Air Quality Forecasting with WRF and CMAQ

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Overview

Overview

Application of WRF-CMAQ for UK Air Quality forecasting

WRF-CMAQ model

WRF-CMAQ Operation

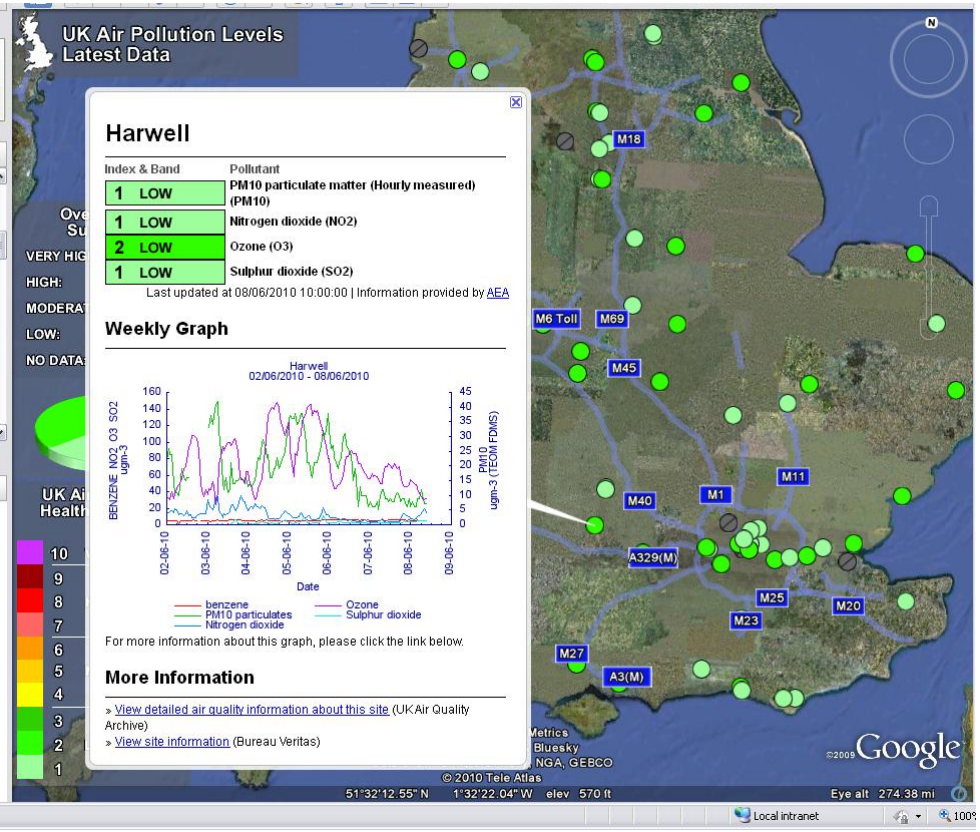
Air Quality Evaluation

Summary

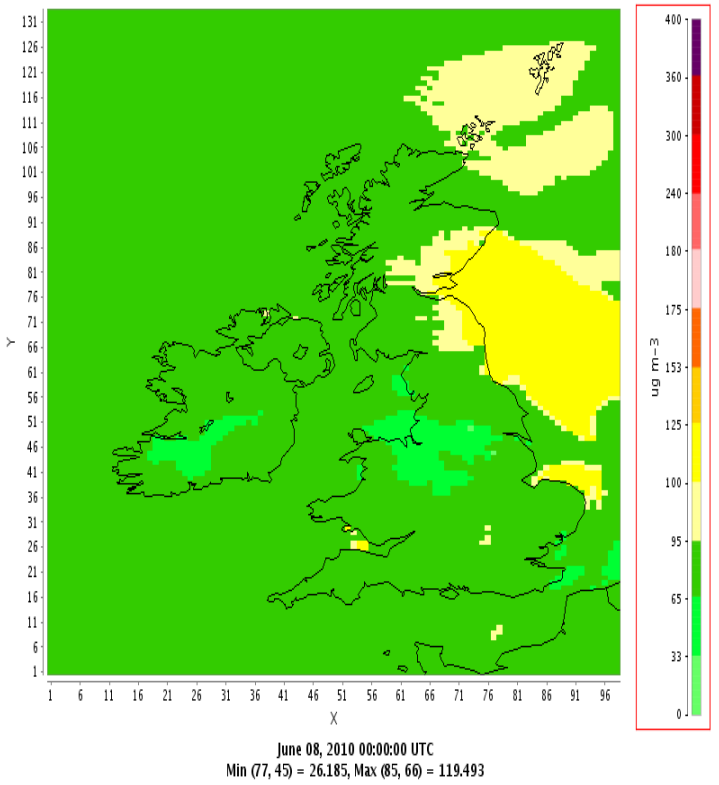
Daily UK Air Quality Forecast

AEA produce an expert AQ forecast for, Ozone, NO_2, PM_{10}, $PM_{2.5}$, SO_2, CO

The 24 and 48 hour CMAQ forecast for Europe and the UK are one of the tools used, along with measurements, weather forecasts, back trajectories and satellite images.



Ozone Daily max



Very High

High

Moderate

Low

WRF-CMAQ Air Quality modelling system

Meteorology Data produced using
WRF (Weather Research and Forecasting) **Model**

Using GFS initial and boundary conditions

Emissions data

EMEP - 50km
NAEI - 1km
Biogenic Potential Inventory
BPI - 50km

CMAQ (Community Multiscalar Air Quality) **Model**

A 'One Atmosphere' Chemical Transport Model including :

Advection, Diffusion, Chemical Transformation, Deposition, Aerosol formation, Emissions

Gas species
Ozone NO_2
SO_2 VOC

Particulate matter
PM_{10} $PM_{2.5}$
Organic PM components
Inorganic PM components

Wet and Dry deposition

Nitrogen, Sulphur

WRF-CMAQ Forecast

WRF and CMAQ are operated as independent models

The UK forecast is nested within a European forecast

- The Advanced Research version of WRF create European and UK hourly numerical weather forecasts, at 48km and 12km resolution and 48 vertical layers.
- A new forecast has been developed at 50km and 10km resolutions for Europe and the UK.
- CMAQ uses the same resolution, with a slightly smaller grid and 25 vertical layers, with 12 layer below 800M

In addition to the Meteorology, Emissions data are required

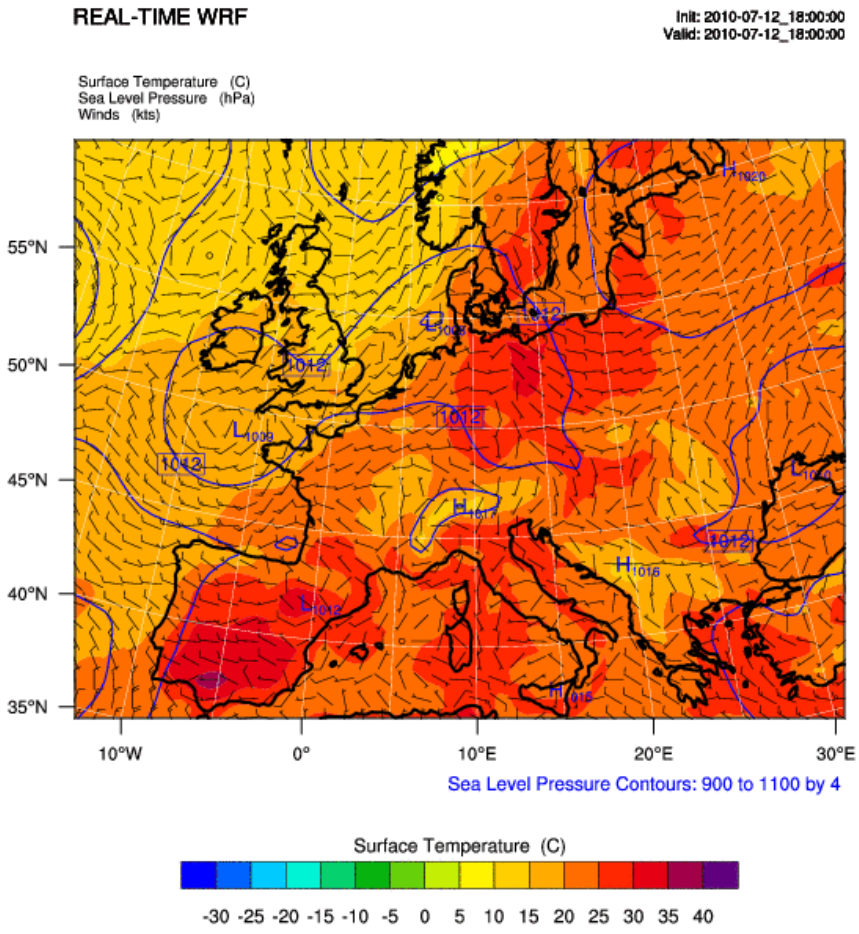
- Annual European and UK emissions are converted to hourly emissions
- Natural emissions are based on the temperature and radiation

