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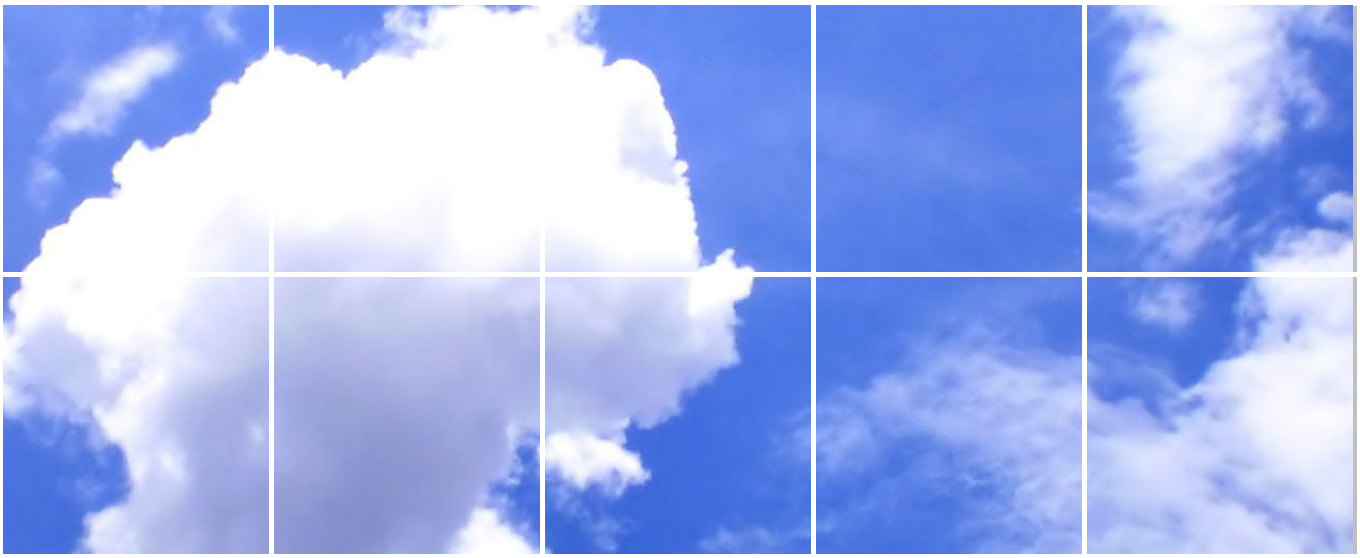

Air Pollution Forecasting

Ozone Pollution Episodes Report (May and July 2008)

Report to Defra and the Devolved Administrations

Unrestricted
AEAT/ENV/R/2730, February 2009
Issue 1.0
February 2009

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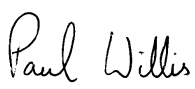
	Signature	
	Date	28/11/08

Executive Summary

This is the most recent in a series of reports for Defra and the Devolved Administrations that describe major UK air pollution episodes.

MODERATE levels of air pollution were measured across the Automatic Urban and Rural Network (AURN) during May and July 2008. During this period, HIGH ozone levels were measured at one station, Hull Freetown, during two distinct episodes.

The first episode was influenced by air masses from Europe; the second was mainly of UK origin; a result of high spring and summer temperatures and still air throughout the UK. Both episodes were accompanied by elevated levels of particulate matter at some sites, probably with a significant component of secondary aerosols due to the weather conditions.

HIGH ozone levels were recorded at the AURN site, Hull Freetown, on two days in May (episode 1) and on one day in July (episode 2). The highest hourly average at Hull Freetown during episode 1 was 194 $\mu g\ m^{-3}$ (index 7) and during episode 2 was 182 $\mu g\ m^{-3}$ (index 7). No other sites recorded HIGH ozone during these periods. The HIGH threshold (also known as the EC Population Information threshold) for ozone is 180 $\mu g\ m^{-3}$ as an hourly mean.

During the May episode 75 sites recorded MODERATE ozone. Forty one of these sites reached index 6 or above on one or more days. The MODERATE threshold for ozone is 100 $\mu g\ m^{-3}$. Sites in Scotland, England, Wales and Northern Ireland were all affected. During the second episode 71 sites recorded MODERATE ozone with 13 of these sites reaching index 6 or above on one or more days.

The EC ozone alert threshold of 240 $\mu g\ m^{-3}$ was not exceeded at any sites.

Main causative factors of the episode are described in detail in this report.

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1 Introduction

Ozone episodes typically occur during spells of warm and sunny weather, as the formation of ozone is dependent on sunshine and high temperatures. Usually these conditions occur in the UK during the summer months when there is a sustained period of high pressure. Ozone is not emitted directly into the atmosphere, rather it is a secondary pollutant formed through the photochemical reaction of volatile organic compounds in the presence of oxides of nitrogen. Due to the nature of formation of ozone, pollution episodes tend to be on the regional or national scale.

The UK is prone to long periods of MODERATE ozone pollution during the summer months, but during two periods in 2008, HIGH levels were recorded at Hull Freetown, where hourly ozone concentrations exceeded the EC Population Information threshold of 180µg m^{-3} on three separate occasions. No other sites exceeded this threshold, although a similar trend was seen at several other AURN sites.

It should be noted that the July 2008 data is provisional at the time of writing this report.

This report provides comprehensive information on:

- Defining the episodes (Section 2)
- Air quality monitoring (Section 3)
- Air quality forecasting (Section 4)
- Reasons for the ozone episodes (Section 5)
- Other pollutants measured during the episodes (Section 6)

2 Defining the Episodes

During late spring and summer 2008, ozone concentrations over much of the UK were MODERATE (index 4 to index 6). MODERATE ozone concentrations are not uncommon during prolonged periods of sunshine and high temperatures. However, in May and July 2008, index 6 concentrations were recorded widely across England, Scotland, Wales and Northern Ireland. Additionally, for a short period of time North East England measured HIGH ozone (index 7). These periods of HIGH ozone concentrations are used to define the episodes, which are:

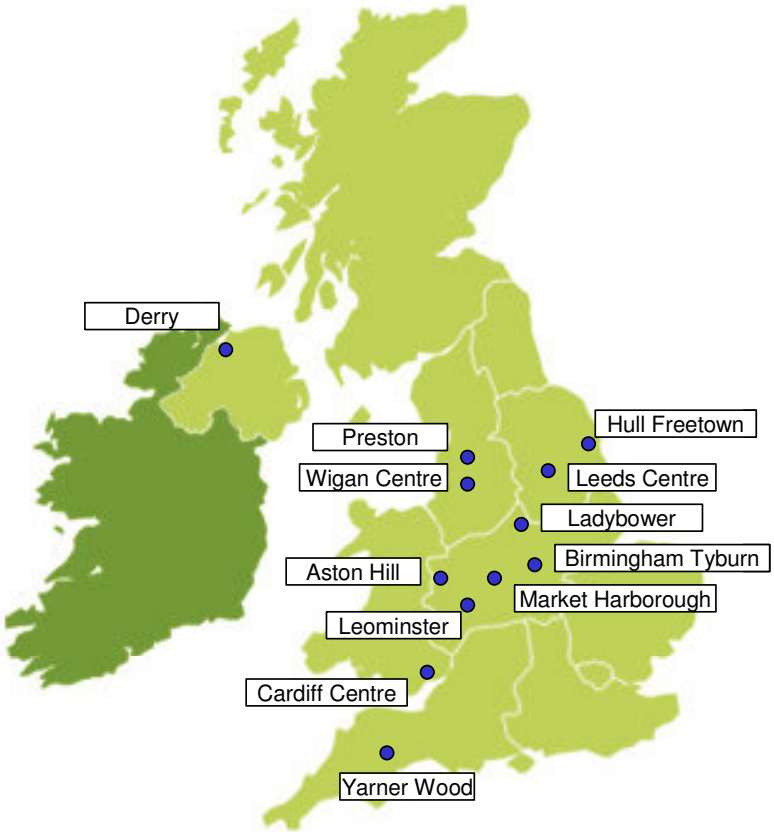
Episode 1 6th – 12th May 2008 (HIGH ozone measured on 09/05/08 and 11/05/08)

Episode 2 23rd – 31st July 2008 (HIGH ozone measured on 27/07/08)

Both of these time periods include some time before and after the peak concentrations were measured.

Figure 2.1 shows the geographical locations of the monitoring stations measuring the twelve highest levels across the UK. It should be noted that both episodes affected much of the UK, although it was only at Hull Freetown that HIGH concentrations were recorded.

Figure 2.1 Geographical locations of the highest ozone concentrations recorded



3 Air Quality Measurements

3.1 Summary

During the episodes there were 79 sites monitoring ozone in the Automatic Urban and Rural Network. There were no periods of significant data loss and average data capture was provisionally 95.6% for May to July 2008.

HIGH ozone levels were recorded at Hull Freetown, on two days in May and on one day in July. The highest hourly average at Hull Freetown during episode 1 was 194 μg m^{-3} (index 7) and during episode 2 was 182 μg m^{-3} (index 7). The HIGH threshold for ozone is 180 μg m^{-3}. No other sites recorded HIGH ozone during these periods.

During the May episode 75 sites recorded MODERATE ozone. 41 of these sites reached index 6 or above on one or more days. The MODERATE threshold for ozone is 100 μg m^{-3} as the maximum of the hourly mean and 8-hourly running mean. Sites in Scotland, England, Wales and Northern Ireland were all affected. During the second episode 71 sites recorded MODERATE ozone with 13 of these sites reaching index 6 or above on one or more days.

3.2 Moderate and High Ozone Levels

Table 3.1 and table 3.2 show the number of days of MODERATE and HIGH levels of ozone at each station across the AURN during episode 1 and episode 2, respectively.

