REPORT

# UK Air Quality Forecasting: Operational Report for October to December 2005

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


AEAT/ENV/R/2137 Issue 1
January 2006

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# Executive Summary

This report covers the operational activities carried out by Netcen and the Met Office on the UK Air Quality Forecasting Contract from October to December 2005. The work is funded by the Department for Environment Food and Rural Affairs (Defra), the Scottish Executive, Welsh Assembly Government and the Department of the Environment in Northern Ireland.

During the fourth quarter of 2005, there were 14 days on which HIGH air pollution was recorded. All of the HIGH measurements were due to $PM_{10}$, none of these were forecast due to the unpredictable and localised nature of these (..often building related) events, reflected in the poor success and accuracy of forecasts within zones and agglomerations (all 0%). Many MODERATE days were measured (mainly for $PM_{10}$ during this quarter) and were forecast with a high degree of success and reasonable accuracy during this quarter. These MODERATE periods are recorded within the forecasting success and accuracy calculations. The forecasting success and accuracy for this quarter for HIGH and MODERATE episodes is summarised in Table 1 below.

Success figures for MODERATE forecasts issued show that a large proportion of measured polluted days were successfully forecast (percentage above 100%)[1]. An average accuracy figure of 65 % indicates that only 35 % of the forecast MODERATE levels were not measured and remained LOW. The accuracy figures tend to be lower due to the precautionary approach that Netcen takes when issuing the daily forecasts- we issue a forecast for MODERATE pollution when there is only a small chance that it will be recorded.

**Table 1 – Forecast success/accuracy for incidents above 'HIGH' and above 'MODERATE', October 1st to December 31st 2005.**

| Region/Area | HIGH | | MODERATE | |
|---|---|---|---|---|
| | % success | % accuracy | % success | % accuracy |
| Zones | 0 | 0 | 158 | 71 |
| Agglomerations | 0 | 0 | 147 | 60 |

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

1. Investigating ways of using automatic software systems to streamline the activities within the forecasting process, thus allowing forecasters to spend their time more productively considering the most accurate forecasts.
2. Researching 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. Improving the NAME model used for ad-hoc analyses. In particular, recent improvements have assisted with investigations of 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. Improving and updating the emissions inventories used in our models.
5. Learning from the events following the Buncefield Fuel Depot explosion, improve the list of contacts between Defra, Met Office and Netcen for use in out-of-hours emergency response.

There were no reported breakdowns in the forecasting service between July and September; all bulletins were delivered to the Air Quality Communications contractor on time.

# Contents

# 1 Introduction

A forecast of the following day's air pollution is prepared every day by Netcen in collaboration with the Met Office. 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 can be updated and disseminated through Teletext, the World Wide Web and a Freephone telephone number 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, and is then included in subsequent air quality bulletins for the BBC, newspapers and many other interested organisations.

This report covers the media forecasts issued during the quarter reported on. 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 every week, on Tuesdays and Fridays, we also provide a long-range pollution outlook. This takes the form of a short text message which is emailed to approximately sixty recipients in Defra and other Government Departments, together with the BBC weather forecasters. The outlook is compiled by careful assessment and review of the outputs from our pollution models, which currently run out to 3 days ahead, and by also considering the long-term weather situation.

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

# 2 New developments during this period

The Met Office have continued with the development of the model "NAMEIII", the resolution of which has now been enhanced. Two model runs are now performed each day (midnight and midday), opposed to the previous one run per day but are currently slow to complete due to the extra data involved, the Met Office are currently investigating ways to speed up the run times. Details of the model enhancements are given below, provided by the Met Office:

Upgrades to both the NAME and TRAJ models in the air quality forecasting system have taken plac this past quarter. Representation of atmospheric dispersion has been improved in both models. NAME 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 meteorology used in the air quality forecasting system has been 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.

Future planned upgrades include implementation of the most recent 2003 emissions data for the UK and Europe into the AQ system and an increase in the horizontal model domain.

# 3 Analysis of Forecasting Success Rate

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. Appendix 3 shows a worked example of how accuracy and success rates are calculated. 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 the quarter reported on are presented in Tables 3.1 (forecasting performance in zones) and 3.2 (forecasting performance in agglomerations) for 'HIGH' days. Table 3.5 provides a summary for each pollutant of the number of days on which HIGH and above pollution was measured, the maximum exceedence concentration and the day and site at which it was recorded. The forecasting performance Tables 3.1 and 3.2 give:

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

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

The forecast success rate (%) is calculated as:

- (Number of episodes successfully forecast/total number of episodes measured) x 100

The forecast accuracy (%) is calculated as:

- (Number of episodes successfully forecast/[Number of successful forecasts + number of wrong forecasts]) x 100

The forecasting success rates for 'MODERATE' days or above for each zone and agglomeration are presented in Tables 3.3 (zones) and 3.4 (agglomerations). Table 3.3 and 3.4 give the same information as in Tables 3.1 and 3.2, but summarised for 'MODERATE' days and above.

## 3.1 FORECAST ANALYSIS FOR OCTOBER 1ST TO DECEMBER 31ST 2005.

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

| ZONES | Central Scotland | East Mids | Eastern | Greater London | Highland | North East | North East Scotland | North Wales | North West & Merseyside | Northern Ireland | Scottish Borders | South East | South Wales | South West | West Midlands | Yorkshire & Humberside | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| measured days | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 7 |
| forecasted days | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ok (f and m) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| wrong (f not m) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| wrong (m not f) | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 7 |
| success % | 100 | 100 | 100 | 0 | 100 | 0 | 100 | 100 | 100 | 0 | 100 | 100 | 0 | 100 | 100 | 100 | 0 |
| accuracy % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

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

| AGGLOMERATIONS | Belfast UA | Brighton/Worthing/ Littlehampton | Bristol UA | Cardiff UA | Edinburgh UA | Glasgow UA | Greater Manchester UA | Leicester UA | Liverpool UA |
|---|---|---|---|---|---|---|---|---|---|
| measured days | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| forecasted days | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ok (f and m) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| wrong (f not m) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| wrong (m not f) | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| success % | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| accuracy % | 0 | 0 | 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 | 0 | 0 | 0 | 0 | 0 | 5 | 7 |
| forecasted days | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| ok (f and m) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| wrong (f not m) | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| wrong (m not f) | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 7 |
| success % | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 0 |
| accuracy % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*** 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 | 0 | 2 | 3 | 30 | 0 | 3 | 0 | 1 | 0 | 4 | 0 | 3 | 5 | 4 | 3 | 7 | 65 |
| forecasted days | 4 | 6 | 8 | 32 | 1 | 2 | 1 | 3 | 4 | 7 | 1 | 14 | 10 | 5 | 8 | 3 | 109 |
| ok (f and m) | 1 | 4 | 6 | 33 | 1 | 2 | 1 | 3 | 4 | 6 | 1 | 11 | 7 | 8 | 9 | 6 | 103 |
| wrong (f not m) | 3 | 3 | 3 | 4 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 5 | 3 | 0 | 0 | 1 | 25 |
| wrong (m not f) | 0 | 0 | 1 | 7 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 0 | 0 | 2 | 17 |
| success % | 100 | 200 | 200 | 110 | 100 | 67 | 100 | 300 | 100 | 150 | 100 | 367 | 140 | 200 | 300 | 86 | 158 |
| accuracy % | 25 | 57 | 60 | 75 | 100 | 40 | 100 | 100 | 100 | 67 | 100 | 69 | 50 | 100 | 100 | 67 | 71 |

