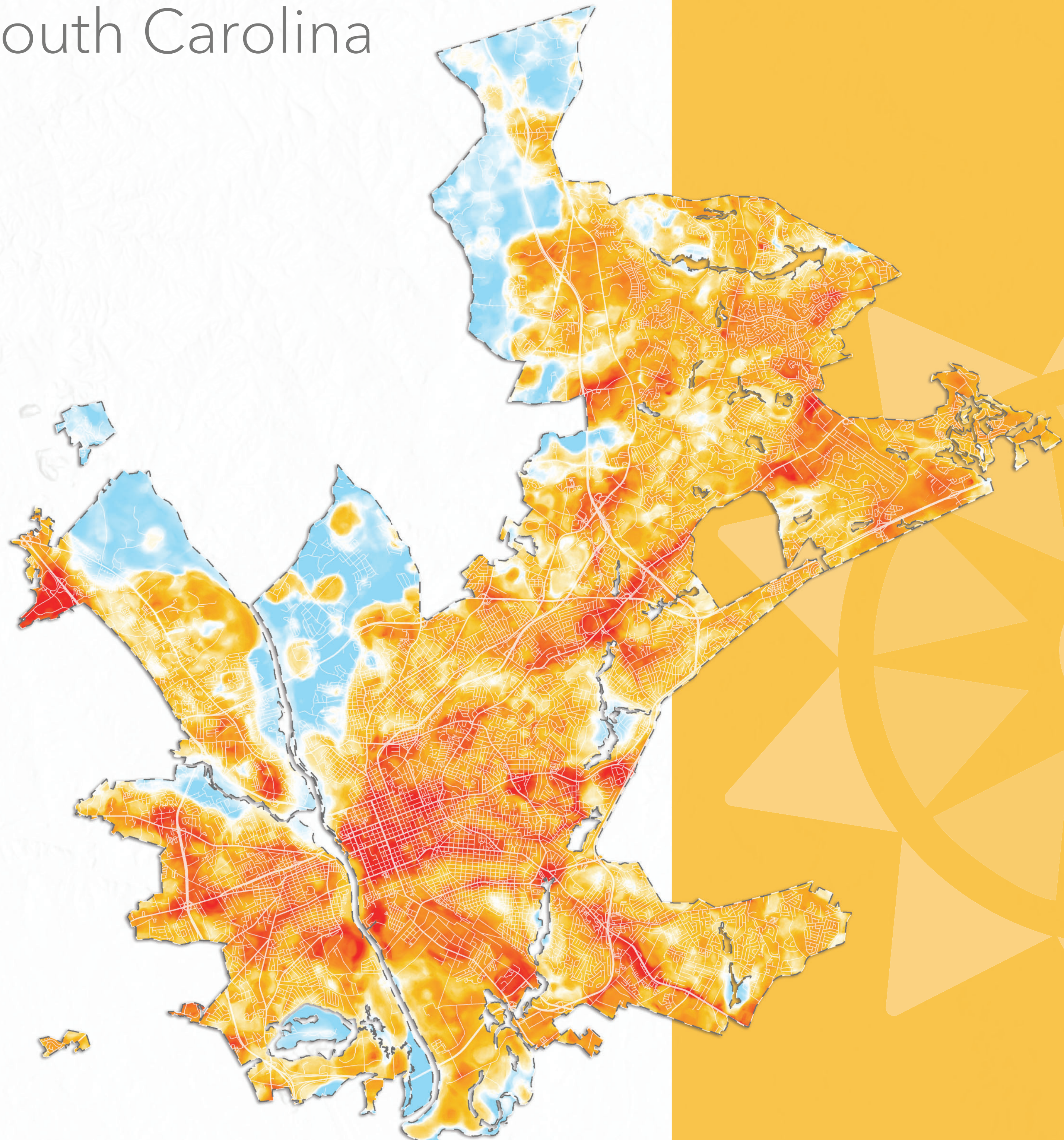
Columbia

South Carolina



CAPA strategies

HEAT WATCH

Report

The CAPA Heat Watch program, equipment, and all related procedures referenced herein are developed through a decade of research and testing with support from national agencies and several universities. Most importantly, these include our partners at the National Integrated Heat Health Information System, the National Oceanic and Atmospheric Administration's (NOAA's) Climate Program Office, and National Weather Service, including local weather forecast offices at each of the campaign sites, The Science Museum of Virginia, and U.S. Forest Service (USDA). Past support has come from Portland State University, the Climate Resilience Fund, and the National Science Foundation. We are deeply grateful to these organizations for their continuing support.

This effort is funded by a NOAA/NIHHIS grant program. The grant application was submitted by the City of Columbia Tree and Appearance Commission with financial support from the Richland County Conservation Commission and Columbia Green; and in-kind support from the University of South Carolina Department of Geography, Benedict College Department of Biology, Chemistry, and Environmental Health; the City of Columbia Planning and Development Services Department and the Public Works Department; and the Richland County Department of Community Planning and Development. In addition, the Charleston Resilience Network, Columbia Garden Club, Gills Creek Watershed Association, Medical University of South Carolina, Richland County Bar Association, SC Energy Office, SC Health Professionals for Climate Action, SC Wildlife Federation, SC Office of Resilience, and Sustain SC all provided letters of support and expressed interest in using the results to inform their work in the future.

This report was prepared by CAPA Strategies, LLC
Summer 2022

Table of Contents

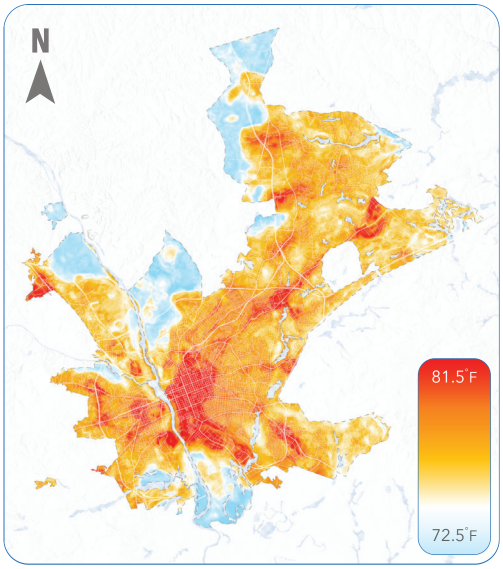
Executive Summary

Major thanks to all of the participants and organizers of the Urban Heat Watch program in Columbia, SC. After months of collaboration and coordination, local organizers and volunteers collected thousands of temperature and humidity data points in the morning and afternoon of August 6th and evening of August 7th, 2022.

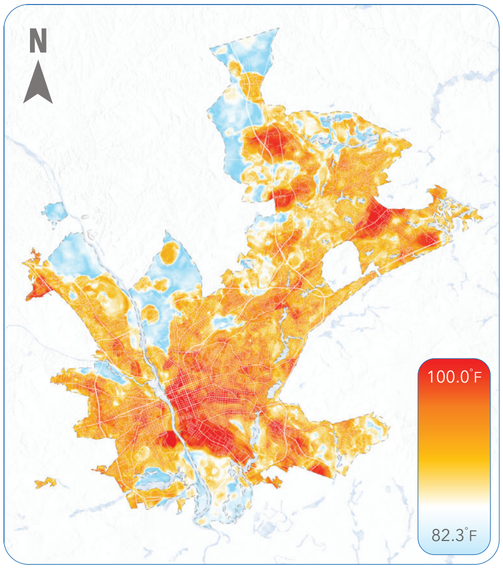
According to the National Weather Service station at the Columbia Metropolitan Airport, there was a brief period (5 to 10 minutes) of light-to-heavy rain during the beginning of the afternoon traverse hour. This brief event may coincide with lower temperature measurements in some regions of the study area, though it is difficult to determine these exact locations. While the afternoon modeling results are relatively consistent with the morning and evening models, interpretations from this period should be made in the context of these weather conditions.

