# Air Pollution Forecasting: Ozone Pollution Episode Report (July-August 2004)

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## INTRODUCTION

HIGH levels of air pollution were measured at the end of July and early August 2004. The UK AURN network recorded ozone levels in index 7 of the Defra HIGH band (90-119 ppb, 180-239 $\mu gm^{-3}$) between 28th July and 10th August (a 14 days' episode). HIGH ozone levels were reported on 5 days and MODERATE concentrations (50-89 ppb, 100-178 $\mu gm^{-3}$) were reported across all 14 days. The highest hourly concentration of the episode was 105 ppb (210 $\mu gm^{-3}$, index 7), which occurred at Sibton on 8th August. The episode covered in this report peaked during three days on: 29th July, 1st August and 8th August 2004. During these three days, HIGH levels of ozone were recorded at three, one and six stations respectively. Moderate levels were recorded at 61 stations, 59 and 45 on each of these respective days.

Measured ozone levels during the episode did not exceed the population warning threshold (an hourly mean concentration in excess of 360$\mu gm^{-3}$ or 180 ppb) and therefore did not trigger an alert. The 3rd Daughter Directive (Directive 2002/3/EC) on ozone in ambient air also established a stricter alert threshold of 240 $\mu gm^{-3}$ (120 ppb) as an hourly average over three consecutive hours. This alert threshold was not exceeded, during the episode.

## DEFINING THE EPISODE

Summer ozone episodes can be hard to delimit because ozone levels are often in the MODERATE band during the summer season. This report covers the period between 28th July to 10th August 2004. As can seen in Figure 1 below, the episode started on 28th July, when more than 30 stations measured MODERATE levels of ozone and 1 station measured HIGH levels (index 7) of ozone. The episode ended on 10th August, when only 8 stations measured ozone levels in the MODERATE band (index 4-5).

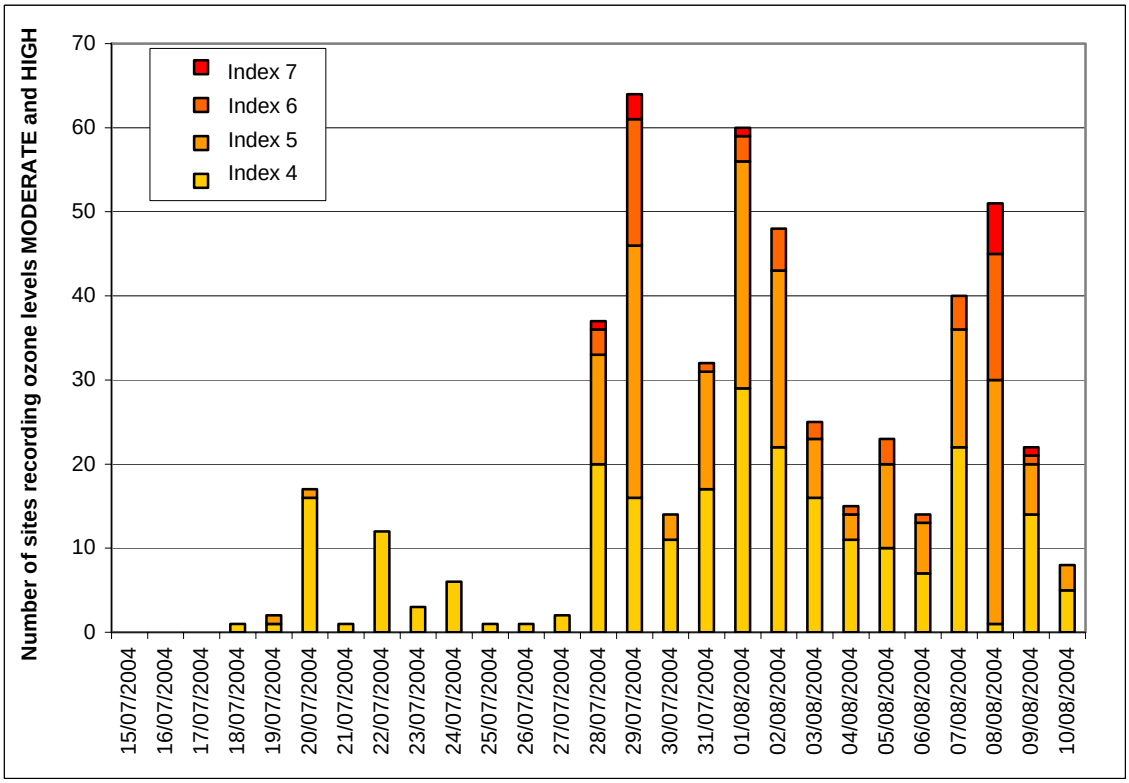



**Figure 1. Ozone Episode Days – number of stations with levels MODERATE and HIGH between 15th July and 10th August.**

## THE OZONE EPISODE

During the episode, 11 stations in the AURN National network recorded HIGH levels of ozone. The highest hourly ozone concentration measured was 105ppb (210 $\mu gm^{-3}$) at Sibton on 8th August. Weybourne reported hourly levels of 100ppb (200 $\mu gm^{-3}$) on the same date. The Northampton monitoring station measured HIGH levels on three days. Redcar and Bournemouth measured HIGH levels on two days. The remaining sites only measured HIGH levels on a single day. Table 1 shows all AURN monitoring stations that measure ozone, together with the number of days with MODERATE and HIGH days. For stations measuring HIGH levels, maximum hourly concentrations and the date are also shown.

**Table 1. Number days of Moderate and High levels at each station across AURN Network**

| Site | Number of days | | Max hourly concentration if High (in ppb) | Date of max hourly concentration |
|---|---|---|---|---|
| | MODERATE | HIGH | | |
| **Northampton** | 11 | **3** | 91 | 29/07 and 08/08/2004 |
| **Redcar** | 11 | **2** | 96 | 08/08/2004 |
| **Bournemouth** | 4 | **2** | 96 | 28/07/2004 |
| **Weybourne** | 12 | **1** | 100 | 08/08/2004 |
| **Wicken Fen** | 12 | **1** | 91 | 29/07/2004 |
| **Coventry Memorial Park** | 11 | **1** | 90 | 29/07/2004 |
| **Sibton** | 11 | **1** | 105 | 08/08/2004 |
| **Norwich Centre** | 10 | **1** | 94 | 08/08/2004 |
| **Middlesbrough** | 8 | **1** | 91 | 08/08/2004 |
| **London Hackney** | 5 | **1** | 93 | 01/08/2004 |
| **Strath Vaich** | 5 | **1** | 90 | 05/08/2004 |
| Rochester | 13 | 0 | - | - |
| Southend-on-Sea | 13 | 0 | - | - |
| High Muffles | 12 | 0 | - | - |
| Hull Freetown | 12 | 0 | - | - |
| London Teddington | 12 | 0 | - | - |
| St Osyth | 12 | 0 | - | - |
| Harwell | 11 | 0 | - | - |
| Market Harborough | 11 | 0 | - | - |
| Bottesford | 10 | 0 | - | - |
| Ladybower | 10 | 0 | - | - |
| Leicester Centre | 10 | 0 | - | - |
| London Haringey | 10 | 0 | - | - |
| Great Dun Fell | 9 | 0 | - | - |
| London Harlington | 9 | 0 | - | - |
| Lullington Heath | 9 | 0 | - | - |
| Portsmouth | 9 | 0 | - | - |
| Aston Hill | 8 | 0 | - | - |
| Leamington Spa | 8 | 0 | - | - |
| Glazebury | 7 | 0 | - | - |
| London Bexley | 7 | 0 | - | - |
| London Westminster | 7 | 0 | - | - |
| Sandwell West Bromwich | 7 | 0 | - | - |
| Sheffield Centre | 7 | 0 | - | - |
| Barnsley Gawber | 6 | 0 | - | - |
| London Bloomsbury | 6 | 0 | - | - |
| London N. Kensington | 6 | 0 | - | - |
| Nottingham Centre | 6 | 0 | - | - |
| Thurrock | 6 | 0 | - | - |
| *Other stations* | <5 | 0 | - | - |

As seen in Figure 1, 29th July, 1st August and 8th August 2004 are particular important; these are when most of the HIGH levels were observed. During these three days, high levels of ozone were recorded at:

- Northampton, Wicken Fen and Bournemouth on Thursday 28th July
- London Hackney on Sunday 1st August and
- Sibton, Weybourne, Norwich Centre, Northampton, Redcar and Strath Vaich on Sunday 8th August.

