Evaluation of High Resolution NWP Model Output of Near-Surface Variables

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1. INTRODUCTION

The model output of Mesoscale Numerical Weather Prediction (NWP) systems with high horizontal and vertical resolutions has shown rapidly improving accuracy and they are used to provide inputs of wind, temperature, stability parameters, mixing depth, and other parameters to atmospheric transport and dispersion models. In order to estimate the uncertainty in these input variables and their effects on the output of the atmospheric and dispersion models, it is necessary to evaluate the accuracy of mesoscale NWP models in terms of these variables, as illustrated by Cox (1998), Seaman(2000) and others. Recently, Hanna, Yang and Yin (2000) and Hanna and Yang (2001) systematically evaluated the accuracy of model output with the horizontal resolution of 12km, from MM5 and RAMS, both widely used in the atmospheric transport and dispersion studies. This paper reports the preliminary results of verification of ARPS with even higher resolution against meteorological data collected from special field experiments.

2. The Advanced Regional Prediction System

ARPS, or Advanced Regional Prediction System, is one of the state of art mesoscale NWP modeling systems (Xue et. al, 2001). It is a multi scale, non-hydrostatic and fully compressible atmospheric predictions system with a data assimilation module and post processing components. ARPS has been successfully used in weather prediction and other applications, and its performance for free atmosphere variables at a resolution of about 30km is comparable to other similar systems (Hou, Kalnay and Droegemeier, 2001).

The ARPS was run in this research in one-way interactive nested-grids with the innermost domain covering about 1 degree by 1 degree latitude/longitude area with a horizontal resolution of 1km. Full physics package was applied and Kain-Fritsch cumulus parameterization scheme was used for the outermost grid with a horizontal resolution of 12km. ETA model analysis is used to provide initial conditions and ETA prognosis is used as the lateral boundary conditions of the outermost grid. The model was run in a purely prognostic mode with observations from NWS upper air and surface observations used only at the initial time of the model integration.

3. Data Sets and Verification Methods

Meteorological data collected during two field experiments are used for the verification of model output. The first experiment was carried out over the Dugway Proving Ground (DPG), Dugway, UT, during the period April 30 --- May 1, 2001, representing a typical spring case with relatively strong synoptic forcing, while the second experiment is characterized by the weakly forced summer time circulation over the Chesapeake Bay (CPB) area during the period of July 21 --- 23, 2001. In the DPG experiments, wind, temperature and dew point are observed at 17 surface stations over an area of about 50kmx50km area, relatively flat but flanked by hills, with an average distance between stations of about 10km. The CPB experiments are designed to study the sea and land breezes and 13 special surface stations, mainly located close to the coast and operated by the MARAK service, are used to collect hourly wind, temperature and dew point. The distance between the stations is roughly 10 to 15km.

The model variables are output every 1 hour or 30 minutes and the raw observational data are at 15 or 60 minutes intervals. Both are averaged to get hourly values for comparison. Time series of model output are plotted against observation for quantitative comparison with emphasize on the evolution of each variables and the prediction of significant weather events, such as wind direction shifts. Various error measures, including bias, absolute error and root mean square error, averaged over all of the stations and over the time period of each experiment, are also calculated. In order to investigate the improvement of accuracy with increasing resolution, the model output from model runs with 12km, 3km and 1 km resolution are presented for comparison.

4. Results and Discussions

In order to save space, the discussion is concentrated on the CPB experiment as the results of the DPG experiment are similar and the weather pattern with the CPB constitutes a tough challenge to meso-scale NWP models. The time series of model output of surface variables are plotted against the corresponding observations, at each station (figures not shown). Generally, the model output with 3km and 1km resolution, with more fine structure simulated, shows a better agreement with the observation. This is especially true for wind direction shifts and temperature extreme values for some stations. However, the results are more or less complicated with a quantitative comparison. Table 1 shows the mean bias (BIAS), root mean square error (RMSE), mean absolute errors (ABSE) and standard deviation of the errors (SDE), averaged over all of the stations and over the 3 day period. It shows that the 1 km runs have highest accuracy with all of the error measures of wind speed. For wind direction, 1km runs have the minimum bias while the 3km runs show minimum for other error measures. As the thermal variable are concerned, the highest accuracy is associated with the 3km or 12 km runs, except for the bias of dew point temperature (not shown). It is thus concluded that with the increase in the resolution from 12km to 3 km, Significant improvement in accuracy is achieved with wind direction and wind speed but not in the thermal variables. With resolution increases to 1 km, some improvement is observed with wind speed and the bias in dew point. The improvement of accuracy is largely associated with better simulation of fine scale flow structures. This is illustrated by comparing the variance (in both time and space) for model output of wind direction with that of the observation (fig. 1). The 12km runs significantly underestimated the variance, while the 3km runs successfully simulated the variance with its magnitude very close to the observation. The 1km runs further improves the variance for some periods but the general quantity remains the same.

Table 1. Averaged Error Errors

Variable	Resolution	*BIAS*	*RMSE*	*ABSE*	*SDE*
Wind	12 km	-21.3	51.5	38.9	46.0
Direction (degree)	3 km	-13.8	47.7	36.7	44.6
	1km	-11.9	51.6	40.1	48.5
Wind Speed (m/s)	12km	0.39	1.85	1.49	1.78
	3km	0.49	1.81	1.47	1.73
	1km	0.39	1.78	1.42	1.70
Temperature (°C)	12km	-1.76	2.64	2.22	1.94
	3km	-1.75	2.27	1.82	1.86
	1km	-1.96	2.68	2.24	1.73

The analysis indicates that ARPS' performance, with root mean square error (rmse) of less than 2 m/s, 50 degrees, and about 2°C in wind speed, wind direction, and temperature, respectively, is comparable with other mesoscale modeling systems widely used in the atmospheric transport and dispersion studies (Hanna, 2000). It is also indicated that with current model physics description and surface characteristic data sets, the uncertainties in mesoscale NMP output can not be reduced with increasing resolution only, although the higher resolution model results are still helpful if appreciate interpretation is applied.

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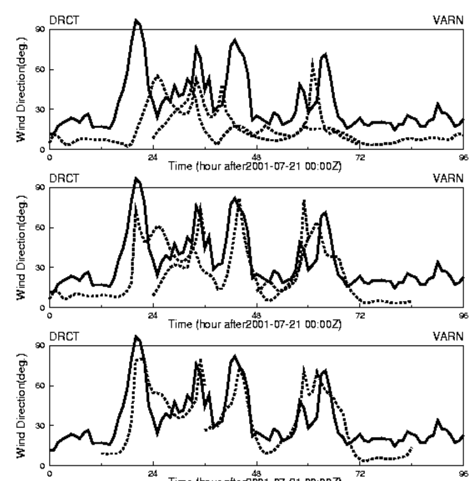

3km (middle) and 1km (lower) runs.

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