Portland Metro
Oregon

HEAT
WATCH
Report

CAPA
strategies

Acknowledgements

Heat Watch Portland Metro was conducted as part of the CAPA-NIHHIS 2023 Heat Mapping Campaign. Learn more about the campaign and this public-private partnership here.

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Executive Summary

We know that extreme heat is the most deadly of all natural disasters and that its impacts are not evenly distributed across people and places. Location matters. Those who live in historically disinvested neighborhoods, with limited access to resources and greenspace, and those struggling with additional health concerns are all at greater risk when it comes to the impacts of extreme heat. Our infrastructure systems (e.g. energy, transportation) are also at risk, which can further compromise a region's capacity to provide essential cooling resources. Heat Watch provides a new level of detail about where heat is most concentrated across cities, improving on coarse satellite-derived descriptions and better describing the human experience of heat.

Accomplishing this high level of detail and spatial coverage is only made possible by the efforts of campaign organizers and local volunteer data collectors, who co-designed a mobile monitoring study with CAPA to measure heat across the diverse land uses and geographical features of your region. Heat-focused partnerships emerged between local stakeholders like residents, municipal staff, health officials, emergency responders, researchers, and non-profit organizations. Throughout the process, teams learned about the Urban Heat Island (UHI) effect in their area and raised awareness of the issue through training, discussions, and media coverage.

Volunteer training in Washington County

Heat Watch is one step in the journey towards adaptation to extreme heat. By bridging innovations in community climate action, sensor technology, and spatial analytics, together we have achieved two main objectives:

1 Developed high resolution descriptions of the distribution of ambient (air) temperature and humidity (heat index) across your region; and

2 Engaged local communities to create partnerships to better understand and address the inequitable risks posed by extreme heat.

The results provide a snapshot in time of how urban heat varies across neighborhoods and how local landscape features affect temperature and humidity. In this report we present the process, mapping outputs, media coverage and photographs from Heat Watch, as well as next steps for how to build on the results.

Executive Summary

The results presented in this report are the traverse point data – the heat measurements collected by participants – and 'area-wide models' which are generated through analysis of the traverse points and their surrounding landscape features. We focus primarily here on temperature to establish a baseline of the results, while relative humidity and heat index results are available separately.

In reviewing the results, please note that while absolute temperatures (e.g. 90.1°F) are provided, we recommend focusing on the distribution of temperatures (e.g. top 20% hottest areas) within each time period. As temperatures rise, the hottest places are likely to remain the hottest. The report also includes an 'Average Model' combining all three time periods as well as a Frequently Asked Questions section with further detail on the data, models and visuals produced.

Morning Area-Wide Predictions (6 - 7 am)

68.8°F
58.8°F

Afternoon Area-Wide Predictions (3 - 4 pm)

92.1°F
77.6°F
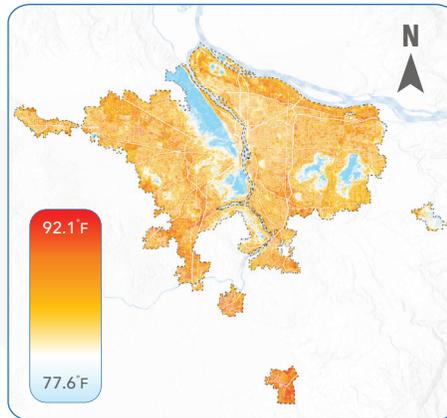
Evening Area-Wide Predictions (7 - 8 pm)

88.3°F
74.6°F

Traverse Points (°F)

6 - 7 am | 3 - 4 pm | 7 - 8 pm

Study Date

July 22nd, 2023

419.6 mi²
Study Area

125
Volunteers
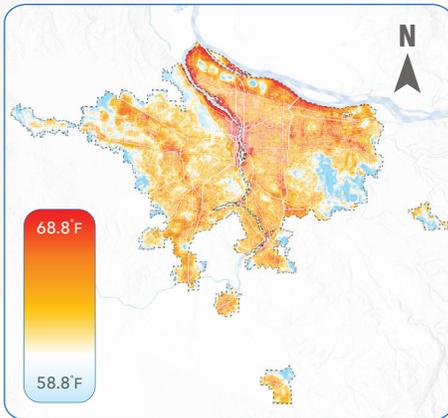
41
Routes

269,622
Measurements

94.6°
Max Temperature

17.2°
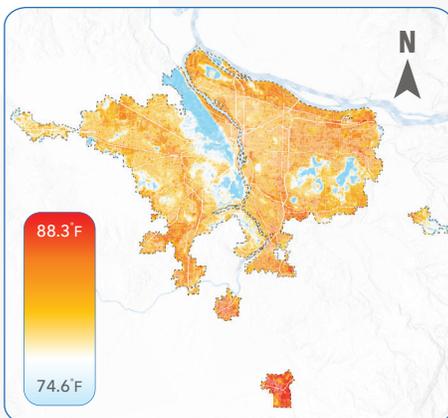Max Temperature Differential
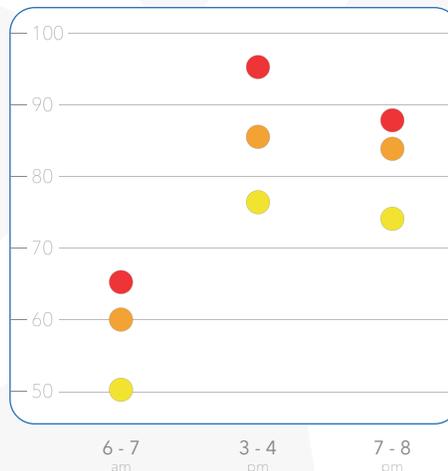
HEAT WATCH

Welcome

Congratulations and thank you to all of the organizers and participants of Heat Watch Portland Metro! After weeks of planning and coordination, local partners successfully completed their heat mapping campaign by collecting thousands of temperature and humidity data points in the morning, afternoon and evening of a long, hot day on July 22nd, 2023. Using this information, CAPA analysts were able to generate highly detailed models of urban heat across the study region and throughout the day.

With this new information, local decision makers will be better equipped to safeguard human life against the growing impacts of extreme heat. Heat Watch serves as an essential part of a broader 'heat planning' framework that provides a comprehensive approach for adaptation to heat. When situated with local contextual information that describes social, physical and economic conditions, Heat Watch data can help to identify people and places at highest risk to extreme heat and drive appropriate intervention strategies and policies.
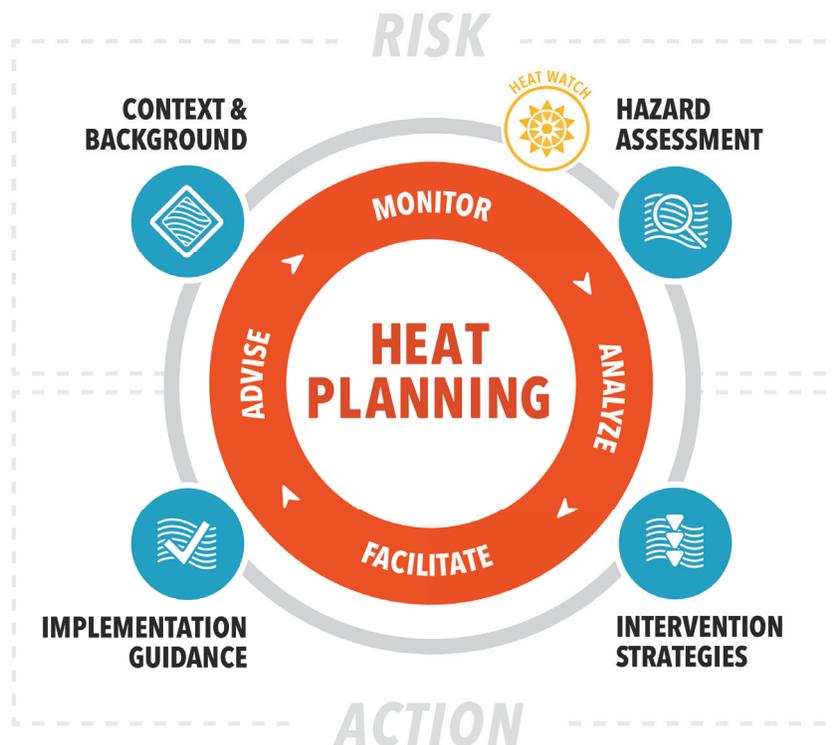
CAPA Strategies is a team of analysts, planners and social scientists who recognize the need for holistic, data-driven, and equity-focused approaches to climate action. Heat Watch is one tool in a systematic process for identifying risks and advancing actions for local adaptation to our warming planet. Through collaborative and community-based approaches such as this, we envision a more connected, informed and climate resilient region.

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] 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
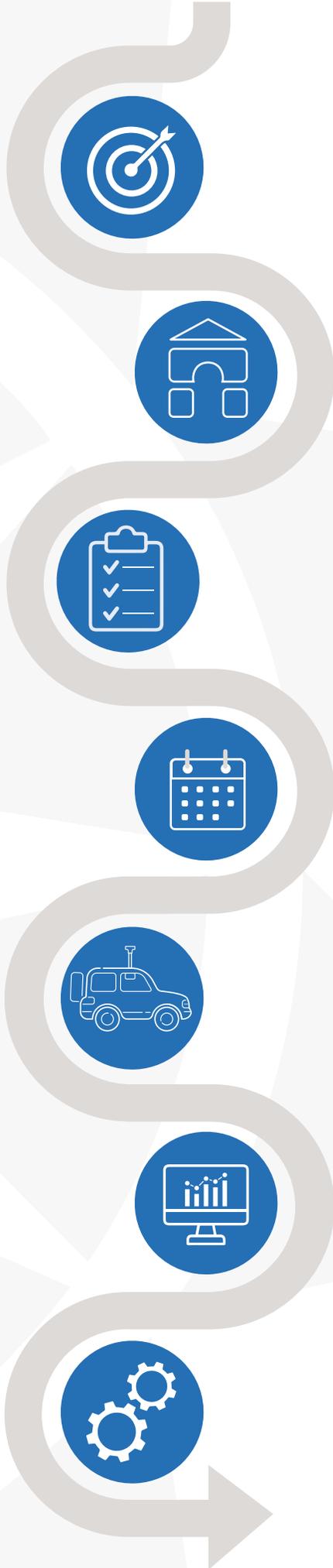
1. Goal Setting

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

2. Engagement

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. Training

Volunteers attend a 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. Activation

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. Execution

Volunteer teams conduct the heat campaign by driving 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. Analysis

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. Implementation

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.

About The Maps

The following sections present results from the campaign: traverse point measurements and area-wide models at morning, afternoon and evening. Below are several key details to keep in mind as you view the results.


Traverse point maps present the near-surface air temperature measurements gathered during the campaign, filtered to usable data for modeling.
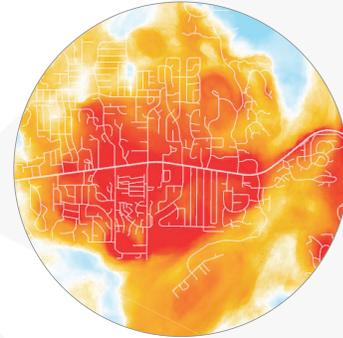
Area-wide maps present high resolution models of temperature across the study area based on the traverse points and Sentinel-2 spectral imagery.

Warmer   Cooler

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

92.3°F
72.1°F

101.6°F
80.5°F
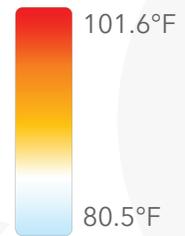
Note that the scales are different between the traverse point and area-wide maps due to the predictive modeling process.

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?

Morning Traverse Points
Temperature (6 - 7 am)

CAPA

HEAT WATCH

65.3°F

50.5°F

N
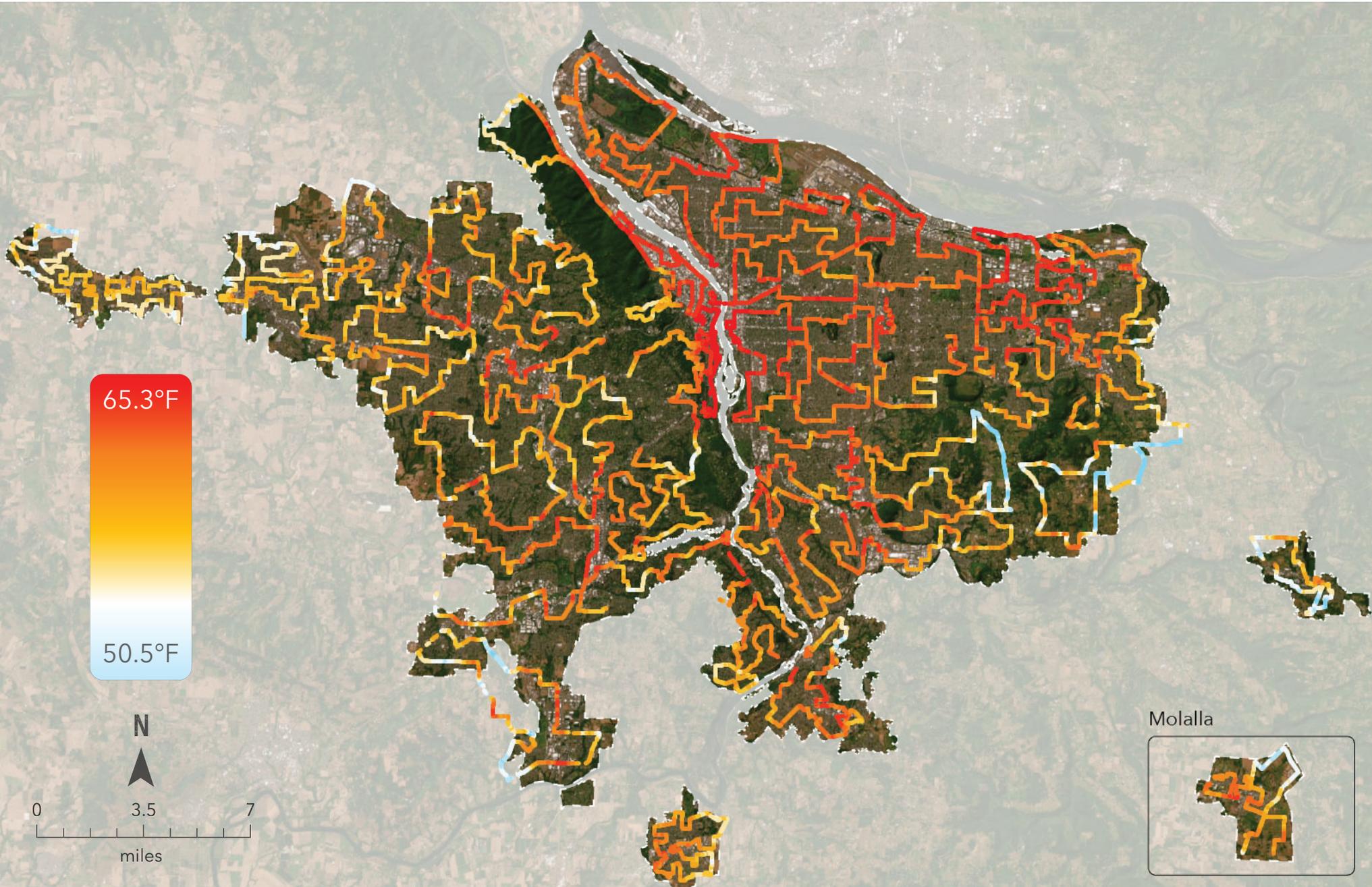
0   3.5   7
miles

Molalla

Morning Area-Wide Model
Temperature (6 - 7 am)