Table 3.1. Number of days of Moderate and High levels at each station across the AURN during Episode 1 (6th – 12th May)

Site	Number of Days		Maximum hourly mean (µg m^{-3})
	High	Moderate	
Hull Freetown	2	5	194
Aston Hill	0	7	174
Ladybower	0	7	170
Market Harborough	0	7	170
Cwmbran	0	7	168
London Teddington	0	7	166
Northampton	0	7	164
Bottesford	0	7	162
Coventry Memorial Park	0	7	162
Wicken Fen	0	7	162
Leicester Centre	0	7	160
London Eltham	0	7	160
Norwich Centre	0	7	160
Sibton	0	7	160
London Haringey	0	7	158
Bournemouth	0	7	156
Eskdalemuir	0	7	156
Great Dun Fell	0	7	156
Southend-on-Sea	0	7	150
St Osyth	0	7	150
Lullington Heath	0	7	146
Portsmouth	0	7	144
Weybourne	0	7	142
Auchencorth Moss	0	7	140
London Harlington	0	7	138
Bush Estate	0	7	136
London N. Kensington	0	7	136
Edinburgh St Leonards	0	7	128
Thurrock	0	7	126
Aberdeen	0	7	122
Cardiff Centre	0	6	176
Wigan Centre	0	6	176
Birmingham Tyburn	0	6	174
Leominster	0	6	174
Yarner Wood	0	6	174
Leeds Centre	0	6	170
Preston	0	6	170
Sandwell West Bromwich	0	6	168
Leamington Spa	0	6	162
Port Talbot Margam	0	6	162
Exeter Roadside	0	6	160
Bristol St Paul's	0	6	158
Strath Vaich	0	6	158
Blackpool Marton	0	6	156
London Hillingdon	0	6	156

Nottingham Centre	0	6	156
Reading New Town	0	6	156
Stoke-on-Trent Centre	0	6	156
Harwell	0	6	152
Liverpool Speke	0	6	150
Narberth	0	6	148
Derry	0	5	172
Bolton	0	5	166
Birmingham Centre	0	5	160
Barnsley Gawber	0	5	156
Fort William	0	5	152
Lerwick	0	5	146
Wirral Tranmere	0	5	144
Mace Head	0	5	136
Newcastle Centre	0	5	134
Gibraltar Bleak House	0	5	126
Rochester Stoke	0	5	122
Sunderland Silksworth	0	5	120
Manchester Piccadilly	0	4	158
Lough Navar	0	4	138
Middlesbrough	0	4	136
Glazebury	0	3	148
Sheffield Centre	0	3	138
London Westminster	0	3	130
Plymouth Centre	0	3	116
Manchester South	0	2	138
Glasgow Centre	0	2	118
High Muffles	0	1	126
London Marylebone Road	0	1	112
London Bloomsbury	0	1	100
Southampton Centre	0	0	96
Salford Eccles	0	0	80
Belfast Centre	no data		
Brighton Preston Park	no data		

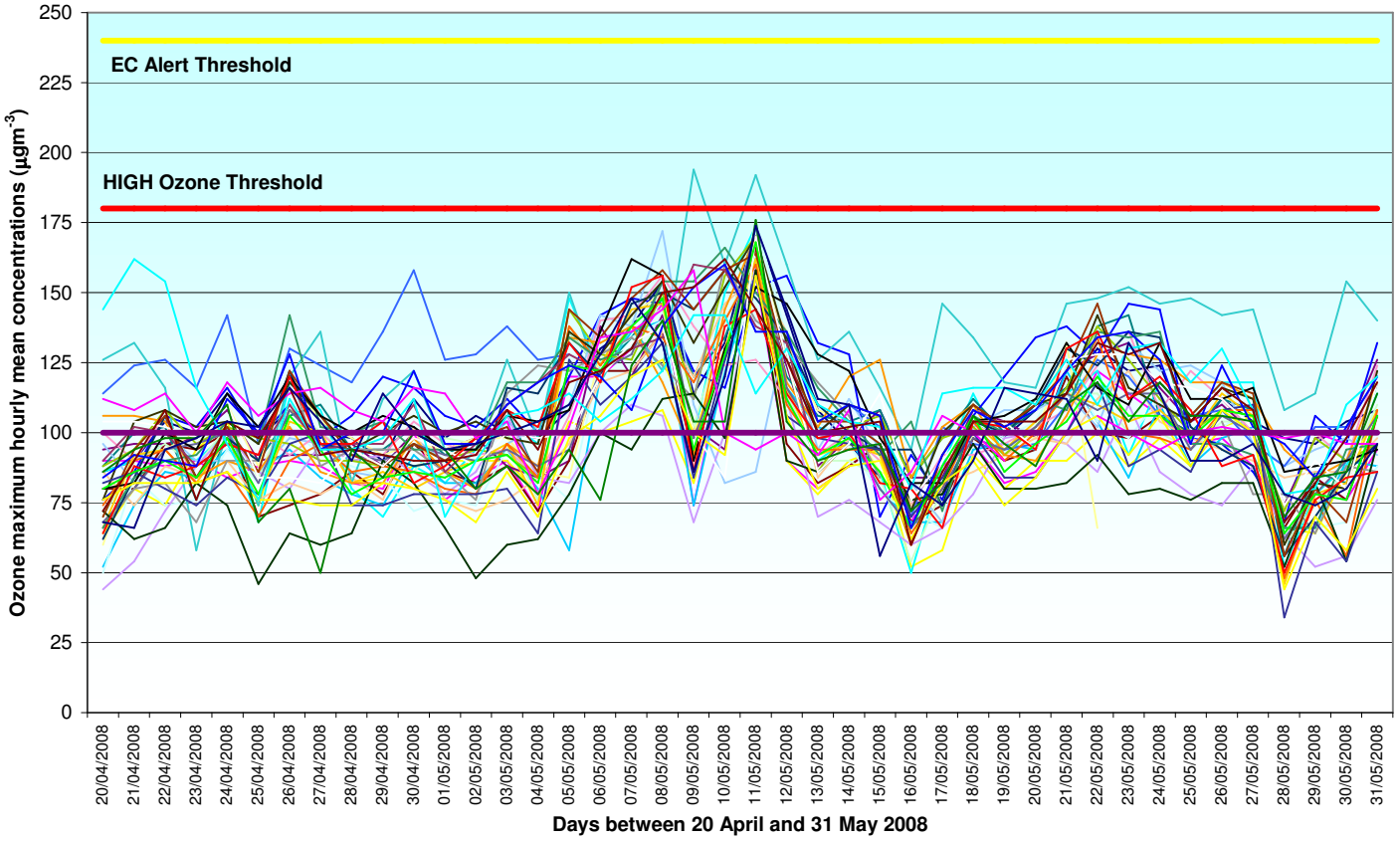
Table 3.2. Number of days of Moderate and High levels at each station across the AURN during Episode 2 (23rd – 31st July)

Site	Number of Days		Maximum hourly mean (µg m^{-3}) *provisional*
	High	Moderate	
Hull Freetown	1	7	182
Southend-on-Sea	0	8	158
Yarner Wood	0	7	172
Sibton	0	7	166
Weybourne	0	7	158
Wicken Fen	0	7	158
Brighton Preston Park	0	6	166
Lullington Heath	0	6	164
Thurrock	0	6	162
London Teddington	0	6	160
London Haringey	0	6	158
Sandwell West Bromwich	0	6	154
London N. Kensington	0	6	152
Market Harborough	0	6	152
Bottesford	0	6	146
Leicester Centre	0	6	142
Portsmouth	0	6	142
Strath Vaich	0	6	140
Rochester Stoke	0	6	134
Lerwick	0	6	112
London Eltham	0	5	156
Bournemouth	0	5	150
Coventry Memorial Park	0	5	142
Birmingham Tyburn	0	5	132
Leeds Centre	0	4	152
Ladybower	0	4	146
Narberth	0	4	144
Wigan Centre	0	4	144
Eskdalemuir	0	4	138
Harwell	0	4	138
London Hillingdon	0	4	138
Barnsley Gawber	0	4	134
Middlesbrough	0	4	132
Birmingham Centre	0	4	130
Bristol St Paul's	0	4	126
Auchencorth Moss	0	4	116
Manchester South	0	4	110
Reading New Town	0	3	150
Leominster	0	3	140
London Westminster	0	3	140
Glazebury	0	3	138
London Harlington	0	3	134
Nottingham Centre	0	3	134
Northampton	0	3	132
Cwmbran	0	3	128

Fort William	0	3	126
London Bloomsbury	0	3	124
Liverpool Speke	0	3	118
Great Dun Fell	0	3	114
Exeter Roadside	0	3	110
Edinburgh St Leonards	0	3	106
Preston	0	2	138
Cardiff Centre	0	2	136
Wirral Tranmere	0	2	136
Blackpool Marton	0	2	128
Mace Head	0	2	122
Bush Estate	0	2	118
Plymouth Centre	0	2	114
Stoke-on-Trent Centre	0	2	114
Gibraltar Bleak House	0	2	110
Sheffield Centre	0	2	108
Sunderland Silksworth	0	2	108
Newcastle Centre	0	1	122
Manchester Piccadilly	0	1	114
Port Talbot Margam	0	1	112
Aberdeen	0	1	108
Lough Navar	0	1	108
Derry	0	1	104
High Muffles	0	1	104
St Osyth	0	1	102
Southampton Centre	0	1	100
Salford Eccles	0	0	98
Belfast Centre	0	0	90
Glasgow Centre	0	0	82
London Marylebone Road	0	0	76
Aston Hill	No data		
Leamington Spa	No data		

Figure 3.1 shows daily maximum hourly ozone recorded on each day during episode 1, and the days surrounding it, at the 41 sites that reached or exceeded ozone pollution index 6 (153µg m^{-3}).

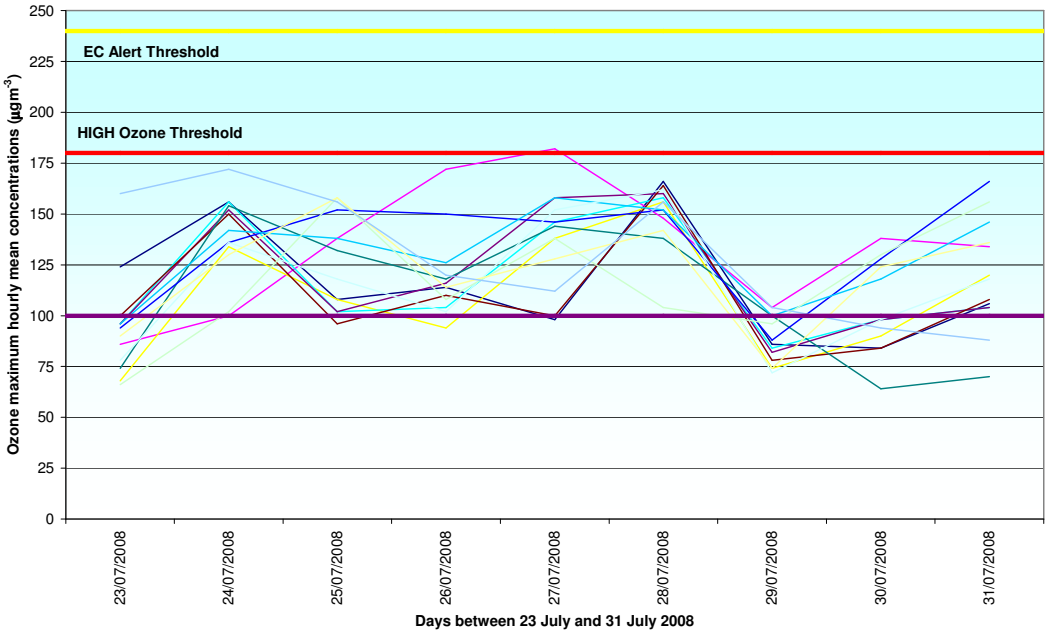
Figure 3.1. Ozone daily maximum hourly mean concentration (µg m^{-3}) for selected AURN stations measuring elevated levels during Episode 1.



