A Multiscalar Thermal Analysis of Urban Playgrounds

Seeing Urban Playgrounds Through a New Lens

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International Conference on Urban Climates
Toulouse, France, 2015

Background & Importance

CHILDREN are not little adults

- Higher surface-area-to-body mass ratio; effects of heat are heightened[1]
- Lower sweat rate – can't cool as efficiently[2]
- Closer to ground

Playgrounds not designed with prevailing climate in mind

- 'Bioclimatic Design'
- Climate Change & Urban Growth → differing **vulnerability** and **adaptation** of children[3]

"Burning Hot: Heat Danger on the Playgrounds - NYC"

- Dozens per year treated for burns from playground surfaces
- ~ three seconds to burn on solid surfaces greater than 60°C (140°F)
- Most playground equipment **not** tested for heat safety.

Meteorologist Amy Freeze: http://wabc.typepad.com/freezefront/2012/

[1]Wenger (2003), [2]Falk (1998), [3]Vanos (*2015*)

Background & Importance

Urban Landscape Design

- outdoor spaces in which children seek or are encouraged to be the most active (e.g., **community playgrounds & parks**) are potentially the most harmful in terms of heat and burn risk from contact with surfaces (Vanos 2015).
- physical and meteorological evidence-base at the correct **spatial scale** is limited in North America to support proper bioclimatic design to mitigate extreme heat (Brown et al. 2015).
- urban heat-health research often employs coarse scales collected from sparse standardized meteorological observations for extreme heat analysis

→ ***the scale of measurement can affect a study's conclusions***

Diverse Park Designs

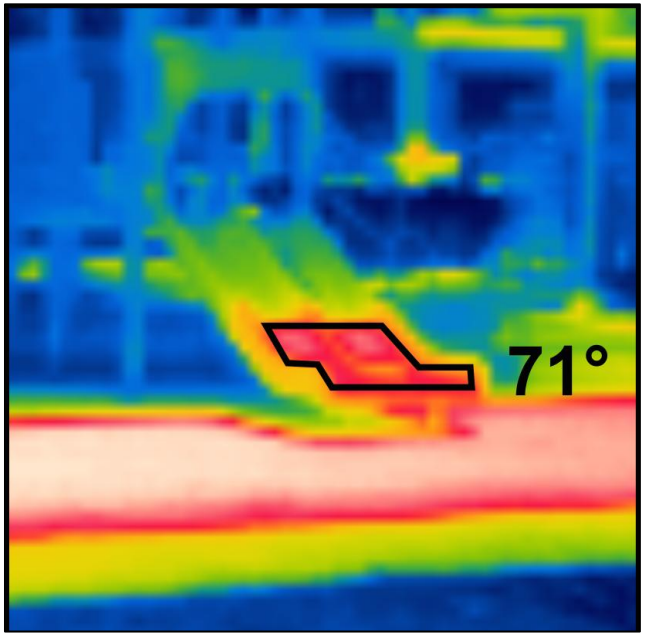
Lubbock, TX

Berlin, Germany

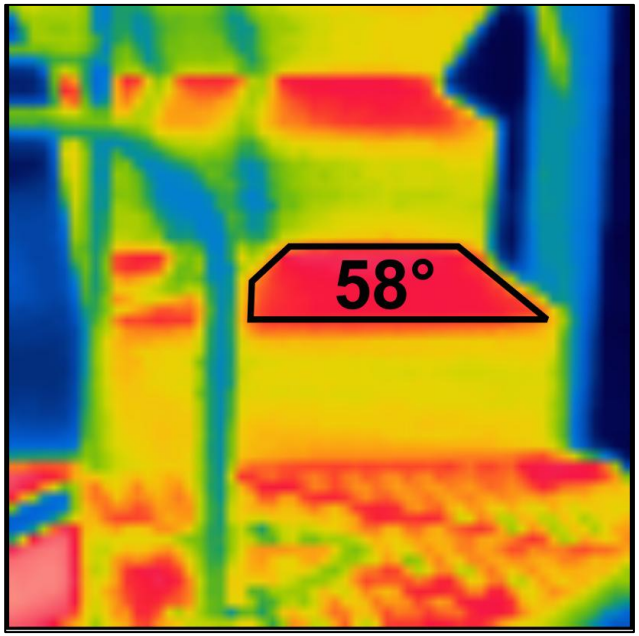
Vanos *(2015)* - *Environment International*

Shade & Surface Temperature

- **Obvious**: playgrounds could use a lot more shade, black surfaces get a whole lot hotter than those painted white[1]
- **Less Obvious:** Well-intentioned changes, such as ‘astro-turf’, rubber and plastic, appears to get even hotter than asphalt in the sun[1]



