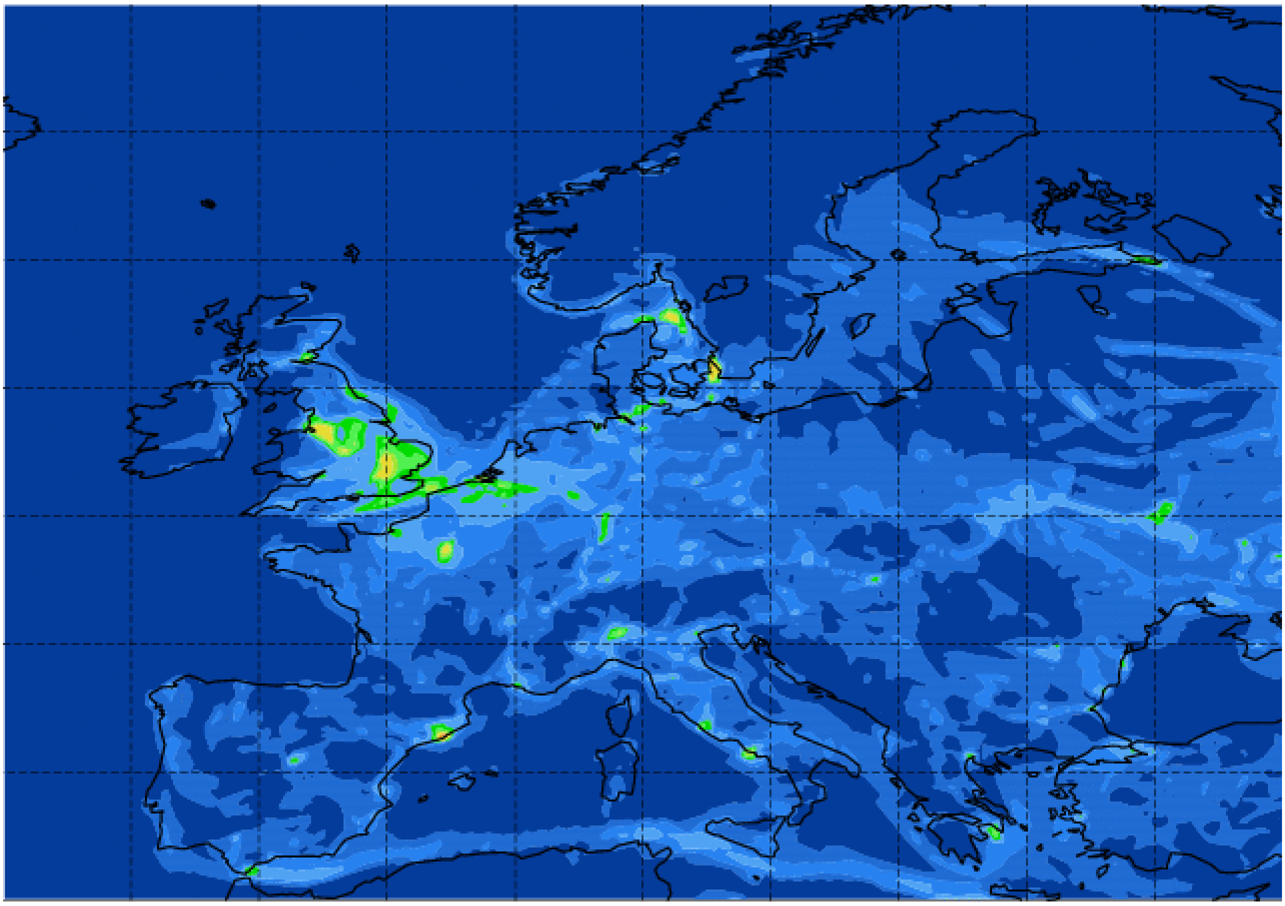
# UK Air Quality Forecasting: Annual Report 2010



**Report for Defra and the Devolved Administrations**

AEAT/ENV/R/3260
ED48946
Issue 1
Date 01/07/2011

Customer:

Defra and the Devolved Administrations

**Customer reference:**

Contract RMP 5270

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**AEA reference:**

ID: AEAT/ENV/R/3260

Ref: ED48946- Issue 1

Contact:

Paul Willis
AEA Technology plc
Gemini Building, Harwell, Didcot, OX11 0QR

t: 0870 190 6602

f: 0870 190 6608

e: paul.willis@aeat.co.uk

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**Author:**

Agnieszka Griffin

**Approved By:**

Paul Willis

**Date:**

01 July 2011

**Signed:**

# Executive summary

This report covers the operational activities carried out by AEA on the UK Air Quality Forecasting Contract for the year 2010. The work is funded by the Department for Environment Food and Rural Affairs, the Scottish Government, Welsh Assembly Government and the Department of the Environment in Northern Ireland.

During 2010, there was a total of twenty six days on which HIGH air pollution was recorded across the UK. Twelve of these days were due to particulate $PM_{10}$, nine due to ozone, four due to $SO_2$ and one due to $NO_2$.

The forecasting success and accuracy for this year is summarised in Box 1, together with the results from the previous calendar year. The overall forecasting success and accuracy rate performance for HIGH episodes is improved compared to the previous year, partly due to a successfully forecast period of MODERATE and HIGH ozone concentrations during May 2010.

The success rate performance for the MODERATE band forecasts was again high, with an overall accuracy figure of around 80% as seen in previous years (this is perhaps the most meaningful and consistent figure from year-to-year). Please note that due to the current definition of +/- 1 index value in each band, success rates can be reported as greater than 100 %.

**Box 1 – forecast success/accuracy for incidents above 'HIGH' and above 'MODERATE' in 2010 *(and 2009)*.**

| ***Region/Area*** | ***HIGH*** | | ***MODERATE*** | |
|---|---|---|---|---|
| | ***% success*** | ***% accuracy*** | ***% success*** | ***% accuracy*** |
| ***Zones*** | 12 *(8)* | 9 *(4)* | 137 *(134)* | 84 *(85)* |
| ***Agglomerations*** | 25 *( 20)* | 19 *(8)* | *129 (139)* | 72 *(72)* |

During this year one ad-hoc report and several detailed news items were provided to Defra and the Devolved Administrations. Most of these reports considered the impact on UK ground-level air pollutant concentrations of the Icelandic Eyjafallajokull volcanic eruption between March and May 2010.

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

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

1. Investigating the use of automatic software systems to streamline the activities within the forecasting process, thereby allowing forecasters to spend their time more efficiently in maximising forecast accuracy.
2. Improving the CMAQ model runs which can be used for daily and ad-hoc analysis.
3. Improving and updating the emissions inventories used in our models.

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## Appendices

# 1 Introduction

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

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

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

This report covers and analyses the media forecasts issued during the 12 months from January 1st to December 31st 2010. Results from forecasting models are available each day and are used in constructing the forecast. The forecasters issue predictions for rural, urban background and roadside environments but, for the purposes of this report, these have been combined into a single “worst-case” category (i.e. the forecasts issued are not analysed by environment type within this report).

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

We continue to use a comprehensive quality control system in order to ensure that the 5-day forecasts provided by the Met Office to the BBC are consistent with the “daily media forecasts” and long-range pollution outlook provided by AEA for Defra and the DAs. The BBC requires 5-day air pollution index forecasts for 337 UK towns and cities for use on its BBC Online service. The quality control review is carried out at 3.00 p.m. daily, with the resulting forecast updating onto the BBC Online Web site at 4.00 a.m. the following morning.

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

# 2 Development of the WRF-CMAQ model for UK AQ Forecasts

The section includes a summary of the development work of the WRF-CMAQ UK air quality forecasting model. During 2010 the main developments were related to the new 50km European - 10km UK nested models and the introduction of automated model evaluation.

It had been agreed with Defra and the Devolved Administration at the beginning of the year that the 10km UK model run was required to meet the EC Directive Requirement on Information and Alert Thresholds being representative of air quality over an area of $100km^2$.

WRF (Weather Research and Forecasting) is a numerical weather model developed in the USA as a collaborative partnership, between several agencies including: National Centre for Atmospheric Research (NCAR), the National Centres for Environmental Prediction (NCEP), the Air Force Weather Agency and the Naval Research Laboratory. The WRF code and documentation are available at www.wrf-model.org.

The CMAQ (Community Multiscalar Air Quality) model was first developed under the US EPA Models-3 project (Byun and Ching, 1999). It is a comprehensive regional Chemical Transport Model (CTM), incorporating meteorology, emissions, land use, chemistry and aerosol processes. For the UK Air Quality forecasts it is driven by weather from WRF, and the emissions are generated using the NAEI (National Atmospheric Emissions Inventory) and EMEP (European Monitoring and Evaluation Program), supplemented by natural emission calculated using the Biogenic Potential Inventory. CMAQ model code and documentation are available at www.cmaq-model.org.

## 2.1 50km European and 10km UK forecasts using WRF-CMAQ models

WRF-CMAQ is used to produce daily AQ forecasts for $O_3$, $NO_2$, CO, $SO_2$ and $PM_{10}$ at both a European and UK scale. During 2010 two versions were in operation:

- 48+12 - 48km and 12km 2 day European and UK forecast available throughout 2010.
- 50+10 - 50km and 10km 2 day European and UK forecast available from mid February 2010

Figures 2.1 and Figure 2.2 show the different geographic extents of the two versions, as available to the AEA forecasting team each day through their forecasting dashboard.

PM is represented by a large number of species and these are combined in the model to represent total PM, equivalent to the $PM_{10}$ captured by the monitoring method. The 50km domain covers a wider spatial area and will help to capture more of the contributions to ambient PM concentrations. The detail of the component species is not used as part of the forecast publication but is available for further analysis if required.

CMAQ produces large daily files in excess of 2.3 Giga bytes of data. An automated system is in place to extract the model values equivalent to the measurement data and stored in a mySQL database for further evaluation.

The current CMAQ mapped outputs are designed to assist the forecasters and use the same air quality bands that are required for the forecast publication. Figure 2.2 shows an example of the spatial distribution of ozone daily maximum; the hourly information is available through the dashboard as an animation.

***Figure 2.1 Examples of the 48 and 50km European domains - Daily maximum $PM_{10}$ - 25th March 2010.***

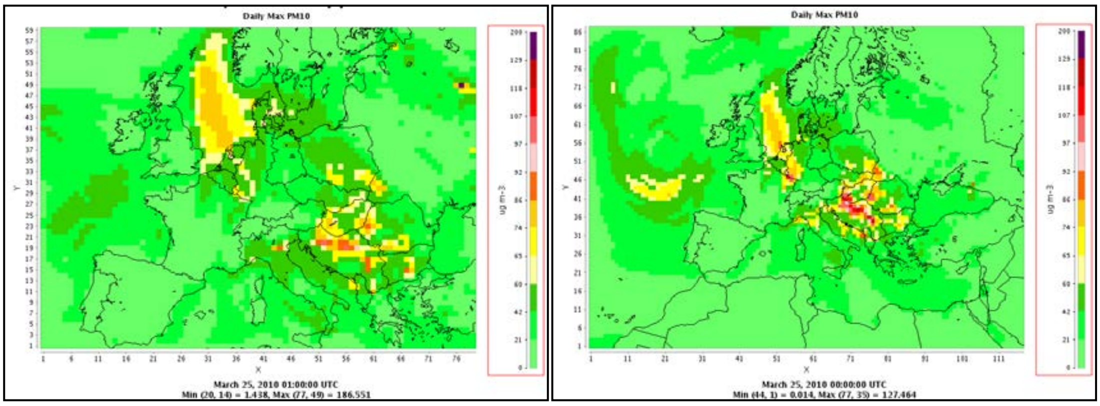
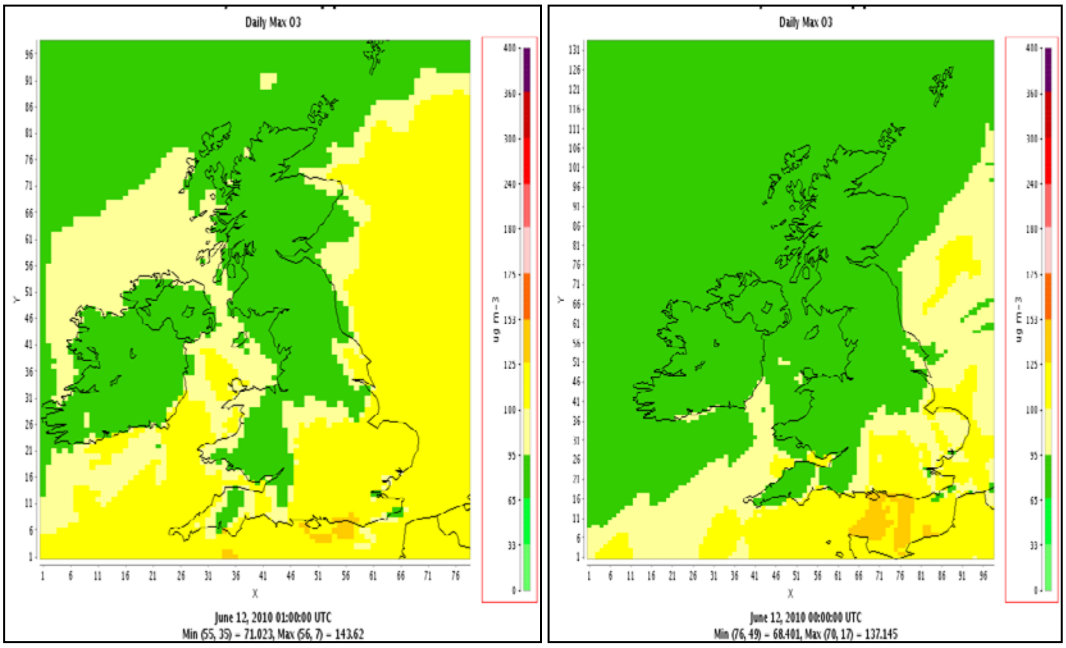



***Figure 2.2 Examples of the 12 and 10 km UK domains – Daily maximum ozone – 12th June 2010.***




## 2.1.1 Advantages of the new 50+10km model:

As well as meeting the statutory requirements defined by Defra and the Devolved Administrations there are also a number of operational advantages to the new 50+10km version of the model:

- The extended European grid has reduced the number of days where WRF fails due to numerical instability.

- Extending the European grid to the west allows for sea-salt emission to develop over the Atlantic for a longer period, improving the representation of sea salt in $PM_{10}$. This can be seen in Figure 2.1 where there is increased $PM_{10}$ in the Atlantic.

Unfortunately due to the larger European and UK grid the WRF simulation takes longer to run. So to reduce the risk that the forecast would not be available on time, the 48+12 model continued operating throughout 2010 to provide a backup forecast.

## 2.2 Automated Model Evaluation

Air quality forecast model evaluation is an ongoing progress. Model values corresponding to monitoring sites are extracted from the daily CMAQ runs and stored in a mySQL database along with the provisional and ratified monitoring data. These are then analyzed using R to produce the daily and monthly evaluations which are presented separately for each forecast species and class of monitoring site (rural, urban background and urban). The format of the model evaluation remains under development and is improved as required.

There are two aims of the evaluation and these are on different time scales:

- Daily evaluation to providing ongoing guidance to the air quality forecasters of how well CMAQ represents the current conditions. This is available on the forecast dashboard alongside the daily images, giving an indication of model performance under the current meteorological conditions. A line plot (Figure 2.3) covers the previous 7 and the next 2 days whilst a skill plot covers the previous14 days. These are produced for a selection of rural, urban background and urban sites. A line plot is also produced for all the sites used for the forecast back trajectories.

- Monthly, Quarterly and Annual evaluation using ratified (or provisional) monitoring data, are used to evaluate overall model performance and are used to guide model development. The same R analysis is used to produce the monthly and daily skill plots (Figure 2.4).

