Evaluating the effects of vertical urban forms on land surface temperature using Google Street View images

Central Arizona-Phoenix Long-Term Ecological Research CAP LTER

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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 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 474 census tracts. In this study, we:

1. Compared the novel spherical fractions 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 (5) to explain the LST variations by combining spherical, planar and social variables.

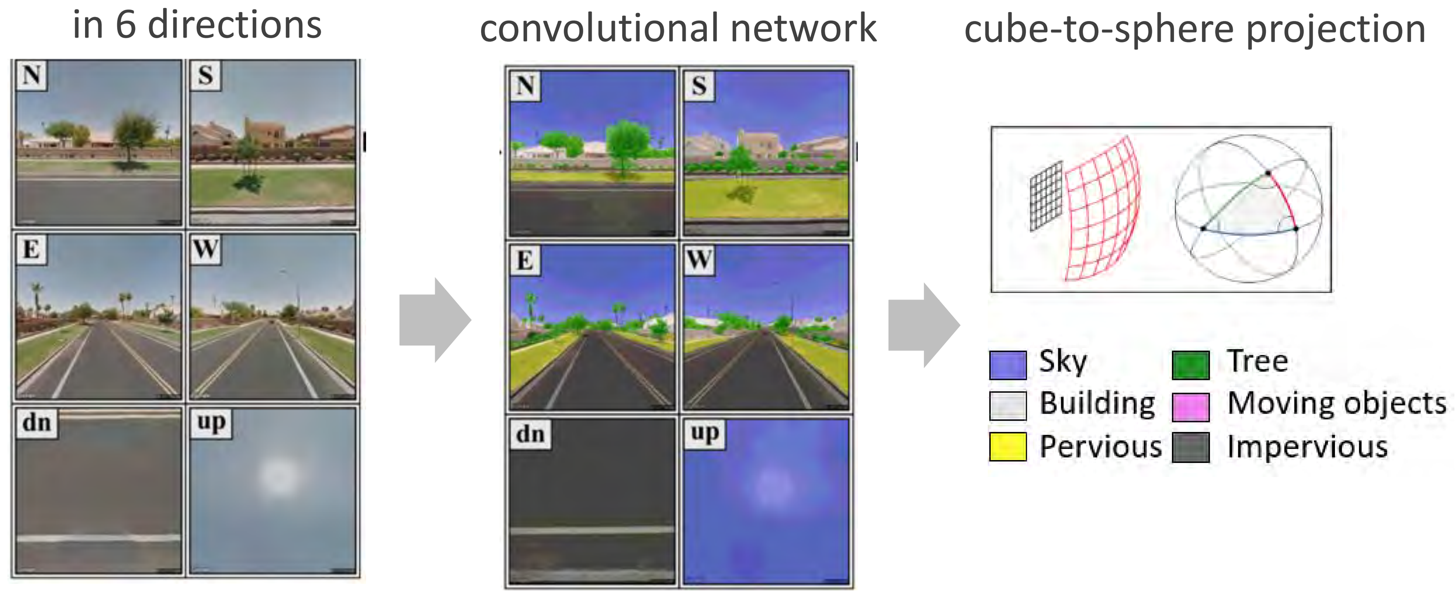
Data

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

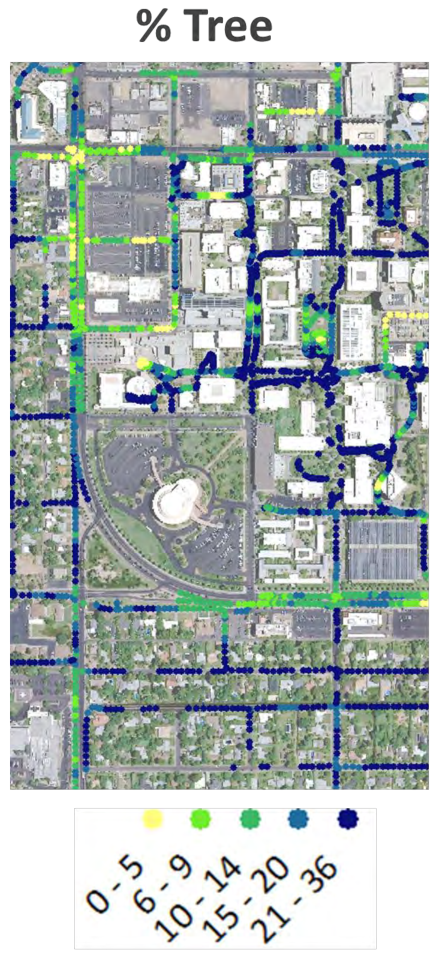
(3) Calculate the percentage of each class based on a cube-to-sphere projection



