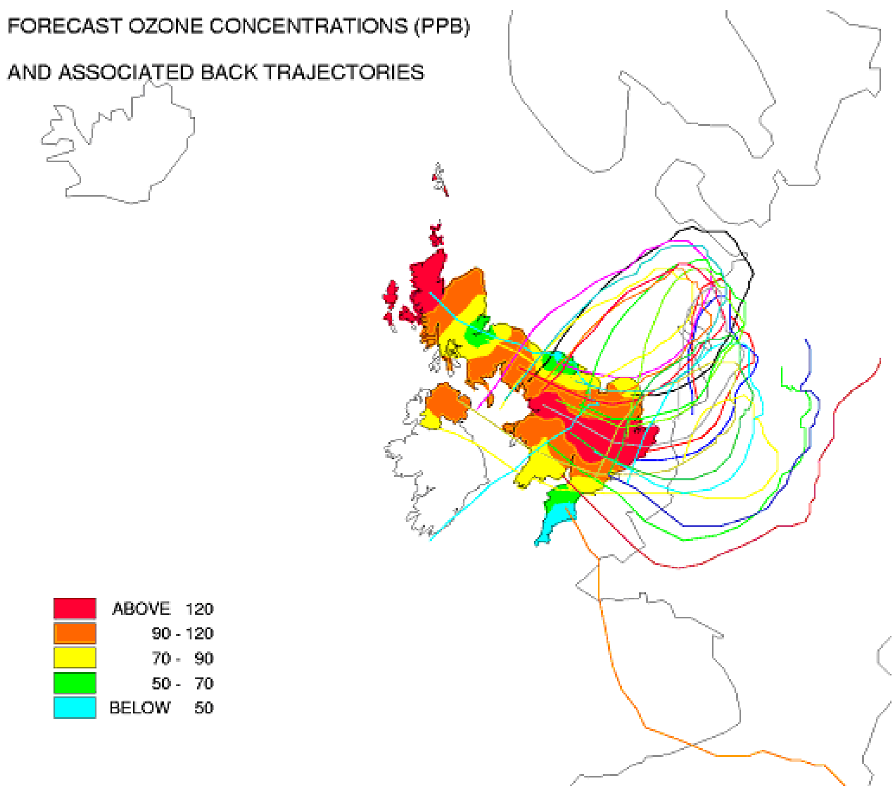
UK Air Quality Forecasting: Annual Report 2005

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/2160/Issue 1
March 2006

netcen
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Met Office

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Title	UK Air Quality Forecasting: Annual Report 2005
Customer	Department for Environment Food and Rural Affairs, the Scottish Executive, the Welsh Assembly Government and the Department for the Environment in Northern Ireland
Customer reference	RMP/1902
Confidentiality, copyright and reproduction	Subject to any prior rights and to the rights of any third party the copyright in the report shall be assigned to the Crown
File reference	ED45099
Report number	AEAT/ENV/R/2160
Report status	Issue 1

AEA Technology plc
National Environmental Technology Centre
Building 551
Harwell
Didcot
Oxfordshire
OX11 0QJ
Tel: +44 (0)870 190 6602
Fax: +44 (0)870 190 6607

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	Name	Signature	Date
Author	Andrew Kent Andrew Cook Mark Harrison Claire Witham Helen Webster		15/3/06
Reviewed by	Paul Willis		20/3/06
Approved by	Jon Bower		25/3/06

Executive Summary

This report covers the operational activities carried out by **Netcen** and the Met Office on the UK Air Quality Forecasting Contract for the year 2005. 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 2005, there was a total of 38 unique days on which HIGH or above air pollution was recorded across the UK for all pollutants. 32 of these days were due to PM_{10} , 5 were due to ozone and there was one day where both ozone and PM_{10} levels were HIGH. There were no instances of high NO_2, SO_2 or CO during 2005. A total of 22 regional days were recorded HIGH in zones, and 20 days in agglomerations. The forecasting success and accuracy for this year is summarised in Table 1 below. The overall forecasting performance for HIGH episodes has dropped marginally in 2005 from the previous year. This was primarily due to highly unpredictable localised PM_{10} related episodes over this period, and the small number of (easier to forecast) ozone episodes in 2005. Success and accuracy rates for MODERATE pollution are significantly better than for HIGH episodes.

Table 1 Forecast success/accuracy for incidents above 'HIGH' and above 'MODERATE' in 2005

Region/Area	***HIGH % success***	***% accuracy***	***MODERATE % success***	***% accuracy***
Zones	77	57	172	86
Agglomerations	10	7	180	69

Developments in the forecasting system in 2005 included improvements to the Netcen Air Quality Forecasting Toolkit and modifications to the Met Office NAME model to improve the particle distribution, reduce model noise and utilise higher spatial resolution meteorological data. The UK has also joined the European Environment Agency's 'Ozone Web' data exchange programme. The BBC have agreed to alter their presentation of pollution levels in line with the nationally recognised index used in the forecasting system.

During this year, several ad-hoc reports were presented to Defra and the Devolved Administrations. Two of these reports analysed ozone pollution episodes during the summer:

- Air Pollution Forecasting: Ozone Pollution Episode Report (Friday 27th May 2005)
- Air Pollution Forecasting: Ozone Pollution Episode Report (June - July 2005)

A further report analysing the December Buncefield oil depot fire was presented to Defra and the Devolved Administrations and has yet to be published. 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.

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Appendices

1 Introduction

Netcen 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 an hourly update on air pollution levels, together with a 24-hour air pollution forecast. These are widely disseminated through the media. The forecasts 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 **Netcen**. 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 including 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 2005. 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, **Netcen** 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 Defra and other government Departments, UK air quality monitoring contractors, 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 Devolved Administrations (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

During 2005, a number of improvements have been introduced to assist with the analysis of forecasting performance and day-to-day forecasting.

2.1 AIR QUALITY FORECASTING TOOLKIT UPDATES

A number of improvements have been made to the AQ Forecasting Toolkit. These include:

- **Links to BBC weather charts.** Wind diagrams can now be viewed for the UK only or for the whole of Europe with a single click. Links to UK regional weather diagrams have been added.

- **Fast access to European web data.** Daily maximum ozone levels in France can now be viewed on the "Pre'Air" website. Links to the European Operational Air Quality Forecasts System (University of Madrid) have been added – these show modelled forecasts for the whole of Europe over various averaging periods for all standard pollutants. The European Air Mass Trajectories Archive has been added as well as the European Environment Agencies "Ozone Web".

- **NAME model data.** A quick link to the raw NAME model data has been added to the toolkit.

- **Administrative information.** The AQ forecasting working instructions were updated in early 2005 and quick links made to these within to toolkit. Email, phone and emergency phone numbers have been added in the "contacts" section for Defra and the Met Office. Email contacts have also been added for Bureau Veritas and DoE Northern Ireland.

2.2 OZONE WEB DEVELOPMENT

During the first quarter of 2005 the UK Air Quality Forecasting contract was varied to include development of software needed for the UK to join the Ozone Web near-real time European data exchange system.

This has involved the development of scripts to extract the data from the Air Quality Archive every hour to submit via the XML data format to the European Environment Agency.

This data went live on Ozone Web (http://ozone.eionet.eu.int/index.jsv) on the 22nd April. Data from 10 rural sites and one urban background site (London Bexley) are submitted, providing good geographical coverage of the UK. The rural sites (in north to south order) are: Strath Vaich, Eskdalemuir, Lough Navar, High Muffles, Ladybower, Aston Hill, Sibton, Harwell, Lullington Heath and Yarner Wood.

Only provisional data are submitted to this system. Users are able to view the latest hourly concentrations in terms of their bandings on the maps (Figure 2.1, below), the station details (Table 2.1) and a bar graph of daily mean concentrations for each site going back over the last 2 weeks (Figure 2.2). There are up-to-date ozone concentrations on this site for a number of other European countries and it is hoped that other countries, particularly France and Germany will join the system in the near future.

This is a useful tool which can be used in AQ forecasting, for identifying imminent ozone episodes throughout Europe. It is particularly valuable in terms of forecasting episodes of ozone because this pollutant tends to be regional in scale, affecting large areas at a time.

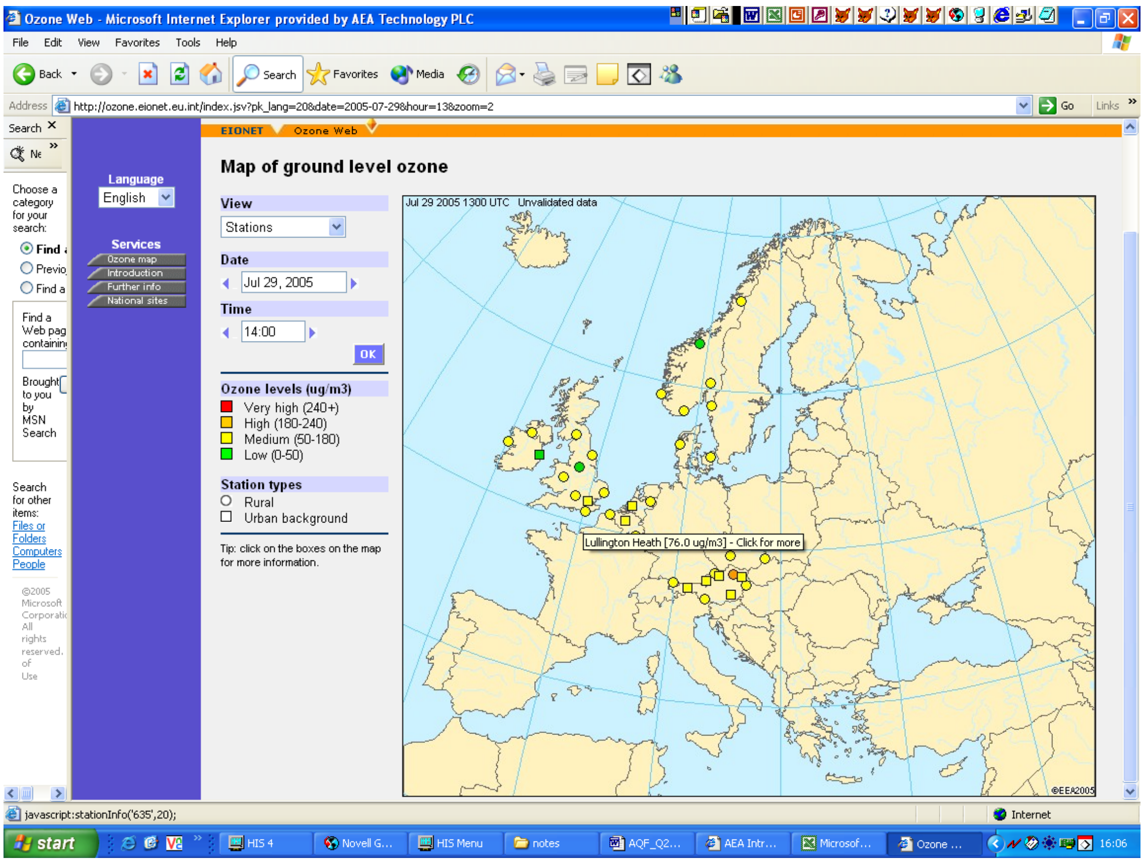


Figure 2.1 Map of ground level ozone

Table 2.1 Basic station information

Station name	Ladybower
Station EU code	GB0037R
Station description	
Station type	rural
Station street	-
Station city	-
Station network	GB025A
Network description	
Station country	United Kingdom
Country ISO code	GB

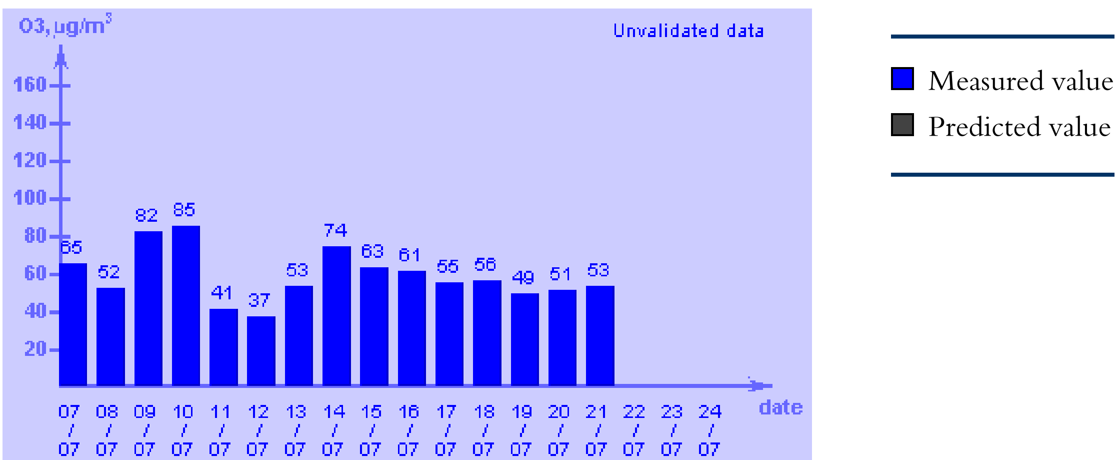


Figure 2.2 History bar graph of daily ozone concentrations

2.3 FOURTH AIR POLLUTION FORECASTING SEMINAR

The Fourth Air Pollution Forecasting Seminar was hosted by the Met Office on behalf of the Department for the Environment, Food and Rural Affairs (Defra) and the Devolved Administrations on Wednesday 27th April 2005 at the Met Office in Exeter.

The seminar was one of an ongoing series of events, hosted by the Met Office and **Netcen** to report on improvements to the air-quality forecasting service commissioned by Defra and the Devolved Administrations.

More than 50 delegates and speakers attended the event. These included delegates from medical and health organisations, local authorities, scientific officers, environmental health and pollution control academics, consultants, representatives from Defra and the Devolved Administrations and the Environment Agency.

The seminar provided a forum for organisations to present their latest research and to highlight any services which they provide in the field of air quality forecasting, air monitoring and modelling technology and health issues relating to air pollution. These presentations provoked much useful and informative discussion.

The success and accuracy rates of the national air pollution forecasts were discussed. Whilst there were some difficulties understanding the definitions of these measures, 2004 was reported by **Netcen** to have been typical in terms of the success and accuracy rates achieved for zones (predominantly ozone pollution in rural areas), but low for agglomerations (urban areas) due to the relatively high incidence of localised and difficult to forecast PM_{10} episodes during this year.

Wide-ranging discussion of the factors affecting the accuracy of the air quality forecasts covered:

- Local pollution sources.
- Unusual trans-boundary PM_{10} events (Saharan dust, forest fires, volcanic eruptions etc.)
- Emissions inventories.

It was reported that the UK is the only European country currently publishing the success rates of air pollution forecasting, based on "actual" reported data and forecast meteorology. By taking out unusual events and using analysis met. data it is possible to improve the reported performance of forecasting models.

It was reported that there are several joint European initiatives to improve and co-ordinate air quality forecasts. These currently involve **Netcen**, the Met Office and Defra:

- Smog Warners co-ordinated by **Netcen** since 1997 – see www.aeat.com/netcen/airqual/forecast/smogwarners
- Ozone Web operated as part of the EC's Clean Air for Europe (CAFE) programme- see http://ozone.eionet.eu.int/index.jsv?pk_lang=20
- A proposal from the Network of European Metereological Sevices (EUMETNET) see www.eumetnet.eu.org

The effects of air pollution on hospital admission and mortality rates encouraged much discussion and re-enforced the importance of research in this area. The Department of Health now has a unique database which contains details of all the research comparing hospital admission and mortality rates with background air pollution. It was reported that patients with some conditions were put at much higher risk of premature death with increased air pollution. Statistically significant factors relating air pollution to hospital admission rates and mortality rates can be confirmed for all major pollutants. The only poor relationship was between increasing ozone and hospital admissions, and this was not fully understood. Published research into the numbers of increased deaths per ppb or $\mu g\ m^{-3}$ of pollution gives us a guide to the scale of the risks and confirms the value of this area of work.

The Met Office Health Forecasting team are trying to encourage the NHS to take preventative action to protect susceptible patients when conditions are likely to adversely affect their health.