CMAQ

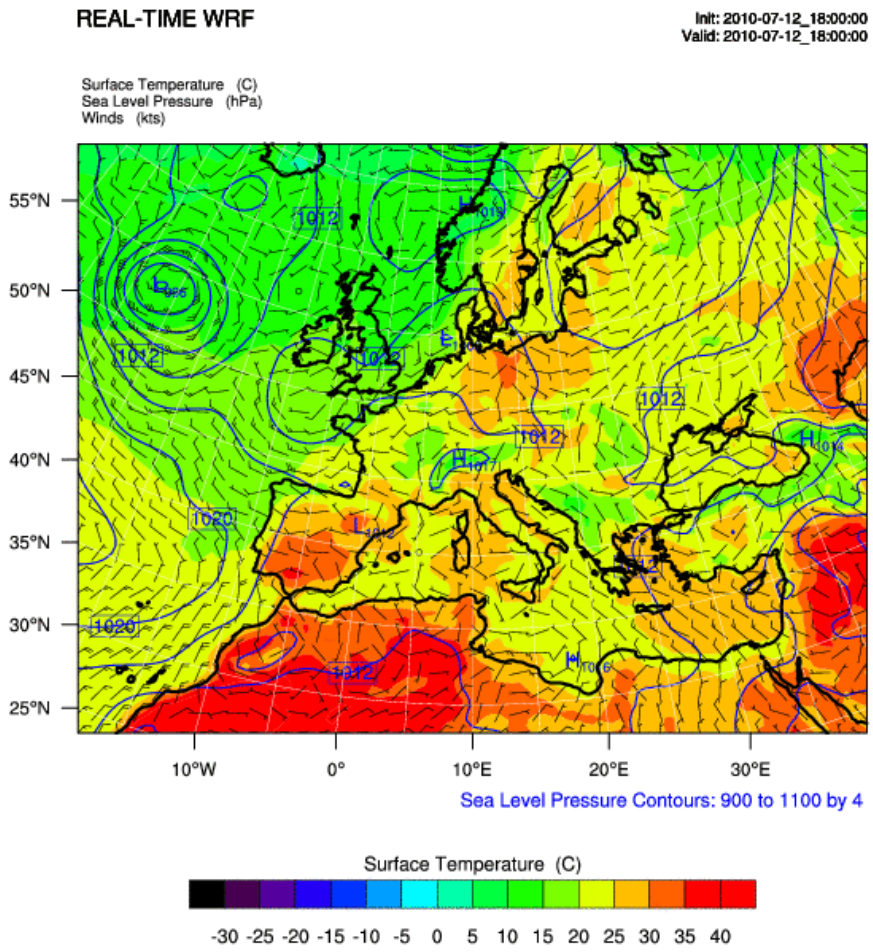
- Version 4.7
- CB5 Chemistry with aerosol and aqueous extensions
- Boundary conditions are from the global STOCHEM global model