CAPA

HEAT WATCH
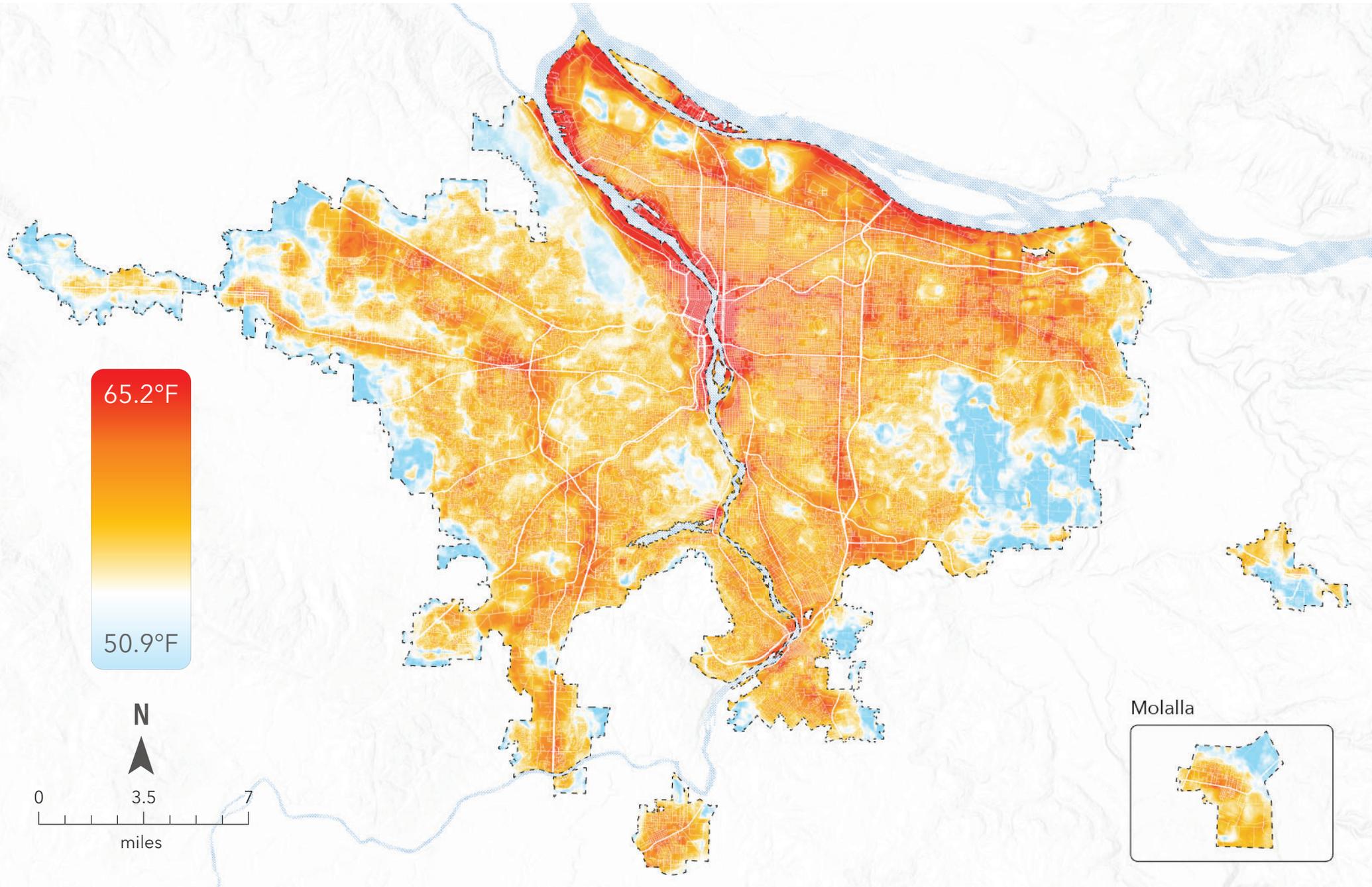
65.2°F

50.9°F

N

0   3.5   7
miles

Molalla

Afternoon Traverse Points
Temperature (3 - 4 pm)

CAPA

HEAT WATCH
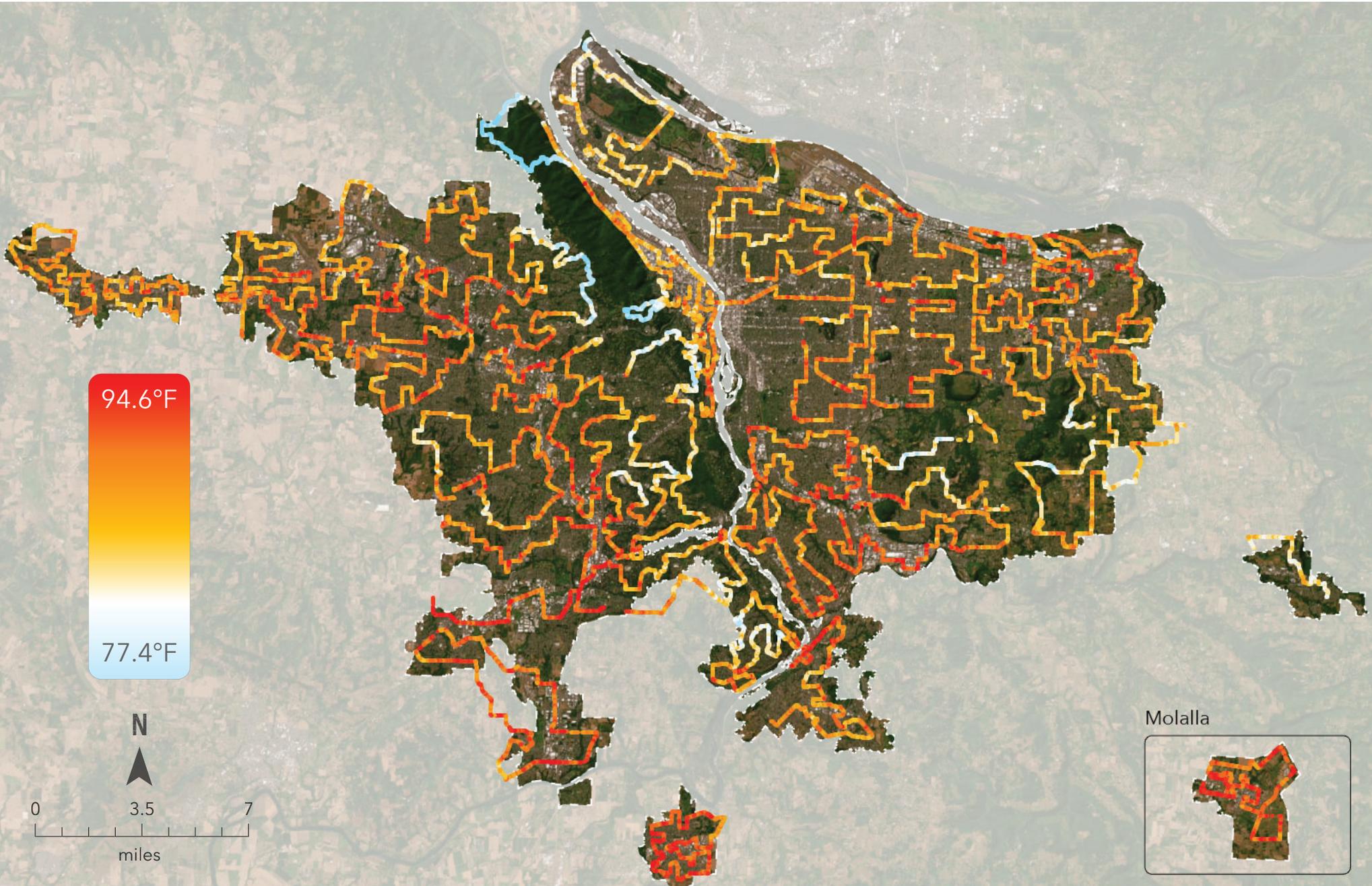
94.6°F

77.4°F

N

0   3.5   7
miles

Molalla

Afternoon Area-Wide Model
Temperature (3 - 4 pm)

CAPA

HEAT WATCH

92.1°F

77.6°F

N
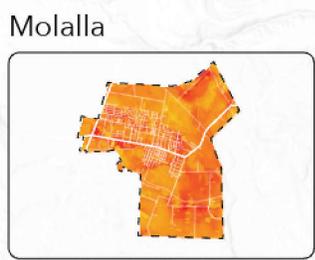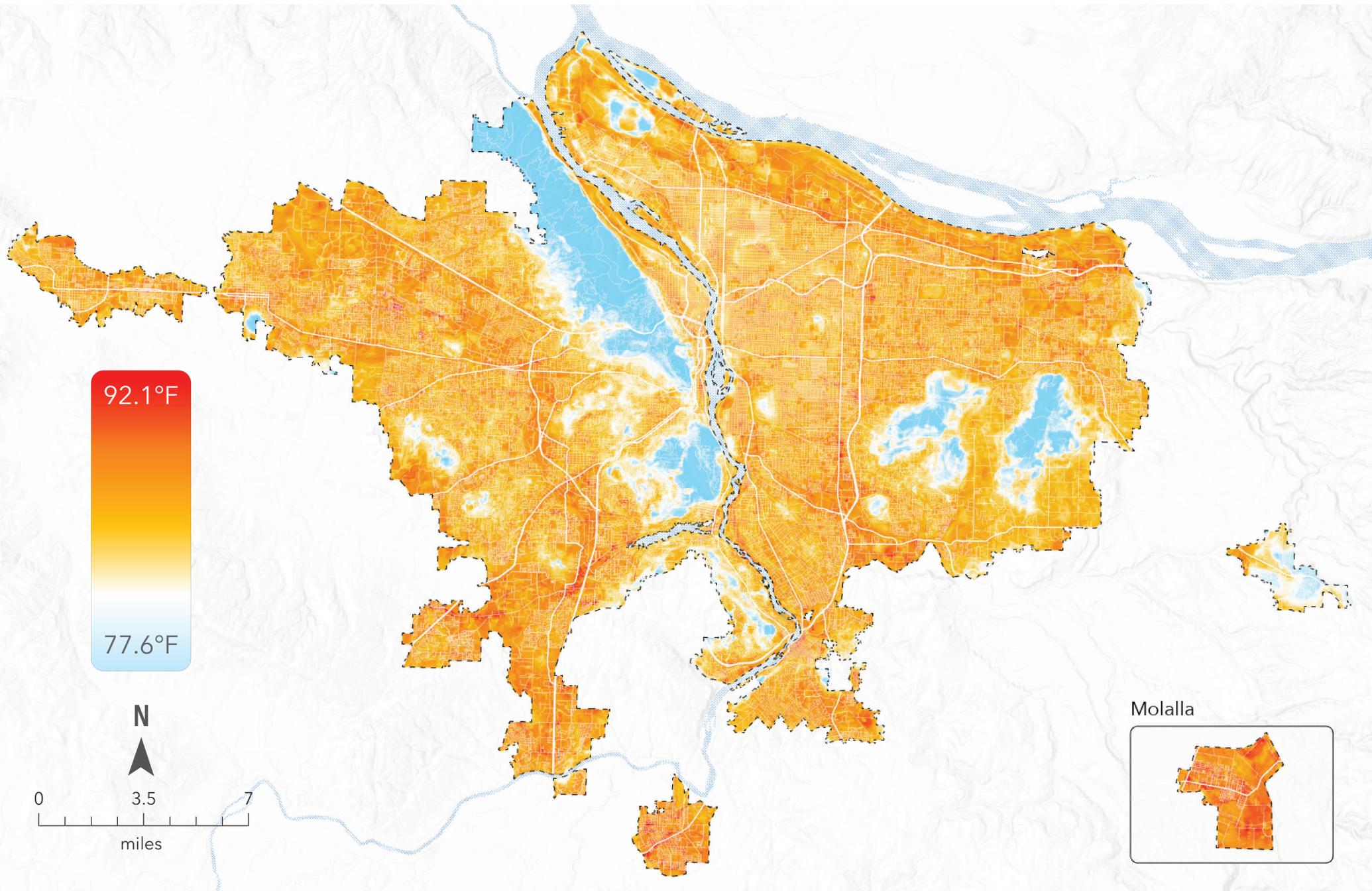
0   3.5   7
miles

Molalla

Evening Traverse Points
Temperature (7 - 8 pm)

CAPA

HEAT WATCH

88.9°F

74.4°F

N

0   3.5   7
miles

Molalla

CAPA

HEAT WATCH
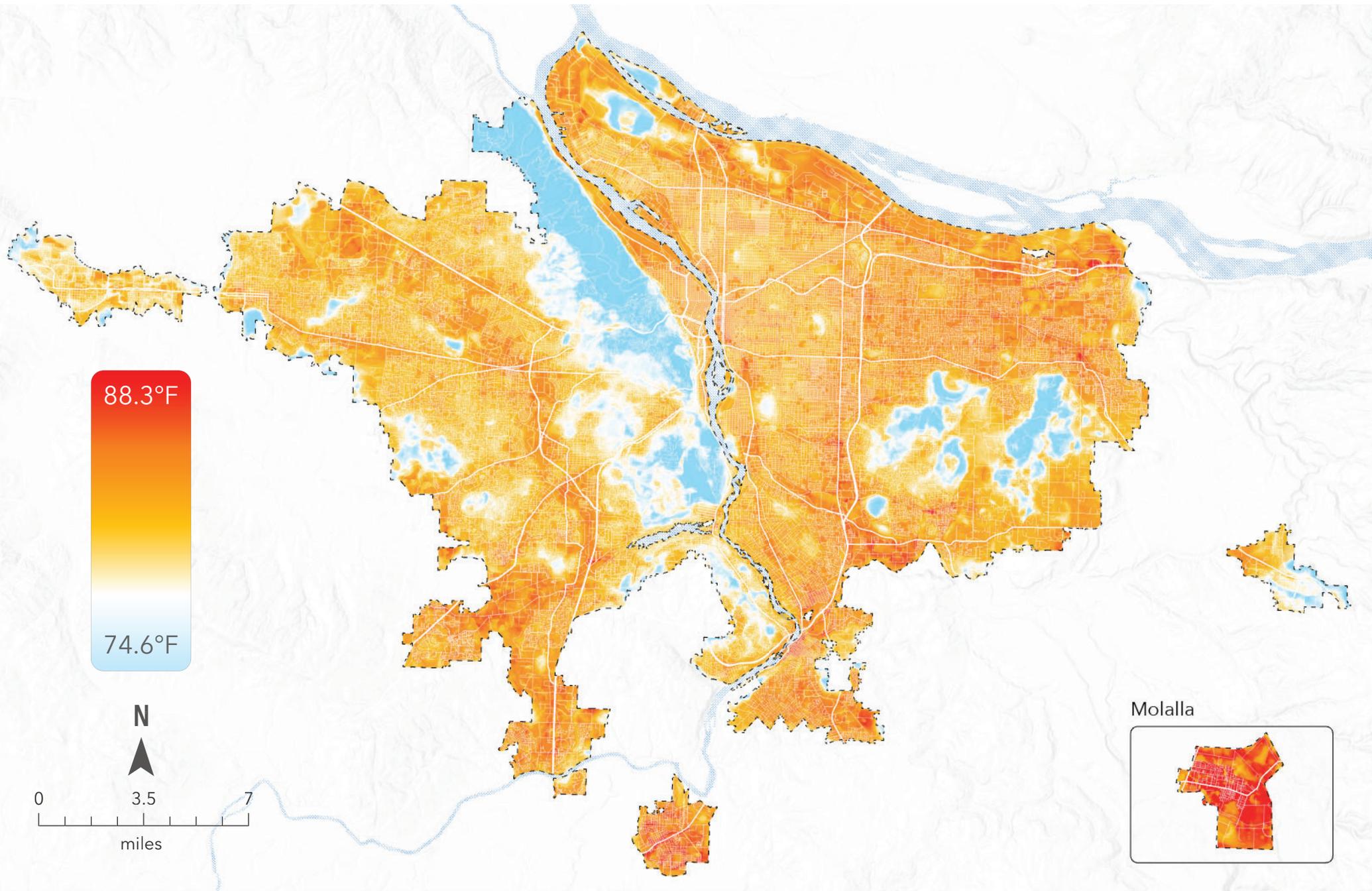
88.3°F

74.6°F

N

0   3.5   7
miles

Molalla

Average Area-Wide Model

The average model is produced by averaging together the morning, afternoon and evening models with equal weight.