***Figure 2.3 Example Ozone daily line evaluation plot for UK rural and remote monitoring sites, for the previous 7 days.***

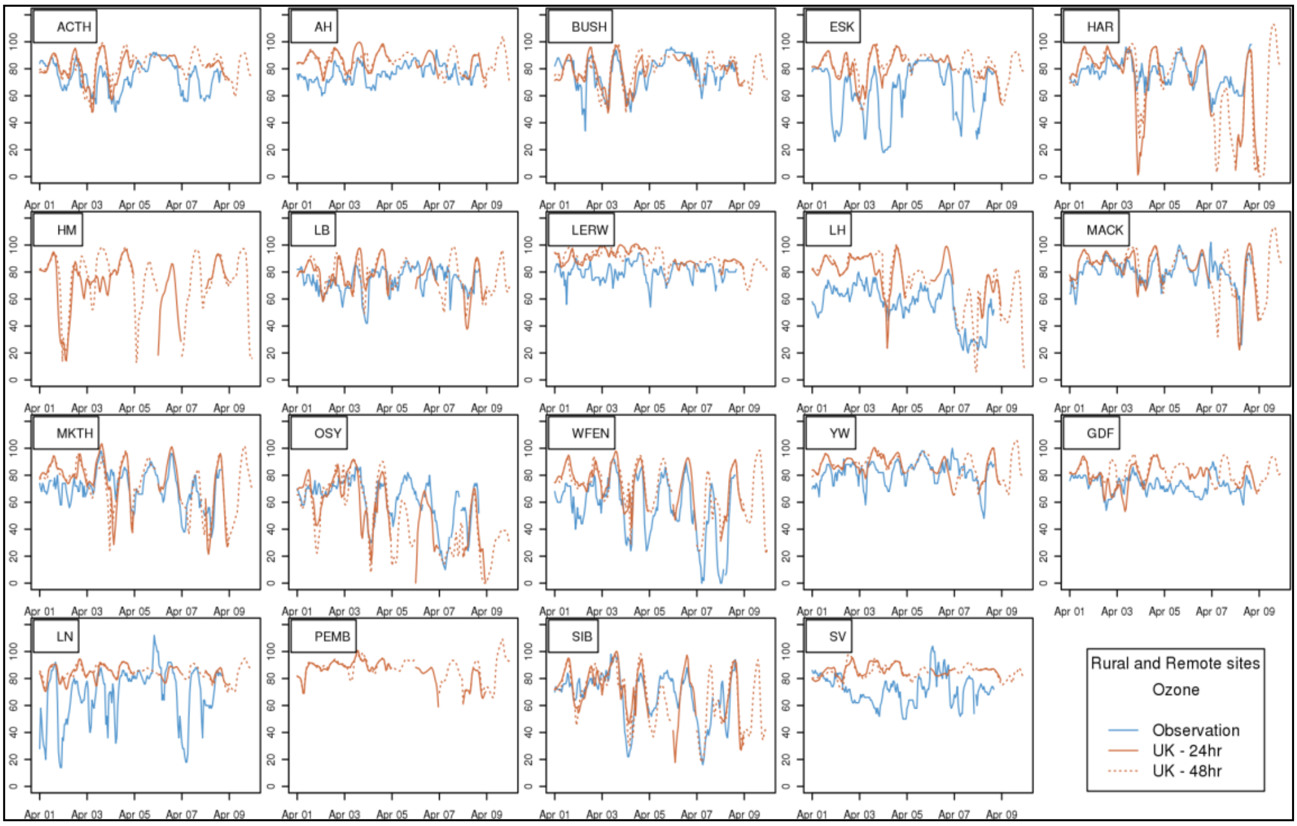
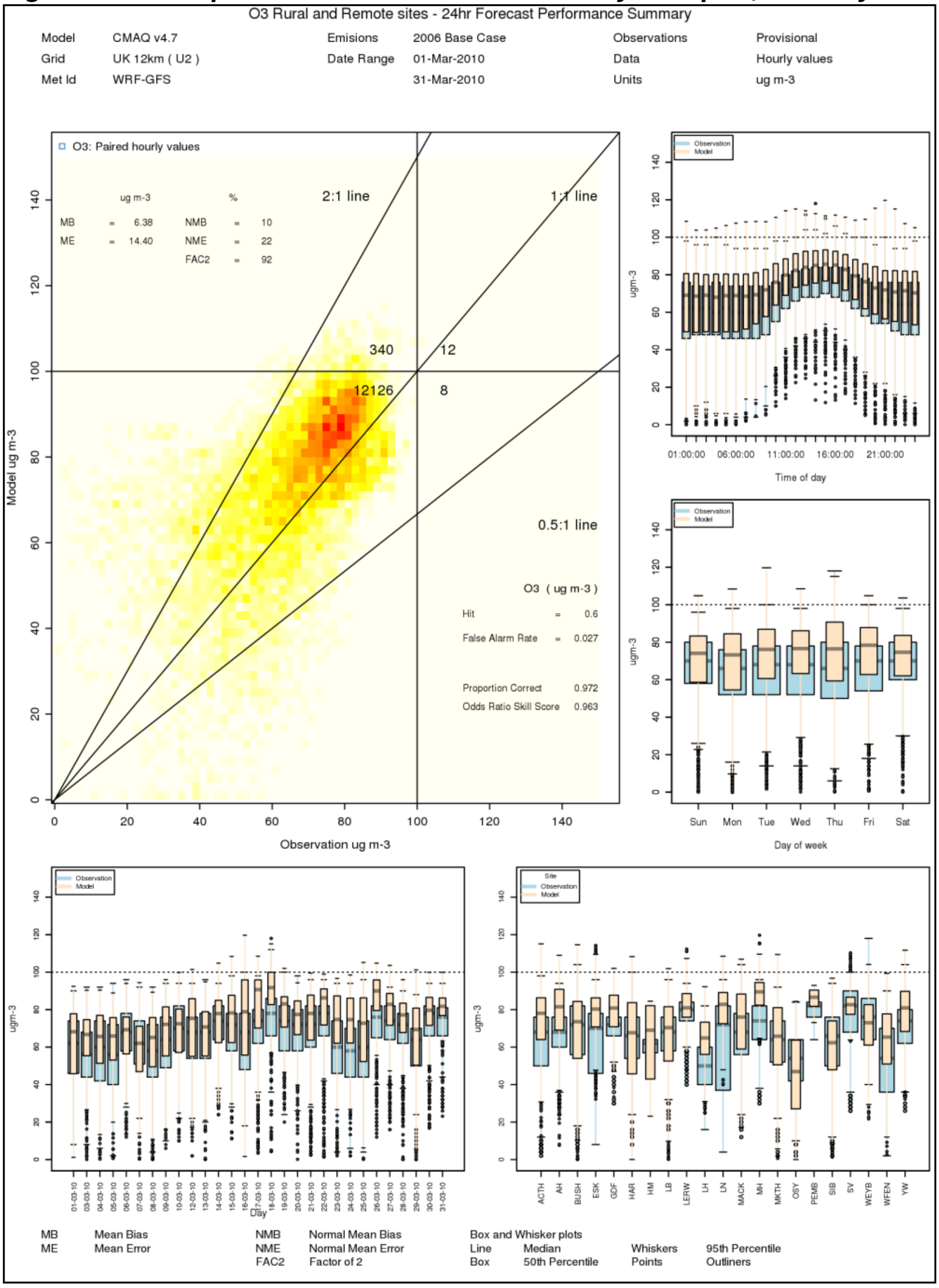


***Figure 2.4 Example rural and remote ozone daily skill plot, monthly evaluation.***




## *Skill Evaluation*

At the end of each month the same sites are evaluated using an analysis similar to the daily skill plot. This follows the specification of the Model Performance Summary demonstrated in the Model Evaluation Protocol (Derwent et al. 2009).

This evaluation includes all paired observation and modelled hourly values. The Normalised Mean Bias and Error (NMB, NME) are the statistical values recommended in the model evaluation protocol (Derwent et al. 2009), and Fractional Bias and Error (FB, FE) as recommended by Agnew et al. 2007. The Performance Summary also includes statistical parameters specific to forecast skill i.e. a 2x2 contingency table, for the number of hits above the low/moderate threshold, from which the hit ratio, false alarm ratio and the odds ratio skill score are calculated - as recommended in the Evaluation of GEMS Regional Air Quality Forecasts (Agnew et al. 2007). These data have been used in the 2010 evaluation presented in section 2.3 below.

***Comparison with other models***

There are currently no formal comparisons with other AQ forecasting models carried out as part of the UK AQ Forecasting contract. On a daily basis the duty forecaster visually compares the WRF-CMAQ forecasts with ECMWF GEMS regional AQ ensemble forecast and the MACC air quality ensemble. Each of these includes up to 11 different air quality forecasts across Europe and by visual inspection any gross anomalies should be immediately apparent.

## 2.3 WRF-CMAQ Forecast evaluation 2010

Table 2.1 shows a summary of the annual model performance for the 12, 10 and 50km CMAQ models for 2010. It summarises the metrics recommended in the Model Evaluation Protocol developed by Derwent et al. 2009. The results show a tendency to overestimate ozone and to underestimate $PM_{10}$.

For $O_3$, $NO_2$ and $PM_{10}$ more than 50% of the paired values fall within a factor of 2 for each of the site classifications. The relatively poor performance of $SO_2$ may be related to the high prevalence of low concentration measured values for this pollutant. The Odds Ratio Skill Score can only produce meaningful results when there are sufficient values above the threshold. It shows that the model performs well at predicting ozone over the low to moderate threshold, but not for $PM_{10}$. If any increase in $PM_{10}$ is due to elevated inorganic PM then it has been shown that CMAQ performs better than if it is caused by dust or PM re-suspension.

The 12km and 10km models perform the same for ozone but the 10km model performs better for $PM_{10}$. For $NO_2$ the factor of 2 is the same but the bias and error are less in the 10km model.

Overall it can be concluded that for 2010 the 10km UK model performed better than the 12km model.

***Table 2.1: Annual performance evaluation of forecast species for rural, urban background and other urban AURN monitoring sites (12km model – Jan-Dec, 10 and 50km Feb-Dec.).***

| | Normal Mean Bias % | | | Normal Mean Error% | | | Factor of 2 % | | | Odds Ratio Skill Score | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12 km | 10 km | 50 km | 12 km | 10 km | 50 km | 12 km | 10 km | 50 km | 10 km | 50 km |
| **$O_3$** | | | | | | | | | | | |
| Rural | 16 | 18 | 19 | 32 | 30 | 31 | 85 | 84 | 86 | 0.97 | 0.96 |
| UrbanBG | 27 | 26 | 40 | 47 | 42 | 48 | 71 | 71 | 72 | 0.97 | 0.97 |
| Urban | 53 | 48 | 69 | 69 | 62 | 76 | 60 | 61 | 58 | 0.98 | 0.97 |
| **$PM_{10}$** | | | | | | | | | | | |
| Rural | -24 | -7 | -16 | 57 | 57 | 51 | 53 | 58 | 62 | * | * |
| UrbanBG | -50 | -31 | -42 | 60 | 53 | 53 | 39 | 54 | 53 | 0.28 | * |
| Urban | -54 | -37 | -43 | 63 | 54 | 54 | 35 | 51 | 51 | 0.42 | 0.20 |
| **$NO_2$** | | | | | | | | | | | |
| Rural | 91 | 53 | 36 | 116 | 88 | 79 | 50 | 50 | 53 | * | |
| UrbanBG | 10 | -1 | -35 | 63 | 55 | 59 | 59 | 59 | 47 | 0.86 | |
| Urban | -22 | -27 | -57 | 52 | 49 | 62 | 57 | 56 | 36 | 0.83 | |
| **$SO_2$** | | | | | | | | | | | |
| Rural | 295 | 228 | 69 | 325 | 287 | 130 | 33 | 30 | 39 | | |
| UrbanBG | 190 | 147 | 23 | 233 | 197 | 93 | 39 | 38 | 45 | | |
| Urban | 194 | 102 | 24 | 235 | 164 | 88 | 34 | 39 | 45 | | |
| * value cannot be calculated due to insufficient values being over the threshold | | | | | | | | | | | |

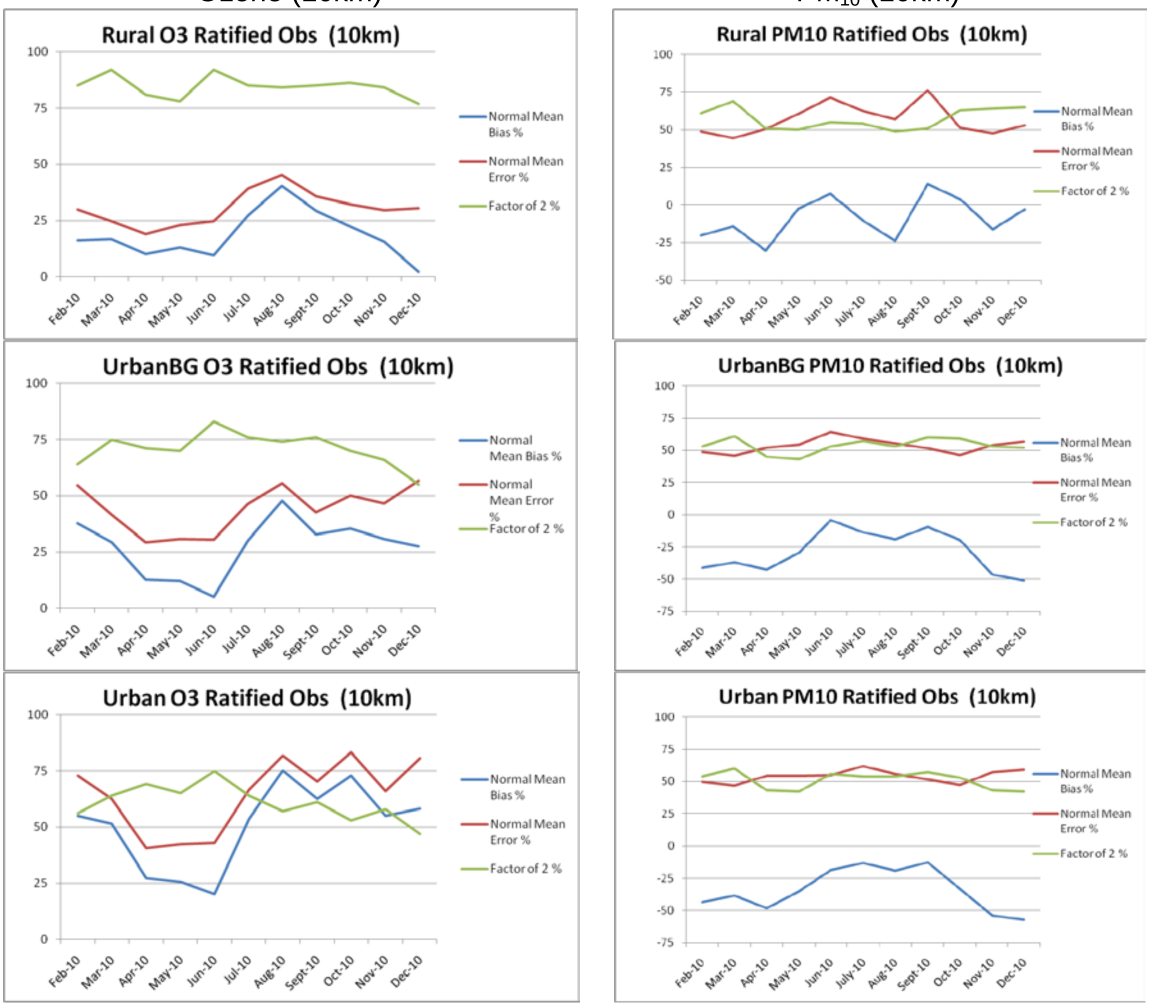
The seasonal variation in the evaluation metrics is shown in Figure 2.5. Performance is better at the rural sites than the urban background or urban sites. This would be expected as the rural sites are selected to reflect the air quality over a similar spatial scale as the 10km model. At the rural sites the over prediction of ozone is higher during July and August. This is similar to the trend seen in 2009. $PM_{10}$ has a lower bias and error during the summer but this has little influence on the number of values within a factor of 2.

$NO_2$ has more than 50% of paired values within a factor of 2, however the bias and error at rural sires are high which is probably again related to low measured concentration values. Similarly the low measured values will have a significant effect on the analysis for $SO_2$.

Both the Model evaluation protocol and the Gems Evaluation (Agnew et al. 2007) document stress the requirement to evaluate the models for the metrics they are to be used for. This will evaluate the skill of the model at providing the regulated metrics, but often these are 8hr or daily averages and will disguise the ability of the model to predict the daily and seasonal peaks and troughs in the measurements. Model evaluation is developing, and will evolve to take into account the Defra model intercomparison whilst also providing the information required by the duty air quality forecaster.

***Figure 2.3 Monthly evaluation of ozone and $PM_{10}$ for rural, urban background and other urban AURN monitoring sites for the 10km model.***

Ozone (10km) | $PM_{10}$ (10km)




## 2.4 2010 Model Development Summary

Developing the 10+50km nested forecast has resulted in better forecast performance in 2010 compared to 2009. However work is still required to ensure that the forecast runs regularly finish before the required times. The automation of WRF-CMAQ is robust in both model configuration and requires little intervention. The new WRF configuration is more stable resulting in fewer failures.