Figure 2 shows hourly ozone concentrations over the episode for all the stations that measured HIGH, as well as stations with a high number of recorded MODERATE days

Locations of the stations that measured HIGH and MODERATE levels of ozone during the episode are shown in Figure 3. The areas affected by the episode are predominately located in the south east of England and the Midlands. During the first peak of the episode, ozone levels were HIGH in the following zones: Eastern, South West, East Midlands and West Midlands. At the end of the episode the Highland and North East zones also measured HIGH levels of ozone.

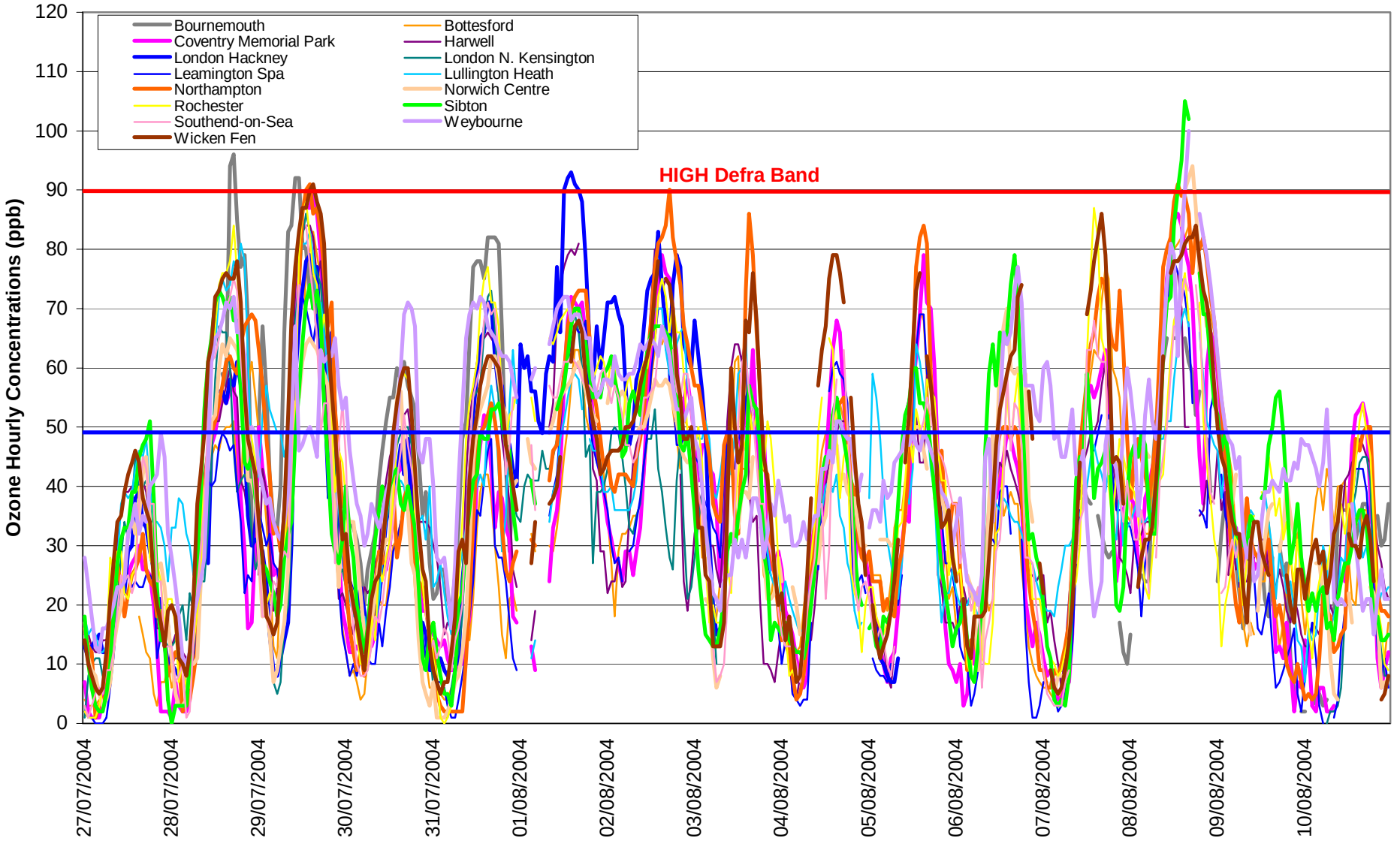



**Figure 2. Hourly Ozone Concentration (ppb) over the episode.**

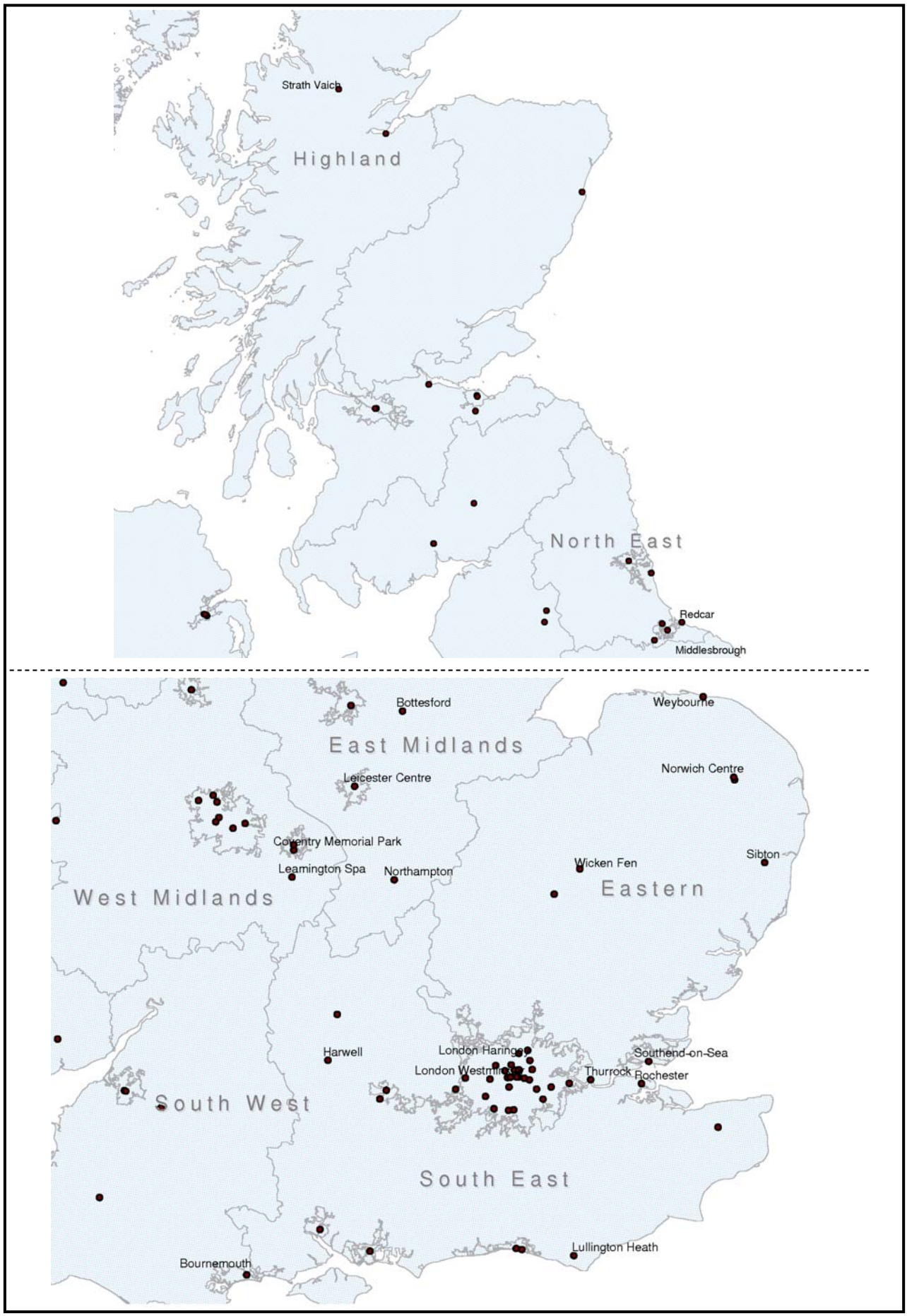



**Figure 3. Location of stations recording the ozone episode**

## REASONS FOR THE EPISODE

The summer ozone episode was characterised by rising 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.