CAPA

HEAT WATCH

79.8°F

70.0°F

N

0   3.5   7
miles

Molalla
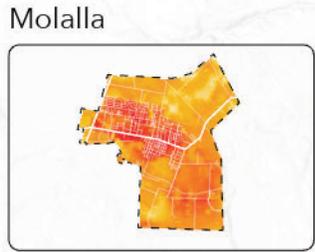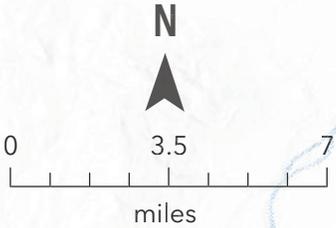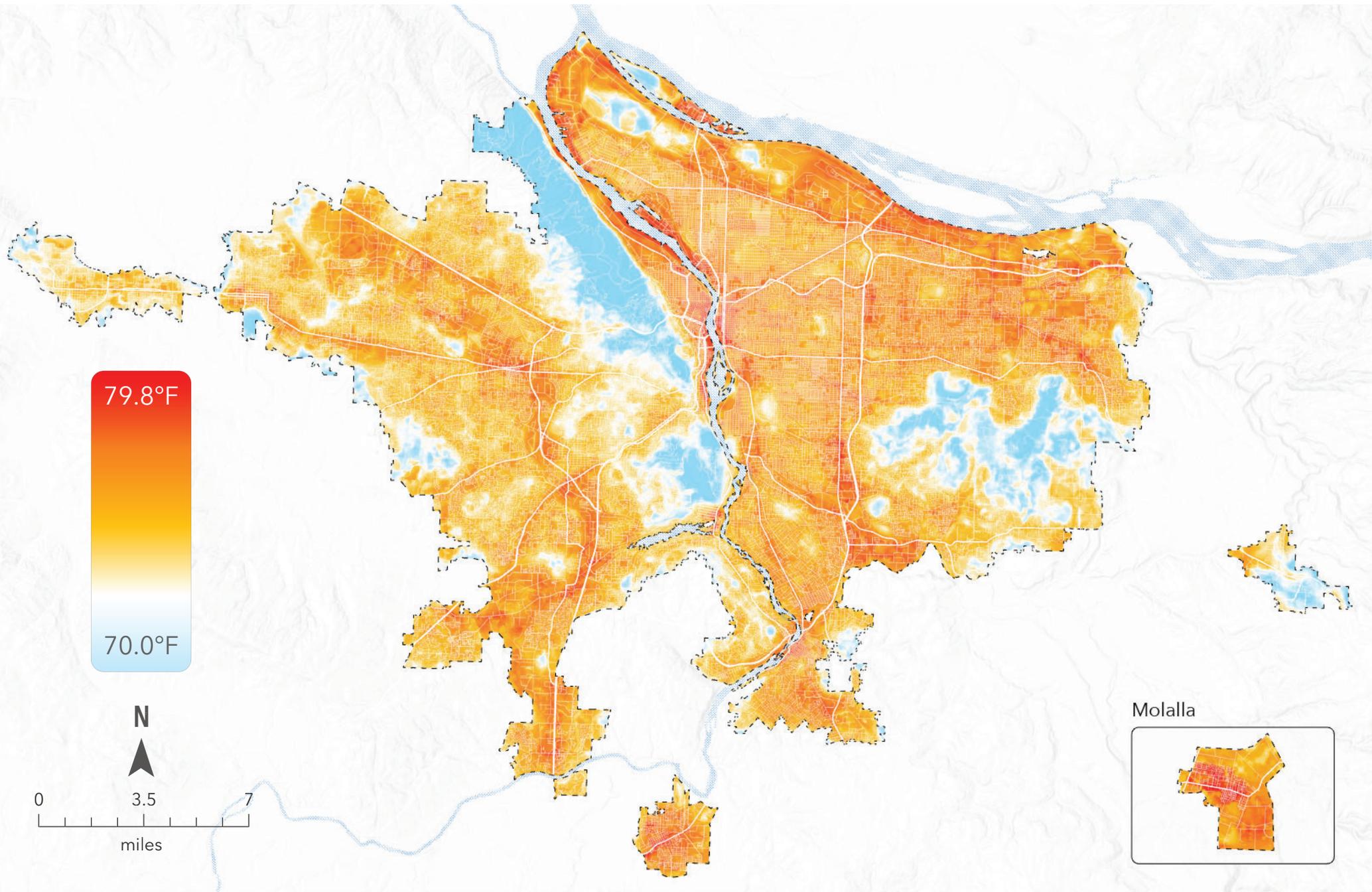
Modeling Method

The three key steps and geospatial processes that allow CAPA analysts to transform traverse point data into area-wide models of temperature.

HEAT WATCH

1 Download & Filter
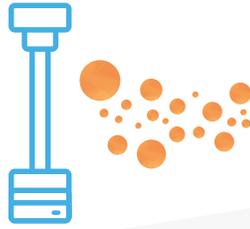
Download raw heat data from sensor SD cards

Compare data with field notes and debrief interview

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

2 Integrate & Analyze
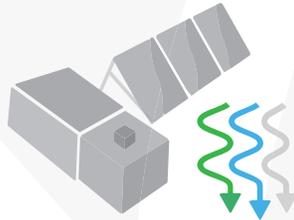
Download multi-band land cover rasters from Sentinel-2 satellite
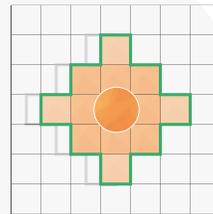
Transform land cover rasters using a moving window analysis
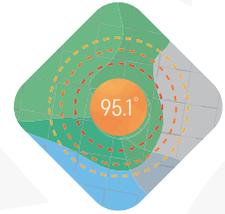
Calculate statistics of each land cover band across multiple radii

95.1°

3 Predict & Validate
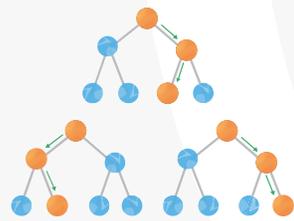
Combine heat and land cover data in Machine Learning model
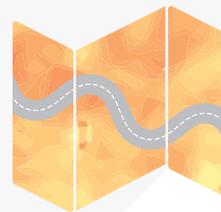
Create predictive raster surface models of each period

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

Technical Notes

Comments on the process, outputs and evaluation of the modeling process.

Accuracy Assessment*	
Model Period	Adjusted R-Squared
6 - 7 am	0.99
3 - 4 pm	0.95
7 - 8 pm	0.99

Accuracy Assessment

To assess the strength of our predictive temperature models, we employ 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.

Field Data

Like all field campaigns, the collection of temperature and humidity data requires adherence to a specific set of protocols and experimental controls. In the event that unreported or undetected error is introduced during the data collection process, the accuracy of the resulting datasets and models may be compromised in quality. While our team has a developed a multi-stage process for quality assurance and quality control (outlier removal), some errors can go unidentified and undetected, and thereby compromise the accuracy of the results. We suggest keeping this nature of field data collection in mind when reviewing the results.

Prediction Areas

The traverse points used to generate the areas wide models do not cover every square mile of the studied area -- rather, we take a sampling approach to gather representative measurements across the diversity of land-use, land-cover, and biophysical attributes of each study area. We suggest keeping this sampling and modeling approach in mind when reviewing the results.

Media

Participant photos and news stories covering the campaign!

KOIN 6

PORTLAND

Heat mapping project underway to better understand effects of rising temps

by: Kelly Doyle
Posted: Jul 22, 2023 / 09:00 AM PDT
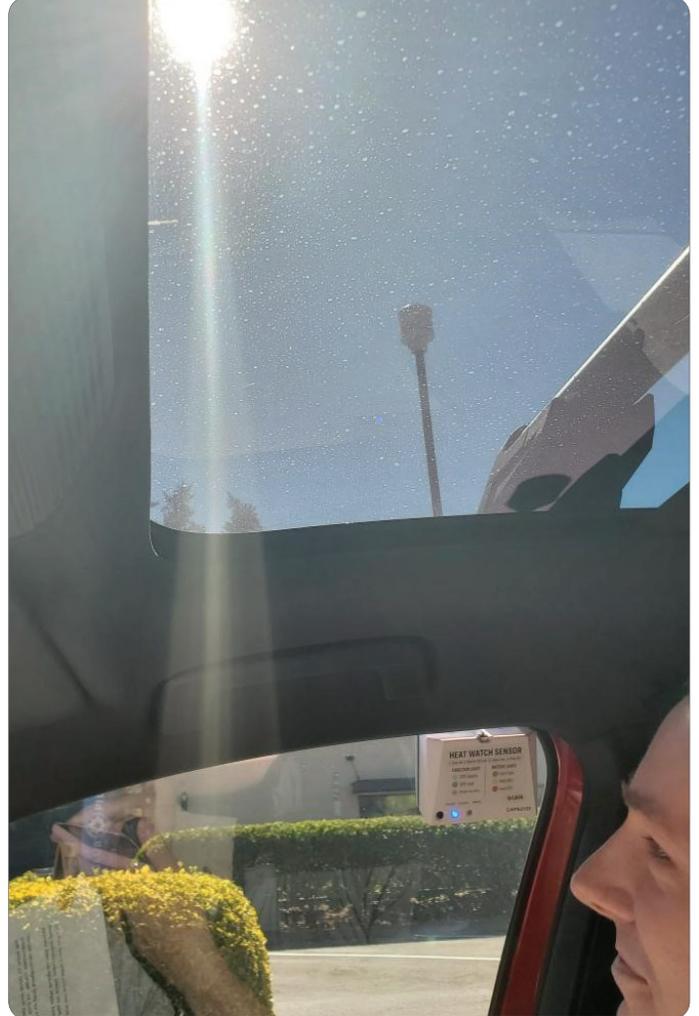Updated: Jul 21, 2023 / 04:37 PM PDT

ENVIRONMENT

Heat mapping campaign to identify neighborhoods most vulnerable to extreme heat

Updated: Jul. 27, 2023, 7:43 a.m. | Published: Jul. 24, 2023, 6:00 a.m.

Media

Participant photos and news stories covering the campaign!

West Linn, Oregon

Team Route 22

Heat Watch data provides new and valuable descriptions of how heat is distributed across your city or region. With these new datasets in-hand, there are several short- and long-term next steps you can follow to build upon this work. We first suggest validating the information with local stakeholders, generating interpretations and meanings through further analysis (see the Additional Analysis section), and/or employing the data across a myriad of applications for heat mitigation and heat preparedness. Consider how different communities and sectors are affected by these results. The collaboration between partners and volunteers who planned and conducted the campaign may also serve as a strong network for future efforts on heat.

Using GIS software you may investigate relationships between heat and the built environment using land use, canopy cover and impervious surface data; assess social vulnerability factors like age and income; and calculate impacts in specific sectors such as energy and public housing. The data may guide you in identifying priority areas for tree planting, planning resilience hubs in high-need areas, or understanding how much heat is present along transportation routes to schools. Such questions and many others can all be better addressed using the high resolution ambient descriptions provided by Heat Watch data.

These new datasets may also prompt and support further research needs into the intersection of heat with overlapping natural hazards like air quality as well as the indoor experience of residents during heat waves, and future projections of heat based on models of emissions levels and climate change. We know that increased temperatures will also lead to increased energy use and grid vulnerability. In fact, nearly all sectors of urban life are likely to be affected by rising temperatures and at inequitable rates of impact to our cities' populations.

Heat Action Plan

A significant longer-term application of Heat Watch results is building out a comprehensive and systematic approach to address the many physical, social and economic threats of extreme heat facing your communities. Developing a "Heat Action Plan" is essential for situating heat data within current conditions and stakeholder interests, defining local risk to extreme heat, and assembling actionable and place-based intervention strategies.

CAPA

HEAT WATCH

As plans can be complex documents requiring technical subject expertise, CAPA aims to support cities with an accessible Heat Action Plan product. This plan builds on Heat Watch data, synthesizes existing local plans, policies, and climate projections, collects social data from local communities, sets priorities, and offers recommendations for heat action at citywide and neighborhood levels. We capture baseline information about exposure, context, and potential risk, while revealing directions for deeper research, analysis, and strategy development. As a comprehensive document, CAPA's Heat Action Plan may serve as the central point of guidance and evaluation of progress towards local resilience to heat.

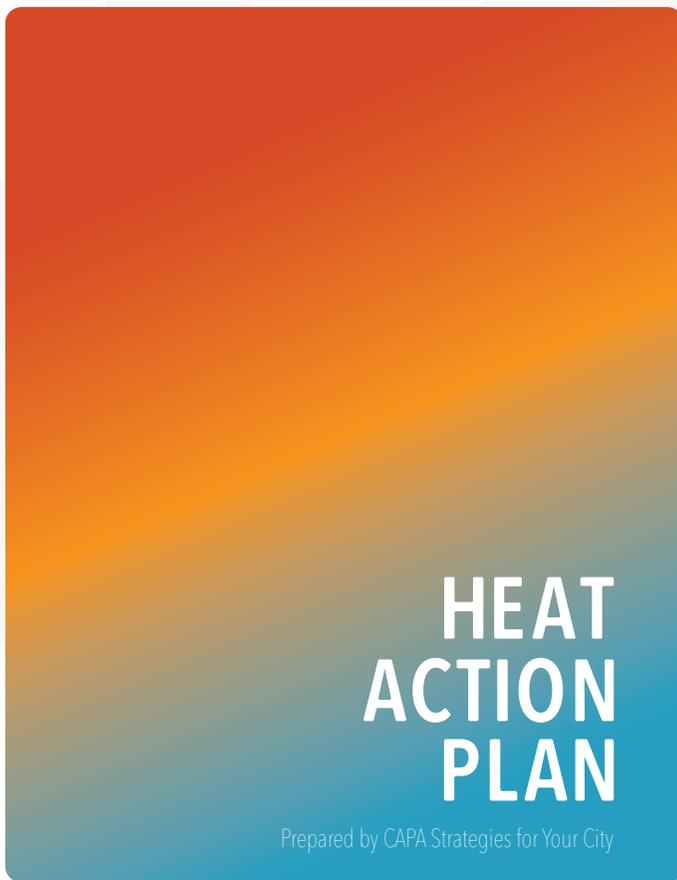## HEAT ACTION PLAN

Prepared by CAPA Strategies for Your City

TABLE OF CONTENTS

We are thrilled to be a part of your path towards heat resilience and look forward to continuing to build a better prepared and more climate-responsive world together!

Frequently Asked Questions (FAQ)

A. Data and Access

A1. How can I access the data from Heat Watch?

All Heat Watch data (traverses, models and metadata) are available on the Open Science Framework (OSF). When first delivered to campaign leaders, the OSF page is provided as a view-only link; once the results are approved by the local team, CAPA will update the OSF page to be publicly accessible. All Heat Watch data, this summary report, and metadata will then be available for download and use by the public.

A2. In what format are the data provided?

The traverse point data from each time period (morning, afternoon and evening) are provided as vector shapefiles.The models from each time period are provided as geo-tiff rasters at 10-meter resolution. In order to view and manipulate these data, GIS software is needed.

A3. What is the accuracy of the traverse point temperature measurements?

The Heat Watch sensor includes a temperature probe that is accurate to ±0.5°C. The response time (the amount of time it takes for the sensor to accurately measure a change in temperature) is 1 second.

B. Relative Humidity and Heat Index

B1. Where are the relative humidity and heat index results, and why are only the temperature results displayed in this report?

The relative humidity measurements and heat index calculations are provided in the traverse shapefiles for each time period; heat index models are provided with the rasters. We focus on temperature data in the report because it is the most plainly understood variable and based more on direct measurements of the environment. Temperature then provides the basis for incorporating relative humidity to calculate heat index.

B2. What is the accuracy of the relative humidity measurements?

The accuracy of the relative humidity sensor is ±3%.

Frequently Asked Questions (FAQ)

B3. What is heat index and how is it calculated?

Heat index is an approximation of the heat felt when the presence of humidity is felt in combination with temperature. We calculate heat index by combining the measured traverse point temperature with its corresponding relative humidity measurement using the same equations as advised by the National Weather Service. Note that there are multiple ways of calculating heat index at various thresholds. To learn more, visit https://www.weather.gov/safety/heat-index.

B4. Where can the relative humidity and heat index data be accessed?

All results are available through OSF, and the relative humidity and heat index data can be viewed and manipulated using GIS software.

C. Maps and Visualization

C1. How can I visualize the data and make maps similar to the report?

You can extract and print any map from this pdf report to use in media and other products. If you wish to visualize the data in similar style (colors, breaks, etc.) using a GIS tool, please see the CAPA Heat Watch Style Guide.

C2. Why do the maps show the temperature range of just that period (e.g. morning minimum temperature to morning maximum temperature), instead of the entire day (i.e. overall minimum to overall maximum)? Wouldn't this allow better visualization of how heat shifts throughout the day?

The temperature range of each time period is used in order to emphasize the distribution of heat within that specific time period. While the data can be visualized differently with the range from the entire day, the differences across the area then become much less apparent in the maps.

C3. Why are the ranges between traverses and models slightly different?

You may notice that for instance the maximum temperature in a traverse point dataset is 94.1°F, whereas the maximum temperature from its corresponding area-wide model is 94.5°F. The reason for this slight discrepancy is inherent to predictive modeling – all models introduce some degree of uncertainty and error. The best-fit model consists of many input variables that may produce a slightly higher or lower prediction of temperatures than measured by the traverses.

HEAT WATCH

Portland Metro
Additional Analysis

Introduction

In this Additional Analysis Report we delve into the intricate relationship between land use, temperature variations, and population dynamics within Clackamas, Multnomah, and Washington Counties, providing a novel view of the challenges and opportunities presented by the extreme heat in the Portland Metro area. Our findings aim to inform policy decisions and strategic planning, contributing to sustainable development and improved quality of life for the region's inhabitants.

In order to align Heat Watch results towards these purposes, we here present the temperature maps across several jurisdictional boundaries, scaled down from the Metro Urban Growth Boundary to individual Counties and Cities. We then analyze the temperature data within these boundaries, identifying patterns of heat with existing land use categories like Residential, Commercial, and Industrial zones, and land cover characteristics including Canopy Cover and Impervious Surfaces. Finally, we assess the proportions of the Portland Metro region's population that experience various levels of air temperature.

Accompanying this report are corresponding datasets summarizing the Heat Watch temperature data across these municipal scales as well as by Census geography, including Block, Block Group, and Tract. Our intention is to make the results accessible and compatible with existing plans, policies and tools used by local decision makers and researchers.

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Multnomah County
Morning Area-Wide Models
Temperature (6 - 7 am)

CAPA

HEAT WATCH

N

0   2.5   5

miles

65.2°F

52.3°F

Multnomah County
Afternoon Area-Wide Models
Temperature (3 - 4 pm)

CAPA

HEAT WATCH

N

0 — 2.5 — 5
miles

91.7°F

77.6°F

88.1°F

74.6°F

N

0   2.5   5
miles

Multnomah County
Average Area-Wide Models

The average model is produced by averaging together the morning, afternoon and evening models with equal weight.