Performance is good for ozone and $PM_{10}$ although ozone is generally over estimated and $PM_{10}$ under estimated. The extended European grid has resulted in a better representation of sea-salt emissions and an improvement in the $PM_{10}$ forecast.

Low pollutant concentrations distort the current evaluations for $NO_2$ and $SO_2$. A different analysis should be investigated for where there are a large number of low measured values.

# 3 Analysis of forecasting success rate

## 3.1 Introduction

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

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

The forecasting success rates for each zone and agglomeration for January - December 2010 are presented in Tables 3.1 (forecasting performance in zones) and 3.2 (forecasting performance in agglomerations) for 'HIGH' days. Tables 3.3 and 3.4 show the same statistics for the MODERATE band. Table 3.5 provides a summary for each pollutant of the number of days on which HIGH and above pollution was measured, the maximum exceedence concentration and the day and site at which it was recorded. The forecasting performance Tables 3.1 and 3.2 give:

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

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

The forecast success rate (%) is calculated as:

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

The forecast accuracy (%) is calculated as:

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

## 3.2 Forecast analysis for 2010

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

| ZONES | Central Scotland | East Midlands | 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* | 3 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 25 |
| *Forecasted days* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| *Ok (f and m)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| *Wrong (f not m)* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| *Wrong (m not f)* | 3 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 22 |
| *Success %* | 0 | 100 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 16 | 100 | 100 | 100 | 100 | 100 | 100 | 12 |
| *Accuracy %* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |

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

| Agglomerations | Belfast Metropolitan Urban Area | Brighton/Worthing/ Littlehampton | Bristol Urban Area | Cardiff Urban Area | Edinburgh Urban Area | Glasgow Urban Area | Greater Manchester Urban Area | Leicester Urban Area | Liverpool Urban Area |
|---|---|---|---|---|---|---|---|---|---|
| *Measured days* | 3 | 0 | 1 | 0 | 0 | 5 | 0 | 2 | 0 |
| *Forecasted days* | 3 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 |
| *Ok (f and m)* | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *Wrong (f not m)* | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| *Wrong (m not f)* | 1 | 0 | 1 | 0 | 0 | 5 | 0 | 2 | 0 |
| *Success %* | 67 | 100 | 0 | 100 | 100 | 20 | 100 | 0 | 100 |
| *Accuracy %* | 50 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 |

*Table 3.2 (cont'd) - Forecast Analysis for UK Agglomerations 'HIGH' band and above **

| Agglomerations | Nottingham Urban Area | Portsmouth Urban Area | Sheffield Urban Area | Swansea Urban Area | Tyneside | West Midlands Urban Area | West Yorkshire Urban Area | Overall |
|---|---|---|---|---|---|---|---|---|
| *Measured days* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 12 |
| *Forecasted days* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| *Ok (f and m)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| *Wrong (f not m)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| *Wrong (m not f)* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 10 |
| *Success %* | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 25 |
| *Accuracy %* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 |

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

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

| Zone | Central Scotland | East Midlands | 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 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Measured days* | 30 | 46 | 104 | 81 | 21 | 18 | 0 | 15 | 41 | 69 | 27 | 55 | 36 | 68 | 38 | 38 | 701 |
| *Forecasted days* | 32 | 53 | 93 | 79 | 33 | 26 | 14 | 29 | 37 | 48 | 29 | 73 | 34 | 67 | 60 | 32 | 755 |
| *Ok (f and m)* | 44 | 72 | 117 | 104 | 42 | 35 | 10 | 34 | 49 | 58 | 39 | 89 | 49 | 93 | 64 | 50 | 959 |
| *Wrong (f not m)* | 5 | 2 | 8 | 10 | 3 | 4 | 4 | 1 | 7 | 13 | 4 | 3 | 2 | 3 | 7 | 1 | 87 |
| *Wrong (m not f)* | 6 | 3 | 12 | 12 | 0 | 0 | 0 | 0 | 6 | 32 | 0 | 4 | 1 | 2 | 4 | 4 | 95 |
| *Success %* | 147 | 157 | 113 | 128 | 200 | 194 | 100 | 227 | 120 | 84 | 144 | 162 | 136 | 137 | 168 | 132 | 137 |
| *Accuracy %* | 80 | 94 | 85 | 82 | 93 | 90 | 71 | 97 | 79 | 56 | 91 | 93 | 94 | 95 | 85 | 91 | 84 |

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

| Agglomerations | Belfast Metropolitan Urban Area | Brighton/Worthing/Littlehampton | Bristol Urban Area | Cardiff Urban Area | Edinburgh Urban Area | Glasgow Urban Area | Greater Manchester Urban Area | Leicester Urban Area | Liverpool Urban Area |
|---|---|---|---|---|---|---|---|---|---|
| *Measured days* | 12 | 24 | 18 | 14 | 2 | 29 | 14 | 2 | 29 |
| *Forecasted days* | 18 | 35 | 17 | 16 | 5 | 26 | 20 | 13 | 21 |
| *Ok (f and m)* | 16 | 39 | 22 | 21 | 3 | 24 | 19 | 4 | 32 |
| *Wrong (f not m)* | 6 | 10 | 2 | 3 | 4 | 11 | 7 | 9 | 5 |
| *Wrong (m not f)* | 3 | 2 | 5 | 0 | 0 | 13 | 2 | 2 | 5 |
| *Success %* | 133 | 163 | 122 | 150 | 150 | 83 | 136 | 200 | 110 |
| *Accuracy %* | 64 | 76 | 76 | 88 | 43 | 50 | 68 | 27 | 76 |

***Table 3.4 (cont'd)*** **- Forecast Analysis for UK Agglomerations 'MODERATE' band and above ***

| *AGGLOMERATIONS* | Nottingham UA | Portsmouth UA | Sheffield UA | Swansea UA | Tyneside | West Midlands UA | West Yorkshire UA | Overall |
|---|---|---|---|---|---|---|---|---|
| *Measured days* | 18 | 21 | 14 | 19 | 15 | 26 | 15 | 272 |
| *Forecasted days* | 17 | 23 | 16 | 19 | 10 | 25 | 17 | 304 |
| *Ok (f and m)* | 20 | 30 | 21 | 26 | 19 | 30 | 25 | 351 |
| *Wrong (f not m)* | 3 | 2 | 4 | 4 | 2 | 5 | 1 | 84 |
| *Wrong (m not f)* | 9 | 1 | 1 | 1 | 1 | 5 | 3 | 53 |
| *Success %* | 111 | 143 | 150 | 137 | 127 | 115 | 167 | 129 |
| *Accuracy %* | 63 | 91 | 81 | 84 | 86 | 75 | 86 | 72 |

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

***Table 3.5 – Summary of HIGH pollution episodes in 2010***

| *Pollutant* | *No. of HIGH days* | *No. of MODERATE days ^* | *Maximum concentration* (Index)* | *Site with max concentration* | *Zone or Agglomeration* | *Date of max conc.* | *Forecast success HIGH days (%)**** [no. incidents, zone or agglomoration days] ** |
|---|---|---|---|---|---|---|---|
| *Ozone* | 2 | 104 | 376 (Index 10) | Weybourne | Eastern | 16/08 | 0% [2] |
| *$PM_{10}$* | 24 | 87 | 152 (Index 10) | Armagh Roadside | Northern Ireland | 26/12 | 17% [30] |
| *$NO_2$* | 1 | 32 | 1209 (Index 10) | Glasgow Centre | Glasgow Urban Area | 17/10 | 100% [1] |
| *$SO_2$* | 4 | 18 | 1194 (Index 10) | Port Talbot Margam | Wales | 24/05 | 0% [4] |

^ *a MODERATE day is not counted on any HIGH day.*

* *Maximum concentration relate to 8 hourly running mean or hourly mean for ozone, 24 hour running mean for $PM_{10}$, hourly mean for $NO_2$, 15 minute mean for $SO_2$ and 8 hour running mean for CO. Units ug/m3 throughout, except CO units mg/m3.*

*** the number of incidents is the total of the number of HIGH days in all zones and agglomerations (i.e. a HIGH day on the same day in many zones or agglomerations is counted as many incidents, not just one)*
**** The success rates for the number of HIGH days in table 3.5 have been calculated using calendar days (ie midnight to midnight) and therefore may not necessarily agree with the success rates calculated within the forecast analysis tables 3.1 and 3.2, which are calculated based on media forecast days starting generally at 3 pm each day.*
*! The forecast success rate for $PM_{10}$ has been calculated using both FDMS and TEOM instruments*

### 3.2.1 General trends

Two HIGH days were recorded for ozone during 2010, one of which occurred in June and the second in August, as shown in figure 3.3. The HIGH days were the result of measurements made at the same monitoring site - Weybourne - on June 27th and on August 16th.

There were five significant HIGH band $PM_{10}$ episodes experienced in 2010, as shown in figures 3.1, 3.2 and 3.4. The causes of the ozone and particulate $PM_{10}$ episodes are detailed in the sections which follow.

There were four HIGH days and eighteen MODERATE days for $SO_2$ measured during the whole calendar year. The highest measured concentration of 1194 µg/m$^3$ was recorded at the Port Talbot Margam site and remaining three HIGH days were recorded at Grangemouth. Both of these sites are identified as industry targeted air quality monitoring sites. Figure 3.5 shows the frequency of the exceedances for 2010.

There was one HIGH day and thirty two MODERATE $NO_2$ days measured throughout the year, as shown in figure 3.7. The one HIGH day was again recorded at Glasgow Centre site (as in 2009). The MODERATE days were measured at roadside air quality sites, including Camden Kerbside, Marylebone Road and Glasgow Kerbside.

### 3.2.2 Particulate matter

MODERATE days were measured at many sites in the monitoring network from January to March 2010. This began with a period of MODERATE pollution around 7-10$^{th}$ January, probably due to increased emissions from domestic heating and queuing traffic during cold, icy and snowy weather. Increases were recorded for $PM_{10}$ only at Glasgow Kerbside, Carlisle Roadside, Armagh Roadside (HIGH), Belfast Centre, Warrington and Salford Eccles.

A further period of increased pollution on Friday January 15$^{th}$ saw MODERATE concentrations of $PM_{10}$ recorded at London Haringey, London Marylebone Road, Chesterfield, Leeds Centre and Leeds Headingley.

MODERATE $PM_{10}$ concentrations were recorded again at sites in northern England, Scotland and Northern Ireland from 10$^{th}$ to 14$^{th}$ of February, corresponding to another period of still, cold weather and probably mainly resulting from local emissions.

There were some periods of MODERATE and HIGH $PM_{10}$ pollution across Scotland and Northern Ireland from 5$^{th}$ till 12$^{th}$ March. Analysis of this episode showed that it was restricted to urban sites and therefore again probably due to increased emissions from domestic heating and queuing traffic during calm weather with low overnight temperatures.

Some shorter periods of MODERATE $PM_{10}$ concentrations were also seen from April to November but are not described in detail here.

In December 2010 four sites reached the VERY HIGH band, eight sites reached HIGH and 79 sites reached the MODERATE band. MODERATE $PM_{10}$ concentrations were first reported across areas of Northern Ireland from December 2$^{nd}$ onwards, most likely due to increased burning of solid fuel or fuel oil for domestic heating during the exceptional cold weather. By December 6$^{th}$ HIGH concentrations of $PM_{10}$ were reported at Derry and MODERATE also across other localised parts of Northern Ireland, northern England and Scotland. On December 7$^{th}$ this worsened further to VERY HIGH $PM_{10}$ at both Derry and Armagh with more widespread MODERATE pollution across the other areas. The increased levels continued with varying degrees of severity all the way through to December 16$^{th}$ when milder air resulted in an improvement.

Periods of MODERATE, HIGH and VERY HIGH $PM_{10}$ pollution continued to be recorded mainly across Northern Ireland from December 19$^{th}$ till 27$^{th}$. A further period of milder weather then improved the situation again from December 28$^{th}$ until the end of the period.

Bonfire Night celebrations resulted in a more significant pollution event this year when compared to 2009. Figure 3.8 below shows a comparison of the number of MODERATE or worse exceedances with earlier years.

Additionally figure 3.9 shows the overall number of MODERATE or WORSE $PM_{10}$ exceedances annually from all pollution sources from the year 2000 onwards, indicating that there is downward trend since 2007.

