Improvements in operational AQ forecasting and development of an on-line air quality forecast model

Paul Agnew Air Quality Seminar 16th July 2009

Overview

- Improvements to operational forecast in the NAME model
- Development of on-line AQ modelling in the UM
- Near-real-time verification

Met Office air quality modellers

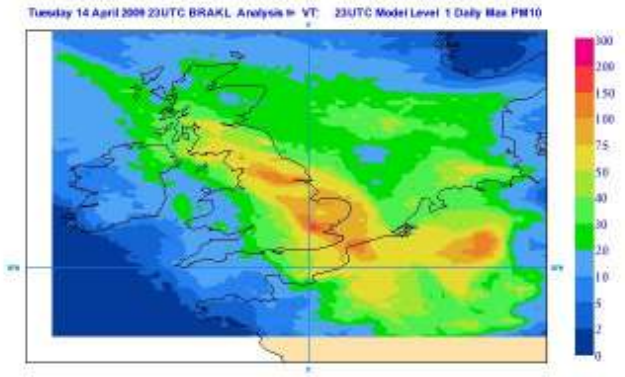
Nick Savage, Claire Witham, Carlos Ordonez, Lucy Davis, Mark Weeks, Robert Thorpe, Paul Agnew

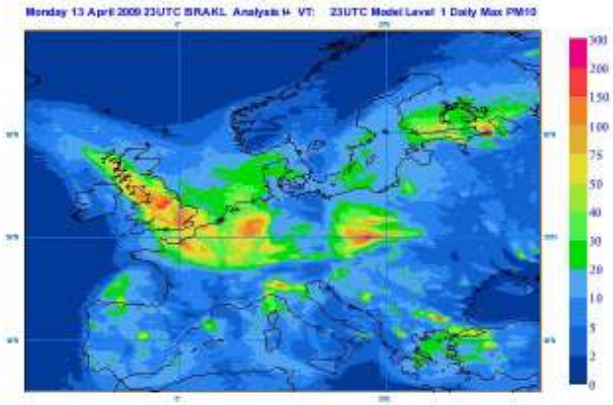
Developing 2 air quality forecast models:

- NAME
  - Current operational model
- AQUM
  - On-line, Eulerian model based on UM

Air Quality Modelling at the Met Office

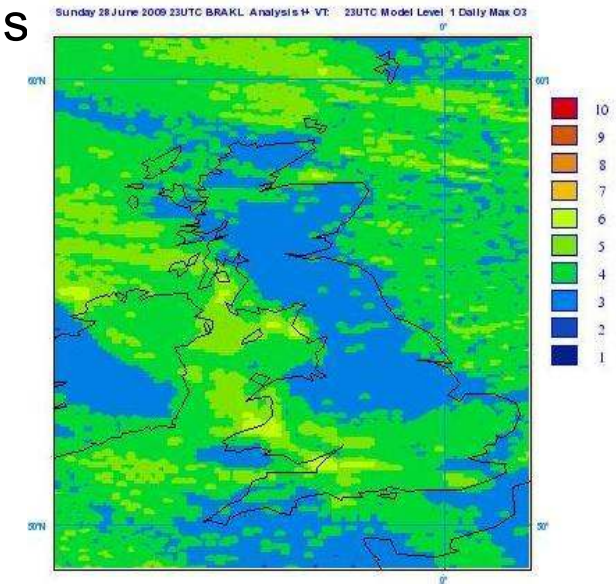
- Met Office provides the BBC national AQ forecast
- Current provision: versatile and reliable forecasting system based on the NAME model
  - Off-line Lagrangian dispersion model
  - Range of scales and domains
  - Sophisticated chemistry and aerosol modelling
  - NAEI UK emissions (1kmx1km)





NAMEIII Ozone modelling developments

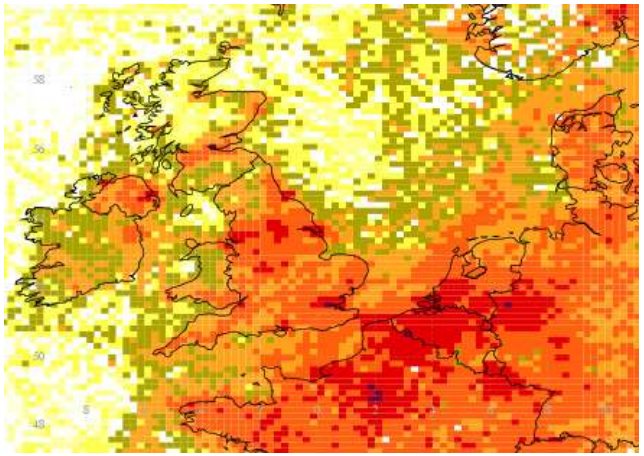
- Previous system:
  - Used background Ozone (O_3) concentrations from the global STOCHEM model
  - Under-predicted O_3 (not used operationally)
  - Full magnitude of peaks in O_3 not captured
- New system:
  - More computational power available
  - Uses a ‘particles everywhere’ approach
  - Major improvements in forecast O_3 concentrations



