Impacts of weather variability on turbulent heat fluxes in Phoenix, AZ and Portland, OR

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Introduction

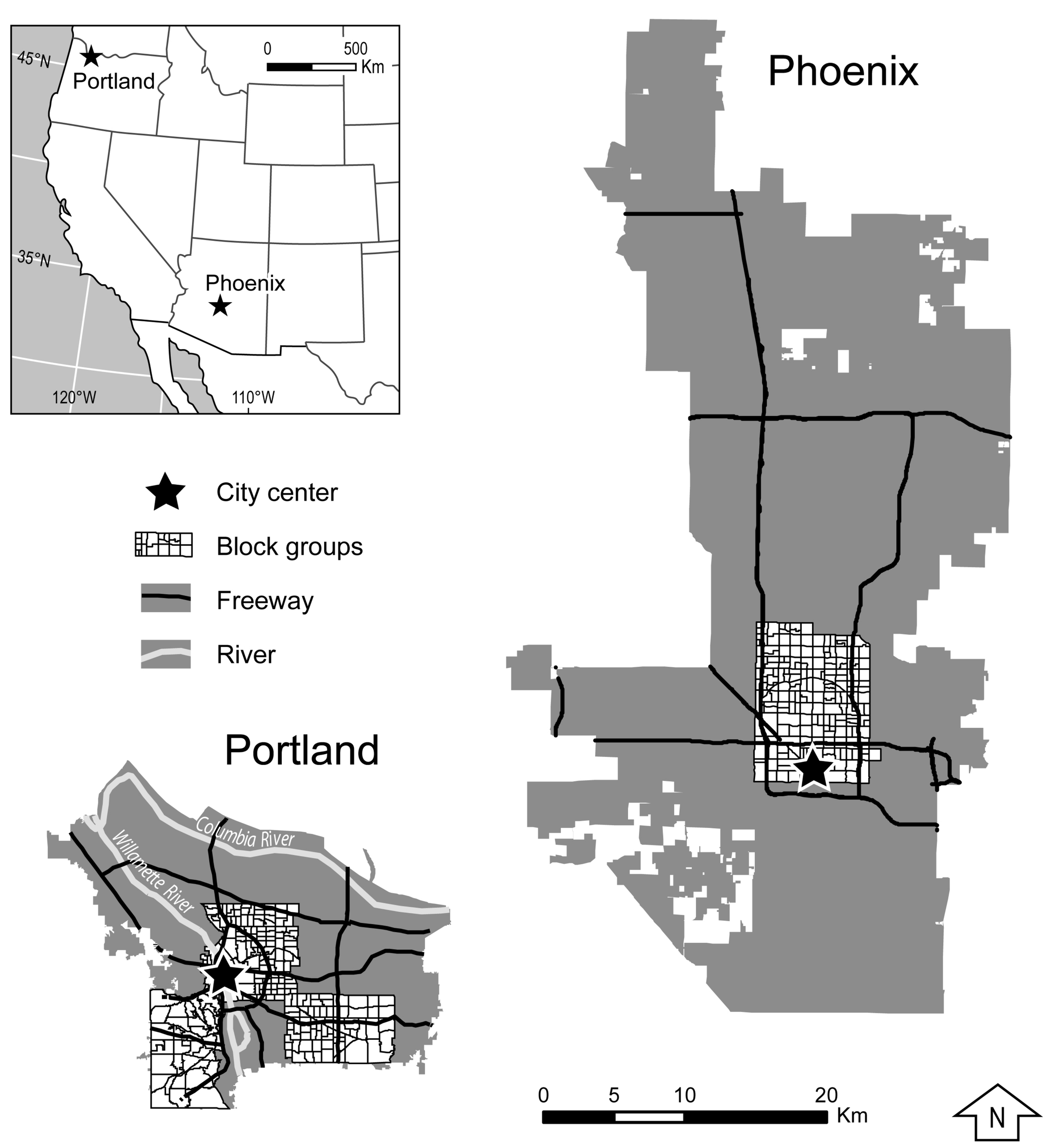
Anthropogenic alterations of land cover are known to significantly change the local surface energy balance and to create a new, local microclimate. Understanding the link between urbanization and microclimate is imperative for urban environmental planners to determine effective design strategies, e.g. altering the vegetation and irrigation regime, to improve urban climate. The knowledge of how to purposefully manipulate the surface energy balance by changing urban surface morphology is crucial to urban climate adaptation. This local-scale above-canopy study examines the relative effects of intra-urban land cover mixes and local climate on the summer daytime surface energy balance in Phoenix, Arizona and Portland, Oregon.

Research Question

How does the mix of land cover affect the summer daytime surface energy balance under climate extremes and norms of two western USA cities with distinct climates, Phoenix and Portland, and what are the relative contributions of climate and variable land cover on the surface energy balance?

Study Sites

Our study areas are located in Phoenix, AZ, and Portland, OR – two cities with distinct climates (desert and marine west coast, respectively), but similarly warm and dry summers. Both study areas comprise ca. 200 Census block groups (length scale 0.5 km) with varying degrees of irrigated vegetation in and around the core of the two cities where UHI mitigation might be considered important.



