APPLICATION OF RAMS/UAM SYSTEM TO AIR POLLUTION EPISODES IN THE WEST MIDLANDS, UK, DURING THE PUMA CAMPAIGN

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1. INTRODUCTION

During the summer campaign of the PUMA (Pollution of Urban Midland Atmosphere) project in 1999, observation and numerical modelling of meteorological conditions and air quality in the West Midlands (WM), UK, have been carried out at an urban scale in order to provide further insight into the dominating processes affecting the photochemical pollution levels in such a typical urban area in the UK. In the study, the Regional Atmospheric Meteorological System (RAMS) is employed as the meteorological model and the Urban Airshed Model (UAM-IV) is used as the photochemical model.

2. MODEL CONFIGURATION

RAMS is configured to have two nested grids: one at meso-scale and the other at urban scale with a horizontal resolution of 8 km and 2 km, respectively. The domain areas are shown in Fig. 1, in which the inner domain (Grid 2) covers WM. The urban area is indicated by a thick boundary in the inner domain.

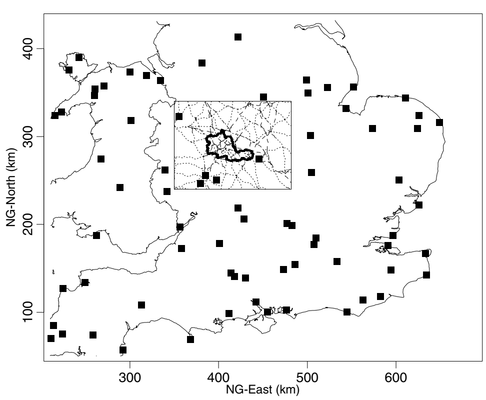

Fig. 1 Configuration of the nested grids. The figure box is the boundary of Grid 1 and the embedded box is the boundary of Grid 2. Solid squares are synoptic scale surface stations.

Other details of grid configuration are given in Table 1, in which L_x, L_y, L_z are domain sizes, and N_x, N_y, N_z are the number of mesh points in the x, y, and z directions, respectively; Δx and Δy are mesh sizes in the x and y directions, respectively. In the vertical, the first level above the ground is at 10 m and other specifications are similar to those in Batchvarova et al. (1999). Initial and boundary conditions of Grid 1 are provided by the mesoscale version of the UKMO Unified Model. Simulation starts at 0000 GMT on 10 June 1999, and ends at 2400 GMT on 26 June.

Table 1 Grid configuration

Grid	L_x (km)	L_y (km)	L_z (km)	N_x	N_y	N_z	Δx, Δy (km)
1	480	248	18	60	48	31	8
2	132	100	18	66	50	31	2

The horizontal domain and mesh sizes of UAM are the same as those for Grid 2 of RAMS; in the vertical, five levels are configured, with three being within the boundary layer. The emissions data are derived from two data sets: inside the WM (bounded by the curves in Grid 2 shown in Fig. 1), the most updated data derived from London Research Centre (LRC), UK, are used; outside the WM, data from the UK National Environmental Technology Centre (NETCEN) are used. All meteorological variables, including 3D wind field, mixing height (MH), and 2D surface temperature, are derived from RAMS output. Boundary conditions (BC) for chemical species are based on measured data.

3. MODELLING RESULTS

RAMS results have been validated by the data from the synoptic network in the UK for Grid 1 and the comparison indicates a very good agreement (not shown here). For Grid 2, eight surface stations provide the diurnal variation of temperature, wind, pressure and humidity. Fig.2 shows the comparison of wind and temperature at Pershore from 10 to 26 June. During the period, as shown in Fig. 2, meteorology is dominated by westerlies except the three days from 24 to 26 June during which easterly wind was observed. Wind speed exhibits a diurnal pattern: increasing during the daytime and decreasing at night. In general, RAMS provides reliable results for all three variables. In particular, RAMS tends to slightly underestimate the minimum temperature for most of days, whereas it reproduces quite well the maximum temperatures for the period.

The hourly modelled meteorological variables (wind speed, wind direction and temperature) at all available stations during the period are plotted against observed ones, as shown in Fig. 3. The overall performance of RAMS is satisfactory. Underestimation of temperature for low values is also evident in the plot and these correspond to nighttime or early morning situations. The poorer performance for wind speed than that for temperature is common for all numerical

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models. It is shown that agreement between model and observation is lower for calm conditions and this may be attributed to local processes that are not well resolved by the model. For high wind speeds, agreement between model and observation is much better than calm conditions and this implies that synoptic scales (generally westerly) dominate and they are well represented by the model.