**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 | 5 | 1 | 0 | 2 | 0 | 6 | 8 | 1 | 1 |
| forecasted days | 9 | 5 | 1 | 1 | 2 | 6 | 5 | 3 | 5 |
| ok (f and m) | 7 | 5 | 0 | 1 | 1 | 7 | 6 | 3 | 4 |
| wrong (f not m) | 2 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| wrong (m not f) | 2 | 0 | 0 | 2 | 0 | 2 | 4 | 0 | 0 |
| success % | 140 | 500 | 100 | 50 | 100 | 117 | 75 | 300 | 400 |
| accuracy % | 64 | 83 | 0 | 33 | 50 | 70 | 55 | 100 | 80 |

| AGGLOMERATIONS | Nottingham UA | Portsmouth UA | Sheffield UA | Swansea UA | Tyneside | West Midlands UA | West Yorkshire UA | Overall |
|---|---|---|---|---|---|---|---|---|
| measured days | 4 | 0 | 0 | 1 | 0 | 4 | 14 | 47 |
| forecasted days | 4 | 4 | 4 | 7 | 0 | 10 | 17 | 83 |
| ok (f and m) | 4 | 3 | 3 | 6 | 0 | 9 | 10 | 69 |
| wrong (f not m) | 1 | 1 | 1 | 1 | 0 | 2 | 10 | 24 |
| wrong (m not f) | 1 | 0 | 0 | 1 | 0 | 1 | 9 | 22 |
| success % | 100 | 100 | 100 | 600 | 100 | 225 | 71 | 147 |
| accuracy % | 67 | 75 | 75 | 75 | 0 | 75 | 34 | 60 |

*** 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 episodes October to December 2005 (Based on latest provisional data)**

| Pollutant | High or above days | Moderate days | Max. conc. (µg /m³) * | Site with max. conc. | Zones or Agglomeration | Date of max conc. | Forecast success HIGH days (%) [no. incidents, zone or agglomeration days] ** |
|---|---|---|---|---|---|---|---|
| Ozone | 0 | 4 | 128 | London Teddington | Greater London | 10/10/05 | N / A [0] |
| $PM_{10}$ gravimetric | 14 | 34 | 200 | Cwmbran | South Wales | 07/12/05 | 0 % [14] |
| $NO_2$ | 0 | 10 | 361 | London Marylebone Road | Greater London | 7/12/05 | N / A [0] |
| $SO_2$ | 0 | 2 | 436 | Salford Eccles | Greater Manchester UA | 21/11/05 | N / A [0] |
| CO | 0 | 0 | 4.1 | Bradford Centre and London A3 Roadside | West Yorkshire UA and Greater London | 09/12/05 and 21/11/05 | N / A [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 (CO units are mg/m3).
** the number of incidents is the total of the number of HIGH days in all zones and agglomerations (ie a HIGH day on the same day in many zones or agglomerations is counted as many incidents, not just one)

**General Observations**

There were 14 zone or agglomeration-day incidents of HIGH band pollution measured during this quarter, measured on 14 separate days. All of these HIGH days were due to $PM_{10}$ only. None of the HIGH levels were forecast successfully due to the inherently unpredictable and localised nature of $PM_{10}$ episodes, around 80 % of which were building work related over the reporting period. Half of the incidents occurred within agglomerations. These HIGH episodes were not considered to broadly represent ambient levels across their associated regions so were therefore not allowed for during the forecasting process.

Thirty four MODERATE days were seen due to $PM_{10}$, measured at geographically diverse locations, mainly as a result of still, cold conditions near roadside and industrial locations with some contributions from areas of coal burning used for domestic heating.

Eight MODERATE days were measured for nitrogen dioxide at the London Marylebone Road AQ station and twenty five MODERATE or above days were measured for $PM_{10}$, all related to traffic emissions combined with meteorological conditions.

Two MODERATE days were measured for SO2 at the Salford Eccles AQ site during a cold spell, likely to have been the result of industrial emissions.

Four MODERATE days were measured for ozone during this quarter. On the 10th October around 20 sites measured the MODERATE band during unusually warm, dry conditions for October towards the south of the UK.

Figures 3.1 – 3.3 show the trends of pollutants in graphical form. A site-by-site breakdown is given in Figures 3.4a and 3.4b.

**$O_3$**

Very few MODERATE days were measured during this quarter as normally expected for the autumn/winter months.

On the 10th October the MODERATE band was measured at around 20 sites, mainly located in London, East Anglia and the south of England. Warm air from Northern Spain was being momentarily drawn up from the south, temperatures above 20 degrees C were seen in the south of England. Interestingly this is the latest date by more than 2 weeks in any calendar year we have seen a substantial number of MODERATE ozone measurements on a single day since measurements began. The highest measurement was experienced at the London Teddington AQ site, at 128 ug/m3.

Figure 3.1 shows the trends in $O_3$ levels over this period.

**$PM_{10}$**

As previously noted none of the 14 HIGH band exceedences were forecast due to their localised and unpredictable nature. Five intermittent HIGH or above days were measured at the Bradford AQ site between the 9th and 16th December as the result of ongoing building works (highest measurement was 168 ug/m3 as a daily maximum 24 hour running mean). Two HIGH days were measured at the Cwmbran site on 7th and 8th December due to localised stone cutting (maximum measurement of 200 ug/m3 as a daily maximum 24 hour running mean). Two HIGH days were measured at the Middlesborough station as the result of ongoing building works on 7th and 8th October, coincident with a period of easterly wind trajectories (maximum measurement here was 114 ug/m3 as a daily maximum 24 hour running mean). Installation of an automatic lavatory near the Belfast Centre AQ site led to two HIGH day measurements on the 10th and 11th October (119 ug/m3 as a daily maximum 24 hour running mean was the highest measurement).

