Testing a Planetary Boundary Layer Scheme in MM5 for the Phoenix Metropolitan Region

S. Grossman-Clarke[1], J.A. Zehnder[2,3], Y. Liu[4] and J.D. Fast[5]

[1]International Institute for Sustainability ASU, P.O. Box 873211, Tempe, AZ 85287-3211 , [2]Department of Geography, ASU; [3]Department of Mathematics, ASU; [4]National Center for Atmospheric Research/RAP, Boulder, CO; [5]Pacific Northwest National Laboratory, Richland, WA

Introduction

Previous atmospheric modeling efforts related to the Central-Arizona Phoenix (CAP) Long-term Ecological Research (LTER) Project:

- Refining the urban land use/cover classification in the fifth-generation PSU/NCAR mesoscale meteorological model MM5 based on remotely sensed data by Stefanov *et al.* 2001.
- Enhancing the MM5 model by characteristics of the urban energy balance such as anthropogenic heat production, sky view factor and increased surface volumetric heat capacity and heat conductivity (Grossman-Clarke *et al.* 2005).
- Apply MM5 for studying urban heat island; nitrogen deposition; effects of historic and future land use changes on weather in the CAP LTER study region.

Current MM5 modeling efforts are:

- Testing a new planetary boundary layer (PBL) scheme that includes the refined urban surface energy budget and a modified version of the Medium Range Forecast (MRF) boundary layer scheme developed at the National Center for Atmospheric Research (*Liu et al.* 2004).
- Important for studying the influence of the urban area on thunderstorm propagation; interactions of the urban and rural thermal environment through mesoscale circulations; influence of land use changes on air quality and near-surface meteorological variables.

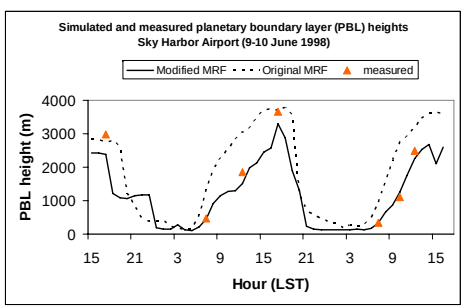

Figure 1: Simulated and measured planetary boundary layer heights at the National Weather Service Station Sky Harbor on Airport on 9-10 June 1998. Simulations were carried out by MM5 using the non-local closure Medium Range Forecast (MRF) boundary layer scheme in its original (Hong and Pan 1996) and modified version (Liu et al. 2004).

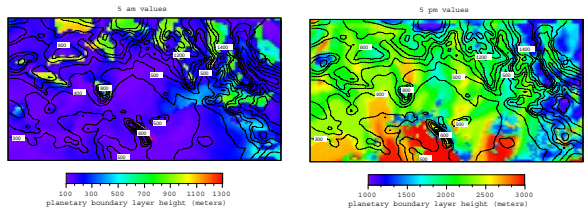

Figure 3: Simulated planetary boundary layer heights in the 2 km x 2 km modeling domain covering the Phoenix metropolitan region and surrounding mountainous and desert areas at 9 June 1998 5 am and 5 pm obtained with the modified version of the MRF scheme by (Liu et al. 2004).

Model Description and Numerical Experiments

- Tendency of original MRF scheme (Hong and Pan 1996) to underestimate near-surface wind speeds and to overestimate sensible heat fluxes and boundary layer heights under free-convection conditions because of empirical description of the convective velocity and use of non-local bulk Richardson number (Liu *et al.* 2004).
- In modified MRF scheme (Liu *et al.* 2004) PBL height is determined by local bulk Richardson number computed between two neighboring model levels.
- Modified MRF scheme was applied and tested in MM5 during a 72-hour simulation starting at 0000 Universal Time (UTC) 8 June 1998, i.e. 1700 Local Standard Time (LST) 7 June 1998.
- Nested simulations with four domains and resolutions of 54 km, 18 km, 6 km and 2 km (size east-west 212 km; north-south 132 km), respectively and 32 vertical layers were performed.
- Initial and boundary conditions provided by the NCEP ETA grid 212 (40 km resolution) analysis and include assimilation of upper air observations.
- Model results were compared with measurements from a field campaign conducted in May/June 1998. Vertical temperature profiles were measured at Sky Harbor Airport five times per day (0800, 1000, 1200, 1400, 1700 LST).

Results and Conclusions

- *Figure 1* shows simulated PBL heights. Original MRF scheme yields up to 1500 m and 200 m higher PBL heights during daytime and nighttime respectively.
- Simulated PBL heights of the modified MRF scheme showed clearly better agreement with the measurements. However, the original MRF scheme captured the magnitude of the maximum PBL height better.
- *Figure 2* shows the regional distribution of PBL heights at 5 am and 5 pm on 9 June 1998 as obtained with the modified MRF scheme.
- *Figure 3* shows the course of simulated and measured wind speeds at a height of 10 m at Sky harbor Airport during the simulation period with significantly improved results for the modified MRF scheme (original MRF calculated near zero wind speeds during daytime).
- Application of the modified MRF scheme in MM5 led to significantly improved results for PBL heights and wind speeds.
- This has an influence on applications of MM5 for investigating the propagation of Thunderstorms in the region, real-time weather forecast and downscaling output of Global Climate models to the region.
- The modified MRF scheme will be tested further against experimental data from two field campaigns conducted in May/June 1998 and June/July 2001 in the Phoenix metropolitan area.

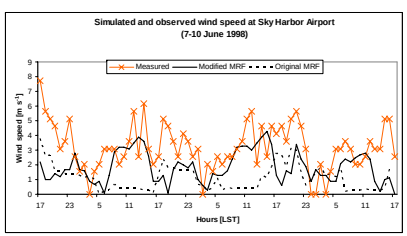

Figure 3:

Simulated and observed wind speeds for June 7, 1998 17:00 LST to June 10, 1998 17:00 LST for the NWS station at Sky Harbor Airport. Simulations were carried out by MM5 using the non-local closure Medium Range Forecast (MRF) boundary layer scheme in its original (Hong and Pan 1996) and modified version (Liu et al. 2004).

References

Fast, J.D., Doran, J.C., Shaw, W.J., Coulter, R.L., Martin, T.J. 2000, J. Geophys. Res. **105**, 22833-22848.

Grossman-Clarke, S., Zehnder J.A., Stefanov W.L., Liu Y., Zoldak, M.A., 2005, Journal of Applied Meteorology (under revision).

Hong, S.Y., H.L. Pan, 1996, *Mon. Wea. Rev.*, **124**, 2322-2339.

Liu, Y., Chen, F., Warner, T., Swerdlin, S., Bowers, J., Halvorson, S. 2004, *Proceedings of the 84th AMS Annual Meeting, 16th Conf. on Numerical Weather Prediction (Seattle, WA) January 12-15, 2004*; paper 22.2.

Stefanov, W. L.; Ramsey, M. S.; Christensen, P. R. Remote Sens. Environ. 2001, **77**, 173-185.