A Study on the forecasting accuracy of the last version of MM5 and WRF model as input fields of Air-Quality models

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1. INTRODUCTION

A real time photochemical air quality forecast system has been implemented for each metropolitan region to support public awareness of air quality issues. The forecast system uses hourly numerical weather data such as wind and air temperature fields with MM5 (Fifth Generation Mesoscale Model) and WRF (The Weather Research and Forecasting) models. Recently, the regional numerical weather forecast models have expanded tremendously due to affordable computer workstations and a parallel computer environment using multi processor platforms (Mass and Kuo, 1998; Snook, 1998). Above all, since wind and air temperature fields play an important role in transport and chemistry of air quality, their forecasts and verifications are also very significant.

The goal of this study is to verify forecasting accuracy in MM5 and WRF models by comparing basic verification statistics between the MM5 and WRF during the spring dust storm season over the central region of Korea. This study focuses on surface verification.

In this study, we verify wind vectors and air temperature fields with the last version of MM5 and WRF models for building a numerical air quality forecast system, describe the basic components of the models, present examples of forecast results, and show how the forecast compares to available observations.

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2. MODEL SETUP

Various numerical experiments were conducted to test wind and air temperature fields of MM5 (version 3.7, released Dec, 2004) and WRF (version 2.2, released Dec, 2006) models that were initialized with RDAPS (Regional Data Assimilation and Prediction System) datasets for forecasting air quality models such as CMAQ, UAM, CALGRID and CAMx in the Korean peninsula. We ran 3 one-way-nested domains starting at a resolution of 30km over Eastern Asia to 10km for the Korean peninsula and 3.3km for the central region of Korea including Seoul (Fig. 1) with 27 vertical sigma levels.

In order to simulate and verify these models, we selected nine dust storm cases at spring of 2006. For these cases the MM5 and WRF models were integrated for 36 hours, and the time resolution was fixed at 180 sec to domain 1, 60 sec to domain2 and 20 sec to domain3, respectively.

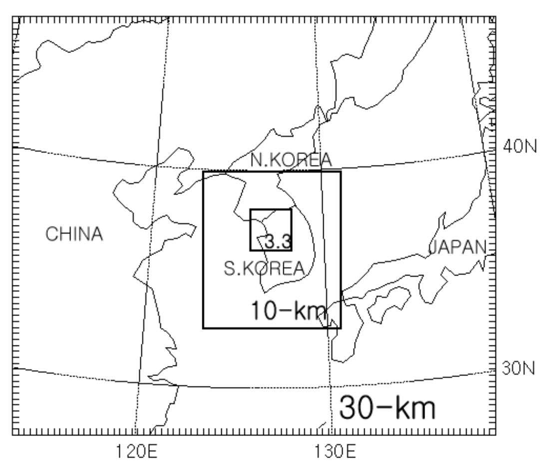

Fig. 1. Location of 30-, 10-, and 3.3-km MM5 and WRF domains used in this study.

We have adopted the physics for MM5 and WRF as shown in Table 1.

Table 1. Summary of numerical experiments

	MM5 (ver. 3.7)	WRF (ver. 2.2)
Microphysics	Graupel (Reisner2)	WSM 6-class graupel
Cumulus	Kain-Fritsch 2	Kain-Fritsch (new Eta)
PBL	MRF	MRF
Radiation	RRTM	LW : RRTM SW : Dudhia
Land surface	5 layer thermal diffusion	5 layer thermal diffusion

3. RESULTS AND CONCLUSIONS

Dataset of nine cases has been collected using all of the domain, and we extracted wind speed, wind direction, air temperature and sea level pressure at the grid point surrounding the location of Seoul monitoring meteorological site, and then interpolated to the observation site.

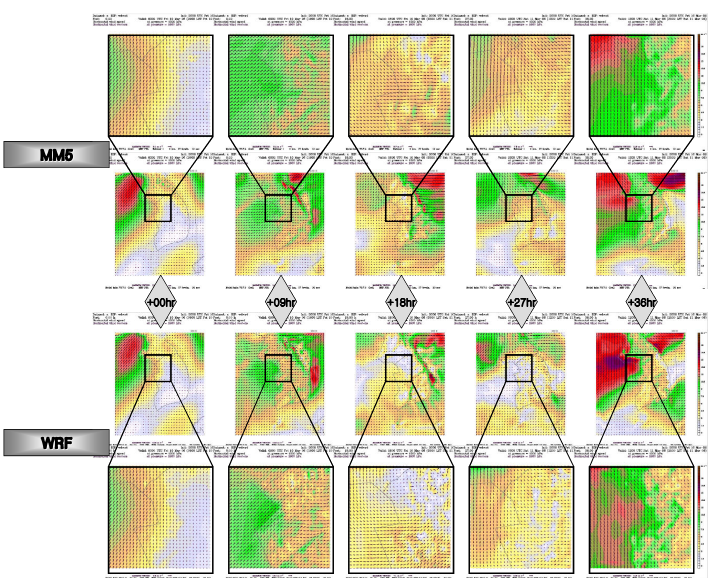

Fig. 2. Spatial distribution of forecasted wind fields between MM5 (above) and WRF (below) at 1000 hPa (from 0000 UTC on 10 Mar 2006 to 1200 UTC on 11 Mar 2006). 2nd and 3rd rows are domain2, and 1st and 4th rows are domain 3, respectively.

