# High $PM_{10}$ episode $11^{th}$-$13^{th}$ September 2002 across the UK

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### *Introduction*

On the 11-13$^{th}$ September 2002 high levels of $PM_{10}$ were recorded at measurement sites across the UK. London experienced separate 3-hour background peaks of 68 $\mu g/m^3$ and 64 $\mu g/m^3$. Edinburgh witnessed a 3-hour peak of over 100 $\mu g/m^3$. Lough Navar, a rural site in Northern Ireland, had a sustained episode of greater than 60 $\mu g/m^3$ for over twelve hours. The meteorology during this period was prevailing easterlies. One possible cause was the extensive forest fires in western Russia observed at that time. This study investigates this possibility by utilising satellite imaginary, UK ground observations and the Lagrangian dispersion model, NAME.

### *NAME Model*

The Numerical Atmospheric dispersion Modelling Environment (NAME) is a 3-D Lagrangian dispersion model. It uses full 3-D meteorology from the Met Office's numerical weather predication model, the Unified Model (Cullen, 1993). NAME can be operated in a backward running mode to investigate the origin of the air at a given time at a given receptor. Thousands of neutrally buoyant inert particles are released from the receptor over a given period and followed backward in time. The particles are moved using negated 3-D winds and a random walk turbulence scheme (Ryall, 1998). The grid box location of each particle at each time step is recorded over the duration of the model run and collated together into an air origin map. The result is a map of all of the possible sources of air over the duration of the model run, reaching the receptor within a given time window.

This approach is a step-change improvement over simple back-trajectories as it incorporates the effects of detailed 3-D wind structure and atmospheric turbulence and amalgamates the routes of many thousands of single trajectories.

### *Model setup*

The NAME model was run backwards for ten days for each 3-hour period from midnight 11$^{th}$ Sept. 2002 to midnight 14$^{th}$ Sept. 2002 for three locations; London, Lough Navar and Edinburgh. Global meteorology was used which has a horizontal resolution of ~60km and 32 vertical levels. A total of 45,000 particles were released over each 3-hour period of interest between the ground and 80m. Particle position information was collected on a ~60km horizontal by 80m vertical grid extending from $40^{o}$W to $60^{o}$E and $20^{o}$N to $80^{o}$N. The particles were assumed to be inert and therefore no account was taken of dry or wet deposition, sedimentation or chemical changes. The amount of material released was arbitrarily set to 1 g/s.

***Results***

The satellite images from the Moderate Resolution Imaging Spectroradiometer (MODIS) rapid response team at NASA-GSFC (http://earthobservatory.nasa.gov/NaturalHazards) clearly show the wide extent of forest fires in Western Russia in late August to early September 2002. Figure 1 shows the image taken on the 4th September. From the images the geographical extent of the fires has been estimated to be contained within the region $28^{o}$E – $40^{o}$E, $52^{o}$N – $60^{o}$N.

Figure 2 shows the modelled air origin maps for London for the 3-hour periods ending at (a) 00Z 12/09/02, (b) 06Z 12/09/02 and (c) 12Z 12/09/02. The four corners of the domain encompassing the fires identified in the satellite images have been marked (+) in each plot and the location of the receptor has also been highlighted (x). The plot is contoured with darker shades representing greater contributions.

Figures 3a-c show the timeseries of observations of $PM_{10}$ and modelled contribution from the domain encompassing the fires (see figure 2) at London, Edinburgh and Lough Navar. The observations shown for London are the average $PM_{10}$ values measured at the Bloomsbury and North Kensington sites.

