

RECONSIDER MODEL PERFORMANCE WITH FDDA IN MULTIPLE NESTED DOMAINS

Qi Mao*, Stephen F. Mueller, and Larry L. Gautney
Tennessee Valley Authority, Muscle Shoals, Alabama

1. INTRODUCTION

Improving air quality simulation relies to a large extent on the accuracy of the meteorological conditions reproduced by a mesoscale model. Four-dimensional data assimilation (FDDA) based on Newtonian relaxation or nudging is a useful technique for enhancing mesoscale model performance (Wang and Warner 1988; Stauffer and Seaman 1990; Haagenson et al. 1990; Mueller et al. 1996; Tanrikulu et al. 2000). The strategy for implementing FDDA to a mesoscale model, however, is not a straightforward approach, especially when the model is initialized with analysis fields generated by FDDA at different scales (Stauffer and Seaman 1994; Fast 1995; Parsons and Dudhia 1997).

This study attempts to focus on the sensitivity of a multiple nested mesoscale model to two types of initializations with or without FDDA analysis nudging. While the results of the model performance evaluation are preliminary, it is hoped that they are informative and instrumental to similar modeling efforts.

2. MODELING APPROACH

2.1 Model and Setup

The Fifth-Generation PSU/NCAR Mesoscale Model (MM5) version 3.5 was run for 96-hour simulations, from 00Z of July 6 through 00Z of July 10, 1999. The model was configured with three domains, with horizontal resolutions of 36, 12, and 4 km for the coarse (D1), intermediate (D2), and fine domain (D3), respectively (Fig. 1). D3 only covered Nashville and its vicinity. Thirty-one sigma layers were specified in the vertical.

2.2 Initialization and FDDA

Five simulations were conducted: three were initialized with the NCEP/NCAR global reanalysis and the other two with the NCEP/Eta analysis data

* Corresponding author address: Qi Mao, TVA, CEB-2A, P.O. Box 1010, Muscle Shoals, AL 35662-1010; e-mail: qmao@tva.gov; tel.: 256-386-2653; fax: 256-386-2499.

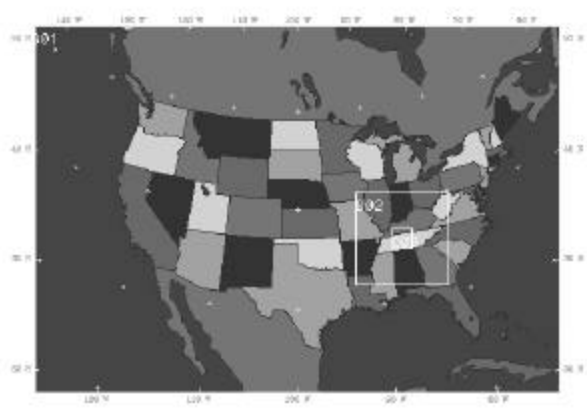


Fig. 1 MM5 modeling domains.

(Table 1). Each simulation was run with the options of a three-dimensional analysis nudging and a surface nudging using the NCEP ADP Global Surface Observations. Simulations E1 and E2 were benchmark runs without FDDA. The time interval for initialization and 3D analysis nudging was 6 hours (E3 and E5) and 12 hours (E4), and that for surface nudging was 3 hours (E5). To minimize the uncertainty of inconsistency of nudging analysis among the multiple domains, FDDA was applied to the coarse domain only in all the simulations.

Table 1. Outline of MM5 simulations.

Exp.	Initialization Data	3D Nudging	Surface Nudging
E1	NCAR	no	no
E2	Eta	no	no
E3	NCAR	yes	no
E4	Eta	yes	no
E5	NCAR	yes	yes

2.3 Model Physics

MM5 model physics and parameterizations used in all the simulations included:

- ? Explicit moisture scheme – mixed phase;
- ? Cumulus parameterization – Kain-Fritsch (excluded from D3);
- ? PBL scheme – NCEP MRF;
- ? Radiation scheme – RRTM;
- ? Ground temperature scheme – OSU/Eta LSM;
- ? Shallow cumulus convection – none.

3. MODEL EVALUATION

Preliminary evaluation of model performance resulting from the simulations was focused on near surface variables, in particular, temperature and wind at seven monitoring locations of the Tennessee valley: Nashville, Knoxville, Memphis, Chattanooga, and Tri-Cities of Tennessee and Huntsville and Muscle Shoals of Alabama. Hourly output of MM5 simulations were compared against the observations at the monitoring sites.

4. RESULTS AND DISCUSSIONS

Figure 2 shows simulated (D2) and observed 2-meter temperatures for Nashville. The simulations were initialized with the NCEP/NCAR reanalysis data. Minor differences are seen among the three simulations during day-2 and -3, for benchmark E1 matches well with the observation. However, the improvement of MM5 performance with the analysis nudging is obvious during the first and the last 24 hours. This improvement resulting from nudging is also true for the other model evaluation sites.

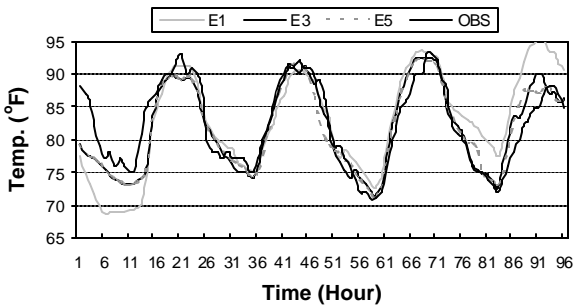


Fig. 2 Simulated and observed 2-m temperatures for Nashville.