Sample O_3 fields output (pollution index values)

NAMEIII Air Quality - 'Particles Everywhere' Approach

- O_3 carried on particles instead of being represented by background fields
- Requires particles present everywhere in model domain – previously only present over emissions sources and locations where they had been advected to
- Initial conditions: Allows model to start with particles everywhere to represent background concentrations for O_3, CO and PM10
- Need to feed in boundary conditions

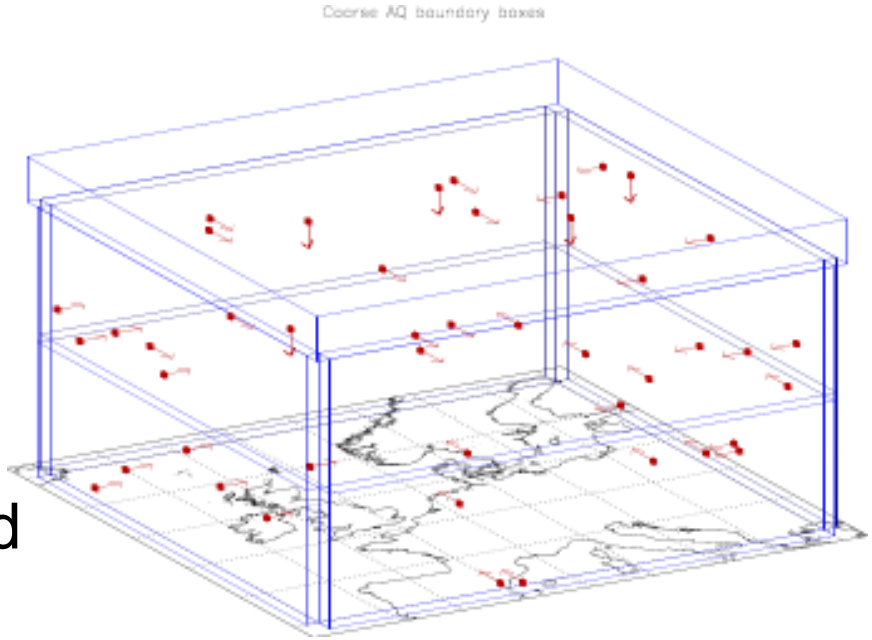


Above: Old system initial PM10

Below: Particles Everywhere – initialized with particles over entire domain

NAMEIII Air Quality - Boundary conditions

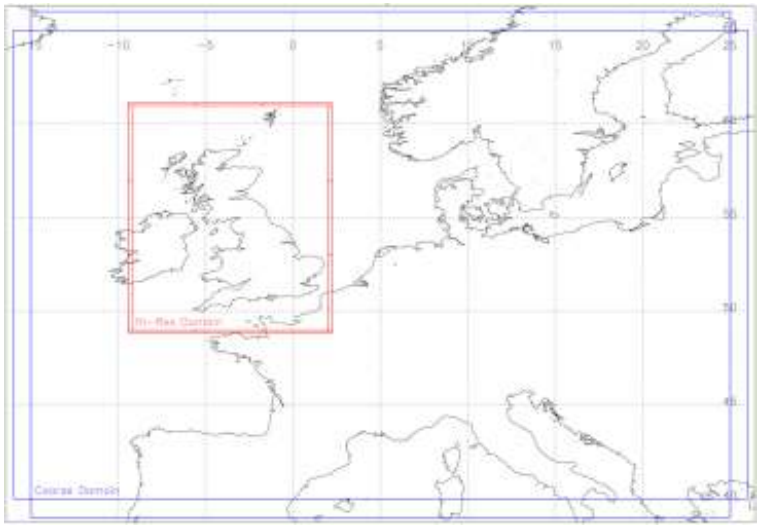
- Ensures a constant influx of background levels at the edges of model domain
- Concentrations derived from mean monthly levels observed at Mace Head.
- Particle release rate determined by dimensions of boundary box and required concentration
- Layer of grid boxes along each horizontal model boundary and a capping layer over the top



Constant influx of particles through boundary boxes

NAMEIII Air Quality - Nesting of domains

- Coarse-resolution (approx 50km) AQ domain run over most of Europe.
  - Uses EMEP emissions data
- High-resolution (approx 8km) AQ domain over UK only
  - Uses concentrations, converted into emissions, from coarse-resolution run for key chemical species
  - Uses NAEI emissions data for UK, EMEP for rest of Europe

