NAME III Document
MD13/6(version 1)
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High Resolution UM Data and NAME III

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Introduction

The NAME III (Numerical Atmospheric Modelling Environment) dispersion model has been running from operational Unified Model, UM, NWP products for many years. These are typically represented by the Global (approx 60 km horizontal resolution) and a UK based Mesoscale (approx 12 km horizontal resolution) models. It is known, through comparison of the Global and Mesoscale models over the UK, that the increase in NWP model resolution has an impact on the prediction of atmospheric dispersion.

Furthermore, it has been recognised that the ability to run NAME on an independently generated meteorological output and optimum resolution has additional advantages:

- Run at any resolution anywhere in the word, not just the UK. This enables comparisons with data, field campaigns etc.
- Ability to reproduce runs with New Dynamics and optimum resolution for old data cases.
- Better representation of effects mostly influenced by high resolution including topographic effects such as valley flows, mesoscale features such as convergence and coastal effects, surface conditions e.g., urban effects.

Incorporating such high resolution effects, is particularly important for the UK because of its natural topographic scale and rich coast line.

Nesting the UM

The procedure is common to all NWP nesting applications. One starts, as we do here, with a global model initialised with a suitable set of data. When it runs, the global simulation provides initial and boundary conditions to a Limited Area Model LAM, at higher resolution inside the original global domain. In turn, the LAM can provide initial and boundary conditions to a higher resolution LAM inside the original LAM's domain. The process can be repeated in principle to an increasingly higher resolution, depending on the computer resources available.

The exact procedure in this case study is given below and is shown schematically in fig. 1. The UM is initialised firstly at global resolution and for a global domain from analysis data at 00Z on the 20/9/1999. This we call the global run and its horizontal resolution is 60km over the UK. The global run is integrated forward in time for 30 hours to 06Z on 21/9/1999. Various parameters are kept every 3hrs. These can be used to analyse and compare with the higher resolution runs but also to start a NAME III simulation, after some further manipulation i.e., put in the right format, order, etc. At the same time, boundary conditions are obtained every 1hr, for the next higher resolution run that has 12km horizontal resolution. A file with all the parameters needed to start the mesoscale run are kept after 3 hours of global model integration time i.e., at 03Z on the 20/9/1999.

The 12km resolution mesoscale run is integrated forward in time for 27hr, again to 06Z on 21/9/1999 and hourly data are kept over the whole domain, to drive NAME III. Moreover, hourly boundary conditions data and a start dump after 2 hrs of integration time i.e, at 5Z on the 20/9/1999 to initialise and run the higher 4km resolution model are obtained.

The 4km model is run forward in time for 25 hr, up to 06Z on the 21/9/1999. Data are obtained every 1hr, to run NAME III as before. The number of vertical levels and structure of vertical grid is the same for all three runs and is the standard 38 levels of the operational model. The LAM domains are shown in fig.2. Table 1 shows various settings and parameters of the model at various resolutions. These are, for each case, the same as the operational or operational to be.

Results

Analysis of meteorology

Before we discuss the dispersion characteristics, we present some basic fields from the UM, at various resolutions, to be used as reference and help explain some of the results.

The synoptic situation, analysis, during the period we study is shown in fig. 3. It is characterised by a low pressure system over the British Islands and the passage of a frontal zone during the 20/9/1999. The models did well to get the general synoptic situation; fig. 4 shows the wind field and orography from the global resolution model.

Figures 5, 6, 7 and 8 show the winds and orography at 12Z, 21Z and 00Z from the global, mesoscale and 4km runs. Only an area over southern England is shown, in order to appreciate the differences between the models. Moreover, this is the area of interest to examine the dispersion characteristics.

All wind vectors are plotted for the global and mesoscale resolutions whereas only a fraction for the 4km run for clarity. First thing to observe is the much better definition of topography with increasing resolution, the colour scheme and intervals is the same for all figures. At 4km, topographic features such as the Thames estuary, South Downs and Isle of White are defined. Moreover, the max height of orography increases and individual peaks are starting to be resolved.

The wind vectors in the global run, depict the general characteristics of the synoptic flow as the low pressure system and frontal zone move across the UK, but not much more. At mesoscale resolution, the flow pattern is more 'rich' in information, with sharp transitions of the wind i.e., fig. 7(a) to the east of the Isle of White and individual local circulations (fig. 8(a)) over the same area, clearly visible. At 4km, only a third of the wind vectors are shown i.e., about the same resolution as the 12km mesoscale run. This is done to avoid over cluttering of the arrows but it also highlights the fact that the flow pattern is different even at that scale. At 12Z, fig. 6, the flow differences between the 12km mesoscale and 4km models are very pronounced, especially over the Channel, Essex and North of London. There are local patterns in the form of confluence/difluence zones, low level jets and stronger flow deceleration over the south coast for example. At 0Z, fig. 8, the local eddy over the Isle of White shown in the mesoscale run, is destroyed in the 4km, due to the fact that the Island is resolved in the latter case and has therefore altered the local flow significantly.

Fig. 9, shows the large scale (resolved) plus convective (parameterised) precipitation, at 12Z on the left and 12hr later on the right, from the three models; global, mesoscale, 4km from the top to bottom of the page. They all register the passage of the front. They all get the basic features about right i.e., the position and extend of the frontal zone, the precipitation near the low centre later in the day. This is not very surprising given that the precipitation in this case is associated with a synoptic scale system that was rather well forecasted. There are difference though in details and structure of precipitation. No opinion is offered here to which is the most accurate, we merely observe the fact that the differences are pronounced even between the 12 km and 4 km models.

NAME III results

In this section, we discuss the results obtained from NAME III. The model has been run for a fictitious release from a boat in the English Channel located at 0.5W 50.5N. The release starts at 07:00 of 20/9/1999 and is continuous for the duration of the available NWP data. The source size $\Delta x = \Delta y = 100$m, $\Delta z = 40$m with a vertical centre of release $z = 20$m above ground level. NAME III has been run in particle mode. The source material is labelled TRACER and is subject to mean advection and turbulent transport and wet deposition.

Figures 10 to 15 present instantaneous air concentration fields for the layer $0 < z < 40m$ agl for 12Z 20/09/1999 and 0Z 21/09/1999; figures 16 to 21 show total wet deposition for 12Z 20/09/1999 and 0Z 21/09/1999 and figure 22 to 24 show the integrated air concentration (dosage) for the same vertical depth as the instantaneous air concentration but only for 0Z 21/09/1999.

Inspection of these plots instantly reveals significant differences in the 'dispersion' fields. These differences range from the resolution of smaller flow features to the general position of the entire plume.

It is worth noting several specific features.

The resolution of the local flow over the south coast results in significantly different plume direction and position, across all three model resolutions, both at 12Z and 0Z. At 12Z the plumes have distinctly different directions and advection velocities. Twelve hours later at 0Z the local flow differences result in the plume missing the Isle of white entirely for the global run, while the higher resolution runs predict very significant concentrations over the entire island. This is entirely consistent with the earlier discussion of the predicted model meterologies.

From the dosage plots we observe that, with increasing NWP resolution, the integrated plume widens. This is likely due to higher resolution models capturing a greater amount of the orographicly induced spread e.g., channelling that the larger scale parameterisations do not represent well. Also the higher resolution data means that 'hot spots', fig 24, caused by local topographic effects are being resolved. This can significantly benefit impact analysis and long term health effect analysis.

The wet deposition highlights another significant difference between the low and high resolution models. At resolutions of 4km much more structure is observed in the NWP precipitation fields while the lower resolution simulations tend to 'spread' out the precipitation. So while the lower resolution model runs cover large parts of the country in deposited tracer, with increasing resolution this area significantly reduces. This has significant ramifications in evaluating such things as water supply and food chain contamination.

Conclusions

With increased resolution the flow and dispersion are affected in multiple ways. The first influence comes from the better representation of topographic features:

- Firstly, changes in the local mean flow can result in both significant differences in plume direction and also in plume spread.
- Greater variation both spatially and in magnitude of the surface roughness impacts considerable on the turbulent dispersion of the plume.

A second influence comes from difference in parameters associated with wet processes i.e., type of precipitation, spatial structure and extent and timing. This affects mostly dispersion and air quality parameters that are influenced by the presence of water in the atmosphere e.g., wet deposition.

This case was synoptically rather well forecasted and all models get the basic features about right i.e., the position and extent of the frontal zone, the precipitation near the low centre later in the day. Nevertheless, even small differences present in the meteorological fields between the different resolution models result in significant differences in the dispersion parameters.

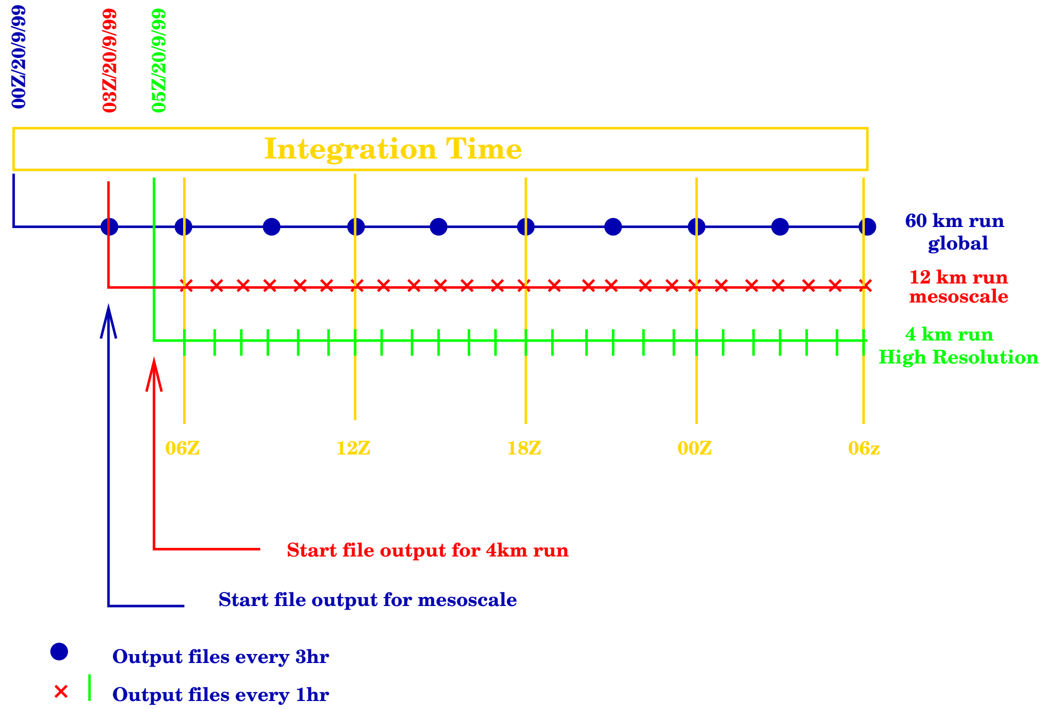


Figure 1: Schematic diagram of the UM nesting.

