Characteristic Performance of WRF/CMAQ 2005

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Introduction

At King's college, operational and diagnostic model evaluations have been conducted on WRF (version 3) and CMAQ (version 4.6) over the UK. The period of prediction covers the year 2005 (hourly). This poster focuses on the use of various analysis techniques (using R and OpenAir) and on evaluation of the performance of CMAQ for the criteria pollutants NO_2, NO_X, and O_3. Comparison has also been made between the meteorological model results and observations. The results of diagnostic evaluation of CMAQ are discussed.

Model Setup

The model domains consist of 4 nested levels (Figure 1). The vertical domain has 23 layers with 7 layers under 800 m. The top pressure level is 100 mb.

Dom1: 81km grid spacing, 47 x 44 cells
Dom2: 27km grid spacing, 39x39 cells
Dom3: 9km grid spacing, 66x108 cells
Dom4: 3km grid spacing, 72x72 cells
Dom5: 1km grid spacing, 61x51 cells

FIGURE 1: CMAQ model domains

Initial and boundary conditions for WRF are from the National Centres for Environmental Prediction (NCEP) FNL (Final) Global Tropospheric Analyses at 1^o x 1^o grid spacing. The radiation scheme is RRTM, the microphysics is Kain-Fritsch (new Eta), PBL Scheme is YSU and the land surface scheme is Noah. The chemical scheme is CB-05 with aqueous and aerosols chemistry with Initial and boundary conditions from STOCHEM. The emissions are derived from EMEP, NAEI, LAEI and EPER all of which are processed for CMAQ by an emissions interface, developed at King's

WRF Evaluation

The predictions of surface wind fields (10m), temperature (2m) and relative humidity (2m) are compared against the observations derived from 26 surface met stations within the CMAQ domain 4. The model predicts seasonal trends well of most parameters, particularly for temperature but slightly over predicts wind speed in winter (Figure 2). The majority of the modelled-observed pairs are close to the x=y line. The statistical measures (Table 1) indicate that the model satisfy the proposed DEFRA protocol apart from wind speed. The Taylor diagrams in Figure 3 also show a range of model diagnostics for each site.

Table 1: Statistical measures for WRF performance on prediction of surface meteorology

Parameters	IA	CORR	RMSE	RMSEs	RMSEu	NMB	NME	NMdnB	NMdnE	MB	ME	MdnB	MdnE	FB	FE
WSPD10	0.73	0.58	2.73	1.5	2.28	27.4	51	31.6	49.4	1.15	2.15	1.14	1.77	28.8	54
WDIR10	0.7	0.43	109.51	61.44	90.65	4.9	31.5	3.7	11.4	9.9	63.12	8.1	25.2	-	-
TEMP2	0.95	0.9	2.58	0.81	2.45	-1	17.6	-0.8	13.4	-0.11	1.96	-0.09	1.5	-	-
RH2	0.78	0.61	12.59	6.1	11.02	2.3	11.7	1.8	8.6	1.88	9.47	1.53	7.18	2.5	12.4

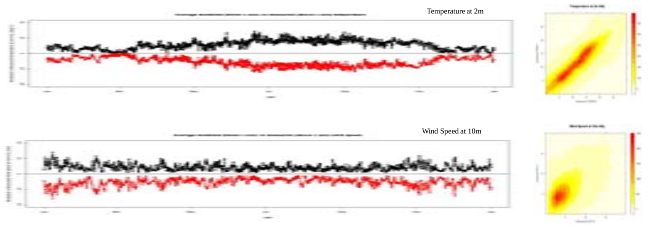

FIGURE 2: Time series and density scatter plots of hourly average of temperature (2m) and wind speed (10m). Black is observation and red is model results * (-1)

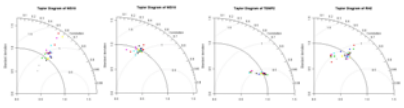

FIGURE 3: Taylor diagram and statistical measures used to quantify WRF performance

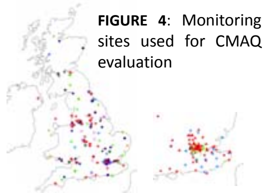

FIGURE 4: Monitoring sites used for CMAQ evaluation

CMAQ Evaluation

Figure 4 shows the wide range of monitoring sites throughout the UK, ~ 106 NO_X sites were used in the CMAQ model evaluation. Figure 5 shows the spatial distribution of NO_X and O_3 concentrations during rush hour with NO_X hot spots clearly observed over the urban areas.

