Impact of Urban Form and Design on Mid-Afternoon Microclimate in Phoenix Neighborhoods

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Introduction

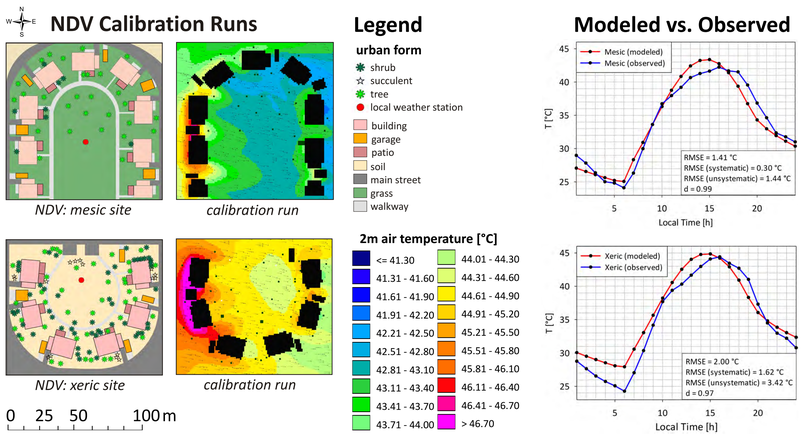
Over the past decades, many cities have been warming due to urban heat island effects, induced by changes in land cover and built forms. Those local climate variations can lead to a higher demand for air conditioning and increased human discomfort in the summer, especially in arid and semiarid environments. This study investigates the impact of urban form and landscaping on the mid-afternoon microclimate in Phoenix, Arizona. The goal is to find the most effective urban form and design strategies to ameliorate temperatures during the summer months and, consequently, to reduce residential energy use and increase human comfort.

Methodology

We simulated near-ground air temperatures for typical neighborhoods in Phoenix using the three-dimensional microclimate model ENVI-met. The model was calibrated using the CAP LTER North Desert Village (NDV) landscape experiment at Arizona State University's Polytechnic campus. This site is an ideal test bed to determine the model's input parameters, since it is a controlled environment recreating four prevailing residential landscape types in the Phoenix metropolitan area (mesic, oasis, xeric, and native). After calibration, we designed five urban form scenarios that represent a realistic cross-section of typical residential neighborhoods in Phoenix. The urban form scenarios follow the Local Climate Zone (LCZ) classification scheme after Stewart and Oke [1]. We then combined the urban form scenarios with mesic and xeric landscape designs and simulated microclimate conditions for these neighborhoods in ENVI-met for June 23, 2011, a typical summer day.