The latest evidence on the links between climate change and air pollution levels were presented and discussed. This is a complex area with many conflicting factors, and there was no simple answer as to whether climate change would make air pollution levels worse in the future. Indeed, emissions of some pollutants are expected to offset the effects of global warming by causing "global dimming".

The seminar agenda is detailed below.

Air Quality, Health and Climate Change, Met Office, Exeter (27/05/2005)	
10:30 – 10:45	Welcome and Introduction from Met Office/Defra
10:45 – 11:15	Air Quality Policy Overview Noel Nelson, Defra
11:15 – 11:45	UK Air Quality Forecasting - Project Update Paul Willis, AEAT netcen
11:45 – 12:15	Recent AQ & Health Research Dr Bob Maynard, Department of Health
12:15 – 12:30	Discussion
13:30 – 14:00	Presenting Environmental Information John Hammond, BBC Weather Centre
14:00 – 14:30	Practicalities of using a health forecast Mark Gibbs, Met Office
15:00 – 15:30	Climate Change & Air Quality Dr Bill Collins, Met Office
15:30 – 16:00	AQEG 3rd report – progress update and latest findings Professor Mike Pilling, Leeds University (AQEG Chair)
16:00 – 16:30	Discussion & Close

2.4 MET OFFICE DEVELOPMENTS

2.4.1 OPERATIONAL SUPPORT

By the end of the financial year 2005-2006, the Met Office Air Quality Forecast System (AQFS) will be fully integrated into the main production processes of the Met Office. This transition will spread knowledge and expertise about the AQFS, and the services it supports, across all areas of the Met Office: Business, Production, Development and Research, thereby affording greater operational resilience and forward development at all levels: customer requirements, support, software, hardware and advancements in modelling air quality.

2.4.2 NAME MODEL

During 2005, the Met Office Atmospheric Dispersion Group (ADG) has improved the representation of atmospheric dispersion in both the NAME and TRAJ models.

Modifications to the operational AQFS include:

- The model now allows for particle splitting when secondary aerosol is created in the chemistry scheme and the resultant particle mass is above a calibrated threshold. This has the consequence of increasing the particle distribution and reducing model noise.
- The meteorological data has increased in resolution from 60 km to 40 km in the horizontal and from 33 to 42 levels in the vertical. This will help resolve smaller air quality features.

Modifications to the development AQFS include:

- An updated version of the NAME chemistry scheme and a new speciation for VOCs based on the latest NAEI emissions data.
- Creation of new emissions source files using the most recent emissions data for the UK and Europe.
- An increase in the area of coverage.

AQFS system process times have been changed to allow increased resolution, increased area of coverage and increased particle numbers in NAME, but maintain delivery times. ADG are also evaluating the benefits of using mesoscale meteorological data to produce higher spatial resolution output within the AQFS. This change in process times will facilitate a future change to the increased resolution meteorology.

ADG have developed a new model core for the AQFS, based around the new version of the Met Office NAME model, "NAMEIII". Comparison runs using NAME III have demonstrated that using plume-rise dynamics for the largest point-source SO_2 emitters combined with better information on stack heights may improve the air quality forecast. Assigning plume rise to individual sources was not possible previously in NAME. More accurate data on stack heights for over 300 sources has just been obtained from Netcen and this will be included in the emissions files.

2.4.3 NAME PERFORMANCE

Following the Met Office identification in 2004 of the need to monitor the day-to-day performance of the air quality forecasts produced by NAME, a new system has been established to quantify the operational performance of NAME. The Met Office continues to work with the GEMS (Global and regional Earth-system (Atmosphere) Monitoring using Satellite and in-situ data) project to implement a forecast skill index for air quality modelling. This project involves many European partners and one outcome will be the comparison of air quality model fields for multiple species against observations from all over Europe. A skill score will be used to determine threshold exceedences of the model forecasts compared to the observational data.

The AQ skill score has several functions:

- to measure current performance
- to assess impacts on model performance from further development
- to provide a quantitative measure of confidence in the overall scientific basis that underlies the NAME model.

One limitation in verifying the AQFS forecasts, particularly immediately after model upgrades, is the delay in receiving ratified observational data. It is proposed to have a number of recent verification periods (for example August 2003) over which the models can be compared. An automated process for routinely providing measured air concentrations stored in the national air quality archive (www.airquality.co.uk) in a suitable format for direct comparison with the NAME air quality forecast data has been successfully implemented. This monitoring data is also being made available to the Met Office Health Forecast team that is providing services for resource & demand management within NHS.

2.4.4 DUST AND SEA SALT FORECASTING

There is growing interest in suspended particulate matter because of their potential adverse impact on human health, visibility and climate. While it is generally recognised that natural sources can contribute significantly to particulate matter, information quantifying the extent of these sources remains scarce. The objective of this work is to develop within the NAME Lagrangian dispersion model an emission parameterisation for a range of natural sources of primary PM_{10}. The accuracy of the emission terms is then to be verified against observed data for specific episodes for which the natural component is thought to contribute significantly to levels of PM_{10}. Once model validation has been completed satisfactorily, estimates may then be made regarding the contribution of natural sources to air quality in the UK.

The main sources of natural particulate matter in the atmosphere have been identified; these include contributions from the uplift of dust, soil and sea salt, as well as those sources of a biological nature such as pollen, fungal spores and bacteria. The work has focussed on the contribution from sea salt and Saharan dust for which a reasonable amount of information is available in the literature although it could be extended to other contributory factors. A dust scheme has been developed within NAME to model the emission and transport of Saharan sand using six bin sizes from 0.06 µm to 60 µm in diameter. The emission scheme is based on that used in the Hadley Centre atmospheric general circulation model, HadAM3[1] which is used to investigate the radiative impact of mineral dust. As the parameterisation had only been tested in the Unified Model (the Met Office's Global Climate Model) on a climatological timescale, work initially focussed on the validity of using such a scheme in NAME over a 1–14 day timeframe. Ancillary files required by the parameterisation include clay fraction, vegetation fraction and the ratio of mass of dust in the size division to total mass. Although these ancillary files were initially only available on a climatology grid ($2.5^0 \times 3.75^0$) they have now been obtained and implemented at higher resolution ($0.83^0 \times 0.55^0$ and $0.18^0 \times 0.18^0$). In this scheme both the emission rate and the particle size distribution are determined as a function of the surface wind speed. Other then the emission scheme, additional factors that were investigated include the sedimentation scheme and the dry and wet deposition of sand particles. These are calculated explicitly as a function of the particle size. Model output is generated at three size categories, 1 µm, 2.5 µm and 10 µm to facilitate model comparison with field measurements acquired at these size ranges (PM_{10}, $PM_{2.5}$, and PM_1).

In order to investigate the performance of the dust scheme it was first necessary to study the accuracy of the emission term. This was initially performed by comparison with existing emission datasets[2] as well as by comparison with satellite imagery. A dust event on 19th to 21st July 2004 was identified and the Meteosat-8 images were acquired in order to compare with NAME output.

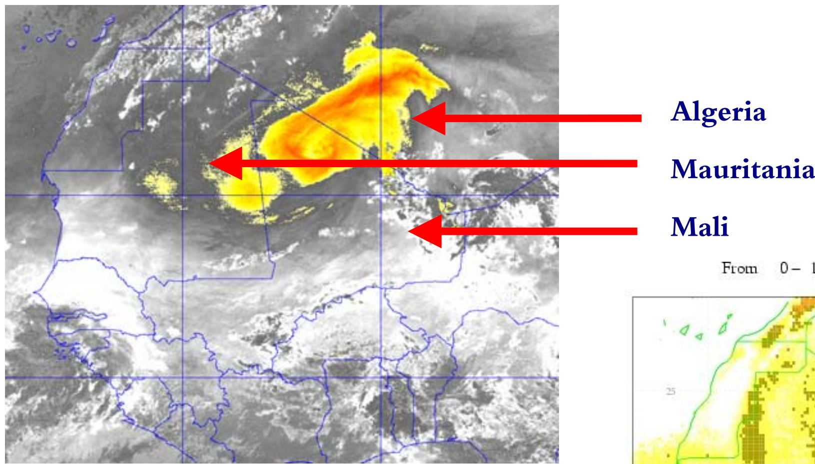
As accurate soil moisture information required by the emission scheme is not currently available, therefore the monthly 30 year average values were used for soil moisture. Despite this simplification, the model satisfactorily represented the evolution of the dust over this three day period. Figure 2.3 shows the satellite imagery together with output from NAME for 19 July 2004 at 1200 UTC. This shows that NAME has picked out the main features of the dust event and compares favourably with other data.

While Figure 2.3 demonstrates the ability of NAME to identify the main plume of sand, satellite imagery is not able to quantify the amounts of dust present in each layer of atmosphere. In order to validate the model quantitatively it is necessary to compare the model with actual PM_{10} measurements.

One factor that must be taken into consideration is the resolution of the model. The first case study that focussed on a small area over the Sahara was run at $0.18^0 \times 0.18^0$ resolution. However, in order to run the model over an area sufficiently large to monitor the transport further a field, the model was run at lower resolution ($0.83^0 \times 0.55^0$). This change in resolution reduced both the detail contained in the meteorology as well as that contained in the ancillary files that describe the surface conditions. To demonstrate these issues the model was run at these two different resolutions over a similar time

[1] Woodward, S., (2001) Modelling the atmospheric life cycle and radiative impact of mineral dust in the Hadley Centre climate model, *Journal of Geophysical Research* **106**, 118,155-18,166
[2] Nickling, W.G. and Gillies, J.A.,(1993) Dust emission and transport in Mali, West Africa, *Sedimentaology*, **40**, 859-868

period. Figure 2.4 shows that the model run at higher resolution picks up the dust event highlighted in Figure 2.3 whereas the model run at lower resolution does not represent the event as well.



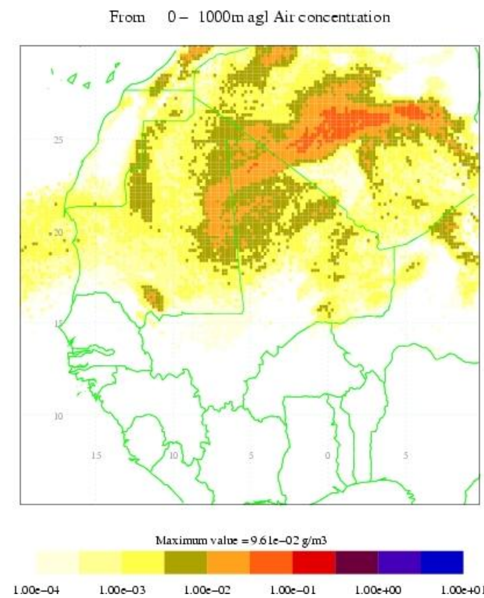


Figure 2.3 Satellite imagery and the NAME model output for 19 July 2004 at 1200 UTC

Diagram (a)

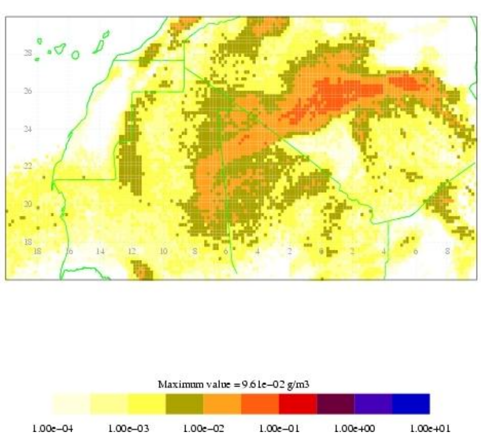


Diagram (b)

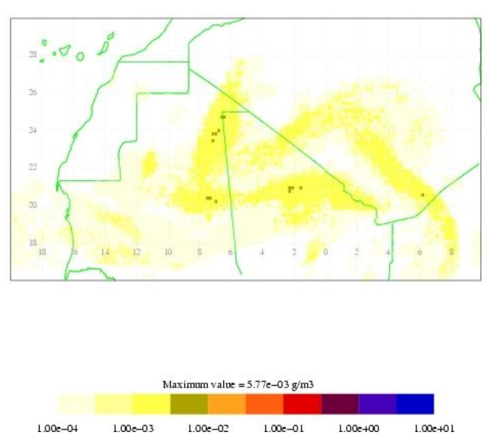


Figure 2.4 Model output for the 19 July 2004 at 1200 UTC. Diagram (a) was generated at $0.18^0 \times 0.18^0$ resolution and Diagram (b) generated at $0.83^0 \times 0.55^0$ resolution.

Another example shows the long-range transport of Saharan dust to the UK during March 2000. At this time Plymouth recorded values of 292 $\mu g\ m^{-3}$. As the model output shown in Figure 2.5 was generated at coarse resolution ($0.830^0 \times 0.550^0$) those same factors highlighted above also apply to this study.

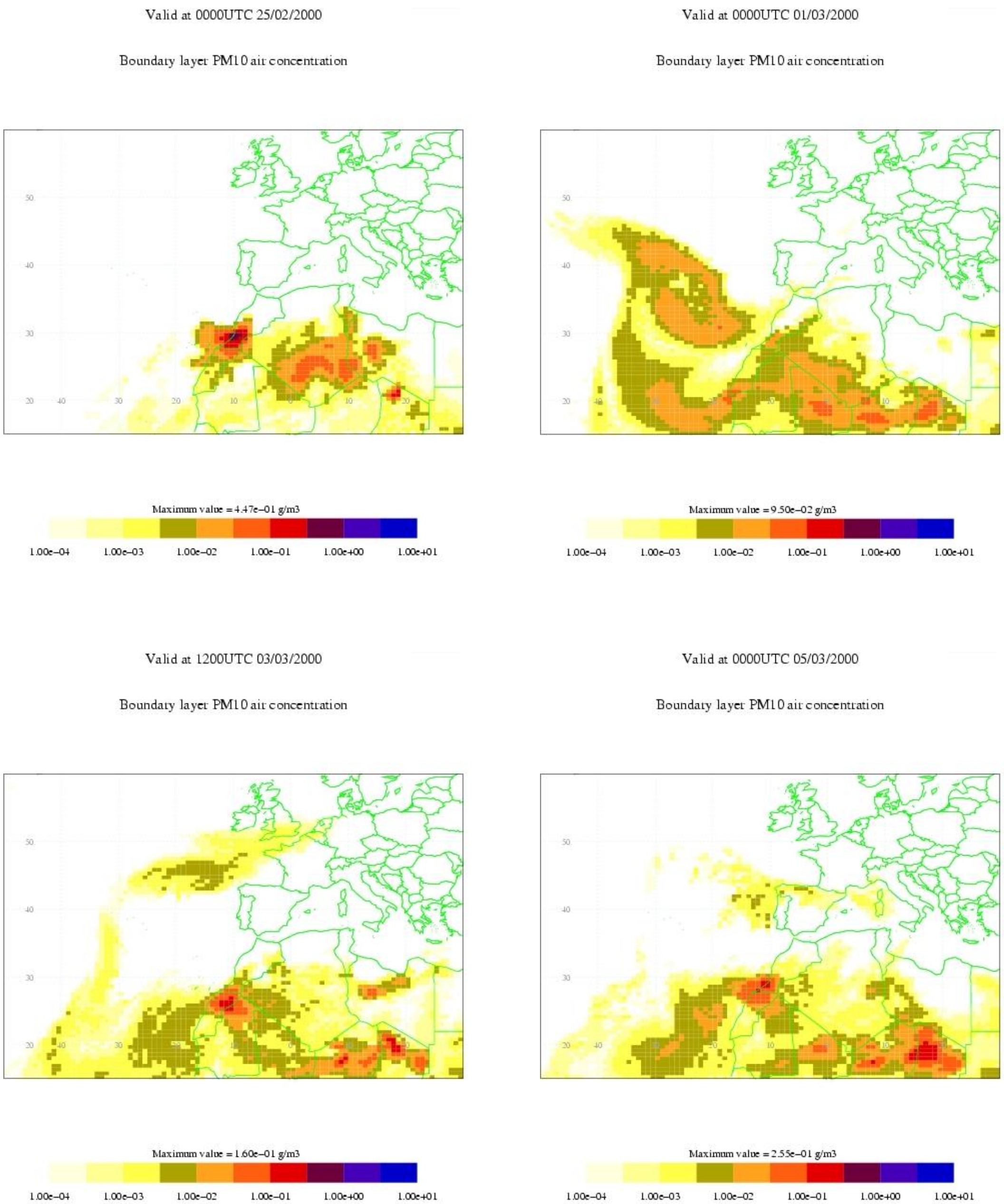


Figure 2.5 Model output highlighting the dust generation and transportation. Plots are for 0000 UTC 25/2/2000, 0000 UTC 1/3/2000, 1200 UTC 03/3/2000 and 0000 UTC 5/3/2000.

