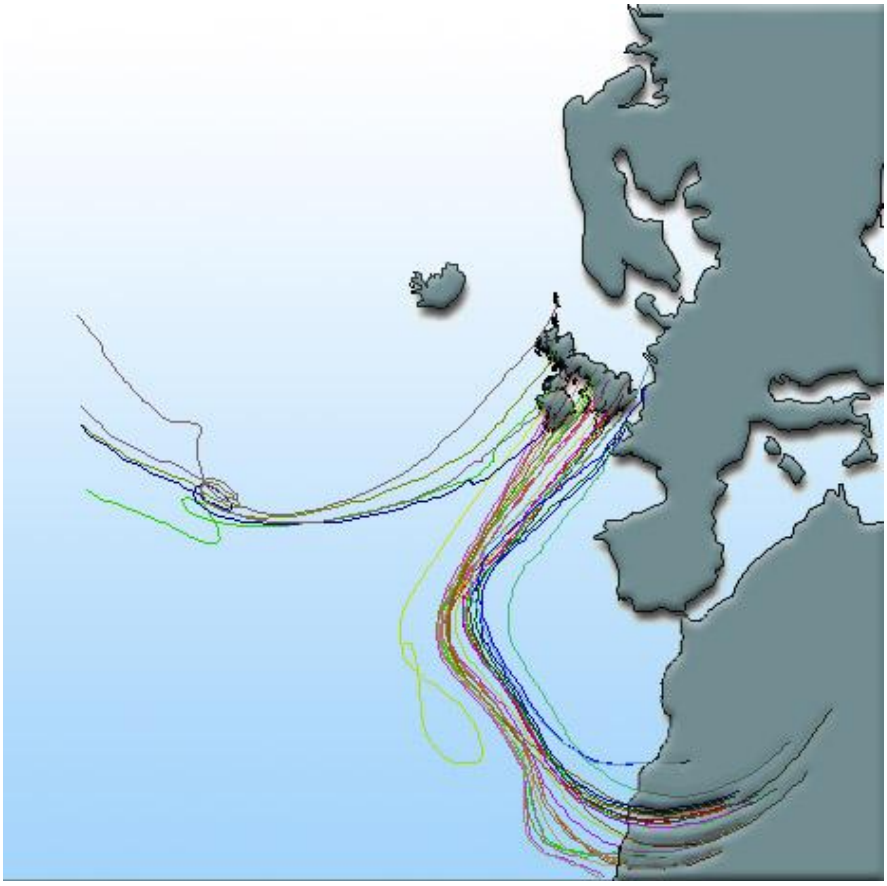
UK Air Quality Forecasting: Annual Report 2008

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/2951/Issue 1
December 2009

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AEA Technology plc
Ambient Air Quality Measurement
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
Author	Andrew Cook	10/01/2010
Reviewed by	Paul Willis	12/02/2010
Approved by	Jon Bower	01/03/2010

Executive Summary

This report covers the operational activities carried out by AEA and the Met Office on the UK Air Quality Forecasting Contract for the year 2008. 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 2008, there was a total of twenty three days on which HIGH air pollution was recorded across the UK. Three of these days were due to ozone, the remainder were for particulate PM_{10}.

The forecasting success and accuracy for this year is summarised in Table 1 below, together with the results from the previous calendar year. The overall forecasting success and accuracy rate performance for HIGH episodes compared very favourably to the previous year, partly due to a successful period of forecasting for MODERATE and HIGH band ozone during May 2008. The success rate performance for the MODERATE band was high, as seen in previous years, with a considerable degree of accuracy. Please note that success rates are able to be greater than 100 %, as detailed in section 3.1.

Table 1 – forecast success/accuracy for incidents above 'HIGH' and above 'MODERATE' in 2008 *(and 2007)*.

Region/Area	***HIGH***		***MODERATE***	
	% success	***% accuracy***	***% success***	***% accuracy***
Zones	233 *(19)*	50 *(15)*	129 *(119)*	86 *(83)*
Agglomerations	88 *(0)*	25 *(0)*	135 *(146)*	71 *(78)*

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

- A UK Particulate Episode from 23rd to 24th January 2008.
- Ozone Pollution Episodes Report (May and July 2008).

Published 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 have continued 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 chemical schemes for secondary PM_{10} and ozone in NAME.
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 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. 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 a 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 2008. 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 (i.e. the forecasts issued are not analysed by environment type within this report).

Twice per week, on Tuesdays and Fridays, AEA 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 337 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.

BSkyB entered into a separate contract with AEA to provide a daily air pollution report and forecasts, however the contract was discontinued after approximately one calendar year due to sponsorship issues. The forecasts had been aired twice-daily by the BSkyB weather presenters at peak viewing times.

The National forecasts are also quality controlled for consistency with forecasts issued by AEA for UK regions and individual local authorities.

2 New developments during this year

During the first quarter the Met Office introduced improved graphics for the forecast maps sent to the AEA forecasting team and coordinated with AEA over the introduction of enhanced back trajectories for the ozone service and interpretation of air pollution events. Those trajectories were immediately useful in the analysis of a Saharan dust event of 23rd – 24th January 2008. To aid interpretation of the event, the dust scheme in NAME was run in a separate simulation and this clearly demonstrated transport of dust from the Sahara to the UK.

The Met Office's comparison of the different air quality model systems used during the contract was also completed during the first quarter. The comparison was conducted over the period of June to August 2003 to remove the influence of improvements to the meteorology during the contract. Changes to the model chemistry were clearly identified in statistics comparing the model results to observations at 67 AURN sites. The most substantial improvements in model performance occurred when height information on the main polluting chimney stacks was included in the emissions data. Modelled sulphur dioxide was much closer to observations, which highlighted the importance of such height information for air quality forecasting.

Also during the first quarter AEA's "Forecast Admin tools" software suite was updated to include: PROMOTE ensemble forecasts, improved back-trajectory plots and additional dust forecast models.

On the 18th April the Met Office responded to a phone call from Defra regarding a strange smell in the south-east of England. Back-trajectories and meteorological data together with AURN observations were used to provide an initial interpretation that the smell had come from a European agricultural source and liaison with the AEA duty forecaster led to the quick release of a short report to this effect. During the day the Met Office Press Office responded to many media and public enquiries about the event. In the following weeks, ammonia and ammonium data from Auchencorth Moss (kindly provided by CEH) were analysed and further enquiries into the source were made in collaboration with the HPA. The AEA forecasting team had worked in collaboration with the Met Office during the event to identify the source of the odour. Two separate runs of the NAME model had confirmed that the air reaching the parts of England reporting the odour had passed over Germany, the air that had reached unaffected Scotland had passed over the sea, to north of Denmark.

During April and May the Met Office liased with SEPA regarding the shut-down and start-up of the Grangemouth oil refinery due to strike action. The Met Office responded to concerns that dust, noticed on the 4th May in eastern Scotland, had come from the refinery and was able to provide evidence that the event had in fact been caused by Saharan dust and had been noticed over much of the UK. This had been a complicated Saharan dust case and it is thought that frontal rainfall activity had caused the dust to be washed out from height over the UK.

During the second quarter considerable development of the air quality system had also been carried out so that it would be based around the NAMEIII model and use the Met Office's latest error checking and reporting system.

The AEA forecasting team investigated a series of unexpected PM_{10} pollution spikes on Sunday 25th May, measured at some sites in North East England. Only Middlesborough and the industrial Scunthorpe Town measured a MODERATE band exceedence on that day, however, a short term episode was also measured at Leeds, Sheffield and York and peaked at midday on the 25th. No obvious source of the pollution could be identified from air mass back-trajectory plots or satellite imagery, however the BBC news website reported moorland fires in Yorkshire over that bank holiday weekend which may have been the cause.

During the third quarter the Met Office obtained and finished processing emissions data for 2005 and 2006 for the UK (from the National Atmospheric Emissions Inventory) and Europe (from EMEP). The 2006 data was scheduled to be incorporated in the National Air Quality Forecast modelling system. Work was carried out to upgrade the modelling system to use an improved 12 km horizontal resolution for met data.

A detailed reanalysis of the Nottingham sulphur dioxide pollution episode in September 1998 has been conducted by the Met Office during the third quarter. This had clearly highlighted the benefits from including high time-resolution information on emission rates from large polluters, as well as information on stack heights etc. The work had also demonstrated the benefits of moving to higher resolution meteorology.

During the final quarter the Met Office implemented a plan to upgrade the routines used in the post-processing of the model output to ensure compliance with changing Met Office software and increased computational efficiency.

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 2008 are presented in Tables 3.1 (forecasting performance in zones) and 3.2 (forecasting performance in agglomerations) for 'HIGH' days. Tables 3.3 and 3.4 show the same statistics for the MODERATE band. 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 2008

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	0	0	0	3	0	0	0	0	1	0	0	1	1	0	0	3	9
Forecasted days	0	4	3	4	0	2	0	1	3	0	1	4	3	3	3	4	35
Ok (f and m)	0	3	2	2	0	0	0	1	2	0	0	0	2	2	2	5	21
Wrong (f not m)	0	1	1	2	0	2	0	0	1	0	1	4	1	1	1	0	15
Wrong (m not f)	0	0	0	3	0	0	0	0	1	0	0	1	1	0	0	0	6
Success %	100	100	100	67	100	100	100	100	200	100	100	0	200	100	100	167	233 (!)
Accuracy %	0	75	67	29	0	0	0	100	50	0	0	0	50	67	67	100	50 (!)

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	0	0	0	0	0	4	0	0	0
Forecasted days	0	4	3	1	0	1	1	1	1
Ok (f and m)	0	1	2	1	0	1	0	1	0
Wrong (f not m)	0	3	1	0	0	0	1	0	1
Wrong (m not f)	0	0	0	0	0	3	0	0	0
Success %	100	100	100	100	100	25	100	100	100
Accuracy %	0	25	67	100	0	25	0	100	0

AGGLOMERATIONS	Nottingham UA	Portsmouth UA	Sheffield UA	Swansea UA	Tyneside	West Midlands UA	West Yorkshire UA	**Overall (!)**
Measured days	0	2	0	0	0	0	2	8
Forecasted days	1	3	0	1	0	3	1	21
Ok (f and m)	0	0	0	0	0	1	0	7
Wrong (f not m)	1	3	0	1	0	2	1	14
Wrong (m not f)	0	2	0	0	0	0	2	7
Success %	100	0	100	100	100	100	0	88 (!)
Accuracy %	0	0	0	0	0	33	0	25 (!)

*** All performance statistics are based on provisional data. Noticeably incorrect data due to instrumentation faults have been removed from the analyses. (!) FDMS PM_{10} datasets have been currently excluded from the analysis.**

Please refer to the start of section 3 for an explanation of the derivation of the various statistics, success >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	55	71	106	134	115	32	54	60	68	36	36	75	61	73	52	120	1148
Forecasted days	69	98	109	120	101	53	69	75	79	47	65	102	82	84	72	98	1323
Ok (f and m)	75	96	123	147	122	48	74	90	94	54	59	108	97	96	76	118	1477
Wrong (f not m)	7	13	9	17	3	11	7	12	6	7	13	13	7	9	13	12	159
Wrong (m not f)	3	5	8	17	1	4	1	2	6	3	1	7	4	1	6	11	80
Success %	136	135	116	110	106	150	137	150	138	150	164	144	159	132	146	98	129(!)
Accuracy %	88	84	88	81	97	76	90	87	89	84	81	84	90	91	80	84	86(!)

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	22	38	24	25	28	25	30	29	24
Forecasted days	33	68	41	38	38	34	51	48	40
Ok (f and m)	26	54	36	37	43	26	42	40	36
Wrong (f not m)	18	26	10	8	7	13	17	15	14
Wrong (m not f)	2	4	2	1	2	9	3	3	1
Success %	118	142	150	148	154	104	140	138	150
Accuracy %	57	64	75	80	83	54	68	69	71

AGGLOMERATIONS	Nottingham UA	Portsmouth UA	Sheffield UA	Swansea UA	Tyneside	West Midlands UA	West Yorkshire UA	Overall (!)
Measured days	25	76	19	49	19	48	61	542
Forecasted days	47	96	44	75	36	62	56	807
Ok (f and m)	30	93	37	77	29	64	64	734
Wrong (f not m)	22	19	18	12	12	17	13	241
Wrong (m not f)	4	7	0	3	0	3	12	56
Success %	120	122	195	157	153	133	105	135(!)
Accuracy %	54	78	67	84	71	76	72	71(!)