Slide half in shade (shade sail), half in sun



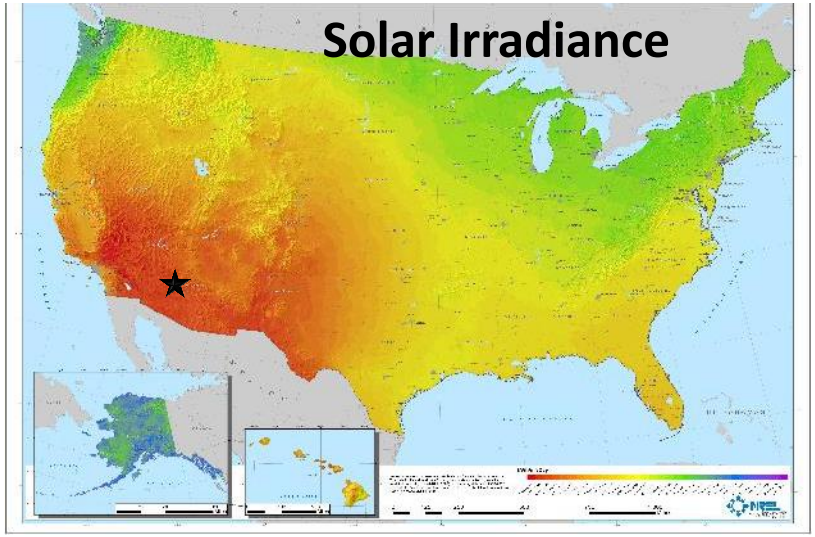
Steps in sun, black; metal powder coated

[1]CPSC; Vanos et al., (in review)

Playground Pilot Sites: Gilbert, AZ

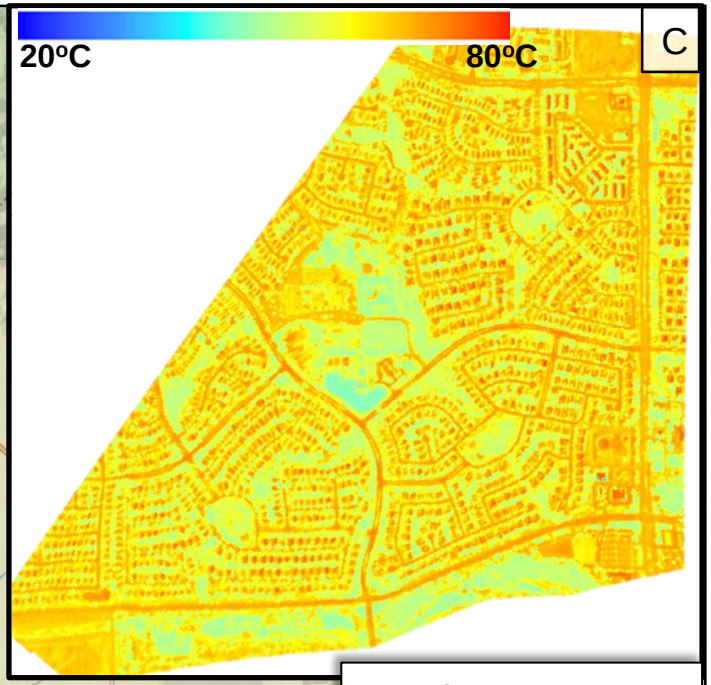
Goal:

- To resolve variability in various scales ('touch' scale → microscale → neighborhood scale)
  - Link remote sensing and touch-scale surface temperatures
  - Assess within-grid temperature variations in playgrounds
  - Provide information for public safety and design standards

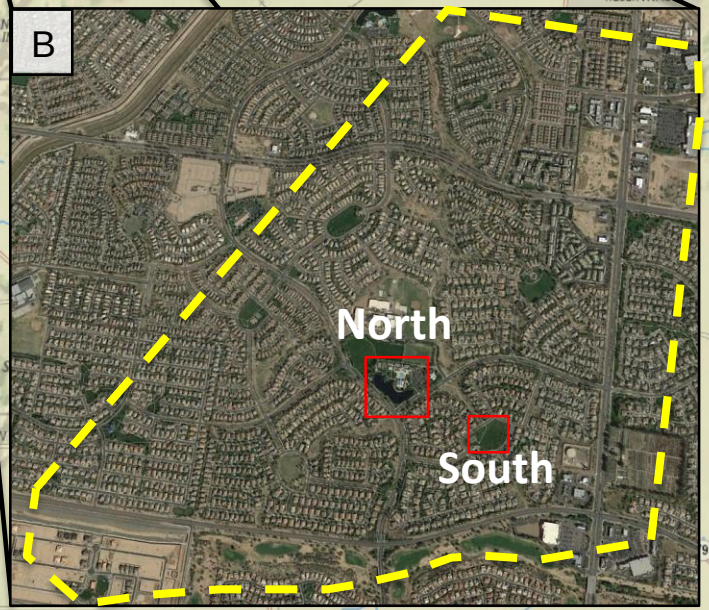


- **AZ:** arid, SUNNY, hot, warming faster than rest of USA, uneven distribution of heat burden (Walsh et al. 2014, Kuras et al., 2014)

