

Charleston Extreme Heat Initiatives Overview

Building toward a City Heat Plan

Janice Barnes, PhD

Climate Adaptation Partners

June 29, 2023

#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
UNC Chapel Hill - SERCC
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

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots

June 29, 2023

Charleston Heat Research

- 1** **CMD Heat Research**
- 2** **CISA Heat Research**
- 3** **HeatWatch Research**
- 4** **Expanding and Sharing Research**

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
June 29, 2023

Charleston Heat Research

1

CMD Heat Research

Used LANDSAT to spatialize hot areas

Used FLIR and GPS to visualize materials that amplify heat

Hosted Heat Charrette at Charleston Medical District

2

CISA Heat Research

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

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

3

HeatWatch Research

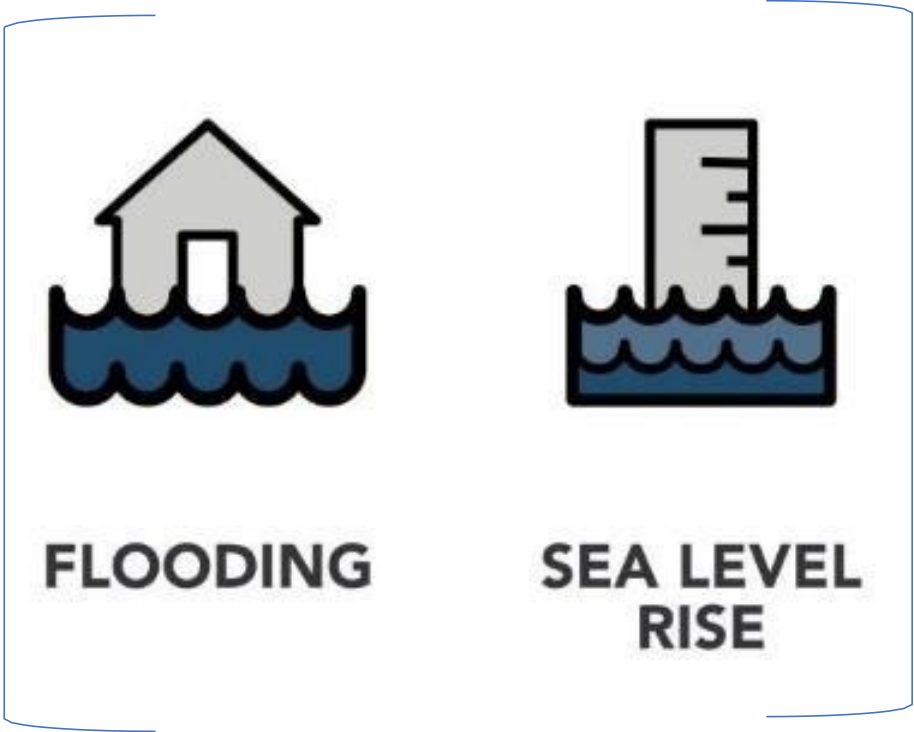
4

Expanding and Sharing Research

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Charleston Vulnerabilities Assessment

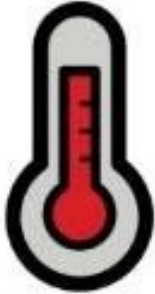


FLOODING

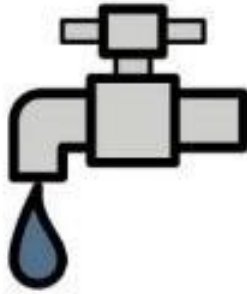
SEA LEVEL RISE



SEISMIC



EXTREME HEAT



WATER SHORTAGE

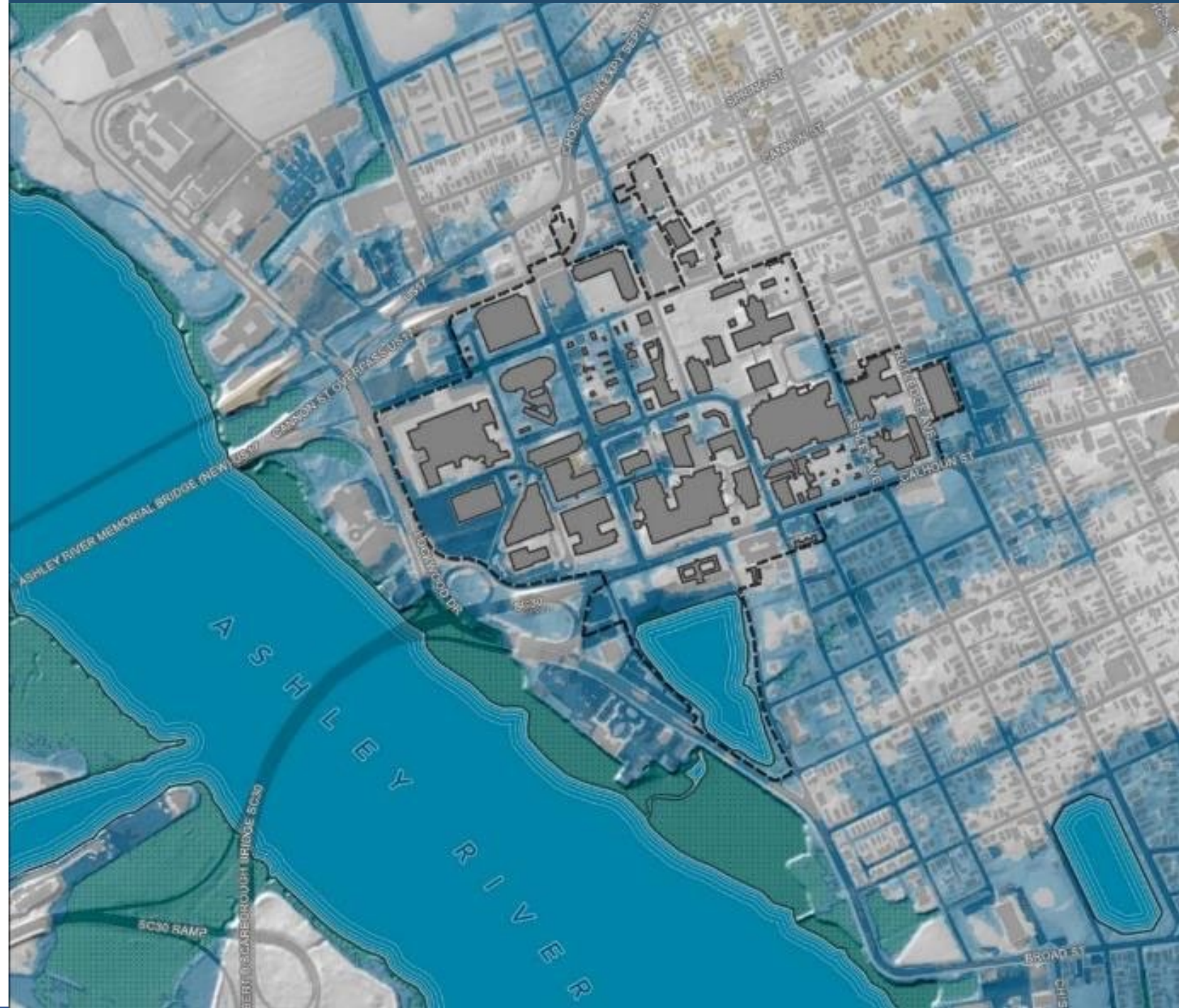
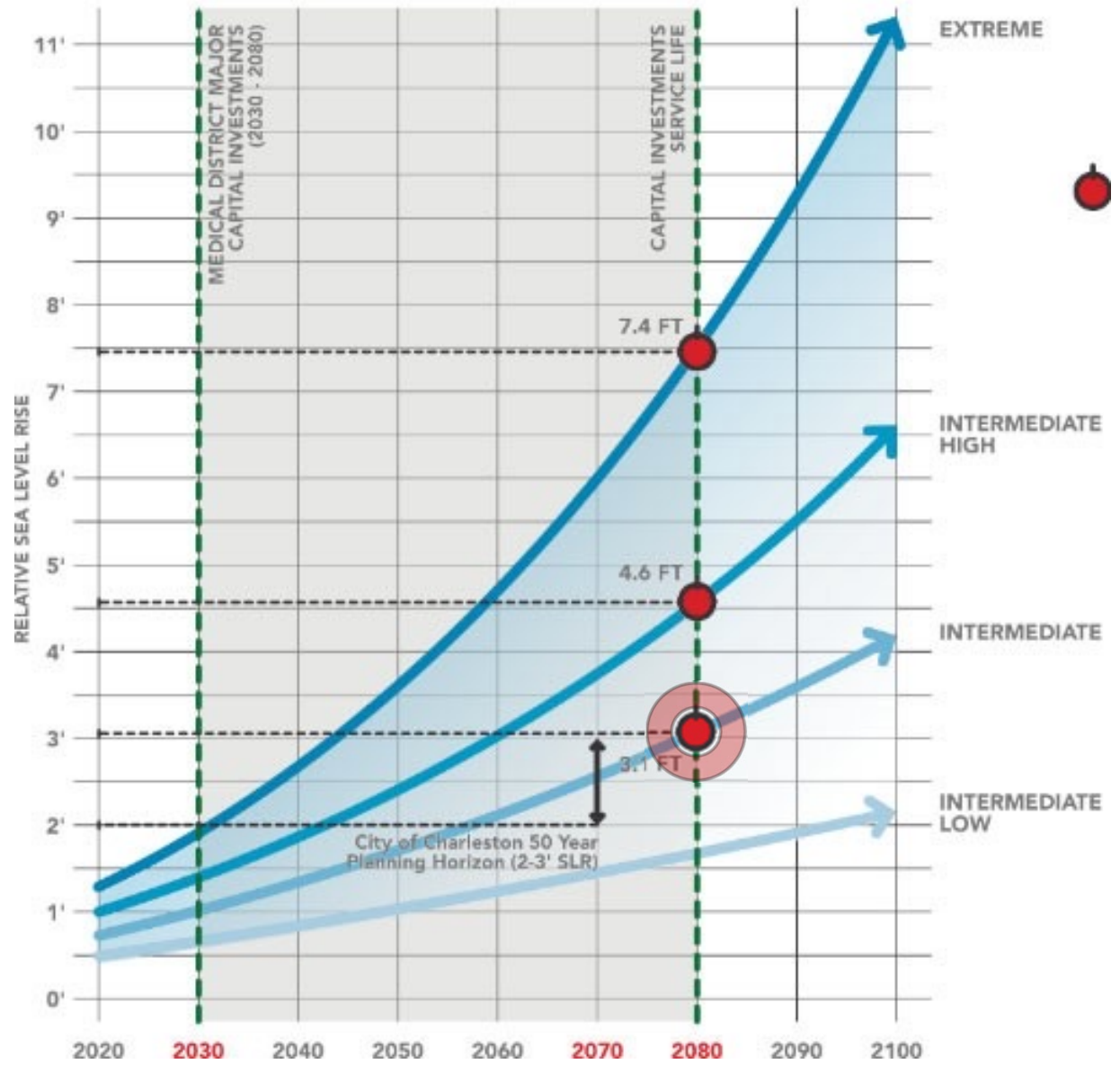


HAZMAT

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Rising Waters



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Upcoming Projects

+\$2 billion @ CMD

MUSC Replacement Hospital

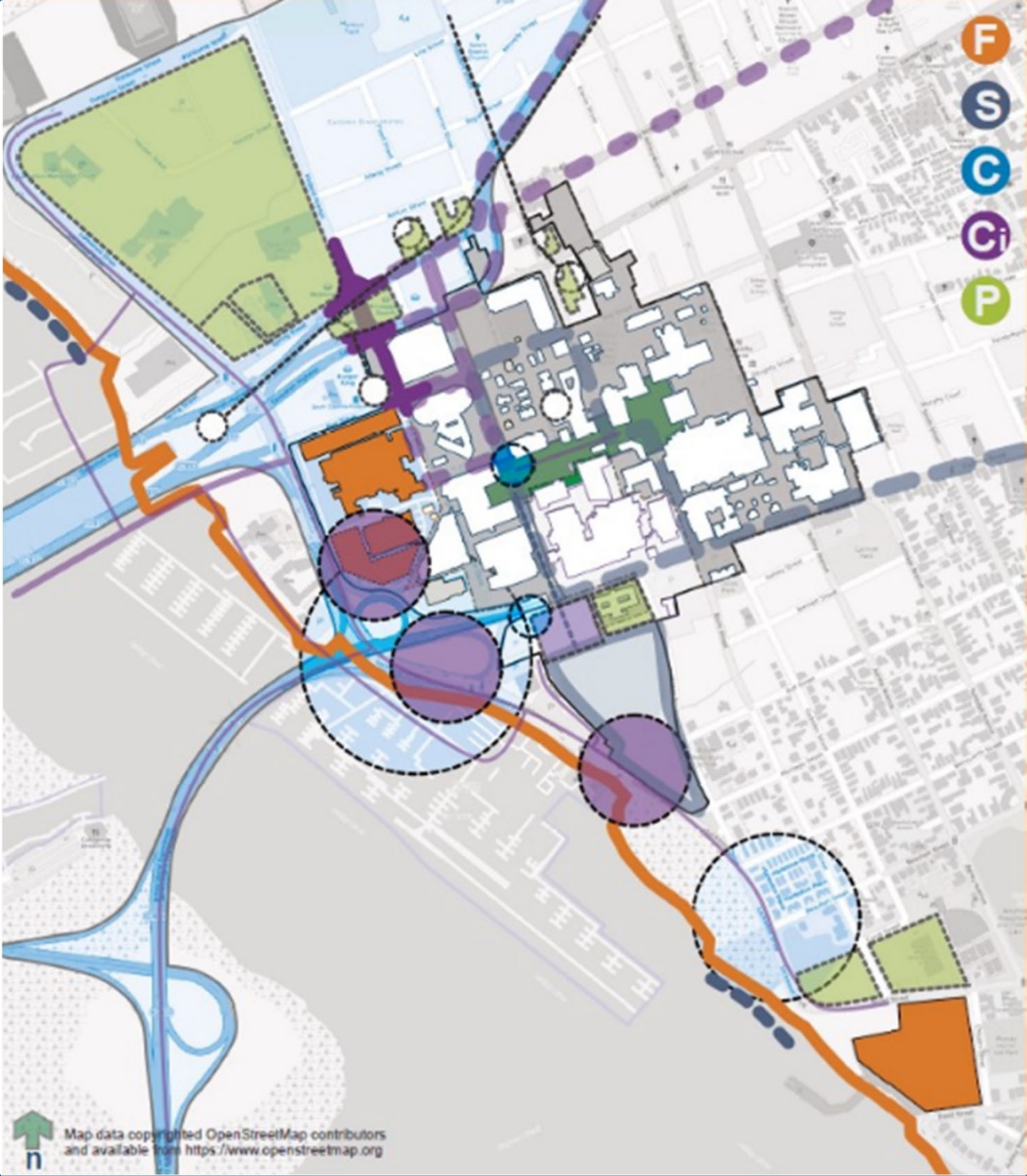
VA Bed Tower, Garage and Upgrades

+ USACE

+ City Projects

+ SC DoT

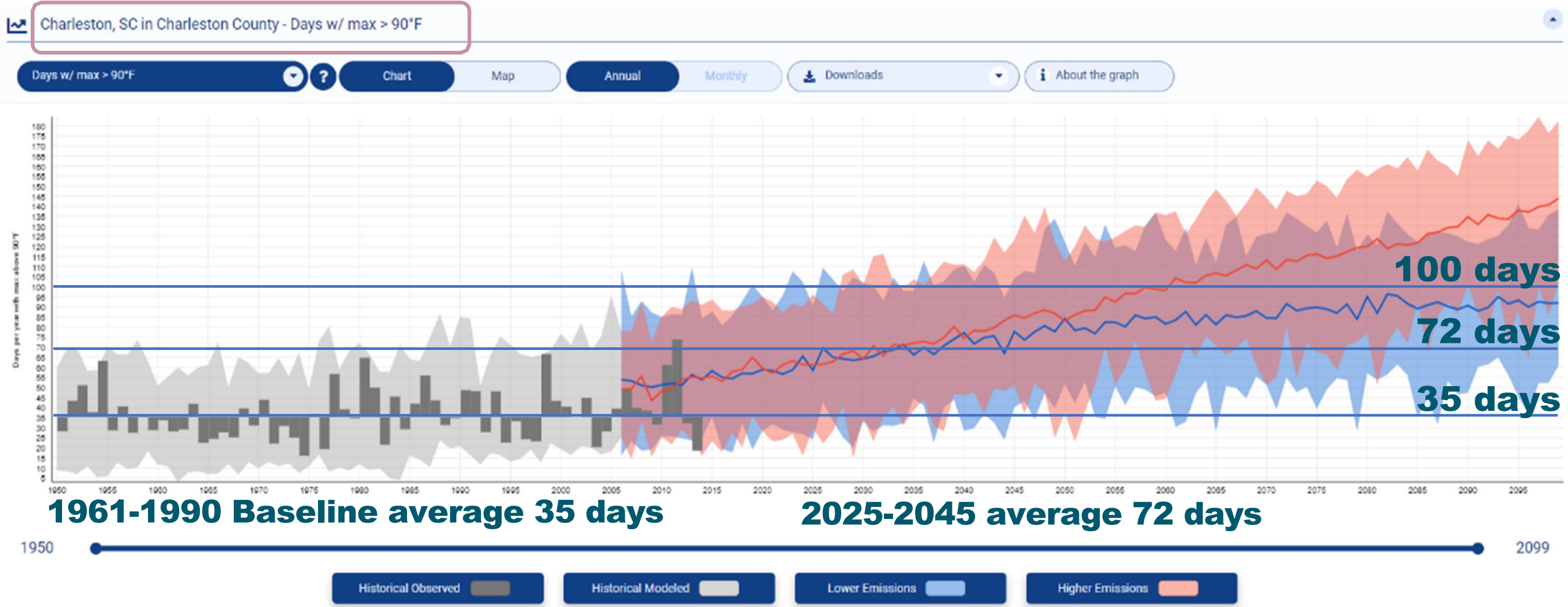
+ West Edge



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June 29, 2023

Rising Heat



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

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Heat is Deadly

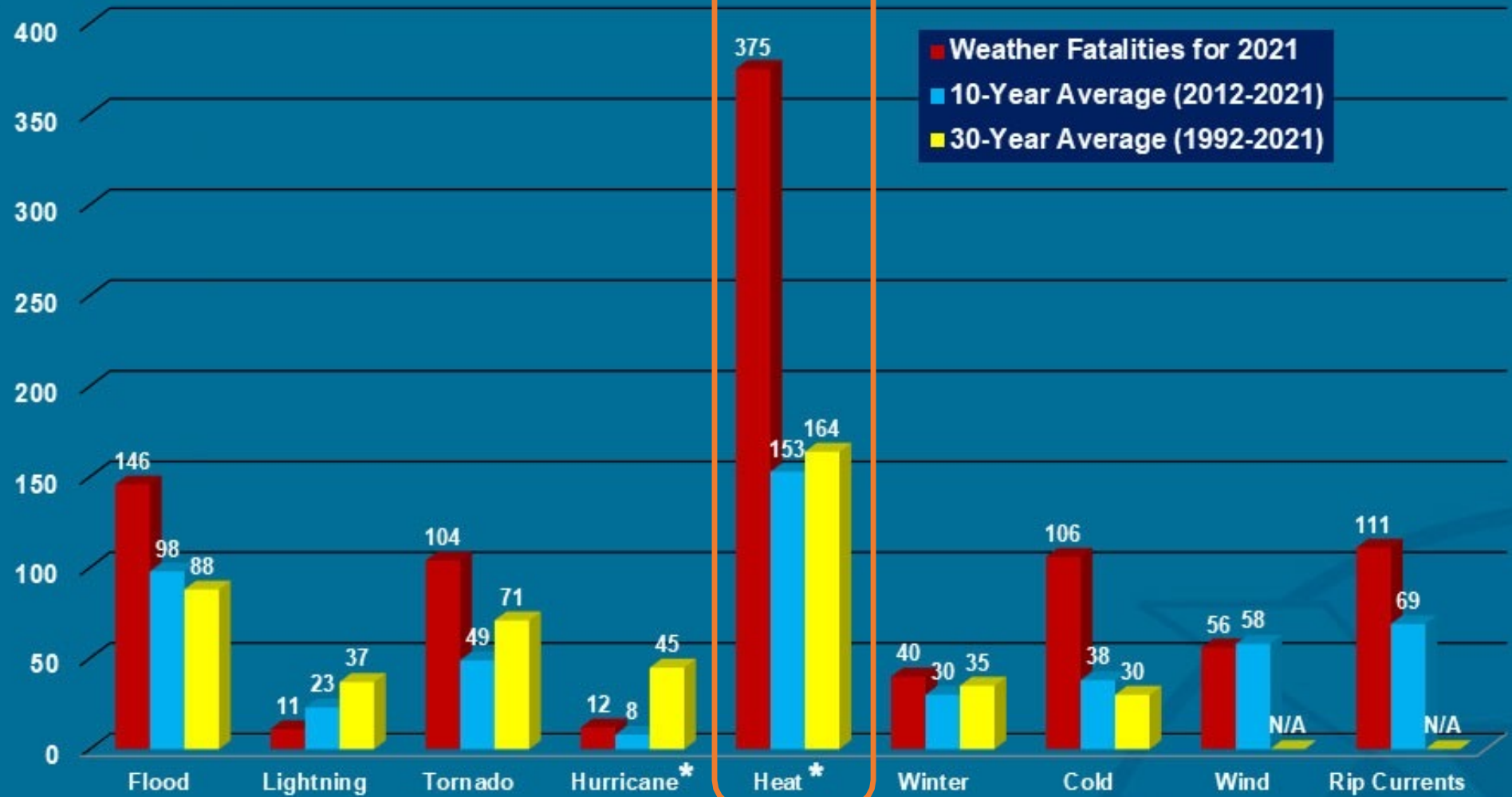
In the south, heat is a given, but it's getting hotter than it used to be.

