Effects of urban land cover modifications in a mesoscale meteorological model on surface temperature and heat fluxes in the Phoenix metropolitan area.

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Introduction

Mesoscale atmospheric models such as the Pennsylvania State University/NCAR's MM5 are usually applied to urban areas in order to predict near-surface atmospheric state variables in a relatively high spatial resolution as well as characteristics of the planetary boundary layer (PBL). Those variables are strongly influenced by the energy, matter and momentum exchange between the land surface and the atmosphere.

Urban micrometeorology is a developing area of research which has begun to address the limited theoretical basis and scarce measurements of land-atmosphere exchange in urban landscapes [1]. The recent standard release version of MM5 includes only one urban land use type based on traditional city center properties; the low density urban and residential areas which predominate in rapidly expanding cities like Phoenix are not well-represented by this land use parameterization.

A new land cover classification for the Phoenix metropolitan area was implemented in the fifth-generation PSU/NCAR mesoscale meteorological model MM5. The single urban category in the existing 25-category United States Geological Survey (USGS) land cover classification was divided into three classes: built-up urban, suburban mesic residential and suburban xeric residential. This allowed us to consider the influence of urban vegetation and irrigation practices in the surface energy budget and hence the evolution of the boundary layer.

Materials and Methods

Land cover data in a 30 m resolution were derived from LANDSAT Thematic Mapper (TM) satellite images [2]. The data were upscaled to a 30-second grid and used to augment and correct the existing USGS land cover scheme in MM5 (Figure 1). The five-layer slab model [3] was utilized to calculate surface energy fluxes and ground temperature. Planetary boundary layer processes were included via the MRF (NCEP- Medium Range Forecast) PBL scheme.

The most important physical parameter distinguishing the urban categories in the two land use classifications is the water availability factor, ***M***. Water availability determines to a high degree the partitioning of the net radiative energy of the land surface into sensible and latent heat fluxes and therefore the ground temperature, $\boldsymbol{T_g}$. Evaporation, ***E***, for each grid cell in the modeling domain was calculated as part of the energy balance equation according to:

$$E = \rho_a C_\Theta C_u M[q_s(T_g) - q_s]$$

with ρ_a being air density, q_a and q_s being the mixing ratio and the saturation mixing ratio of water vapor, C_Θ and C_u being exchange coefficients for heat and momentum respectively.

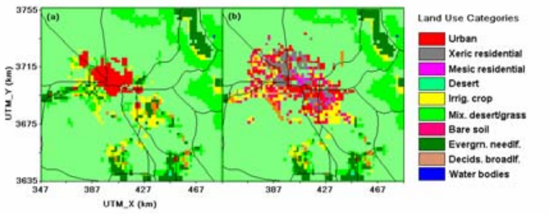

Figure1: 2 km x 2 km Land use map for the Phoenix metropolitan area using (a) USGS land data and (b) 1998 satellite data

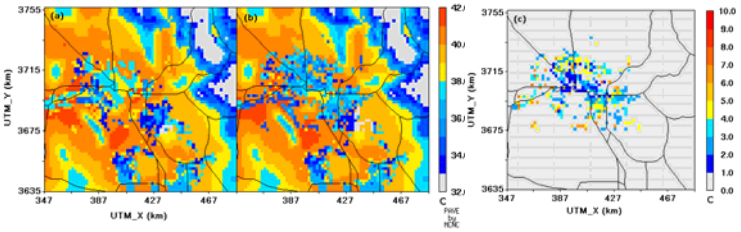

Figure 2: Simulated ground temperature using (a) USGS land use data and (b) 1998 satellite data, (c) differences between the two simulations.

The following moisture availability factors were assigned to the three urban categories:

Built-Up Land	0.02
Mesic residential	0.20
Xeric Residential	0.10

Two 72-hour simulations starting on May 28 2001 at 5:00 pm local time were performed with MM5 on a 2 km x 2 km grid using (1) the old MM5 land use classification and (2) the new land use classification. Differences in the simulated latent heat fluxes, ground temperature and 2m air temperature as well as the boundary layer height were evaluated for the two model versions.