CAPA

HEAT WATCH

N

0   2.5   5
miles

79.5°F

70.0°F

Multnomah County Land Use Summary

Land use classifications and policies can affect many physical characteristics of the built and natural environment that influence temperatures on a hot day. For instance, industrially zoned areas may be exempt from tree canopy requirements; alternatively, multi-family residential areas could require a heat-conscious building layout and vegetation requirements to facilitate the movement of cool air.

In this analysis, we examine the existing relationship between major land use classifications and heat using afternoon air temperature data from the Heat Watch campaign. We summarize and compare the temperature statistics of each land use category to the overall average temperature (86.2°F) and also visualize the distribution of heat across adjacent land uses.

Land Use Code (Metro)

- RUR
- POS
- FUD
- SFR
- COM
- MFR
- MUR
- IND

Temperature Difference from Mean by Land Use Class

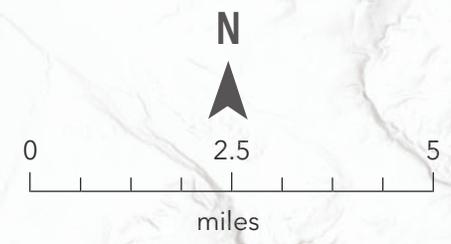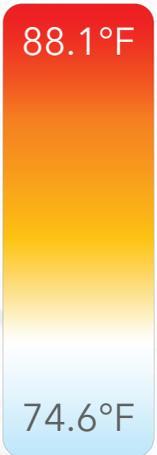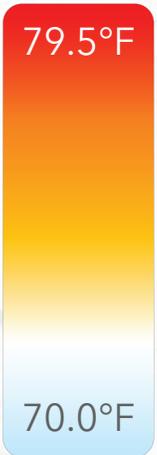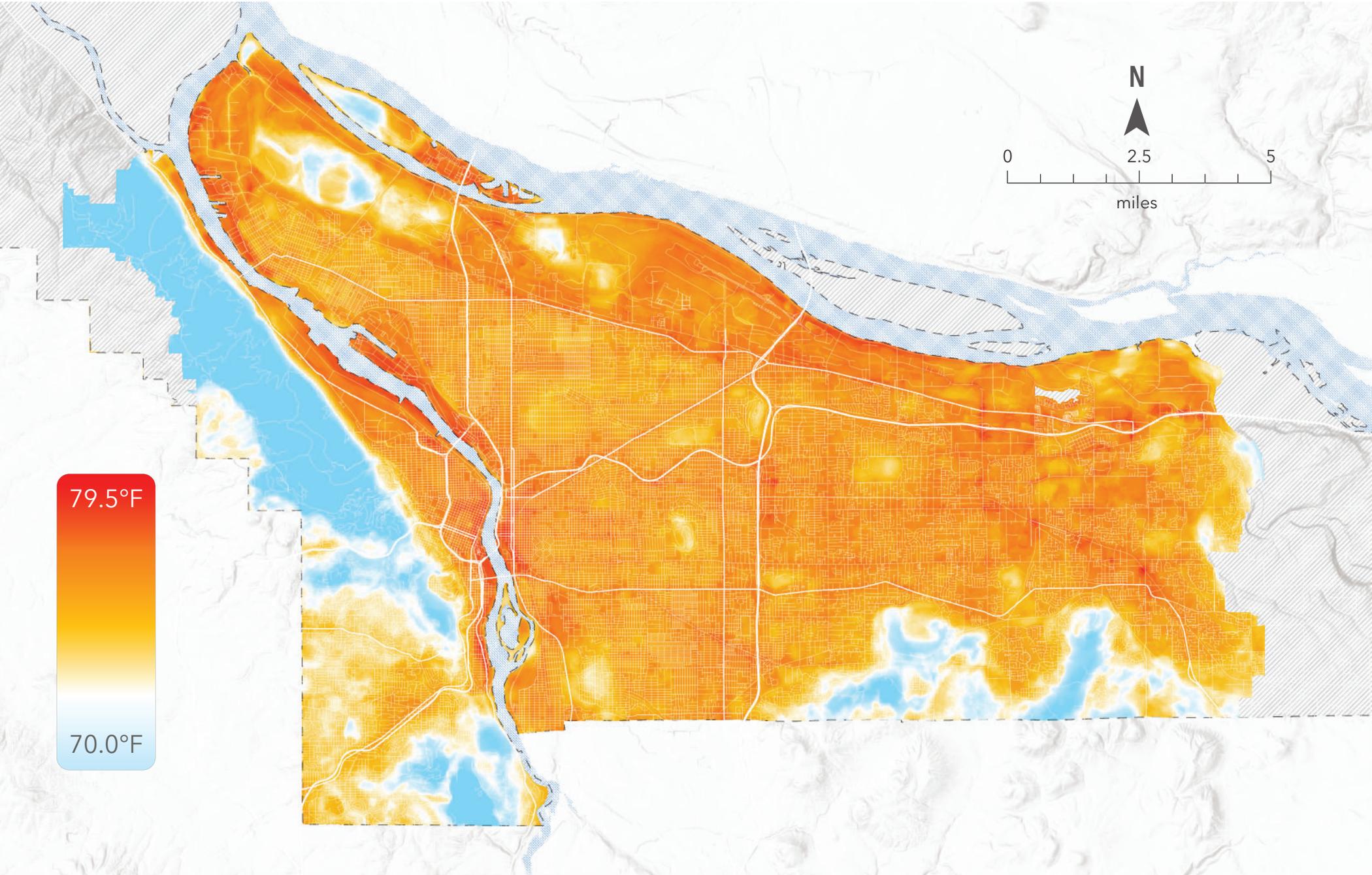| Land Use Code	Land Use Description	Percent of Study Area	Difference from Mean (°F)
RUR	Rural	4.9	-2.4
POS	Parks and Open Space	15.6	-0.2
FUD	Future Urban Development	0.1	-0.1
SFR	Single Family Residential	43.2	0.0
COM	Commercial	0.6	0.5
MFR	Multi-Family Residential	7.6	0.6
MUR	Mixed-Use Residential	9.1	0.7
IND	Industrial	18.9	0.7

As shown in the graph above, differences by land use align with typical expectations of heat, with Rural areas exhibiting the coolest afternoon temperatures, followed by Future Urban Development and Parks and Open Space as cooler than the average temperature across the map. Comprising 43.2% of the overall area, Single Family Residential naturally measures very near to the overall mean, while Commercial, Multi-Family Residential and Mixed-Use Residential all measure hotter than the area average. The hottest land use across the area, comprising 18.9% of the study area, is Industrial.

Multnomah County Land Cover Summary

We also examined patterns of heat by land cover, a spatial variable describing the presence of vegetation and human-made developments on the land's surface. In regards to heat, areas with greater amounts of tree canopy may benefit from the cooling effects of evapotranspiration and shade, while areas with greater amounts of impervious surfaces may witness the heat-concentrating effect of dense building materials and low-albedo (non-reflective) surfaces. In this analysis, we track trends in land cover, heat and population density by City.

Characteristics by City in Multnomah County Study Area

County/City	AF Mean	AF Min	AF Max	AF Range	AF StD	% Canopy	% Impervious	Size (sqmi)	Population	Pop density
Multnomah	86.4	82.8	89.7	6.9	0.9	24.7	47.4	179.1	791,000	4,128
Fairview	86.6	84.2	89.0	4.8	0.6	20.5	35.6	3.5	9,500	2,714
Gresham	86.0	80.7	89.8	9.1	1.2	26.4	48.9	23.4	110,000	4,695
Maywood Park	86.7	85.7	88.1	2.4	0.3	32.5	46.4	0.2	1,000	5,882
Portland	85.5	77.6	91.7	14.1	1.9	29.7	48.5	145.0	650,000	4,483
Troutdale	86.2	83.1	89.3	6.2	0.8	21.6	40.5	6.0	16,500	2,741
Wood Village	87.1	85.6	90.4	4.8	0.5	17.6	64.7	0.9	4,000	4,255

Percent Canopy & Afternoon Mean Temperature

Percent Impervious & Afternoon Mean Temperature

Population Density & Afternoon Mean Temperature

Canopy (2019, Metro)

Impervious Surface (2022, GISA)

Afternoon Heat Model (2023, CAPA)
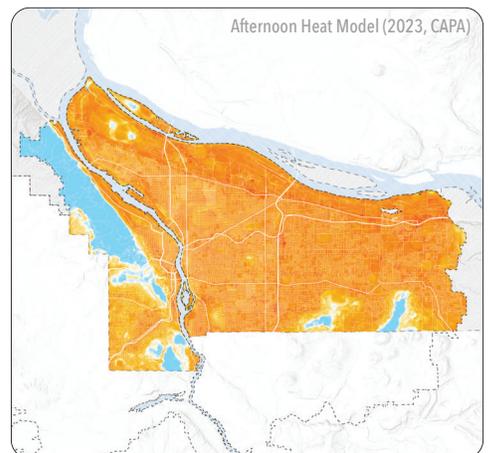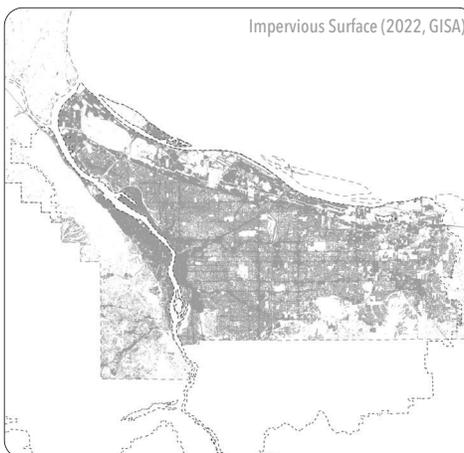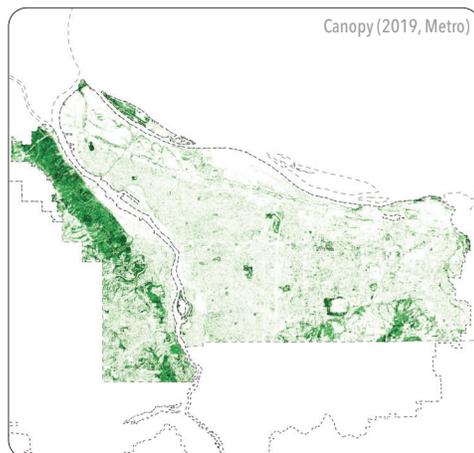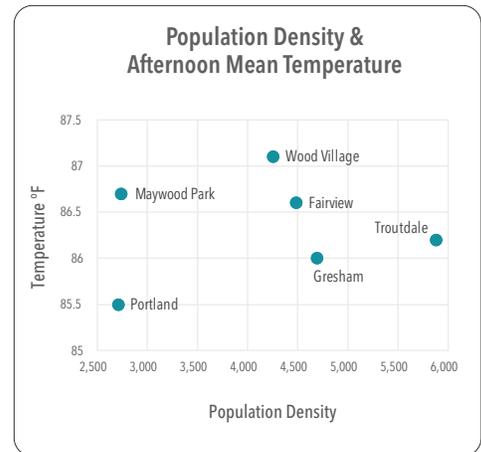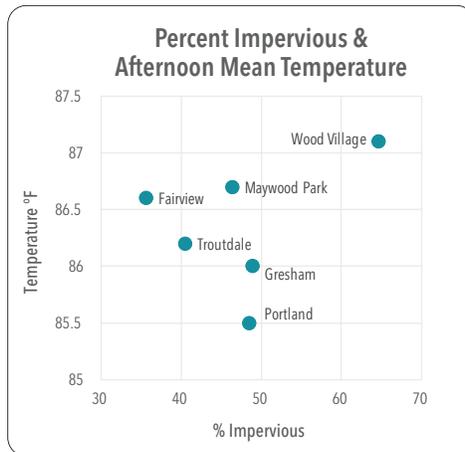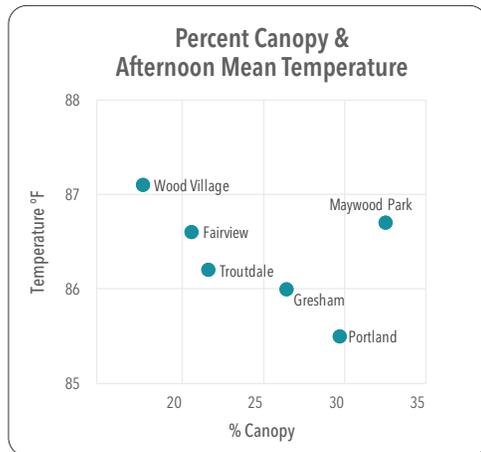
Clackamas County
Morning Area-Wide Models
Temperature (6 - 7 am)