Methodology

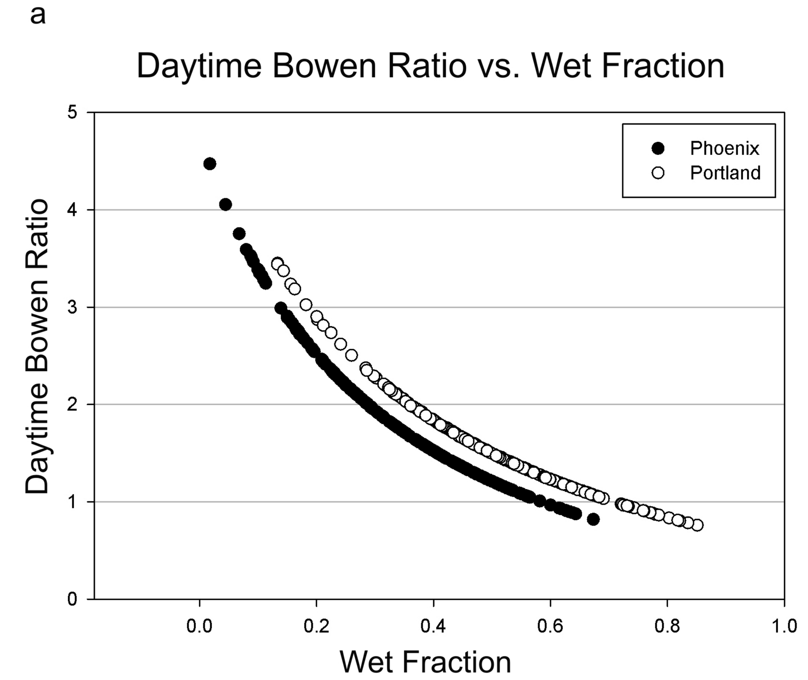
To estimate the summer daytime surface energy balance in Phoenix and Portland, we used the Local-Scale Urban Meteorological Parameterization Scheme (LUMPS) developed by Grimmond and Oke (2002). LUMPS simulates the surface energy balance of urban areas at the local or neighborhood scale (0.01–100 km^2). The modeled surface energy balance is driven by the net all-wave radiation $Q^* = Q_E + Q_H + \Delta Q_S$ [Wm^{-2}], where Q_E and Q_H are the turbulent latent and sensible heat fluxes and Q_S is the heat storage. Heat fluxes in LUMPS are simulated based on hourly meteorological observations (air temperature, relative humidity, atmospheric pressure, and precipitation) and basic land cover characteristics (plan-area fractions of vegetation, buildings, impervious surfaces, soil, and water bodies).

We investigated the partitioning of net all-wave radiation into sensible and latent heat fluxes as well as heat storage for a typical dry summer month (June for Phoenix, July for Portland) and two extreme weather scenarios in the two cities. The basecase scenario represented normal climate conditions averaged for the past 11 years (1999-2009). Extreme weather scenarios (maximum and minimum temperatures and incoming solar radiation) were created from observations over the past 40 years (1970-2009).

Results - Energy Partitioning

Daytime Bowen ratios (sensible ÷ latent heat) were higher in Phoenix than Portland due to more sensible heating proportional to latent heating in desert environments, i.e. because of low vegetation fraction (wet fraction). Bowen ratios varied inversely with wet fraction between and within cities. At the same time, the ratio of Q_H to available energy was positively correlated with impervious surface cover in both cities.

