#WaterAND Heat
Using Community Science to Address Hazard Bias

Janice Barnes, PhD

climate adaptation partners (CAP)

August 02, 2023

janice@climateadaptationpartners.com

climate adaptation partners
resilience through collaborative partnerships

#SharingIsCaring

A Coalition Around Heat Research in Charleston, South Carolina

Climate Adaptation Partners

Charleston Medical District

City of Charleston Office of Sustainability and Resilience

City of Charleston GIS and Planning Teams

MUSC Office of Sustainability

Roper St. Francis Healthcare

Ralph H. Johnson VA Medical Center

Fernleaf Interactive

MUSC Office of Health Promotion

City of Charleston Wellness Committee

South Carolina Sea Grant

Carolinas Integrated Sciences Assessment

The Citadel James B. Near Center for Climate Studies

Southeast Regional Climate Center

North Carolina State University

Appalachian State

MUSC Arboretum

Charleston Resilience Network

Charleston Healthy Business Coalition

CAPA Strategies

NOAA NIHHIS Team

South Carolina Department of Health and Environmental Control

South Carolina Health Professionals for Climate Action

South Carolina Interfaith Power and Light

College of Charleston

Clemson University

South Carolina Aquarium

City of Charleston Planning

MUSC School of Nursing

MUSC Medical School

University of South Carolina

State of South Carolina Meteorology Team

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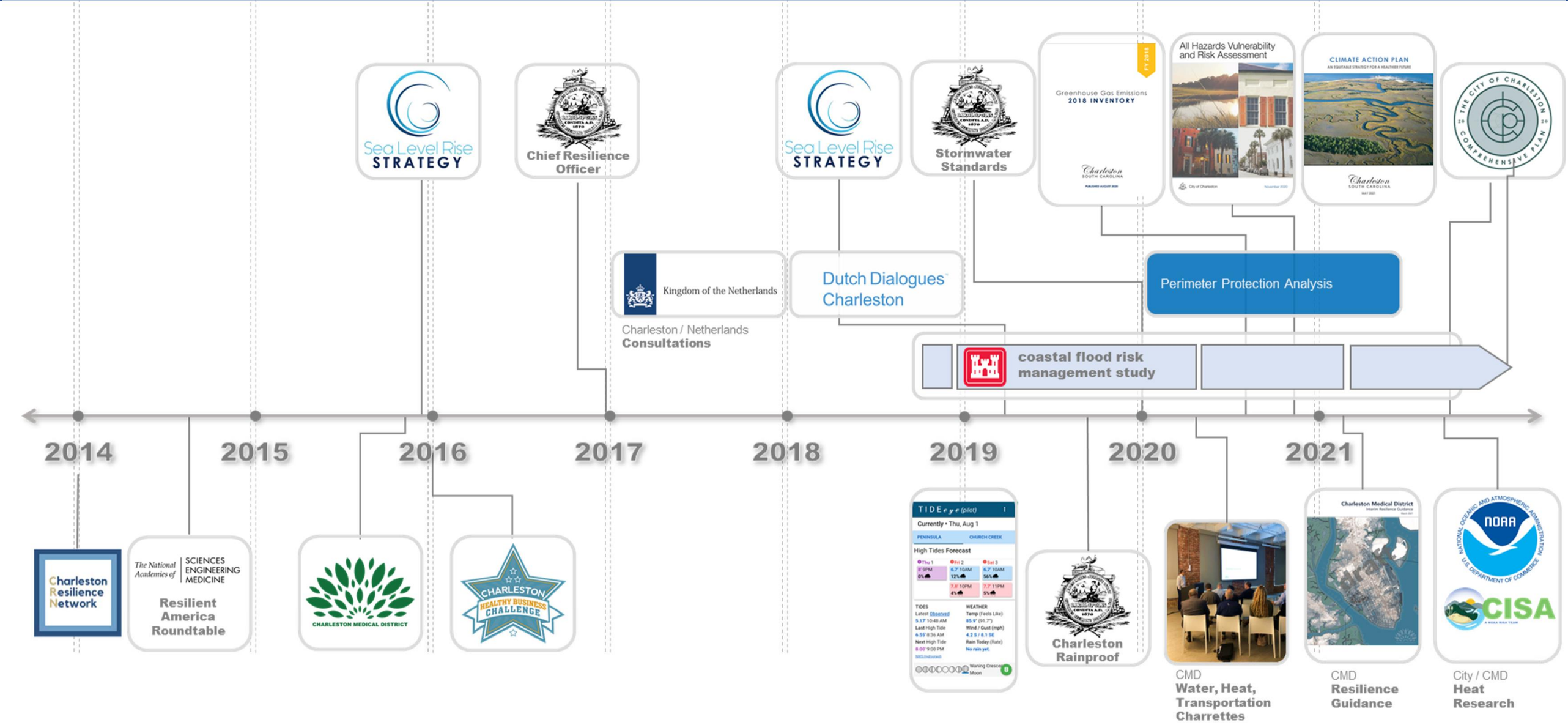
Charleston Heat Research

1 CMD Heat Research

2 CISA Heat Research

3 HeatWatch Research

4 Expanding and Sharing Research



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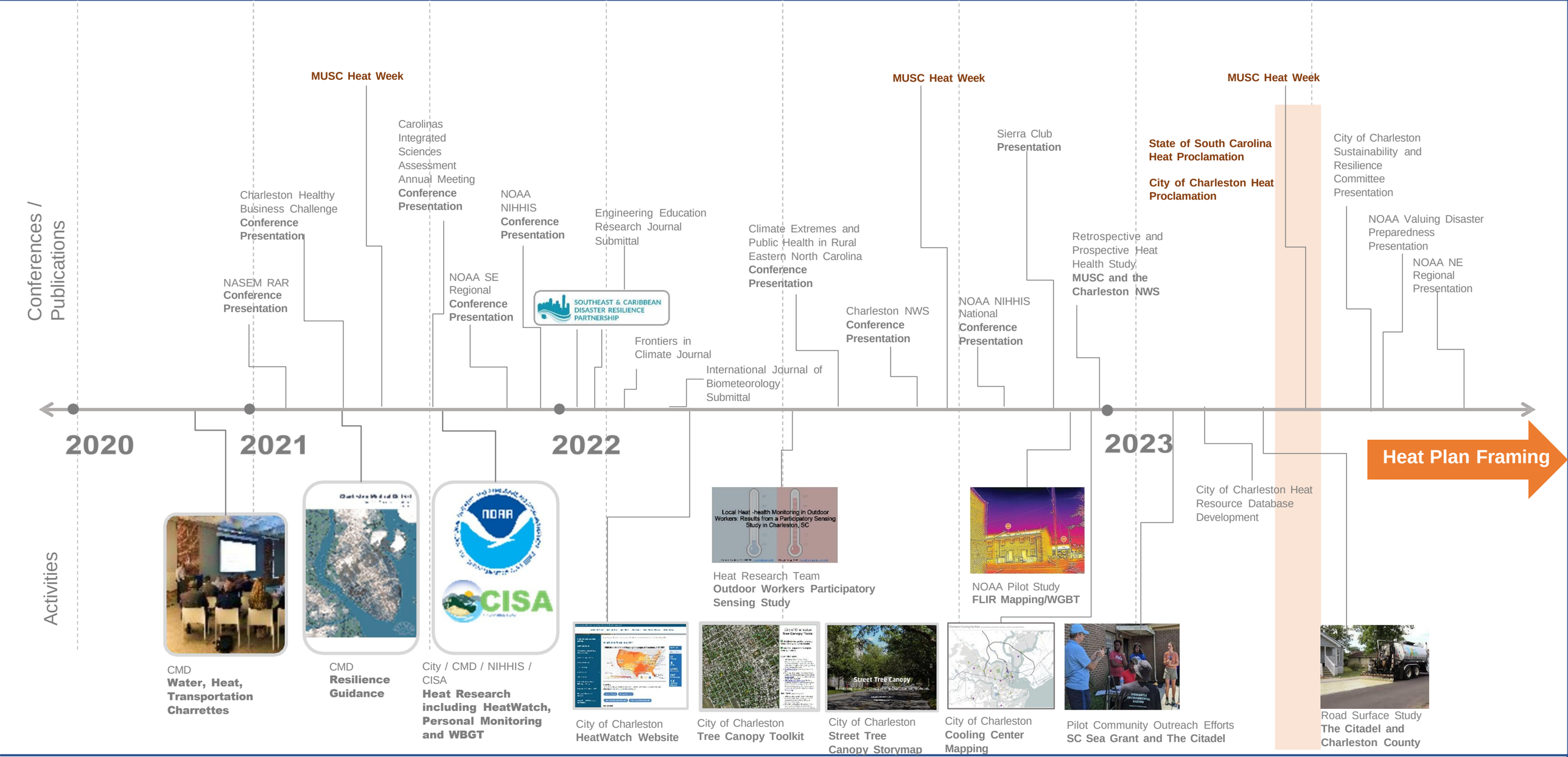

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Charleston Heat Research

1 CMD Heat Research

Used LANDSAT to spatialize hot areas

Janice Barnes, Climate Adaptation Partners
Leo Temko, Climate Adaptation Partners

Used FLIR and GPS to visualize materials that amplify heat

Hosted Heat Charrette at Charleston Medical District

Dennis Frazier, Charleston Medical District
Rick McMahon, Ralph Johnson VA Medical Center
Ken Hill, Roper St. Francis Hospital
Christine von Kolnitz, MUSC
Ray Huff, Clemson
Mark Wilbert, City of Charleston CRO (formerly)
Steve Hargett, Charleston Medical District (retired CFO MUSC)
Dr. Susan Johnson, MUSC Director, Office of Health Promotion, member of City Wellness Committee

Kirstin Dow, USC
Chip Konrad, UNC-Chapel Hill

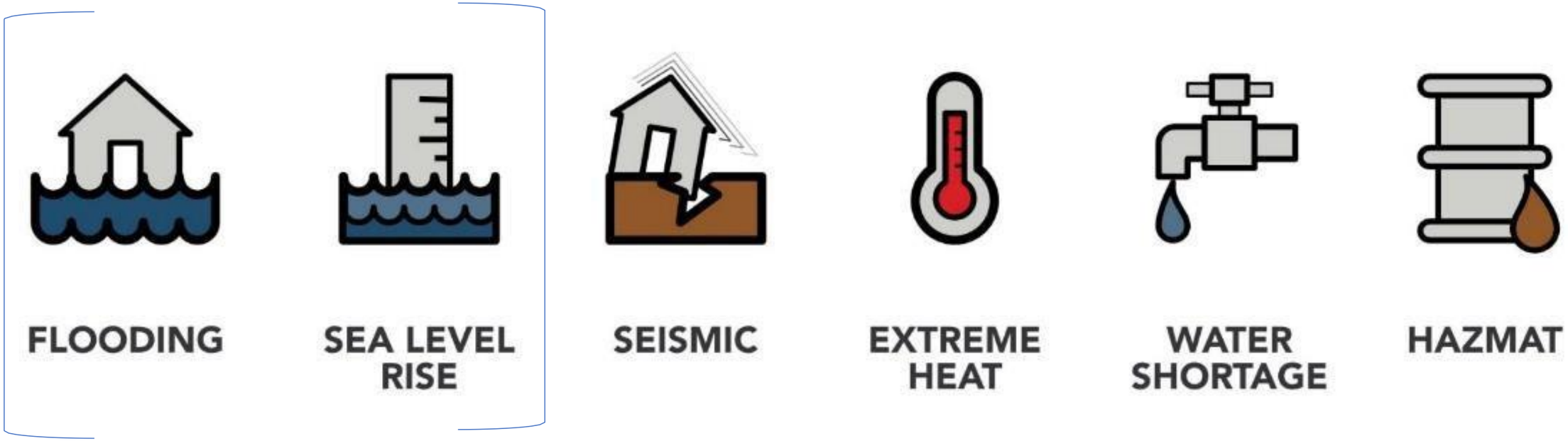
City of Charleston
Fernleaf

2 CISA Heat Research

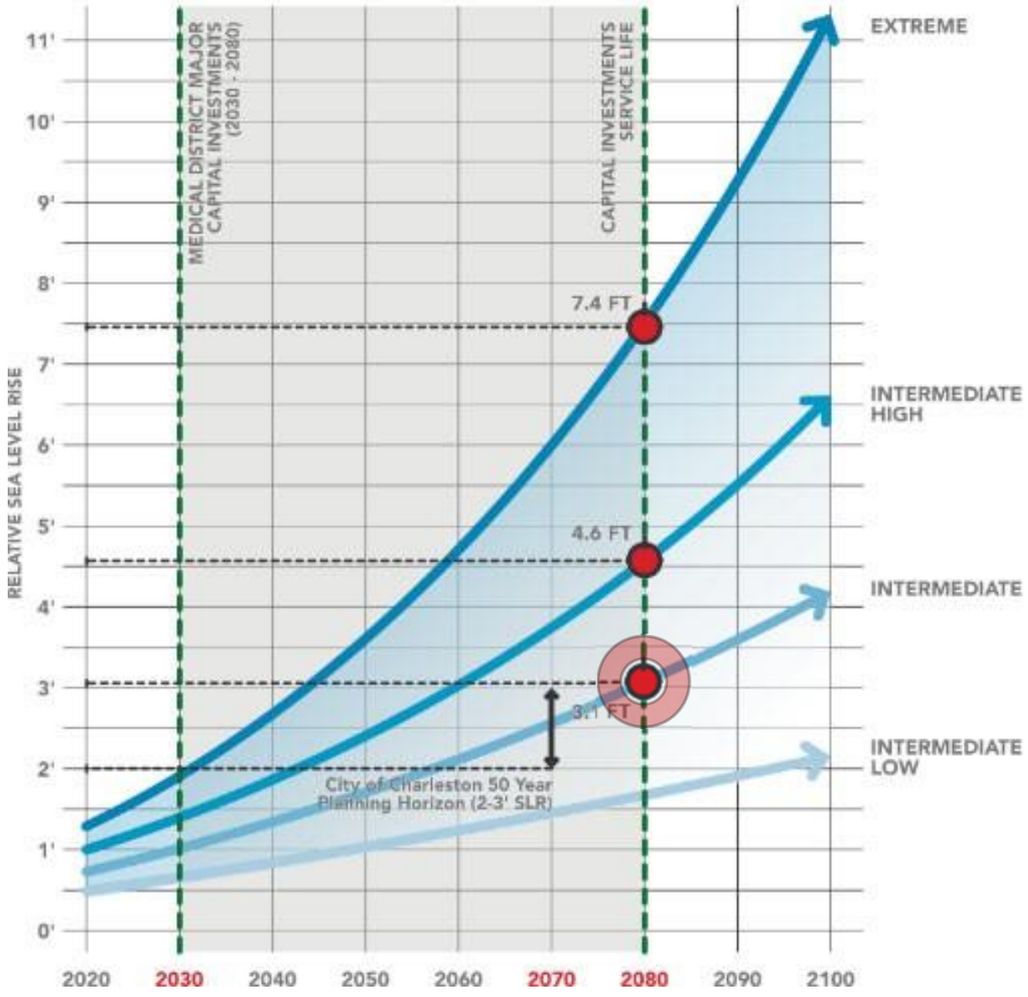
3 HeatWatch Research

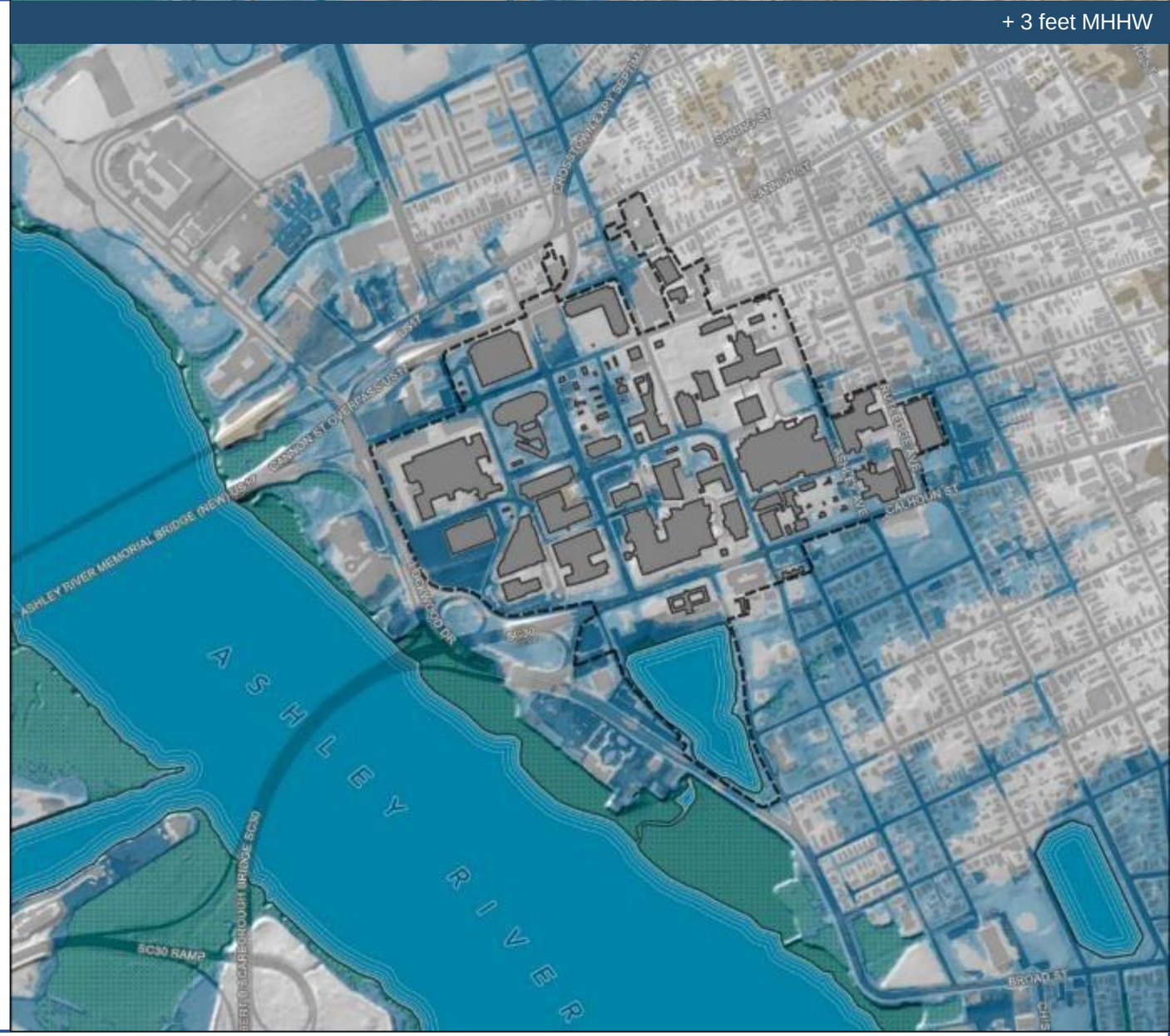
4 Expanding and Sharing Research

Charleston Vulnerabilities Assessment



Rising Waters





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Upcoming Projects

+$2 billion @ CMD

MUSC Replacement Hospital

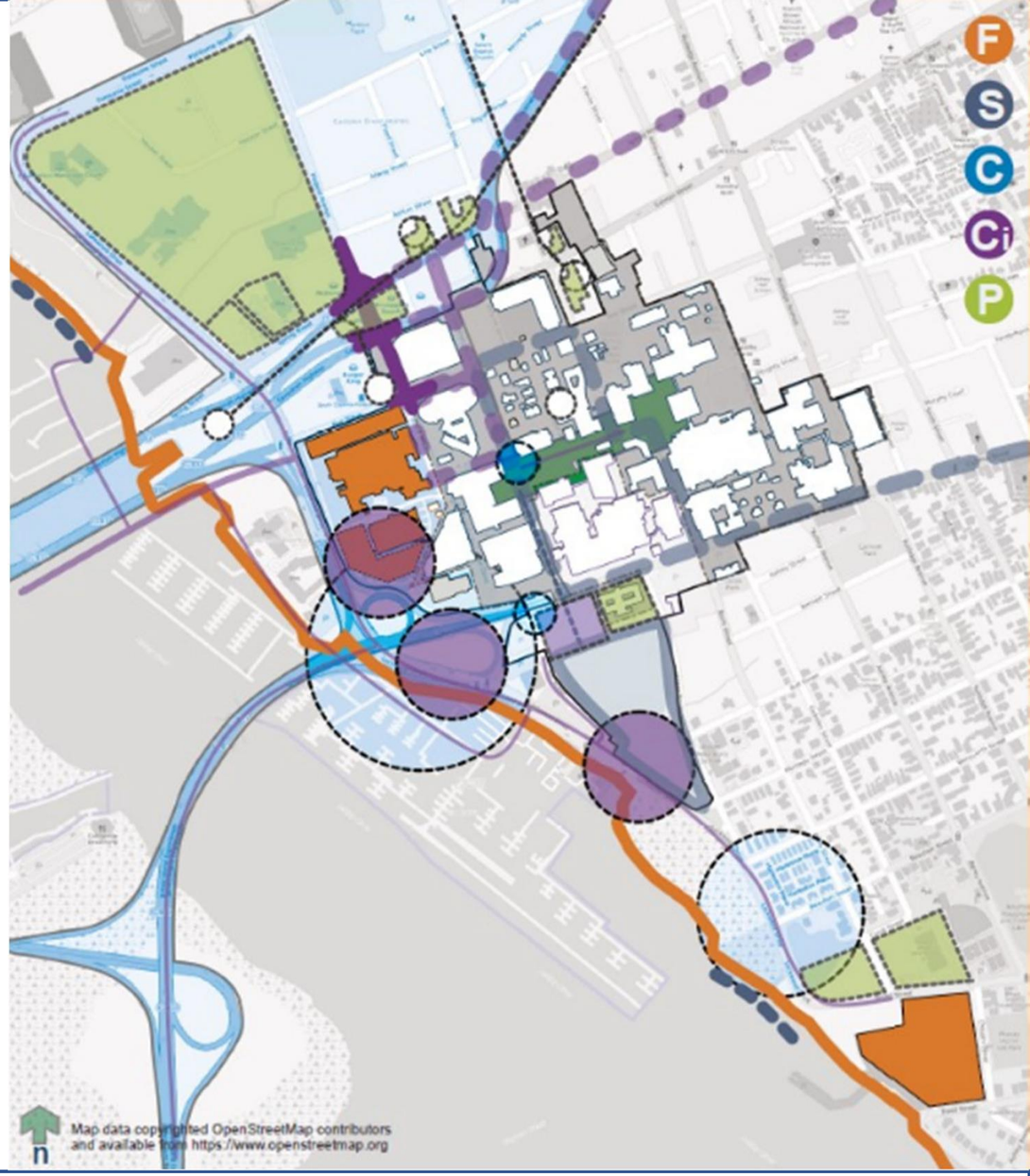
VA Bed Tower, Garage and Upgrades

+ USACE

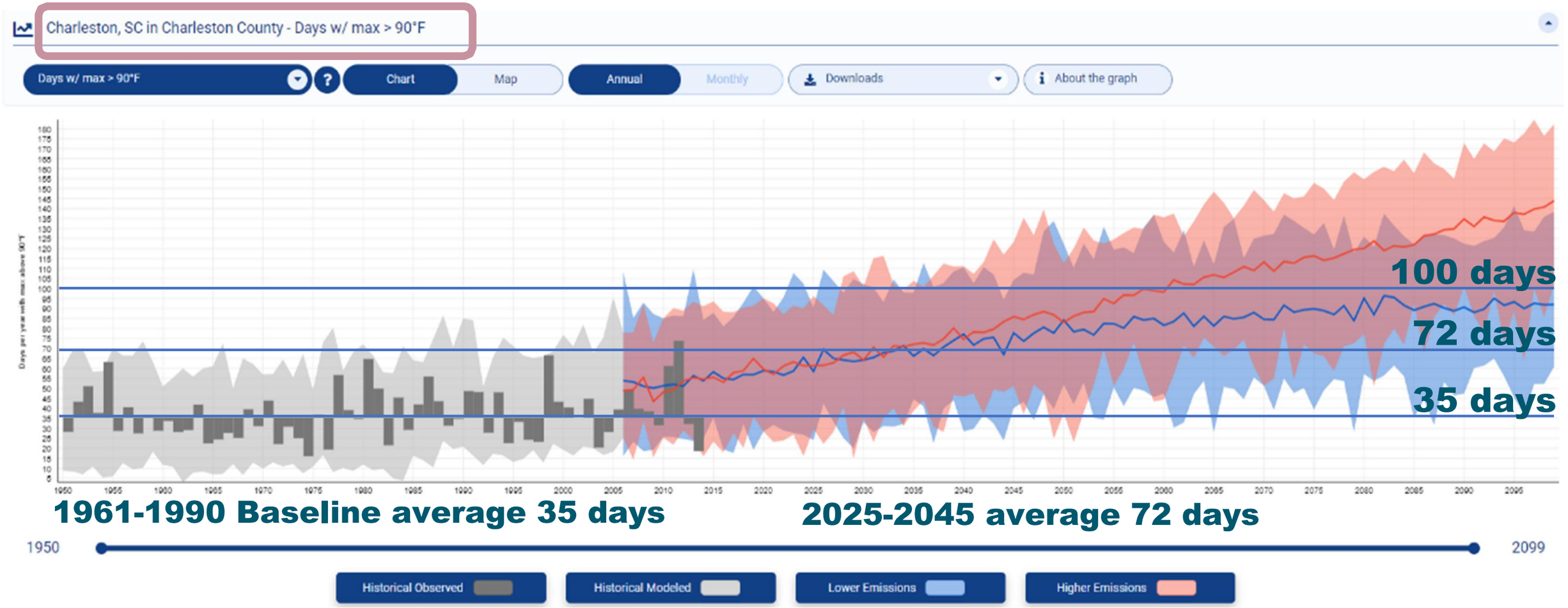
+ City Projects

+ SC DoT

+ West Edge



Rising Heat



Source: US Climate Resilience Toolkit / Dr. Kirstin Dow / CISA

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Heat is Deadly

In the south, heat is a given, **but it's getting hotter than it used to be**.

