Evaluating the effect of 3D urban form on neighborhood land surface temperature using Google Street View

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Introduction

Incorporating the vertical urban form in surface temperature assessments is important, because shading effects are not well captured in traditional planar view remote sensing data. The impact of vertical urban forms on land surface temperature (LST) has not been sufficiently addressed due to a lack of high-resolution urban form data [3, 4].

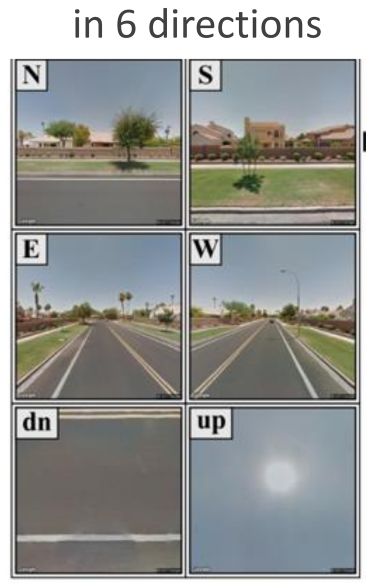
To fill this gap, this study employs a novel spherical urban fraction metric derived from segmented 360° Google Street View (GSV) imagery [2]. Google provides an immense collection of Street View images, enabling city-wide fine-scale measurements to address vertical urban form dimensions. The study area is the city of Phoenix, AZ which is made up of 1,339 census block groups. In this study, we:

1. Compared the novel GSV spherical fractions [2] with the planar land cover fractions derived from high resolution aerial imagery [1].
2. Examined the relationships of the two datasets with LST using correlation and linear regression analysis.
3. Developed robust global and local models to explain the LST variations by integrating spherical, planar and social variables.

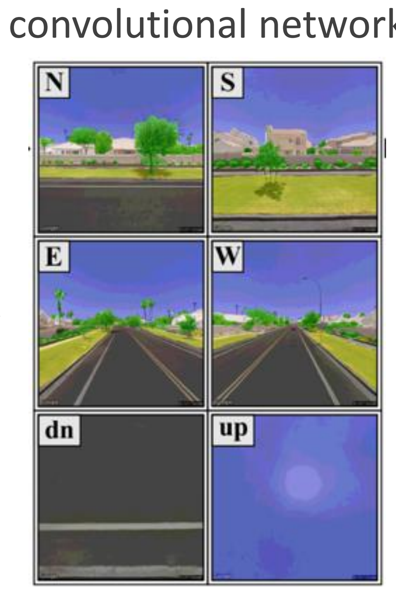
Data

Google Street View Image Classification

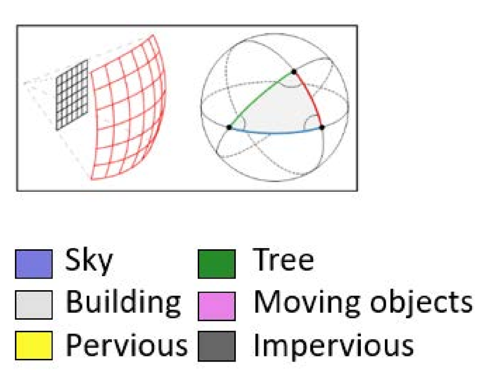
(1) 90° Field of view images from Google Street View in 6 directions



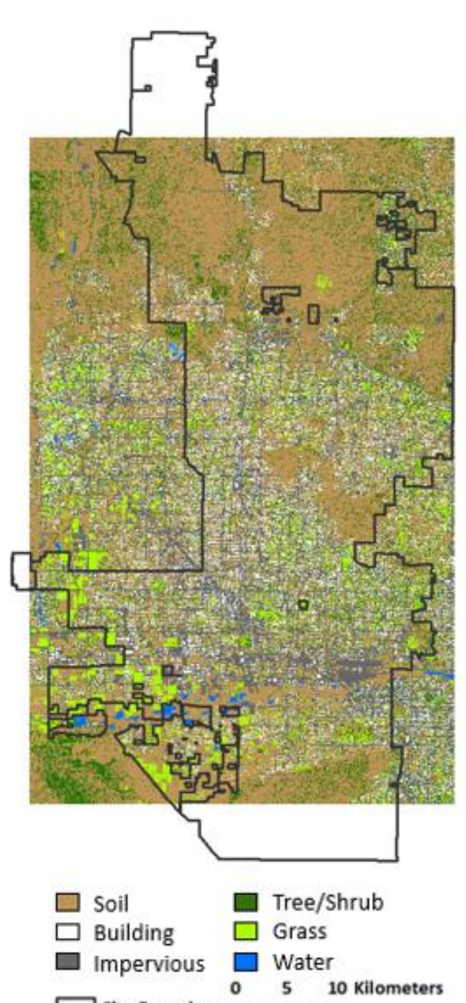
(2) Image classification using fully convolutional network