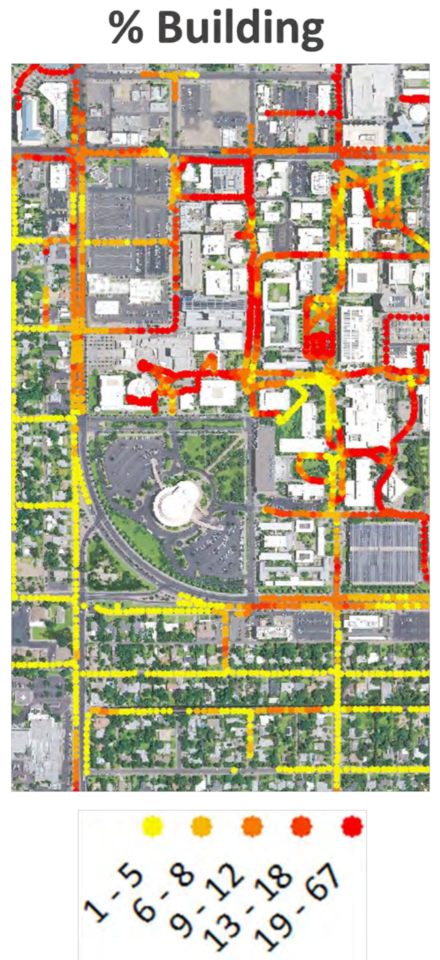
Spherical Fractions from Google Street View

Planar Land Cover from NAIP Imagery

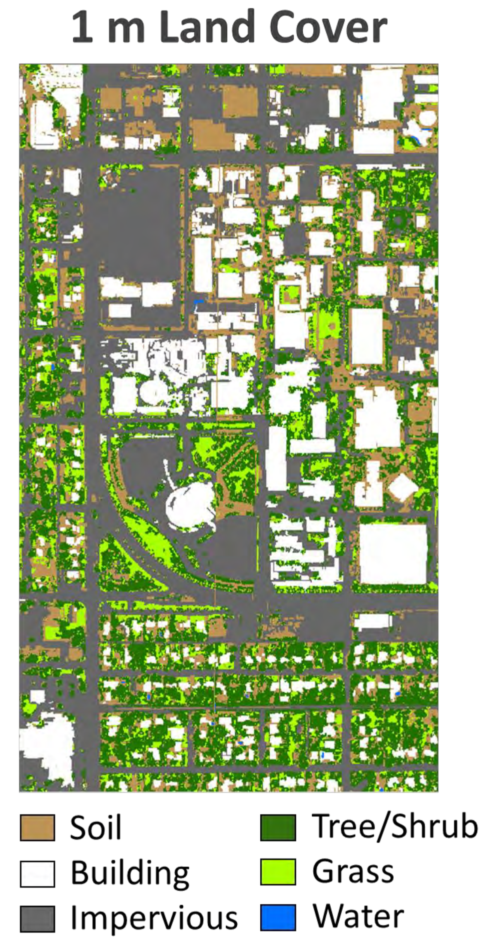
% Tree



% Building



1 m Land Cover



*The overall accuracy of the spherical dataset is 95% (2). The overall accuracy of the planar (NAIP land cover) dataset is 91.8% (1).