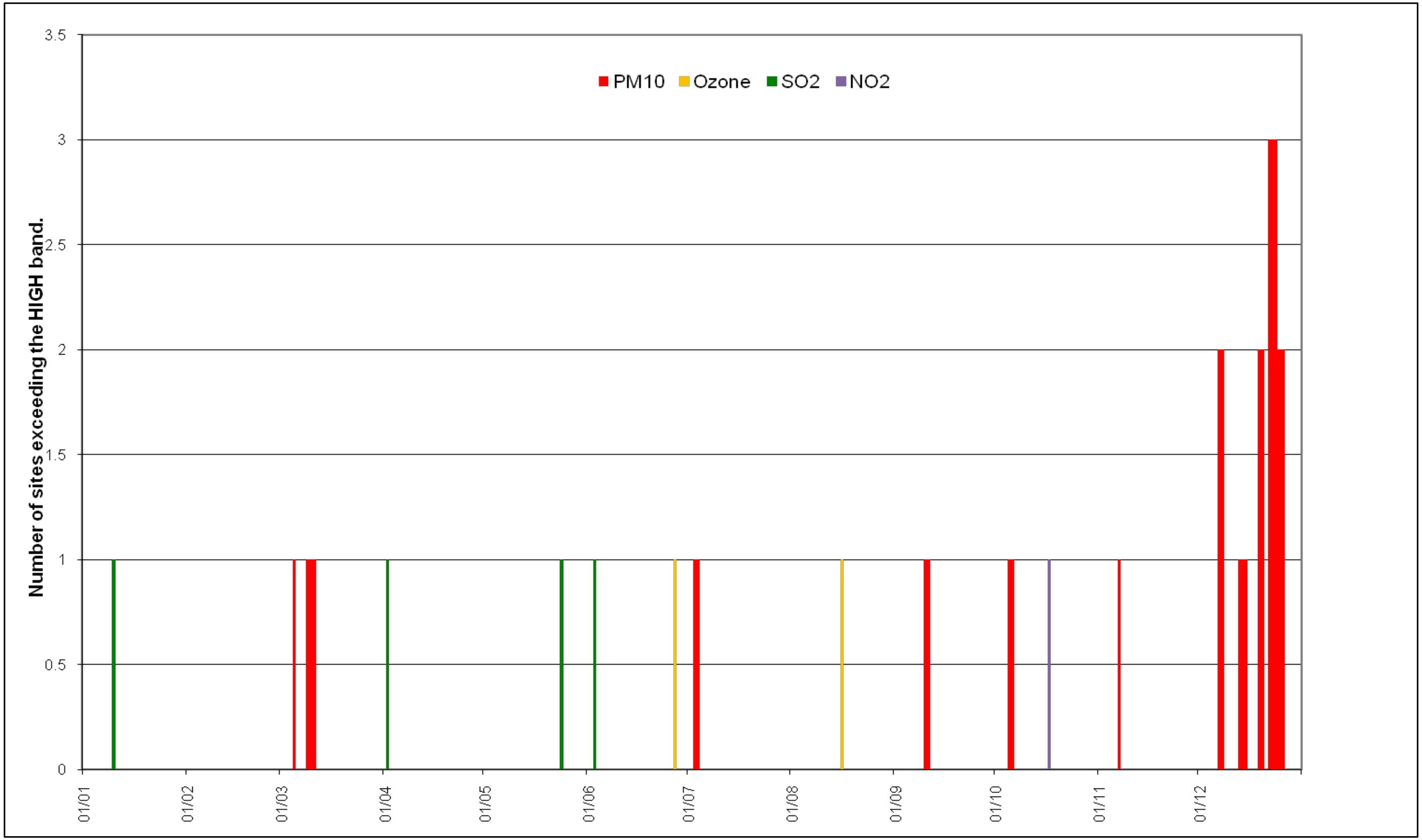



***Figure 3.1*** *Number of stations with air pollution levels of HIGH and above for days throughout 2010.*

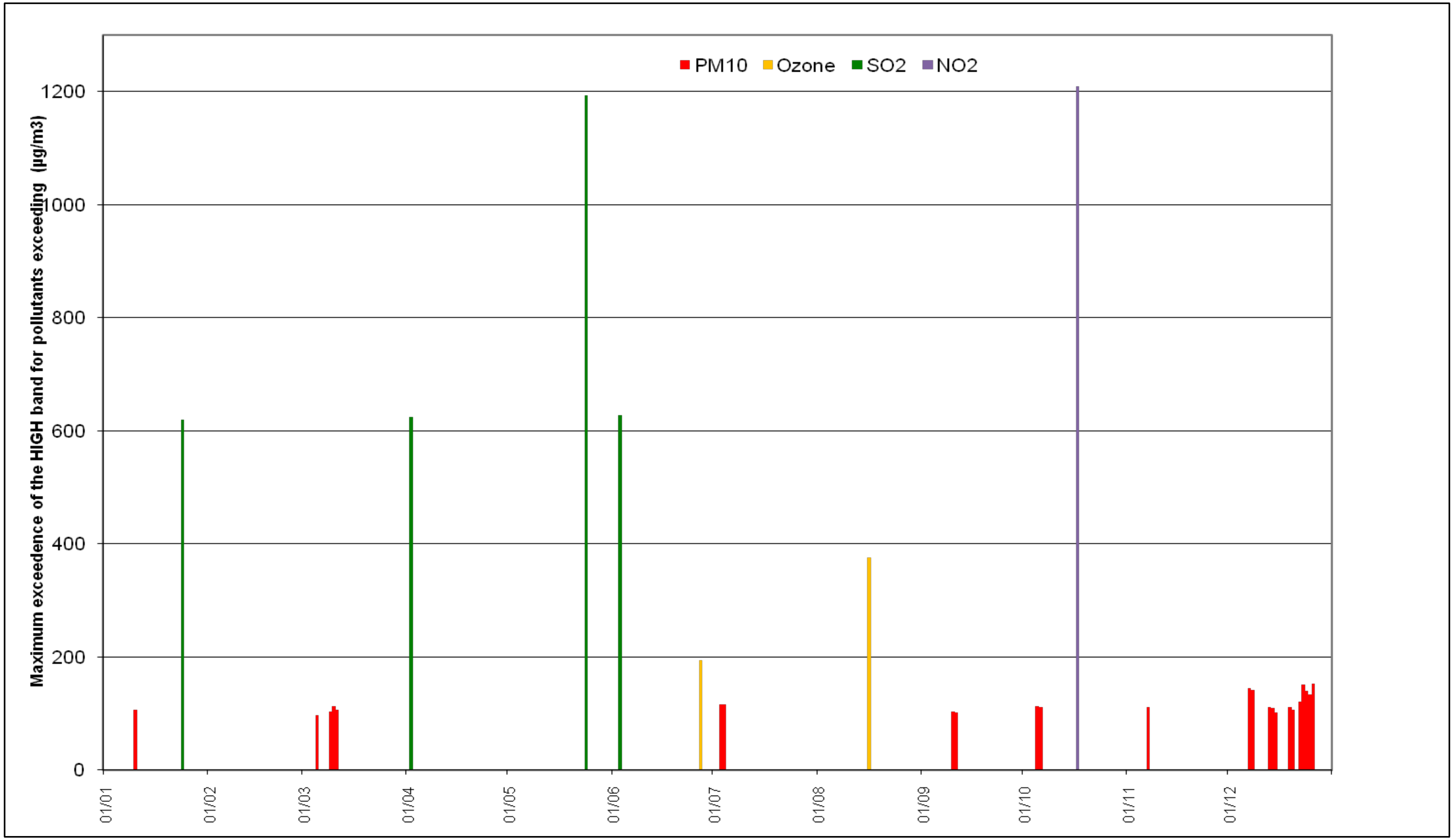



***Figure 3.2*** *Maximum exceedance when air pollution levels were HIGH and above for days throughout 2010*

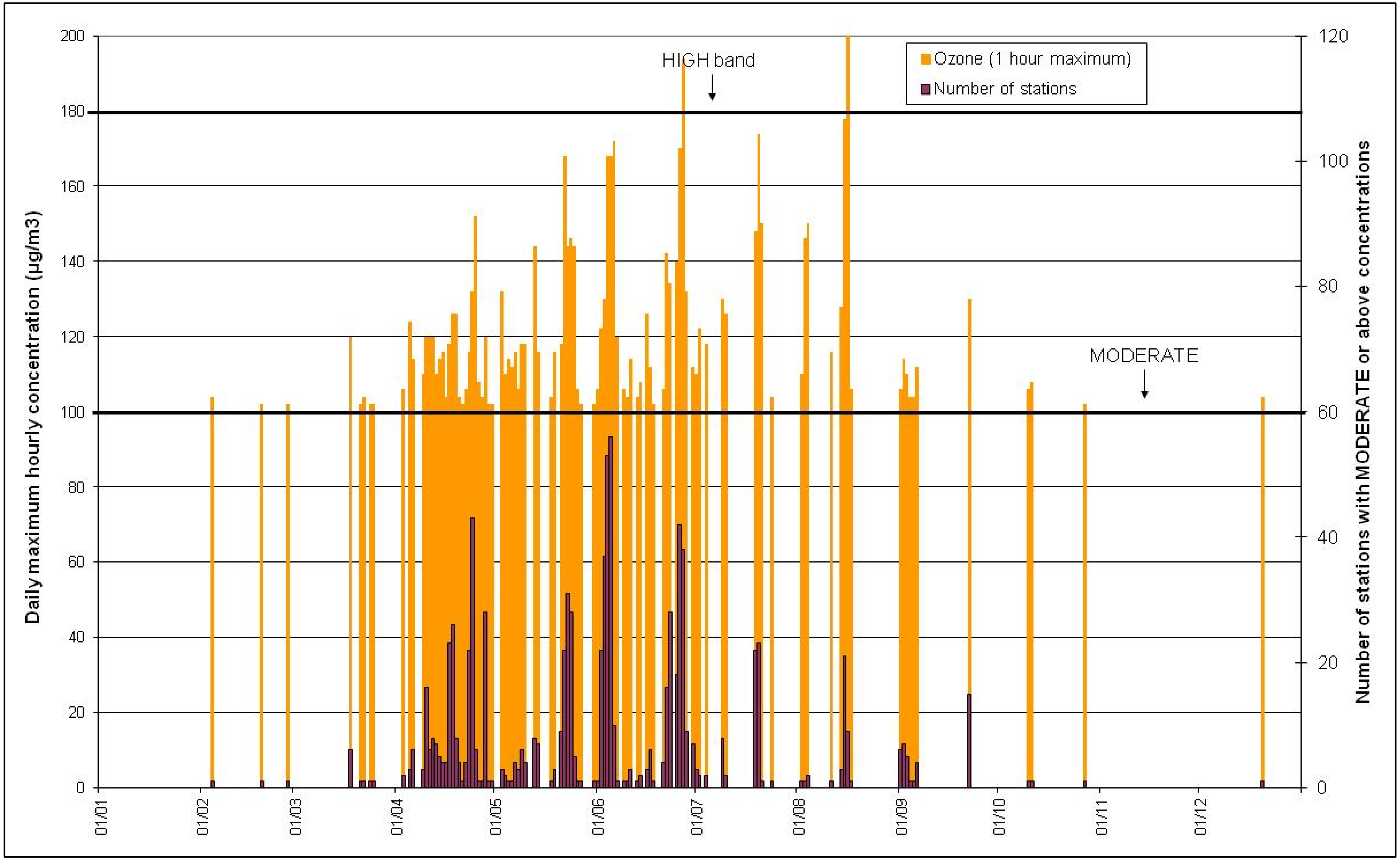



***Figure 3.3*** *Daily maximum hourly ozone concentration across AURN Network with total number of stations measuring moderate or above levels of ozone during 2010.*

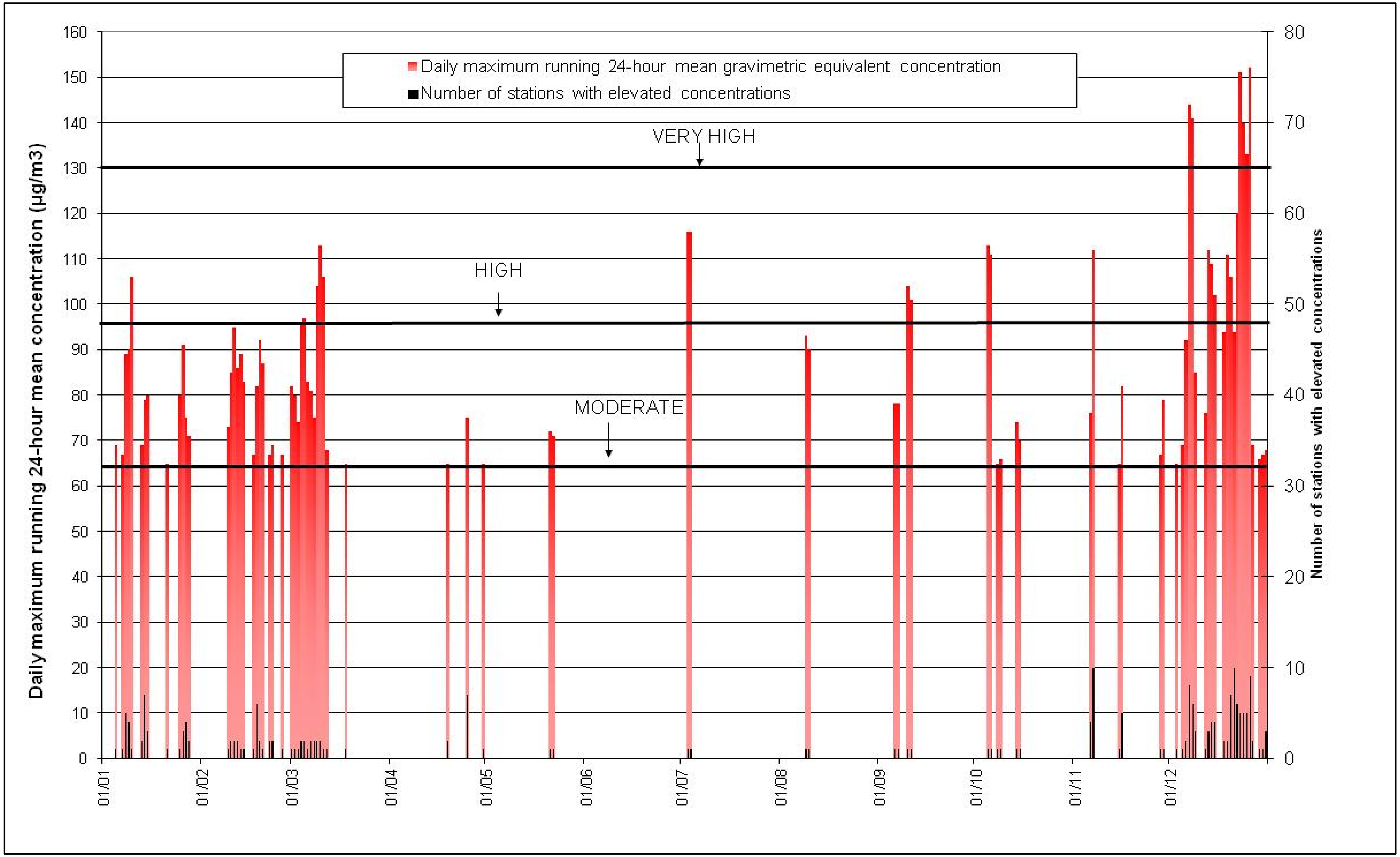



***Figure 3.4** Daily maximum running 24-hour mean $PM_{10}$ concentration across AURN Network with total number of stations measuring moderate or above levels during 2010*

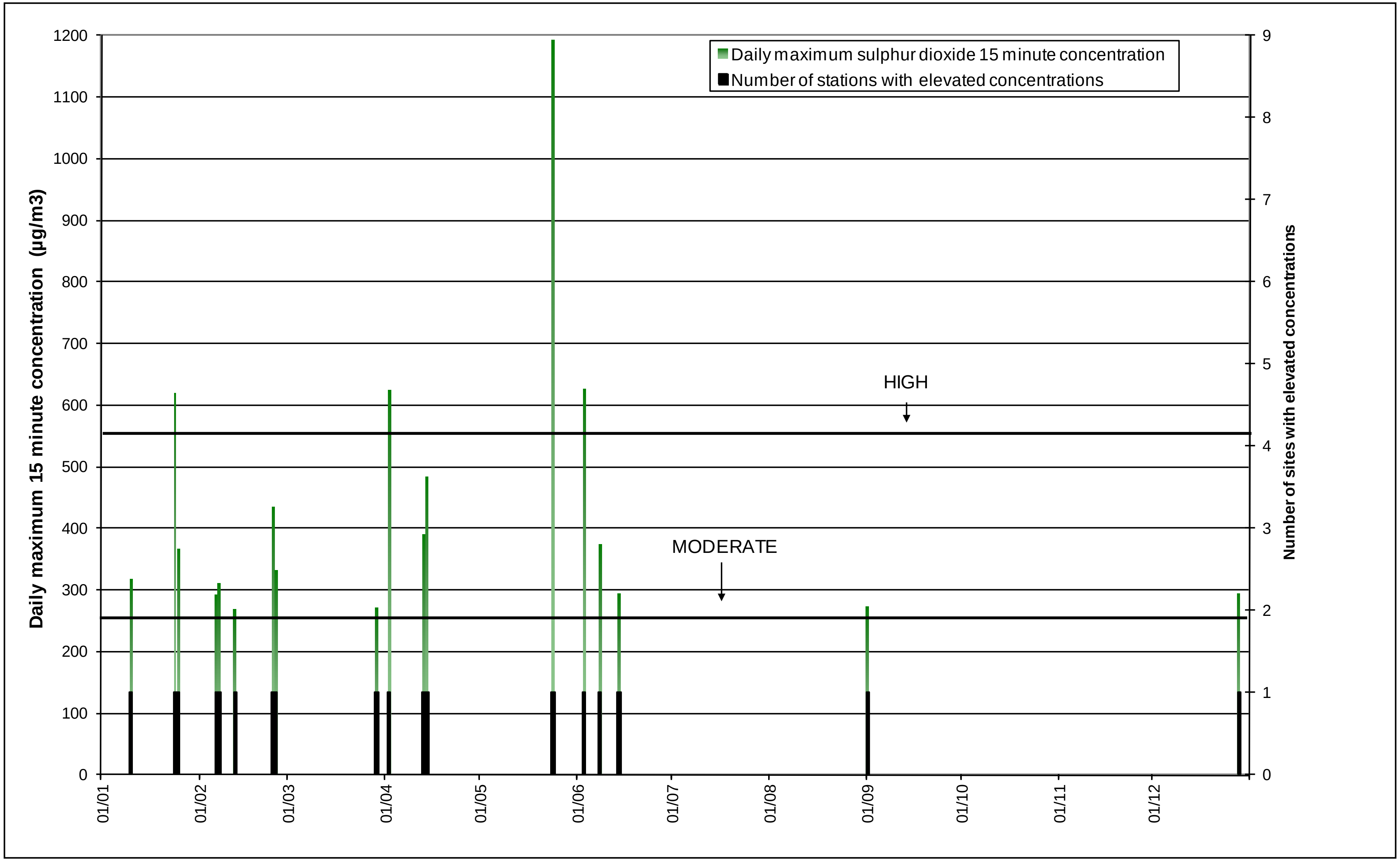



***Figure 3.5*** *Maximum 15 minute average concentrations of $SO_2$ across AURN Network with total number of stations measuring moderate or above levels during 2010*