Two HIGH days were measured at London Marylebone Road on the 20th and 21st December during a cool period with light winds, under high pressure meterological conditions. The MODERATE band was forecast for these days, the final measurement average at Marylebone Road (112 ug/m3 as a daily maximum 24 hour running mean) had not unfortunately been forecast to within 1 index band.

One HIGH day was seen at the Derry AQ site on 22nd November, during a cold spell. The Belfast Centre AQ site reached index 6 here for $PM_{10}$. The MODERATE band was generally forecast for Northern Ireland over the cold spell but the final Derry measurement average (100 ug/m3 as a daily maximum 24 hour running mean) was greater than one index band above the forecast for the Northern Ireland zone on the 22nd .

Nine sites or more measured MODERATE band particulate $PM_{10}$ on the 8th October and in a second period between 21st and 22nd November. On the 8th October the MODERATE sites were geographically spread over England, although two-thirds were in Greater London. This happened at the end of a three day period of predominantly easterly wind trajectories with dry, sunny conditions in England and Wales, day time temperatures were warm at 20 degrees C. Thirteen then eleven sites measured the MODERATE band on the 21st and 22nd November respectively: two in Northern Ireland likely due to domestic heating, up to four in London as the result of traffic and poor dispersion conditions, Glasgow centre again likely due to poor dispersion, up to six sites in the north of England, many the result of industry combined with traffic emissions in still, cold, foggy conditions.

Figure 3.2 shows the trends in $PM_{10}$ levels over this period.

**$NO_2$**

Ten MODERATE days were seen during this period, 80 % of these measured at Marylebone Road (all likely to have been traffic related).

**$SO_2$**

Sulphur dioxide levels did not reach the HIGH band during this period. Two MODERATE days were measured only at the Salford Eccles AQ site during a cold spell, likely to have been the result of industrial emissions.

Figure 3.3 shows the trends in $SO_2$ levels over this period with $NO_2$ also included.

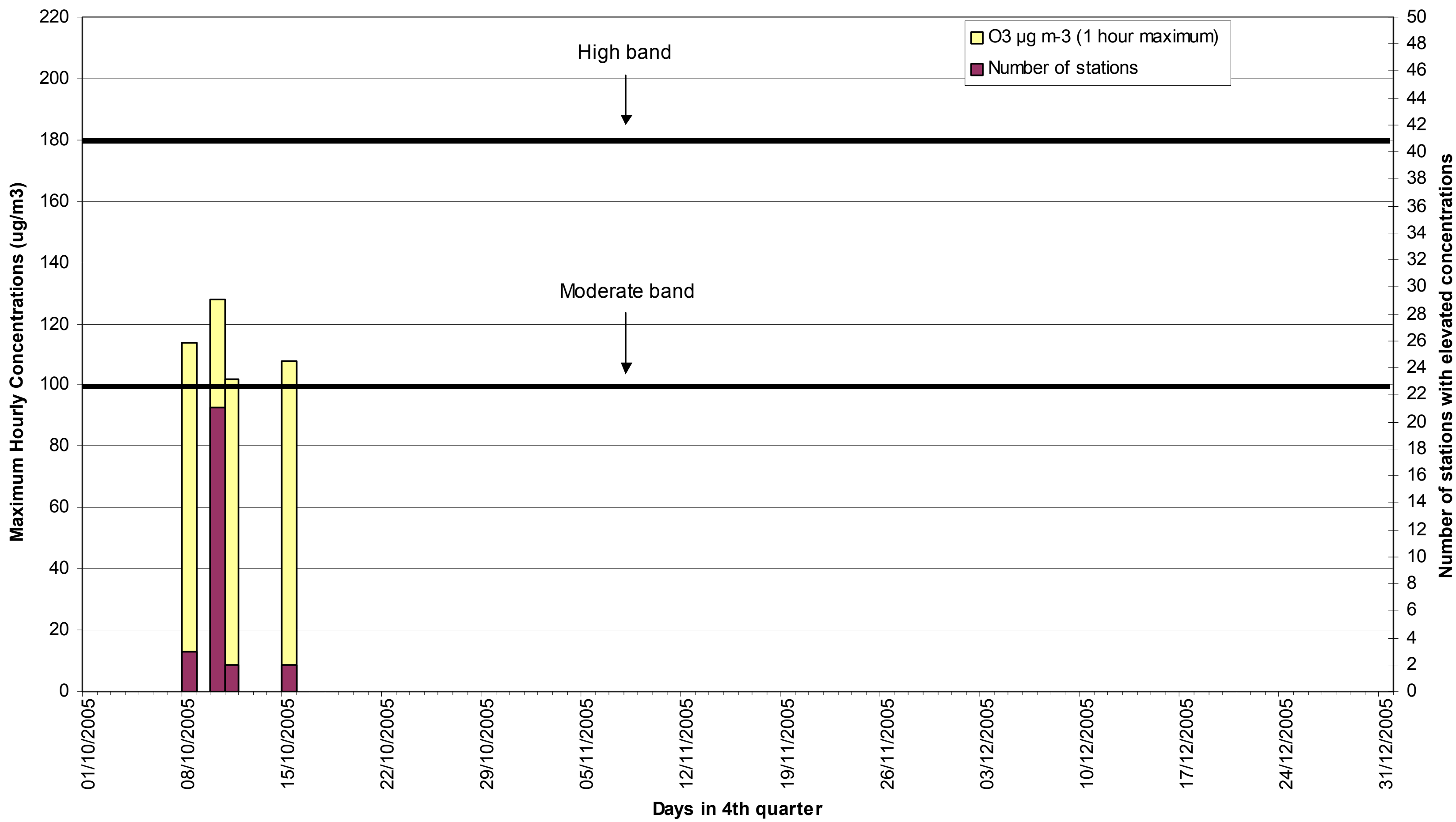



**Figure 3.1 Daily maximum hourly ozone concentration across AURN Network with total number of stations measuring MODERATE or above levels of ozone over 4$^{th}$ quarter 2005.**