Increased heat exposure impacts health.

Heat kills more people annually than any other weather hazard.



Weather Fatalities 2021



*Due to an inherent delay in the reporting of official heat fatalities in some jurisdictions, this number will likely rise in subsequent updates.

*The fatalities, injuries, and damage estimates found under Hurricane/Tropical Cyclone events are attributed only to the wind.

IMAGE CREDIT: NWS

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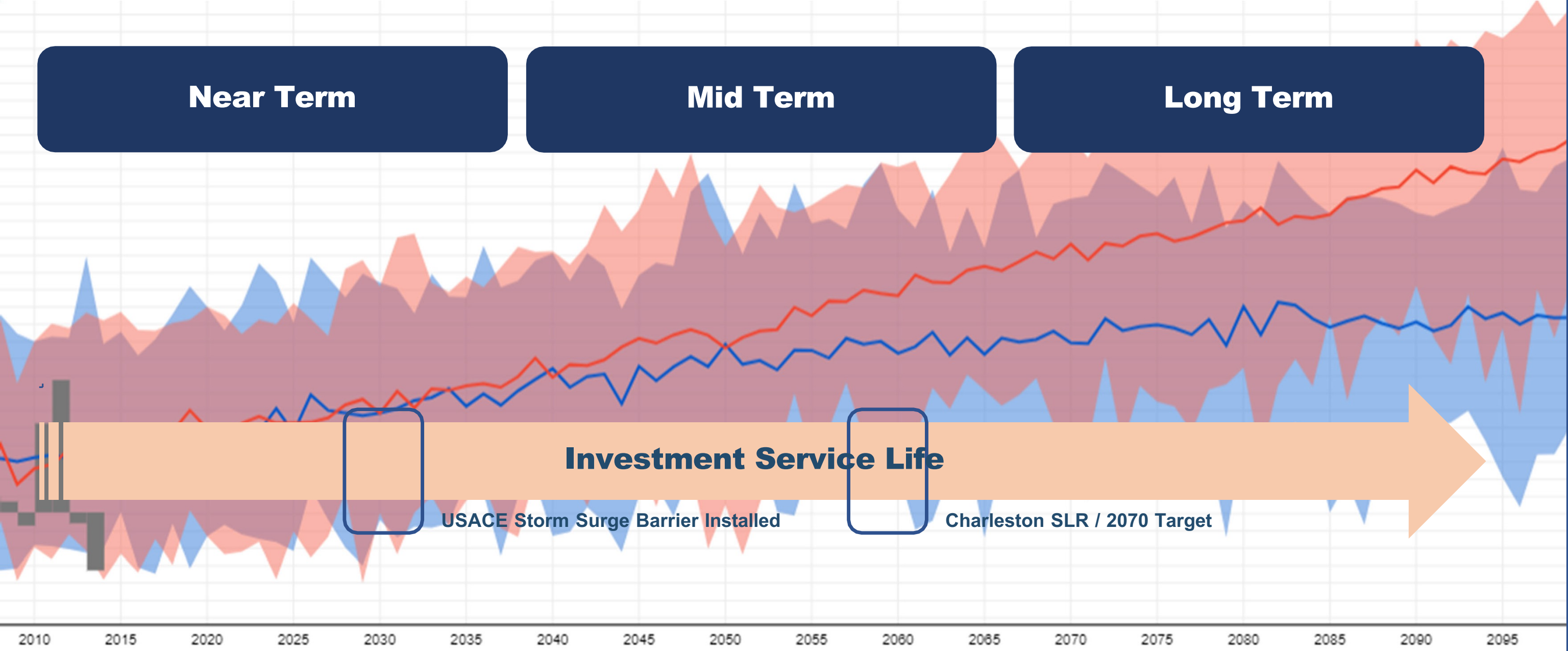
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Investment Service Life

Near Term

Mid Term

Long Term



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June 29, 2023

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)

0 150 300 600 Meters

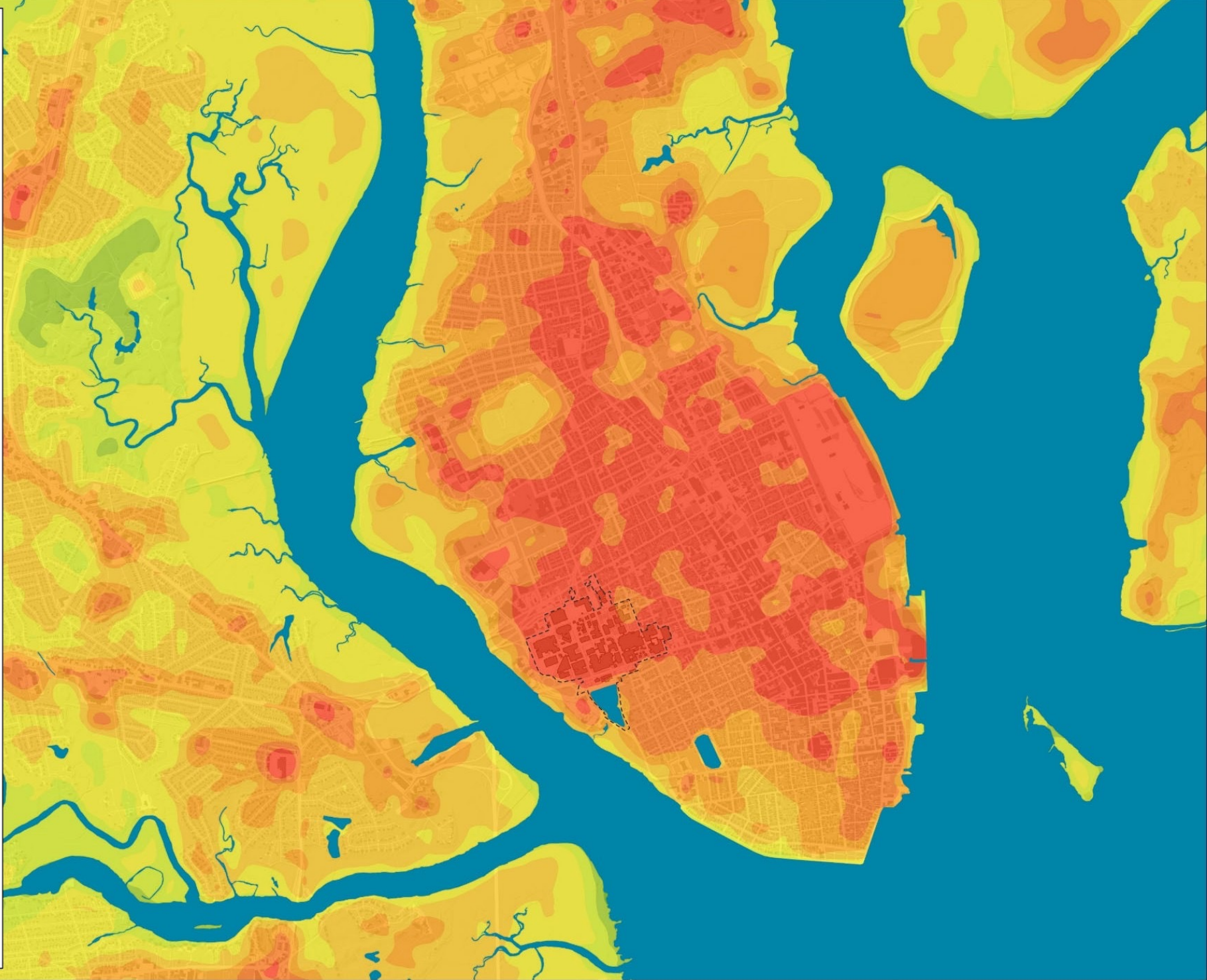
--- CMD Boundary

CMD Surface Temperature
4 July 2020 (fahrenheit)

- ≤68.207362
- ≤74.39359
- ≤77.570302
- ≤80.245427
- ≤82.920553
- ≤85.595679
- ≤88.270804
- ≤91.447516
- ≤94.958619
- ≤102.649605

Credits: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community
City of Charleston Data: (2020, July 15). Retrieved from <https://data-charleston-sc.opendata.arcgis.com>
National Flood Hazard Layer (NFHL) | FEMA.gov. (2020, July 15). Retrieved from <https://www.fema.gov/national-flood-hazard-layer-nfhl>
USGS TNM Download. (2020, April 29). Retrieved from <https://viewer.nationalmap.gov/basic>
Halsey Map (1949) courtesy of Historic Charleston Foundation
Bathymetry: Charleston Harbor (2018)
Bathymetric Digital Elevation Model - NOAA/NOS Estuarine Bathymetry - NOAA Data Catalog. (2020, August 03). Retrieved from <https://data.noaa.gov/dataset/dataset/charleston-harbor-s080-bathymetric-digital-elevation-model-noaa-nos-estuarine-bathymetry>
Landsat Products: USGS. (2020, August 05). EarthExplorer. USGS - U.S. Geological Survey. Retrieved from <https://earthexplorer.usgs.gov>
Bing Map Tiles: Microsoft product screen shot(s) reprinted with permission from Microsoft Corporation

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resilience through collaborative partnerships



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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

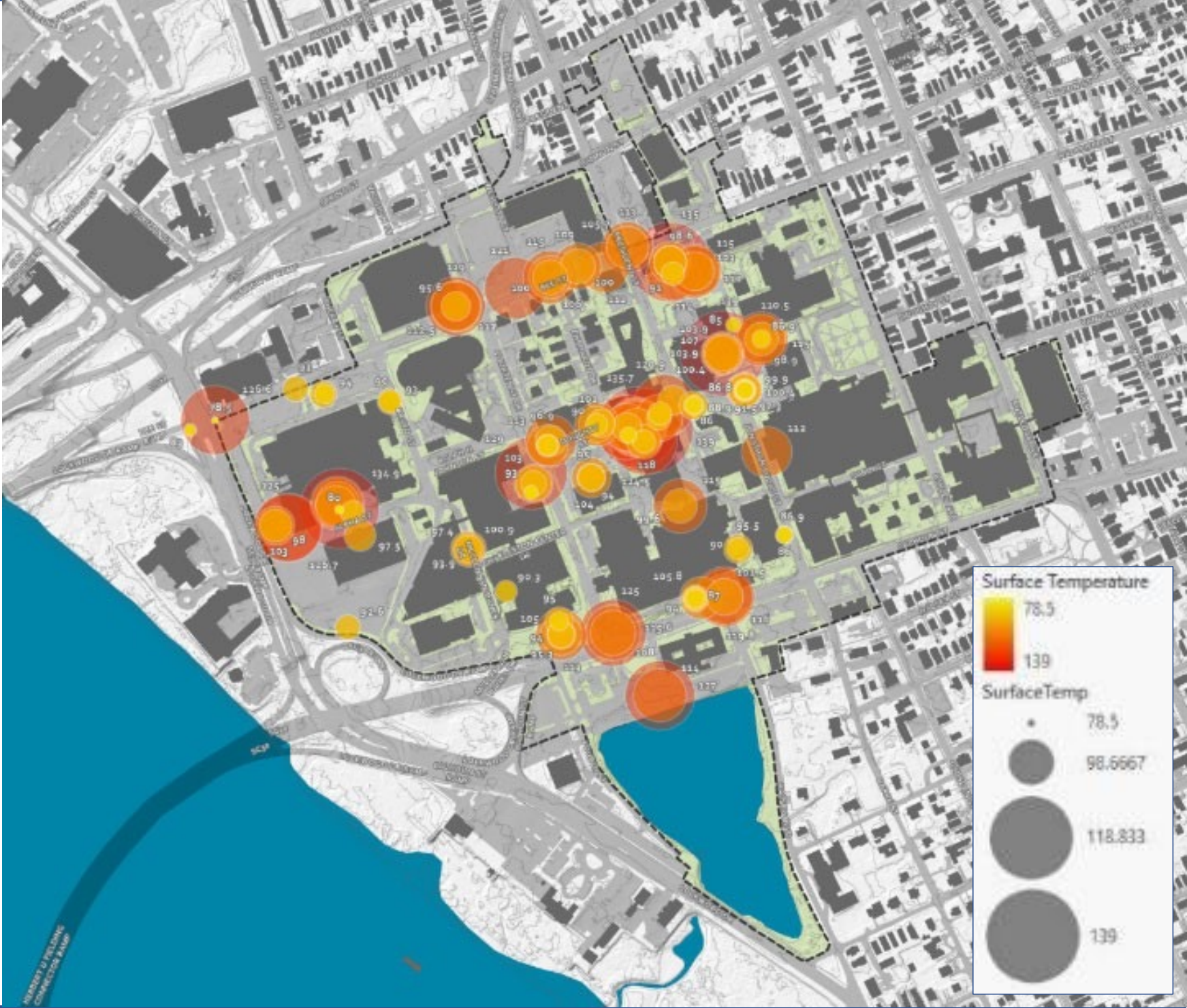
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Surface Temperature Points

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
 © 2020 Time and Date AS



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Doughty Street & Greenway

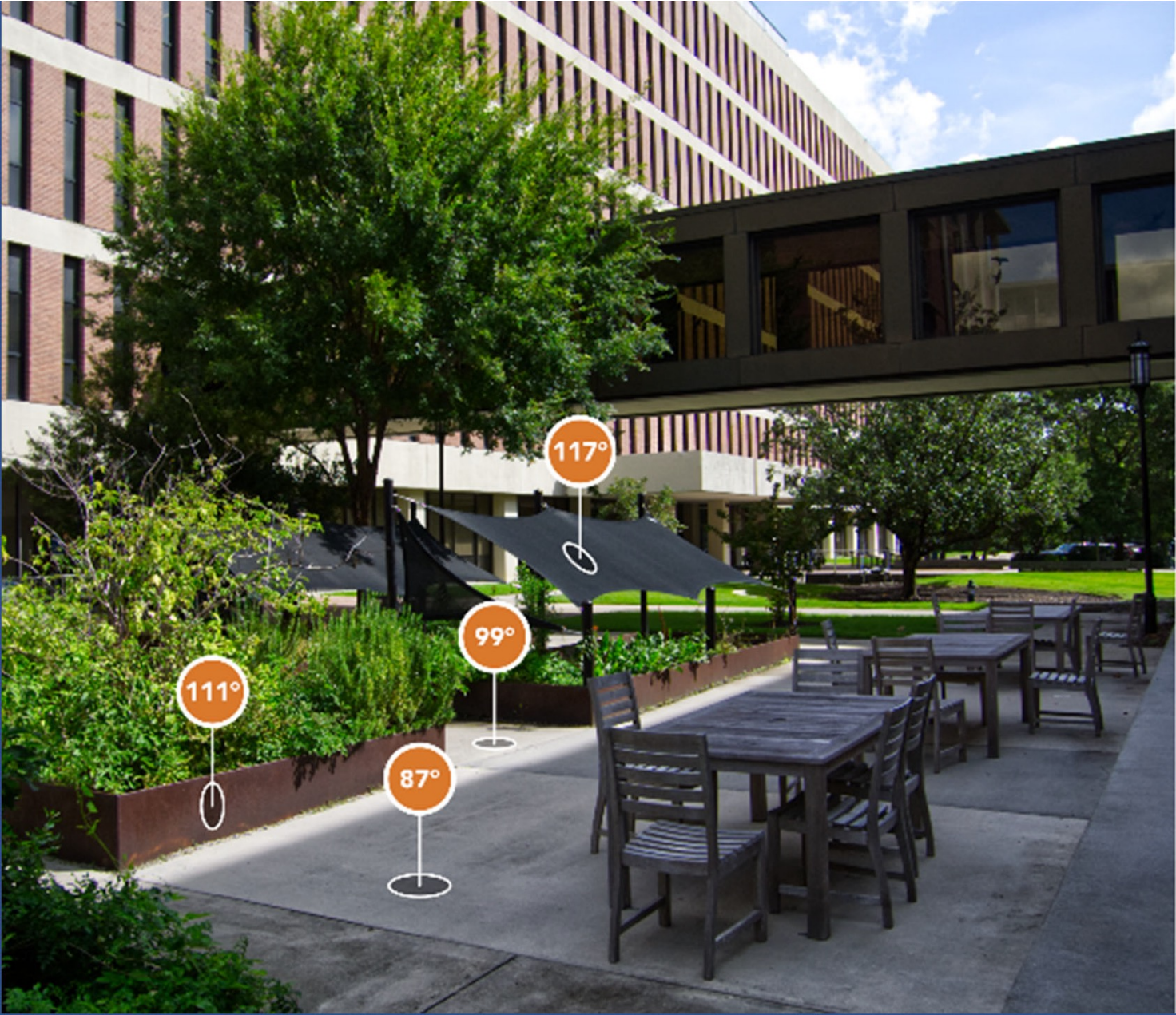


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Memorial Garden & Drug Discovery-BioEngineering Plaza



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Urban Farm



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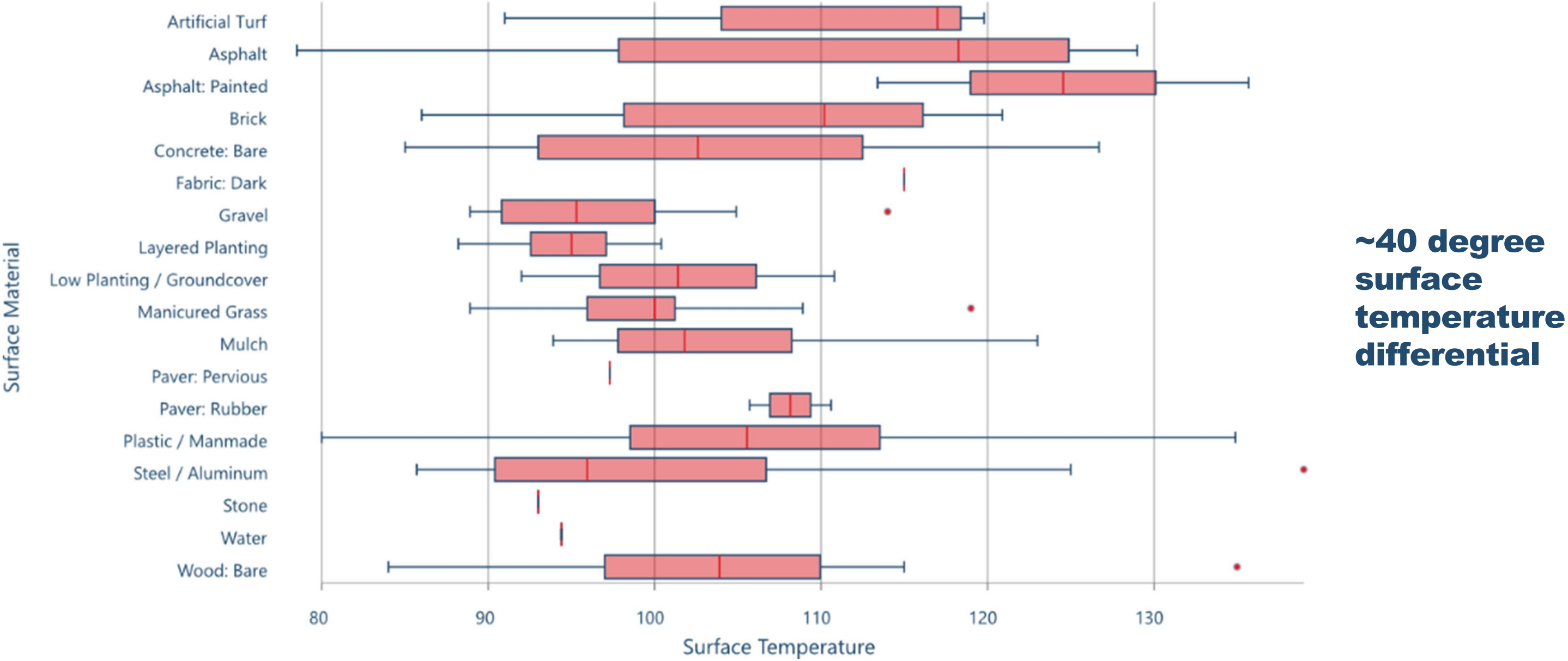
Bee Street



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Material Type / Temperature Distribution



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Summer 2020 Charleston Medical District Charrettes

How is heat addressed?