Although this point verification identifies model biases and makes qualitative comparisons, but it can not evaluate the model ability which produces better or worse mesoscale structures between MM5 and WRF (Lin *et al*., 2005).

Fig. 2 shows horizontal distribution of wind fields on 1000 hPa simulated by MM5 and WRF at 0000 UTC on 10 March to 1200 UTC on 11 March, 2006. As a result, there were a few differences in wind vectors in the sea and land surface area and some spatial resolution differences between MM5 and WRF model.

Figs. 3 to 6 show hourly variation of wind speed and wind direction between simulated and observed at Seoul monitoring meteorological site. These results between MM5 & WRF have similar biases because of similar physics as seen in Fig. 7. Both models have bias errors of 1-3ms^{-1} wind speed at daytime, but those of MM5 mean errors are slightly less than WRF for all of the domain (Fig. 7b). Deviation and correlation coefficient of wind speed varies on a case by case basis (Table 1).

The MM5 wind direction biases are less than 30 degrees, but those of WRF increase in more than 30 degrees during 20-27 forecasting hours (Fig. 8). Both models underestimate strongly in the minimum temperature at dawn. The WRF mean errors are larger than those of MM5 in the night time, and diminished to zero in daytime (Fig. 9).

Table 2 provides some statistics on the performance of each model such as correlation coefficient, the root mean square error (RMSE) and the statistical bias error are provided.

In the case of wind speeds and directions for MM5 and WRF, correlation coefficients were shown in about 0.7 and the MM5 RMSE were slightly smaller than those of WRF. In the case of the air temperature time series, all of the MM5 correlation coefficients were 0.77, and those of WRF were more than 0.89 with low RMSE.

In comparison of sea level pressure, the correlation coefficients were more than 0.94 together with low RMSE and bias.

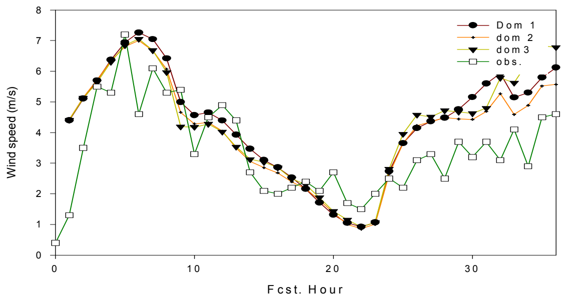

Fig. 3. Hourly variation of wind speed of domain 1,2,3 simulated by MM5 and that observed at Seoul site (one of nine cases)

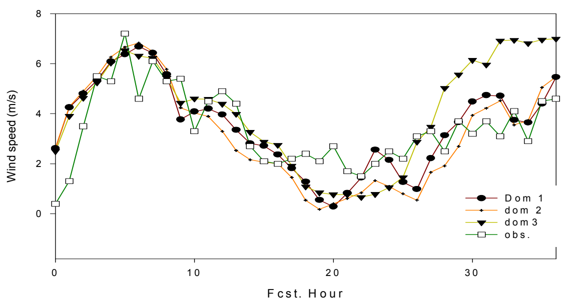

Fig. 4. Same as Fig. 3 except for WRF

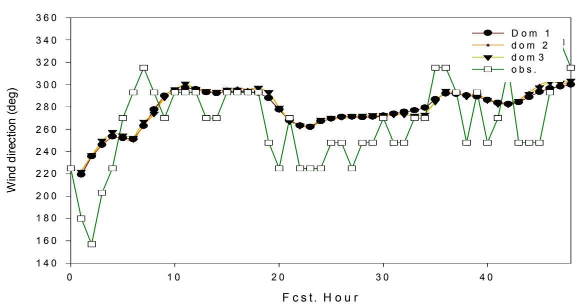

Fig. 5. Same as Fig. 3. except for hourly variation of wind direction

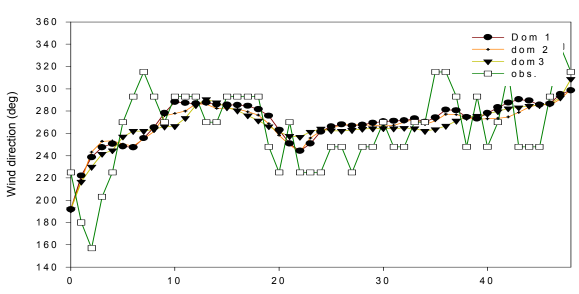

Fig. 6. Same as Fig. 5. except for WRF.