a



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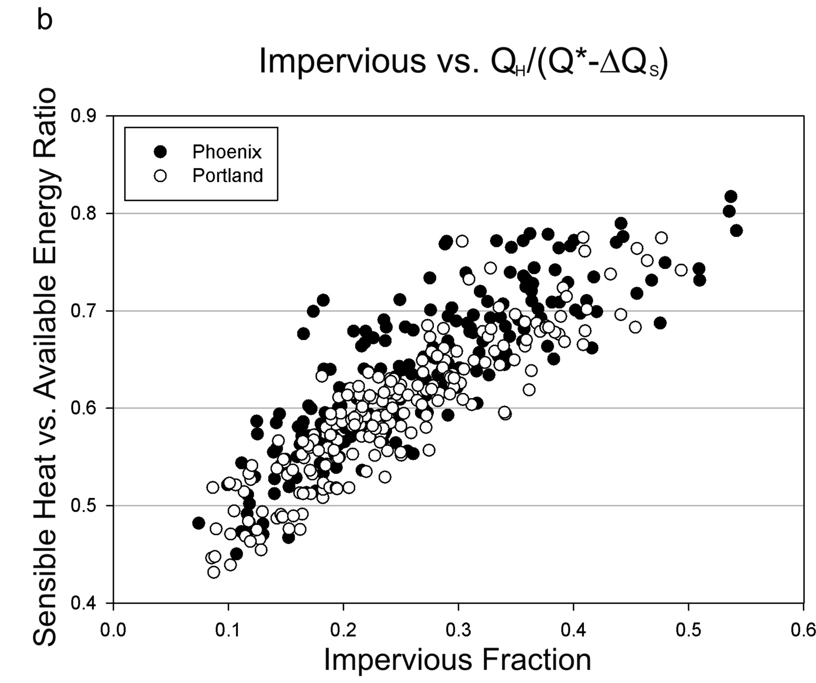
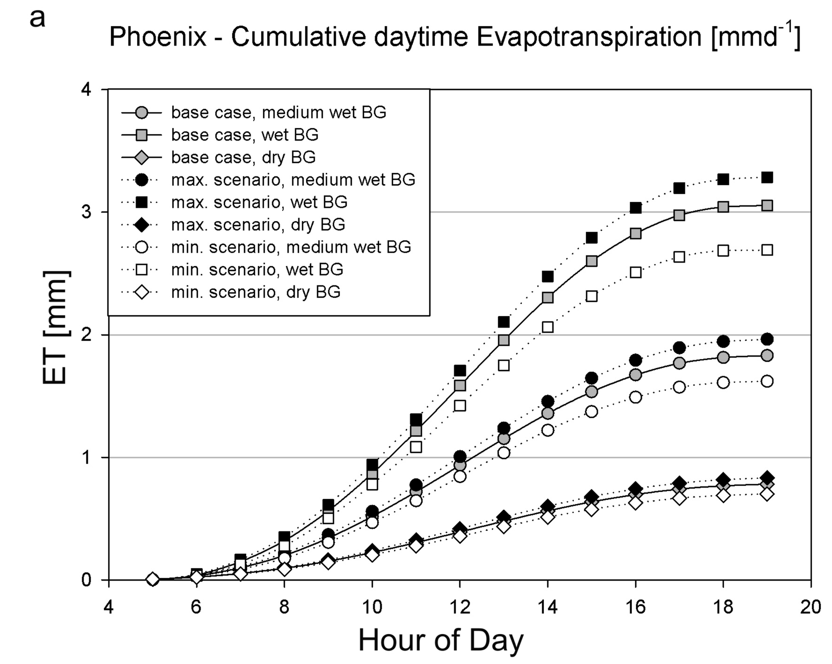


Results - Latent Heat

In LUMPS, the latent heat flux Q_E directly corresponds to the hourly evapotranspiration (ET) rate measured in mm h^{-1}. Cumulative daytime ET was similar for average weather conditions across medium wet to wet sites (i.e.,medium to high vegetation fraction) in Phoenix and Portland. Dry sites (i.e., low vegetation fraction) in Phoenix had an overall lower ET. Typically, dry sites were less sensitive to weather variations than wet sites in both cities. Under extreme weather conditions, ET varied more in Portland (b) than in Phoenix (a).

a



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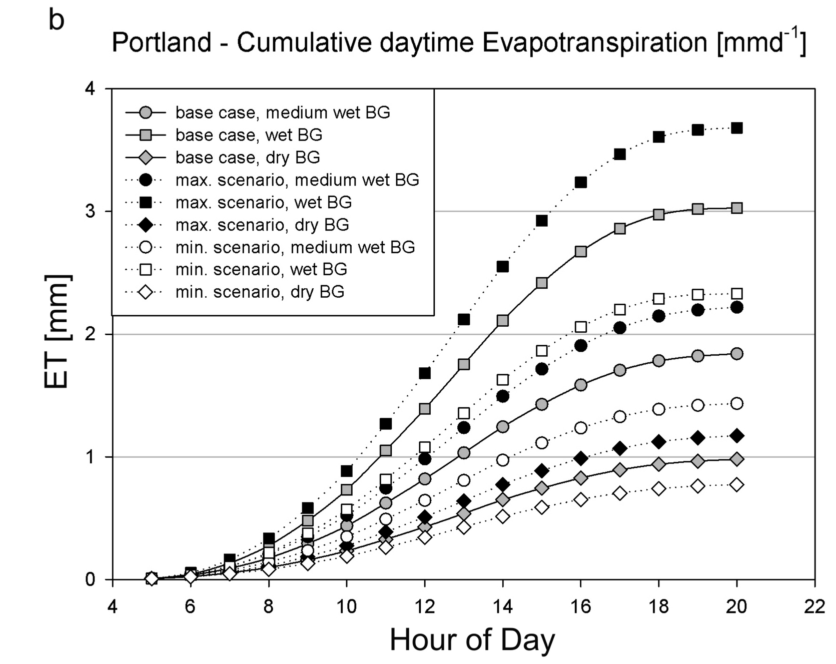

Conclusions

Results suggest that land cover manipulation could offset influences of high weather extremes on ET in Portland to a certain degree, but not in Phoenix. Consequently, land cover strategies will have a different impact on the surface energy balance under different climates. Our results confirm findings of previous studies showing that the spatial context of land cover strategies is important and that planning strategies have to be designed appropriate to the climatic region and to the related urban environment.

References

Grimmond CSB, Oke TR. 2002. Turbulent heat fluxes in urban areas: observations and a local-scale urban meteorological parameterization scheme (LUMPS). *Journal of Applied Meteorology* **41**: 792-810.

Acknowledgements

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