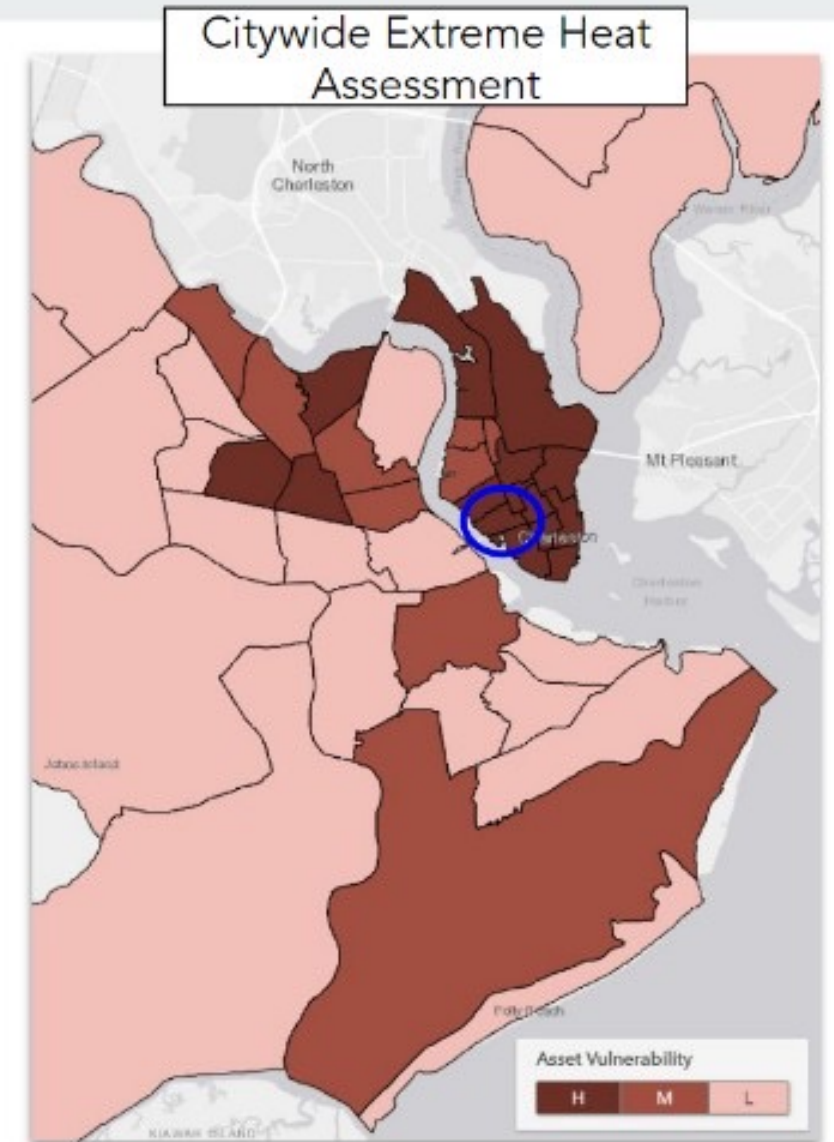


Vulnerability to Extreme Heat

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

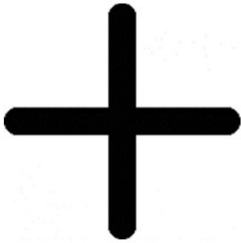
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CISA Heat Research: Measuring Personal Temperature Exposure & WBGT



**Thermochron or Hydrochron
iButton**



**GPS and Heart Rate
Data at the Individual
Level**



**Hand-held device that
estimates wet bulb globe
thermometer**

Three Groups of Outdoor Workers

WBGT Pilot Sites

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Charleston Heat Research

1 CMD Heat Research

2 CISA Heat 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

3 HeatWatch Research

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

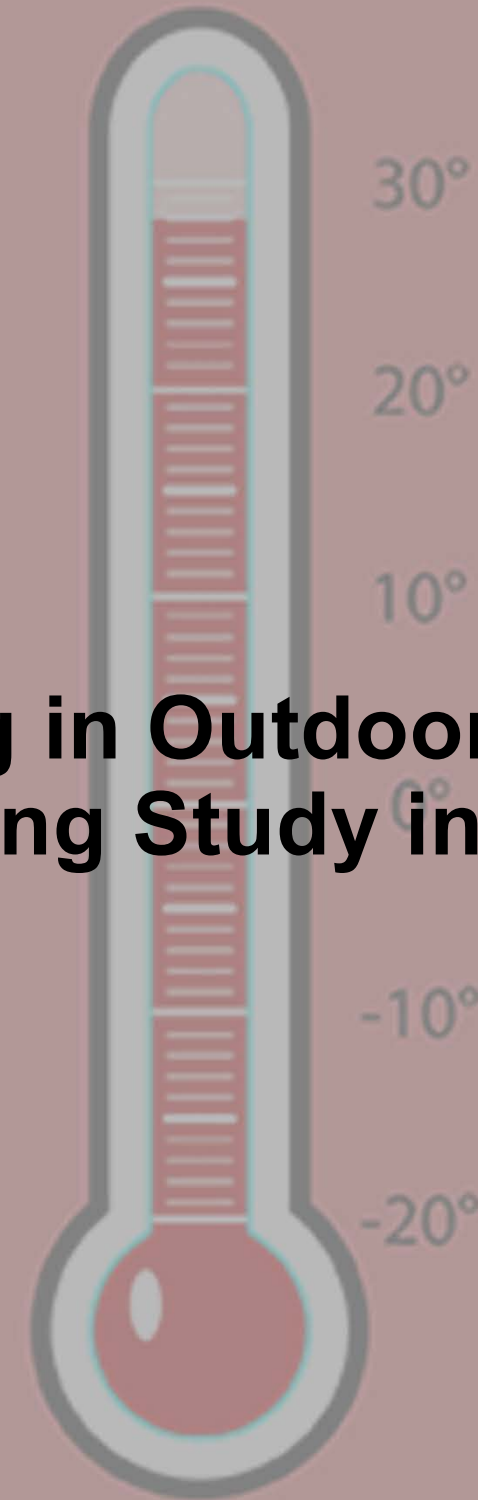
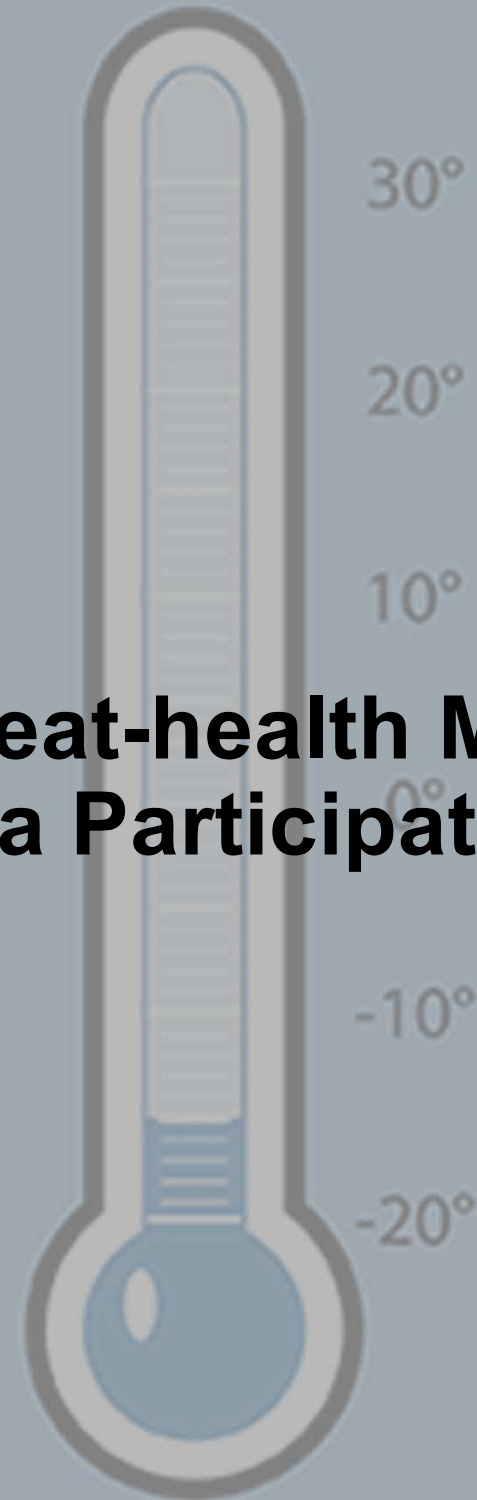
Climate Adaptation Partners
Janice Barnes
Leo Temko

4 Expanding and Sharing Research

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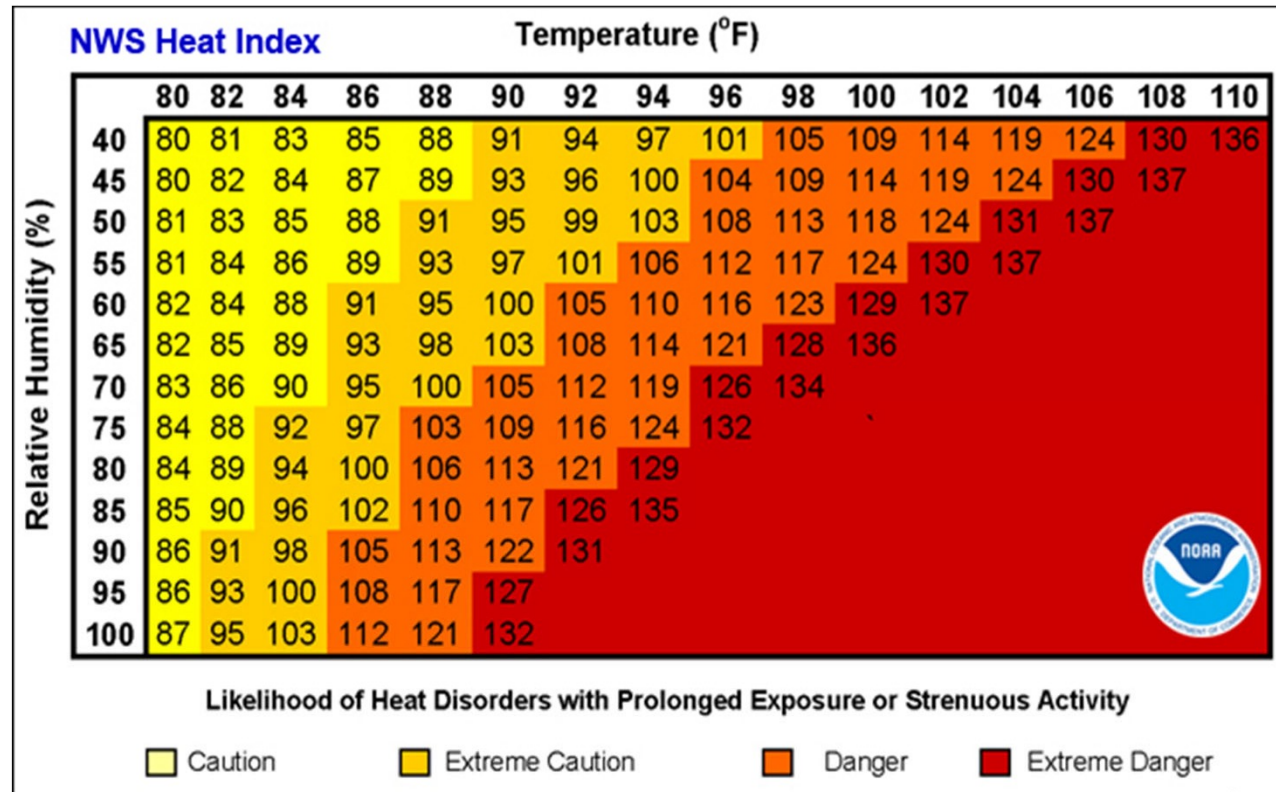
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Local Heat-health Monitoring in Outdoor Workers: Results from a Participatory Sensing Study in Charleston, SC



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)



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

Heat Index → Takes into account temperature + relative humidity



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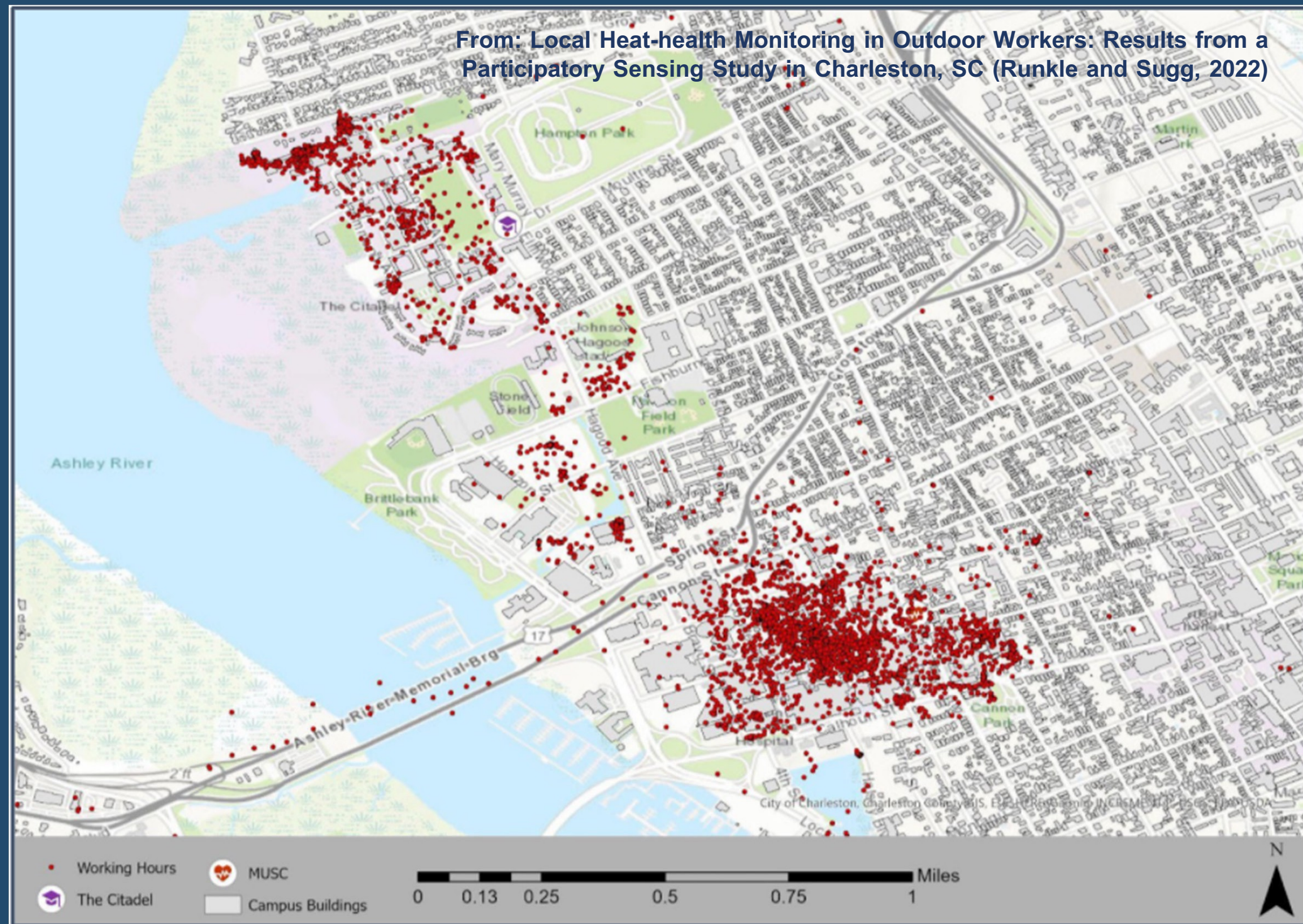
Continuous Monitoring of Personal Heat Index in an Occupationally Exposed Population

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

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



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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):

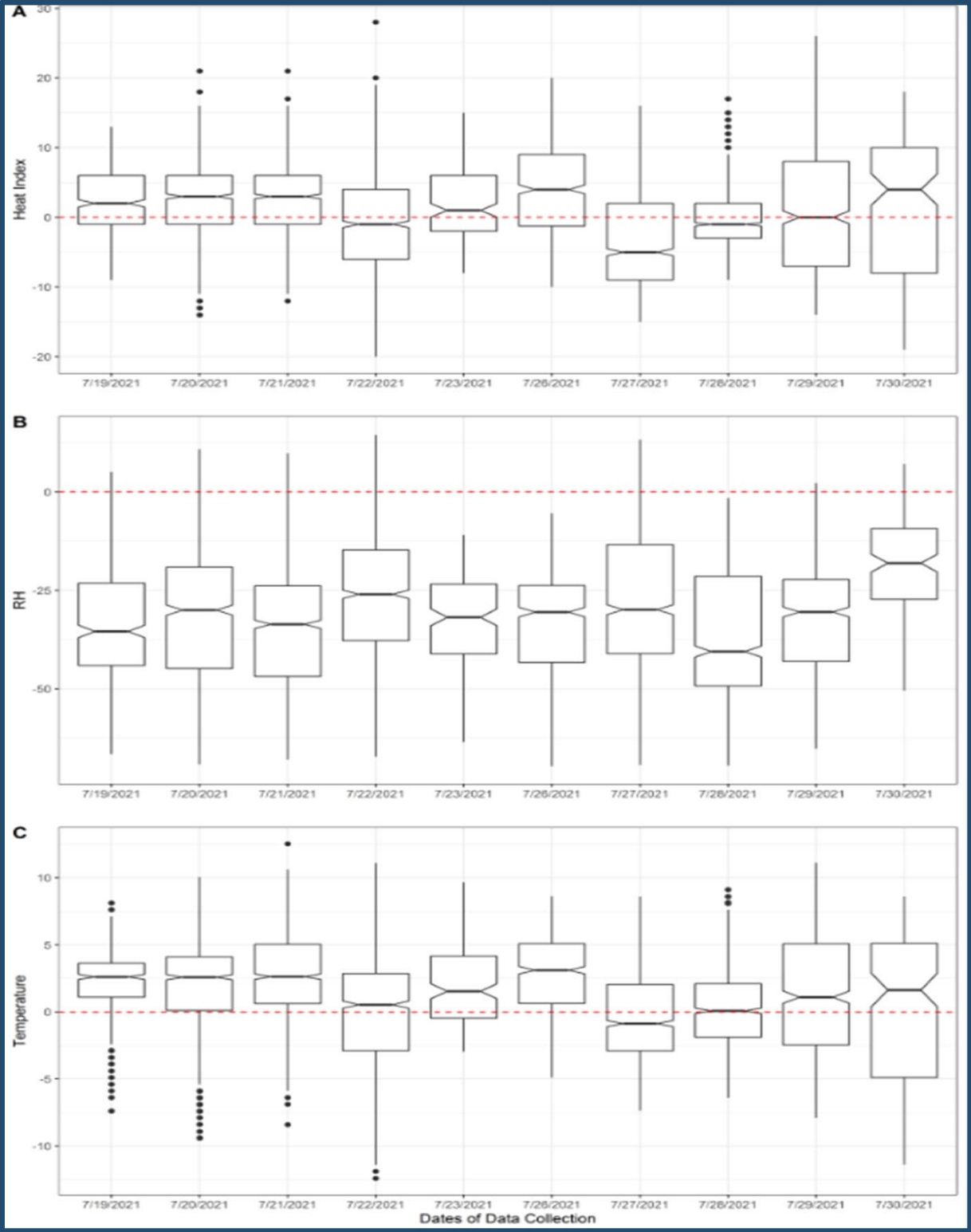
	Monday 7/19		Tuesday 7/20		Wednesday 7/21		Thursday 7/22		Friday 7/23	
	 		 		 		 		 	
Average Temperature	77.7°	81.5°	77.8°	82.5°	78.1°	83.5°	78.3°	85.0°	78.3°	84.0°
Max Temperature	97.8°	87.0°	97.8°	88.0°	97.7°	90.0°	97.8°	90.0°	97.8°	89.0°
Minimum Temperature	62.8°	76.0°	62.8°	77.0°	62.8°	77.0°	65.5°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