European Grid – Surface Conditions

48km European Grid

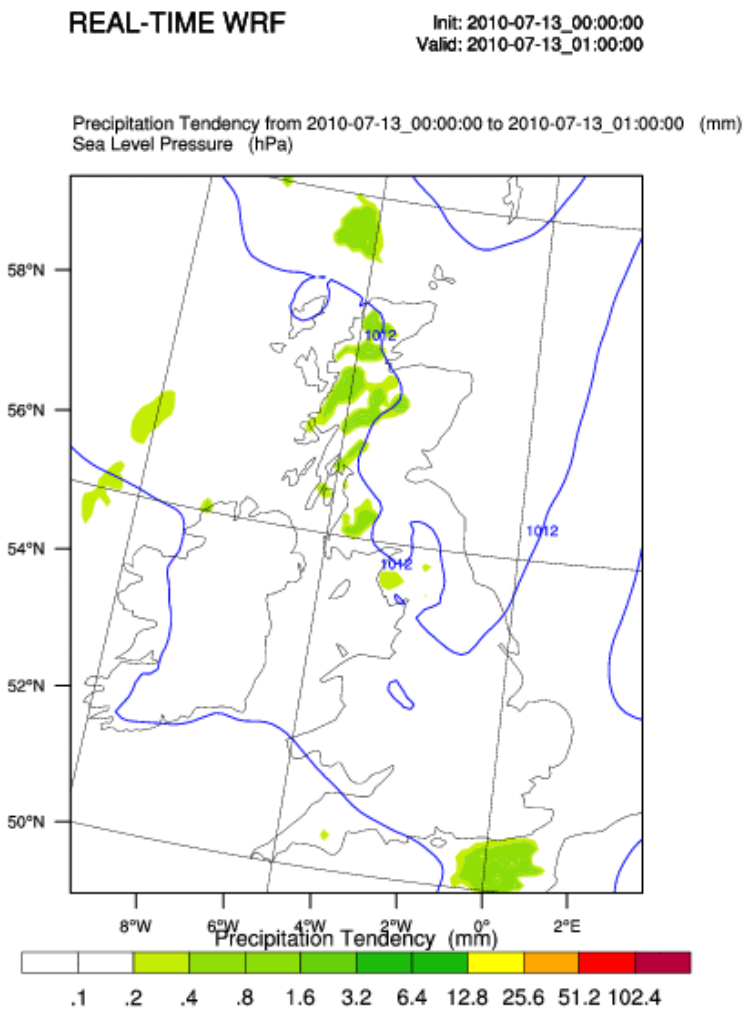


50km European Grid

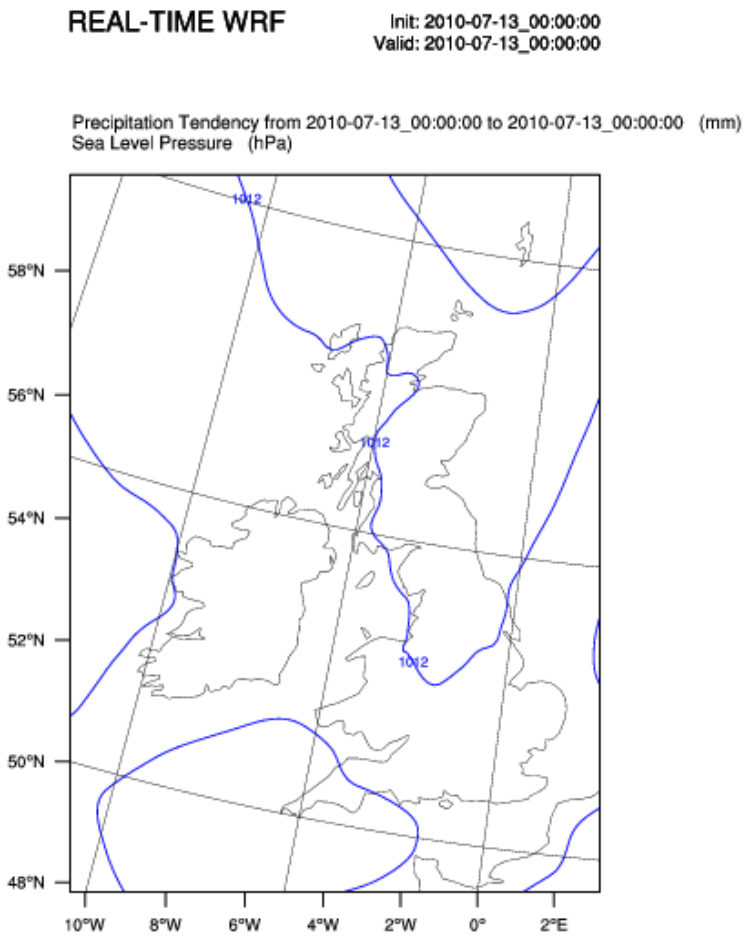


UK – Rain

12km UK Grid

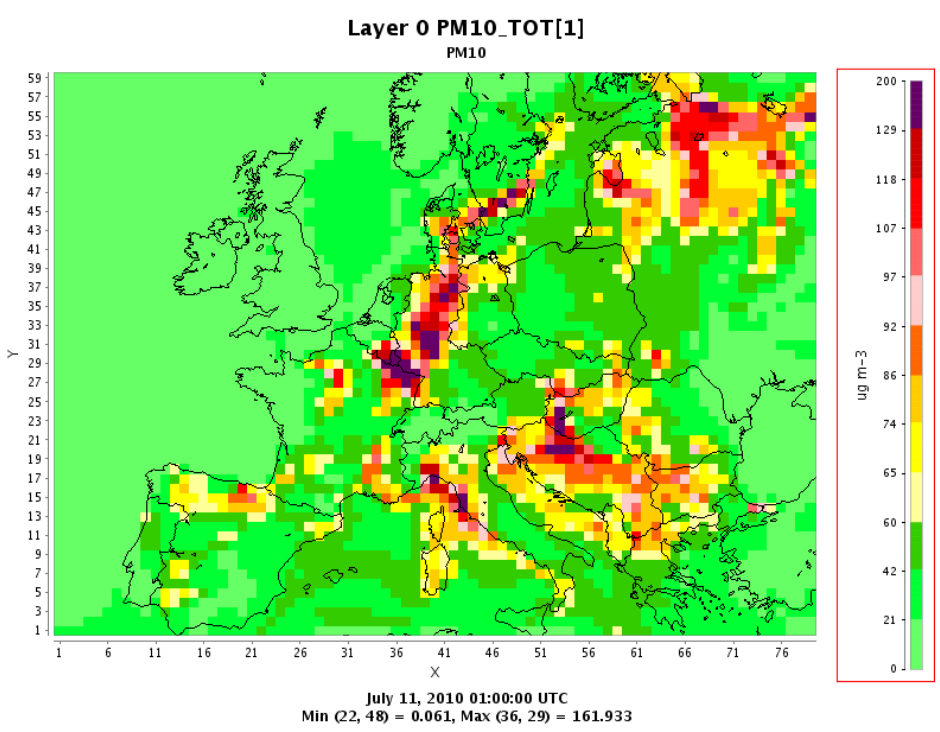


10km UK Grid

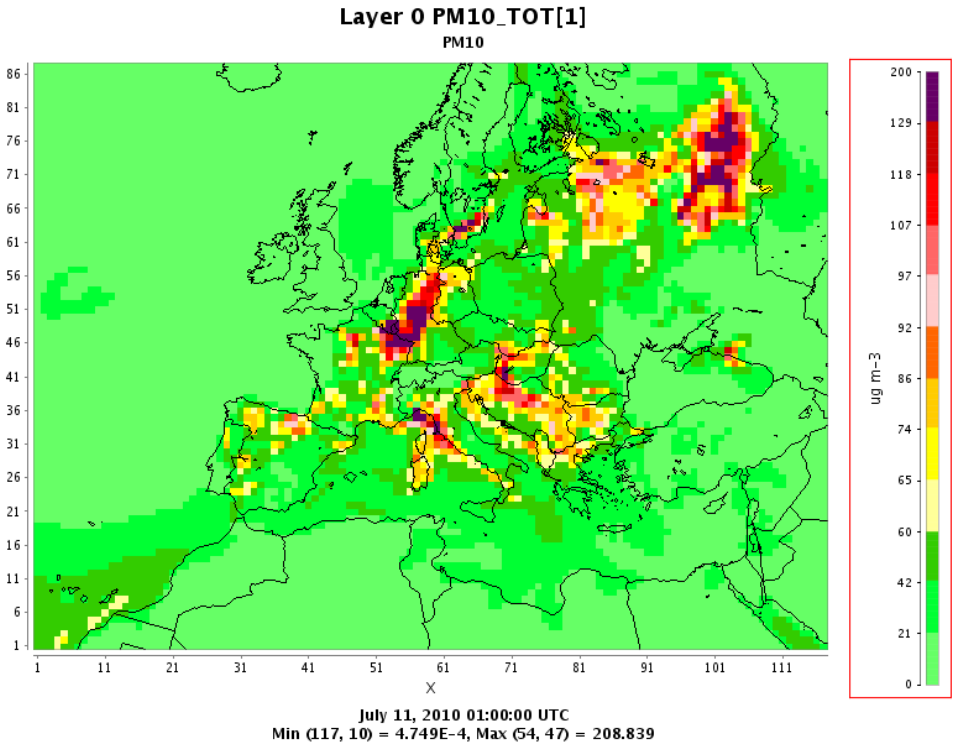


European Grid – PM_{10}

48km European Grid
2006 emissions

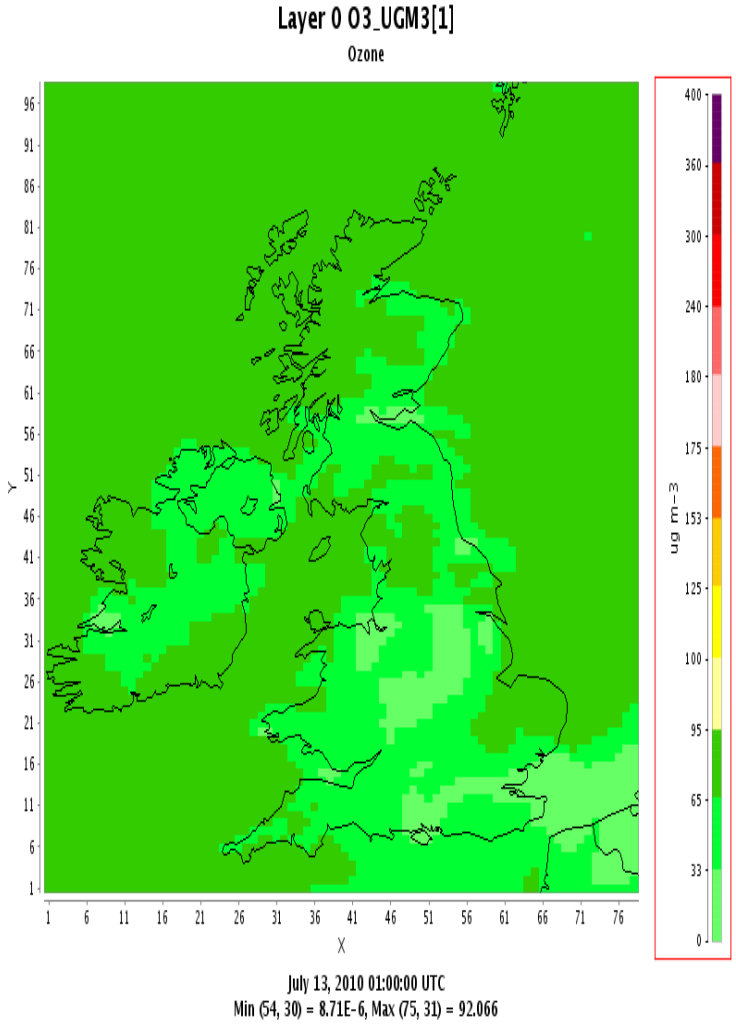


50km European Grid
2007 emissions

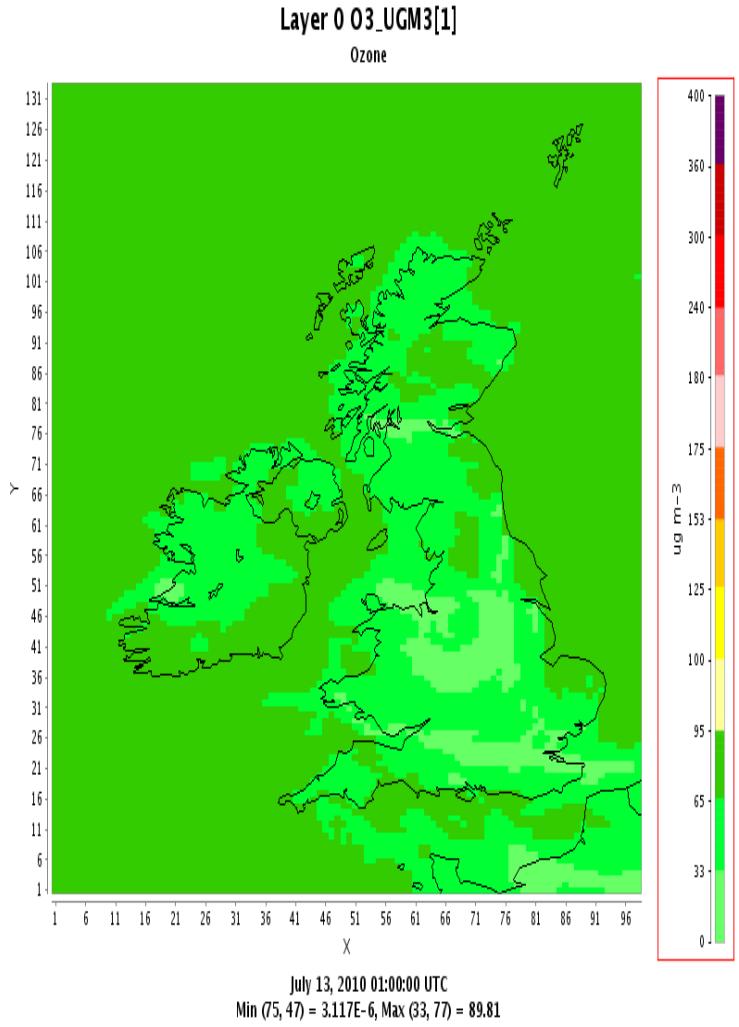


UK Grid - Ozone

12km UK Grid - 2006 emissions



10km UK Grid – 2007 emissions



WRF - CMAQ Operation

AIM:

- 10:00 Update the AQ forecast for Today
- 14:00 AQ forecast for tomorrow

Operation:

• May 2009	Daily European (48km) 24hr and 48hr forecast
• October 2009	Daily European (48km) and UK (12km) 24hr and 48hr forecast
• January 2010	Started the 50km European and 10km UK forecast
• February 2010	Daily forecasts for both configurations

WRF - CMAQ operation

AIM:

- 10:00 Update the AQ forecast for Today
- 14:00 AQ forecast for tomorrow

Daily Operation*:

- 4:30 Download GFS data (3:30 winter)
- 5:00 Start WRF
- 5:40 Start CMAQ
- 7:50 WRF Finished
- 9:40 CMAQ Finished for 24hr Europe and UK forecast
- 9:20 CMAQ Finished for Europe 48hr forecast
- 12:10 CMAQ Finished for UK 48hr forecast

* 13th July 2010 48km and 12km forecast