Rainshowers on the afternoon of the 6th are likely to have cooled temperatures in northern/ northwest areas. Therefore, there is greater confidence in the high afternoon values than the low afternoon values particularly in those regions. Due to rain on the evening of the 6th, the 7-8 pm mapping was done on Sunday the 7th. While the daytime highs were 93°F and 87°F respectively for the 6th and 7th, the underlying patterns of heating are consistent and can be compared.

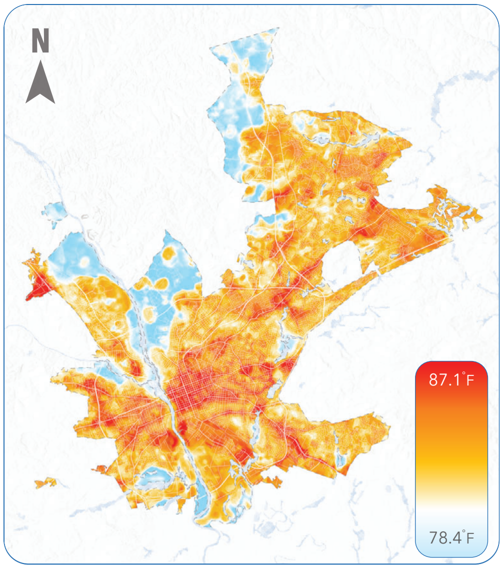
Morning Area-Wide Predictions (6 - 7 am)



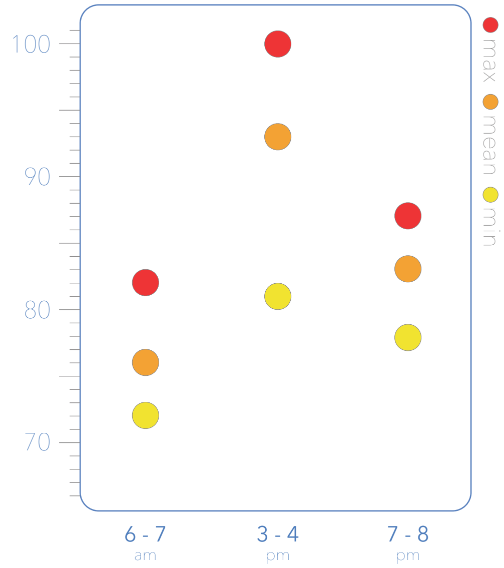
Afternoon Area-Wide Predictions (3 - 4 pm)



Evening Area-Wide Predictions (7 - 8 pm)



Traverse Points (°F)



Study Date

August 6-7th, 2022

188 mi²
Study Area

37
Volunteers

16
Routes

71,872
Measurements

100.2°
Max Temperature

18.5°
Temperature Differential

HEAT WATCH

Learn more about the background and goals of each Heat Watch 2022 campaign city at https://nihhis.cpo.noaa.gov/Urban-Heat-Islands/Mapping-Campaigns/Campaign-Cities

Purpose & Aims

We know that climate-induced weather events have the most profound impact on those who have the least access to financial resources, historically underserved communities, and those struggling with additional health conditions. Infrastructure is also at risk, which can further compromise a region's capacity to provide essential cooling resources.

CAPA Strategies offers an unparalleled approach to center communities and infrastructure facing the greatest threat from the impact of increasing intensity, duration, and frequency of extreme heat. This report summarizes the results of a field campaign that occurred on August 6th & 7th, 2022 and with it we have three aims:

1

Provide high resolution descriptions of the distribution of temperature and humidity (heat index) across an urban area

2

Engage local communities and create lasting partnerships to better understand and address the inequitable threat of extreme heat

3

Bridge innovations in sensor technology, spatial analytics, and community climate action to better understand the relationships between urban microclimates, infrastructure, ecosystems, and human well-being.

With a coordinated data-collection campaign over several periods on a hot summer day, the resulting data provide snapshots in time of how urban heat varies across neighborhoods and how local landscape features affect temperature and humidity.

Campaign Process

CAPA Strategies has developed the Heat Watch campaign process over several iterations, with methods well established through peer-reviewed publications[1], testing, and refinement.

The current campaign model requires leadership by local organizers, who engage community groups, new and existing partner organizations, and the media in generating a dialog about effective solutions for understanding and addressing extreme heat.

CAPA provides training, equipment, and support to the recruited community groups as they endeavor to collect primary temperature and humidity data across a metropolitan region.

The seven main steps of the campaign process are summarized to the right. An overview of the analytical modeling methodology is presented later in this report and described at full length in peer-reviewed publications.

1. Set Goals

Campaign organizers determine the extent of their mapping effort, prioritizing areas experiencing environmental and social justice inequities. CAPA then divides this study area into sub-areas ("polygons"), each containing a diverse set of land uses and land covers.

2. Establish

Organizers recruit volunteers, often via non-profits, universities, municipal staff, youth groups, friends, family, and peers. Meanwhile, CAPA designs the data collection routes by incorporating important points of interest such as schools, parks, and community centers.

3. Prepare

Volunteers attend an online training session to learn the why and how of the project, their roles as data collectors, and to share their personal interest in the project. Participants sign a liability and safety waiver, and organizers assign teams to each polygon and route.

4. Activate

With the help of local forecasters, organizers identify a high-heat, clear day (or as near to one as possible) and coordinate with their volunteer teams. Once confirmed, CAPA ships the sensor equipment and bumper magnets to be distributed to campaign participants.

5. Execute

Volunteer teams conduct the heat campaign by driving and/or bicycling sensor equipment along pre-planned traverse routes at coordinated hour intervals. Each second the sensors collect a measurement of ambient temperature, humidity, longitude, latitude, speed and course.

6. Analyze

Organizers collect and return the equipment, and CAPA analysts begin cleaning the data, as described in the Mapping Method section below, and utilize machine learning algorithms to create predictive area-wide models of temperature and heat index for each traverse.

7. Implement

Campaign organizers and participants review the Heat Watch outputs (datasets, maps, and report), and campaign teams meet with CAPA to discuss the results and next steps for addressing the distribution of extreme heat in their community.

[1] The most relevant and recent publications to the Heat Watch campaign process include:

Shandas, V., Voelkel, J., Williams, J., & Hoffman, J., (2019). Integrating Satellite and Ground Measurements for Predicting Locations of Extreme Urban Heat. Climate, 7(1), 5. https://doi.org/10.3390/cli7010005

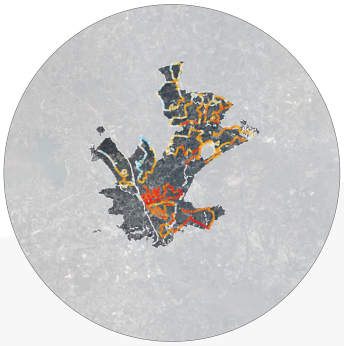
Voelkel, J., & Shandas, V. (2017). Towards Systematic Prediction of Urban Heat Islands: Grounding Measurements, Assessing Modeling Techniques. Climate, 5(2), 41. https://doi.org/10.3390/cli5020041

CAPA

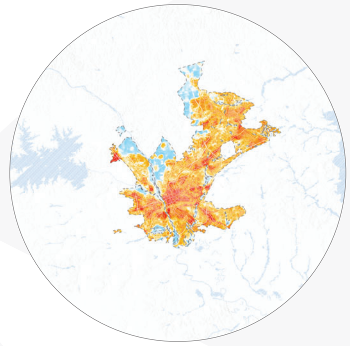
About The Maps

HEAT WATCH

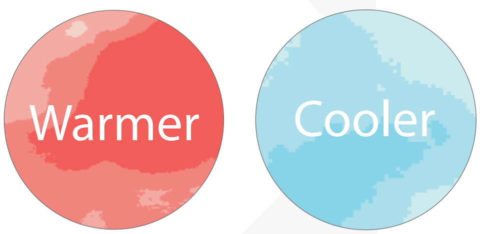
The following sections present map images from the Heat Watch campaign and modeling process. Two sets of maps comprise the final results from the campaign process, and they include:



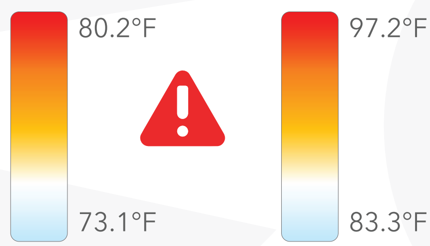
Point temperatures collected in each traverse period, filtered to usable data.