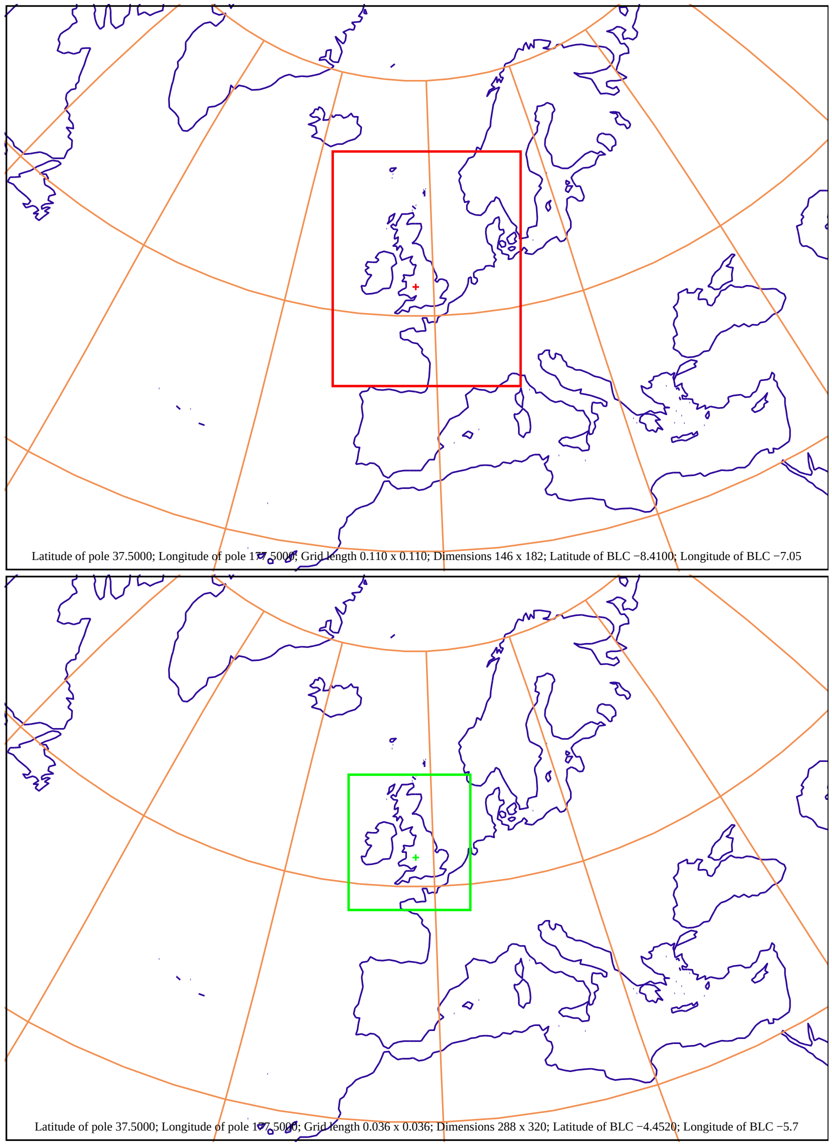


Figure 2: Domains of the UM for the different resolutions. Top domain is the 12km mesoscale. Bottom is the domain for the 4km resolution model. The global model runs over the whole globe, part of which is shown.

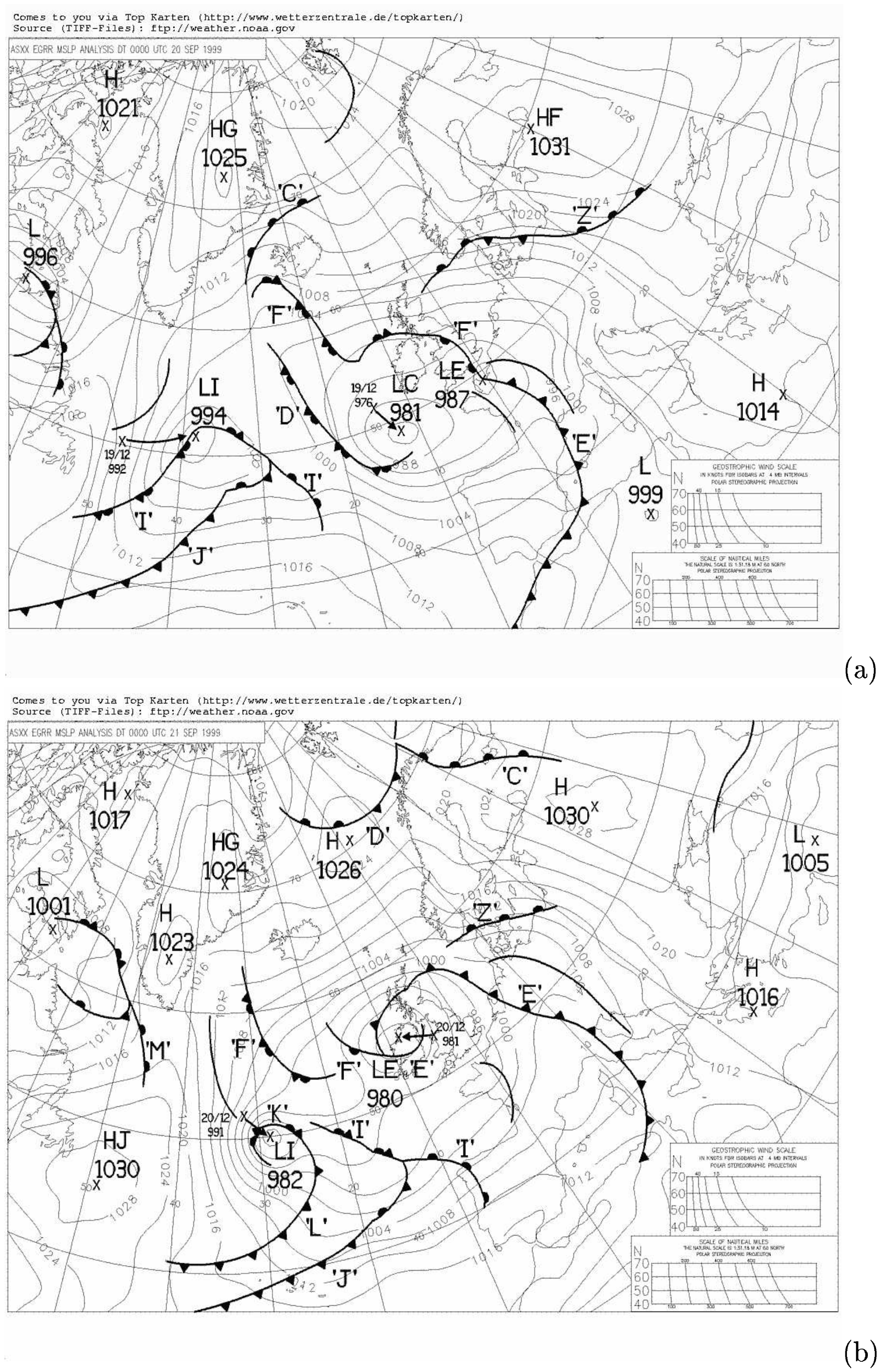


Figure 3: Synoptic analysis at 0Z on the 20/9/1999 (a) and 21/9/1999 (b)

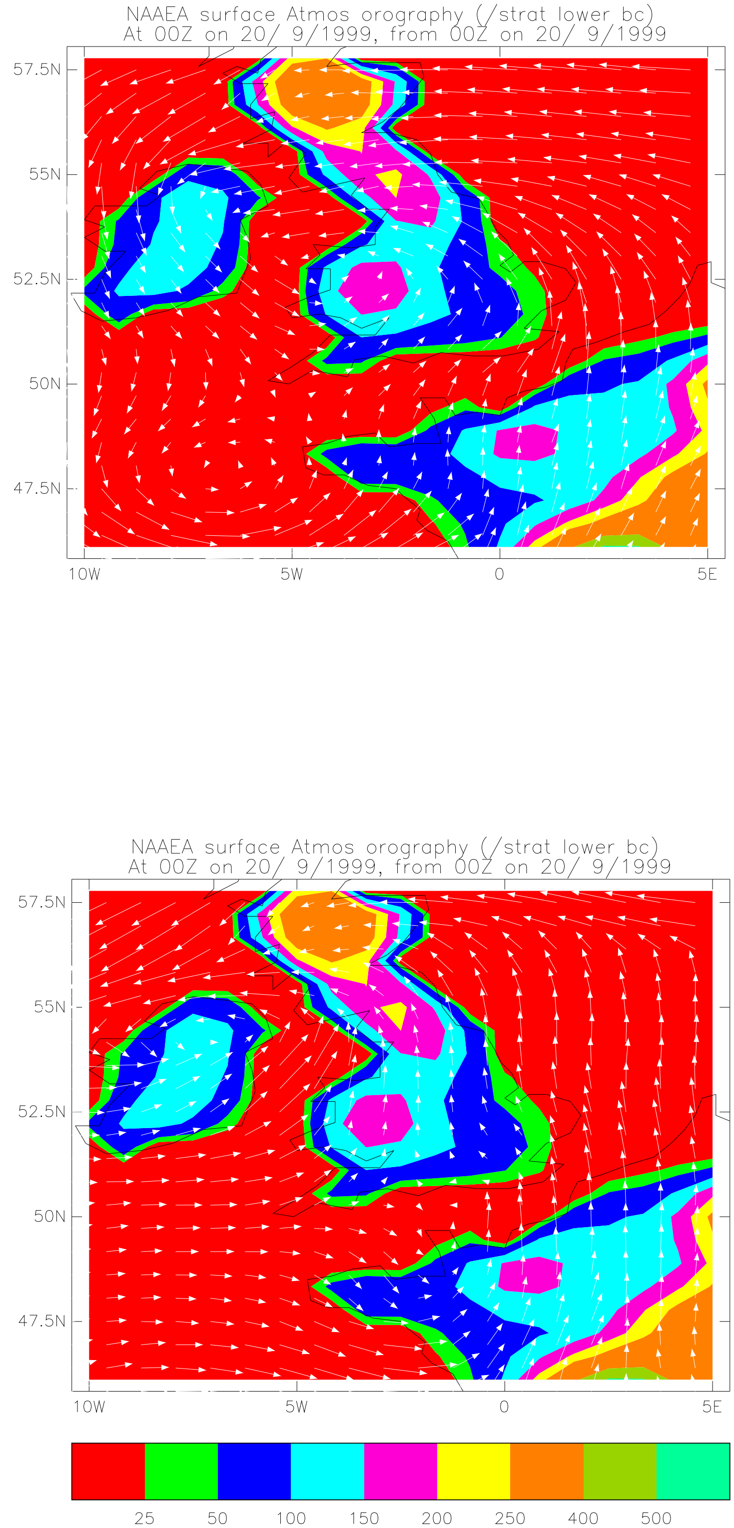


Figure 4: Orography and wind from the global UM at 12Z on 20/9/1999 top figure and 0Z on 21/9/1999 bottom figure.

