Office model results. Due to the exceptional plume buoyancy and meteorological conditions, the smoke and other emissions from the fires rose high into the atmosphere before dispersing. This helps explain why ground level impacts on air quality were minimised.

The Met Office has modelled several alternative scenarios for other meteorological conditions and their conclusion was that, even under a range of other conditions to those experienced in the real case, the modelled predicted ground-level pollution concentrations would not have been significantly higher.

5 Breakdowns in the service

All bulletins were successfully delivered to the Air Quality Communications contractor on time and there were **no reported breakdowns** in the service over the year.

There was a **100% success rate** in uploading the forecast bulletins to the Air Quality Communications contractor and no breakdowns in the service were reported during the rest of the year.

6 Additional or enhanced forecasts

No formal enhanced forecasts can be issued until the format of the new service has been agreed with Defra and the Devolved Administrations. Nevertheless, there have been numerous informal discussions by email and telephone between the AEA Energy and Environment forecasters and Defra during this period. In particular, these were frequent during the ozone pollution episode at the end of June and July.

The air pollution forecast is always re-issued to Teletext, Web and Freephone services at 10.00 a.m. local time each day, but this is only updated when the pollution situation is changing.

The bi-weekly air pollution outlooks have continued to be delivered successfully to Defra and other government departments by email on Tuesdays and Fridays.

7 Ad-hoc Services

During this year, four ad-hoc reports were presented to Defra and the devolved administrations. This detailed the extent and circumstances of pollution episodes and are listed below:

- Initial review of Air Quality aspects of the Buncefield Oil Depot Explosion
- An ad-hoc report detailing HIGH ozone levels during June and July.
- Two ad-hoc reports detailing particulate episodes experienced in May and September 2006.

All episode reports can be found on the National Air Quality Archive at (www.airquality.co.uk/archive/reports/list.php).

In addition to these formal reports, regular contact was maintained with Defra and the Devolved Administrations throughout regarding possible 'HIGH' pollution levels over the UK.

8 Ongoing Research

8.1 INCREMENTAL DEVELOPMENTS

AEA Energy & Environment and the Met office will continue to:

1. Investigate ways of using automatic software systems to streamline the activities within the forecasting process, thus allowing forecasters to spend their time more efficiently considering the most accurate forecasts.
2. Research the chemistry used in our models, in particular the NO_x->NO_2 conversion used in NAME, and the chemical schemes for secondary PM_{10} and ozone.
3. Improve the NAME model runs that can be used for ad-hoc analyses, in particular with regard to investigating the possible long-range transport of PM_{10} pollution from European sources and the long-range transport of particles from Saharan Dust Storms.
4. Improve and update the emissions inventories used in our models.

9 Scientific Literature Review

This section reviews a selection of the scientific literature available in the public domain that is relevant to air quality forecasting. A list of reports produced by the UK Met Office during 2006 is also provided at the end of this section.

Recent literature concerned with air quality forecasting is summarised below.

9.1 CLUSTER OF EUROPEAN AIR QUALITY RESEARCH PROJECTS - FUMAPEX PROJECT

The main objectives of this project were the improvement of meteorological forecasts for urban areas, the connection of NWP (numerical weather prediction) models to UAP (urban air pollution) and exposure models, the building of improved UAQIFS (Urban Air Quality Information and Forecasting Systems), and their application in cities in various European climates.

The necessary steps were scheduled to evolve in ten separate, but inter-linked Work Packages realised by 16 participants and 6 subcontractors who represent leading NWP centres, research organisations, and organisations responsible for urban air quality, population exposure forecast and control, and local/city authorities from ten European countries.

The main objective of FUMAPEX was to yield improved, validated, inter-compared, and accessible UAQIFS implemented in an increasing number of European cities. The conclusions listed in the final report on completion of the project were:

