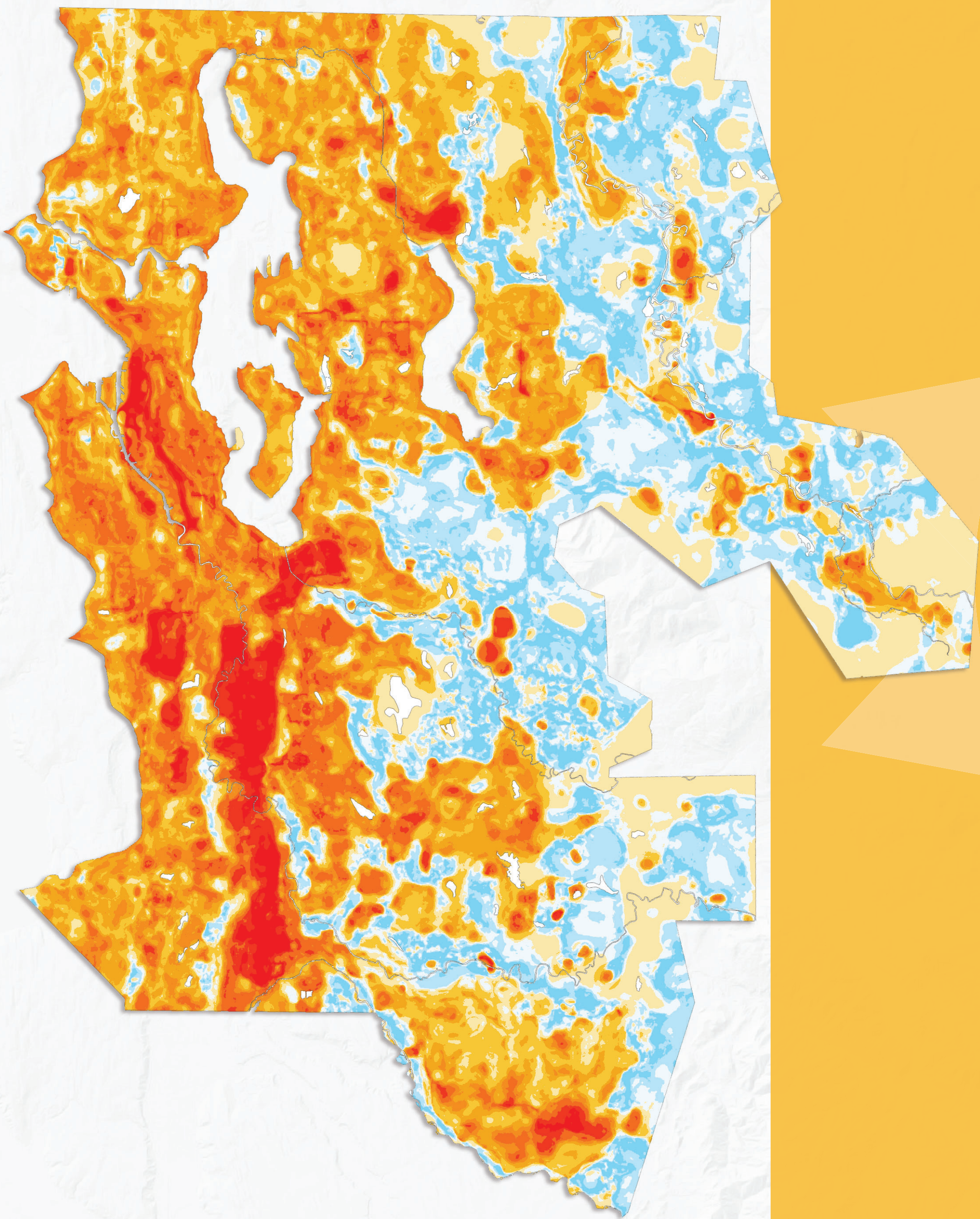
Seattle & King County
Washington



CAPA strategies

Heat Watch
Report

CAPA strategies

Heat Watch

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.

CPO NOAA CLIMATE PROGRAM OFFICE

NIHHIS NATIONAL INTEGRATED HEAT HEALTH INFORMATION SYSTEM

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

This report was prepared by CAPA Strategies, LLC
Summer 2020

Credit: David Hoffman

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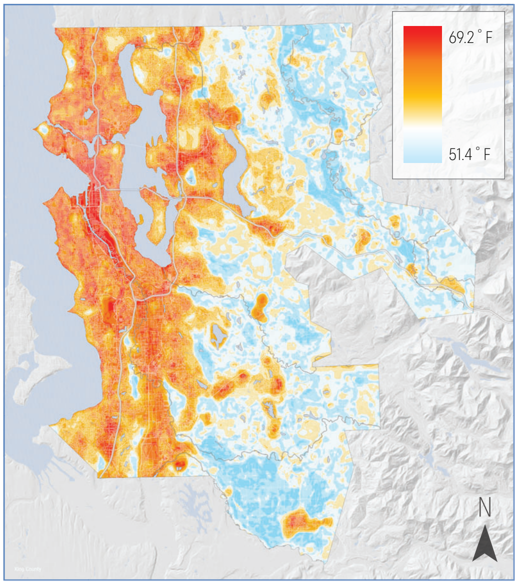
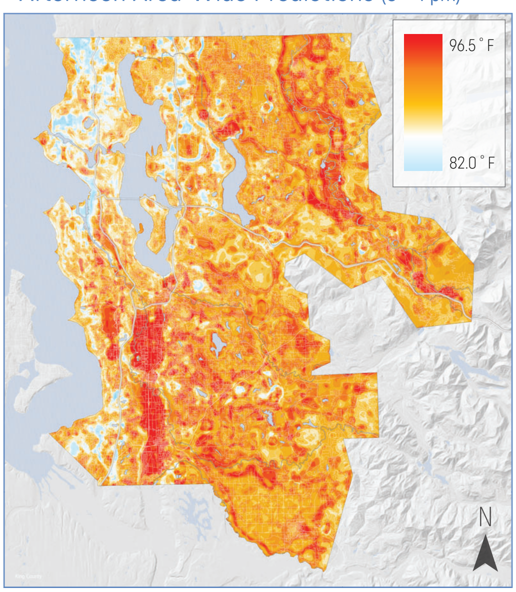
Morning Area-Wide Predictions (6 - 7 am)

