Air Pollution Forecasting: Pollution Episode Report (March and April 2003)

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INTRODUCTION

From mid-March through to the end of April 2003, the UK urban air monitoring network recorded elevated pollution levels. During the early part of this period, the HIGH pollution was limited to elevations of particulate matter, although MODERATE levels of ozone were also widespread at the time. Towards the end of the period, an episode involving both ozone and PM_{10} was recorded.

The purpose of this report is to detail the extent and duration of the AQS Objective exceedances resulting from these elevated levels and to describe the weather situation and other causal factors that may have contributed to the event. The final data for the period of the event has yet to be ratified, all statistics and charts are based on provisional data as used in the actual forecasting process.

This report has divided the period into three discrete sections. The first section, from 15th March to 30th March, details the duration and extent of the first episode, which involved only PM_{10}. The second section, falling between the two episodes, was a time when most of the network sites were reporting LOW concentrations. The third section of the report period covers the second pollution episode, 12th to 30th April, which involved both PM_{10} and ozone.

Table 1 shows the number of sites in MODERATE, HIGH and VERY HIGH bands for ozone and PM_{10} on each day covered by the report. It also lists the maximum exceedance concentration for each pollutant for each day (24 hour running average for PM_{10} and hourly/ 8 hourly running mean for ozone). Tables 2 and 3 list each site in the network to have reported MODERATE concentrations or more, the number of days in the MODERATE, HIGH and VERY HIGH band and the maximum exceedance concentration for each site. Table 4 is a summary of the number of days on which MODERATE, HIGH and VERY HIGH concentrations were recorded for both PM_{10} and ozone separately and then for both pollutants combined. Figure 1 is a time series chart showing the changing 24 hour running mean concentrations for each site to have reported HIGH concentrations or above. Figure 2 is a time series chart of changing hourly ozone concentrations for each site to have reported HIGH concentrations or above over the period. Figures 3 to 11 are selected back trajectories showing the origin of air masses affecting the UK over the period.

DEVELOPMENT OVER TIME

- **15th to 31st March**

This period was dominated by elevated levels of PM_{10}. On 15th March there were only 2 sites in the network measuring concentrations in the MODERATE band and this rose to 3 the following day. The forecast back trajectories (figure 3) indicate that the UK was receiving air masses from the continent at the time. These are conditions that often result in elevated PM_{10} levels in the UK as a secondary component from mainland Europe is introduced. The sites involved at this time were Belfast Clara Street (converted to a TEOM equivalent on which the Defra bandings are based for the purpose of this report), Glasgow Kerbside and Scunthorpe. These sites often report relatively high levels of particulate pollution due to local characteristics such as industrial and roadside emissions and these were likely compounded by a secondary PM_{10} component.

On 17th March the number of sites reporting MODERATE concentrations rapidly increased to 10 despite the fact that the back trajectories remained almost identical. The first concentrations reported in the Defra HIGH band occurred on 18th March at both Glasgow Kerbside and Belfast Clara Street. Between 19th and 21st of March, concentrations dropped again and, on 21st March there were only 5 sites reporting MODERATE concentrations and no HIGH concentrations reported. Back trajectories showed that much of the UK was still being affected by continental air until 21st March when Atlantic air masses became more

influential (figure 4). Back trajectories for 22nd March (figure 5) onwards indicate a change in wind direction back towards the continent which resulted in rising concentrations again. HIGH concentrations were reported between 22nd and 26th March with the main episode. On 24th March, there were 3 network sites (Glasgow Kerbside, Belfast Clara Street and Leamington Spa) reporting HIGH concentrations and a maximum 24 hour running mean concentration of 93 μgm^{-3} was reached at Leamington Spa. While increased levels of PM_{10} at Glasgow Kerbside and Belfast Clara Street can be justified by local sources with the possible addition of a secondary component, it is hard to explain the HIGH levels at Leamington Spa. This site has comparatively low background levels and reaching such high levels suggests that a local source such as construction activity may be involved, particularly given the rapid increase in levels. On 24th March at 7.00 Leamington Spa was reporting a 24 hour running average of just 30 μgm^{-3}. This had risen to the 89 μgm^{-3} (well into the HIGH band) by 15.00 the same day and peaked at 104 μgm^{-3} (the VERY HIGH band) at 11.00 on the following morning. This was the only occasion of VERY HIGH levels in this first episode. The back trajectories (figure 6) provide little justification that a significant continental component was involved at the height of this event, although it should be remembered that they only track back 96 hours. Longer trajectories may have shown air masses originating from more Central Europe.