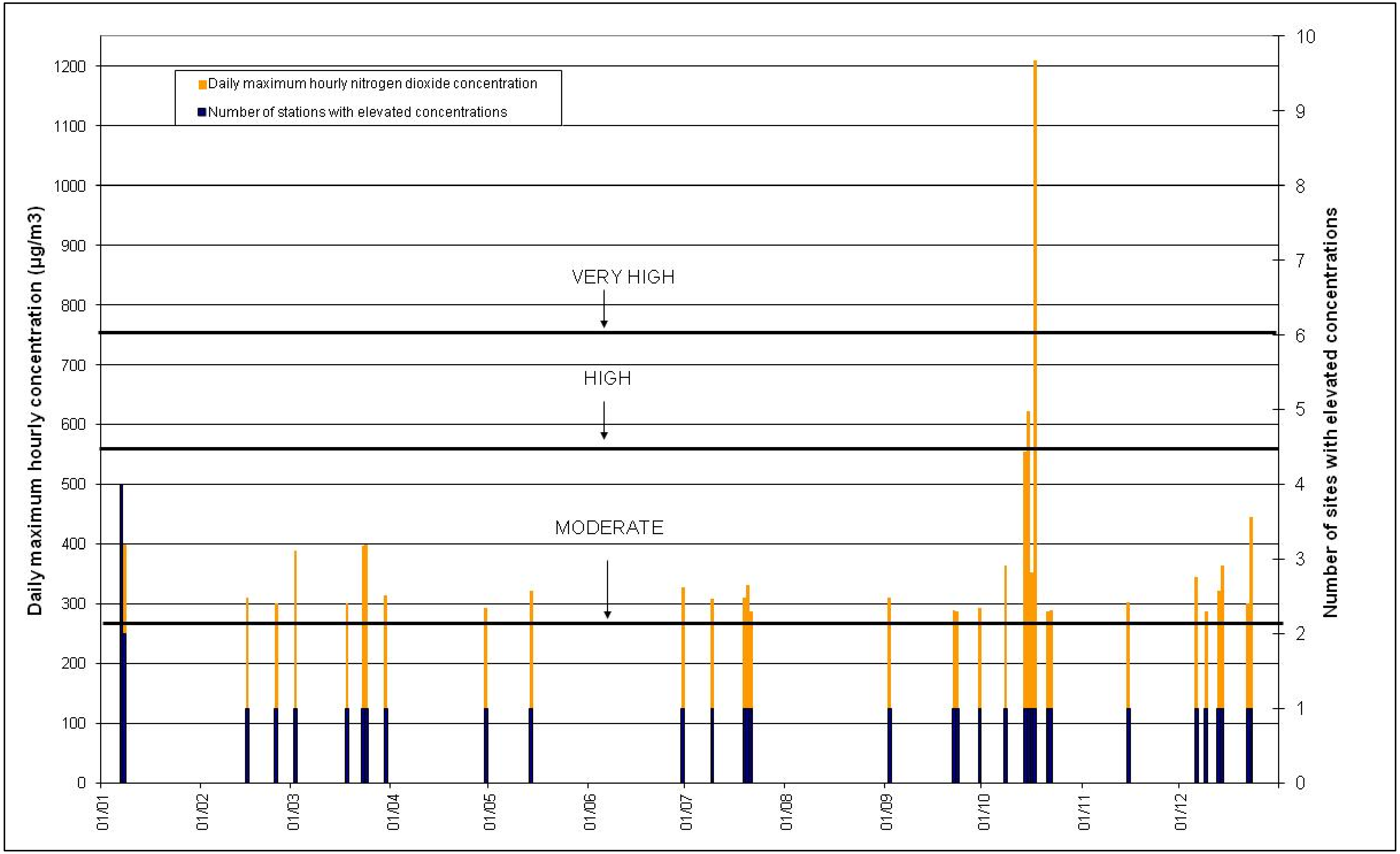



***Figure 3.6*** *Daily Maximum hourly average of $NO_2$ across AURN Network with total number of stations measuring moderate or above levels during 2010*

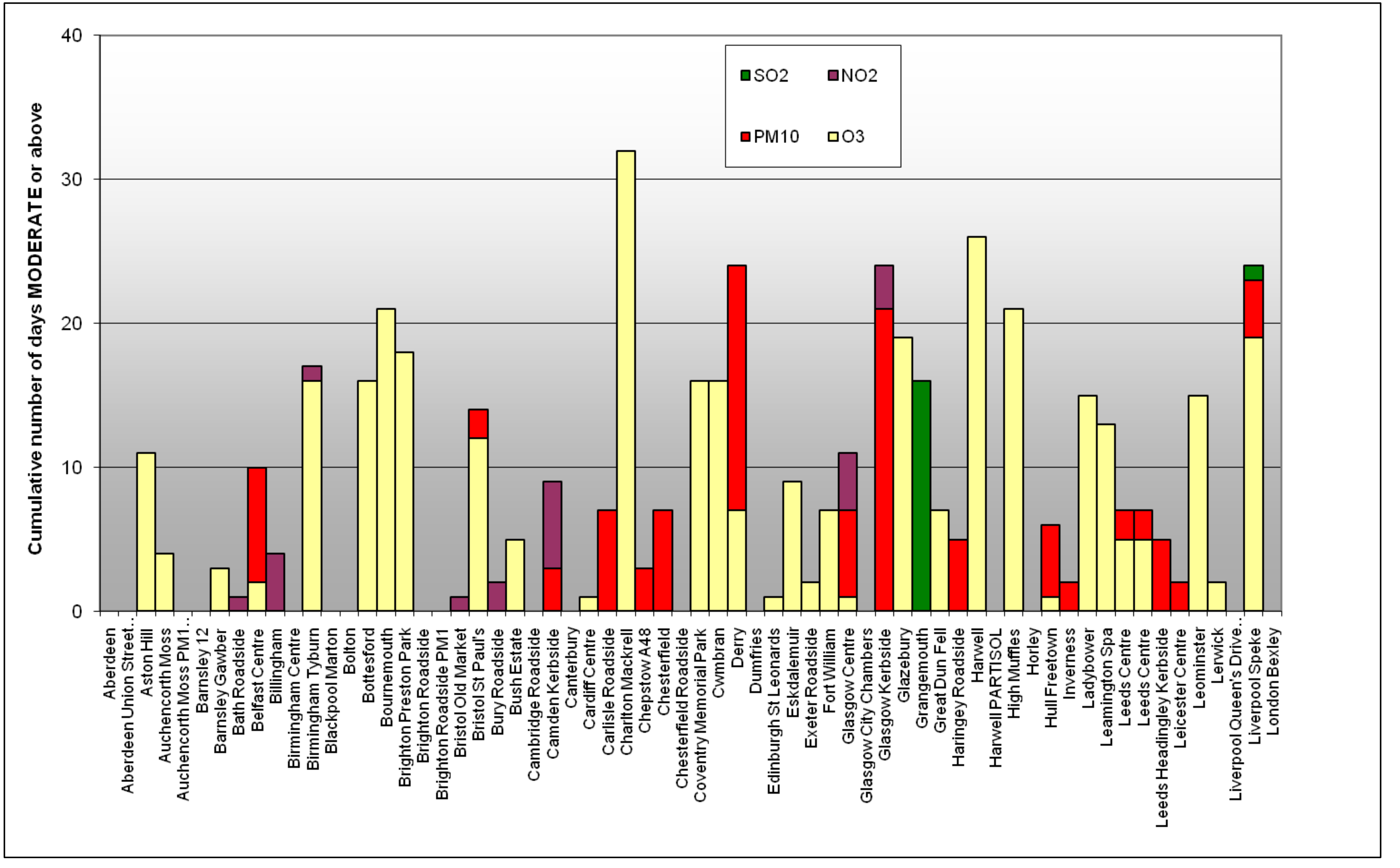



*Figure 3.7a Number of pollutant days moderate and above for each AURN Network station during 2010 (site names A-L)*

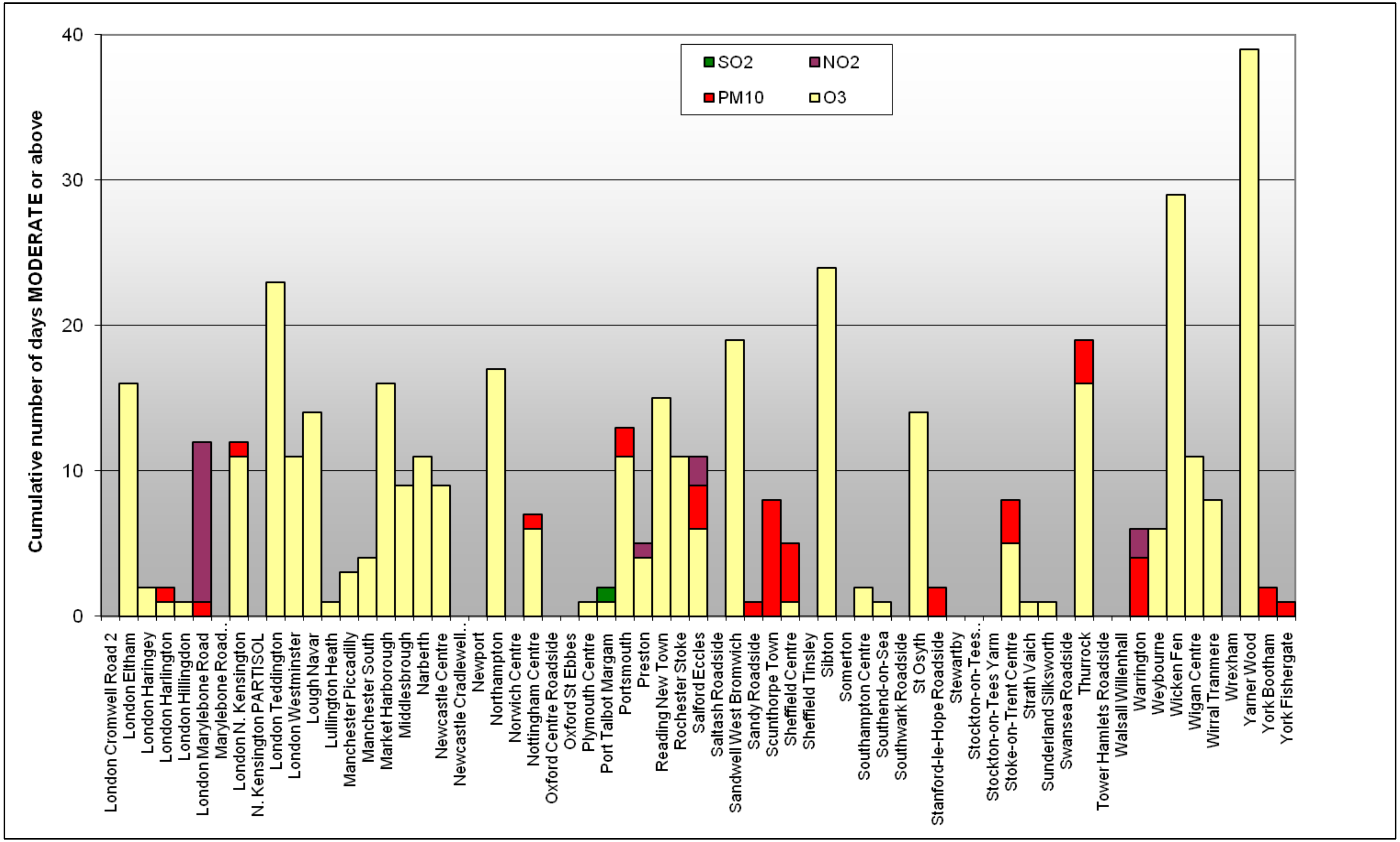



**Figure 3.7b** Number of pollutant days moderate and above for each AURN Network station during 2010 (site names L-Y)

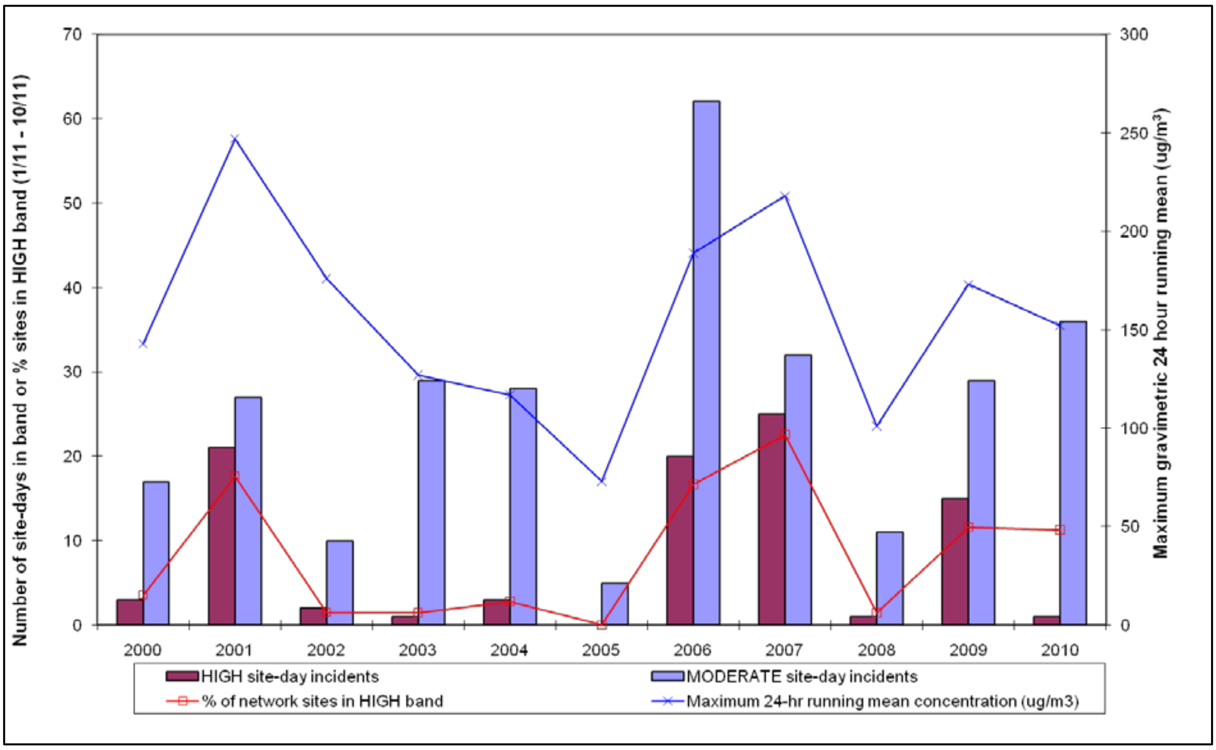



***Figure 3.8*** Number of sites exceeding the MODERATE and HIGH $PM_{10}$ bands over 1st November to 10th November annually from the year 2000 onwards with additional descriptive statistics.

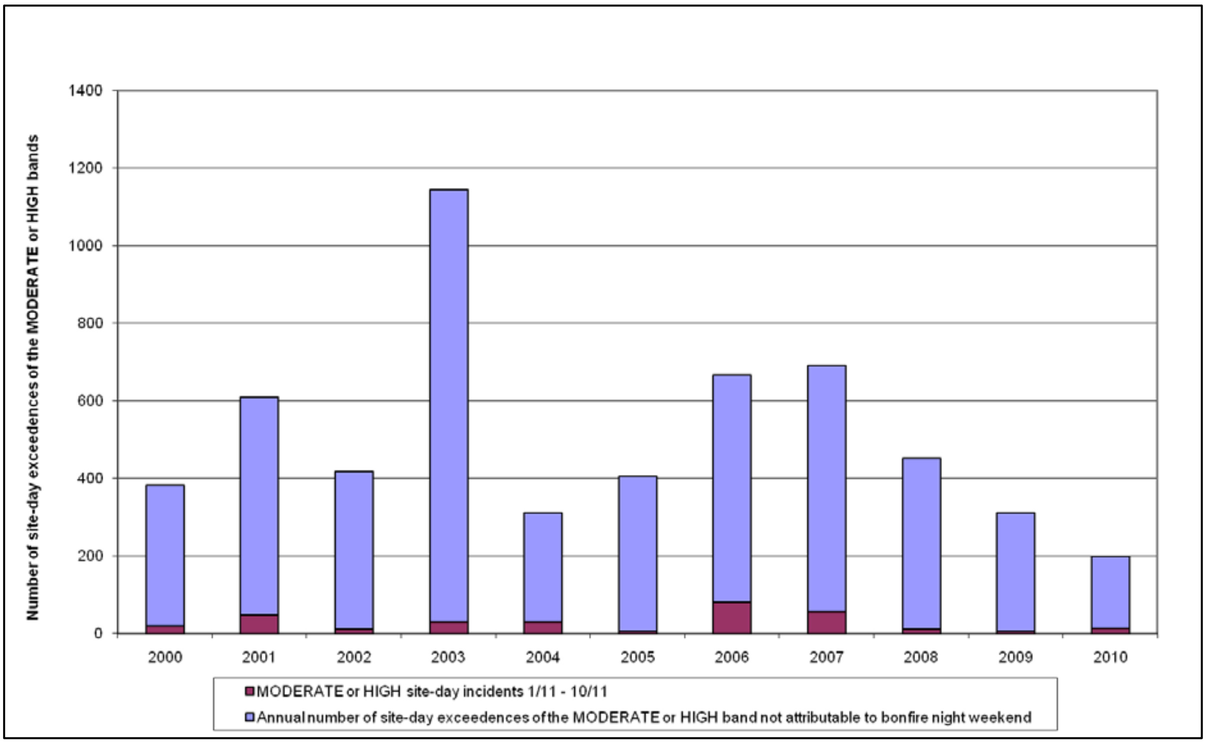



***Figure 3.9*** *Annual number of site-day exceedances of the MODERATE or HIGH $PM_{10}$ band for 2000 – 2010.*

### 3.2.3 Ozone

MODERATE days were measured at many of the AURN network sites between March and mid-July 2010. Further shorter periods with MODERATE or worse ozone were seen at the beginning of August and mid-September, as shown in figure 3.3. In 2010 only one monitoring site, namely Weybourne reached the HIGH band (on two occasions). The first HIGH day coincided with a significant number of MODERATE exceedances at other network sites, but the second occurance at the beginning of August, although exceptional in magnitude, was not widespread. The year 2010 can therefore be considered a year of no significant UK HIGH ozone air pollution episodes.