As part of diagnostic evaluation, oxidant partitioning between NO_2 and OX (OX = O_3+NO_2) show the variation of NO, NO_2, O_3, OX as a function of NO_X mixing ratios during all seasons. Figure 6 shows the results during the day in winter and summer. There was good agreement between observations and modelled results during daytime and nighttime (not shown here) with small biases of OX in summer. Overall, this shows that CMAQ represents the photochemistry well.

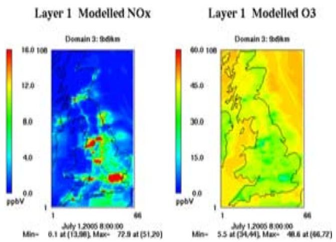

FIGURE 5: Predicted NO_X and O_3 concentrations (Domain 3)

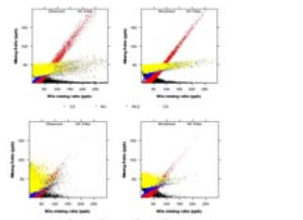

FIGURE 6: Comparison between modelled and observed partitioning oxidant

The CMAQ model is able to reproduce the seasonal trend of observed NO_2 and O_3 concentrations well. Figure 7 shows that the measured concentrations are predicted well during the afternoon period, although there is an under prediction of NO_X and over prediction of O_3 during the night. This may be associated with the prediction of wind speed.

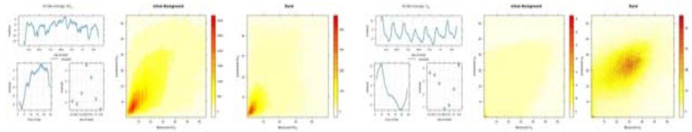

FIGURE 7: Diurnal errors and density of the scatter plot between model results and observations; NO_X/NO_2 and O_3

The model bias varies by day of the week and is a maximum on Wednesday. This may be as a consequence of the methods used to create the hourly NO_X emissions profiles and is currently under investigation. Nevertheless, the density scatter plots show the majority of modelled-observed pairs are close to the x=y line at urban background and rural sites.

The statistical measures (not shown here) indicate that CMAQ would satisfy the proposed DEFRA protocol with relative small biases between observations and model results.

Polar plots are used determine if the model correctly predicts source contribution at specific sites. For example, Figure 8 shows a PM source which is not related to combustion (and is not included in the emissions inventory) at Woolwich and that during E-NE winds at ZG3 site results in high concentrations of NO_X possibly from Tilbury.

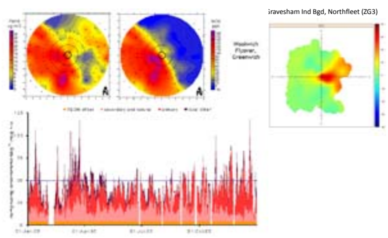

FIGURE 8: Polar plot of NO_X and PM_{10} and at ZG3 site

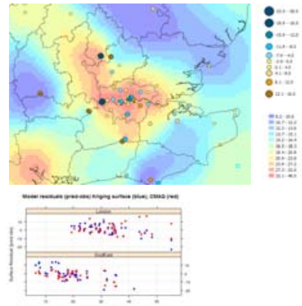

FIGURE 9: Comparison of Point Measurements and Grid models (NO_X)

There are also problems associated with a comparison of model results (which represent a grid average) and observations at a point, particularly in urban areas. Figure 9 shows some recent work on creating measurement surfaces, through interpolation, and their use in site selection prior to model evaluation.

Conclusion

Evaluation of the WRF/CMAQ model would be very difficult without improvements in tools to process large datasets into meaningful diagnostics. OpenAir provides many of these tools. Furthermore, other packages in R can enhance model evaluation still further. Both R and OpenAir show the considerable benefits of open source products.