Phoenix Urban Heat Island and Tree & Shade Subcommittee

Urban Heat in Phoenix: Patterns, Causes, Impacts

David Hondula, ASU Urban Climate Research Center

Arizona State University

Design Aspirations: ASU research has purpose and impact and the university connects with communities through mutually beneficial partnerships

Sustainable Cities Network
Arizona State University

Center for Smart Cities and Regions
Arizona State University

Julie Ann Wrigley Global Institute of Sustainability
Arizona State University

Central Arizona-Phoenix Long-Term Ecological Research
CAP LTER

Urban Climate Research Center
Arizona State University

Decision Center for a Desert City
Arizona State University

Herberger Institute for Design and the Arts
Arizona State University

URExSRN

School for the Future of Innovation in Society
Arizona State University

15+ academic units and major initiatives supporting urban heat research

School of Geographical Sciences and Urban Planning
Arizona State University

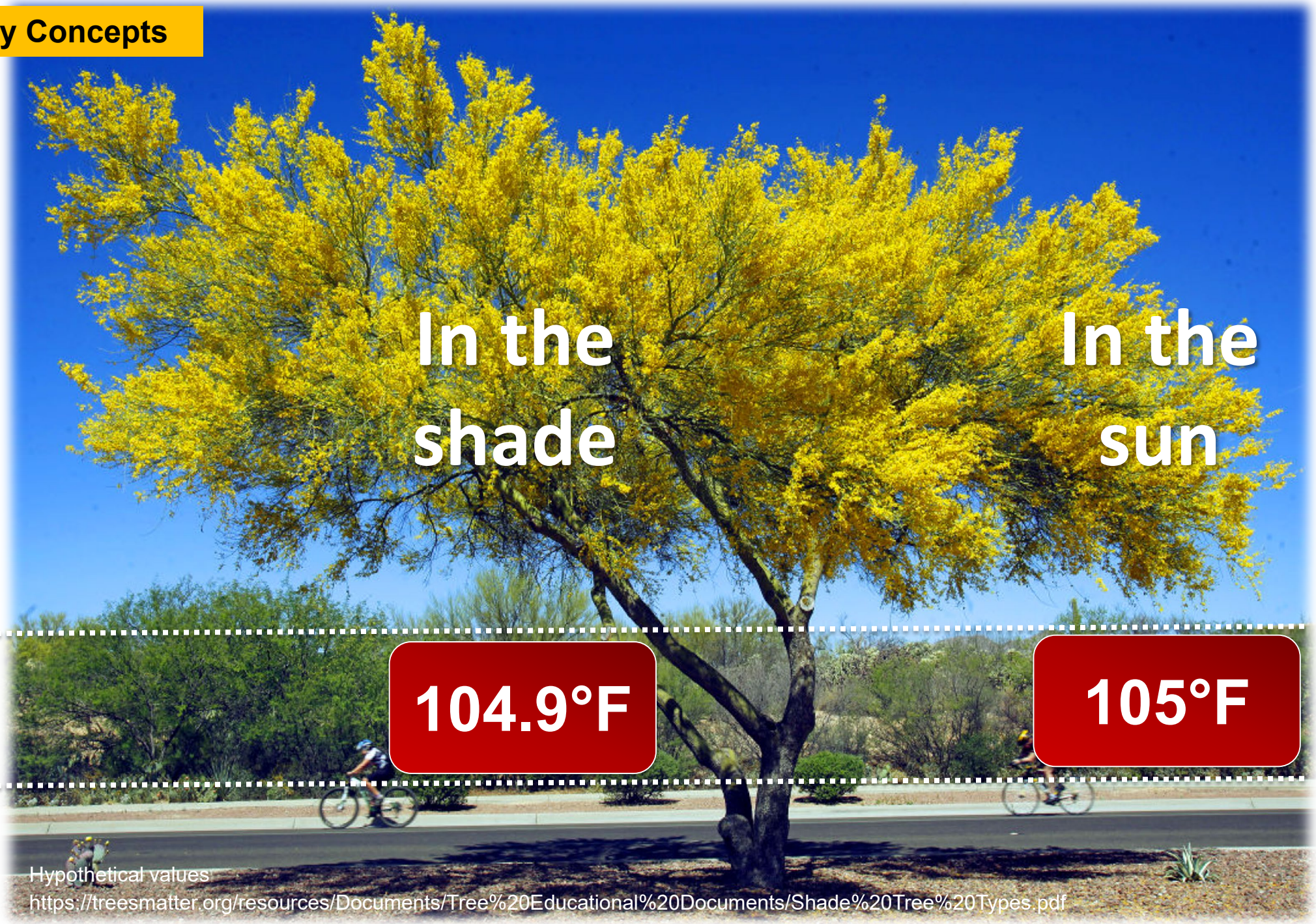
College of Health Solutions
Arizona State University

Healthy Urban Environments Initiative
Arizona State University

Knowledge Exchange for Resilience
Arizona State University

ASU National Center of Excellence on Smart Innovations
Arizona State University

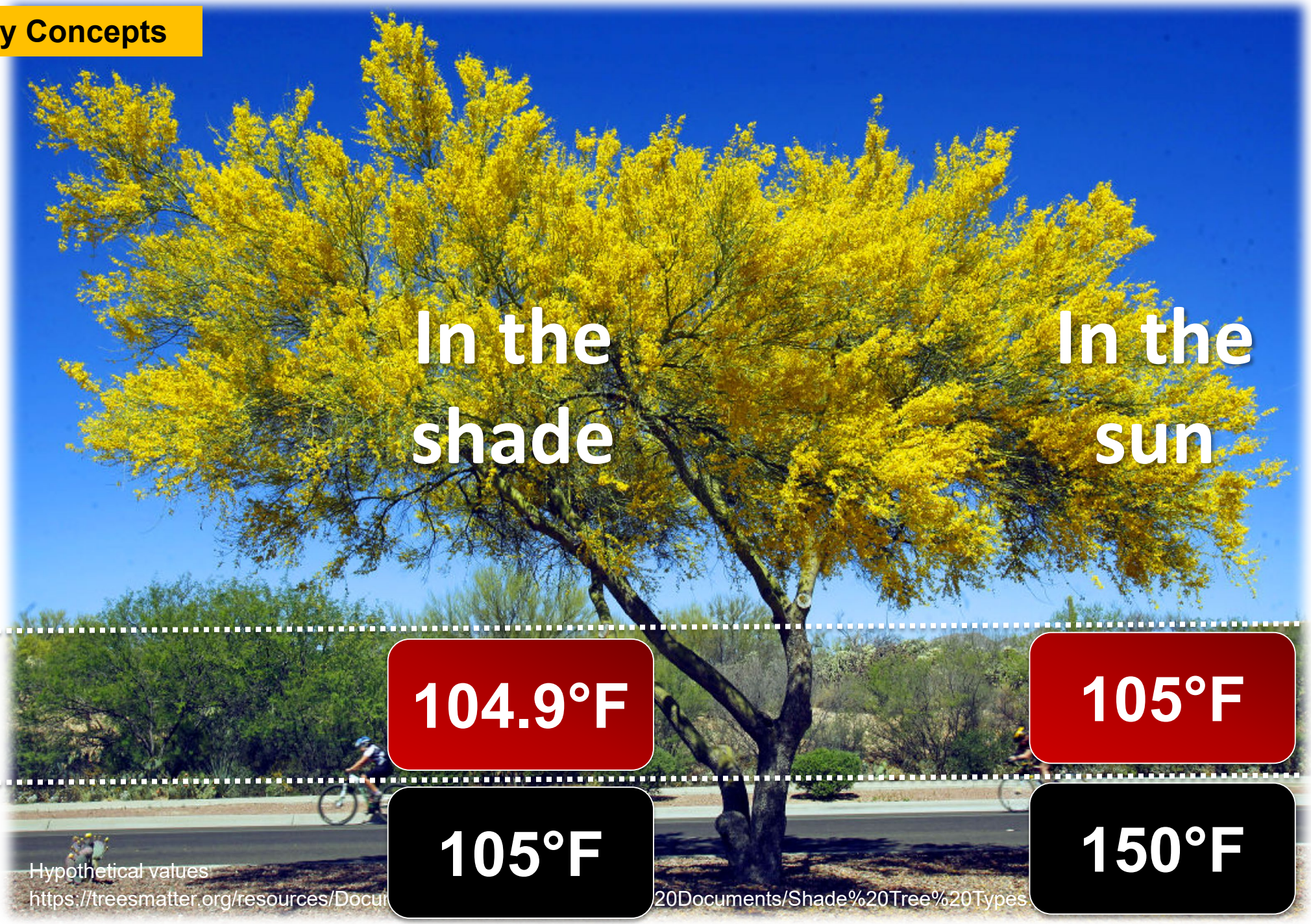
Urban Heat Island Key Concepts



Air Temperature (reported on TV)

Hypothetical values
https://treesmatter.org/resources/Documents/Tree%20Educational%20Documents/Shade%20Tree%20Types.pdf