"Urban areas modify significantly many parameters that affect micrometeorology, including surface roughness, moisture, albedo and, correspondingly, dynamical and thermal structures in the urban boundary layer. They are additionally affected by heating and other energy consuming processes acting as anthropogenic energy sources. A large fraction of anthropogenic emissions to the atmosphere also occur within this very same area, where also a large majority of the western populations are located. Until now air quality models have been unable to reliably estimate air pollution levels especially during the events with the most urgent need for reliable information, namely the air pollution episodes. Latest improvements in numerical weather prediction (NWP) models, realised in FUMAPEX, allow the inclusion of urban area features, and therefore, describe the state of the urban mixing layer more realistically than ever before. This is an essential prerequisite for reliable air quality modelling in urban areas. Urban populations are mobile throughout their daily activities. Large fractions of the population concentrate on traffic arteries during the rush hours, when the air quality especially in these environments is the poorest. People concentrate in downtown areas during the daytime simultaneously when the air quality is lowered through traffic and other emissions. On the other hand, urban populations spend large fractions of their time in indoor environments, where the building partly shields them from the pollution in the ambient air. These phenomena have profound effects on actual population exposures within cities and should be accounted for when evaluating air quality and planning actions aiming at protection of the public health. FUMAPEX demonstrates the integration of NWP with air quality modelling systems in six target cities and combines such urban air quality information and forecasting systems (UAQIFS) with the modelling of population exposures during episode conditions. Such an integrated UAQIFS allows for reliable air quality and exposure forecasting and supports effective decision-making in short-term air quality management and emergency preparedness. Additionally, these systems are valuable tools in long-term city planning for the optimization of urban environments in terms of minimised population exposure and associated health risks. Applications of the suggested integration strategy and improved UAQIFS are demonstrated in the six target cities considered: urban air pollution episode forecasts and assessments for Helsinki, Oslo, Bologna, Torino and Castellon/ Valencia, and urban emergency preparedness modelling for Copenhagen. Additionally, some tests and validations of the improved models were done for Paris, London, Marseilles and Basel."

Further information can be found at: http://fumapex.dmi.dk/

9.2 CAMBRIDGE ENVIRONMENTAL RESEARCH CONSULTANTS - THE "PROMOTE" PROJECT

A project on air quality and UV forecasting at the European, National and Local scales.

The project is sponsored by the European Space Agency/Framework 6 Global Monitoring for the Environment and Security Programme (GMES). The forecasts will make use of satellite and ground based measurements and a range of models for different spatial scales. A model called "ADMS-Urban" is being used to provide high resolution local forecasts. The main phase of the project, which is current, will last from 2004 – 2008.

In late March 2007 the city of London launched an innovative service called "airTEXT", delivering air pollution alerts and health advice via SMS text messages to those who suffer from asthma and other conditions related to poor air quality. CERC developed airTEXT using information from ESA's PROMOTE project. The service works by combining satellite data from ESA's Envisat on regional air quality forecasts provided by PROMOTE with information on local road traffic patterns and monitoring stations around the city. PROMOTE additionally aims to construct and deliver a sustainable and reliable operational service to support informed decisions on the atmospheric policy issues of stratospheric ozone depletion, surface ultraviolet (UV) exposure, air quality and climate change.

GMES (Global Monitoring for Environment and Security) is a next flagship initiative for space in Europe. It was confirmed as the European Union's priority at the 2001 Summit in Gothenburg, where the Heads of State and Government requested that "the Community contribute to establishing by 2008 a European capacity for Global Monitoring for Environment and Security". ESA is the main partner to the European Union in GMES and has contributed with programmatic activities since 2001 to the GMES endeavour. ESA has worked on the development of GMES pilot services in close conjunction with a large community of operational users. ESA is also working on multi-mission facilities and ground segment operations and is preparing the Space Component for GMES with a series of studies and preparatory activities for the development of a series of satellites missions (the sentinels) and the integration of national and European missions to guarantee continuity of data and services.

GMES is the response to the need by Europe for geo-spatial information services. It provides autonomous and independent access to information for policy-makers, particularly in relation to environment and security.

GMES represents also the European contribution to the international Global Earth Observation System of Systems, GEOSS, which was established at the third Earth Observation Summit in Brussels, in February 2005.