After 25th March, as figure 1 shows, levels at most sites decreased. Scunthorpe, Belfast Clara Street and Sheffield Centre were notable exception, rising over 28th and 29th March. Belfast Clara Street reached a peak of 98 μgm^{-3} (just lower than the VERY HIGH band) on 28th March. Scunthorpe reached 24 hour running mean levels of 95 μgm^{-3} on 29th March. Sheffield just entered the HIGH band for a short time on 29th March with a 24 hour running mean of 79 μgm^{-3}. The reason for this is likely the proximity of Glasgow Kerbside to the significant roadside source and emissions from the nearby steelworks at Scunthorpe. Specific local sources near the Sheffield Centre site can only be speculative but, being a city centre site, it is likely that road traffic emissions may have contributed. All 3 sites reported dropping concentrations thereafter and by 31st March there were only 2 sites reporting MODERATE concentrations. The UK was being influenced by clean Atlantic air masses from the west on 31st March (figure 7).

While this episode was limited to PM_{10}, figure 2 indicates that levels of ozone, although limited to the MODERATE band, were following a similar trend, also peaking between 23rd and 25th March before dropping off again.

- **1st April to 12th April**

Pollution concentrations over this period were generally low across the network as figure 1 confirms. For the first week of April there were only 2 sites that reported MODERATE concentrations. These were Scunthorpe (on 1st and 3rd April) and Leamington Spa (on 4th and 5th April). The wind conditions during this time were typified by the back trajectories for 5th April (figure 8) which illustrate how the UK was fed by clean north westerly air masses originating over the Atlantic.

Increasing PM_{10} levels which reached the MODERATE band at Scunthorpe and Thurrock on 6th and 7th April are not associated with any significant change in the back trajectories. These are likely the result of local sources which may have been exacerbated by worsening dispersion conditions. Both sites are known to be influenced by local industry – the steelworks near Scunthorpe and an organochemicals processing factory near Thurrock. This explains the notably sharp rise into the VERY HIGH band of the PM_{10} 24 hour running mean concentration measured at Thurrock over 9th April. This rose from 32 μgm^{-3} at 23.00 on 8th April to 117 μgm^{-3} at 22.00 on 9th April. Despite these sites, 2 days (2nd and 6th April) saw every network site reporting concentrations in the LOW band once more.

- **12th to 30th April**

By 12th April, levels across the network, particularly at the Scunthorpe site were beginning to rise again. This was the beginning of a second episode which included PM_{10} and ozone. Back trajectories for 12th April show that the winds have swung round from an easterly direction and were bringing air from Scandinavia and central Europe. By 13th April, south easterly winds were bringing the UK air masses that had crossed significant European pollution sources (see figure 9). Concentrations at Scunthorpe rose more than at other sites and by the end of 13th April it was reporting a 24 hour running average concentration of 90 μgm^{-3}, well into the HIGH band. On 14th April winds had become strong and southerly (see figure 10). Interestingly, there were Saharan dust storms (details of which can be found on the internet at the links provided below) reported at this time[1][2]. These internet links provide MODIS (Moderate Resolution Imaging Spectroradiometer) images of the Saharan dust storm events, taken from the Terra satellite. These images both show the tan coloured swirls of Saharan dust over the UK and surroundings. As one of the links suggests[2], the greyer haze is more likely to be air pollution rather than

[1] http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=10183
[2] http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=10181

Saharan dust. These dust storms are likely to have contributed to UK particulate levels as a result of the strong winds from the continent between 14th April and 18th April.

Scunthorpe was the only site to have reported VERY HIGH concentrations of PM_{10} during this period (reaching a maximum 24 hour running mean concentration of 118 μgm^{-3} on 18th April. Redcar also entered the HIGH band over 16th and 17th April, reaching a maximum 24 hour running mean of 94 μgm^{-3} on 16th April. The Redcar site is located in close proximity to a number of heavy industries which are likely to have contributed to the HIGH levels recorded. Levels declined again on 19th April. The back trajectories show the wind direction to have moved easterly/ north easterly again which, while removing the influence of Saharan dust, would still expose the UK to air masses that had passed over significant European industrial sources. In fact, the back trajectories on 19th April were very similar to those on 9th April when Thurrock was the only network site reporting elevated PM_{10} concentrations. From 19th April onwards, the wind direction moved between south easterly and north easterly (see figure 11) and PM_{10} levels remained significantly lower than they had been over the previous week. Only Scunthorpe and Port Talbot reported HIGH concentrations again during the period (on 20th and 24th at Scunthorpe and on 23rd at Port Talbot). Port Talbot PM_{10} concentrations are known to be influenced by the large steelworks nearby and it is likely that this local source was a contributory factor. By 26th April all sites in the UK automatic air monitoring network were reporting LOW concentrations again, and the winds were south westerly, bringing air from the Atlantic.

Elevated ozone concentrations were closely correlated with elevated concentrations of PM_{10} and HIGH levels were recorded on 16th, 17th and 18th April, the same time as VERY HIGH concentrations of PM_{10}. Network sites that reported HIGH ozone levels were Harwell, Wigan Leigh and Strath Vaich; all rural sites. As table 1 shows, this episode was not as pronounced for ozone as it was for PM_{10}. Only 3 sites reported HIGH concentrations over 3 days and the highest concentration of 93 ppb (at Harwell on 18th April) was only just into the HIGH band.