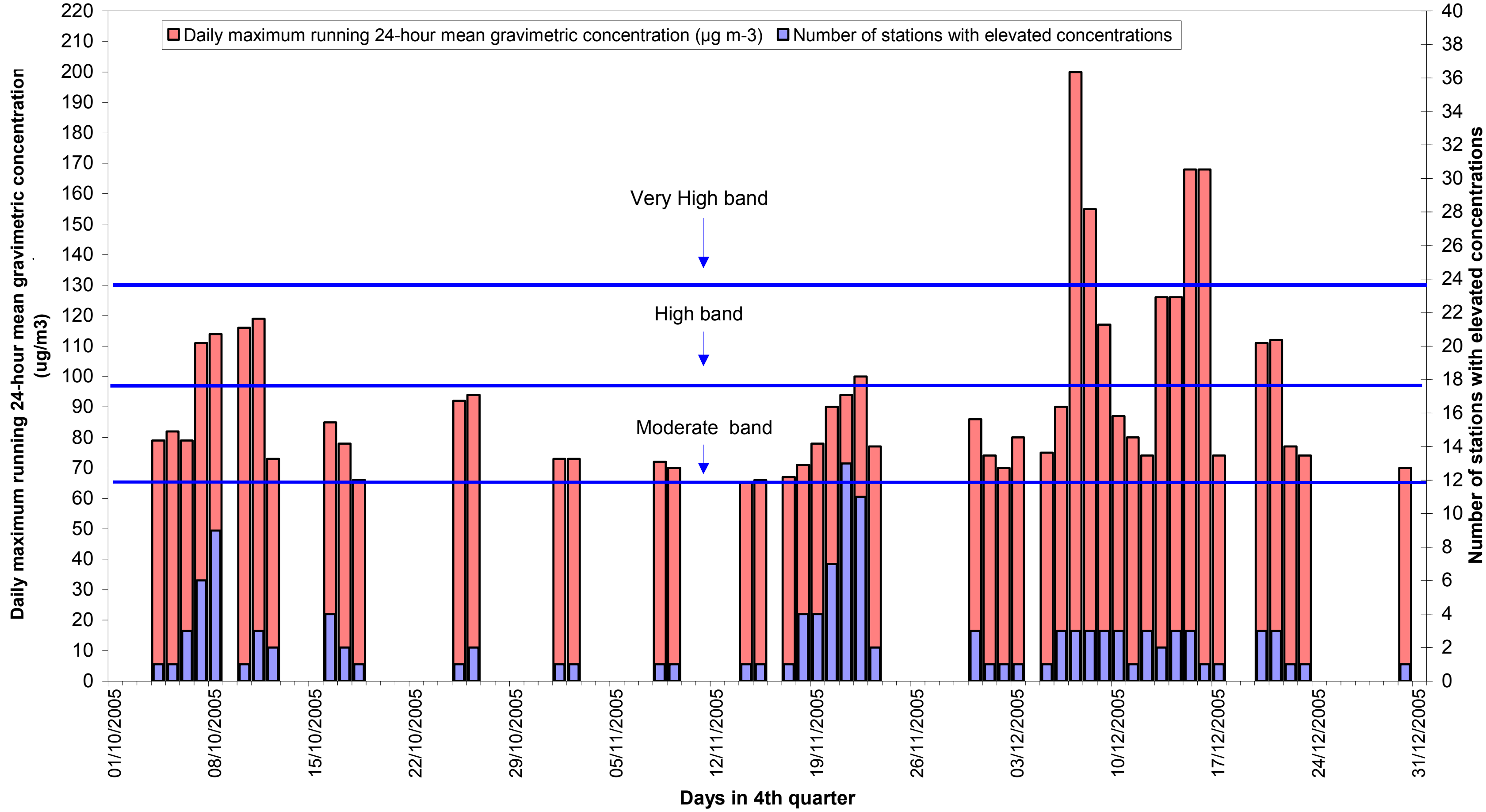



**Figure 3.2 Daily maximum running 24-hour mean $PM_{10}$ concentration across AURN Network with total number of stations measuring MODERATE or above levels over the 4$^{th}$ quarter 2005**

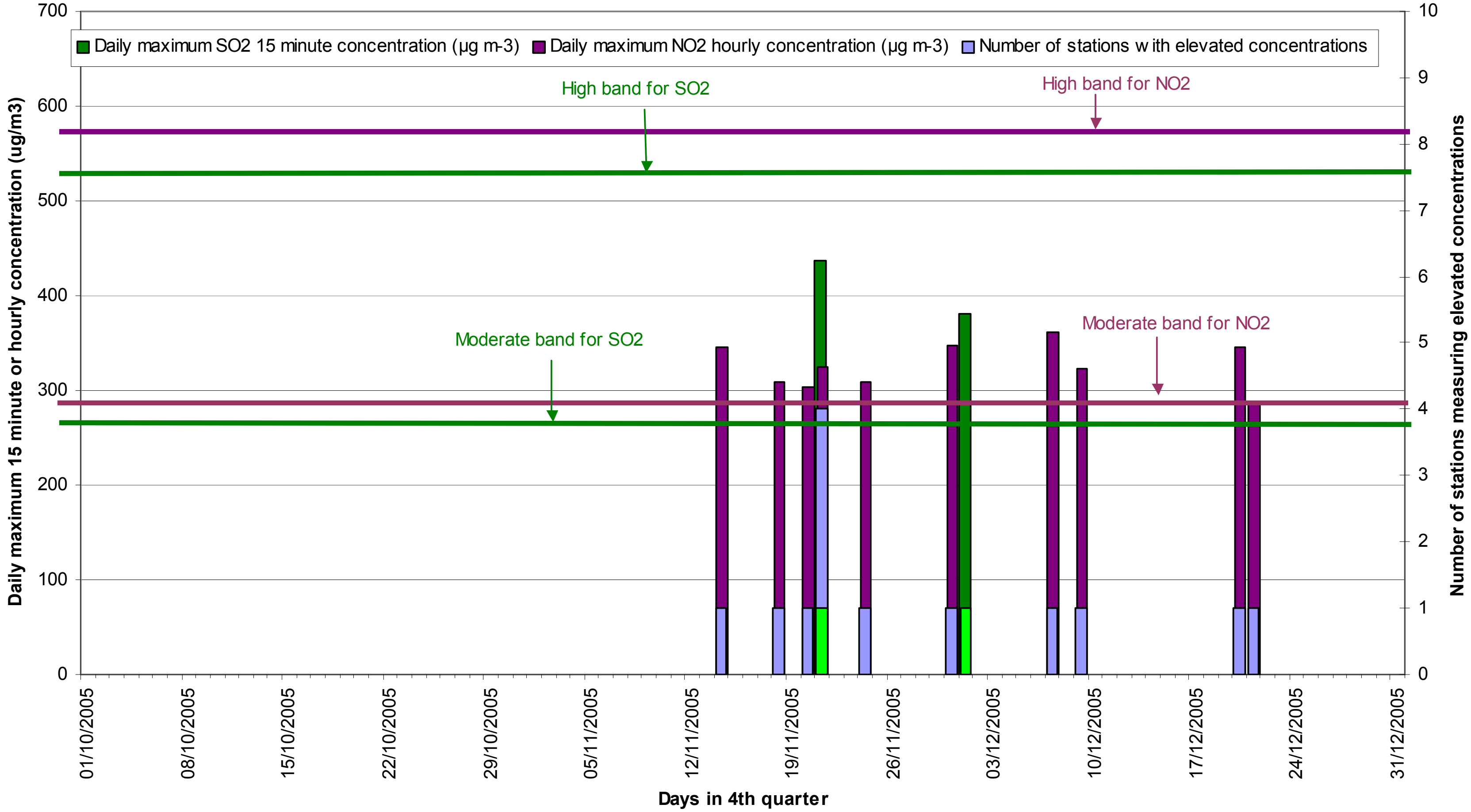



**Figure 3.3 Maximum 15 minute average concentrations of $SO_2$ and hourly average of NO2 across AURN Network with total number of stations measuring MODERATE or above levels over the 4th quarter 2005**