Increased heat exposure impacts health.

Heat kills more people annually than any other weather hazard.

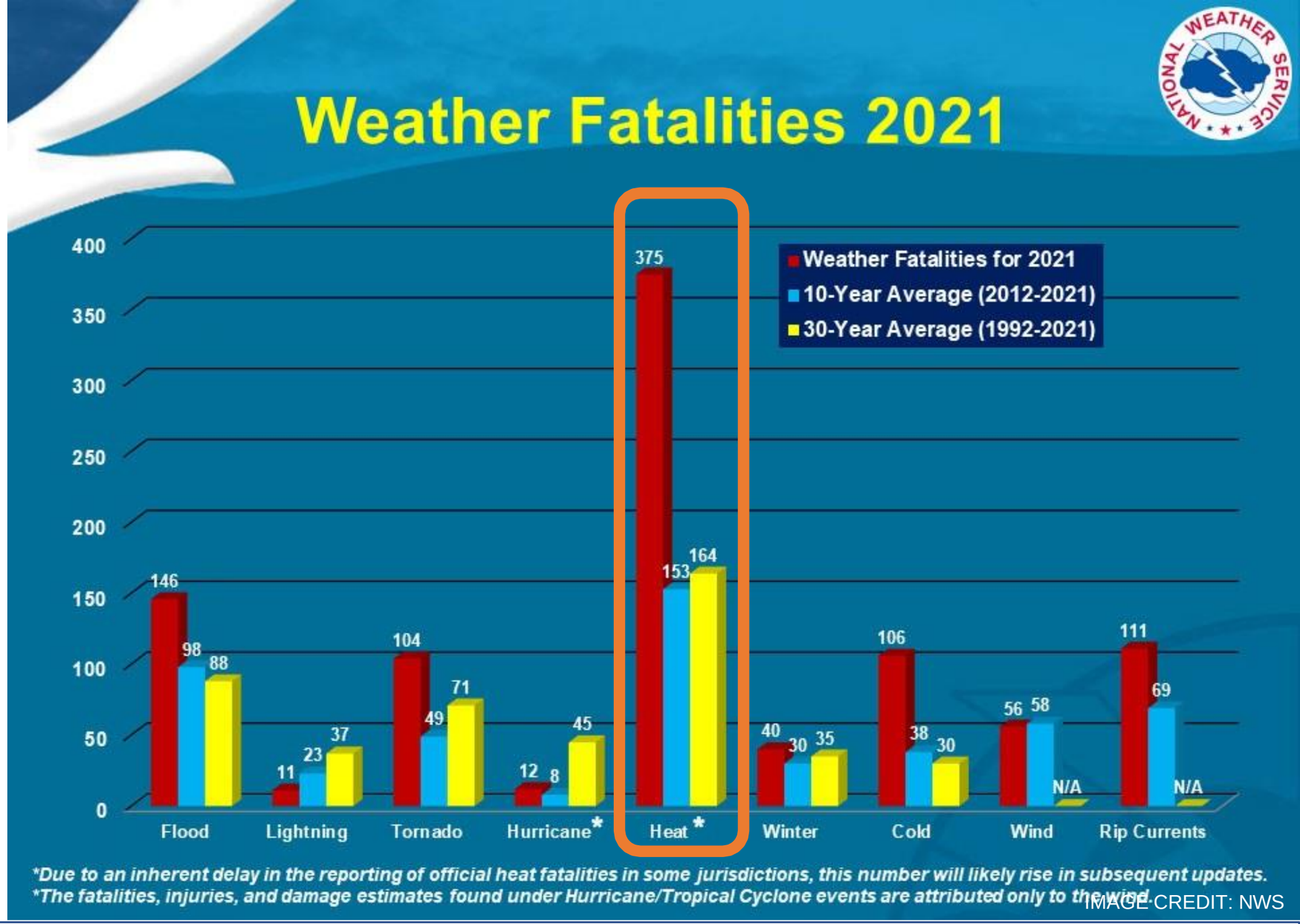

IMAGE CREDIT: NWS

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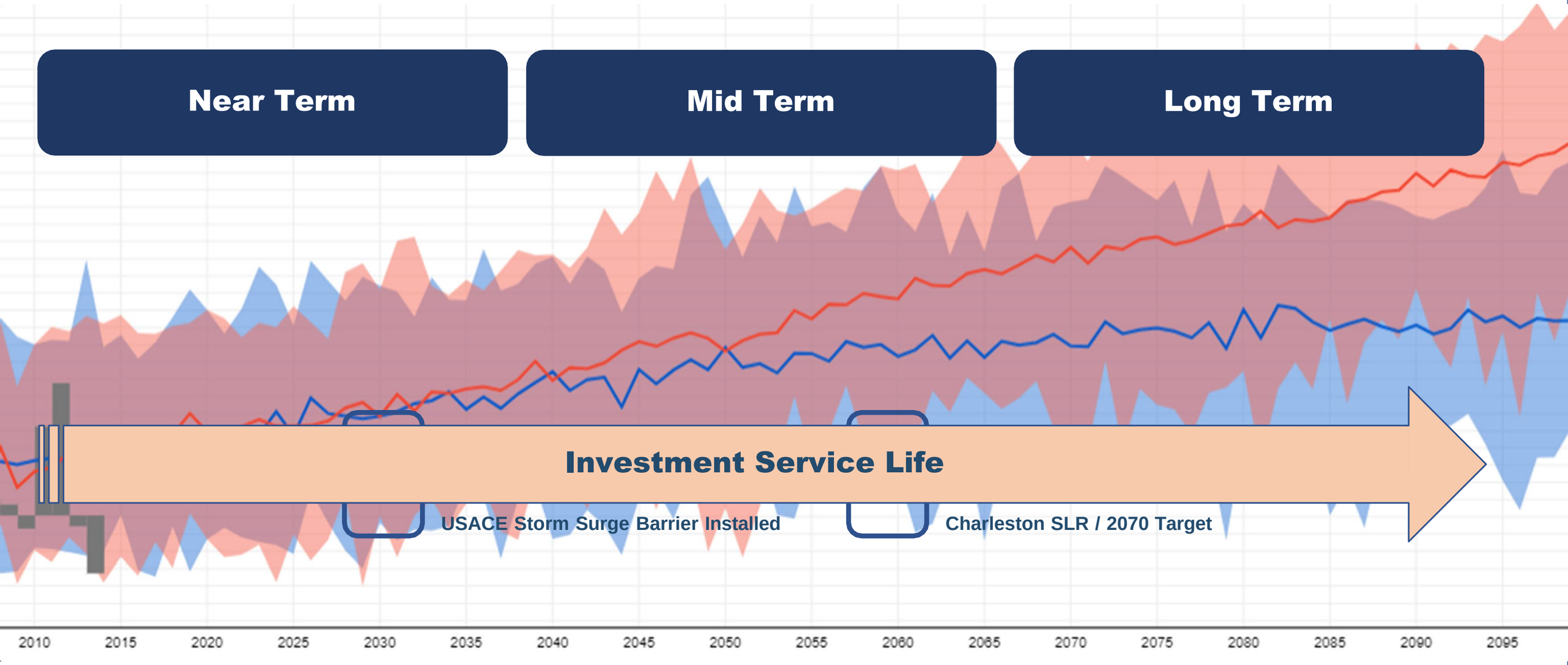
Investment Service Life



Surface Temperature

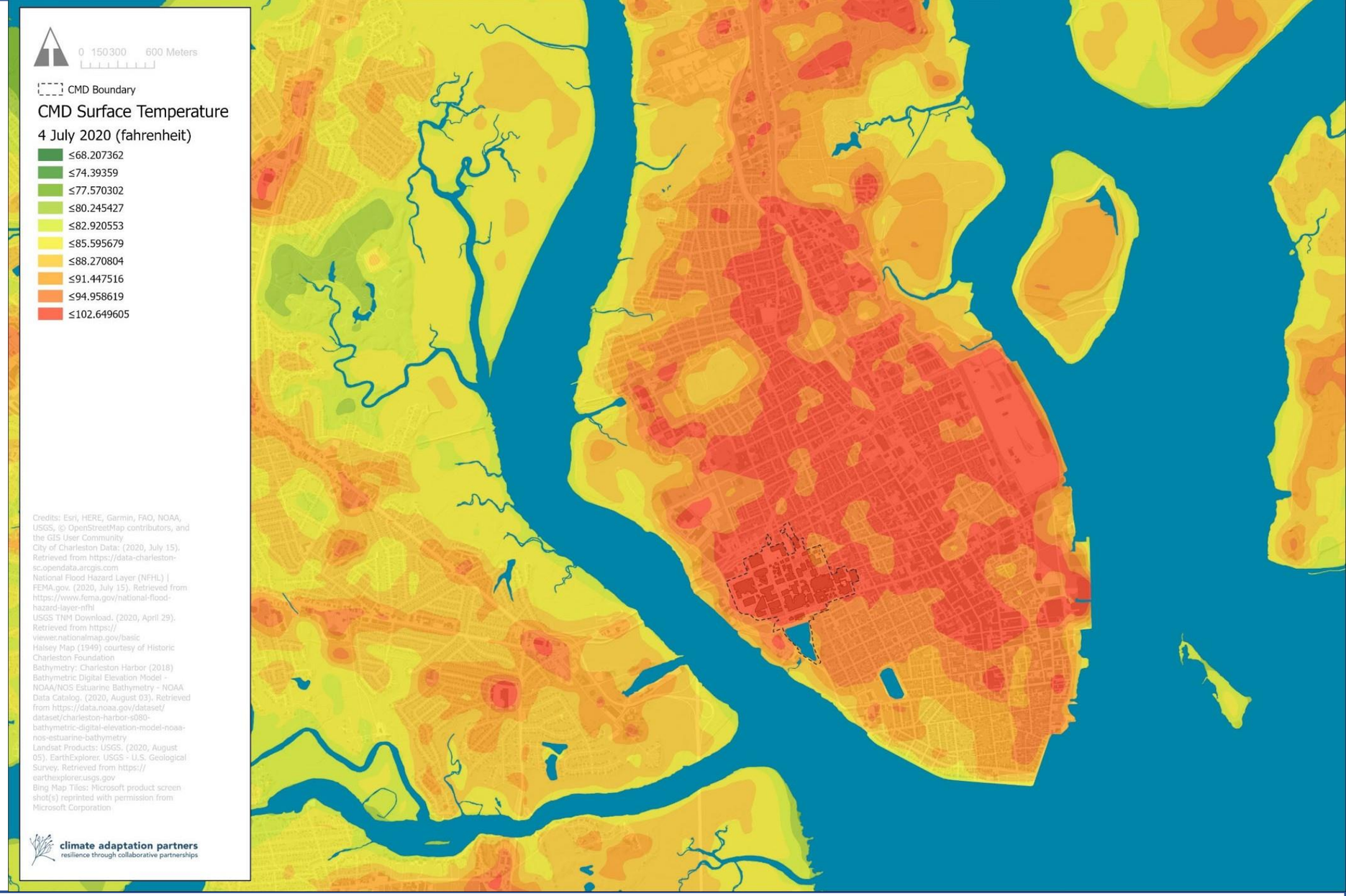
Landsat 8 Operational Land Imager (OLI)

NDVI

- Band 4: Red
- Band 5: Near Infrared

Land Surface Temperature

- Band 10: Thermal Infrared Sensor (TIRS1)



FLIR ONE Gen 3

Outputs

Relative comparison

Surface temperature

Accuracy of +/- 5%

Range -20C-+120C

Limitations

Single Surface only

Battery Life / Circuit Impact

Image Registration

ArcGIS Collector + Bad Elf GPS Pro

Outputs

Geolocated survey points

Custom web-enabled app

Web-hosted geospatial layer ready for GIS processing

Limitations

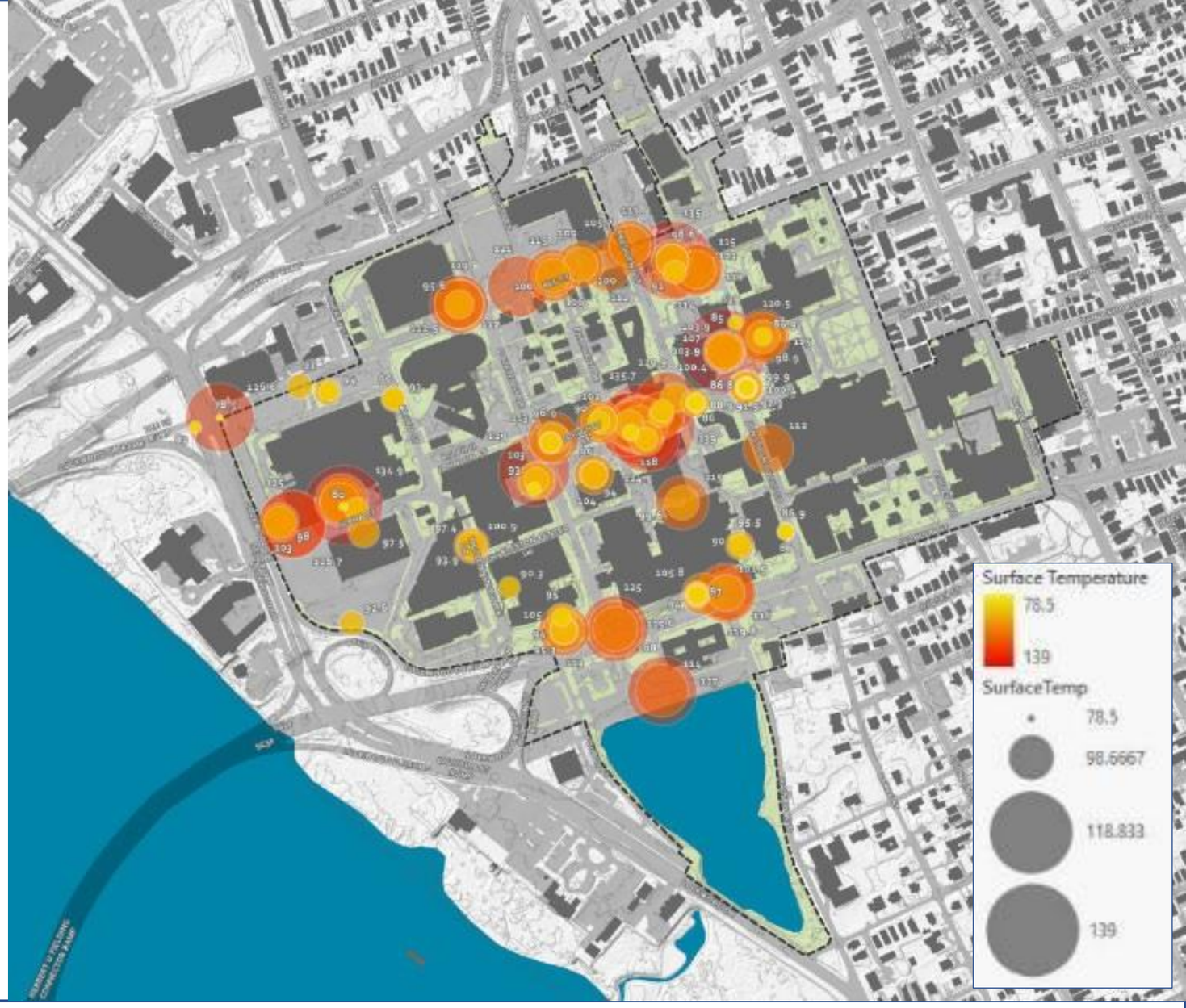
2.5m Stationary Accuracy

Environmental obstructions can limit accuracy

Surface Temperature Points

27 AUGUST 2020	12 am	6 am	12 pm	6 pm
TEMPERATURE deg. f (high)	75	88	91	90
WIND mph (direction)	1 (nne)	2 (w)	9 (w)	8 (ssw)
HUMIDITY %	94	82	63	80

Historical weather data sourced from timeanddate.com



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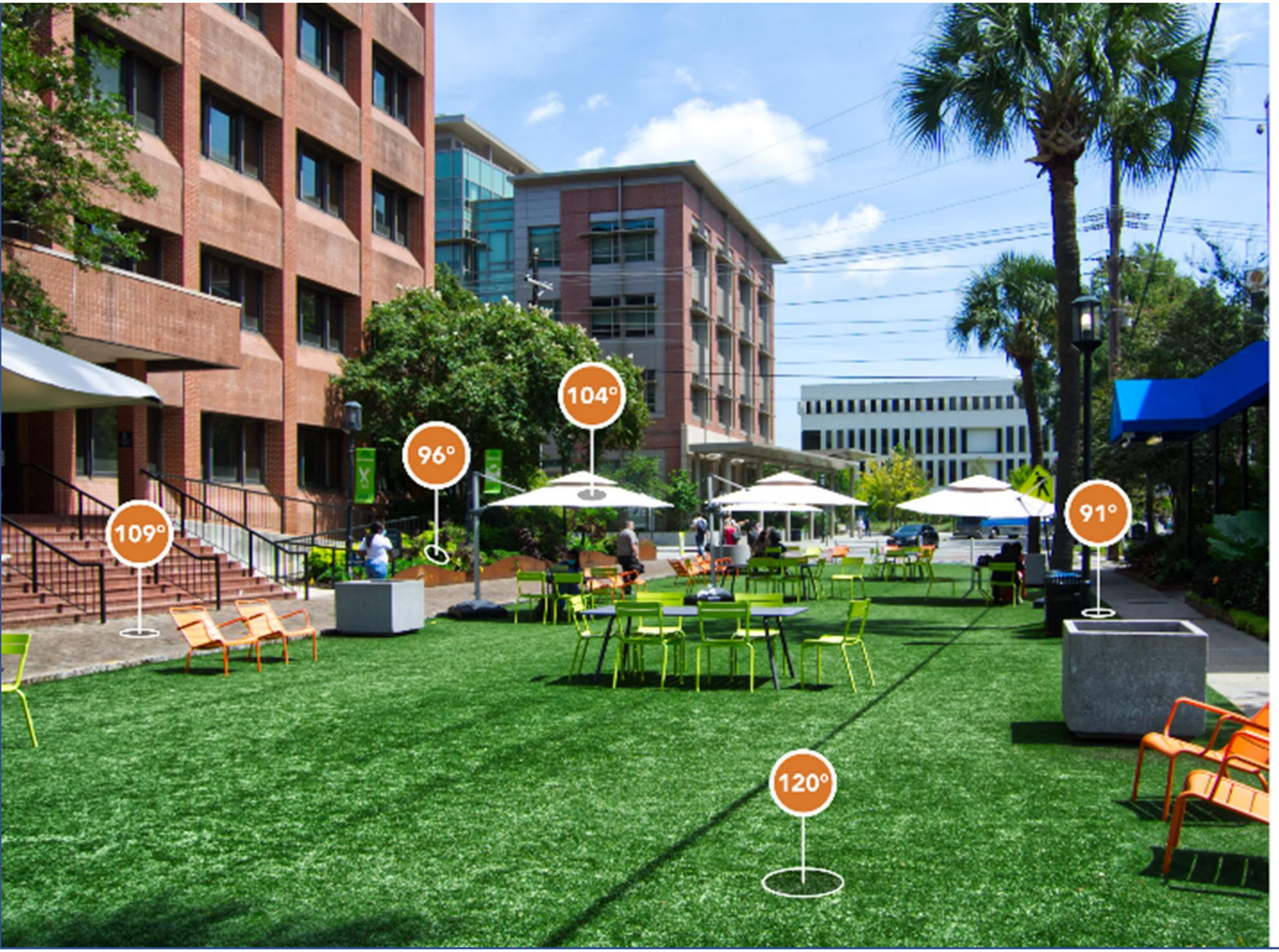
Doughty Street & Greenway



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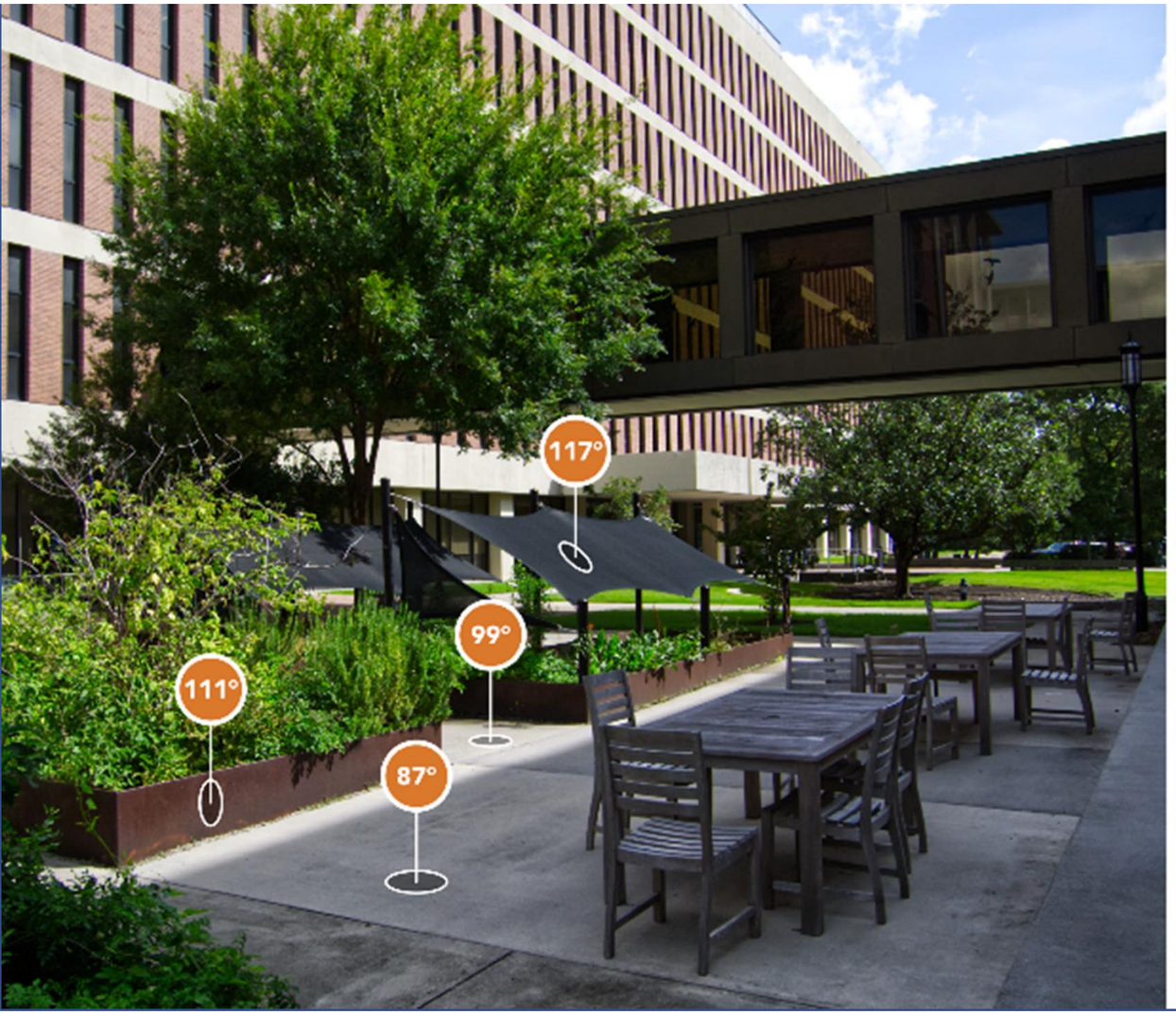
Memorial Garden & Drug Discovery-BioEngineering Plaza