Figure 3.10 shows that 2010 was another low year for the number of ozone episodes. The maximum recorded concentration was much higher than recently, but as discussed earlier this was due to an an isolated incident on one day at the Weybourne monitoring site in East Anglia in August 2010. This incident was probably due a plume of continental European ozone pollution just brushing the far east of the UK on this day.

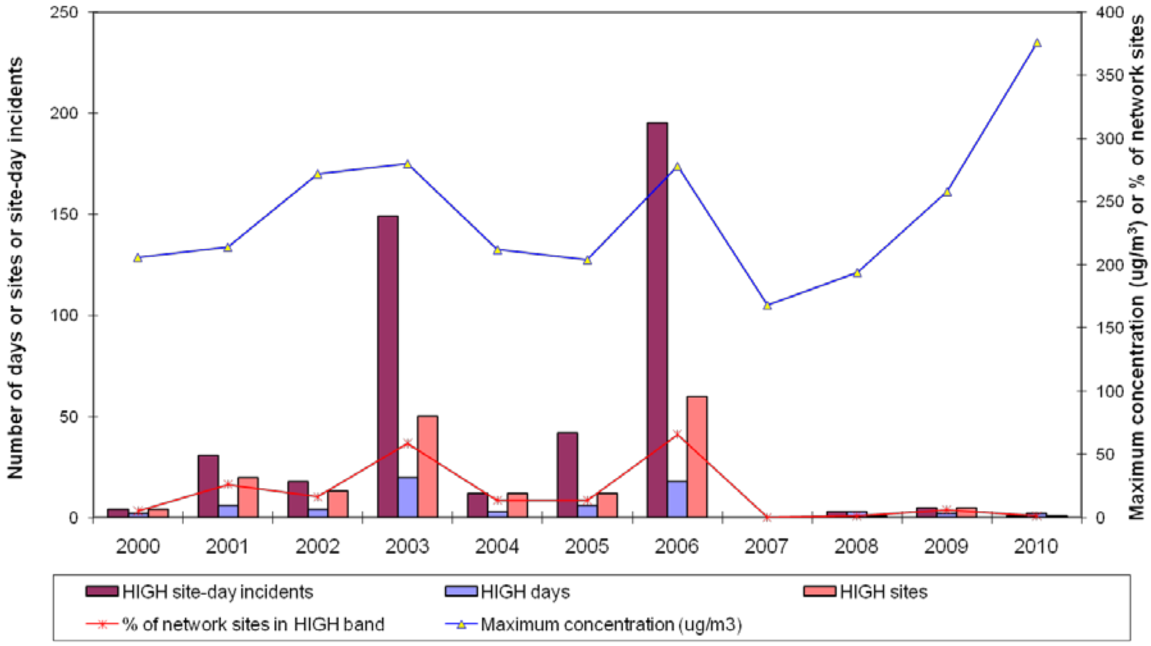



***Figure 3.10*** *UK ozone episodes summarized for years 2000 onwards.*

### 3.2.4 Sulphur Dioxide

There were 45 sites in the AURN air quality monitoring network measuring $SO_2$ concentrations in 2010. The number of MODERATE or above days per annum measured in the network is shown in figure 3.11 from the year 2000 onwards. The number of days of MODERATE exceedances per year is low but has been rising since 2007. The exceedances continue to be at monitoring sites in mainly industrial locations.

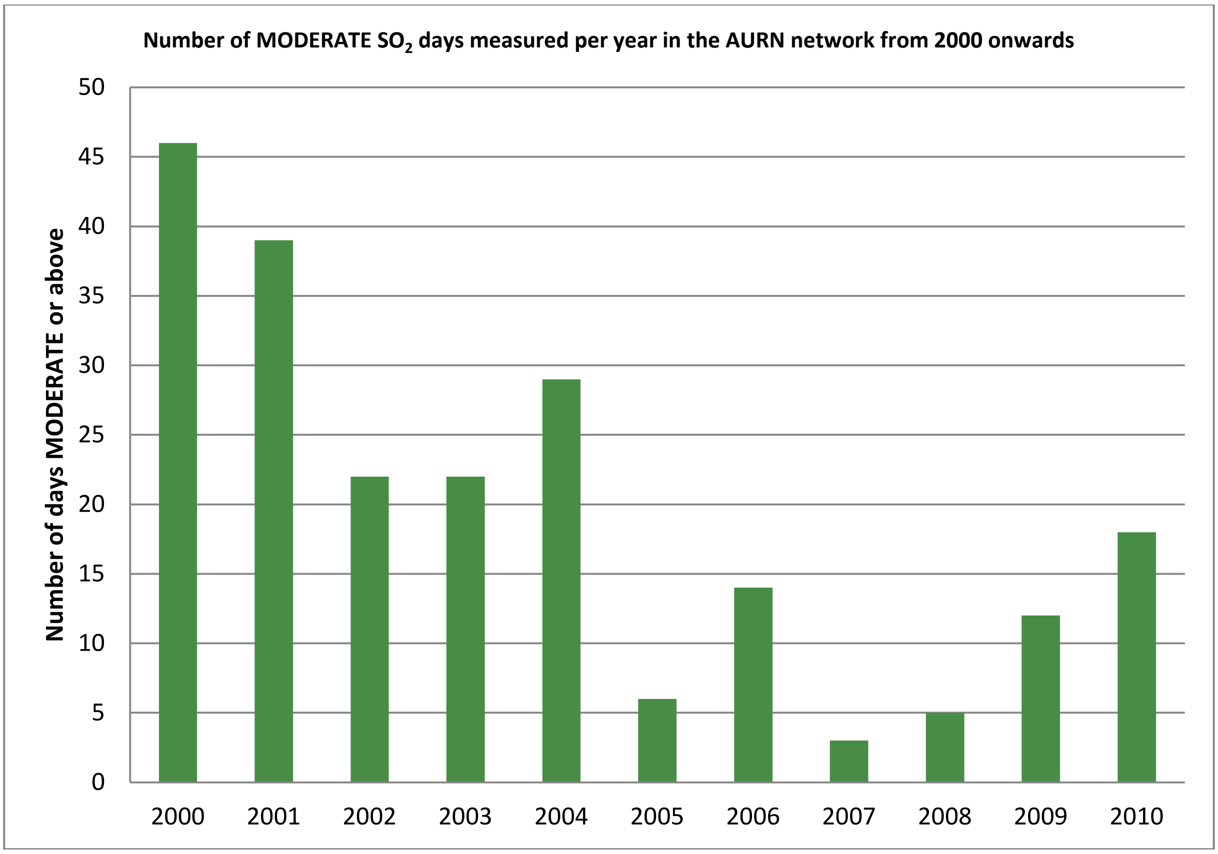



***Figure 3.11*** *Number of MODERATE $SO_2$ network days measured per annum*

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

### 3.2.5 Nitrogen Dioxide

Thirty seven MODERATE days for nitrogen dioxide were measured during the year. The vast majority of these were experienced at kerbside and roadside sites due to their proximity to road traffic. Eleven days with exceedances occurred at London Marylebone Road in 2010, followed by the Camden Kerbside site with 6 days. There was one HIGH day measured at Glasgow Centre in mid-October due to a diesel generator nearby. Figures 3.7a and b show all the sites which measured MODERATE nitrogen dioxide levels in 2010.

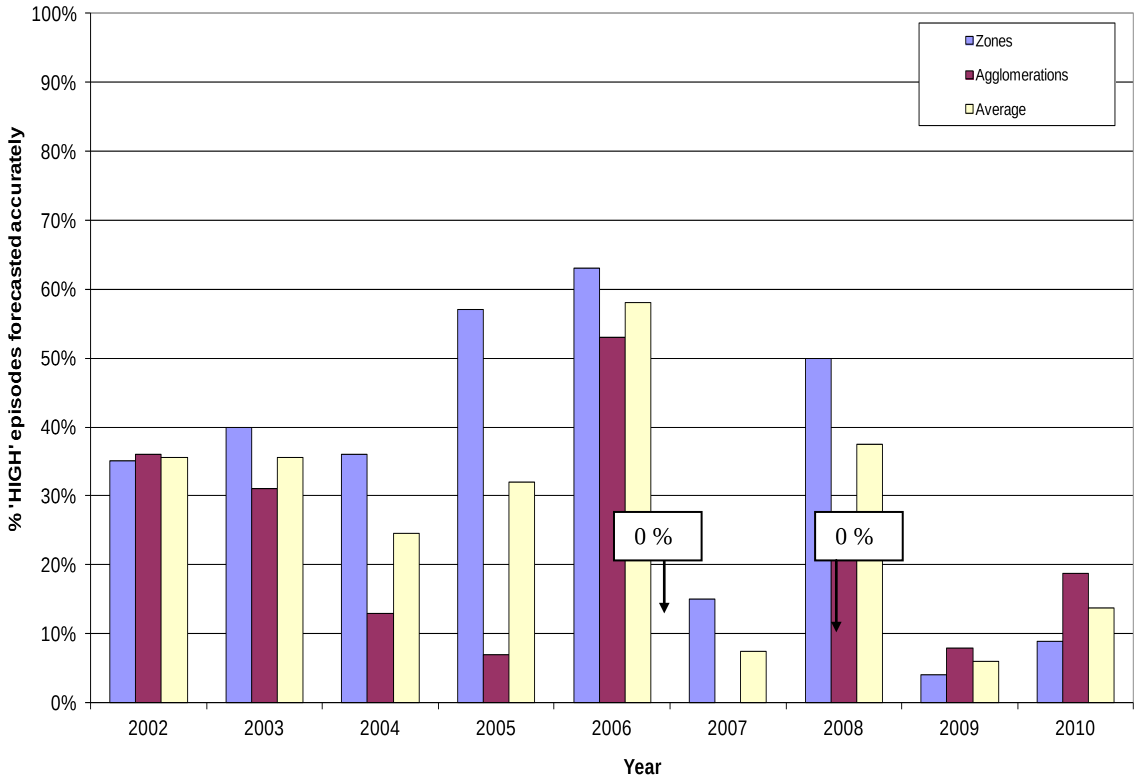
MODERATE days were measured at many sites in the monitoring network between January to March. In particular there were some periods of MODERATE pollution around 7-10$^{th}$ January, probably due to increased emissions from domestic heating and queuing traffic during cold, icy and snowy weather. Increases were recorded for $NO_2$ at Bury Roadside, Billingham, Warrington and Salford Eccles. A further period of increased pollution on Friday January 15$^{th}$ saw MODERATE concentrations of $NO_2$ at Bury Roadside again.

# 3.3 Comparison with years 2002 onwards

### 3.3.1 Overall Forecasting Accuracy Rate

Figure 3.12 shows the forecasting accuracy rates for HIGH pollution episodes for the whole of the UK for years 2002 to 2010. This is the percentage of HIGH days that were accurately forecast according to the criteria agreed with Defra and specified at the beginning of section 3 of this report.

***Figure 3.12*** *Forecasting Accuracy rate for HIGH pollution episodes for the UK, 2002-2010*




* 2002 was a partial year for forecasting analysis calculations.

The overall forecasting success rate for the HIGH band in 2010 was better than in 2009.

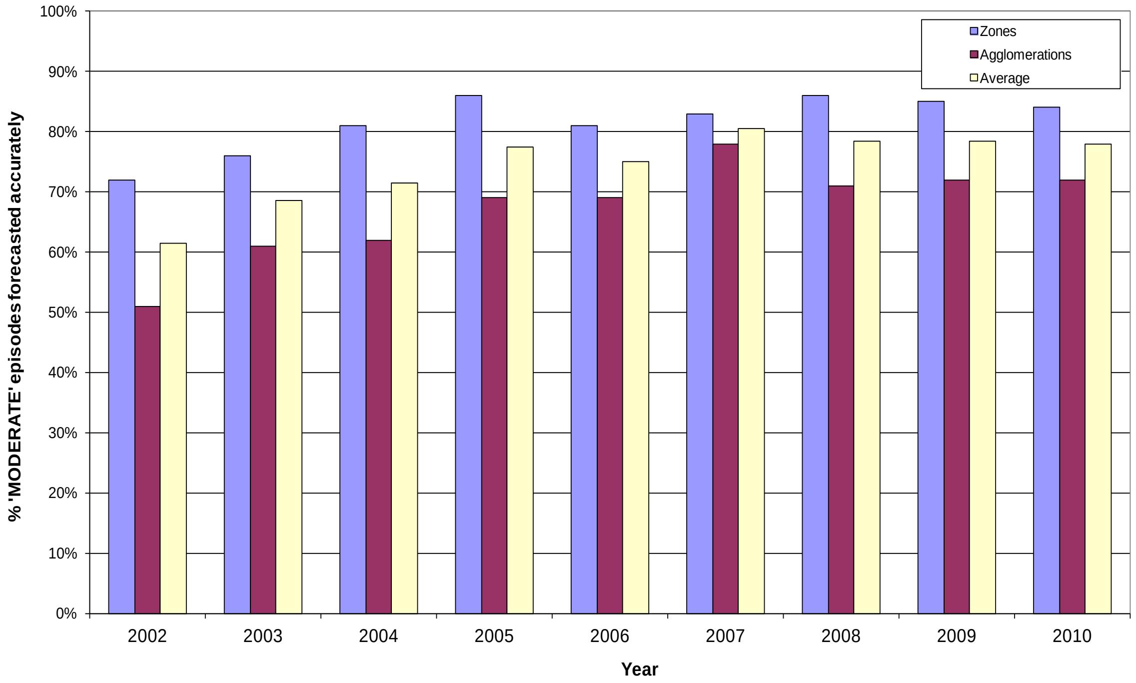
This was despite the low prevalence of HIGH ozone pollution episodes again in 2010.

However, there were several periods of stable winter weather conditions resulting in incidents of HIGH nitrogen dioxide and $PM_{10}$ particulate pollution which could be forecast reasonably accurately by the forecasting models and the forecasting team.

In general due to the complex origins of $PM_{10}$ pollution our capacity to successfully predict elevated $PM_{10}$ levels remains less than that for ozone using the forecast models available. This was partially addressed during 2010 by incorporating additional European particulate model run results into our system which are freely available for public access on the internet.

Because of the infrequent nature of HIGH UK pollution episodes in recent years the percentage of MODERATE days that were accurately forecast is perhaps a better measure of forecast performance. Figure 3.13 below shows that this has remained stable or increased slightly over the period illustrated.

***Figure 3.133*** *Forecasting Accuracy rate for MODERATE pollution episodes for the UK, 2002-2010*




* 2002 was a partial year for forecasting analysis calculations.

Figure 3.14 below confirms that 2010 was typical of recent years in terms of the overall low number of HIGH band $PM_{10}$ measurements recorded.