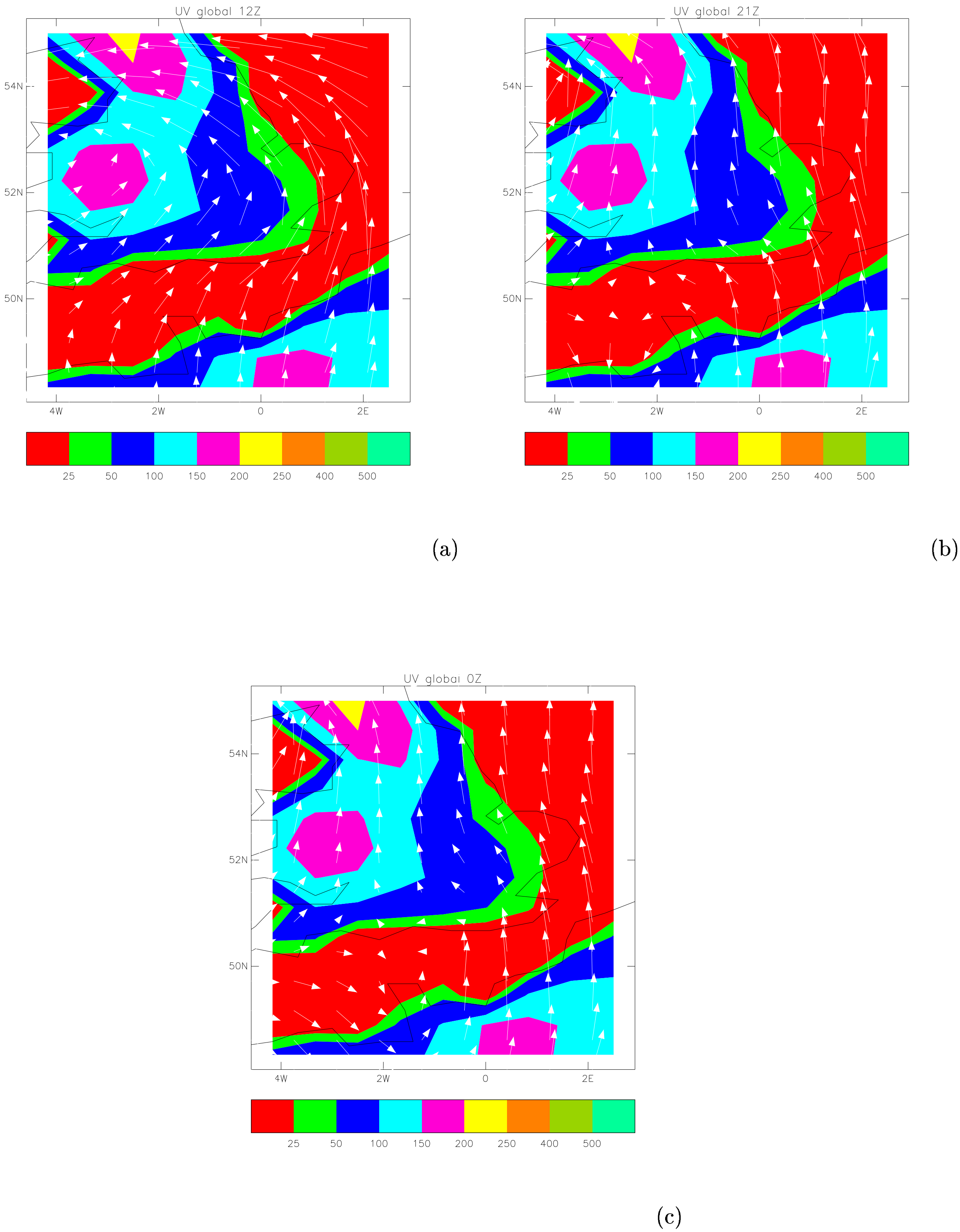


Figure 5: Orography and wind from the global UM at (a) 12Z and (b) 21Z on 20/9/1999 and (c) 0Z on 21/9/1999.

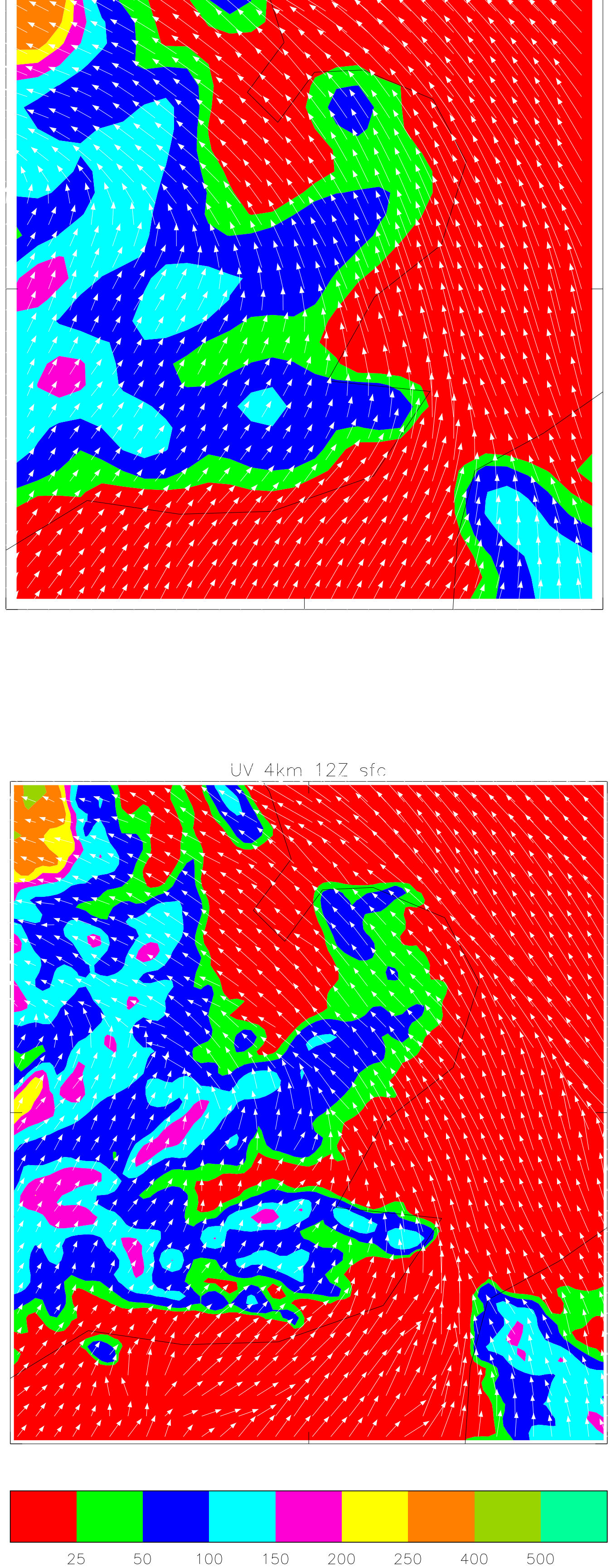


Figure 6: Orography and wind from the mesoscale (top) and 4km (bottom) UM at 12Z on 20/9/1999.

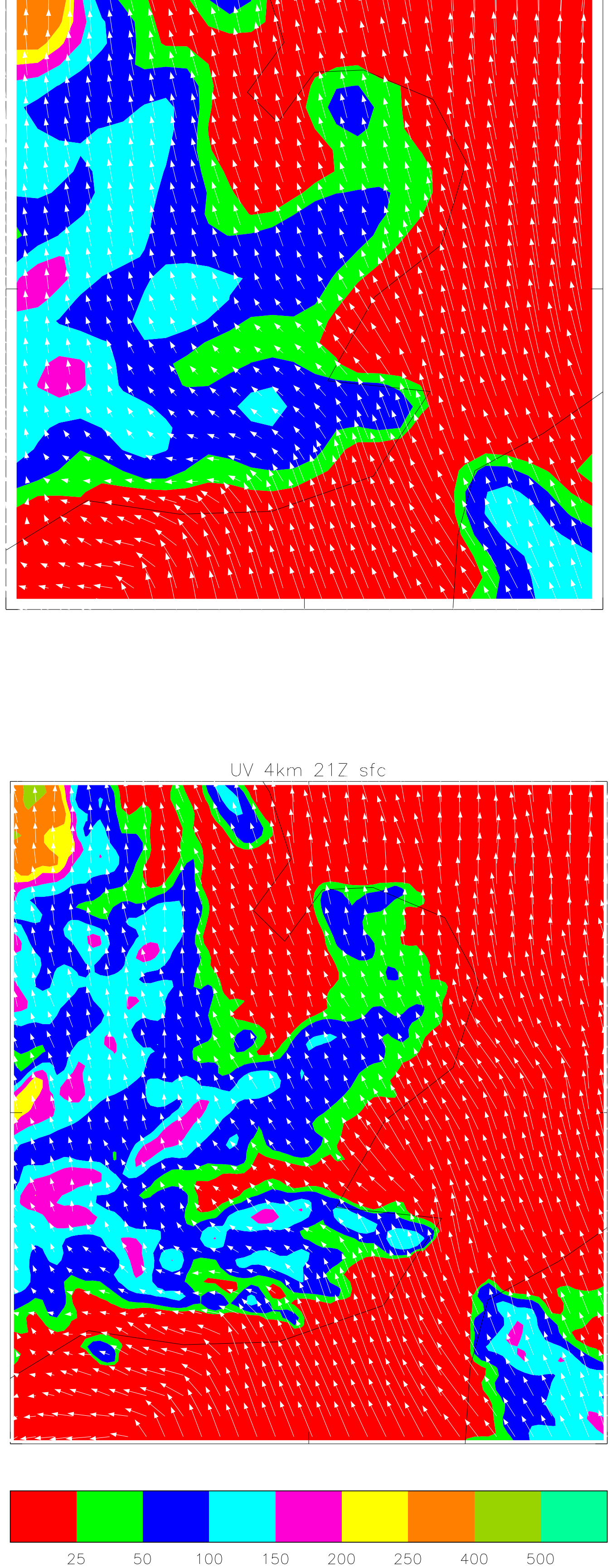
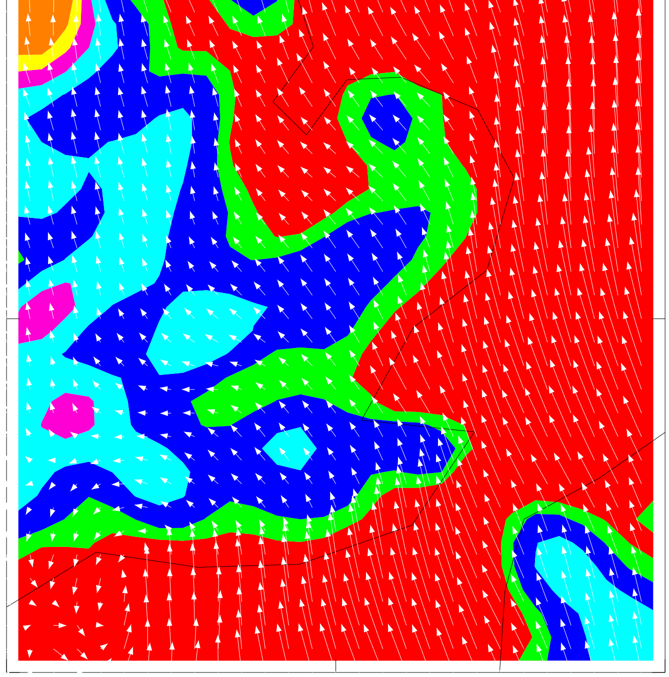


Figure 7: Orography and wind from the mesoscale (top) and 4km (bottom) UM at 21Z on 20/9/1999.



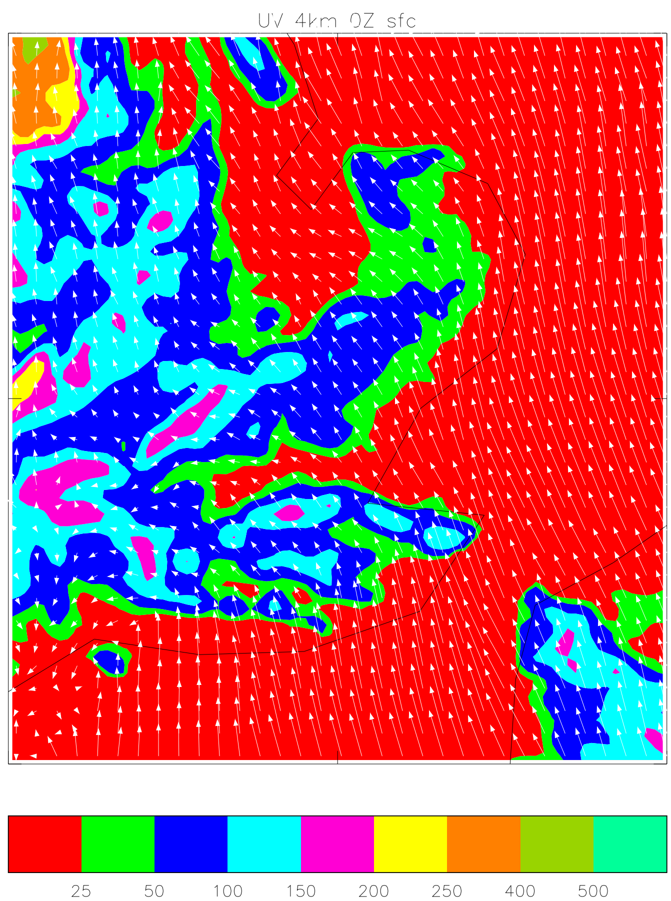


Figure 8: Orography and wind from the mesoscale (top) and 4km (bottom) UM at 0Z on 21/9/1999.