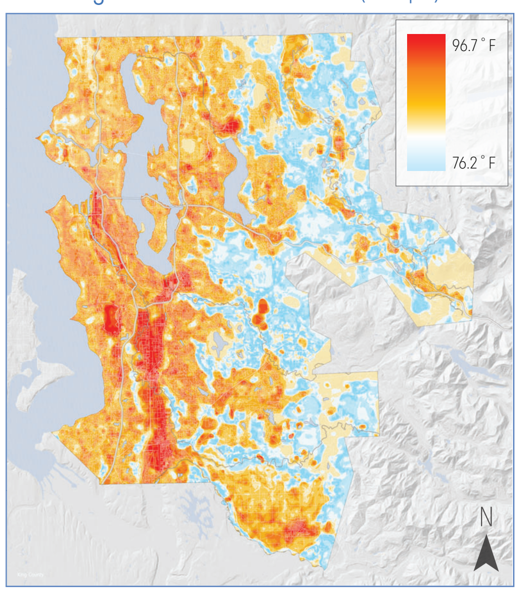


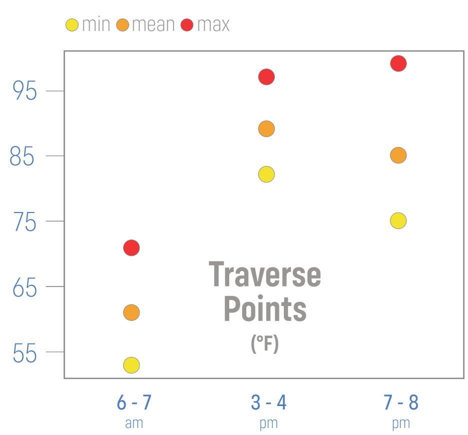
Major thanks to all of the participants and organizers of the Urban Heat Watch program in King County, WA. After months of collaboration and coordination, local organizers and volunteers collected thousands of temperature and humidity data points in the morning, afternoon, and evening of a long, hot campaign day on July 27th, 2020.

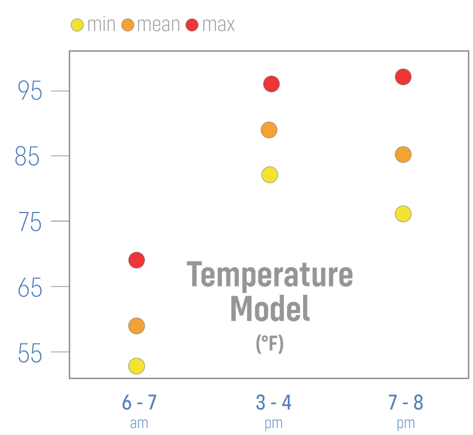
Afternoon Area-Wide Predictions (3 - 4 pm)



Evening Area-Wide Predictions (7 - 8 pm)







Study Date

July 27th, 2020

17
Volunteers

15
Routes

110,107
Measurements

98.8°
Max Temperature

23.4°
Temperature Differential

Heat Watch

Learn more about the background and goals of each Heat Watch 2020 campaign city at https://nihhis.cpo.noaa.gov/Urban-Heat-Island-Mapping/Campaign-Cities.

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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 July 27th, 2020, 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.

CAPA strategies

Heat Watch

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

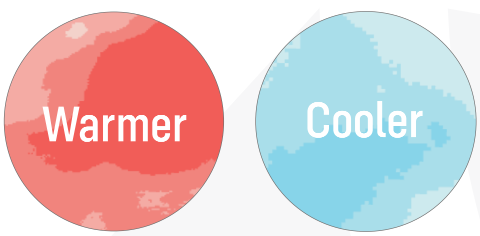
Voelkel, J., & Shandas, V. (2017). Towards Systematic Prediction of Urban Heat Islands: Grounding Measurements, Assessing Modeling Techniques. Climate, 5(2), 41. https://doi.org/10.3390/cli5020041

About The Maps

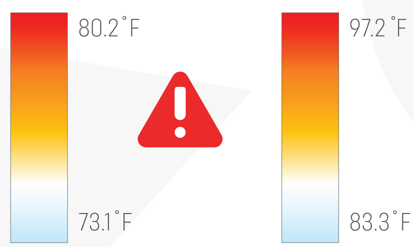
The following sections present map images from the Heat Watch campaign and modeling process. Two sets of maps comprise the final results from the campaign process, and they include:

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?