WRF - CMAQ Operation

AIM:

- 10:00 Update the AQ forecast for Today
- 14:00 AQ forecast for tomorrow

Operation – over winter:

- We have an extra hour of processing time
- On average we finished the 24hr forecast by 9:00
- On average we finished the 48hr forecast by 13:00

BUT

- On some days this could be as late as 11:15 and 14:50
- As we move into Summer Time we lose an hour of processing time

Evaluation of CMAQ AQ Forecast

Daily

To provide a daily update on model performance for the duty forecaster

- A line plot of provisional observations vs. model for the previous 7 days along with the 24hr and 48hr forecast
- A skill plot to show how well CMAQ has performed in the previous 14 days

Monthly

A monthly evaluation of model performance over the previous month based on provisional observations.

Quarterly

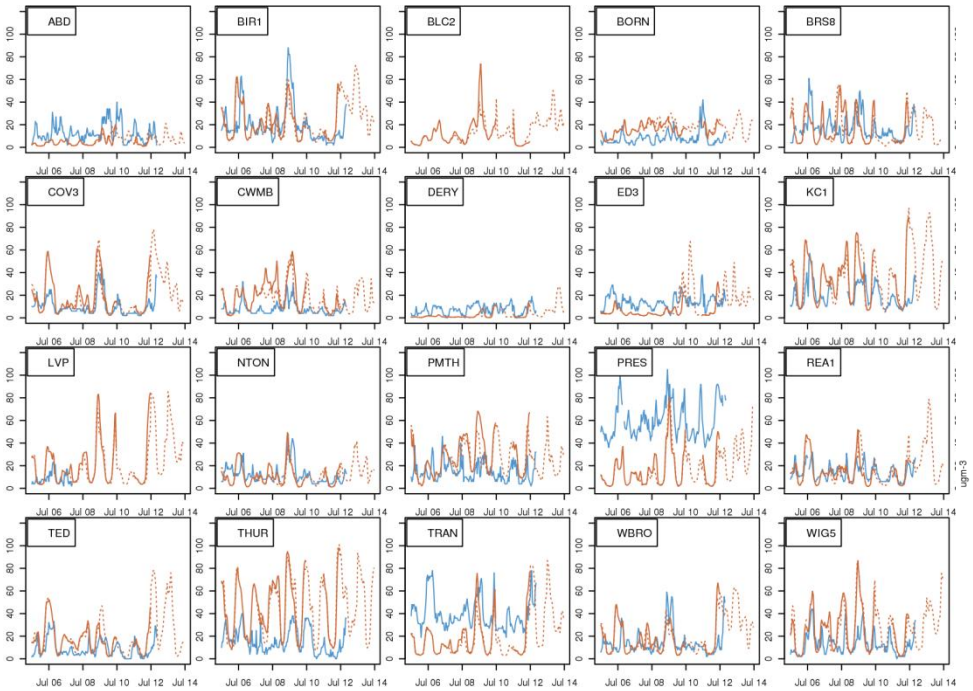
A repeat of the monthly evaluation based on ratified observations.

The Monthly and Quarterly evaluations build up a seasonal profile.

Daily Evaluation

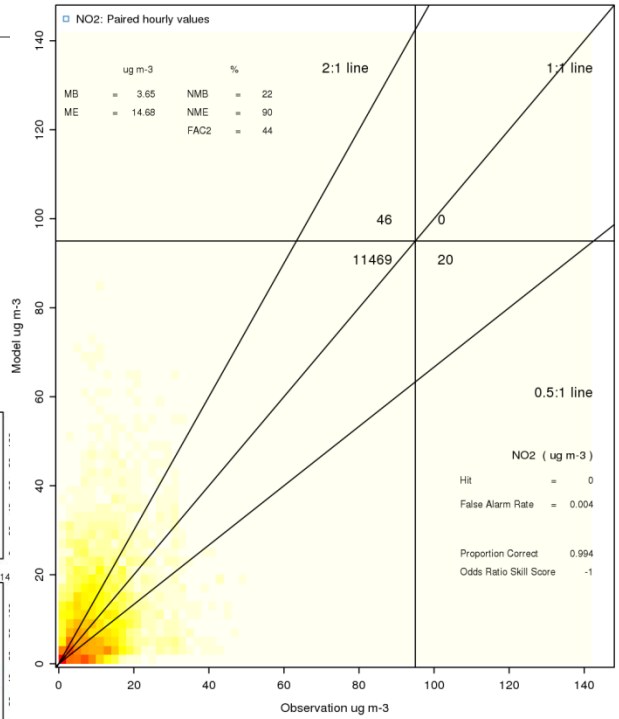
NO_2 – Urban Background Sites

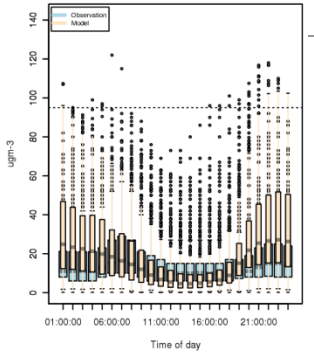
Plots of the last 7 days

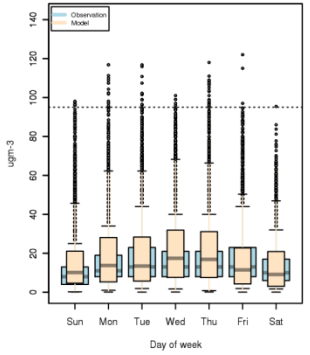


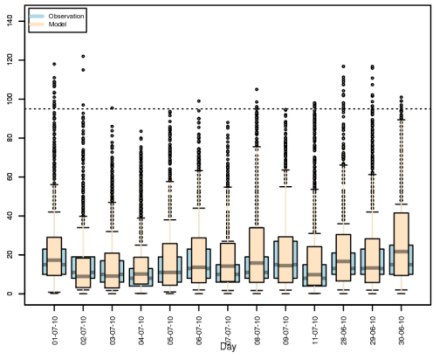
NO2 Urban Bckground sites - 24hr Forecast Performance Summary

