Cooling the City: Integrating ground-based measurements with modeling scenarios to address urban heat stress among vulnerable populations.

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The mounting evidence about the impacts of climate change on human health presents an urgent need to understand the implication of rising temperatures on the inhabitants of cities, where the majority of people now live. Acute increases in the magnitude, intensity, and duration of extreme weather events has the potential for causing major disruptions in commerce, social process, and human fatalities, especially among vulnerable populations (e.g. older adults, pre-existing health conditions, those with limited coping capacity). One such event is extreme heat, which causes more deaths across the globe per year than all other natural disasters combined. While numerous studies confirm and describe the creation of and processes that mediate urban heat islands (UHIs), few examine the opportunities for mediating microclimate through alternative physical design of the built environment. In this study, we ask two research questions: (1) what built environment characteristics help to explain the presence of UHIs? and (2) to what extent do alternative physical designs help to reduce ambient temperatures in UHIs? We address these questions by assessing the UHIs in the City of Portland, Oregon (USA) through a five stage research process. First, we conducted a series of vehicle-based temperature traverses to identify UHIs where vulnerability populations currently live. Second, we divided the city into 100m grid cells, and conducted a clustering analysis -- normal mixture modeling -- to define the built environment factors that help to explain the presence of UHIs in the study area. The land cover in the grid cells were further divided into seven distinct types of urban morphology. Third, using a computational fluid dynamic (CFD) model, ENVI-met, and a local weather station for calibration, we simulated the spatial distribution of temperature in all of the land cover categories. Fourth, we assessed, the extent to which modifications to the physical designs of the built environment, including land cover characteristics in the select sites would reduce temperatures. Finally, using the seven distinct types of urban morphology, we applied the promising modifications that provided the greatest reduction in ambient temperatures to rest of the city.

We found that six variables helped to predict over 90% of local variation in urban heat: percent canopy, percent vegetation, biomass density, mean building height, total building volume, building height standard deviation. While the canopy, vegetation, and biomass were negatively associated to heat intensity, and the building variables provided a net increase in local UHIs. We note that the seven types of urban morphologies encompass approximately 62% of the city -- the remaining 38% were a mix of multiple types. By exploring several modifications to the built environment, the ENVI-Met model demonstrated that the average temperature of study site can be decreased from 0.5 to 5.5oC by altering the ratios of green and grey infrastructure. Citywide, Highly promising options include increasing density of housing, while strategically introducing green infrastructure to development sites. In addition, by scaling up specific scenarios to the whole city we describe a patterns of development that can simultaneously reduce temperatures, while supporting the meeting many (although not all) development pressures.

Keywords: Urban Heat , Physical Design of Cities, Micro-climatology, Portland, Oregon (USA)