Study Sites

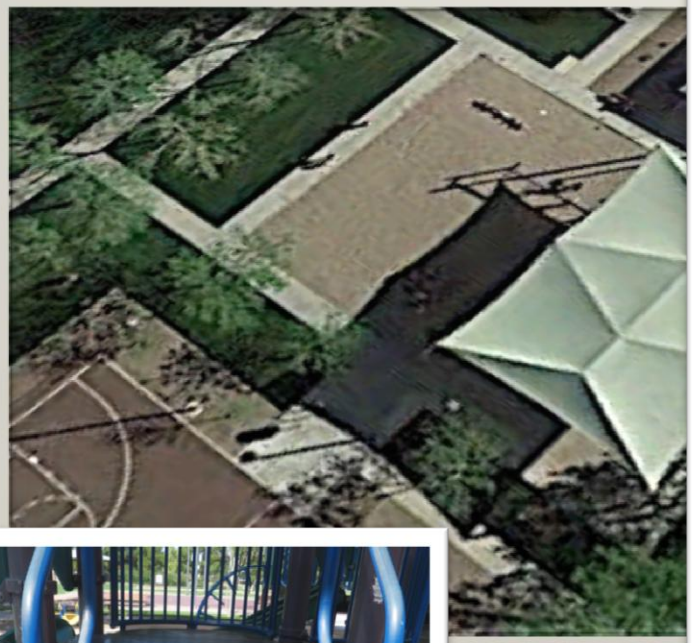


MASTER Remote Sensing Image



Kilometers
0 2 4 8 12 16
N

North Playground



South Playground

Data

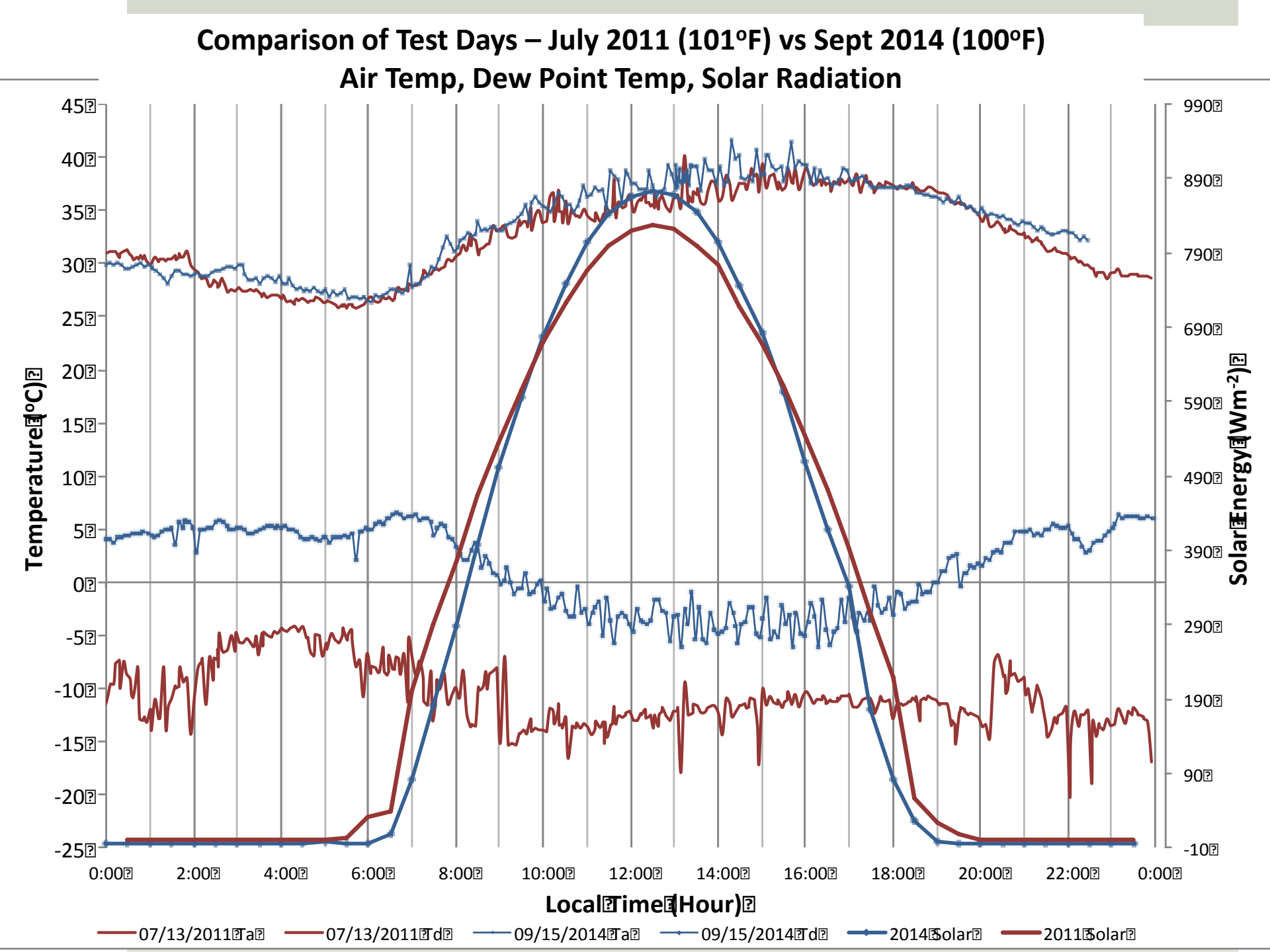
1) Remotely Sensed: MODIS/ASTER (**MASTER**)[1]
hyperspectral airborne sensors **-** NIR band ~6.8m resolution