The plots shown here represent the transport of Saharan dust, self-generated by the model as a function of the surface wind speed, to the UK. While the timing of the arrival of the dust proves to be accurate, at present the model is over predicting the amounts transported to the UK.

In addition to the resolution issues highlighted earlier, there are a number of uncertainties with respect to the input parameters used in the emission scheme. These include factors A, B and C, the clay fraction, the soil moisture content, the surface wind speed and the vegetation fraction. Therefore studies were undertaken examining the affect of these parameters to the resultant maximum concentration of dust observed at Plymouth during this episode. Table 2.2 highlights the percentage change observed when altering the value for each parameter from 90 % of the initial value to 110 %. It can be seen that the model is very sensitive to the changes to the input parameters. This also helps explain the sensitivity of the model to the resolution at which it is run. Clearly if the model is run at higher resolution the input parameters used by the dust scheme will be more representative of the area that it is representing.

Table 2.2 Sensitivity study of the parameters included in the emission scheme.

Parameter	**Resulting Percentage change**
C	498 %
B	323 %
Clay fraction	296 %
Moisture	236 %
Surface wind	233 %
A	167 %
Vegetation fraction	62 %

Progress has also been made regarding the modelling of the contribution from sea salt to levels of PM_{10}. A scheme[3] has been implemented which models the emission of sea salt particles using two bin sizes to represent particles between 0.1 µm and 10 µm in diameter.

The most prominent mechanism for the generation of sea salt aerosols is through the entrained air bubbles bursting during whitecap formation producing film droplets and jet drops. Additional energy supplied by the wind to the sea surface causes direct production of sea-salt particles through the production of spumes (see Figure 2.6). The parameterisation implemented into NAME includes both the generation of sea salt particles indirectly through production by bubbles and directly through production by spumes. Both the emission rate and the particle size distribution are determined as a function of the surface wind speed. As with the Saharan dust, other parameters such as dry deposition, gravitational settling and in-cloud and below-cloud scavenging were also investigated. Again, model output is generated at three size categories, 1 µm, 2.5 µm and 10 µm.

[3] Gong, S.L. and Barrie, L.A., (1997) Modelling sea-salt aerosols in the atmosphere 1. Model development, Journal of Geophysical Research, 102, 3805-3818

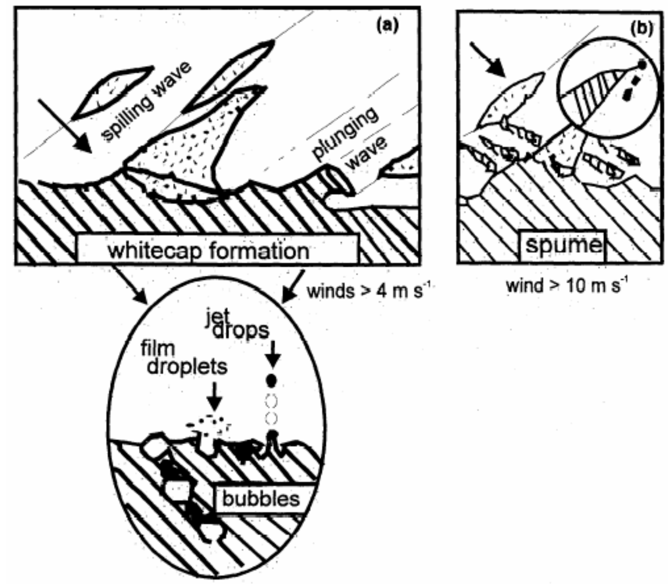


Figure 2.6 Mechanisms for sea-salt aerosol generations. Two mechanisms are presented (a) indirect production by bubbles and (b) direct production by spumes.

In order to validate the scheme the model was run for a three month spell over the autumn of 1998. This timeframe was chosen as there were a number of instances during which it was thought that sea salt could have contributed significantly to the levels of PM_{10} observed. Figure 2.7 shows model output for the first half of October 1998 for Lough Navar (a rural observation site in Northern Ireland). The sea salt component is labelled as “salt component”. A model run was also performed using NAME in conjunction with NAEI / EMEP emissions of primary pollutants (including PM_{10}) together with chemistry to generate the secondary sulphate and nitrate aerosols. The output from this model run was labelled as “PM10_total component” with the sum of these labelled as “Sum of salt and PM10_total”. These are both plotted against the observed PM_{10} data acquired from The UK National Air Quality Information Archive (http://www.airquality.co.uk/archive/index.php).

The model shows that during the first eight days of the simulation sea salt does not contribute significantly to the levels of PM_{10} observed. However, during the second half of the timeframe shown here there are a number of instances where sea salt can be seen to be the major component of the observed PM_{10} at this remote site. In general however it can be seen that the existing PM_{10} modelling (labelled as PM10_total _component) does not compare very well with the observed values because at present it does not include such natural sources such as uplift of dust, soil and sea salt, as well as those sources of a biological nature such as pollen, fungal spores and bacteria.

As expected model output at more inland and more urban environments show sea salt to be a much smaller component of observed PM_{10}. As such the model may be used at present to identify potential sea salt episodes but in order to assess the accuracy of the concentrations that the model generates comparison against speciated PM_{10} is required.

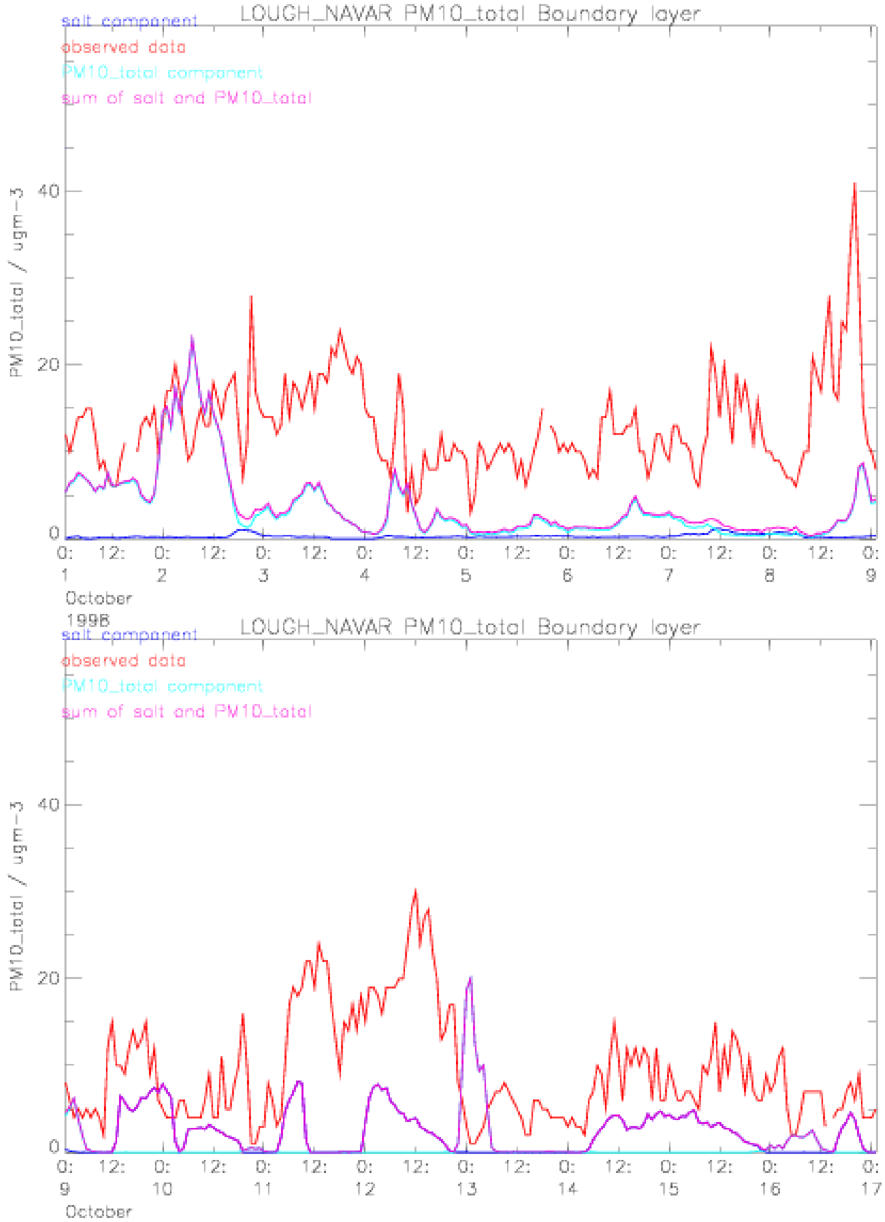


Figure 2.7 Model output for October 1998.

While comparing the model output against observed PM_{10} data from The UK National Air Quality Information Archive is useful, in order to assess the accuracy of the salt scheme itself it is necessary to obtain speciated PM_{10} data. Contacts have been established at the University of Brighton and at the University of Exeter who have such datasets. Future work will focus on comparing the output from the model against these two datasets.

In a similar way to the Saharan dust, it is possible to run the model over a longer time frame in order to assess the contribution of sea salt to PM_{10} over the UK as a whole. Model output showing the maximum sea salt concentration and cumulative total over a three month period is shown in Figure 2.8.

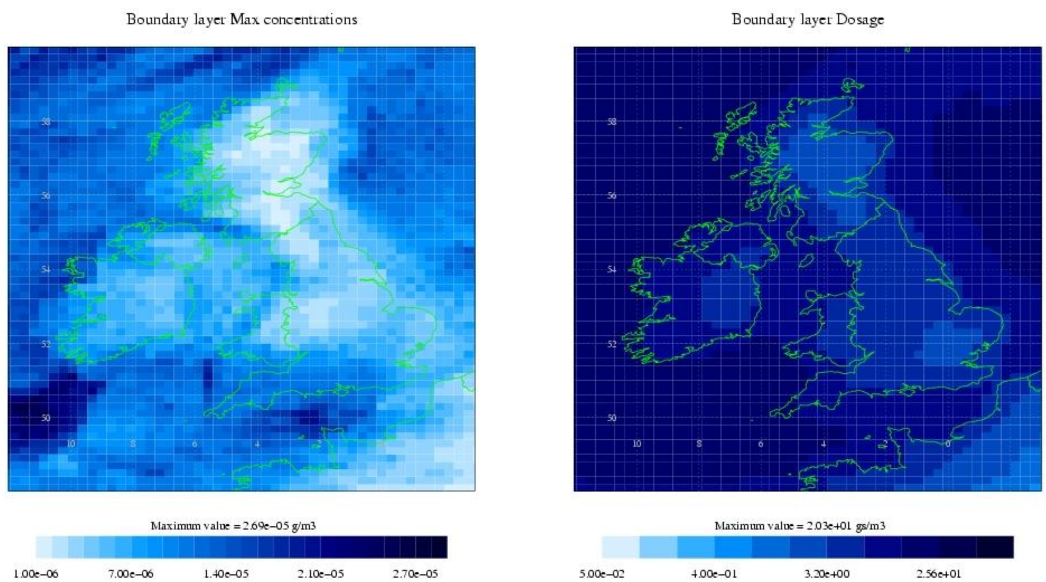


Figure 2.8 Model output highlighting the maximum concentration and the cumulative concentrations of sea salt over the period 1/10/98 – 31/12/98.

This study shows that sea salt alone is unlikely to produce an exceedence of the air quality objectives with a maximum air concentration (daily averaged) of around 10 $\mu g\ m^{-3}$ over land. The model also suggests that while inland areas generally experience lower amounts of sea salt, sea salt is still a contributory factor for these areas. Further model runs were performed over the same period for the year 2003 and also for August 1999 to May 2000. These runs generated broadly similar results indicating a relatively steady contribution from sea salt from year to year.

The work to date has shown that modelling the transport of Saharan dust and sea salt in NAME can provides useful information for regulatory bodies regarding the impact of natural sources of PM_{10}. For example, it has been shown that sea salt alone is unlikely to give rise to an exceedence of the Air Quality Directive limits for PM_{10}. While less frequent, the transport of Saharan dust has more potential to produce an exceedence. The model can be run over both long time spans to assess the geographical impact of Saharan dust and sea across the UK as well as over shorter time frames to study particular PM_{10} episodes.

2.5 BBC AIR QUALITY INDEX MODIFICATIONS

On 20th July 2005, Paul Willis (**Netcen**) sent a letter to the producer of the BBC, which had been endorsed by Defra. The letter explained that the AQ index value-to-banding conversion being employed by the BBC was not in line with accepted UK standards (in which banding changes occur every 3 index values, COMEAP AP Index). Two index values were being used for both the MODERATE and HIGH bands, as reflected in all the associated BBC media locations. The BBC (Andrew Lane, BBC Weather Centre) agreed to implement the changes.

2.6 PROJECT REVIEW MEETINGS

2.6.1 5TH MAY MEETING

A project review meeting was held at **Netcen** on 5th May 2005. The following were present: Janet Dixon, Martin Meadows (Defra), Alistair Manning (Met Office), Paul Willis, Jon Bower and Jaume Targa (**Netcen**). Topics discussed/actions decided included:

- Progress was presented on the EEA ozone data exchange programme. The ozone data was extracted from the UK Air Quality Archive and sent to the EEA “real-time” ozone website. Jaume Targa attended a EUMETNET meeting in April where it was confirmed that the a proposal for real-time ozone data and forecasting website was still to go ahead despite similarities with the EEA ozone web programme.

- It was reported to the group that the 4th Forecasting Seminar hosted by the Met Office at Exeter had been well attended (see section 2.3, above). Among other presentations, it was noted that the Department of Health database linking air pollution to hospital admissions showed a good correlation among all pollutants except ozone. The Met Office are currently developing a health forecasting system focussed on “heatwaves” but also including other environmental factors such as air quality. It was noted that the BBC was changing their presentation of weather and air quality forecasts on television to include less clear triangular symbols for air quality. **Netcen** agreed to comment on these new symbols.

- The Met Office provided an update to changes in the NAME model and their services (detailed in section 2.4, above). These included the new version of the NAME model core, the introduction of multiple rather than single particle trajectories, and improved operational resilience by incorporating the air quality forecasting system into the standard Met Office operations.

- The Defra contacts in the event of an air pollution episode were reviewed.

2.6.2 7TH SEPTEMBER MEETING

A project review meeting was held at **Netcen** on 7th September 2005. The following were present: Janet Dixon, Martin Meadows (Defra), Martin Cumper (Met Office), Paul Willis, Jon Bower (**Netcen**). Topics discussed/actions decided included:

- Defra were re-considering the basis for press releases to avoid degrading “newsworthiness” of air quality.

- Met Office were liaising with BBC over some delays in updating the 5-day forecast on the BBC site.

- Met Office were to check if air pollution episodes could be issued in the same form as severe weather warnings on the Met Office and BBC web pages, as an alternative to press releases.