CONCLUSION

- The period between 15th March and 30th April saw several network sites in the HIGH and VERY HIGH PM_{10} bands on several occasions and for several days at a time. MODERATE concentrations were recorded at widespread sites across the network from a prolonged period.

- The sites that reported HIGH and VERY HIGH concentrations over the period are those that are associated with significant local industrial and road traffic sources (Glasgow Kerbside, Redcar, Port Talbot, Thurrock, Scunthorpe). It is likely that these sources (possibly exacerbated by poor atmospheric dispersion) were a major causal factor. Leamington Spa was an exception to this and it is likely HIGH levels recorded here can be attributed to some temporary local factor such as nearby construction work.

- While the back trajectories sometimes failed to explain the extent and timing of these elevated concentrations, it is likely that an additional contribution to UK domestic PM_{10} levels resulted from a secondary continental component. This secondary component is likely to have been compounded between 14th and 18th April when Saharan dust storms influenced the UK.

- MODERATE ozone concentrations were reported throughout the network across the period. HIGH concentrations of ozone corresponded with increased concentrations of PM_{10} at times when back trajectories indicated continental air masses influencing the UK. It is likely that these air masses, brought in continental ozone and ozone precursors to the UK in addition to a secondary PM_{10} component. Warm temperatures and long hours of bright sunshine, which are necessary to allow the ozone forming chemical reactions to take place, typified the period.

Table 1 – changing concentrations over time – Air Quality Bands

	PM_{10}					Ozone			
Date	**Max exceedance (µg m-3)**	**Number of MOD sites**	**Number of HIGH sites**	**Number of V HIGH sites**		**Max exceedance (ppb)**	**Number of MOD sites**	**Number of HIGH sites**	**Number of V HIGH sites**
15/03/03	53	2				54	1		
16/03/03	62	3				57	7		
17/03/03	63	10				62	7		
18/03/03	79	11	2			62	5		
19/03/03	88	20	1			65	6		
20/03/03	74	20				64	5		
21/03/03	59	5				63	5		
22/03/03	81	6	1			61	5		
23/03/03	85	9	1			83	30		
24/03/03	93	16	3			81	39		
25/03/03	104	15	2	1		77	24		
26/03/03	91	26	2			70	24		
27/03/03	74	27				66	24		
28/03/03	99	17	1			75	14		
29/03/03	96	36	3			63	6		
30/03/03	79	15	1			62	10		
31/03/03	52	1				62	11		
01/04/03	54	1				61	5		
02/04/03	46					57	3		
03/04/03	50	1				57	2		
04/04/03	54	1				58	2		
05/04/03	53	1				58	4		
06/04/03	46					52	3		
07/04/03	72	2				55	4		
08/04/03	68	2				58	2		
09/04/03	117	3	1	1		55	5		
10/04/03	87	2	1			54	5		
11/04/03	58	1				58	9		
12/04/03	59	1				69	24		
13/04/03	90	1	1			70	24		
14/04/03	112	4	1	1		67	10		
15/04/03	107	20	1	1		80	25		
16/04/03	110	23	1	1		92	55	1	
17/04/03	116	18	2	1		91	56	2	
18/04/03	119	16	1	1		93	69	1	
19/04/03	98	2				79	38		
20/04/03	82	33	1			75	48		
21/04/03	84	40	1			75	50		
22/04/03	99	7				73	39		

	PM_{10}					Ozone			
Date	**Max exceedance (µg m-3)**	**Number of MOD sites**	**Number of HIGH sites**	**Number of V HIGH sites**		**Max exceedance (ppb)**	**Number of MOD sites**	**Number of HIGH sites**	**Number of V HIGH sites**
23/04/03	75	5	1			81	50		
24/04/03	76	3	1			65	30		
25/04/03	69	4				61	7		
26/04/03	54	2				65	18		
27/04/03	43					67	44		
28/04/03	37					56	5		
29/04/03	40					66	22		
30/04/03	42					63	20		