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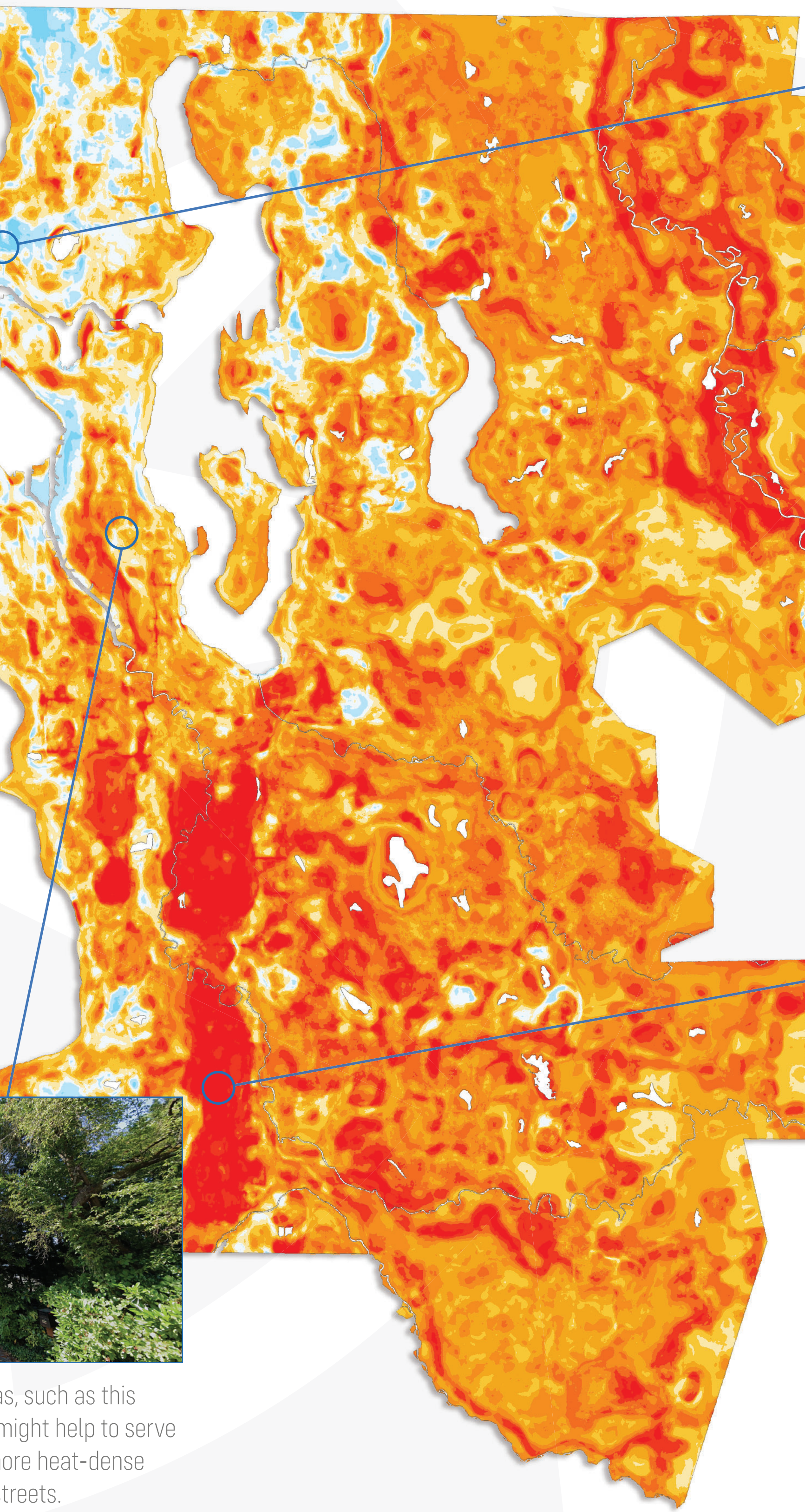
Initial Observations

Heat Watch

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.



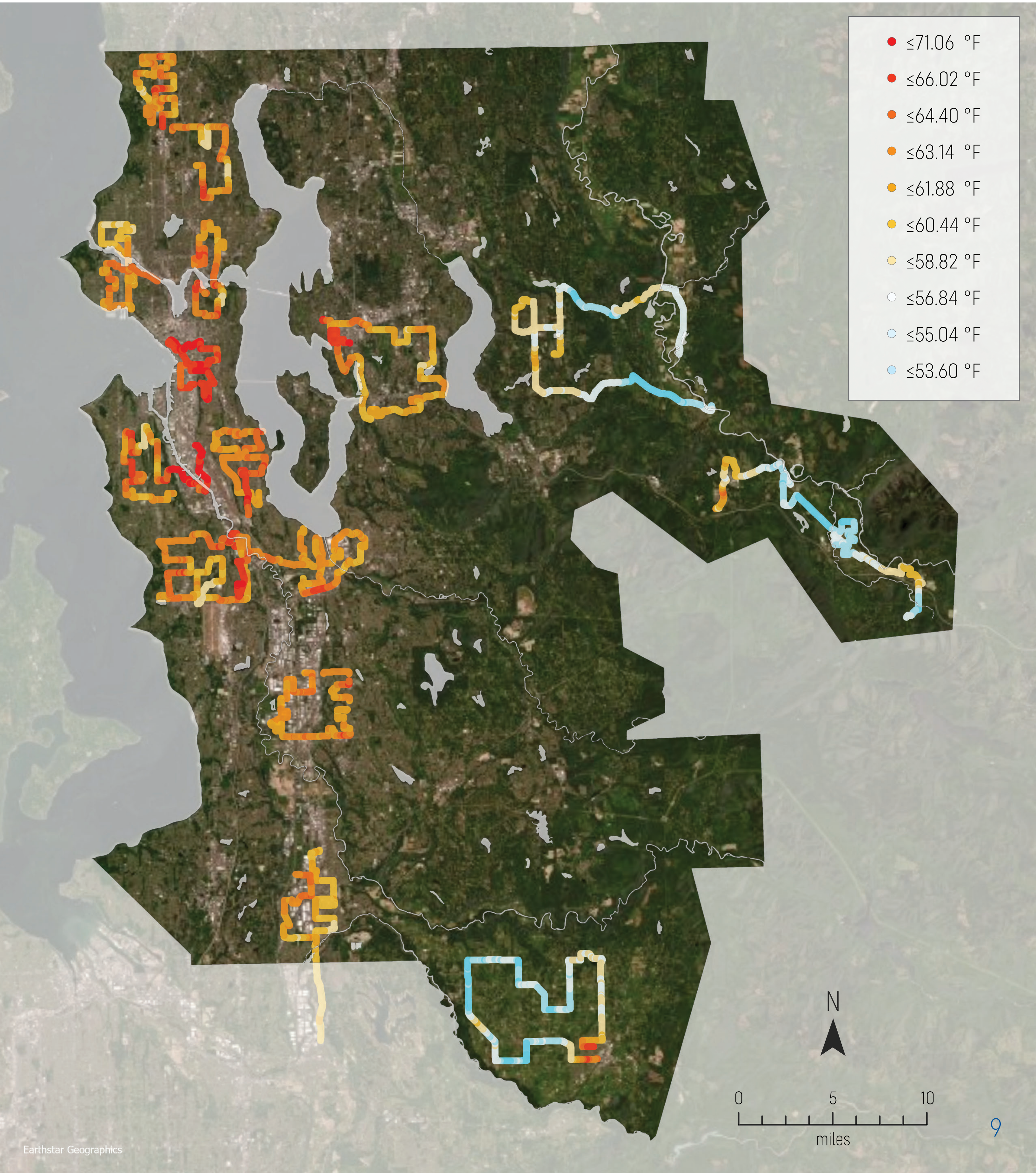
Shaded residential areas keep neighborhoods cool during summer heat waves and lower the risk of heat-related illness for residents.