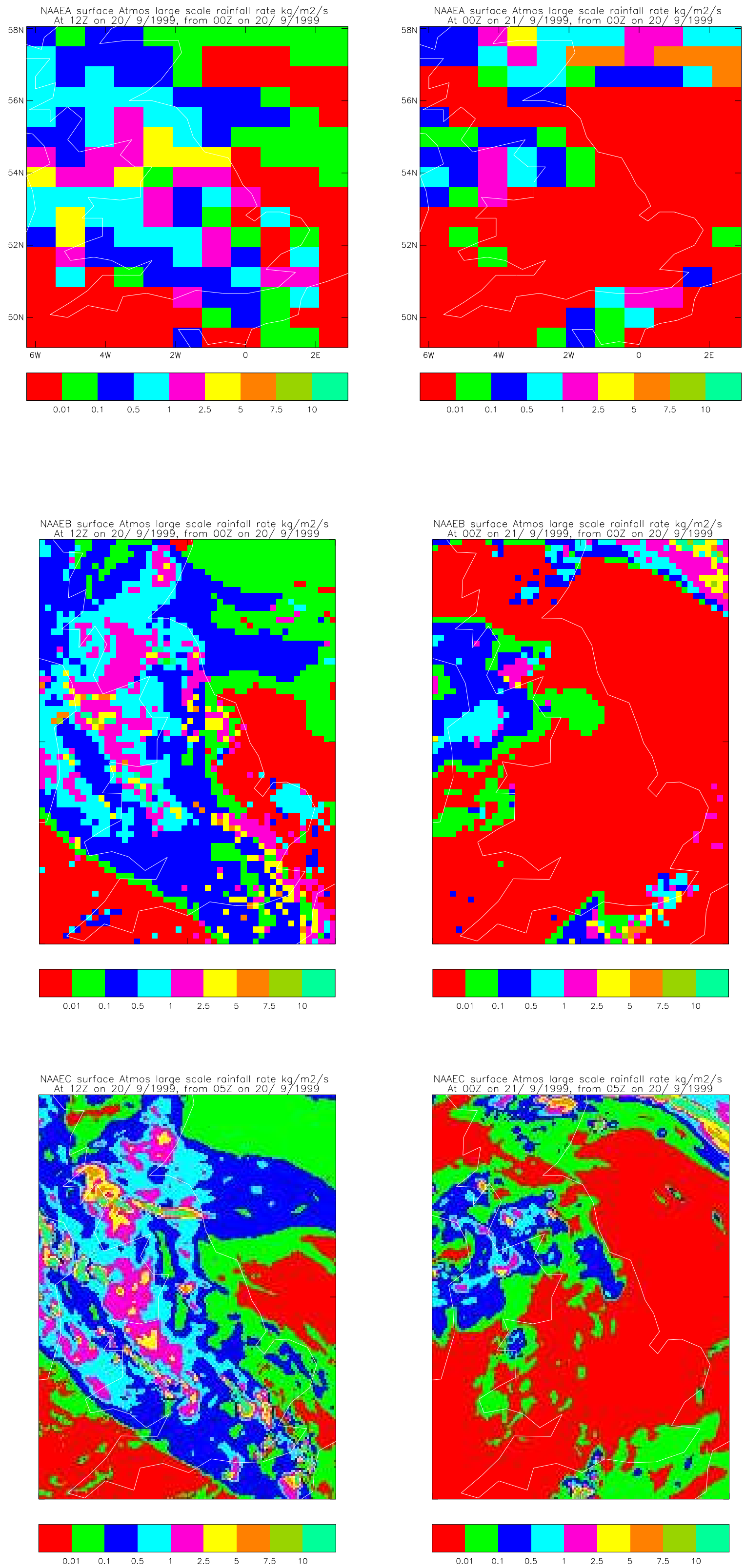


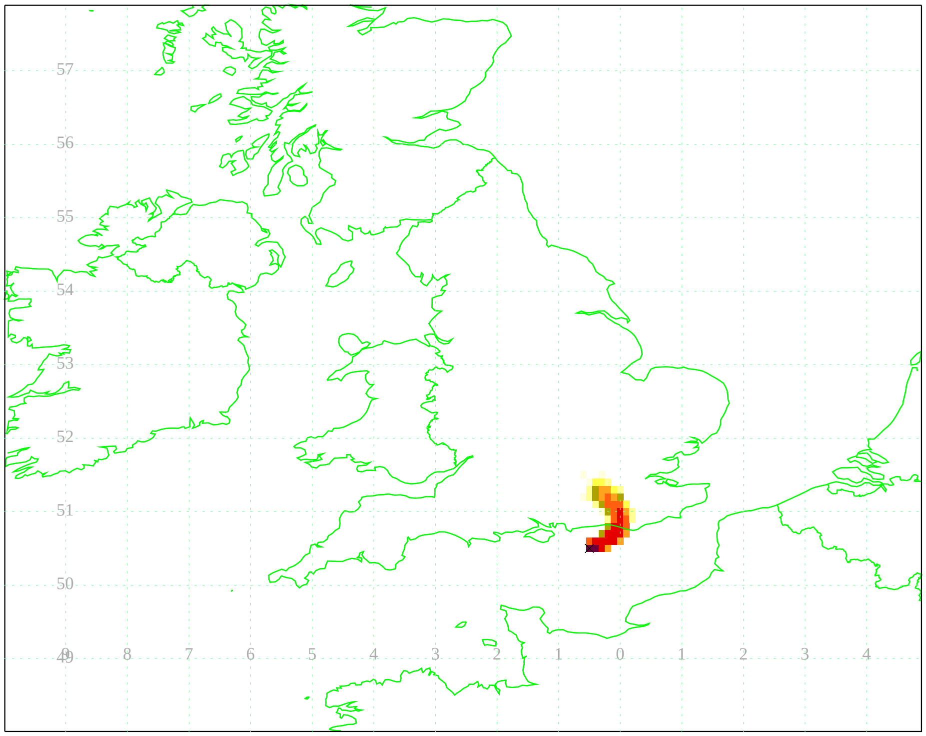
Figure 9: Precipitation from the UM at the various resolutions: top to bottom is from the global, mesoscale and 4km respectively. Left column is at 12Z on 20/9/1999, right column at 0Z on 21/9/1999.

NAME III (version 2.0)

PPtest

From 0 − 40m agl Air Concentration

Valid at 1200UTC 20/09/1999



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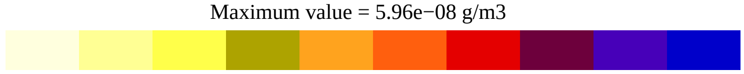

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End of release: 0700UTC 21/09/1999
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Release location: 0.5000W 50.5000N
Release height: 20.000m agl