- July 13 2011 mid-afternoon LST, peak T2m was 38.0^{o}C (100^{o}F)

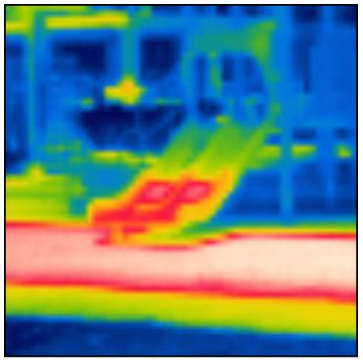
2) In-situ: Hand IRT, FLIR camera, and microclimate

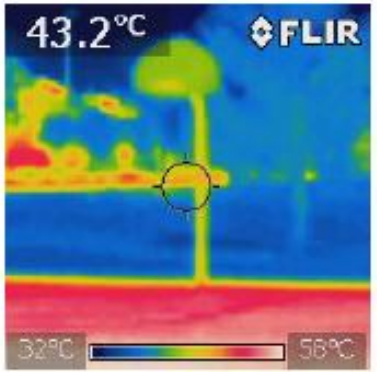
- September 15 2014, Peak T2m was 38.5^{o}C (101^{o}F)
- FLIR handheld IR photos
- Onsite portable & mobile weather station

[1]Harlan, NSF GEO-0816168, UVCC


Comparison of Test Days – July 2011 (101°F) vs Sept 2014 (100°F)
Air Temp, Dew Point Temp, Solar Radiation
Temperature (°C)
Solar Energy (Wm-2)
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
990
890
790
690
590
490
390
290
190
90
-10
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Local Time (Hour)
07/13/2011 Ta
07/13/2011 Td
09/15/2014 Ta
09/15/2014 Td
2014 Solar
2011 Solar