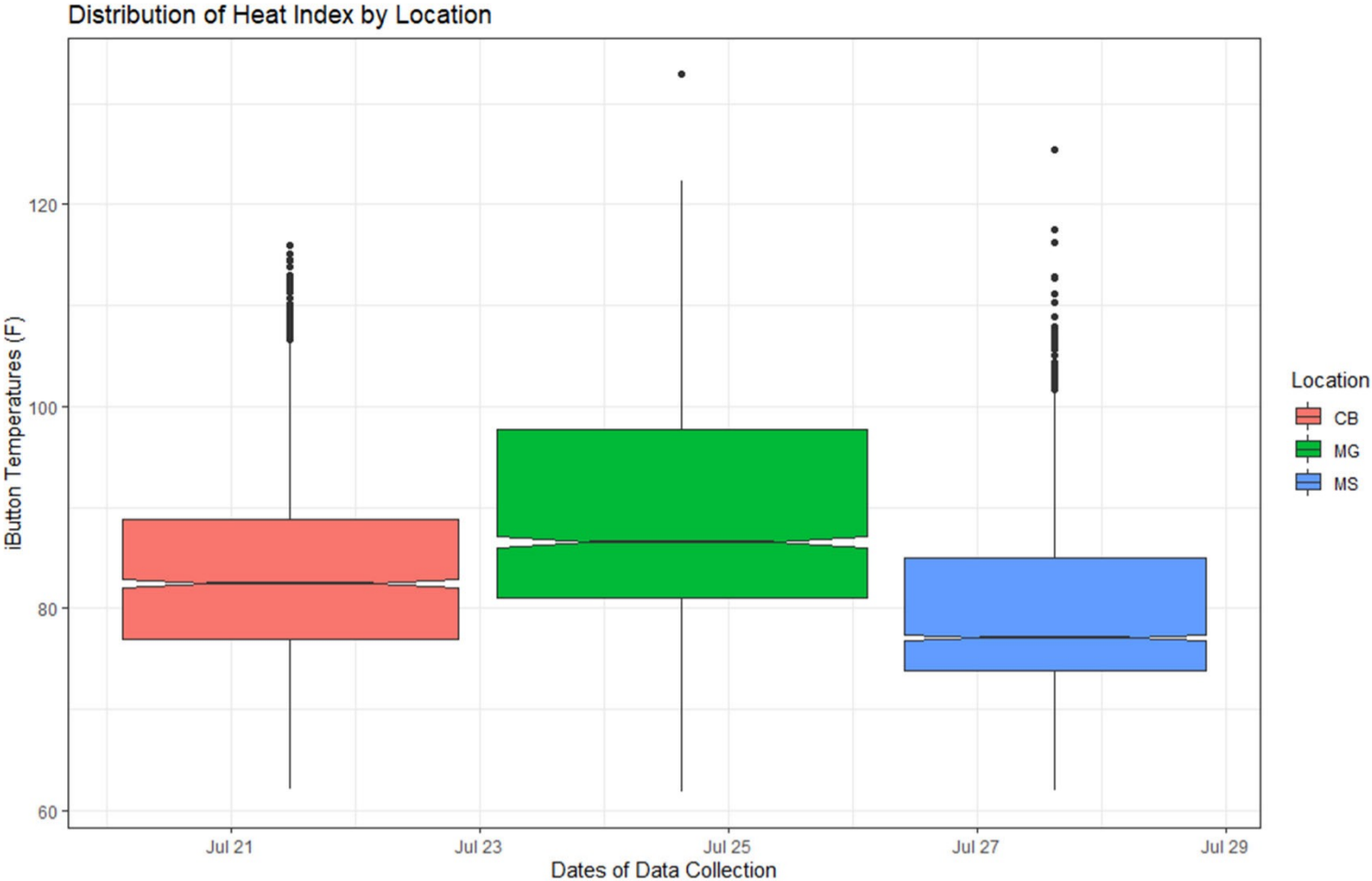


Key Messages

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

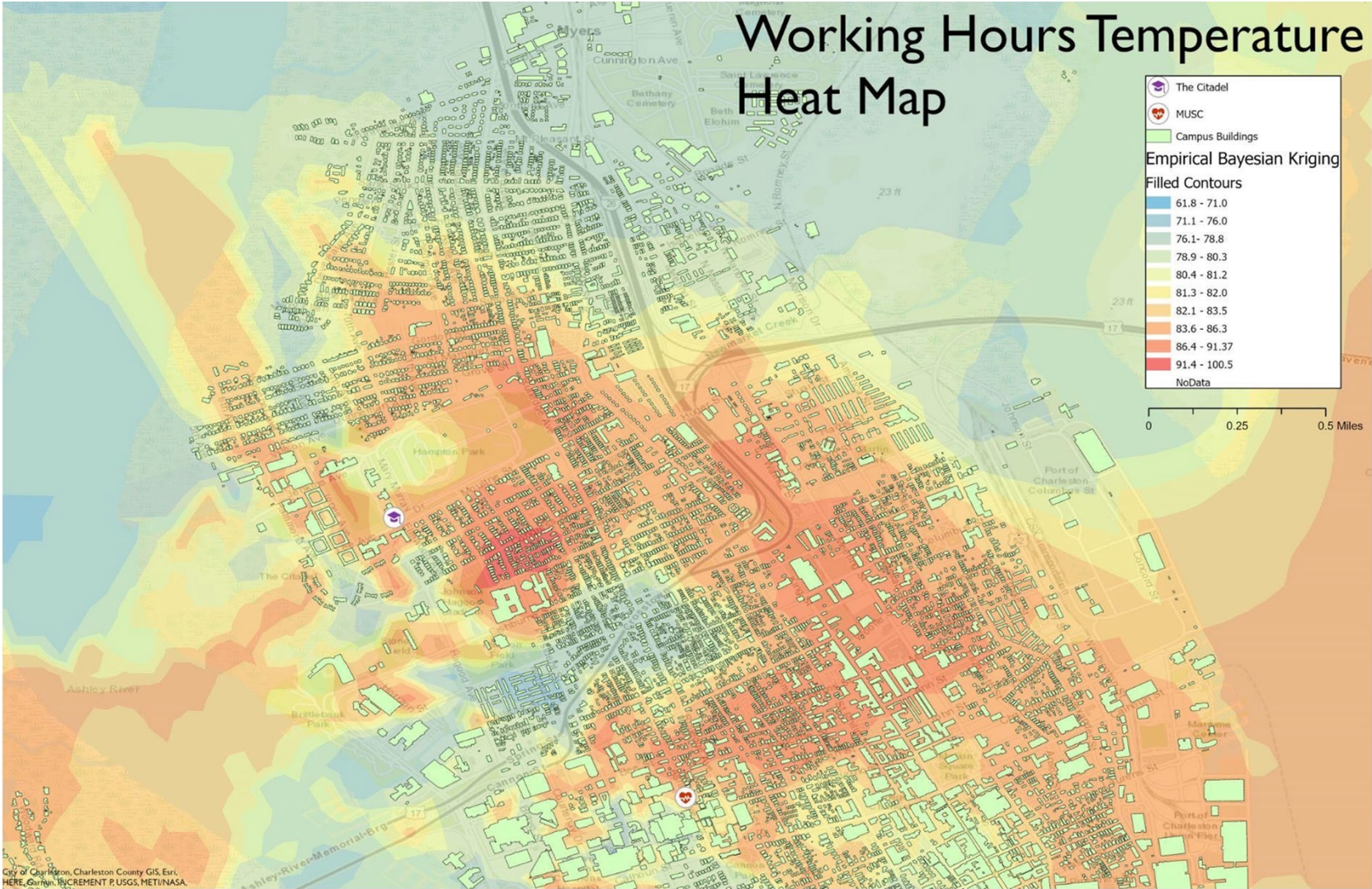


Key Messages

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.**



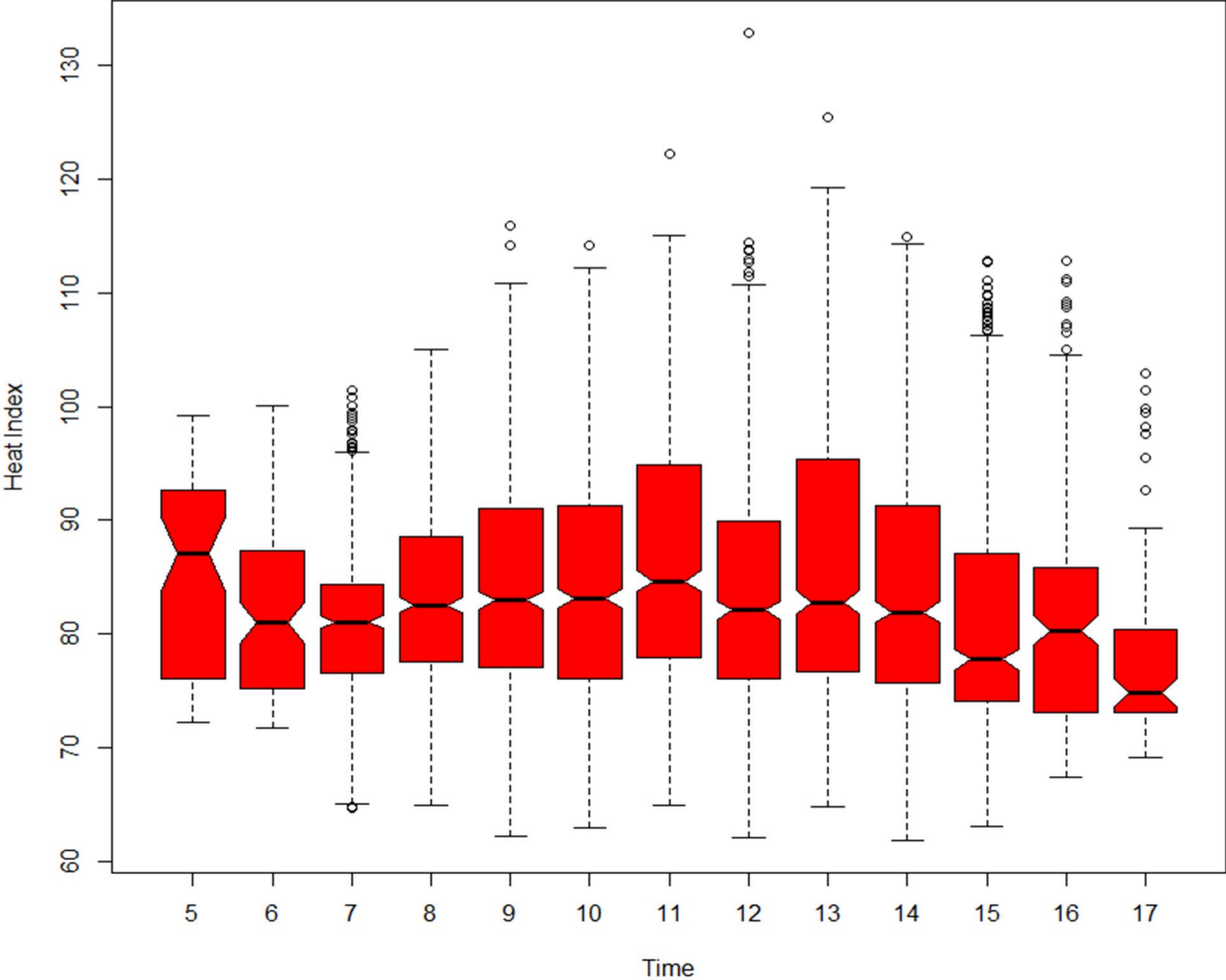
Temperatures modelled based on observations from hydrochron temperature and humidity sensors worn by volunteers July 18-31, 2021

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)



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

1

**CMD Heat
Research**

2

**CISA Heat
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

3

**HeatWatch
Research**

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

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

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



3. Wind speed
4. Solar Radiation



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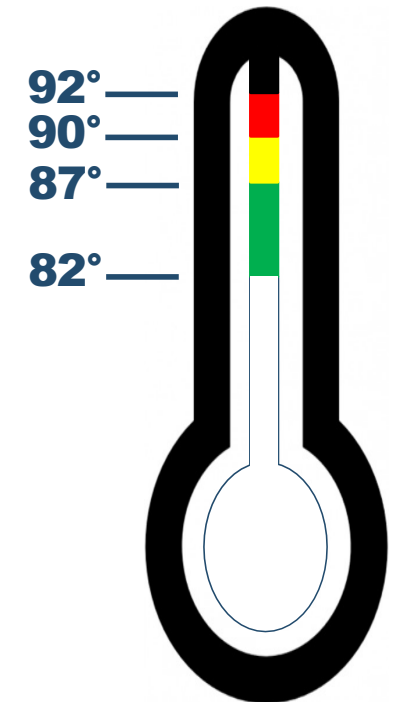
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HEAT SEASON DATA COLLECTION

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

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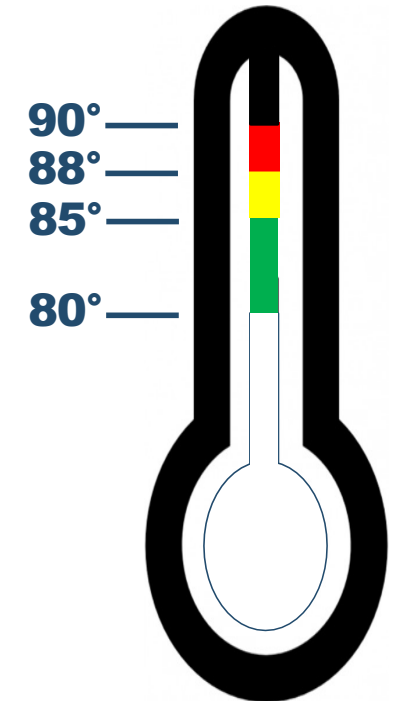
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HEAT SEASON DATA COLLECTION

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 personnel.
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

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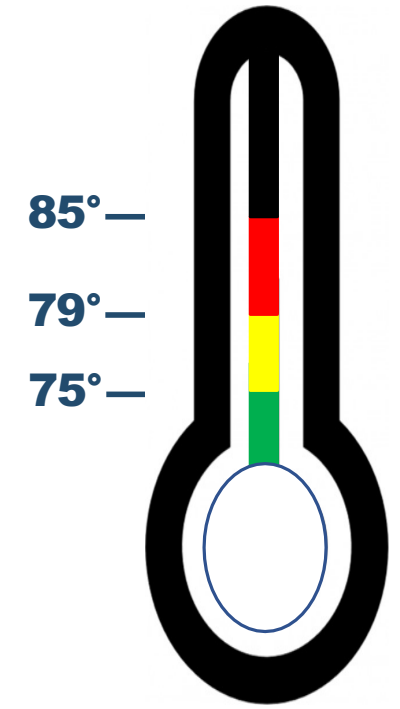
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HEAT SEASON DATA COLLECTION

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 activities allowed, but be alert for prodromes of heat-related illness in prolonged events
Low (Green Flag)	71-74.9	All activities 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

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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)*



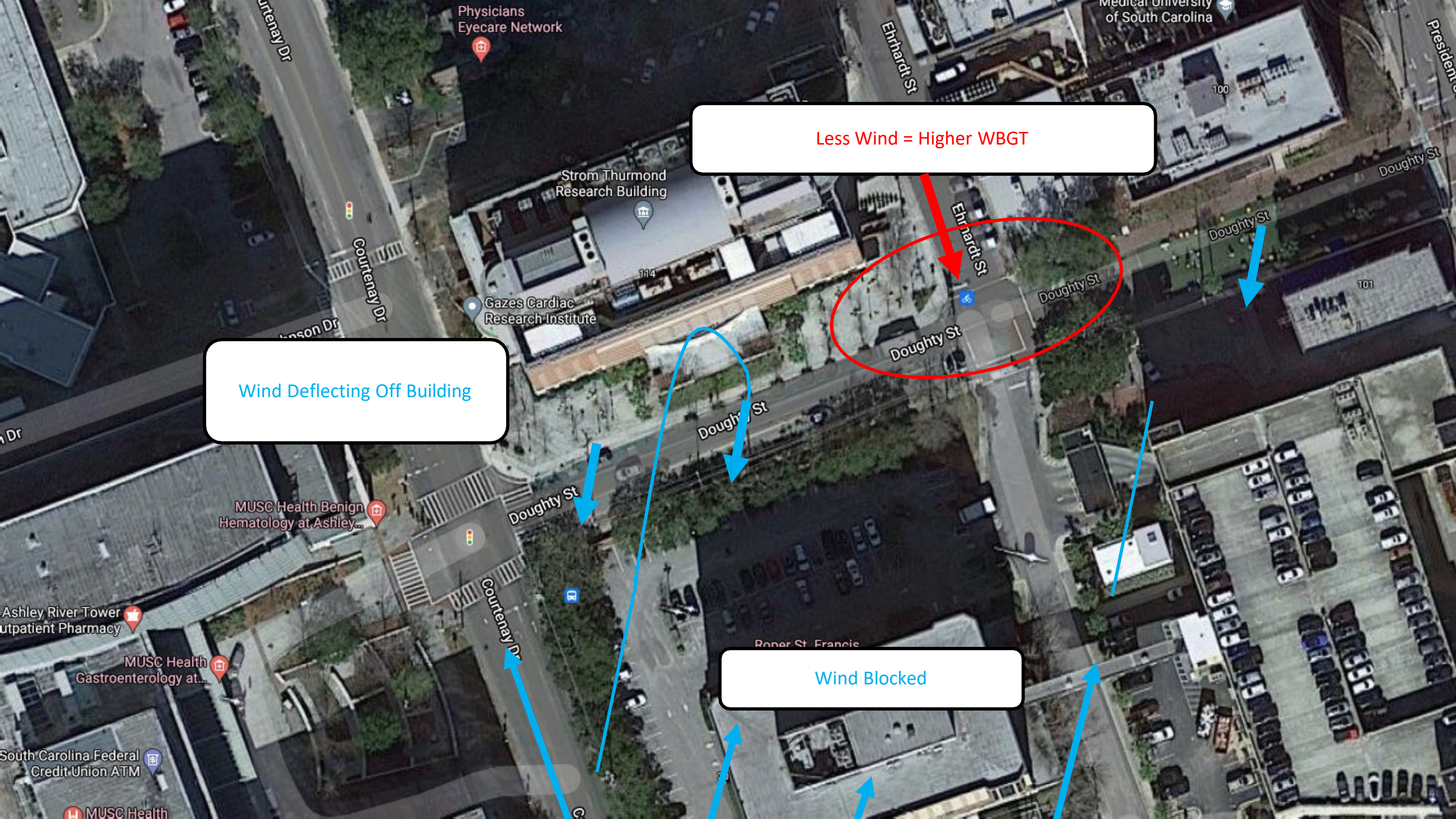
3. Openness of landscape

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



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Less Wind = Higher WBGT

Wind Deflecting Off Building

Wind Blocked

Physicians Eyecare Network

Medical University of South Carolina

Strom Thurmond Research Building

Gazes Cardiac Research Institute

MUSC Health Benign Hematology at Ashley...

Ashley River Tower Outpatient Pharmacy

MUSC Health Gastroenterology at...

South Carolina Federal Credit Union ATM

MUSC Health

Courtenay Dr

Courtenay Dr

Doughty St

Courtenay Dr

Doughty St

Ehrhardt St

Ehrhardt St

Doughty St

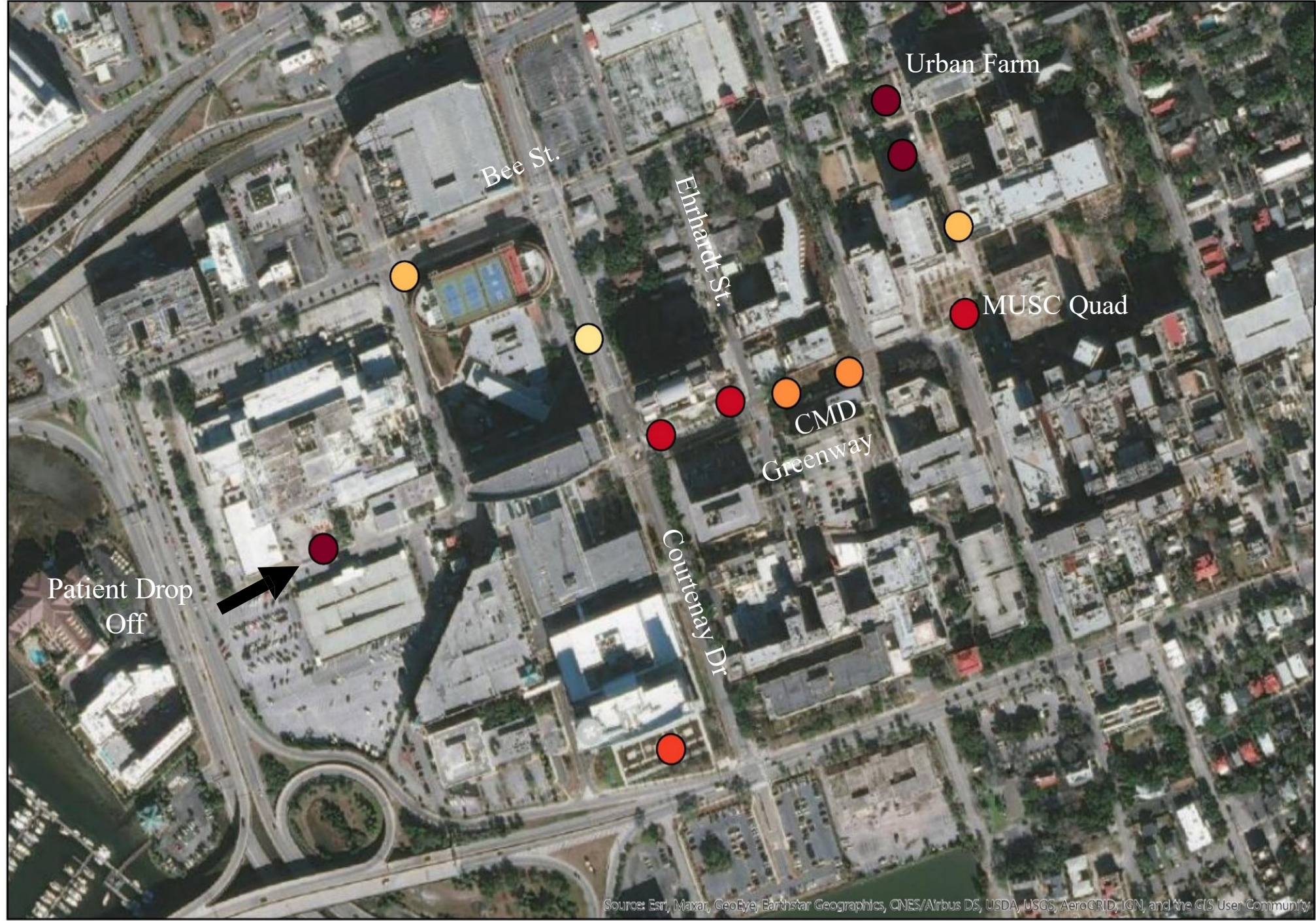
Doughty St

Doughty St

Doughty St

President St

Roper St. Francis



Maximum WBGT at each location

WBGT (°F)



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
 June 29, 2023

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

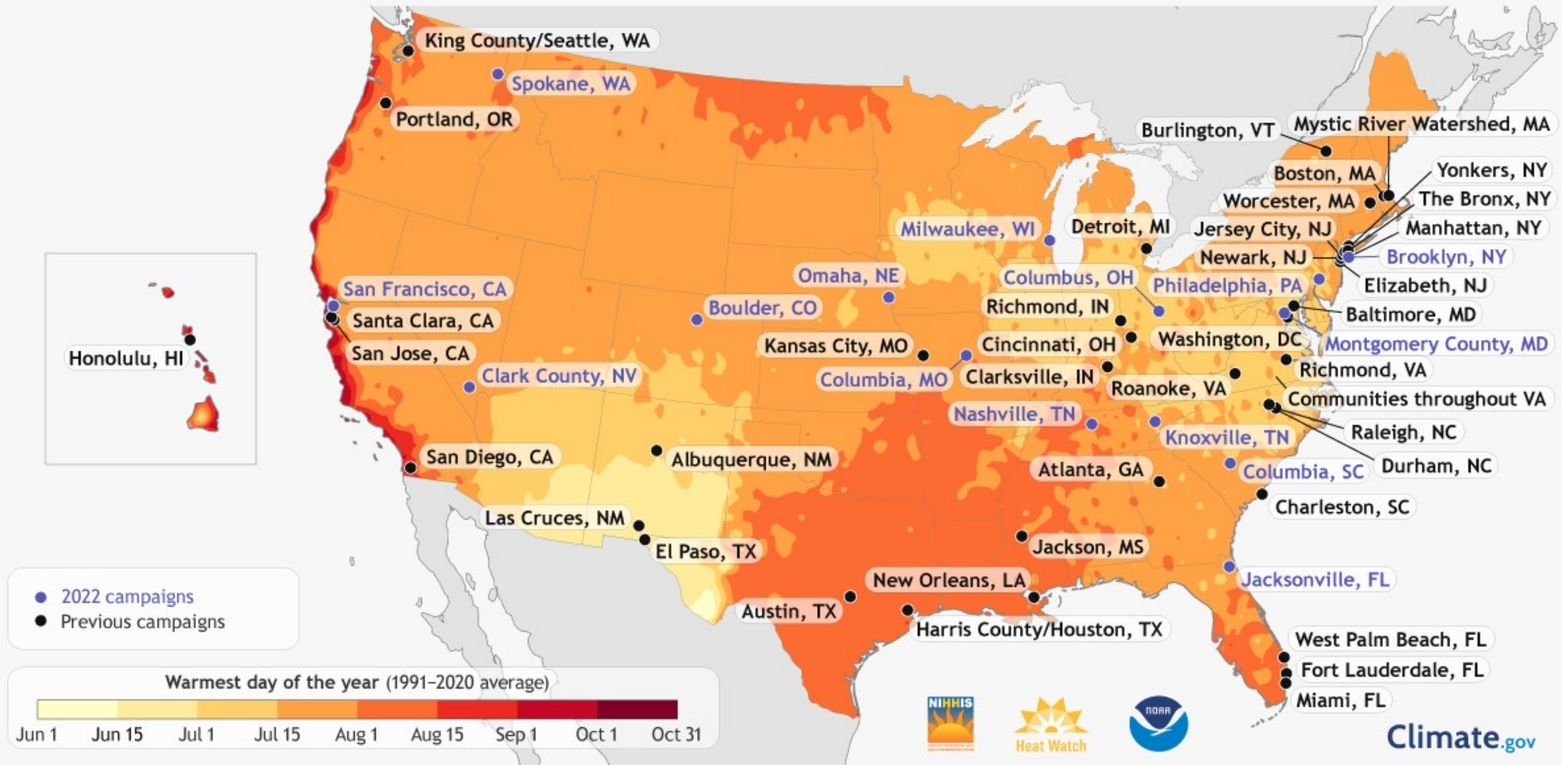
- Medical University of South Carolina Arboretum
- Citadel James B. Near Center for Climate Studies
- Charleston Resilience Network (Over 120 organizations)
- Charleston Medical District
- South Carolina Interfaith Power and Light
- Carolinas Integrated Sciences and Assessments
- Medical University of 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