* All performance statistics are based on provisional data. Noticeably incorrect data due to instrumentation faults have been removed from the analyses (!) FDMS PM_{10} datasets have been currently excluded from the analysis.

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

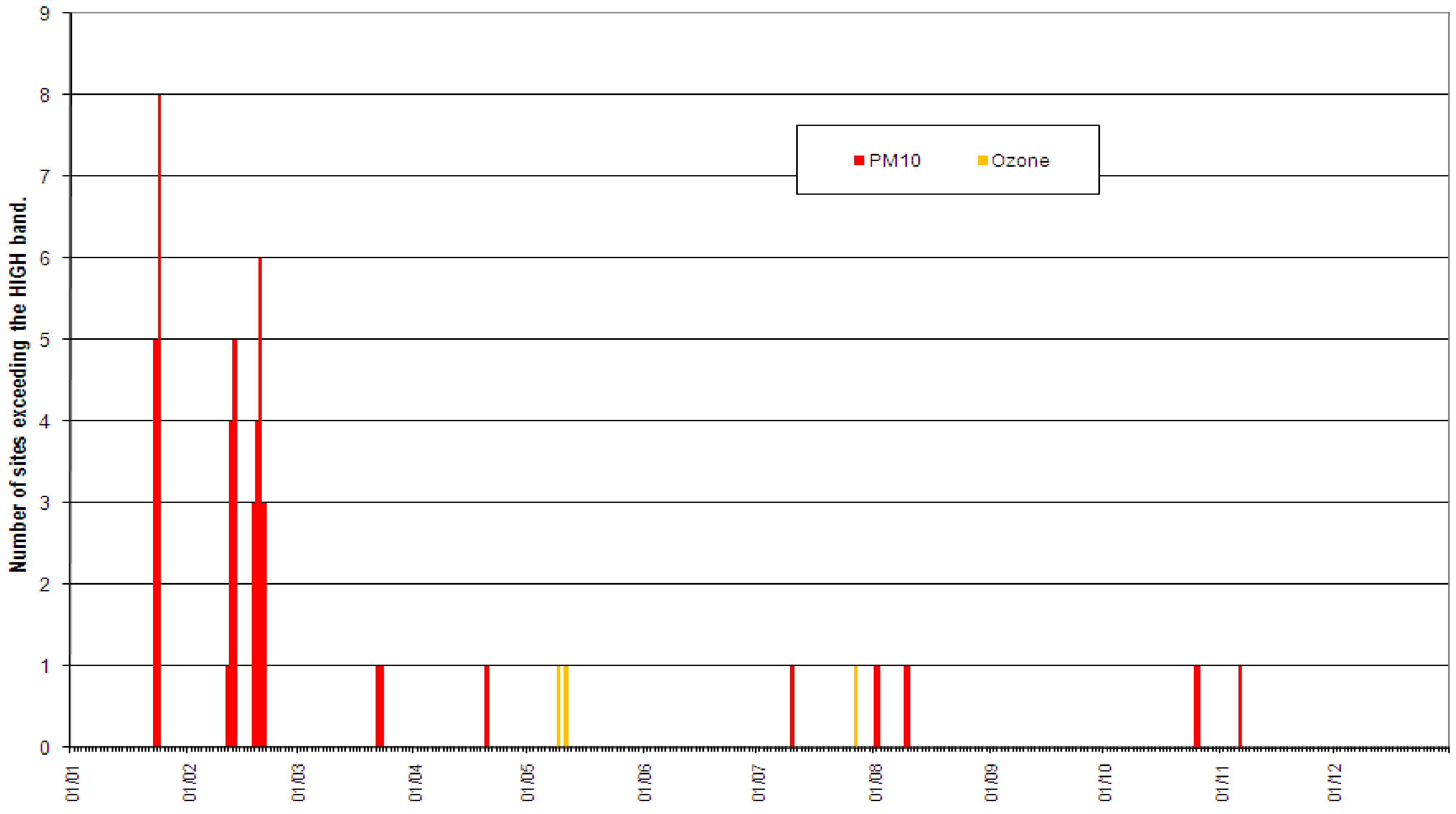

Figure 3.1 Number of stations with air pollution levels of HIGH and above for days throughout 2008.

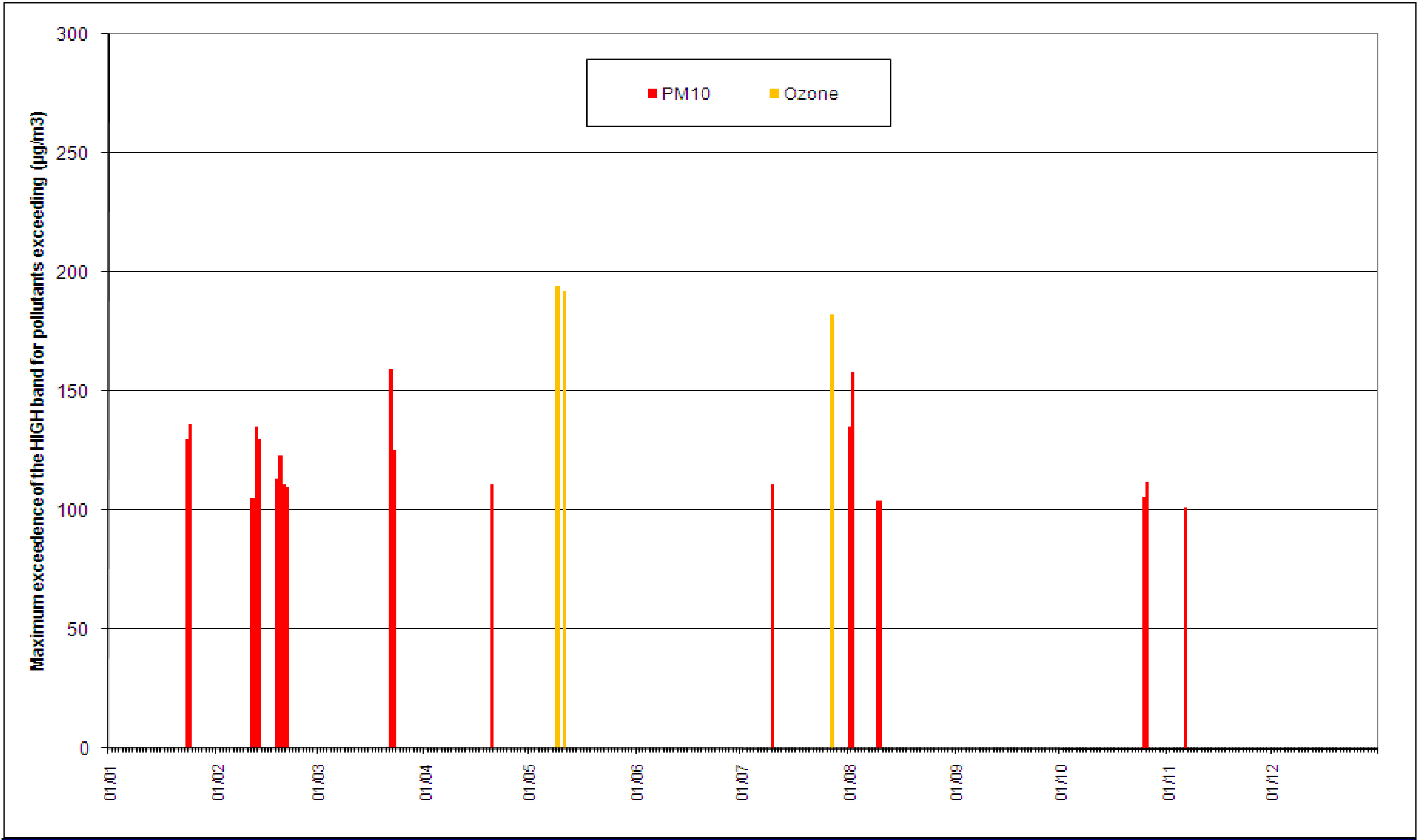

Figure 3.2 Maximum exceedence when air pollution levels were HIGH and above for days throughout 2008.

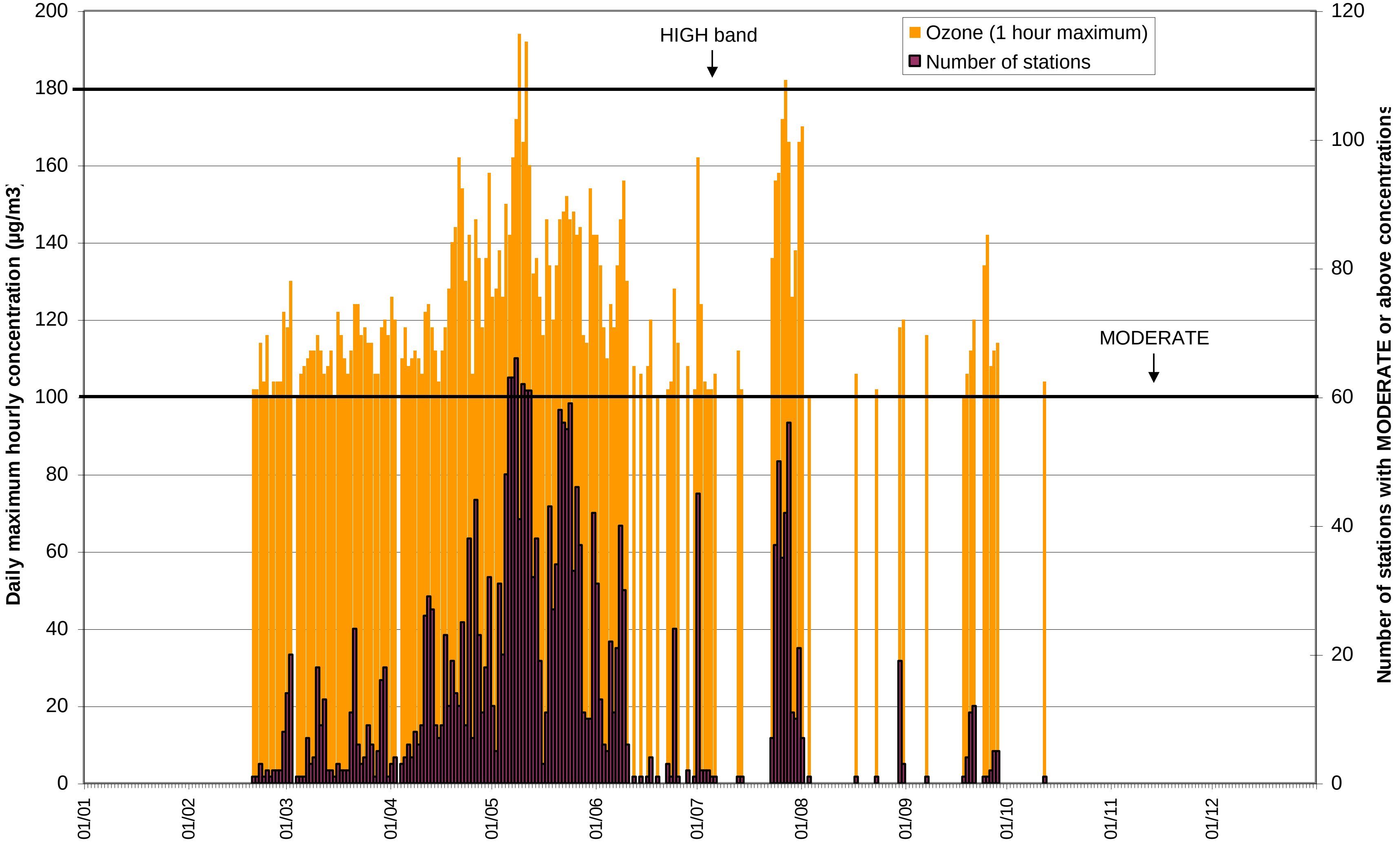

Figure 3.3 Daily maximum hourly ozone concentration across AURN Network with total number of stations measuring moderate or above levels of ozone over 2008.