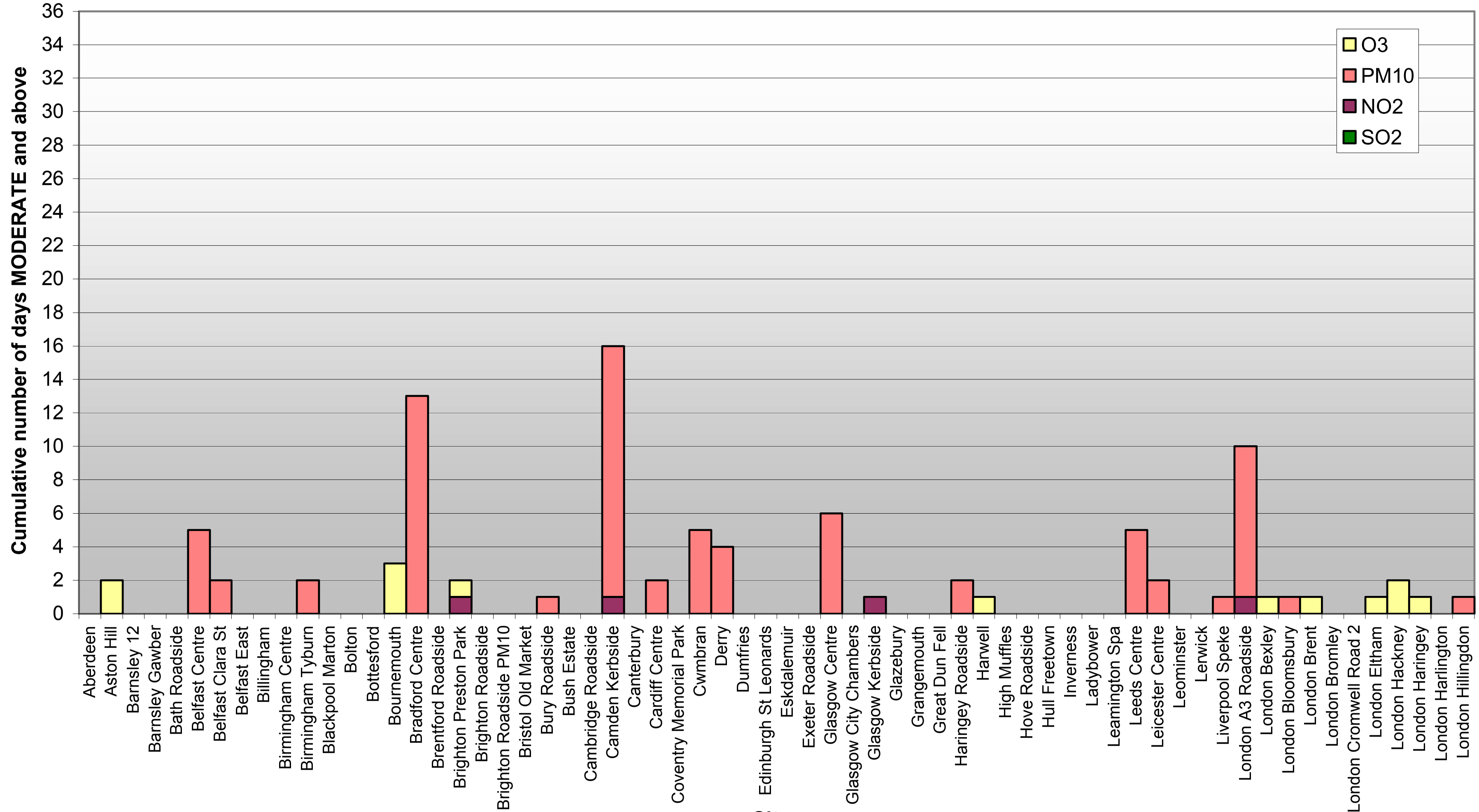



**Figure 3.4a Number of days moderate and above for each AURN Network station over 4th quarter 2005 – provisional data**

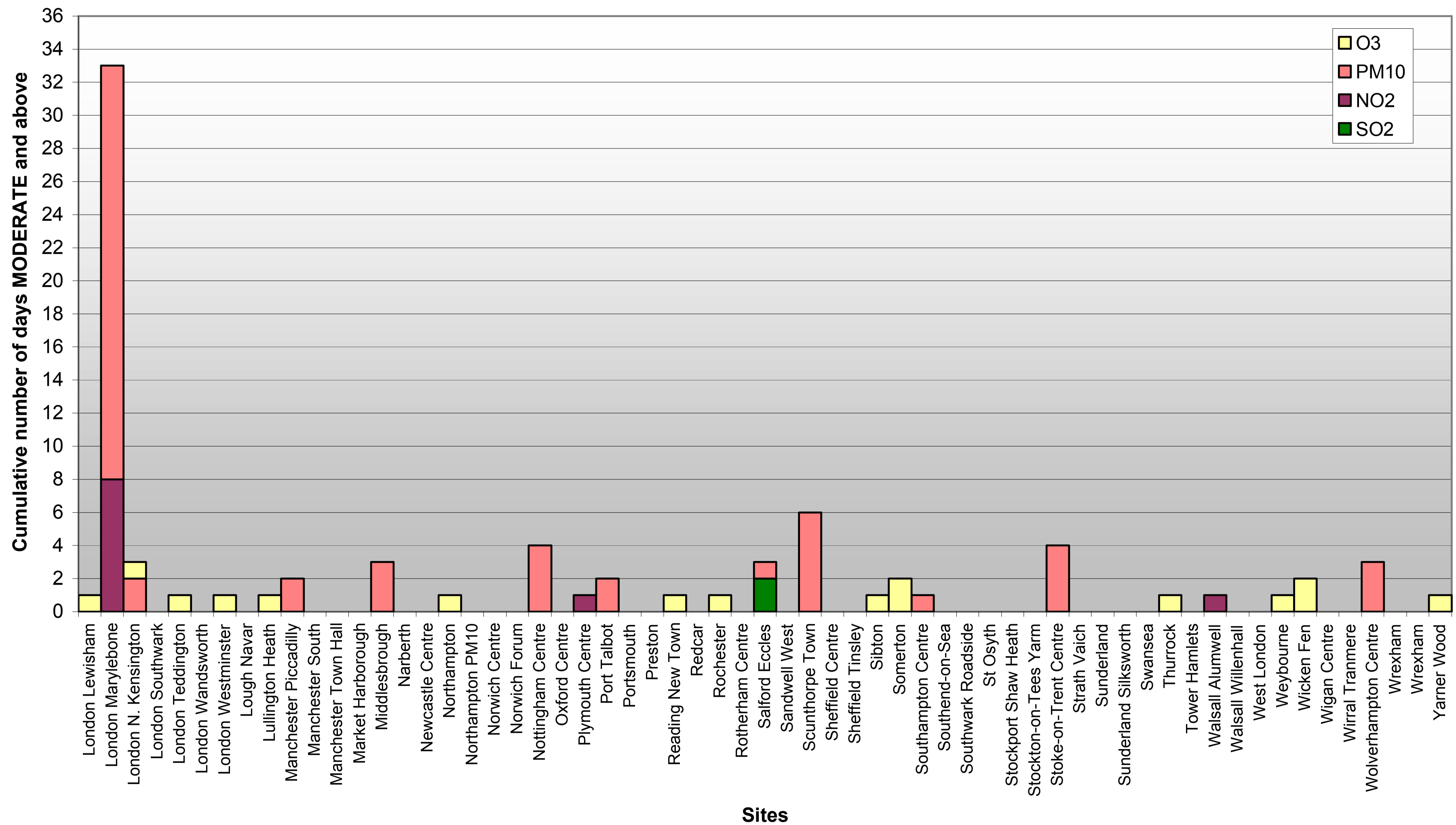



**Figure 3.4b Number of days moderate and above for each AURN Network station over 4th quarter 2005 – provisional data**

# 4 Breakdowns in the service

All bulletins were successfully delivered to the Air Quality Communications contractor on time. There were no reported breakdowns in the service over this three-month period.

# 5 Additional or enhanced forecasts

No formal enhanced forecasts can be issued until the format of the enhanced service has been agreed with Defra and the Devolved Administrations.

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

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

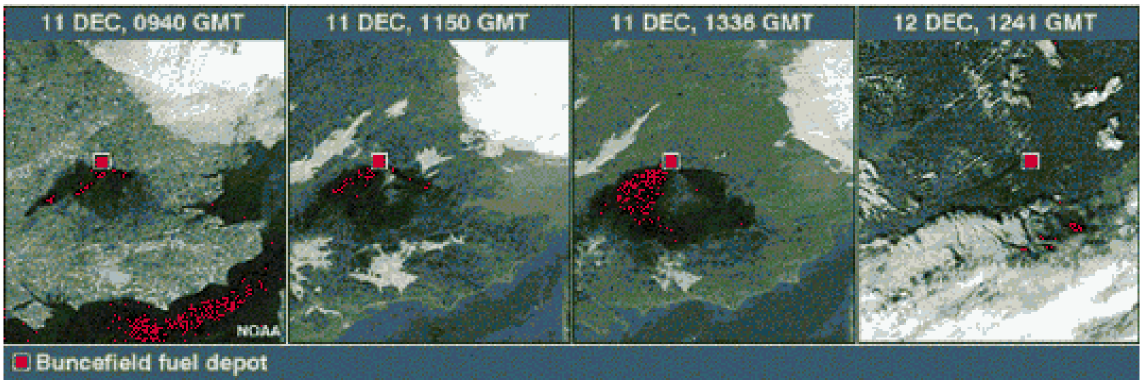
# 6 Ad-hoc services and analysis

## 6.1 BUNCEFIELD OIL DEPOT FIRE

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. Ground level wind speeds were light and from a north-westerly direction, encouraging a proportion of the resulting plume of unburnt oil and petroleum vapours, gaseous combustion products and smoke to drift towards Greater London. A second proportion spread out towards the south-east of England, covering the counties of Hertfordshire, Berkshire, Oxfordshire and Surrey within around 6 hours, as a response to the wind direction at higher altitudes. Met office research concluded that the plume had kept buoyant enough to travel through the planetary boundary layer and remain at an altitude well above ground level during the several day duration of the fire. Wind speeds had generally