Wide asphalt roadways with sparse vegetation appear to absorb heat throughout the day and remain hot, offering no refuge to pedestrians.

Preserved natural areas, such as this stretch of vegetation, might help to serve as a buffer between more heat-dense areas and residential streets.

Morning Traverse Points

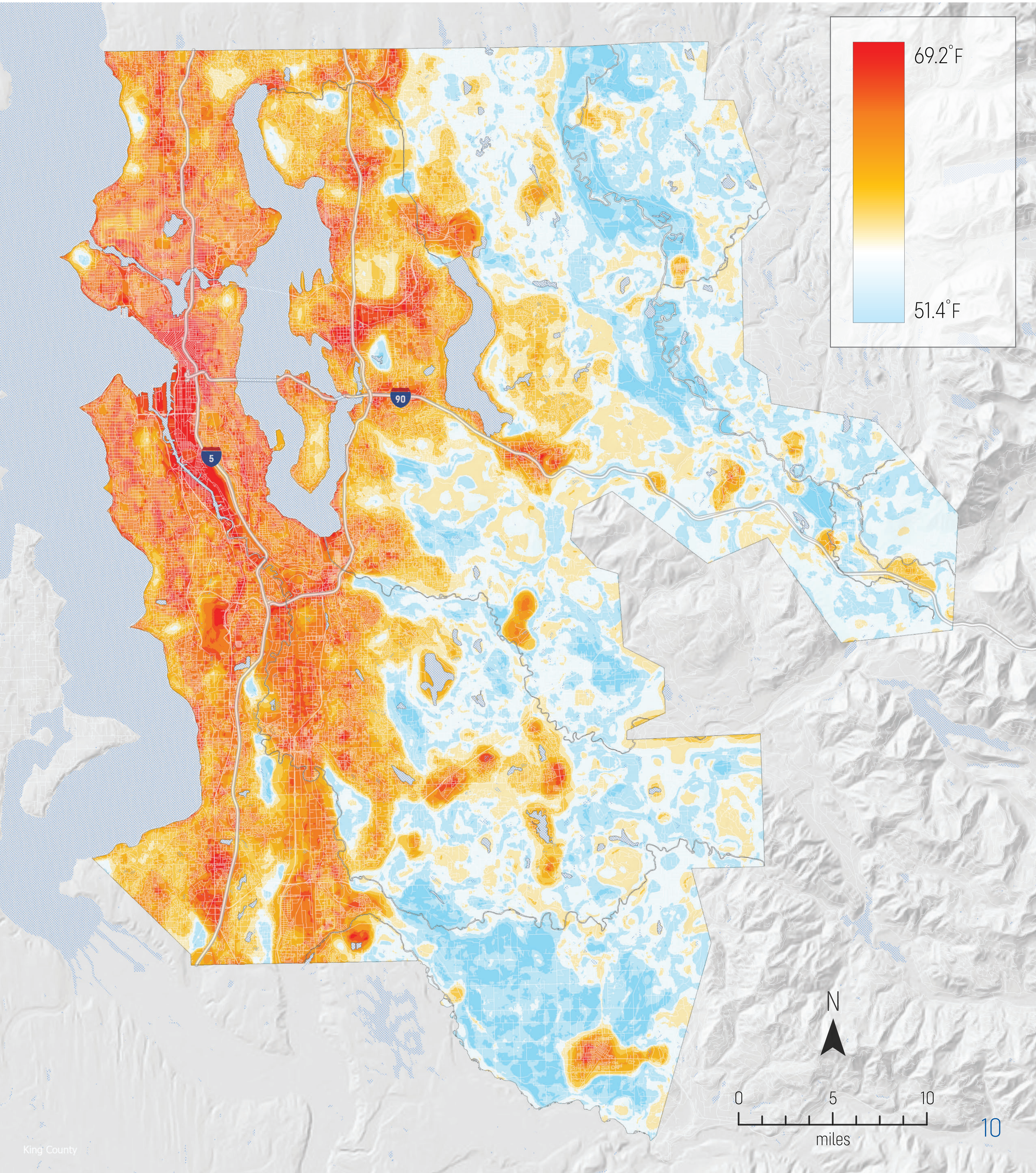
(6 - 7 am)



Morning Area-Wide Predictions

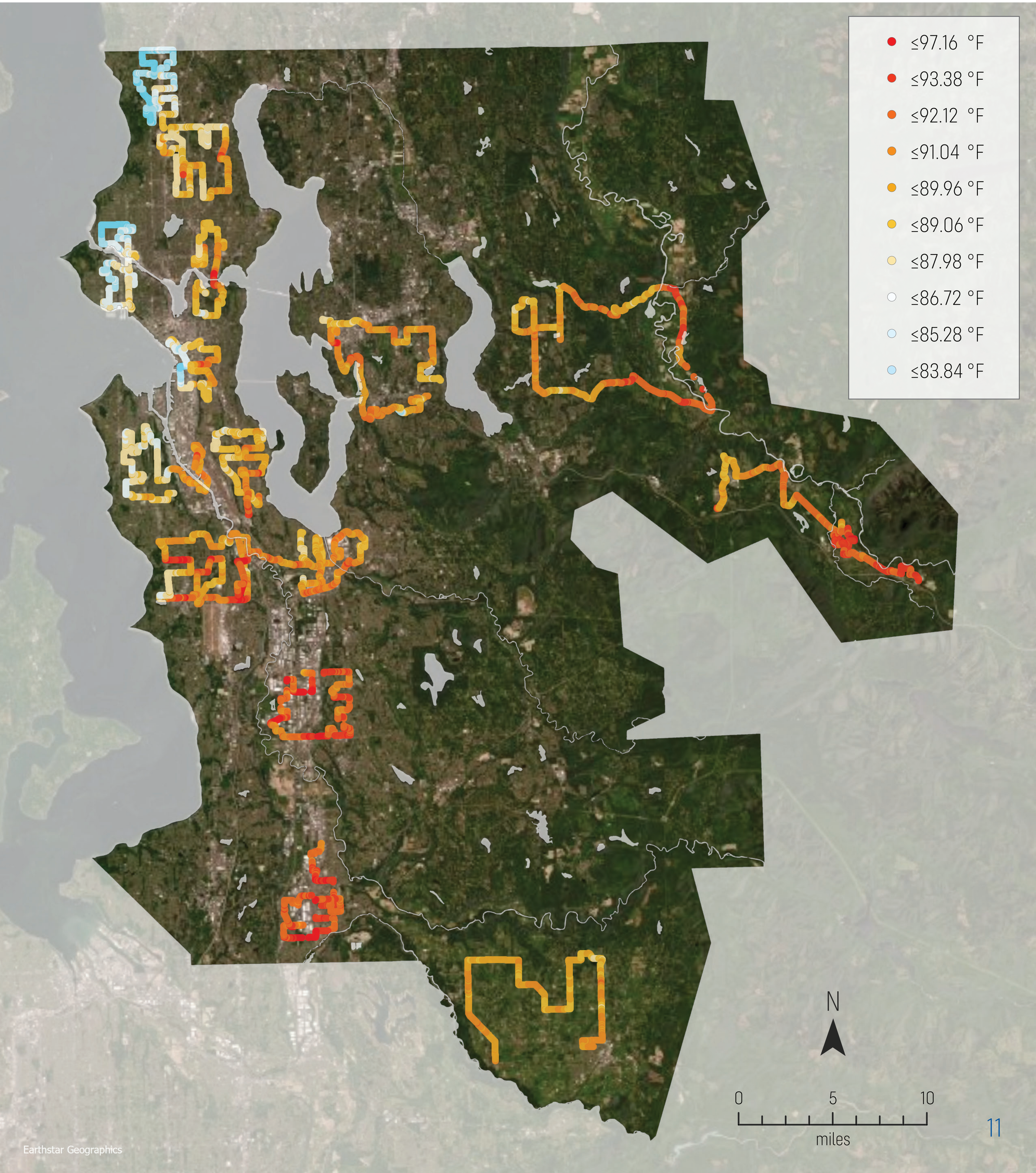
Temperature (6 - 7 am)