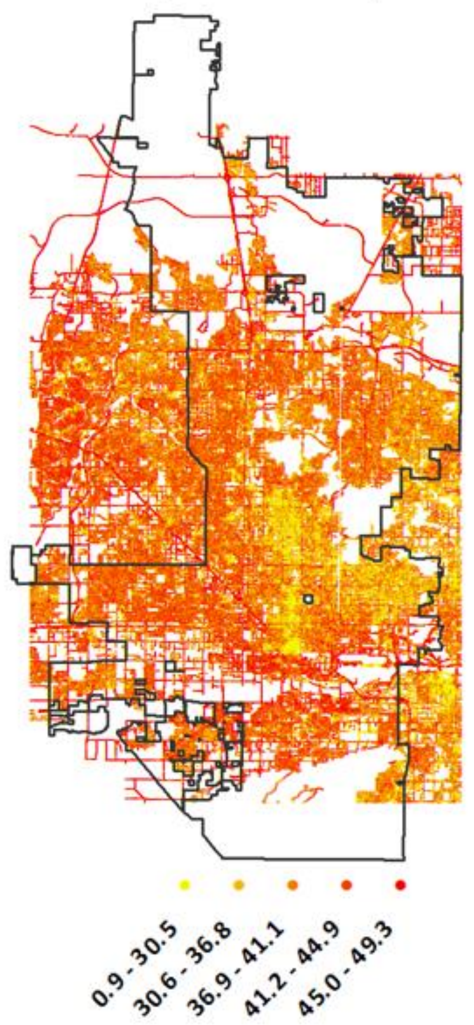
(3) Calculate the percentage of each class based on a cube-to-sphere projection