picked up from Monday afternoon onwards dispersing the plume in a south easterly direction on higher altitude winds and out over the Atlantic, corresponding with a one day wind direction change, air was then coming from the north-east until Tuesday. Even after the fire had cooled and had eventually extinguished at the end of that week, no obvious ground level elevated measurements had been observed at UK National Network AQM sites, suggesting that the effects of the plume had remained above ground level throughout or had experienced sufficient ground level dispersion conditions at the end of the incident as to not be measured 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 below show the extent of the plume over the first 24 hours of the fire starting, at various stages of dispersion.




A more detailed analysis has been provided below 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 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 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 suggested that the plume reached a height of 3000 m during Sunday 11th December, 2005 and a height of 2000 m on Monday 12th December 2005. 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 reality. On Sunday 11th December 2005, the plume fanned out over a wide area (see Figure 1). 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-westwards from the oil depot (see Figure 2). 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 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.

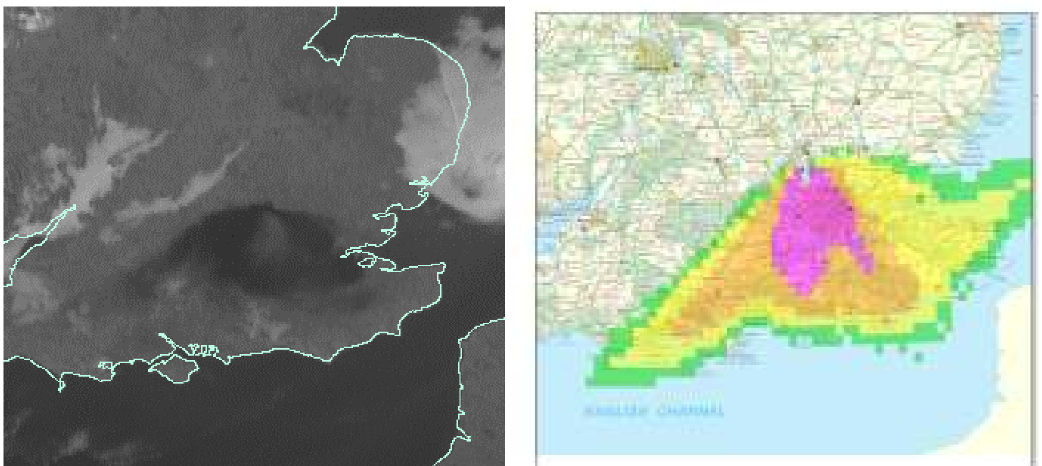


*Figure 1: Comparison of NAME predicted plume (0 - 4 km) at 1400 UTC Sunday 11th December, 2005 with satellite imagery.*