### Temperature

During the episode, maximum temperatures reached *circa* 30ºC, as can been seen in Figure 4. This temperature was measured at London Heathrow. Although, the maximum temperatures over the episode remain well above 25ºC, HIGH levels of ozone were not measured during every day of the episode. This is due to the influence of air masses re-circulating over Europe and over the UK, which is discussed below.

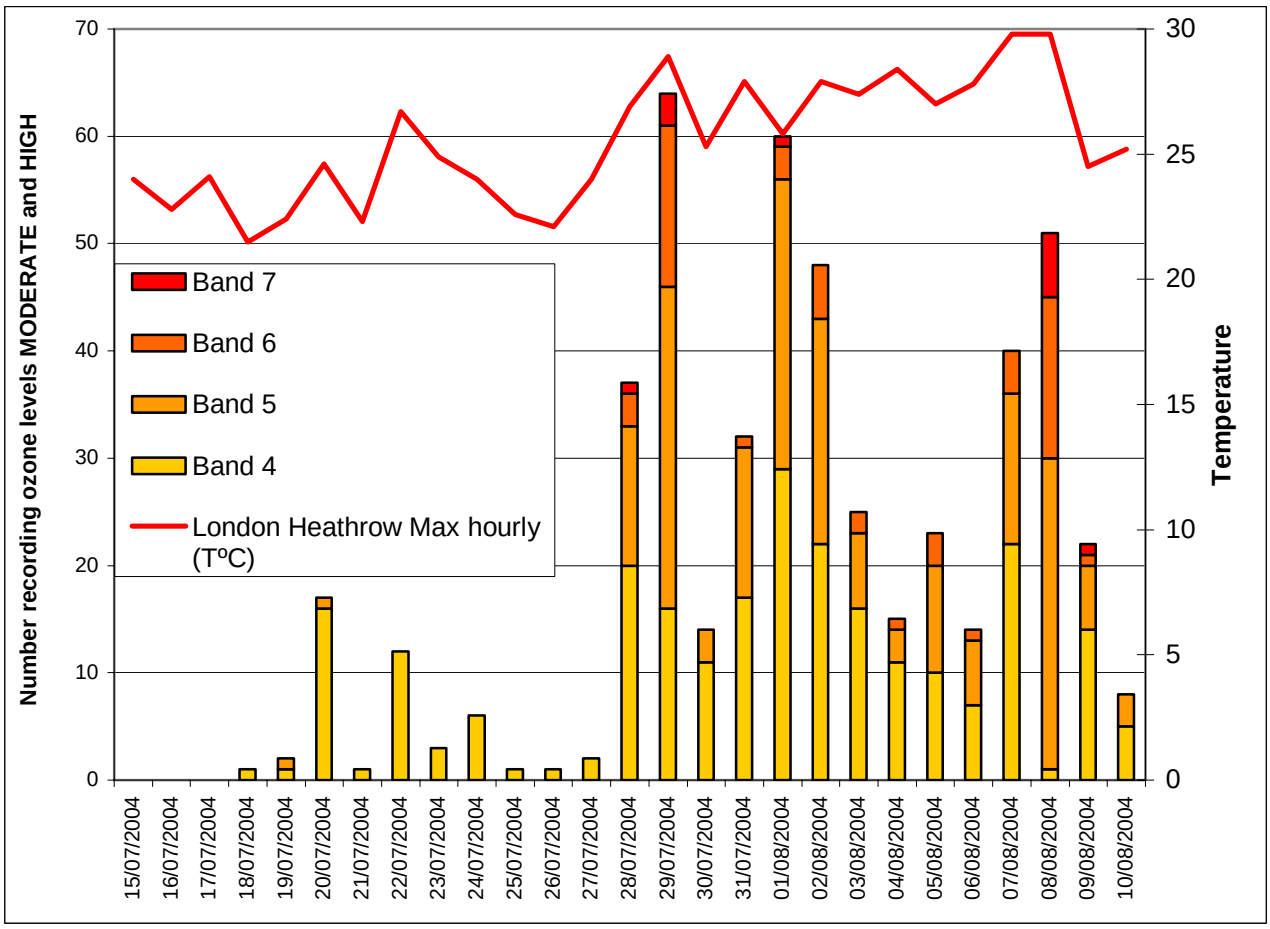



**Figure 4. Temperature profile alongside number of stations recording ozone levels moderate or above.**

### Re-circulation of air masses

Figure 5 shows the 96 hours airmass back-trajectories on the important three days over the episode. It is clear that the re-circulation of air masses over Europe - and then over the UK - had a great influence on HIGH levels measured those days (specially the 29$^{th}$ July and 8$^{th}$ of August). Airmass back trajectories re-circulated over Europe bring continental ozone precursors to the UK.

This re-circulation, in conjunction with high temperatures and UK ozone precursor emissions (specially over Greater London Urban Area), was the main reason for ozone levels reaching Defra's HIGH band.