63.7°F

50.9°F

Sandy

Molalla

N

0   2   4

miles
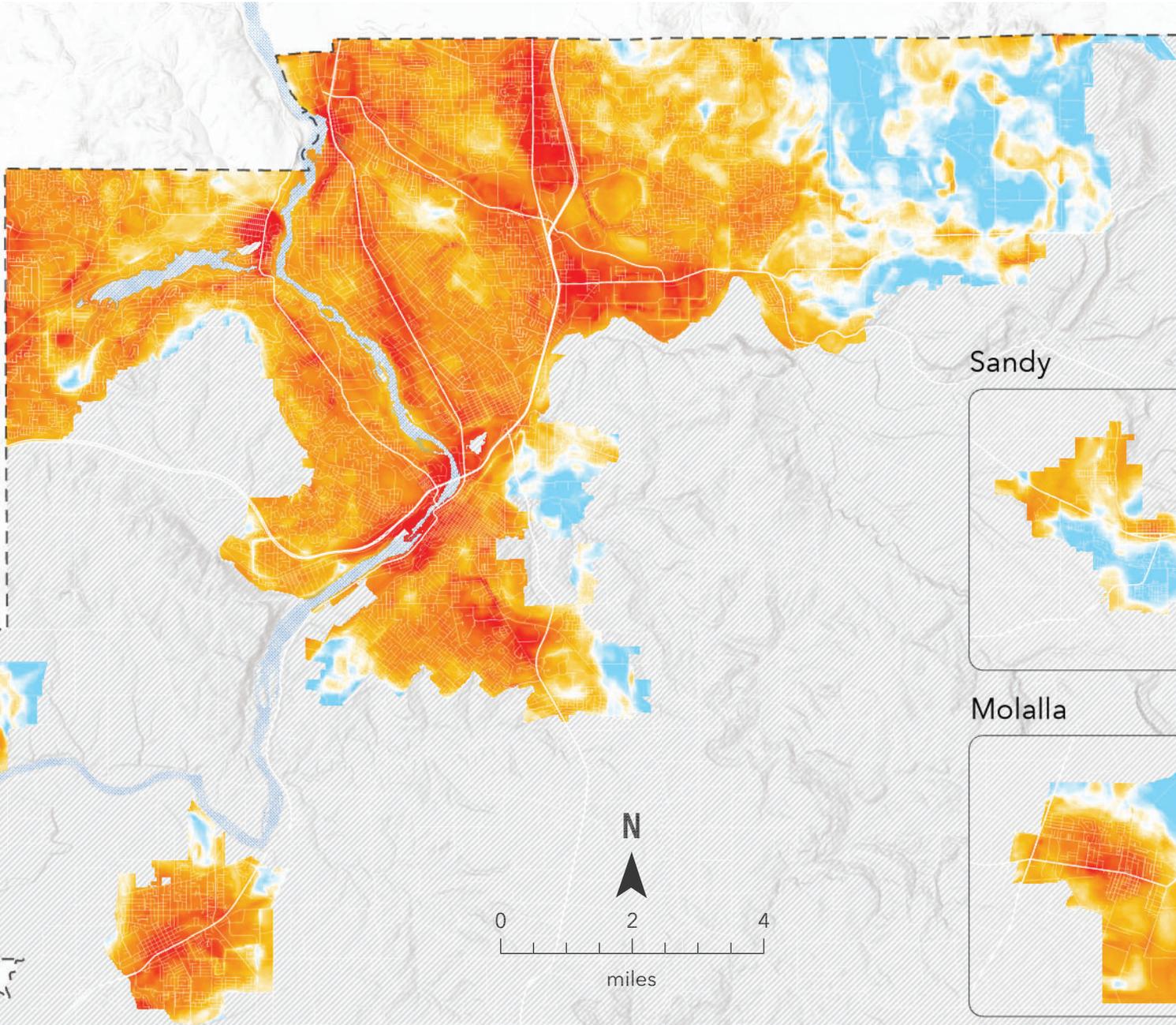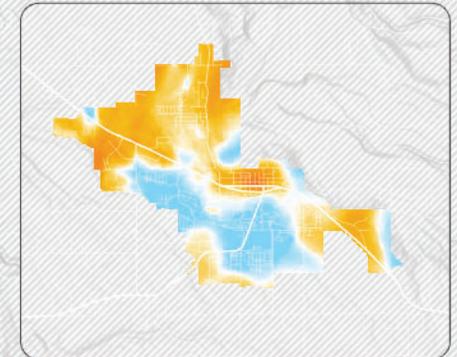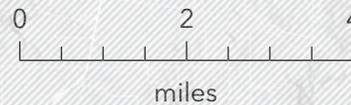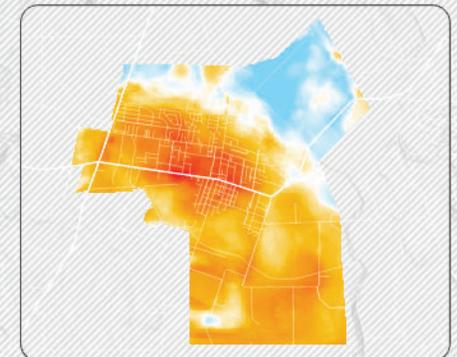
Clackamas County
Afternoon Area-Wide Models
Temperature (3 - 4 pm)
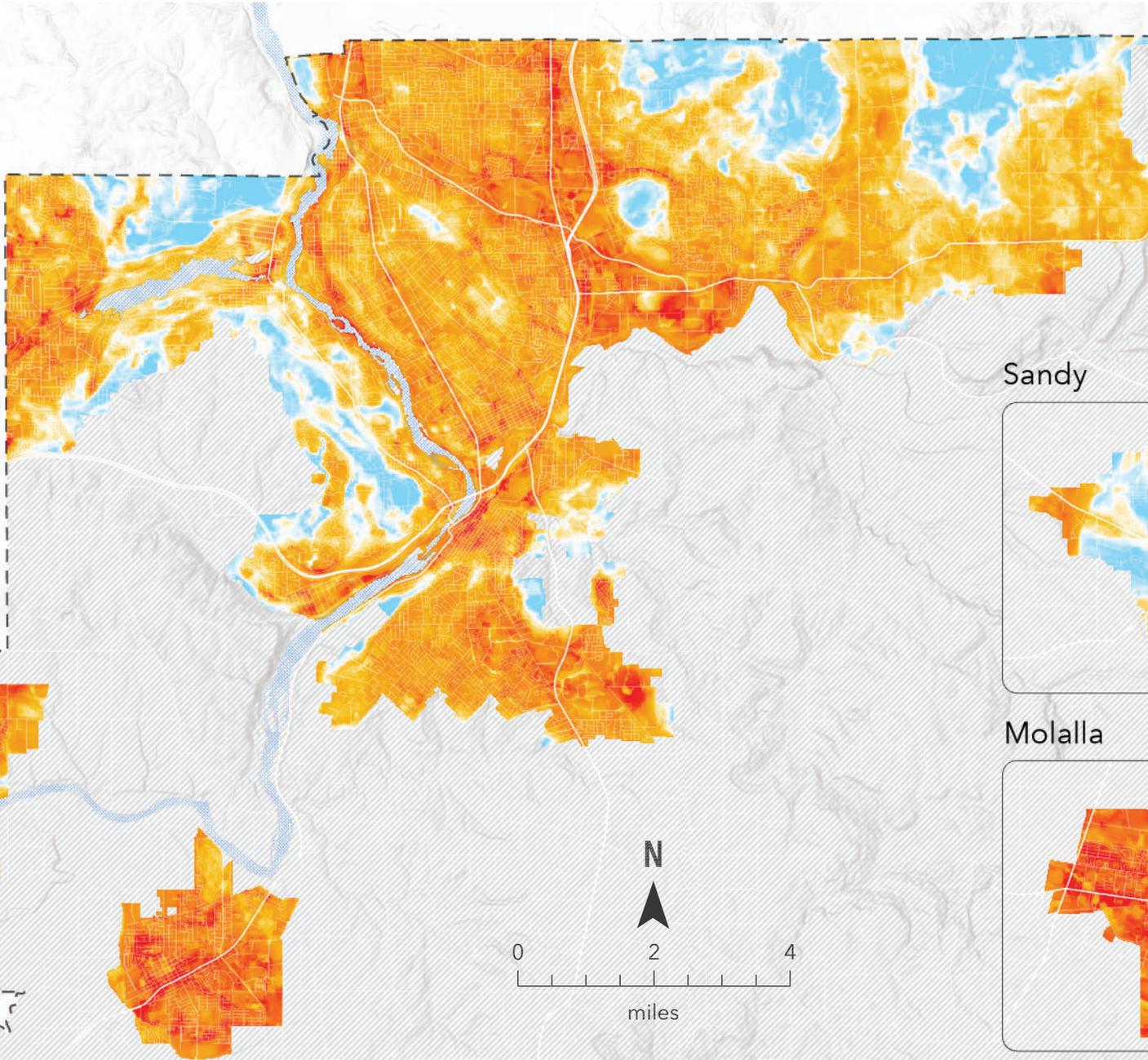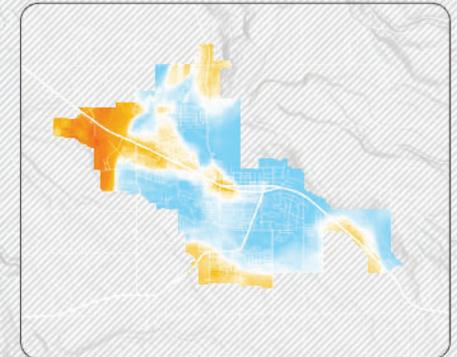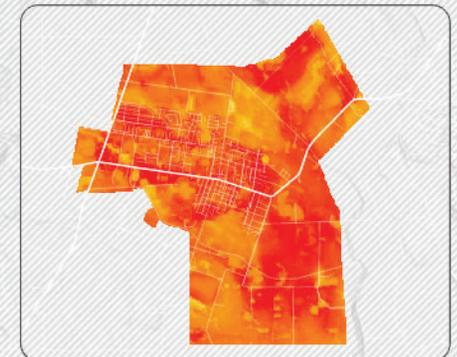
Clackamas County
Evening Area-Wide Models
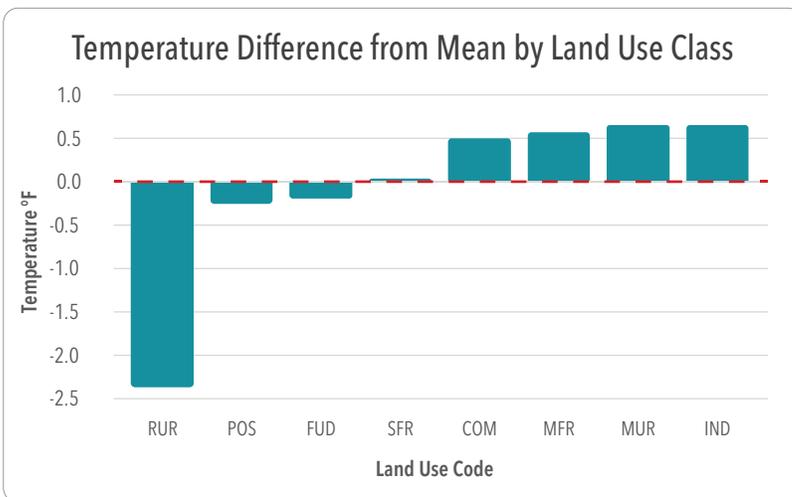Temperature (7 - 8 pm)

CAPA

HEAT WATCH

88.3°F

76.7°F

Sandy

Molalla

N

0   2   4

miles
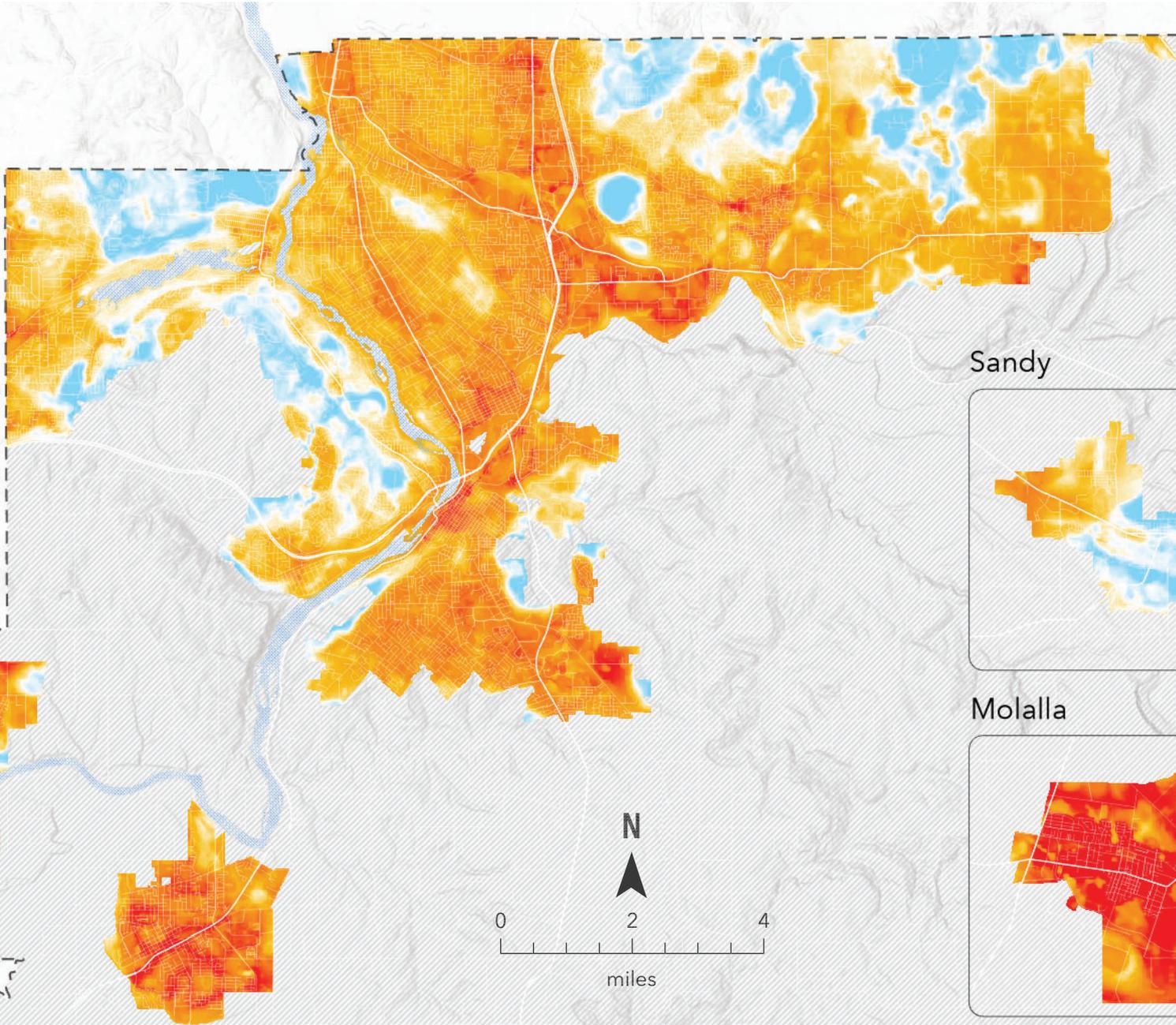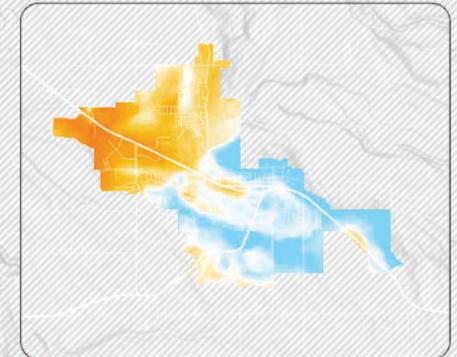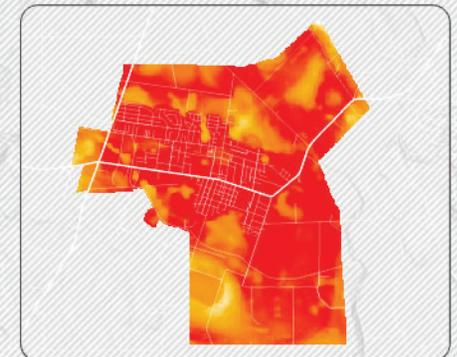
Clackamas County
Average Area-Wide Models

The average model is produced by averaging together the morning, afternoon and evening models with equal weight.

79.8°F

71.8°F

Sandy

Molalla

N

0   2   4
miles

Clackamas County
Land Use Summary

Land use classifications and policies can affect many physical characteristics of the built and natural environment that influence temperatures on a hot day. For instance, industrially zoned areas may be exempt from tree canopy requirements; alternatively, multi-family residential areas could require a heat-conscious building layout and vegetation requirements to facilitate the movement of cool air.

In this analysis, we examine the existing relationship between major land use classifications and heat using afternoon air temperature data from the Heat Watch campaign. We summarize and compare the temperature statistics of each land use category to the overall average temperature (86.1°F) and also visualize the distribution of heat across adjacent land uses.
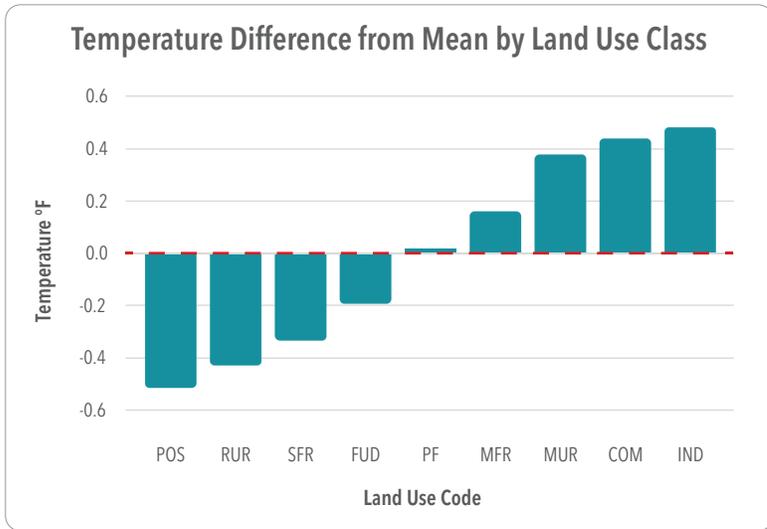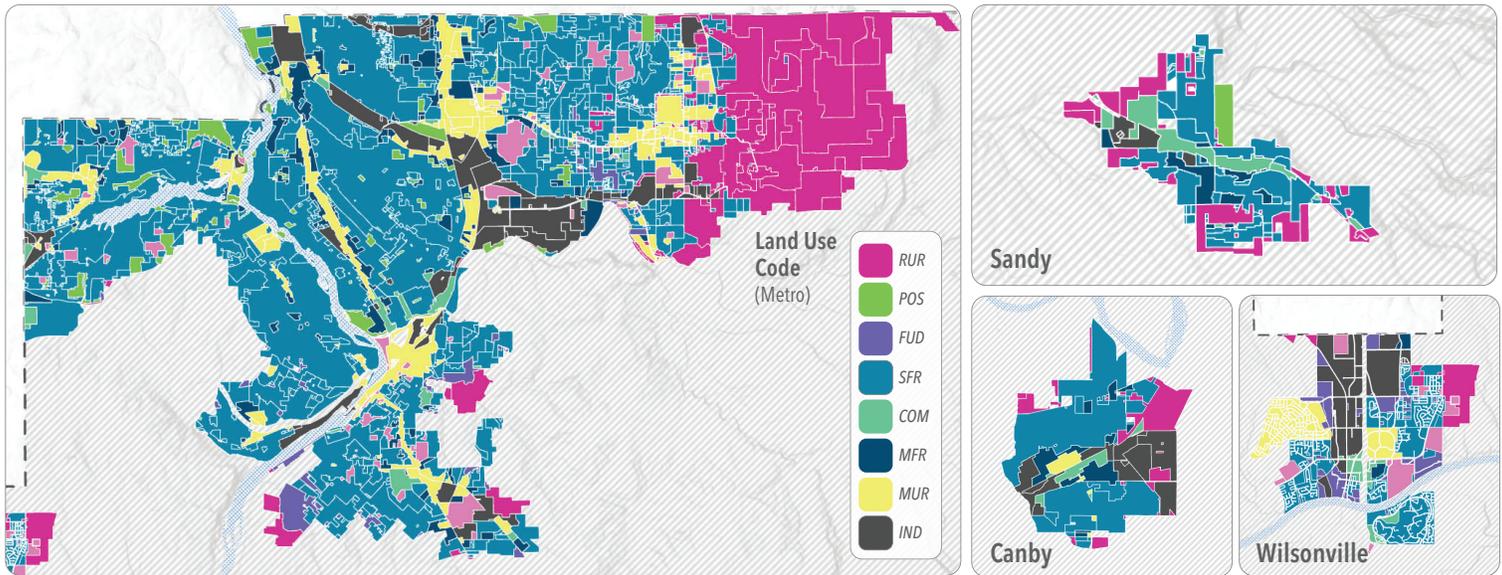
Land Use Code (Metro)

- RUR
- POS
- FUD
- SFR
- COM
- MFR
- MUR
- IND

Sandy

Canby

Wilsonville

Temperature Difference from Mean by Land Use Class

Temperature °F — Land Use Code: POS, RUR, SFR, FUD, PF, MFR, MUR, COM, IND

Land Use Code	Land Use Description	Percent of Study Area	Difference from Mean (°F)
POS	Parks and Open Space	2.4	-0.5
RUR	Rural	20.5	-0.4
SFR	Single Family Residential	50.0	-0.3
FUD	Future Urban Development	1.9	-0.2
PF	Public Facilities	3.1	0.0
MFR	Multi-Family Residential	4.6	0.2
MUR	Mixed-Use Residential	7.0	0.4
COM	Commercial	2.1	0.4
IND	Industrial	8.5	0.5

Aligning with expectations, Parks and Open Space and Rural areas are found to be the coolest of land uses in Clackamas County. Single Family Residential and Future Urban Developments are also cooler than the area average, which may be explained by the lower population density and high amount of vegetation and canopy cover located in these areas. Multi-family Residential and Mixed-Use Residential areas, however, are warmer than the average, as are Commercial and Industrial areas.

