A comprehensive assessment of the thermal environment of two PASS neighborhoods

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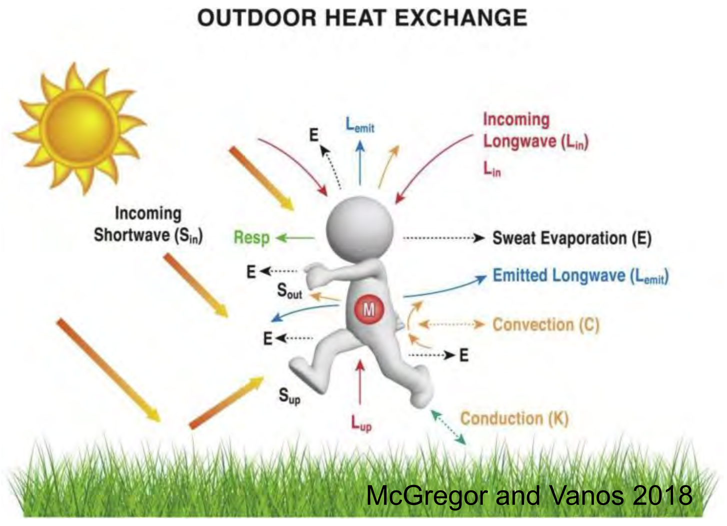
Central Arizona-Phoenix Long-Term Ecological Research
CAP LTER

Background

Using an integrated social-ecological framework, CAP LTER researchers have established important connections between residential landscape characteristics, heat stress, and social inequity[1]. Neighborhoods with a higher incidence of adverse human health outcomes related to heat reported in PASS 2006 and 2011 also had less vegetation, higher land surface and air temperatures, and were the most impoverished[2]. CAP researchers have also found that differences in microclimate within residential landscapes drive activity time and abundance of other living creatures, such as lizards, aphids, and arthropods[3].

However, researchers have also acknowledged the limitations of using land surface temperature (LST) and air temperature as measures of the thermal environment, and called for higher resolution micro-level measurements at a scale and location relevant to humans and other urban organisms[4].