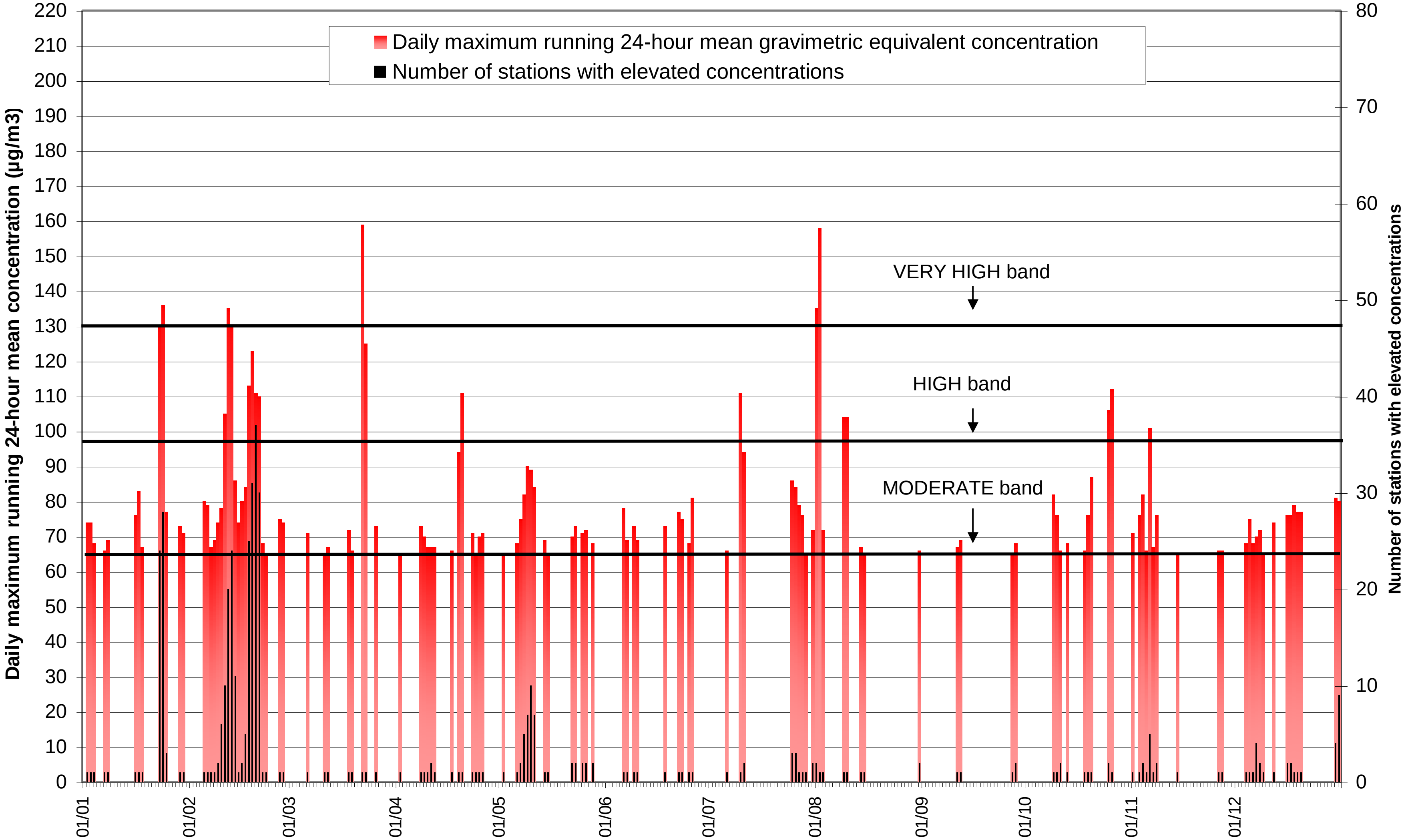

Figure 3.4 Daily maximum running 24-hour mean PM_{10} concentration across AURN Network with total number of stations measuring moderate or above levels over 2008

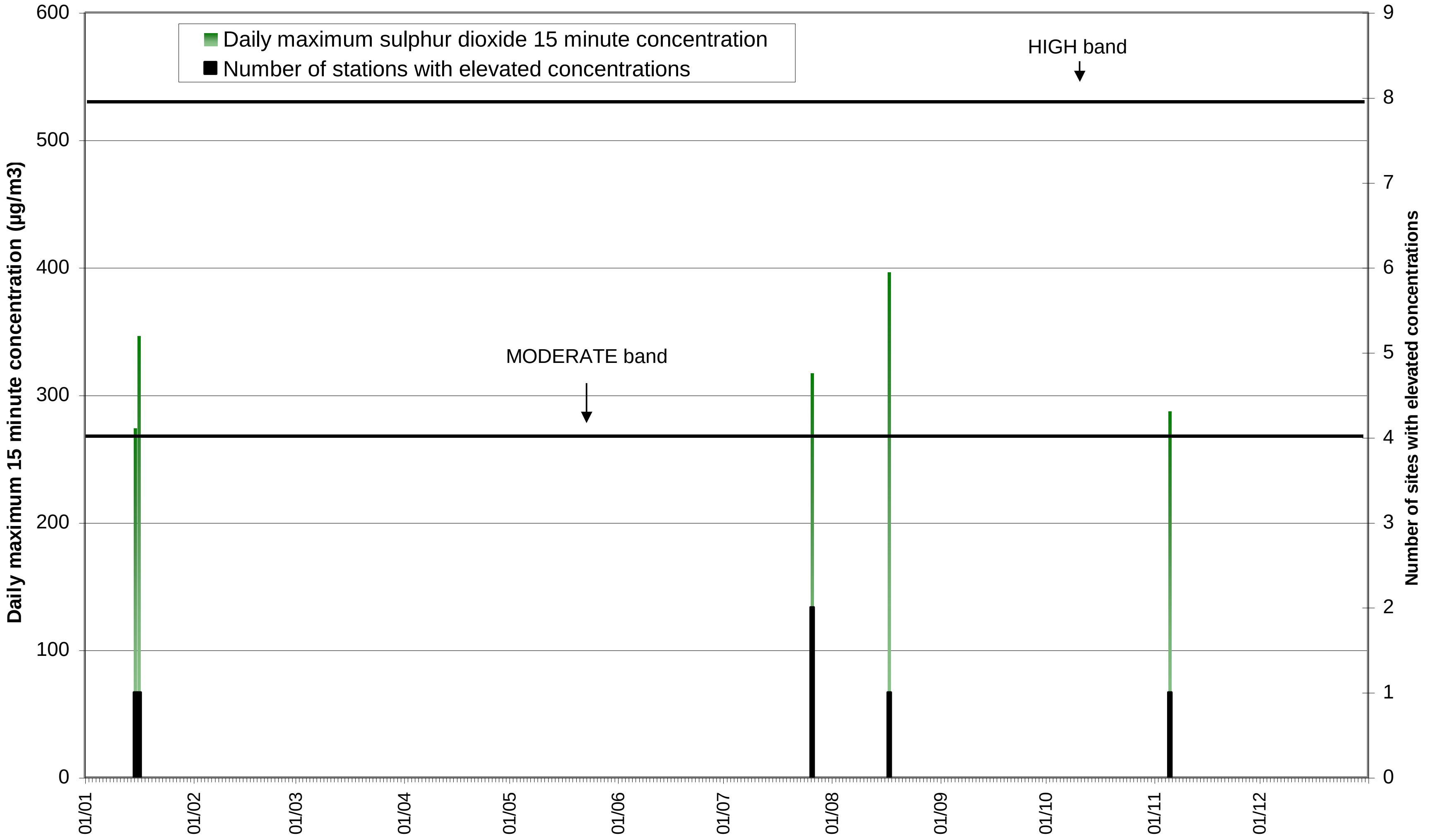

Figure 3.5 Maximum 15 minute average concentrations of SO_2 across AURN Network with total number of stations measuring moderate or above levels over 2008

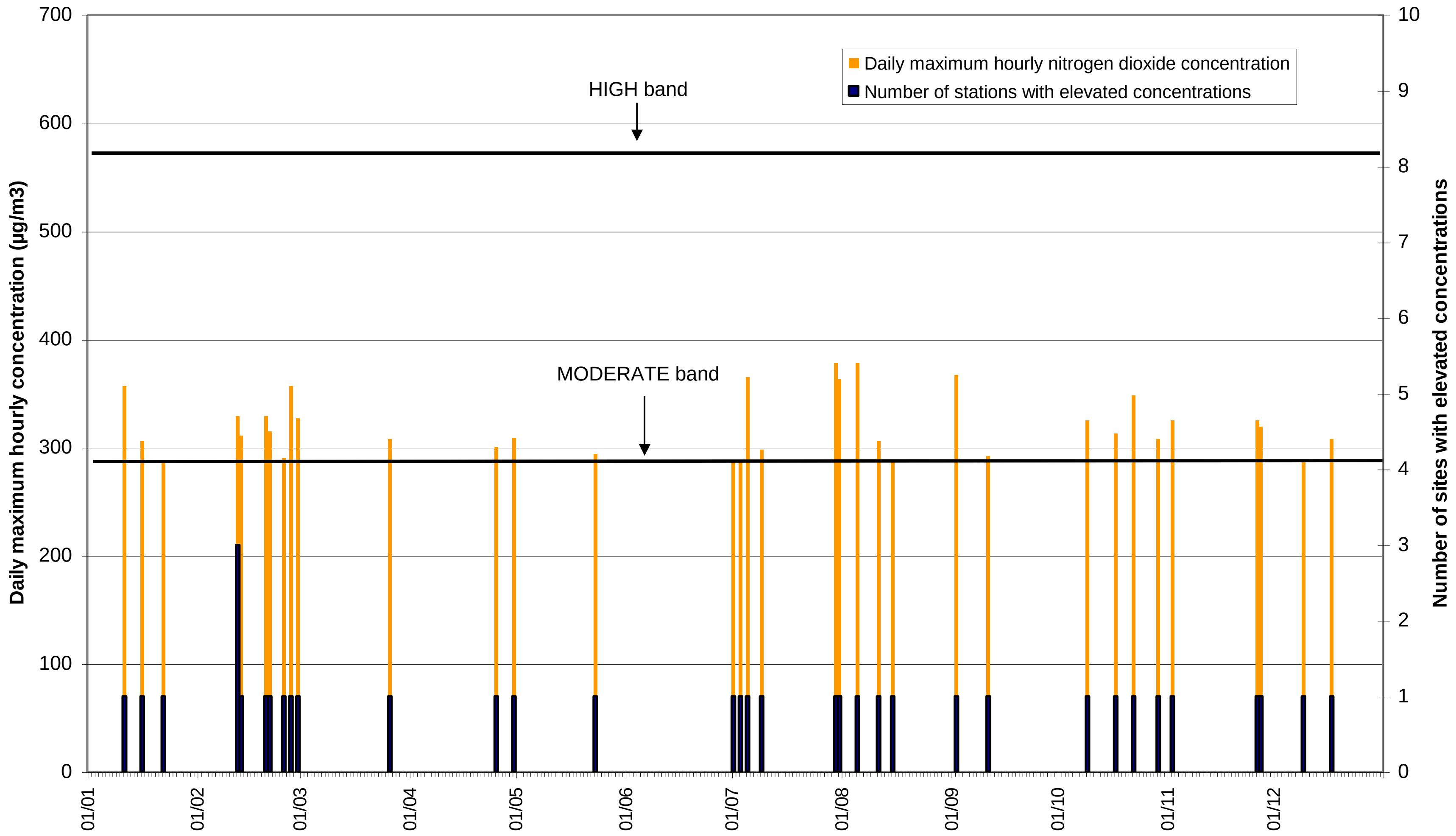

Figure 3.6 Daily Maximum hourly average of NO_2 across AURN Network with total number of stations measuring moderate or above levels over 2008