The mean biases of the simulated 2-meter temperatures for the seven sites are illustrated in Figure 3. Several features are noticed. First, MM5 performs better when nudging is applied, regardless which type of initialization is used. The simulation that has the least bias is the one with both the 3D and surface nudging turned on. Next, the mean bias becomes larger as the horizontal resolution of the modeling domains increases. It appears that the trend is independent of nudging. This is somewhat in contradiction with the conventional wisdom, for a higher resolution model is generally believed to be able to perform better than a lower resolution one. Finally,

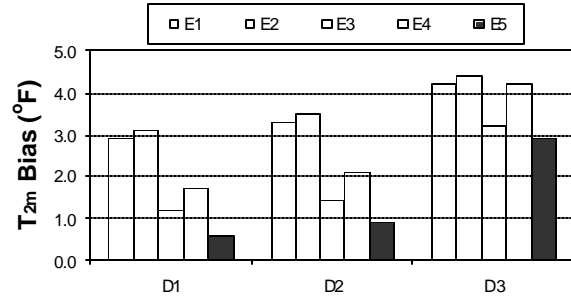


Fig. 3 Mean biases of 2m temperature simulations.

simulations initialized with the NCAR reanalysis (E1, E3) have relatively smaller biases than those initialized with the Eta analysis (E2, E4) for the same nudging options. This is true for all three modeling domains. However, the differences of bias do not necessarily imply which initialization is better for the simulations because the time intervals of both analyses are not the same. Most of these features are also exhibited in the analysis of mean absolute error (Table 2). Much improvement was achieved in temperature simulations with a 3D analysis nudging. It became even better when the surface nudging was also applied.

Table 2. Mean absolute errors of 2m temperature simulations.

Exp.	D1	D2	D3
E1	4.9	5.3	6.2
E2	4.0	4.5	4.6
E3	3.0	3.5	4.2
E4	3.0	3.5	4.3
E5	2.7	3.1	3.8

It is observed that the same FDDA nudging technique, which results in considerable improvement in near surface temperature simulations, almost has no effect on near surface wind. Table 3 shows the absolute errors of hourly 10-meter wind speeds averaged over the seven monitoring sites during the 96-hour simulations. No significant changes are found among the simulations with or without the FDDA nudging, nor across the modeling domains with different resolutions, as is observed in the temperature simulations (Table 2).

Table 3. Mean absolute errors of 10-meter wind speed simulations.

Exp.	D1	D2	D3
E1	1.6	1.6	1.7
E2	1.7	1.7	1.6
E3	1.5	1.5	1.5
E4	1.5	1.5	1.7
E5	1.5	1.5	1.5

5. SUMMARY

Meteorological simulations with the MM5 version 3.5 were run for 96 hours for the region around Nashville, Tennessee. The model was configured with one coarse and two nested domains and initialized with the NCAR reanalysis and the Eta analysis data. Five simulations were conducted with or without FDDA 3D analysis and surface nudging.

Preliminary model evaluation was focused on near surface temperature and wind speed using observations at seven monitoring sites in the Tennessee valley. It is found that both the 3D analysis and the surface nudging significantly enhanced the temperature simulation but had no noticeable impact on near surface wind speed. It is also found that for any given simulation the coarse domain resulted in the least mean temperature bias and absolute error among the three modeling domains. More investigations are needed to reach any conclusions.

6. ACKNOWLEDGMENTS

This work was supported by the Public Power Institute of Tennessee Valley Authority.

7. REFERENCES

Fast, J.D., 1995: Mesoscale Modeling and Four-Dimensional Data Assimilation in Areas of Highly Complex Terrain. *J. Appl. Meteor.*, **12**, 2762–2782.

Haagenson, P. L., K. Gao, Y.-H. Kuo, 1990: Evaluation of Meteorological Analyses, Simulations, and Long-Range Transport Calculations Using ANATEX Surface Tracer Data. *J. Appl. Meteor.*, **12**, 1268–1283.

Mueller, S. F., A. Song, W. B. Noms, S. G., R. T. McNider, 1996: Modeling Pollutant Transport during High-Ozone Episodes in the Southern

Appalachian Mountains. *J. Appl. Meteor.*, **11**, 2105–2120.

Parsons, D. B., J. Dudhia, 1997: Observing System Simulation Experiments and Objective Analysis Tests in Support of the Goals of the Atmospheric Radiation Measurement Program. *Mon. Wea. Rev.*, **10**, 2353–2381.

Stauffer, D. R., N. L. Seaman, 1990: Use of Four-Dimensional Data Assimilation in a Limited-Area Mesoscale Model. Part I: Experiments with Synoptic-Scale Data. *Mon. Wea. Rev.*, **6**, 1250–1277.

Stauffer, D. R., N. L. Seaman, 1994: Multiscale Four-Dimensional Data Assimilation. *J. Appl. Meteor.*, **3**, 416–434.

Tanrikulu, S., D. R. Stauffer, N. L. Seaman, A. J. Ranzieri, 2000: A Field-Coherence Technique for Meteorological Field-Program Design for Air Quality Studies. Part II: Evaluation in the San Joaquin Valley. *J. Appl. Meteor.*, **3**, 317–334.

Wang, W., T. T. Warner, 1988: Use of Four-Dimensional Data Assimilation by Newtonian Relaxation and Latent-Heat Forcing to Improve a Mesoscale-Model Precipitation Forecast: A Case Study. *Mon. Wea. Rev.*, **12**, 2593–2613.