Clackamas County Land Cover Summary

We also examined patterns of heat by land cover, a spatial variable describing the presence of vegetation and human-made developments on the land's surface. In regards to heat, areas with greater amounts of tree canopy may benefit from the cooling effects of evapotranspiration and shade, while areas with greater amounts of impervious surfaces may witness the heat-concentrating effect of dense building materials and low-albedo (non-reflective) surfaces. In this analysis, we track trends in land cover, heat and population density by City.

Characteristics by City in Clackamas County Study Area

County/City	AF Mean	AF Min	AF Max	AF Range	AF StD	% Canopy	% Impervious	Size (sqmi)	Population	Pop density
Clackamas	86.2	83.6	89.2	5.6	0.7	28.9	42.6	61.2	224,500	3,587
Canby	87.1	85.5	91.1	5.6	0.6	17.0	50.9	3.8	17,500	4,617
Gladstone	86.5	85.2	88.9	3.7	0.4	24.6	52.1	2.3	12,000	5,172
Happy Valley	85.5	81.8	89.0	7.2	0.9	33.9	22.4	8.3	23,000	2,764
Johnson City	86.7	85.7	87.2	1.5	0.3	11.0	76.9	0.2	600	3,000
Lake Oswego	85.5	80.1	90.1	10.0	1.2	45.0	25.5	11.4	40,000	3,524
Milwaukie	86.6	84.3	89.1	4.8	0.4	24.2	53.4	4.9	21,000	4,330
Molalla	87.5	85.8	90.2	4.4	0.5	26.6	51.3	2.3	9,500	4,204
Oregon City	86.5	82.9	89.6	6.7	0.7	26.2	43.5	9.3	37,000	3,983
Rivergrove	85.9	84.3	87.1	2.8	0.6	41.2	22.7	0.4	400	1,000
Sandy	84.7	82.1	87.4	5.3	0.8	33.6	36.6	3.1	11,500	3,662
West Linn	85.6	81.4	89.3	7.9	1.0	38.7	29.1	7.9	27,000	3,418
Wilsonville	86.7	84.0	91.1	7.1	0.6	24.2	46.2	7.4	25,000	3,369

Percent Canopy & Afternoon Mean Temperature

Percent Impervious & Afternoon Mean Temperature

Population Density & Afternoon Mean Temperature

Canopy (2019, Metro)

Impervious Surface (2022, GISA)

Afternoon Temperature Model (CAPA)

Washington County
Morning Area-Wide Models
Temperature (6 - 7 am)

CAPA

HEAT WATCH
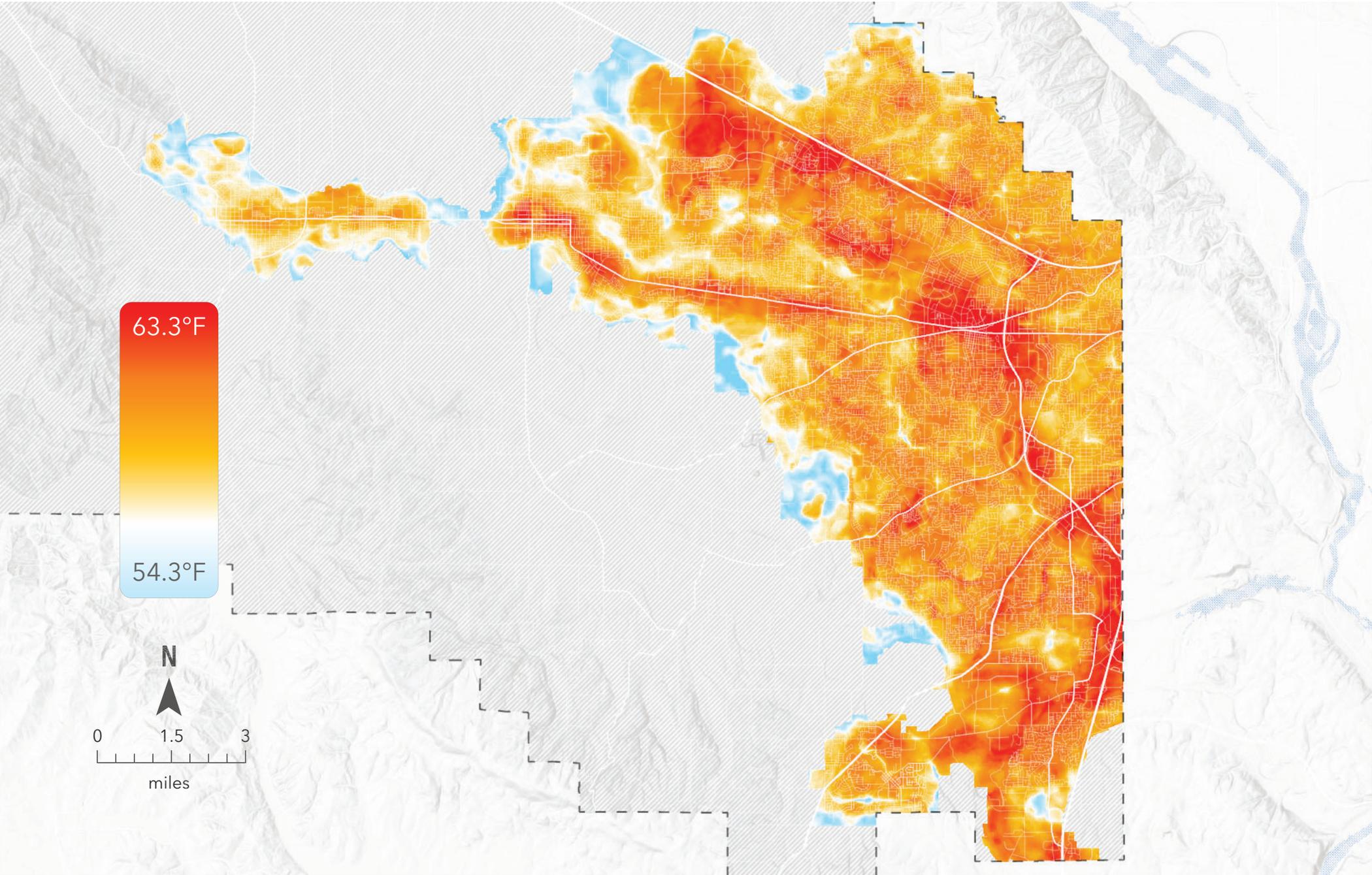
63.3°F

54.3°F

N

0   1.5   3
miles

Washington County
Afternoon Area-Wide Models
Temperature (3 - 4 pm)

CAPA

HEAT WATCH

92.1°F

81.6°F

N
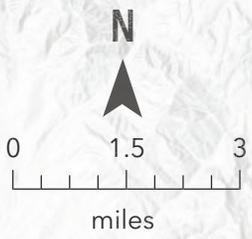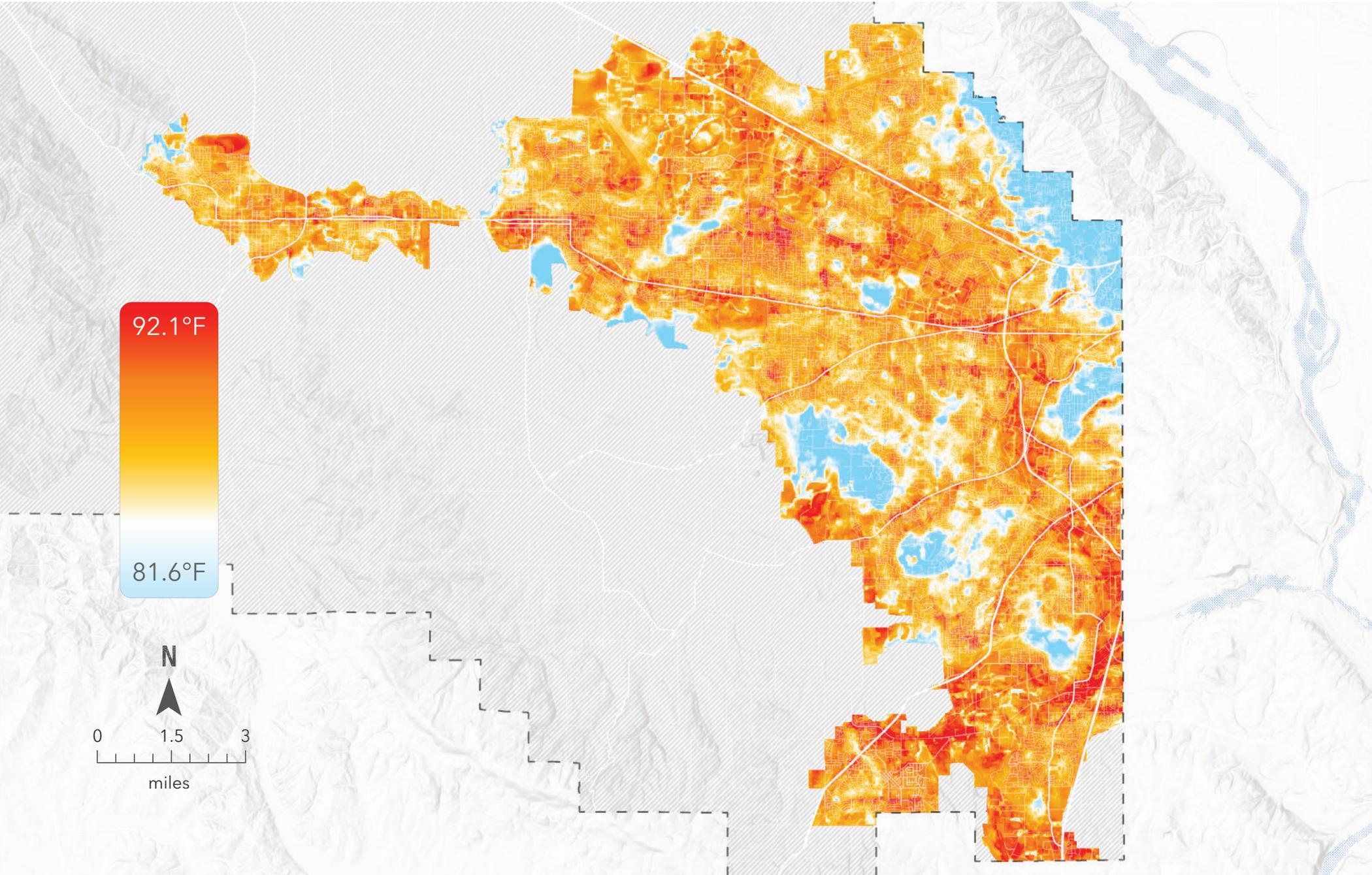
0   1.5   3

miles

Washington County
Evening Area-Wide Models
Temperature (7 - 8 pm)

CAPA

HEAT WATCH
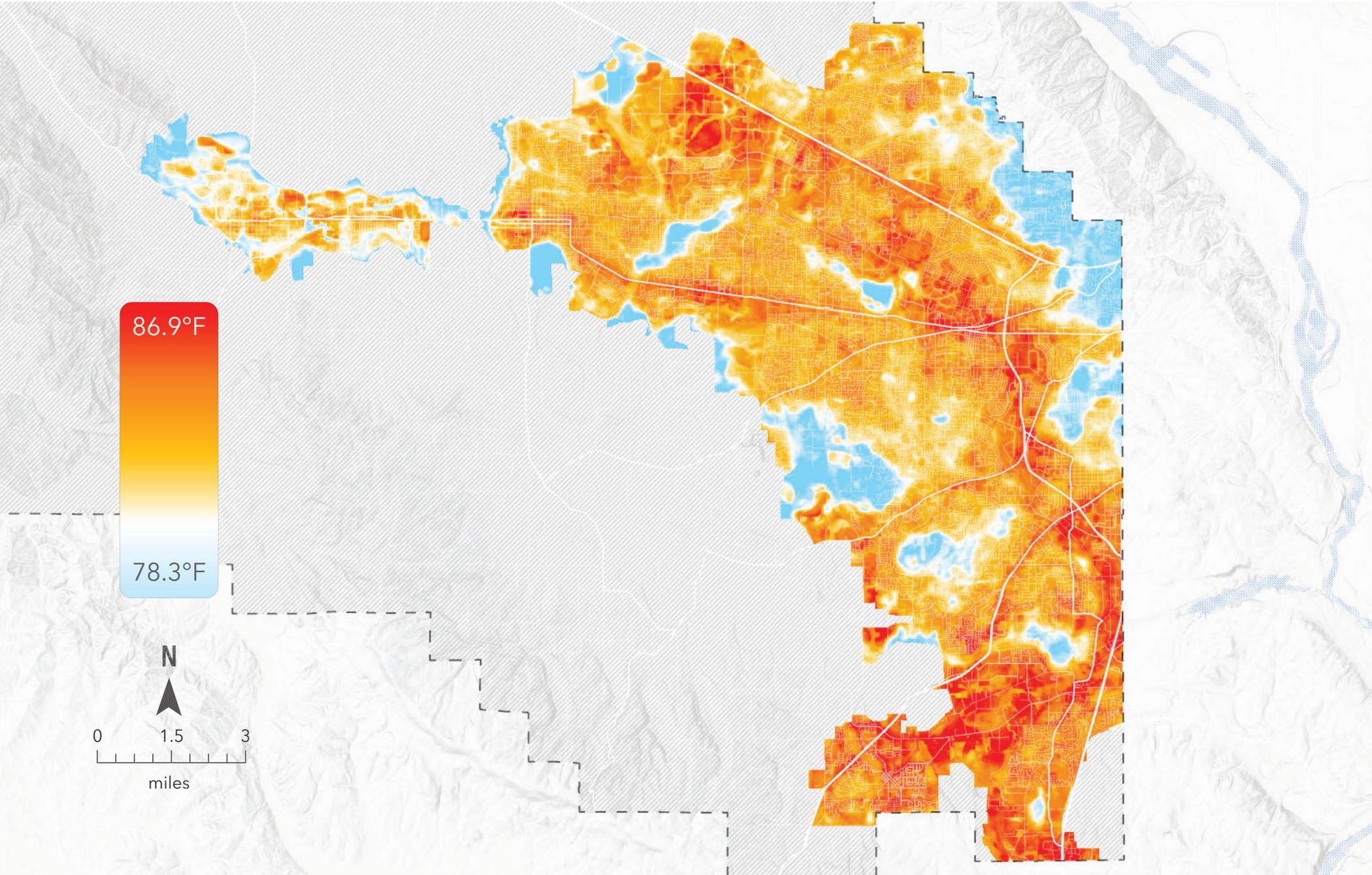
86.9°F

78.3°F

N

0   1.5   3

miles

Washington County
Average Area-Wide Models

The average model is produced by averaging together the morning, afternoon and evening models with equal weight.

CAPA

HEAT WATCH

79.4°F

72.6°F

N

0   1.5   3

miles

CAPA

HEAT WATCH

Land use classifications and policies can affect many physical characteristics of the built and natural environment that influence temperatures on a hot day. For instance, industrially zoned areas may be exempt from tree canopy requirements; alternatively, multi-family residential areas could require a heat-conscious building layout and vegetation requirements to facilitate the movement of cool air.