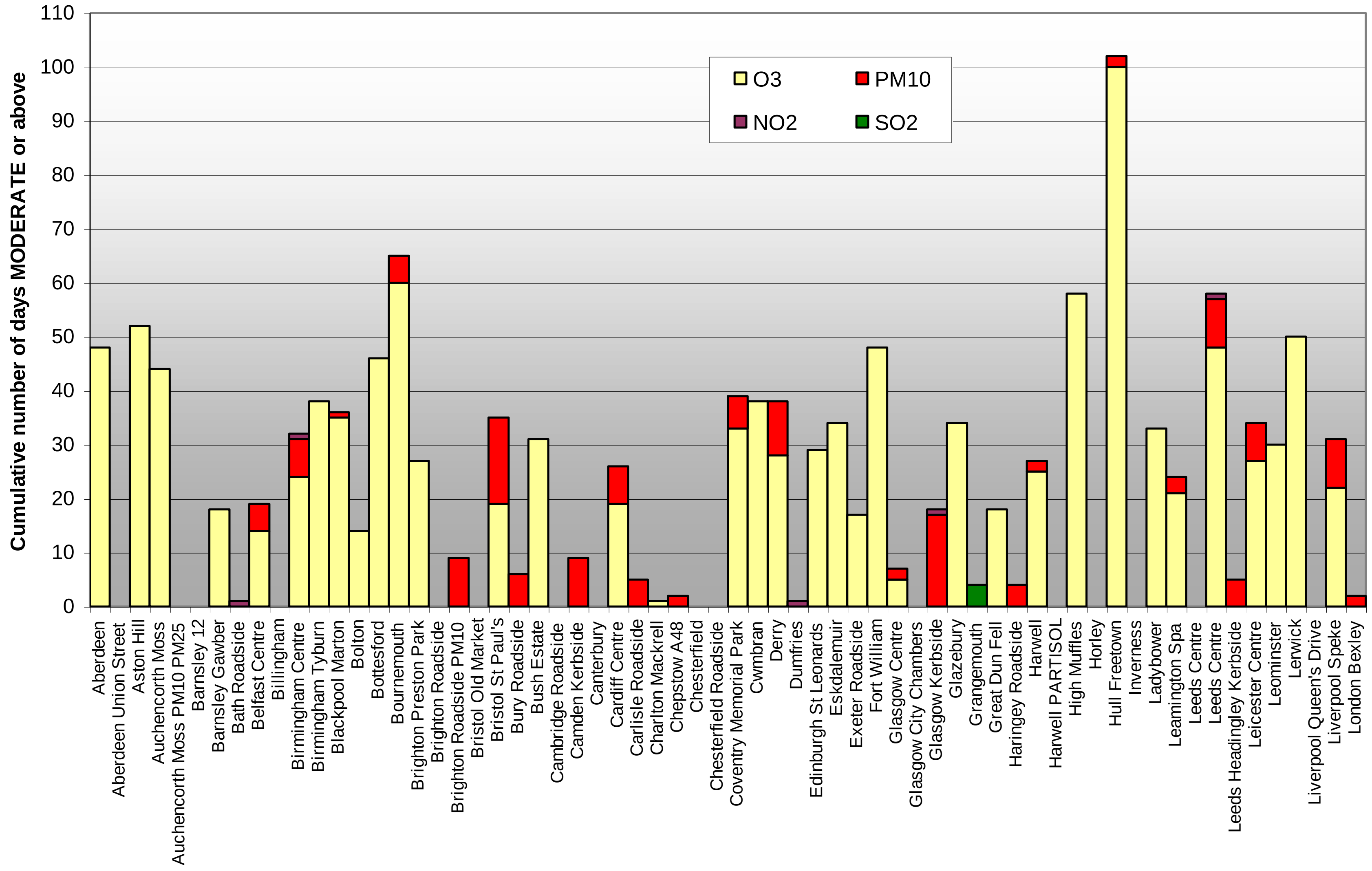

Figure 3.7a Number of pollutant days moderate and above for each AURN Network station over 2008 (site names A-L) – provisional data

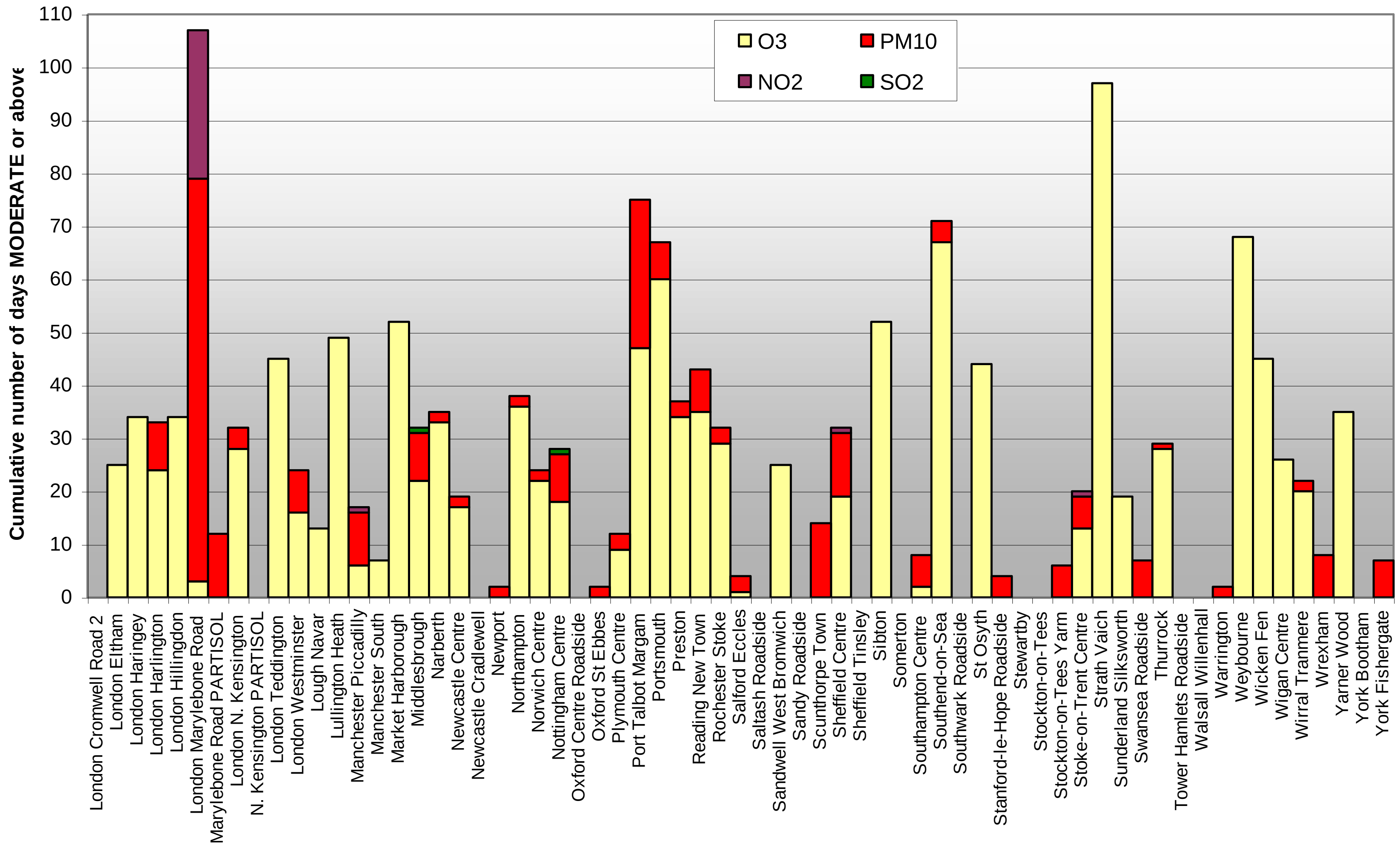

Figure 3.7b Number of pollutant days moderate and above for each AURN Network station over 2008 (site names L–Y) – provisional data

Table 3.3 – Summary of HIGH episodes year 2008

Pollutant	*No. of HIGH days*	*No. of MODERATE days ^*	*Maximum concentration* (Index)*	*Site with max concentration*	*Zone or Agglomeration*	*Date of max conc.*	*Forecast success HIGH days (%)**** **[no. incidents, zone or agglomeration days] ****
Ozone	3	32	194 (Index 7)	Hull Freetown	Yorkshire and Humberside	09/05	100 % [3]
PM_{10}	20	112	159 Indicative gravimetric (Index 10)	Wirral Tranmere	North West and Merseyside	22/03	6 % ! [44]
NO_2	0	34	378 (Index 4)	Marylebone Road	London	30/07	N/A [0]
SO_2	0	5	396 (Index 5)	Nottingham Centre	Nottingham UA	17/08	N/A [0]
CO	0	0	5.4 (Index 2)	Port Talbot Margam	Swansea UA	23/02	N/A [0]

^ a MODERATE day is not counted on any HIGH day.
** 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 (i.e. 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.*
! the forecast success rate for PM_{10} has been calculated using TEOM measurements only due to current uncertainty over the limits to be set for the new FDMS-PM_{10} instruments. Seventeen HIGH TEOM- PM_{10} zone or agglomeration days were measured during the year, forty four zone or agglomeration days were measured in total by both FDMS and TEOM instruments.

General trends

Three HIGH days were recorded for ozone this reporting year, two of which happened in May, as shown in figure 3.3. However the three HIGH days were the result of HIGH measurements made at only one air quality site in the network (Hull Freetown in Yorkshire).

There were three significant HIGH band PM_{10} episodes experienced in 2008, two of which occurred during the month of February, as shown in figures 3.1, 3.2 and 3.4. In total twenty HIGH days were measured throughout the year for PM_{10}. The causes of the ozone and particulate PM_{10} episodes are detailed in the sections which follow.

Only five MODERATE SO_2 days were measured during the whole calendar year, 80 % of the MODERATE days occurred as a result of exceedences at the industrial Grangemouth AQM site. Figure 3.5 shows the frequency of the exceedences.

Thirty four MODERATE NO_2 days were measured throughout the year at a relatively even time distribution, as shown in figure 3.6. Twenty eight MODERATE days were measured at the busy London Marylebone Road kerbside site.

Particulate matter

The first particulate episode of the year occurred in late January and had been caused primarily by long range transport of dust, as a result of sandstorms in Africa. On Wednesday 23rd and Thursday 24th January more than twenty sites per day reached the MODERATE band or higher. Eight of the network sites measured levels of PM_{10} particulate matter at air pollution index 7 (HIGH) or above, and two of those sites also went on to record VERY HIGH pollution at index 10. Over the same period a further eighteen individual monitoring sites recorded MODERATE PM_{10} air pollution at index 4 to 6. Satellite imagery in combination with air mass back-trajectory plots revealed the cause of this particulate episode had been long range transport of dust as a result of sandstorms in Africa, with a possible albeit unlikely contribution from forest fires, also in Africa but further south. Of the eight sites measuring PM_{10} at index 7 or above, three were located in London, two in the South East and three in South Wales. In addition to three roadside sites reaching the HIGH band, index 7 or above was also measured at one remote site in Wales, one urban centre and one rural site in the south of England and an urban centre site in London. No significant increase in airborne particulate matter was recorded across Scotland or Northern Ireland over the duration of the episode. In total twenty seven sites measured PM_{10} air pollution in the MODERATE or HIGH bands over the 2-day episode and these were all considered to have been primarily the result of the long range transport of particulate matter.

Two winter pollution episodes occurred during February. During the first episode, from Sunday 10th to Wednesday 13th, more than about 10 sites reached or exceeded the MODERATE band daily on each of the four days. The episode happened as a result of a build up of traffic related, and in some areas industrial related, pollution in below-freezing overnight temperatures and very low wind speeds. At the height of the episode, on the 13th, eighteen sites reached the MODERATE band and a further five sites went on to reach the HIGH band. The MODERATE sites were a mixture of urban and roadside sites in London, several urban sites in the Midlands, a mixture of urban / industrial and roadside sites in the north of England, Glasgow Centre, Bristol St Paul's AQM site, and urban sites in Northern Ireland as a result of domestic fuel burning used for heating. Of the five HIGH sites, three were urban centre sites in the north of England (Nottingham, Sheffield and Leeds). The monitoring site in Leeds may have recorded contributions from local industry. Birmingham Centre and Glasgow Kerbside also reached the HIGH band. The highest running 24-hour mean recorded was 130 ug/m^3 (the threshold of the VERY HIGH band) at Leeds Centre on the 13th.

Over the second episode, between Monday 18th and Wednesday 20th, during a period of daily temperatures near freezing in England and overnight temperatures well below zero in many parts of the UK, twenty sites or more reached or exceeded the MODERATE band on a daily basis. At the height of the episode, on the 20th, thirty sites reached the MODERATE band and a further seven sites reached the HIGH band. The MODERATE sites were a mixture of urban and roadside sites widely distributed over England and Wales. The HIGH sites were predominantly roadside sites (for example Glasgow Kerbsite, London Marylebone Road kerbside, Brighton, Carlisle and Wrexham roadside sites) and two urban sites (Sheffield Centre and London Westminster). The site at Westminster is situated in a confined car parking area, surrounded by residential properties and taller buildings and is therefore likely to be significantly affected by winter episodes. The site at Sheffield Centre may have measured contributions from local industrial emissions. The highest 24- hour running mean measured on the 20th was 111 ug/m^3 at Sheffield Centre.

Other MODERATE days were measured throughout the reporting period, the majority of which were experienced at the London Marylebone Road kerbside site, with a total of seventy six MODERATE or higher days measured at that single location as a result of traffic related pollution. The Port Talbot Margam site measured twenty eight MODERATE or higher days during the year, primarily the result of a major steel works situated to the south–west of the monitoring site. Glasgow Kerbside AQM site measured seventeen MODERATE or above days as a result of traffic related pollution.