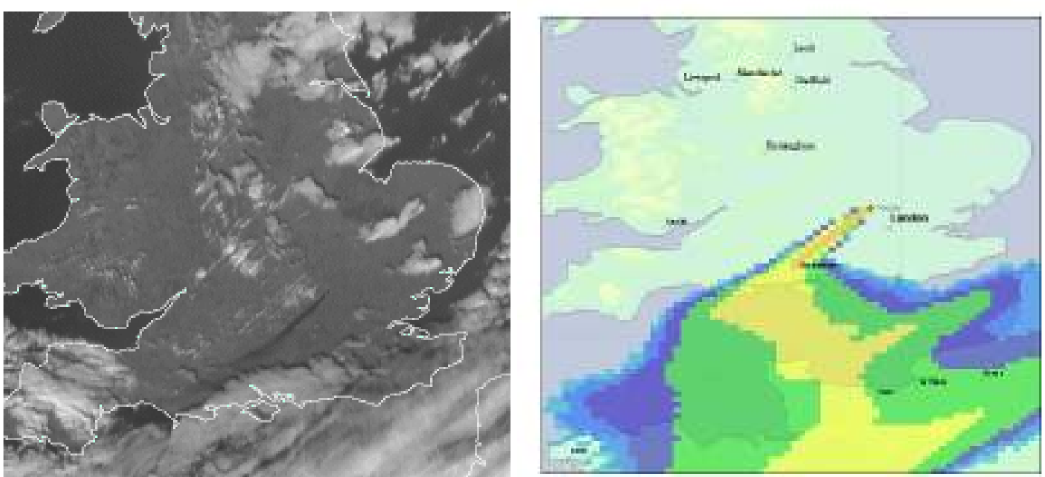


*Figure 2: Comparison of NAME predicted plume (0 – 4 km) at 1300 UTC Monday 12th December, 2005 with satellite imagery.*

# 7 Ongoing research

Netcen and the Met office will also 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.
5. Improve the list of contacts between Defra, Met Office and Netcen for use in out-of-hours emergency response, as learned from the events following the Buncefield Fuel Depot explosion.

# 8 Forward work plan for January to March 2006

Major tasks include:

- Ongoing daily air pollution forecasting activities.
- Ongoing improvements to NAME model, including:
  - Increase in the horizontal model domain
  - Update of emissions inventory used in the model.
- Publication of quarters 2, 3, 4 and Annual 2005 reports on the Air Quality Archive Web Site.
- Publication of an ad-hoc report on the air quality impact of the Buncefield fuel depot explosion.
- Improve list of contacts between Defra, Met Office and Netcen for use in out-of-hours emergency response.
- Plan the next AQ forecasting seminar to be held by Netcen in April 2006

# 9 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

## The UK Air Pollution Indices

| Old Banding | Index | Ozone 8-hourly/ Hourly mean | | Nitrogen Dioxide Hourly Mean | | Sulphur Dioxide 15-Minute Mean | | Carbon Monoxide 8-Hour Mean | | $PM_{10}$ Particles 24-Hour Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $\mu gm^{-3}$ | ppb | $\mu gm^{-3}$ | ppb | $\mu gm^{-3}$ | ppb | $mgm^{-3}$ | ppm | gravimetric $\mu gm^{-3}$ |
| **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 |
| **MODERATE** | | | | | | | | | | |
| | 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 |
| **VERY HIGH** | | | | | | | | | | |
| | 10 | $\geq$ 360 $\mu gm^{-3}$ | $\geq$ 180 ppb | $\geq$ 764 $\mu gm^{-3}$ | $\geq$ 400 ppb | $\geq$1064 $\mu gm^{-3}$ | $\geq$ 400 ppb | $\geq$ 23.2 $mgm^{-3}$ | $\geq$ 20 ppm | $\geq$ 130 $\mu gm^{-3}$ |