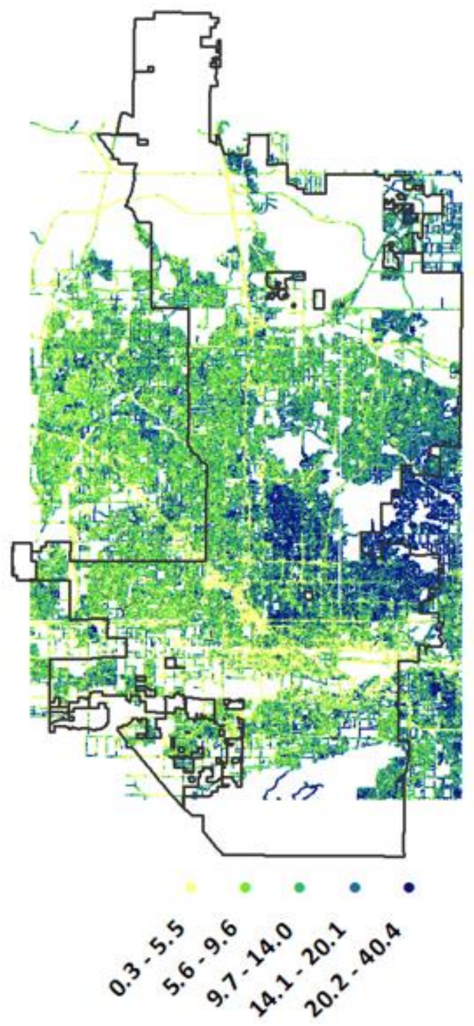
1-m Planar land cover map



Spherical % Sky



Spherical % Tree



Method and Results

1. Comparisons between the Spherical and Planar Fractions at Census Tract Level

Fig. 1 Boxplots of the Spherical and Planar Fractions

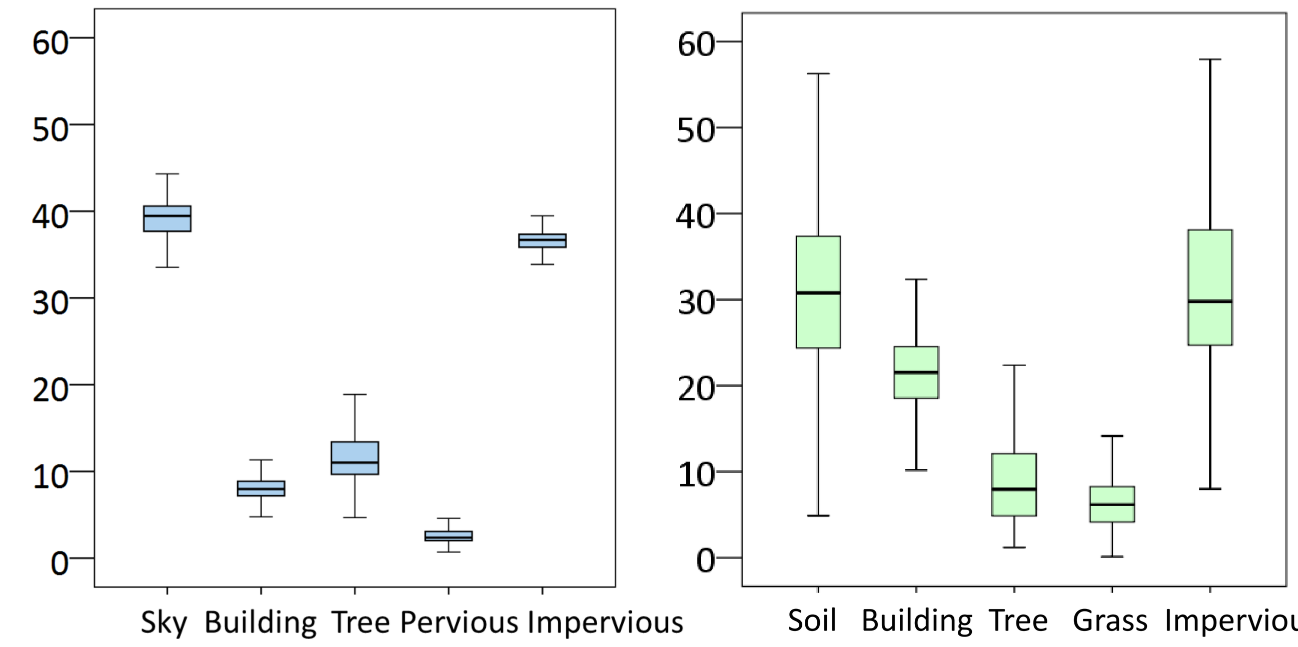
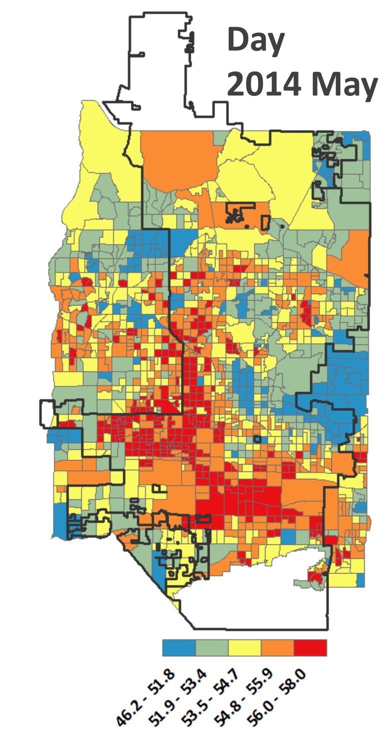


