6.07 SENSITIVITY ANALYSIS OF MM5 TO METEOROLOGICAL PARAMETERS DURING AN EPISODE PERIOD FOR LONDON

Fragkou, E. R. S. Sokhi, E. Batchvarova and N. Kitwiroon
Atmospheric Sciences Research Group, Science and Technology Research Centre (STRC), University of Hertfordshire, UK

INTRODUCTION

As most cities suffer from serious air quality problems (*Mayer, H.*, 1999), urban air pollution is a major focus of research and regulatory activity. Meteorology is well known to be an important factor contributing to air quality and meteorological models are of increasing importance in air pollution studies (*Seaman, N. L.*, 2000). In most countries, including the UK, mesoscale meteorological models have traditionally been used only for regional and not urban scales. However, before such models can be applied to urban areas it is important to assess the model performance through sensitivity analysis to identify the key parameters that most influence their accuracy. This would lead to the adaptation of mesoscale models for applications to the urban environment (*Biswas, J. and S. T. Rao*, 2001). In relation to air quality assessment such analysis would be particularly important for episodic periods when levels of air pollutants can exceed European limit values.

This paper presents the results of a sensitivity analysis using the MM5 PSU/NCAR mesoscale meteorological model. The model has been applied to the urban area of London during an episodic period and sensitivity analysis has been conducted on various meteorological parameters. The importance of the boundary conditions is examined using the introduction of an 81 km resolution coarse outer domain. The issue of the size and number of domains in MM5 has been often addressed in papers, but usually with reference to the inner domain (*Steed, R. et al*, 2000). The difference in the model predictions caused by three distinct vertical resolution set-ups (high, middle, coarse) within the Planetary Boundary Layer (PBL) is also described. Three PBL parameterisation schemes have been tested, in order to suggest which one of the schemes is more suitable for London simulations. The sensitivity to various PBL schemes has been discussed in several cases (*Bright, D. R. and S. L. Mullen,* 2002), but not specifically for the urban PBL. Finally, soil moisture availability has been changed to investigate the effects of this surface parameter in the case of London. Soil moisture is an important parameter associated with land-surface processes and has been studied in various MM5 applications (*New, M. et al*, 2003, *Cheng, F. Y. et al,* 2002).

METHOD AND SIMULATIONS

MM5 Version 3 Release 6 (MM5v3.6), compiled with PGI version 4.0-2 and operated on the Linux RedHat 7.3 platform, was used in this study. All runs were performed for the first three days of the PM_{10} episode period in London, which lasted from the 17th to the 23rd of February 2003. Model runs were compared with measurements from the London Weather Centre station (LWC) as it reflects the influence of the general urban environment. A reference run was defined, with the following MM5 physics options: 1) Grell cumulus scheme, 2) Simple Ice (Dudhia) explicit moisture scheme, 3) Cloud-radiation scheme, 4) Pleim-Xiu Land-Surface Model ground temperature scheme and 5) Pleim-Chang (PX) PBL parameterisation scheme. The PX scheme was only recently introduced in the MM5 options, and it is therefore not widely represented in the literature (*Xiu, A. and J. E. Pleim,* 2001). In the reference run four domains of the following dimensions and resolutions were included (Table 1). The central Latitude and Longitude of the coarse domain was 52.0N and 0.10W respectively, and the Lambert Conical Conformal map projection was used. The first and second domains were one-way nested and for the rest of the domains two-way nesting was applied.

Table 1. Domain sizes and dimensions used in the reference run

Domain no.	Domain size (number of grid points)	Domain resolution (km)
1	35x35	81
2	58x58	27
3	61x61	9
4	70x70	3

The vertical resolution of 23 pressure levels progressively increased towards the surface and comprised the following levels (mb): 1000, 998, 995, 991, 985, 980, 970, 960, 950, 940, 930, 910, 890, 870, 850, 800, 700, 600, 500, 400, 300, 200, 100. MM5 was initialised using the AVN-MRF analysis data from NOAA. The sensitivity runs conducted are shown in Table 2.

Table 2. Sensitivity runs performed

Run	Vertical resolution	4th domain – 81km resolution	PBL parameterisation	Soil moisture availability (%)
Reference	High	YES	Pleim-Chang	Default
Run 1	Middle	YES	Pleim-Chang	Default
Run 2	Coarse	YES	Pleim-Chang	Default
Run 3	High	NO	Pleim-Chang	Default
Run 4	High	YES	MRF	Default
Run 5	High	YES	Blackadar	Default
Run 6	High	YES	Pleim-Chang	-50%
Run 7	High	YES	Pleim-Chang	+50%
Run 8	High	YES	MRF	+100%