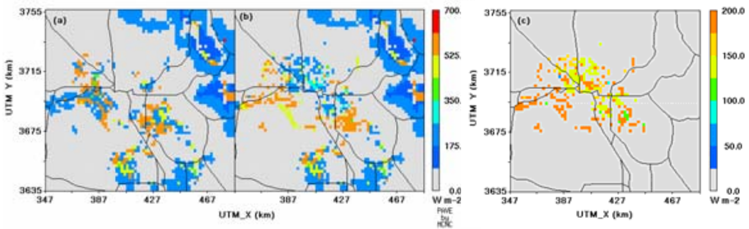

Figure 3: Simulated latent heat fluxes using (a) USGS land use data and (b) 1998 satellite data and (c) differences between the two simulations.

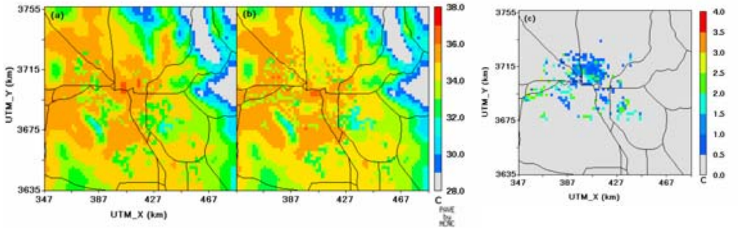

Figure 4: Simulated air temperature at 2m using (a) USGS land use data and (b) 1998 satellite data and (c) differences between the two simulations.

Results and Conclusions

The simulated ground temperatures and latent heat fluxes are shown for 29 May 2001, 2:00 pm in Figure 2 and Figure 3 respectively. Ground temperatures and energy fluxes are mostly determined by physical characteristics of the earth surface and therefore reflect the spatial inhomogeneity of the land use distribution in the modeling domain. In the urban area significant differences in the simulated ground temperatures of up to 4 K were found between the two model versions corresponding to differences in latent heat fluxes. The air temperatures at 2 m height (Figure 4) are influenced by the surface heat fluxes and advection. The temperature variation between grid cells is less than changes are at ground level. The results of this study show that urban land use is also likely to have a significant impact on the height of the planetary boundary layer (Figure 5) which has a significant influence on pollutant concentrations.

There are a number of advantages of applying MM5 for the CAP/LTER region. First, we will be able to use the model as a dynamic interpolation scheme, providing a fine scale distribution of surface meteorological parameters. These can be used in driving other process based ecological, microclimate or air quality models. The model may be used to test development and design strategies. For example, choices of building material, roofing and pavement, spacing of structures affect the albedo, thermal conductivity and turbulent transfer from the surface, all of which govern the local climate.

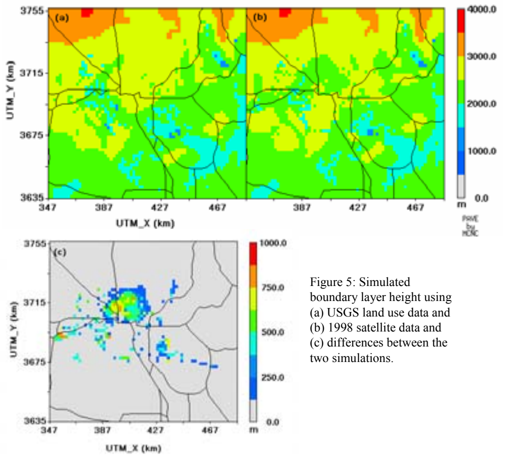

Figure 5: Simulated boundary layer height using (a) USGS land use data and (b) 1998 satellite data and (c) differences between the two simulations.

References

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