Other HIGH concentrations were measured periodically throughout 2008 at localized locations, for example:

- Wirral Tranmere AQM as a result of green waste burning over a bank holiday weekend in late March.

- Liverpool Speke AQM site as a result of bonfire night celebrations.

Typical contributory factors to localized and regional elevated PM_{10} levels include:

- 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, particularly during warm settled weather.
- Southerly air masses bringing long range transport of dust from Africa.

Bonfire Night celebrations yielded a lower number of exceedences this year when compared to both 2006 and 2007. Figure 3.8 below shows a comparison of the exceedences with earlier years.

Additionally figure 3.9 shows the overall number of PM_{10} exceedences annually from all pollution sources from the year 2000 onwards, indicating that this year has been the fifth highest for elevated particulate levels in recent years and was lower than both 2006 and 2007.

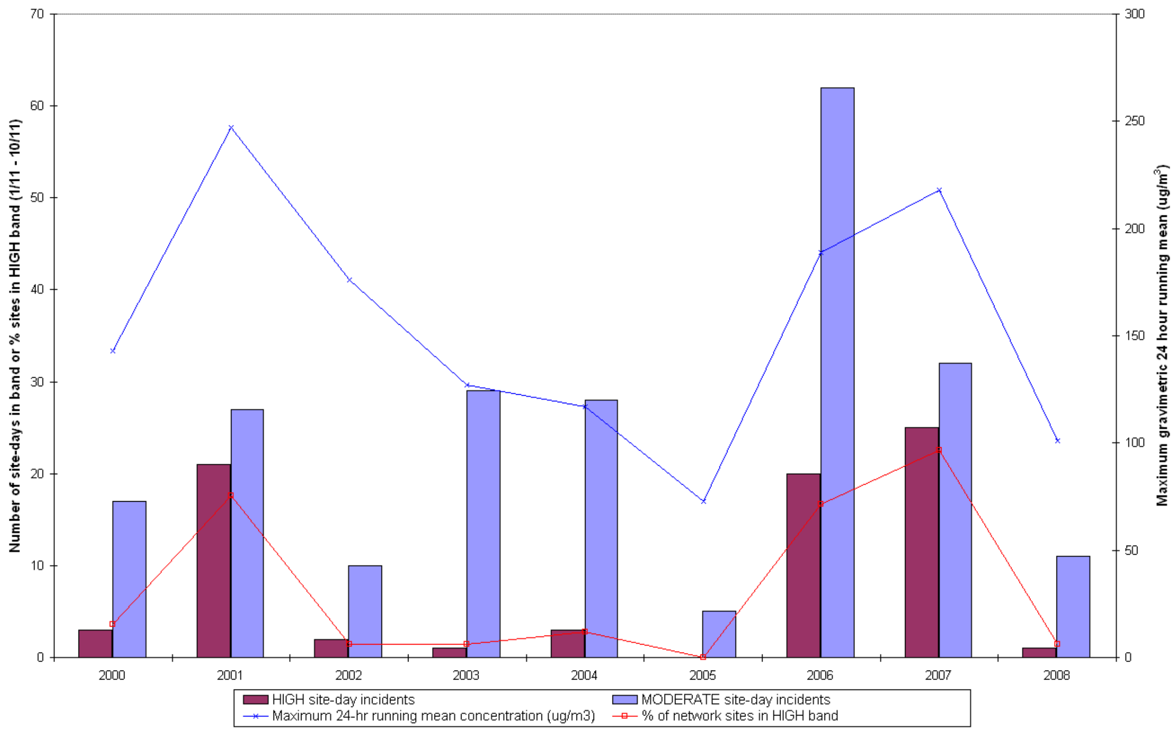

Figure 3.8: Number of sites exceeding the MODERATE and HIGH PM_{10} bands over 1st November to 10th November annually from the year 2000 onwards with additional descriptive statistics.

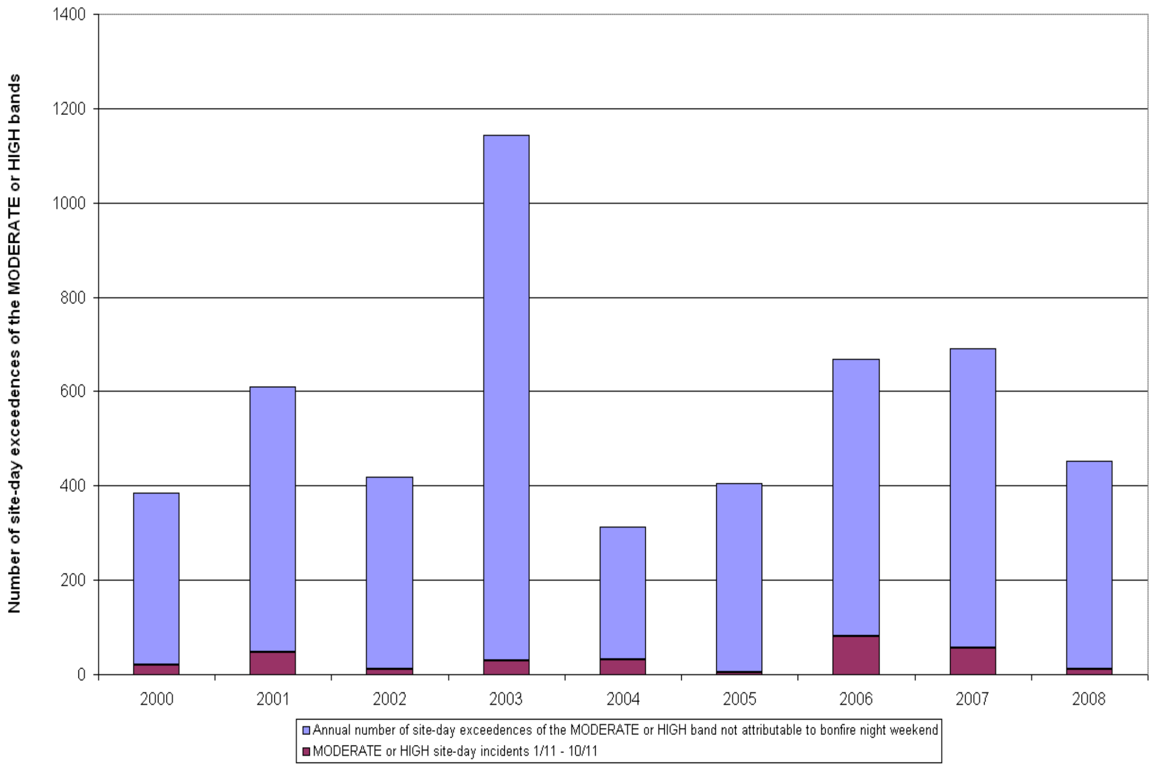

Figure 3.9: Annual number of site-day exceedences of the MODERATE or HIGH PM_{10} band for 2000 – 2008.

Ozone

MODERATE days were measured at a substantial number of network sites between the middle of April and early June. An additional shorter spell of exceedences was seen in late July, as shown in figure 3.3. Only one site, namely Hull Freetown in the Yorkshire area, reached the HIGH band during 2008. The three HIGH days measured at Hull Freetown occurred on days showing a significant number of MODERATE exceedences at network sites, two days of which were in early May and one in late June. The year 2008 can therefore be considered a year of no significant HIGH episodes.

Figure 3.10 shows that 2008 has been the second lowest year recorded for elevated ozone levels from the year 2000 onwards in terms of all statistics for the HIGH band; only three HIGH days were measured at a single AQM site and the highest hourly measurement was approximately 30 ug/m^3 lower than the average of the highest hourly measurement of years from the year 2000 onwards.

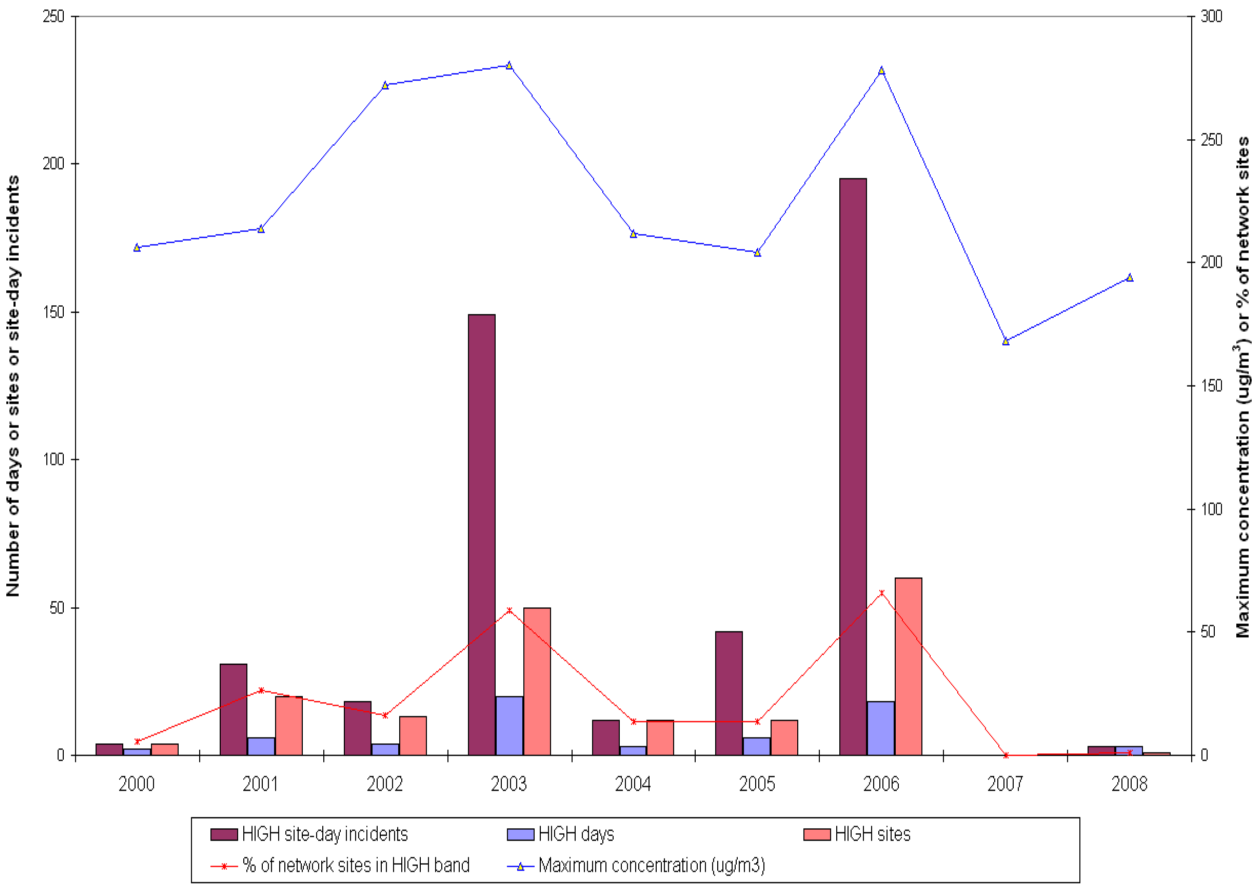

Figure 3.10: UK ozone episodes summarized for years 2000 onwards.

Sulphur Dioxide

The number of SO_2 measuring sites in the network was reduced from around 75 to 40 (a reduction of approximately 45%) from October 2007 onwards, however the addition of a number of new SO_2 monitoring sites during 2008 swelled the number of network instruments to 45. The number of MODERATE or above days per annum measured in the network is shown in figure 3.11 from the year 2000 onwards. The number of days of exceedences per year has fallen dramatically over the last 7 years, by as much as approximately 90% based on an average of the four most recent years.