The EC alert threshold is 240µg m^{-3} as an hourly average, except in the case of action plans, when the threshold is 240µg m^{-3} as an hourly average to be exceeded in three consecutive hours.
The HIGH ozone threshold is the same as the ozone information threshold, 180 µg m^{-3} . The MODERATE ozone threshold is 100 µg m^{-3}

Figure 3.2 shows daily maximum hourly ozone recorded on each day during episode 2, and the days surrounding it, at the 13 sites that reached or exceeded ozone pollution index 6 (153µg m^{-3}). The pink line is Hull Freetown, which just reached 182 µg m^{-3} (provisional data) on the 27th July 2008.

Figure 3.2. Ozone daily maximum hourly mean concentration (µg m^{-3}) during Episode 2 for selected AURN stations measuring elevated levels.



3.3 Hull Freetown Hourly Concentrations

Figure 3.3 shows the hourly ozone data collected from the Hull Freetown site during the first episode in May 2008. The EC alert threshold is not exceeded at any time, and the information threshold (HIGH threshold) of 180µg m^{-3} is only exceeded during one hour beginning 16:00 on the 9th May 2008 and during three consecutive hours beginning 12:00 on the 11th May 2008.

Figure 3.3. Ozone hourly mean concentration (µg m^{-3}) at Hull Freetown during Episode 1

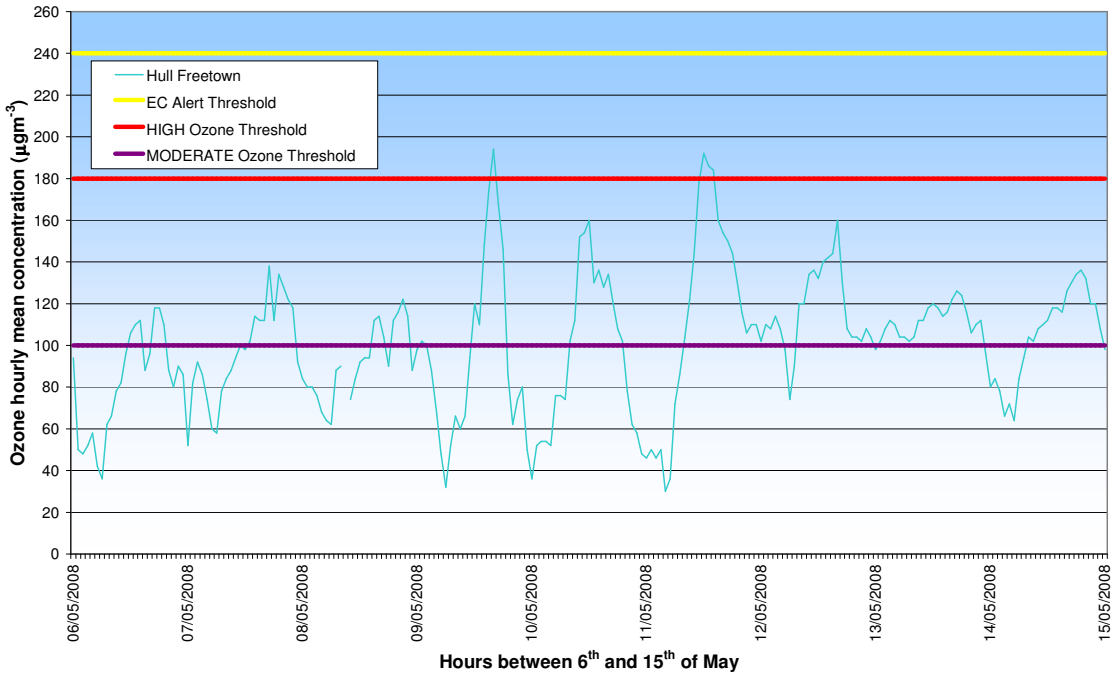
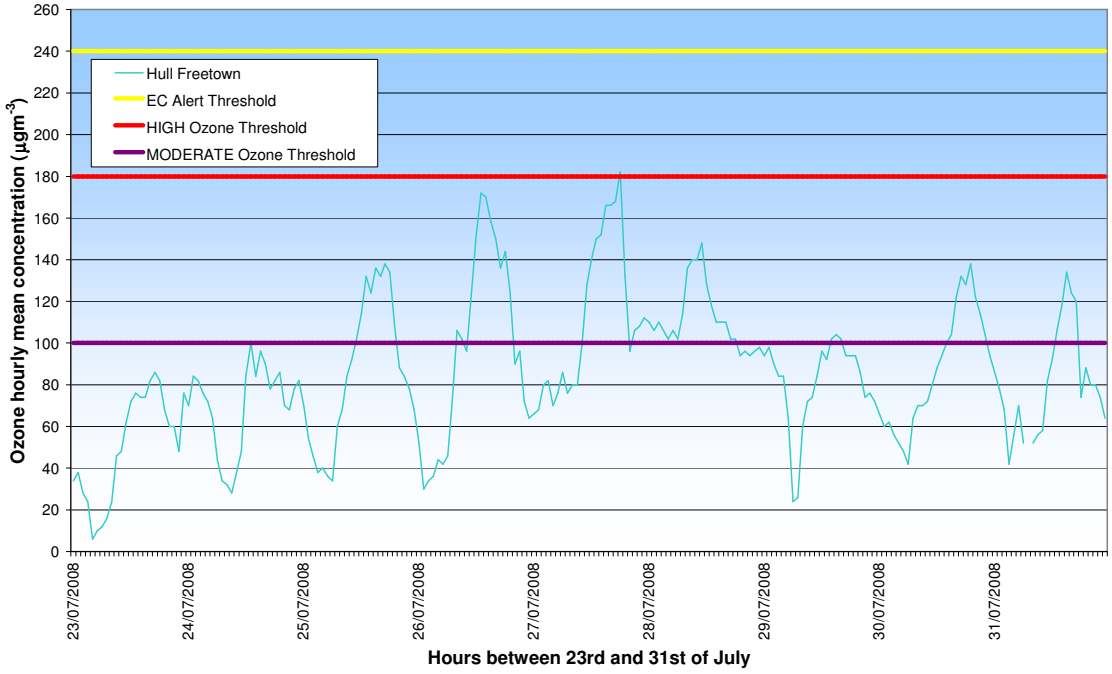


Figure 3.4 shows the hourly data collected from the Hull Freetown site during the second episode in July 2008. The EC alert threshold is not exceeded at any time, and the information threshold (HIGH threshold) of 180µg m^{-3} is only exceeded during one hour beginning 18:00 on the 27th July 2008.

Figure 3.4. Ozone hourly mean concentration (µg m^{-3}) at Hull Freetown during Episode 2



These data are provisional at the time of writing this report

3.4 Historical AURN Ozone Maxima

Compared to hourly measurements made since 1973, the peak ozone levels measured at the AURN network during the two episodes in May and July 2008 are relatively low. This is consistent with the fact that Summer 2008 experienced generally unsettled weather, with higher than average rainfall. Table 3.3 summarises ozone hourly maximum data across the AURN since 1973.

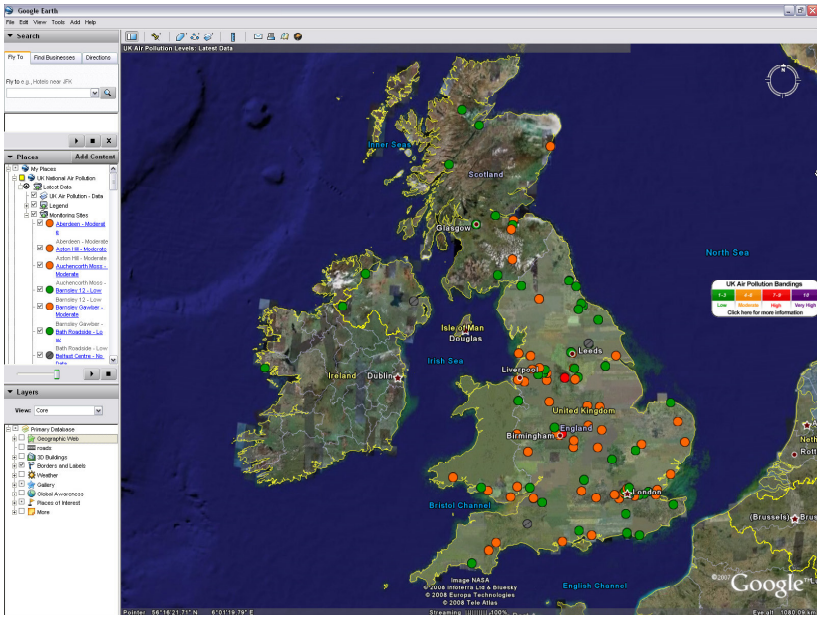
Table 3.3. Maximum Ozone Hour mean across the AURN since 1973

Year	Site	Country	Site type	Hourly Max µg m-3	Data Capture
1973	Central London	England	URBAN BACKGROUND	272	95.5
1974	Central London	England	URBAN BACKGROUND	328	90.8
1975	Central London	England	URBAN BACKGROUND	184	88.9
1976	Central London	England	URBAN BACKGROUND	288	78.1
1977	London Islington	England	URBAN BACKGROUND	254	87.8
1978	Central London	England	URBAN BACKGROUND	298	81.6
1979	Stevenage	England	SUBURBAN	216	86.2
1980	Stevenage	England	SUBURBAN	168	90.6
1981	Sibton	England	REMOTE	414	78.1
1982	Stevenage	England	SUBURBAN	328	81.1
1983	Stevenage	England	SUBURBAN	336	76.2
1984	Stevenage	England	SUBURBAN	348	95.6
1985	Central London	England	URBAN BACKGROUND	298	87.2
1986	Harwell	England	RURAL	274	92.7
1987	Harwell	England	RURAL	214	82
1988	Yarner Wood	England	RURAL	218	94.7
1989	Lullington Heath	England	RURAL	272	95.7
1990	Lullington Heath	England	RURAL	322	89.8
1991	Yarner Wood	England	RURAL	252	98.4
1992	Great Dun Fell	England	REMOTE	282	98.4
1993	Stevenage	England	SUBURBAN	266	98.2
1994	Sibton	England	REMOTE	254	95.6
1995	Lullington Heath	England	RURAL	268	95.5
1996	Sibton	England	REMOTE	242	92.7
1997	Leamington Spa	England	URBAN BACKGROUND	232	95.8
1998	Rochester	England	RURAL	240	93.3
1999	Barnsley Gawber	England	URBAN BACKGROUND	248	95.6
2000	Barnsley Gawber	England	URBAN BACKGROUND	206	96.5
2001	Birmingham East	England	URBAN BACKGROUND	214	97.9
2002	Sibton	England	REMOTE	218	99.1
2003	Middlesbrough	England	URBAN INDUSTRIAL	280	94.9
2004	Sibton	England	REMOTE	212	96.3
2005	Portsmouth	England	URBAN BACKGROUND	204	99.2
2006	Wicken Fen	England	RURAL	278	99.3
2007	Blackpool Marton	England	URBAN BACKGROUND	168	98.0