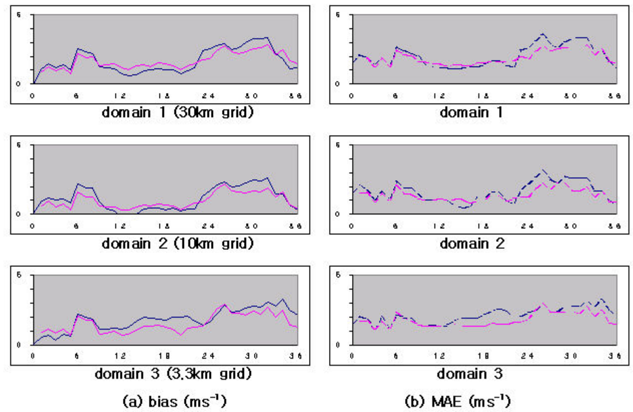

Fig. 7. Wind speed bias (a) and mean absolute error (b) versus forecast hour for MM5 (red line) and WRF (blue line). N. Forecasts were started at 0000 UTC and nine cases were averaged.

Table 1. Coefficient of correlation of wind speed for each cases between model output and observation data

Model	Dom -ain	Case numbers 1	2	3	4	5	6	7	8	9
MM5	1	.68	.77	.59	.78	.82	.63	.56	.81	.48
	2	.73	.82	.60	.78	.82	.58	.53	.83	.48
	3	.69	.83	.58	.72	.82	.41	.60	.81	.44
WRF	1	.78	.79	.58	.74	.64	.53	.37	.81	.48
	2	.79	.80	.51	.75	.71	.58	.47	.82	.52
	3	.62	.86	.57	.67	.29	.49	.62	.61	.40

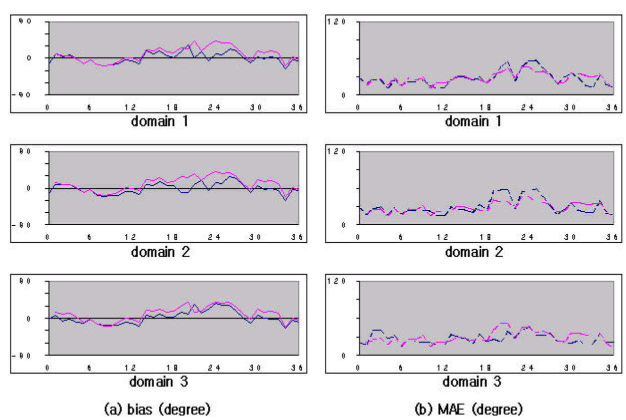

Fig.8. Wind direction bias (a). Plus for counter clockwise, minus for clockwise, and MAE (b) versus forecast hour for MM5 (red line) and WRF (blue line).

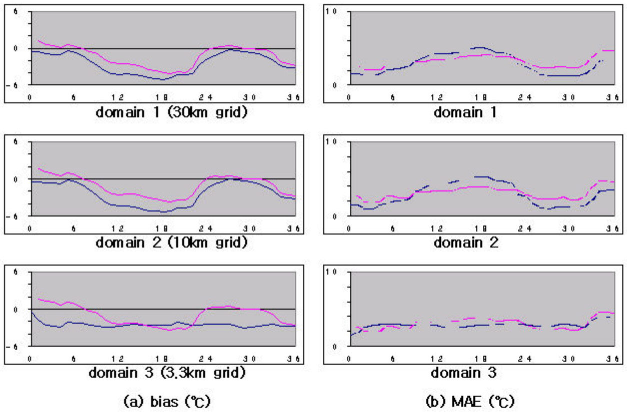

Fig. 9. Same as Fig. 7. except for surface temperature

Table 2. Verification statistics for MM5 and WRF models

Domain \ Model		Correlation coefficient		BIAS		RMSE	
		MM5	WRF	MM5	WRF	MM5	WRF
wind speed	1	.73	.73	1.62	1.66	2.20	2.35
	2	.71	.75	0.93	1.08	1.63	1.94
	3	.71	.68	1.48	1.81	2.13	2.43
wind direction	1	.69	.68	12.43	-0.77	42.53	44.31
	2	.68	.67	12.09	-3.52	43.51	46.36
	3	.66	.74	13.08	1.20	43.39	39.25
air temperature	1	.77	.90	-1.39	-2.46	3.78	3.42
	2	.77	.90	-1.15	-2.41	3.68	3.47
	3	.77	.89	-1.02	-2.52	3.60	3.15
sea level pressure	1	.97	.94	1.68	0.90	1.97	1.70
	2	.97	.95	1.70	-0.63	1.99	1.51
	3	.97	.95	1.73	0.21	2.02	1.39

Consequently, in the future, for advanced forecasting air quality models, it is necessary to improve wind vectors within boundary layer model through data assimilation between simulated and observed meteorological parameters. In addition, the latest land use data and model ensemble construction should be required.

4. ACKNOWLEDGEMENTS

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