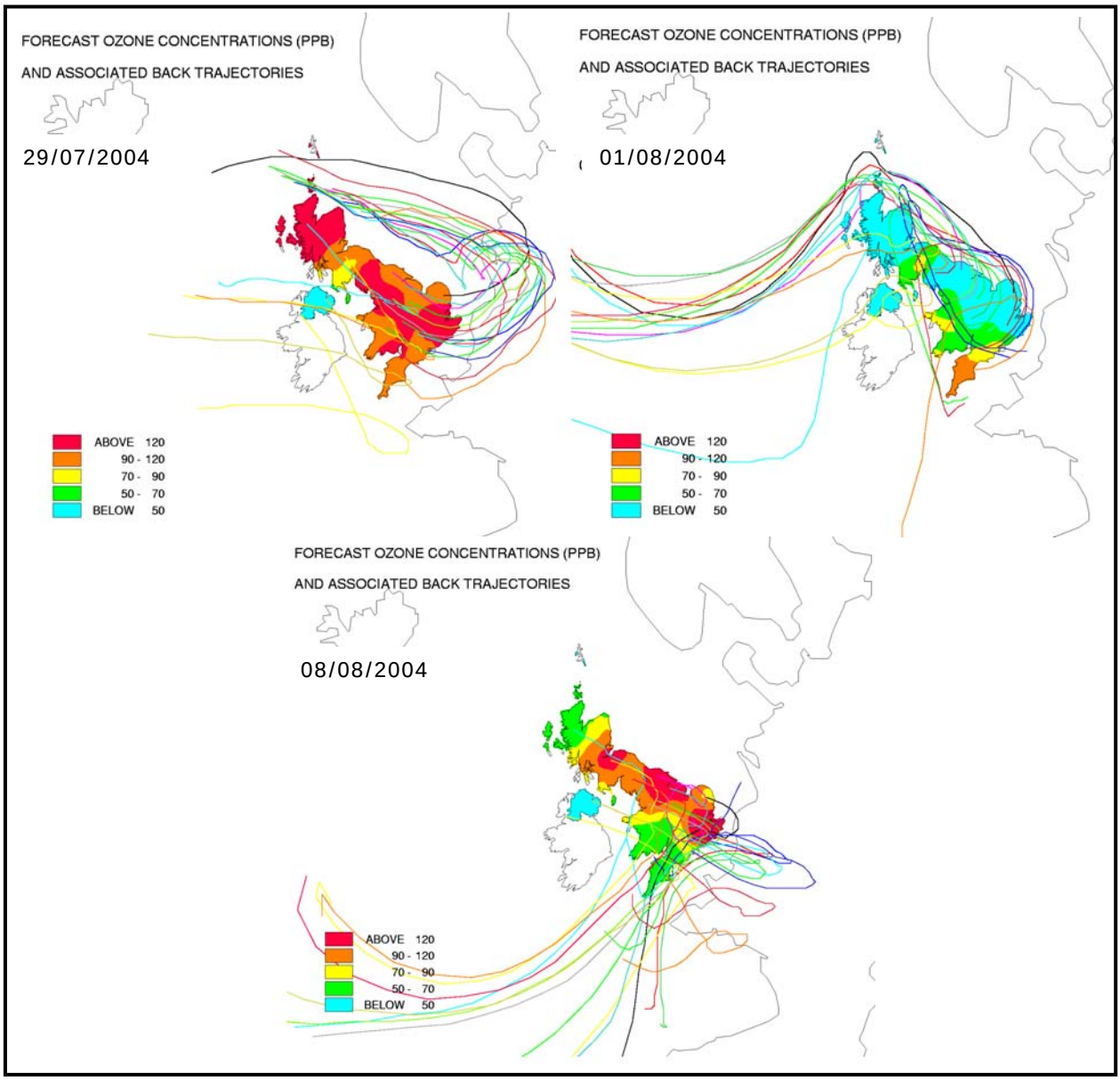



**Figure 5. 96-hour air masses back trajectories for 29th July, 1st and 8th of August.**

The influence of UK emissions on the episode has been investigated by examining ozone levels along the back trajectory crossing Greater London Urban Area (see Figure 6). The back-trajectory drawn in Figure 6 was typical on 29th July and 8th August. On both days, air masses re-circulated over Europe before entering the UK. Air then circulated from south England (Lullington Heath in this example) to the Midlands (e.g. Northampton) across the Greater London Urban Area. Figure 7 shows daily maximum hourly concentrations over the episode for six stations located along this back-trajectory: three AURN[1] stations and three stations in the HBAPMN[2].

The measured concentrations on 29th July and 8th August show that ozone levels were strongly related to the airmass back-trajectory. Levels of ozone entering the UK (Lullington Heath) are depleted when entering Greater London UA (represented by London Haringey). This depletion is due to $NO_x$ scavenging and involves $O_3$ being converted back to $O_2$. However, this depletion is followed by a much greater increase of $O_3$ downwind. This is shown clearly by ozone concentrations at Borenhamwood, St Albans, Silsoe and Northampton. As shown in Figure 7, ozone levels increase downwind of London, declining slightly again when reaching Northampton city. Between Lullington Heath and Silsoe (both rural stations), there is a difference of around 20 ppb (40$\mu gm^{-3}$).

[1] Automatic Urban and Rural Network – http://www.airquality.co.uk
[2] Herts. & Beds. Air Pollution Monitoring Network - http://www.seiph.umds.ac.uk/hbnet.htm