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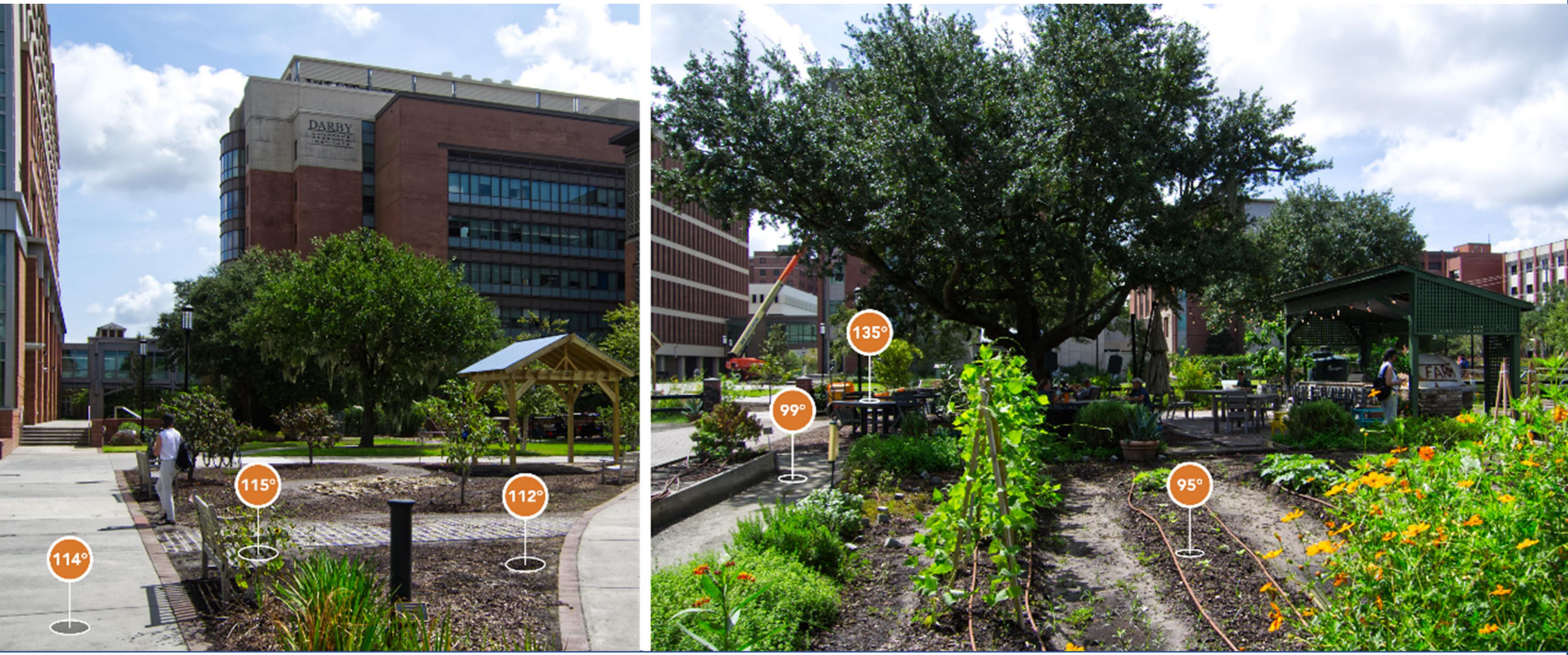
Urban Farm



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Bee Street

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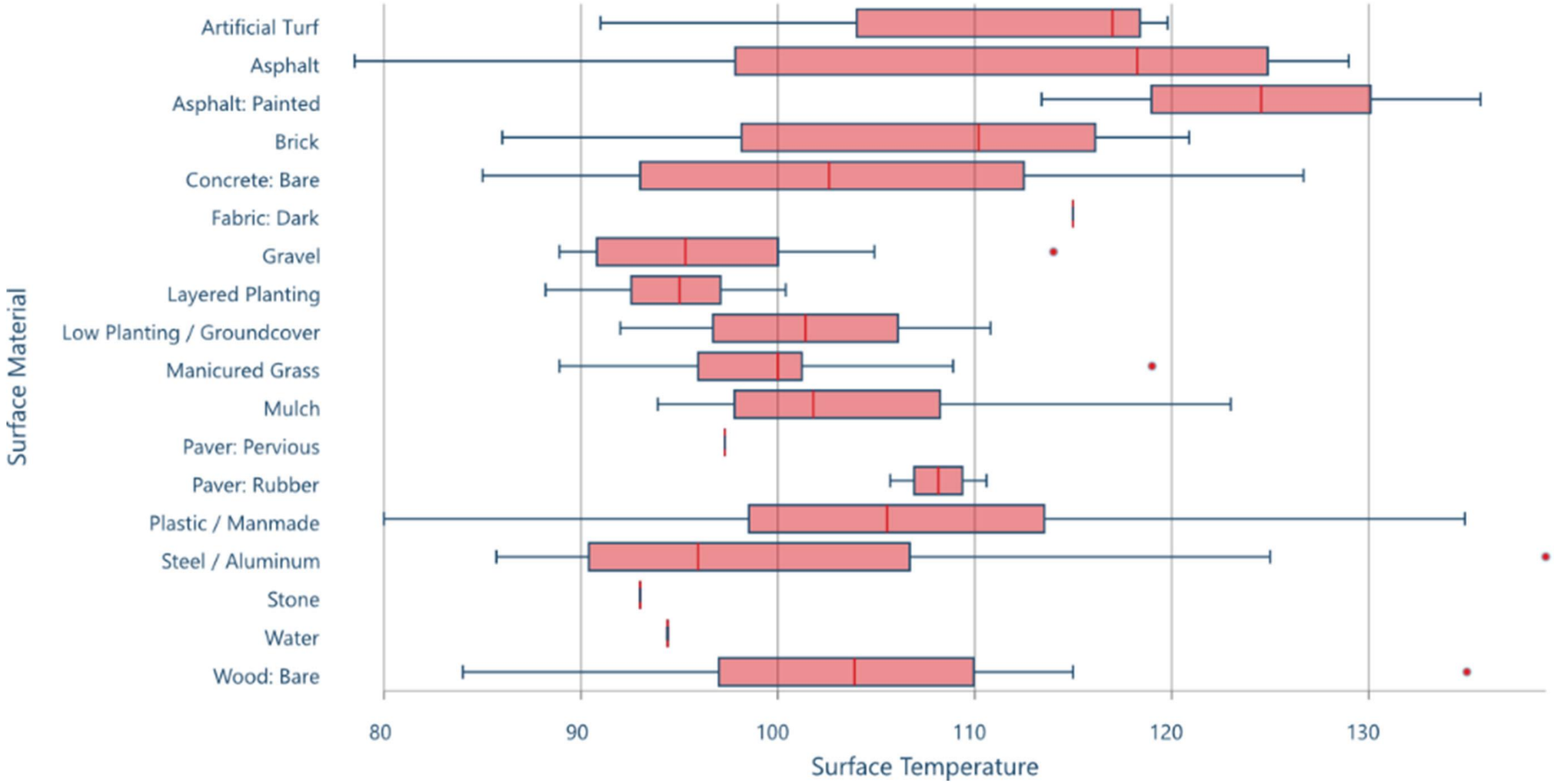
Material Type / Temperature Distribution



~40 degree surface temperature differential

Summer 2020 Charleston Medical District Charrettes

How is heat addressed?

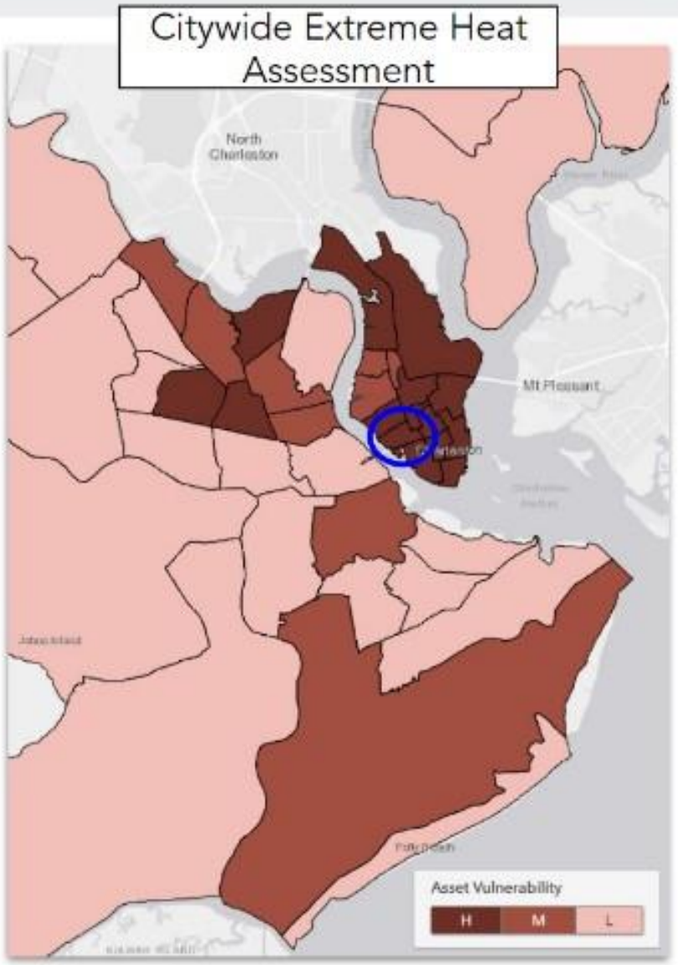
NEMAC+FernLeaf

Vulnerability to Extreme Heat

Key Indicators for the Medical District area:

- Highly developed (more than 70%)
- Sensitive populations (54% households with members 65+ or under 18)
- Low tree canopy (less than 6% area with significant coverage)
- Moderate Socioeconomic Status vulnerability (CDC)

Note: Does not consider populations *served* within the Medical District



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Charleston Heat Research

1 CMD Heat Research

2 **CISA Heat Research**

3 HeatWatch Research

4 Expanding and Sharing Research

CISA Heat Research: Measuring Personal Temperature Exposure & WBGT

Thermochron or Hydrochron iButton

GPS and Heart Rate Data at the Individual Level

Three Groups of Outdoor Workers

Hand-held device that estimates wet bulb globe thermometer

WBGT Pilot Sites

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4 Expanding and Sharing Research

Used ibuttons and gps-enabled watches to monitor participant heart rate during workhours across four weeks

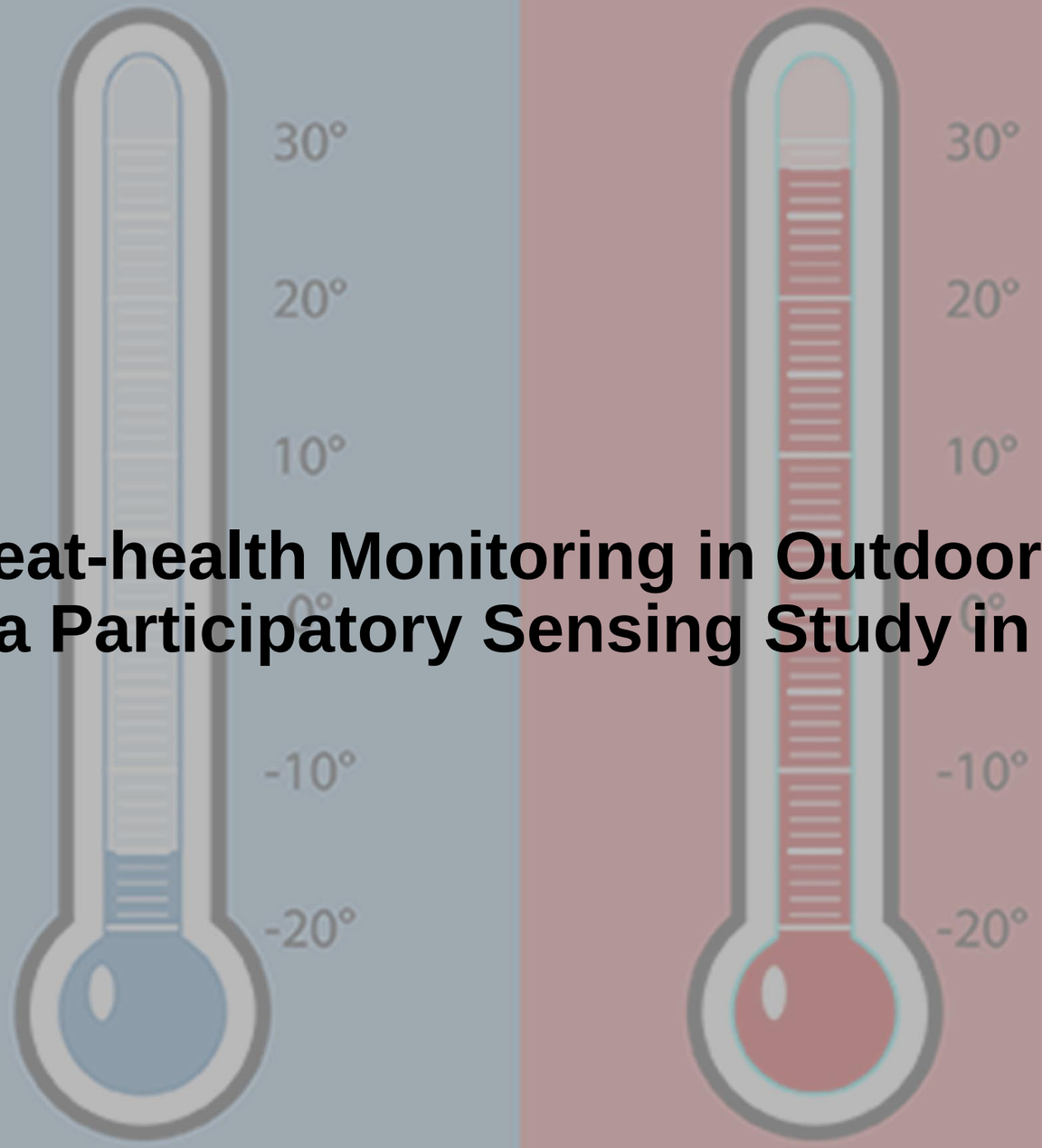
Used wet bulb globe temperature (WBGT) device to measure temperature, humidity and wind speed at designated areas across a number of days

PI: Dr. Kirstin Dow, USC
Stafford Mullin
Grant Farmer
Dr. Jen Runkle, NC State
Dr. Maggie Sugg, Appalachian State

MUSC
Dr. Jerry Reves, MUSC
Robin Smith, MUSC Arboretum and Grounds
Major Dorothy Simmons, MUSC Public Safety
Christine Von Kolnitz, Director of MUSC Sustainability and Recycling

The Citadel
Dr. Scott Curtis, The Citadel James B Near Center for Climate Studies
Jonathan Lewellyn, The Citadel Grounds

Climate Adaptation Partners
Janice Barnes
Leo Temko



Local Heat-health Monitoring in Outdoor Workers: Results from a Participatory Sensing Study in Charleston, SC

Jennifer Runkle, PhD, MSPH jrrunkle@ncsu.edu Maggie Sugg, PhD kovachmm@appstate.edu

Measuring Heat Index Exposure

From: Local Heat-health Monitoring in Outdoor Workers: Results from a Participatory Sensing Study in Charleston, SC (Runkle and Sugg, 2022)

NWS Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Often measured at **weather stations** at airports or removed from city centers

Heat Index → Takes into account temperature + relative humidity

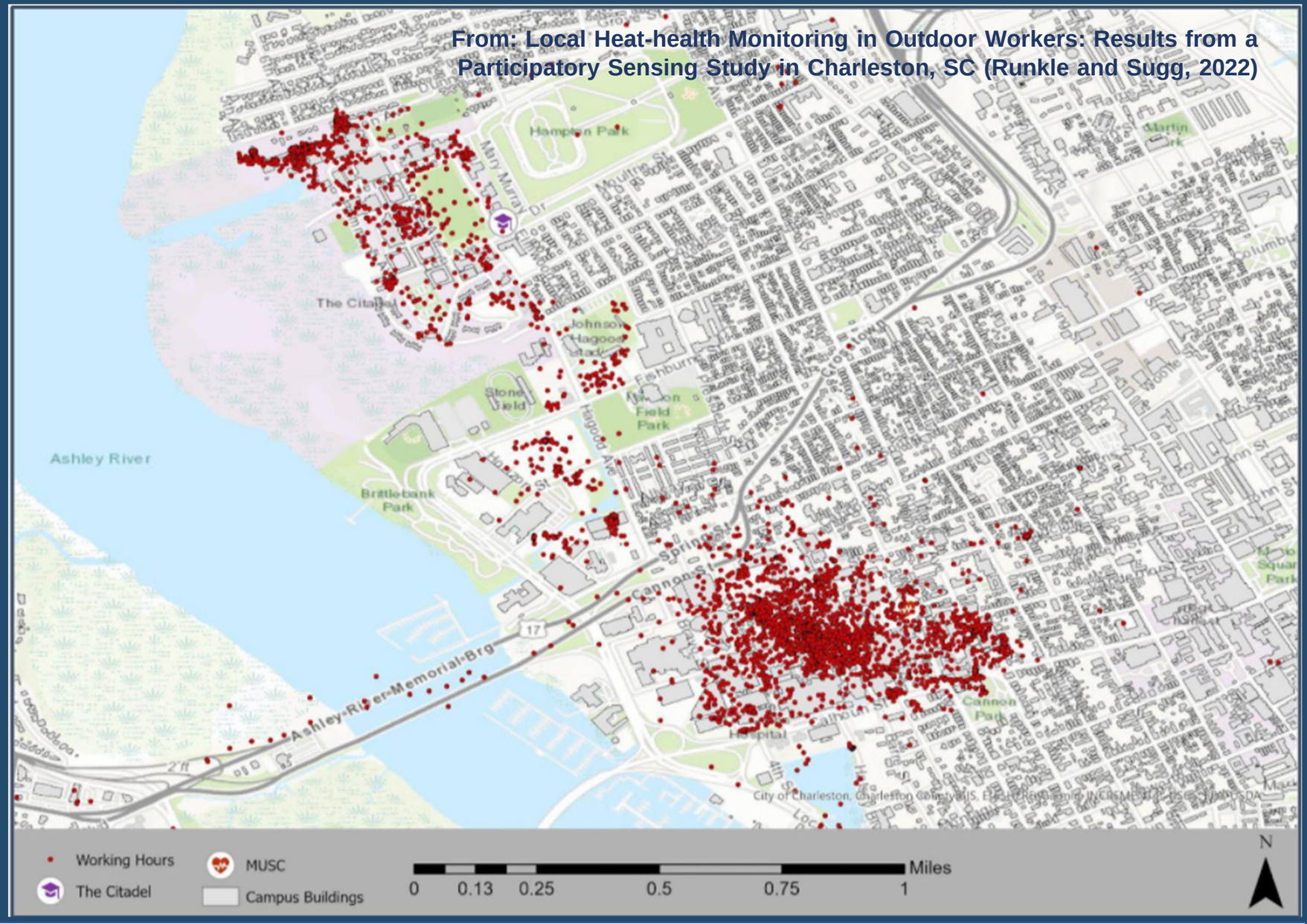
Continuous Monitoring of Personal Heat Index in an Occupationally Exposed Population

3 groups of participants
8,500 observations

Examine exposure misclassification relative to HeatWatch and Weather Station

- Quantity heat exposure metrics (intensity, frequency, and duration) and health effects

- Compare individual experienced temperatures with data from UHI campaign in Charleston



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Key Messages

From: Local Heat-health Monitoring in Outdoor Workers: Results from a Participatory Sensing Study in Charleston, SC (Runkle and Sugg, 2022)

We observed that on average, **worker's personal ambient temperature experience was higher than that recorded at the local weather station**. This was especially true for maximum temperature (the highest temperature recorded for a given day).

Summary of The Citadel Results

Below is the daily temperature exposure for **Week #1** for all participants combined (first column) and for the local weather station (second column):

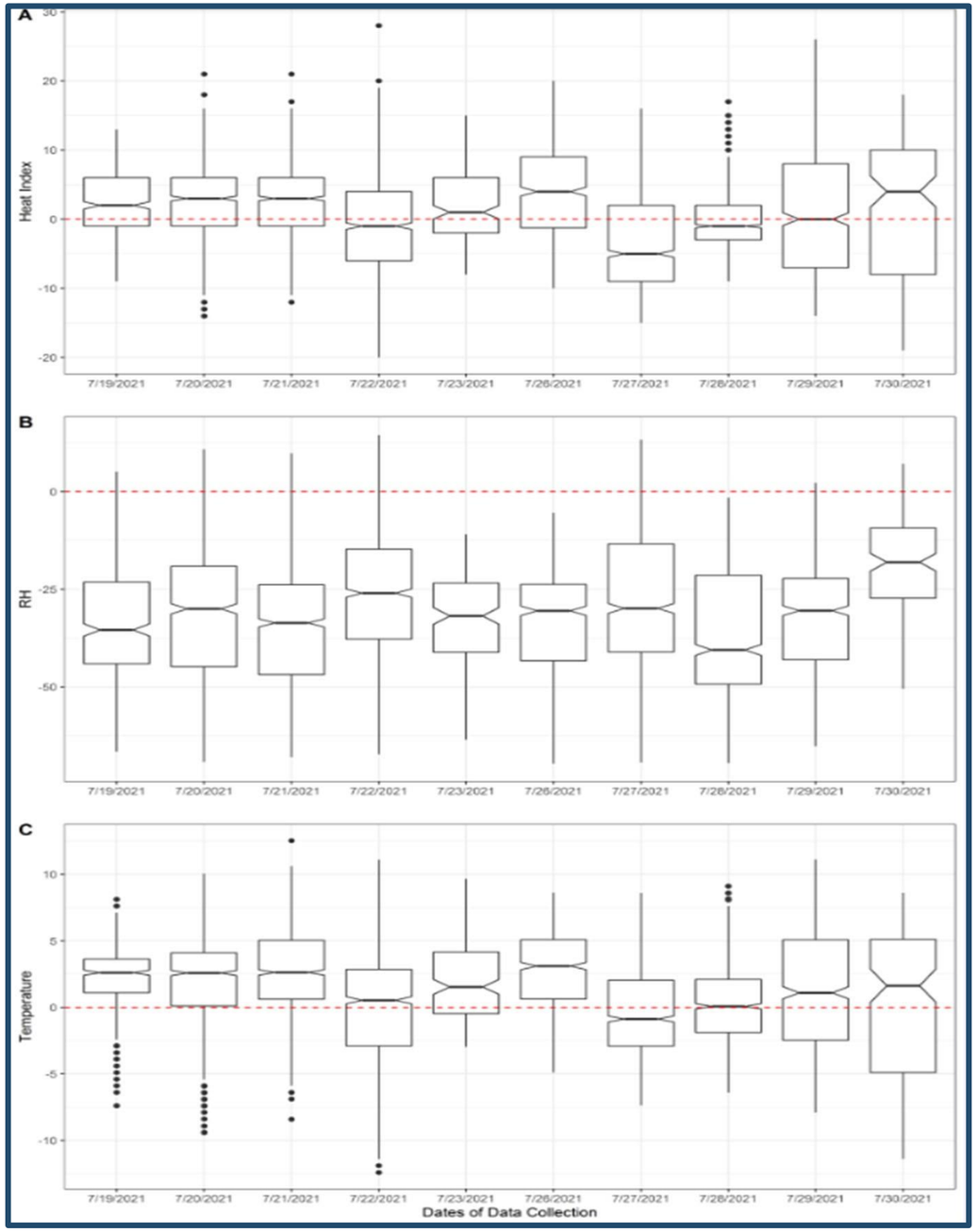
	Monday 7/19		Tuesday 7/20		Wednesday 7/21		Thursday 7/22		Friday 7/23	
Average Temperature	**77.7°**	81.5°	**77.8°**	82.5°	**78.1°**	83.5°	**78.3°**	85.0°	**78.3°**	84.0°
Max Temperature	**97.8°**	87.0°	**97.8°**	88.0°	**97.7°**	90.0°	**97.8°**	90.0°	**97.8°**	89.0°
Minimum Temperature	**62.8°**	76.0°	**62.8°**	77.0°	**62.8°**	77.0°	**65.5°**	80.0°	**66.3°**	79.0°

All Participants | Weather Station

Key Messages

From: Local Heat-health Monitoring in Outdoor Workers: Results from a Participatory Sensing Study in Charleston, SC (Runkle and Sugg, 2022)

We observed on average **worker's personal heat index experience was higher than the local weather station**. However, these differences between worker and weather station heat index values were not as high as the temperature.

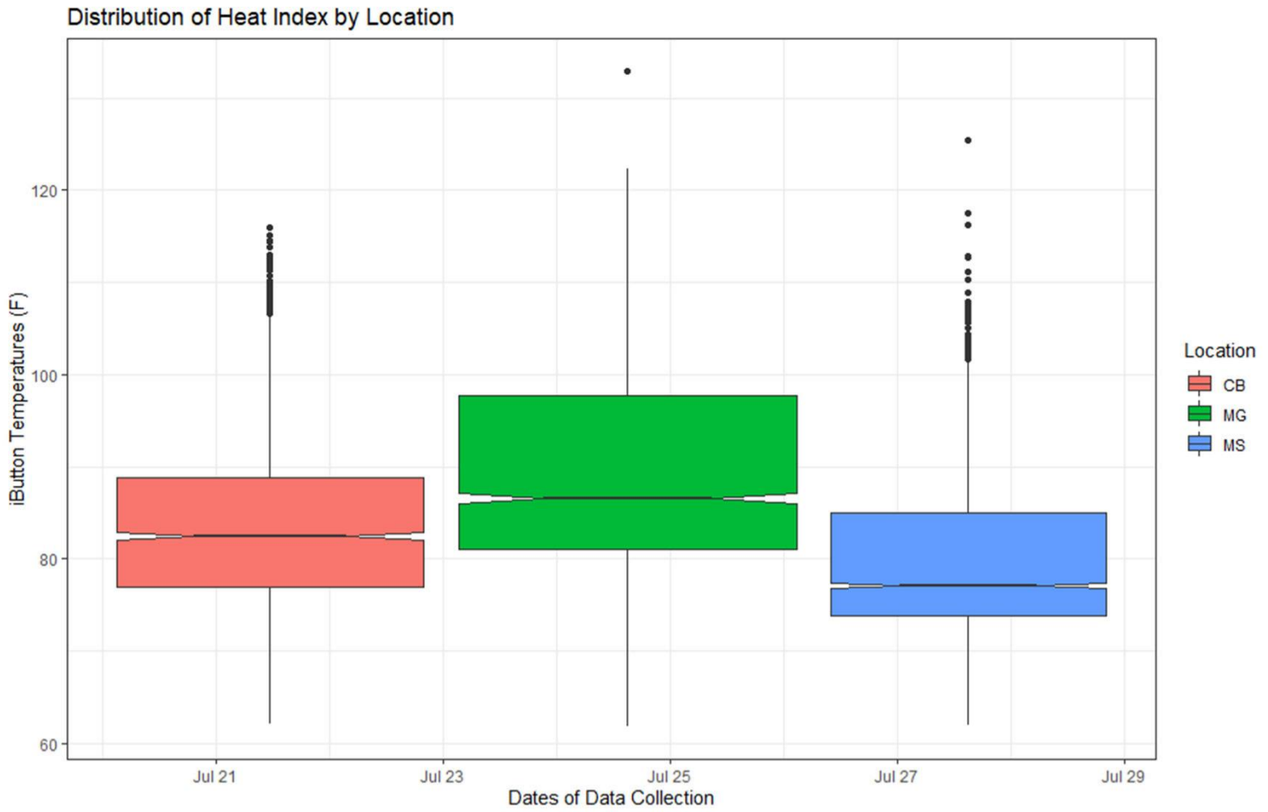


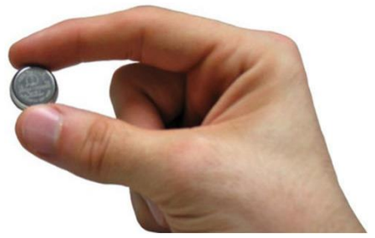
Key Messages

From: Local Heat-health Monitoring in Outdoor Workers: Results from a Participatory Sensing Study in Charleston, SC (Runkle and Sugg, 2022)

Personal temperatures and heat index **values were highest for grounds workers**, particularly at MUSC.