Area-wide heat maps, displaying either the modeled temperature or heat index across the entire study area at each traverse period.



The data are classified by natural breaks in order to clearly illustrate the variation between warmer (red) and cooler (blue) areas across the map.



Note that the scales are different between the traverse point and area-wide maps due to the predictive modeling process.

How does your own experience with heat in these areas align with the map?

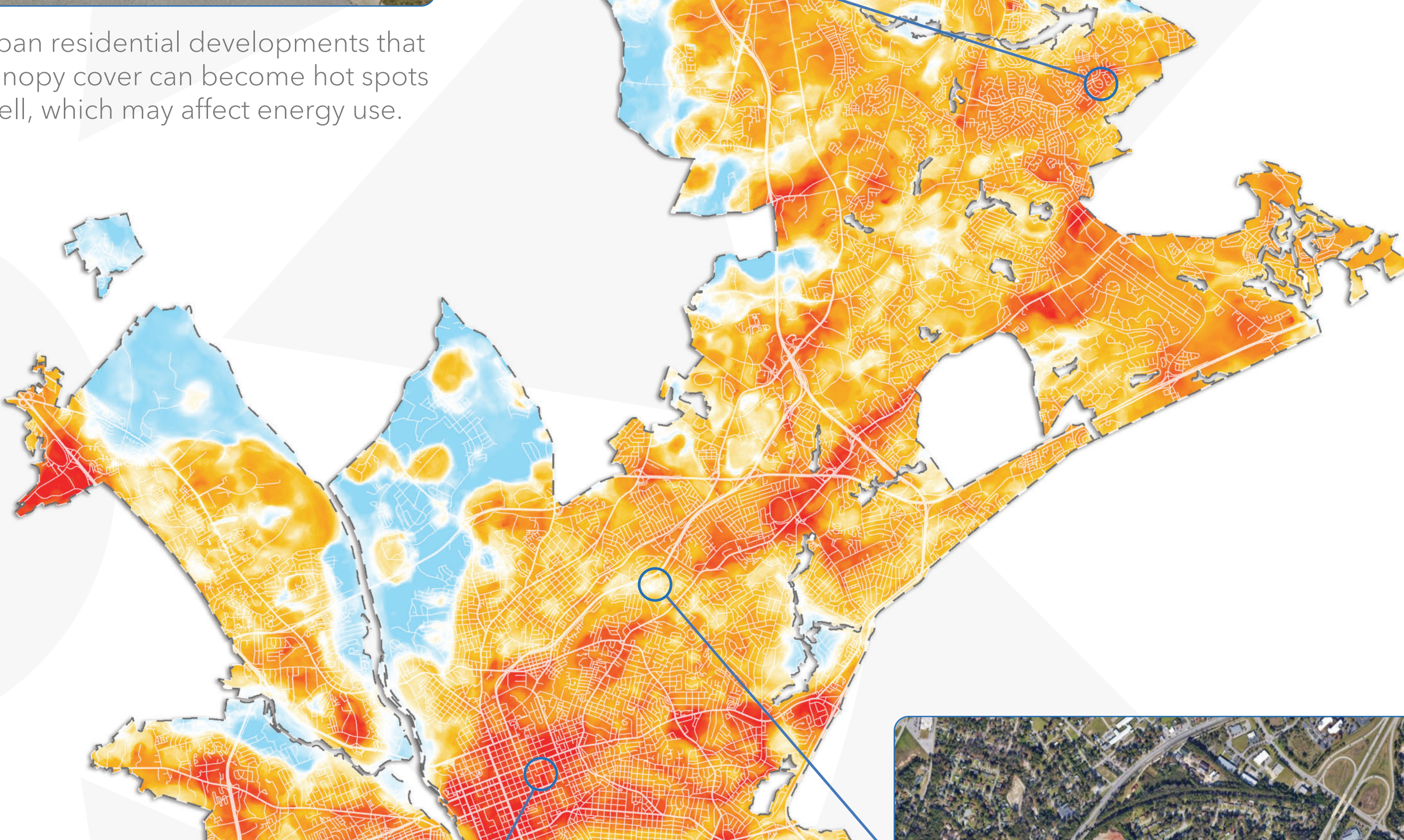
Find your home, place of work, or favorite park on the maps and compare the heat throughout the day to your personal experience.

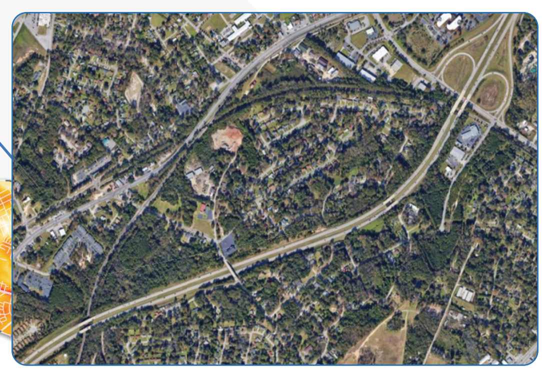
What about the landscape (trees, concrete buildings, riverside walkway) do you think might be influencing the heat in this area?

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.

Suburban residential developments that lack canopy cover can become hot spots as well, which may affect energy use.





Preserved forest provides a significant heat buffer between residential areas and land uses like highways or commercial centers.

Areas with large swaths of impervious surfaces, like the Barnwell Street Lot (Stationary Sensor Site #7), seem to absorb and retain heat throughout the day.