Table 2 – PM_{10} site concentrations by band and duration

Site	Number days MODERATE	Number days HIGH	Number days VERY HIGH	Maximum 24 hour running mean (µg m^{-3})
Scunthorpe	31	10	5	119
Leamington Spa	9	3	1	104
Thurrock	15	2	1	117
Glasgow Kerbside	22	7		91
Belfast Clara St. (TEOM equivalent)	18	4		99
Redcar	11	2		94
Sheffield Centre	12	1		80
Port Talbot	11	1		75
London Bloomsbury	21			70
London Marylebone Rd	20			72
Bury Roadside	18			72
Stockton-on-Tees Yarm	17			67
London Bexley	14			61
London A3 Roadside	13			67
Bradford Centre	11			73
London Eltham	11			62
London Hillingdon	11			59
Hull Freetown	10			63
Leeds Centre	9			73
London N. Kensington	9			55
Manchester Piccadilly	9			67
Wolverhampton Centre	9			62
Wigan Leigh	8			61
Cardiff Centre	7			62
Haringey Roadside	7			52
Salford Eccles	7			62
Birmingham Centre	6			60
Grangemouth	6			62
Aberdeen	5			65
Blackpool	5			57
Bristol Centre	5			62
Derry	5			69
Southampton Centre	5			59
Glasgow Centre	4			54
London Brent	4			53
Narberth	4			67
Preston	4			71
Bolton	3			63
Portsmouth	3			52
Swansea	3			52
Wirral Tranmere	3			59
Canterbury	2			53
Coventry Memorial Park	2			55
Edinburgh Centre	2			67
Newcastle Centre	2			55
Northampton	2			56
Norwich Centre	2			58
Nottingham Centre	2			59
Rochester	2			59
Southend-on-Sea	2			54
Stockport Shaw Heath	2			54
Stoke-on-Trent Centre	1			54

* Belfast Clara Street uses a gravimetric analyser (BAM) – for the purpose of this report, data has been converted to TEOM equivalent to allow comparisons with the other sites in the network.

Table 3 – Ozone site concentrations by band and duration

Site	Number days MODERATE	Number days HIGH	Number days VERY HIGH	Maximum hourly/ 8 hourly mean mean (ppb)
Harwell	34	2		93
Strath Vaich	35	1		91
Wigan Leigh	25	1		92
Sibton	42			88
Bottesford	30			73
Yarner Wood	27			87
Redcar	26			65
Port Talbot	25			87
Lullington Heath	25			83
Northampton	21			84
Somerton	21			85
Bournemouth	21			80
Narberth	20			85
Swansea	19			77
Wicken Fen	19			71
Coventry Memorial Park	17			80
Bolton	17			80
St Osyth	17			72
Great Dun Fell	16			67
Blackpool	16			75
Aston Hill	16			75
Norwich Centre	16			66
Birmingham East	15			81
Plymouth Centre	15			66
Rochester	14			70
Leamington Spa	14			79
Hull Freetown	14			67
Glazebury	14			83
London Bexley	13			78
Bush Estate	13			66
Derry	13			72
Ladybower	13			80
London Teddington	13			67
Thurrock	11			73
Portsmouth	11			67
Bristol Centre	11			76
Sandwell West Bromwich	11			71
Southend-on-Sea	10			69
Salford Eccles	10			78
Lough Navar	10			65
London Eltham	9			84
Eskdalemuir	9			62
Southampton Centre	9			67
London N. Kensington	9			65
London Haringey	8			64
Wolverhampton Centre	8			71
London Lewisham	8			73
Birmingham Centre	7			69
London Hackney	7			66
London Southwark	6			64
Wirral Tranmere	6			71
Stoke-on-Trent Centre	5			66
Rotherham Centre	5			68
Newcastle Centre	5			63
London Hillingdon	5			69
Exeter Roadside	5			59
Leeds Centre	5			64

Site	Number days MODERATE	Number days HIGH	Number days VERY HIGH	Maximum hourly/ 8 hourly mean mean (ppb)
London Westminster	4			57
Manchester South	4			61
Preston	4			70
Glasgow Centre	4			58
Nottingham Centre	4			56
Sheffield Centre	4			58
Weybourne	4			54
Barnsley Gawber	3			61
London Bloomsbury	3			61
Bradford Centre	3			61
High Muffles	3			54
Edinburgh Centre	3			54
Belfast Centre	3			57
Cwmbran	2			52
London Wandsworth	2			52
Manchester Piccadilly	2			56
Cardiff Centre	2			53
London Marylebone Rd	1			65

Table 4 - Overall pollution episode summary

Band (index)	Number of days
Very high (index 10)	7
High (index 7-9)	15
Moderate (index 4-6)	25

Figure 1- 24 hour running mean concentrations of PM10 at all sites exceeding HIGH band and above