Distribution of Heat Index by Location



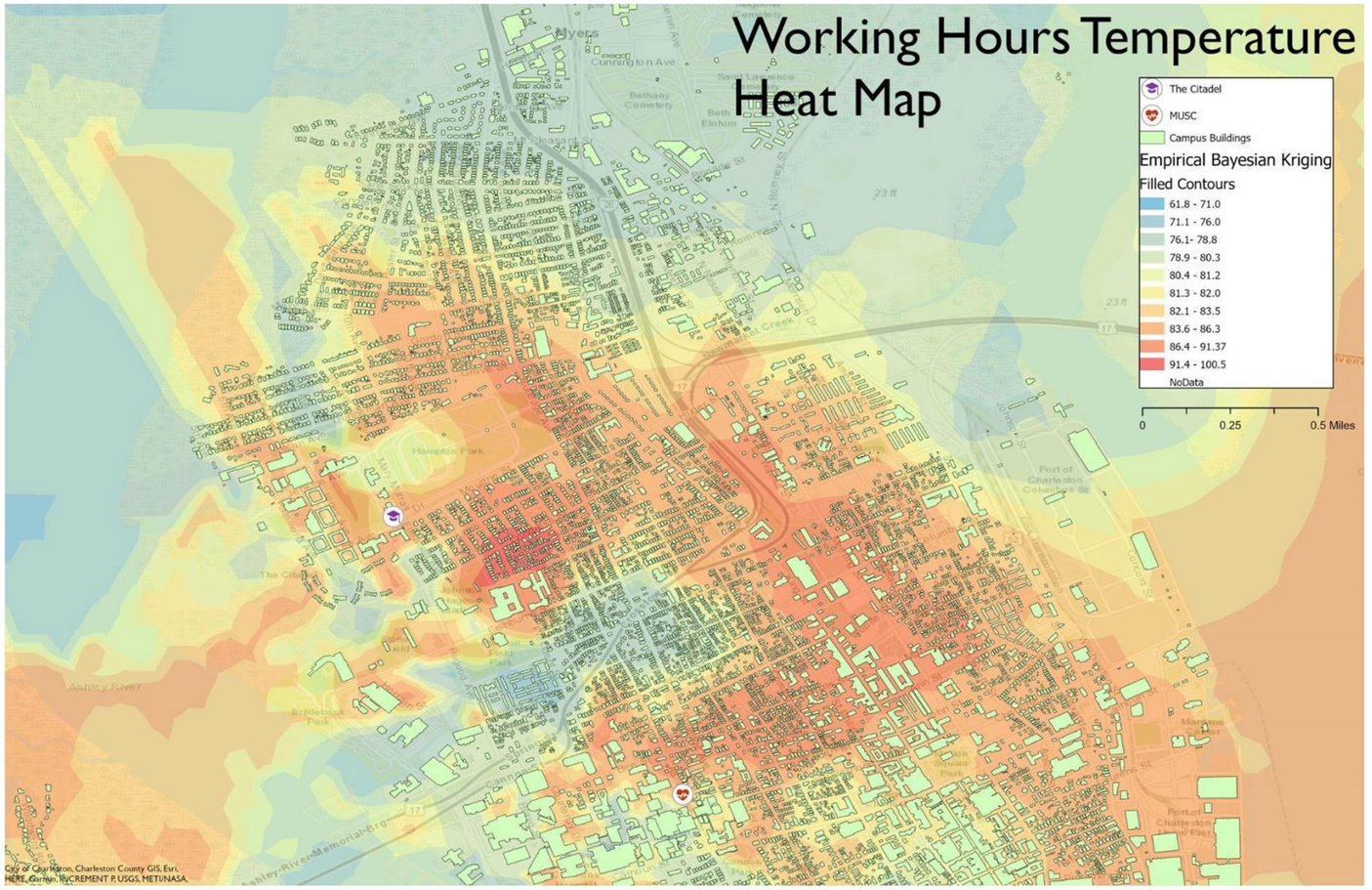


Key Messages

From: Local Heat-health Monitoring in Outdoor Workers: Results from a Participatory Sensing Study in Charleston, SC (Runkle and Sugg, 2022)

We also noted that the **average recorded heat index values for CB and MG were 85F or higher**.

According to the National Institute for Occupational Safety and Health (NIOSH), **heightened heat prevention measures should be triggered for workers**.



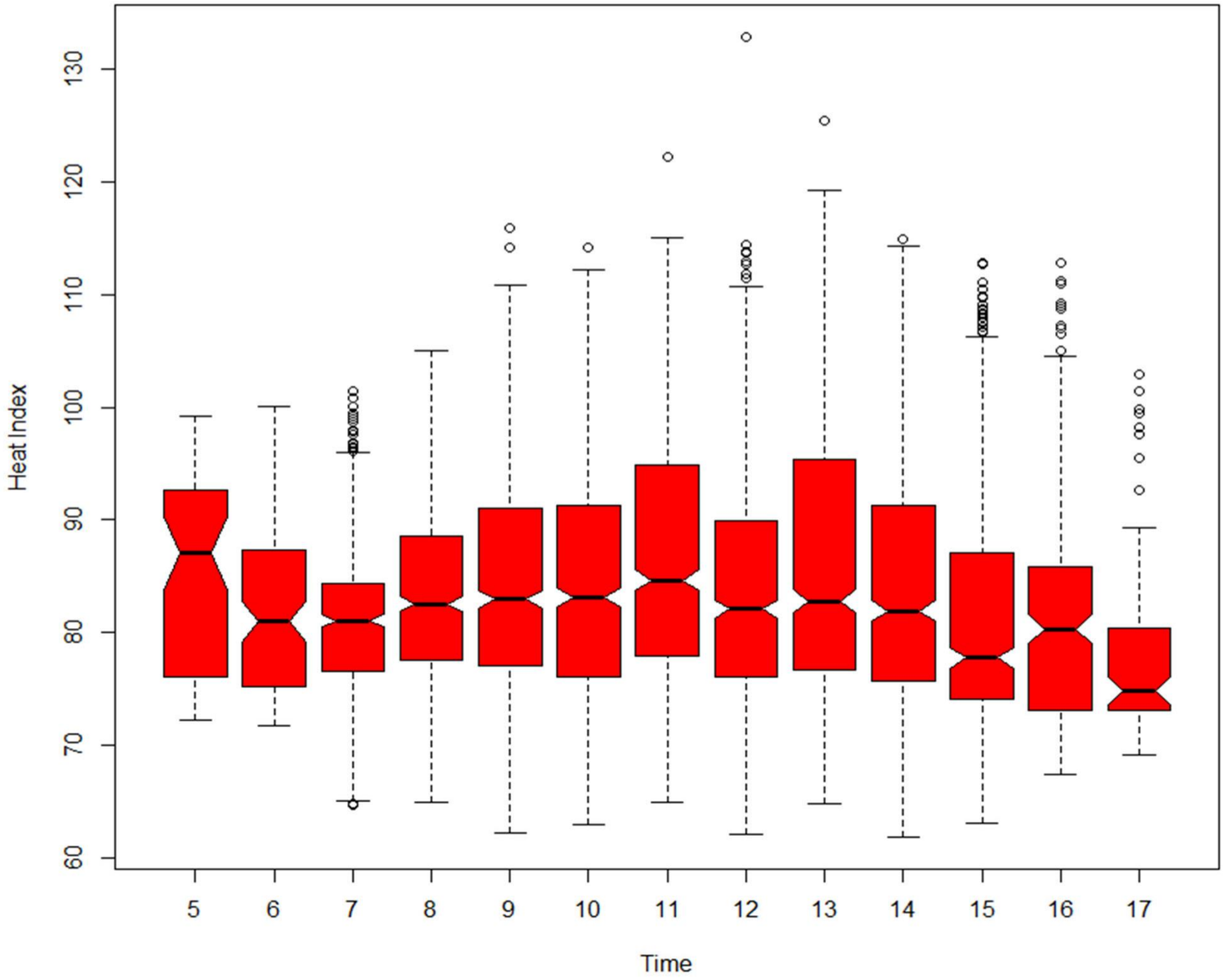
Temperatures modelled based on observations from hydrochron temperature and humidity sensors worn by volunteers July 18-31, 2021

Key Messages

From: Local Heat-health Monitoring in Outdoor Workers: Results from a Participatory Sensing Study in Charleston, SC (Runkle and Sugg, 2022)

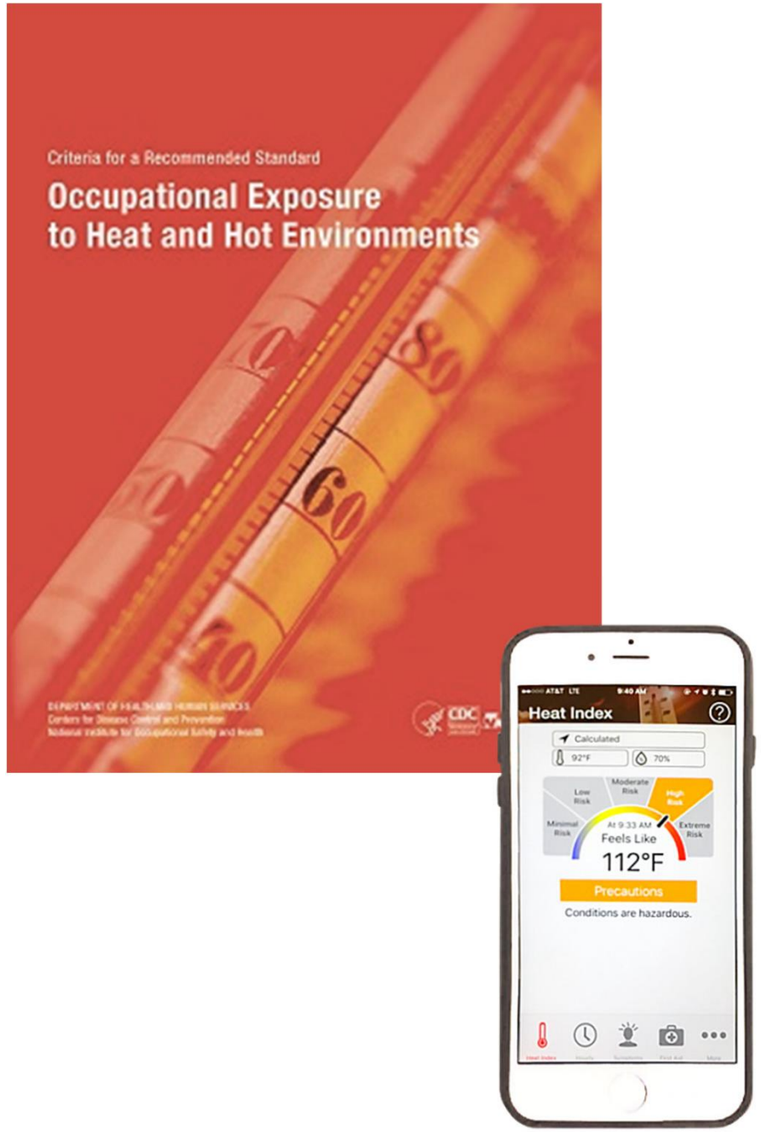
We noted that workers **were shifting their workday to include more work outdoors in the earlier parts of the workday**.

Distribution of Heat Index by Time



NIOSH Recommendations

From: Local Heat-health Monitoring in Outdoor Workers: Results from a Participatory Sensing Study in Charleston, SC (Runkle and Sugg, 2022)



https://www.cdc.gov/niosh/docs/2016-106/

There are a number of ways workers can protect themselves from extreme heat including:

Leadership

1. **Limit time in the heat and/or increase recovery time** in a cool environment
2. **Reduce energy expenditure** demands of the job to generally cooler times of the day
3. **Conduct trainings** about heat stress and how to recognize the signs/symptoms at work
4. **Increase rest breaks and shorten work periods** during extreme heat periods
5. Develop and use **heat acclimatization plan** at work
6. Implement a **buddy system** where workers observe each other for signs of heat intolerance
7. Require workers to conduct **self-monitoring**

Personal

1. **Increase physical fitness** outside of work
2. **Drink water frequently**

Charleston Heat Research

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Used ibuttons and gps-enabled watches to monitor participant heart rate during workhours across four weeks

PI: Dr. Kirstin Dow, USC
Stafford Mullin
Grant Farmer
Dr. Jen Runkle, NC State
Dr. Maggie Sugg, Appalachian State

Used wet bulb globe temperature (WBGT) device to measure temperature, humidity and wind speed at designated areas across a number of days

PI: Dr. Chip Konrad, UNC Chapel Hill
Jordan Clark
Stafford Mullin
Grant Farmer
Student Volunteers

3 HeatWatch Research

4 Expanding and Sharing Research

Patterns of Heat Stress Across the Landscape and Its Measurement using Wet Bulb Globe Temperature

Dr. Chip Konrad

Director of the NOAA Southeast Regional Climate Center

Carolina Integrated Science and Assessments Program (CISA)

Professor, Department of Geography

University of North Carolina at Chapel Hill

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Measures of Heat Stress

1. Air temperature
2. Humidity

Heat Index

3. Wind speed
4. Solar Radiation

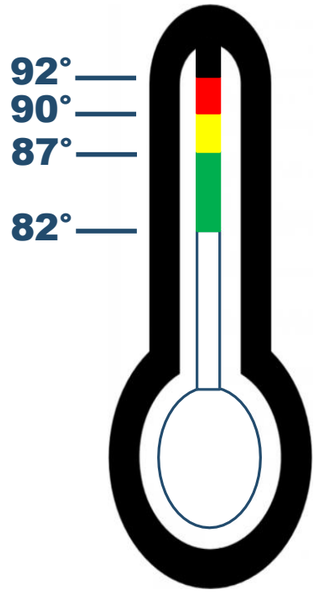
Wet-Bulb Globe Temperature (WBGT)

WBGT THRESHOLDS: High School Athletics Associations

Many states have developed requirements for high school sports practice

WBGT Activity Guidelines and Rest/Break Guidelines for Athletes

Heat Category	WBGT Index (F)	Activity Guidelines
No Flag	Under 82	Normal activities
Low (Green Flag)	82-86.9	Three (3) separate four (4) minute rest breaks per hour of activity
Moderate (Yellow Flag)	87-89.9	Maximum two (2) hour activity time. Four (4) separate four (4) minute rest breaks per hour of activity. For football, student-athletes are restricted to helmet, shoulder pads and shorts during activity.
High (Red Flag)	90-91.9	Maximum one (1) hour activity time. Five (5) separate four (4) minute rest breaks. No protective equipment permitted. No conditioning activities permitted.
Extreme (Black Flag)	Over 92	No outdoor activities



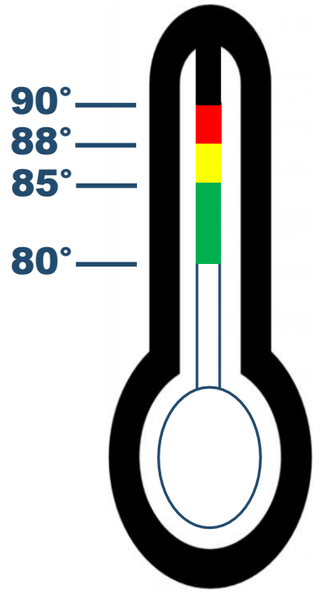
Source: Georgia, South Carolina, and Florida High School Athletics Association

WBGT THRESHOLDS: United States Military

WBGT Activity Guidelines and Rest/Break Guidelines for Athletes

Heat Category	WBGT Index (F)	Activity Guidelines
No Flag	Under 80	Normal Activities
Low (Green Flag)	80-84.9	Discretion required in planning heavy exercise for unseasoned personnel. This is a marginal heat stress limit for all presonnel.
Moderate (Yellow Flag)	85-87.9	Strenuous exercise and activity should be curtailed for new and unacclimated personnel during first 3 weeks of heat exposure.
High (Red Flag)	88-89.9	Strenuous exercise curtailed for all personnel with less than 12 weeks training in hot weather.
Extreme (Black Flag)	Over 90	Physical training and strenuous exercise suspended for all personnel

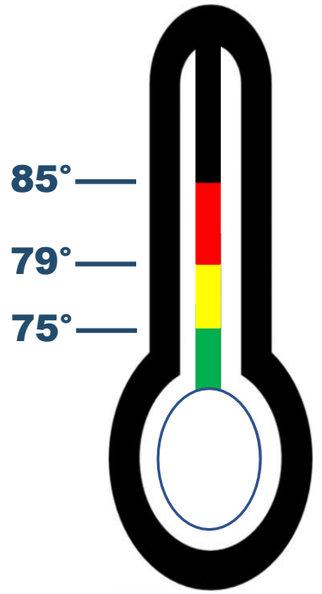
Source: U.S Military Heat Stress Index



WBGT THRESHOLDS: American Academy of Pediatrics

WBGT Activity Guidelines and Rest/Break Guidelines for Athletes

Heat Category	WBGT Index (F)	Activity Guidelines
No Flag	Under 71	All activties allowed, but be alert for prodromes of heat-related illness in prolonged events
Low (Green Flag)	71-74.9	All activties allowed, but be alert for prodromes of heat-related illness in prolonged events
Moderate (Yellow Flag)	75-78.9	Longer rest periods in the shade; enforce drinking every 15 minutes
High (Red Flag)	79-84.9	Stop activity of unacclimatized persons and other persons with high risk; limit activities of all others (disallow long-distance races, cut down further duration of other activities)
Extreme (Black Flag)	Over 85	Cancel all athletic activities

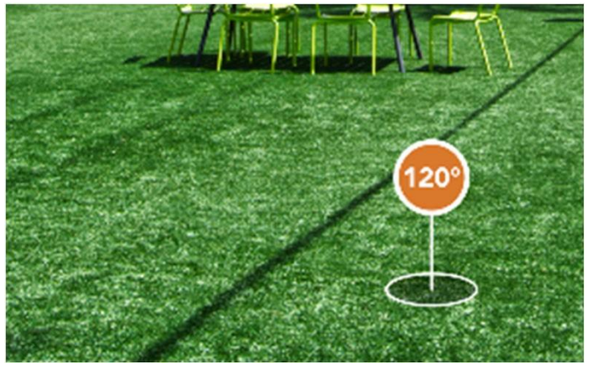


Source: American Academy of Pediatrics

Local patterns of heat stress (WBGT) across a landscape

1. Surface type

Asphalt/concrete is hottest, especially if it is dark colored.
Artificial turf is hotter, but natural grass is hot.



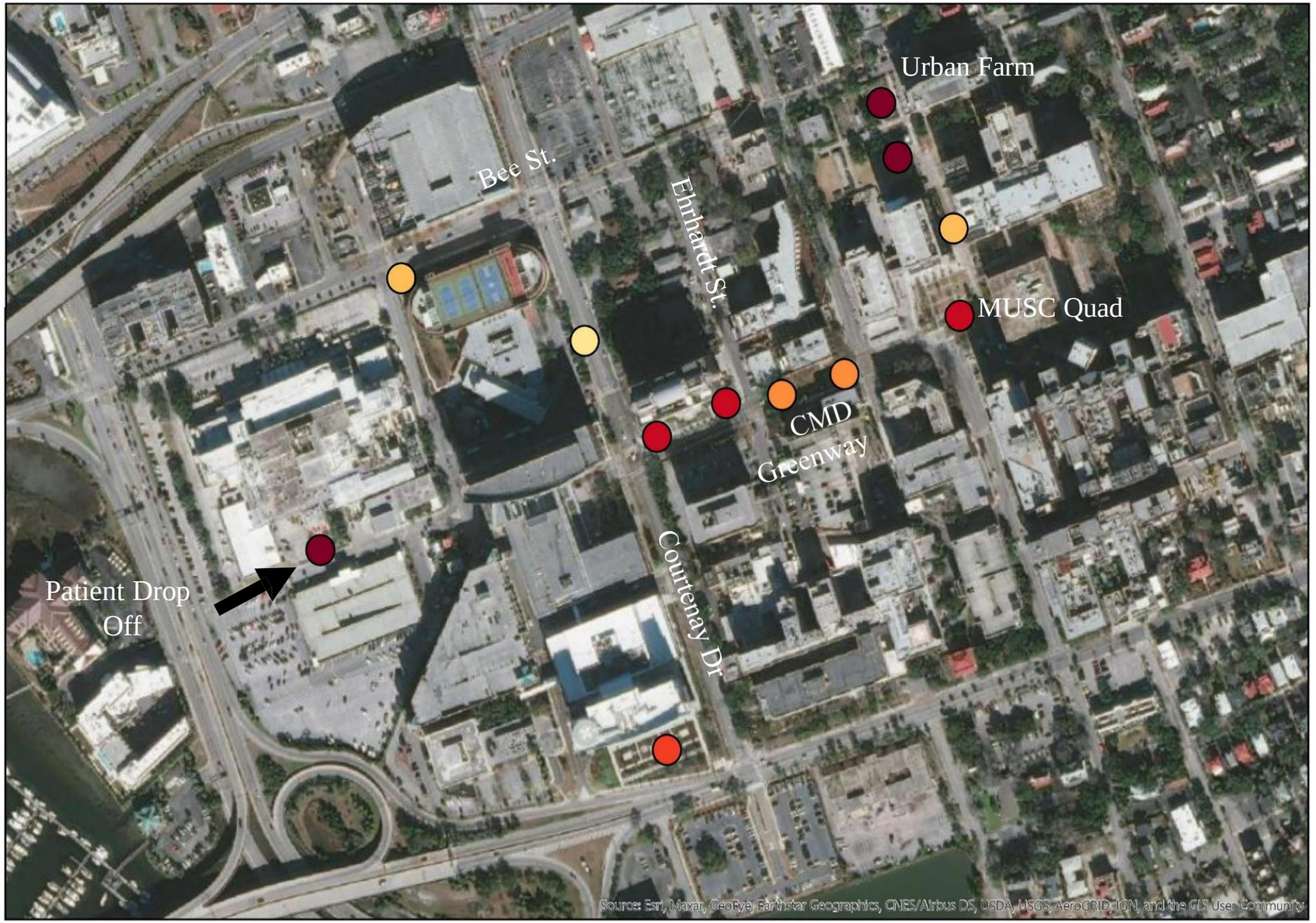
2. Degree of shade

Surfaces that have been shaded most of day are the coolest.
(e.g. north side of quad)

3. Openness of landscape

Closed (lots of trees/buildings nearby) -Hottest (lowest wind speeds)
Open (few trees/buildings) – Coolest (highest wind speeds)


Less Wind = Higher WBGT
Wind Deflecting Off Building
Wind Blocked
Physicians Eyecare Network
Strom Thurmond Research Building
Gazes Cardiac Research Institute
Courtenay Dr
Ehrhardt St
Doughty St
MUSC Health Benign Hematology at Ashley...
Ashley River Tower
MUSC Health Gastroenterology at...
South Carolina Federal Credit Union ATM
Medical University of South Carolina
100
101
114



Maximum WBGT at each location

WBGT (°F)