Heat Watch



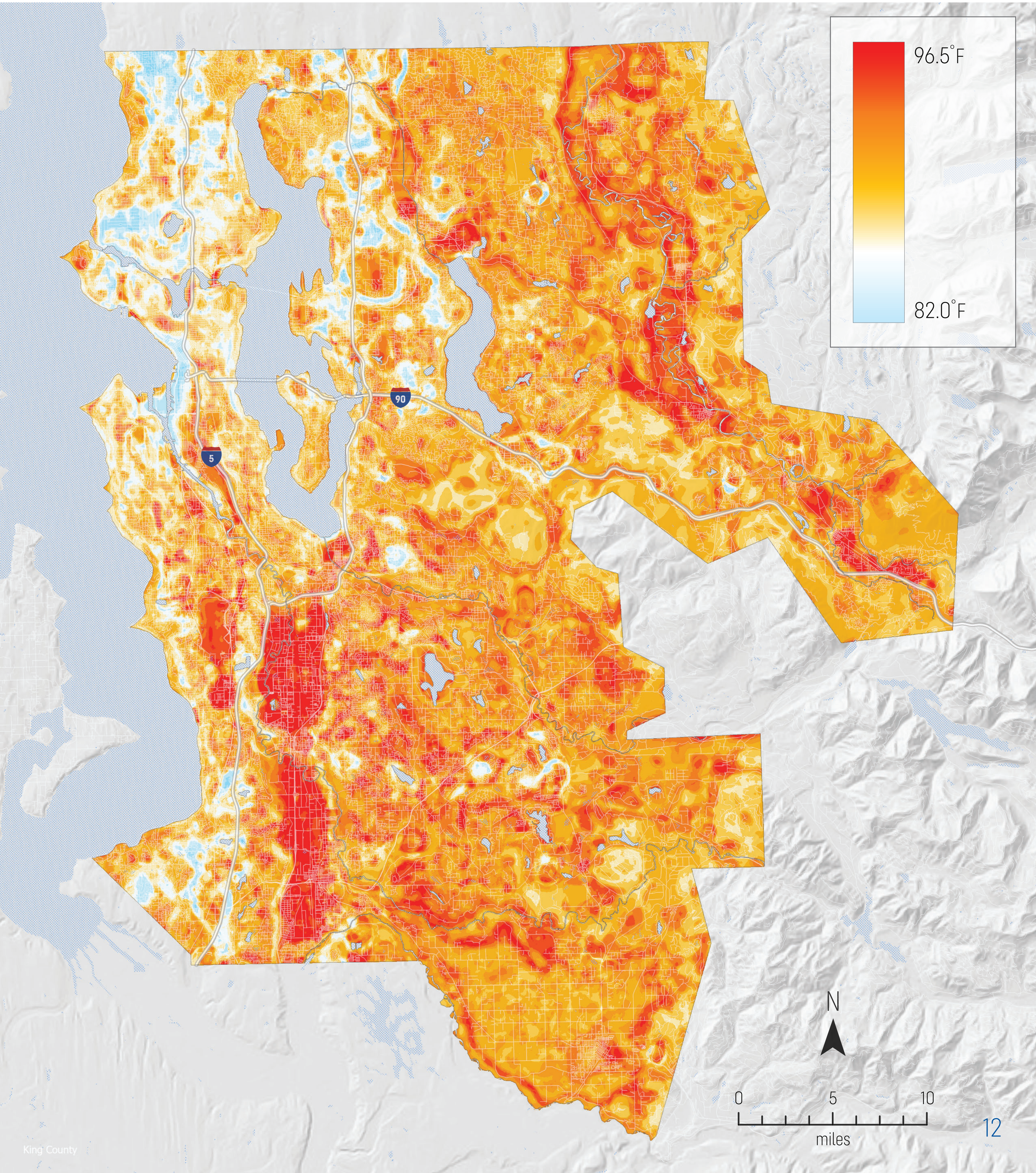
Afternoon Traverse Points

(3 - 4 pm)