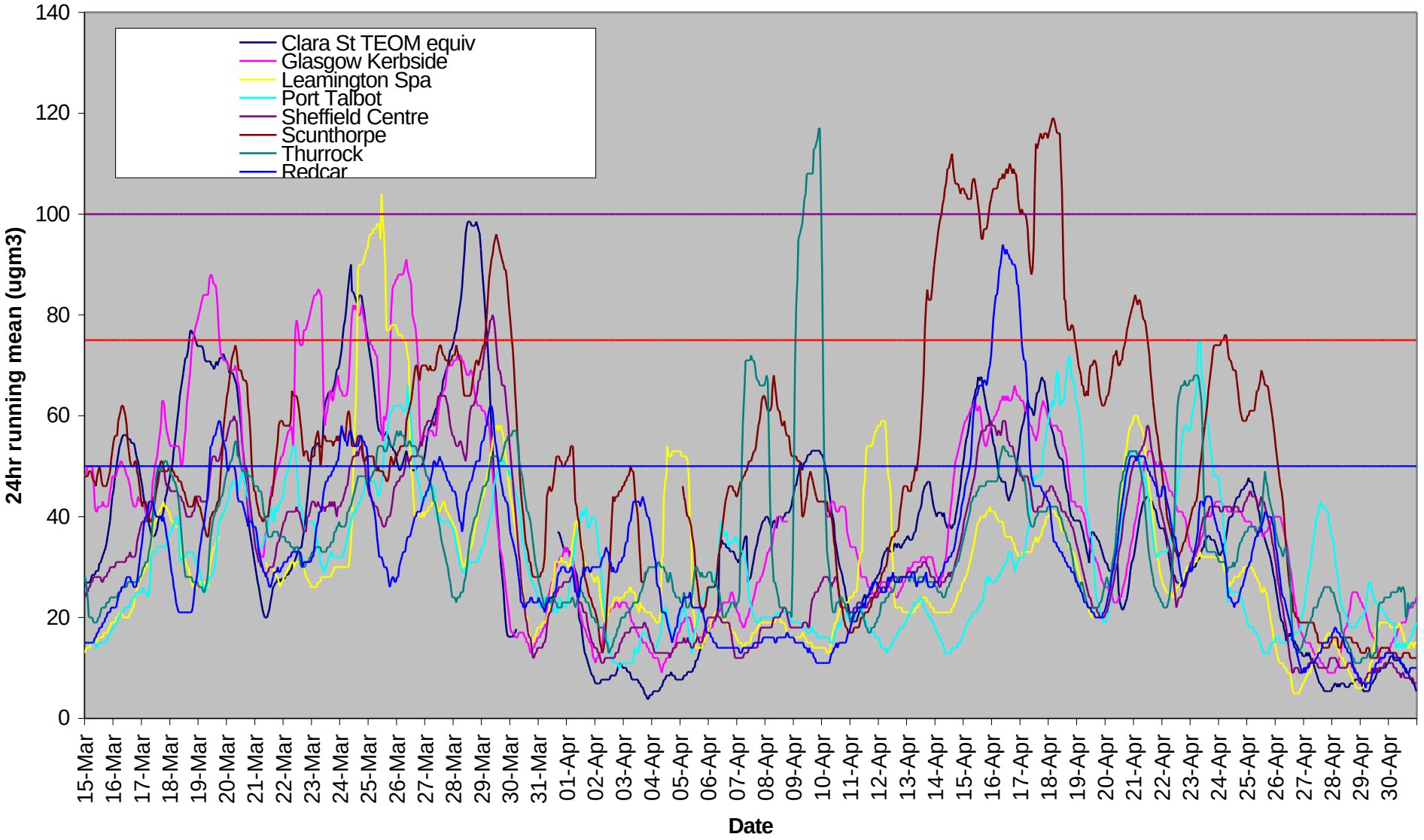

Figure 2 - Hourly mean concentrations of ozone at all sites exceeding HIGH band and above