Pollutant: TRACER
Met data: NWP Flow.Regional
Run time: 1122UTC 04/04/2005

Figure 10: Global Air Concentration at 12Z 20/9/1999

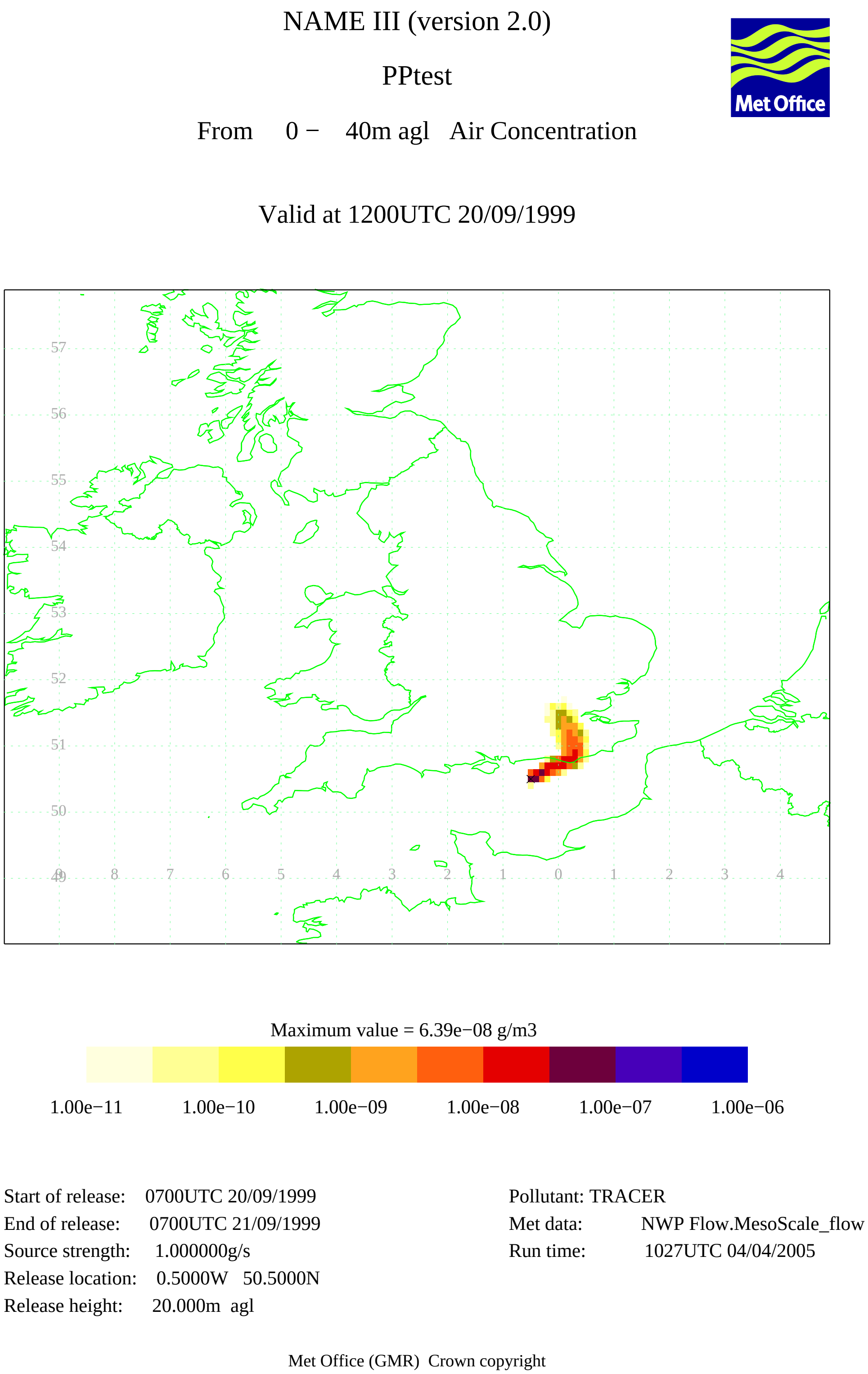


Figure 11: Mesoscale (12 km) Air Concentration at 12Z 20/9/1999

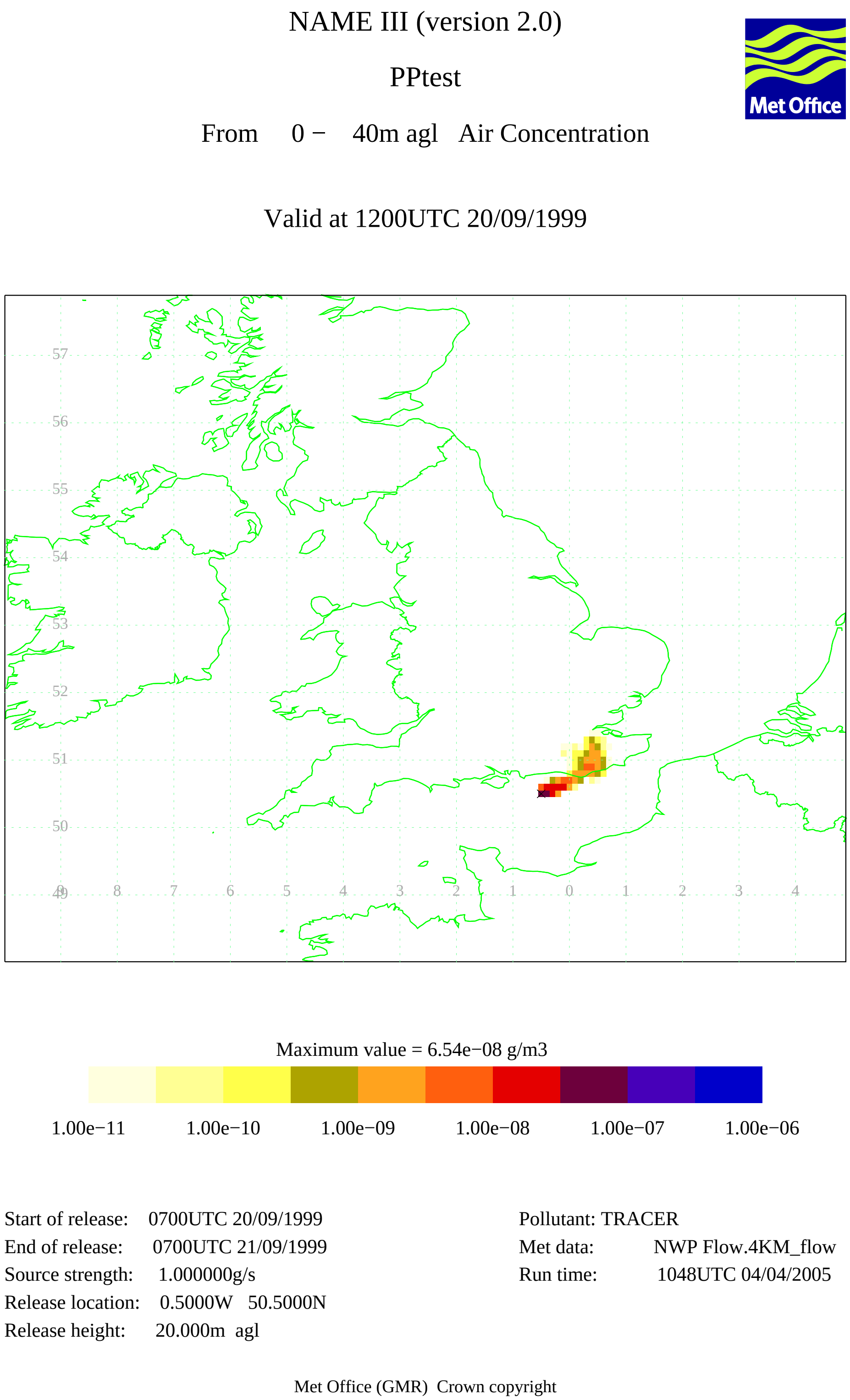


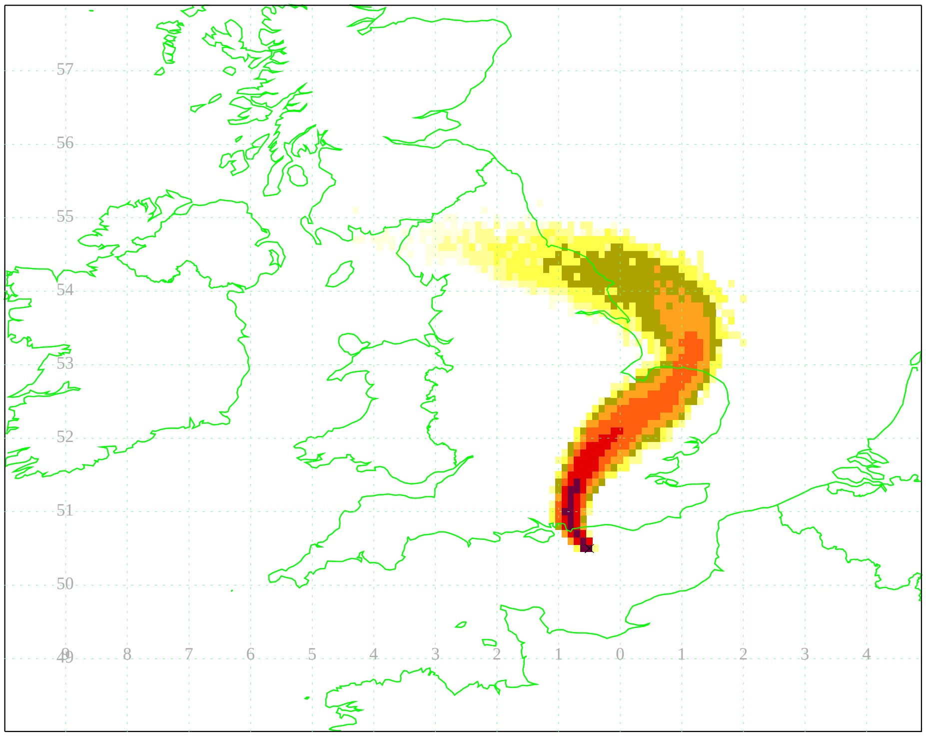
Figure 12: 4km Air Concentration at 12Z 20/9/1999

NAME III (version 2.0)

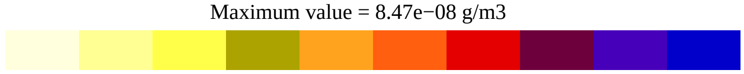
PPtest

From 0 − 40m agl Air Concentration

Valid at 0000UTC 21/09/1999



Maximum value = 8.47e−08 g/m3



1.00e−11 1.00e−10 1.00e−09 1.00e−08 1.00e−07 1.00e−06

Start of release: 0700UTC 20/09/1999
End of release: 0700UTC 21/09/1999
Source strength: 1.000000g/s
Release location: 0.5000W 50.5000N
Release height: 20.000m agl