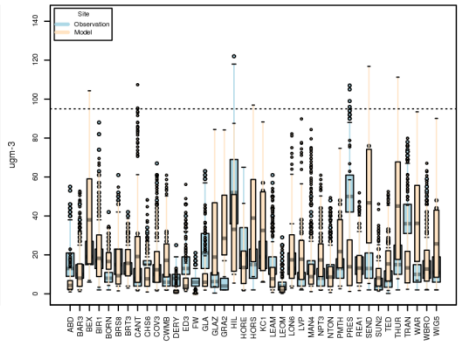
Model	CMAQ v4.7	Emisions	2006 Base Case	Observations	Provisional
Grid	UK 12km (U2)	Date Range	28-Jun-2010	Data	Hourly values
Met Id	WRF-GFS		12-Jul-2010	Units	ug m-3





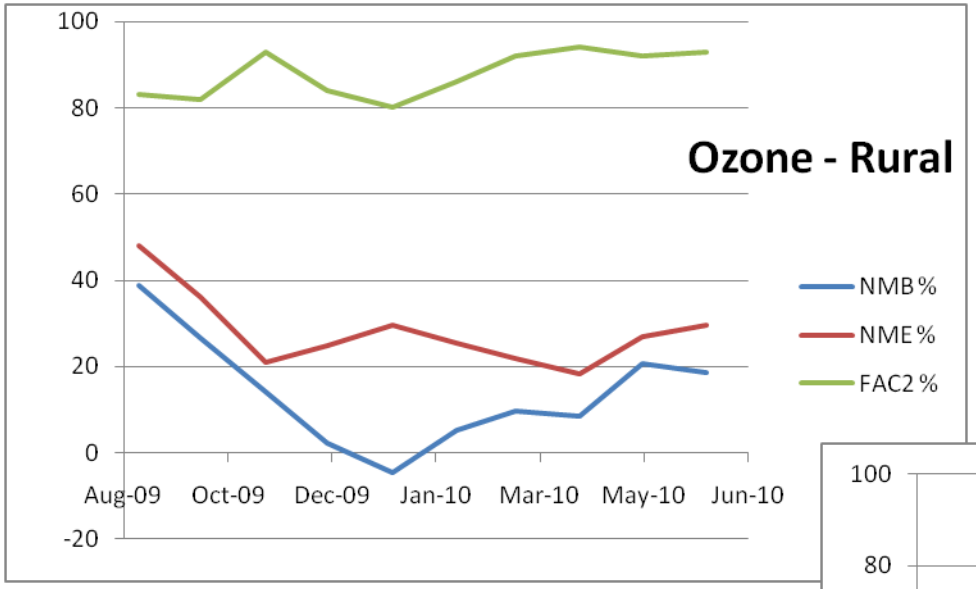


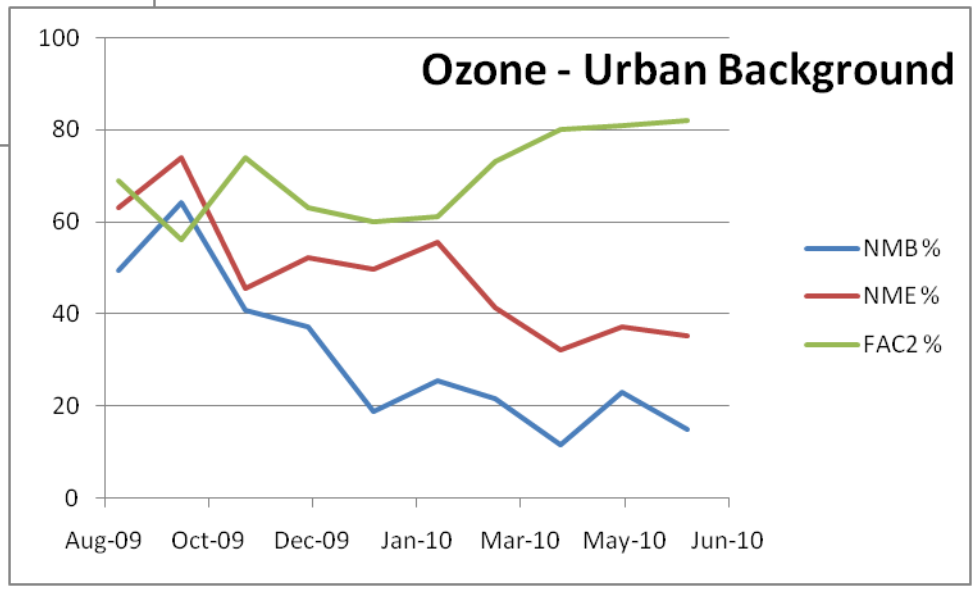




MB	Mean Bias	NMB	Normal Mean Bias	Box and Whisker plots	
ME	Mean Error	NME	Normal Mean Error	Line	Median
		FAC2	Factor of 2	Box	50th Percentile
				Whiskers	95th Percentile
				Points	Outliners