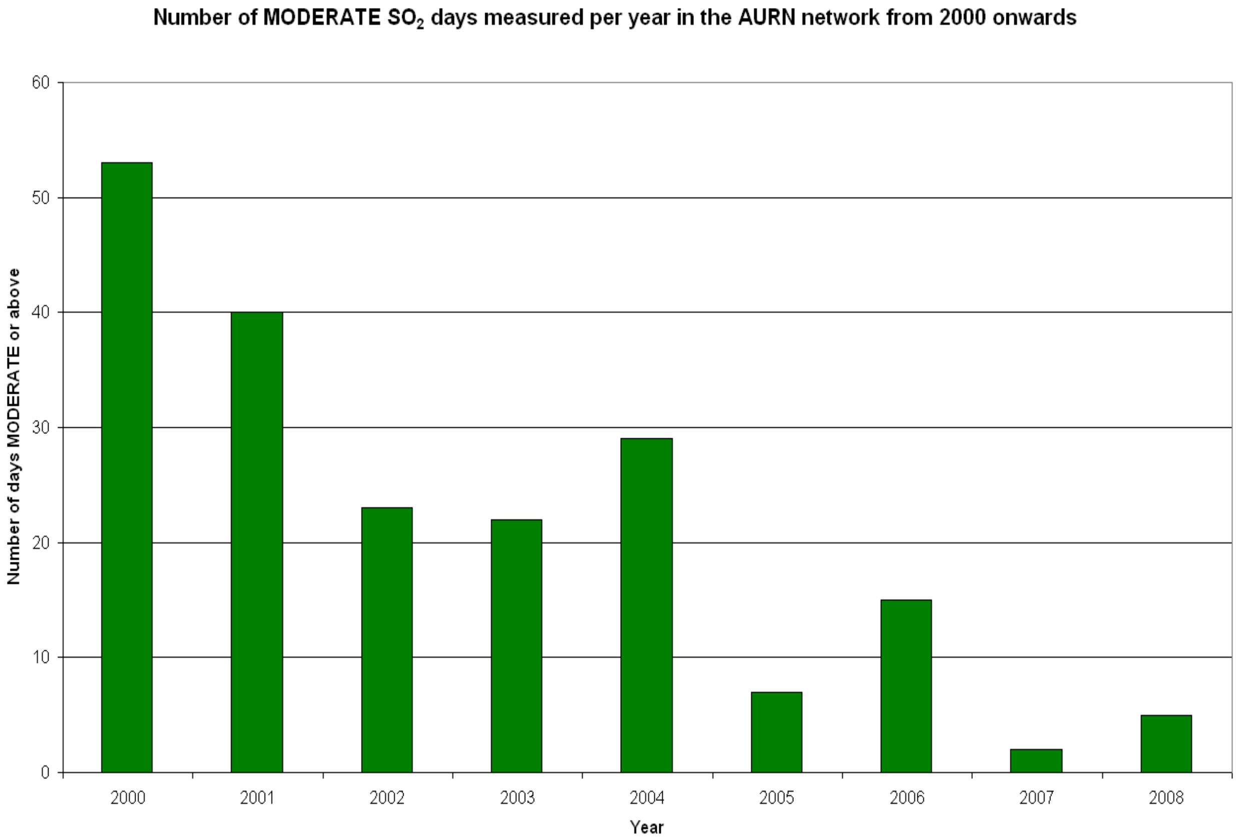

Figure 3.11: Number of MODERATE SO_2 network days measured per annum

A significant reduction in the number of exceedences over recent years is likely to be the result of an improvement in and proliferation of abatement technologies to control the release of sulphur dioxide and other pollutant species coupled with a downturn in the use of coal for domestic heating.

Nitrogen Dioxide

Thirty four MODERATE days were measured during the year. The vast majority of these were experienced at the London Marylebone kerbside site due to its proximity to road traffic. The remainder were measured at three sites on the 12th February, primarily the result of poor dispersion conditions during a spell of cold weather, two sites of which were described as "urban centre". The two roadside sites Dumfries and Bath Roadside also measured a MODERATE day each during the final quarter of the year, both were thought to have been the result of traffic congestion. Figures 3.7a and b show the sites which measured MODERATE nitrogen dioxide levels in 2008.

3.3 COMPARISON WITH YEARS 2003 ONWARDS

FORECASTING SUCCESS RATE

Figure 3.12 shows the forecasting success rates for the whole of the UK for years 2002 to 2008. This is the percentage of HIGH days that were correctly forecast.

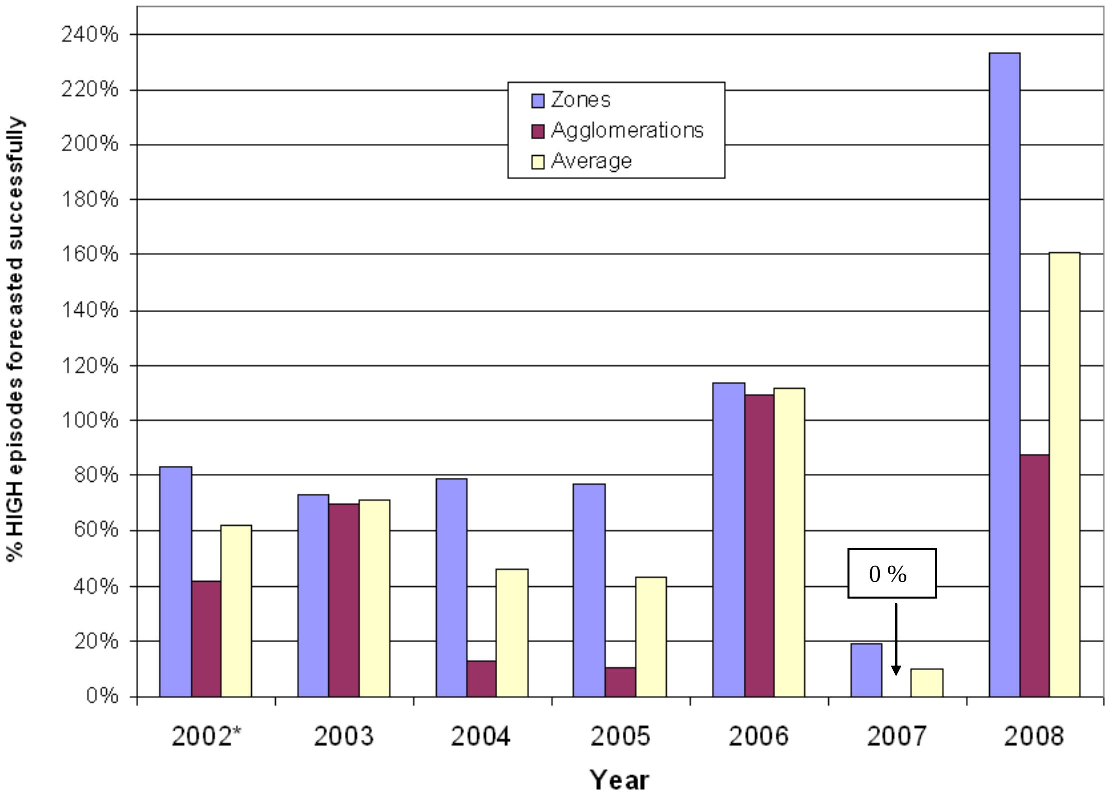

Figure 3.12 - Forecasting Success Rates for the whole of the UK, 2003-2008
*** 2002 was a partial year for forecasting analysis calculations.**

The overall forecasting success rate for the HIGH band in 2008, including that for zones, was, by a significant margin, the highest seen since forecasting analysis began, in 2002.

A high success rate of 233 % for 2008 was primarily the result of a period of successful forecasting for HIGH band ozone in mid May combined with the fact that only one site measured in the HIGH band, on three occasions, during the summer. Therefore the number of successful forecasts significantly outweighed the number of HIGH ozone days measured (NB. please see section 3.1 for an explanation of how forecasting success rates are calculated). A similar number of HIGH band PM_{10} days were measured in agglomerations and zones, however the accuracy figure of the HIGH forecasts, primarily forecasted for ozone, was only half that of zones, hence only a respectable success rate of 88% was attained for agglomerations. Our capacity to successfully predict elevated PM_{10} levels remains less than that for ozone using the forecast models we presently have access to, although this was partially addressed during 2008 by using various European particulate model run results which were freely available for public access on the internet.

Figure 3.13 shows that although 2008 was an average year in terms of total MODERATE and HIGH band exceedences for PM_{10} it has also been the lowest so far in terms of HIGH band measurements over the past nine years.

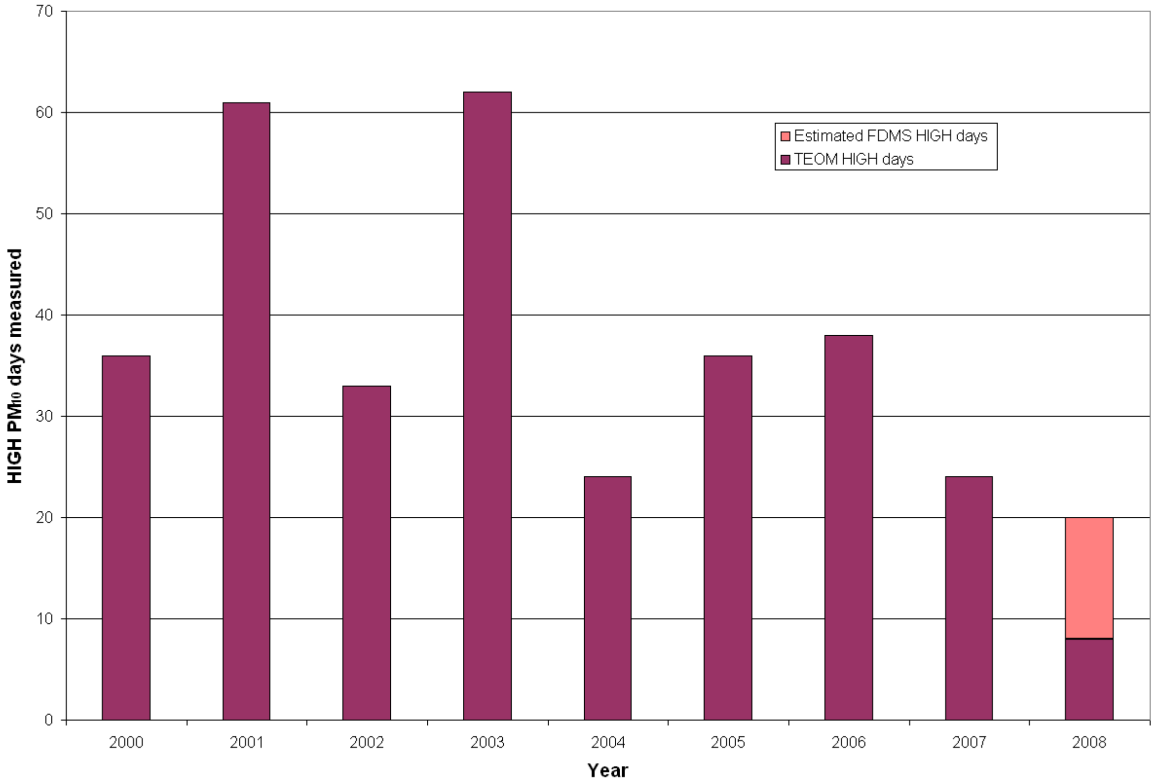

Figure 3.13 – Number of HIGH band measurements for PM_{10} in the UK, 2000-2008.

LOCALISED INFLUENCES

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In addition to the difficulties of forecasting long range transport of particulates, there are also problems 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 2008:

- Scunthorpe is surrounded by local heavy industry, which often results in unpredictable elevated concentrations of PM_{10}.
- Port Talbot Margam monitoring station is located to the north east 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.
- Wirral Tranmere AQM site measured 2 HIGH days in late March as a result of green waste burning over a bank holiday weekend.

OVERALL CONTRIBUTION FROM UK AND EUROPE IN SUMMER

Figure 3.14 shows the number of network days measured above various thresholds for ozone during the summers of the last nine years. The total number of days in the MODERATE band could be considered average compared to years 2000 onwards. Three HIGH days were measured, however at only one site in the network, which is very similar to the year 2000's four HIGH site-day incidents. Years 2004 and 2005 yielded 12 and 20 HIGH site-day incidents respectively.