Pollutant: TRACER
Met data: NWP Flow.Regional
Run time: 1122UTC 04/04/2005

Figure 13: Global Air Concentration at 0Z 21/9/1999

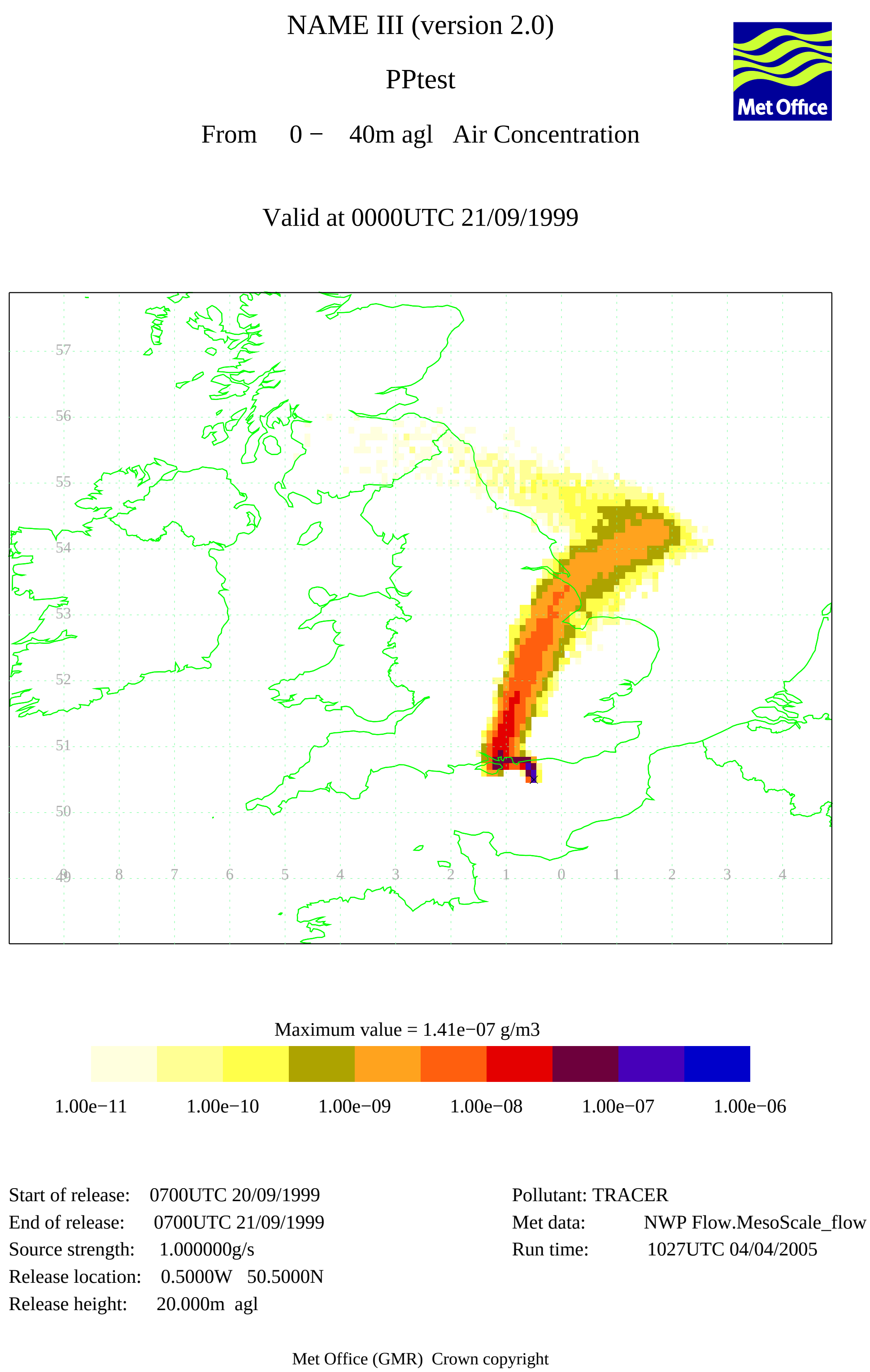


Figure 14: Mesoscale (12 km) Air Concentration at 0Z 21/9/1999

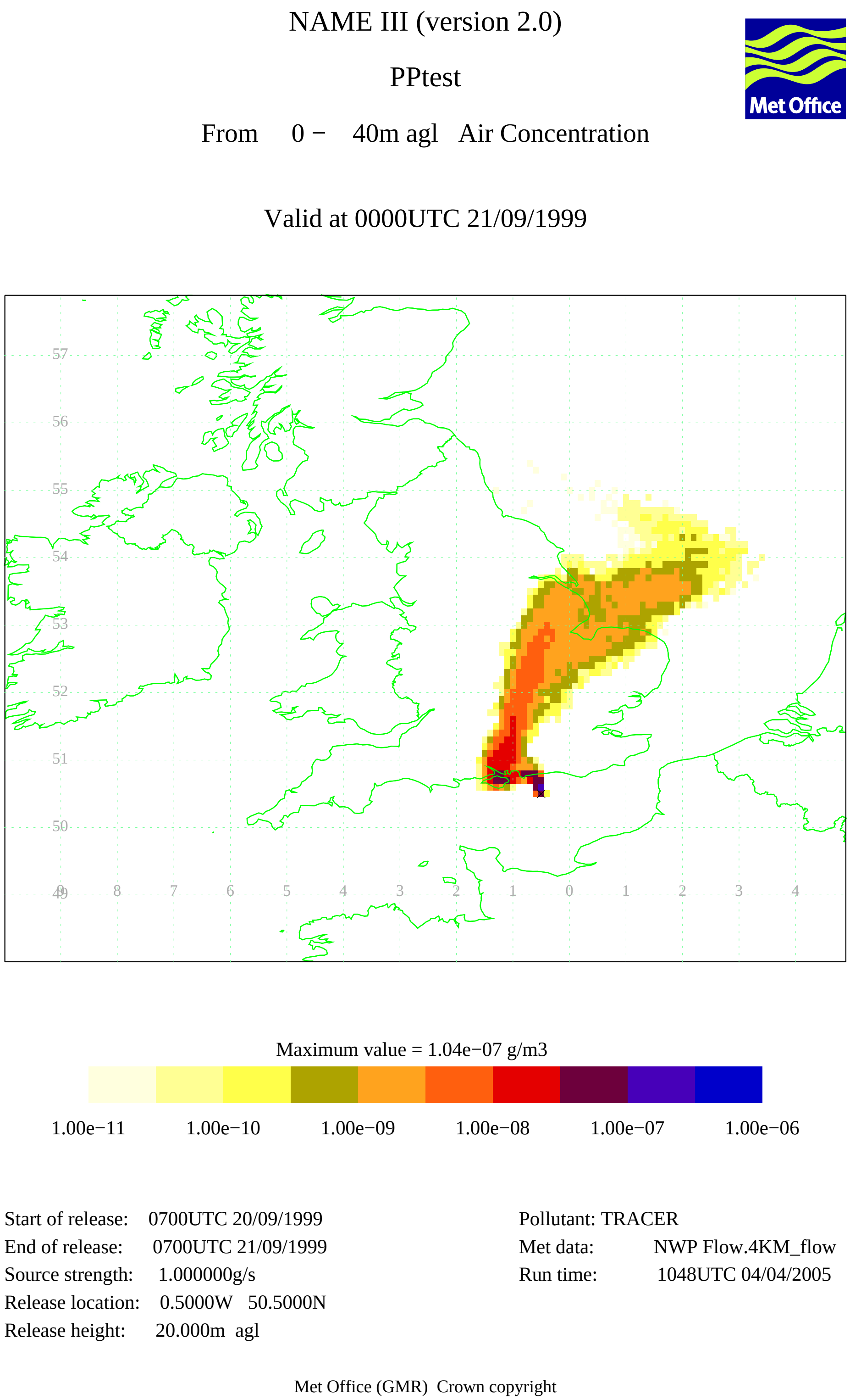


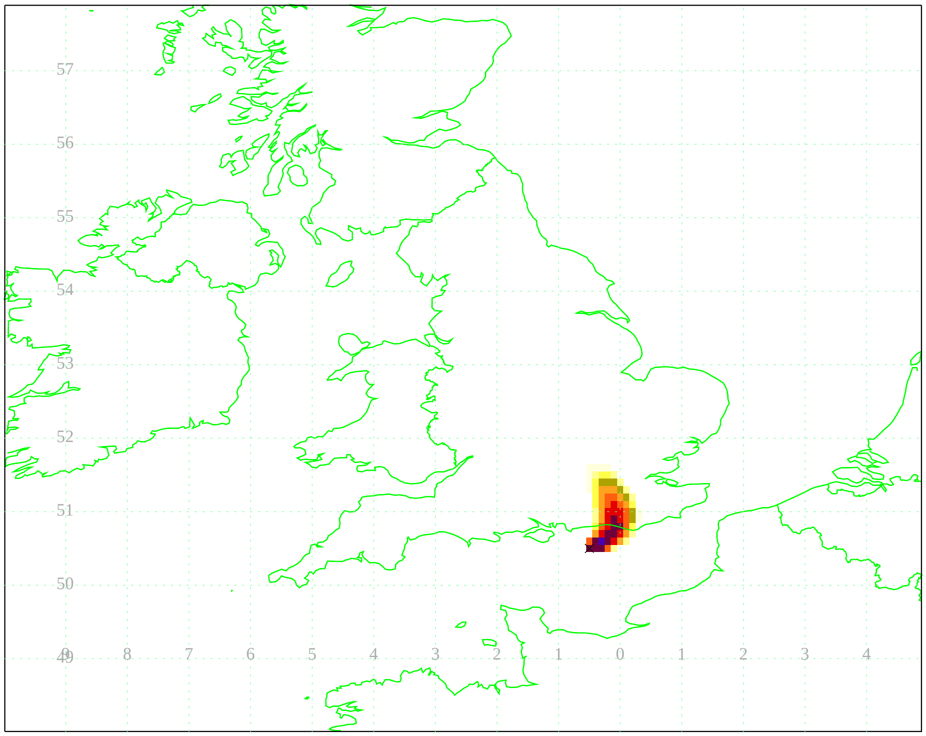
Figure 15: 4km Air Concentration at 0Z 21/9/1999

NAME III (version 2.0)

PPtest

Boundary layer   Total deposition

Valid at 1200UTC 20/09/1999



Maximum value = 1.19e−05 g/m2

1.00e−09   1.00e−08   1.00e−07   1.00e−06   1.00e−05   1.00e−04

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End of release: 0700UTC 21/09/1999
Source strength: 1.000000g/s
Release location: 0.5000W 50.5000N
Release height: 20.000m agl

Pollutant: TRACER
Met data: NWP Flow.Regional
Run time: 1122UTC 04/04/2005

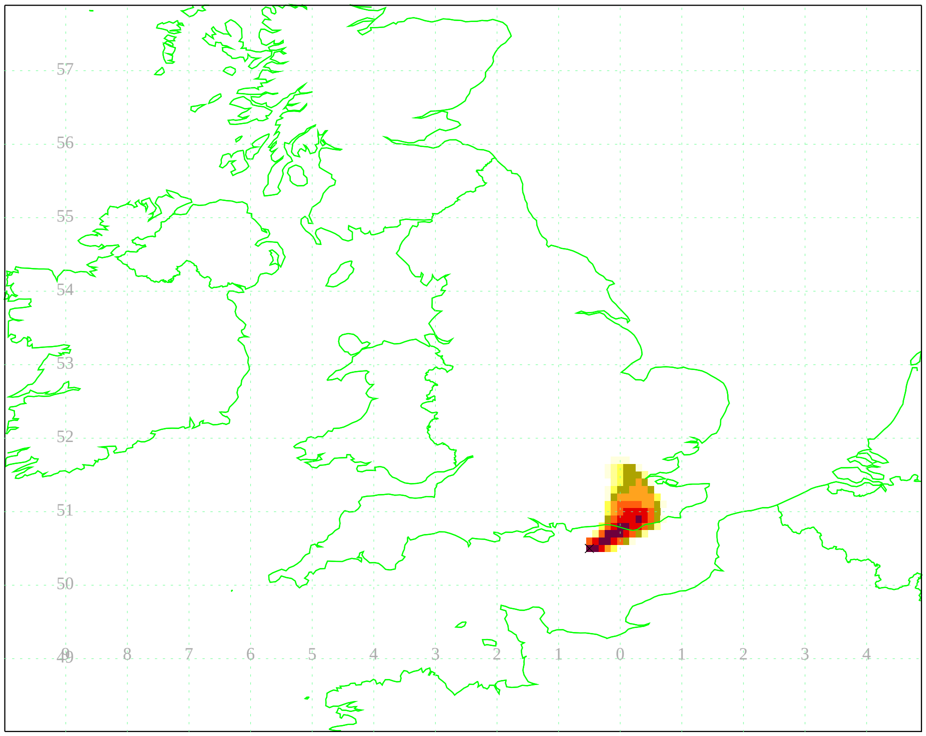
Figure 16: Global deposition at 12Z 20/9/1999

NAME III (version 2.0)

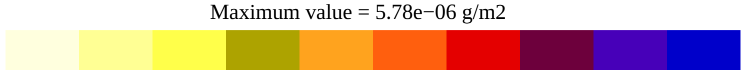
PPtest

Boundary layer   Total deposition

Valid at 1200UTC 20/09/1999



Maximum value = 5.78e−06 g/m2



Start of release: 0700UTC 20/09/1999
End of release: 0700UTC 21/09/1999
Source strength: 1.000000g/s
Release location: 0.5000W 50.5000N
Release height: 20.000m agl

Pollutant: TRACER
Met data: NWP Flow.MesoScale_flow
Run time: 1027UTC 04/04/2005

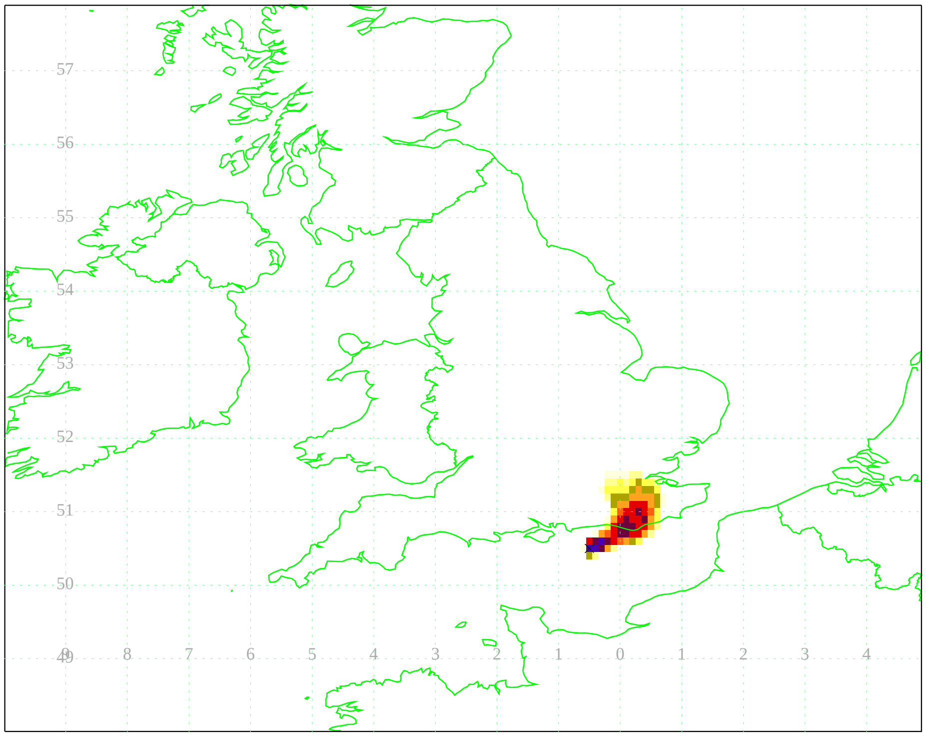
Figure 17: Mes deposition at 12Z 20/9/1999

NAME III (version 2.0)

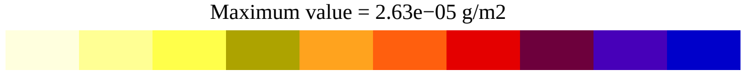
PPtest

Boundary layer   Total deposition

Valid at 1200UTC 20/09/1999



Maximum value = 2.63e−05 g/m2



1.00e−09   1.00e−08   1.00e−07   1.00e−06   1.00e−05   1.00e−04

Start of release: 0700UTC 20/09/1999
End of release: 0700UTC 21/09/1999
Source strength: 1.000000g/s
Release location: 0.5000W 50.5000N
Release height: 20.000m agl