Morning Traverse Points

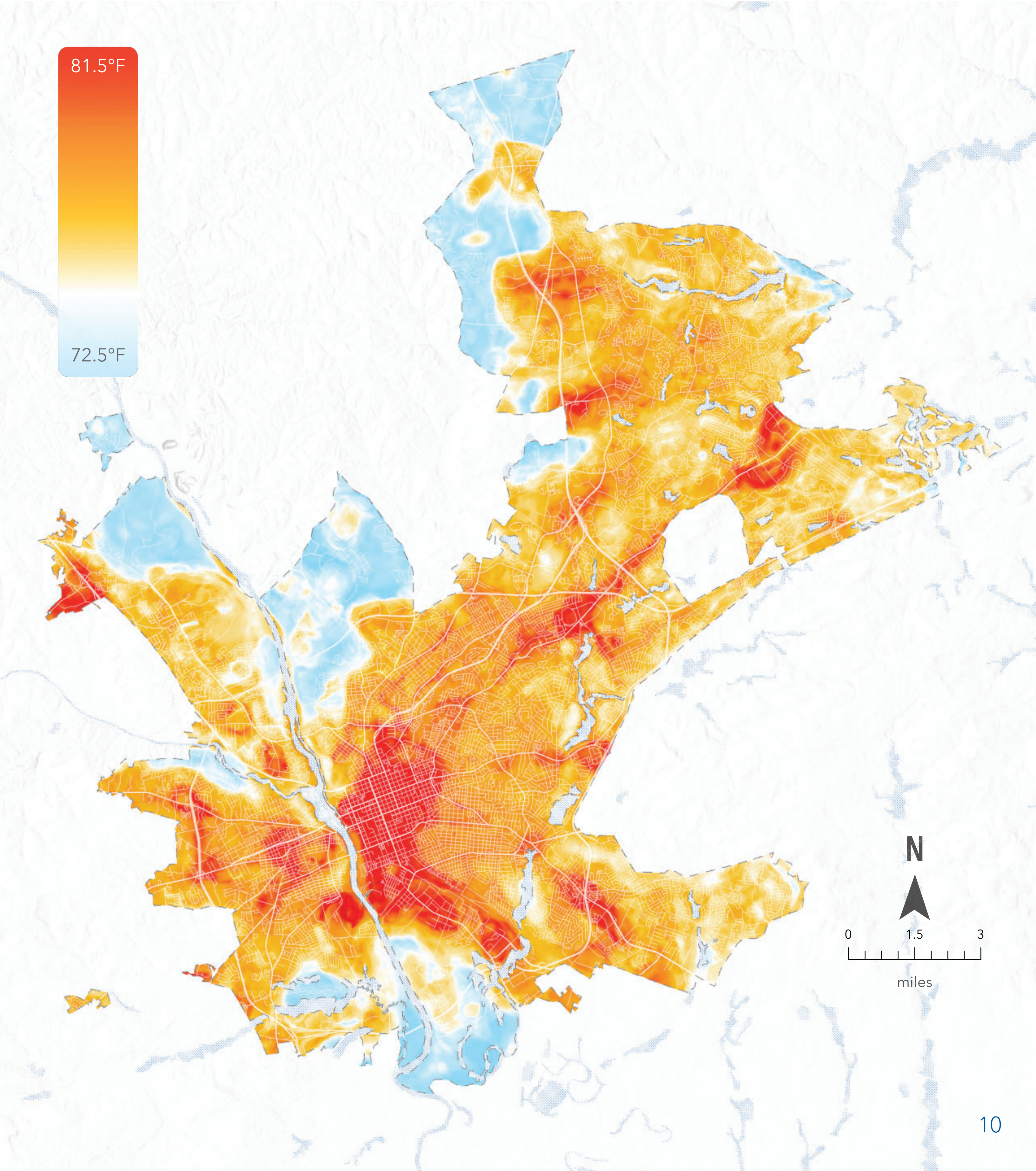
Temperature (6 - 7 am)

Over 27,000 unique temperature measurements are displayed in this map. However, due to technical issues with the temperature sensors, as well as possible field issues, data were unable to be retrieved from several regions of the map. The resulting area-wide models (next page) provide predictions in these regions based on the sampling of similar land uses and land where data were successfully retrieved. Interpretations of the models should be made in this context.

Morning Area-Wide Model

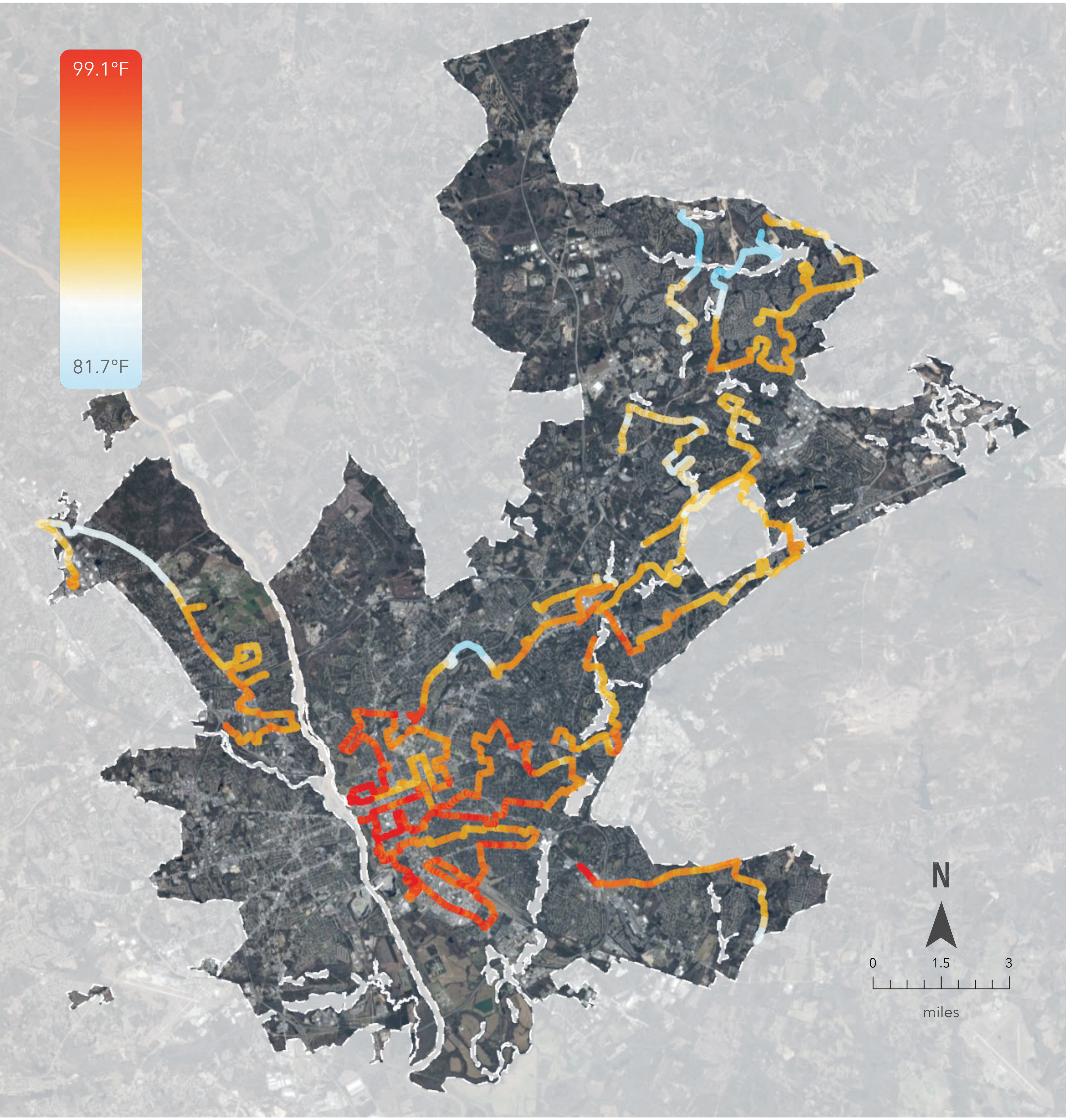
Temperature (6 - 7 am)

HEAT WATCH



Afternoon Traverse Points

Temperature (3 - 4 pm)