Urban Heat Island Key Concepts



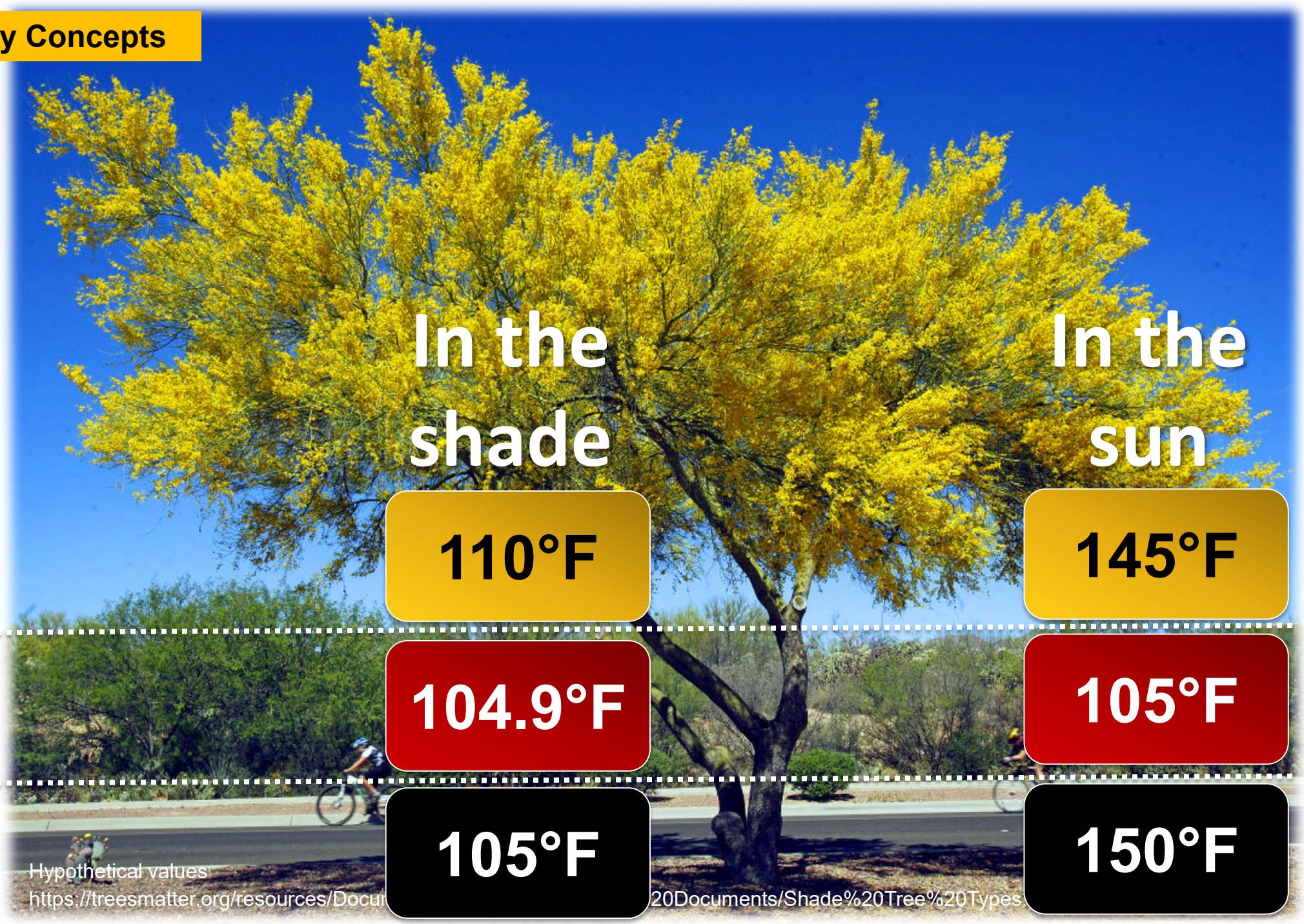
Air Temperature (reported on TV)

Surface Temp. (satellite imagery)

Hypothetical values

https://treesmatter.org/resources/Docu 20Documents/Shade%20Tree%20Types

Urban Heat Island Key Concepts



Thermal Index (what we feel)

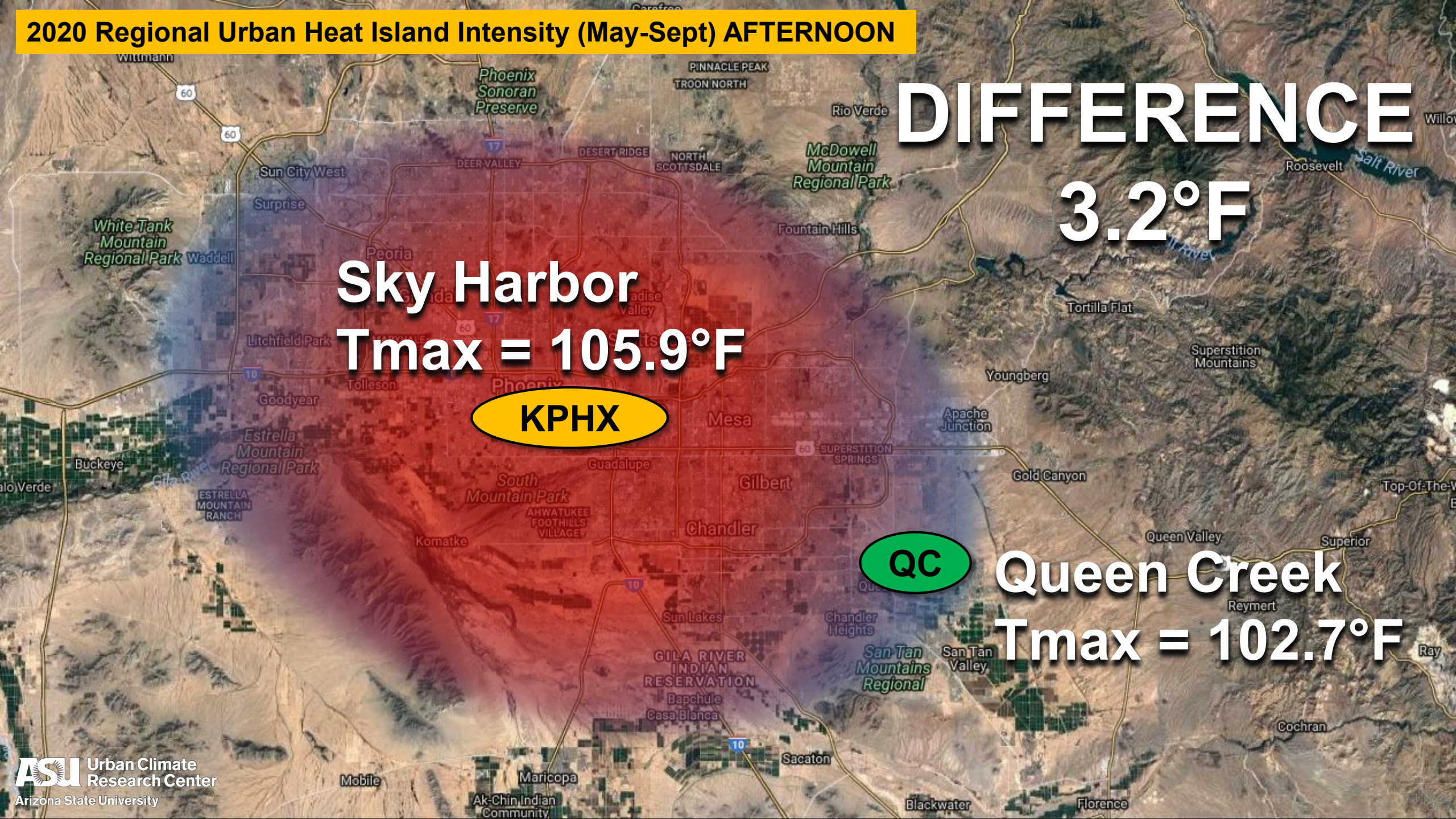
Air Temperature (reported on TV)

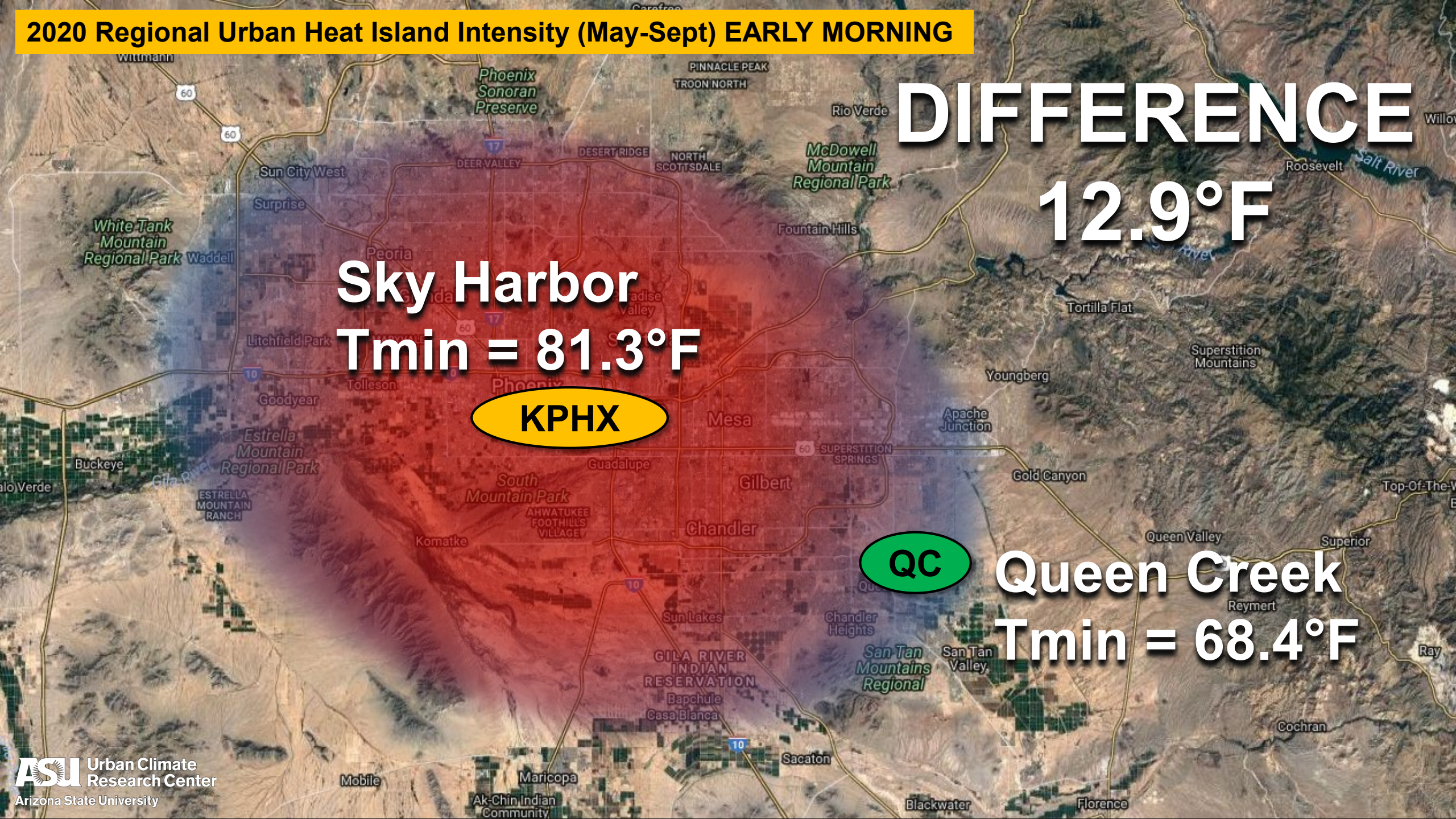
Surface Temp. (satellite imagery)