- **Netcen** were to develop ideas and suggest dates for the next AQ forecasting seminar

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 to December 2005 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 for 'MODERATE' and above concentrations. 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. Forecasting performance is summarised in Tables 3.1 and 3.2, which 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 2005

3.2.1 GENERAL TRENDS

Figures 3.1 to 3.4 show that PM_{10} and ozone are the two pollutants that most commonly arise in the UK as health affecting episodes. Figures 3.3 and 3.4 illustrate the different temporal scales in episodes of these pollutants. PM_{10} episode are typically of a higher magnitude (HIGH and VERY HIGH bands) and frequency (44 regional days of HIGH or VERY HIGH concentrations) than ozone episodes. PM_{10} episodes remained fairly localised with only a small number of sites reach the HIGH band on each occasion. Ozone episodes in 2005 have had a lower magnitude (reaching the HIGH band but no VERY HIGH concentrations), a lower frequency (HIGH concentrations were recorded on 6 regional days) but occurred on a much wider spatial scale, with many sites experiencing HIGH concentrations at the same time during regional episodes. PM_{10} concentrations show no particular seasonal pattern because they are affected by short-term meteorological factors such as wind direction, speed and the presence and emission of local sources. In contrast, ozone has a strong seasonal relationship - being a photochemical secondary pollutant it is dependent on the seasonal factors such as the length of the day, air temperature and presence of sustained fine weather and associated UV light to drive the chemical reactions. As a result, concentrations throughout the year rise through spring to reach a late summer peak.

Figures 3.5 and 3.6 show the daily maximum 15-minute SO_2 means and daily maximum hourly NO_2 means, respectively for 2005. No HIGH concentrations of NO_2, SO_2 or CO were measured in 2005. Figure 3.7 shows the cumulative number of MODERATE and above days at each site in the AURN across 2005.

It is important to make the distinction between the regional HIGH episode days presented in Tables 3.1 to 3.4 and unique HIGH days. The 'overall' category in Tables 3.1 to 3.4 are the sum of all HIGH days across all the zones or agglomerations or the sum of all MODERATE days across all the zones or agglomerations. Hence a single day of HIGH concentrations measured in two different zones is presented as two days in the 'overall' category whereas it is actually a single unique day measured across several locations. In 2005 11 unique days of VERY HIGH PM_{10} concentrations were measured and 21 days of HIGH PM_{10} concentrations were measured. Ozone concentrations were recorded in the HIGH band on 5 unique days and there were no days of VERY HIGH ozone concentrations. There was a single day (31st August) on which both ozone and PM_{10} concentrations were reported in the HIGH band. In total, this results in 38 unique days where concentrations of all pollutants were at the HIGH band or above in 2005.

It should be noted that the fourth quarter data from 2005 used in this analysis remains provisional at the time of writing and some data may change in the final ratified data set.

3.2.2 PARTICULATE MATTER

HIGH concentrations were measured periodically throughout 2004 at localised locations. The first quarter of the year was largely free of episodes although there was one day, 29th March when the Brighton Roadside site just entered the HIGH band with a maximum 24-hr running mean of 100 $\mu g\ m^{-3}$. The weather on this day was calm and it is likely that the episode was caused by the poor dispersion conditions coincident with the local road traffic source.

There were 7 days of measured HIGH and above concentrations in the second quarter of 2005. Wigan Centre reported 2 of these days on 13th and 14th May when levels of up to

109 μg m^{-3} were measured . Although there is no obvious explanation for this episode it is likely that it was the result of local sources due to the small number of sites that were affected. Two days of VERY HIGH concentrations were reported by the Edinburgh St. Leonards monitoring station on 21st and 22nd May when levels of up to 155 μg m^{-3} were recorded. The episode was attributed to construction work in preparation for the repaving of a nearby car park and these VERY HIGH concentrations were not representative of ambient concentrations. The other 3 HIGH days occurred over 28th and 29th May and 14th June and were all limited to the Port Talbot monitoring site. These were attributed to emissions from the nearby steelworks. Due to their unforeseeable nature, none of these episodes was successfully forecast within ±1 index.

The third quarter saw 13 HIGH episodes and again none of these were successfully forecast. Of these days, 3 were reported by the Port Talbot monitoring site between 11th and 14th July. These were attributed once again to emissions from the steelworks and south westerly winds which transport steelworks emissions in the direction of the monitoring station. Middlesborough recorded 4 HIGH days, between 5th and 8th September which were associated with elevated levels from nearby building works. Construction activity including stone-cutting was responsible for a HIGH event measured at Wolverhampton on 23rd August. Similar ongoing work near to the Bradford monitoring station resulted in 5 HIGH days being measured there on 31st August and 1st, 6th, 7th and 8th September. Rochester reported HIGH concentrations on 3rd and 4th August, despite its rural location. In this instance, an examination of the co-located $PM_{2.5}$ monitoring data revealed that the particles were almost exclusively coarse in nature. It is possible that the north easterly wind direction and dry summer time conditions, coincident with ploughing in the adjacent field, resulted in a localised dust event captured by the site.

Data from the final quarter of 2004 suggests a greater magnitude of particulate episodes than the other quarters but it should be noted that at the time of writing data from October to December 2005 remains provisional and is subject to change pending final ratification. During this period there were 12 days of HIGH concentrations measured none of which were successfully forecast due to their unpredictable and sporadic nature. The Middlesborough station reported two HIGH days on 7th and 8th October. These elevated concentrations were attributed to building works in the immediate vicinity. The Derry monitoring station reported a day of HIGH concentrations on 22nd November. It was particularly cold weather in N.Ireland during this time and one possible explanation for this increase is increased emissions from coal-fired domestic heating systems that are common in N.Ireland coupled with still conditions associated with high pressure. Concentrations at Cwmbran on 7th and 8th December reached the HIGH band as a result of localised stone-cutting. On 9th and then from 13th to 16 December, data at the Bradford site once again indicated HIGH concentrations resulting from the ongoing construction work. Calm high pressure meteorological conditions and associated poor dispersion coupled with road traffic emissions at Marylebone Road resulted in HIGH concentrations at the site on 20th and 21st December.

PM_{10} is by its nature, hard to predict and the HIGH and above episodes noted here are all typical examples of episodes that the forecasting system fails to predict due to highly localised and unforeseeable sources. In most of these cases, the local levels where the HIGH is measured, are not representative of regional ambient levels that most individuals will be exposed to.

3.2.3 OZONE

There were 6 days of HIGH ozone concentrations measured in 2005, all of them falling during the summer season between May and August. There were no VERY HIGH episodes. The first of these HIGH episodes occurred on May 27th when concentrations

reached 204 $\mu g\ m^{-3}$. The episode was short in duration, lasting only one day, and was measured at 7 sites across the south east of England: 4 in suburban London, 2 in the south east (one of which was rural) and one on the south coast (Portsmouth). This episode is described more fully in the ad-hoc episode report on the Air Quality Archive:
http://www.airquality.co.uk/archive/reports/cat12/0507251038_O3_episode_27may2005.pdf

A series of HIGH ozone days followed at the end of June. On 19th June and from 23rd to 25th June, a total of 8 monitoring sites in south eastern England reported HIGH concentrations. The maximum hourly concentration over this period was 202 $\mu g\ m^{-3}$ measured at Weybourne on 24 June. However, this did not correspond to the height of the episode which occurred the previous day (23rd June) when 6 sites were reporting HIGH concentrations. The episode was caused by typically seasonal fine weather and coincident continental air masses. The ad-hoc episode report covering these days is available from the Air Quality Archive:
http://www.airquality.co.uk/archive/reports/cat12/0510261510_O3_episodes_June&July_2005.pdf

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	4	4	0	3	0	0	2	1	0	5	2	1	0	0	22
Forecasted days	0	1	4	4	0	0	0	0	0	0	0	5	0	1	0	0	15
Ok (f and m)	0	0	6	5	0	0	0	0	0	0	0	5	0	1	0	0	17
Wrong (f not m)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Wrong (m not f)	0	0	0	1	0	3	0	0	2	1	0	2	2	1	0	0	12
Success %	100	100	150	125	100	0	100	100	0	0	100	100	0	100	100	100	77
Accuracy %	0	0	100	83	0	0	0	0	0	0	0	71	0	50	0	0	57

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	1	0	0	0	2	0	0	0	0
Forecasted days	0	3	0	0	0	0	0	0	0
Ok (f and m)	0	1	0	0	0	0	0	0	0
Wrong (f not m)	0	2	0	0	0	0	0	0	0
Wrong (m not f)	1	0	0	0	2	0	0	0	0
Success %	0	100	100	100	0	100	100	100	100
Accuracy %	0	33	0	0	0	0	0	0	0

AGGLOMERATIONS	Nottingham UA	Portsmouth UA	Sheffield UA	Swansea UA	Tyneside	West Midlands UA	West Yorkshire UA	Overall
Measured days	0	2	0	4	0	2	9	20
Forecasted days	0	3	0	0	0	0	3	9
Ok (f and m)	0	1	0	0	0	0	0	2
Wrong (f not m)	0	2	0	0	0	0	3	7
Wrong (m not f)	0	1	0	4	0	2	9	19
Success %	100	50	100	0	100	0	0	10
Accuracy %	0	25	0	0	0	0	0	7

*** All performance statistics are based on provisional data. Obviously incorrect data due to instrumentation faults have been removed from the analyses. 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	9	50	142	147	44	45	15	74	51	52	9	94	51	76	54	76	989
Forecasted days	51	124	151	178	98	86	48	109	90	85	53	152	112	129	113	94	1673
Ok (f and m)	44	107	169	200	93	86	45	119	95	84	47	154	109	133	101	112	1698
Wrong (f not m)	9	22	15	13	14	12	8	7	7	15	9	16	13	12	22	6	200
Wrong (m not f)	2	3	11	15	0	8	0	2	4	3	0	5	6	7	2	4	72
Success %	489	214	119	136	211	191	300	161	186	162	522	164	214	175	187	147	172
Accuracy %	80	81	87	88	87	81	85	93	90	82	84	88	85	88	81	92	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	12	58	0	7	30	18	35	34	29
Forecasted days	28	110	62	45	42	32	63	83	58
Ok (f and m)	26	104	1	15	51	23	65	66	65
Wrong (f not m)	9	17	61	33	4	13	9	21	6
Wrong (m not f)	1	4	0	2	2	8	5	3	0
Success %	217	179	100	214	170	128	186	194	224
Accuracy %	72	83	2	30	89	52	82	73	92

AGGLOMERATIONS	Nottingham UA	Portsmouth UA	Sheffield UA	Swansea UA	Tyneside	West Midlands UA	West Yorkshire UA	Overall
Measured days	22	43	14	57	10	60	45	474
Forecasted days	62	106	51	86	40	93	71	1032
Ok (f and m)	41	89	39	95	27	92	56	855
Wrong (f not m)	25	26	16	12	17	15	27	311
Wrong (m not f)	2	8	1	9	0	5	18	68
Success %	186	207	279	167	270	153	124	180
Accuracy %	60	72	70	82	61	82	55	69

*** All performance statistics are based on provisional data. Obviously incorrect data due to instrumentation faults have been removed from the analyses. Please refer to the start of section 3 for an explanation of the derivation of the various statistics, figures >100 % may occur.**

Table 3.5 Summary of HIGH episodes year 2005

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 **
Ozone	6	157	204 (Index 7)	Portsmouth	Portsmouth UA	27th May	79 % [12]
PM_{10}	35	135	168 (Index 10)	Bradford	West Yorkshire UA	15th & 16th Dec	0 % [37]
NO_2	0	29	525 (Index 6)	London A3 Roadside	Greater London	13th May	[0]
SO_2	0	7	503 (Index 6)	Grangemouth	Central Scotland zone	28th Jan	[0]
CO	0	0	6.4 (Index 2)	Tower Hamlets Roadside	Greater London	30th June	[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.

** in square brackets are the total of the number of '**regional HIGH days**' in all zones and agglomerations. HIGH incidents on the same day in several zones/ agglomerations are counted as multiple HIGH days rather than a single unique incident. This distinction is explained further below.

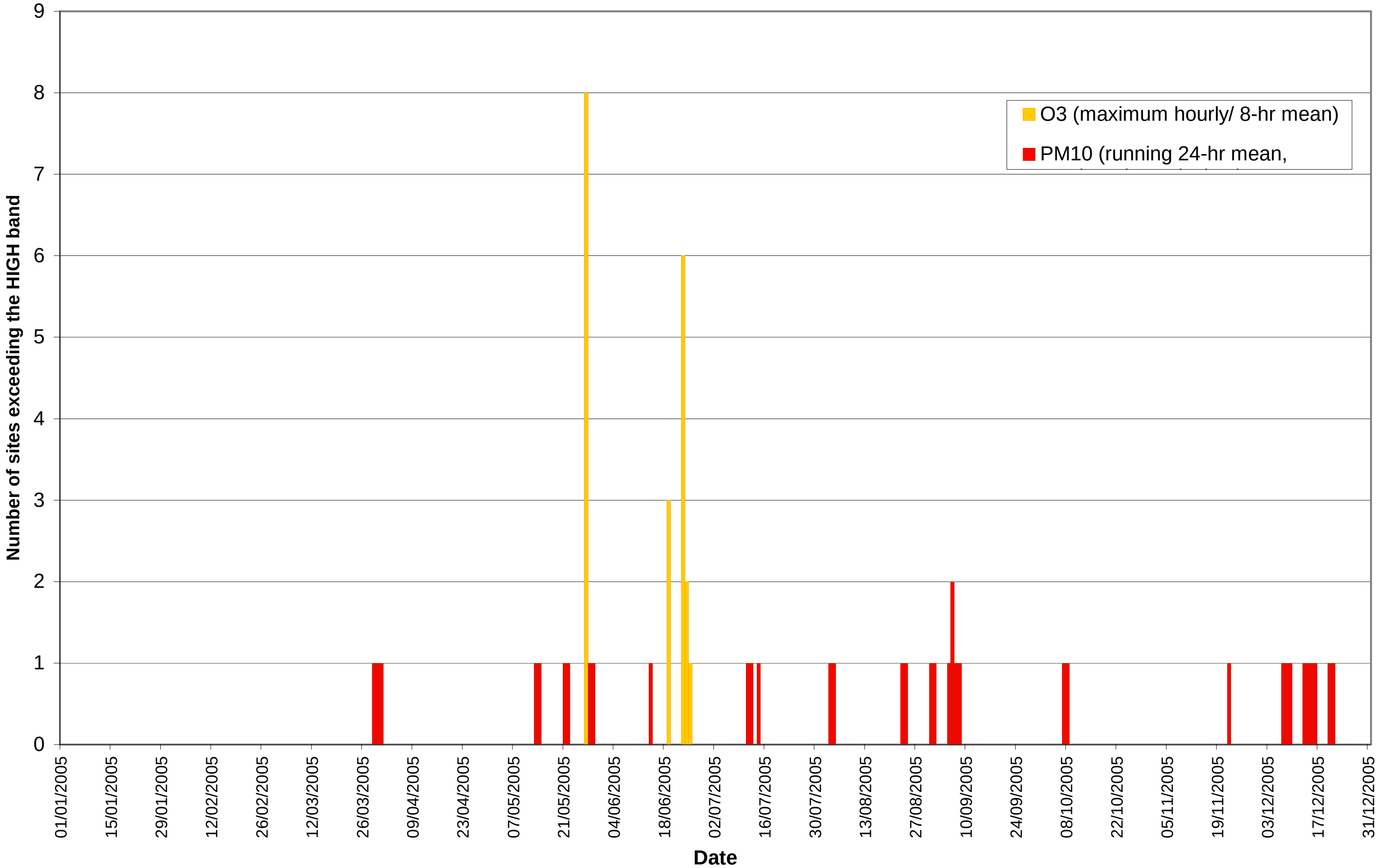


Figure 3.1 Number of stations with air pollution levels of HIGH and above for days throughout 2005.