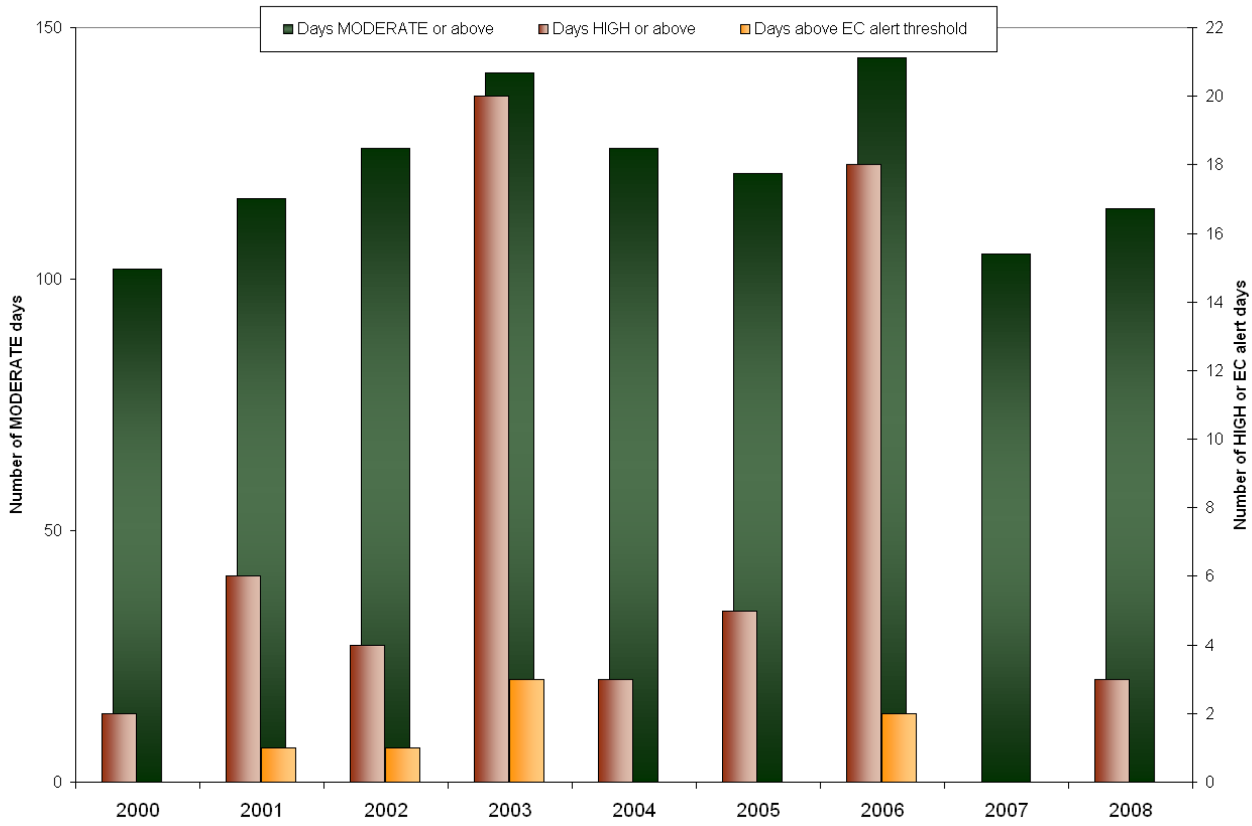


Figure 3.14 –Total network days exceeding various thresholds for ozone over the summers of 2000 onwards.

Figure 3.15 shows the percentage contribution of air masses reaching the UK from either Europe or recirculated air from the UK/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 software automated "per-region" analysis of 96-hour forecast air mass back-trajectory plots for all MODERATE days from April to the end of September.

The chart indicates that 2008 was the highest year seen so far, over the past 9 years, for the percentage contribution of European air masses to UK ozone levels. Despite the high European air mass contributions experienced during the summer months, however, the number of observed MODERATE and HIGH band exceedences for ozone was average when compared to recent years. This seemingly counter-intuitive observation could be explained by the fact that, on more than twice the number of days during April and May when compared to 2007, the UK received air from Europe. Those months are typically the time of year during which the highest number of MODERATE exceedences for ozone are measured in the UK resulting from 'background' Atlantic air. Therefore the higher number of days when the UK received air from Europe during the early summer may not have had a significant impact on the number of ozone exceedences measured during the summer as a whole. As with 2007, the warmest months, June to August, were predominantly characterised by Atlantic air masses.

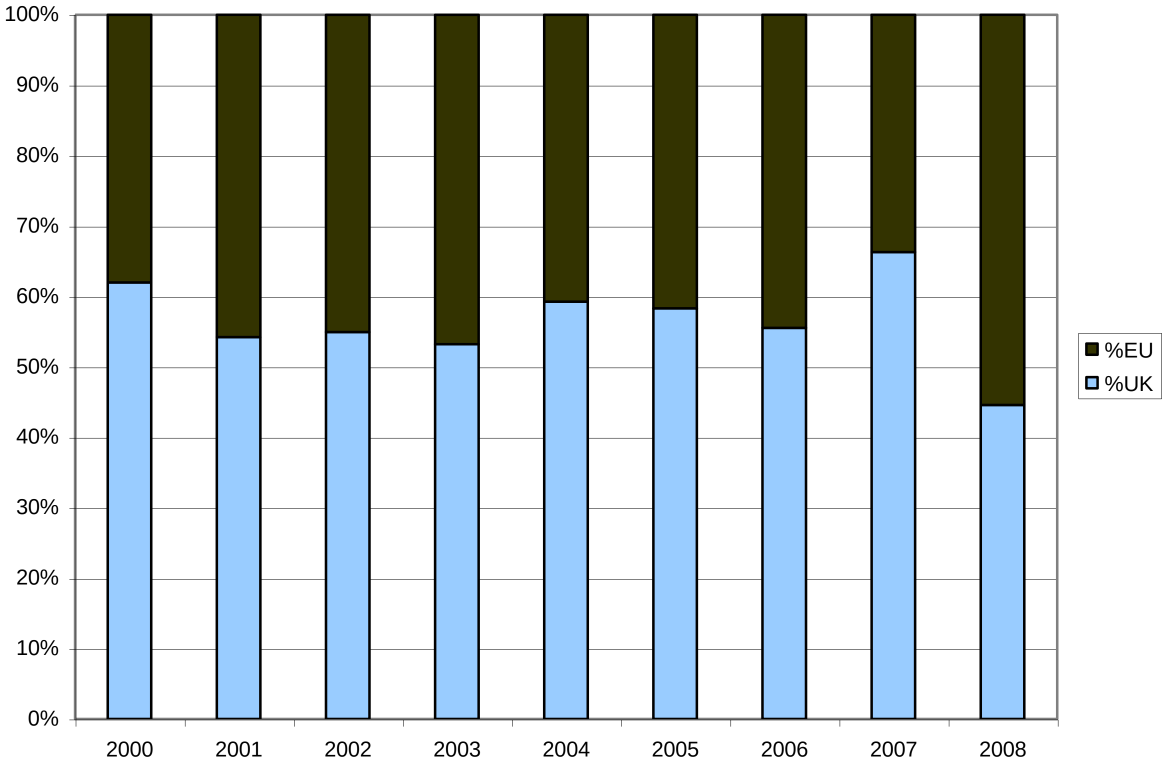


Figure 3.15 – source contributions for MODERATE or above exceedences of ozone over summers from 2000 onwards.

4 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 year.

5 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 forecasters and Defra during this period.

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.

6 Ad-hoc Services

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

- A UK Particulate Episode from 23rd to 24th January 2008 (Cook, Willis, Witham).
- Ozone Pollution Episodes Report (May and July 2008) (Rachel Yardley).

All episode reports which have been published 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.

7 Ongoing Research

AEA and the Met office continue to develop the air quality forecasting systems by:

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 NAME 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.

8 Project and other related meetings

8.1 PROJECT MEETINGS

Regular project meetings continued to be held at Harwell over the course of the year, on January 23rd 2008, July 1st 2008 and December 2nd 2008.

8.2 ANNUAL AIR QUALITY FORECASTING SEMINAR

The Seventh National Air Quality Forecast Seminar took place at City Hall in London on Wednesday 14th May 2008. The event was attended by around 80 delegates who had an interesting day following the agenda described overleaf.

Air Quality Forecasting Seminar –14th May 2008

Agenda	
09:30 – 10:00	**Coffee & Registration**
10:00 – 10:40	**Developments at DEFRA – Janet Dixon –(DEFRA)**
10:40 – 10:55	**Setting Air Quality Guidelines for the long term effects of halogens, hydrogen, halides, metals and metalloids - Stephen Holgate (Southampton University)**
10:55 – 11:10	**Ozone in the United Kingdom - a report from the Air Quality Expert Group – David Carslaw (University of Leeds)**
11:10 – 11:30	**Recent air pollution episodes from local UK emissions – Paul Willis - AEAT**
11:30 – 11:50	**Ozoneweb – Paul Willis - AEAT**
11:50 – 12:20	**Modelling the health impacts of air pollution episodes - the GEMS project – John Gulliver – (University of the West of Scotland & Imperial College)**
12:20 – 14:00	**LUNCH**
14:00 – 14:30	**The PREVAIR forecasting service and applications - Laurence Rouil (INERIS)**
14:30 – 14:50	**The influence of long-range transport in recent UK air pollution events – Claire Witham – Met Office**
14:50 – 15:25	***Assessing particulate health impacts using Models-3 - Power industry experience* - Steve Griffiths – (E.ON Engineering)**
15:25 – 16:00	**The Open-Source Air Pollution Project – David Carslaw (University of Leeds)**

8.3 COST ES0602

COST ES0602 – "Towards a European Network on Chemical Weather Forecasting and Information Systems".

COST ES0602 Meeting in Thessaloniki, May 7th to 9th 2008
Paul Willis of AEA and Paul Agnew of the Met Office attended this meeting as the UK representatives. Jaume Targa of AEA attended as an invited expert representing the EEA. There were working group meetings plus an interesting workshop on public air quality information systems.

There was much discussion and presentation of the latest developments in air quality databases, use of air quality forecast models, and presentation of air quality information to the public.

- Most countries were supportive of the future use of the EEA's near-real-time database as the primary source of air quality data for episode analysis and forecasting model input.
- An ensemble of models will look at the accuracy of forecasting the 2006 air pollution episodes. Data from around 20 UK rural and urban background monitoring sites were suggested by Paul Willis for model validation
- Paul Willis presented the UK's air quality data on Google Earth, and the BSkyB air quality forecast. Both of which were extremely well received by the meeting.
- Useful contact was made with the USEPA Airnow representative, for future review and exchange of ideas on public air quality information systems.

Paul Willis and Jaume Targa operated the UK AQ forecasting systems remotely from Greece during the course of the meeting.

COST ES0602 Meeting in Warsaw, Nov 3rd to 4th 2008
This was a working meeting of the COST action attended by the UK's two representatives - Paul Willis of AEA and Paul Agnew of the Met Office.

The meeting reviewed progress on the three main areas of the COST Action:

- WG1 – Exchange of AQ forecasts and input data.
- WG2 - Multi-scale forecasting, multi-model ensemble, boundary data.
- WG3 - Dissemination and visualization

9 Related projects

During the previous year of 2007 AEA had entered into separate contracts with BSkyB and the Kent Air Quality Partnership to provide text based air quality forecasts for the whole of the UK and the Kent area respectively. AEA ensured that these forecasts, issued under separate contracts, were consistent with the national forecasts for Defra, the DAs and the BBC.

The BSkyB forecasting contract expired during 2008 and was not renewed, predominantly due to funding problems. The year 2007 had yielded no HIGH days due to ozone and only one site in the AURN monitoring network had entered the HIGH band for ozone during 2008.

The KentAir forecast has continued to be issued as a short piece of descriptive text detailing the pollution levels expected in the Kent area for the current and following day. In addition to the AURN network sites, air quality levels measured at sites in the Kent AQ network are also taken into account when making an assessment of the forecast for the region. The forecast issued is also sent to the KentAir website at http://www.kentair.org.uk. .

10 Scientific Literature Review

This section reviews a selection of the scientific literature available in the public domain that is relevant to air quality forecasting in 2008 and 2009.

Recent developments concerned with air quality forecasting are summarised below, with relevant internet links provided at the end of each section.

10.1 FURTHER DEVELOPMENTS OF THE MET OFFICE'S NAME MODEL

At the end of the first quarter of 2009 the Met Office did not renew their previously collaborative contract with AEA for national UK Air Quality Forecasting, therefore developments to the NAME forecasting model continued during 2009 independently of the UK Air Quality Forecasting contract. An air quality seminar, held in the summer of 2009, revealed recent developments to the model which continues to be used to support 5-day ahead air quality forecasting for the BBC. An improved ozone forecasting model now uses more computational power for prediction using a "particles everywhere" approach , in which ozone is effectively carried on particles, rather than being represented by background fields. The earlier model had assumed "particles" had only been present over emission sources or areas where the pollution had advected to. NAME III has been developed to allow a constant influx of background pollution into boundary boxes. A coarse boundary box size of 50 km is used over most of Europe and a higher resolution of 8 km over the UK. Emission data from EMEP (A co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe) feeds the European model and data from the NAEI (National Atmospheric Emission Inventory) is fed into the UK model. According to the Met Office the earlier ozone foreacasting model had exhibited a significant negative bias whereas the improved model showed a major improvement, with an overall small positive bias.

