Simulation of the Meteorological Conditions of the Houston-Galveston Area with WRF for the TexAQS 2000 Episode

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1. INTRODUCTION

The Weather Research and Forecasting (WRF) modeling system is a next-generation mesoscale meteorological model that is expected to be widely used in operational and research weather forecast in the future. WRF can be used to simulate the meteorological fields for air quality modeling as well (Klausmann et al 2003). The weather parameters such as surface wind and air temperature play a key role determining air quality in a region. Therefore, it is very important that the meteorological simulations are accurate to correctly model air quality.

In this study, WRF and MM5 simulated meteorological conditions for the Houston/Galveston area during the TexAQS-2000 episode were compared. Both MM5 and WRF were used with four nested domains. The WRF simulation results were rather disappointing. Without the grid-nudging tool, WRF simulations were not able to propagate the synoptic weather changes from the coarse to nested domains. Then, we re-simulated the same episode with MM5 and WRF using the single 4-km eastern Texas domain. Through the evaluation with the extensive meteorological measurements available for the TexAQS2000, we verified that WRF generated comparable meteorological features as MM5. In addition, a set of sensitivity tests was performed to evaluate different land-surface models and PBL parameterizations that were implemented in WRF.

2. NUMERICAL EXPERIMENTS

WRF version 2.0.3.1 (Michalakes et al 2004) and MM5 version 3.6.7 were used for simulation TexAQS 2000 which is an intensive field study in Houston/Galveston area for ozone and other pollutant issues during Aug-Sep, 2000. In this study, we focus on Aug 22 to Sep 2. The Eta reanalysis data, which is in 40 km resolution, is used as initial condition and boundary condition for the experiments. For physical options, the same parameterizations are used in both simulations. They are WSM 3-cleass simple ice scheme for microphysics, RRTM scheme for radiation, MRF scheme for PBL parameterization and Noah LSM for land-surface model.

There are two experiments. One is the nested domains including 108-km for whole US, CONUS at 36-km, 12-km for Southern States, and 4-km for Eastern Texas. Two-way nesting was applied for the first and second domains while one-way nesting was applied for the rest of them (Gill et al 2004). The other is single domain in 4 km resolution simulations covering eastern Texas.

3. NESTED DOMAINS SIMULATIONS

The results of nested domains simulations were not acceptable. Figure 1 shows time series of 2 m temperature for the 4 km domain. Compared with observations, WRF resulted very flat diurnal variations following sunrise and sunset only. There were no synoptic scale changes realized in the simulations. The IC/BC was generated by the ETA reanalysis data but they only could affect the boundary that synoptic signals were not able to propagate from the coarse to fine domains.

Same as WRF, MM5 cannot simulation the comparable synoptic weather phenomena as well without a nudging tool (not shown). Therefore, we conclude that the main cause of the WRF's failure was due to the lack of grid-nudging tool that can assimilate the synoptic patterns simulated in the coarse domain into the fine domain. The nesting mechanism only allows changes through the boundaries and as a result, the inner domain could not represent the observed meteorological conditions properly.

4. SINGLE DOMAIN SIMULAIONS

In the single small domain experiment, WRF performed much better than the nested domain experiment for simulating the meteorological conditions of HGA. WRF could capture the maximum 2 m temperature on urban sites while underestimated the minimum value (figure 2). But, compared with MM5, WRF predicted the daily minimum temperatures more adequately than MM5 especially for urban sites. Both models predicted the observed temperature very closely for rural sites. However, minimum and maximum temperatures were mildly underestimated.

For PBL height, the MRF scheme was applied for both simulations. They were able to show the development of PBL height and consisted with the observations at daytime (Figure 3). The scattered diagrams showed that WRF simulated PBL heights slightly better than MM5. The R^2 value of WRF was 0.6847 that was a little higher than MM5 (0.6132).

The model performance characteristics for 10 m winds at urban and rural sites were quite similar. Without a nudging tool, the time series of simulation results show somewhat noisy but on some days, such as Aug 26 ~ 29, the simulated wind speeds were very close to the observations.