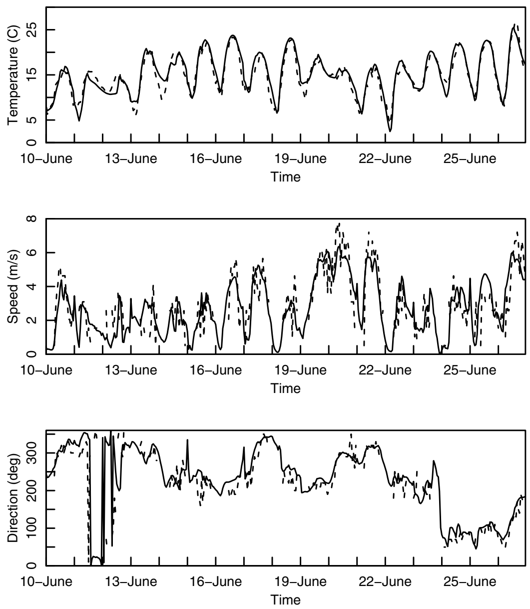

Fig. 2 Time variation of temperature (upper panel), wind speed (middle panel), and wind direction (lower panel) from 10 to 26 of June 1999 at Pershore. Dashed lines: observation; solid lines: RAMS results.

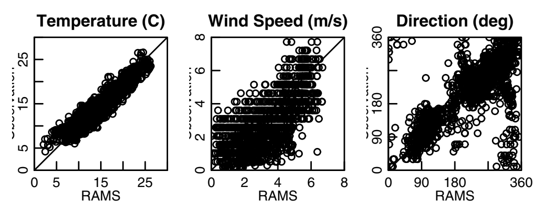

Fig. 3 Hourly observed data plotted against the modelled values from all available stations during the period of 10-26 of June 1999.

Fig. 4 presents a comparison between the modelled (UAM) and observed chemical variables at an urban site, Birmingham East. In general, UAM results of NOx agree reasonably well with the observational data. Daytime minimum values are the result of well-mixed concentration in the boundary layer. This implies the MH produced from RAMS is in a reasonable range. Several peaks of NOx are not reproduced by UAM, especially the one in the morning of 16 June, which shoots over 100 ppb. This may be attributed to power station emissions together with a low-level inversion in the early morning of that day. The lower panel of Fig. 4 shows the O_3 concentration at Birmingham East during the period. In this case, BC of O_3 was specified as constant of 30 ppb, representing the climatological background concentration of O_3 in this area. The results indicate that UAM with such BCs underestimates the O_3 concentration at the station for most of days. A huge discrepancy occurs on 25 and 26 June during which wind direction was easterly. It is suggested that for the relatively flat region in the UK, regional transport of O_3 can be very important for easterly episodes.

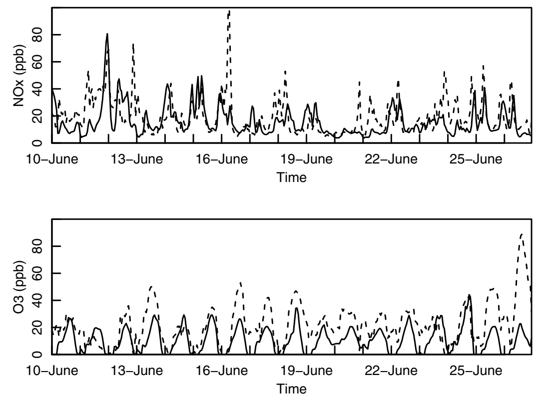

Fig. 4 NOx (upper panel) and O_3 (lower panel) from 10 to 26 of June 1999 at Birmingham East. Dashed lines: observation; solid lines: UAM results.

In order to confirm this, we use the observational data at an upwind station to construct a vertical profile of O_3 as its BC: above the MH, a constant value (the maximum O_3 of the day at the station) is used; within the MH, a linear profile is specified, with the ground value being the same as the hourly data at the station. With this profile, the results are significantly improved and they are shown in Fig. 5. This strongly suggests that appropriate BCs are essential for the simulation.

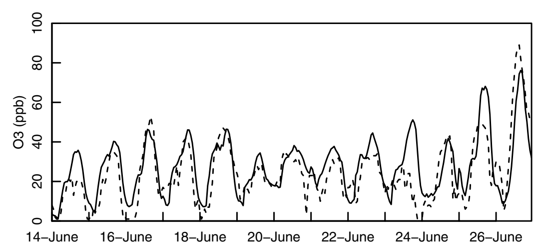

Fig. 5 Concentration of O_3 from 14 to 26 of June 1999 at Birmingham East for the new BC profile of O_3.

4. REFERENCE:

Batchvarova, E., X.-M. Cai, S.-E. Gryning and D.G. Steyn (1999) Modelling internal boundary layer development in a region with complex coastline. *Boundary-Layer Meteorol.*, **90**, 1-20.