- ≤76.9
- ≤84.6
- ≤88.8
- ≤92.7
- ≤93.6
- ≤94.8
- ≤95.7

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August 02, 2023

climate adaptation partners
resilience through collaborative partnerships

Charleston Heat Research

1 CMD Heat Research

2 CISA Heat Research

3 HeatWatch Research

4 Expanding and Sharing Research

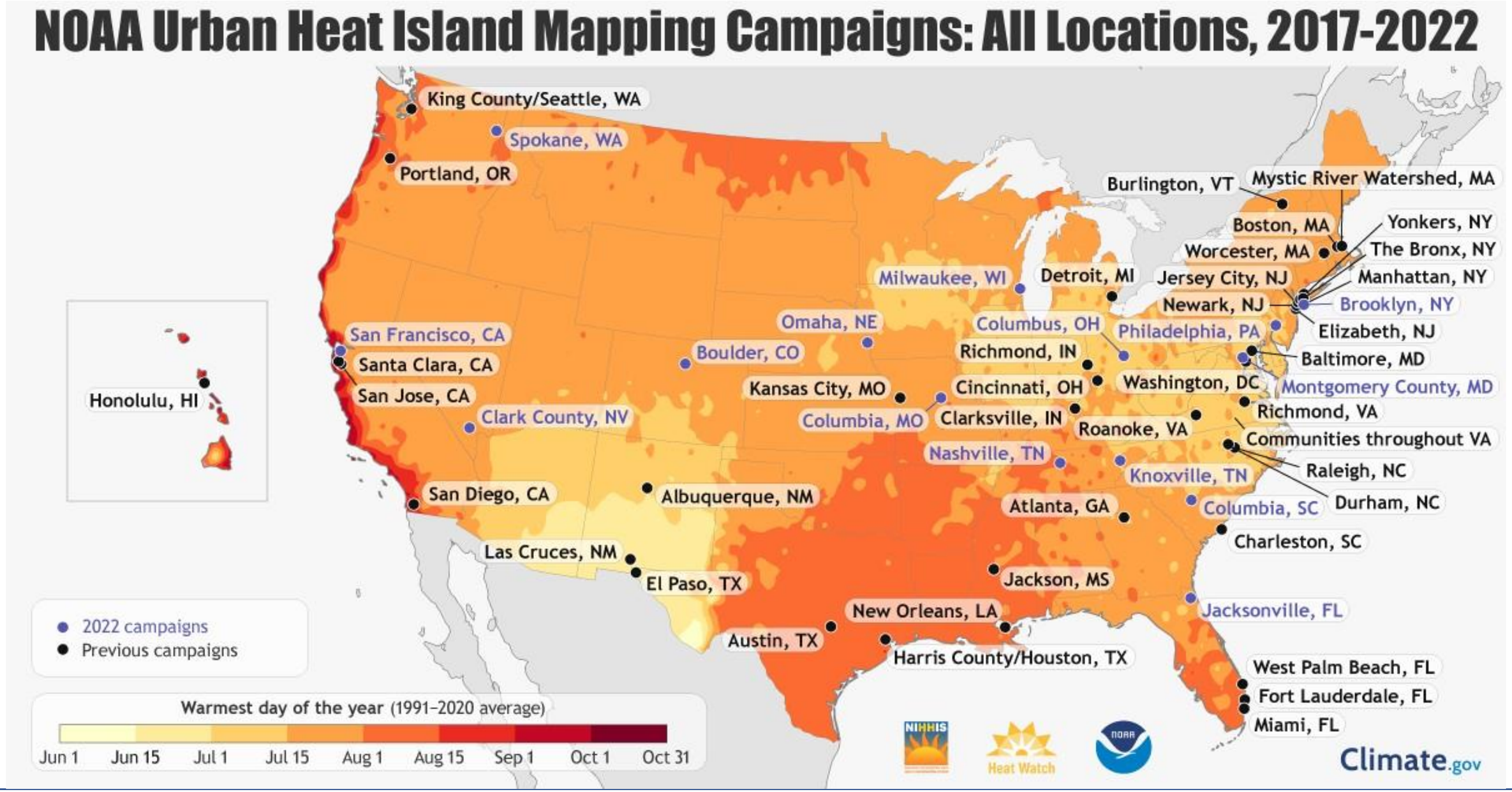
Lead Organization(s)

- City of Charleston, Climate Adaptation Partners

Partner Organizations

- Medical University of South Carolina Arboretum
- Citadel James B. Near Center for Climate Studies
- Charleston Resilience Network (Over 120 organizations)
- Charleston Medical District
- South Carolina Interfaith Power and Light
- Carolinas Integrated Sciences and Assessments
- Medical University of South Carolina Institute for Air Quality Studies
- Medical University of South Carolina Office of Health Promotion
- Medical University of South Carolina Sustainability Office
- National Weather Service Charleston

Used car-mounted devices to measure temperature and humidity on one representative day



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Charleston HeatWatch

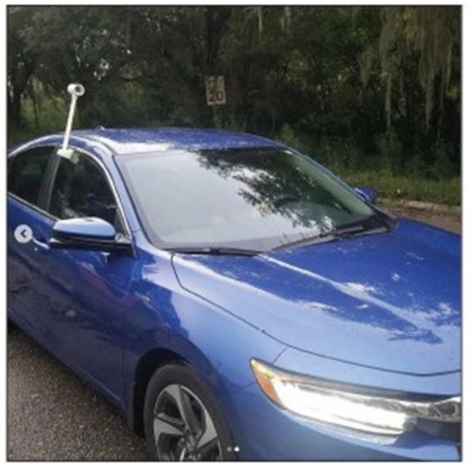
Driving Team
Simon and Darla Ghanat
Lyndsey and Matthew Davis
Susan and Greg Lovelace
Catherine Parker and Ben Stone
Deidre Ragan and Aidan Ragan Fillippa
Will McCloud
Grant Farmer
Rebecca Starkey
Al Harpring
Scott Curtis
Bonnie Ertel
Darcy Everett
Christine von Kolnitz
Pamela Ferguson
Andrea Forgacs
Kweku Brown
Emma Larsen

FLIR Team
Shawn McKay
Amanda Mushal
Stewart Weinberg
Starr Hazard

CAPA

Media

HEAT WATCH



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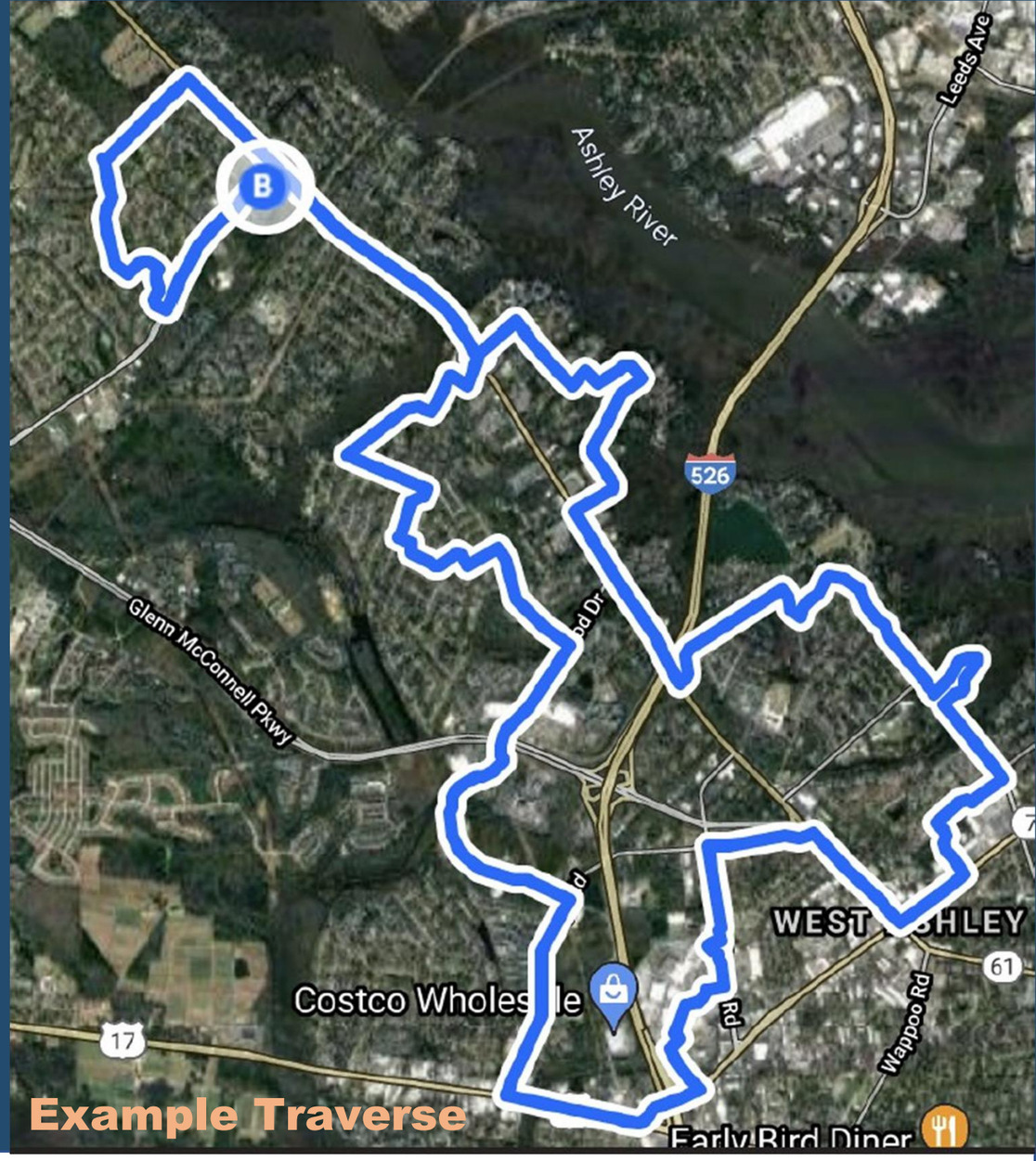
Charleston HeatWatch

Coverage Area
NOAA Funding for 100 SM
10 Traverses @10 SM / Traverse

Initial Charleston screening
excluding water and wetlands
~69 SM
Remainder for North Charleston adjoining area

Data Collection
July 31, 2021
Morning, Afternoon, Evening Traverses

Volunteers
10 Driving Teams
3 FLIR Teams
1 Coordinating Team



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Charleston Area Heat Watch Context

Life Expectancy at Birth

Grid - 1 Square Mile

CHS HeatWatch Study Area

CHS Life Expectancy at Birth

CDC Life Expectancy (census tract)

- 67 yr - 73 yr
- 74 yr - 76 yr
- 77 yr - 79 yr
- 80 yr - 81 yr
- 82 yr - 86 yr
- no data

MEDIAN INCOME DATA
U.S. Census Bureau's American Community Survey (ACS) 2015-2019 5-year estimates. Table(s): B19013B, B19013C, B19013D, B19013E, B19013F, B19013G, B19013H, B19013I, B19049, B17053

HEALTH INSURANCE COVERAGE DATA
U.S. Census Bureau's American Community Survey (ACS) 2015-2019 5-year estimates. Table(s): B27010

POPULATION DATA
U.S. Census Bureau's American Community Survey (ACS) 2015-2019 5-year estimates. Table(s): B01001

EDUCATION DATA
U.S. Census Bureau's American Community Survey (ACS) 2015-2019 5-year estimates. Table(s): 2

ELEVATION DATA
U.S. Geological Survey. 2019. 3D Elevation Program 3-Meter Resolution Digital Elevation Model. accessed April 16, 2021 at URL https://www.usgs.gov/core-science-systems/ngp/3dep/data-tools

CDC SVI DATA
Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program. CDC Social Vulnerability Index 2018 Database US. https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html. Accessed 04/2021

LIFE EXPECTANCY DATA
National Center for Health Statistics. U.S. Small-Area Life Expectancy Estimates Project (USALEEP): Life Expectancy Estimates File for (Jurisdiction): 2010-2015). National Center for Health Statistics. 2018. Available from: https://www.cdc.gov/nchs/nvss/usaleep/usaleep.html.

LANDCOVER & NEIGHBORHOOD DATA
City of Charleston GIS

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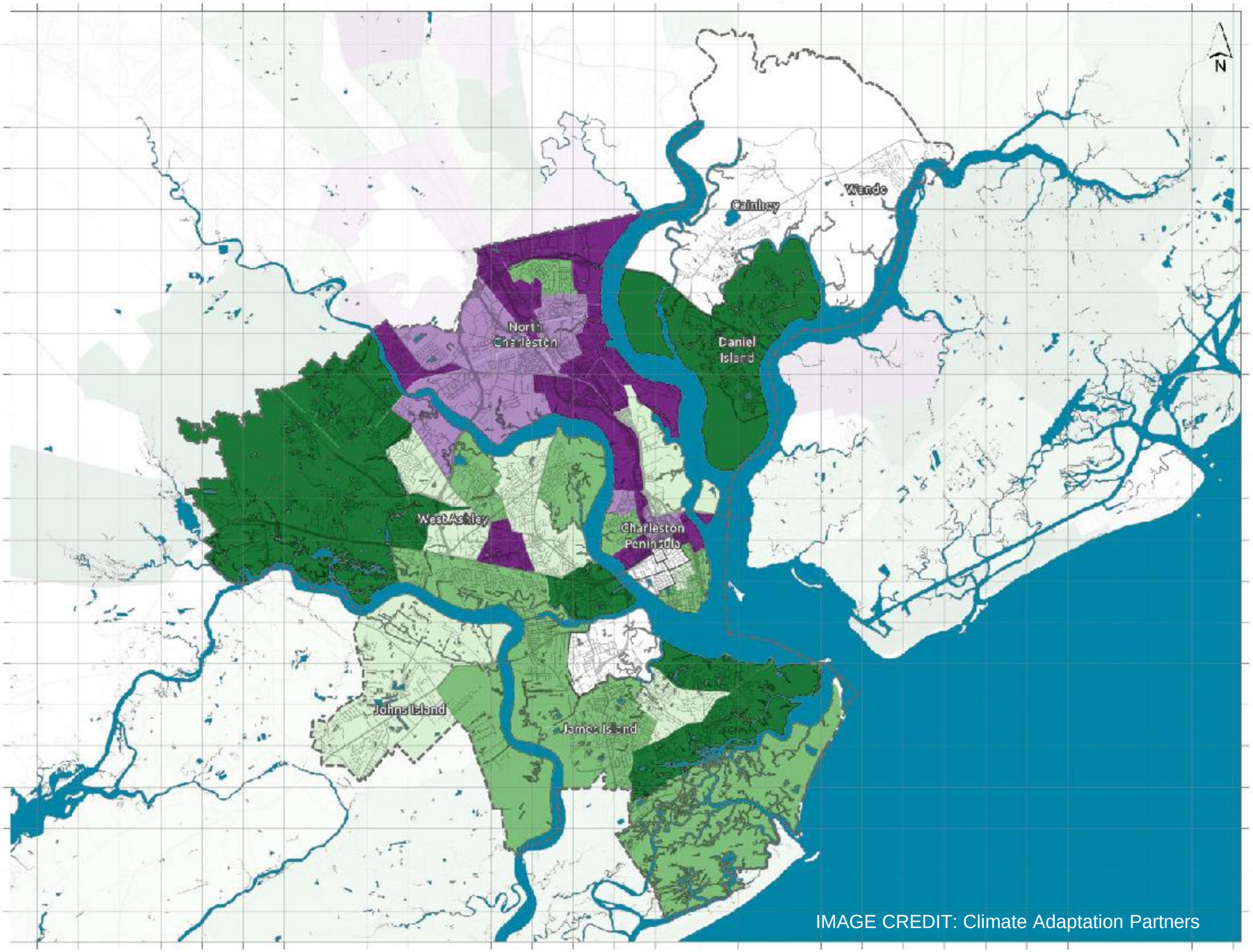

IMAGE CREDIT: Climate Adaptation Partners

HeatWatch Results

27
Volunteers

10
Routes

57,948
Measurements

95.9°
Max Temperature

11.8°
Temperature Differential

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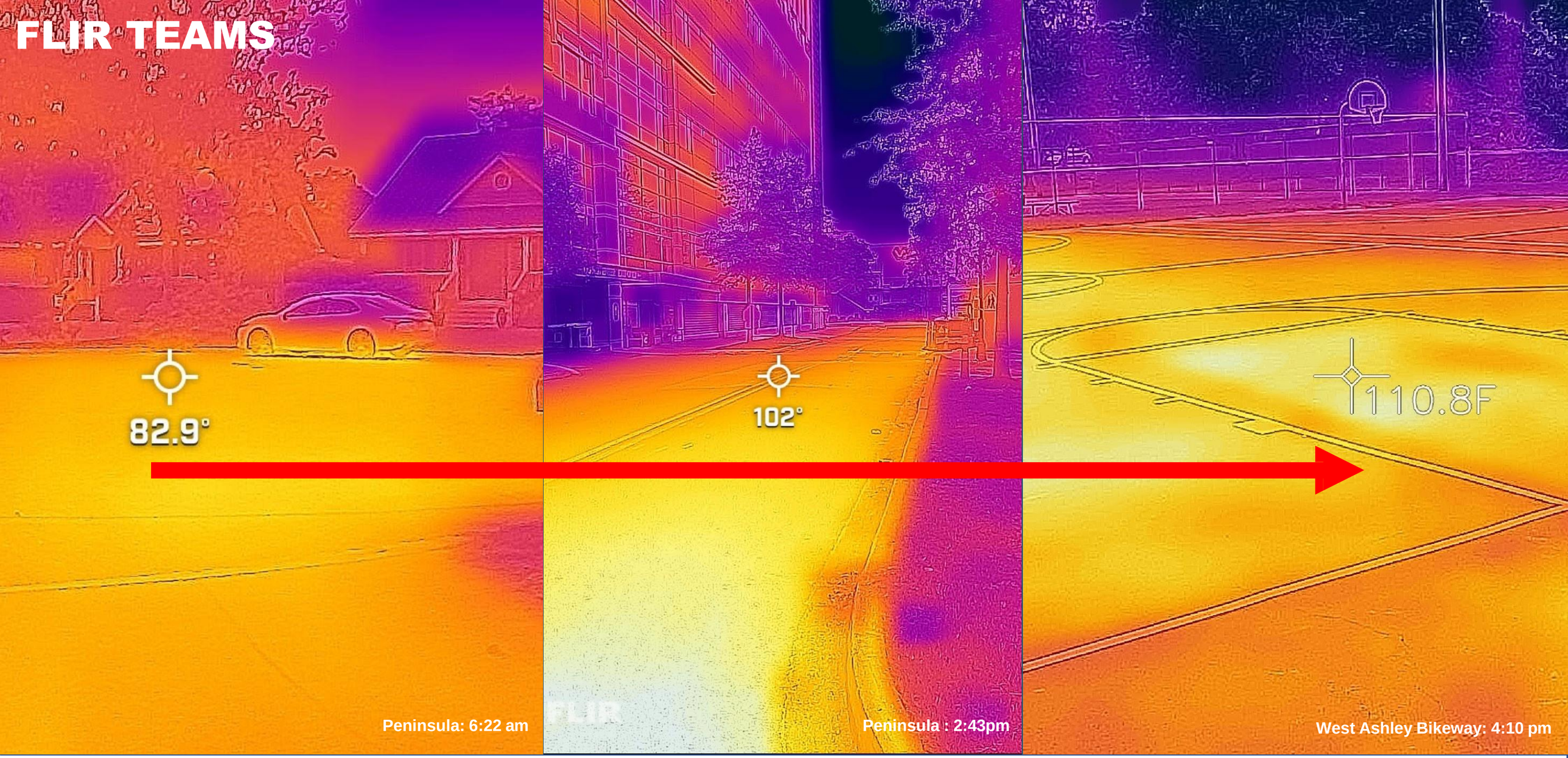

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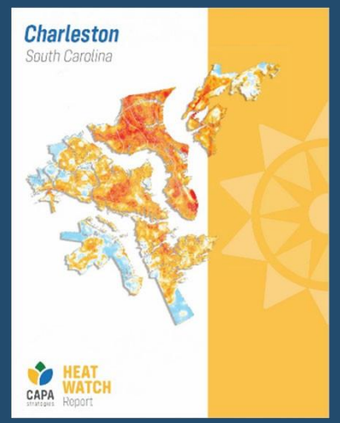
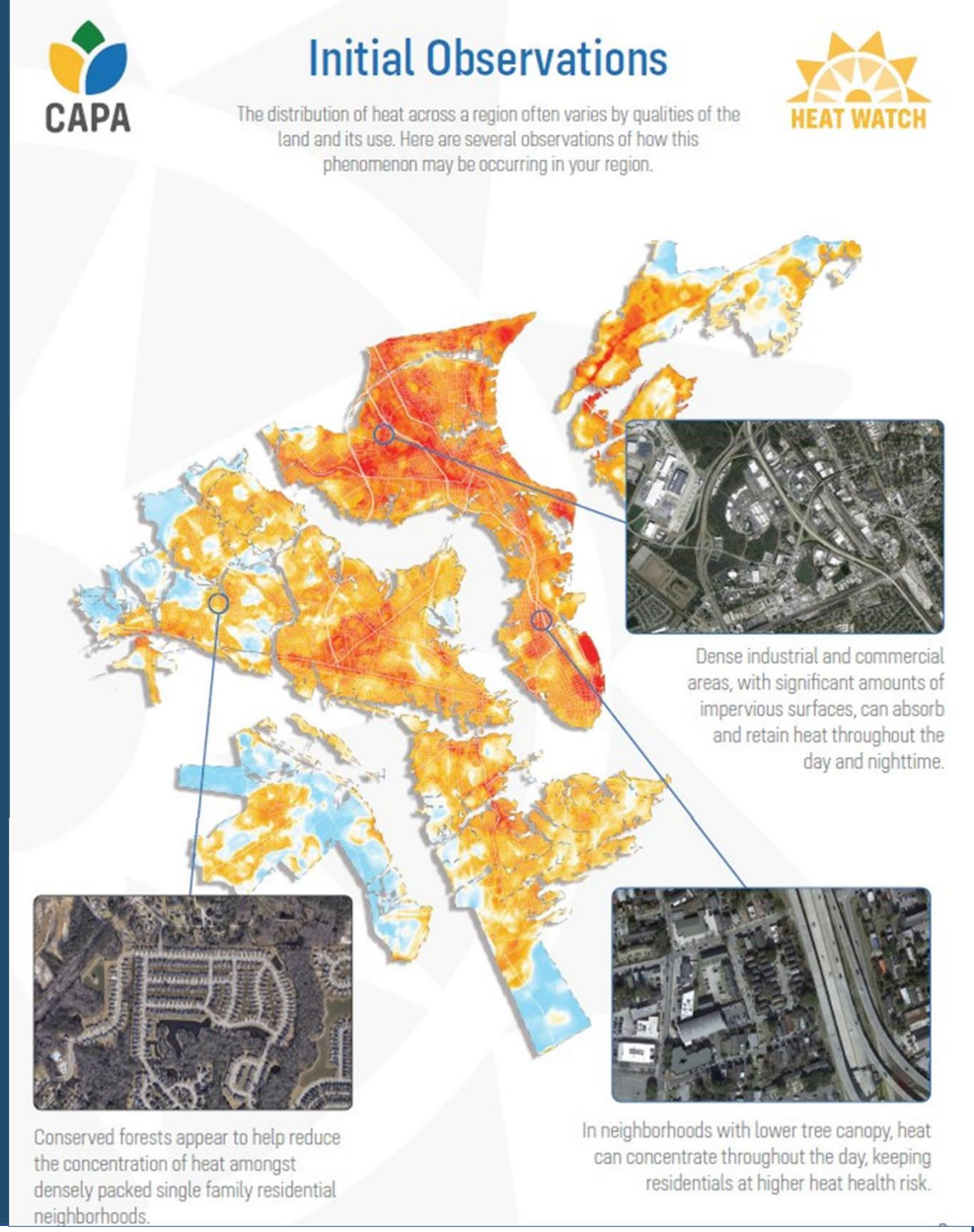
HeatWatch Summary

1. More effect of density of development
2. Peninsula was far warmer
3. Conserved Forest was cooler and offered a bigger impact on cooling than water bodies
4. No effect of swampy areas versus regular forest



Open Science Forum
https://osf.io/b4tfy/

City of Charleston GIS Team
https://www.charleston-sc.gov/2513/HeatWatch-Charleston-2021



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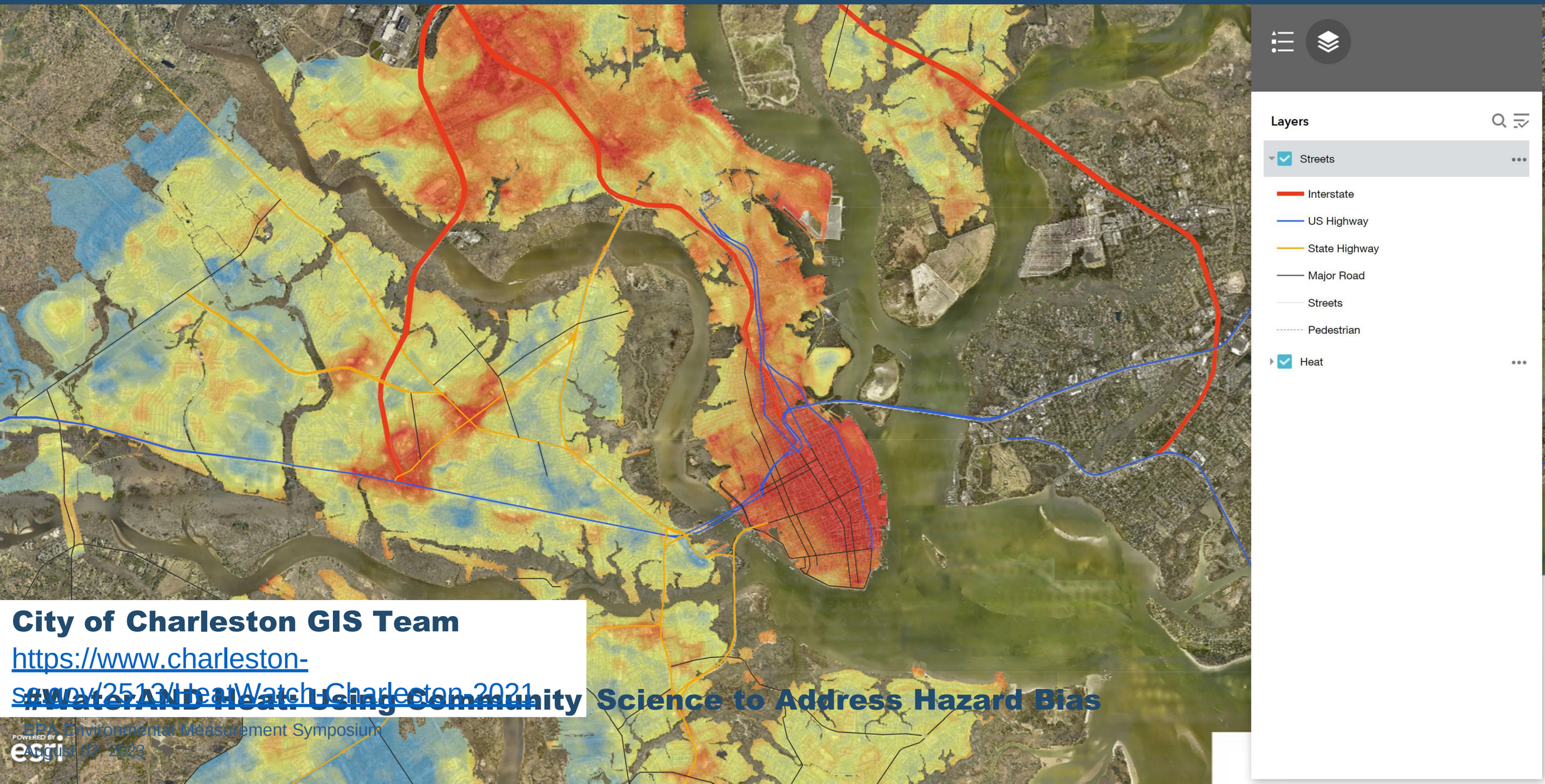
HeatWatch Summary



City of Charleston GIS Team

https://www.charleston-sc.gov/2513/HeatWatch-Charleston-2021

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Charleston Heat Research

1 CMD Heat Research

2 CISA Heat Research

3 HeatWatch Research

4 Expanding and Sharing Research

City of Charleston Resilience, GIS, and Planning Departments
Climate Adaptation Partners
University of South Carolina
The Citadel James B. Near Center for Climate Studies
South Carolina Sea Grant
UNC-Chapel Hill
MUSC Sustainability, Office of Health Promotion, Nursing, Epidemiology, Emergency Department, and Arboretum
National Weather Service Charleston
State of South Carolina Meteorology Office

NOAA NIHHIS and Pilot Research Team
City of Miami
City of Phoenix
City of Las Vegas
Drexel University

City of Philadelphia
City of Columbus

NOAA Pilot Project

Journal Publications
Philly & Columbia HeatWatch

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NOAA Pilot Project

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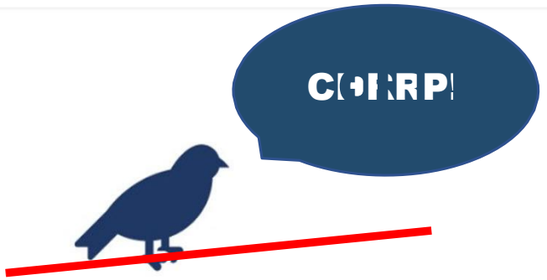

Charleston Heat-Health Research Project

The Charleston Heat-Health Research Project (CHHRP) was created by a group of health professionals, climate scientists, city planners, students and researchers to learn more about heat impacts in the community.