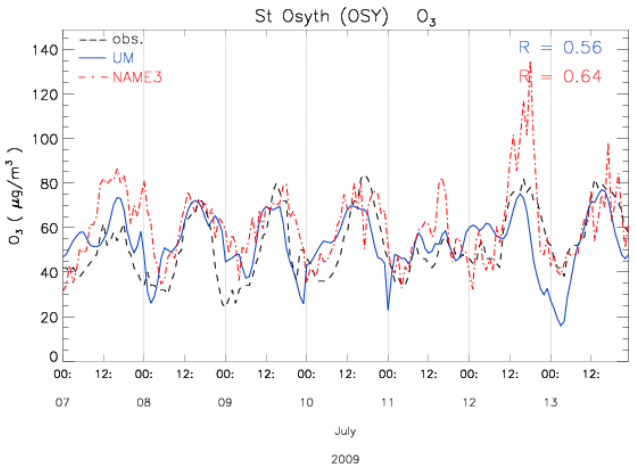


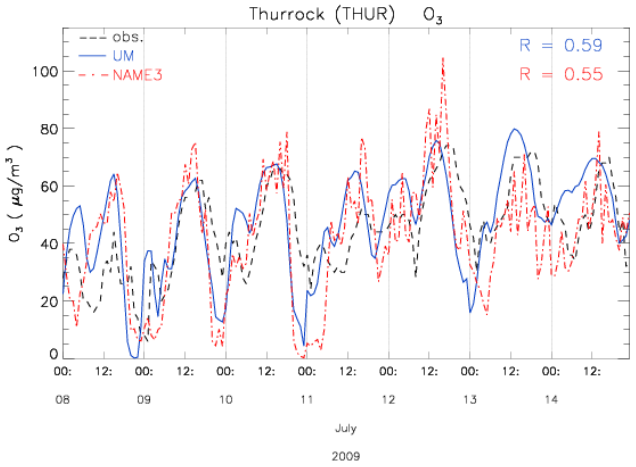
Air Quality model domains

High-resolution boundary boxes

Improvements to urban and rural ozone forecasting

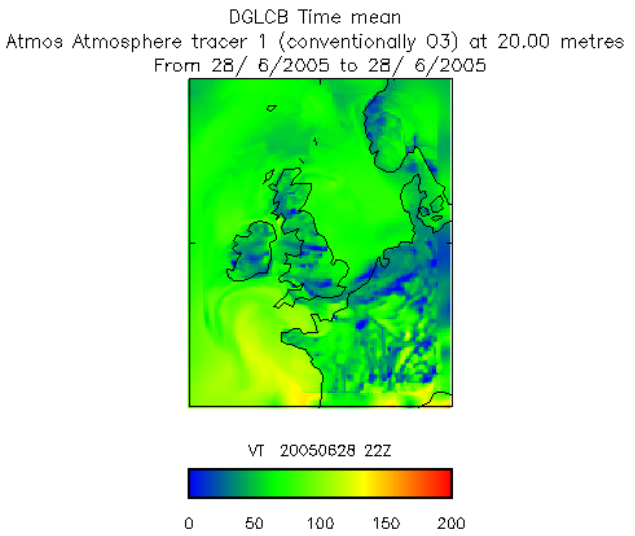
- Previous system exhibited a significant negative bias
- New configuration shows major improvement, with overall small positive bias





AQ modelling in the Unified Model: AQUM

- The UM is an Eulerian model, offering a number of advantages:
  - On-line modelling, which allows:
    - closer integration of meteorology and chemistry
    - availability of wider range of meteorological fields to chemistry parameterisations
  - Incorporation of lateral boundary fluxes from a global model
  - Use of the operational framework of the UM
  - Potential for including feedbacks between composition and meteorology
    - Influence of composition on radiation, cloud physics and visibility forecasting