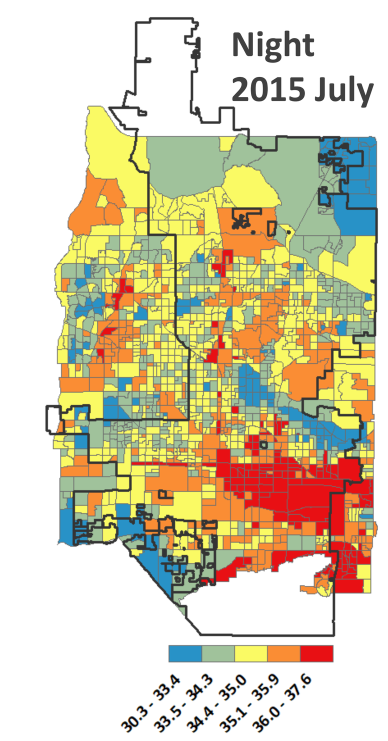
Table 1 Paired T-Test

	Spherical mean	Planar mean	Correlation Coeff.	Paired Differences	
				Mean	Std. Deviation
Building	8.0	22.1	.11	-14.1**	5.5
Tree	12.0	9.1	.43**	2.9**	5.3
Impervious	36.4	31.3	.30**	5.0**	11.9

** Significant at 0.01 level

ASTER LSTs





2. Correlation and Global Regression Analysis with Land Surface Temperature (Day and Night)

Table 2 Pearson's Correlation Coefficients with LST

Spherical Fraction	Day LST	Night LST	Planar Fraction	Day LST	Night LST
Sky	.52**	.11*	Soil	.09**	-.22**
Building	.21**	.32**	Building	.08**	-.15**
Tree	-.58**	-.35**	Tree	-.48**	-.31**
Pervious	-.46**	-.47**	Grass	-.35**	-.28**
Impervious	.34**	.37**	Impervious	.23**	.51**

** Significant at 0.01 level, * Significant at 0.05 level.

Table 3 Global Regressions with LST

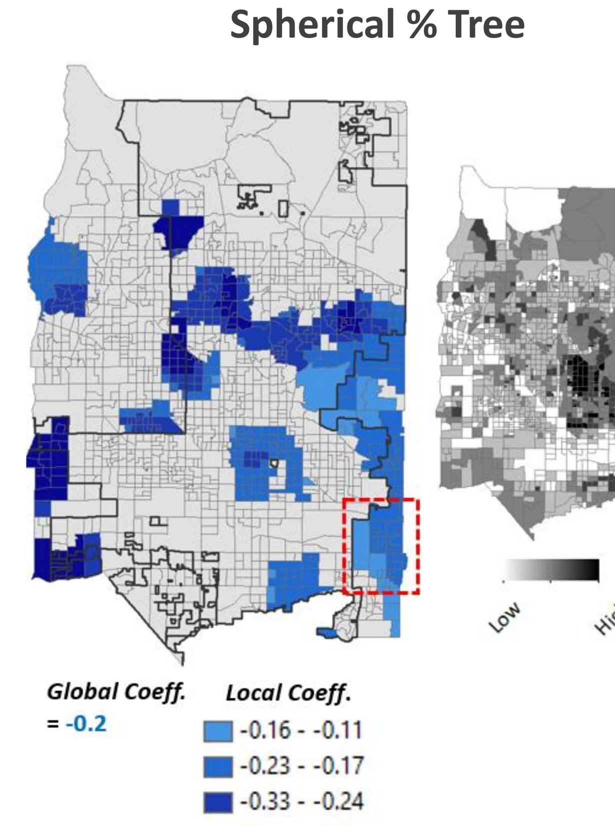
Global Regression		Spherical	Planar	Spherical + Planar	Spherical + Planar + Social
Day	R^2	.31	.36	.46	.60
	Adj. R^2	.31	.36	.46	.59
Night	R^2	.31	.32	.43	.43
	Adj. R^2	.31	.32	.42	.43

3. Local Regression Analysis with Land Surface Temperature (Day)

Table 4 Comparisons of Global and Local Regressions

Day LST	Global Model	Local Model
R^2	.60	.80
AICc	4081	3733
Moran's I	.1**	.001
Residual Pattern	Clustered	Random