In this analysis, we examine the existing relationship between major land use classifications and heat using afternoon air temperature data from the Heat Watch campaign. We summarize and compare the temperature statistics of each land use category to the overall average temperature (86.4°F) and also visualize the distribution of heat across adjacent land uses.
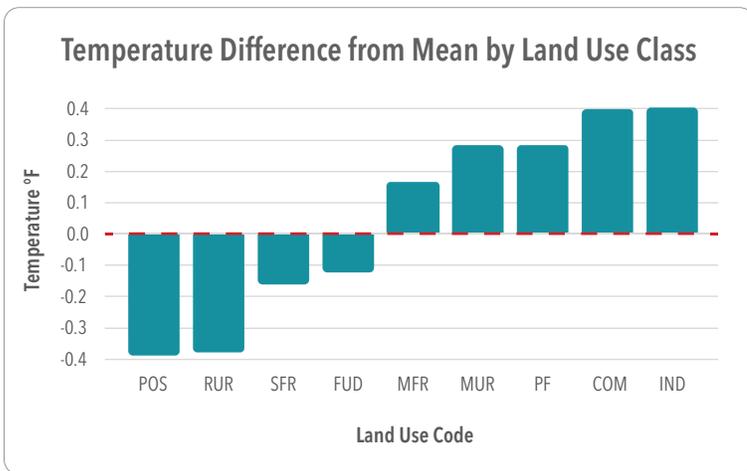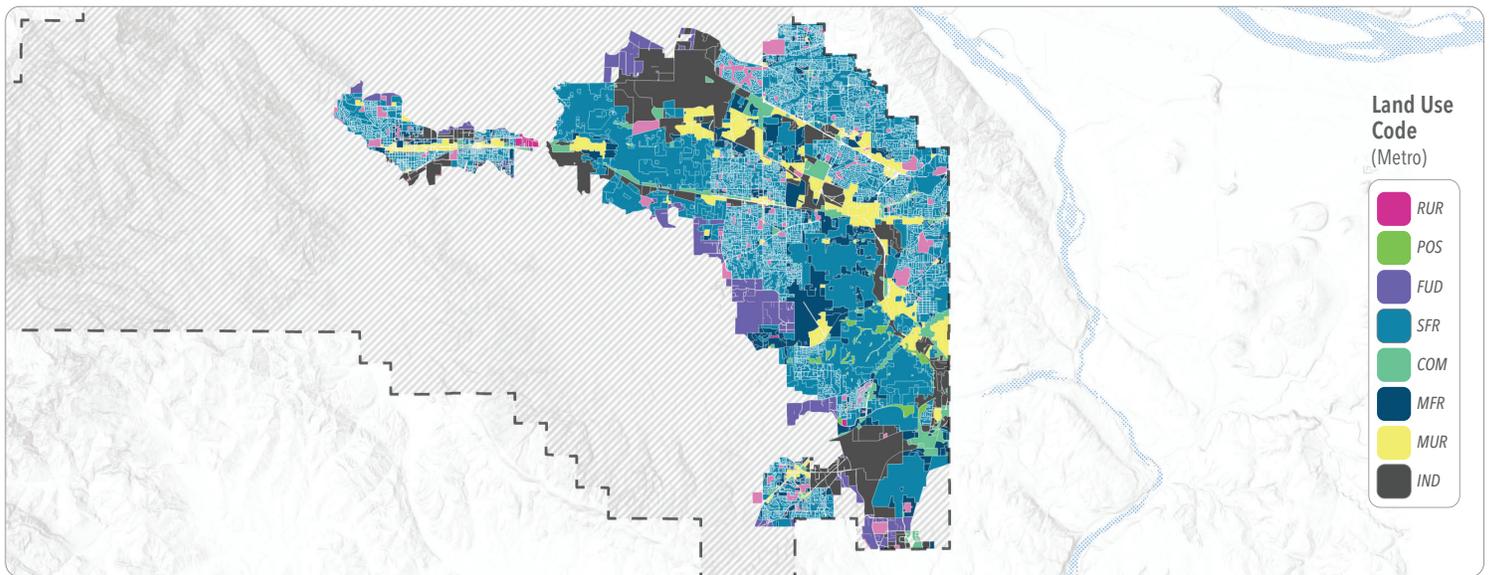
Land Use Code (Metro)

- RUR
- POS
- FUD
- SFR
- COM
- MFR
- MUR
- IND

Temperature Difference from Mean by Land Use Class

Land Use Code	Land Use Description	Percent of Study Area	Difference from Mean (°F)
POS	Parks and Open Space	0.8	-0.4
RUR	Rural	0.3	-0.4
SFR	Single Family Residential	50.0	-0.2
FUD	Future Urban Development	6.6	-0.1
MFR	Multi-Family Residential	10.4	0.2
MUR	Mixed-Use Residential	7.2	0.3
PF	Public Facilities	3.7	0.3
COM	Commercial	4.1	0.4
IND	Industrial	17.0	0.4

Aligning with expectations, Parks and Open Space and Rural areas are found to be the coolest of land uses in Washington County. Single Family Residential and Future Urban Developments are also cooler than the area average, which may be explained by the greater amounts of vegetation and canopy cover located in these areas. Multi-family Residential and Mixed-Use Residential areas, however, are warmer than the average, as are Commercial and Industrial areas.
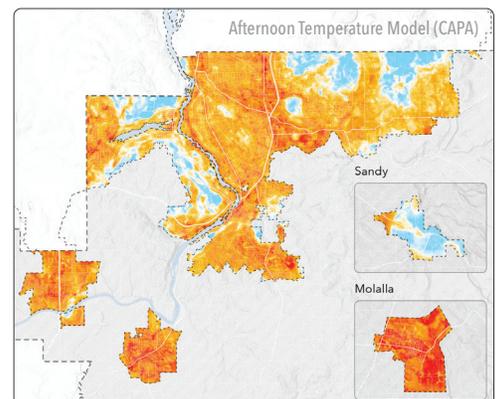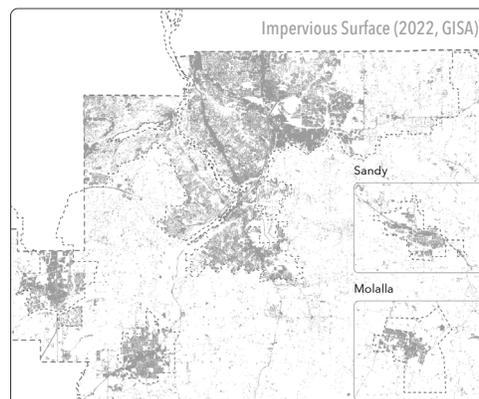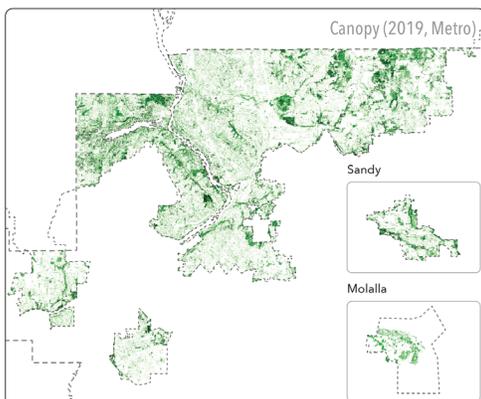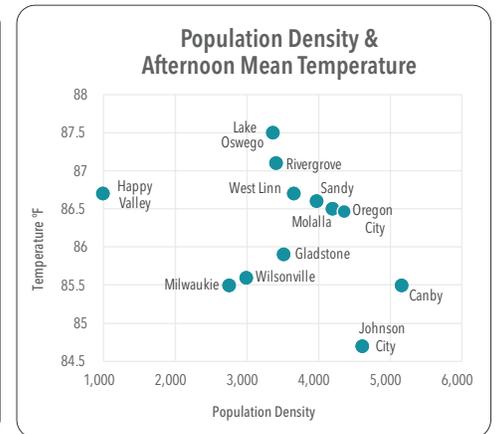
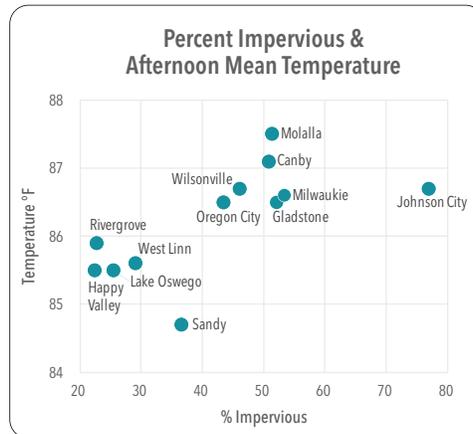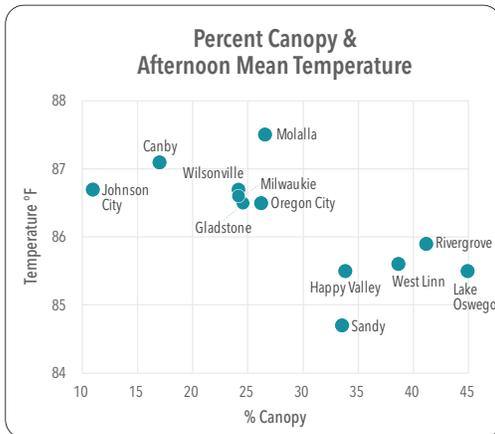# Washington County Land Cover Summary

We also examined patterns of heat by land cover, a spatial variable describing the presence of vegetation and human-made developments on the land's surface. In regards to heat, areas with greater amounts of tree canopy may benefit from the cooling effects of evapotranspiration and shade, while areas with greater amounts of impervious surfaces may witness the heat-concentrating effect of dense building materials and low-albedo (non-reflective) surfaces. In this analysis, we track trends in land cover, heat and population density by City.

Characteristics by City in Washington County Study Area

County/City	AF Mean	Min	Max	Range	AF StD	% Canopy	% Impervious	Size (sqmi)	Population	Pop density
Washington	86.6	84.0	90.0	6.0	0.6	24.3	51.9	77.8	352,600	4,565
Beaverton	86.5	83.3	90.6	7.3	0.6	26.5	55.3	19.8	98,000	4,949
Cornelius	86.6	84.6	89.0	4.4	0.4	13.7	59.2	2.0	12,500	6,250
Durham	86.7	85.1	89.3	4.2	0.7	52.3	29.9	0.5	1,600	3,019
Forest Grove	86.4	83.8	88.4	4.6	0.5	17.5	46.7	5.9	25,000	4,252
Hillsboro	86.5	81.9	89.4	7.5	0.6	19.2	52.2	24.3	108,000	4,444
King City	86.5	85.5	89.4	3.9	0.5	16.9	67.7	0.9	5,000	5,556
Sherwood	86.9	85.0	91.1	6.1	0.5	24.3	48.2	4.3	20,000	4,640
Tigard	86.4	83.5	90.6	7.1	0.7	26.5	53.2	11.8	55,000	4,657
Tualatin	86.7	83.5	92.1	8.6	0.7	22.0	54.8	8.3	27,500	3,313

Percent Canopy & Afternoon Mean Temperature

Percent Impervious & Afternoon Mean Temperature

Population Density & Afternoon Mean Temperature

Canopy (2019, Metro)

Impervious Surface (2022, GISA)

Afternoon Heat Model (2023, CAPA)

Population Exposure Analysis
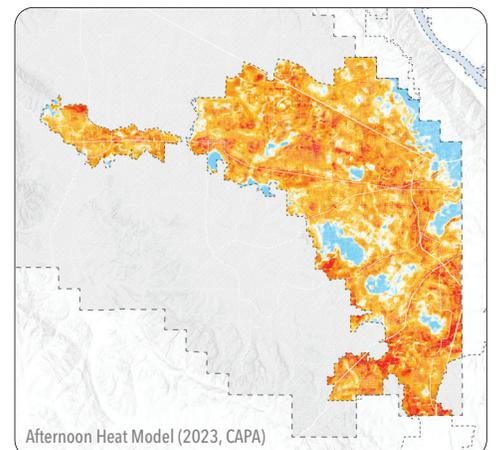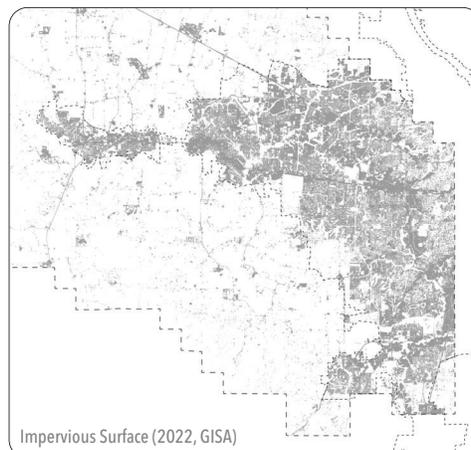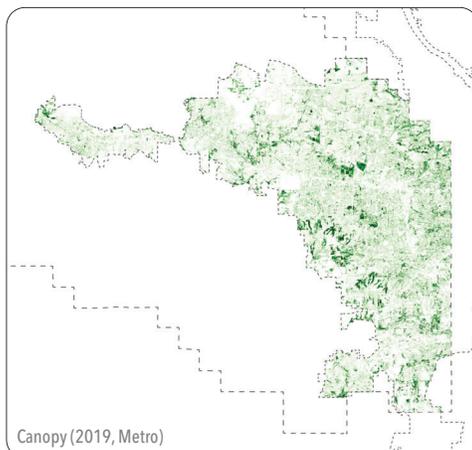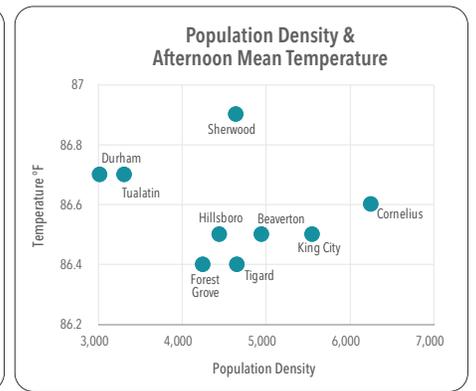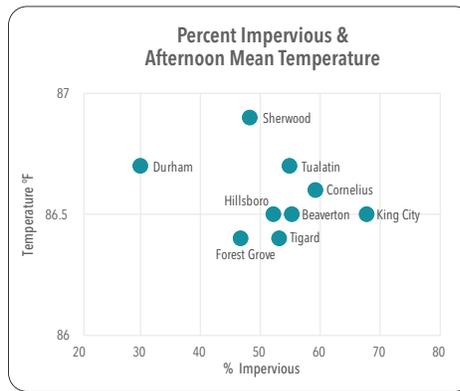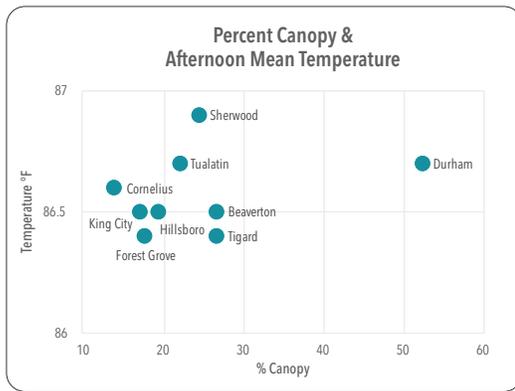
In this analysis we explore the portion of the Portland Metro region's population that experience elevated levels of air temperature based on the heat maps produced from the Heat Watch campaign. While the heat data were collected on one hot summer day across a specific range of temperatures, we can apply the same findings of relatively cooler and hotter locations across a range of summertime scenarios.

Deciles
Afternoon Model

1	77.6 - 79.0°F
2	79.0 - 80.5°F
3	80.5 - 81.9°F
4	81.9 - 83.4°F
5	83.4 - 84.9°F
6	84.9 - 86.3°F
7	86.3 - 87.8°F
8	87.8 - 89.2°F
9	89.2° - 90.7°F
10	90.7° - 92.1°F

Molalla

Percent of Population Exposed to Temperature Deciles

% Population Exposed by Temperature Decile				
Decile	Ave %	AM %	AF %	PM %
1	<0.0	<0.0	<0.0	<0.0
2	0.1	<0.0	0.1	0.1
3	0.2	0.1	0.2	0.3
4	0.9	0.8	0.9	1.0
5	4.0	5.5	4.8	6.3
6	15.4	22.0	33.7	20.1
7	43.7	45.7	59.3	63.1
8	33.7	22.7	0.9	8.4
9	1.9	2.5	<0.0	0.5
10	<0.0	0.6	<0.0	0.1

In order to normalize the heat data, we divided the range of temperatures from the composite model into ten equal ranks or "deciles". At each decile in the table below we can see what percentage of the population is exposed to the corresponding level of temperature; for instance, 59.3% of the Metro population experienced the 7th decile of temperatures, or according to the map above, a temperature range of 86.3-87.8°F during the afternoon. We can also sum the percentages above a certain rank to determine the portion of the population experiencing temperatures above a threshold such as above 80°F or 90°F.