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
June 29, 2023

NOAA Urban Heat Island Mapping Campaigns: All Locations, 2017-2022



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
June 29, 2023

climate adaptation partners
resilience through collaborative partnerships

Charleston HeatWatch



Media

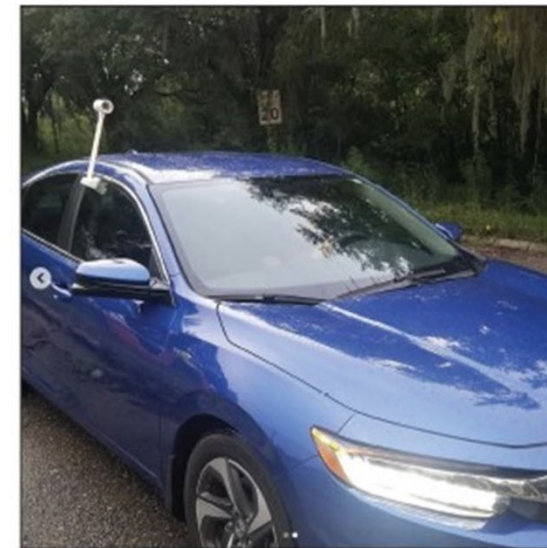
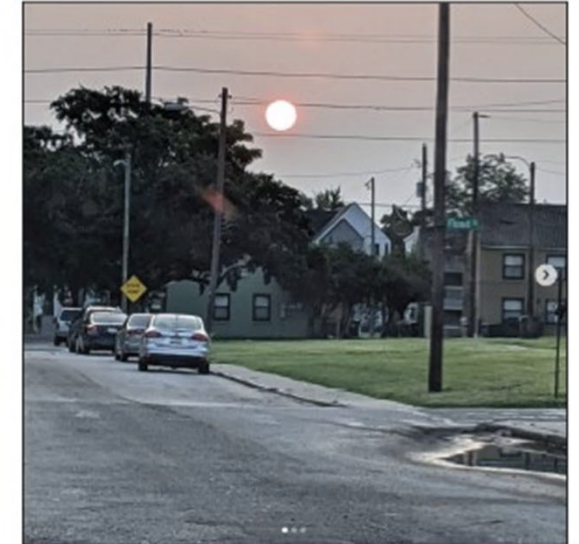


Driving Team

- 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



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
June 29, 2023

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

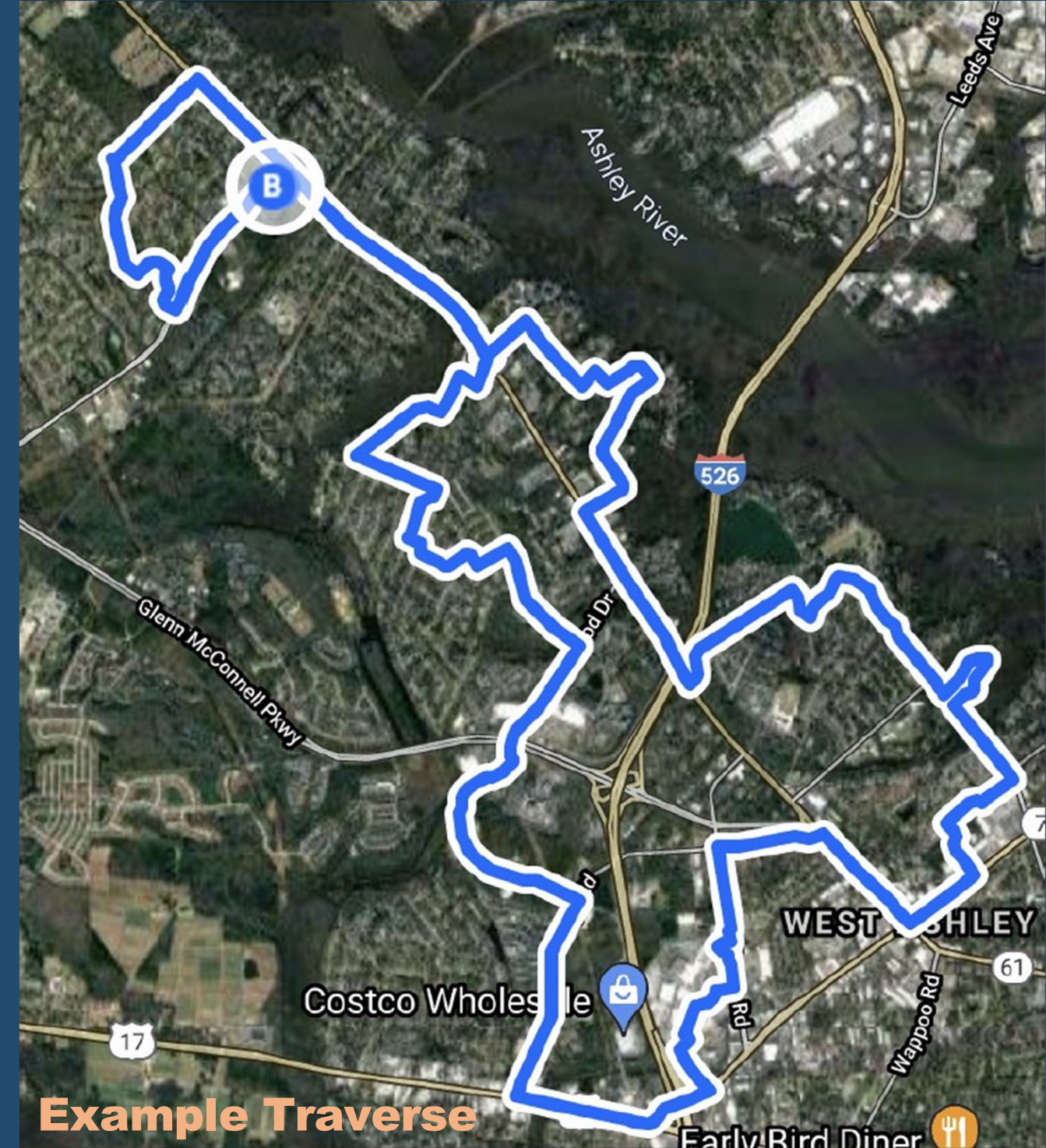
Data Collection

July 31, 2021

Morning, Afternoon, Evening Traverses

Volunteers

10 Driving Teams
3 FLIR Teams
1 Coordinating Team



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
June 29, 2023

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)



MEDIAN INCOME DATA
U.S. Census Bureau's American Community Survey (ACS) 2015-2019 5-year estimates. Tables: B19012B, B19013C, B19013D, B19013E, B19013F, B19013G, B19013I, B19013J, B19049, B19053

HEALTH INSURANCE COVERAGE DATA
U.S. Census Bureau's American Community Survey (ACS) 2015-2019 5-year estimates. Table: B27012

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

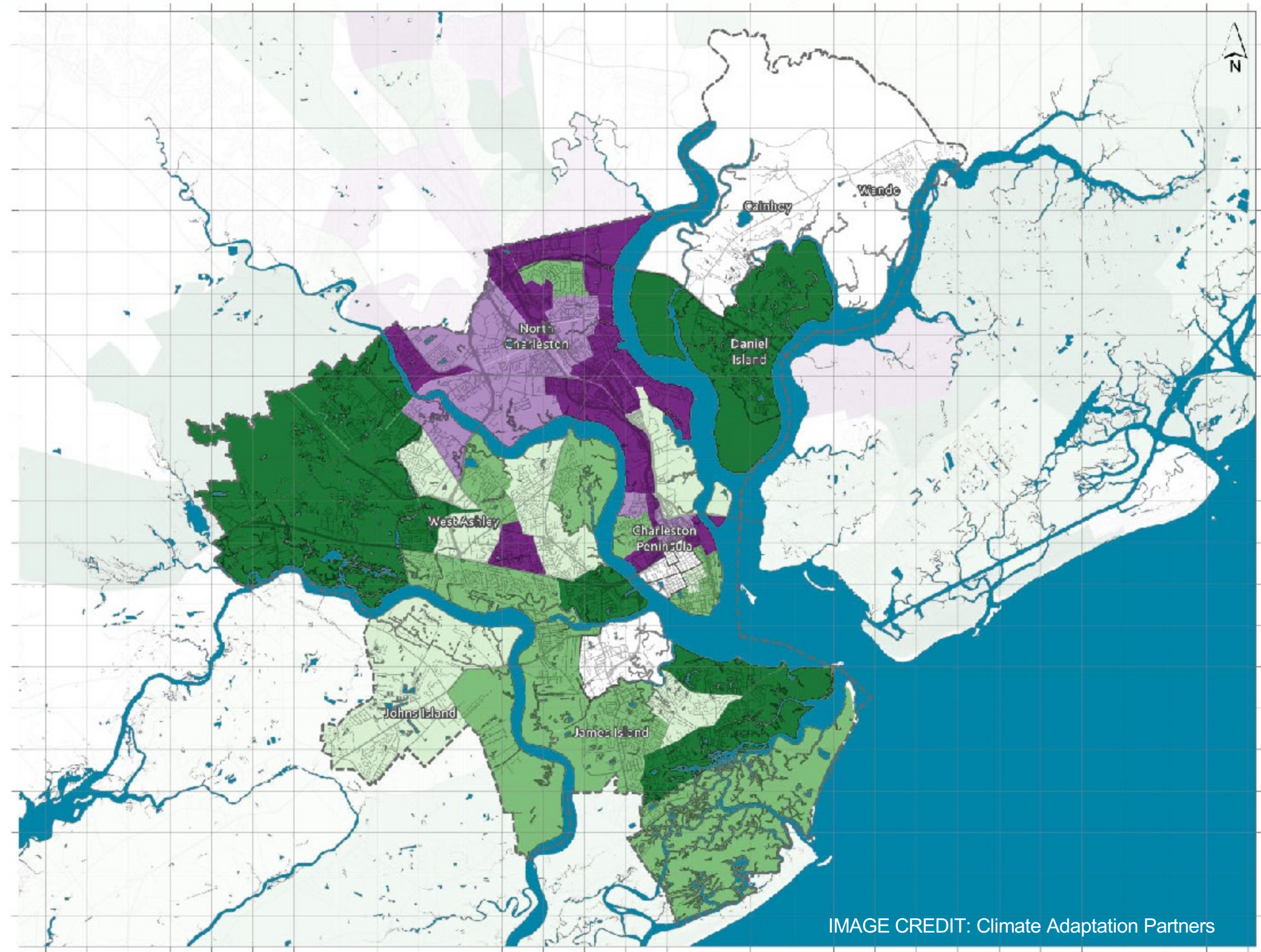
EDUCATION DATA
U.S. Census Bureau's American Community Survey (ACS) 2015-2019 5-year estimates. Table: B15002

ELEVATION DATA
U.S. Geological Survey, 2019, 3D Elevation Program 3-Meter Resolution Digital Elevation Model, accessed April 16, 2021 at URL: <https://www.egs.gov/econ-science-systems/ngpp/?d=plata-tools>

CDC VY DATA
Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Ecopsychiatry Research, Analysis, and Services Program. CDC Social Vulnerability Index: 2016 Database USA. https://www.atdsr.cdc.gov/placeandhealth/svi/data_documentation_download.html. Accessed 04/20/21

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/nssr/usaleep/usaleep.html>

LANDCOVER & NEIGHBORHOOD DATA
City of Charleston GIS



HeatWatch Results



27
Volunteers

10
Routes

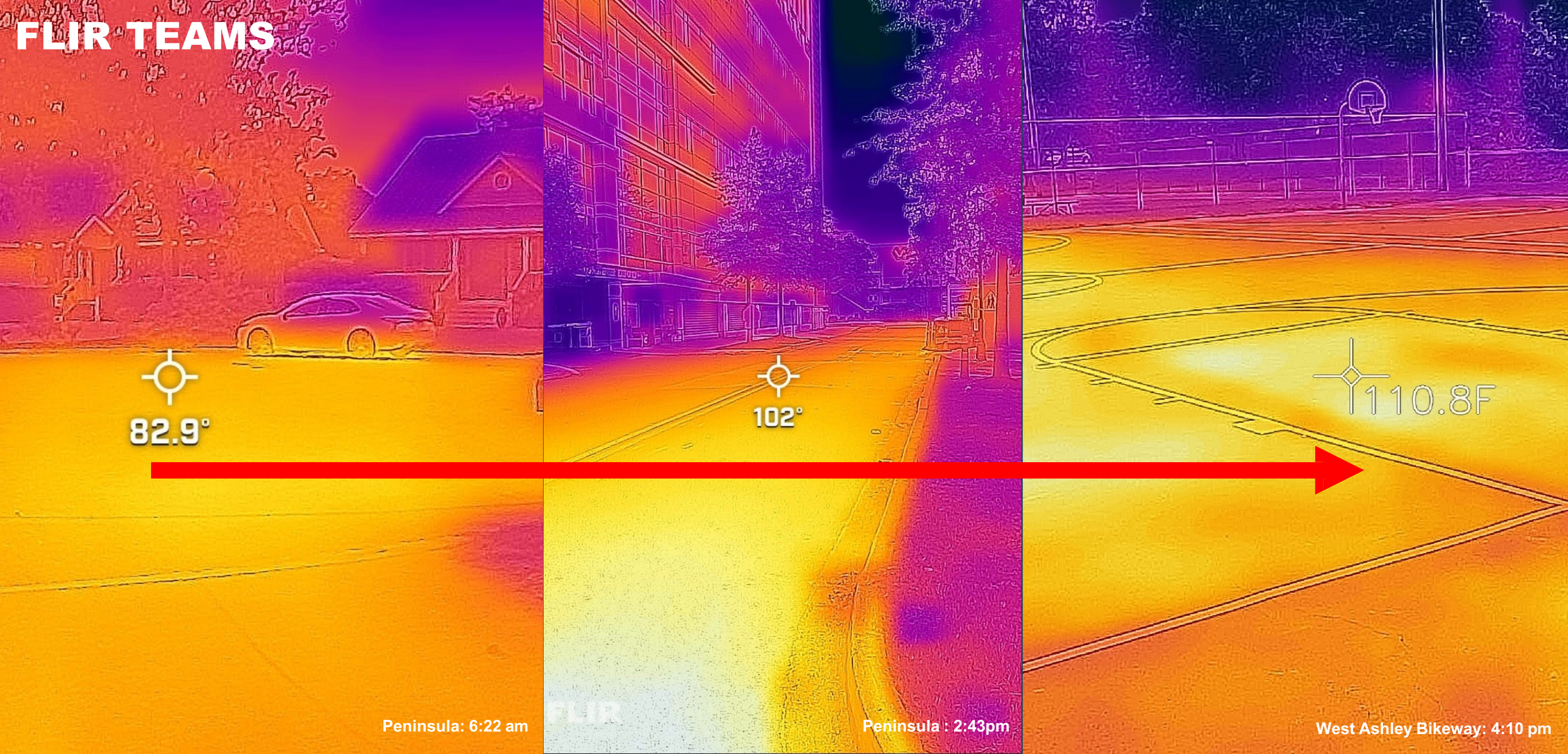
57,948
Measurements

95.9°
Max Temperature

11.8°
Temperature
Differential

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NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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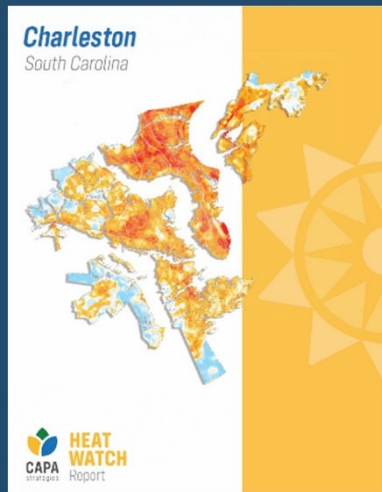


Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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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

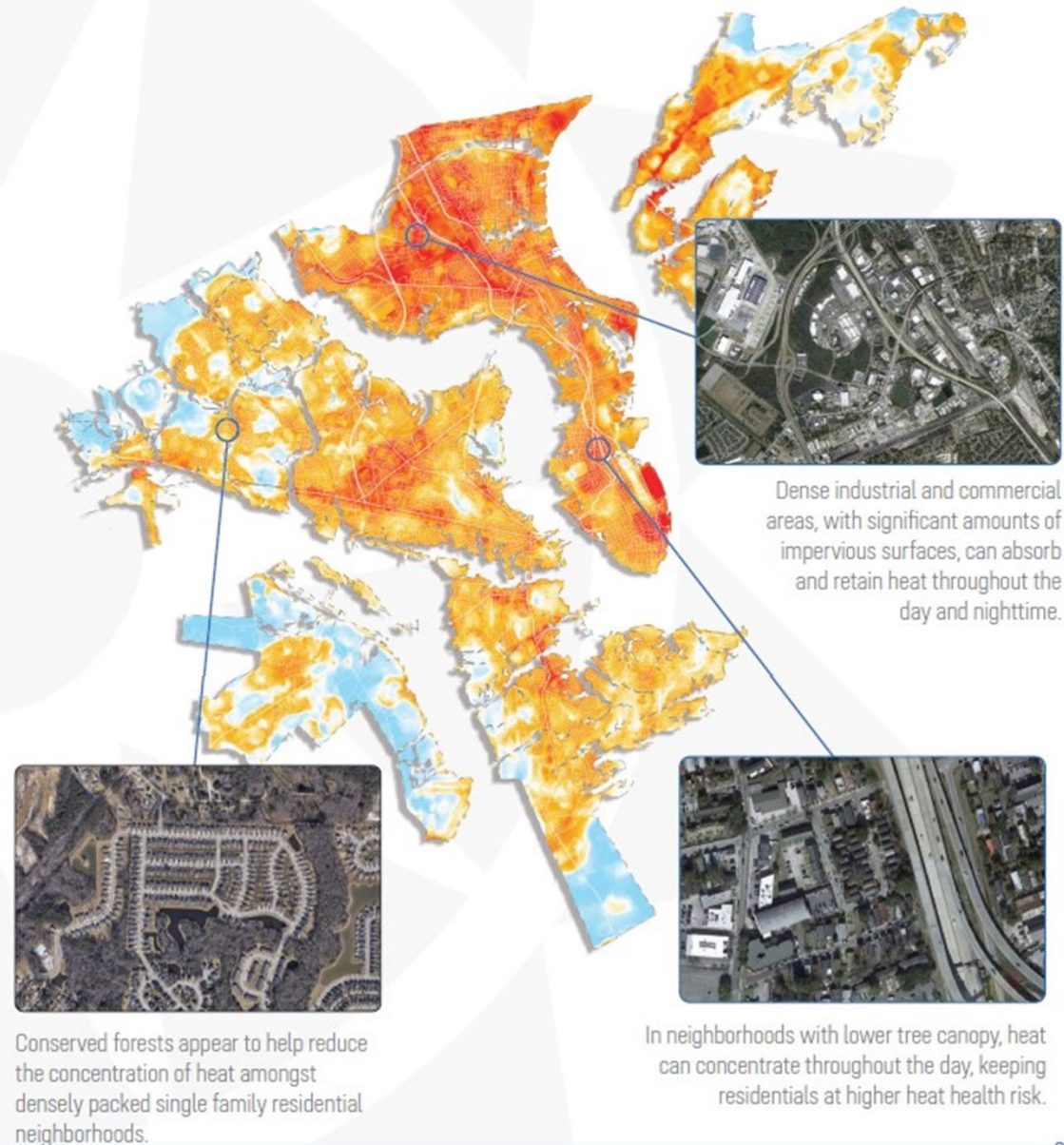
<https://www.charleston-sc.gov/2513/HeatWatch-Charleston-2021>



Initial Observations



The distribution of heat across a region often varies by qualities of the land and its use. Here are several observations of how this phenomenon may be occurring in your region.



Dense industrial and commercial areas, with significant amounts of impervious surfaces, can absorb and retain heat throughout the day and nighttime.

Conserved forests appear to help reduce the concentration of heat amongst densely packed single family residential neighborhoods.