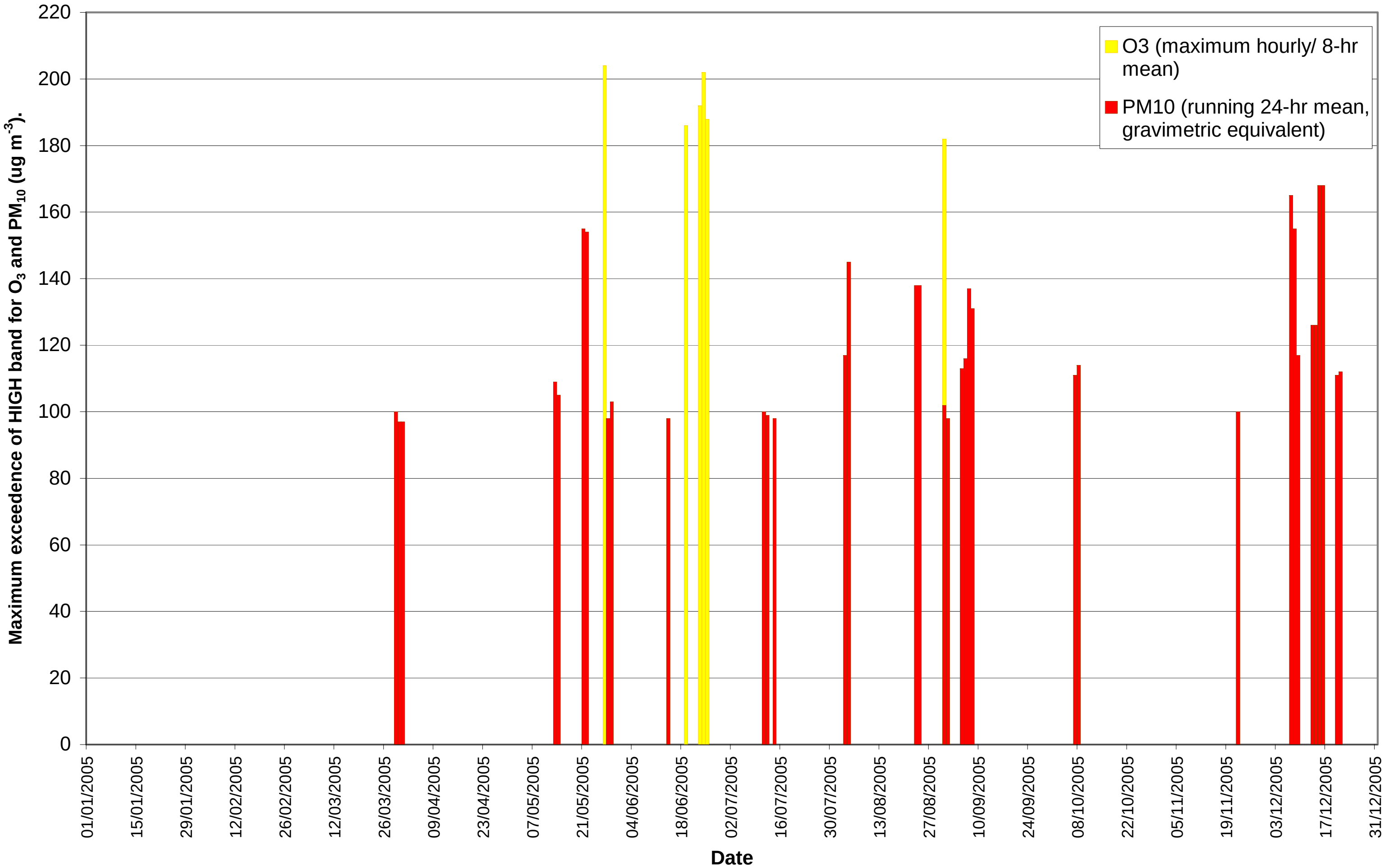


Figure 3.2 Maximum exceedence when air pollution levels were HIGH and above for days throughout 2005.

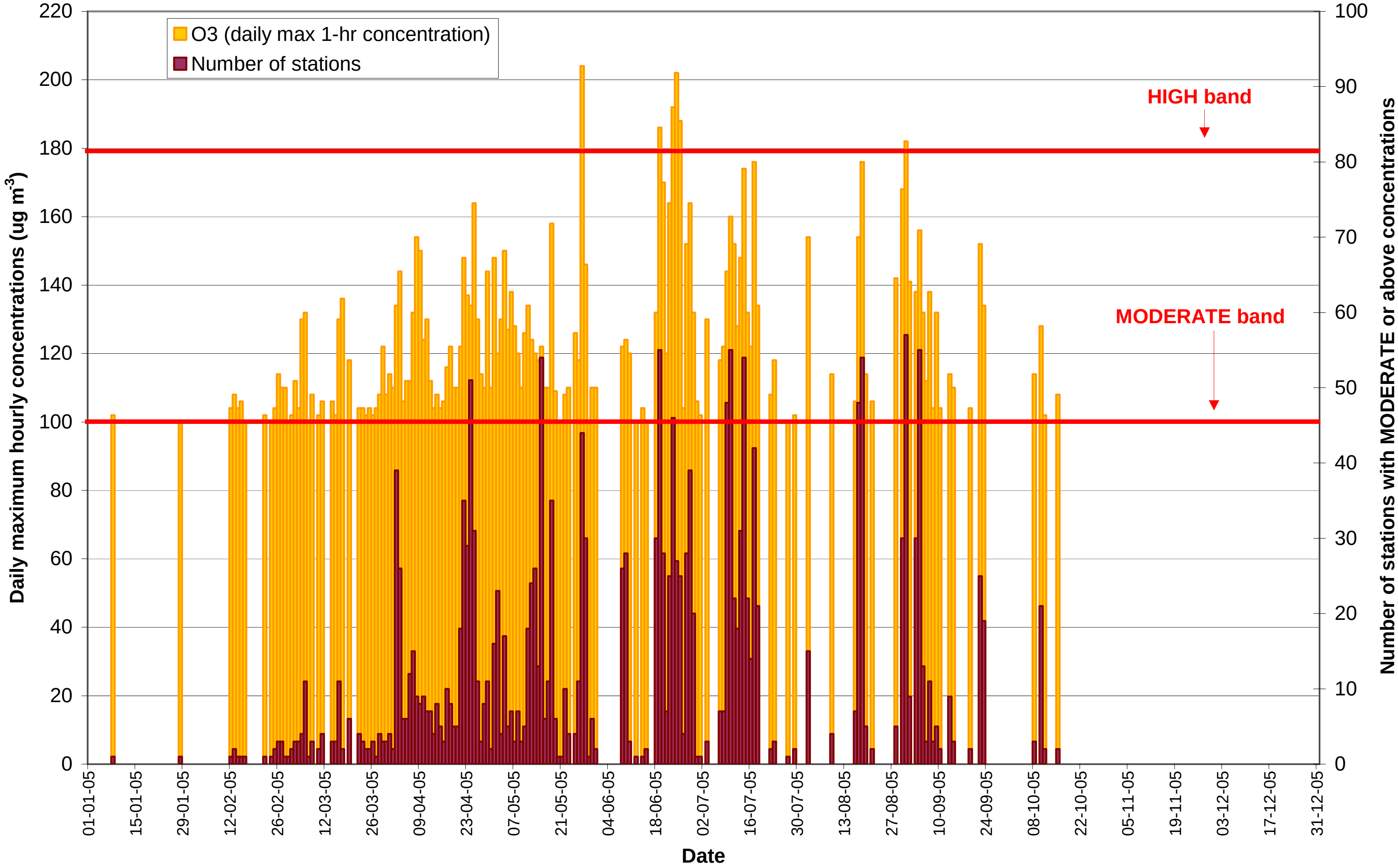


Figure 3.3 Daily maximum hourly ozone concentration across the AURN with total number of stations measuring MODERATE or above levels of ozone over 2005.

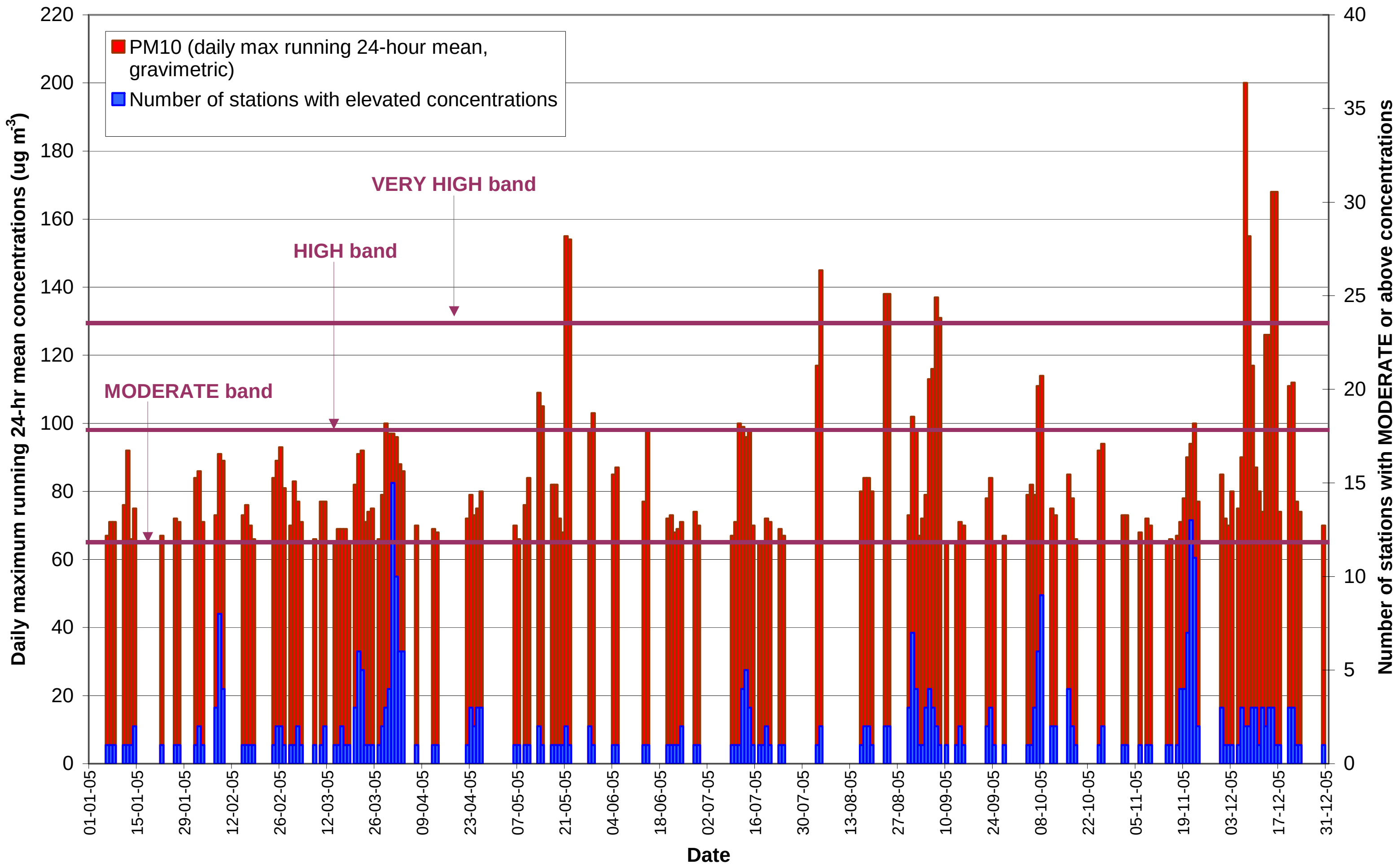


Figure 3.4 Daily maximum running 24-hour mean PM_{10} concentration across the AURN with total number of stations measuring MODERATE or above levels over 2005.

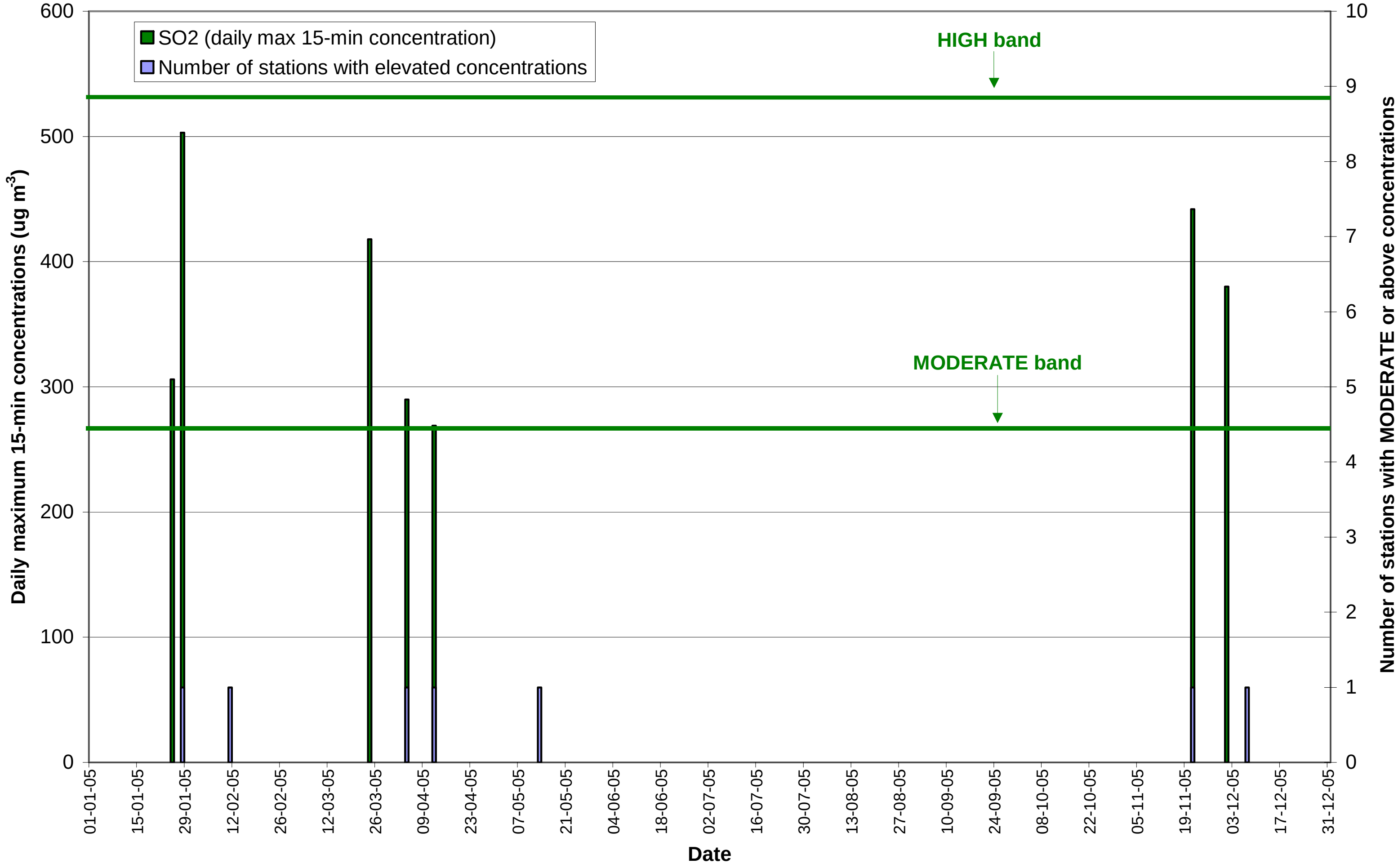


Figure 3.5 Maximum 15-minute average concentrations of SO_2 across the AURN with total number of stations measuring MODERATE or above levels over 2005.

