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

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Overview

• Improvements to operational forecast in the NAME model

• Development of on-line AQ modelling in the UM

• Near-real-time verification
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
NAME III 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
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
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

![Graphs showing O3 and NO2 concentrations over time](image-url)
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

Fractional Gross Error for $O_3$

Modif. Norm. Mean Bias for $O_3$
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 ~100µg/m³
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