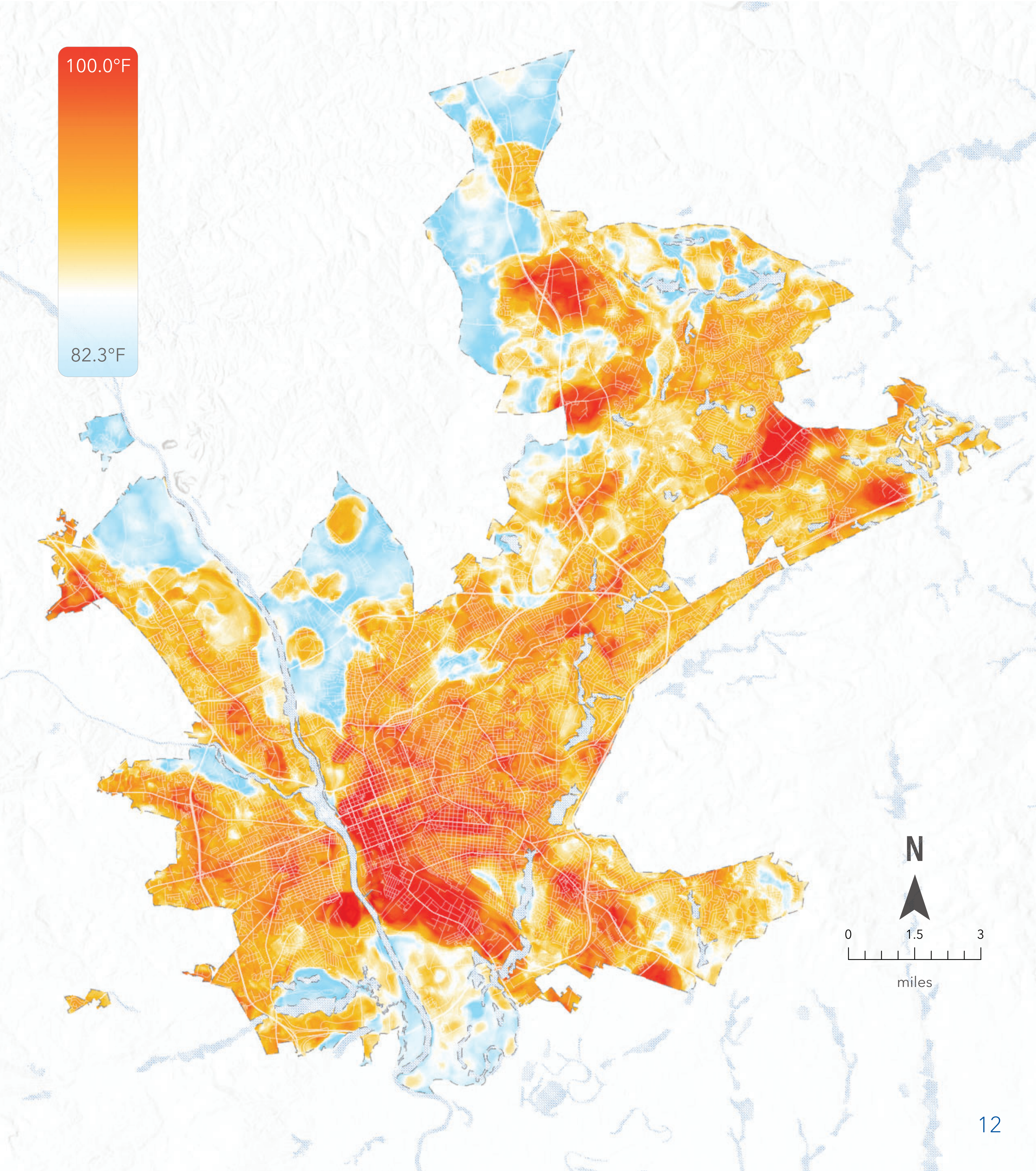


Over 18,000 unique temperature measurements are displayed in this map. However, due to technical issues with the temperature sensors, as well as possible field issues, data were unable to be retrieved from several regions of the map.

The resulting area-wide models (next page) provide predictions in these regions based on the sampling of similar land uses and land where data were successfully retrieved. Interpretations of the models should be made in this context.

Afternoon Area-Wide Model

Temperature (3 - 4 pm)



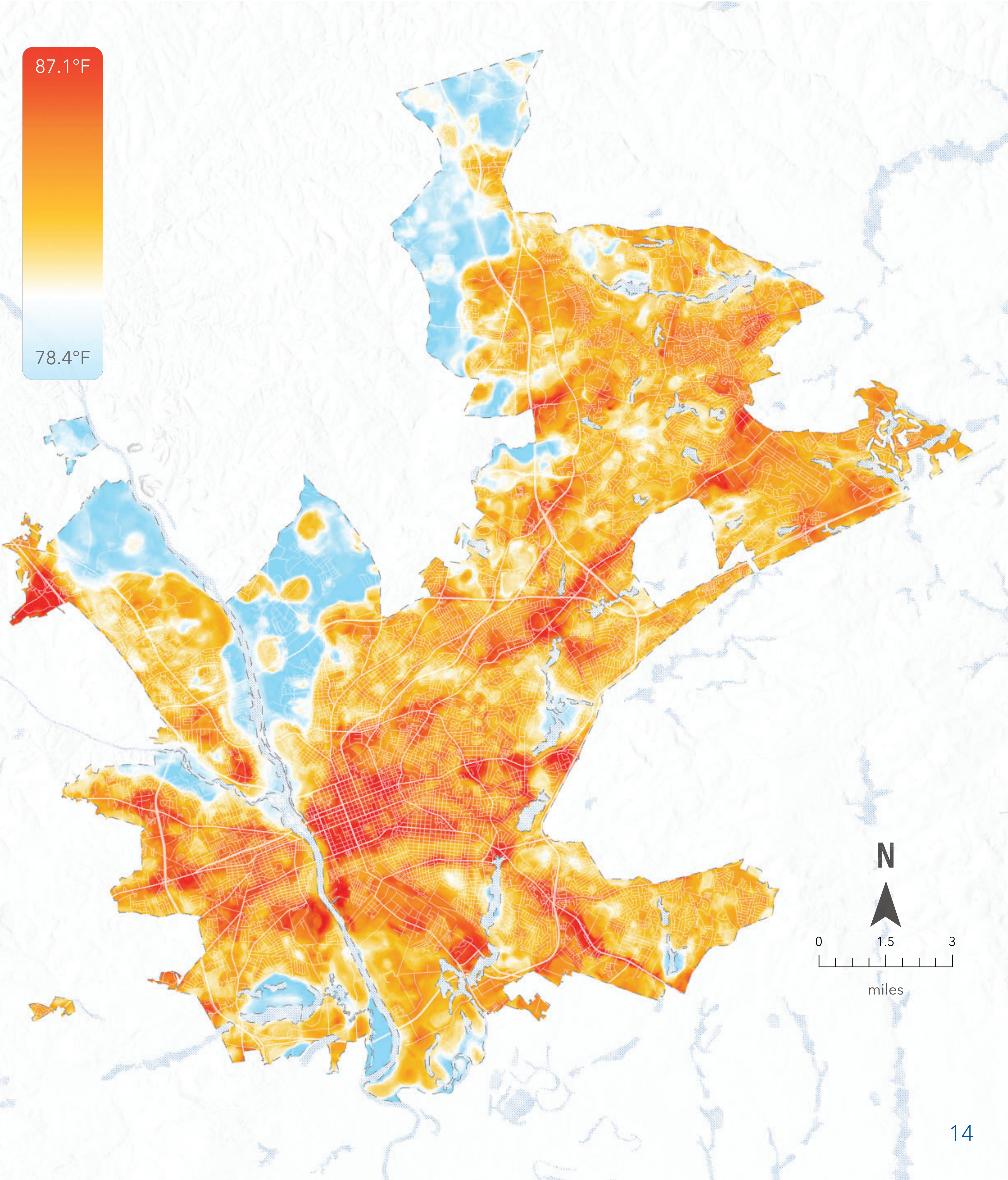
Evening Traverse Points

Temperature (7 - 8 pm)

Over 25,000 unique temperature measurements are displayed in this map. However, due to technical issues with the temperature sensors, as well as possible field issues, data were unable to be retrieved from several regions of the map. The resulting area-wide models (next page) provide predictions in these regions based on the sampling of similar land uses and land where data were successfully retrieved. Interpretations of the models should be made in this context.