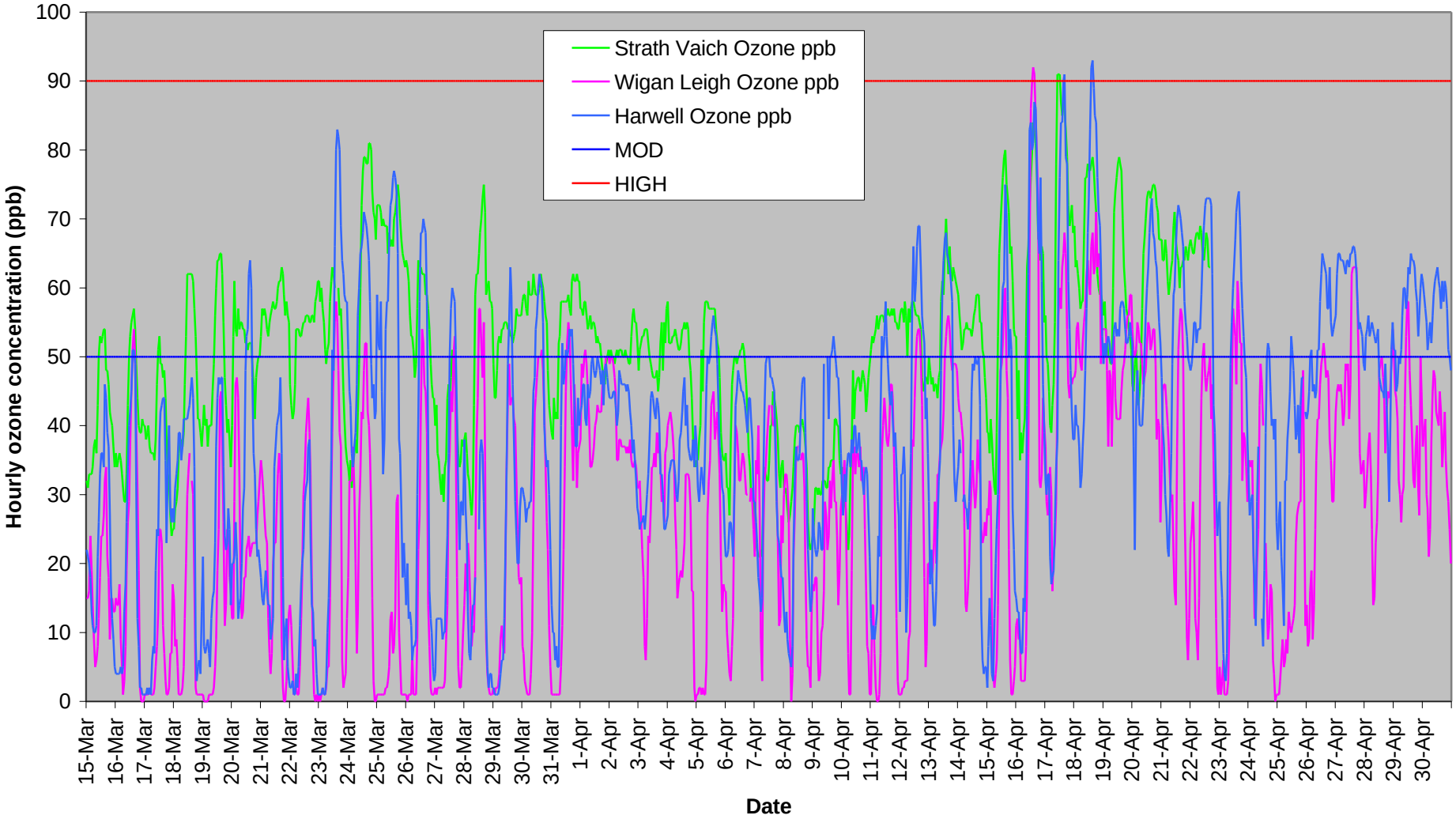

Figure 3 – Four day forecast back trajectories UK, 16th March 2003

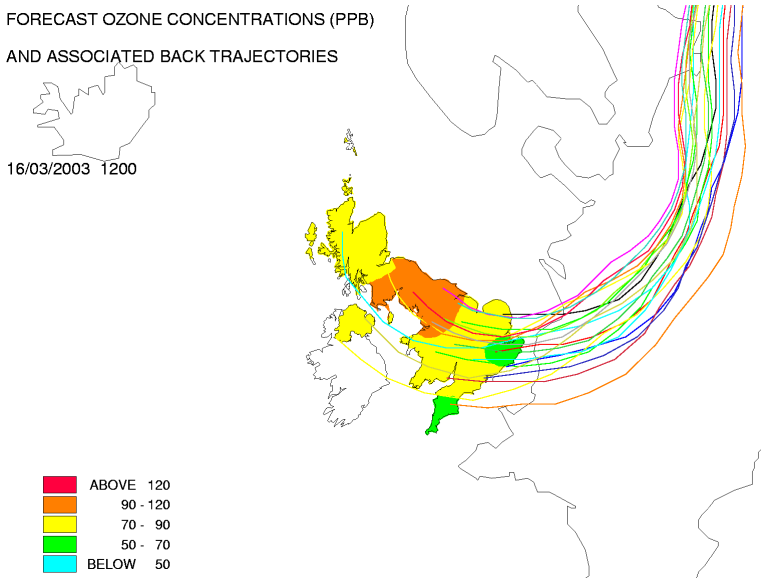

Figure 4 – Four day forecast back trajectories UK, 21st March 2003

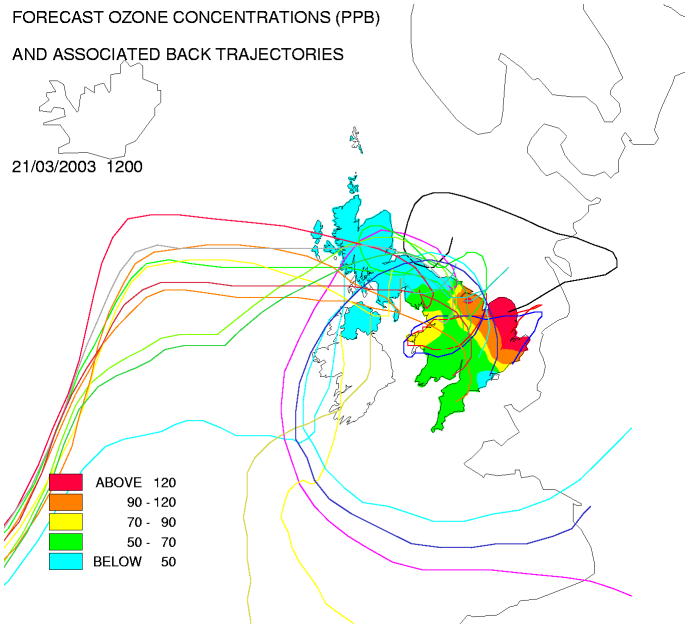

Figure 5 – Four day forecast back trajectories UK, 22nd March 2003