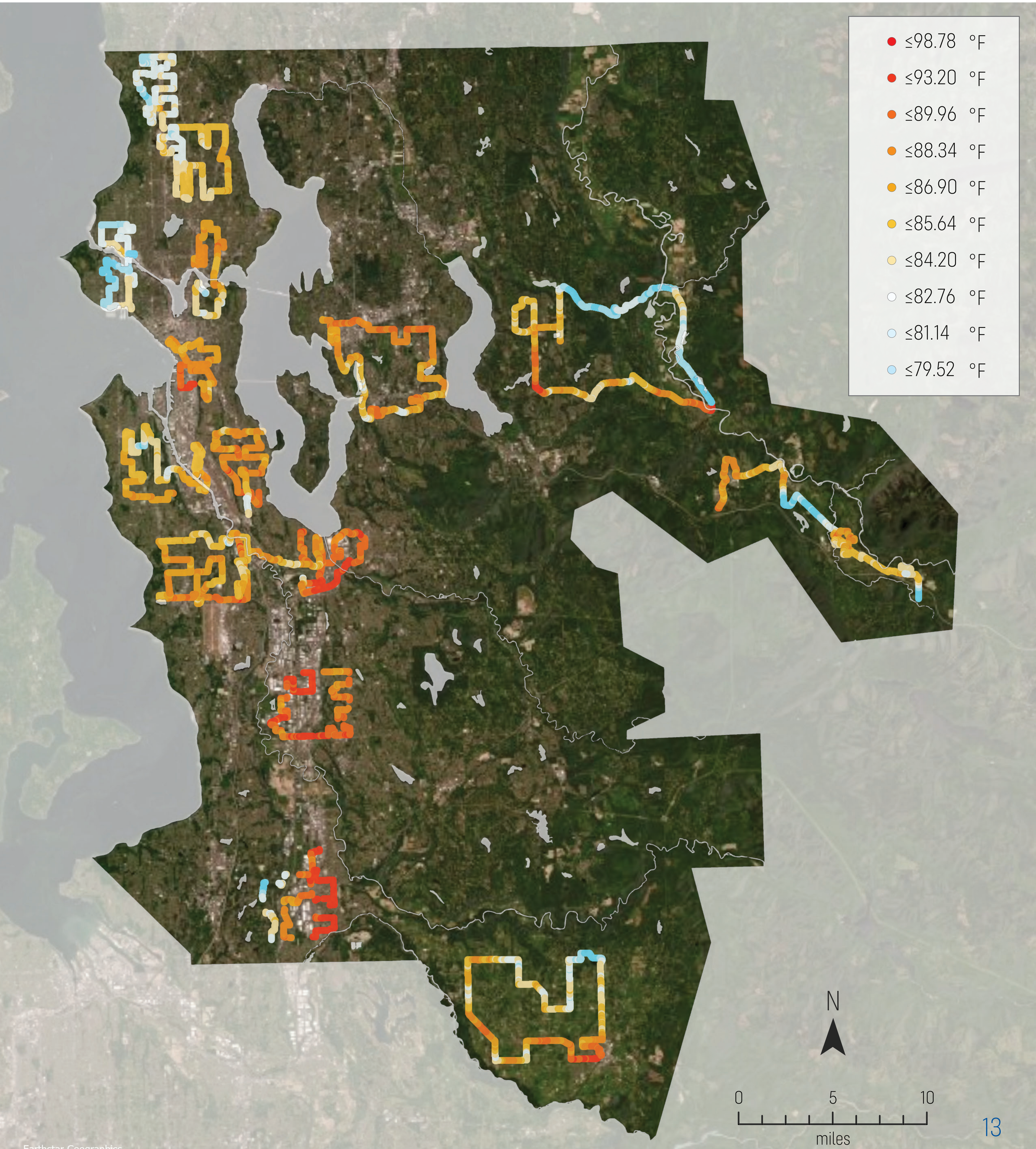
Afternoon Area-Wide Predictions

Temperature (3 - 4 pm)