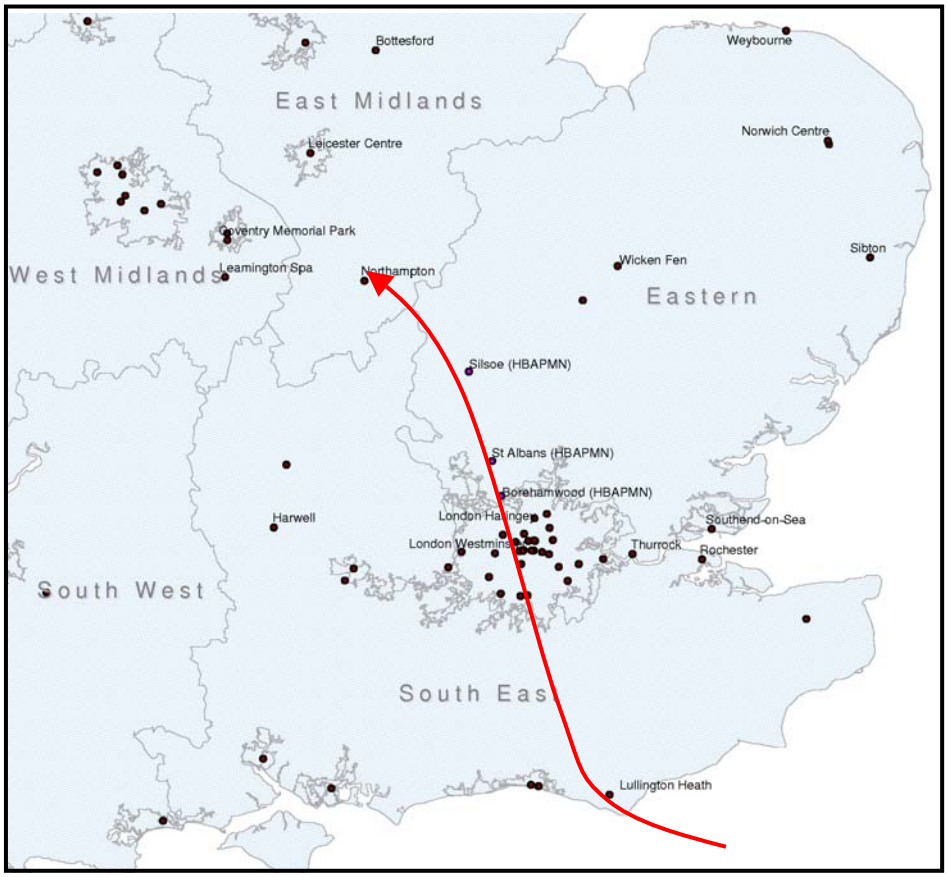



**Figure 6. Air mass back-trajectory over Greater London Urban Area.**

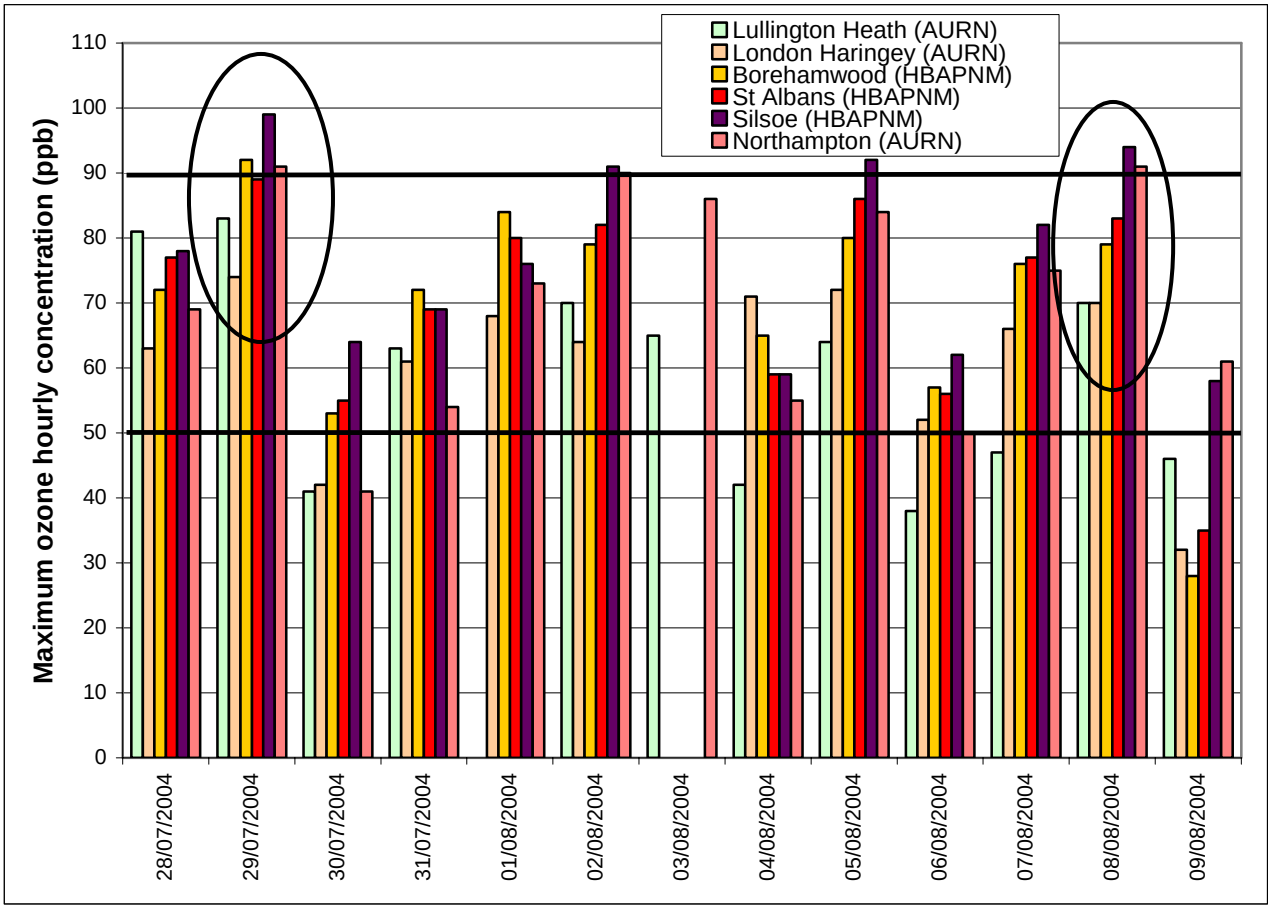



**Figure 7. Daily maximum ozone concentration.**

## EPISODE SUMMER 2003 vs. SUMMER 2004

The summer ozone episode was characterised by high temperatures and air masses re-circulating over northern Europe. The combination of these two events resulted in elevated levels of air pollution.

Compared to the ozone episode in August 2003, this episode was not as persistent or as widespread, due primarily to changes in air back trajectories through out the episode bringing clean air from the Atlantic. Moreover, temperatures did not reach more than 30° C. As can be seen in Figure 8 below, temperatures measured in 2003 were much higher than those measured in 2004. Day 1 to Day 14 represents the different episode days in 2003 and 2004. For example, day 1 corresponds to the day that the episode started in 2003 (01/08/2003) and the day that the episode started in 2004 (28/07/2004).

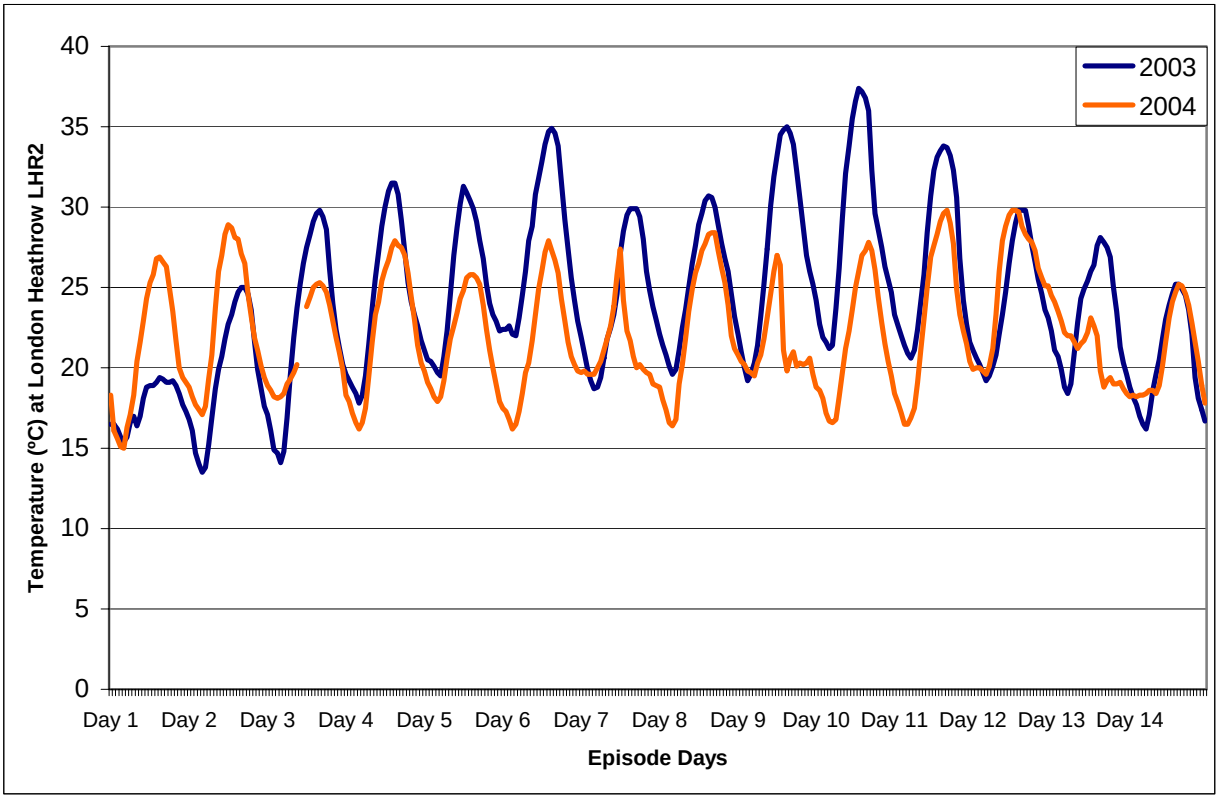



**Figure 8. Hourly temperature at London Heathrow during 2003 and 2004 episode.**

Figures 9 to 22 show paired back trajectories for the 2003 (left) and 2004 (right) summer episodes. The persistence of air masses re-circulation over Europe was continuous throughout the episode period in 2003. The August 2003 episode was notable for a number of reasons:

- Duration
- High temperatures and
- The highest ozone concentration recorded in UK for over a decade.

By contrast, during the episode in 2004, air masses re-circulating over Europe have not dominated so much. Rather, the episode was characterised more by airmasses originating in the Atlantic. This has not encouraged a build up of concentrations, as happened in 2003, and has resulted in lower overall ozone levels.