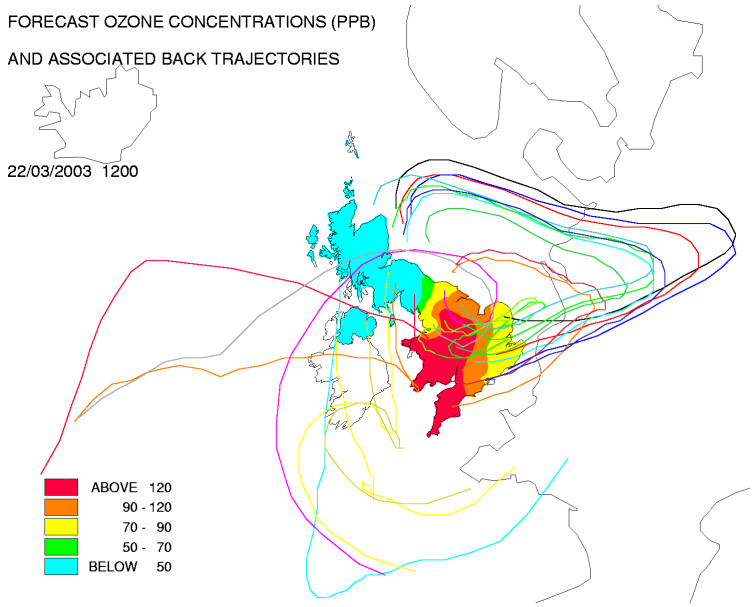

Figure 6 – Four day forecast back trajectories UK, 25th March 2003

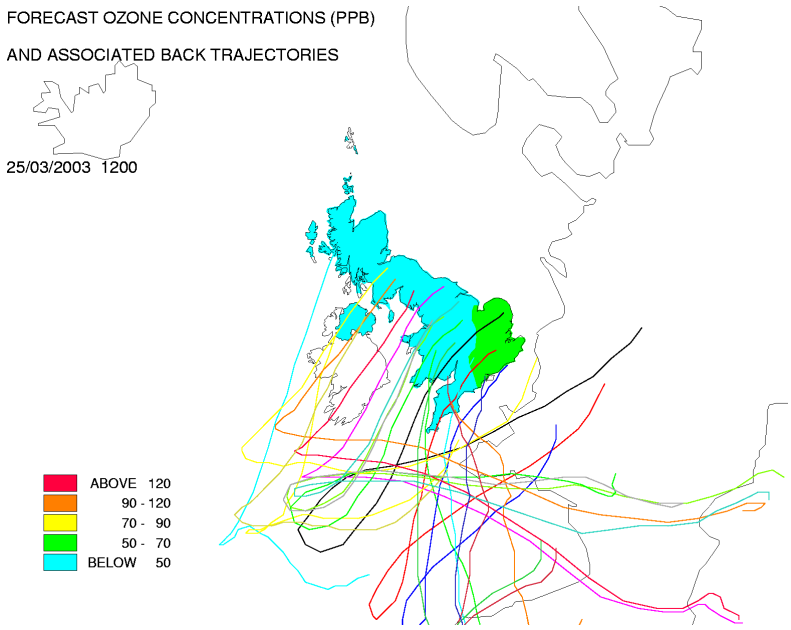

Figure 7 – Four day forecast back trajectories UK, 31st March 2003

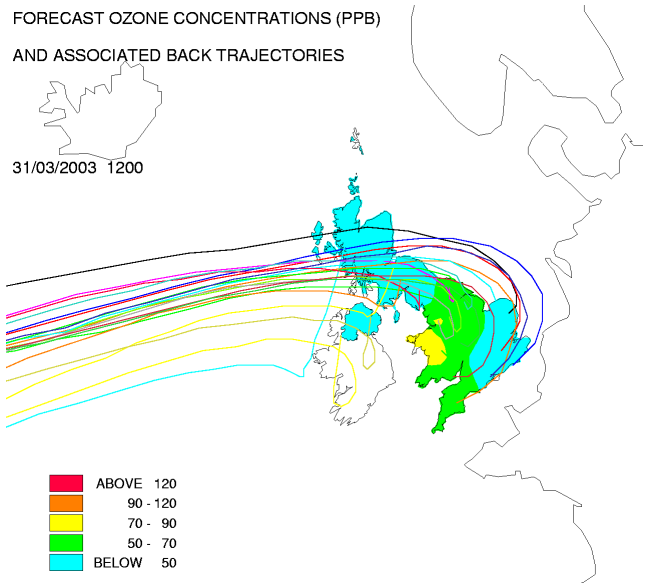

Figure 8 – Four day forecast back trajectories UK, 5th April 2003