3.5 Real-time Data Displays

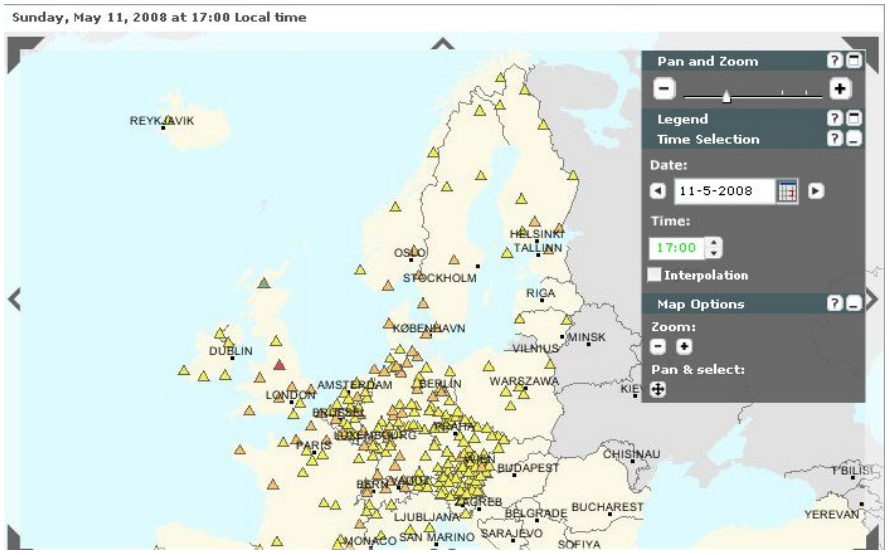
During the 2008 ozone pollution episodes a number of new enhanced publicly accessible data displays were available for the first time - UK data on Google Earth and European-wide data on the EEA OzoneWeb, - shown below in Figure 3.5 and Figure 3.6 to illustrate the extent of elevated concentrations during Episode 1.

Figure 3.5 Real-time Google Earth™ display for 10 May 2008



Source: www.airquality.co.uk

Figure 3.6 Ozone levels on the European Environment Agency website on 11 May 2008



Source: www.eea.europa.eu/maps/ozone

4 Air Quality Forecasting

Daily air quality forecasting continued as usual during May and July 2008. The twice-weekly air pollution forecast emails were delivered on schedule and are detailed in tables 4.1 to 4.8. The HIGH levels experienced in the first episode were forecast in advance and a warning sent to the relevant people on the 9th May.

Table 4.1 Air quality forecasting email on 2nd May

From: Paul Willis To: Air Quality Forecast Recipients Subject: Air pollution Forecast for Friday May 2nd to Tuesday May 6th	02/05/2008 15:10

Dear Colleagues,

Sunshine and showers (some heavy and thundery) are expected to continue throughout the weekend, with clean westerly air influencing the UK. However, it is expected to become warmer with temperatures up to 20 degrees in south-east , and by early next week a building area of high pressure will turn the incident air for the UK and Ireland around to an easterly direction.
Moderate air pollution is expected to continue at index 4 in rural and suburban areas - due to increased seasonal background ozone. In town and city centres where NOx emissions scavenge the ozone, air pollution is expected to remain low at index 1-3.
As temperatures rise and the air moves round to a more southerly and then easterly direction, approaching the UK from across France and Spain,this may bring a risk of further increases in Moderate levels of ozone and PM10 particualte matter later in the Bank Holiday weekend.

Paul Willis
AEA

Table 4.2 Air quality forecasting email on 6th May

From: Jaume Targa To: Air Quality Forecast Recipients Subject: Air Pollution Forecast for Tuesday 6th to Friday May 9th	06/05/2008 15:44

Dear colleagues,

The high pressure system situated between the UK and Scandinavia will continue through the week. This will keep the UK with warmer temperatures reaching a maximum of 22 degrees on Thursday.

Air mass back trajectories arriving over the UK will have re-circulated over the Continent bringing a nice cocktail of pollutants and ozone precursors.

Although, this could be seen as a typical situation for an ozone episode, the slight windy conditions and maximum temperatures only reaching up to 22 degrees will result in levels approaching up to **MODERATE levels (Index 5 - 6).** If temperatures go above 23-24 degrees, we might see some stations rural stations reaching high levels for small periods of time. HOWEVER, this is unlikely...

PM10 and NO2 levels might reach moderate levels due to a combination of local pollution and continental contribution.

Ozone will reach moderate levels (index 5 and 6), specially at rural and remote sites. Urban background sites will remain index 4-5.

Yours,

Jaume Targa

Table 4.3 Air quality forecasting email on 9th May	
From: Jaume Targa To: Air Quality Forecast Recipients Subject: HIGH episode - Air Pollution Forecast for Friday 9th to Monday May 12th	09/05/2008 09:56

Dear Colleagues,

The first HIGH ozone episode is likely to be today and continue over the weekend!

The High pressure system over Denmark is bringing sunny and warm weather over England and Scotland. Maximum temperatures are likely to reach 26 degrees over the South East, 22-23 degrees over the Midlands and 21 degrees over Scotland. This is likely to continue until Monday.

During the past 2-3 days, we have been experiencing moderate (index 5-6) levels across the UK. As weather conditions remain stable and become warmer, we are likely to be reaching HIGH levels (index 7) of air pollution due ground level ozone.

Air masses backtrajectories re-circulating over the continent will be approaching the UK bringing less clean air with PM, NO2 and ozone precursors. This coupled with UK own emissions, warmer temperatures and long hours of sunshine will result in the first High ozone episode in the UK.

The likely areas affected over today and the weekend are:

Friday - High levels over England and south Scotland (Index 7)

Saturday - High levels over England and Wales (less likely over Scotland) (Index 7)

Sunday - High levels over England and Wales (Index 7)

Monday - High levels over England, Wales and Northern Ireland (Index 7)

Best regards,

Jaume Targa
AEA

Table 4.4 Air quality forecasting email on 13th May	
From: Michael Harfoot To: Air Quality Forecast Recipients Subject: Air pollution forecast for Tuesday 13th to Friday 16th May	13/05/2008 12:09

Dear colleagues,

The UK experienced an ozone event over the weekend. Sites that reported high air pollution index values for the 24 hour period from Sunday to Monday morning were:

Glazebury
Wigan Centre
Hull Freetown
Ladybower
Cwbran
Birmingham Tyburn

For the coming few days temperatures across the UK will fall and incident air masses will originate from the North Sea and Scandinavia, transporting lower ozone precursor compounds than the air masses encountered over the weekend from Northern and Eastern Europe. As a result, the ozone event has receded and as the week progresses air pollution levels will fall to low levels across Scotland, Ireland, Northern England and Wales. Parts of South Eastern England may continue to experience moderate air pollution from ground level ozone.

Best regards,

Mike Harfoot

After ratification of this provisional data, only Hull Freetown remained in the high air pollution bracket for ozone.

Table 4.5 Air quality forecasting email sent on 23rd July

From: Paul Willis To: Air Quality Forecast Recipients Subject: Air pollution forecast for Tuesday July 22nd to Friday July 26th, 2008	23/07/2008 09:36

Dear colleagues,

High pressure will build over the southern UK bringing warmer settled weather for the rest of the week. Temperatures may reach 30 degrees in the south east by Friday.
Air masses will move from a northerly to easterly continental direction by Thursday, bringing the likelihood of Moderate air pollution later in the week, possibly even high due to ozone if the weather forecast holds.

Paul Willis
AEA

Table 4.6 Air quality forecasting email sent on 25th July

From: Paul Willis To: Air Quality Forecast Recipients Subject: Air Pollution Forecast for Friday July 25th to Monday July 28th	25/07/2008 12:30

Dear Colleagues,

It is expected to become fresher with showers across the south-west of England today, but remaining very warm elsewhere across the UK. Showers, perhaps thundery, may crop up across all areas of the UK during the afternoon.
For the eastern part of the UK air masses will still be passing across northern Europe before reaching us on Friday, and this is likely to maintain moderate levels of air pollution due to ozone at index 5 or 6. Due to the showers and more cloudy conditions it now looks unlikely that concentrations will reach index 7 (High) in any areas.
Across the rest of the weekend it will remain warm with some showers and light winds in the south of England. Some long-range transport of pollutants to the UK from Europe is likely to continue and thus air pollution due to ground-level ozone is likely to continue to remain Moderate throughout.
Concentrations of PM10 particulate matter may also reach Moderate at index 4 or 5 near to roads or industrial locations today, decreasing to Low again over the weekend.

Paul Willis
AEA

Table 4.7 Air quality forecasting email sent on 28th July

From: Paul Willis To: Air Quality Forecast Recipients Subject: Air Pollution over the weekend	28/07/2008 09:29

Dear All,

Ozone concentrations remained Moderate at Index 5 or 6 (as forecast) for most of the network sites, including some of those in Scotland where it was also warm!
One site - Hull Freetown, recorded a "High" concentration of 180 ug/m3 at index 7 for just one hour yesterday. This isn't consistent with what was measured elsewhere in the region so it will be interesting to see the results of next weeks' QA/QC visit - which should tell us if that instrument is over-reading.
Similar levels of ozone are expected again today, with a forecast of thunderstorms spreading across southern England from the south-west later.
Mike Harfoot and Rachel are the forecasters for this week.
Please let me know if you need any further information.
Best wishes,
Paul

The data for the July episode is currently provisional, however, the data in figure 3.2 indicate that several other AURN stations measured elevated ozone concentrations during this period. Furthermore, the hourly data time series for Hull Freetown shown in figure 3.4 does not indicate an instrument malfunction. This exceedence will be confirmed following ratification of the data.