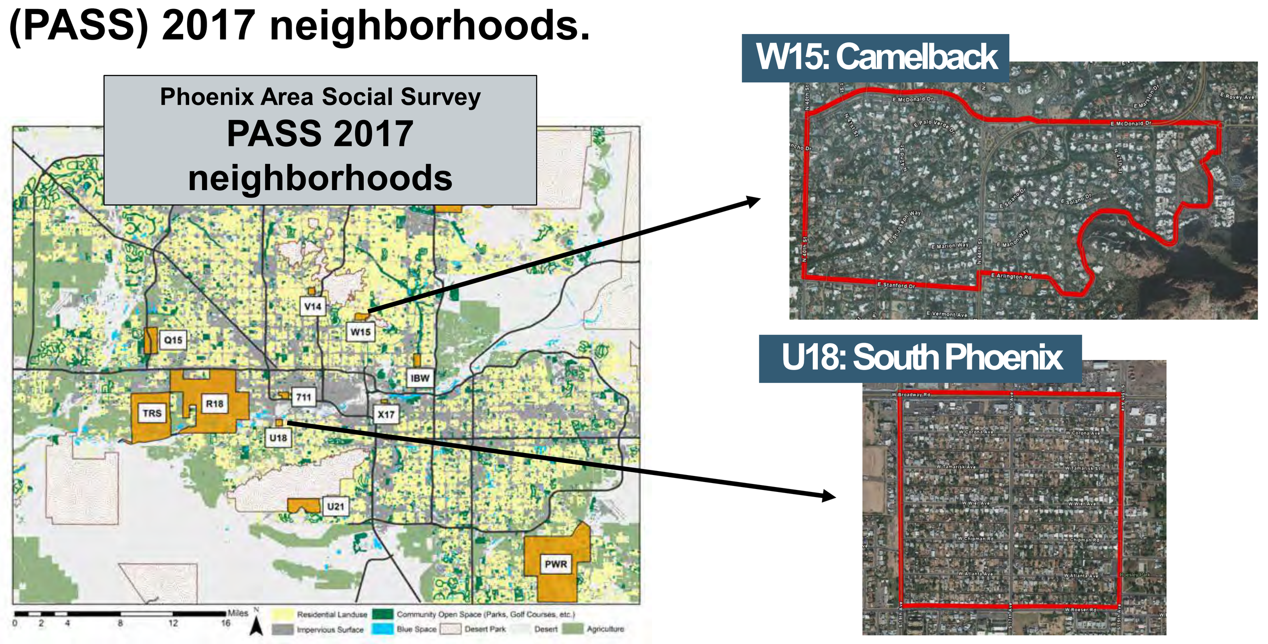


The extent to which people may gain or lose heat from the environment is a function of many variables[5], including:

- air temperature
- humidity
- wind speed
- radiant energy (e.g. solar and infrared radiation

The CAP IV proposal[6] calls for **"expanding our environmental heat research by placing new emphasis on the entirety of the thermal environment rather than focusing only on air temperature…because air temperature alone represents only a portion of the energy balance that determines heat stress for urban organisms."**

Thus, with assistance from a CAP Grad Grant, we used new, state-of-the-art biometeorological instrumentation to measure the entirety of the thermal environment within two Phoenix Area Social Survey (PASS) 2017 neighborhoods.



Research Objectives

1) Produce a dataset of the thermal environment within PASS 2017 neighborhoods that is relevant to and useable by all interested CAP researchers and that complements and enhances CAP's ongoing long-term research efforts

2) Identify how human heat-health outcomes, demographics, and residential landscape characteristics (e.g. yard with trees, grass, swimming pool, etc.) reported in PASS 2017 are related to the various components of the entirety of the thermal environment.

3) Identify how the entirety of the thermal environmental is driven by the proportional land cover characteristics of the built environment and urban ecological infrastructure (UEI).

Methods

1. Neighborhood selection

We selected two PASS neighborhoods for study that had contrasting built environments, UEI, incidence of heat-related illness, and demographics (Table 1). Both neighborhoods also encompassed CAP bird census and ESCA sites.

Table 1: Selected PASS 2017 neighborhood characteristics

ID	Location	Mean per capita income	Non-White residents	Yard with trees	Yard with pool	Heat illness	Bird distance	ESCA distance
U18	Phoenix, Salt River (Audobon)	$12,000	95%	56%	3%	44%	243 m	444 m
W15	Phoenix, Camelback Mountain	$73,000	12%	93%	70%	22%	308 m	597 m

**Note*: Variables obtained from PASS 2017 Report (Larson et al. 2017) and PASS 2017 responses. Bird distance and ESCA distance refer to the mean distance from PASS households in each neighborhood to the nearest bird census and ESCA sites.