The double peak structure (figure 3a) in the London observations is reflected in the modelled concentrations. The air-origin maps for the times of the two peaks and the low point in-between are shown in figure 2. The map of the 3-hour period marking the low point (figure 2b) shows that the origin of the air was more diffuse with significant contributions from the Atlantic. The observations are uniformly elevated by background levels of 15-30 $\mu g/m^3$, reflecting the normal diurnal pattern of $PM_{10}$ concentrations at London during an easterly flow. The second observed peak for the period 9am – noon will have a significant extra burden from local traffic sources compared to the first peak at 9pm - midnight. The timings of the peaks in the observations are identical to those modelled, namely at the 3-hour periods centred on 22:30 11/9/02 and 10:30 12/9/02. Considering the first peak, the increase in the measured value is approximately 53 μg/m$^3$ (assume the background is 15 μg/m$^3$) whereas the model produces a peak reaching 8.9e-5 μg/m$^3$. The model total is assuming all 225 grid boxes in the fire-area domain are each emitting 1 g/s of material. In order to scale this modelled value to the measured value, a total fire source of 134 g/s (12 Mtonnes per day) would be required. Using the same method but a background level of 30 μg/m$^3$ to reflect increased morning traffic, the second peak implies a total fire source of 19 Mtonnes per day.

The timeseries at Edinburgh, figure 3b, shows that the observed and modelled peaks are consistent with an indication that the model timing of the peak is 1-3 hours ahead of the observed peak. Assuming a background level of 20 μg/m$^3$, the scaling technique implies a total fire source of 25 Mtonnes per day.

The timeseries at Lough Navar, figure 3c, of the observed $PM_{10}$ and the modelled values show good agreement with the single sustained (more than 12 hours) episode occurring simultaneously in both. Assuming a background level of 10 μg/m$^3$, the scaling technique implies a total fire source of 22 Mtonnes per day.

From the satellite pictures it is probable that only 5-10% of the domain area is actually on fire, this would reduce the average total fire source from 20 Mtonnes per day to 1-2 Mtonnes per day. These numbers are based on the assumption that the effects of all of the fires in the domain are observed and that there was no loss of material due to wet or dry deposition during transport from the fire domain to the UK.

A report by NOAA (www.arl.noaa.gov/ss/transport/fires.html) estimated the amount of particulate matter emitted from a hectare of burning forest was 5kg/hr. The area identified in the satellite is approximately 67 Mha and if it was all burning forest this would produce approximately 8 Mt of particulate matter per day. This quantity is an over-estimation because only a relatively small fraction of the whole area was ablaze. The amount of material lost during transport to the UK will be significant but further work is required to attempt to quantify this.

The start times of the episodes at the three locations are significantly different. At London it began at 6-9pm 11$^{th}$ Sept., at Edinburgh it was 3-6am 12$^{th}$ Sept. and at Lough Navar the episode didn’t start until 9am-noon 12$^{th}$ Sept.. The observed episode start times are all mirrored by the modelled arrival times of air from the identified fire-domain.

## *Conclusions*

The NAME modelling of the transport of air from the region in Western Russia identified as an area with significant forest fires coincides with an observed episode of high $PM_{10}$ across much of the UK. This study concentrated on three locations; London, Edinburgh and Lough Navar. At each location the start and end times of the observed episodes are consistent with the modelling of air transported from the fire region, even the double peak structure in the observations at London are replicated by the modelling. The extent of the fire region was estimated from high resolution satellite imaginary.

By a relatively crude scaling argument the magnitude of the fires in Western Russia would need to have been between 1-20 Mtonnes per day during the period when air from that region dispersed to the UK. This value ignores the potentially large loss processes on route due to wet and dry deposition and sedimentation. The travel time from the fire area to London was estimated to be 7-9 days. This estimated value is of the same order of magnitude as that calculated assuming an emission rate from the literature of 5 kg/Ha/hr.