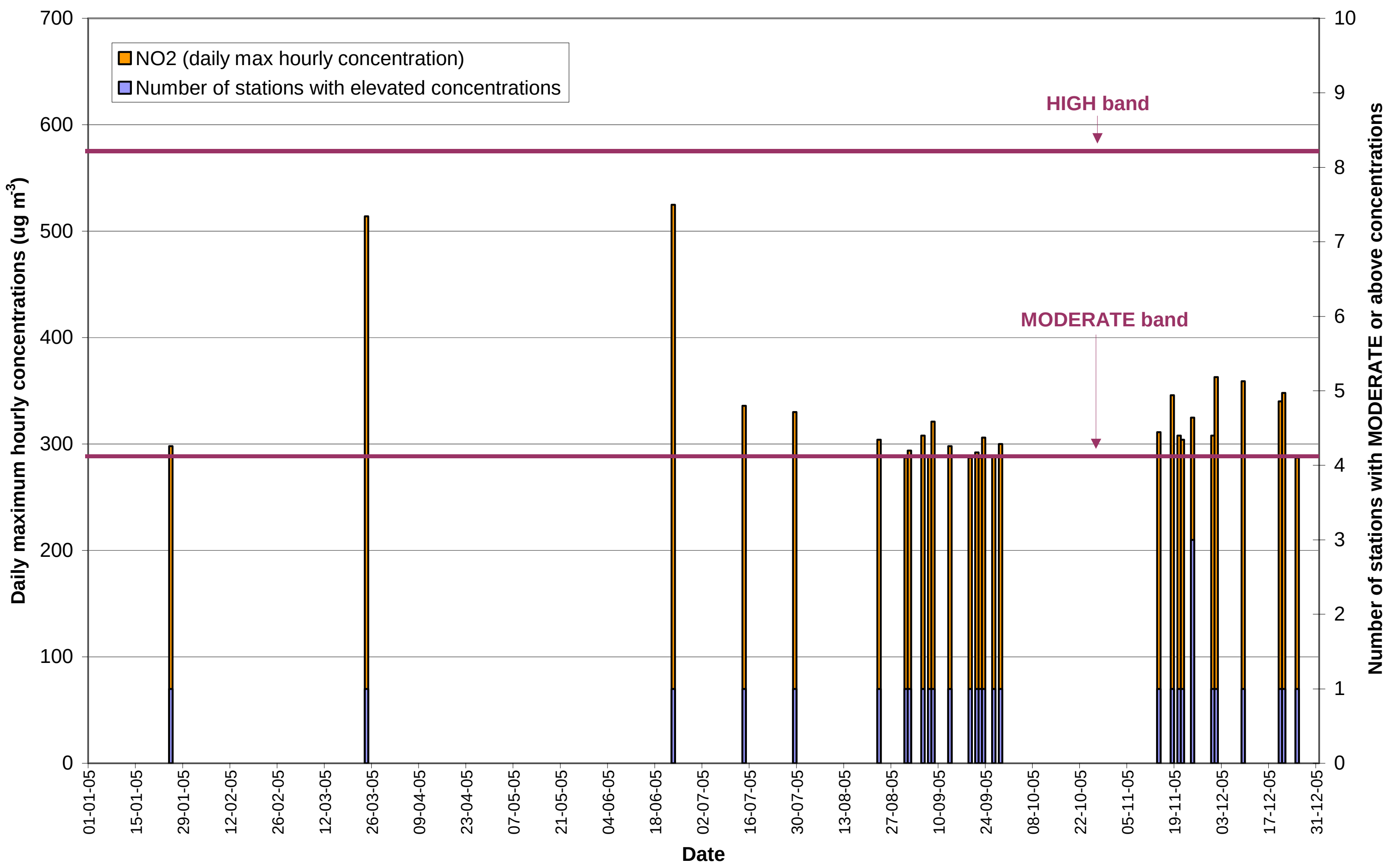


Figure 3.6 Daily maximum hourly average of NO_2 across the AURN with total number of stations measuring MODERATE or above levels over 2005.

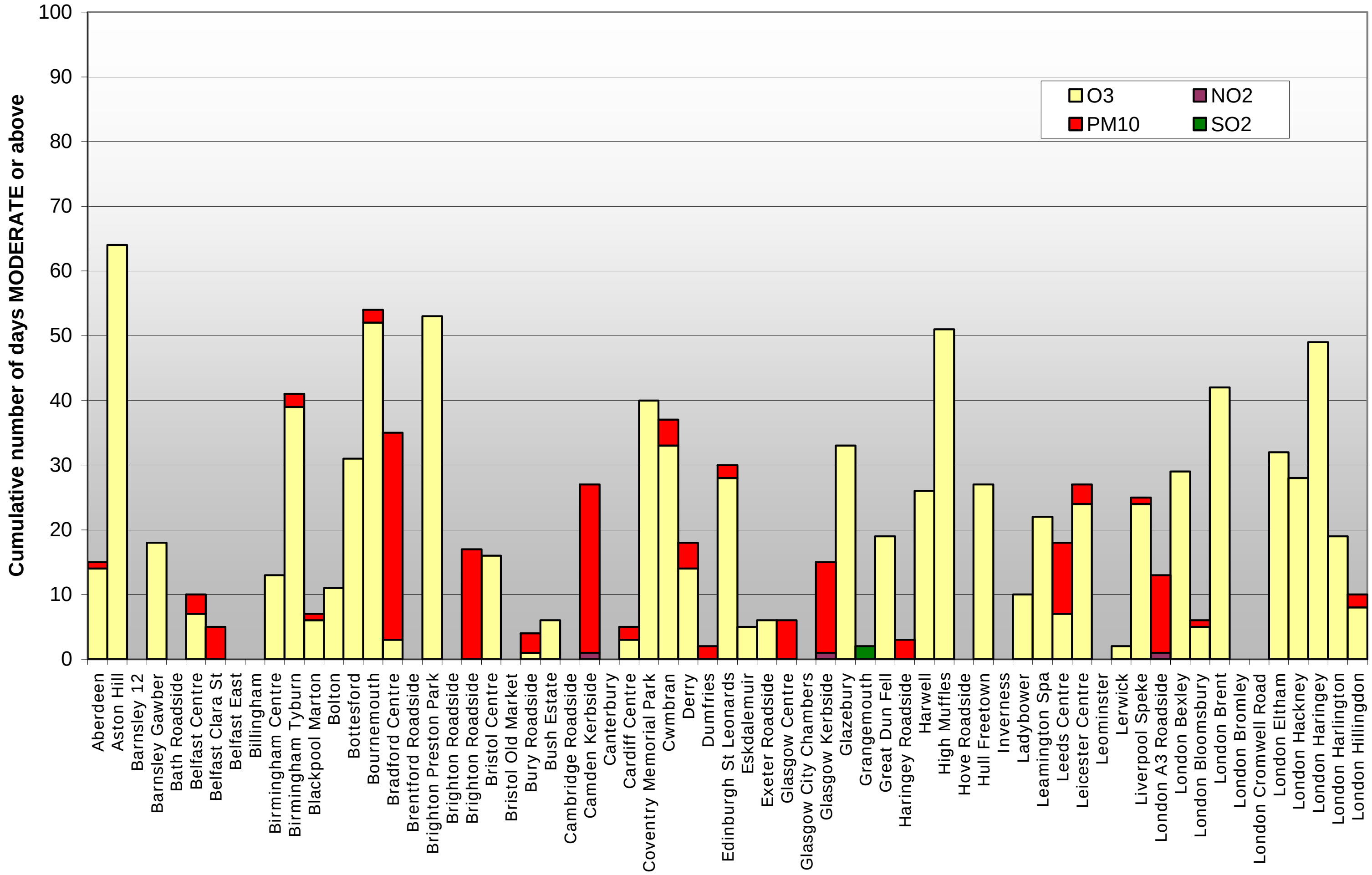


Figure 3.7a Number of days MODERATE and above for each the AURN station over 2005 – provisional data.

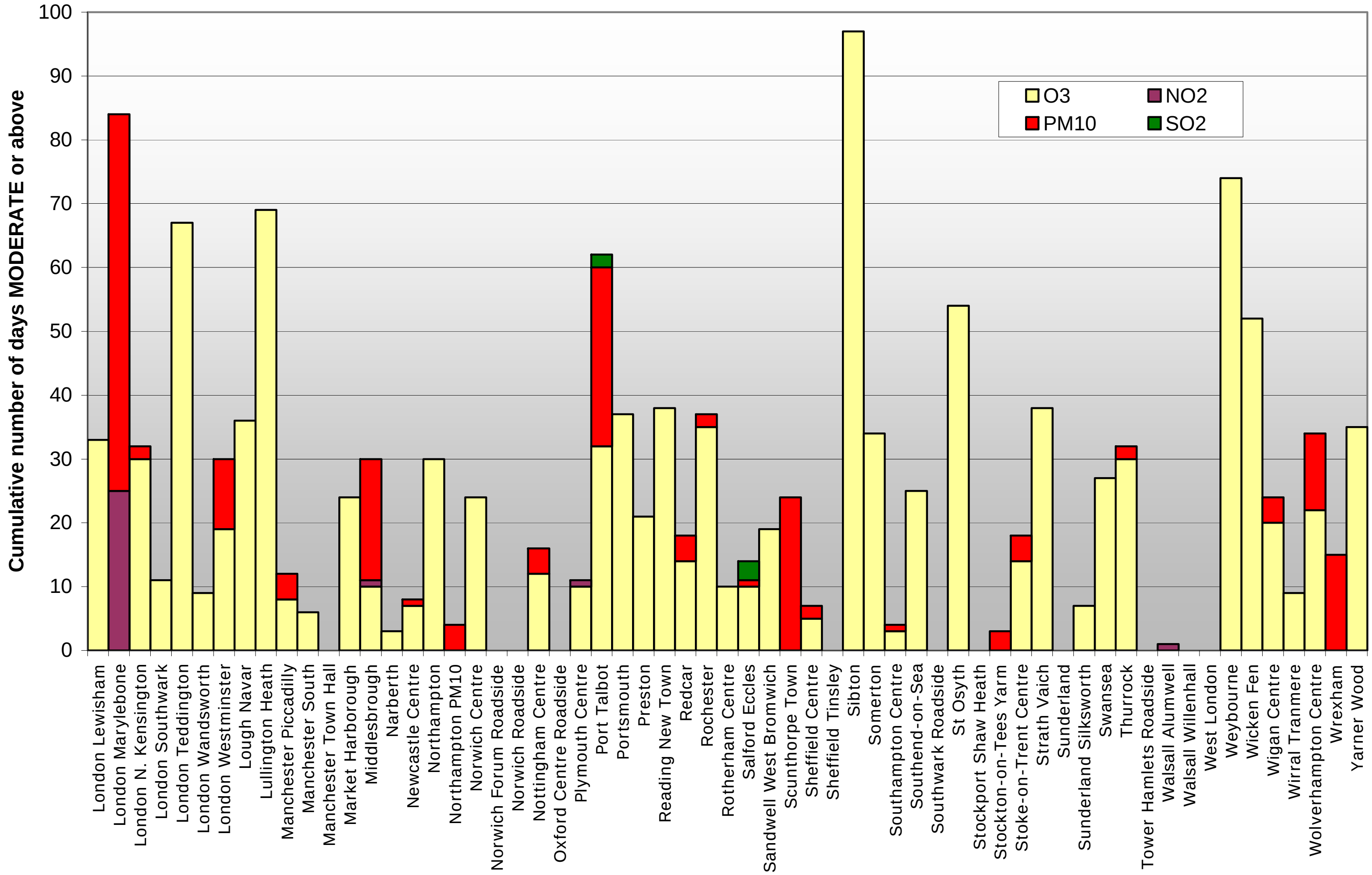


Figure 3.7b Number of days MODERATE and above for each the AURN station over 2005 – provisional data.

3.3 COMPARISON WITH PREVIOUS YEARS (2003-2005)

3.3.1 FORECASTING SUCCESS RATE

Figure 3.8 below shows the forecasting success rates for the whole of the UK for 2003 to 2005. This is the percentage of HIGH days that were correctly forecast.

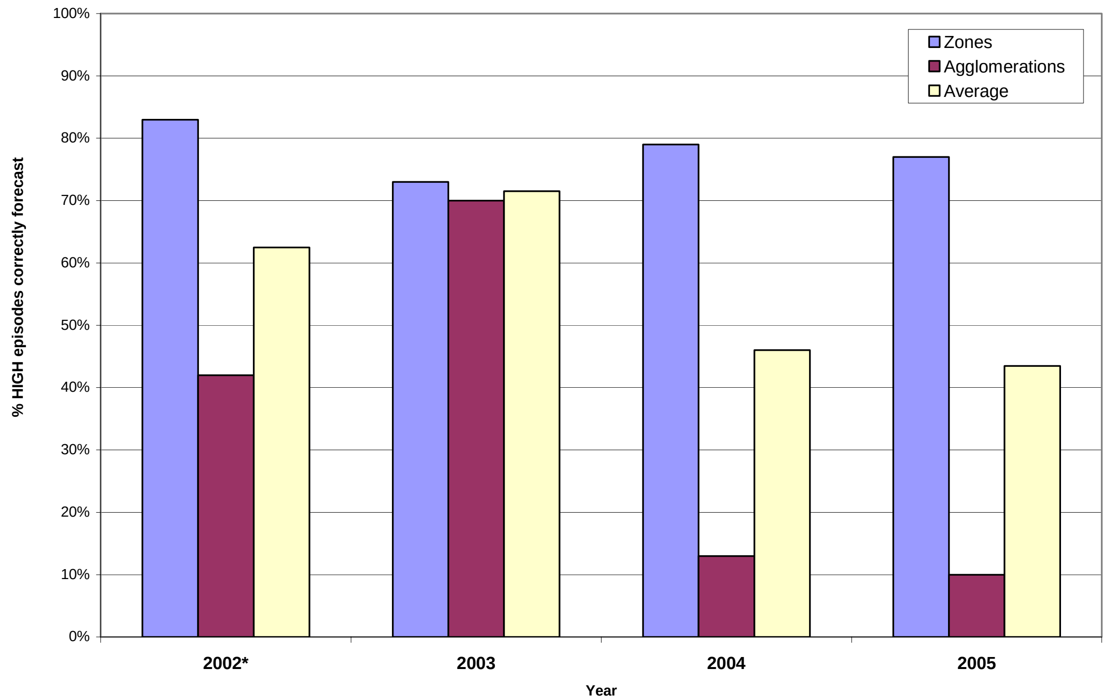


Figure 3.8 - Forecasting Success Rates for the whole of the UK, 2003-2005

The forecasting success rate in 2005 was very similar to the performance in 2004, showing a slight drop in success rate in both zones and agglomerations. The success rate dropped from 79% to 77% in zones and from 13% to 10% in agglomerations. On average the success rate dropped from 46% to 44%.

The contrast between forecasting success in zones compared with agglomerations is very marked – this is because built up urban areas contain a greater number of localised, unpredictable sources and hence the episodes (most often PM_{10} episodes) that are often measured in agglomerations are typically unforeseeable. Almost all of the HIGH episodes measured in 2005 were associated with local PM_{10} emissions sources such as construction works and stone-cutting on nearby industrial sources.

The forecasting success rate in zones tends to be higher due to the higher proportion of ozone episodes in these geographical areas resulting from the limited extent of NO_x scavenging from road traffic sources. Ozone episodes are more likely to build over several successive days of fine weather, these episodes are more easily predicted, explaining the comparative success in forecasting for zones than agglomerations.

The forecasting system currently predicts ozone episodes with a greater degree of success and accuracy than PM_{10}. In 2003 the zones and agglomerations success rates were much more similar due to the exceptionally large number of ozone episodes (correctly predicted) in this heat wave year.

In terms of MODERATE forecasts, which by far represent the majority of forecasts issued, a different picture is seen, with a 172% success rate for zones and 180% success for agglomerations (success rates are able to exceed 100% as an agreement of within one index band is used for the analysis).

3.3.2 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 2005:

- 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 furnace are known to contribute to local PM10 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 Centre reported elevated concentrations through long periods of the latter half of 2005 that were associated with long-term construction works in close proximity to the monitoring site.

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 rest of 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 **Netcen** forecasters and Defra during this period. In particular, these were frequent during the ozone pollution episodes on 27th May and during the episode from 19th to 25th June.

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 Buncefield oil depot fire that began on Sunday 11th December and lasted the following week required particular care and attention on behalf of the forecasting team. Forecasts during this week involved meticulous examination of the available AURN monitoring data plus examination of additional data from the London Air Quality Network. Prior to daily forecasts or email bulletins being issued there were ongoing discussions among senior air pollution scientists at **Netcen**, the Met Office and with the field team.

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

6.1 OZONE EPISODE REPORTS

During 2005, two ad-hoc pollution episode reports (both concerning summer ozone concentrations) were presented to Defra and the Devolved Administrations. These detailed the extent and circumstances of the episodes and are listed below:

- Air Pollution Forecasting: Ozone Pollution Episode Report (Friday 27th May 2005)
- Air Pollution Forecasting: Ozone Pollution Episode Report (June - July 2005)

6.2 BUNCEFIELD OIL DEPOT FIRE, 11/12/2005

Another example of the ad-hoc services provided in 2005 was the analysis of concentrations and meteorology in the week immediately following the Buncefield oil depot fire on 11th December 2005. Both **Netcen** and the Met Office coordinated their analysis to provide Defra and the Devolved Administrations with continuously updated information regarding public exposure to emissions from the fire. Included here is a summary of this analysis. A full report is to be published in spring 2006 on the Air Quality Archive.