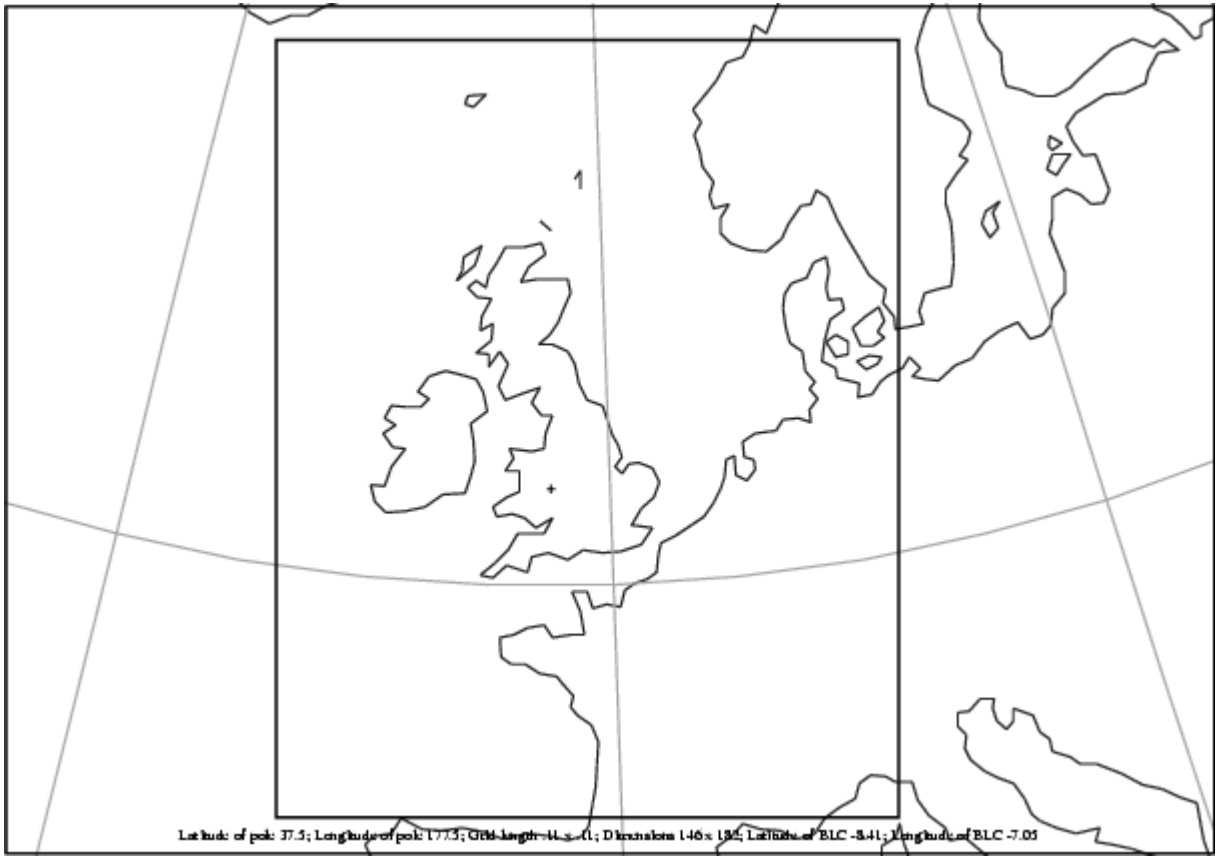
An ozone field from an AQUM case study

Air Quality in the Unified Model: AQUM

- We have developed an AQ forecast model in the UM
- Uses the UKCA framework developed for climate modelling
- Modifications made for AQ forecasting
  - Limited area model
  - Enables boundary fluxes of pollutants
  - Modified chemistry scheme
  - Emissions representation

Resolution

- Initial horizontal resolution is 12x12 km with a domain the same as the old UK-Mesoscale model
- 38 model levels from the surface to 39 km