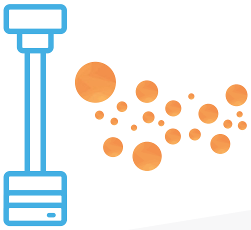
Evening Area-Wide Model

Temperature (7 - 8 pm)



Mapping Method

1 Download & Filter

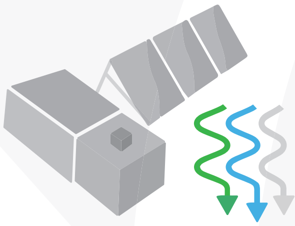


Download raw heat data from sensor SD cards

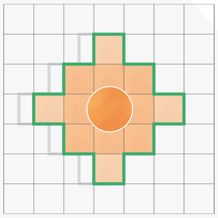
Compare data with field notes and debrief interview

Trim data to proper time window, speed, and study area

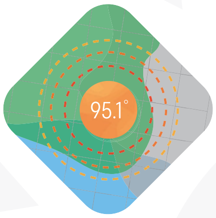
2 Integrate & Analyze



Download multi-band land cover rasters from Sentinel-2 satellite

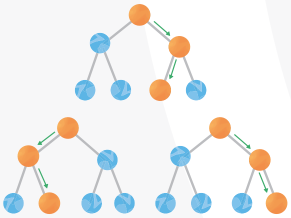


Transform land cover rasters using a moving window analysis

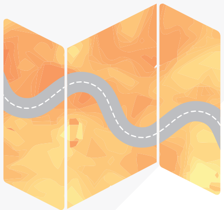


Calculate statistics of each land cover band across multiple radii

3 Predict & Validate



Combine heat and land cover data in Machine Learning model



Create predictive raster surface models of each period

Perform cross validation using 70:30 holdout method

The most relevant and recent publications include:

Shandas, V., Voelkel, J., Williams, J., & Hoffman, J., (2019). Integrating Satellite and Ground Measurements for Predicting Locations of Extreme Urban Heat. Climate, 7(1), 5. https://doi.org/10.3390/cli7010005

Voelkel, J., & Shandas, V. (2017). Towards Systematic Prediction of Urban Heat Islands: Grounding Measurements, Assessing Modeling Techniques. Climate, 5(2), 41. https://doi.org/10.3390/cli5020041

CAPA

Accuracy Assessment

HEAT WATCH

Accuracy Assessment*	
Traverse	Adjusted R-Squared
6 - 7 am	0.98
3 - 4 pm	0.98
7 - 8 pm	0.97

Field Data

Like all field campaigns, the collection of temperature and humidity data requires carefully following provided instructions. In the event that user error is introduced during the data collection process, outputs may be compromised in quality. While our team has a developed a multi-stage process for assessing and reviewing the datasets, some errors cannot be identified or detected, and therefore can inadvertently compromise the results.

Some examples of such outputs may include temperature predictions that do not match expectations for an associated landcover (e.g. a forested area showing relatively warmer temperatures). We suggest interpreting the results in that context.

Prediction Areas

The traverse points used to generate the area-wide maps do not cover every square mile of the study area. Rather, the approach with Heat Watch is to sample the study area's range of diverse land uses & land covers, such as lakes, forests, residential neighborhoods and shopping malls. Modeled areas that are made up of land uses and land covers that are closely sampled (i.e. traverses within 1,000 meters) can be interpreted with more confidence than those areas that are not closely sampled.

*Accuracy Assessment: To assess the strength of our predictive temperature models, we used a 70:30 "holdout cross-validation method," which consists of predicting 30% of the data with the remaining 70%, selected randomly. An 'Adjusted R-Squared' value of 1.0 is perfect predictability, and 0 is total lack of prediction. Additional information on this technique can be found at the following reference: Voelkel, J., and V Shandas, 2017. Towards Systematic Prediction of Urban Heat Islands: Grounding measurements, assessing modeling techniques. Climate 5(2): 41.

Media


Geography at South Carolina
YOUR WORLD IS WAITING
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Physical / Environmental Geography
Environment-Society Relationships
Geographic Information Science
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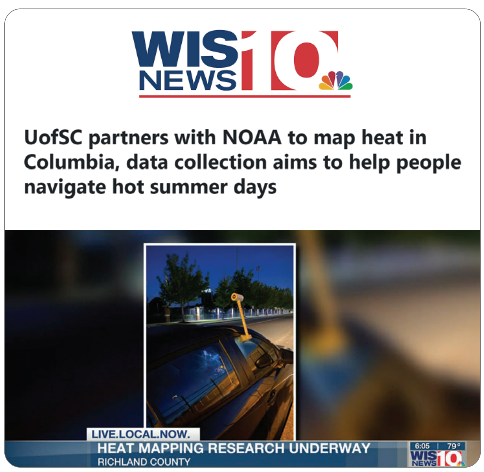
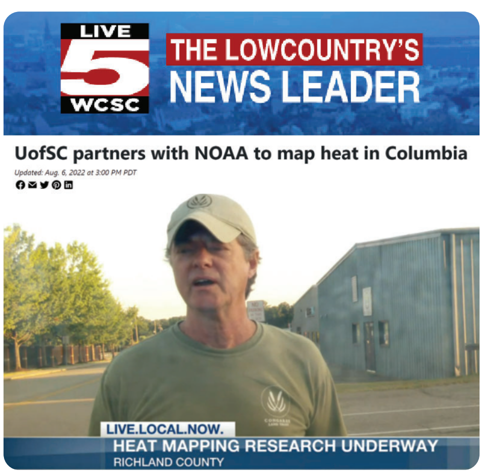
NEWS19
Why are certain parts of Columbia hotter than others? Researchers are working to find out


WIS NEWS 10
UofSC partners with NOAA to map heat in Columbia, data collection aims to help people navigate hot summer days
LIVE.LOCAL.NOW.
HEAT MAPPING RESEARCH UNDERWAY
RICHLAND COUNTY


15 NEWS
UofSC researchers will be "heat-mapping" across SC Saturday
by Briasia Russ
Friday, August 5th 2022


LIVE 5 WCSC
THE LOWCOUNTRY'S NEWS LEADER
UofSC partners with NOAA to map heat in Columbia
Updated: Aug. 6, 2022 at 3:00 PM PDT
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HEAT MAPPING RESEARCH UNDERWAY
RICHLAND COUNTY


WIS NEWS 10
Richland County joins nationwide climate mapping, weather data to help with extreme heat
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Stationary Sensor Analysis

Sensor & Installation

Several weeks prior to campaign day,

local organizers installed a set of HOBO stationary sensors in targeted locations across Columbia. The sensors recorded temperature and humidity measurements every five minutes continuously for several months, including on the day of the Heat Watch campaign. Spread across a diverse range of land uses and land covers, the sensors provide a robust temporal dataset to match with the rich spatial information that Heat Watch volunteers collect through the mobile campaign.