For the middle and coarse vertical resolutions mentioned in Table 2, 23 vertical levels are also used but their density varies below 1500m.The following pressure levels (mb) are defined respectively: 1000, 995, 990, 985, 980, 970, 950, 930, 900, 890, 850, 700, 680, 650, 600, 550, 500, 450, 400, 350, 300, 200, 100 and 1000, 990, 980, 960, 890, 850, 800, 750, 700, 650, 600, 550, 500, 450, 400, 350, 300, 250, 200, 150, 100, 50. In Runs 4 and 5 the Five-Layer Soil Model scheme is combined with the Medium Range Forecast (MRF) and Blackadar PBL schemes (*MM5*, 2004). Run 3 is identical to the reference run, but excludes the coarse domain. For Runs 6 and 7, the soil moisture availability was changed from the land use table (LANDUSE.TBL) in the MM5/Run directory. The soil moisture availability of 10% is given as the default value. This was reduced to 5% (Run 6) and increased to 15% (Run 7) for the urban land use category for winter. Run 8 was performed using the MRF scheme and 20% soil moisture availability.

RESULTS AND DISCUSSION

Amongst the wide range of MM5 output parameters six were chosen here for the sensitivity analysis based on their importance for air pollution applications, namely air temperature, relative humidity, wind speed, sensible and latent heat fluxes and PBL height. Figures 1 and 2 display the predicted surface temperature and wind speed values produced by three PBL schemes (Runs 4, 5 and Reference) along with the observations from the LWC for the first 60 hours of the simulation period.

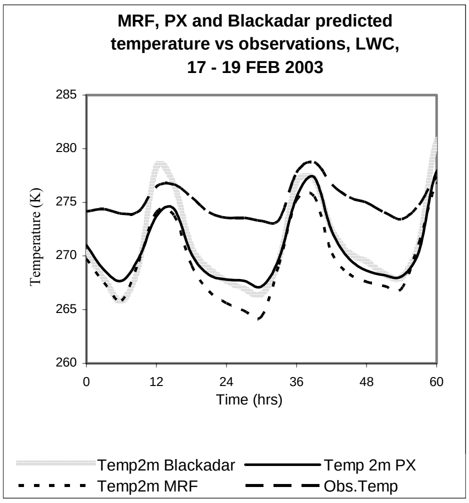

Figure 1. MM5 predicted temperature vs. observations using different PBL schemes

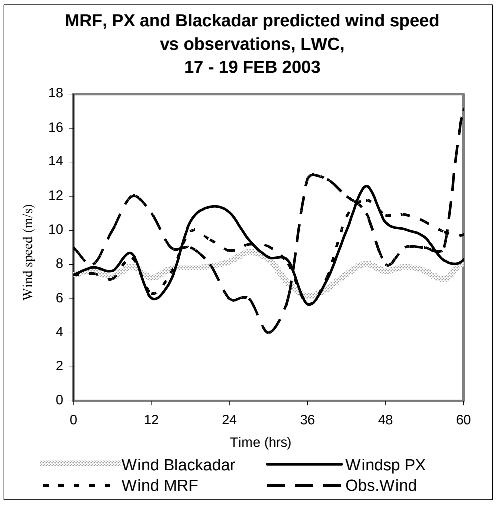

Figure 2. MM5 predicted wind speed vs. observations using different PBL schemes

In the case of temperature (Figure 1), the model results follow the pattern of the measurements, with more notable under-predictions for the minimum temperatures. *Zhang, D. L. and W. Z. Zheng* (2004) report the same effect for MRF and Blackadar but with a less pronounced underestimation for a rural central US location in summer. This underestimation of temperature may be due to the inability of the Grell Cumulus Scheme used with all PBL schemes to accurately simulate cloudiness, probably caused by a tendency to underestimate cloudiness (*Xiu, A. and J. E. Pleim,* 2001). A larger discrepancy between the observed and modelled patterns is found for wind speed (Figure 2). The magnitude of the MRF and PX predictions is closer to the observations than that of the Blackadar scheme. All schemes underestimate the observed values during the daytime, while the peaks generated by PX and MRF occur about 10 hours later than the measured ones. The MRF scheme simulates a nocturnal PBL height of more than 300m, whereas the other two schemes indicate height less than 200m. Substantially larger differences are observed between the schemes for the latent than for the sensible heat fluxes, but no pattern could be identified (results are not shown here).

The Blackadar (Run 5) and MRF (Run 4) produced time series for relative humidity are in phase but slightly over predict the observed values, while more variability is shown in the PX predictions of RH (Figure 3). The role of soil moisture availability is tested using the MRF scheme. The default moisture availability value of 10% in Run 4 (Table 2) has been increased to 20% for the sensitivity run 8 (RH incr20 in Figure 4).