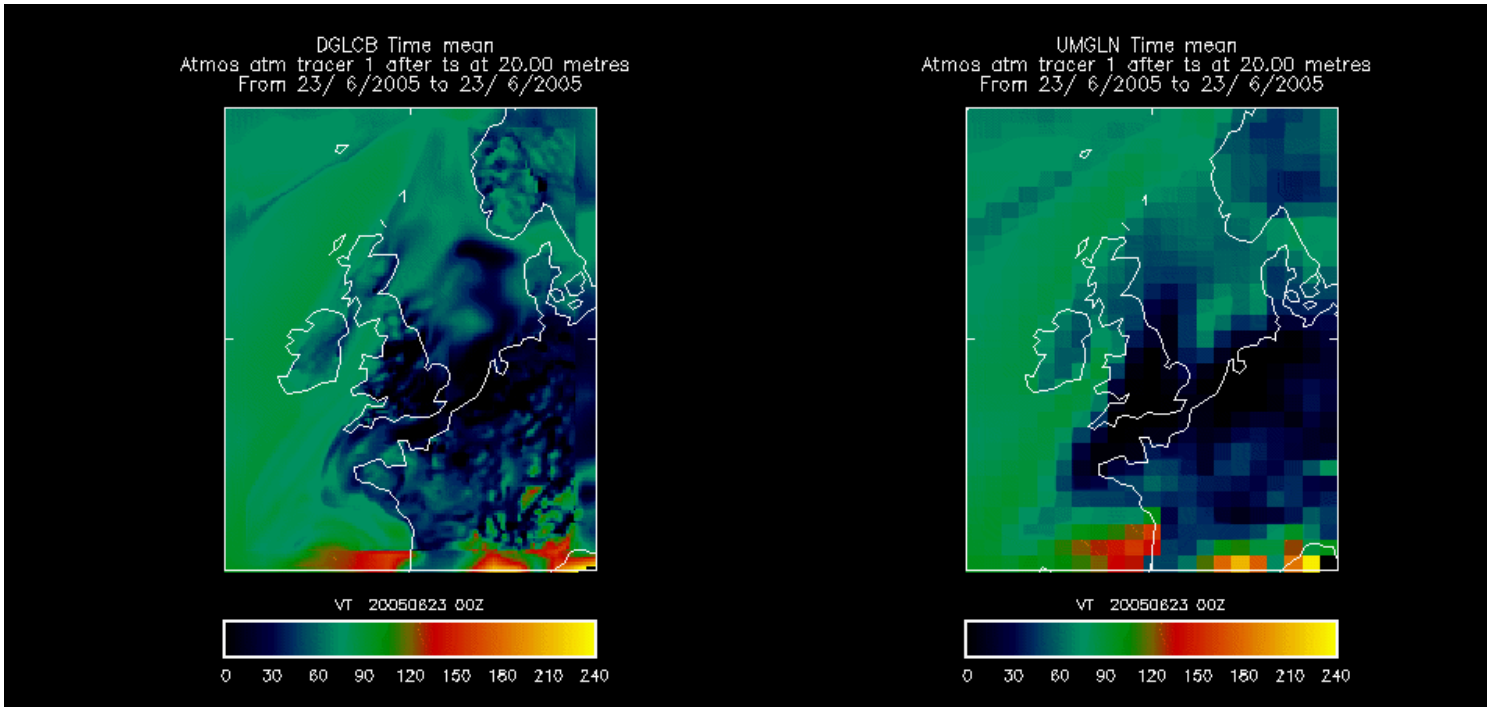
Chemistry schemes

- Two chemistry schemes have been used so far
  - ‘Standard Tropospheric Chemistry’. 26 tracers (9 of them emitted), 27 photolysis reactions and ~100 gas-phase reactions; oxidation of methane, ethane and propane. Used for initial test of the forecasting suite
  - Regional AQ mechanism. 40 tracers (16 of them emitted), 23 photolysis reactions and ~115 gas-phase reactions. Oxidation of both C2-C3 alkenes, isoprene and aromatics. Used for case studies and forecasts. Based on STOCHEM chemical mechanism

Lateral boundary conditions for AQ forecasts

- Daily transfer of forecast fields from GEMS - GRG in Grib format
- Data for O3, NOx, CO and HCHO
- Met data from North Atlantic and European Model
- Case studies - use Met Office UM global model run to make LBCs (chemical and meteorological).

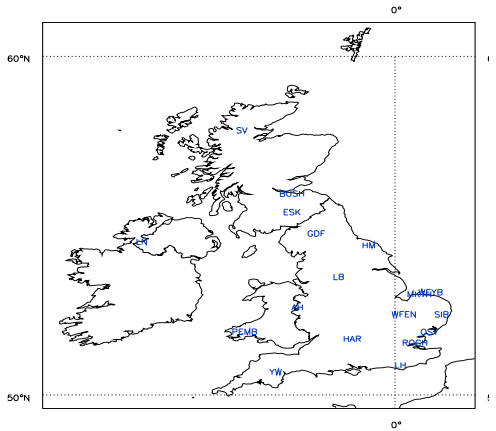
Lateral boundary pollutant fluxes

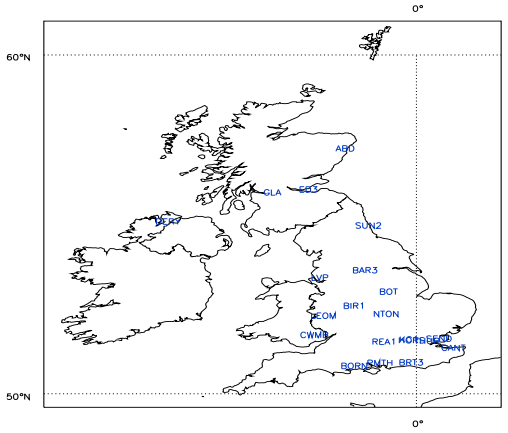


- Ozone episode across the SE of the UK. 19th - 24th of June 2005, 7 AURN stations with at least one hourly average > 180 μgm^{-3} (HIGH)