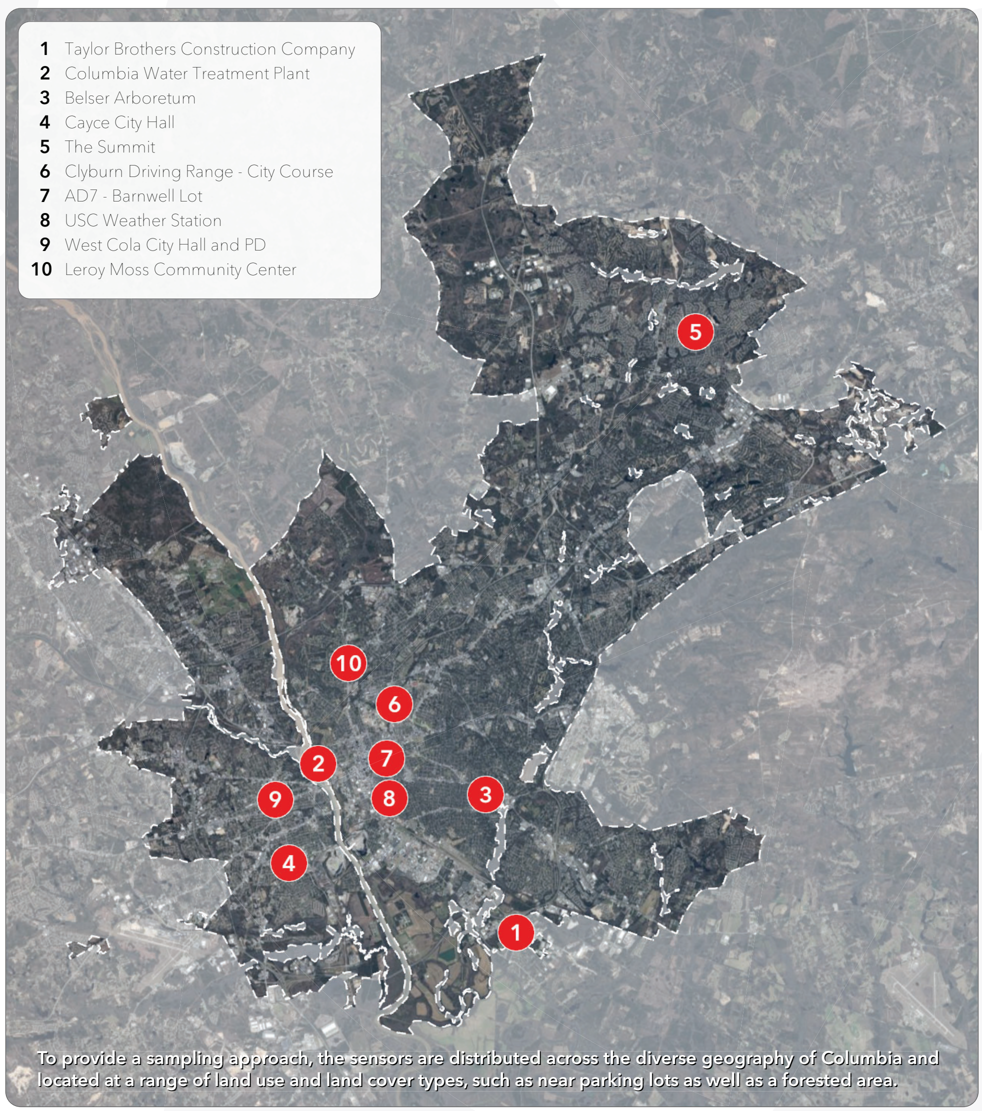
While these stationary and mobile methods differ slightly in their instrumentation and experimental design, we can make descriptive comparisons of the datasets to address two primary questions:

1. How do temperatures between sensor locations vary on campaign day compared to other summer days?
2. How do the Heat Watch models compare with the stationary sensor measurements at morning, afternoon and evening?

The following pages present several approaches and findings towards answering these questions.

Onset HOBO MX2302A Sensor

HOBO sensors at locations #2 and #3.



HOBO sensor sites across Columbia.

Stationary Sensor Analysis

Temporal Analysis

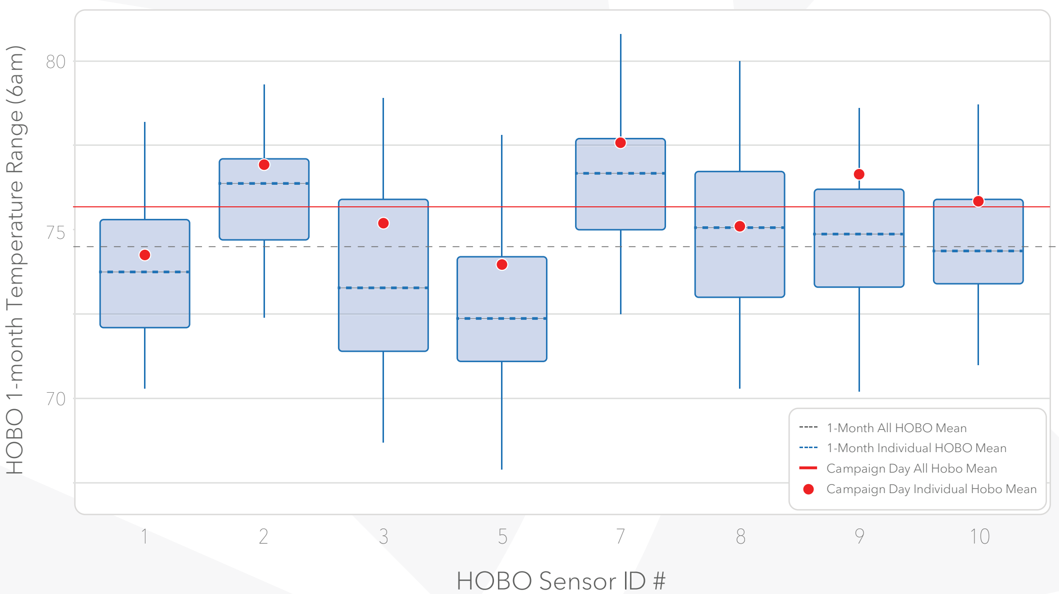
1

How do temperatures between sensor locations vary on campaign day compared to other summer days?

The purpose of this question is to help determine if a single-day capture of temperature measurements can indeed represent the distribution of temperatures across an area on a typical hot summer day. We compare each HOBO sensor against the average of all HOBOs over a four-week period surrounding the campaign day. In other words we ask, is sensor #1 typically warmer or cooler than the average of all sensors, and, is sensor #1 warmer or cooler than average on campaign day?

The results of this analysis for the morning period are displayed in the graph below and for all three time periods in the table. The 5-minute interval HOBO measurements are averaged to summarize each hour in the morning (6am to 7am), afternoon (3pm to 4pm) and evening (7pm to 8pm), matching the hours of the campaign. The campaign day values are represented in the graph by the red horizontal line (all-sen-sor mean) and red dots (individual sensor mean); the one-month period values are represented by the dashed blue horizontal line (all-sensor mean) and dashed blue bar in each box and whisker plot (single-sensor mean).

Campaign Day vs. 1-Month HOBO Mean (6am)



	Morning				Afternoon				Evening			
ID	6am 1-month average	Difference from area mean	6am campaign day average	Difference from area mean	3pm 1-month average	Difference from area mean	3pm campaign day average	Difference from area mean	7pm 1-month average	Difference from area mean	7pm campaign day average	Difference from area mean
1	73.7	-0.8	74.3	-1.4	93.6	2.4	97.2	2.8	84.5	-0.4	83.0	0.0
2	76.0	1.5	76.9	1.2	91.6	0.4	96.1	1.7	85.9	1.0	85.0	2.0
3	73.3	-1.2	75.2	-0.5	88.5	-2.7	92.8	-1.6	83.4	-1.5	81.2	-1.8
5	72.4	-2.1	74.0	-1.7	91.7	0.4	90.2	-4.2	84.5	-0.3	81.4	-1.6
7	76.5	2.0	77.6	1.9	92.4	1.2	95.3	1.0	86.4	1.6	84.5	1.5
8	74.9	0.4	75.1	-0.6	92.9	1.6	97.1	2.7	85.5	0.6	82.4	-0.6
9	74.8	0.3	76.6	0.9	89.6	-1.6	94.7	0.3	83.8	-1.0	83.0	0.0
10	74.6	0.1	75.8	0.2	91.3	0.0	91.6	-2.8	85.4	0.5	83.6	0.6
Avg	74.5	-	75.7	-	91.2	-	94.4	-	84.9	-	83.0	-

Note: Due to HOBO sensor malfunction, data are missing for sensors #4 and #6.