5. SENSITIVITY TESTS

Three sensitivity tests were set to evaluate the implementation of land-surface model and PBL scheme in WRF. The results shown above were simulated with the MRF scheme and Noah LSM that was set as control run (**C-WRF**). The sensitivity studies were setup as follows:

R1-YSU---change MRF scheme to YSU scheme
R2-Yamada---change MRF to Yamada scheme
R3-RUCY---apply RUC-LSM &Yamada scheme.

The results were shown in Figures 5 & 6. The performance of R1-YSU and R2-Yamada simulation are very similar to the control run (C-WRF) and close to the observations, not only for the 2 m temperature but also the PBL height. R3-RUCY didn't simulation the meteorological conditions as good as the others. It underestimated the daily maximum temperature but overestimated the minimum temperature. In addition, the R3-RUCY simulation always under-predicted PBL height at daytime. For nighttime PBL height, the MRF and Yamada scheme report the estimated value while the YSU scheme perform what MM5-MRF scheme does that reports a fixed value (~17 m) after sunset.

5. CONCLUSION

WRF was used to simulate the meteorological conditions of Houston/Galveston area for TexAQS 2000 episode. In the nest experiment, the simulation failed because of the lack of the grid-nudging tool in WRF model that the fine domains couldn't get any synoptic information from the coarse domain. In the single 4-km domain simulation, WRF model showed a good performance. Simulated 2 m temperature was highly correlated to the observations but mildly underestimated maximum and minimum temperature. The developments of PBL height are captured well by WRF model. For 10 m wind speed, it is hardly to generate a good simulation without a data assimilation scheme.

6. REFERANCE

Gill, D., J. Michalakes, J. Dudhia, W. Skamarock, and S. G. Gopalakrishnan, 2004: Nesting in WRF 2.0. Joint MM5/WRF Users Workshop, Boulder, Colorado, June 22-25, 2004.

Klausmann, A. M., M. Phadnis, and J. Scire, 2003: The Application of MM5/WRF Models to Air Quality Assessments. The Thirteenth MM5 Users' Workshop, June 10-11, 2003, Boulder, CO, USA.

Michalakes, J., D. Gill and J. Abernethy, 2004: WRF 2.0 SOFTWARE. Joint MM5/WRF Users Workshop, Boulder, Colorado, June 22-25, 2004.

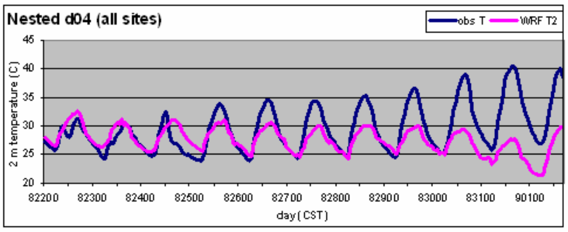

Figure 1. Time series of 2 m temperature in domain 4 from nested domain experiment.

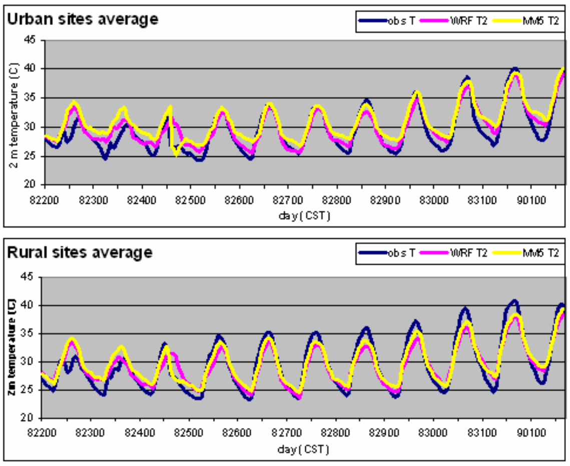

Figure 2. Time series of 2 m temperature top: 5 urban sites average and bottom: 5 rural sites average from single domain experiment.