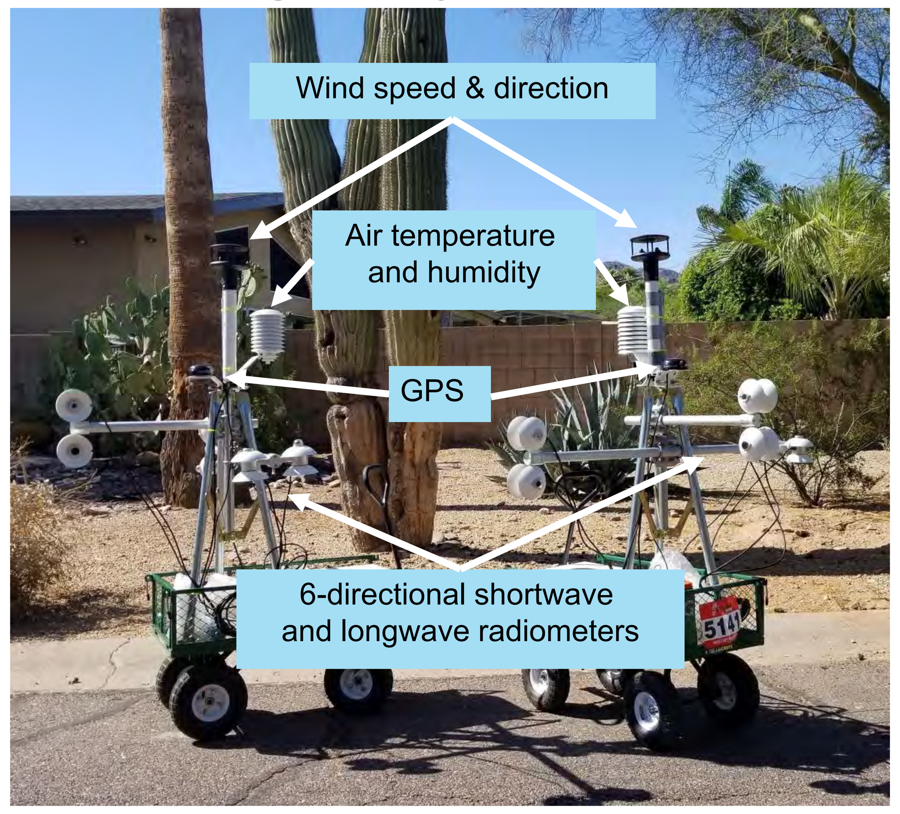
Representative homes*

*Note: For privacy reasons, households shown are not PASS 2017 households.

2. Measuring the thermal environment using MaRTy

MaRTy is a state-of-the-art mobile weather station that simultaneously measures air temperature, humidity, wind speed, and radiant energy flux densities (6-directional short and longwave radiation) at 2-second intervals[7].

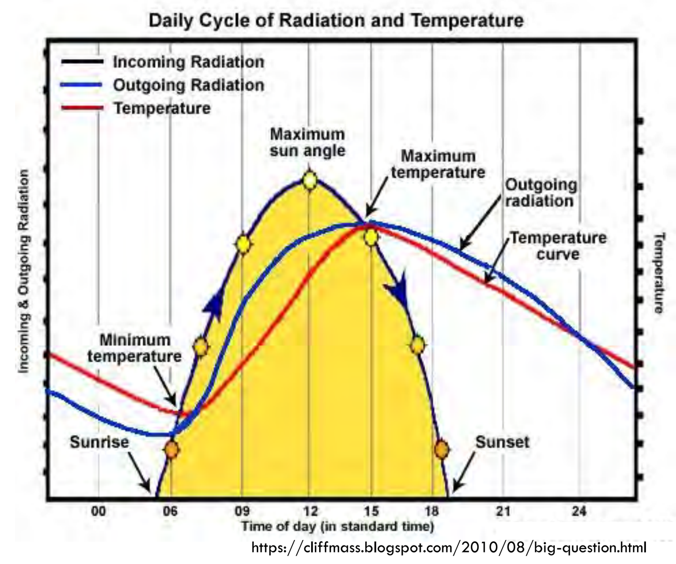
From these data, we can calculate mean radiant temperature (MRT). MRT is one of the most important thermal variables to evaluate heat loss and heat gain of a body and is currently considered the best meteorological parameter for predicting heat stress[8].



3. Neighborhood traverses

We conducted 3-mile walking traverses along sidewalks within each neighborhood. The routes were selected to maximize the number of PASS 2017 households, ESCA, and bird census sites.

The traverses occurred near the summer solstice, June 20th and 24th (one day for each neighborhood) and again on October 1st and 3rd (near the fall equinox). Measurements were taken at 12-1 pm (time of maximum sun angle) and at 4-5 pm (time of maximum temperature) on each day in each neighborhood.

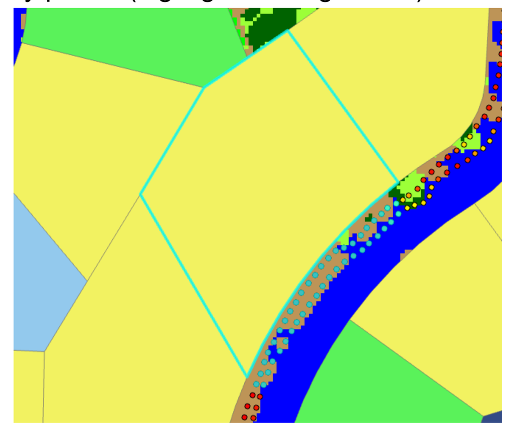


4. Relating MaRTy measurements to PASS 2017 (RO2)

RO2 analysis is ongoing. We will use parcel data from the Maricopa Assessor's database to select MaRTy observations that were obtained in front of the property belonging to a given PASS 2017 household. The figure on the right shows an example of one parcel's MaRTy measurements to be used in the analysis (parcel and observations highlighted in light blue).