Table 4.8 Air quality forecasting email sent on 29th July

From: Michael Harfoot To: Air Quality Forecast Recipients Subject: Air Quality Forecast Tuesday 29th July to Friday 1st August	29/07/2008 11:43

Dear colleagues,

This week's weather will be dominated by an Atlantic low pressure system that is forecast to persist off the West coast of Ireland. This system will be variable conditions to the UK with some heavy rainfall and cloudiness in amongst sunny spells. Daytime temperatures should remain in the high teens and twenties but windspeeds, which are set to be fair with strong gusts today and tomorrow, will drop as the week progresses.

The wind direction will remain mostly south westerly, bringing largely clean Atlantic air masses to the UK. As a result air pollution is likely to be lowest in the south west of the UK, although moderate levels of ground level ozone may still be encountered here as it forms by reaction in the warm and sometimes sunny conditions. Across northern and eastern parts of England and Scotland, air pollution is expected to be greater, again mostly as a result of ground level ozone, however, it is unlikely that high index values will be encountered. Air pollution index values for nitrogen dioxide and PM10 are forecast to be low across the whole of the UK.

Many thanks,

Mike

5 Reasons for the Episodes

As reported by Targa (2004, 2005 and 2006) and Kent (2003), summer ozone episodes over the UK are usually characterised by high temperatures and air masses re-circulating over northern Europe and the UK. These conditions typically result in summer smog episodes as the ozone precursor chemicals react in the presence of sunlight and high temperatures. The same is true of the two episodes discussed in this report, in May and July 2008.

5.1 Temperature

May 2008 was uncharacteristically warm, with temperatures in England on average 2.4°C higher than normal. July was also warmer than usual, but to a lesser extent. Both months experienced about 5% more sunshine than average. Table 5.1 below shows the monthly weather summaries produced by the Met Office for May and July.

Table 5.1 – Monthly weather summaries for May and July 2008 (Met Office)

May	July
Mean temperatures generally 2 to 3 °C above average, but only 1 to 2 °C above average across eastern parts of Scotland and NE England. Provisionally, the warmest May in the series back to 1914 for the UK, Scotland and Northern Ireland. Rainfall well above average across southern areas of England and Wales, but below average across central and northern areas of the UK. Sunshine ranging from below average across south-western areas of the UK to well above average across northern areas of Scotland. Great Malvern (Worcestershire) recorded a maximum temperature of 27.5 °C on the 11th. Kinbrace (Highland) recorded a temperature of -6.2 ºC on the 19th. Manston (Kent) recorded 121.4 mm during the 4-day period between 24th and 27th.	Mean temperatures ranged from close to average across SW England and S Wales to over 1 °C above average across Scotland. Rainfall was generally above or well above average across Northern Ireland, England and Wales, but close to average across East Anglia. Rainfall over Scotland ranged from below average across the north-west to above average across the south-east. Sunshine was generally close to average across the UK. Cambridge NIAB (Cambridgeshire) recorded a maximum temperature of 30.2 °C on the 28th. Katesbridge (County Down) recorded a minimum temperature of 0.8 °C on the 13th. Pershore College (Worcestershire) recorded 59.0 mm in the 24-hour period ending 0900 UTC on the 29th (including an hourly total of 28.8 mm in the hour ending 0000 UTC on the 29th).

Source: http://www.meto.gov.uk/climate/uk/2008/index.html

Globally, May 2008 was the eighth warmest on record. Temperatures in Europe were up to 3°C higher than average, with the exception only of Spain and Portugal. Similarly, much of Europe experienced above average temperatures in July, and globally this month was the fifth warmest July since records began.

Table 5.2 – Weather weekly assessments during ozone episodes from the Met Office
Episode 1: 6th – 12th May
1st to 8th May: Low pressure over the north of the UK on the 1st with some heavy and thundery showers in the south. A ridge of high pressure then extended across the North Sea and covered much of the UK. Clear skies in the south led to a cool night on the 2nd/3rd, with Benson (Oxfordshire) recording a minimum temperature of 3.2 °C. A very mild night on the 3rd/4th, with Yeovilton (Somerset) recording an overnight minimum temperature of 14.8 °C. Some showers and isolated thunderstorms on the 4th. Temperatures during this period peaked at 25.4 °C at Wisley (Surrey) on the 7th.
9th to 11th May: The high pressure temporarily broke down, with a generally cyclonic synoptic situation. However, Wiggonholt (Sussex) recorded a temperature of 26.4 °C on the 9th. At the same time, widespread thunderstorms in the west gave 2 cm of hail on the M4 in Wiltshire. Great Malvern (Worcestershire) recorded a maximum temperature of 27.5 °C on the 11th. Low cloud and patchy fog spread from the North Sea into north-east England overnight.
12th to 13th May: High pressure over the Faeroes with a ridge of high pressure over much of the UK. Persistent low cloud and fog affected eastern coasts. A cool night on the 12th/13th, with Redesdale Camp (Northumberland) recording a minimum temperature of 3.4 °C.
Episode 2: 23rd – 31st July
22nd to 28th July: Generally more settled through this period as an increasingly hot and humid southerly flow took hold. The temperature reached 29.7 °C at Kew Gardens (London) on the 27th and 30.2 °C at Cambridge NIAB (Cambridgeshire) on the 28th. Much of England saw temperatures reaching the mid to high 20s on most days, with the main exception being along north-eastern coasts plagued by misty low cloud and sea fog. On the 25th, some thundery rain affected the south-west during the morning and the north-west during the evening. On the evening of the 26th, isolated thunderstorms broke-out across East Anglia and the East Midlands. Later on the 28th, more-widespread heavy rain and thunderstorms developed in the south-west, and spread north-eastwards during the evening and night. Hourly rainfall totals of 20-30 mm occurred across parts of the south-west Midlands on the evening of the 28th.
29th to 31st July: Often wet and breezy in the west, while considerably warmer and drier across central and eastern areas. The rain turning heavy in the west later on the 30th and during the 31st, before moving north-eastwards during the evening and night of the 31st as a band of thundery downpours. On the 31st, Boulmer (Northumberland) recorded 52.2 mm, whilst the temperature reached 29.5 °C at Holbeach (Lincolnshire) on the 31st.

Source: Met Office (http://www.meto.gov.uk/climate/uk/2008/)

Figures 5.1 and 5.2 indicate the maximum daily temperature plotted against the number of sites that exceeded pollution index thresholds on each day during the episodes. Figure 5.1 in particular, clearly shows the correlation between high temperatures and high levels of ozone across the AURN.

Figure 5.1. Number of Stations with MODERATE and HIGH levels during Episode 1 with temperature profile across the South East.

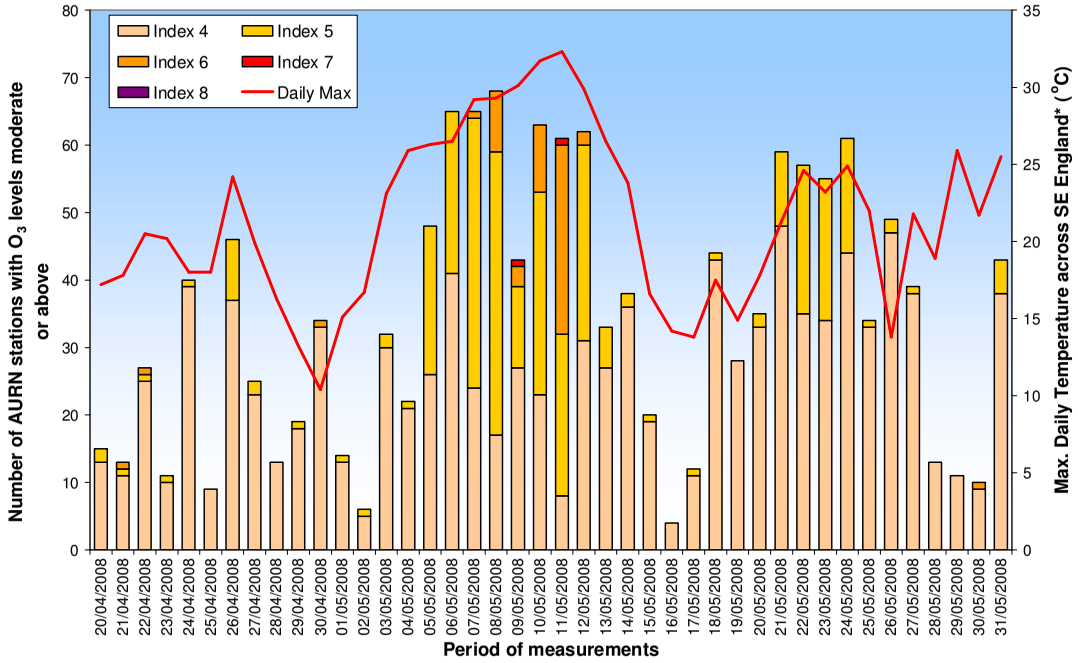
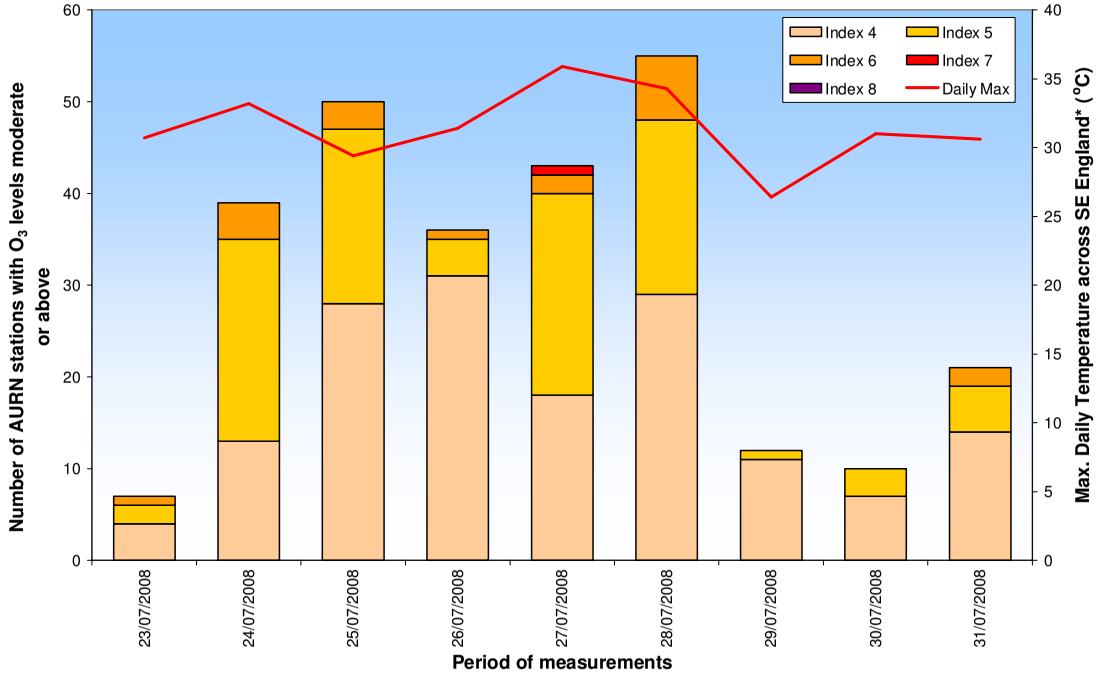


Figure 5.2. Number of Stations with MODERATE and HIGH levels during Episode 2 with temperature profile across the South East.