Further information can be found at: http://www.esa.int/esaLP/LPgmes.html

9.3 CAMBRIDGE ENVIRONMENTAL RESEARCH CONSULTANTS

CERC have released a recent report on developments and future developments in air quality forecasting. This covers rural forecasting, urban forecasting, regional chemistry and transport modeling and future projects. Two years of past data have been used to validate a third future year using an in-house (ADMS-Urban) developed model. Reasonably high success rates were attained with variable rates of accuracy for ozone in South East England and reasonable success and accuracy rates for particulate measurements at Glasgow Kerbside. The report mentions the "Lifecare" programme which will use satellite measurements of air composition as boundary conditions for regional and local scale models and for a stratospheric model to calculate total ozone and hence UV indicators. Among the Lifecare products are listed:
air quality forecast data on continental scale, European scale and regional scale (e.g. Central Europe) for particulates, O3, NO2, resolution of 5km – 1km, air quality forecast data on local scale for European pilot cities. Monitoring of NO2 and aerosol.

The conclusions of the report were:
Urban forecasts on fine scales can be made using an advanced Gaussian dispersion model if emissions inventories met forecasts are sufficiently accurate. Rural forecasts of ozone, PM10 in the UK are amenable to forecasting using empirical methods. Advances in operational regional forecasting systems through the improvement of emissions inventories, mesoscale models and satellite and ground based data assimilation will provide benefits for both regional flux estimates, rural forecasts and urban forecasts.

http://bscct01.bsc.es/aqforecast-en/developments.psp

9.4 AIRNOW PROGRAM

The United States' EPA, NOAA, NPS, tribal, state, and local agencies developed the AIRNow Web site to provide the public with easy access to national air quality information. The web site offers daily nationwide AQ forecasts for over 300 major U.S. cities as well as real-time nationwide and regional real-time ozone air quality maps covering 46 U.S. states and parts of Canada, updated on an hourly basis.

The air quality data used in the maps, and to generate forecasts, are collected using either federal reference or equivalent monitoring techniques or techniques approved by the state, local or tribal monitoring agencies. Although some preliminary data quality assessments are performed, the data are not fully verified and validated through the quality assurance procedures officially used to submit and certify data on the EPA Air Quality System. Data are therefore used on the AIRNow web site only for the purpose of reporting AQ Information.

This program is also mentioned in a document relating to air quality forecasting activities in the United States 2006 which can be found at:

http://www.narsto.org/files/files/AQForecastingEPA.pdf

Reports produced by the UK Met Office during 2006 are listed below, with a brief summary included:

* 'Measurement and modelling of air pollution and atmospheric chemistry in the U.K. West Midlands conurbation: Overview of the PUMA Consortium project', Science of the Total Environment Journal number 360, 5-25, 2006. Harrison R.M., Yin J., Tilling R.M., Cai X., Seakins P.W., Hopkins J.R.Lansley D.L., Lewis A.C., Hunter M.C., Heard D.E., Carpenter L.J.Creasey D.J., Lee J.D., Pilling M.J., Carslaw N., Emmerson K.M., Redington A., Derwent R.G., Ryall D., Mills G. and Penkett S.A.

Data resulting from intensive measurement campaigns undertaken in 1999 in the West Midlands conurbation, which included detailed speciation of VOCs and component analysis of aerosols, was modelled using two generic model types. A good simulation of primary and secondary pollution in urban background environments was created.

* 'Dispersion Modelling Studies of the Buncefield Oil Depot incident', Hadley Centre Technical Note 69, Met Office, August 2006. Webster H.N., Abel S.J., Taylor J.P., Thomson D.J., Haywood J.M. and Hort M.C.

This report describes emergency response work undertaken by the Met Office at the time of the event and results from plume modelling studies carried out subsequently. Measurements taken from an aircraft during the incident indicated that the plume was mainly composed of soot, with unexceptional levels of non-particulate pollutants encorporated. A copy can be found at:

http://www.metoffice.gov.uk/research/hadleycentre/pubs/HCTN/HCTN_69.pdf

* 'Forecasting a healthy summer', Barometer, 4, 17, 2006. Witham, C. This web-based publication explains the effect of summer weather on air quality levels.

http://www.metoffice.gov.uk/publications/barometer/issue4/healthy_summer.html

10 Forward work plan for 2007

- The two tables below summarise both the weekly and annual activity for 2006/2007 (Table 10.1 and 10.2 respectively).