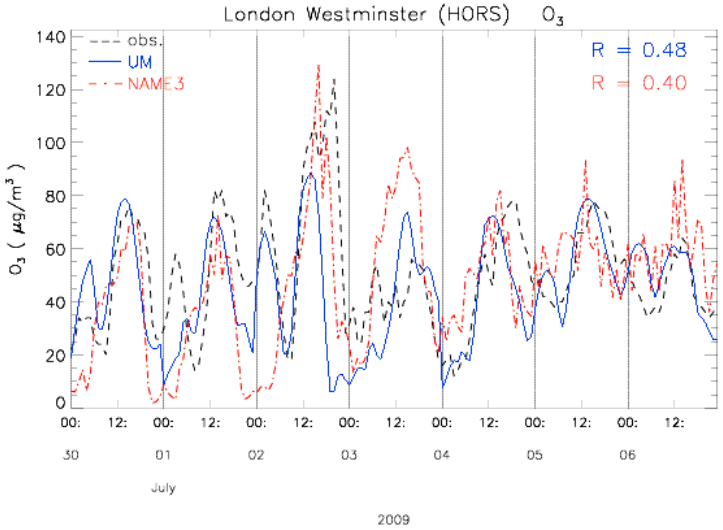
Near Real Time Verification

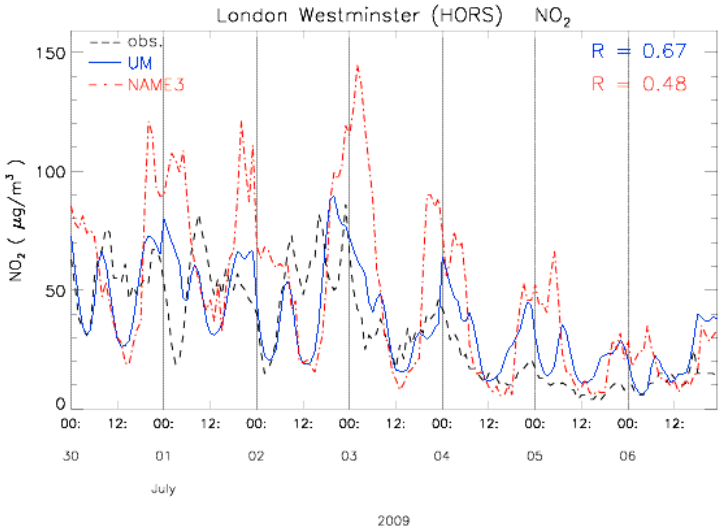
- Routine verification against surface observations from AURN: Data sent courtesy of AEA
- Use of data from Remote, Rural, Suburban and Urban Background sites
- Measurements of O3, NO2, NO, CO, SO2, PM10 and PM2.5
- Data converted to BUFR and sent to ECMWF (GEMS/MACC)
  - AQ Obs from across Europe available
- Quick method of checking forecast on a daily basis





Near Real Time Verification





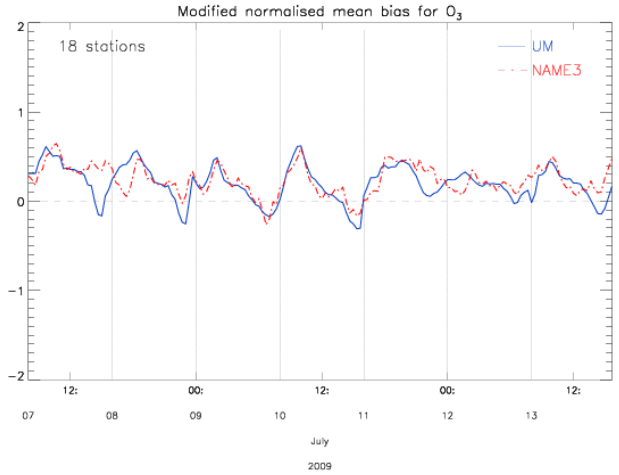
Verification metrics

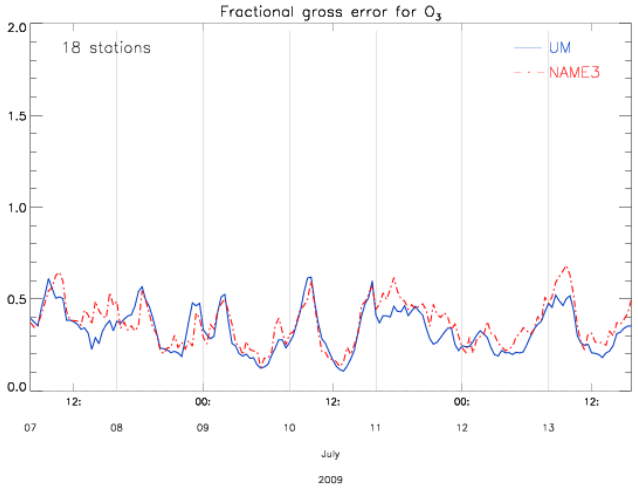
- Main verification metrics used

$$B_n' = \frac{2}{N}\sum_i \left(\frac{f_i - o_i}{f_i + o_i} \right)$$

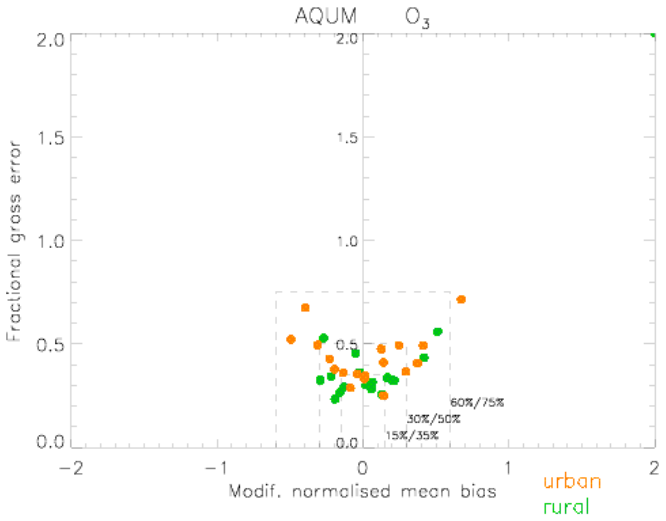
$$E_n' = \frac{2}{N}\sum_i \left| \frac{f_i - o_i}{f_i + o_i} \right|$$