LEARN ABOUT THE PROJECT

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Why is the NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION (NOAA) sponsoring this work?

- Extreme heat is the number one weather related killer in the United States
- Heat-related health impacts likely will increase with climate change
- **Informed by Climate and Equity Roundtable Events, NOAA is working with four communities to understand heat health impacts and address community needs (in Charleston, Miami, Las Vegas, Phoenix)**

RESOURCES:

- National Integrated Heat Health Information System (NIHHIS)
- Interagency resource: Heat.gov

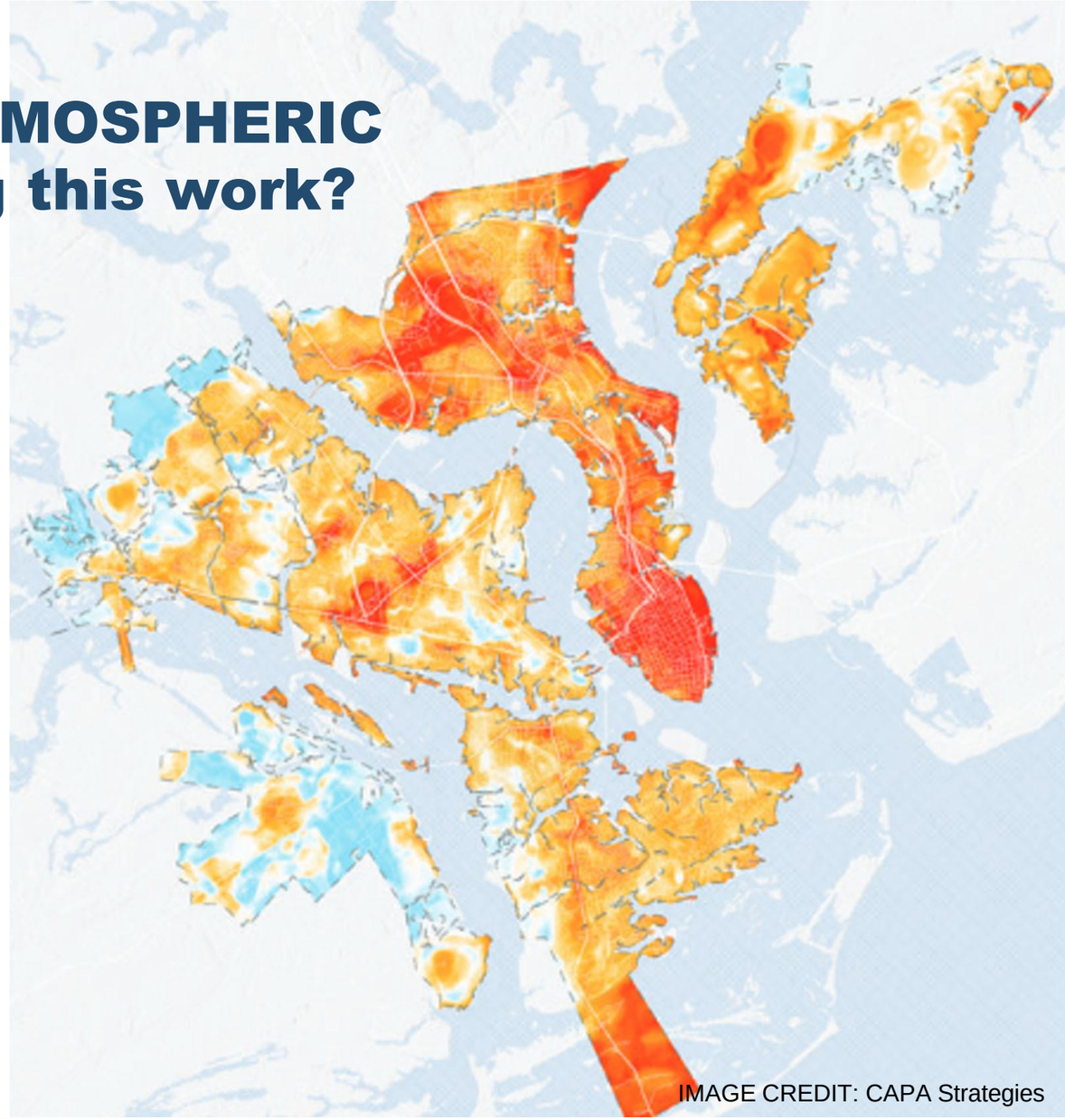

IMAGE CREDIT: CAPA Strategies

PARTNERS

Funding

+

Administration and Outreach

+

climate adaptation partners
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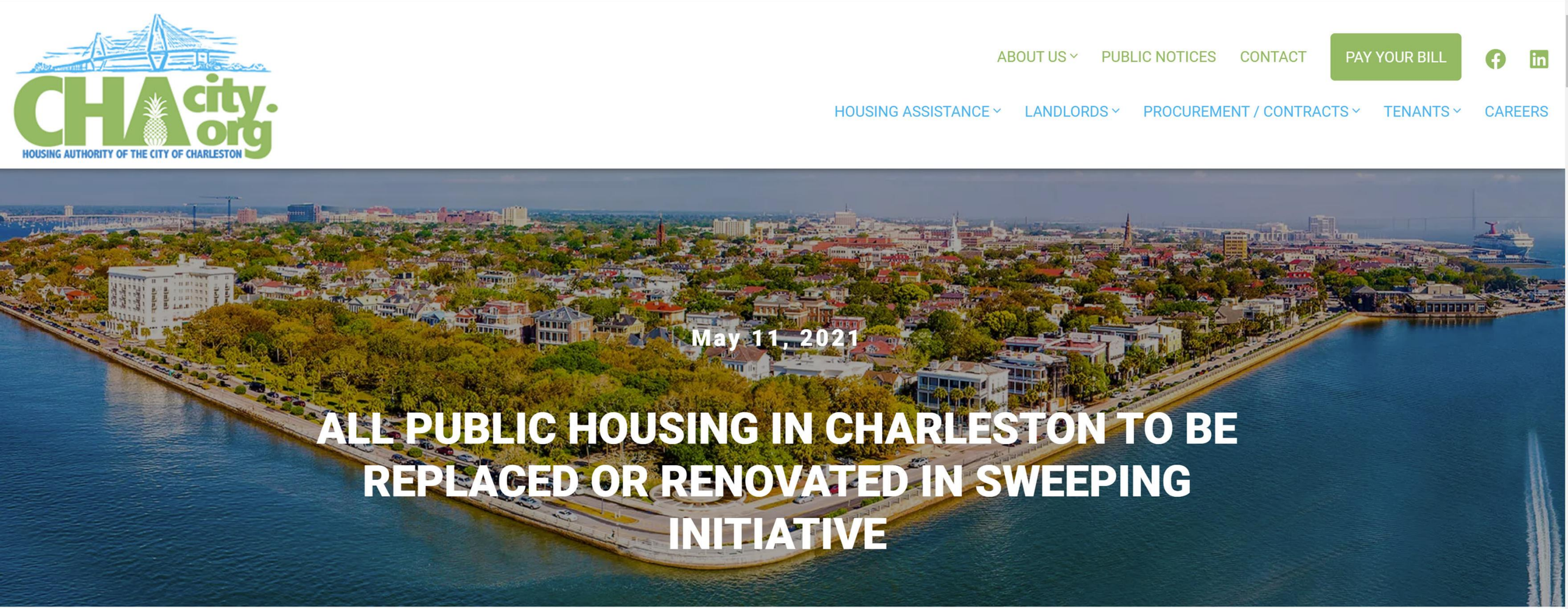
THE CITADEL
THE MILITARY COLLEGE OF SOUTH CAROLINA

MUSC Health
Medical University of South Carolina

HEAT SEASON DATA COLLECTION

IMAGE CREDIT: City of Charleston



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HEAT SEASON DATA COLLECTION

Near to the CMD, Gadsden Green is in a hot part of Charleston.

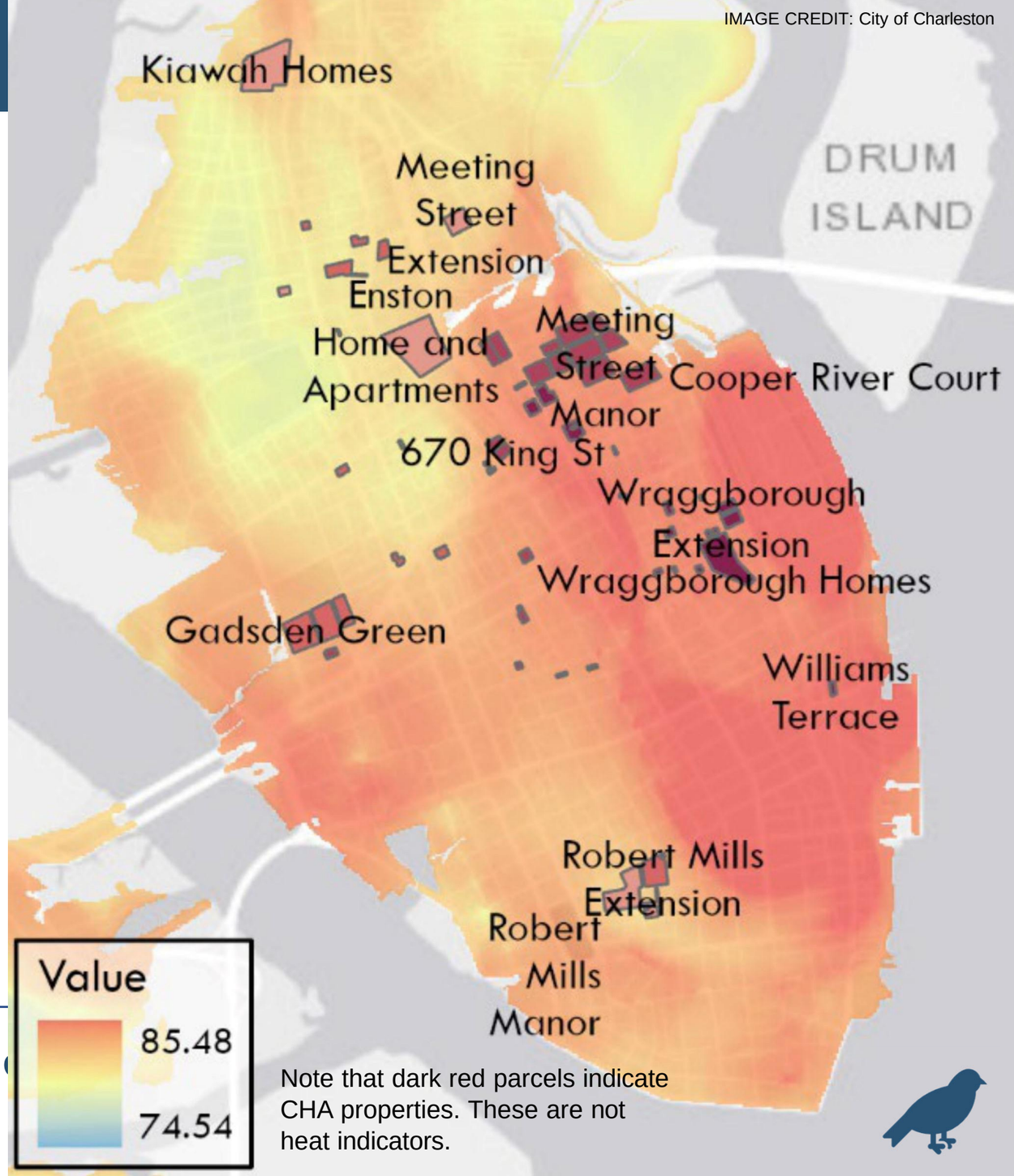
We hoped to better understand heat impacts by:

Phase 1 (LEARN):

- recording hot temperatures in the community
- identifying materials that make heat feel worse
- talking about how heat affects health

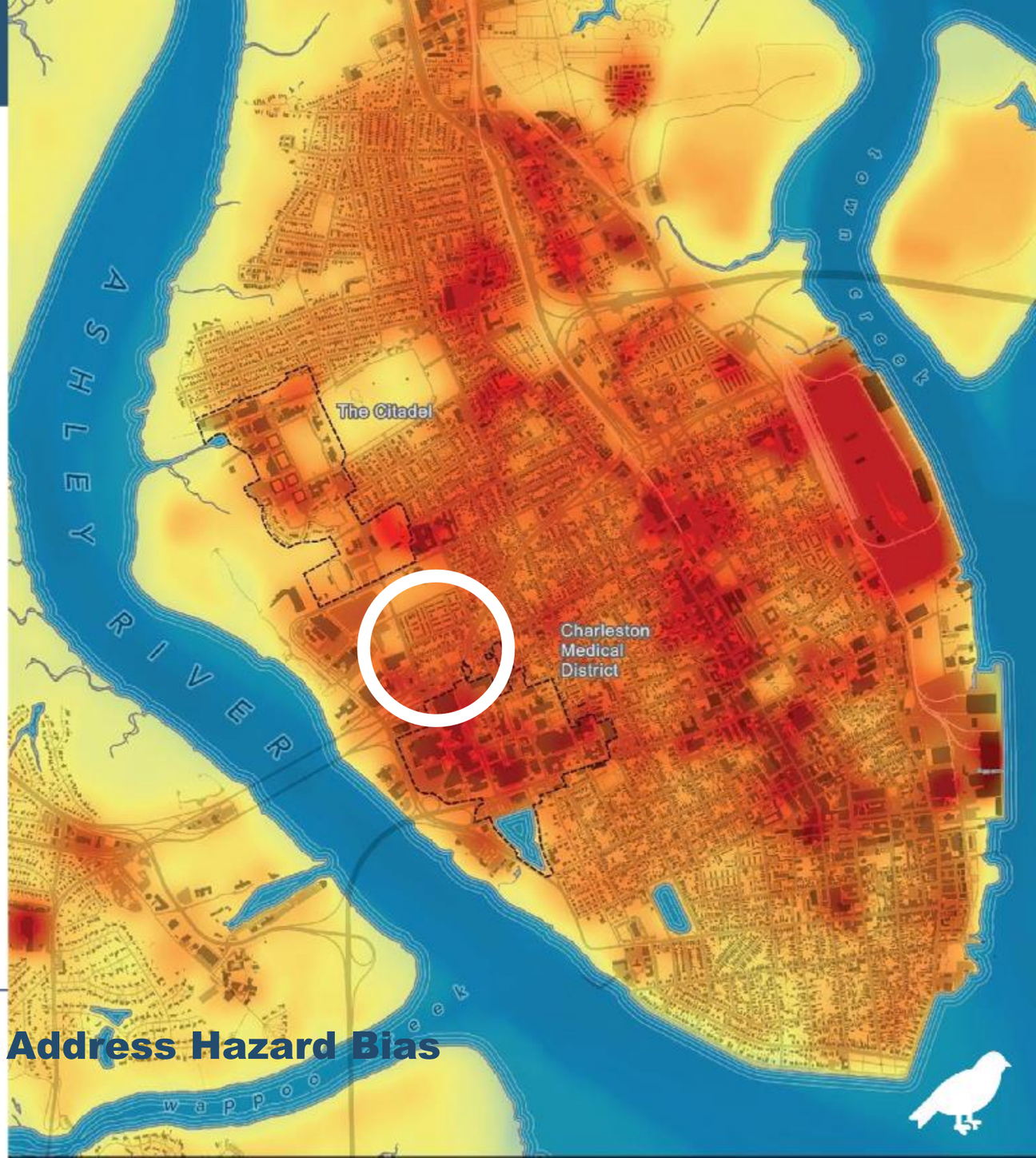
Phase 2 (ACT):

- identifying resources to help cope with heat
- finding solutions to help cool the environment



HEAT SEASON DATA COLLECTION

Figure 2: Gadsden Green Land Cover



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HEAT SEASON DATA COLLECTION

ENVIRONMENTAL CONDITIONS DURING OBSERVATION

Atmospheric Readings were collected in Gadsden Green during the 09/04/2022 study

- 6am – 8am
  - 115 Observations
  - Average Air Temperature: 78° F
  - Average Relative Humidity: 90%
  - Average Heat Index: 87° F

- 2pm – 4pm
  - 140 Observations
  - Average Air Temperature: 89° F
  - Average Relative Humidity: 65%
  - Average Heat Index: 104° F

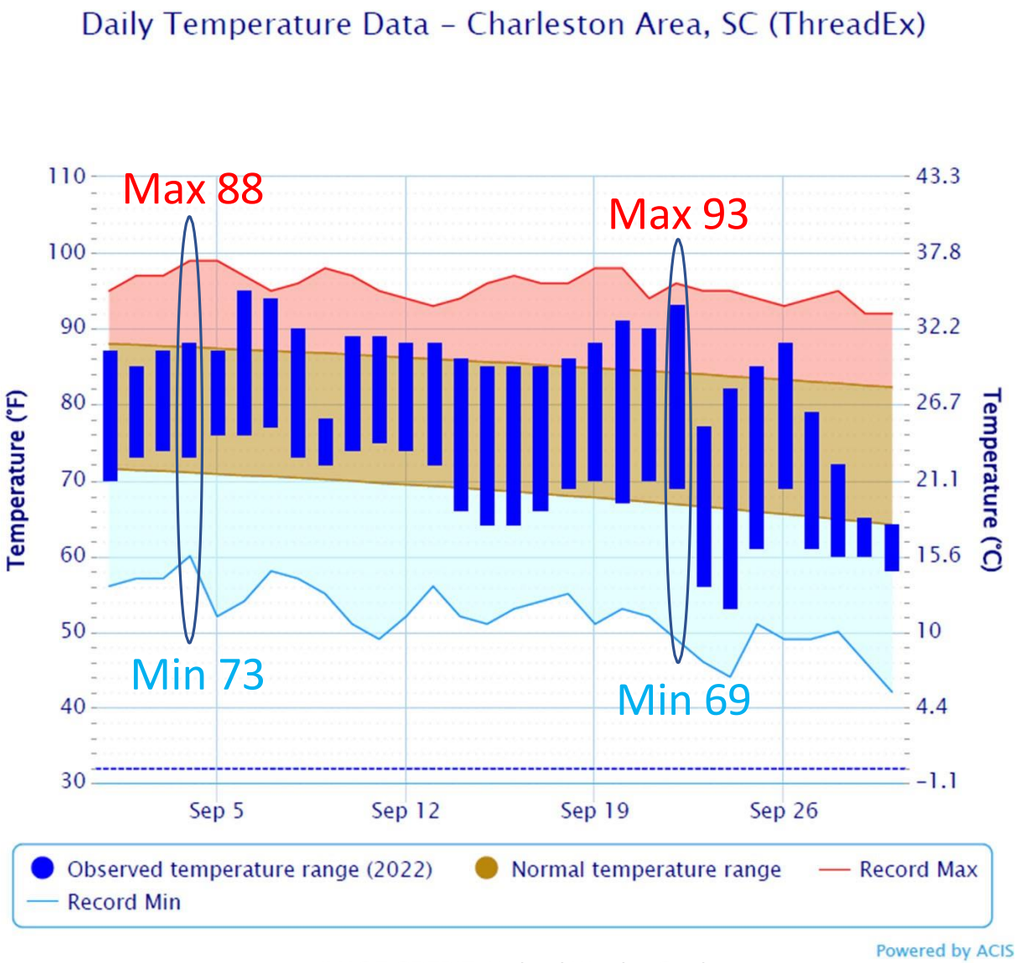

IMAGE CREDIT: National Weather Service

HEAT SEASON DATA COLLECTION

COLLECTION SITE

Data Collection focused on Gadsden Green and Gadsden Green Extension

- Four Kestrel WBGT Locations
- FLIR imagery focused on:

landscape	buildings
asphalt (roads)	**clay tile** (roofs)
concrete (sidewalks)	**shingles** (roofs)
grass (lawns)	**painted brick** (walls)
bare earth (dirt)	**unpainted brick** (walls)
sand (playgrounds)	**metal** (windows / doors)
mulch (plant areas)	**glass** (windows)
rubber (play surfaces)	**wood** (benches / fences)

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HEAT SEASON DATA COLLECTION

FLIR IMAGES FROM GADSDEN GREEN

- 223 FLIR Images Analyzed
- 13 Distinct Material Types were Captured
- 488 Unique Temperature Readings
- FLIR teams captured morning and afternoon images to match the WBGT observation periods
- FLIR teams captured sunny and shaded surfaces
- Temperatures reported are typically AVERAGES estimated across contiguous surface areas

HEAT SEASON DATA COLLECTION

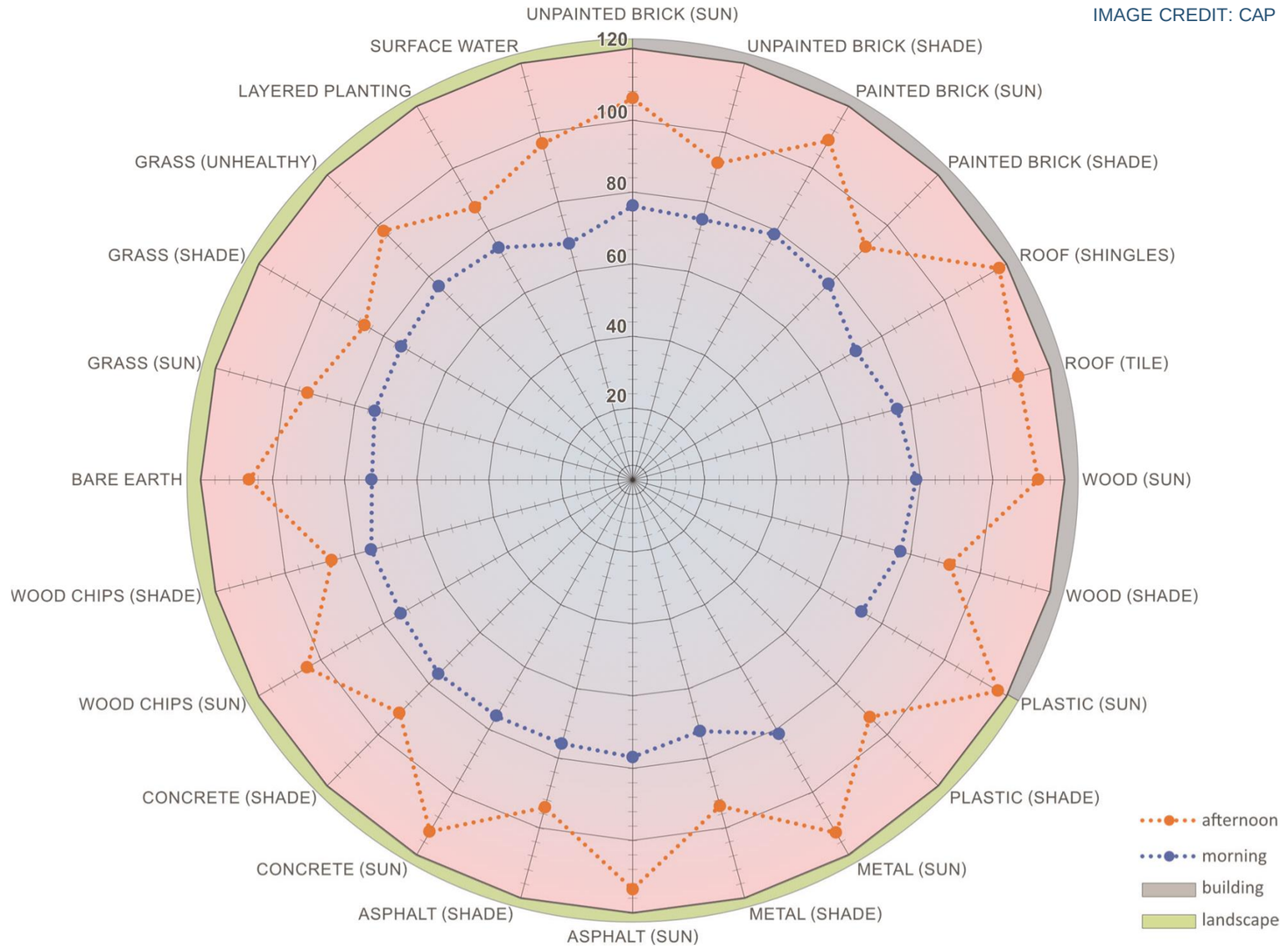
SURFACE TEMPERATURES IN GADSDEN GREEN

This is a summary of temperature AVERAGES of various materials in Gadsden Green, including:

- temperature **averages** captured in the morning (blue line) and afternoon (red line)
- surfaces in (**sun)** and in (**shade)**

What does this tell us?