Spherical % Tree

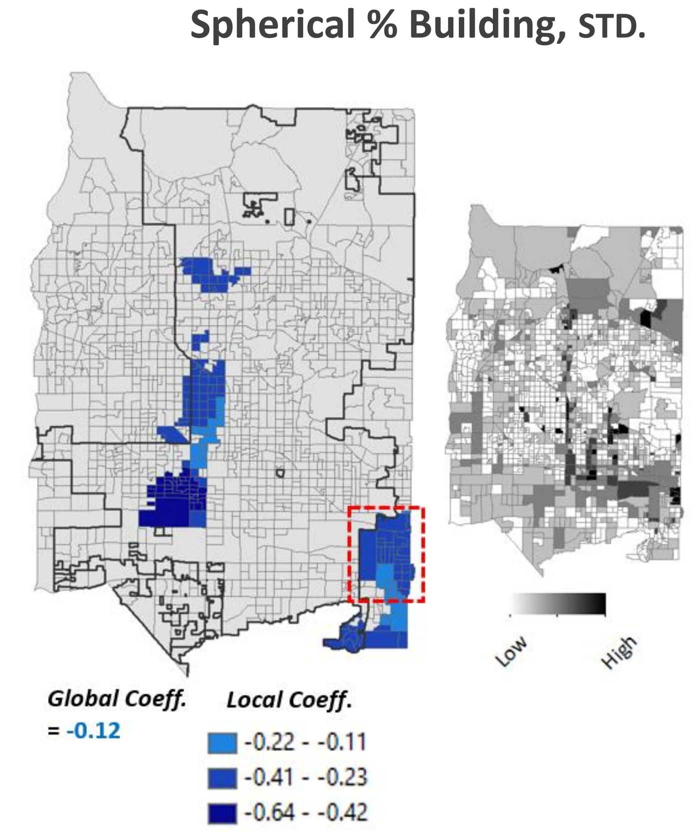


Within the red box

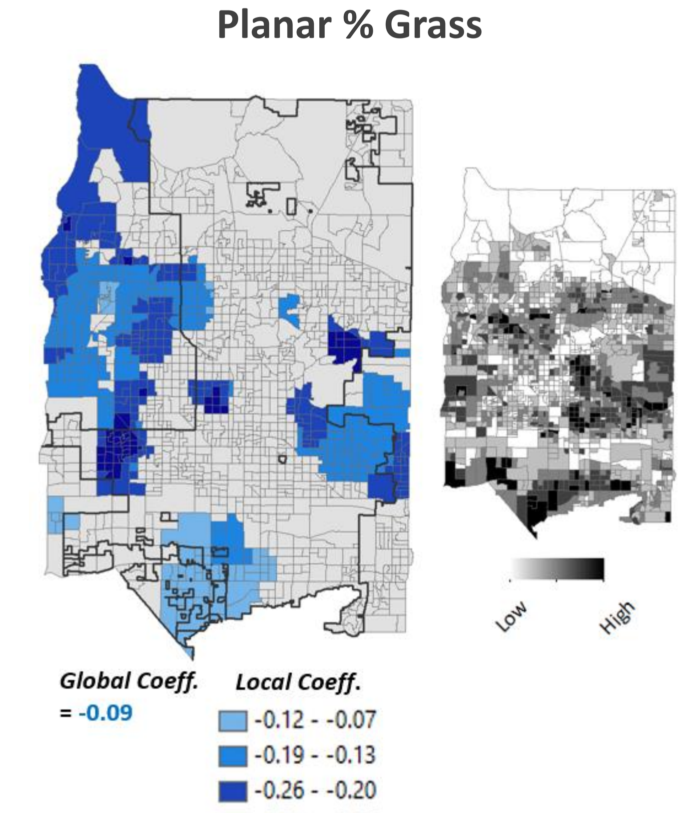
Google street view of the ASU Tempus campus

Google street view of the nearby residential neighborhood

Spherical % Building, STD.



Planar % Grass



Findings

1. The spherical factions have less variations compared to planar fractions, because they are biased towards street views.
2. Adding spherical fractions from Google Street View imagery, daytime and nighttime LSTs in Phoenix are predicted more accurately, compared to the planar land cover factions. In addition, the geographically weighted regression further improved the model fit versus the ordinary least square regression method; the R^2 increased from 0.6 to 0.8.
3. The geographically weighted regression coefficient maps feature the places where certain urban form changes are especially effective for heat mitigation, supporting the search for the optimal urban form design of desert cities.

Acknowledgements

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