Method and Results

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

Fig. 1 Boxplots of the Spherical and Planar Fractions

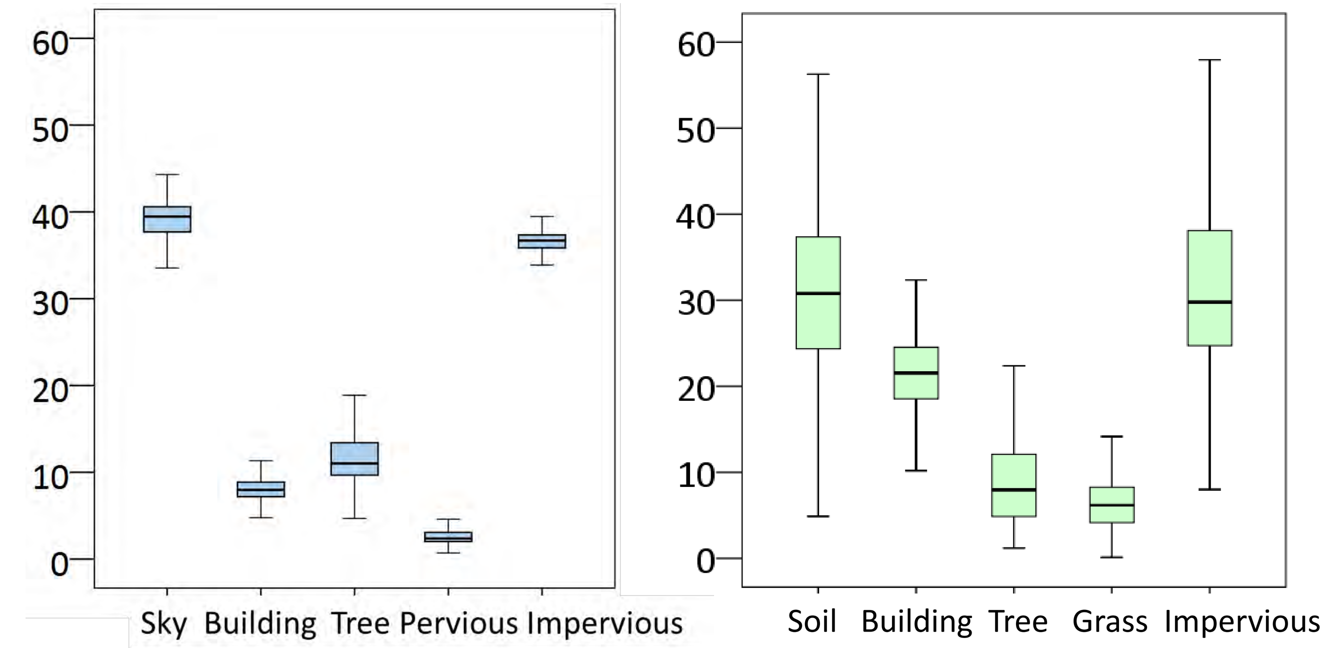


Table 1 Paired T-Test

	Spherical mean	Planar mean	Correlation Coeff.	Paired Differences Mean	Paired Differences Std. Deviation
Building	8.1	21.4	.06	-13.3**	4.8
Tree	11.9	8.8	.48**	3.1**	4.5
Impervious	36.4	31.9	.33**	4.4**	10.8

** Significant at 0.01 level

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	.53**	.11*	Soil	-.05	-.30**
Building	.24**	.35**	Building	.10*	-.16**
Tree	-.64**	-.39**	Tree	-.51**	-.36**
Pervious	-.50**	-.50**	Grass	-.37**	-.28**
Impervious	.40**	.41**	Impervious	.36**	.58**

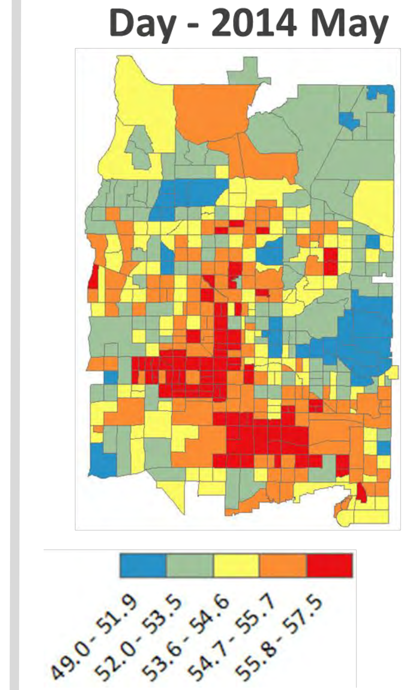
** Significant at 0.01 level, * Significant at 0.05 level.

Table 3 Global Regressions with LST

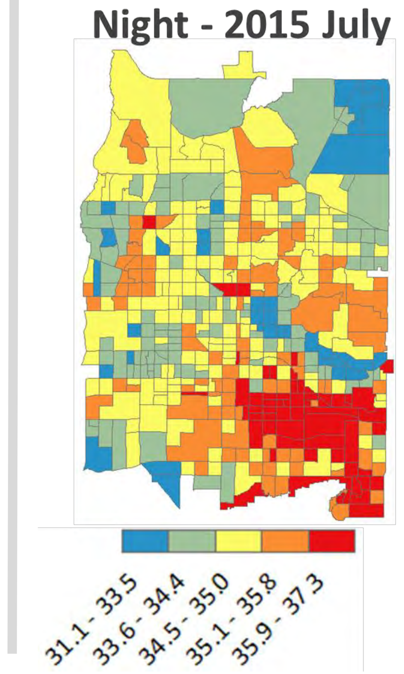
Global Regression		Spherical	Planar	Spherical + Planar	Spherical + Planar + Social
Day	R^2	.48	.38	.57	.71
	Adj. R^2	.47	.37	.56	.70
Night	R^2	.24	.37	.51	.52
	Adj. R^2	.24	.37	.50	.52