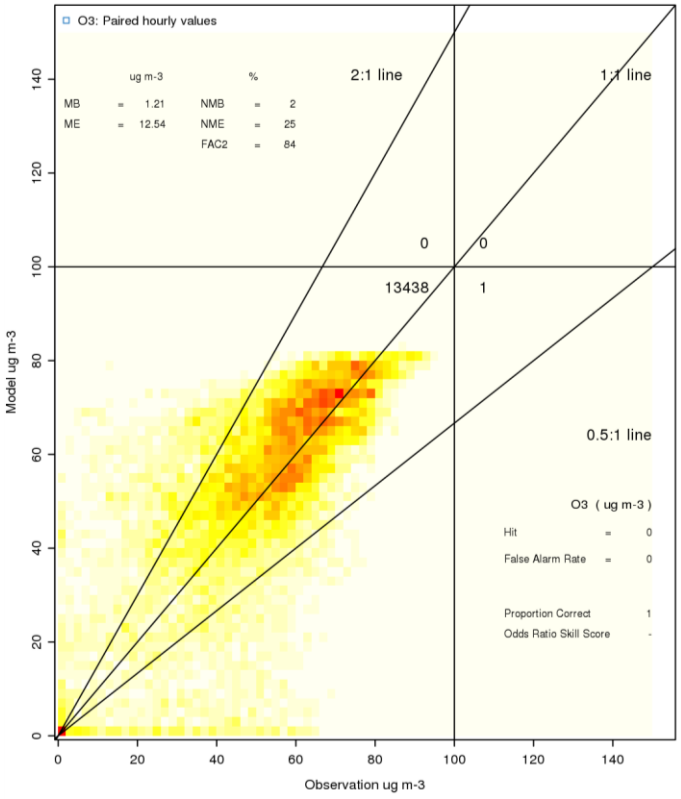
Ozone - Monthly Evaluation



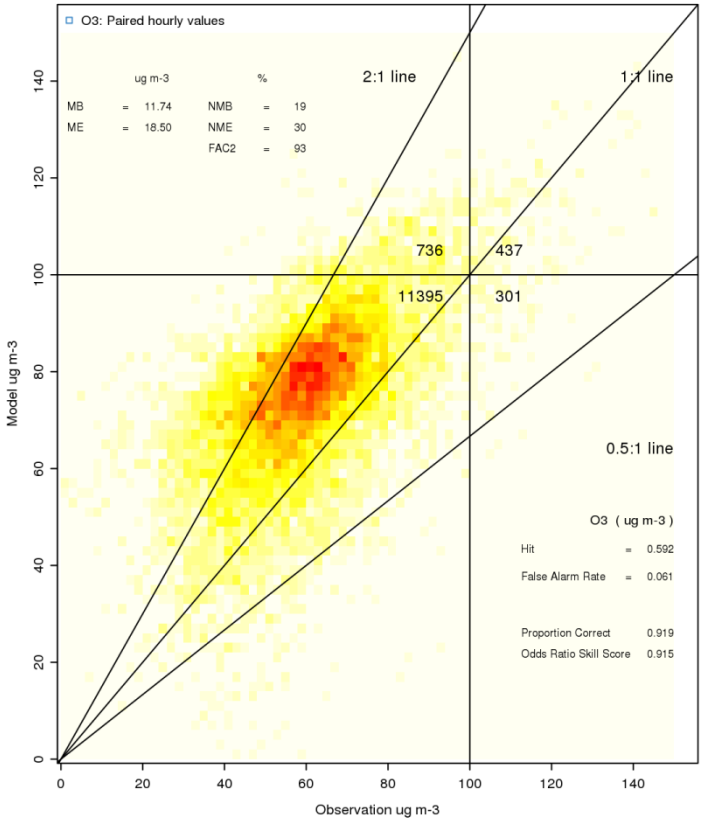


Ozone – Rural and Remote sites

December 2009

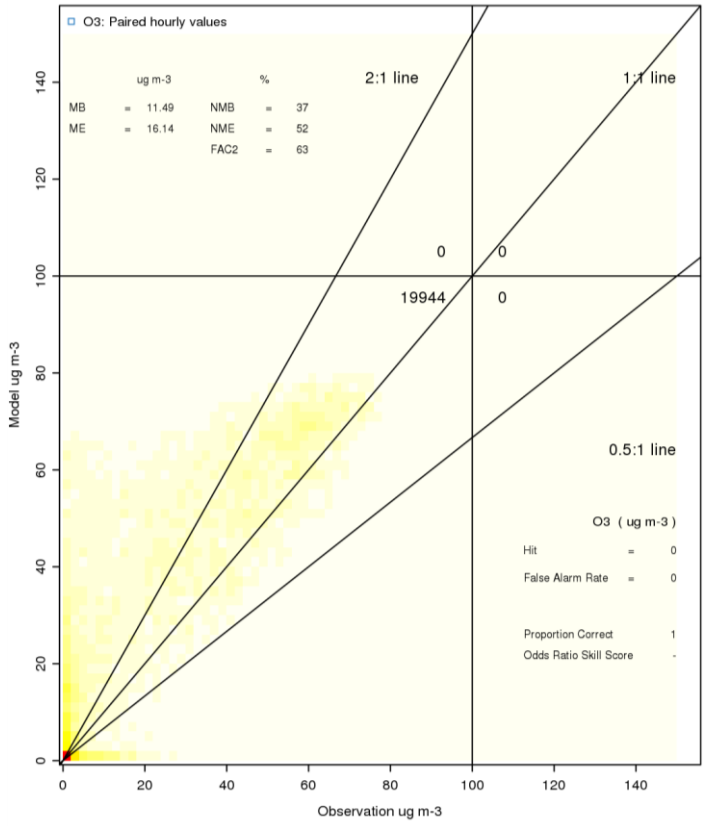


June 2010



Ozone Urban Background sites

December 2009



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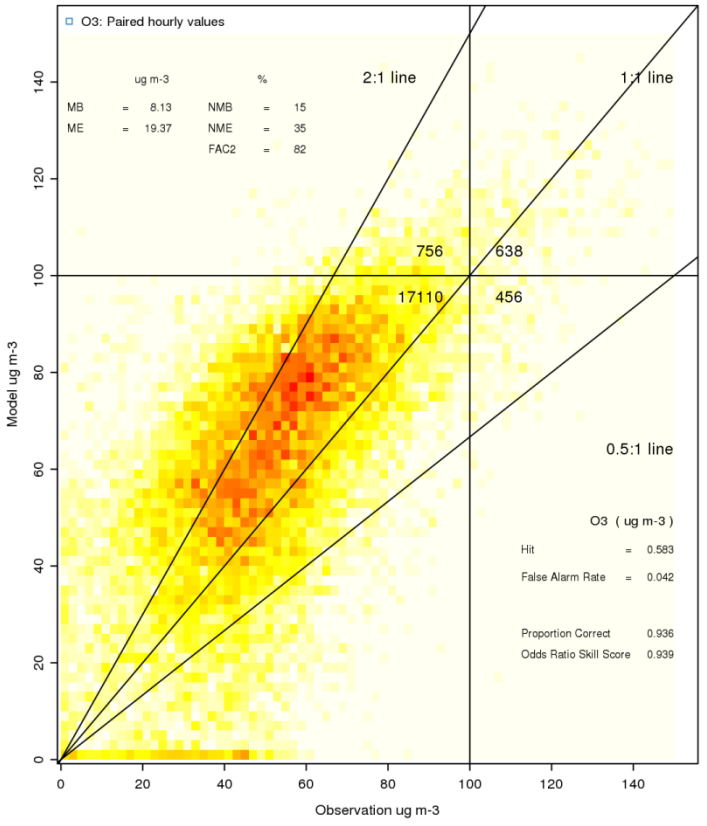
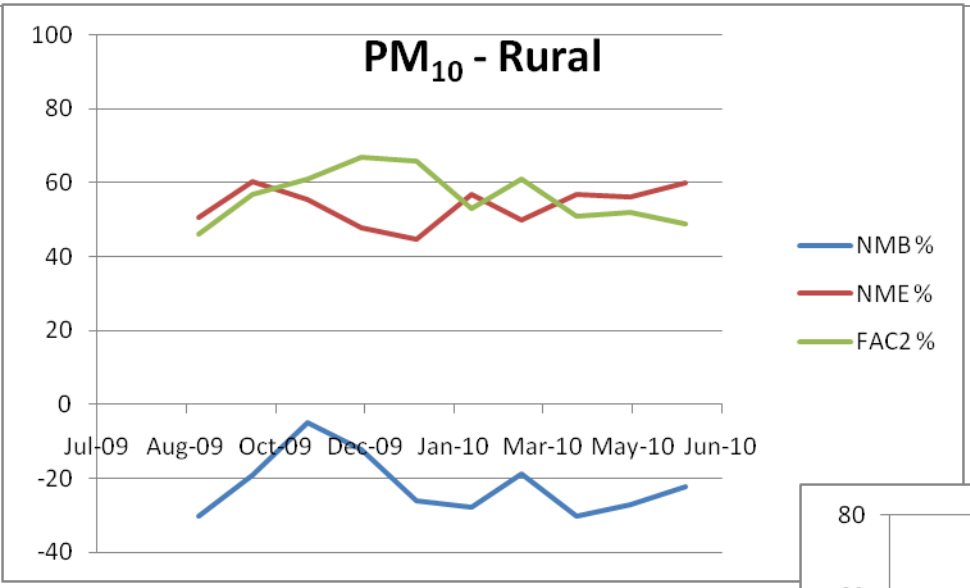
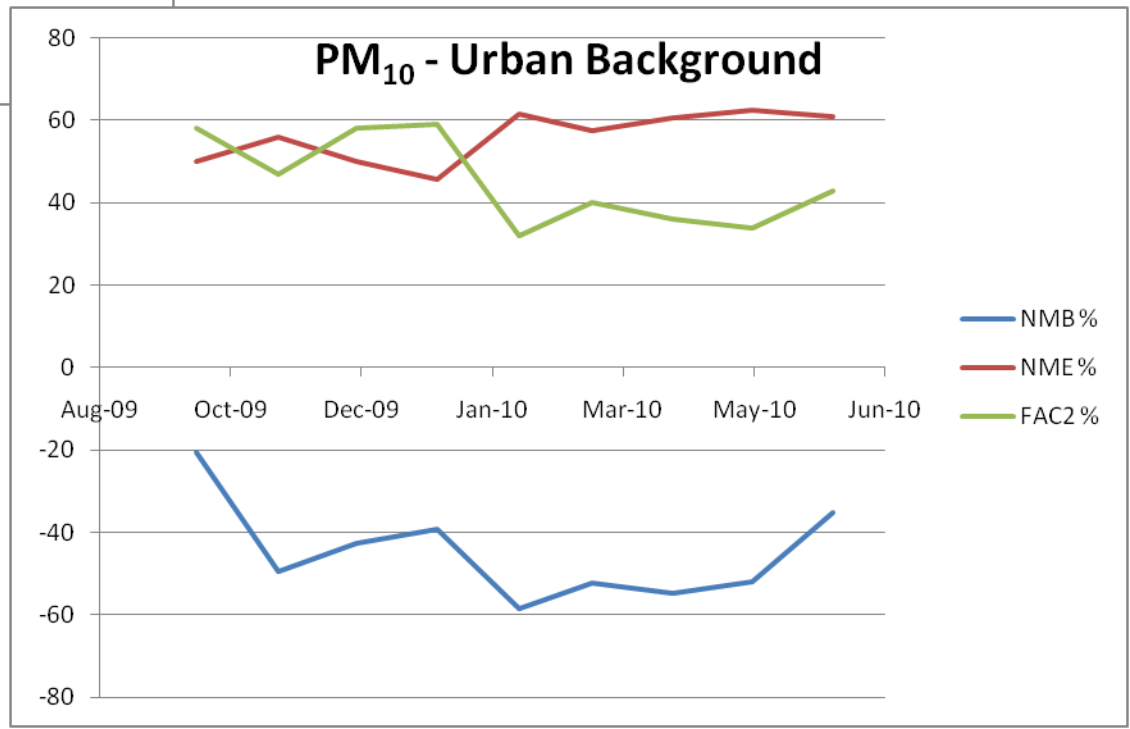