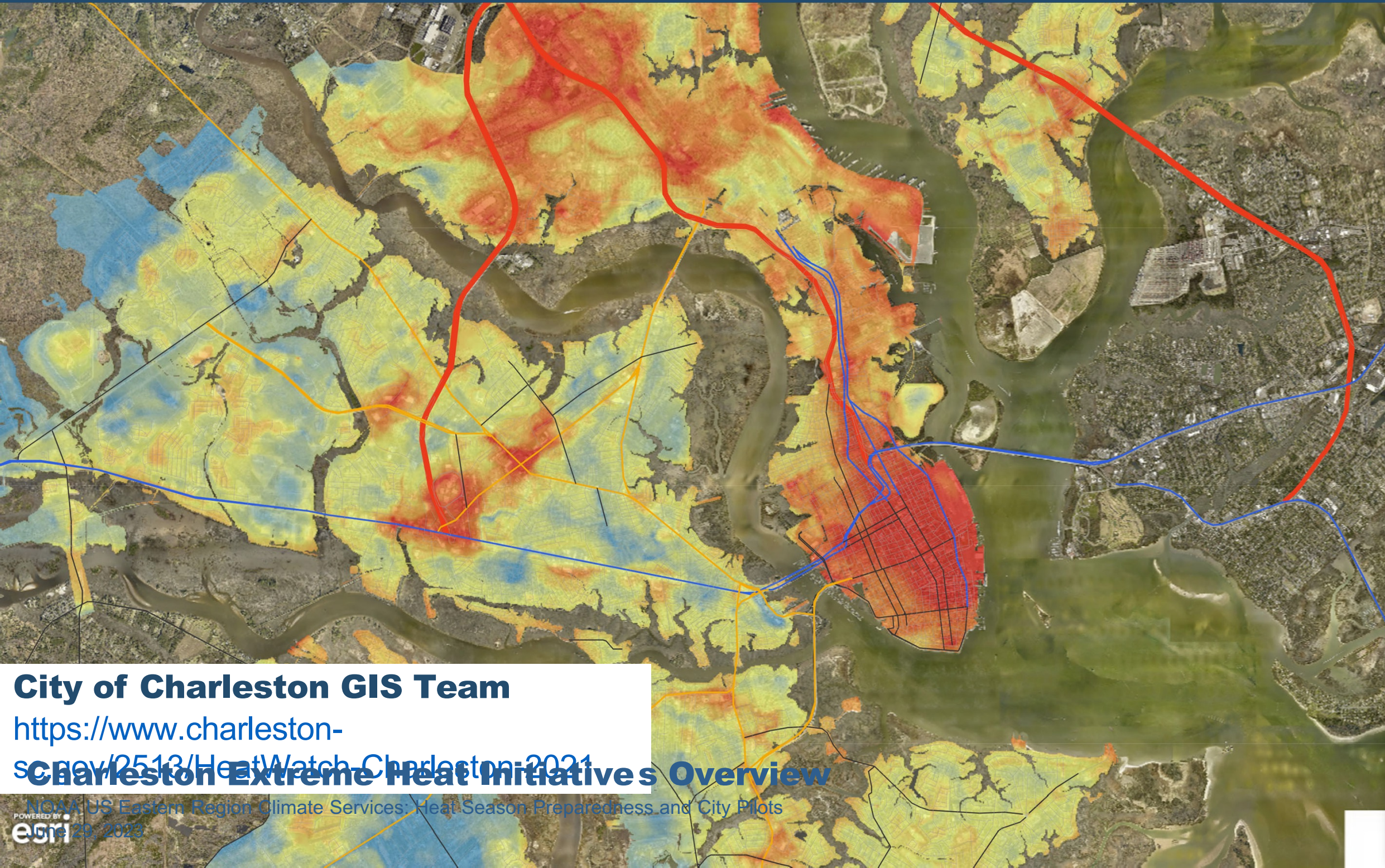
In neighborhoods with lower tree canopy, heat can concentrate throughout the day, keeping residential at higher heat health risk.

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resilience through collaborative partnerships

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NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
June 29, 2023

HeatWatch Summary



Map navigation icons: a hamburger menu icon, a search icon, and a layer stack icon.

Layers

- Streets
- Interstate
- US Highway
- State Highway
- Major Road
- Streets
- Pedestrian
- Heat

City of Charleston GIS Team
<https://www.charleston-sc.gov/2513/HeatWatch-Charleston-2021>
Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
POWERED BY **esri** | 29, 2023

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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

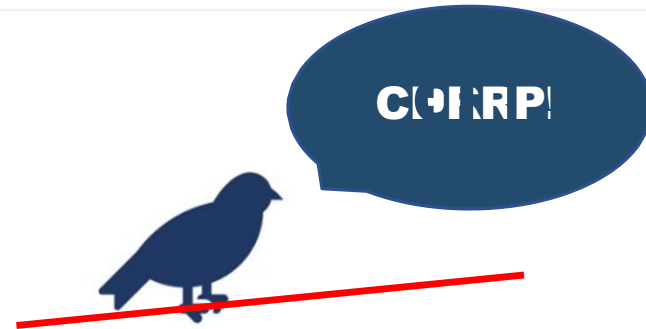
NOAA Pilot Project

Journal Publications
Philly & Columbia HeatWatch

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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NOAA Pilot Project



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](#)

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
June 29, 2023

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](#)

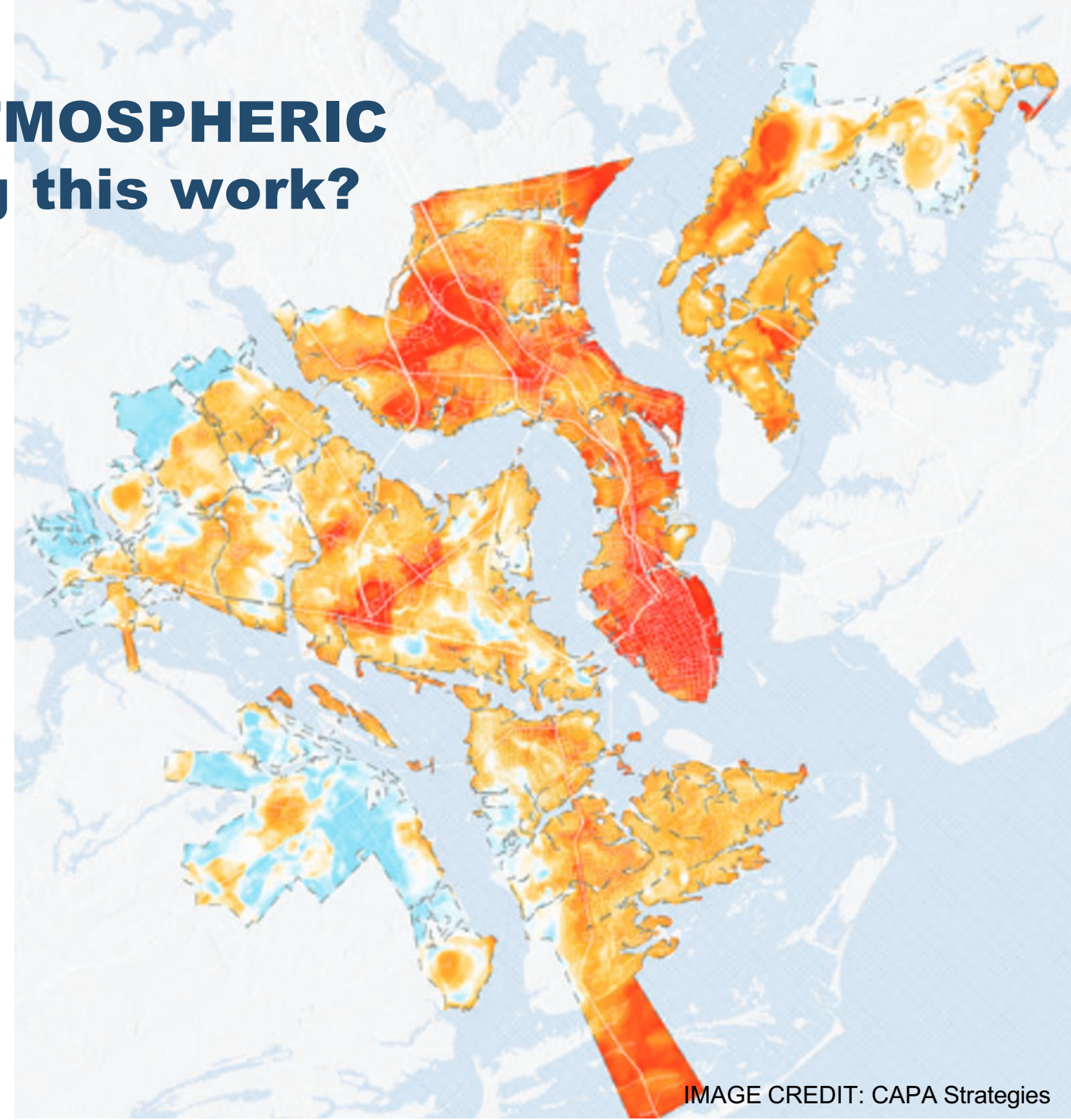


IMAGE CREDIT: CAPA Strategies

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NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots

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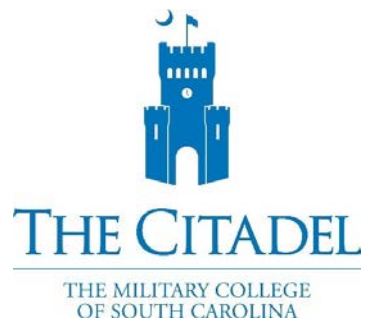
PARTNERS



Funding



**Administration
and Outreach**



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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HEAT SEASON DATA COLLECTION



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[PUBLIC NOTICES](#)

[CONTACT](#)

[PAY YOUR BILL](#)



[HOUSING ASSISTANCE](#) ▾

[LANDLORDS](#) ▾

[PROCUREMENT / CONTRACTS](#) ▾

[TENANTS](#) ▾

[CAREERS](#)



May 11, 2021

**ALL PUBLIC HOUSING IN CHARLESTON TO BE
REPLACED OR RENOVATED IN SWEEPING
INITIATIVE**

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

We hoped to better understand heat impacts by:

Phase 1 (LEARN):

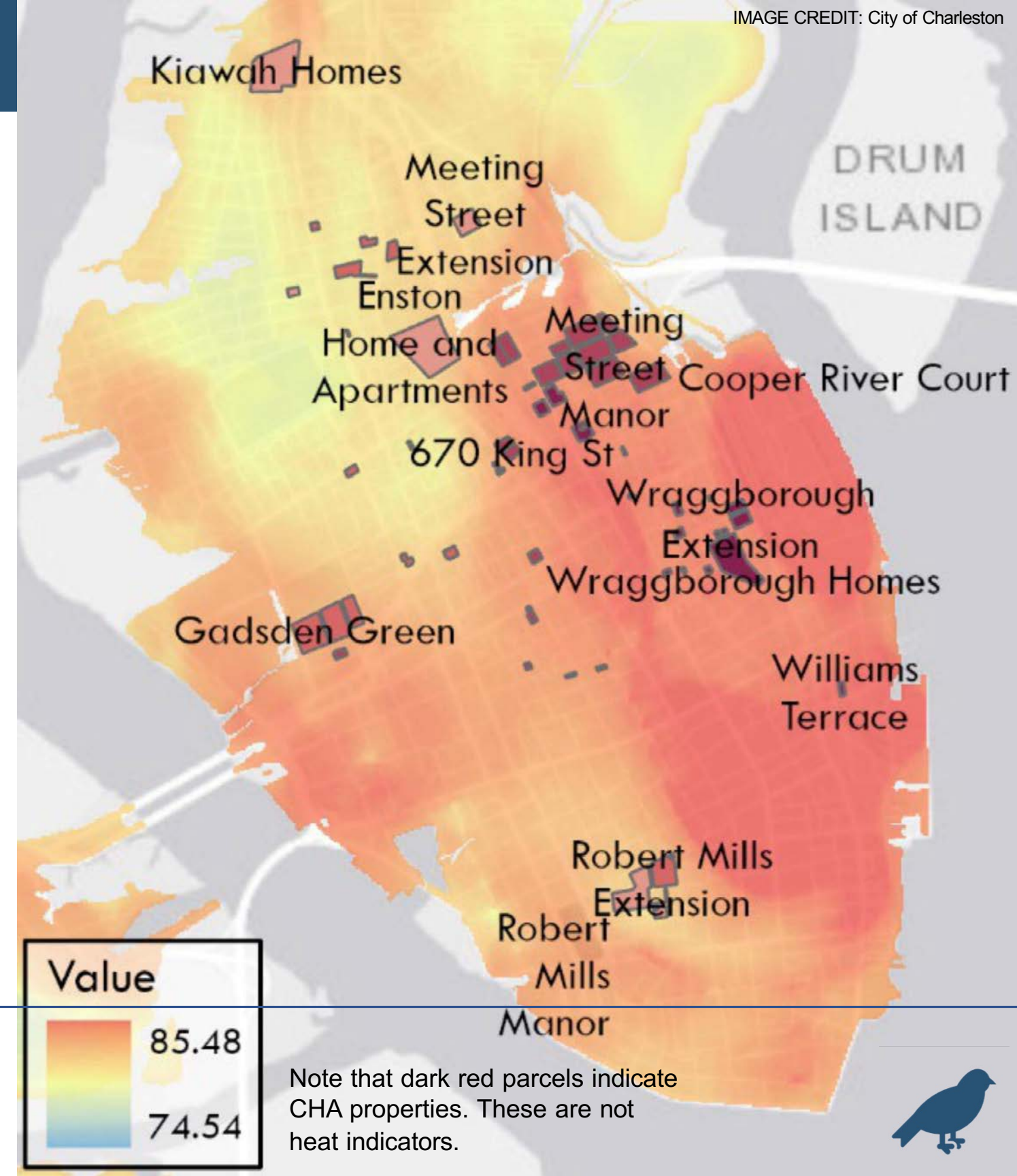
- recording hot temperatures in the community
- identifying materials that make heat feel worse
- talking about how heat affects health

Phase 2 (ACT):

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

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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HEAT SEASON DATA COLLECTION



Figure 2: Gadsden Green Land Cover



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Plots
June 29, 2023



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

Daily Temperature Data – Charleston Area, SC (ThreadEx)

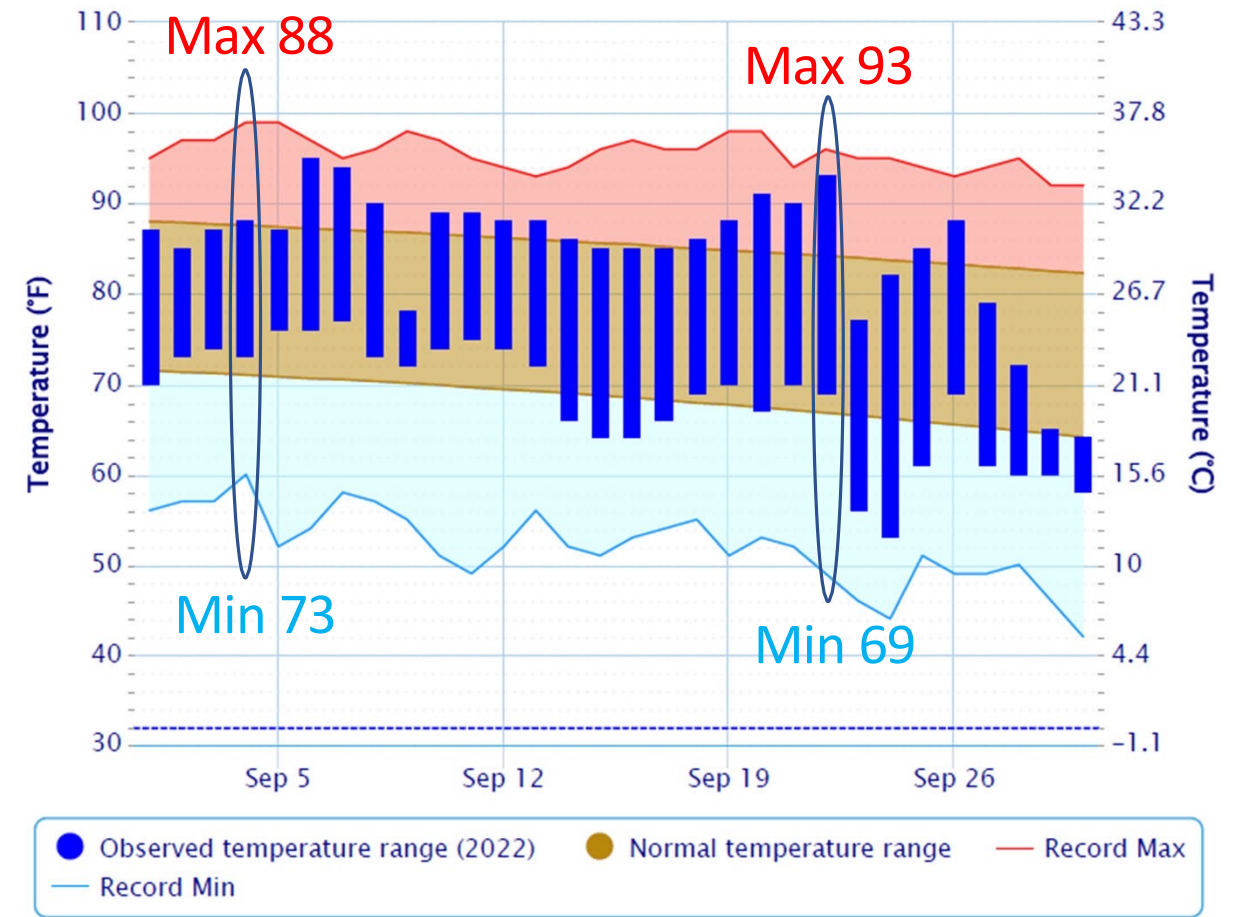


IMAGE CREDIT: National Weather Service

Powered by ACIS

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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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

asphalt (roads)

concrete (sidewalks)

grass (lawns)

bare earth (dirt)

sand (playgrounds)

mulch (plant areas)

rubber (play surfaces)

buildings

clay tile (roofs)

shingles (roofs)

painted brick (walls)

unpainted brick (walls)

metal (windows / doors)

glass (windows)

wood (benches / fences)



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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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



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots

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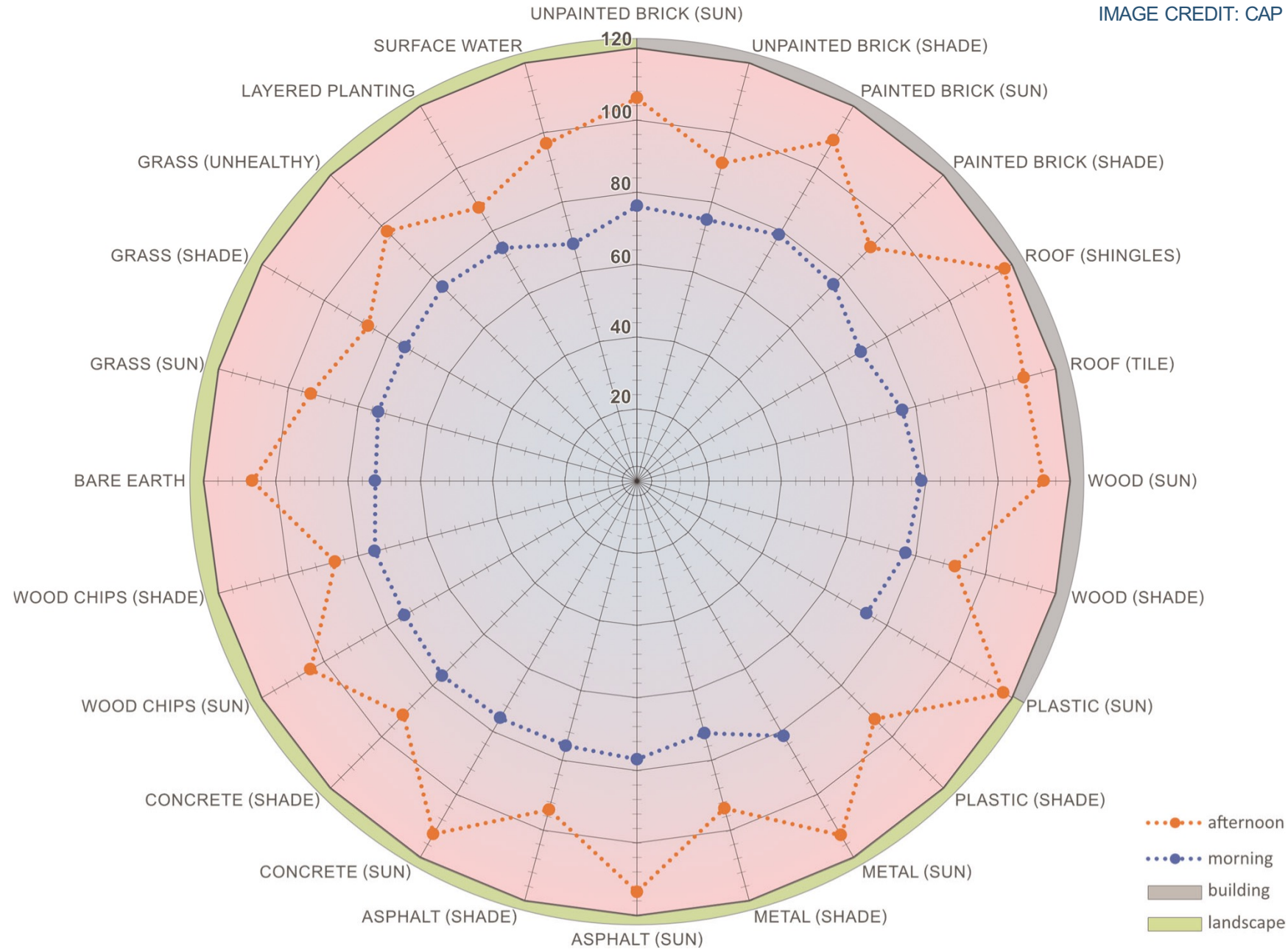
HEAT SEASON DATA COLLECTION

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?