ASTER LSTs

Day - 2014 May



Night - 2015 July

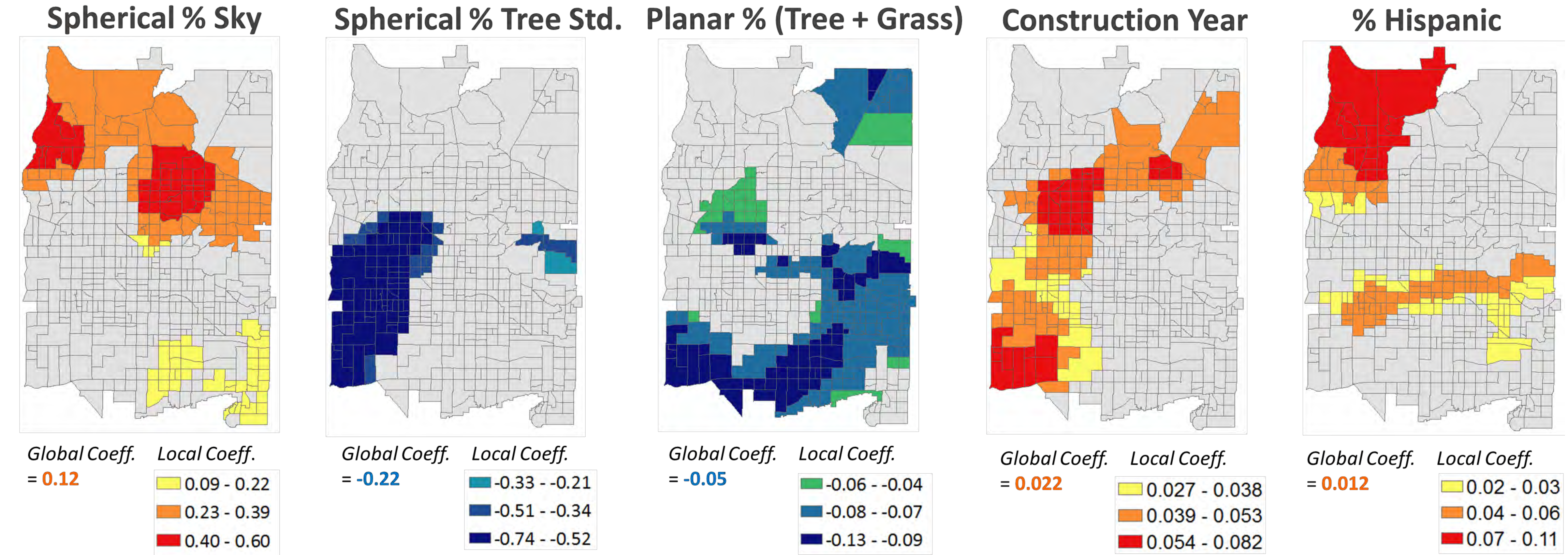


3. Local Regression Analysis with Land Surface Temperature (Day)

Table 4 Comparisons of Global and Local Regression

Day LST	Global Model	Local Model
R^2	.71	.85
AICc	1188	1067
Moran's I	.2**	.005
Residual Pattern	Clustered	Random

Spherical % Sky | Spherical % Tree Std. | Planar % (Tree + Grass) | Construction Year | % Hispanic



Findings

1. The spherical factions have less variations compared to planar fractions, because they are biased towards street views.
2. At census tract level, the spherical and planar fractions for tree and impervious classes are significantly correlated. For the building class, the spherical fraction (walls) has no correlation with the planar fraction (rooftops).
3. Compared to using planar fractions alone, adding spherical fractions captures a significant amount of explained variance in LST. R^2 increased by about 0.2. Adding social variables further improves the R^2 to 0.71 for the daytime regression.
4. Compared to the global model, the local model is valuable in uncovering the spatially varied relationships between urban forms and LST, and addressing the issue of spatial autocorrelation. Parameter estimates from the local model highlight specific areas in Phoenix that are strongly affected by certain urban forms. Identifying these areas will greatly contribute to targeted heat mitigation strategies for the summer.

Acknowledgements

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Please send comments or questions to yzhan169@asu.edu

Thank you!