Urban Heat Island Key Concepts

Table 1: Basic Characteristics of Surface and Atmospheric Urban Heat Islands (UHIs)[4]

Feature	Surface UHI	Atmospheric UH
Temporal Development	• Present at all times of the day and night • Most intense during the day and in the summer	• May be small or non-existent during the day • Most intense at night or predawn and in the winter
Peak Intensity (Most intense UHI conditions)	• More spatial and temporal variation: ▪ Day: 18 to 27°F (10 to 15°C) ▪ Night: 9 to 18°F (5 to 10°C)	• Less variation: ▪ Day: -1.8 to 5.4°F (-1 to 3°C) ▪ Night: 12.6 to 21.6°F (7 to 12°C)
Typical Identification Method	• Indirect measurement: ▪ Remote sensing	• Direct measurement: ▪ Fixed weather stations ▪ Mobile traverses
Typical Depiction	• Thermal image	• Isotherm map • Temperature graph


2020 Regional Urban Heat Island Intensity (May-Sept) AFTERNOON
DIFFERENCE
3.2°F
Sky Harbor
Tmax = 105.9°F
KPHX
QC
Queen Creek
Tmax = 102.7°F
Phoenix Sonoran Preserve
PINNACLE PEAK
TROON NORTH
Rio Verde
McDowell Mountain Regional Park
Sun City West
Surprise
White Tank Mountain Regional Park
Waddell
Peoria
Fountain Hills
Litchfield Park
Goodyear
Tolleson
Phoenix
Mesa
Tortilla Flat
Superstition Mountains
Youngberg
Apache Junction
Gold Canyon
Estrella Mountain Regional Park
Buckeye
South Mountain Park
Guadalupe
Gilbert
Chandler
Komatke
Queen Valley
Superior
Sun Lakes
Chandler Heights
San Tan Mountains Regional
San Tan Valley
Reymert
GILA RIVER INDIAN RESERVATION
Bapchule
Casa Blanca
Cochran
Sacaton
Mobile
Maricopa
Ak-Chin Indian Community
Blackwater
Florence
Roosevelt
Salt River
Top-Of-The-World
Ray
ASU Urban Climate Research Center
Arizona State University


2020 Regional Urban Heat Island Intensity (May-Sept) EARLY MORNING
DIFFERENCE
12.9°F
Sky Harbor
Tmin = 81.3°F
KPHX
QC
Queen Creek
Tmin = 68.4°F
Phoenix Sonoran Preserve
PINNACLE PEAK
TROON NORTH
Rio Verde
McDowell Mountain Regional Park
Roosevelt
Salt River
Sun City West
Surprise
DESERT RIDGE
NORTH SCOTTSDALE
DEER VALLEY
White Tank Mountain Regional Park
Waddell
Fountain Hills
Peoria
Litchfield Park
Tolleson
Goodyear
Tortilla Flat
Superstition Mountains
Youngberg
Apache Junction
Mesa
SUPERSTITION SPRINGS
Gold Canyon
Estrella Mountain Regional Park
Buckeye
ESTRELLA MOUNTAIN RANCH
Guadalupe
South Mountain Park
AHWATUKEE FOOTHILLS VILLAGE
Gilbert
Chandler
Komatke
Queen Valley
Superior
Sun Lakes
Chandler Heights
San Tan Mountains Regional
San Tan Valley
Reymert
GILA RIVER INDIAN RESERVATION
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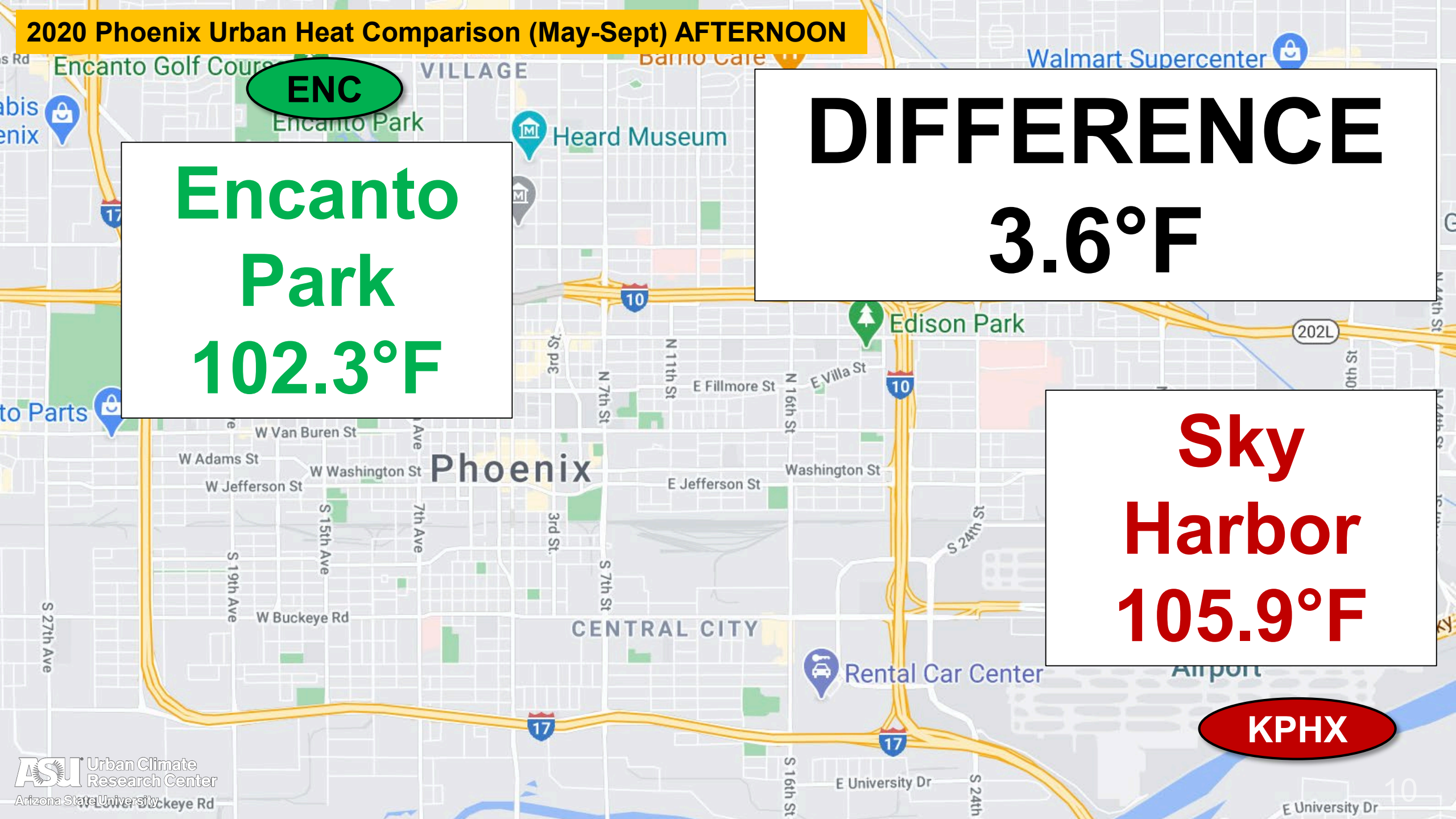
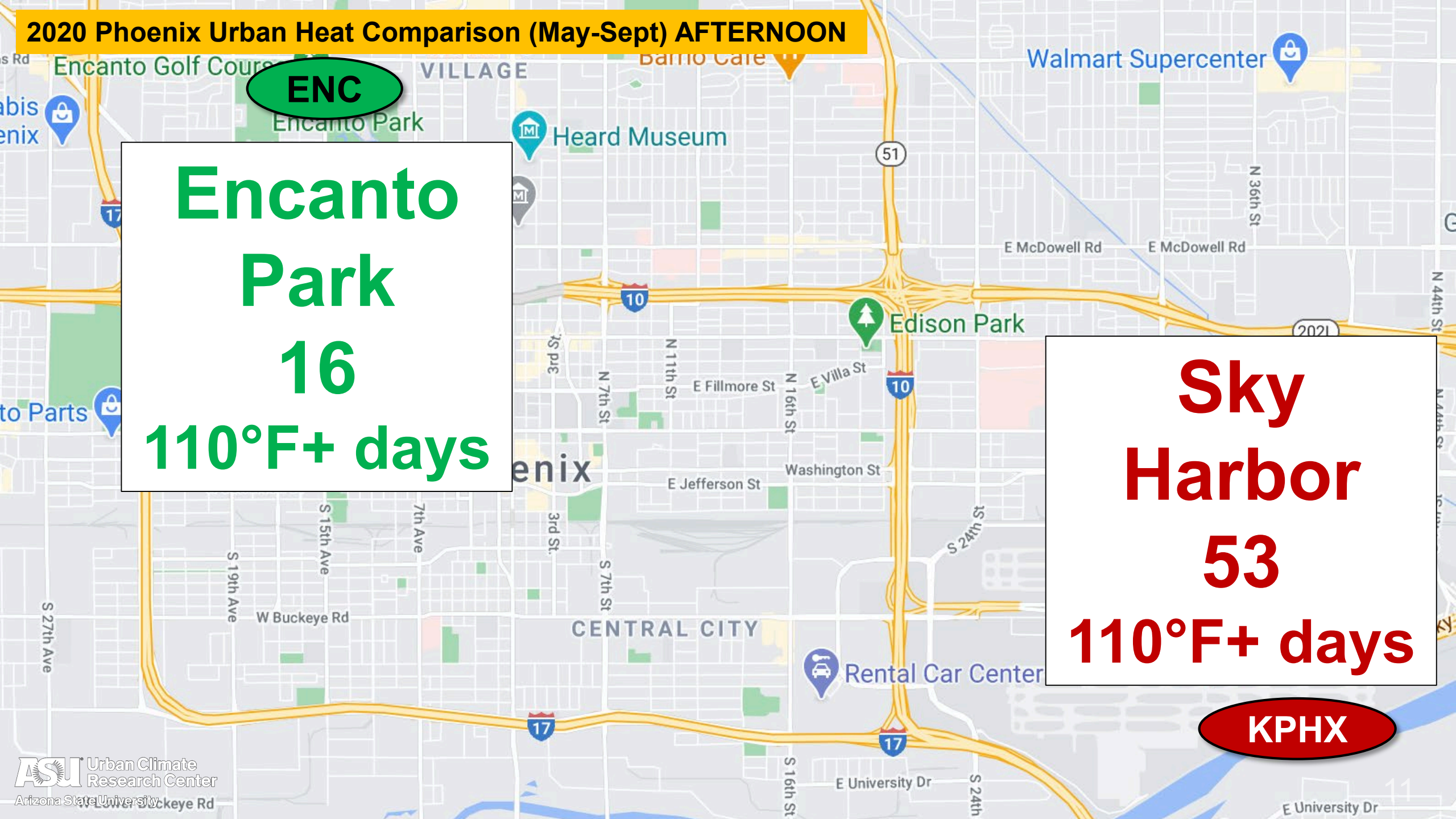