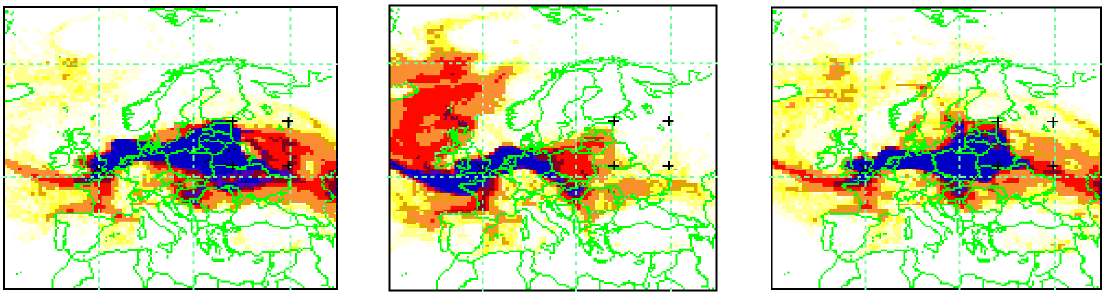
Further work is required to explore the impact of deposition and sedimentation on the material transported from Western Russia to the UK during the period of the fires. It would also be interesting to apply this approach at other European sites closer to Western Russia and also to assess the impact of the episode on other species such as carbon dioxide, carbon monoxide and methyl chloride.

## *Bibliography*

Cullen, M.J.P., The Unified Forecast/Climate Model, *Meteorological Magazine UK*, 1449, 81-94, 1993

Ryall, D.B. and R. H. Maryon, Validation of the UK Met Office's NAME model against the ETEX dataset, *Atmospheric Environment*, 32, 4265-4276, 1998.

Figure 1: Satellite image of western Russia from MODIS for the 4th Sept 2002



(a) (b) (c)

Figure 2: 10 day Back-attribution maps for London, 3 hour periods ending (a) 00Z 12/09/02, (b) 06Z 12/09/02 and (c) 12Z 12/09/02

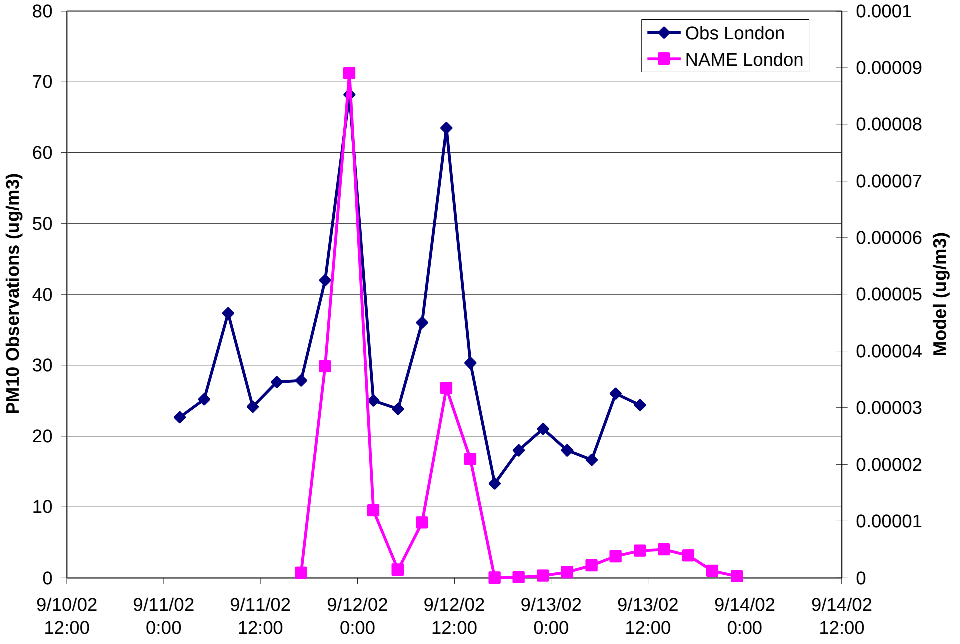



Figure 3a: Timeseries of observed background $PM_{10}$ and modelled air concentration from the estimated area on fire in Western