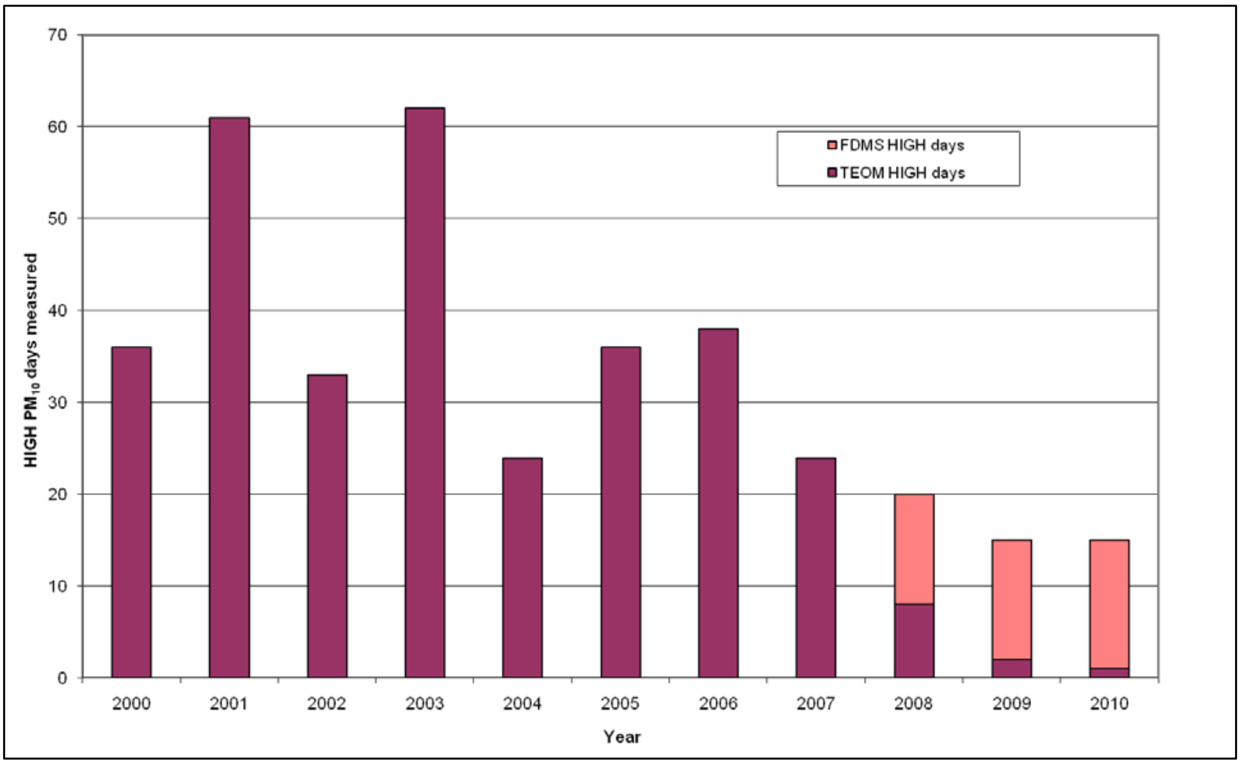



***Figure 3.144*** *Number of HIGH band measurements for $PM_{10}$ in the UK, 2000-2010.*

### 3.3.2 LOCALISED INFLUENCES

In addition to the difficulties of forecasting long range transport of particulates, there are also problems in forecasting accurately in areas where local effects on pollution are significant and unpredictable. The following are examples of such sites that reported HIGH concentrations during 2010:

- Port Talbot Margam monitoring station is located to the north east of the Corus Steelworks. As a result, emissions from the works are known to contribute to local $PM_{10}$ concentrations when winds are south-westerly.
- Grangemouth is an industrial site, which often results in unpredictable elevated concentrations of $SO_2$.
- Glasgow Central reported elevated $PM_{10}$ and $NO_2$ concentrations as a result of a nearby generator for a local farmers market.

# 4 Breakdowns in the service

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

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

# 5 Additional or enhanced forecasts

No formal enhanced forecasts were issued this year as the format of any such additional information is still under consideration. Nevertheless, there have been numerous informal discussions by email and telephone between the AEA forecasters and Defra during this period.

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

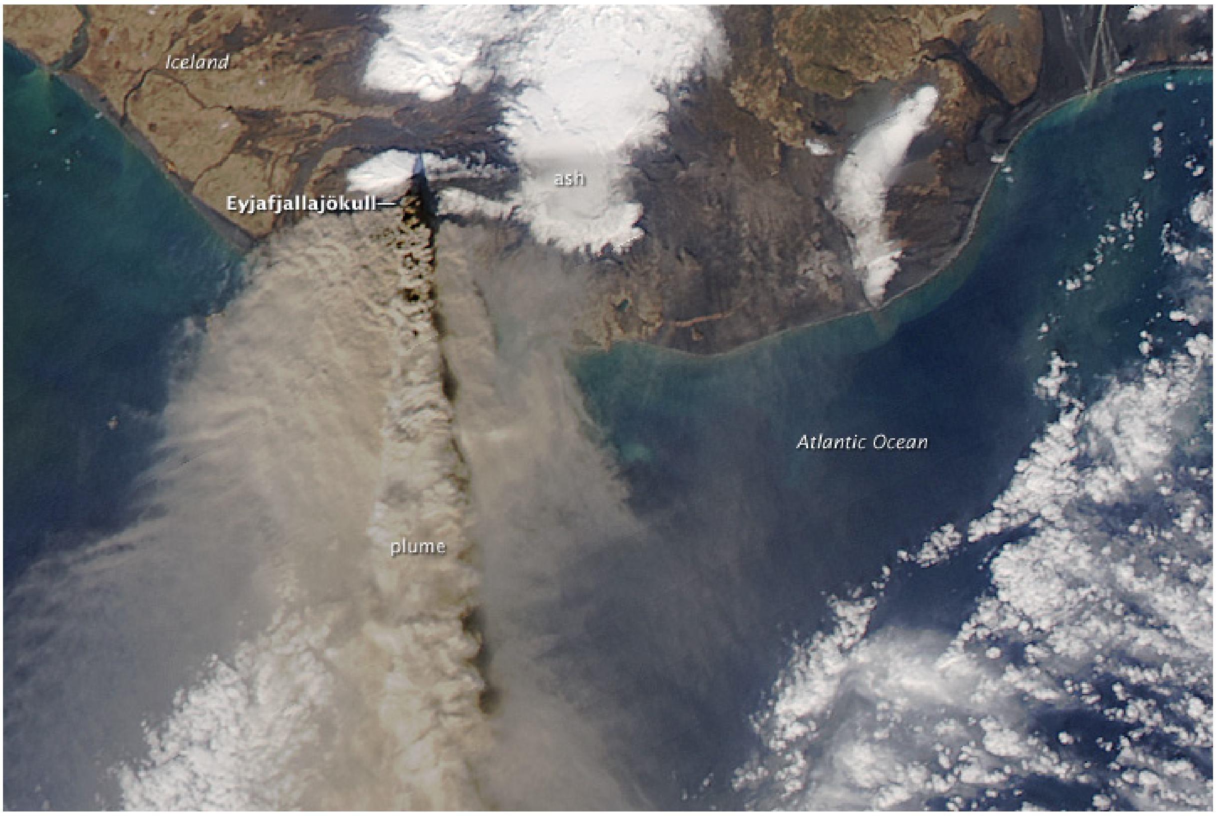
The bi-weekly air pollution outlooks have continued to be delivered successfully to Defra and other government departments by email on Tuesdays and Fridays.

# 6 Ad-hoc Services

AEA provided numerous ad-hoc updates to Defra and the Devolved Administrations during the Icelandic volcanic eruption in Spring 2010. A brief summary of our findings is presented here.

In March 2010 a small fissure eruption close to Eyjafjallajökull volcano was observed, but with no significant ash emissions to disrupt air travel or impact on air quality. On April 14th the sub-glacial summit eruption began at Eyjafjallajökull, resulting in the much publicised air traffic disruption and initially causing much concern over ground-level air quality.

***Figure 6.1*** *Satellite image of the eruption from Eyjafjallajökull volcano*

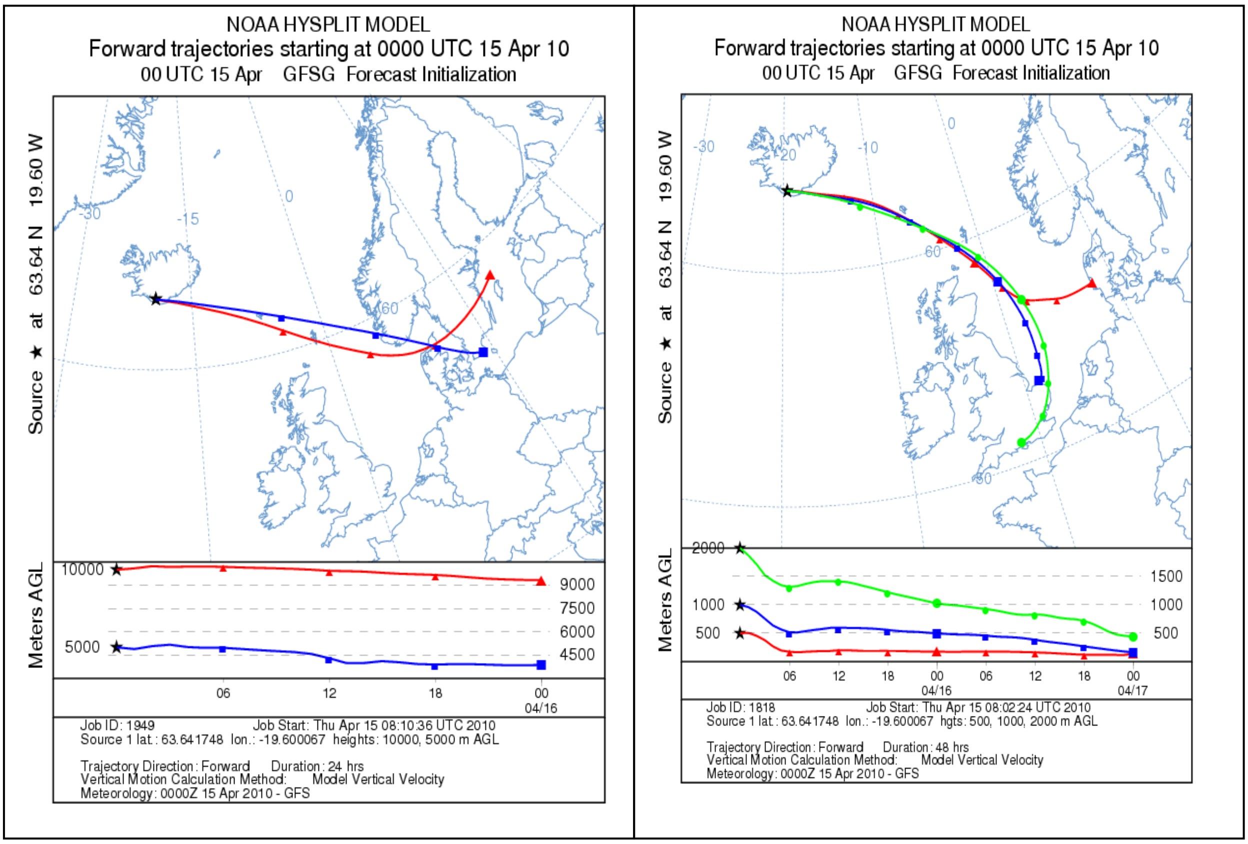



On May 4th the Icelandic Metrological Office (IMO) released an update stating that the eruption had become more explosive and was producing more ash. This coupled with the metrological conditions at the time were responsible for transporting the ash cloud over the UK.

During periods when the plume was over or close to the UK daily analysis of UK air quality monitoring results were provided to assess if there was any ground-level impact.

Subsequently, the NOAA Hysplit particle model and 96 - hour back trajectories were used to track the likely path of the plume and any possible plume grounding, as illustrated in Figure 6.2 overleaf.

***Figure 6.2*** *NOAA Hysplit Model Re**sults***




Levels of $PM_{10}$ continued to remain LOW throughout across the UK with little evidence of any plume grounding in the monitoring data.

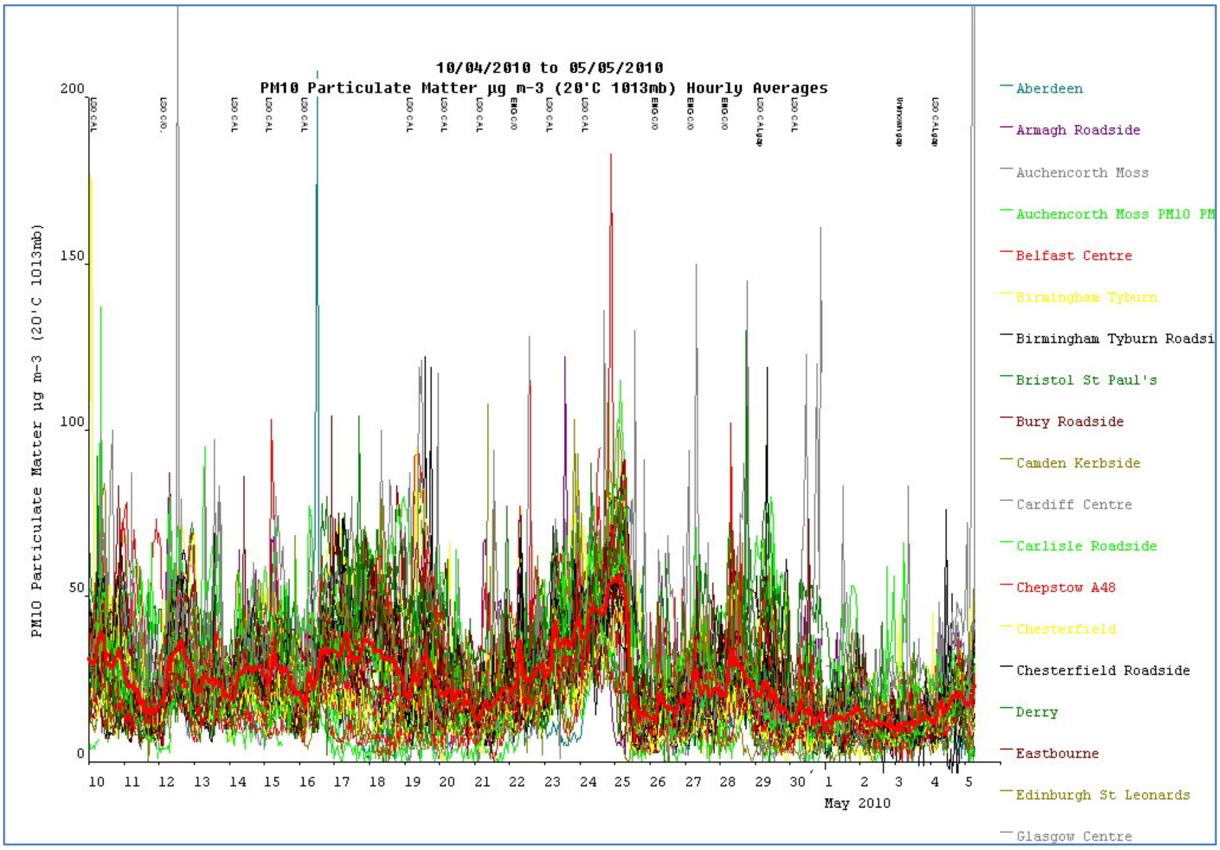
The graph of $PM_{10}$ concentrations in Figure 6.3 shows some increase in background hourly concentrations across all sites on May 4th, although within the "normal" variation of LOW pollution levels. The increase was ~20 µg/m$^3$ in the $PM_{10}$ non-volatile fraction and also seen in $PM_{2.5}$.

Since other pollutants showed no increases at the same time the volcanic ash could be a possible cause of this increase in the background levels. The thick red line in the graph represents the average concentration across all sites.

There were however no increases in concentrations of $SO_2$ across the AURN, a gaseous pollutant commonly expected to be found in volcanic plumes.

It was therefore concluded that the ground-level impact of the plume observed over the UK was minimal in terms of near-real-time, health effects related air quality monitoring, and after five weeks of eruption the volcano steadily slowed down.

***Figure 6.3:*** *$PM_{10}$ concentrations as measured by the AURN: 4[th] April – May 5[th] 2010*



# 7 Ongoing Research

AEA continues to develop the air quality forecasting systems by:

1. Investigate ways of using automatic software systems to streamline the activities within the forecasting process, thus allowing forecasters to spend their time more efficiently considering the most accurate forecasts.

2. Research the chemistry used in our models, in particular the CMAQ chemical schemes for secondary $PM_{10}$ and ozone.

3. Improve the automated validation analysis and plots.

4. Improve and update the emissions inventories used in our models.

# 8 Project and other related meetings

## 8.1 Project meetings

Regular quarterly project meetings continued to be held at Harwell over the course of the year.

## 8.2 Annual air quality forecasting seminar

The Ninth National Air Quality Forecast Seminar took place at Imperial College London on 14th July 2010. The event was attended by around 38 delegates who had an interesting day following the agenda described overleaf.