2020 Phoenix Urban Heat Comparison (May-Sept) AFTERNOON
ENC
Encanto Park
102.3°F
DIFFERENCE
3.6°F
Sky Harbor
105.9°F
KPHX
Encanto Golf Course
VILLAGE
Walmart Supercenter
Heard Museum
Edison Park
Phoenix
CENTRAL CITY
Rental Car Center
Airport
W Van Buren St
W Adams St
W Washington St
W Jefferson St
E Fillmore St
E Villa St
E Jefferson St
Washington St
W Buckeye Rd
E University Dr
N 7th St
N 11th St
N 16th St
3rd St
7th Ave
S 15th Ave
S 19th Ave
S 27th Ave
S 7th St
S 16th St
S 24th St
202L
10
17
Urban Climate Research Center
Arizona State University


2020 Phoenix Urban Heat Comparison (May-Sept) AFTERNOON
ENC
Encanto Park
16
110°F+ days
Sky Harbor
53
110°F+ days
KPHX
Encanto Golf Course
VILLAGE
Encanto Park
Heard Museum
Walmart Supercenter
Edison Park
E McDowell Rd
E Fillmore St
E Villa St
E Jefferson St
Washington St
CENTRAL CITY
Rental Car Center
E University Dr
W Buckeye Rd
N 7th St
N 11th St