IMAGE CREDIT: CAP



HEAT SEASON DATA COLLECTION

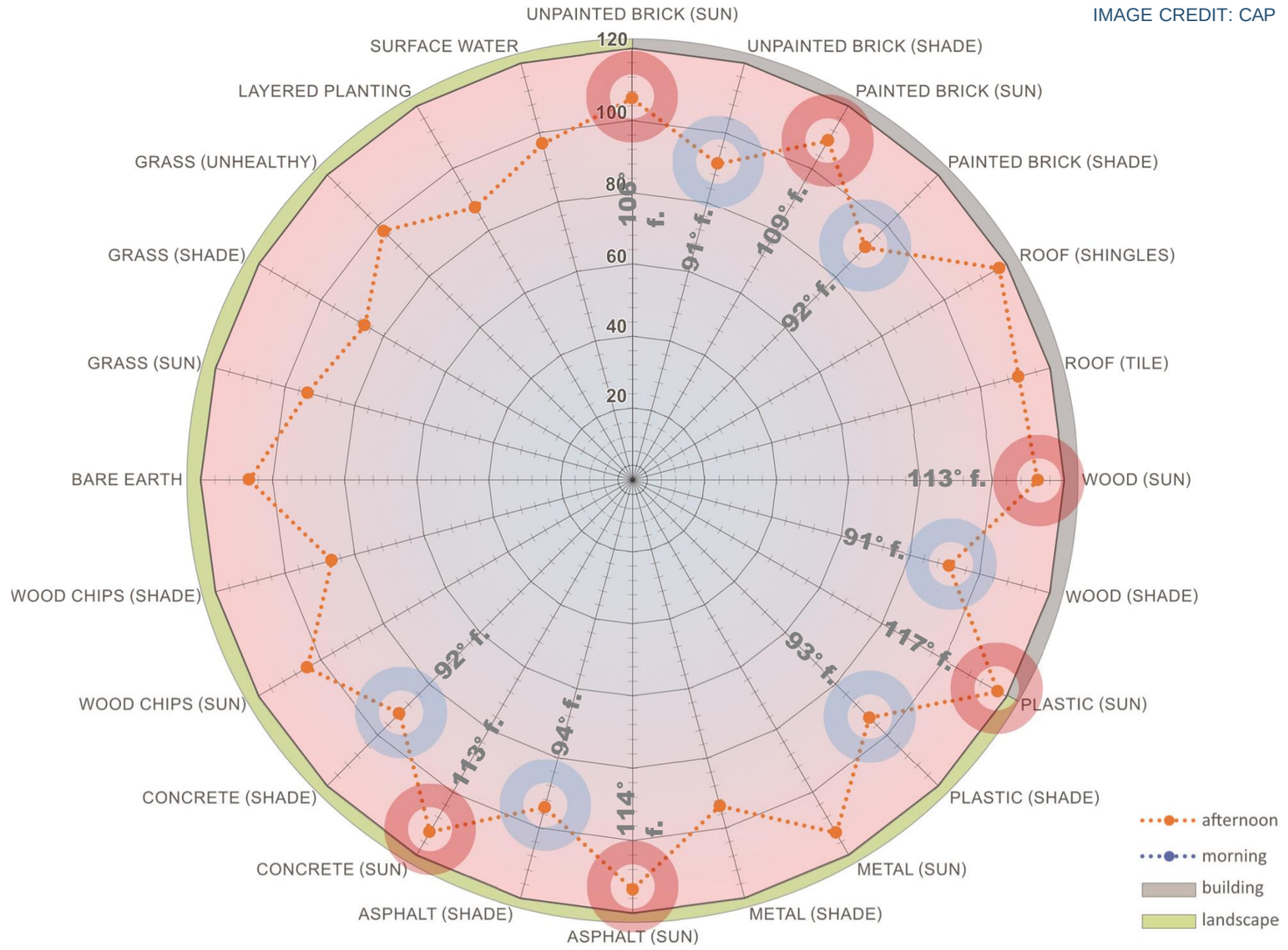
SURFACE TEMPERATURES IN GADSDEN GREEN

Notice how the **average temperatures** of some materials observed in the **afternoon** vary significantly.

This diagram reinforces how important shade is to cooling. Shaded materials are significantly cooler than unshaded.

Average material temperatures varied as much as **24 degrees** between sun and shade.

IMAGE CREDIT: CAP



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SURFACE TEMPERATURES IN GADSDEN GREEN

The next two images illustrate the surface temperature differences in **sunny** and **shaded** conditions.

This image of an **exposed stoop** in Gadsden Green shows grass, concrete, and brick in direct sun.

Note the temperature differences between the lighter-colored concrete and darker-colored concrete.

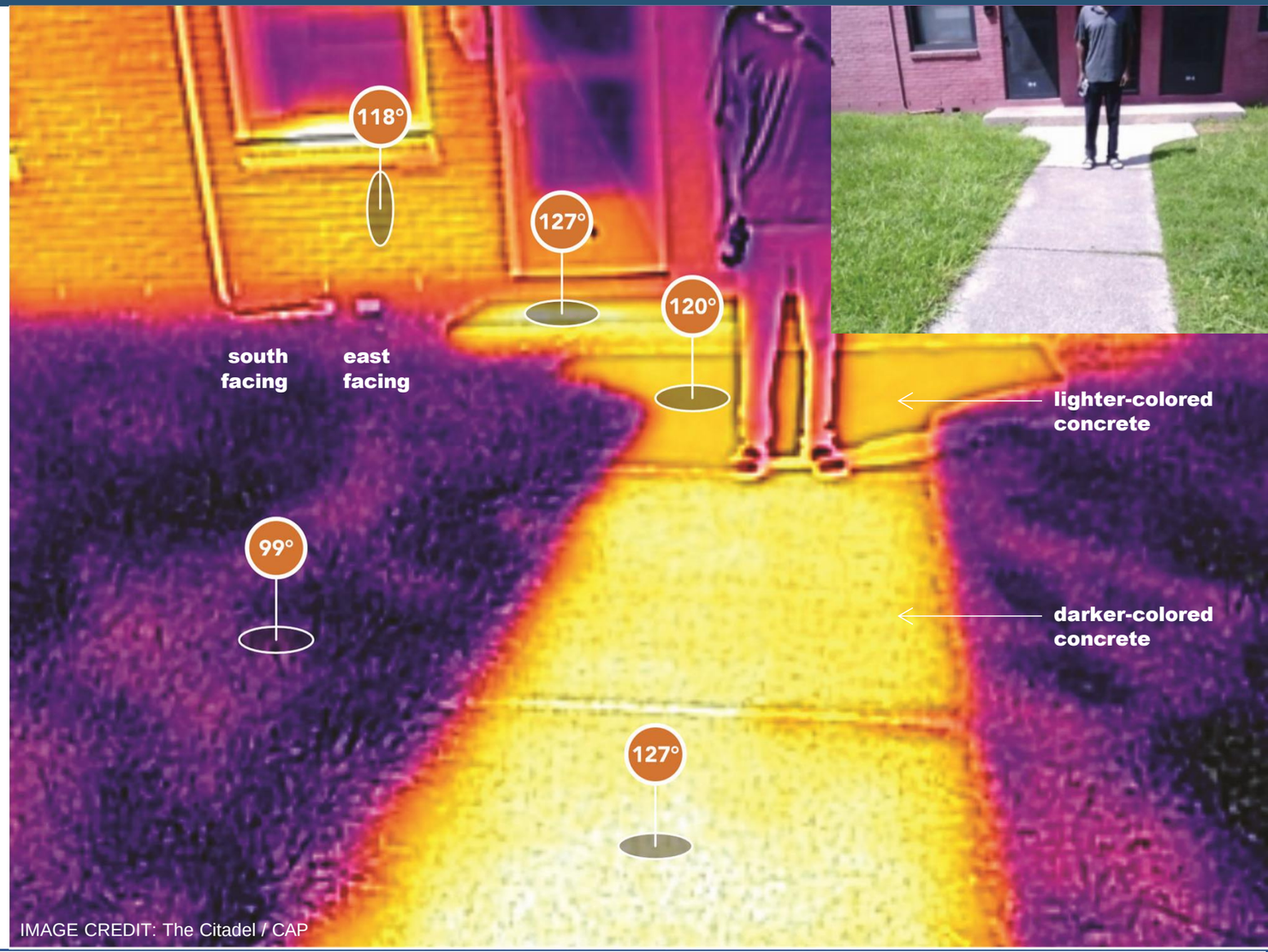


IMAGE CREDIT: The Citadel / CAP

HEAT SEASON DATA COLLECTION

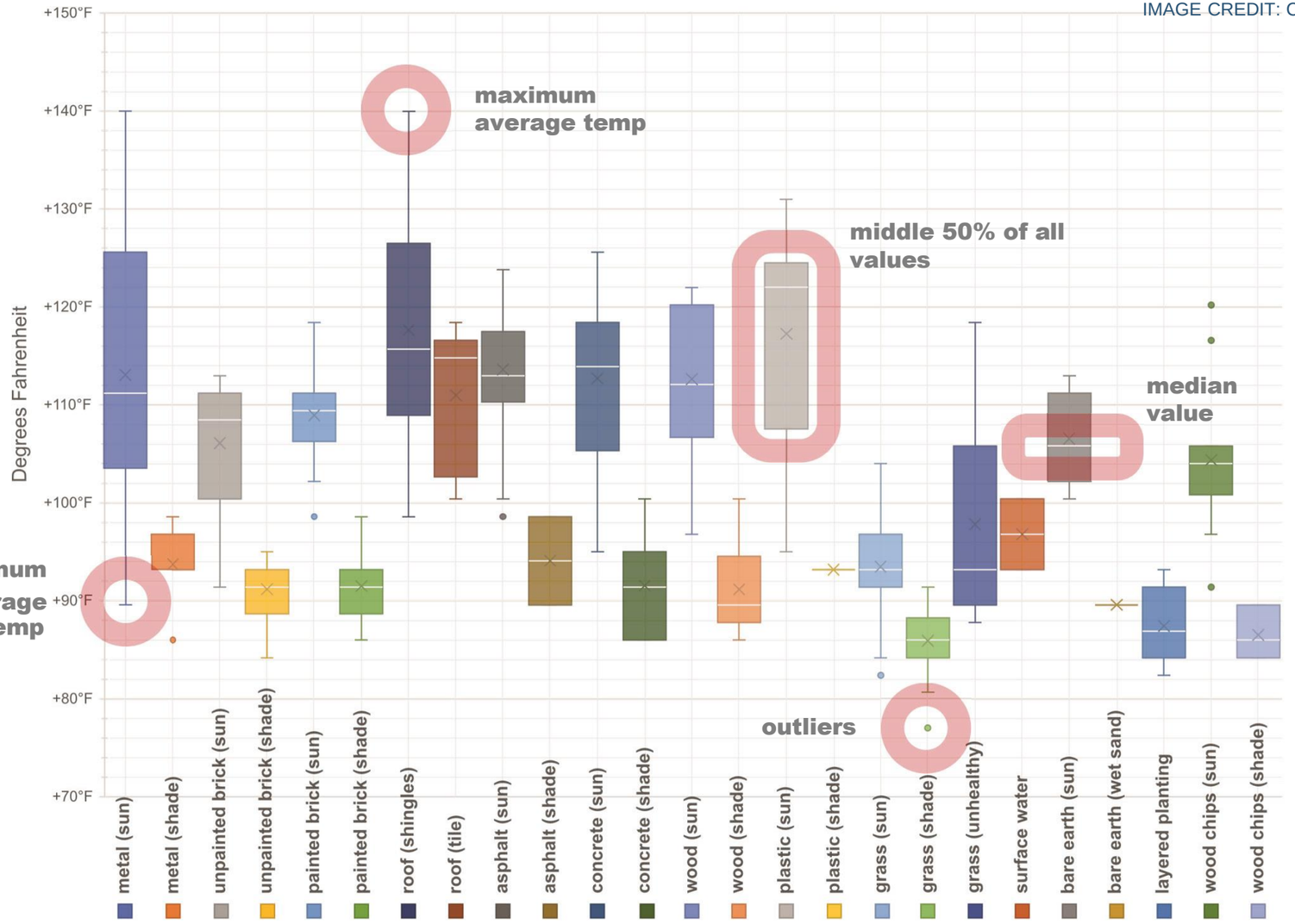
SURFACE TEMPERATURES IN GADSDEN GREEN

This is a “Box and Whisker” plot showing the distribution of **afternoon** surface temperature **averages** that provides another way to look at the data.

Box and Whisker plots show where most of the collected temperatures fall (the box) as well as the highs and lows (the whiskers).

This illustrates how temperature values are clustered (showing trends and important deviations of those trends).

IMAGE CREDIT: CAP



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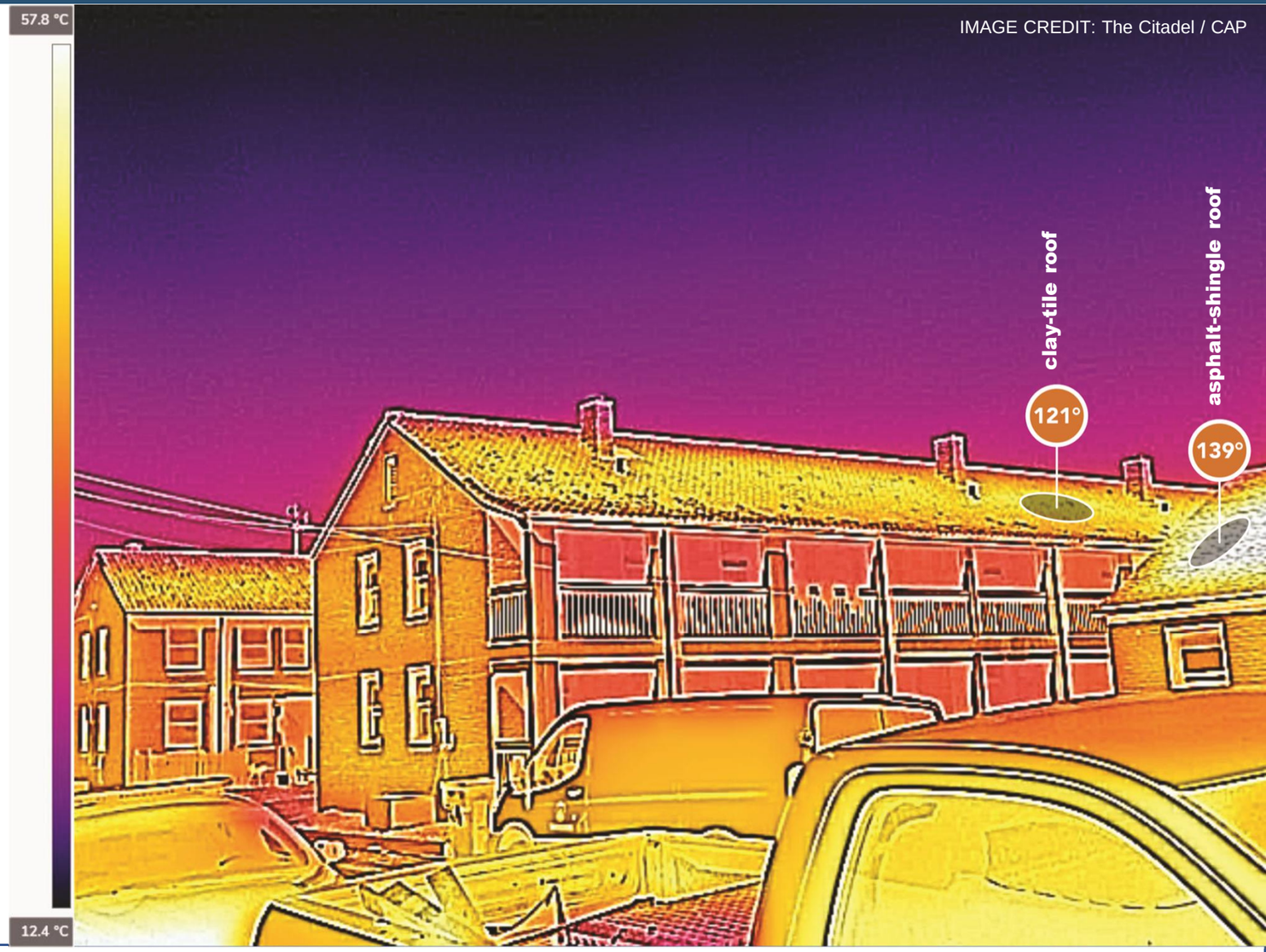
SURFACE TEMPERATURES IN GADSDEN GREEN

This image is from Gadsden Green and includes the two different roof types:

- The blue and red painted brick buildings have dark-colored **clay-tile** roofs.
- The green painted brick building has a dark-colored **asphalt-shingle** roof.

Note that the clay tile roof has a temperature of 120° and the asphalt shingle roof is much warmer at 139°



HEAT SEASON DATA COLLECTION

SURFACE TEMPERATURES IN GADSDEN GREEN

It’s important to note that there can be significant variation between similar materials as well. This image shows two asphalt shingle roofs (one lighter and one darker)

HEAT SEASON DATA COLLECTION

SURFACE TEMPERATURES IN GADSDEN GREEN

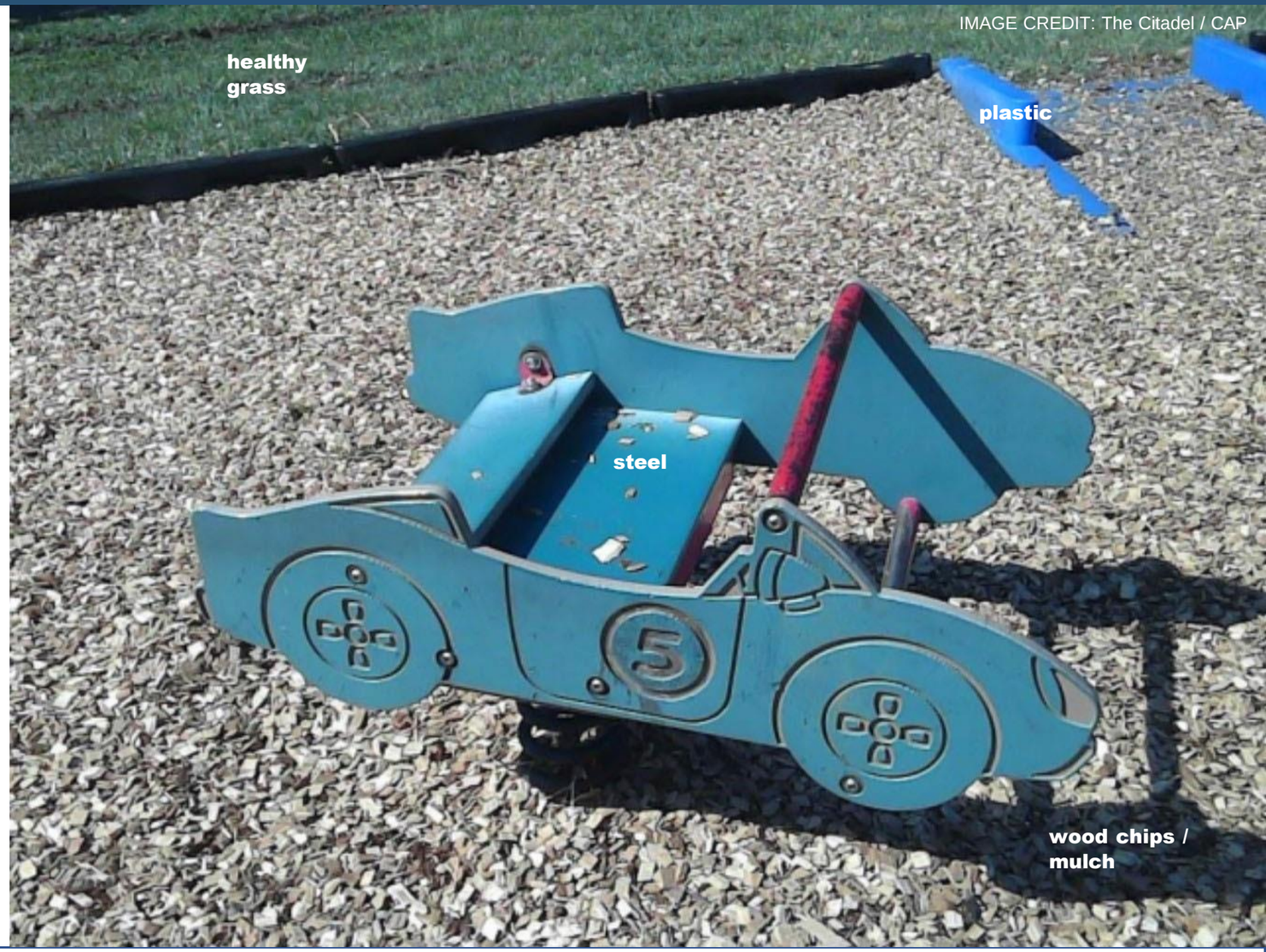
It’s important to note that there can be significant variation between similar materials as well. This image shows two asphalt shingle roofs (one lighter and one darker)

Note that the darker colored asphalt shingle roof is significantly warmer than the lighter asphalt shingle roof.

HEAT SEASON DATA COLLECTION

SURFACE TEMPERATURES IN GADSDEN GREEN

This image, from the Gadsden Green Extension playground, includes many different surface materials: healthy grass, wood chips / mulch, steel, and plastic.



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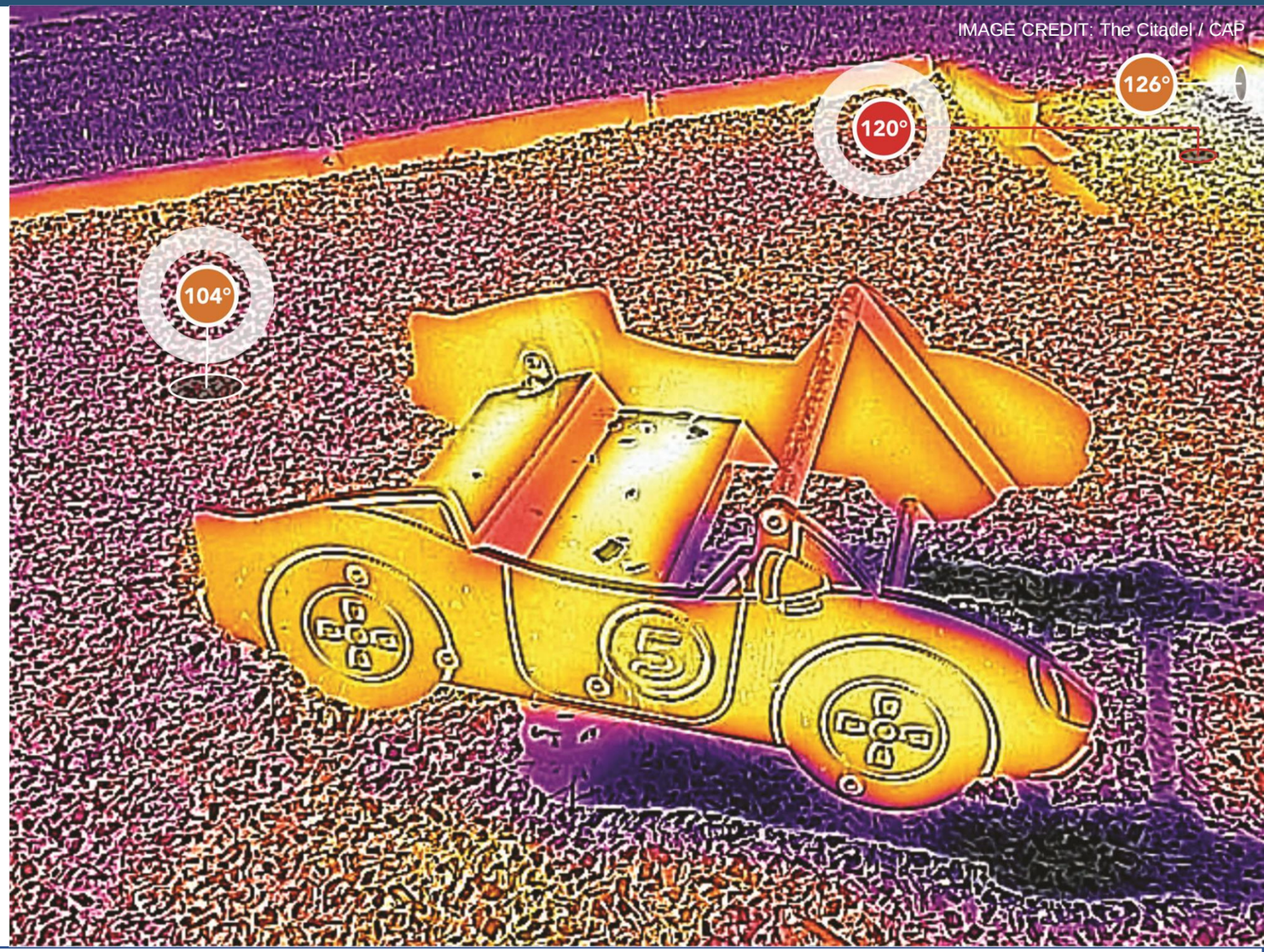
SURFACE TEMPERATURES IN GADSDEN GREEN

Note that the wood chips / mulch areas are significantly warmer than the grass areas.