We will then use logistic regression to relate select PASS 2017 questions related to human heat-health outcomes, demographics, and residential landscape characteristics (e.g. yard with trees, grass, swimming pool, etc.) to the average MRT, and air temperature from the observations taken in front of each household.

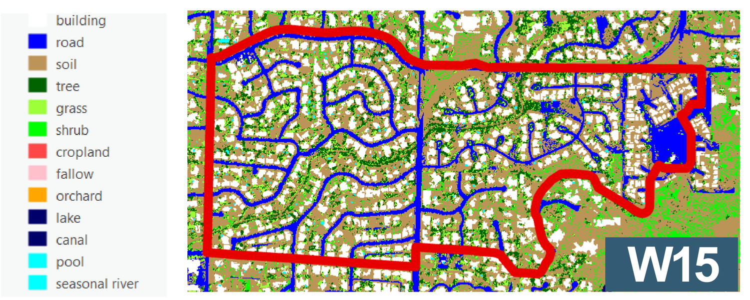
Example of MaRTy observation selection by parcel (highlighted in light blue).



*Note: For privacy reasons, household shown is not a PASS 2017 household.

5. Relating MaRTy measurements to the built environment & UEI (RO3)

RO3 analysis is currently ongoing. Once available, we will use the most recent land cover classification data processed for CAP LTER by Dr. Yujia Zhang from 1 meter resolution NAIP imagery to relate the built environment and UEI to MRT. Because MRT is very sensitive to shade, we will also conduct a shadow impact analysis using 2014 USGS Metro Phoenix LiDAR data available from the ASU Geospatial Hub. Ongoing work includes identifying at which scale land cover features have the greatest impact on MRT.



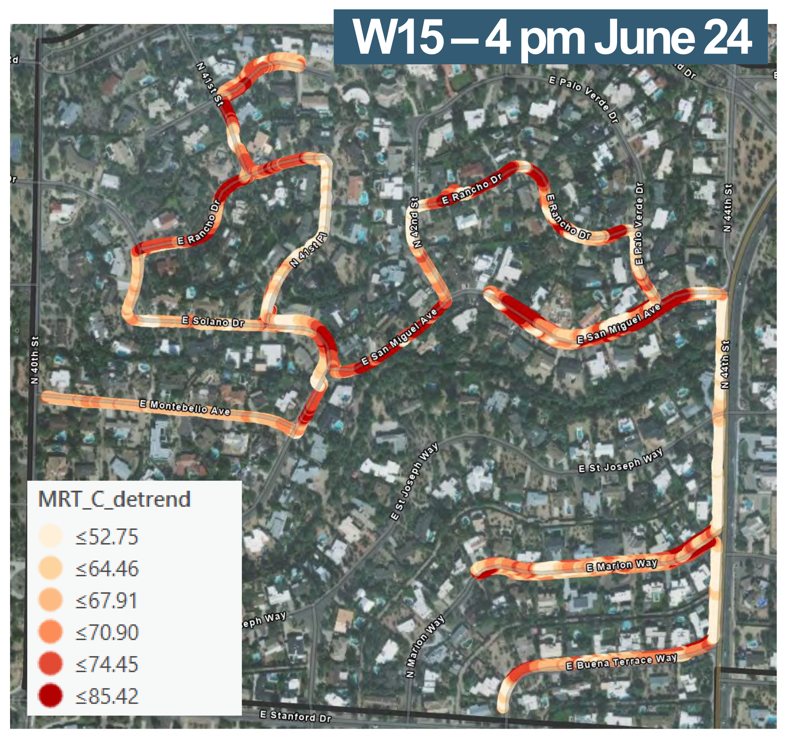
Example 2010 land cover classification from NAIP imagery for the W15 neighborhood (top). Demonstration of ArcGIS tool: Shadow Impact Analysis (right).