N 16th St
3rd St
7th St
S 15th Ave
S 19th Ave
7th Ave
S 27th Ave
S 24th St
S 16th St
N 36th St
N 44th St
51
10
17
202L
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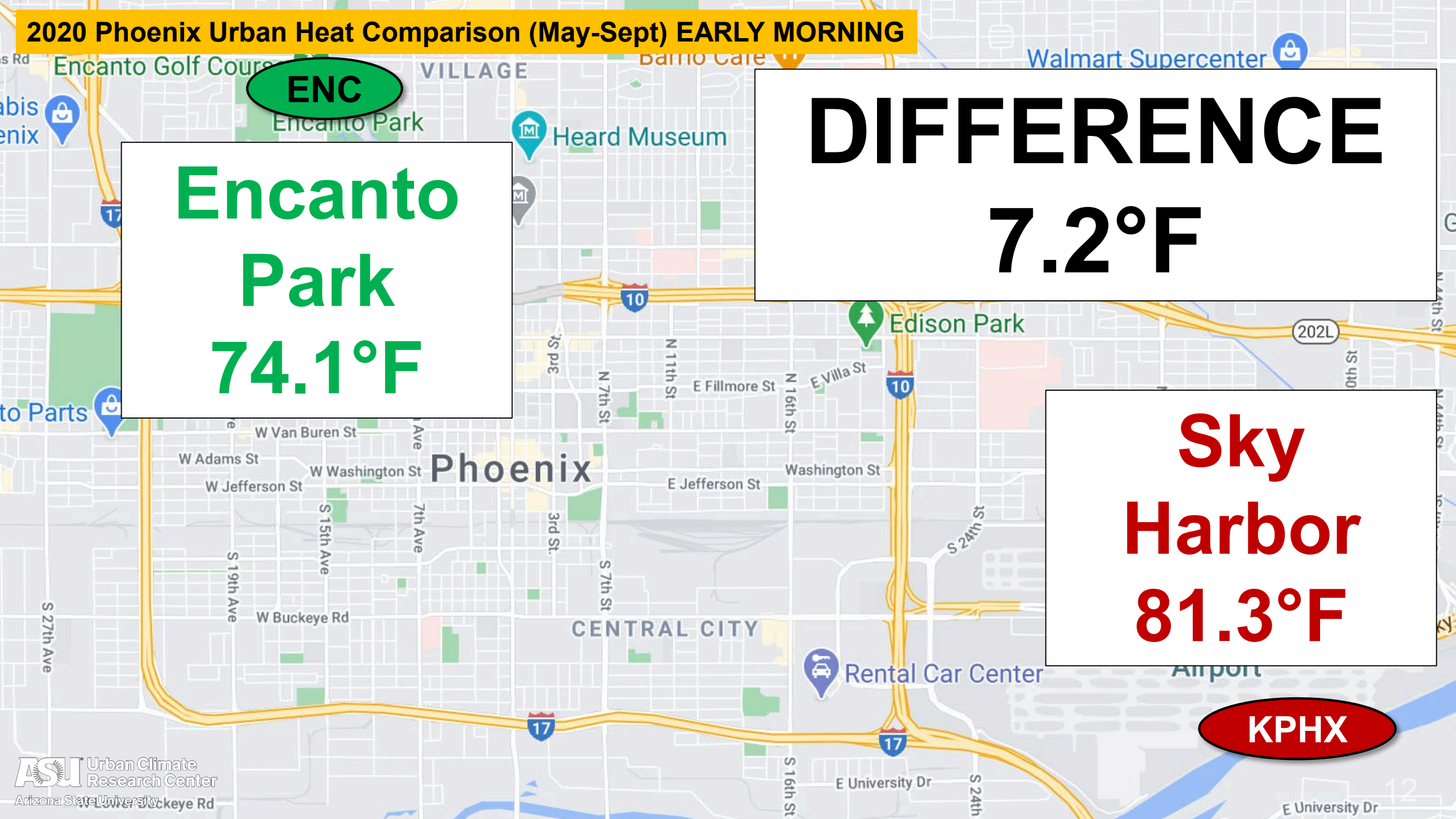
2020 Phoenix Urban Heat Comparison (May-Sept) EARLY MORNING
ENC
Encanto Park
74.1°F
DIFFERENCE
7.2°F
Sky Harbor
81.3°F
KPHX
Encanto Golf Course
VILLAGE
Heard Museum
Walmart Supercenter
Edison Park
Phoenix
CENTRAL CITY
Rental Car Center
Airport
W Van Buren St
W Adams St
W Washington St
W Jefferson St
E Fillmore St
E Villa St
E Jefferson St
Washington St
W Buckeye Rd
E University Dr
N 7th St
N 11th St
N 16th St
3rd St
7th Ave
S 15th Ave
S 19th Ave
S 27th Ave
S 7th St
S 16th St
S 24th St
202L
10
17
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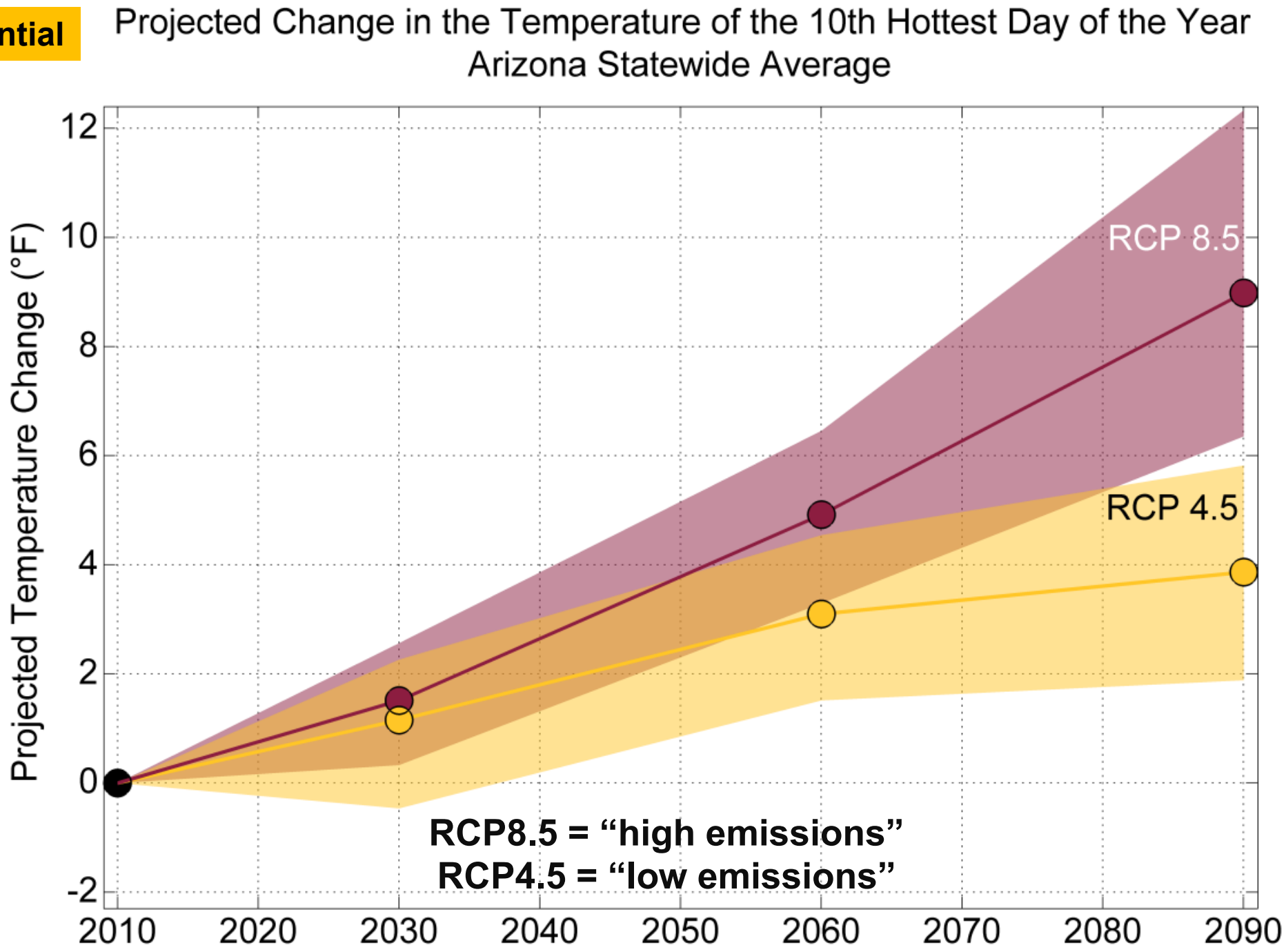
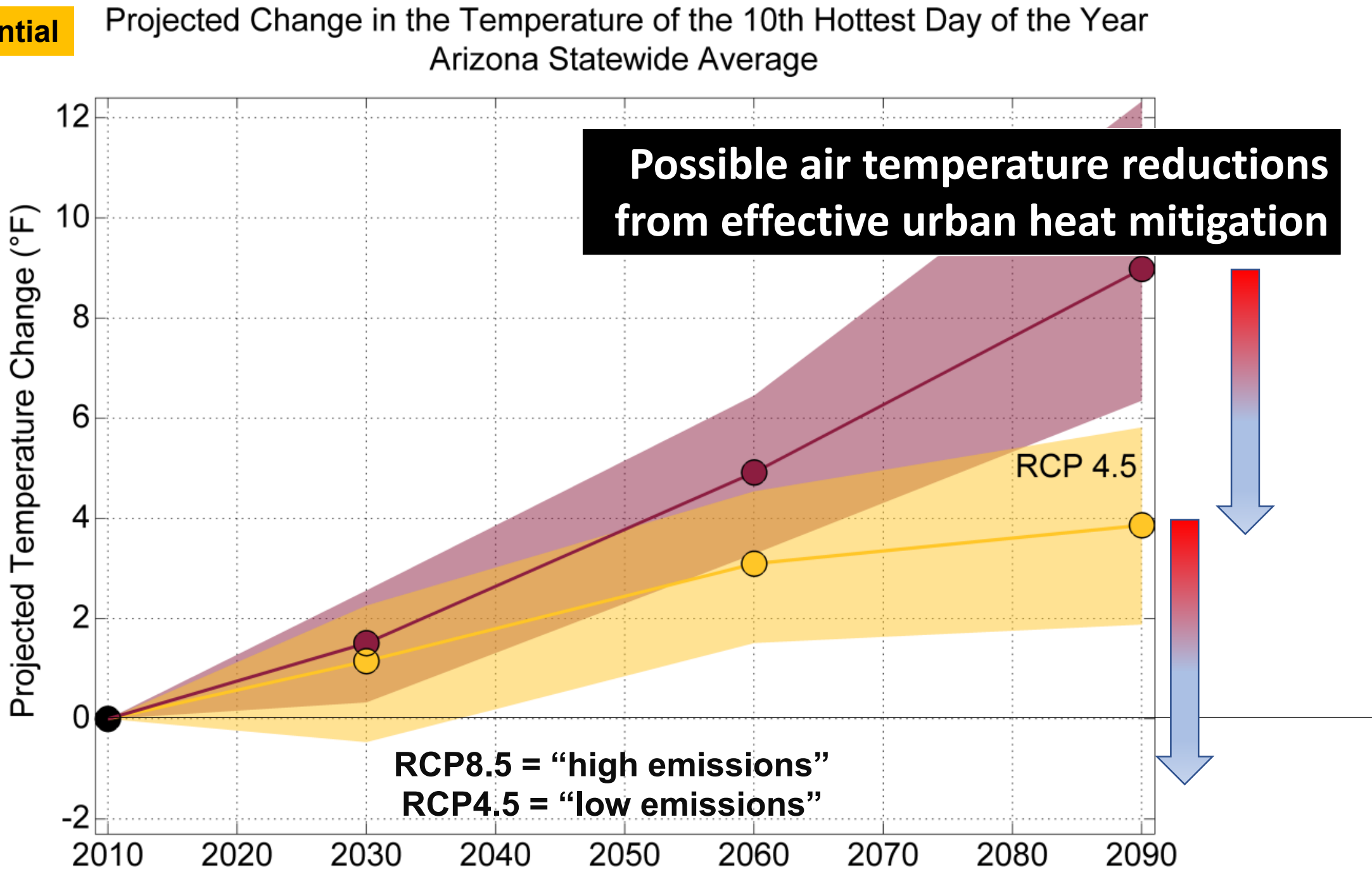
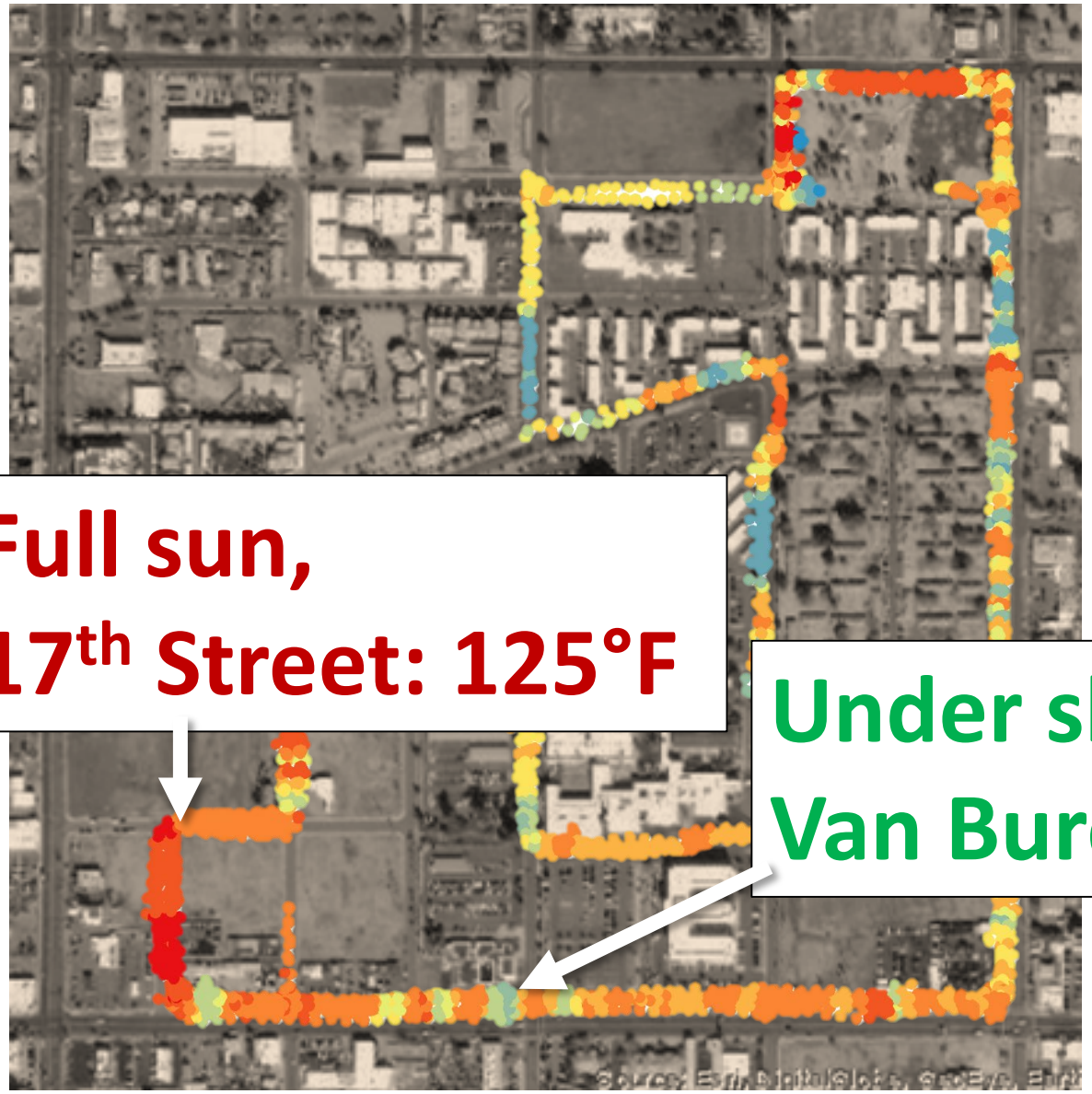
Mitigation Potential