5.2 Re-circulation of Air Masses

Air quality forecasting in the UK relies on the analysis of air masses. AEA uses back-trajectory plots to show the movement of air masses over the past few days. Air masses originating and travelling over low-pollution areas, such as the Atlantic Ocean, tend to bring clean air to the UK. Conversely, air masses that have travelled over polluted land or have been circulating over a small area for a long period of time are likely to bring polluted air with them.

Figures 5.3 to 5.7 are 96-hour back trajectory plots showing the movement of air masses prior to arriving in the UK, for the days around both episodes.

Until the 6th May these trajectories show relatively clean air being brought into the UK from the Atlantic. From the 6th May the air circulating over Europe, combined with high temperatures, was the cause of the ozone episode. As temperatures dropped from the 12th May, ozone levels were also reduced, even though the back trajectories indicate that air was still recirculating over Europe.

Figure 5.3 96 hours air mass back trajectories during first episode (1st –4th May)

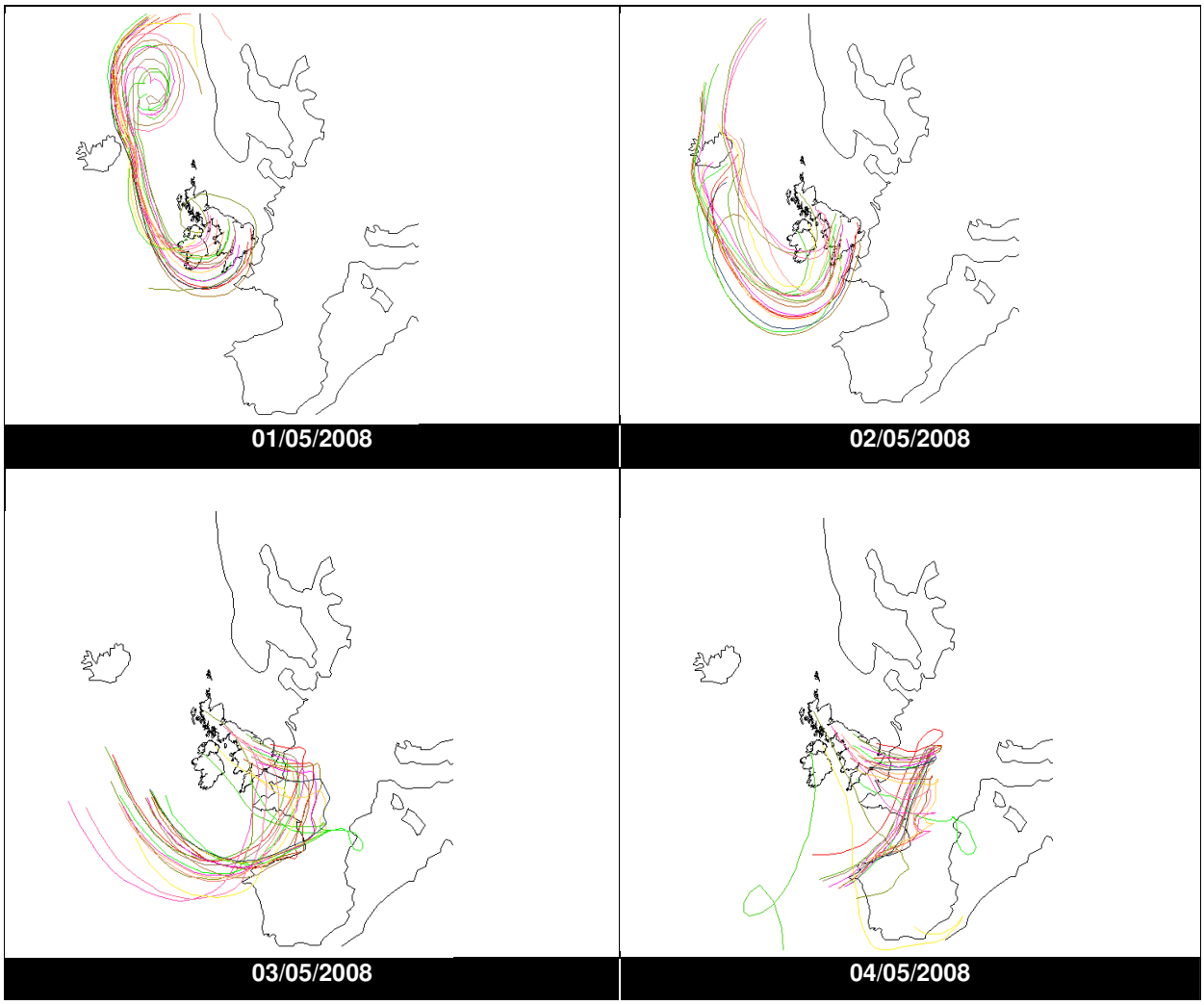


Figure 5.4 96 hours air mass back trajectories during first episode (5th –10th May)

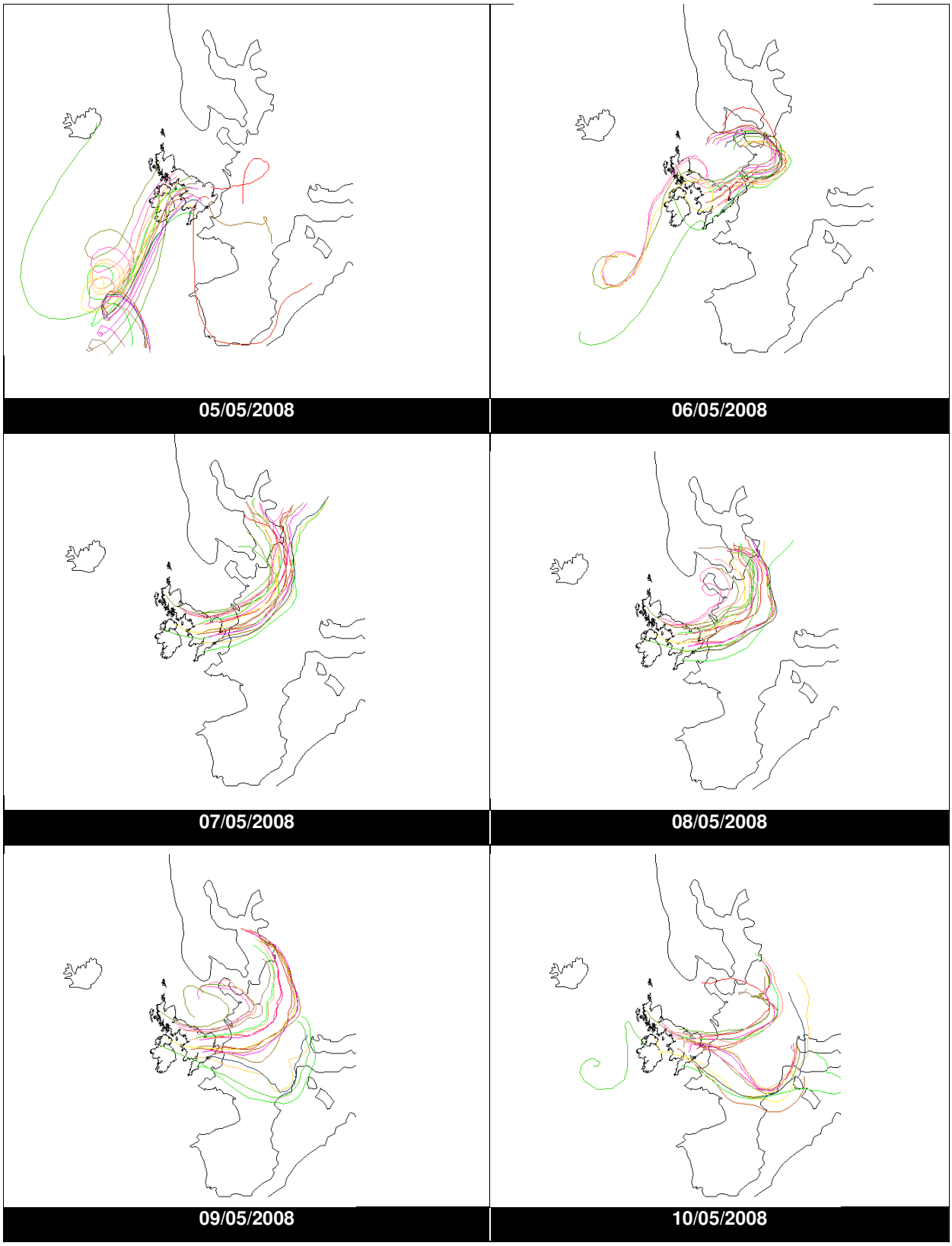
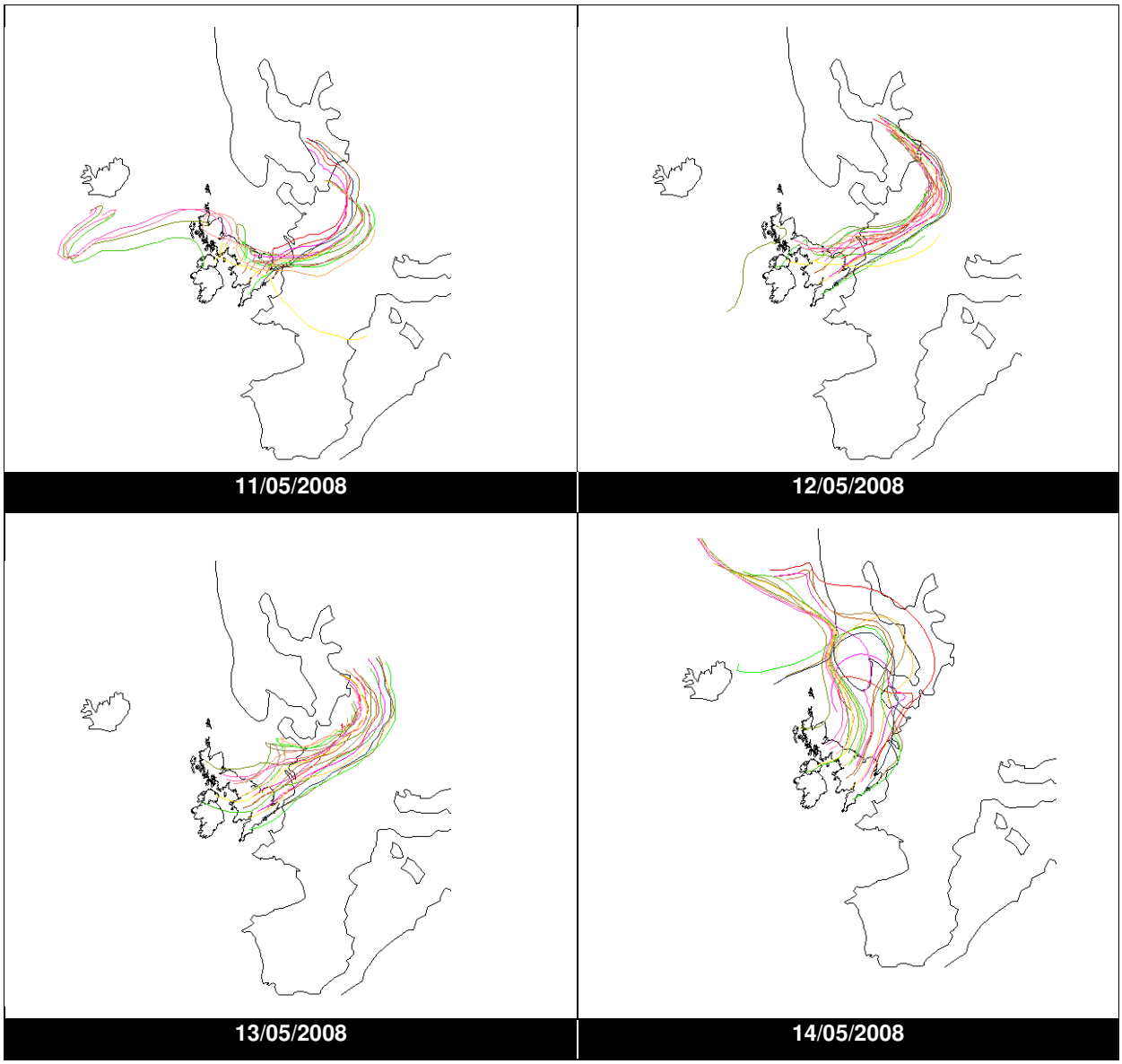