The fire started in the early hours of the generally clear morning of Sunday 11th December at the Buncefield oil depot in Hemel Hempstead, Hertfordshire. The resulting plume of unburnt oil and petroleum vapours, gaseous combustion products and smoke was highly buoyant due to the heat of the fire and rose high into the atmosphere. During Sunday 11th December ground level wind speeds were light and from a north-westerly direction. There was significant wind shear in the upper atmosphere with lower level winds from a north-westerly direction transporting the plume towards the south-east and winds from a north-easterly direction at higher levels transporting the plume south-westwards. The plume spread out over a wide area covering the counties of Hertfordshire, Berkshire, Oxfordshire and Surrey within around 6 hours. Modelling by the Met Office suggested that most of the plume remained aloft with minimal mixing down to the ground. Wind speeds picked up from Monday afternoon onwards dispersing the plume at high altitude in a south-westerly direction and out over the Channel. Air was then coming from the north-east until Tuesday. Even after the fire had cooled and had eventually been extinguished at the end of that week, no obvious ground level elevated measurements had been observed at UK National Network air quality monitoring sites, suggesting that the effects of the plume had remained above ground level throughout or that there was sufficient ground level dispersion at the end of the incident to maintain LOW air pollution at the nearest AQ stations in the south east.

As a pre-cautionary approach, **Netcen** forecast MODERATE levels across Greater London, Eastern and the South East zones across that week starting from the Sunday of the incident

The satellite images (Figure 6.1) show the extent of the plume over the first 24 hours of the fire starting, at various stages of dispersion.

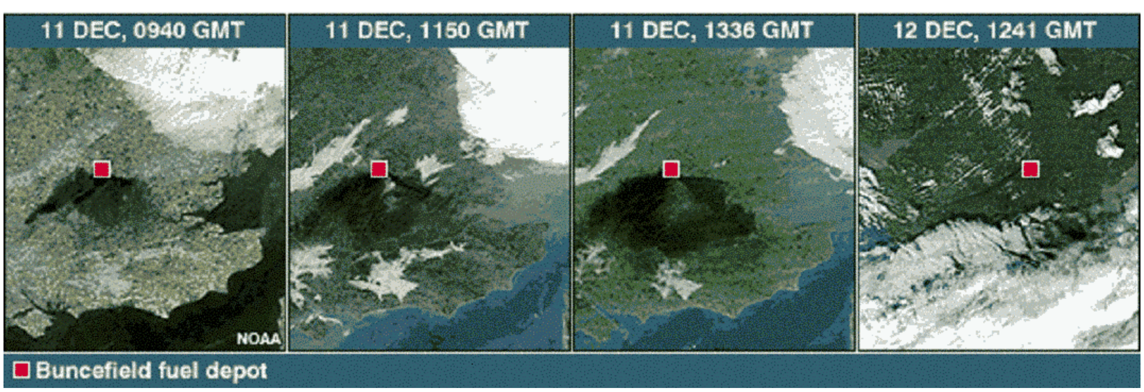


Figure 6.1 Satellite images of the Buncefield plume development

A more detailed analysis was provided by the Met Office:

A large explosion occurred at the Buncefield oil depot in Hemel Hempstead, Hertfordshire, UK (51.76N 0.429W) just after 06UTC on Sunday 11th December 2005. The resulting blaze was the largest industrial fire in Europe to date. At the height of the blaze, 20 tanks at the oil depot operated by Total and Texaco were on fire. Each tank was reported to hold up to 3 million gallons of fuel (unleaded, super-unleaded, motor spirit, gas oil, ultra low sulphur diesel and jet fuel). During Sunday 11th December, no efforts were made to bring the major fire under control, as fire crews assessed the situation, determined how best to tackle the event and assembled fire fighting equipment. On Monday 12th December 2005, serious efforts to cool and then extinguish the fire with water and foam were undertaken by the Hertfordshire fire brigade. The fire was rapidly extinguished during Tuesday 13th and Wednesday 14th December 2005.

The plume from the Buncefield oil depot incident was modelled using the Met Office's atmospheric dispersion model, NAME (Numerical Atmospheric dispersion Modelling Environment). The precise nature of the release was initially unknown and there is still some uncertainty associated with the source details. Observations and satellite images of the plume were used to assess the vertical height attained by the plume and to validate model results. In the main, a high pressure system dominated the weather and the atmosphere was stable, suppressing vertical mixing. The buoyancy of the plume, caused by the intense heat of the fire, resulted in the plume rising well clear of the boundary layer. The temperature inversion at the top of the boundary layer acted as a lid, trapping most of the plume aloft and preventing significant material from coming back down to ground. As the plume buoyancy decreased, due to fire fighting activities, and turbulent mixing increased, due to increasing wind speeds, there was concern over a greater risk of plume grounding.

Observations and a comparison of the NAME predicted plume with satellite imagery suggested that the plume reached a height of 3000 m during Sunday 11th December. Initially, the modelled release height was based on these observations and a unit release of a tracer was chosen. The model results are useful in defining the geographical spread of the plume but, since a nominal release rate was chosen, the magnitude of the modelled concentrations should not reflect true concentrations within the plume. On Sunday 11th December 2005, the plume fanned out over a wide area (see Figure 6.2). This was caused by a significant amount of wind shear in the atmosphere; lower level winds were north westerly, transporting material to the south-east whilst upper level winds were north-easterly, transporting material to the south-west. On Monday 12th December 2005, the plume was much narrower and being transported south west from the oil depot (see Figure 6.3). On Tuesday and Wednesday 13th and 14th December 2005, winds were from a northerly direction and the plume was reported to still be elevated. NAME predicted that most of the plume remained aloft with minimal mixing back to ground within the UK. This is in agreement to observations from the national automatic air quality monitoring network which suggests that there was no major grounding events. Observations suggest that grounding was limited to regions close to the source. Work is, however, ongoing to assess the extent and magnitude of grounding.

Subsequent studies enabled the rise of the buoyant plume to be modelled using the plume rise scheme and the incorporation of emission estimates. Further work is continuing to increase our understanding of the incident and to utilise all available observations to improve and validate modelling of the plume.

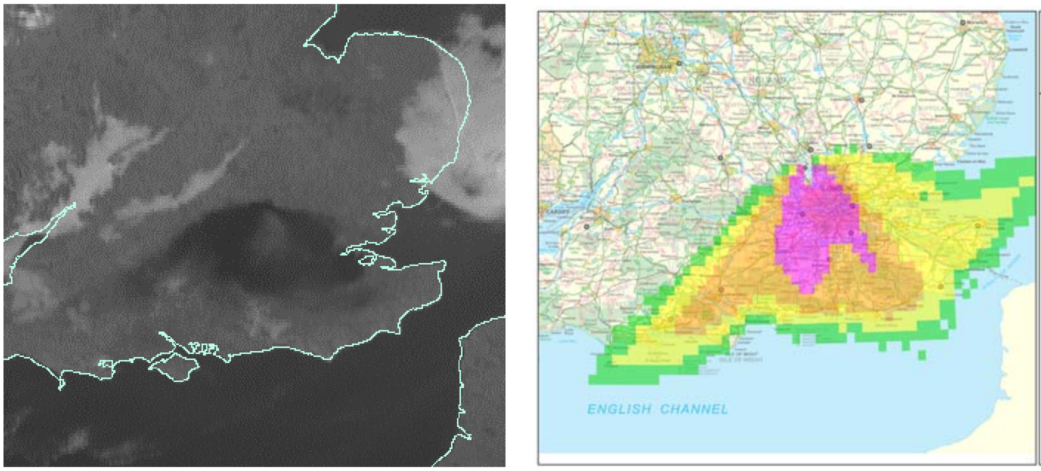


Figure 6.2 Comparison of NAME predicted plume (0 - 4 km) at 1400 UTC Sunday 11th December, 2005 with satellite imagery.

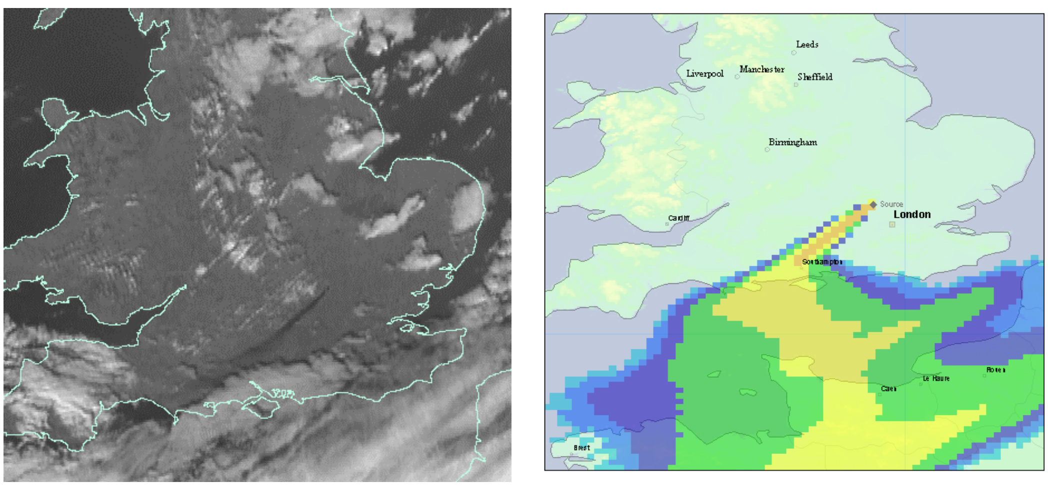


Figure 6.3 Comparison of NAME predicted plume (0 – 4 km) at 1300 UTC Monday 12th December, 2005 with satellite imagery.

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

In addition to these formal reports, regular contact was maintained with the Department throughout regarding possible 'HIGH' levels over the UK.

7 Ongoing Research

As part of a programme of ongoing improvement and development to the Forecasting system, **Netcen** and the Met Office 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 forest fires in Russia and the long-range transport of particles from Saharan Dust Storms.
4. Improve and update the emissions inventories used in our models.

Work is currently ongoing to improve the representation of ozone in the NAME chemistry scheme. Results are promising and this development should lead to improved results for other species that are involved in ozone chemistry. A new nitrate chemistry scheme has also been investigated.

The development of the forecast skill index and verification of the performance of the NAME model is ongoing.

8 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 2005 is also provided at the end of this section. Recent literature concerned with air quality forecasting is summarised below.

8.1 AIR QUALITY FORECASTING IN NORTHERN AMERICA

8.1.1 THE NOAA/EPA AIR QUALITY FORECASTING CAPABILITY

The original identification of the need for a national scale air quality forecasting system in the United States is discussed on the National Ocean and Atmospheric Administration's National Weather Service web page[4] that argues the economic case for forecasts to allow preventative action to reduce exposure among sensitive individuals. It is stated that for each 1% reduction in the adverse health impacts of air pollution in USA, there would be a $1 billion cost saving each year. Consequently, Congress has directed the NOAA to develop a national forecasting system to provide forecast guidance on national scale to benefit local/ state forecasters across the 300 or so cities across the USA that have previously had to issue health focussed public AQ forecasts without the benefit of high-powered national forecasting technology that supports national weather forecasting.

In 2004 when the service first became operational, the scale of the system was limited to 1-hr and 8-hr average ozone forecasts one day in advance over a domain covering North eastern America. In 2005 the domain was expanded to cover a greater area spanning central and eastern USA. The modelled area now includes areas from just east of the Rocky Mountains to the Atlantic and Gulf coasts. Hour-by-hour forecasts, through midnight the following day, are available online, providing information for the onset, severity and duration of poor air quality to more than 180 million people[5]. This enables state and local agencies from 13 additional states to issue enhanced and more geographically specific ozone-based air quality warnings to the public.

It is envisaged that national scale ozone forecasts will be operational within a few years, to be followed by the introduction of national particulate matter forecasts and then the introduction of forecasts for other pollutants within the decade and forecasts extending out to 2 days and beyond. Figure 8.1 below provides a definitive illustration of the current system and the developments taking place currently and in the future[6] and Figure 8.2 provides an example of an ozone forecast made using the expanded model domain.

[4] http://www.nws.noaa.gov/ost/air_quality/4FAQF_FactSheet_update111705.pdf
[5] http://www.noaanews.noaa.gov/stories2005/s2449.htm
[6] http://www.nws.noaa.gov/ost/air_quality/AQF_Capability_30Nov04.pdf

	Current AQ Alerts	*NWS Initial Operational Capability: September, 2004*	*NWS Capability: 5-Year Vision*	*NWS Capability: 10-Year Vision*
Purpose: Limit adverse effects from poor AQ, by providing:	Next-day warnings for large cities	State-of-the-science **ozone** forecast guidance: - to assist state / local AQ forecasters - to assist people at risk from poor AQ	State-of-the-science **ozone** forecast guidance - to assist state / local AQ forecasters - to assist people at risk from poor AQ	State-of-the-science ozone and **particulate matter** forecast guidance: - to assist state / local AQ forecasters - to assist people at risk from poor AQ
Products for Public	Daily AQ alerts; predicted interpretive AQ Index category	Hour-by-hour predictions of air pollutant concentrations in digital and graphical formats	Hour-by-hour predictions of air pollutant concentrations in digital and graphical formats	Hour-by-hour predictions of air pollutant concentrations available in state-of-the-art formats
Coverage	Approximately 300 cities	Entire Northeast United States	**Nationwide**	Nationwide
Pollutants Forecasted	Air Quality Index for ozone; some cities include particulate matter	Ground-level ozone	Ground-level ozone	Ground level ozone, **particulate matter**, possibly others
Forecast Period	Next-day; also through weekends	Forecast guidance issued through midnight next day	Forecast guidance issued through midnight next day	Forecast guidance extended to **2 days** or beyond
Spatial Resolution	Alerts are community-wide; little/ no other spatial information	12 kilometer grid for northeast U.S	**5 km** grid for Nation	**2.5** kilometer grid for Nation
Temporal Resolution	Daily	Hourly and 8-hr averages each hour throughout the forecast period	Hourly and 8-hr averages each hour throughout the forecast period	Hourly and 8-hr averages each hour throughout the forecast period

Figure 8.1 Summary of the Air Quality Forecast Capability: Current vs. Future

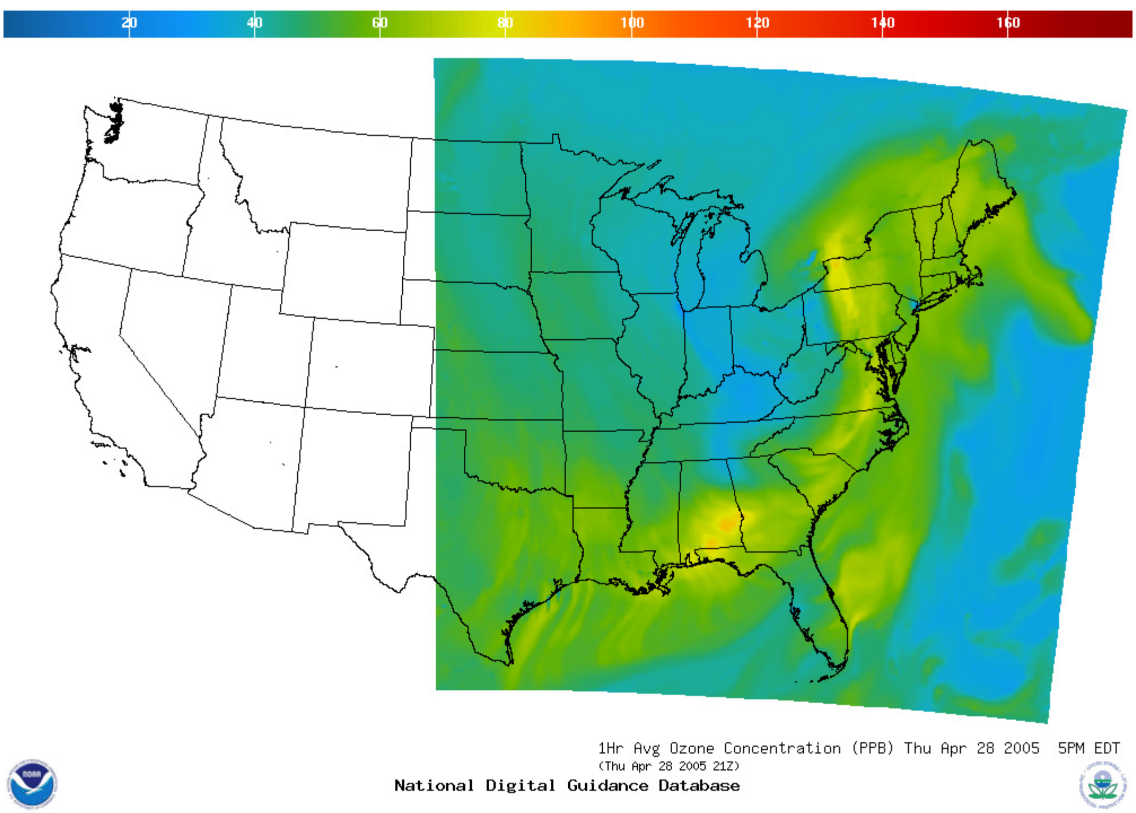


Figure 8.2 An example the 1-hr ozone forecast with the expanded model domain (NOAA)

