Influence of Urbanization on Weather in the Phoenix Metropolitan Region

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Introduction

The goal of our work is to gain a better understanding of meteorological processes potentially influenced by urbanization in the Phoenix metropolitan region. The fifth-generation Pennsylvania State University and National Center for Atmospheric Research (PSU/NCAR) Mesoscale Meteorological Model (MM5) is used in order to investigate if the increasing extent of the Phoenix metropolitan region affects:

- ❖ The development and propagation of summer monsoonal thunderstorms.
- ❖ How mesoscale circulations due to the variability in urban and rural land use interact with the mesoscale thermal circulations due to complex terrain;
- ❖ How past and potential future land use changes influence near surface atmospheric state variables and characteristics of the planetary boundary layer.

In order to apply MM5 in such process studies with high confidence it needs to be ensured that the surface energy balance as well the planetary boundary layer (PBL) are represented in the model with high accuracy. Therefore current MM5 modeling efforts include:

- ❖ Testing the PBL scheme (MRF, *Liu et al.* 2004) against data from meteorological field studies.
- ❖ Using historical land use data in order to assess MM5's ability to capture present and past seasonal behavior of near-surface air temperatures, wind speeds and the urban heat island effect.

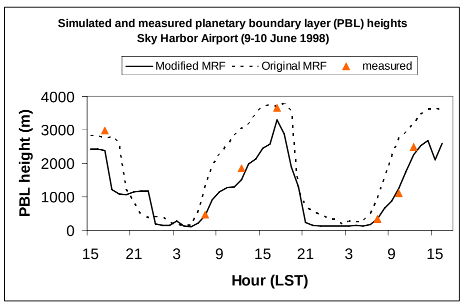

Figure 1: Simulated and measured planetary boundary layer heights at Sky Harbor on Airport on 9-10 June 1998. Simulations were carried out by MM5 using the non-local closure Medium Range Forecast (MRF) boundary layer scheme in its original and modified version (Liu et al. 2004).

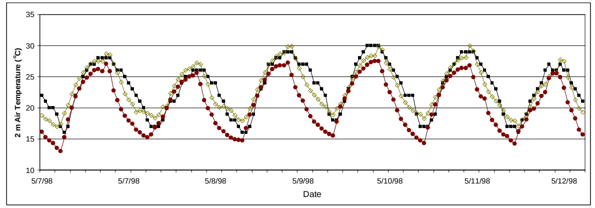

Figure 1: Simulated (enhanced (-◇-) and original version (-•-) of MM5) and measured (-■-) 2 m air temperatures at Sky harbor Airport for the time period 7 May to 12 May 1998.

Model Description and Numerical Experiments

MM5 was enhanced by a refined land cover classification and simple modifications to the urban surface energy balance (Grossman-Clarke *et al.* 2005). Bulk approaches for characteristics of the urban surface energy budget were introduced in the model:

- ❖ Increased heat storage capacity
- ❖ Long-wave radiation trapping
- ❖ Production of anthropogenic heat

Anthropogenic heating, Q_a, was added to the governing equation for air temperature (last term):

$$\frac{\partial T}{\partial t} = -\mathbf{V}\cdot\nabla T + \frac{1}{\rho_a c_p}\left(\frac{\partial p'}{\partial t} + \mathbf{V}\cdot\nabla p' - \rho_0 g w\right) + \frac{\dot{Q}}{c_p} + \frac{T_0}{\theta_0} D_T + \frac{1}{\rho_a c_p}\frac{\partial Q_a}{\partial z}$$

where **V** horizontal wind vector; *w* vertical velocity; *p'* (Pa) perturbation pressure; subscript 0 denotes the reference state; Q heating rate due to diabatic processes (i.e. net radiative flux convergence and divergence and phase changes of water during fog, cloud formation and precipitation); D_T horizontal and vertical diffusion. The first term describes horizontal and vertical advection, while the second term in parenthesis describes the adiabatic warming.

- ❖ MM5 simulations were carried out for 1 May 1998 to 12 June 1998.
- ❖ Inner modeling domain resolutions 2 km (size east-west 212 km; north-south 132 km).
- ❖ 32 vertical layers.

Results and Conclusions

Simulation results were tested against surface meteorological, radar wind profiler and radiosonde data from a field campaign:

- ❖ *Figure 1*: simulated and observed PBL heights at Sky Harbor Airport for 9-10 June 1998. The simulated PBL heights of the modified MRF scheme are in good agreement with the measurements
- ❖ *Figure 2:* Simulated and measured 2 m air temperatures at Sky Harbor Airport for 7 May to 12 May 1998. The model behavior for those days is representative for the whole simulation period, i.e. a consistently improved model performance of the enhanced version of MM5 was achieved.
- ❖ *Figure 3:* Simulated and observed vertical profiles of potential temperature for 9 June 1998 at Sky Harbor Airport indicating a good agreement between observed and simulated data, i.e. the evolution of the PBL as well as magnitude of PBL height are well represented in the model.

Conclusions: The model changes resulted in a significantly improved model performance for near-surface meteorological variables and upper air data during the whole simulation time period. The simulation results support the application of this version of MM5 in studying the influence of urbanization on weather in the Phoenix metropolitan region.

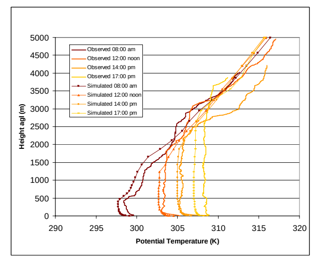

Figure 3: Simulated and observed vertical profiles of potential temperature for 9 June 1998 at Sky Harbor Airport.

References

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