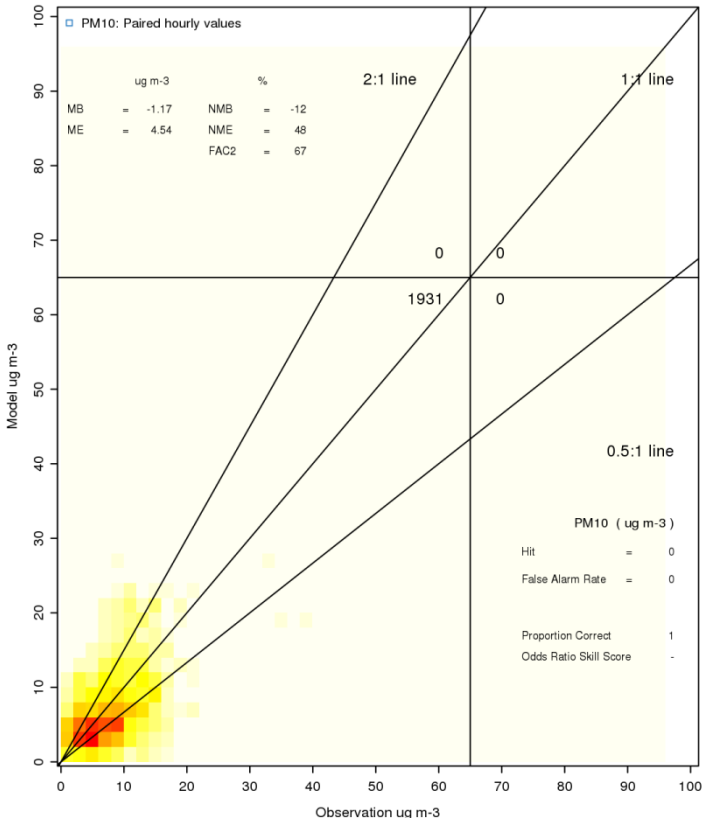
PM_{10} - Monthly Evaluation





PM_{10} – Rural and Remote sites

December 2009



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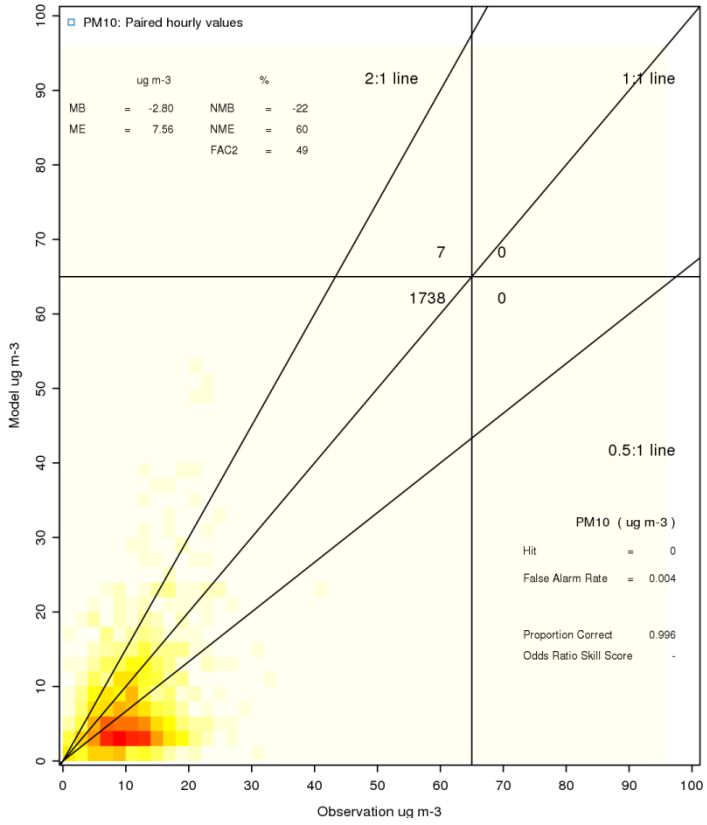
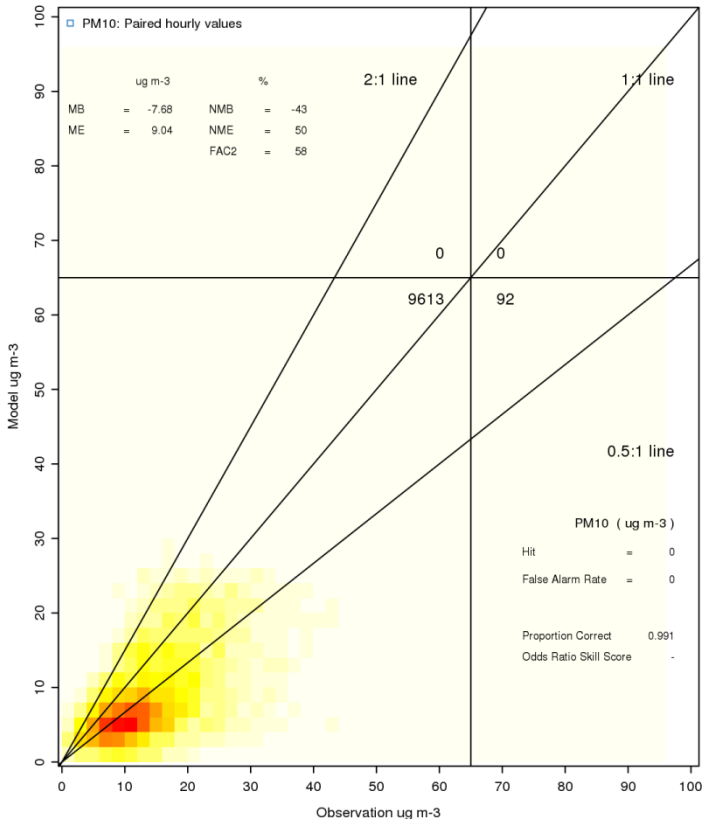