Mitigation Potential



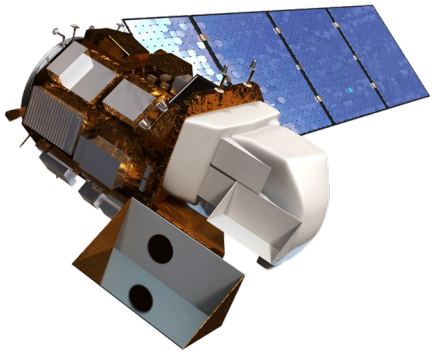
Thermal Index “PET” Measurements in Edison-Eastlake



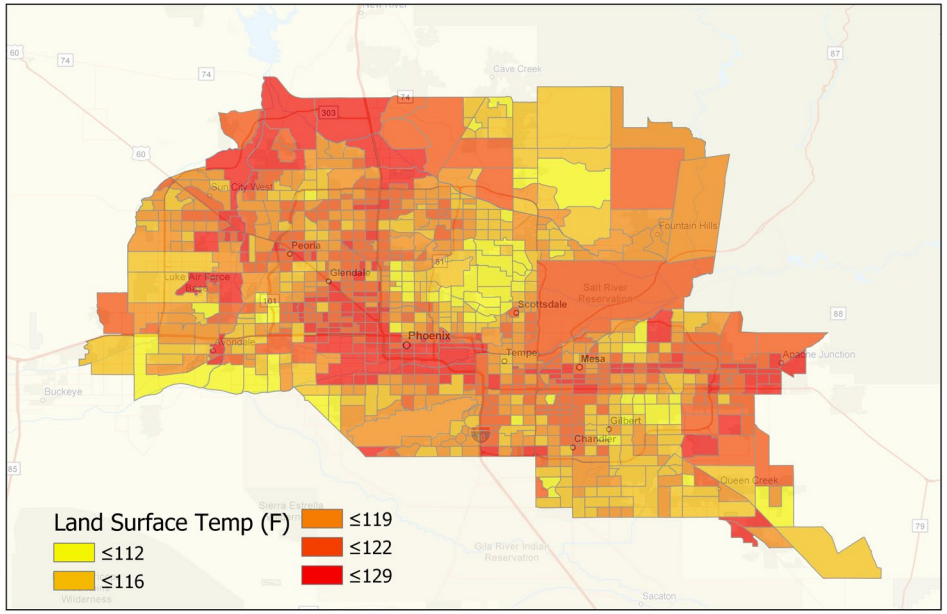
Full sun,
17th Street: 125°F

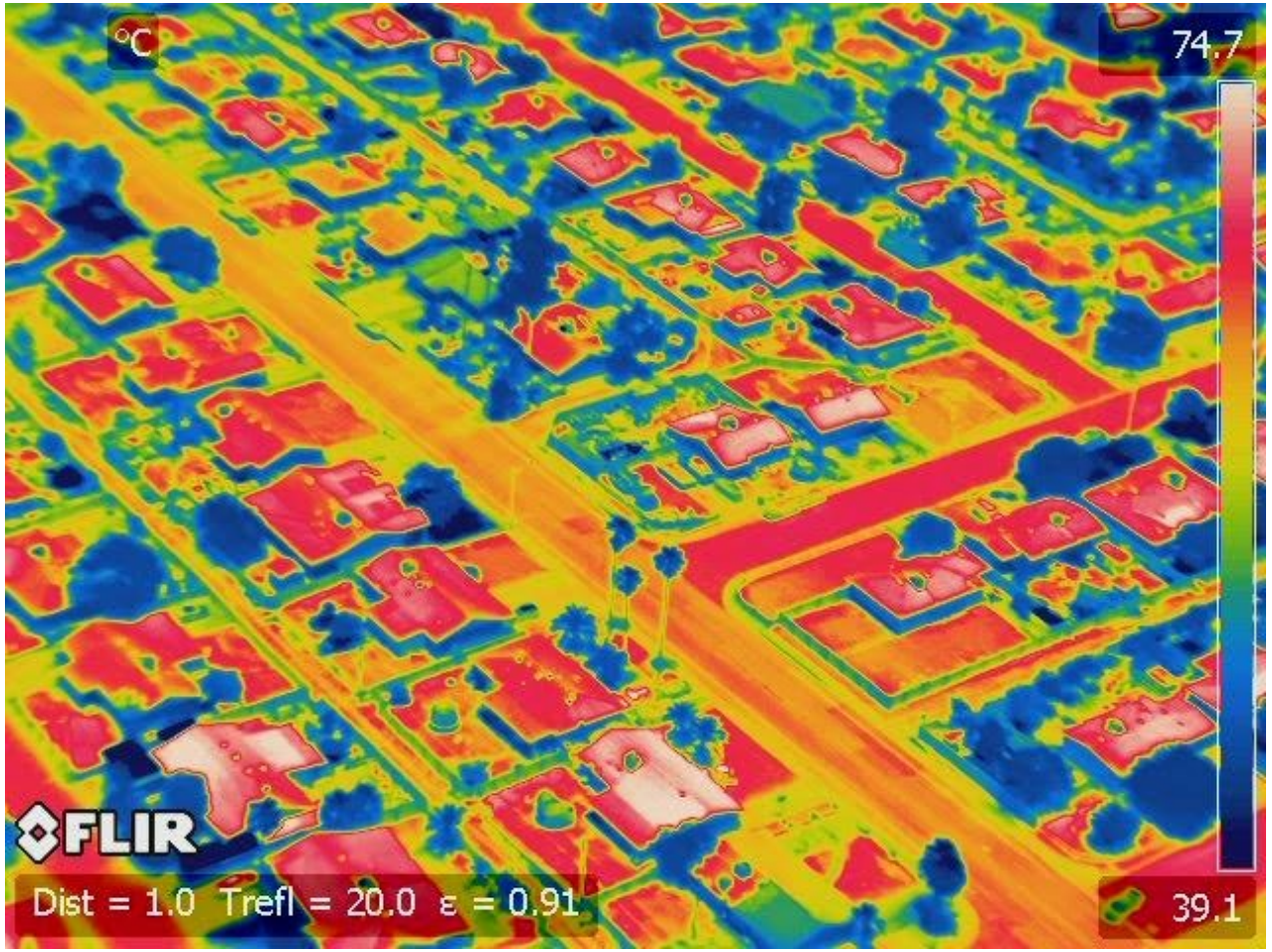
Under shade tree,
Van Buren: 99°F

Spatial Patterns



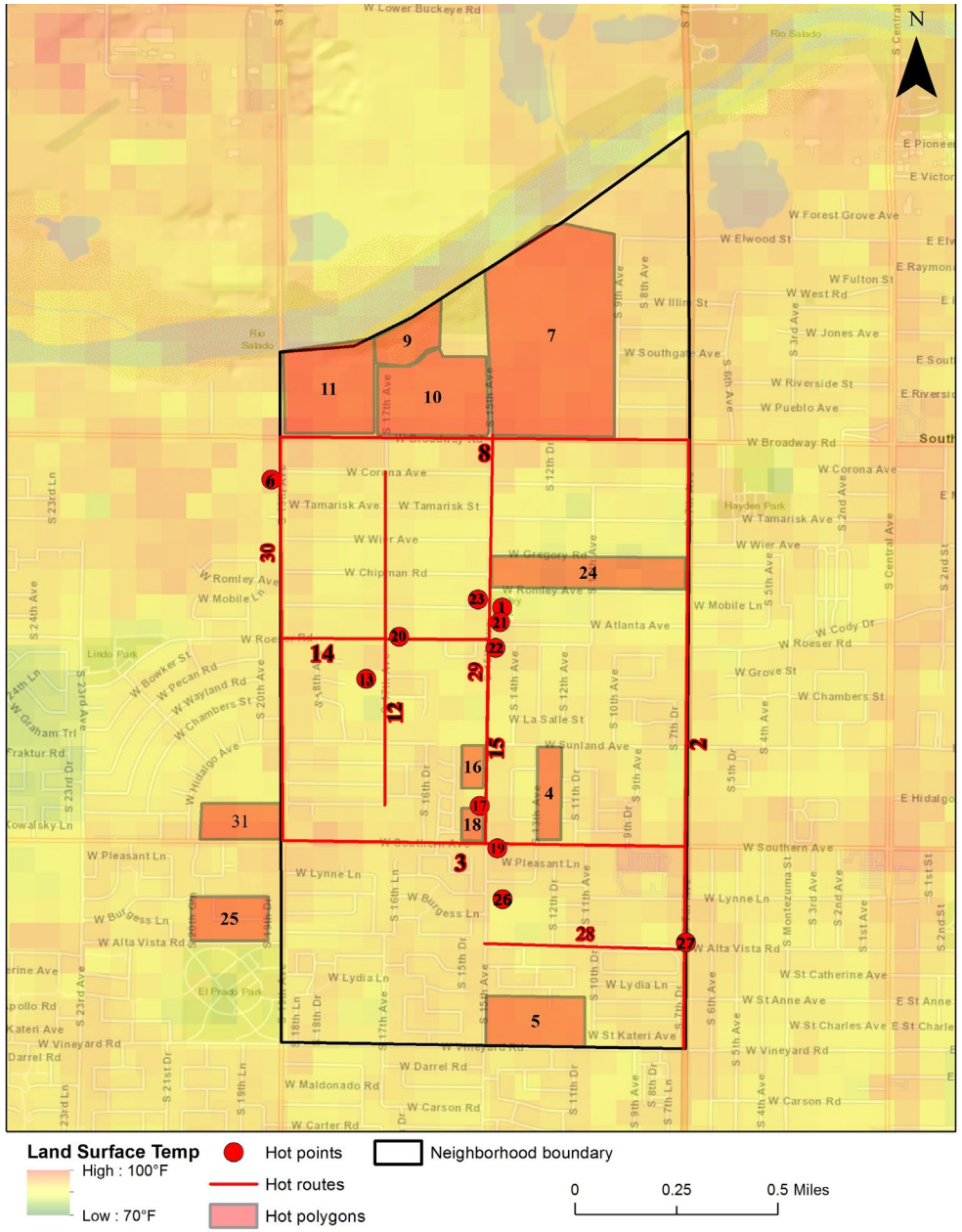
Avg LST by Census Tract





Where is the urban heat island the strongest?

Spatial Patterns



NATURE'S COOLING SYSTEMS PROJECT

The Nature Conservancy Arizona

PRC Phoenix Revitalization Corporation

PUENTE MOVEMENT

Maricopa County Public Health WeArePublicHealth.org

CAZCA CENTRAL ARIZONA CONSERVATION ALLIANCE

ASU Urban Climate Research Center Arizona State University

UREx SRN

CENTER FOR WHOLE COMMUNITIES

RAIL

Where is the urban heat island the strongest?

Drivers of Urban Heat

Lack of vegetation, lack of evaporative cooling, shading

Anthropogenic heat released from heated or cooled buildings

Heat released by traffic

Building materials store solar heat and release it at night

Tall buildings trap air in to the street canyons and reduce wind speed within the city

Long-wave radiation is reflected from walls back to street level

Due to the UHI a city centre can be over 10 degrees warmer than the surrounding countryside

Waste Heat

Impervious Surfaces

Urban Geometry

Impacts of Urban Heat

Criteria for Selection of Neighborhoods

Heat

Low vegetation coverage

Low vegetation index

High surface temperature

Usage

High use of public spaces

High transit use

History & Opportunity

High % vacant lots

Invitation from community

Slated housing, renovation, or capital improvement projects

Community

Strong sense of community identity

Potential for mutual learning (residents:stakeholders)