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NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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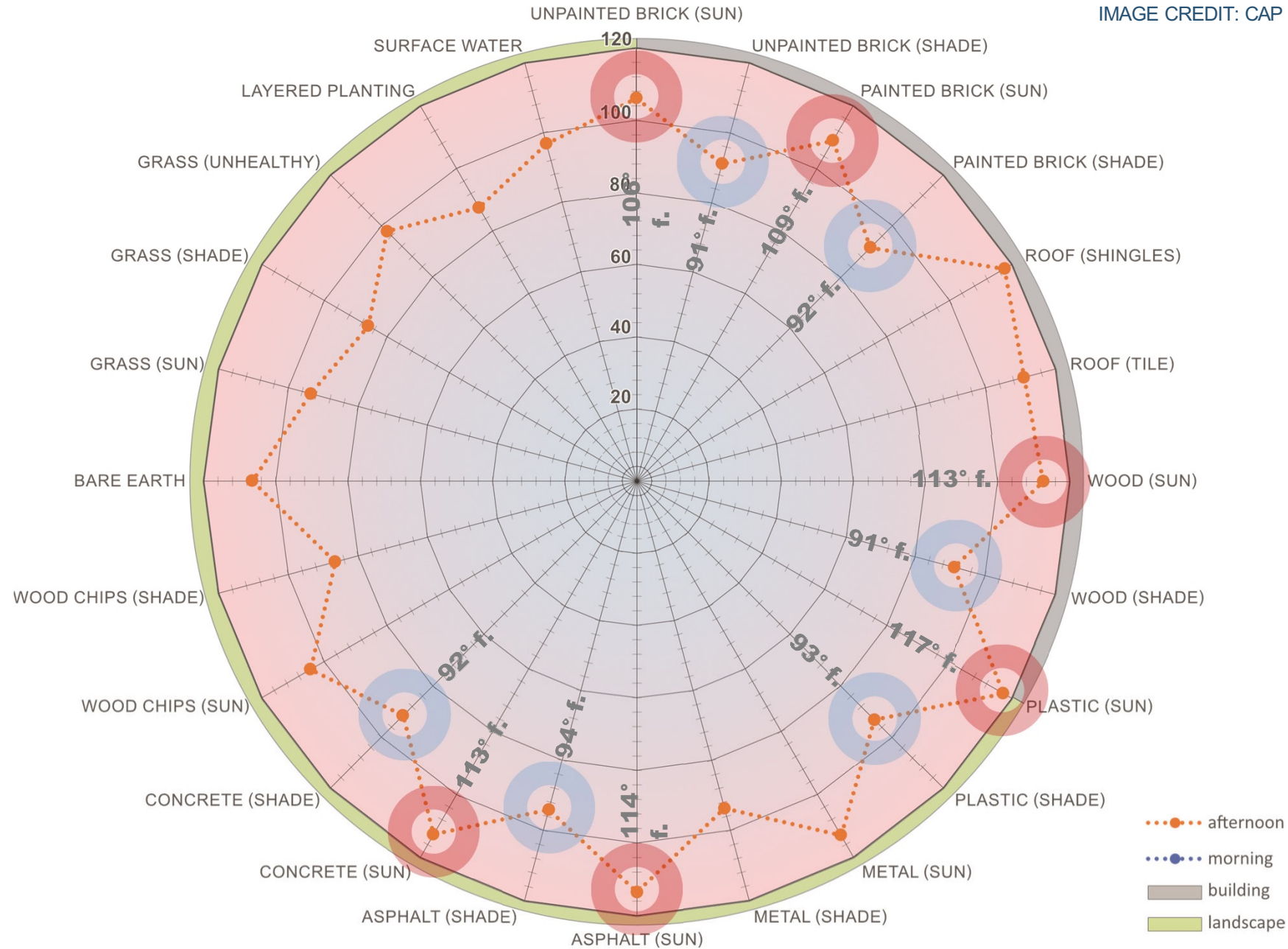
HEAT SEASON DATA COLLECTION

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.



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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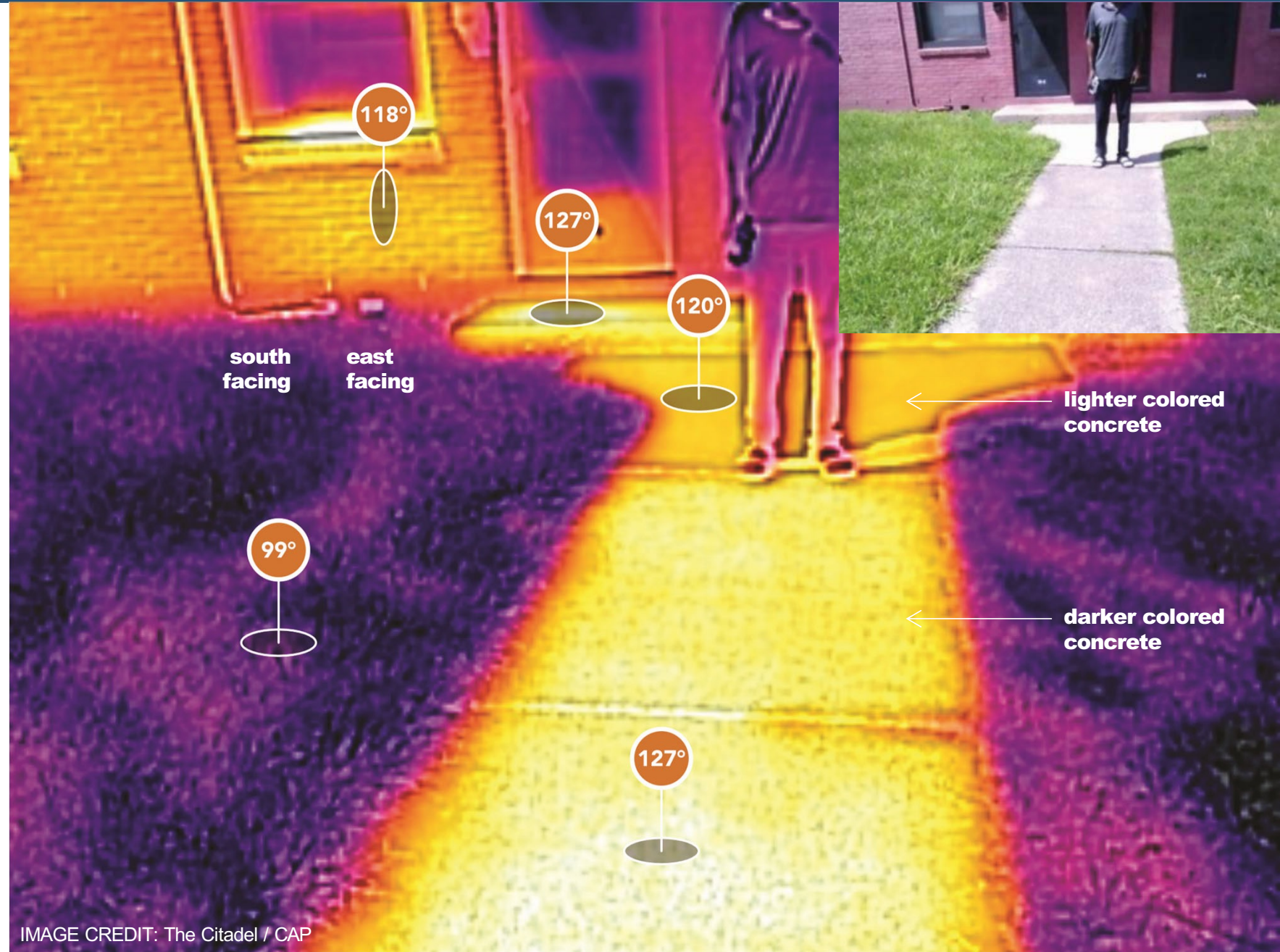
HEAT SEASON DATA COLLECTION

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.



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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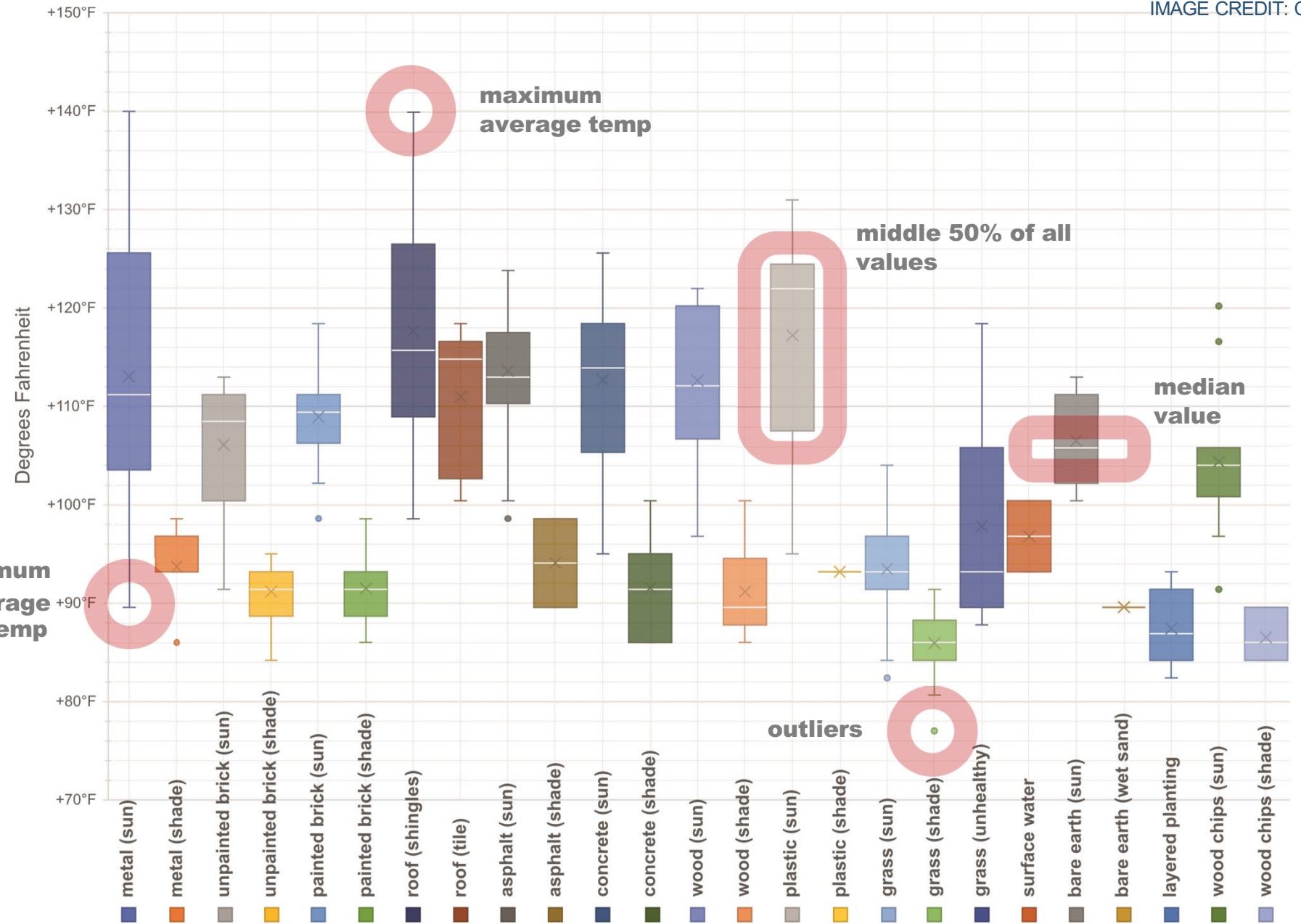
IMAGE CREDIT: CAP

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).



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots

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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°



IMAGE CREDIT: The Citadel / CAP

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NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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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)



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NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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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.



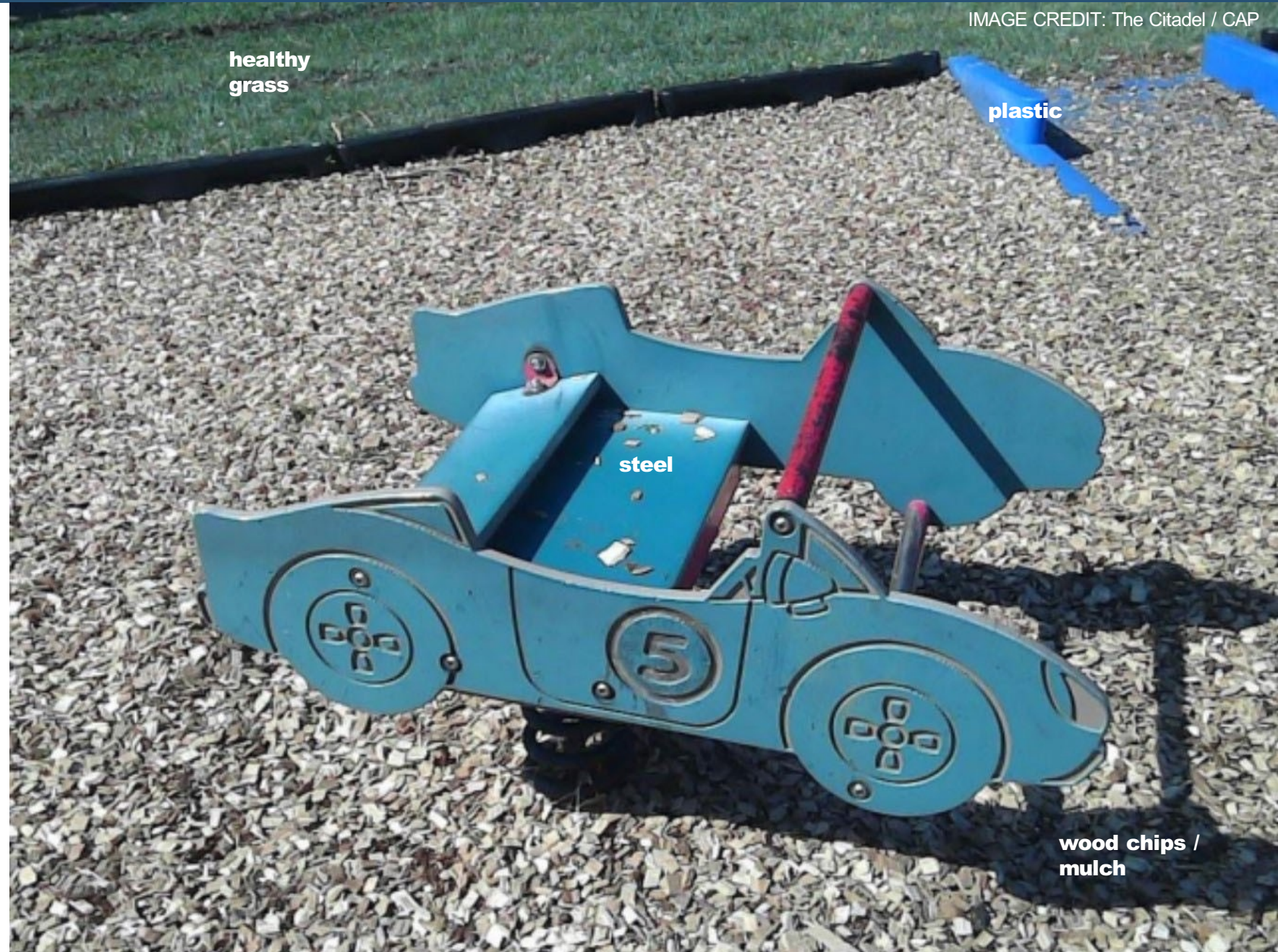
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HEAT SEASON DATA COLLECTION

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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NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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HEAT SEASON DATA COLLECTION

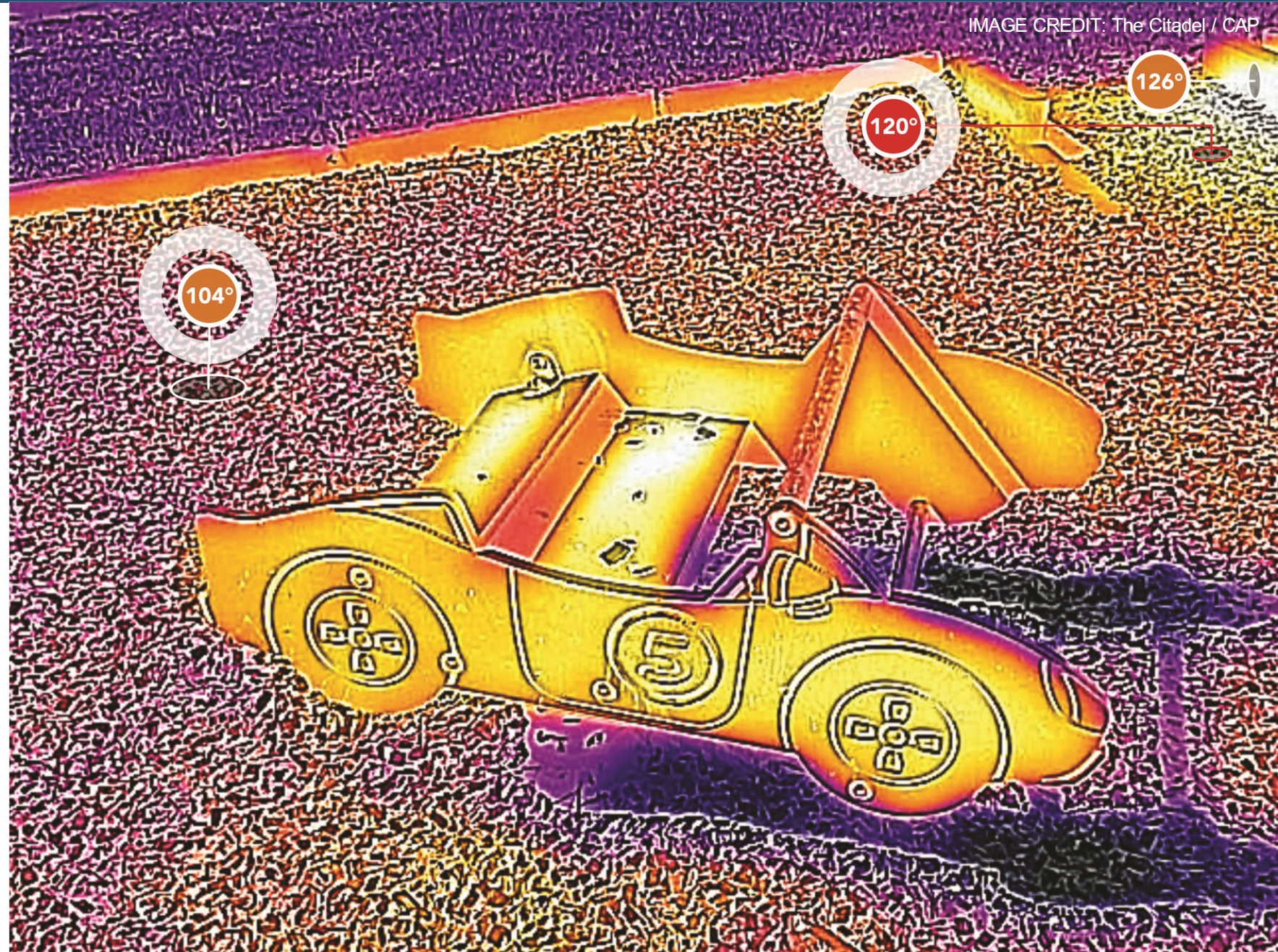
SURFACE TEMPERATURES IN GADSDEN GREEN

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°



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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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



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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HEAT SEASON DATA COLLECTION