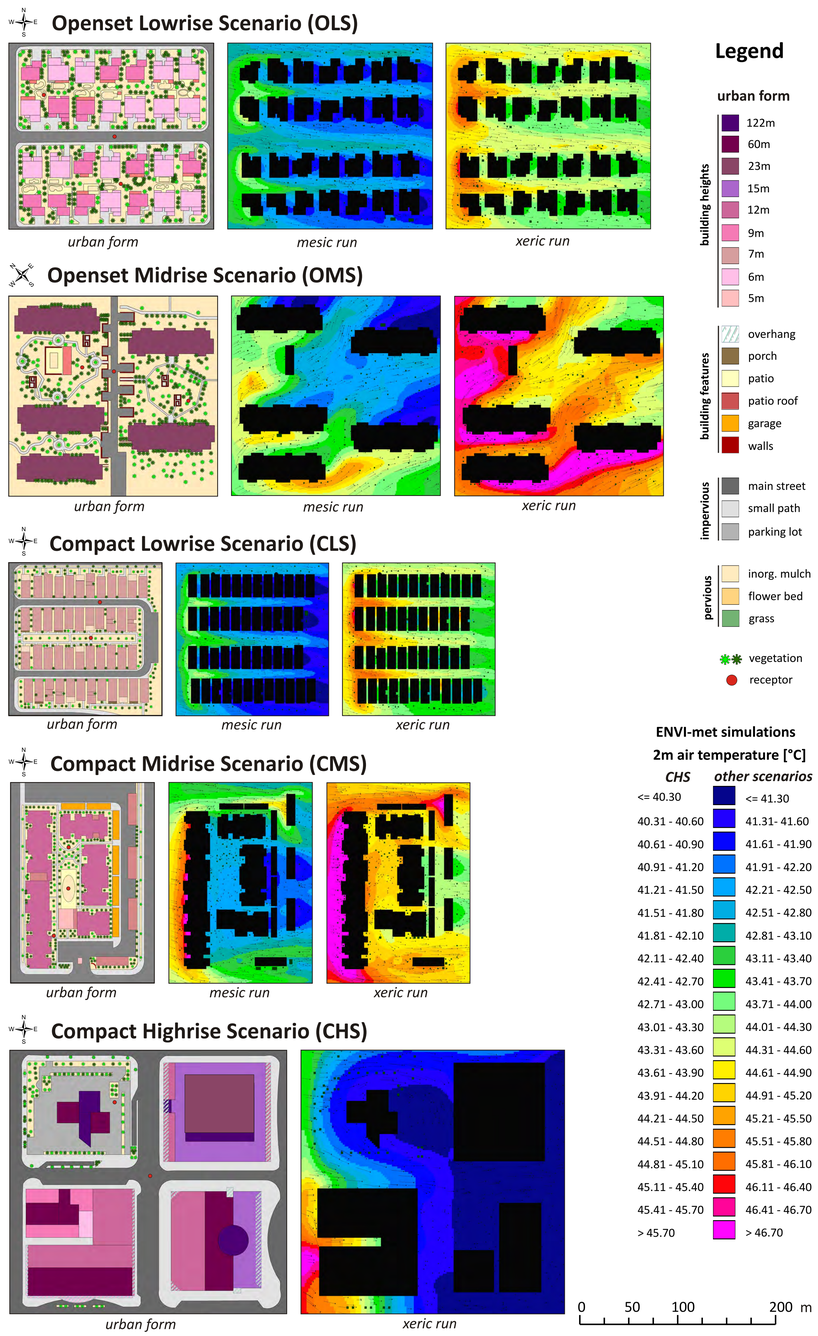
Model Calibration Results

For a detailed discussion of calibration results, see [2].



Simulation Results

Snapshots of the air temperature distribution at 2m height and wind vectors for each combined urban form and landscaping scenario for June 23, 2011, 15:00h

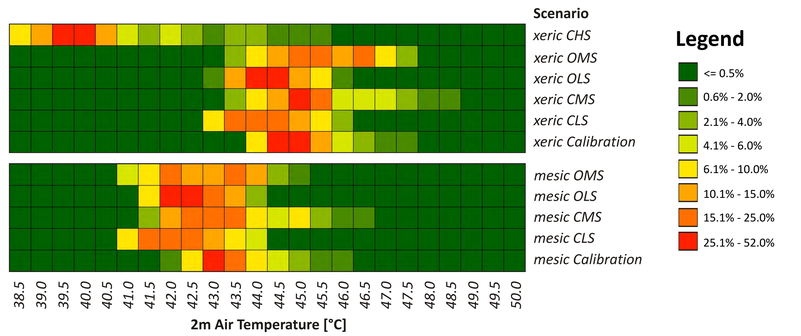


Landscaping Scenarios mean air temperature [°C]	
Native	36.13
Xeric (w/o CHS)	35.84
Oasis	35.42
Mesic	33.52

Urban Form Scenarios air temperature [°C] at 15:00h		Urban Form Scenarios mean air temperature [°C]
OMS	44.90	35.61
CMS	44.74	35.43
OLS	43.88	35.05
CLS	43.71	34.82
CHS	40.74	36.07

Key Findings

- The hierarchy of landscaping scenarios reflects the magnitude of the respective latent heat flux.
- The diurnal spatially averaged air temperature is highest for the CHS, but mid-afternoon air temperatures are lowest. The daily air temperature amplitude for the CHS is relatively low.
- Air temperatures in the midrise scenarios are higher than in the lowrise scenarios.
- Air temperatures in the openset scenarios are lower than in the compact scenarios, whereas wind speed is higher in the openset scenarios.
- Advection is important for the temperature distribution in the urban form scenarios. For example, in the CMS, the building to the west has a shielding effect, keeping high temperatures away from the courtyard. This is also reflected in the spatial variation of air temperatures, which is highest for this scenario.
- There is a relatively high correlation between surface temperatures and incoming short-wave radiation. It ranges from 0.42 for the xeric OMS to 0.73 for the highrise scenario.
- Shading patterns and surface materials impact surface temperatures and can be used to influence local temperatures.



Histogram for 2m air temperature distribution in each scenario: For each scenario (rows), the occurrence of temperatures (rounded to 0.5 °C) in percent (columns) is mapped.

References

[1] Ian D. Stewart, Tim R. Oke, 2012, Local Climate Zones for Urban Temperature Studies. *Bulletin of the American Meteorological Society*, 93(12):1879–1900.
[2] Ariane Middel, Kathrin Häb, Anthony J. Brazel, Chris Martin, Subhrajit Guhathakurta, 2012, Urban form, landscape design, and microclimate in Phoenix, Arizona. *8th International Conference on Urban Climate (ICUC8)*, August 2012, Dublin, Ireland.

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