Previously surveyed

Health & Vulnerability

High rate heat deaths / heat-related illnesses

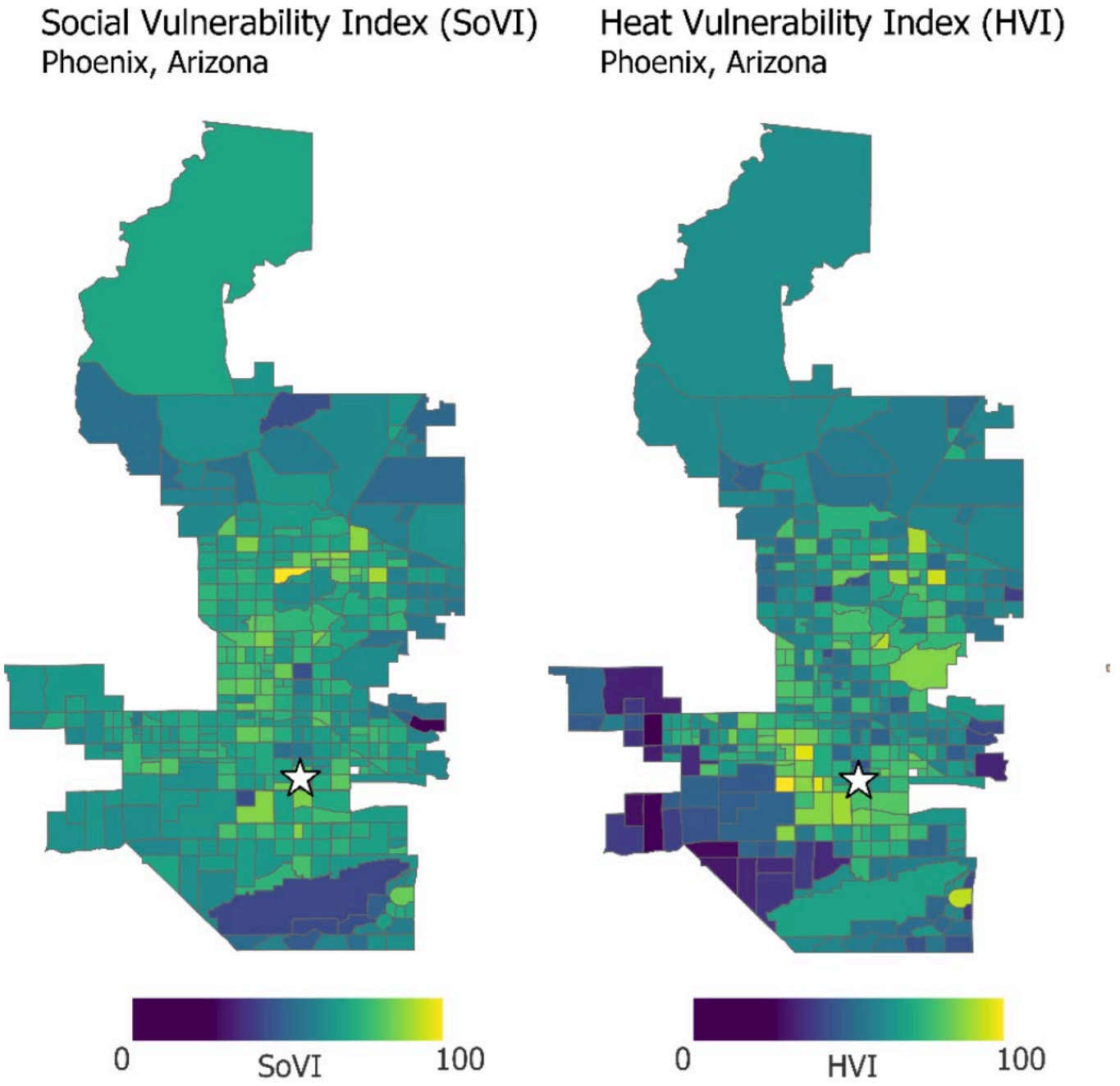
Low-income

High rates of self-reported heat concerns

Lack of A/C

NATURE'S COOLING SYSTEMS PROJECT

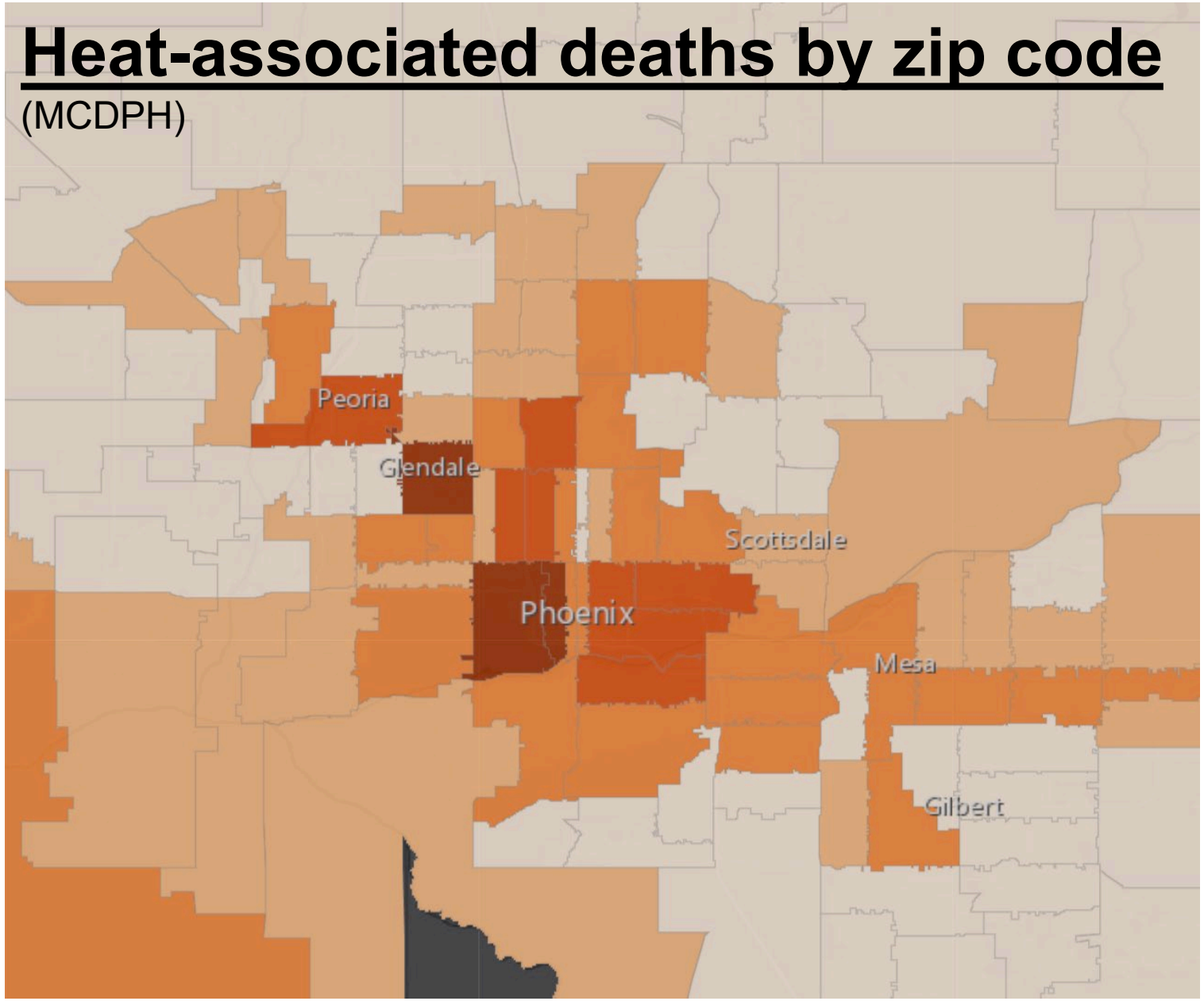
Impacts of Urban Heat



Impacts of Urban Heat

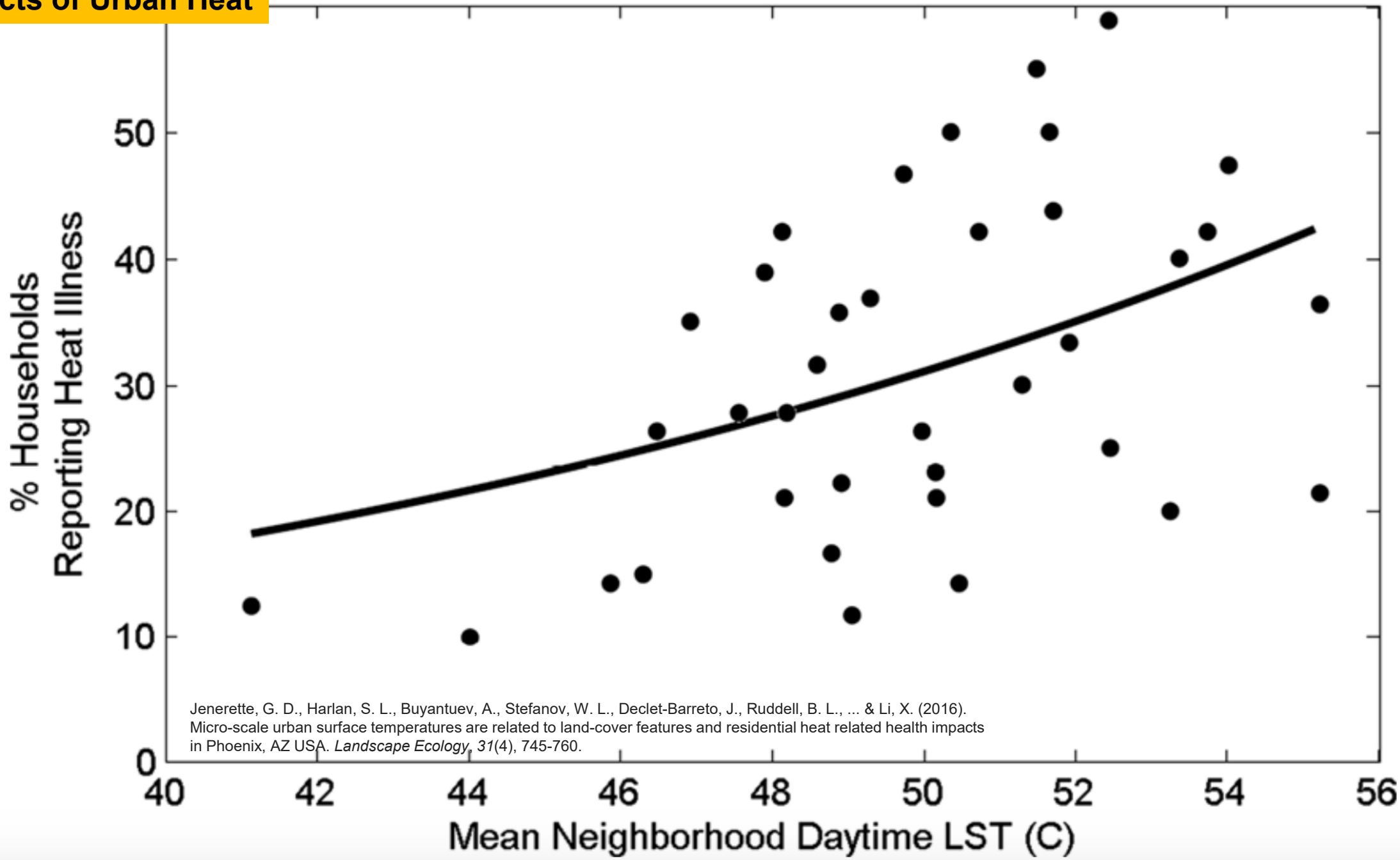
Heat-associated deaths by zip code

(MCDPH)



http://maricopa.maps.arcgis.com/apps/MapJournal/index.html?appid=61d7ac3b92184446b5208f898cd933d9

Impacts of Urban Heat



Jenerette, G. D., Harlan, S. L., Buyantuev, A., Stefanov, W. L., Declet-Barreto, J., Ruddell, B. L., ... & Li, X. (2016). Micro-scale urban surface temperatures are related to land-cover features and residential heat related health impacts in Phoenix, AZ USA. *Landscape Ecology*, *31*(4), 745-760.

Impacts of Urban Heat

"I ride the bus and sometimes I go to the bus stop and it is really hot. Also, my apartment, it's also really hot in there….I have to go to bus stations and there is no shade structure. There is nothing. There are no trees along the way…I wish that there were more trees where I live…because there is nothing."

Active Transportation Recommendations/Toolbox

MARICOPA ASSOCIATION of GOVERNMENTS

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Programs / Transportation / Active Transportation / Active Transportation Plan / Active Transportation Toolbox / Pedestrian Infrastructure / Shade and

Shade and Thermal Comfort

MAG Targets for 20-minute Walking Routes

Excellent shade coverage	**60%**
Good shade coverage	30%
Minimum acceptable shade coverage	20%

Active Transportation Recommendations/Toolbox

Shade Design Considerations