Visible & Infrared Imagery

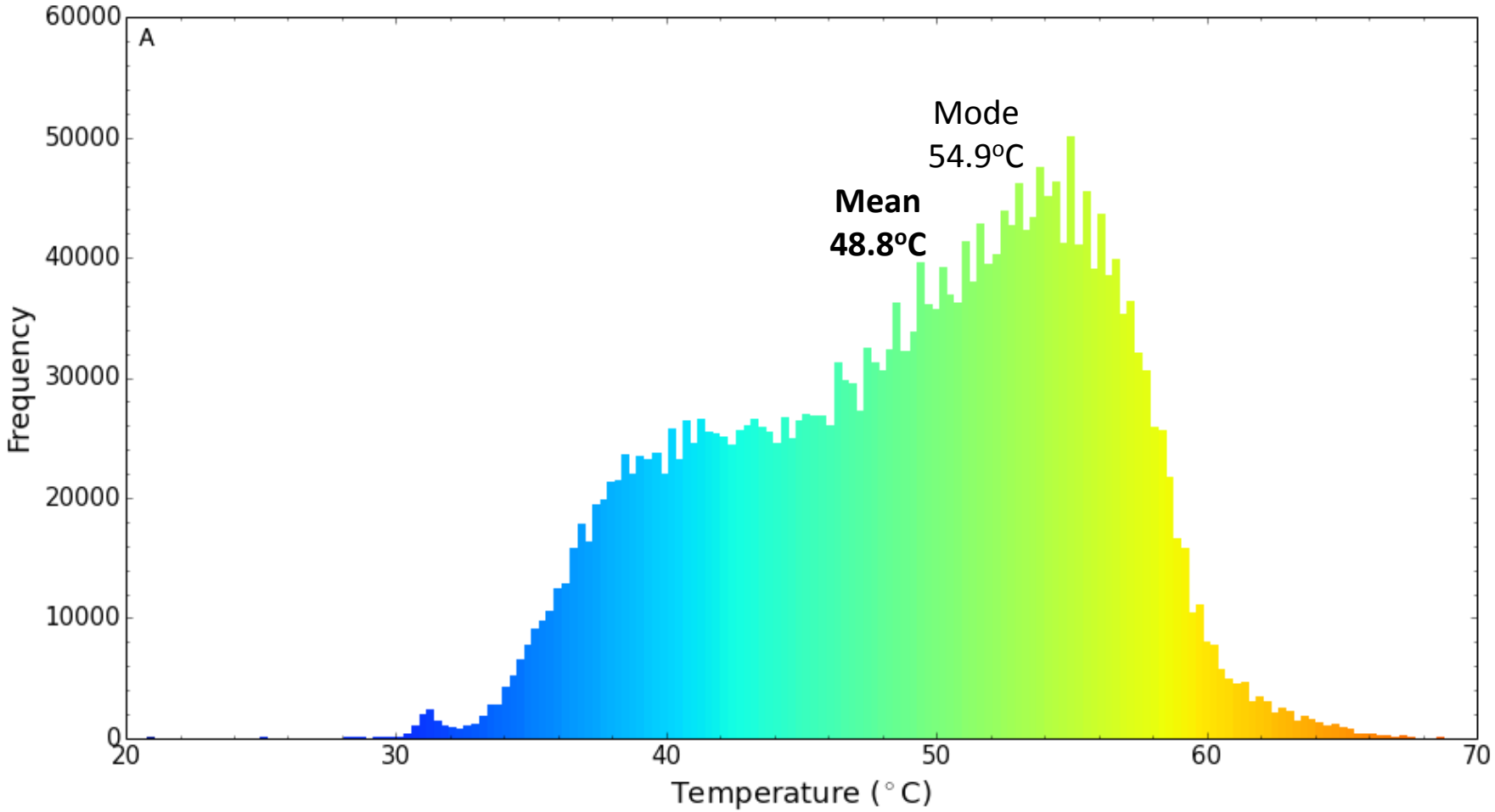




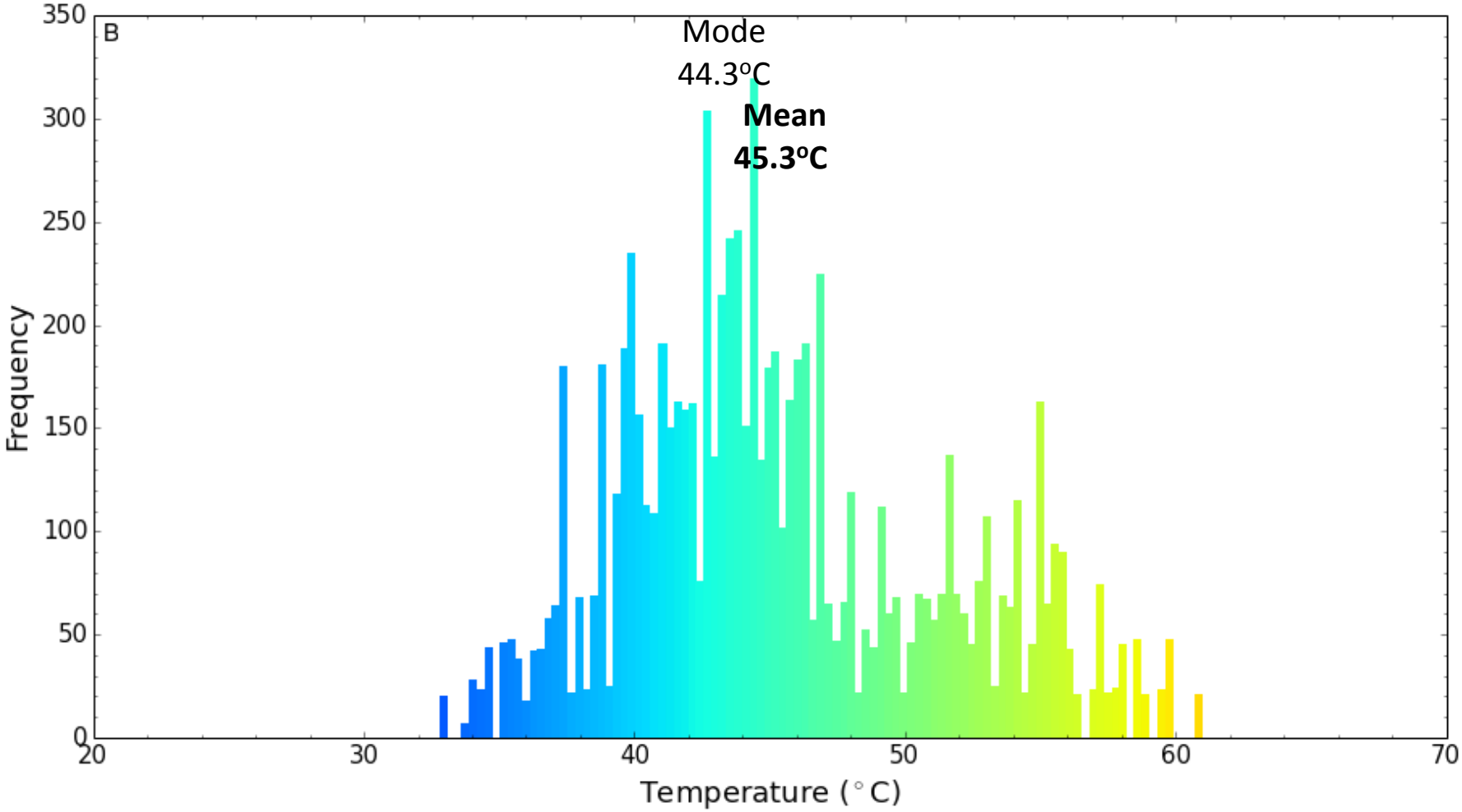
	Contact Time:	3 sec	5 sec	1 min
Metal	Uncoated	60°C	57°C	51°C
Coated Metal[1]	Lacquer Coat: 100µm	68°C	61°C	51°C
	Powder: 90µm	65°C	60°C	51°C
	Enamel: 160µm	63°C	59°C	51°C
Stone Material	Concrete, granite, asphalt	73°C	60°C	56°C
Plastic[2]	Polyamide, acrylglass, duroplastic	77°C	74°C	60°C
Wood	Bare, low moisture	99°C	93°C	60°C