Figure 5.5 96 hours air mass back trajectories during first episode (11th –14th May)



Before the second ozone episode, air masses arriving in the UK had originated or passed over the clean Atlantic Ocean. However, by the 27th July much of the air influencing the UK had been present over a very small area - the UK and Western Europe – for the past 96 hours. This recirculation did not allow the dispersion of pollutants and, coupled with temperatures of over 35°C in some parts of the UK, this was sufficient to cause elevated levels of ozone at many AURN stations, and an exceedence of the information threshold at Hull Freetown on the 27th July.

Figure 5.6 96 hours air mass back trajectories during second episode (24th –27th July)

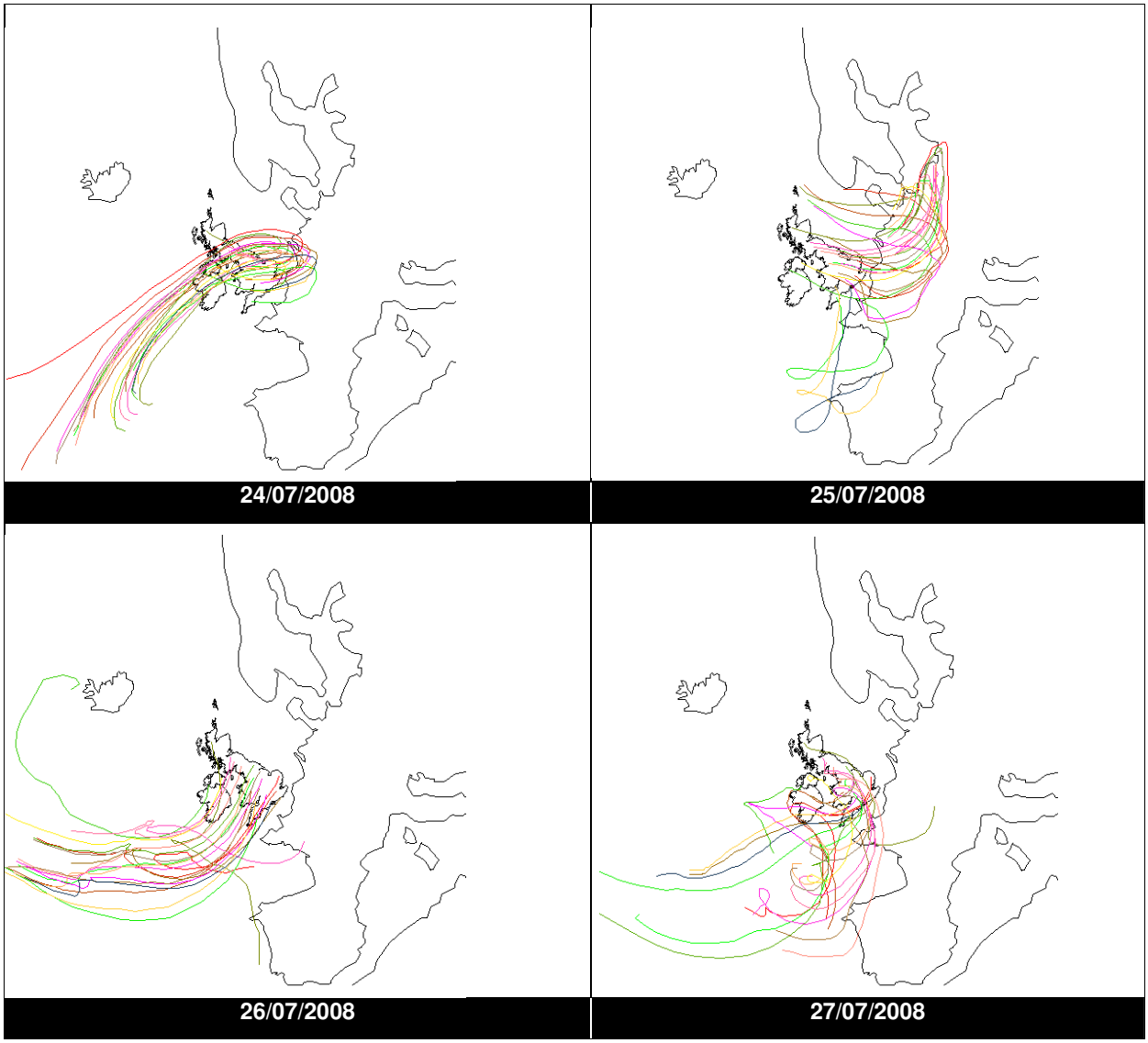
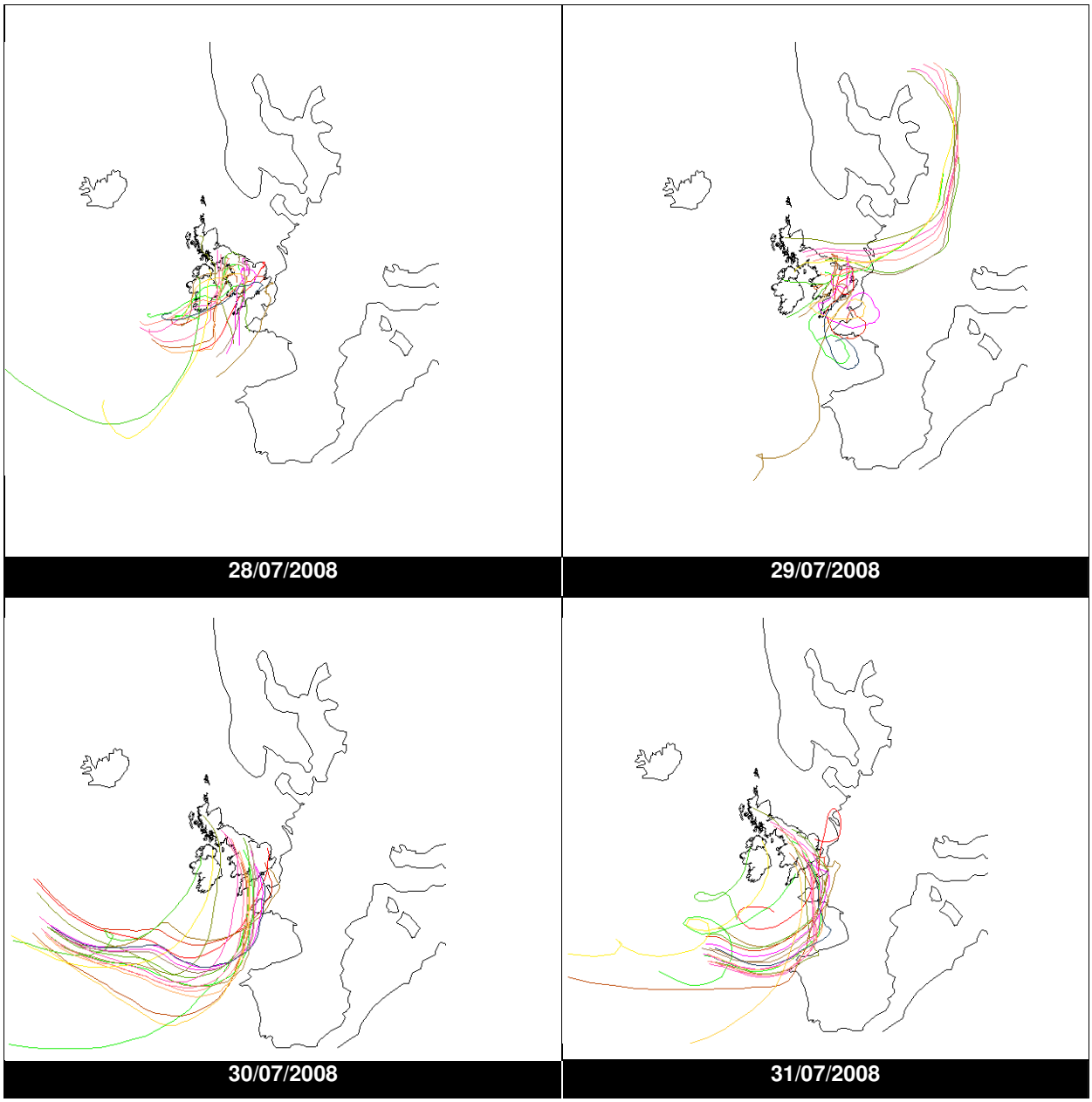


Figure 5.7 96 hours air mass back trajectories during second episode (28th –31st July)



6 Other Pollutants Measured

During the ozone episodes in May and July 2008, several other air pollutants were measured at AURN monitoring stations.