Pollutant: TRACER
Met data: NWP Flow.4KM_flow
Run time: 1048UTC 04/04/2005

Figure 18: 4km deposition at 12Z 20/9/1999

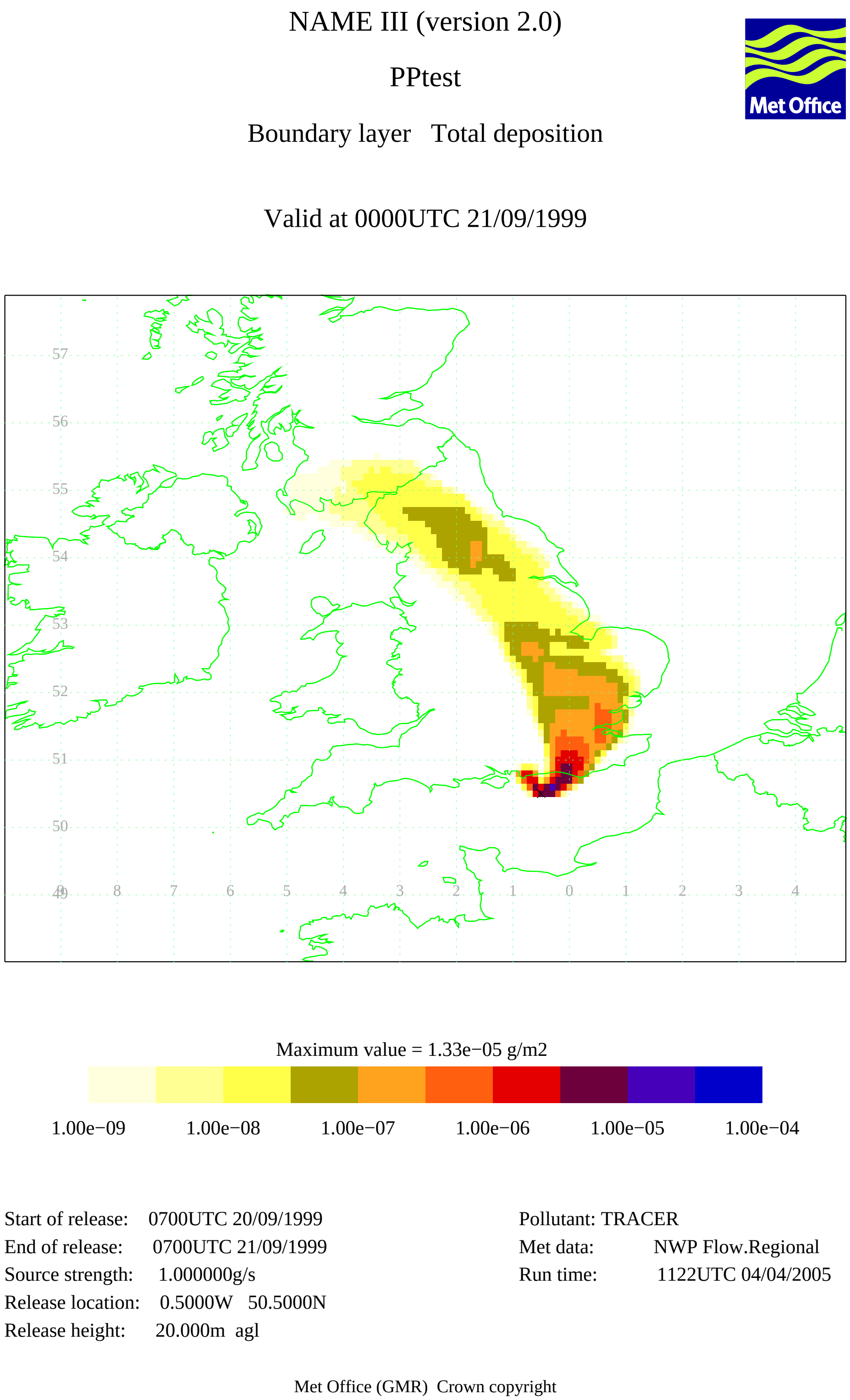


Figure 19: Global deposition at 0Z 21/9/1999

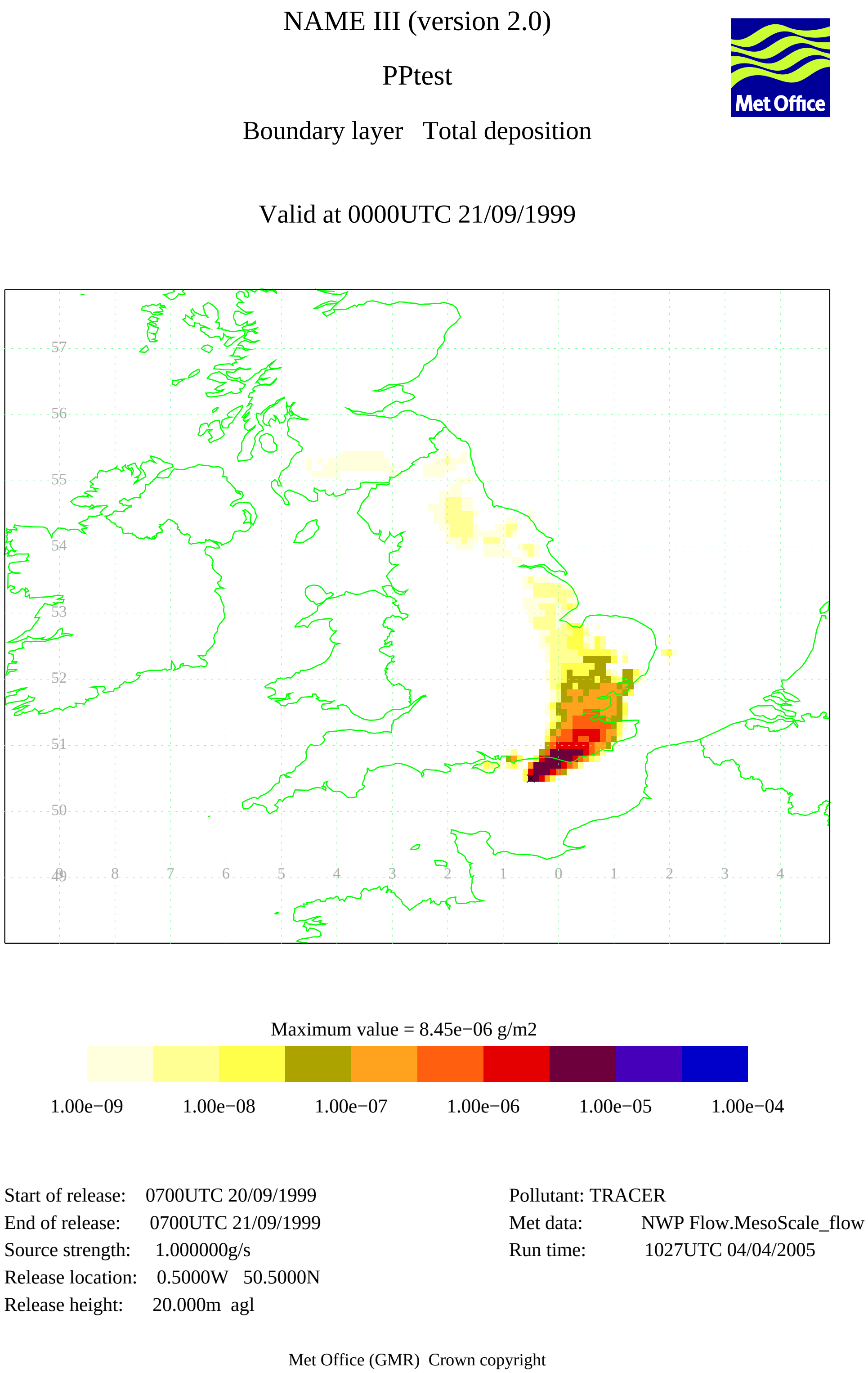


Figure 20: Mes deposition at 0Z 21/9/1999

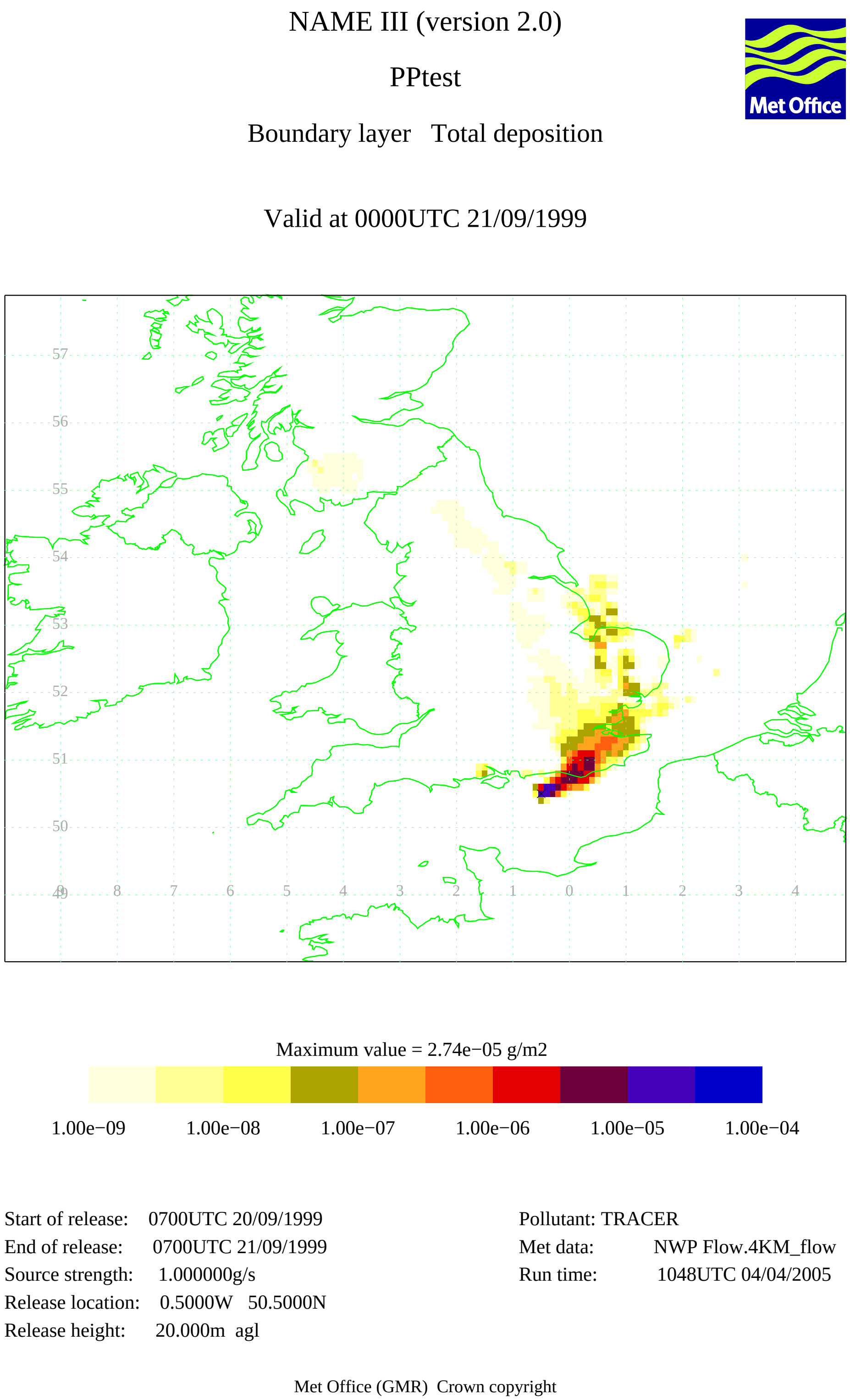


Figure 21: 4km deposition at 0Z 21/9/1999

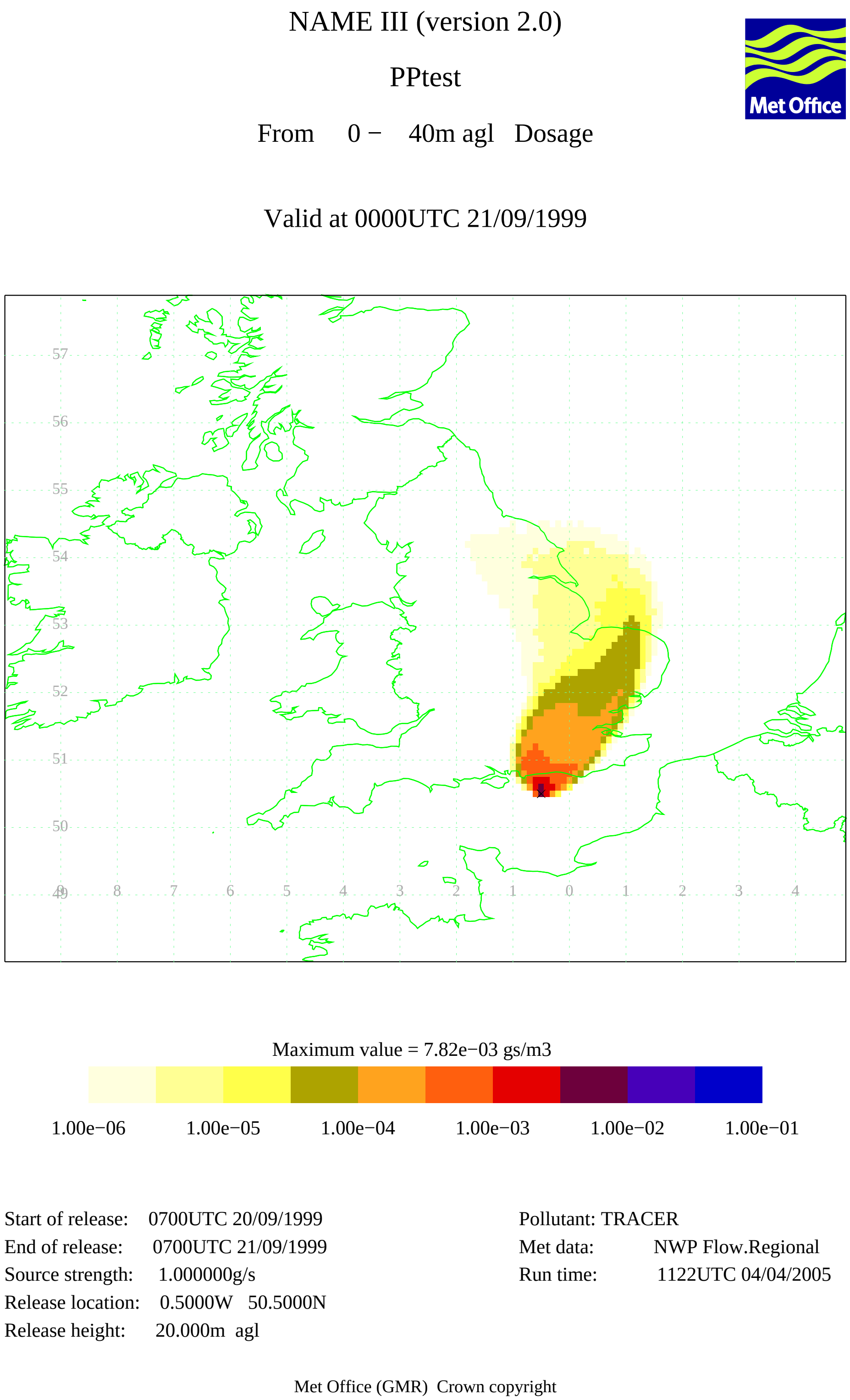


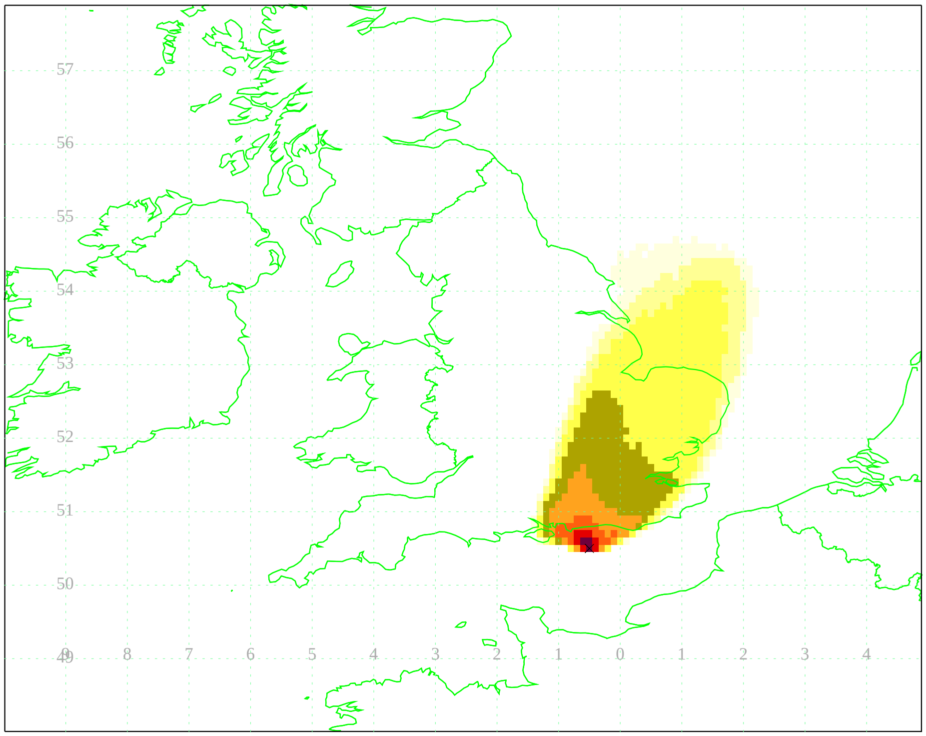
Figure 22: Global dosage at 0Z 21/9/1999

NAME III (version 2.0)

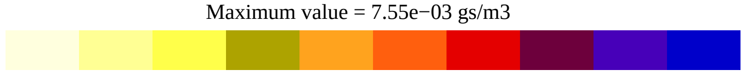
PPtest

From 0 − 40m agl Dosage

Valid at 0000UTC 21/09/1999



Maximum value = 7.55e−03 gs/m3



Start of release: 0700UTC 20/09/1999
End of release: 0700UTC 21/09/1999
Source strength: 1.000000g/s
Release location: 0.5000W 50.5000N
Release height: 20.000m agl

Pollutant: TRACER
Met data: NWP Flow.MesoScale_flow