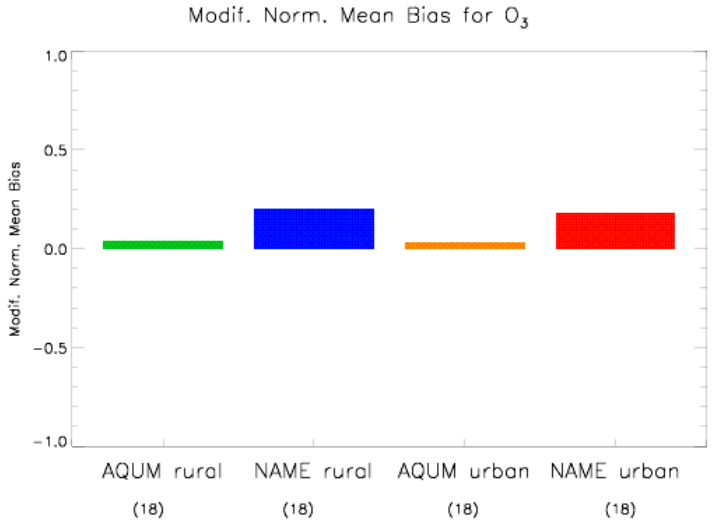
- Symmetric wrt under/over-prediction
- Currently implementing threshold exceedance metrics
- See GEMS verification report