### UK Air Quality Forecasting Seminar - 14th July 2010

| Agenda | |
|---|---|
| **09.30 – 10.00** | **Coffee & Registration** |
| **10.00 – 10.20** | **Defra News Update – Dr. Samantha Lawrence** |
| **10.20 – 10.40** | **Paul Willis, AEA – UK Air Quality Forecasting Project Update** |
| **10.40 – 11.00** | **Paul Agnew, Met Office, Modelling the transport and deposition of volcanic emissions from Iceland to the UK** |
| **11.00 – 11.20** | **Dr. Gary Fuller, KCL, Impact of flight ban on air quality around airports** |
| **11.20 – 11.40** | **Richard J Harding, CEH, Monitoring systems for Volcanic Ash Deposition** |
| **11.40 -12.00** | **Dr. Elisa Carboni, EODG Oxford group, Volcanic emission into the atmosphere measured by satellite** |
| **12.00 – 12.45** | **LUNCH** |
| **12.45 – 13.00** | **Open "Stand up" session of short news items**<br>**Inc. "Innovative Communications Developments" from Dr Mike Short, O2** |
| **13.00 – 13.30** | **Dr. Ann Webb, Manchester University, UV Index: public forecast, personal health** |
| **13.30 – 14.00** | **Nick Andrews, HPA, Rapid mortality monitoring during heatwaves** |
| **14.00 – 14.30** | **Dr. Matt Smith, National Pollen and Aerobiology Research Unit, University of Worcester, Pollen allergy - the triggers** |
| **14.30 – 15.00** | **Tea Break** |

| | |
|---|---|
| **15.00 – 15.30** | **Dr. Andrea Fraser, AEA – WRF/CMAQ modelling for UK AQ Forecasts** |
| **15.30 – 16.00** | **Jaume Targa, EEA ETC/ACC, Latest developments in near real time data exchange across Europe** |
| **16.00 Close** | |

## 8.3 COST ES0602

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

**COST ES0602 Meeting in Copenhagen, May 17th -18th 2010**

Paul Willis attended the latest ES0602 Chemical Weather COST meeting at the EEA in Copenhagen on May 17th to 18th. The meeting included a Workshop on "Needs, challenges and new ideas for an integrated and effective air quality service and information provision." There was much discussion of current information services including the EEA's Ozoneweb and Eye-on-Earth, GMES in-situ co-ordination (GISC), and the WMOs GURME programme. The interest focussed on how these could be improved and extended and also made compliant with INSPIRE and SEIS requirements. There was also an a presentation by Valentin Foltescu of the EEA focussing on health impacts of pollutants and "causal determination"

# 9 Related projects

AEA ensured that any forecasts, issued under separate contracts, were consistent with the national forecasts for Defra, the DAs and the BBC.

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

# 10 Scientific Literature Review

This section reviews a selection of the scientific literature available in the public domain that is relevant to air quality forecasting in 2010.

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

## 10.1 Comprehensive Modelling of the Earth System for Better Climate Prediction and Projection (COMBINE)

The European integrating project COMBINE brings together research groups to advance Earth system models (ESMs) for more accurate climate projections and for reduced uncertainty in the prediction of climate and climate change in the next decades. COMBINE will contribute to better assessments of changes in the physical climate system and of their impacts in the societal and economic system. The proposed work will strengthen the scientific base for environmental policies of the EU for the climate negotiations, and will provide input to the IPCC/AR5 process.

http://www.combine-project.eu/

## 10.2 AIRNow-International

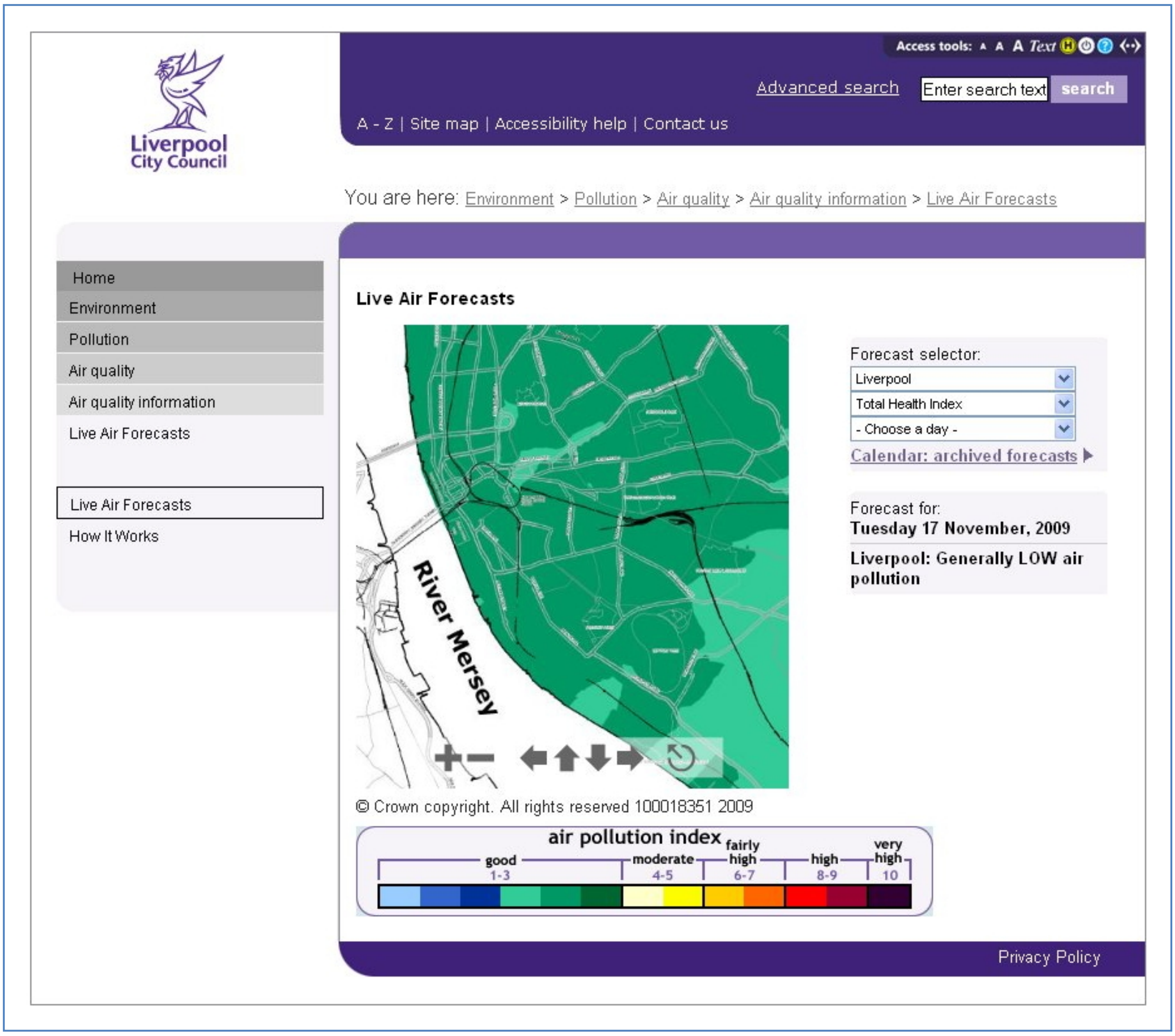
The goal of AIRNow-International is to strengthen relationships among governments and international organizations by sharing the technology to transform air quality data into vital information. AIRNow-International is poised to become the centerpiece of the United States Environmental Protection Agency's (EPA) real-time air quality reporting and forecasting program. The system is a redesign of the AIRNow information technology infrastructure that distributes current air quality information for the United States and Canada. The AIRNow-International software suite is being built to support and embrace the Global Earth Observation System of Systems (GEOSS) concept. The new U.S. EPA AIRNow system, which became operational in Spring 2009, is based on the AIRNow-International system software but with an added forecasting module to store the forecast information provided by U.S. air agencies.

http://www.earthzine.org/2010/01/25/airnow-international-the-future-of-the-united-states-real-time-air-quality-reporting-and-forecasting-program-with-geoss-participation

# 10.3 Air Quality Forecasting in the United Kingdom (CERC) - Liverpool

Air quality forecasts and alerts have been developed for Liverpool City Council. Validation is ongoing with the system expected to go live in Spring 2010. Forecasts are shown as detailed colour contours overlaid on a zoomable background image that will be linked to www.liverpool.gov.uk.

Alerts will be sent to individuals registered by the City Council.



## 10.4 Air Quality Forecasting System (SAFAR) and Weather Services for CWG

System of Air Quality Forecasting and Research (SAFAR) system for the air quality is developed by the Indian institute of Tropical Meteorology (IITM), Pune and weather information and forecasting is done by India Meteorological Department (IMD). This SAFAR project involves 4 components to facilitate the current and 24 advance forecasting, namely, the development of emission inventory of air pollutants for NCR and defining air quality index for India, network of eleven Air Quality Monitoring Stations (AQMS) equipped with 11 automatic weather stations to provide near real time air quality information , 3-D atmospheric chemistry transport forecasting modelling coupled with weather forecasting model to provide 24 hour advance forecast of air pollutant levels and Display on LED and LCD screens located at 20 different locations in Delhi in a public friendly format and displaying the online detailed information through the Web portal developed for CWG as: http://safar.tropmet.res.in/

## 10.5 Regional air quality forecasting in the Met Office Unified Model™

The UKCA (UK Chemistry and Aerosols) programme is developing a new UK community atmospheric chemistry-aerosol global model suitable for a range of topics in climate and environmental change research. Schemes for atmospheric chemistry and aerosols have been coupled to the Met Office Unified Model™ (Met UM), used for forecasting on timescales from hours through seasons to centuries. Based on developments of UKCA for chemistry climate applications, the **AQUM** (Air Quality in the Unified Model) project is developing a regional air quality forecasting capability. This limited area model version will be operationally running as a test suite for real time forecasting of O3, NOx, CO, SO2 and particulate matter (PM10 and PM2.5) by spring 2010.
http://www.ukca.ac.uk/wiki/images/6/6d/CO_EGU_2009_Edited.pdf

# 11 Forward work plan for 2011

The two tables below summarise both the weekly and annual planned activity for 2011(Table 10.1 and 10.2 respectively).

***Table 11.1*** *Weekly Activity Chart*

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

***Table 11.2*** *Annual Activity Chart*

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

# 12 Hardware and software inventory

Defra and the Devolved Administrations have funded the development of the WRF and CMAQ models for UK Air Quality Forecasting purposes. Defra and the Devolved Administrations also own the web pages used to display the forecasts.

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

# 13 References/Internet links

UK Air Quality Forecasting reports on the UK-AIR library:
http://uk-air.defra.gov.uk/library/

www.cmaq-model.org

www.wrf-model.org

http://www.rmets.org/

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

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

Agnew et al. 2007 Evaluation of GEMS Regional Air Quality Forecasts
http://www.meas.ncsu.edu/aqforecasting/research.html

http://www.cerc.co.uk/air-quality-forecasting/austria.html

http://web.t-online.hu/dasy/forecast/Budapest.htm

http://www.earthzine.org/2010/01/25/airnow-international-the-future-of-the-united-states-real-time-air-quality-reporting-and-forecasting-program-with-geoss-participation

http://www.combine-project.eu/

http://www.gmes-atmosphere.eu/

Review of Air Quality Modelling in Defra
**Authors:** Prof. Martin Williams, Roger Barrowcliffe, Prof. Duncan Laxen and Prof. Paul Monks

# Appendices

# Appendix 1 – UK Air Pollution Index

**CONTENTS**

| Banding | Index | Ozone 8-hourly/ Hourly mean | | Nitrogen Dioxide Hourly Mean | | Sulphur Dioxide 15-Minute Mean | | Carbon Monoxide 8-Hour Mean | | $PM_{10}$ 24-Hour Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $\mu gm^{-3}$ | ppb | $\mu gm^{-3}$ | ppb | $\mu gm^{-3}$ | ppb | $mgm^{-3}$ | ppm | Gravimetric equivalent $\mu gm^{-3}$ |
| | Proposed FDMS limits / TEOM limits | | | | | | | | | |
| LOW | 1 | 0-32 | 0-16 | 0-95 | 0-49 | 0-88 | 0-32 | 0-3.8 | 0.0-3.2 | 0 –19 / 0–21 |
| | 2 | 33-66 | 17-32 | 96-190 | 50-99 | 89-176 | 33-66 | 3.9-7.6 | 3.3-6.6 | 20–40 / 22-42 |
| | 3 | 67-99 | 33-49 | 191-286 | 100-149 | 177-265 | 67-99 | 7.7-11.5 | 6.7-9.9 | 41-62 / 43-64 |
| | | | | | | | | | | |
| MOD | 4 | 100-126 | 50-62 | 287-381 | 150-199 | 266-354 | 100-132 | 11.6-13.4 | 10.0-11.5 | 63-72 / 65-74 |
| | 5 | 127-152 | 63-76 | 382–477 | 200-249 | 355-442 | 133-166 | 13.5-15.4 | 11.6-13.2 | 73-84 / 75-86 |
| | 6 | 153-179 | 77-89 | 478-572 | 250-299 | 443-531 | 167-199 | 15.5-17.3 | 13.3-14.9 | 85-94 / 87-96 |
| | | | | | | | | | | |
| HIGH | 7 | 180-239 | 90-119 | 573-635 | 300-332 | 532-708 | 200-266 | 17.4-19.2 | 15.0-16.5 | 95-105 / 97-107 |
| | 8 | 240-299 | 120-149 | 636-700 | 333-366 | 709-886 | 267-332 | 19.3-21.2 | 16.6-18.2 | 106-116 / 108-118 |
| | 9 | 300-359 | 150-179 | 701-763 | 367-399 | 887-1063 | 333-399 | 21.3-23.1 | 18.3-19.9 | 117-127 / 119-129 |
| | | | | | | | | | | |
| V. HIGH | 10 | ≥ 360 $\mu gm^{-3}$ | ≥ 180 ppb | ≥ 764 $\mu gm^{-3}$ | ≥ 400 ppb | ≥1064 $\mu gm^{-3}$ | ≥ 400 ppb | ≥ 23.2$mgm^{-3}$ | ≥ 20 ppm | ≥ 128 / 130 $\mu gm^{-3}$ |

| *Banding* | *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 – UK Forecasting Zones and Agglomerations

**CONTENTS**

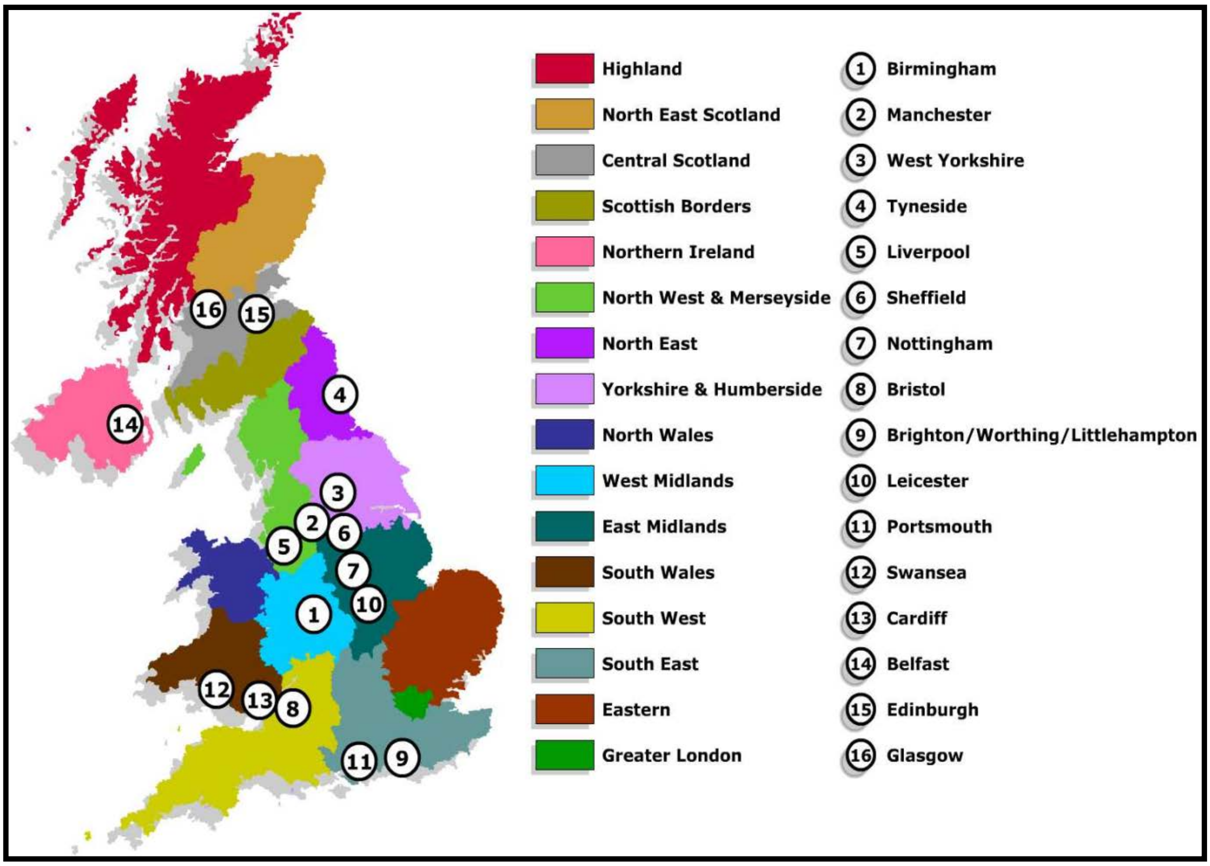
## UK Forecasting Zones

| *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 |

## UK 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 UK forecasting zones and agglomerations



AEA
The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR

Tel: 0870 190 1900
Fax: 0870 190 6318

www.aeat.co.uk