The new "Air Quality Unified Model" is an Eulerian model, in which the focus is on the fluid motion at specific locations in the space through which the fluid flows, opposed to a Langarian model which would focus on individual fluid parcels as they move through both space and time. The Air Quality Unified Model could provide many advantages over earlier models; for example closer integration of meteorology and chemistry, and the potential for including factors such as influence of atmospheric composition on radiation and on cloud physics. The new forecasting model initially used a resolution of 12 km x 12 km and contained 38 levels from ground level to 39 km (the mid-upper Stratosphere). Up to summer 2009 two chemistry schemes had been used in the model: 'Standard Tropospheric Chemistry' which included 26 tracers (9 of them emitted), 27 photolysis reactions and approximately 100 gasphase reactions, and a regional AQ mechanism incorporating 40 tracers (16 of them emitted), 23 photolysis reactions and approximately 115 gas-phase reactions.

The long term development goal is to produce a combined Eulerian-Lagrangian modelling system with the NAME model embedded within the Unified Model.

http://www.ukca.ac.uk/documents/MW_RMS.pdf

10.2 DEVELOPMENT OF AEA'S WRF-CMAQ MODEL FOR UK AQ FORECASTS

During the course of 2009 AEA began to develop a new in-house model for air quality forecasting to supplement the UK Air Quality Forecasting contract. The global model aims to combine two sub models; the Weather Research and Forecasting (WRF) model and the Community Multiscalar Air Quality (CMAQ) Model. The WRF model is fed using real time global forecasting data and CMAQ is a 'One Atmosphere' chemical transport model which includes such effects as atmospheric advection, diffusion, chemical transformation, deposition, aerosol formation and data taken from four emissions inventory sources. The WRF model is a 3-D Eulerian model which was initially developed by the National Center of Atmospheric Research (in the USA) and among other variables attempts to take into account high resolution topography, horizontal and vertical wind components, cloud microphysics and temperature disturbances. The WRF-ARW outputs are then fed into the CMAQ model to produce the air quality forecast. The UK forecast is nested within a European forecast. At present a 48 km European grid and a 12 km UK grid are being used. Annual emissions for NOx, particulate matter, CO, NH_3, VOCs and SO_2 are processed using standard temporal factors into hourly emissions ready for the AQ model. Currently one day ahead forecast maps are produced for both the UK and Europe.

http://www.airquality.co.uk/reports/cat12/0907231150_3_Allen_Fraser_AQ_Forum_Jul09v2.pdf

10.3 NORTH CAROLINA STATE UNIVERSITY.

Forecasting chemical weather with a coupled meteorology-chemistry model system, from 2004 to 2009.

In a 5-year project N.C.S.U. Air Quality Forecasting group are developing an up to date AQF model system which is capable of forecasting both ozone and particulate matter in the short- and long-term and is applicable for both research studies and real-time operational forecasts. The AQF model system was to be initially developed based on the existing NOAA's Weather Research and Forecast Air Quality (WRFAQ) prediction system and then tested using different scenarios for emissions, chemistry and meteorology in the U.S. The proposed research was intended to significantly enhance the fundamental understanding of ozone and particulate matter, the processes controlling them and improve the capabilities of air quality models in reproducing and forecasting them.

http://www.meas.ncsu.edu/aqforecasting/research.html#current

10.4 SONOMA TECHNOLOGY

Founded in 1982, Sonoma Technology, Inc. is a company of about 40 technical staff members, based in California, providing air quality and meterological research and services. Their capabilities include meteorological and air quality measurements, modeling, specialized software development, exposure assessment and air quality forecasting. Their recent work includes major studies across the United States, Mexico, Egypt, and China.

Sonoma Technology develops specialized forecast models that allow agencies to forecast air quality for themselves. The forecasting models use applications ranging from basic tools to mathematically-based tools such as classification and regression trees, neural networks, and fuzzy logic.

http://www.sonomatech.com/aq_studies.htm

10.5 CALIOPE: AN OPERATIONAL AIR QUALITY FORECASTING SYSTEM FOR THE IBERIAN PENINSULA, BALEARIC ISLANDS AND CANARY ISLANDS.

The Caliope project, funded by the Spanish Ministry of the Environment, established an air quality forecasting system for Spain in late 2007, with the intention of increasing knowledge on transport and dynamics of pollutants in Spain and to inform the population about the real-time levels of pollutants. The first quantitative verification study performed used two chemistry transport models, CMAQ and CHIMERE, for a reference year (2004), at a spatial resolution of approximately 20×20 km for the Iberian Peninsula. Both models were shown to perform similarly for ground-level ozone. The mean normalised gross error remained below 15–20% during the summertime, when ozone episodes typically occur. Early in 2008 there were still several development tasks required to improve the forecasting system to resolve the underestimation of PM_{10} particulate mass during summertime from the CMAQ model and the overestimation from the CHIMERE model. The forecasting problems for particulate PM_{10} outlined the need for inclusion of local natural erosion emissions resulting from saltation processes, especially for dry ground conditions during the summertime in the Iberian Peninsula. Also, the definition of the model forecast should be able to better reproduce specific atmospheric circulations in the study area. The resolution of horizontal grid size applied in the project (18 and 22 km) was considered adequate for addressing background air quality in the geographical areas under study. However, for urban/industrial areas with a pervasive influence of anthropogenic emissions on a local scale, finer grid sizes are needed for addressing processes related to gas-phase and aerosol secondary pollutants. Emission inventories with fine resolutions (of the order of 1 km^2) were considered a pre-condition for the feasibility of high-resolution AQ forecasting systems, as taken into practice in France, United Kingdom, Portugal and Germany.

http://www.adv-sci-res.net/2/89/2008/asr-2-89-2008.html

10.6 ENSEMBLE AIR QUALITY MODELING FORECAST SYSTEM FOR BEIJING OLYMPIC GAMES 2008 (CERC).

Within the month leading up to the start of the Beijing Olympics, which was held between the 8th and 24th August 2008, Chinese officials had introduced a series of measures to improve air quality for the event. A new tool was installed in the capital city to allow monitoring of the effectiveness of those implemented measures.

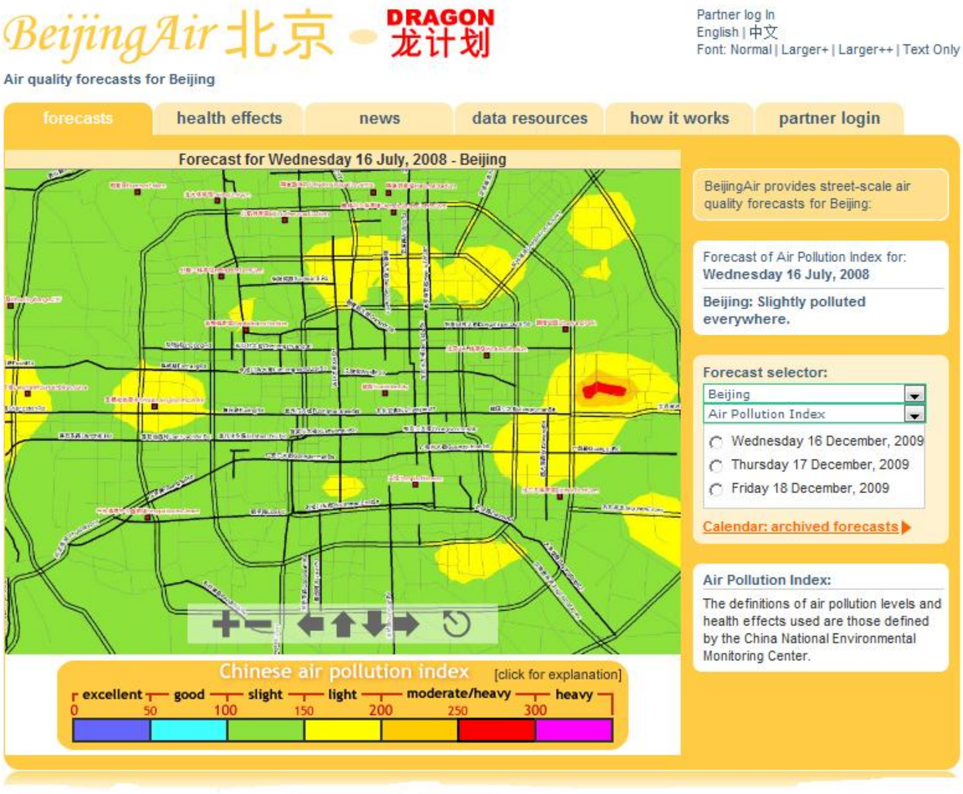
Poor air quality could have caused problems for the Olympic athletes and hindered the performance of those competing outdoors. As the main source of air pollution in the Beijing urban area was vehicle emissions, restrictions on car traffic began on the 20th July, in order to take half of Beijing's 3.5 million vehicles off the road. From late July until late September, only private vehicles were allowed to drive on alternating days and cars with high emissions were prohibited from travelling in the area.

On behalf of the European Space Agency, Cambridge Environmental Research Consultants (CERC) installed a high resolution air quality forecasting system at the Beijing Municipal Environmental Protection Bureau which allowed Chinese authorities to monitor the effect that contra- pollution measures had had on air quality levels at street level.

The system, which used real time data from 27 monitors within the municipality of Beijing, was considered to have been highly flexible and rapidly adjustable to take into account, for example, the special emission reduction measures that were implemented leading up to and during the Games.

Operational street scale air quality forecasts for Beijing were generated from early July onwards. Three-day forecasts were posted daily and were accessible on the Beijing Air Quality website at www.beijingairquality.cn. The forecasts were shown in the form of high-resolution pollution contour maps that predicted levels of nitrogen dioxide, ozone, particles and sulphur dioxide for Beijing's eight districts. The public were able to view maps of each pollutant separately or view the total health index of all pollutants monitored.

The final forecasts used a combination of air quality measurements, surface data and model predictions. Regional modelling using the "Chimere" chemistry-transport model had been provided by the Royal Netherlands Meteorological Institute (KNMI) and the more detailed local modelling was done by CERC's "ADMS-Urban" model.



BeijingAir street-scale air quality forecast for 16th July 2008.

http://www.beijingairquality.cn

11 Forward work plan for 2009

- The two tables below summarise both the weekly and annual planned activity for 2009 (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												

12 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.

13 References/Internet links

UK Air Quality Forecasting reports on the National Air Quality Archive:
www.airquality.co.uk/archive/reports/list.php

Weather journal:
http://www.rmets.org/

Atmospheric Environment Journal:
http://www.uea.ac.uk/~e044/ae_newpages/atmosenv.html

The KentAir website:
http://www.kentair.org.uk/pollutionlevels.php

Miscellaneous References:

http://www.ukca.ac.uk/documents/MW_RMS.pdf

http://www.airquality.co.uk/reports/cat12/0907231150_3_Allen_Fraser_AQ_Forum_Jul09v2.pdf

http://www.meas.ncsu.edu/aqforecasting/research.html#current

http://www.sonomatech.com/aq_studies.htm

http://www.adv-sci-res.net/2/89/2008/asr-2-89-2008.html

http://www.beijingairquality.cn

Appendix 1 - Air Pollution Index

CONTENTS

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 equivalent μgm^{-3} Proposed FDMS limits / TEOM limits
LOW	1	0-32	0-16	0-95	0-49	0-88	0-32	0-3.8	0.0-3.2	0 –19 / 0–21
	2	33-66	17-32	96-190	50-99	89-176	33-66	3.9-7.6	3.3-6.6	20–40 / 22-42
	3	67-99	33-49	191-286	100-149	177-265	67-99	7.7-11.5	6.7-9.9	41-62 / 43-64
MOD	4	100-126	50-62	287-381	150-199	266-354	100-132	11.6-13.4	10.0-11.5	63-72 / 65-74
	5	127-152	63-76	382–477	200-249	355-442	133-166	13.5-15.4	11.6-13.2	73-84 / 75-86
	6	153-179	77-89	478-572	250-299	443-531	167-199	15.5-17.3	13.3-14.9	85-94 / 87-96
HIGH	7	180-239	90-119	573-635	300-332	532-708	200-266	17.4-19.2	15.0-16.5	95-105 / 97-107
	8	240-299	120-149	636-700	333-366	709-886	267-332	19.3-21.2	16.6-18.2	106-116 / 108-118
	9	300-359	150-179	701-763	367-399	887-1063	333-399	21.3-23.1	18.3-19.9	117-127 / 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	≥ 128 / 130 μgm^{-3}

Banding	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

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