[1]Polyurethane Enamel-Coated Steel; [2]UV stabilized high-density polyethylene

Afternoon Land Surface Temperature Distribution
Full Neighborhood - MASTER



Afternoon Land Surface Temperature Distribution Within Playgrounds - MASTER



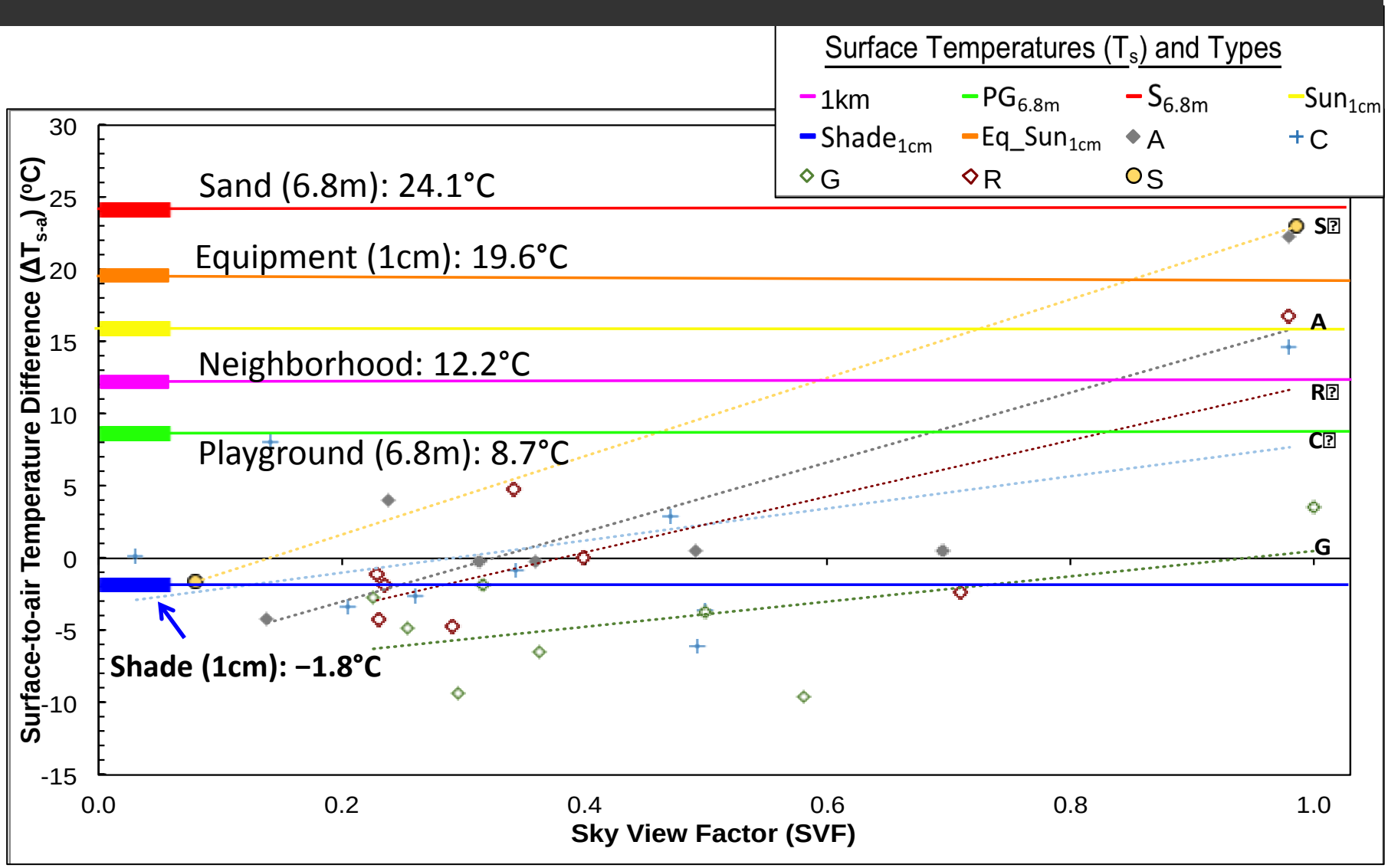
In-Situ Surface Temperature Results

NORTH Playground	Sun (°C)	Shade (sail) (°C)	Shade (tree) (°C)
'Jumpy' Surface (ground cover)	**87.2** (188 F)	46.7 (116 F)	42.2 (107 F)
Sand	**62.8** (145 F)	33.9 (93 F)	32.8 (91 F)
Posts of Playground	51.1 (124 F)	38.9 (102 F)	38.3 (100 F)
Metal Slide	**74.1 (165 F)**	**45.0 (113 F)**	-
Bouncy Rider (handle red)	46.1 (115 F)		
Bouncy Rider (seat red)	**62.2** (143 F)		

SOUTH Playground	Sun (°C)	Shade (tree) (°C)
Sand	**59.4 (138 F)**	**33.9 (93 F)**
Basketball Court, green	60.0 (140 F)	
Splash Pad	42.2 (107 F)	
Slide, plastic, green	71.1 (159 F)	43.9 (111 F)

Bench – 64 °C

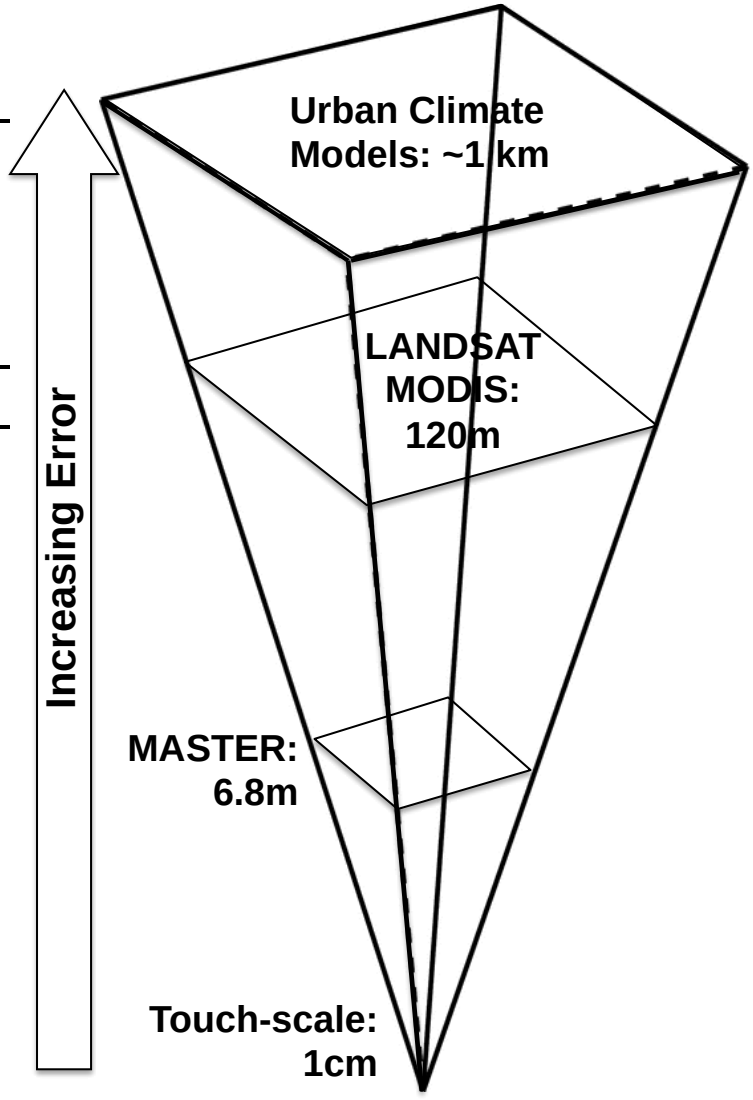
Surface-to-air temperature deltas



Scale Offsets: represent errors from touch-scale

Playground Equipment Category	(1) Playground offset of 1cm to 6.8m scale (°C)	(2) Playground offset of 1cm to 1km scale (°C)
Sitting - Child	13.6	10.1
Walking	9.9	6.4
Holding	8.0	4.5
Sitting – Adult & Child	8.8	5.3
Average	**10.1**	**6.6**