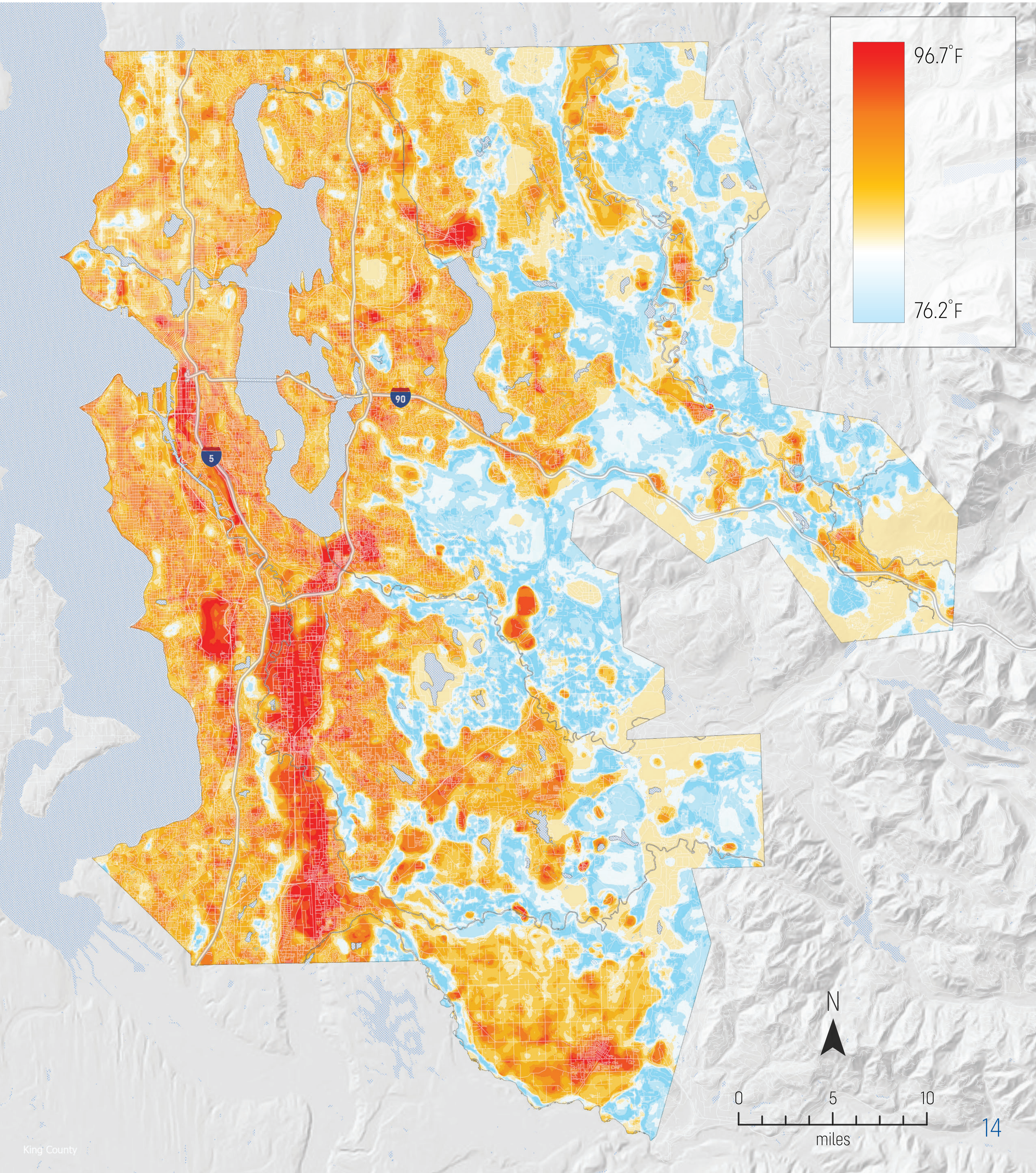
Evening Traverse Points

(7 - 8 pm)



Evening Area-Wide Predictions

Temperature (7 - 8 pm)

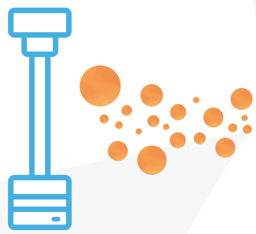


Mapping Method

CAPA strategies

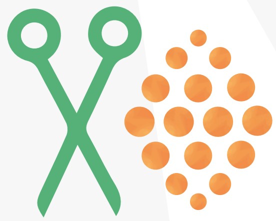
Heat Watch

1 Download & Filter



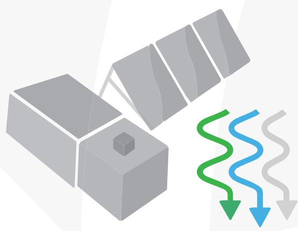
Download raw heat data from sensor SD cards

Compare data with field notes and debrief interview

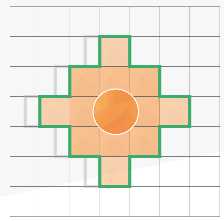


Trim data to proper time window, speed, and study area

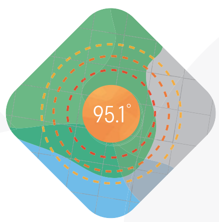
2 Integrate & Analyze



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

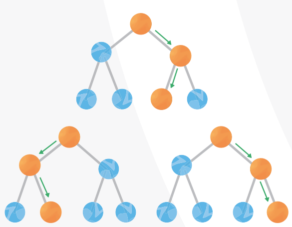


Transform land cover rasters using a moving window analysis

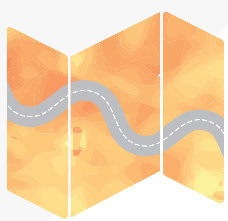


Calculate statistics of each land cover band across multiple radii

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

Accuracy Assessment*	
Traverse	R-Squared
6 - 7 am	0.99
3 - 4 pm	0.99
7 - 8 pm	0.99

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 areas wide maps do not cover every square of the studied area. Due to the large number of data collected, however, our predictive models support the extension of prediction to places beyond the traversed areas. The temperature and heat index values provided are modeled outputs; actual temperature and heat index on any given day, and at any point in time, may vary from what is shown in the maps.

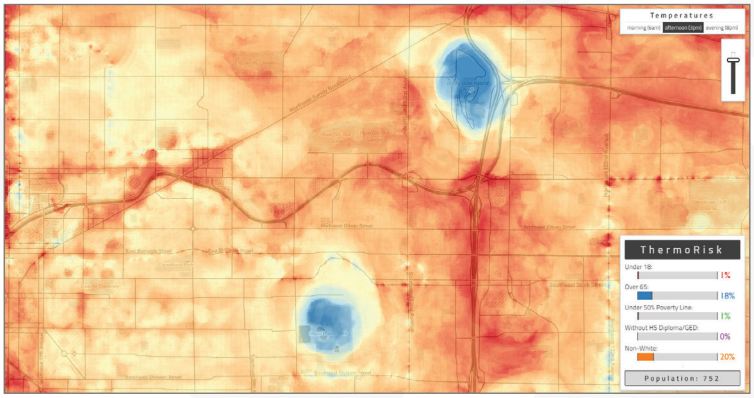
*Accuracy Assessment: To assess the strength of our predictive temperature models, we used a 70:30 "holdout cross-validation method," which consists of predicting 30% of the data with the remaining 70%, selected randomly. An 'Adjusted R-Squared' value of 1.0 is perfect predictability, and 0 is total 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.

CAPA strategies

Next Steps

Heat Watch

To further explore how your community's heat distribution affects local populations and infrastructure, we have created a suite of tools that help to organize these variables in user-friendly interfaces.