The following table lists the AURN stations that recorded the twelve highest concentrations of ozone during these episodes.

Table 6.1. Twelve AURN stations with the highest hourly ozone concentrations during the two episodes

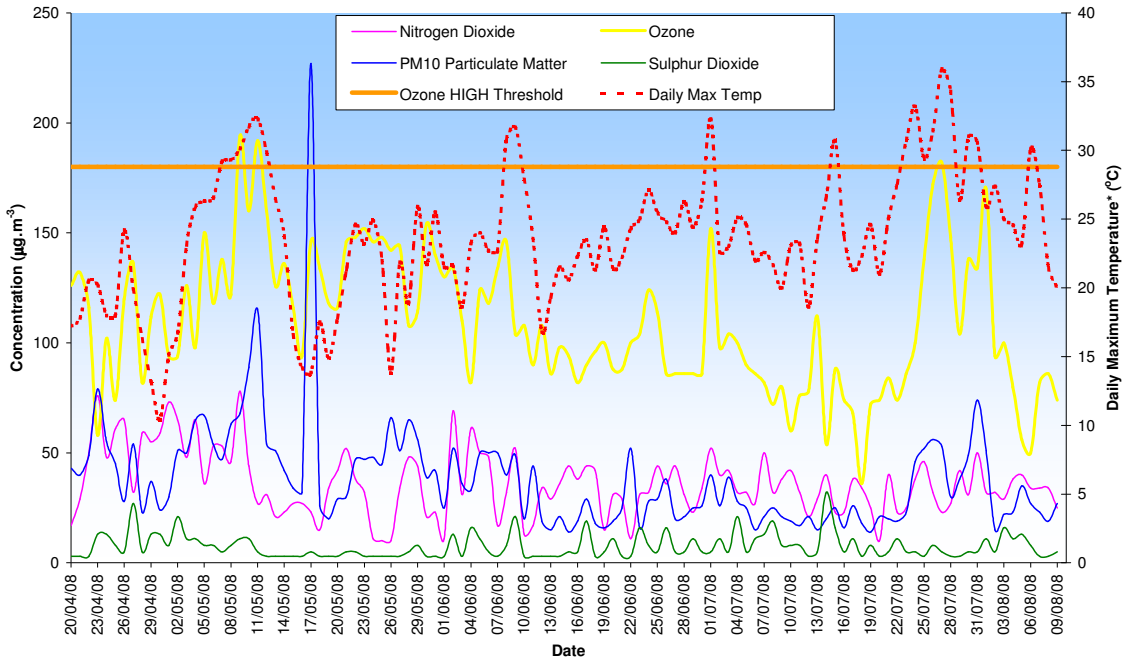
Site	Maximum Hourly Ozone Concentration (µg m^{-3})
Hull Freetown	194
Wigan Centre	176
Cardiff Centre	176
Aston Hill	174
Yarner Wood	174
Birmingham Tyburn	174
Leominster	174
Derry	172
Market Harborough	170
Leeds Centre	170
Preston	170
Ladybower	170

For each of these sites, Figures 6.1 to 6.3 provide a time series of other important pollutants for the period 20th April 2008 to 31st July 2008.

Figure 6.1 confirms that there is a correlation between ozone concentration at Hull Freetown and high ambient temperature (as measured in SE England). It shows peaks in the concentrations of PM_{10} and to some extent, NO_2, during the episodes, specifically on the dates 9th May, 11th May, 27th July and 31st July.

Figure 6.2 and 6.3 show the time series for ozone and PM_{10} particulates, respectively, for the other sites. It is clear that these sites all exhibit a similar ozone trend, and that there is some correlation between high ozone and high PM_{10} concentrations. This is due to a combination of stagnant air over the UK and secondary particulate matter transported from across continental Europe.

Figure 6.1. Maximum hourly concentrations of pollutants at Hull Freetown during the period 20th April to 9th August 2008.



**Daily maximum temperature measured at London Heathrow*

Figure 6.2. Daily maximum hourly concentrations of ozone at the most polluted sites during the period 20th April to 9th August 2008

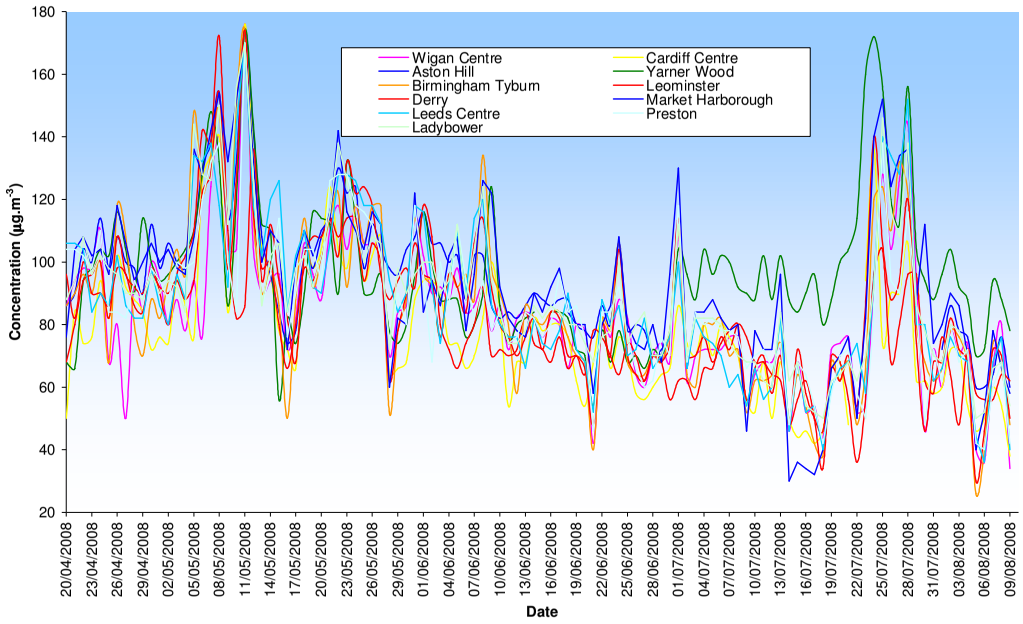
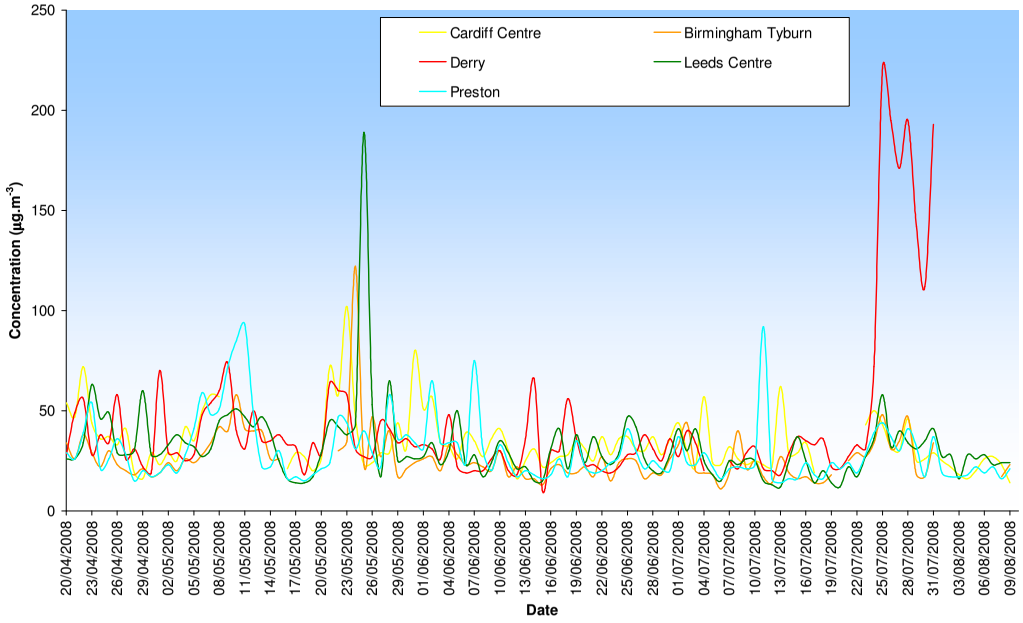


Figure 6.3. Daily maximum hourly concentrations of PM_{10} at these sites during the period 20th April to 9th August 2008



Note that July data are provisional and not yet ratified

7 References

Targa, J (2006) Air Pollution Forecasting: Ozone Pollution Episode Report (June-July 2006)

Targa, J (2006) Air Pollution Forecasting: Ozone Pollution Episode Report (June-July 2005)

Targa, J (2004) Air Pollution Forecasting: Ozone Pollution Episode Report (July-August 2004)

Kent, A (2003) Air Pollution Forecasting: Ozone Pollution Episode Report (August 2003)

Appendix A

UK Air Pollution Bandings and Index and the Impact on the Health of People who are Sensitive to Air Pollution

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 $\mu g\ m^{-3}$	
		μgm^{-3}	ppb	μgm^{-3}	ppb	μgm^{-3}	ppb	mgm^{-3}	ppm	TEOM	(Grav. Equiv.)
LOW											
	1	0-32	0-16	0-95	0-49	0-88	0-32	0-3.8	0.0-3.2	0-16	0-21
	2	33-66	17-32	96-190	50-99	89-176	33-66	3.9-7.6	3.3-6.6	17-32	22-42
	3	67-99	33-49	191-286	100-149	177-265	67-99	7.7-11.5	6.7-9.9	33-49	43-64
MODERATE											
	4	100-126	50-62	287-381	150-199	266-354	100-132	11.6-13.4	10.0-11.5	50-57	65-74
	5	127-152	63-76	382–477	200-249	355-442	133-166	13.5-15.4	11.6-13.2	58-66	75-86
	6	153-179	77-89	478-572	250-299	443-531	167-199	15.5-17.3	13.3-14.9	67-74	87-96
HIGH											
	7	180-239	90-119	573-635	300-332	532-708	200-266	17.4-19.2	15.0-16.5	75-82	97-107
	8	240-299	120-149	636-700	333-366	709-886	267-332	19.3-21.2	16.6-18.2	83-91	108-118
	9	300-359	150-179	701-763	367-399	887-1063	333-399	21.3-23.1	18.3-19.9	92-99	119-129
VERY HIGH											
	10	≥ 360 μgm^{-3}	≥ 180 ppb	≥ 764 μgm^{-3}	≥ 400 ppb	≥1064 μgm^{-3}	≥ 400 ppb	≥ 23.2 mgm^{-3}	≥ 20 ppm	≥ 100	≥ 130

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.

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