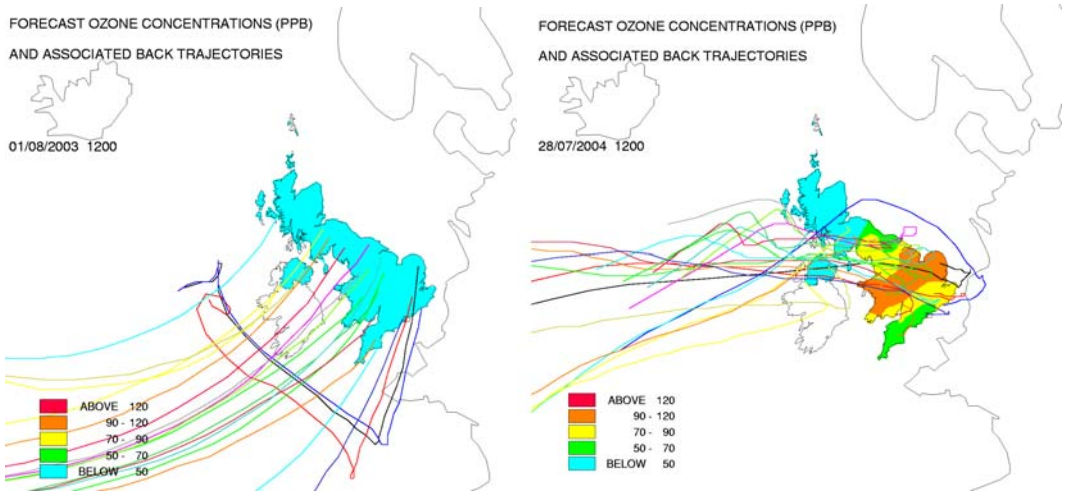



**Figure 9 – Four days forecast back trajectories UK, Day 1**

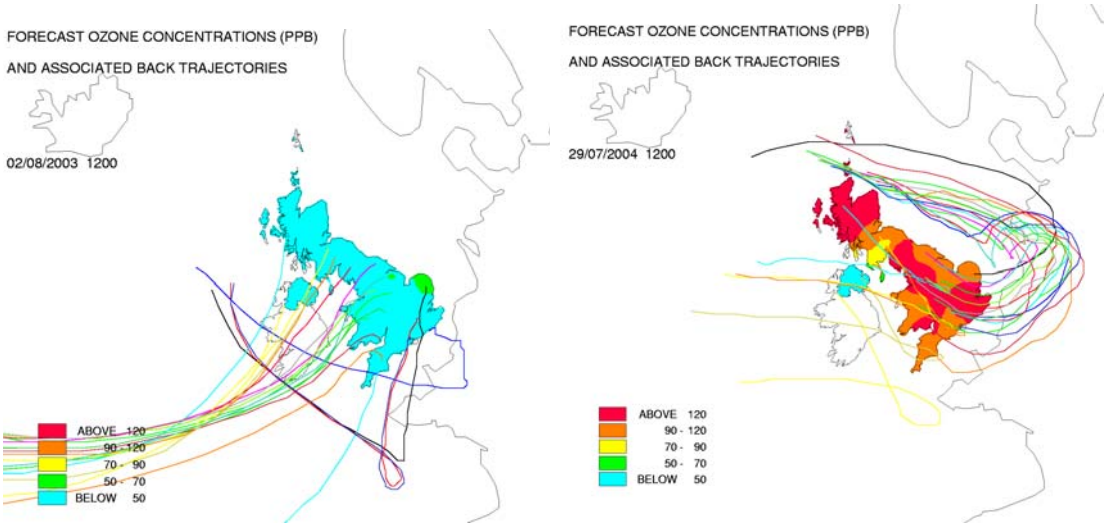



**Figure 10 –Four days forecast back trajectories UK, Day 2**

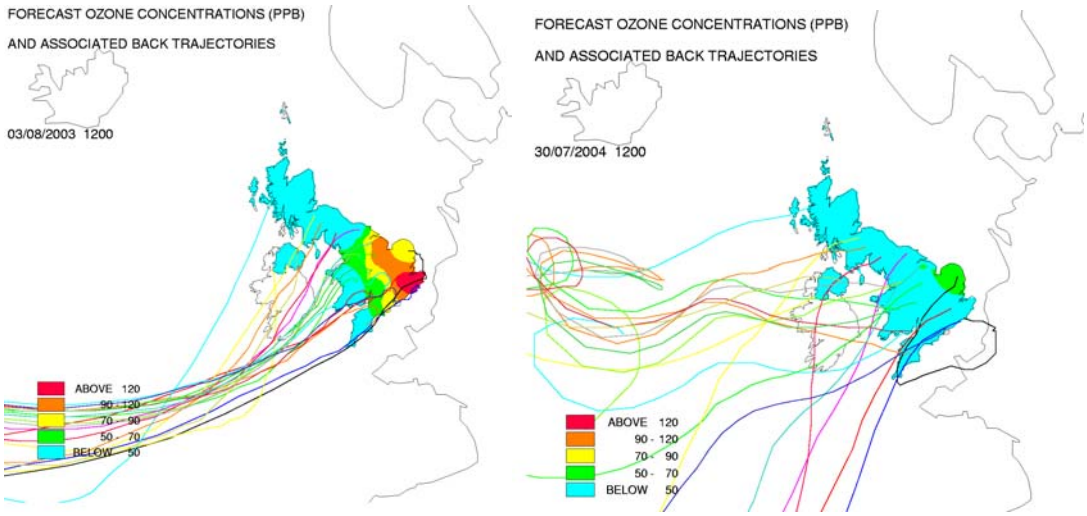



**Figure 11 – Three days forecast back trajectories UK, Day 3**

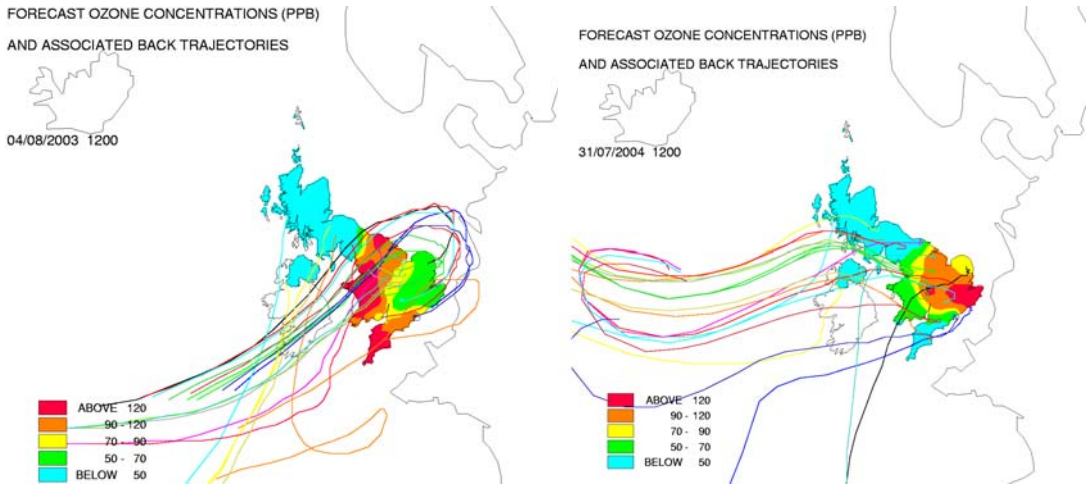



**Figure 12 – Four days forecast back trajectories UK, Day 4**

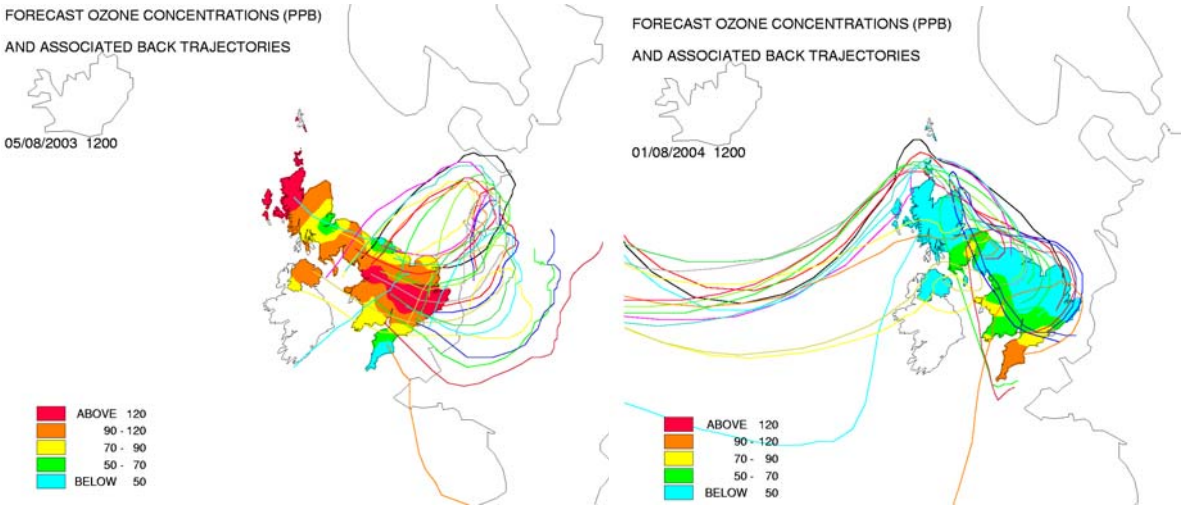
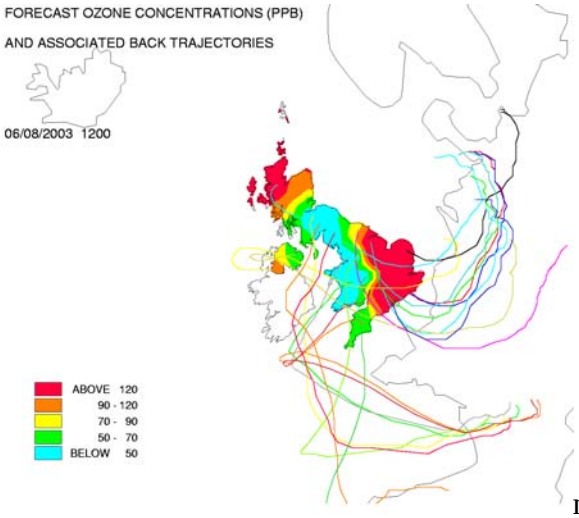