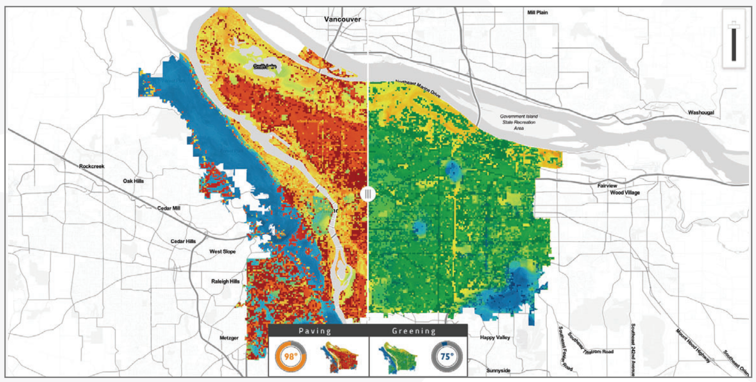


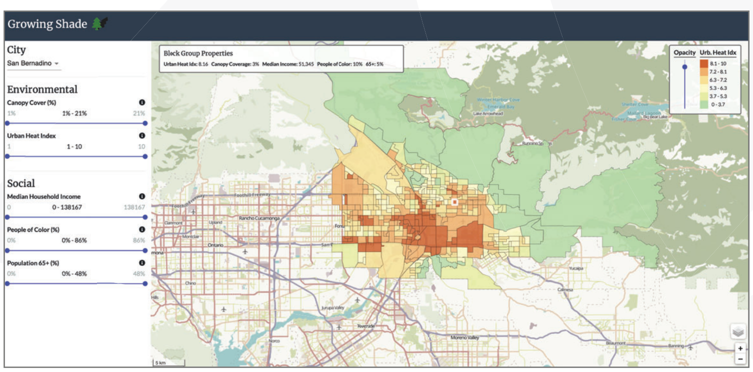
Social Vulnerability

Use Heat Watch data and publicly available demographic information to explore the intersection of urban heat and social vulnerability to better understand the needs of local communities facing the most acute impacts of a warming planet.

Built Environment Scenarios

Using computer models and municipal infrastructure data, this tool shows the effect on heat of changing the built environment. We explore scenarios of increased paving versus greening on heat at the scale of a city block.





Growing Shade

Using publicly available data on sociodemographics and land use, this tool identifies areas where expanding tree canopy would have the most direct benefit to social and environmental conditions.

Growing Capacity

Moving beyond data acquisition and decision support tools, CAPA offers resources and services to build and implement climate preparedness strategies. At CAPA we aim to make climate planning as accessible as possible by offering multiple scales of resources to fit your needs and capacity. Explore openly available tools, request place-specific analyses, or engage our team in facilitating outreach and planning processes.

Media


LOCAL NEWS

King County, Seattle launch heat mapping project to identify effects of rising temperatures

15 volunteers drove around King County and Seattle on Monday to figure out which areas suffer the most in hot weather.

@capa_heatwatch @capaheatwatch

www.capastrategies.com

CAPA
strategies

Heat Watch

Appendix : Q & A

Questions posed by the Seattle & King County project team
Answers provided by CAPA Strategies

Q1: What should the reader be taking away from the maps? At a high level, what did the data show about how land use and land cover in our [Seattle/King County] area affect temperature?

For the reader to make sense of these maps, looking across scales will be helpful. At the county-wide scale, we'll bring your attention to different patterns occurring across urban and rural areas by time of day and land cover. The major patterns noted across the three time periods in King County can be described as:

(1) the morning temperature distribution shows that areas with the most amount of concrete and building mass, i.e. downtown Seattle and the Renton to Auburn corridor, likely retain and emit the previous day(s)' heat through the nighttime, keeping the area relatively warm;

(2) the afternoon map shows that heat is more evenly distributed across the county, as compared to the morning and evening maps -- in other words, the entire area is heating up. Even within this more even distribution, elevated temperatures are seen in more open areas (e.g., Renton to Auburn corridor and the Snoqualmie Valley) and cooler temperatures are seen in north Seattle and a limited number of other locations, including downtown Seattle. Mid-day shadowing from taller buildings in downtown is a likely reason for the relatively cooler afternoon temperatures in downtown;

(3) in the evening, east King County, which is a less urban and more forested area, shows notable cooling in relation to the rest of the county and across the other time periods. More urbanized areas (i.e. areas with more concrete and higher concentration of buildings) are still retaining heat into the evening; and,

(4) while farmland and forested areas warm up in the afternoon to a similar degree as urban areas, the morning and evening maps indicate that these rural land covers release heat and cool more rapidly than urban areas through the nighttime.

Q2: Why are certain areas holding heat longer than others? Are there any particular messages about unique areas (e.g. downtown mid-day cooling, North Bend/Snoqualmie Valley area in east King County, the hot zone in the Renton/Kent/Auburn area)?

In downtown Seattle, the massive amounts of concrete and building material absorb, retain, and emit heat constantly through the day and night, though the tall buildings also create large swaths of shade during the afternoon that help to cool the air. (continued on next page)

North Bend and Snoqualmie largely follow temporal patterns described above for urban developments.

Renton, Kent, and Auburn fall within a long and continuous commercial-industrial corridor of low tree canopy cover and significant amounts of asphalt. The influence of these heat-intensifying factors is apparent in surrounding neighborhoods. One potential policy intervention could be increasing tree canopy cover in especially hot areas. For example, Portland City Council recently passed amendments to city development code that effectively removed exemptions that relate to trees in commercial, industrial, and heavy industrial areas.

Q3: Are there any key insights on the influence of water?

Many factors can be at play with water, such as waterbody size, the land covers immediately surrounding the waterbody, and wind. Our model does not yet account for wind, as it is a challenging meteorological variable to fully assess across a large area, though the influence of a waterbody as large as the Sound could certainly play a role with a strong wind. Several Weather Underground stationary sensors on the western side of Seattle indicate that a western wind may have been blowing in the afternoon hours of our campaign. While definitely worth further investigation with more reliable meteorological information, we could posit that this wind may have helped cool off the downtown area (in addition to mid-day shadowing), and possibly pushed a warm air mass further east.

Q4: Were there any surprises that our data uncovered? How do our results compare with other cities that have been mapped in the Pacific Northwest?

The heat signal from urban land covers is very similar to other Northwestern cities that we've mapped, as described above, with industrial land-uses and high building volume concentrating much of the heat, and urban tree canopy providing the primary source of heat mitigation. One potentially surprising aspect is the extent to which the sampling was done during a singular day of high heat, as opposed to a several day (or even week-long high heat stretch). If the climate models are correct, and the PNW will see longer stretches of high heat days, then we may see an amplification of temperatures in the hottest areas of the region.

Q5: Does the 24°F temp difference across the county means that you could take the same person and drop them in two parts of the county at the same time and they would experience temperatures that are as much as 24 degrees different. Is that an accurate characterization?

Yes, that is an accurate statement about simultaneous differences in temperature. The campaign area is large indeed, and weather does vary by micro-climatological differences, including longitude/latitude, elevation, wind, humidity, etc. The model accounts for the influence of land covers up to one kilometer away from each grid cell, so the predicting variables are very different in the west near water versus the east near forest and farmland, which is essentially how differences in locations are considered.