PM_{10} – Urban Background sites

December 2009



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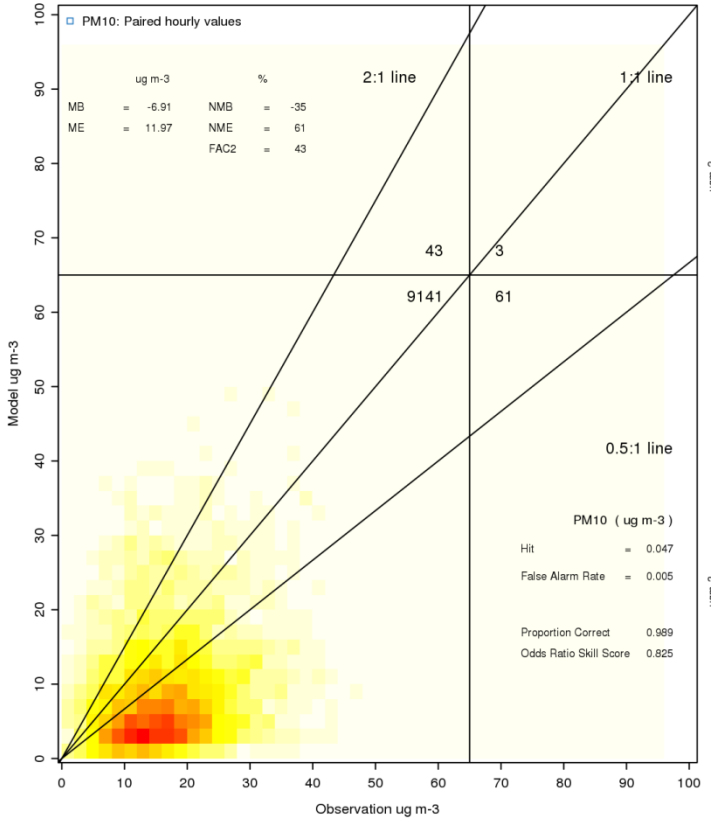
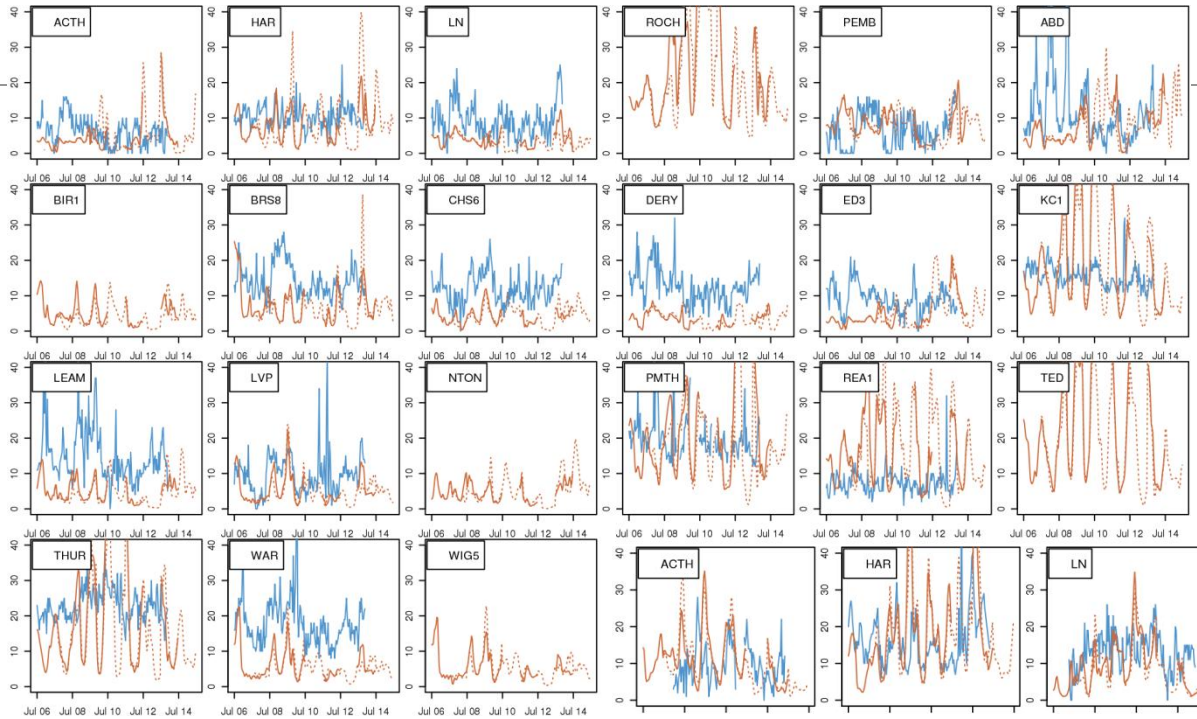
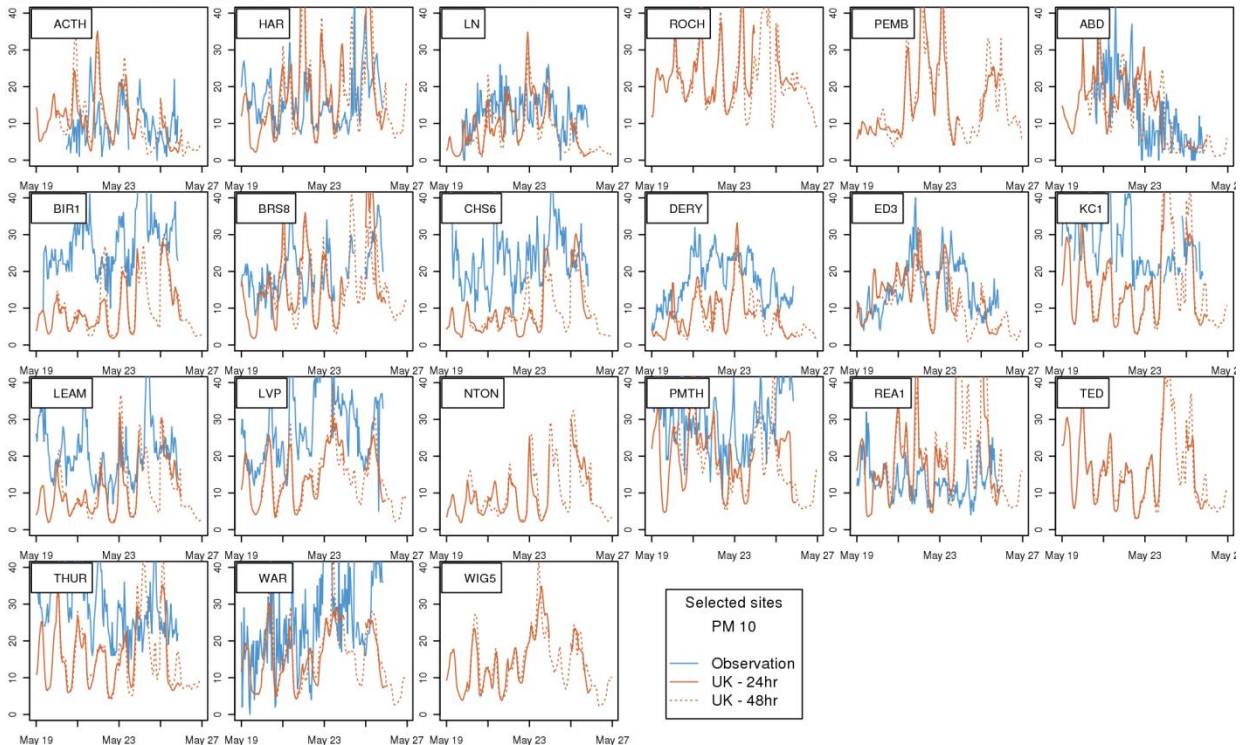


PM_{10}

July 2010



May 2010



Further evaluation

CMAQ is a one atmosphere model and where more detailed measurements of other components are available e.g. speciated PM and acid deposition these will be used for further evaluation.

Improvements

Based on the evaluation improvements will continue.

Improve the computer performance to finish the forecast sooner.

- Investigate the effect of snowy conditions on performance

The new 50km and 10km simulations predict lower ozone.

The 2008 NAEI emissions have just been made available these will be incorporated as soon as the European emissions are available.

The Emissions will be continually updated to current knowledge.

Summary

AEA run a daily 24hr and 48hr WRF-CMAQ Air Quality Forecast

This is used by the duty forecaster as one of the tools to produce the UK Air Quality Forecast on behalf of Defra and the DA's

AEA produce a twice daily update to the AQ forecast these are disseminated via the internet (www.airquality.co.uk), media bulletins and a freephone information service (0800 556677).

The evaluation shows that there is a tendency to overestimate ozone and underestimate PM_{10} with the original WRF-CMAQ model. Ozone is reduced in the new model.

WRF is more stable with the new larger European grid

Thank you
Any Questions?

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