Community Involvement

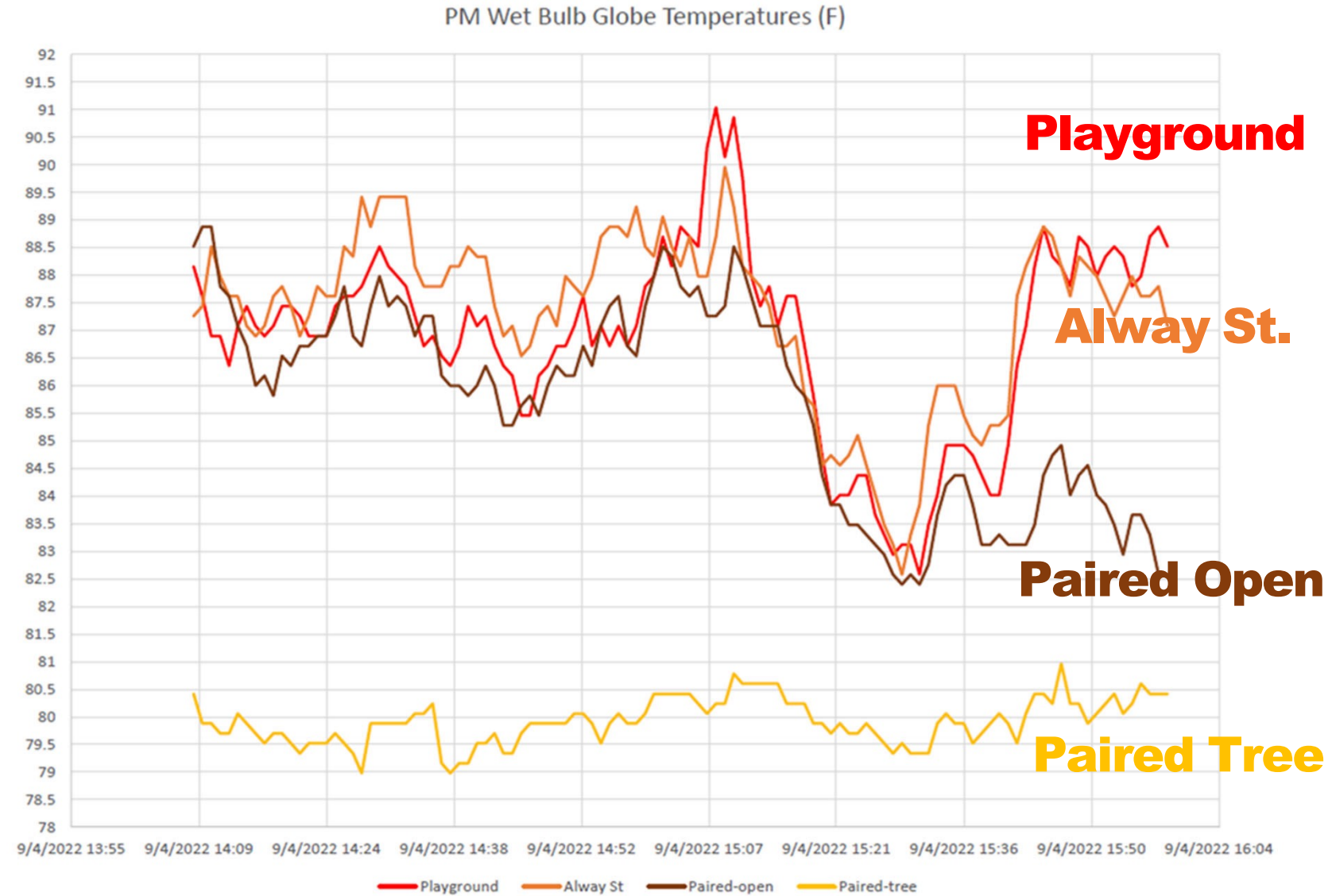
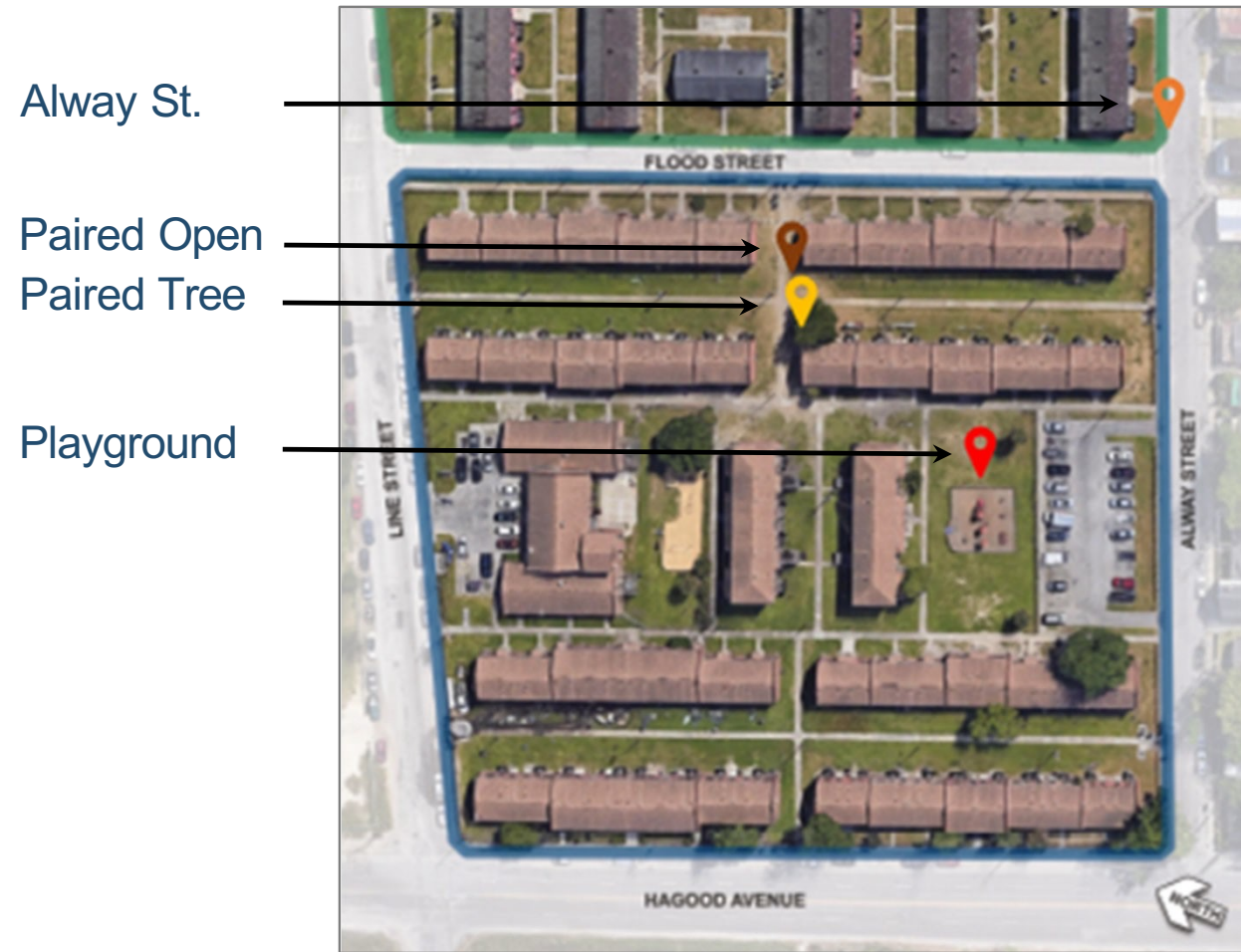


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HEAT SEASON DATA COLLECTION

OUTDOOR TEMPERATURE READINGS



Also: considering wind direction and cooling effect

*Flags are U.S. military standard

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NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
June 29, 2023



Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
June 29, 2023

Sharing Research

Providing Open Access GIS resources for knowledge sharing

NOAA

- [HeatWatch ArcGIS Resource](#)

Open Science Framework

- <https://osf.io/b4tfv>

City of Charleston

- [HeatWatch](#)
- [Tree Canopy Tools App](#)
- [Street Tree Canopy Storymap](#)



Tree Canopy Tools Street Tree Canopy Storymap

About

City of Charleston Tree Canopy Tools

- Use the Layer List tool to select layers for display (some expand)
- And the Legend tool to display layer symbology

Layer Information

- SPA Basins:** These Drainage Basins (Watersheds) are within a Special Protection Area due to flood risk. A Watershed is the area within which precipitation falling to the ground will drain to a single outlet point.
- FEMA Flood Zones:** Areas of particular flood risk.
- Flood Warning Streets:** These streets have an automated flood warning activated when the tide exceeds 8 feet but may also experience flooding during heavy rain events.
- CDC Social Vulnerability Index:** This layer, created by the Center for Disease Control ranks census tracts for vulnerability based on 15 factors, including poverty, lack of vehicle access, and housing inaccessibility. More info on [Social Vulnerability](#).

Tree Layers: (expandable group)

- Streets % Tree Canopy Cover:** These street segments are displayed in varying shades of green based on the percent of street area covered by tree canopy.
- Potential Planting Area:** This polygon feature was created by selecting areas classified as pervious (non-tree, non-wetland vegetation) and removing existing trees and buildings, as well as (most) athletic fields, golf courses, cemeteries, etc. Since it was created from the land cover

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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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>

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots

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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

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots

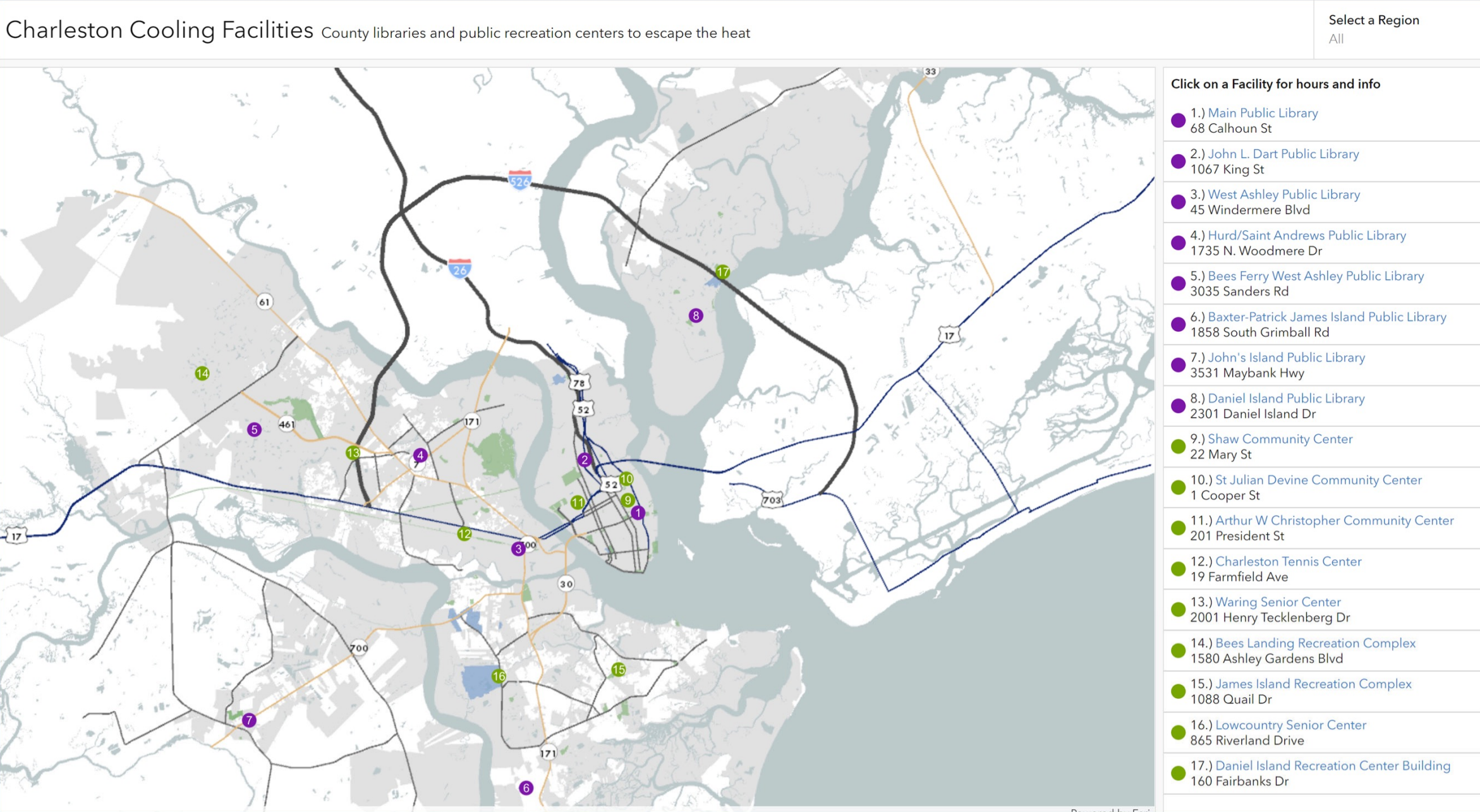
June 29, 2023

Collecting Existing Extreme Heat Resources

City of Charleston
Resilience, GIS, and
Planning Teams

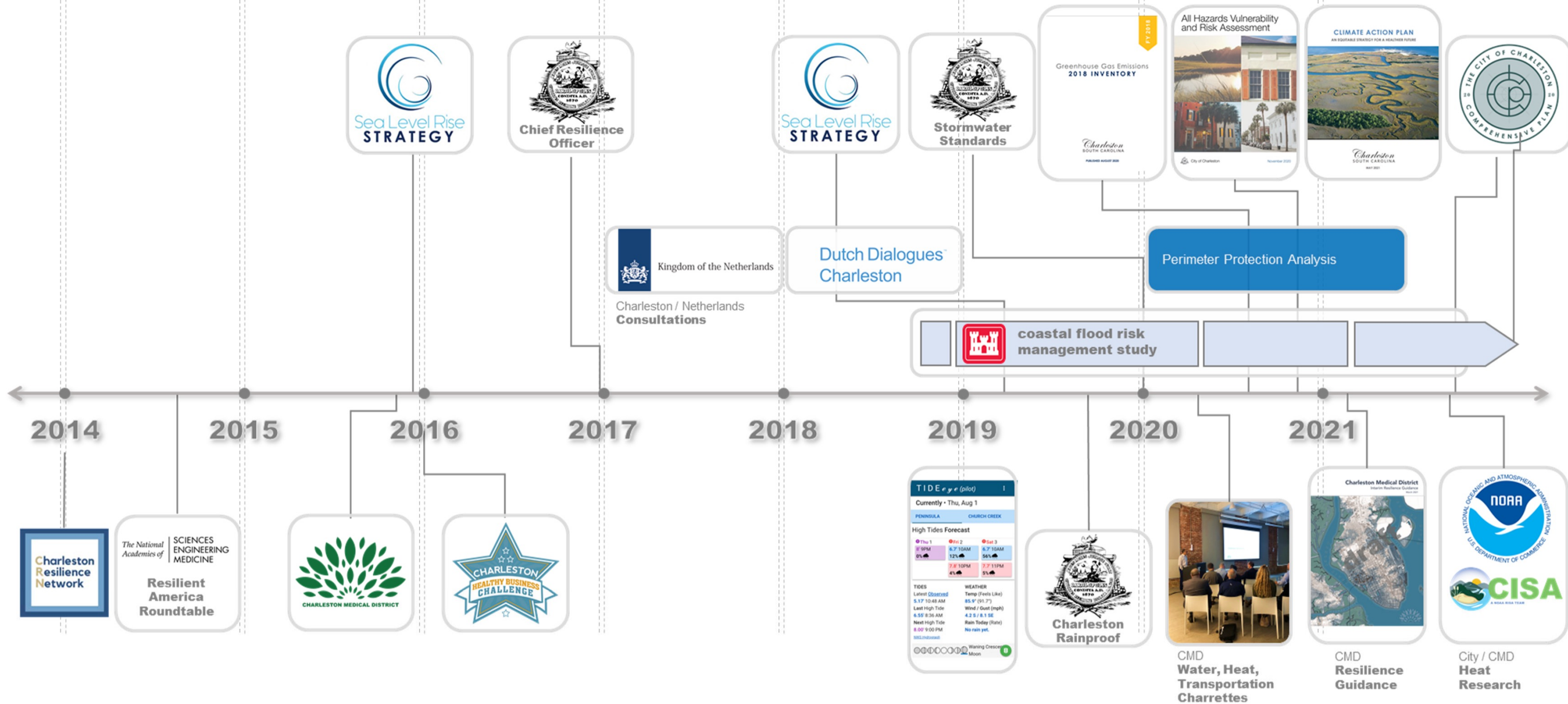
MUSC Medical
Professionals

Winter 2023 College
of Charleston Intern



Charleston Extreme Heat Initiatives Overview

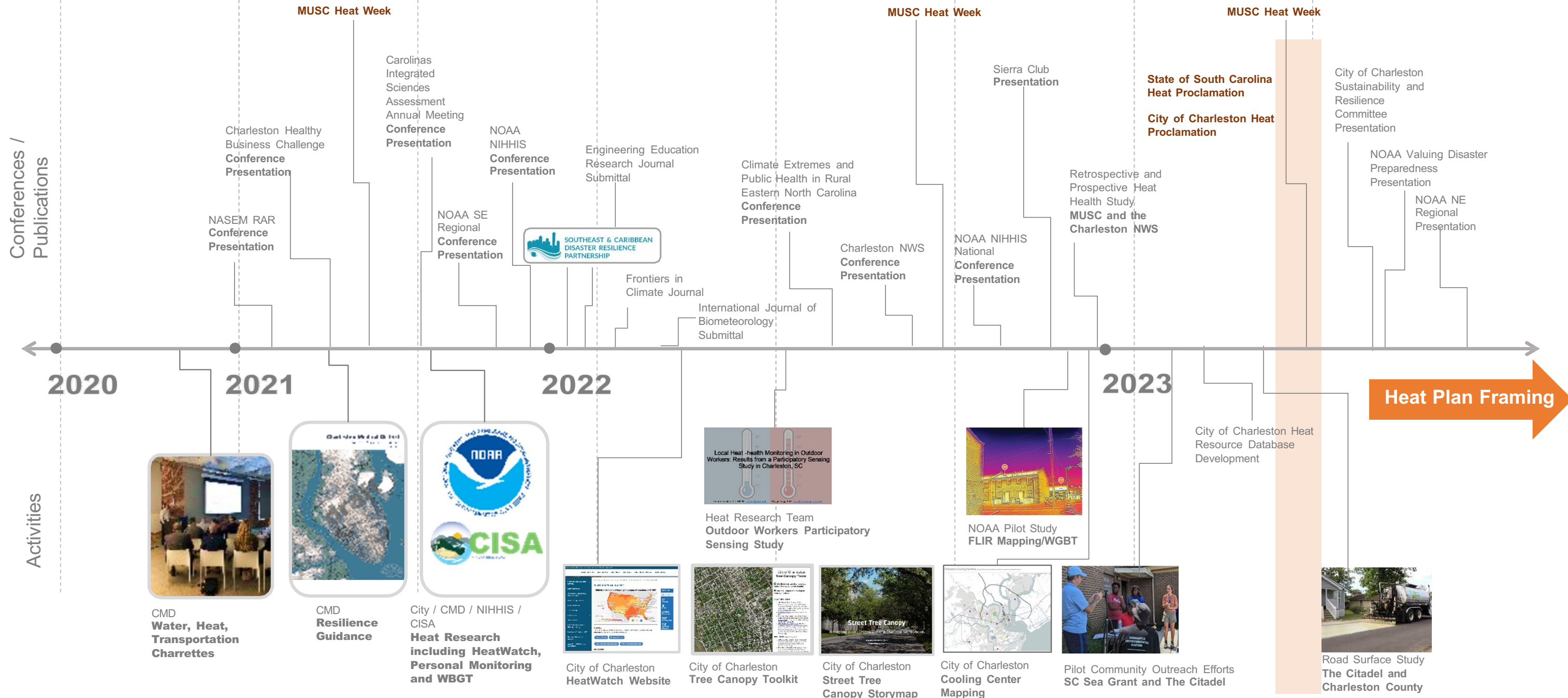
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Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots
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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>

Charleston Extreme Heat Initiatives Overview

NOAA US Eastern Region Climate Services: Heat Season Preparedness and City Pilots

June 29, 2023

Get Involved

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

**Increase
Awareness**

**Increase
Coping
Capacity**

**Increase
Mitigation**

**Increase
Adaptation**

Proclamations Help!

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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

\$451.4 M

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

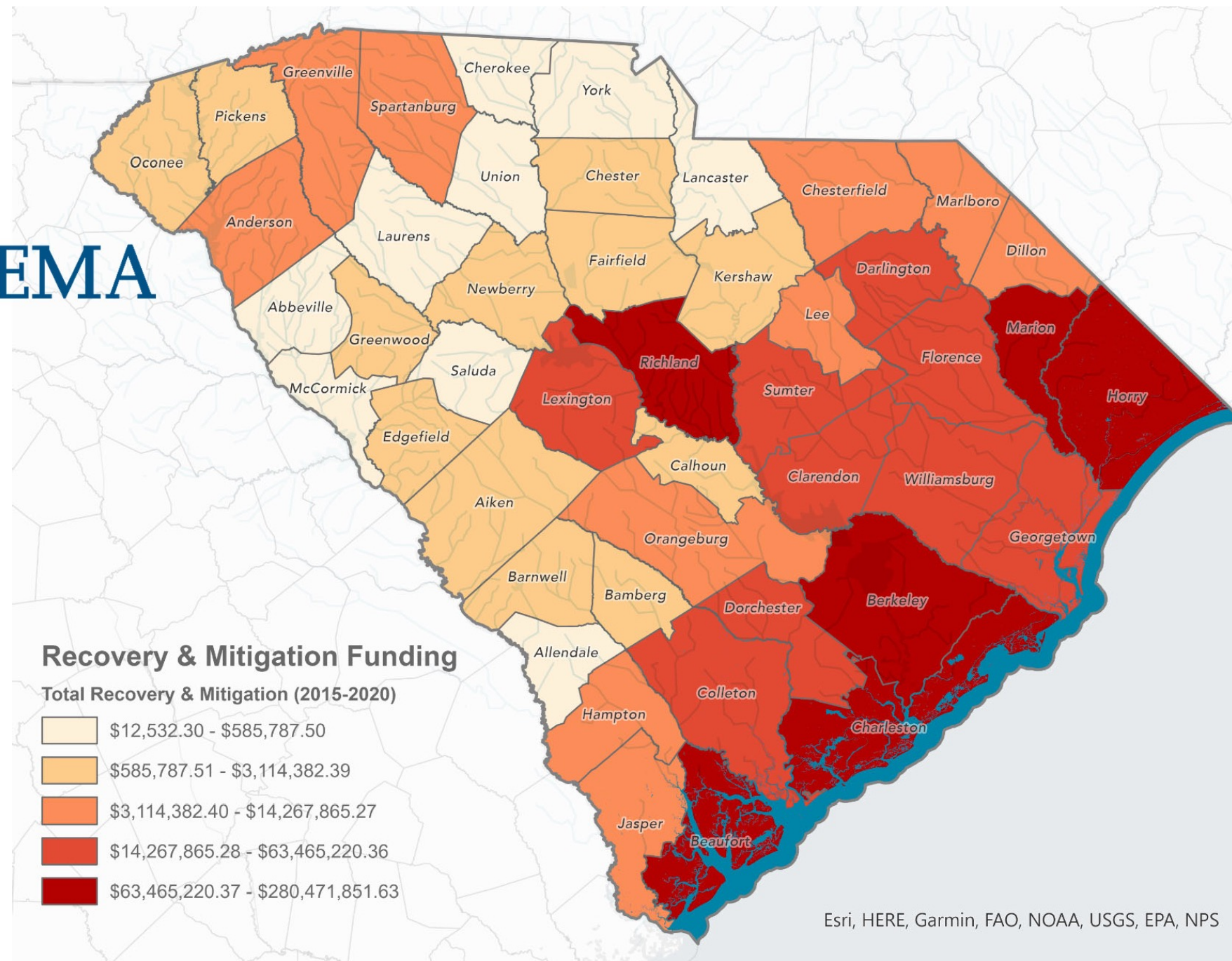
\$1.87 B

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.



FEMA



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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Building toward a City Heat Plan

Janice Barnes, PhD

Climate Adaptation Partners

June 29, 2023