Table 10.1 Weekly Activity Chart

1 Task	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Daily Forecast							
Forecast Outlook Summary							

Table 10.2 Annual Activity Chart

2 Task	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Quarterly Reports												
Quarterly Progress Meetings												
Annual reports												
Seminars												

11 Hardware and software inventory

Defra and the Devolved Administrations own the code for the ozone and secondary PM_{10} models, but not the graphical interface for these. Defra and the Devolved Administrations own the software for delivering the air pollution forecast to the Air Quality Communications system. Defra and the Devolved Administrations also own the web pages used to display the forecasts.

No computer hardware being used on this project is currently owned by Defra and the Devolved Administrations.

12 References/Internet links

http://fumapex.dmi.dk/

http://www.esa.int/esaLP/LPgmes.html

http://bscct01.bsc.es/aqforecast-en/developments.psp

http://www.narsto.org/files/files/AQForecastingEPA.pdf

http://www.airquality.co.uk/archive/reports/list.php.

Appendix 1 - Air Pollution Index

CONTENTS

Old Banding	Index	Ozone 8-hourly/ Hourly mean		Nitrogen Dioxide Hourly Mean		Sulphur Dioxide 15-Minute Mean		Carbon Monoxide 8-Hour Mean		PM_{10} 24-Hour Mean
		μgm^{-3}	ppb	μgm^{-3}	ppb	μgm^{-3}	ppb	mgm^{-3}	ppm	gravimetric μgm^{-3}
LOW										
	1	0-32	0-16	0-95	0-49	0-88	0-32	0-3.8	0.0-3.2	0–21
	2	33-66	17-32	96-190	50-99	89-176	33-66	3.9-7.6	3.3-6.6	22-42
	3	67-99	33-49	191-286	100-149	177-265	67-99	7.7-11.5	6.7-9.9	43-64
MOD										
	4	100-126	50-62	287-381	150-199	266-354	100-132	11.6-13.4	10.0-11.5	65-74
	5	127-152	63-76	382–477	200-249	355-442	133-166	13.5-15.4	11.6-13.2	75-86
	6	153-179	77-89	478-572	250-299	443-531	167-199	15.5-17.3	13.3-14.9	87-96
HIGH										
	7	180-239	90-119	573-635	300-332	532-708	200-266	17.4-19.2	15.0-16.5	97-107
	8	240-299	120-149	636-700	333-366	709-886	267-332	19.3-21.2	16.6-18.2	108-118
	9	300-359	150-179	701-763	367-399	887-1063	333-399	21.3-23.1	18.3-19.9	119-129
V. HIGH										
	10	≥ 360 μgm^{-3}	≥ 180 ppb	≥ 764 μgm^{-3}	≥ 400 ppb	≥1064 μgm^{-3}	≥ 400 ppb	≥ 23.2mgm^{-3}	≥ 20 ppm	≥ 130 μgm^{-3}

Old Banding	New Index	Health Descriptor
LOW		
	1 2 3	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants
MODERATE		
	4 5 6	Mild effects unlikely to require action may be noticed amongst sensitive individuals
HIGH		
	7 8 9	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.
VERY HIGH		
	10	The effects on sensitive individuals described for "HIGH" levels of pollution may worsen.

Appendix 2 - Forecasting Zones and Agglomerations

CONTENTS

1	Table showing the Air Pollution Forecasting Zones and Agglomerations, together with populations (based on 1991 census).
2	Map of Forecasting Zones and Agglomerations.

Forecasting Zones

Zone	Population
East Midlands	2923045
Eastern	4788766
Greater London	7650944
North East	1287979
North West and Merseyside	2823559
South East	3702634
South West	3728319
West Midlands	2154783
Yorkshire and Humberside	2446545
South Wales	1544120
North Wales	582488
Central Scotland	1628460
Highland	364639
North East Scotland	933485
Scottish Borders	246659
Northern Ireland	1101868

Forecasting Agglomerations

Agglomeration	Population
Brighton/Worthing/Littlehampton	437592
Bristol Urban Area	522784
Greater Manchester Urban Area	2277330
Leicester	416601
Liverpool Urban Area	837998
Nottingham Urban Area	613726
Portsmouth	409341
Sheffield Urban Area	633362
Tyneside	885981
West Midlands Urban Area	2296180
West Yorkshire Urban Area	1445981
Cardiff	306904
Swansea/Neath/Port Talbot	272456
Edinburgh Urban Area	416232
Glasgow Urban Area	1315544
Belfast	475987

Map of forecasting zones and agglomerations