- Values represent error, and demonstrate a scale mismatch
- The coarser scales underestimate dangerous T_s within playgrounds
- It is at the touch-scale (~1cm scale) where children experience extreme temperatures—at times resulting in burns or damage to the skin



Logarithmic display of scales used in urban climate research

Further Assessments

- Account for the differential heating and cooling of each material type (ground, surface) and condition (sun, shade) for time detrending
- Further observations within the biophysical environment to develop discrete scale offset models account
- Apply to other climate zones

Strategies for Mitigating Hot Playground Exposure

- Need *standards* for materials used in playgrounds (equipment and ground)
- Shade is effective; brings surface temperatures into safe range
- Both natural (tree) and artificial (shade sail) shade types were associated with significant reductions in T_s
- Burns potential diminished; burns completely avoidable

Thank you!

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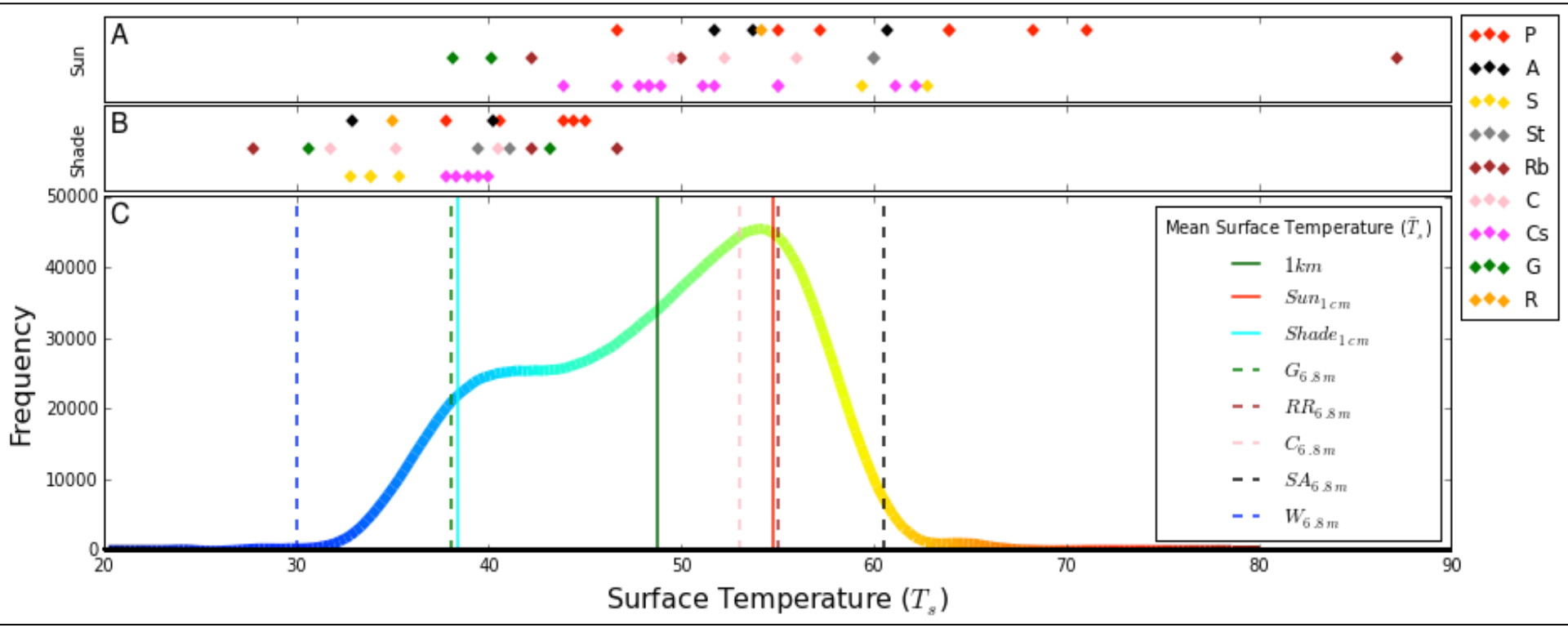
Observed surface temperatures



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(ISO 13732, 2010)

Study Site: Power Ranch Community (Gilbert, AZ)

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