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

# Appendix 2 - Forecasting Zones and Agglomerations

## CONTENTS

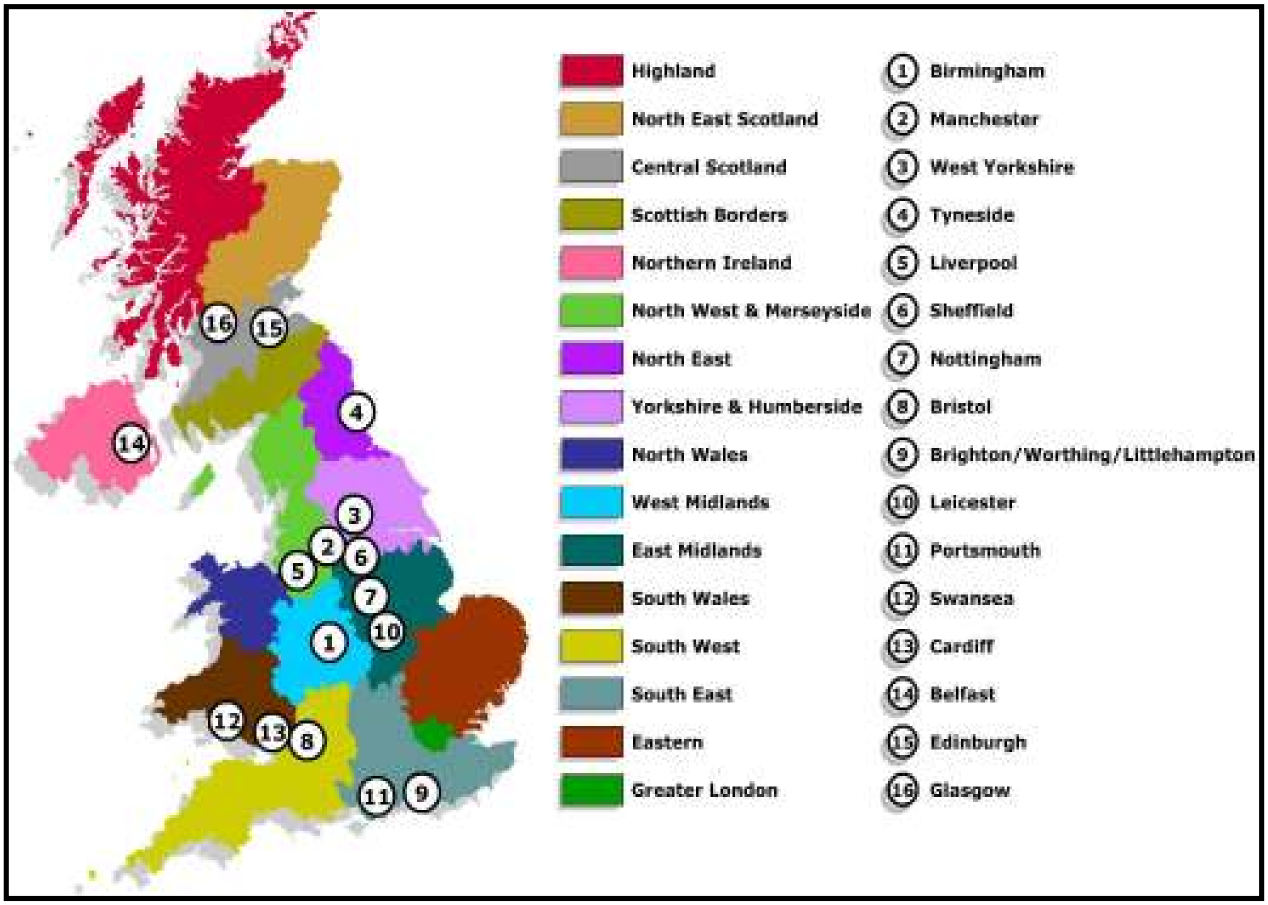
**Forecasting Zones**

| Zone | Population |
|---|---|
| | |
| **East Midlands** | 3084598 |
| **Eastern** | 5119547 |
| **Greater London** | 8278251 |
| **North East** | 1635126 |
| **North West and Merseyside** | 3671986 |
| **South East** | 6690881 |
| **South West** | 4364704 |
| **West Midlands** | 2970505 |
| **Yorkshire and Humberside** | 2816363 |
| | |
| **South Wales** | 1578773 |
| **North Wales** | 720022 |
| | |
| **Central Scotland** | 1813314 |
| **Highland** | 380062 |
| **North East Scotland** | 1001499 |
| **Scottish Borders** | 254690 |
| | |
| **Northern Ireland** | 1104991 |

**Forecasting Agglomerations**

| Agglomeration | Population |
|---|---|
| | |
| **Brighton/Worthing/Littlehampton** | 461181 |
| **Bristol Urban Area** | 551066 |
| **Greater Manchester Urban Area** | 2244931 |
| **Leicester** | 441213 |
| **Liverpool Urban Area** | 816216 |
| **Nottingham Urban Area** | 666358 |
| **Portsmouth** | 442252 |
| **Sheffield Urban Area** | 640720 |
| **Tyneside** | 879996 |
| **West Midlands Urban Area** | 2284093 |
| **West Yorkshire Urban Area** | 1499465 |
| | |
| **Cardiff** | 327706 |
| **Swansea/Neath/Port Talbot** | 270506 |
| | |
| **Edinburgh Urban Area** | 452194 |
| **Glasgow Urban Area** | 1168270 |
| | |
| **Belfast** | 580276 |

**Map of UK forecasting zones and agglomerations**



# Appendix 3 – Worked Example of How UK Forecasting Success and Accuracy Rates are Calculated.

## CONTENTS

## *A worked example showing how forecasting accuracy and success rate are defined and calculated in this report*

This analysis is based on an imaginary period of high pollution concentrations in South East England which occurred during warm weather and resulted in the formation of photochemical ozone. There were 4 days on which HIGH concentrations were measured; 29th July, 30th July, 1st August and 2nd August. Over the slightly longer period from 29th July – 3rd August, there were 6 days on which HIGH levels were either measured or forecast. During the whole reporting period, there were no other observations of HIGH band measurements, either forecast or actual. 31st July was a cooler day and measurements did not reach the HIGH band, despite being forecasted. Measured air pollution and previous day forecast are shown below for each day during this period, in terms of index and descriptive bands:

| ***Date*** | ***28/7*** | ***29/7*** | ***30/7*** | ***31/7*** | ***1/8*** | ***2/8*** | ***3/8*** | ***4/8*** |
|---|---|---|---|---|---|---|---|---|
| ***Measured Index value (M)*** | **5** (MOD) | 7 (HIGH) | 7 (HIGH) | 6 (MOD) | 7 (HIGH) | 7 (HIGH) | 5 (MOD) | 5 (MOD) |
| ***Forecast Index value (F)*** | 5 (MOD) | 6 (MOD) | 7 (HIGH) | 7 (HIGH) | 8 (HIGH) | 5 (MOD) | 7 (HIGH) | 6 (MOD) |

Based on the figures above, the success and accuracy of predicting HIGH episodes (>= Air Pollution index 7) for the South East Zone may be analysed as shown below:

| ***Date*** | ***28/7*** | ***29/7*** | ***30/7*** | ***31/7*** | ***1/8*** | ***2/8*** | ***3/8*** | ***4/8*** |
|---|---|---|---|---|---|---|---|---|
| ***Measured Index value (M)*** | **5** (MOD) | 7 (HIGH) | 7 (HIGH) | 6 (MOD) | 7 (HIGH) | 7 (HIGH) | 5 (MOD) | 5 (MOD) |
| ***Forecast Index value (F)*** | 5 (MOD) | 6 (MOD) | 7 (HIGH) | 7 (HIGH) | 8 (HIGH) | 6 (MOD) | 7 (HIGH) | 6 (MOD) |
| ***HIGH forecast or measured*** | No, so not used in calculations | Yes | Yes | Yes | Yes | Yes | Yes | No, not used in calcs |
| ***OK- Agreement of F and M to +/- 1 index band*** | N/A | Yes | Yes | Yes | Yes | Yes | No | N/A |

| | |
|---|---|
| ***HIGH days measured*** | 4 |
| ***HIGH days forecast*** | 4 |
| ***OK (M and F) [i.e. Agreement of F and M to +/- 1 index band*** | 5 |
| ***Wrong (F not M)*** | 1 |
| ***Wrong (M not F)*** | 0 |

The forecasting **success** during this period is calculated as:

[OK (M and F) / HIGH days measured]*100 = [5/4]*100 **= 125 %**

The corresponding **accuracy** is calculated as:

[OK (M and F) / {OK (M and F) + Wrong (M not F) + Wrong (F not M)}]*100

= [5 / {5+0+1}]*100 = [5/6]*100 = **83**

The analysis is then repeated for each of the 16 UK zones and 16 UK agglomerations.