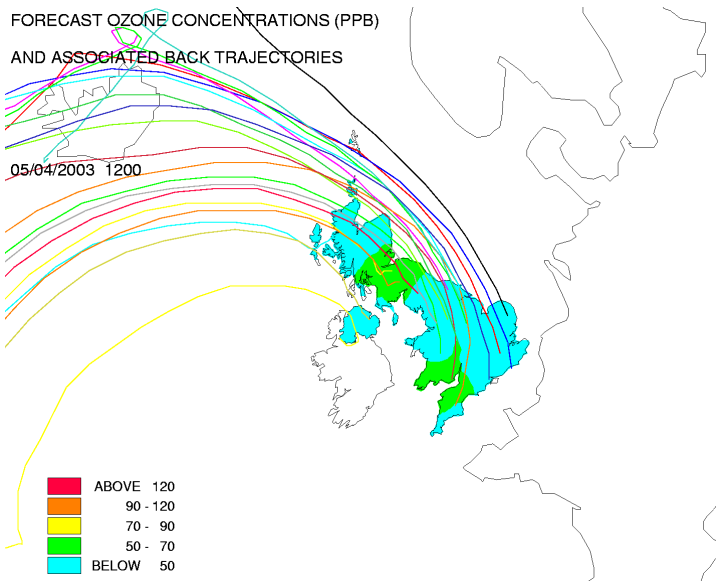

Figure 9 – Four day forecast back trajectories UK, 13th April 2003

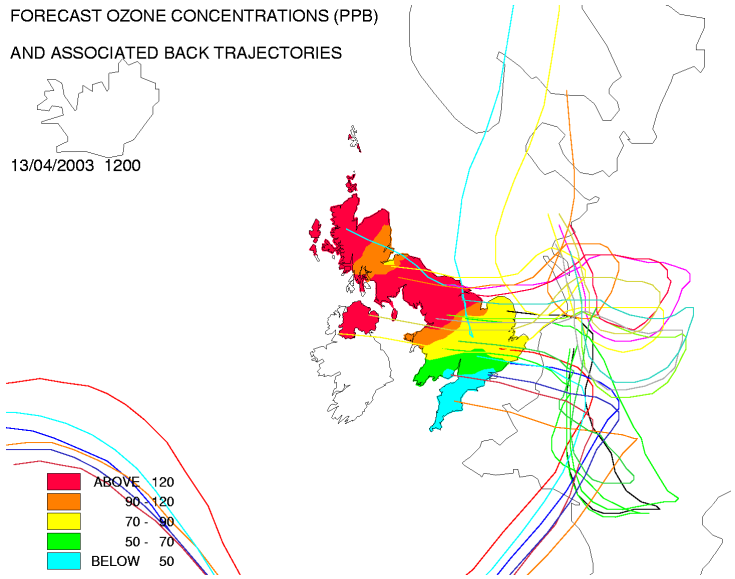

Figure 10 – Four day forecast back trajectories UK, 14th April 2003

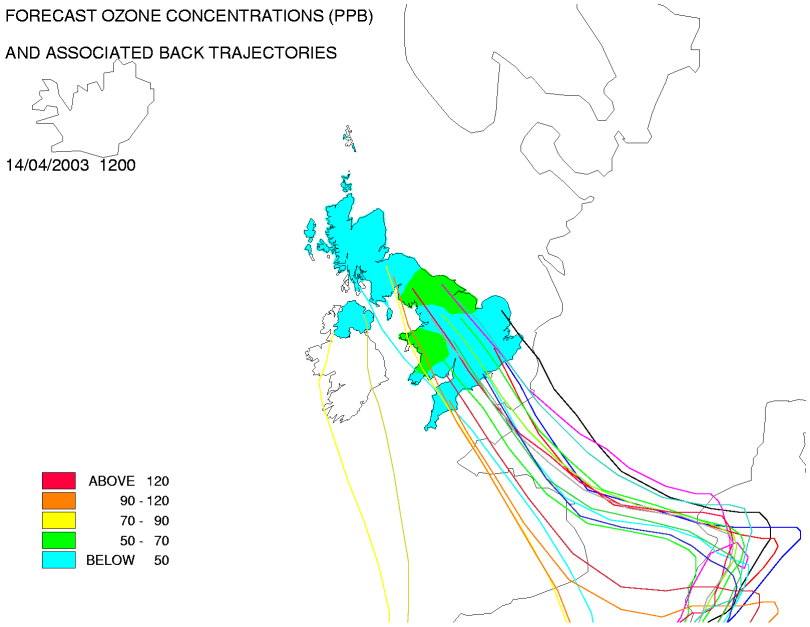

Figure 11 – Four day forecast back trajectories UK, 19th April 2003