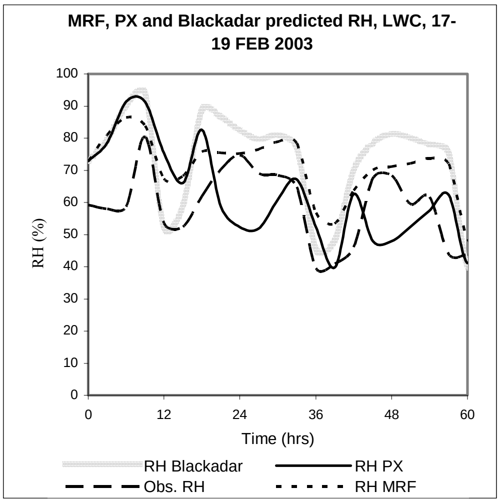

Figure 3. MM5 predicted relative humidity vs. observations using different PBL schemes

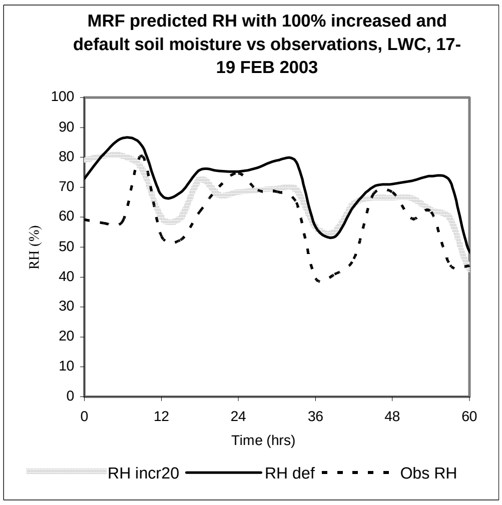

Figure 4. MM5 predicted relative humidity vs. observations using increased and default soil moisture availability

This modification results to slightly lower relative humidity and thus the observed values are better reproduced. No significant effect was observed on the values of temperature, heat fluxes and PBL height. For a central US location in summer, a similar modification of soil moisture caused a much more pronounced effect in all mentioned parameters (*Cheng, F. Y. et al*, 2002). A change of 50% in moisture availability (Runs 6 and 7) did not have a significant impact on any of the parameters in this study.

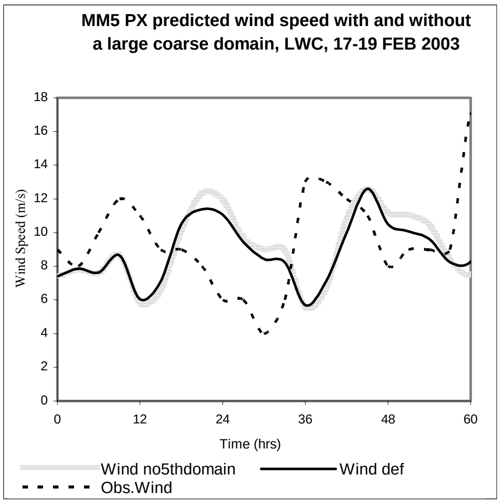

Figure 5. MM5 PX predicted wind speed with and without 81km resolution domain

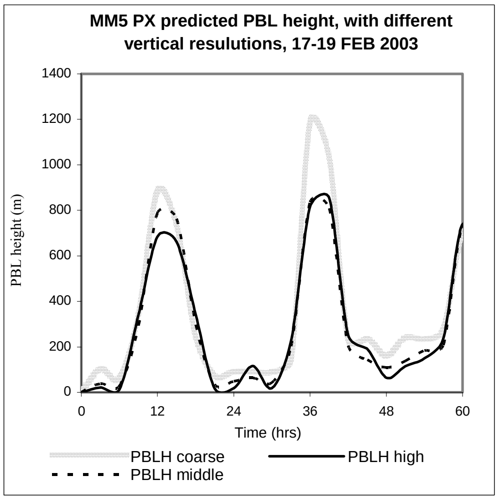

Figure 6. MM5 PX predicted PBL height with different vertical resolutions

Excluding the coarse domain of 81km resolution (Run 3) yields only slightly increased wind speed values compared to the default case, and no effect for all the other examined parameters is found (Figure 5). The different vertical resolution (Runs 1 and 2) mainly influences the prediction of the PBL height and wind speed. The introduction of a high vertical resolution leads to lower PBL heights.

CONCLUSIONS

The conducted sensitivity tests reveal that the MRF PBL scheme has a better performance for all parameters discussed except temperature, while PX demonstrates more substantial discrepancies for relative humidity, and Blackadar for wind speed. The application of high vertical resolution improves the PBL height simulation, whereas excluding the 81km resolution domain had a small impact. Before a firm decision can be reached on any recommendation further detailed sensitivity analysis will be continued. The lack of meteorological measurements also can constrain the final conclusions and recommendations, as only limited data was available from one station (LWC).

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