Many shade studies only examine shade patterns around noon and that has limited impact on thermal comfort. LEED ND v4 provides some specific standards for increasing shade to minimize the urban heat island effects. In contrast, the principles below can be applied contextually when selecting and designing shade at the site or corridor-level. The design principles are followed by examples illustrating those guiding concepts. These shade design principles are intended to be complementary to other existing meta-principles (adopted by the City of Phoenix) for reducing the impacts of urban heat.

Design Principles for Shade[9]

1. **Simulate worst case scenario:** Create shade simulations through use of tools such as Revit, SketchUp, Rhino, or ENVI-met for worst case scenarios for time of year and time of day. In Maricopa County, that is during May through October in afternoon hours.
2. **Connectivity:** Through modeling and/or by inspecting shade percentage for achieving a Thermally Comfortable Pedestrian Route (TCPR) as described above, ensure pedestrian pathways adjacent to the project site have opportunities to occur in shaded conditions, especially in late afternoon.
3. **Solar orientation:** Strive to maximize shading between May to October during afternoon hours. Also:
    - Rights-of-way orientation:
        - East-west (E-W) oriented rights-of-way are the most difficult to shade with buildings. However, the

Active Transportation Recommendations/Toolbox

Shade Considerations: *Awning combined with tree shade*

Location: E. Adams St. and N. 1st St, Phoenix
Latitude: 33°26'40.71"N
Longitude: 112°04'18.95"W
Date: April 3, 2018
Time of photo: 11:49 AM
Solar declination (degrees):* 5.5
Solar azimuth:* 158.22
Solar elevation:* 60.39
Cosine of solar zenith angle:* 0.8694
Aspect (facing): South
* NOAA Solar Position Calculator

Shade type: Building awning & small trees
Quality of shade: Light/ partial shade/
When most effective: May-July
Why this type of shade: Architectural choice
ROW considerations: 20'-0" Sidewalk area
Constraints: Metal awning, no tall trees
Material (effectiveness): Metal slats (durable)

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