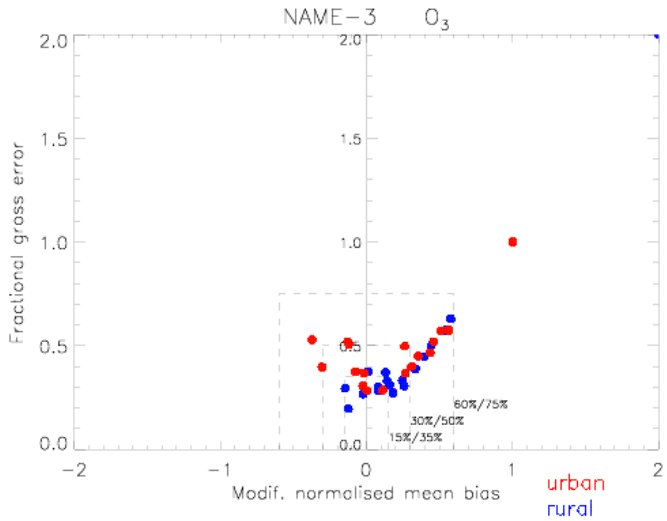


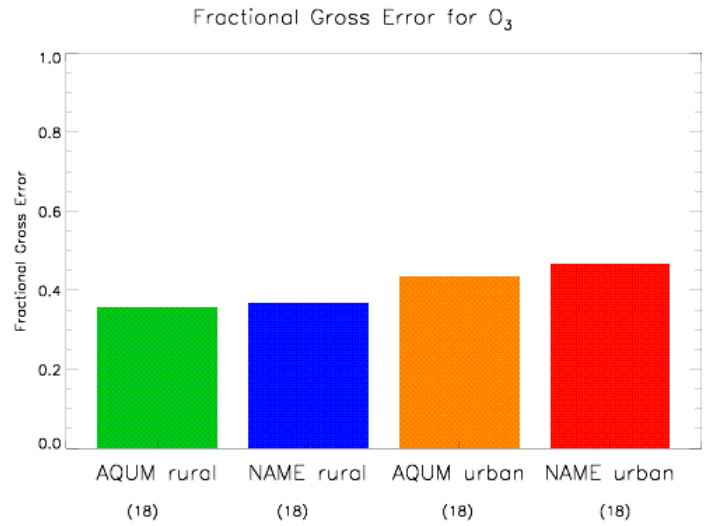


Summarising performance



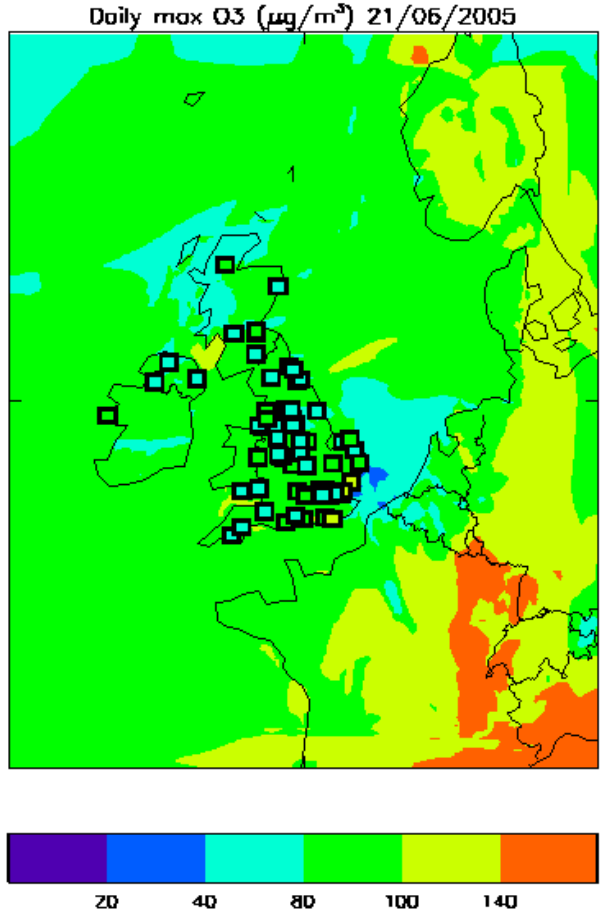


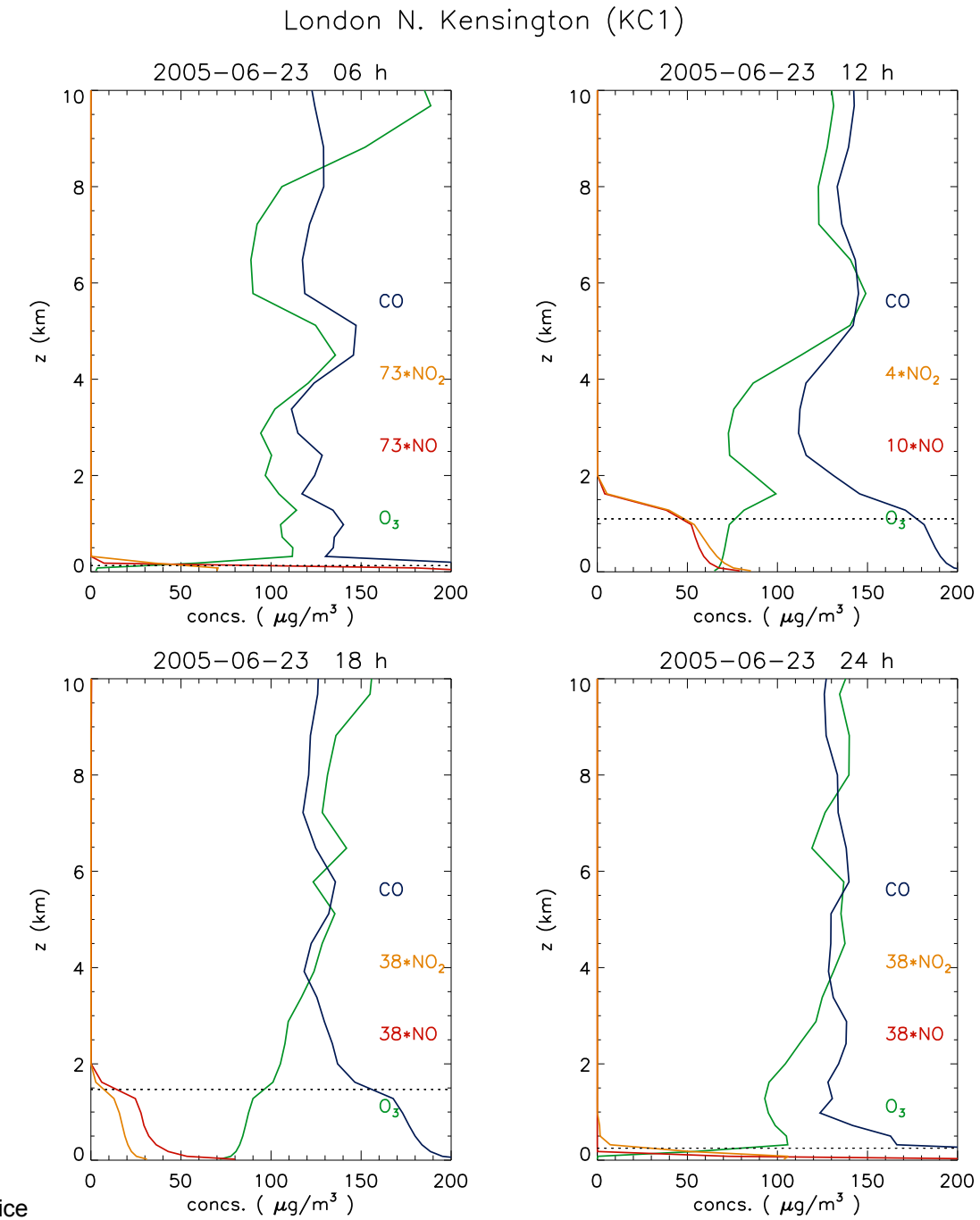




Comparison of field plots against stations

- Field plots of the entire domain allow a fuller picture of pollution conditions to be visualised
- Enable greater understanding of the evolution of any episode than that available from time series
- Over-plotting station observations aids model validation





Observations required for model validation

- Vertical profiles not routinely available
  - Routine measurements from ground-based ozone lidars would provide real benefits to improving models

- Improvements to precision of AURN CO measurements
  - A valuable tracer for diagnosing model transport behaviour
  - Currently no better than ~100$\mu g/m^3$

Looking ahead…..

- Near/Medium term
  - AQUM
    - regional air quality forecast
    - lateral boundary conditions for city level forecasts
    - feedbacks of composition on meteorology
  - NAME
    - city level forecasts
- Medium/Long term
  - Combined Eulerian-Lagrangian modelling system with NAME embedded within the UM