Stationary Sensor Analysis

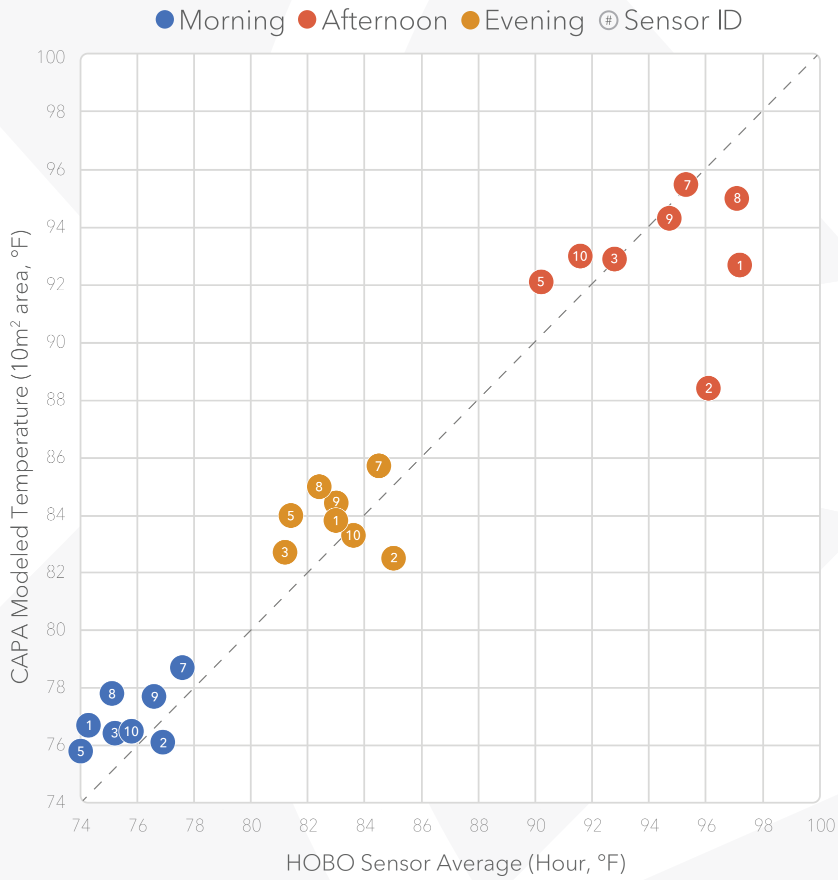
Stationary vs. Modeled

2

How do the Heat Watch models compare with the stationary sensor measurements at morning, afternoon and evening?

In order to address this question we can directly compare the CAPA Heat Watch modeled temperatures with the HOBO sensor measurements during each of the campaign hours. These comparisons are plotted in the graph against the dotted line that shows one-to-one correspondence between HOBO measurements and modeled temperature. The data are also summarized in the table.

Stationary Sensor Measurements vs. Modeled Temperature (10m² area)



	Morning			Afternoon			Evening		
ID	CAPA Model (°F)	HOBO Mean (°F)	CAPA - HOBO Differences (°F)	CAPA Model (°F)	HOBO Mean (°F)	CAPA - HOBO Differences (°F)	CAPA Model (°F)	HOBO Mean (°F)	CAPA - HOBO Differences (°F)
1	76.7	74.3	2.4	92.7	97.2	-4.5	83.8	83.0	0.8
2	76.1	76.9	-0.8	88.4	96.1	-7.7	82.5	85.0	-2.5
3	76.4	75.2	1.2	92.9	92.8	0.1	82.7	81.2	1.5
5	75.8	74.0	1.8	92.1	90.2	1.9	84.0	81.4	2.6
7	78.7	77.6	1.1	95.5	95.3	0.2	85.7	84.5	1.2
8	77.8	75.1	2.7	95.0	97.1	-2.1	85.0	82.4	2.6
9	77.7	76.6	1.1	94.3	94.7	-0.4	84.3	83.0	1.3
10	76.5	75.8	0.7	93.0	91.6	1.4	83.3	83.6	-0.3

Note: Due to HOBO sensor malfunction, data are missing for sensors #4 and #6.

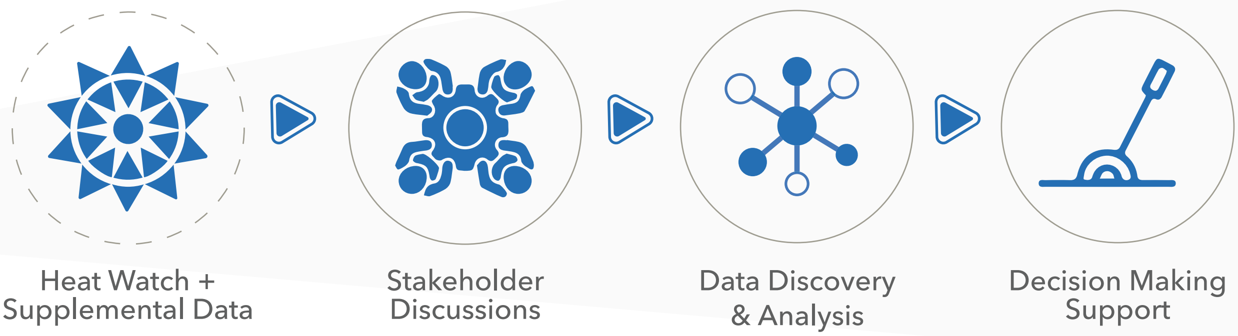
Next Steps

Put your Heat Watch data to work!

CAPA Insights aims to enhance your understanding of Heat Watch data and support challenging planning decisions through innovative visuals, interpretations, and application tools.

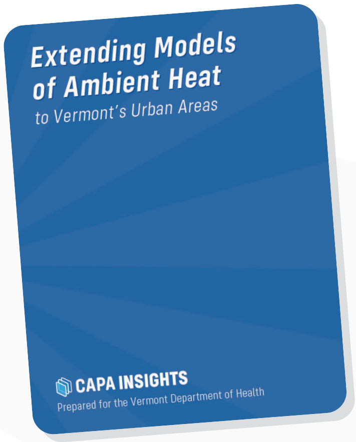
With Insights, you can pose questions like:

- What are the useful ways of summarizing heat data, and what can these tell us about heat in relation to geography?
- Which patterns of land cover are generating hot spots and cool spots throughout the day?
- Who is most disproportionately affected by heat, and what is there to do about it?



Insights also provides the ability to extend your Heat Watch data to surrounding areas, and generate high resolution ambient models of heat in nearby cities and towns of similar geographic make-up.

This approach incorporates regional differences, and also makes evaluations with satellite-derived land surface readings to provide the most accurate models possible.



Explore the full suite of Insights tools, with a case study from Vermont and learn more here.

Next Steps

GROWING CAPACITY

Now that you have completed a Heat Watch campaign, you have a better understanding of where urban heat is occurring in your region, and who is at risk of exposure. You may be wondering what to do next: how to mitigate that exposure, or help your region adapt to a hotter future. If you would like to take the next steps in preparing for climate change, CAPA's Growing Capacity services can help.

Growing Capacity is an arm of CAPA Strategies which emphasizes place-based solutions, substantive community engagement, and the translation of data into action. These services ask not only "where do climate risks exist?," but "what can we do about them?" Growing Capacity services offer a systematic way to integrate data and accelerate climate adaptation in your area. We do this by reducing common barriers that limit action; making climate adaptation accessible to your colleagues and communities; and facilitating opportunities for collaboration, learning, and problem solving.

Growing Capacity services reflect a holistic approach to climate change mitigation and adaptation. Our process is rooted in social scientific thinking, interdisciplinarity, and a mission of equity. This adds up to capacity-building solutions which are actionable, tailored to your region, and promote climate resilience for all.

We offer a range of services to support you in your climate adaption efforts, no matter how big or small. Choose from our offerings below to create a Growing Capacity package that fits your needs and budget.

Whether your climate adaption goals require increased community-based research, data synthesis, public outreach, network-building, or novel interventions, the Growing Capacity team is here to assist you.

Jurisdictional Scan

Comprehensive Report

Capacity Assessment

Comprehensive Report, Analysis

Community Knowledge Assessment

Workshops, Surveys, Focus Groups, Interviews

Resource Development

Strategic plans, Handbooks, Policy language, Tools for education/outreach

? Want to start a conversation about Growing Capacity in your region? Contact us at *info@capastrategies.com*

CAPA
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HEAT WATCH