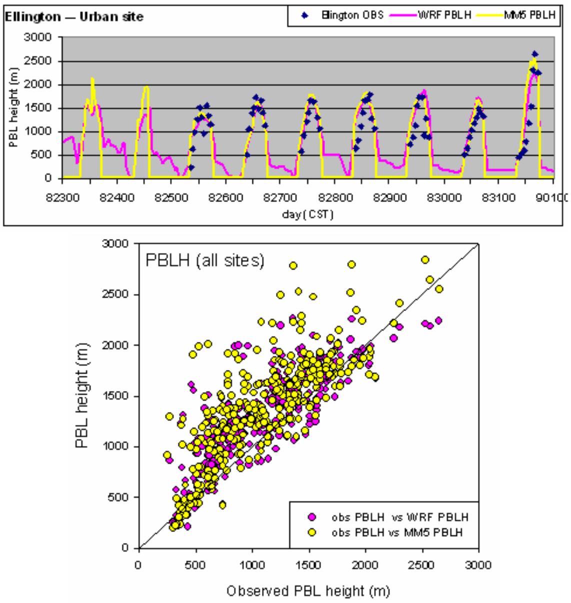

Figure 3. Time series (top) and scattered diagram (bottom) of PBLH from single-domain experiment

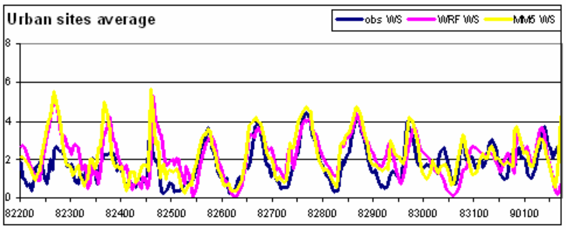

Figure 4. Time series of 10 m wind speed.

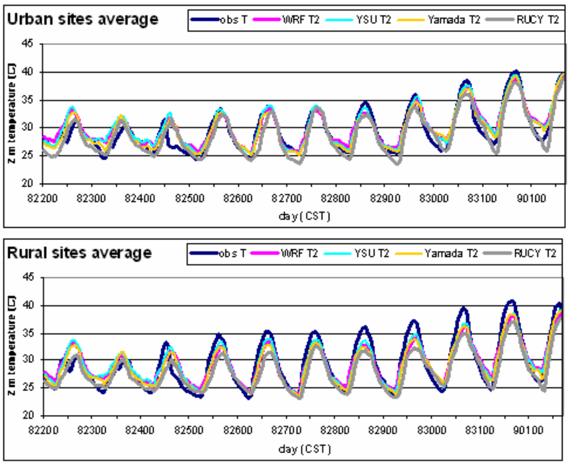

Figure 5. same as figure 2 but from sensitivity test simulations.

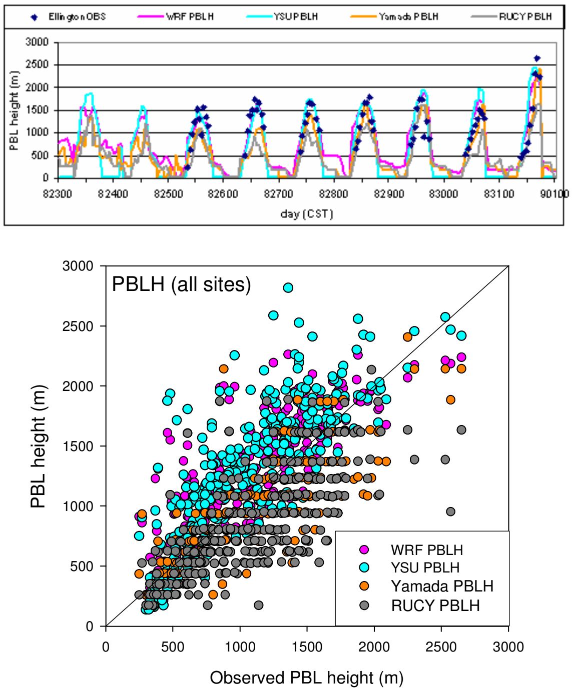

Figure 6 same as figure 3but from sensitivity test simulations.