The hottest surfaces in this area are the plastic and steel surfaces.

But there is also another important principle illustrated by this image

The radiant heat emitted by the plastic is significantly increasing the surface temperature of the adjacent wood chips / mulch by nearly 20°



HEAT SEASON DATA COLLECTION

WBGT IN GADSDEN GREEN

Collection Period:

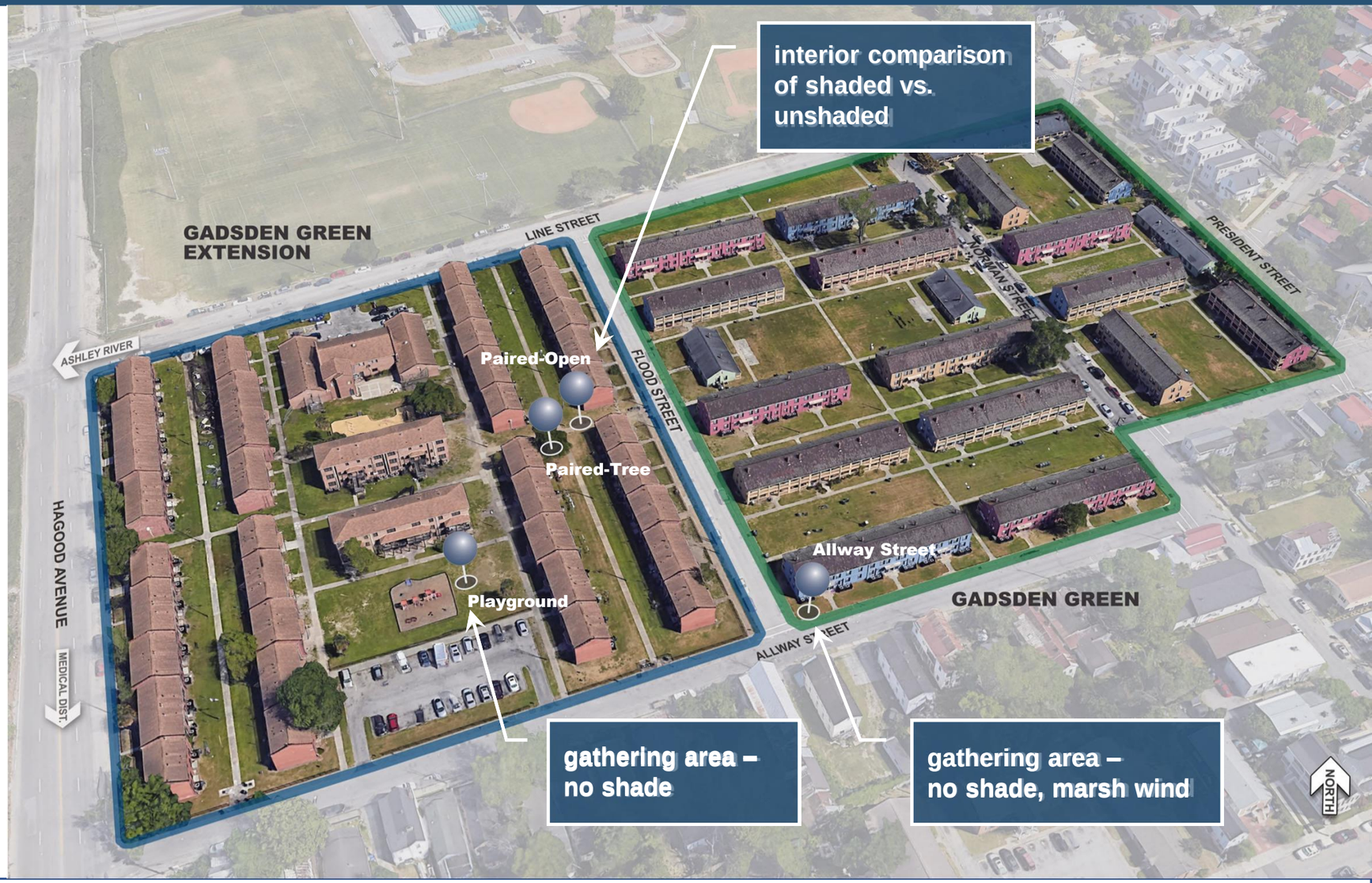
- September 4, 2022
- ~ 6-8 am and 2-4 pm
- Locations informed by community input

Counts (minute averages):

- ~120 am & ~120 pm

Analysis Process:

- Examine WBGT time series
- Examine WBGT components
- Compare published WBGT health "flag" thresholds



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Community Involvement

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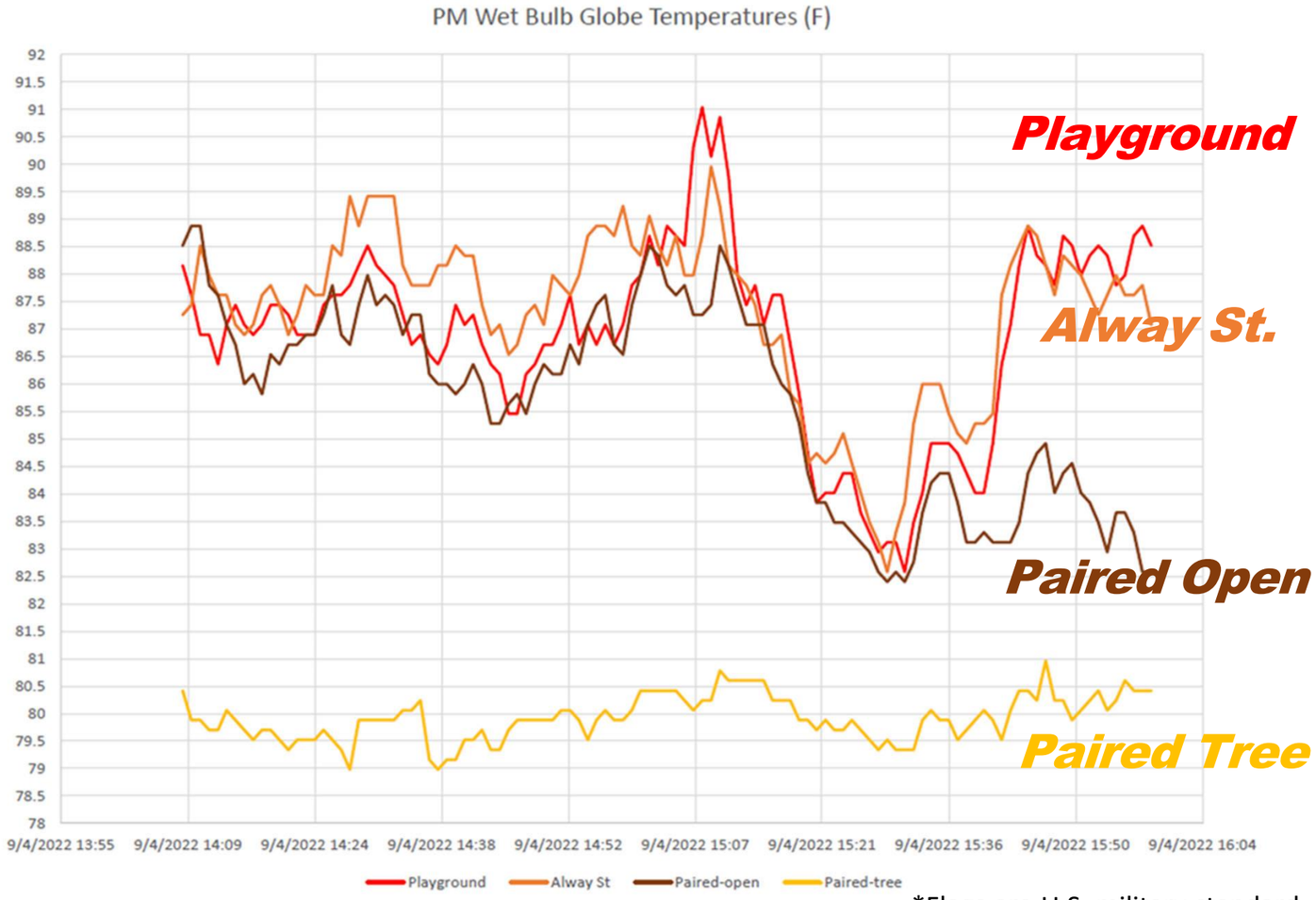
OUTDOOR TEMPERATURE READINGS

Alway St.

Paired Open

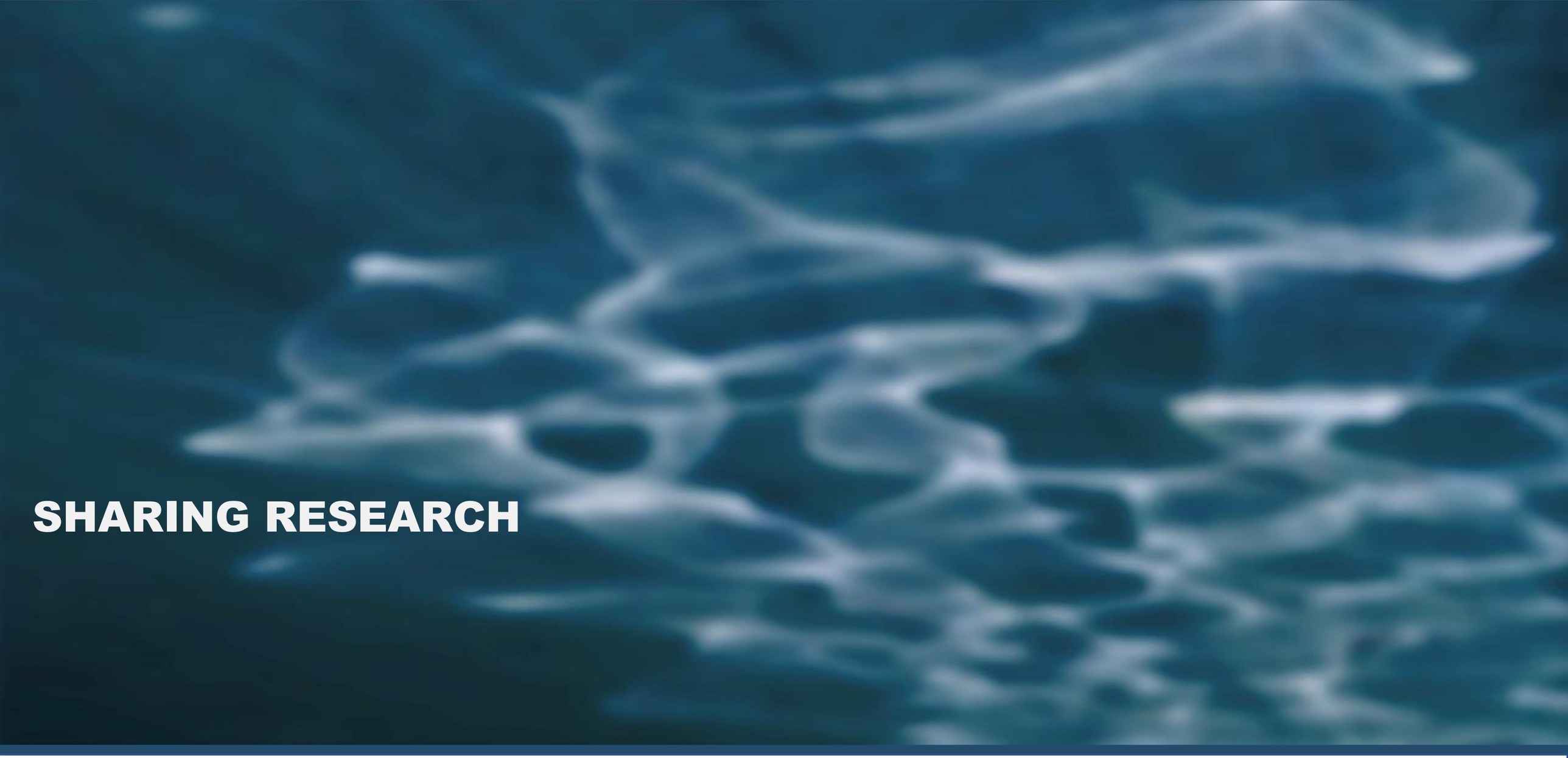
Paired Tree

Playground



Also: considering wind direction and cooling effect

*Flags are U.S. military standard



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Sharing Research

***Providing Open Access GIS** resources for knowledge sharing*

NOAA

- [HeatWatch ArcGIS Resource]

Open Science Framework

- [https://osf.io/b4tfy]

City of Charleston

- [HeatWatch]
- [Tree Canopy Tools App]
- [Street Tree Canopy Storymap]

Sharing Research

Publishing Results *to build the knowledge base*

Journal of Biometeorology

Sugg, M.M., Runkle, J.D., Dow, K., Barnes, J., Pearce, J., Bossak, B., Curtis, S.

Individually experienced heat index in a coastal Southeastern US city among an occupationally exposed population.

Int J Biometeorol **66**, 1665–1681 (2022). https://doi.org/10.1007/s00484-022-02309-y

Advances in Environmental Engineering

Larsen E, Ghanat S, Curtis S.

Experience with Active Learning: The Charleston, SC, USA Urban Heat Island Effect.

Adv Environ Eng Res **2022**;3(2):9

doi:10.21926/aeer.2202020.

Frontiers in Climate

Barnes, J. and Dow, K.

Water AND Heat: Intervening in Adaptation Hazard Bias

Frontiers in Climate, 29, June 2022

https://doi.org/10.3389/fclim.2022.868017

Sharing Research

***Starting Research on Health Outcomes** from Temperature (HOT)*

Retrospective Study

designed to produce a statewide temperature dose response curve. Temperature would be the variable of interest and death the outcome

Prospective Study

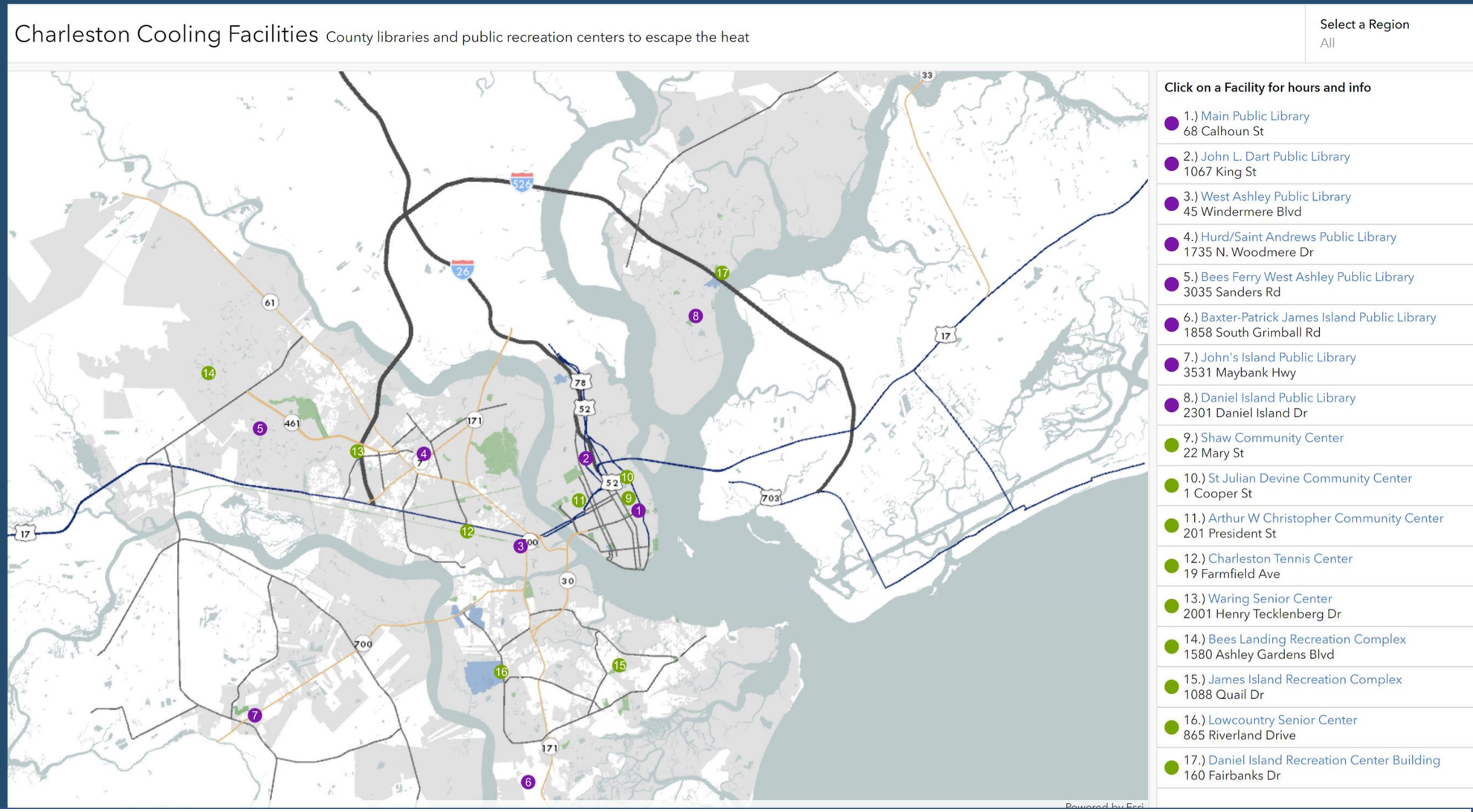
compares temperature and air quality with morbidity and mortality in Charleston - clinical data gathered from MUSC, Roper and Regional EMS and temperature and air quality from sensors and weather department

Collecting Existing Extreme Heat Resources

City of Charleston Resilience, GIS, and Planning Teams

MUSC Medical Professionals

Winter 2023 College of Charleston Intern



#WaterAND Heat: Using Community Science to Address Hazard Bias

EPA Environmental Measurement Symposium
August 02, 2023

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Outcomes to Date

Collaborative growth and progress on complementary activities

CMD introduced heat into its draft resilience strategy and to its respective masterplanning teams

MUSC declared July 2021, 2022, and 2023 Heat Awareness Month

City of Charleston added extreme heat to the Charleston Comprehensive Plan

https://www.charleston-sc.gov/DocumentCenter/View/31227/Final-City-Plan-Adopted-October-12-2021

Charleston Tourist Bureau plans heat risk training for guides and new hydration stations

South Carolina's Draft Strategic Statewide Resilience and Risk Reduction Plan includes images of Heat Mapping from Charleston and Columbia Heat Watch activities (to be finalized in July 2023)

https://scor.sc.gov/sites/scor/files/Documents/5.%20Draft%20Other%20Hazards%20Vulnerability%206.5.23.pdf

Get Involved

Motivating Local Action *to Address Climate Impacts and Build Resilience*

Increase Awareness

Increase Coping Capacity

Increase Mitigation

Increase Adaptation

Proclamations Help!

Statewide Disaster Funding 2015-2021

$1.42 B

FEMA storm-related disaster recovery and mitigation **project total funds*** 2015-2020. *Of this $1.19B is federal obligation*. The balance is match funding

FEMA

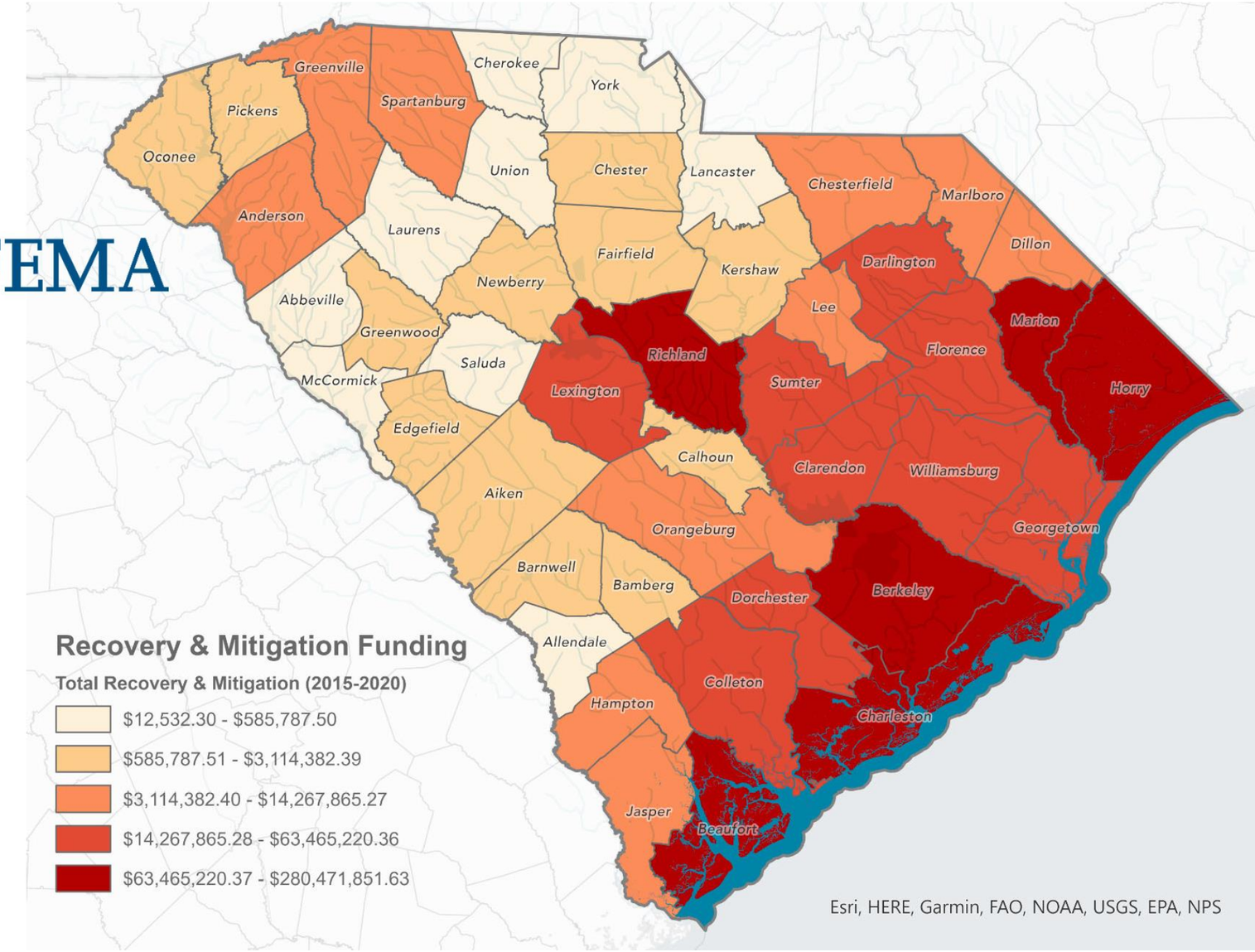
$451.4 M

HUD Community Development Block Grant (CDBG) storm-related disaster recovery and mitigation grant totals as of August 2021

$1.87 B

Total FEMA + HUD storm-related disaster recovery and mitigation project values 2015 – August 2021 (excluding Wildfire and BioHazard)

*This excludes FEMA's Individual Assistance (IA), Individuals and Households (IHP), Housing Assistance (HA), and Other Needs Assistance (ON) programs.



NOTE: These data were compiled in a 2021 federal disaster recovery funding study by The Nature Conservancy, Southern Environmental Law Center, and Climate Adaptation Partners. The results of that study are forthcoming.

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Possible Additional NOAA Collaborations

- increasing research resources, to expand **Heat Health Disparities** research, including **better understanding of energy insecurity** across South Carolina

- linking NOAA/NIHHIS and our campaigns to FEMA/HUD disaster recovery investments to **integrate heat resilience into recovery investments**, such as green and other infrastructure

- **deepening collaboration across the RISAs(CAPs) and other research teams** working to support the integration of climate information into decision making, sharing lessons and pilot work, and extending the research investments

- along with SCOR, **engaging counties and municipalities across the State** to better integrate heat risk awareness and heat reduction strategies in planned investments

- **shared indicators and reporting to value heat** in disaster preparedness and recovery planning

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