**Figure 13 – Four days forecast back trajectories UK, Day 5**




missing 2004 backtrajectory

**Figure 14 – Four days forecast back trajectories UK, Day 6**

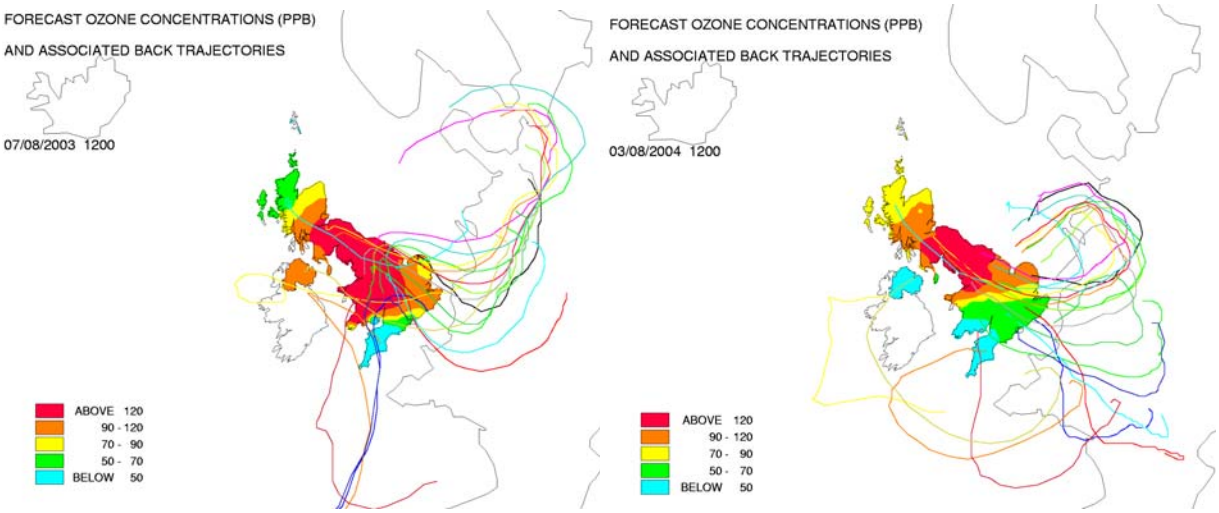



**Figure 15 – Four days forecast back trajectories UK, Day 7**

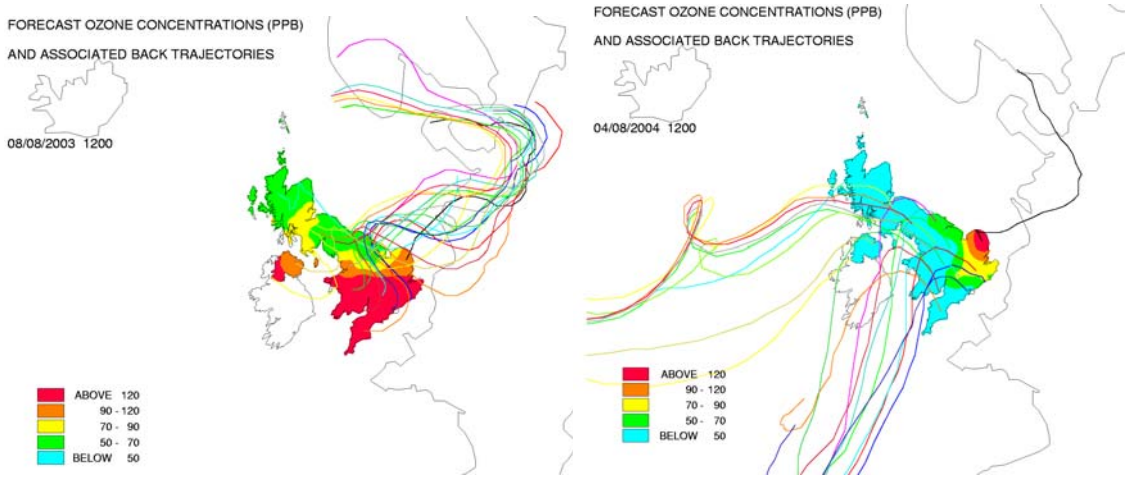



**Figure 16 – Four days forecast back trajectories UK, Day 8**

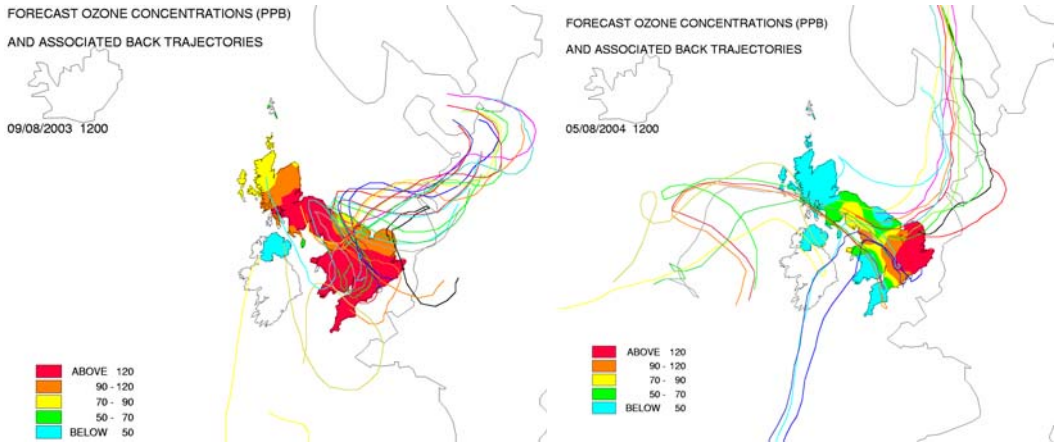



**Figure 17 – Four days forecast back trajectories UK, Day 9**

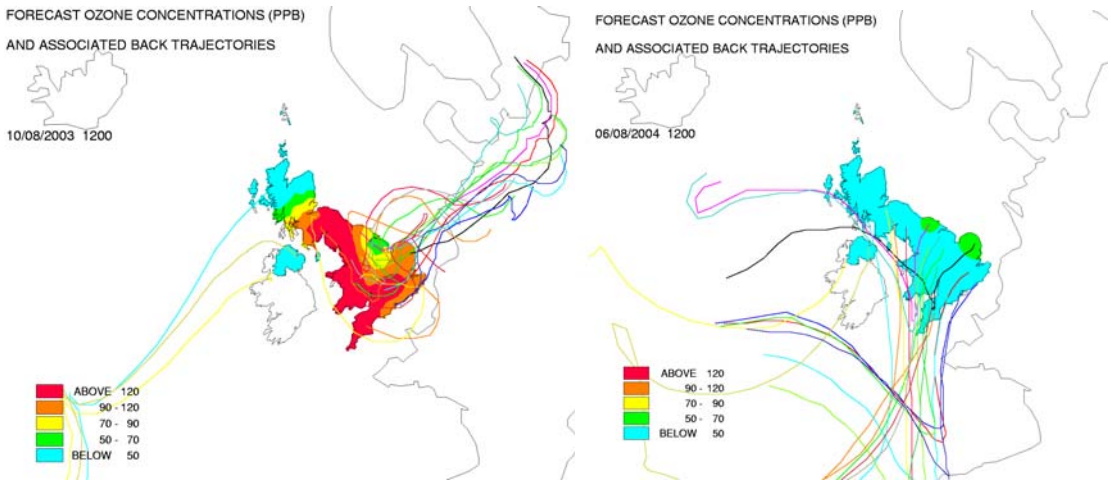



**Figure 18– Four days forecast back trajectories UK, Day 10**

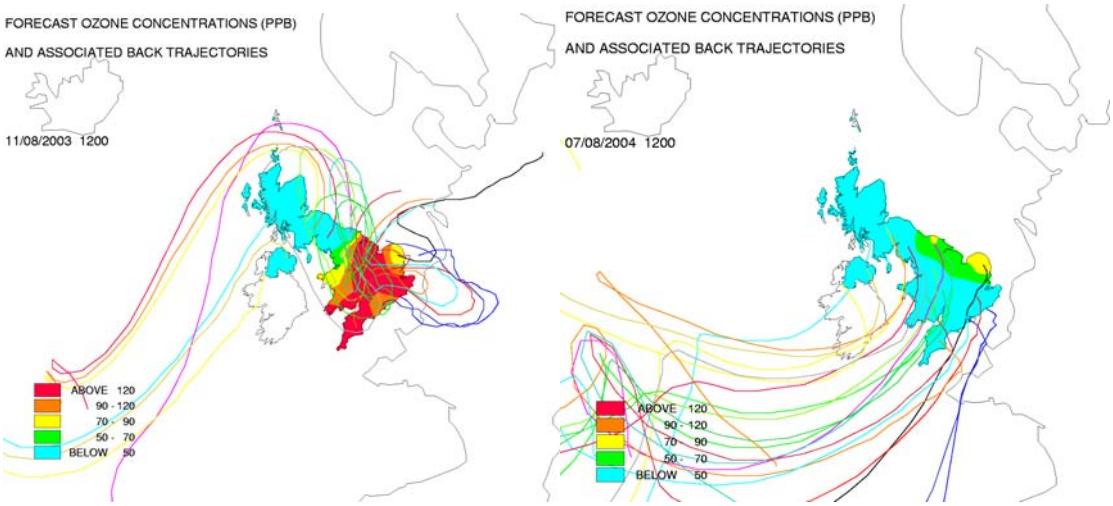



**Figure 19 – Four days forecast back trajectories UK, Day 11**

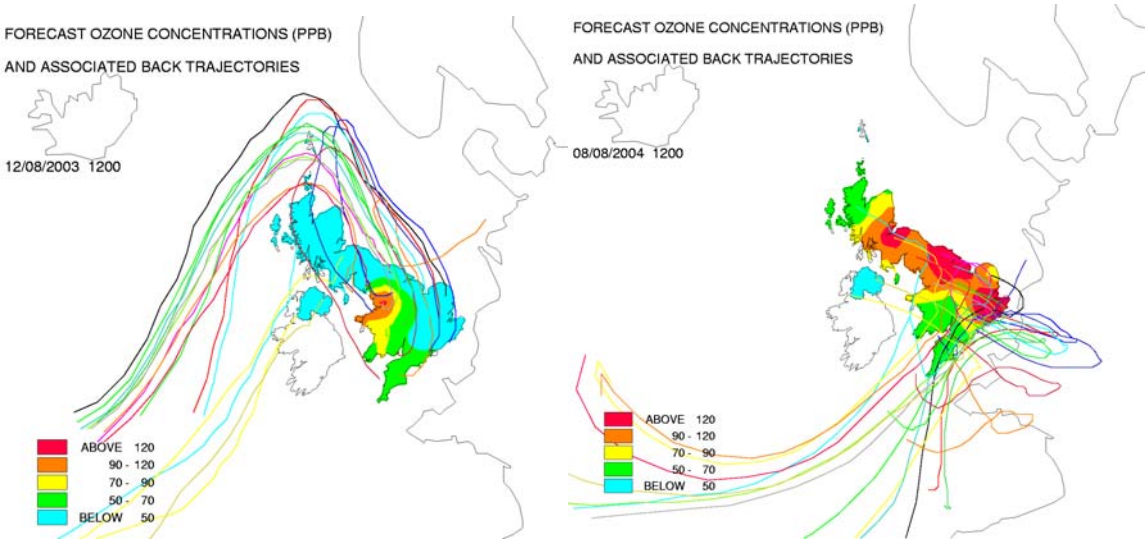
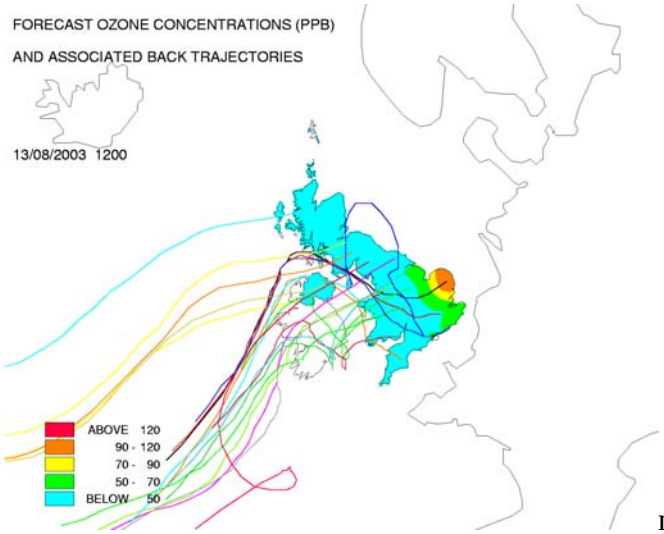



**Figure 20 – Four days forecast back trajectories UK, Day 12**




missing 2004 backtrajectory

**Figure 21 – Four days forecast back trajectories UK, Day 13**

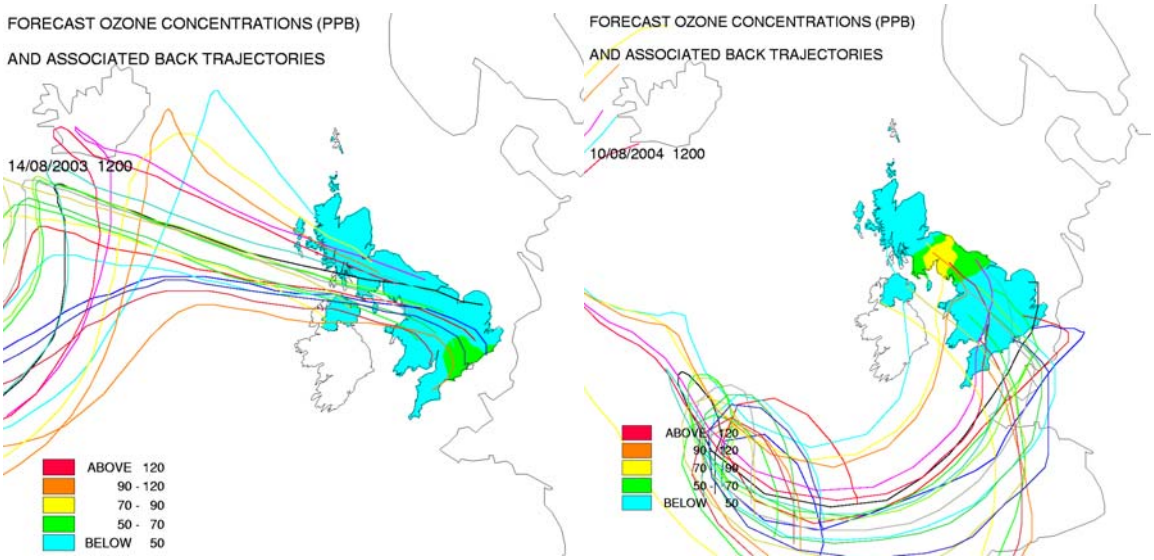



**Figure 22 – Four days forecast back trajectories UK, Day 14**

# SUMMARY

The main features of the July/August 2004 ozone episode may be summarised as follows:

- High summer temperatures resulted in the first ozone episode of 2004.
- The area affected by the episode was limited to the south east England and the Midlands, extending northwards towards the end of the episode.
- Re-circulating air over Europe and the UK during the episode brought airmasses with abundant ozone precursors to parts of the UK, providing ideal conditions for ozone generation.
- Changes of airmass back trajectories brought the episode to an end as clean air arrived from the Atlantic
- The highest hourly average ozone concentration recording during the episode was 105 ppb (210 $\mu gm^{-3}$, index 7), which occurred at Sibton on 8$^{th}$ August.
- Measured ozone levels during the August episode did not exceed the population warning threshold (an hourly mean concentration in excess of 360$\mu gm^{-3}$) and therefore did not trigger an alert.
- The Directive 2002/3/EC on ozone in ambient air establishes a stricter alert threshold of 240 $\mu gm^{-3}$ (120 ppb) as an hourly average over three consecutive hours. This alert threshold was not exceeded.
- Comparison with the August 2003 ozone episode showed that 2004 was characterised by:
  - Lower temperatures and peak ozone levels
  - Smaller area of UK affected
  - Reduced episode duration, without the sustained build-up of levels seen in 2003
  - More influence of Atlantic as opposed to Continental airmasses