The 21st Conference on Weather Analysis and Forecasting/17th Conference on Numerical Weather Prediction was held in the summer of 2005. Several presentations of research relevant to air quality forecasting were made at this meeting, many of which detail developments in forecasting in the USA. The agenda for this conference can be found at: http://ams.confex.com/ams/WAFNWP34BC/techprogram/program_299.htm#Session18590

A presentation entitled 'NOAA-EPA's New National Air Quality Forecast Capability: Transitioning Research to Operations'[7], detailed the basic organisation of the forecasting system and the partnership between the NOAA and Environmental Protection Agency (EPA) in operating the forecasts. The system was developed in close cooperation between NOAA, EPA, and state and local air quality forecasters. NOAA/EPA researchers and NWS developers adapted and integrated the EPA's Community Multi-scale Air Quality (CMAQ) model for NWS' operational environment and adapted NWS' operational mesoscale weather forecast models (Eta-12, transitioning to WRF), to provide meteorological parameters needed to drive the air quality emissions preprocessing and reactive transport codes. The CMAQ system is a comprehensive atmospheric chemistry and transport model that simulates various chemical and physical processes that are important for modelling atmospheric trace gas transformations and distributions. The meteorological input is by way of the NWS/ National Centers for Environmental Prediction (NCEP) Eta model at 12 km, which was used to provide meteorological predictions for the CMAQ model to produce 48-hr ozone predictions[8].

The system began operation in September 2004, providing twice-daily predictions of hour-by-hour ground-level ozone concentrations at 12 km resolution across a modelling domain spanning north eastern USA. These 'forecast guidance' products are hosted on operational dataservers that are fully backed up, archived and with near-real-time verification to provide an indication of forecast accuracy. The presentation highlighted the required accuracy of 90% and reliability of 95% on-time delivery that was attained during the testing phase of the summer of 2004. This performance is being maintained as the system expands to cover a wider domain in North America. During the summer of 2005 the system was upgraded to improve guidance accuracy, improve model linkage, update emissions information, improve treatments of solar radiation for photolysis rate estimation, and improve treatments of vertical mixing and transport within clouds.

The EPA's role is to develop, maintain and update emissions inventory information used in the model; provide current monitoring data for verification, and provide forecast guidance regarding a health-based air quality index. Air quality forecasters at a state and local level are also are working in conjunction with the project to examine local area performance and utility and collaborations with the Canadian air quality forecast community are facilitating development in longer-range objectives in particulate matter forecasting. The intention is to deploy nationwide ozone forecasts within 5 years will be followed by the addition of particulate matter forecasts and an extended forecast period-out to day 2 and beyond.

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[7] 'NOAA-EPA's New National Air Quality Forecast Capability: Transitioning Research to Operations' http://ams.confex.com/ams/WAFNWP34BC/techprogram/paper_95064.htm

[8] 'Update to and Recent Performance of the NAM-CMAQ Air Quality Forecast Model at NCEP operations' http://ams.confex.com/ams/pdfpapers/94666.pdf

An examination of the ongoing development and performance of the American forecasting system through 2005 was also presented at this conference[6]. The presentation detailed the upgrades to both the CMAQ model and the Eta-12 model in 2005 including:

- 6 hour cycling for initial CMAQ conditions
- use of the NCEP Global Forecast System (GFS) ozone predictions to prescribe CMAQ upper lateral boundary conditions,
- updates to the CMAQ model cloud scheme and emissions
- the Eta model's land surface model was also upgraded and its effect on air quality forecasts.

The model performance was evaluated against the EPA AIRNOW observation network using the NCEP Forecast Verification Systems (FVS).

8.1.2 AEROSOL FORECASTING

An investigation into an air quality episode affecting the Upper Mid West and Great Lakes area of the USA during early February 2005 was presented with particular regard to analysis by the Eta-CMAQ model forecasts during this conference[9]. Many air pollution warnings had been issued in the Upper Mid West and the Great Lakes regions between January 31st and February 4th 2005. Air Quality Index (AQI) issued on the EPA web site in Minnesota peaked at 155 ('unhealthy') on January 31st and in the Chicago area, the AQI measured between 110 and 140 ('unhealthy for sensitive groups') for most of this first week of February.

The episode was attributed to the slow passing of a large high pressure system centered over the Great Lakes during the period, accompanied by extensive cloudiness and snow. These atmospheric conditions resulted in reduced atmospheric mixing and a high rate of atmospheric particle formation and growth due to high relative humidity in the lower levels.

The Eta-CMAQ Air Quality Forecast System was used in the research mode to predict the Particulate Matter (PM) concentration and the speciation during the episode. The model result was verified by comparing its Aerosol Optical Depth (AOD) and fine particles ($PM_{2.5}$) concentration predictions with the observed values by the Aerometric Information Retrieval Now (AIRNOW) network. The speciation analyses show that nitrate and anthropogenic organic particles were the most significant component of the episode.

8.1.3 PARAMETERISATION OF PLANETARY BOUNDARY LAYER IN AIR QUALITY FORECASTING

A further presentation made at the 21st Conference on Weather Analysis and Forecasting discussed the importance of correctly representing the planetary boundary layer (PBL) when using dispersion models in air quality forecasting systems. This presentation[10] highlighted the difficulties of measuring the PBL height and the lack of observations of this important parameter. PBL physics plays a significant role in numerical weather prediction and particularly on air quality forecasting. Surface ozone concentrations predicted by a chemical transport model are strongly dependent on PBL height estimates used in the model. The verification of the accuracy of PBL height prediction and its

[9] 'Aerosol forecast by Eta-CMAQ for the poor air quality episode in early February 2005'
http://ams.confex.com/ams/pdfpapers/94822.pdf

[10] 'Planetary Boundary Layer height and surface ozone verification in the NOAA/EPA Air Quality Forecast System'
http://ams.confex.com/ams/WAFNWP34BC/techprogram/paper_95210.htm

influence on surface ozone concentration forecasts using the Eta and CMAQ models was presented. The CMAQ ozone forecasts rely on PBL heights that are computed by the Eta atmospheric model. RAOBS observational data are used to verify the PBL height. Estimated observed PBL heights as well as computed Eta PBL heights are incorporated into NCEP's Forecast Verification System (FVS). The study used different statistical parameters to investigate the spatial distribution of PBL height errors and explored the dependencies between predicted PBL height accuracy and surface ozone concentration errors.

8.2 SMOKE PLUME FORECASTING FROM FOREST FIRES, AUSTRALIA, JANUARY 2005

A useful air quality presentation made at the 21st Conference on Weather Analysis and Forecasting focussed on a particle pollution episode resulting from large scale forest fires in Australia[11]. The area affected by these fires was the hills region immediately inland from Perth, the capital city of the state of Western Australia with a population of 1.5 million people. The wildfire outbreaks spanned an 8 day period from the night of 15th to 23rd January 2005. This region is particularly susceptible to such problems because urbanisation has encroached in narrow corridors into thick dry sclerophyll forest. This fire outbreak was the largest fire in the southwest of Western Australia's northern jarrah forests for 45 years. A significant feature of this event was the extensive smoke plume that covered large parts of the heavily urbanised metropolitan area for several days, producing the highest concentrations of particulate pollution in Perth's history with a corresponding sharp increase in the risk of respiratory illnesses to the local population.

The multi-facetted role of the operational meteorologists during the event included: ongoing provision of detailed fire weather support over both short and medium time frames to the operation fire combating agencies; comments on the reasons for the severity of the smoke pollution and forecasts of its future location and intensity, and explanations for some spectacular views of the fire smoke plume and pyrocumulus lenticularis that dominated the skyline one afternoon. These services were an integral component of the fire control efforts and made extensive use of a variety of satellite, aircraft and surface based observation techniques and utilised a range of numerical model output. Fire agencies declared the meteorological support provided to be highly successful.

8.3 DEVELOPMENTS IN URBAN AIR QUALITY FORECASTING MADE BY CERC

Cambridge Environmental Research Consultants (CERC) has been developing a capability to make regular local scale operational forecasts in urban environments using its ADMS-Urban model. The system is outlined at http://www.cerc.co.uk/services/forecast.htm and summarised here. The system uses data from national emissions records and the local inventories currently used in the Local Authority Review and Assessment procedure, vehicle flows on major roads, outputs from industry, releases from residential and commercial areas. Pollution from continental Europe is also taken into account. These data are then used in conjunction with forecast meteorological parameters (wind speed and directions, temperature and cloud cover), which are obtained from the PA

[11] 'Perth, Western Australia wildfires of January 2005: Meteorological challenges of fire control and smoke plume predicition in a forest - urban environment' http://ams.confex.com/ams/WAFNWP34BC/techprogram/paper_94863.htm

WeatherCentre. The model output is a data file that indicates air quality levels over the next 3 days which can subsequently be used as the basis for a wide variety of media including maps, animations, tables and summaries for dissemination on the web. CERC have used this system to generate high resolution maps which can be in the form of colour-coded air quality "contours" over-laid on a map of the area, or as labels over specific streets, suburbs or towns.

8.4 ADVANCES IN DISPERSION MODELLING PARAMETERISATION USING LIDAR REMOTE SENSING

The final report of the Invest to Save ISB52-11 project to improve air quality forecasting was published in late 2004. The project run by a consortium of Qinetiq, Met Office, University of Salford and University of Essex examined the use of lidar remote sensing to improve the accuracy of descriptions atmospheric parameters such as turbulent diffusion used in the dispersion models employed in air quality forecasting systems.

The research focussed mainly on improving dispersion model performance across urban environments where urban effects on turbulence are often inadequately represented. The report notes that urban air pollution episodes most commonly occur when wind speeds are light and mixing heights are shallow, leading to poor dispersion but that measurements of these parameters in large cities are rarely made despite their importance for dispersion modelling. The study promotes the use of lidar remote sensing technology as a means of gathering accurate information on such parameters. Lidars were used to gather three-dimensional wind flow data from urban environments for incorporation into dispersion models. The study emphasised the benefits of lidar as a means of gathering this information:

- Lidar can make more precise measurements than conventional radar
- Lidar can probe the atmosphere to a greater height than most tall masts
- Lidars can make lower atmosphere measurements above urban environments that would otherwise be inaccessible to aircraft or tethered balloons

The process uses lidars to measure the Doppler shift of light back-scattered from fine aerosol particles such as water droplets and dust. Sampling at a range of angles and combining the results of two lidars allows the assembly of a three-dimensional airflow picture. Typical scanned volumes are a few cubic km with the probes separated by up to 10 km. This new dual Doppler lidar technique allows velocity components to be estimated by solving for the flow where the beams intersect. The system has been deployed on a summer and winter trial. This is the first time that two identical lidar systems have been used to make simultaneous measurements of the wind field. The use of two lidar instruments in this capacity requires careful siting and alignment of the two lidars. In addition, the data also facilitates the estimation of a number of important parameters that are used or calculated in atmospheric dispersion models.

Computer software, developed at Essex University aided in the visualization and interpretation of the lidar atmospheric data. This data was then compared with complementary dispersion model data collected from the UK Met Office NAME model, and the ADMS model, both of which are much used in the United Kingdom for air quality forecasting.

The performance of the lidars was assessed in the final project report through the quality of the data collected and its impact upon improving the accuracy of dispersion model predictions. The key finding was to highlight the significant differences in observed and modelled values of the mixing height, most noticeable across the urban-rural boundary. The report therefore concludes that there is scope and need for refinement of the existing models of urban mixing height. The observed differences help explain why the urban pollution concentrations were underestimated using current models, though this observation was dependent upon the prevailing conditions.

The Project represented a unique opportunity to gain mixing heights, flow and turbulence data using lidar remote sensing over a city for the improvement of dispersion models that are used in air quality forecasting. Current experience in the Met Office shows that the required measurement heights and spatial sampling over a conurbation can only be achieved through these lidar remote sensing techniques.

8.5 MET OFFICE PUBLICATIONS DURING 2005

A list of peer-reviewed publications produced by the UK Met Office Atmospheric Dispersion Group during 2005/6 are listed below:

- Jones A.R. and Thomson D.J.,'Simulation of time series of concentration fluctuations in atmospheric dispersion using a correlation –distortion technique', Boundary-Layer Meteorology 118, 25-54, 2006.
- Vione D., Maurino V., Minero C., Pelizzetti E., Harrison M.A.J., Olariu R-I. and Arsene C., Photochemical reactions in the tropospheric aqueous phase and on particulate matter, Chem. Soc. Rev., 2006.
- Gloster J., Champion H.J., Mansley L.M., Romero P., Brough T. and Ramirez A., 'The 2001 epidemic of foot-and-mouth disease in the United Kingdom: epidemiological and meteorological case studies', The Veterinary Record 156, 793-803, 2005.
- Harrison M.A.J, Heal M.R., Cape J.N., Evaluation of the pathways of tropospheric nitrophenol formation using a multiphase model, Atmospheric Chemistry and Physics 5, 1679-1695, 2005.
- Harrison M.A.J., Barra S., Borghesi D., Vione D., Arsene C. and Olariu R.I., Nitrated phenols in the atmosphere: a review, Atmospheric Environment 39, 2, 231-248, 2005.
- Kinra S., Lewendon G., Nelder R., Herriott N., Hort M., Harrison S. and Murray V., Evacuation decisions in a chemical air pollution incident: cross sectional survey, British Medical Journal 330, 1471,2005.
- Morrison N.L. and Webster H.N., 'An assessment of turbulence profiles in rural and urban environments using local measurements and NWP results', Boundary-Layer Meteorology 115, 223-239, 2005.
- Reimann S., Simmonds P.G., Manning A.J., Cunnold D.M., Wang H.J., Li J., McCulloch A., Prinn R.G., Huang J., Weiss R.F., Fraser P.J., OÿDoherty S., Greally B.R., Stemmler K., Hill M. and Folini D., 'Assessment of European methyl chloroform emissions by analysis of long-term measurements', Nature 433, 506-508, 2005.

- Simmonds P.G., Manning A.J., Derwent R.G., Cias P., Ramonet M., Kazan V., Ryall D., A burning question. Can recent growth rate anomalies in the greenhouse gases be attributed to large-scale biomass burning events?, Atmospheric Environment 39, 14, 2513-2517, 2005.

- Thomson D.J. and Devenish B.J., 'Particle pair separation in kinematic simulations', J. Fluid Mech. 526, 277-302, 2005.

9 Forward work plan to 31st May 2006

- The two tables below summarise both the weekly and annual activity for 2006 (Table 10.1 and 10.2 respectively) to the end of the current contract in May 2006.

Table 10.1 Weekly Activity Chart

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

Table 10.2 Annual Activity Chart

Task	Apr	May
Quarterly Reports		
Quarterly Progress Meetings		
Annual reports		
Seminars		

10 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.

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	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants
	3	
MODERATE		
	4	
	5	Mild effects unlikely to require action may be noticed amongst sensitive individuals
	6	
HIGH		
	7	Significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be
	8	needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their
	9	“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