Run time: 1027UTC 04/04/2005

Figure 23: Mes dosage at 0Z 21/9/1999

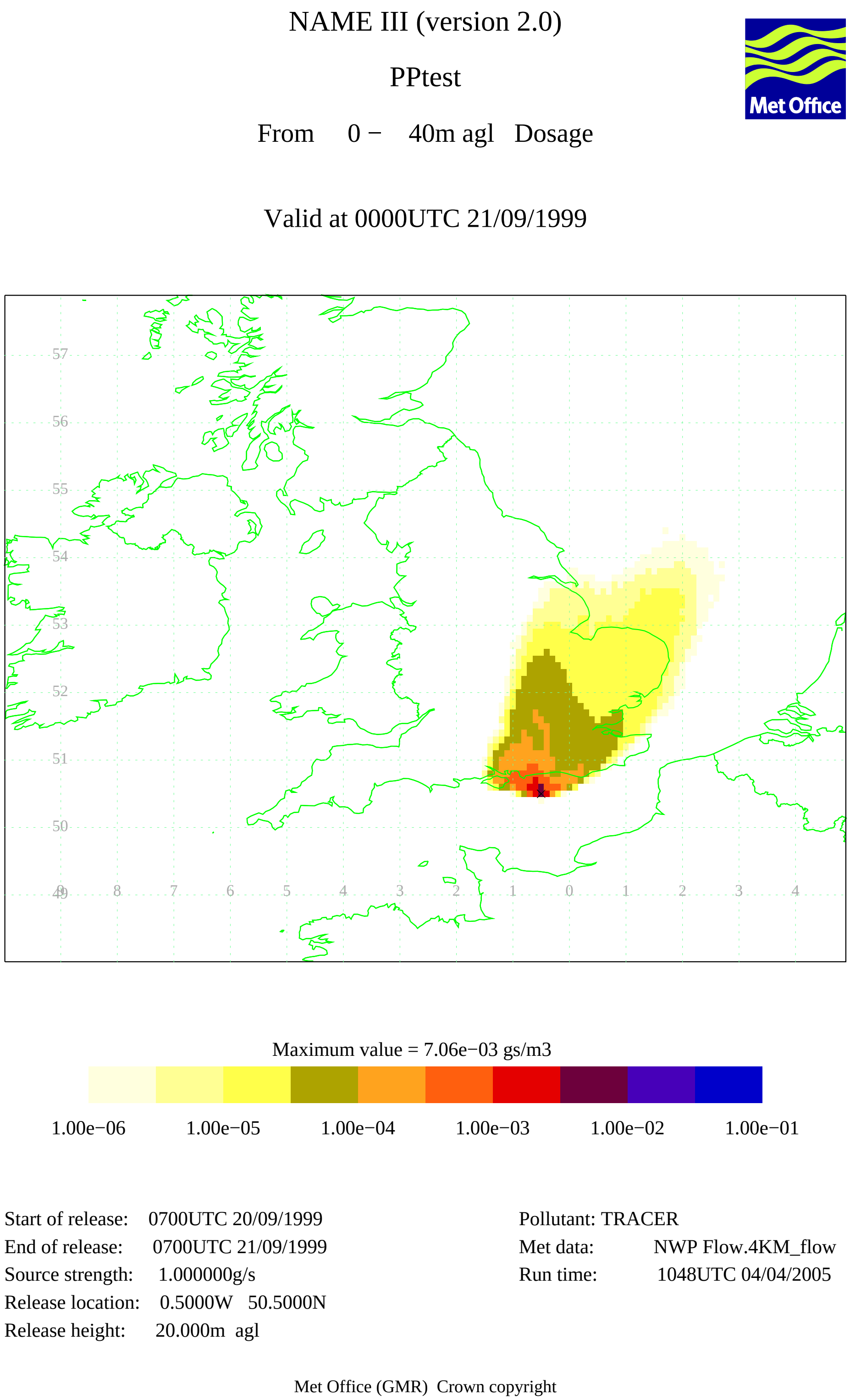


Figure 24: 4km dosage at 0Z 21/9/1999

Annex A: Tables

Table 1: Settings at various resolutions. LS=Large scale; GWD =gravity wave drag.

	Global	Mesoscale	4 km
Gridpoints (Nx,Ny)	(432, 325)	(146, 182)	(288, 320)
Time step	20 min	5 min	100 sec
Resolution in ^{o}	0.83333 X 0.55	0.11 x 0.11	0.036 X 0.36
LS precip	3B	3B	3C
Convection	4A	4A	3C
GWD	4A	4A	off
Horizontal diffusion	off	stn	stn
Vertical diffusion	ramped	off	off

Table 2: From NAME III

	Global	Mesoscale	4 km
Max Air Concentration			
12Z 20/9/1999	5.96×10^{-8}	6.36×10^{-8}	6.54×10^{-8}
0Z 21/9/1999	8.47×10^{-8}	1.41×10^{-7}	1.04×10^{-7}
Wet deposition			
12Z 21/9/1999	1.19×10^{-5}	5.78×10^{-6}	2.63×10^{-5}
0Z 21/9/1999	1.33×10^{-5}	8.45×10^{-6}	2.74×10^{-5}
Dosage 0Z 21/9/1999	7.82×10^{-3}	7.55×10^{-3}	7.06×10^{-3}