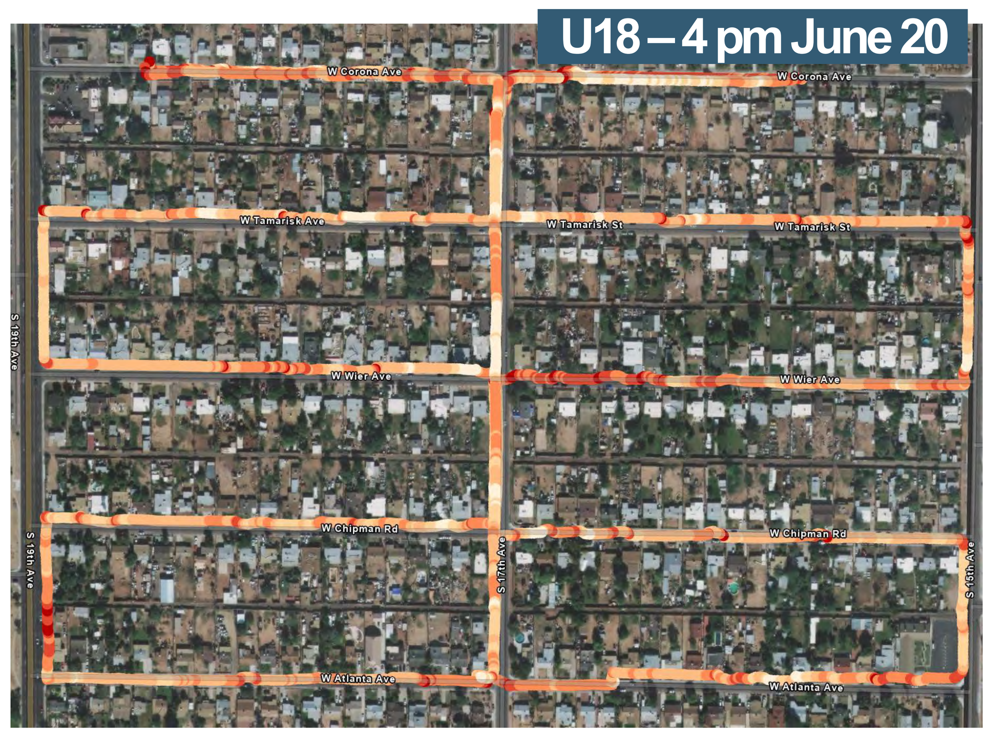
Results

As a visual example of the data collected, mean radiant temperature from the 4 pm traverses conducted in June is plotted (right). During these traverses, MRT ranged from a low of 13.84 °C to 85.42 °C (Table 2). Both U18 and W15 experienced greater variability at 4 pm than 12 pm, though W15 was more variable overall.

Table 2. Summary statistics of detrended MRT (°C) from MaRTy observations made on June 20th, 2019 (in U18 neighborhood) and June 24th, 2019 (in W15 neighborhood).

Traverse	Mean	SD	Max	Min	Range
U18 - 12 pm	60.83	5.50	69.52	19.62	49.89
U18 - 4 pm	64.14	9.82	80.17	14.33	65.84
W15 - 12 pm	60.60	5.27	71.03	27.30	43.73
W15 - 4 pm	63.56	14.50	85.42	13.84	71.58





Significance for CAP LTER

In addition to directly responding to the call in the CAP IV proposal to measure the entirety of the thermal environment (***Climate and Heat***) and pursuing individual research questions related to contextualizing socioeconomics and UEI (dis)services of households within the thermal environment (***Residential Landscapes***), we are making every effort to link our measurements to existing CAP long-term datasets, such as the bird census, PASS, and ESCA, so that our data may be used to examine how non-human animals are responding to the stressor of heat (***Adapting to City Life***).

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