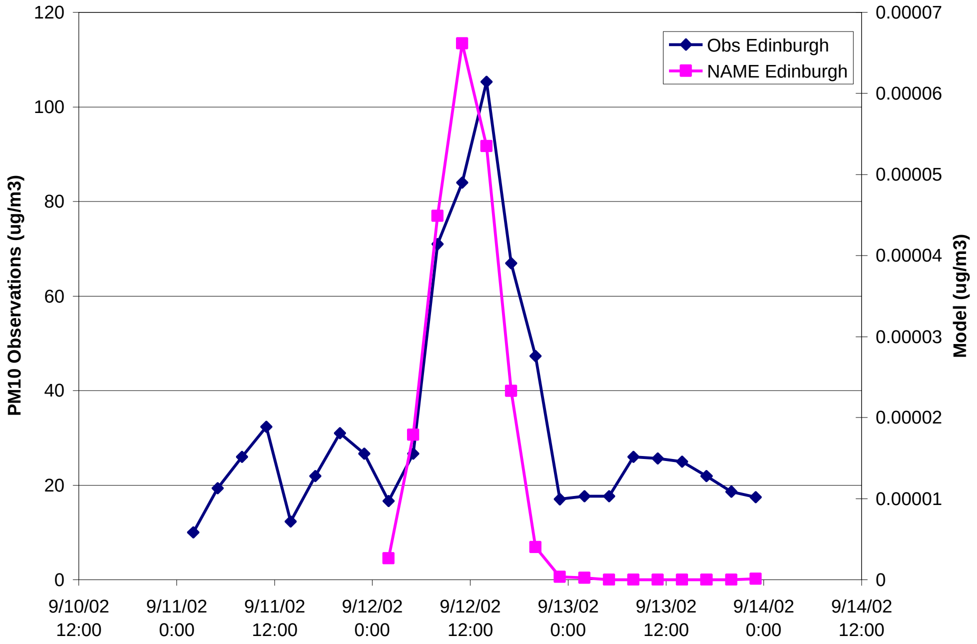



Figure 3b: Timeseries of observed background $PM_{10}$ and modelled air concentration from the estimated area on fire in Western Russia at Edinburgh.

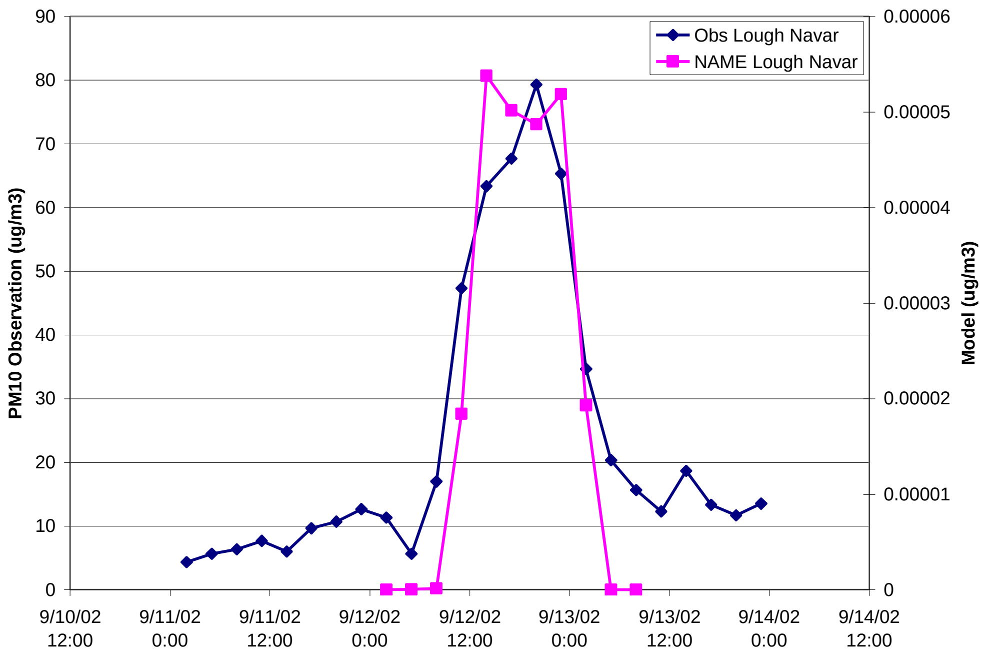



Figure 3c: Timeseries of observed background $PM_{10}$ and modelled air concentration from the estimated area on fire in Western Russia at Lough Navar a rural site in Northern Ireland.