Information provided from this analysis may be applied to scale the level of emergency response on a given hot day, and the mapping version can be used to understand where people are most exposed. These results can also be integrated with existing heat vulnerability indexes to improve on land surface temperature descriptions and provide ambient heat data at higher resolution (Source: Heat Vulnerability Index Methodology, Multnomah County Health Department 2023)

Appendix

| County	City	Am Mean	Am Min	Am Max	Am Range	Am StD	Af Mean	Af Min	Af Max	Af Range	Af StD	Pm Mean	Pm Min	Pm Max	Pm Range	Pm StD	Ave Mean	Ave Min	Ave Max	Ave Range	Ave StD	% Canopy	% Impervious	Size (sqmi)	Population	Pop density
Clackamas		59.7	52.0	63.7	11.7	0.9	86.4	80.1	91.1	11.0	0.6	83.5	76.7	88.3	11.6	0.8	76.6	71.6	79.8	8.2	0.6	27.8	44.3	61	224,500	3,622
Clackamas	Canby	59.8	56	61.8	5.8	1.1	87.1	85.5	91.1	5.6	0.6	84.4	81.9	87	5.1	0.8	77.1	74.7	79.8	5.1	0.7	17.0	50.9	3.79	17,500	4,617
Clackamas	Gladstone	60.2	57.3	61.7	4.4	0.7	86.5	85.2	88.9	3.7	0.4	83.9	81.6	86	4.4	0.6	76.9	75.5	78.1	2.6	0.4	24.6	52.1	2.32	12,000	5,172
Clackamas	Happy Valley	58.3	52	62.3	10.3	1.4	85.5	81.8	89	7.2	0.9	82.3	78.5	86.8	8.3	1.2	75.4	72.9	78.6	5.7	0.9	33.9	22.4	8.32	23,000	2,764
Clackamas	Johnson City	61	60.3	61.5	1.2	0.3	86.7	85.7	87.2	1.5	0.3	83.9	83.4	84.5	1.1	0.2	77.2	76.5	77.5	1	0.2	11.0	76.9	0.2	600	3,000
Clackamas	Lake Oswego	59.7	55.5	63.7	8.2	1	85.5	80.1	90.1	10	1.2	81.8	76.7	86.1	9.4	1.2	75.7	71.6	78.6	7	1.01	45.0	25.5	11.35	40,000	3,524
Clackamas	Milwaukie	60.3	57.7	63	5.3	0.8	86.6	84.3	89.1	4.8	0.4	83.5	80.4	85.6	5.2	0.5	76.8	74.6	78.6	4	0.4	24.2	53.4	4.85	21,000	4,330
Clackamas	Molalla	59.9	57.3	62.3	5	0.9	87.5	85.8	90.2	4.4	0.5	85.9	82.5	88.3	5.8	1	77.8	75.7	79.7	4	0.7	26.6	51.3	2.26	9,500	4,204
Clackamas	Oregon City	59.7	55.1	62.6	7.5	1.3	86.5	82.9	89.6	6.7	0.7	83.7	79.1	86.4	7.3	0.9	76.7	73.6	78.9	5.3	0.7	26.2	43.5	9.29	37,000	3,983
Clackamas	Rivergrove	60	57.1	61.3	4.2	0.6	85.9	84.3	87.1	2.8	0.6	82.1	80	83.3	3.3	0.8	76	74.4	77.2	2.8	0.6	41.2	22.7	0.4	400	1,000
Clackamas	Sandy	57.8	52.5	61.1	8.6	1.4	84.7	82.1	87.4	5.3	0.8	81.8	78.8	84.4	5.6	1.1	74.7	71.9	77.2	5.3	0.9	33.6	36.6	3.14	11,500	3,662
Clackamas	West Linn	60	56.5	62.4	5.9	0.8	85.6	81.4	89.3	7.9	1	82.2	78	85	7	1	75.9	73.4	78.3	4.9	0.7	38.7	29.1	7.9	27,000	3,418
Clackamas	Wilsonville	59.5	54	62.7	8.7	1.2	86.7	84	91.1	7.1	0.6	83.7	80.3	86.8	6.5	0.8	76.6	74.5	79.6	5.1	0.7	24.2	46.2	7.42	25,000	3,369
Multnomah		60.2	53.5	65.2	11.7	1.0	86.4	77.6	91.7	14.1	0.8	83.2	74.6	88.1	13.5	0.9	76.4	70.0	79.5	9.5	0.8	23.6	50.1	179.1	791,000	4,504
Multnomah	Fairview	60.4	56.4	63.2	6.8	1.1	86.6	84.2	89	4.8	0.6	83.6	79.9	85.9	6	0.8	76.8	74.5	78.8	4.3	0.7	20.5	35.6	3.5	9,500	2,714
Multnomah	Gresham	60	53.5	63.9	10.4	1.3	86	80.7	89.8	9.1	1.2	83.3	77.5	88.1	10.6	1.4	76.4	72.4	79.5	7.1	1.15	26.4	48.9	23.43	110,000	4,695
Multnomah	Maywood Park	60.6	59.7	62	2.3	0.5	86.7	85.7	88.1	2.4	0.3	83.5	82.8	84.4	1.6	0.3	76.9	76.5	77.9	1.4	0.2	32.5	46.4	0.17	1,000	5,882
Multnomah	Portland	60.4	54.5	65.2	10.7	1.6	85.5	77.6	91.7	14.1	1.9	82.4	74.6	86	11.4	2.1	76.1	70	79.4	9.4	1.7	29.7	48.5	145	650,000	4,483
Multnomah	Troutdale	59.2	54.9	61.9	7	1	86.2	83.1	89.3	6.2	0.8	83.3	78.7	87.1	8.4	1.2	76.2	73.6	79.2	5.6	0.9	21.6	40.5	6.02	16,500	2,741
Multnomah	Wood Village	60.5	57.7	62.7	5	0.9	87.1	85.6	90.4	4.8	0.5	84.1	82.1	86.5	4.4	0.6	77.2	75.3	79.2	3.9	0.6	17.6	64.7	0.94	4,000	4,255
Washington		59.3	54.5	63.3	8.8	1.0	86.6	81.9	92.1	10.2	0.6	83.0	78.3	86.9	8.6	0.7	76.6	72.6	79.4	6.8	0.6	24.3	51.9	77.8	39,178	4,565
Washington	Beaverton	60	55.6	62.8	7.2	1	86.5	83.3	90.6	7.3	0.6	83	79.2	85.9	6.7	0.8	76.5	73.8	78.9	5.1	0.7	26.5	55.3	19.8	98,000	4,949
Washington	Cornelius	58.1	55.4	60.1	4.7	0.9	86.6	84.6	89	4.4	0.4	82.3	80.6	84.1	3.5	0.6	75.4	73.9	77	3.1	0.5	13.7	59.2	2	12,500	6,250
Washington	Durham	60.4	57.7	62.8	5.1	1.1	86.7	85.1	89.3	4.2	0.7	83.1	81.5	84.9	3.4	0.8	76.7	75.1	78.5	3.4	0.8	52.3	29.9	0.53	1,600	3,019
Washington	Forest Grove	57.7	54.5	60.5	6	0.9	86.4	83.8	88.4	4.6	0.5	82.1	78.5	84.2	5.7	0.8	75.4	73.4	77	3.6	0.6	17.5	46.7	5.88	25,000	4,252
Washington	Hillsboro	59	54.6	63.3	8.7	1.4	86.5	81.9	89.4	7.5	0.6	82.9	78.3	85.2	6.9	0.8	76.1	72.6	78.4	5.8	0.8	19.2	52.2	24.3	108,000	4,444
Washington	King City	59.9	56.5	61.3	4.8	0.8	86.5	85.5	89.4	3.9	0.5	83.4	81.8	85	3.2	0.5	76.6	74.8	78	3.2	0.5	16.9	67.7	0.9	5,000	5,556
Washington	Sherwood	59	55.2	61.3	6.1	1.1	86.9	85	91.1	6.1	0.5	83.8	82	86.1	4.1	0.6	76.6	74.6	79.3	4.7	0.6	24.3	48.2	4.31	20,000	4,640
Washington	Tigard	60	55.6	62.9	7.3	1	86.4	83.5	90.6	7.1	0.7	83.1	79.6	85.7	6.1	0.8	76.5	74	79.2	5.2	0.7	26.5	53.2	11.81	55,000	4,657
Washington	Tualatin	60	56.6	62.6	6	0.9	86.7	83.5	92.1	8.6	0.7	83.6	79.9	86.9	7	0.8	76.8	74.1	79.4	5.3	0.6	22.0	54.8	8.3	27,500	3,313

Land Use Summary by County and City

County	Zone Class	Description	SQM Zone	SQM Total	%Zone	AM Mean	Am Min	AM Max	AF Mean	AF Min	AF Max	PM Mean	PM Min	PM Max	Ave Mean	Ave Min	Ave Max
Clackamas																	
	COM	Commercial	2.3	110.5	2.1	60.2	59.7	60.6	86.8	86.2	87.5	84.0	83.5	84.6	77.0	76.6	77.4
	FUD	Future Urban Development	2.1	110.5	1.9	59.3	58.9	59.8	86.2	85.7	86.6	83.1	82.6	83.5	76.2	75.9	76.5
	IND	Industrial	9.4	110.5	8.5	60.0	59.3	60.7	86.8	86.1	87.6	84.0	83.2	84.7	76.9	76.4	77.5
	MFR	Multi-Family Residential	5.0	110.5	4.6	60.2	59.6	60.7	86.5	85.9	87.2	83.5	82.9	84.1	76.8	76.3	77.2
	MUR	Mixed-Use Residential	7.7	110.5	7.0	59.4	58.8	59.9	86.7	86.2	87.2	83.7	83.2	84.2	76.6	76.2	77.0
	PF	Public Facilities	3.4	110.5	3.1	59.8	59.3	60.2	86.4	85.8	87.0	83.6	83.0	84.2	76.6	76.2	77.0
	POS	Parks and Open Space	2.7	110.5	2.4	59.7	59.2	60.1	85.8	85.4	86.5	82.4	82.0	82.9	76.0	75.7	76.4
	RUR	Rural	22.6	110.5	20.5	58.0	57.1	58.8	85.9	85.3	86.5	82.8	82.1	83.5	75.6	75.1	76.1
	SFR	Single Famiy Residential	55.2	110.5	50.0	59.1	58.5	59.6	86.0	85.5	86.5	82.9	82.4	83.4	76.0	75.6	76.4
Multnomah																	
	COM	Commercial	1.1	177.6	0.6	59.6	58.9	60.2	86.3	85.7	87.0	83.3	82.8	83.9	76.4	76.0	76.9
	FUD	Future Urban Development	0.2	177.6	0.1	58.9	57.8	60.2	85.7	85.0	86.3	82.6	81.8	83.6	75.7	75.3	76.3
	IND	Industrial	33.5	177.6	18.9	60.9	60.1	61.7	86.6	85.7	87.3	83.7	83.0	84.4	77.1	76.5	77.6
	MFR	Multi-Family Residential	13.5	177.6	7.6	60.8	60.5	61.2	86.4	85.9	86.9	83.4	83.1	83.8	76.9	76.6	77.2
	MUR	Mixed-Use Residential	16.1	177.6	9.1	61.1	60.7	61.4	86.5	86.0	87.0	83.6	83.2	83.9	77.1	76.7	77.3
	PF	Public Facilities	0.0	177.6	0.0	-	-	-	-	-	-	-	-	-	-	-	-
	POS	Parks and Open Space	27.6	177.6	15.6	60.1	59.7	60.7	85.6	85.1	86.3	82.5	82.1	83.1	76.1	75.8	76.6
	RUR	Rural	8.8	177.6	4.9	58.5	57.9	59.2	83.4	82.7	84.2	80.4	79.7	81.2	74.1	73.6	74.7
	SFR	Single Famiy Residential	76.8	177.6	43.2	60.1	59.6	60.6	85.8	85.2	86.4	82.7	82.2	83.3	76.2	75.8	76.6
Washington																	
	COM	Commercial	4.9	118.5	4.1	83.4	83.0	83.8	86.9	86.3	87.5	83.4	83.0	83.8	76.8	76.4	77.1
	FUD	Future Urban Development	7.8	118.5	6.6	82.6	82.0	83.2	86.3	85.7	86.9	82.6	82.0	83.2	75.6	75.1	76.1
	IND	Industrial	20.1	118.5	17.0	83.5	82.7	84.1	86.9	86.0	87.6	83.5	82.7	84.1	76.7	76.1	77.2
	MFR	Multi-Family Residential	12.3	118.5	10.4	83.0	82.6	83.4	86.6	86.2	87.1	83.0	82.6	83.4	76.3	76.0	76.6
	MUR	Mixed-Use Residential	8.6	118.5	7.2	83.2	82.9	83.6	86.7	86.2	87.3	83.2	82.9	83.6	76.6	76.3	76.9
	PF	Public Facilities	4.3	118.5	3.7	82.8	82.4	83.2	86.3	85.8	86.7	82.8	82.4	83.2	76.1	75.7	76.4
	POS	Parks and Open Space	1.0	118.5	0.8	82.6	82.3	83.0	86.1	85.7	86.5	82.6	82.3	83.0	76.1	75.8	76.4
	RUR	Rural	0.4	118.5	0.3	81.9	81.4	82.3	86.1	85.7	86.5	81.9	81.4	82.3	75.0	74.7	75.3
	SFR	Single Famiy Residential	59.2	118.5	50.0	82.7	82.4	83.0	86.3	86.0	86.7	82.7	82.4	83.0	76.0	75.8	76.3

Portland
Afternoon Area-Wide Model
Temperature (3 - 4 pm)

CAPA

HEAT WATCH

91.7°F

77.6°F

N
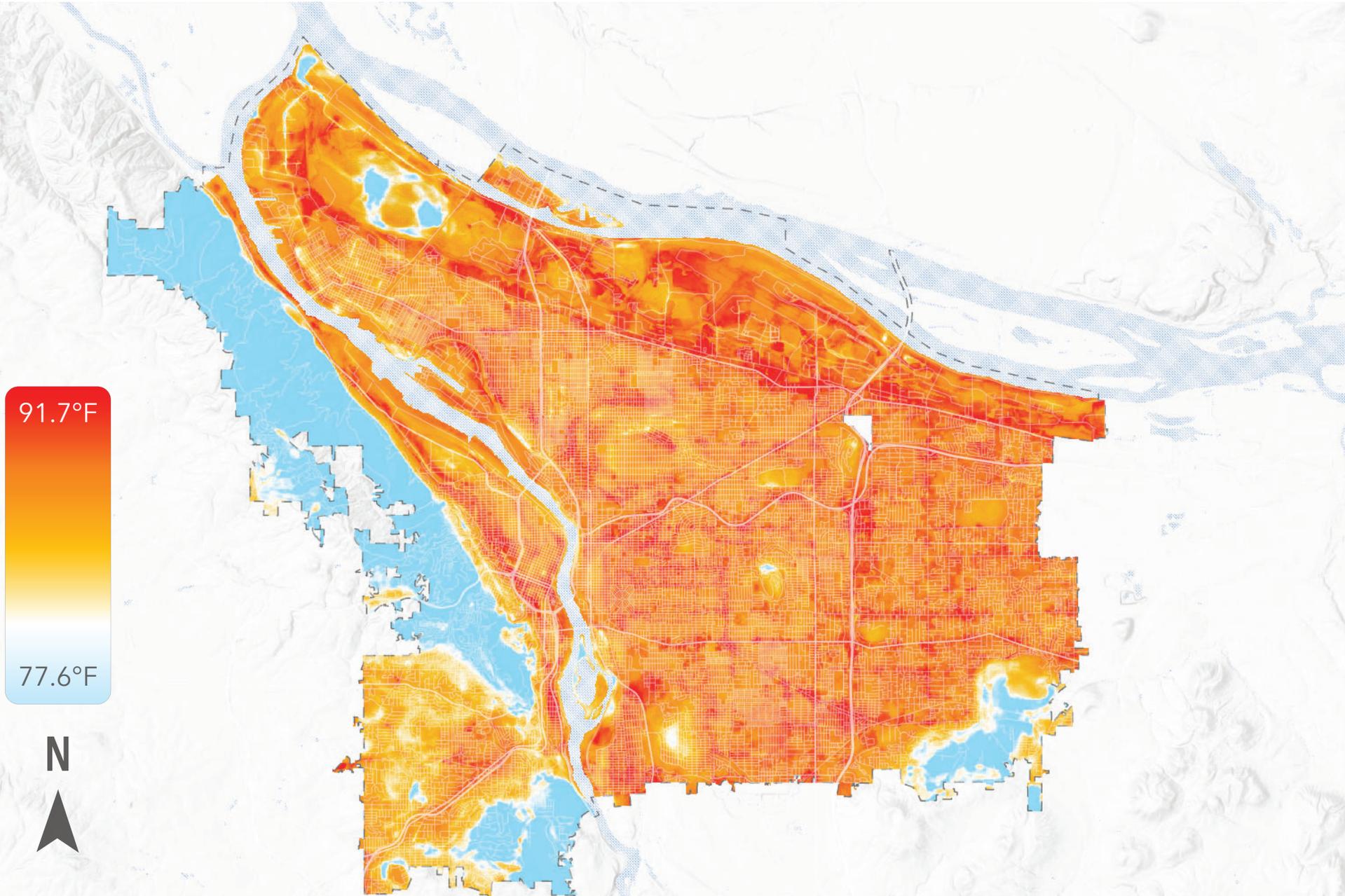
Gresham
Afternoon Area-Wide Model
Temperature (3 -4 pm)
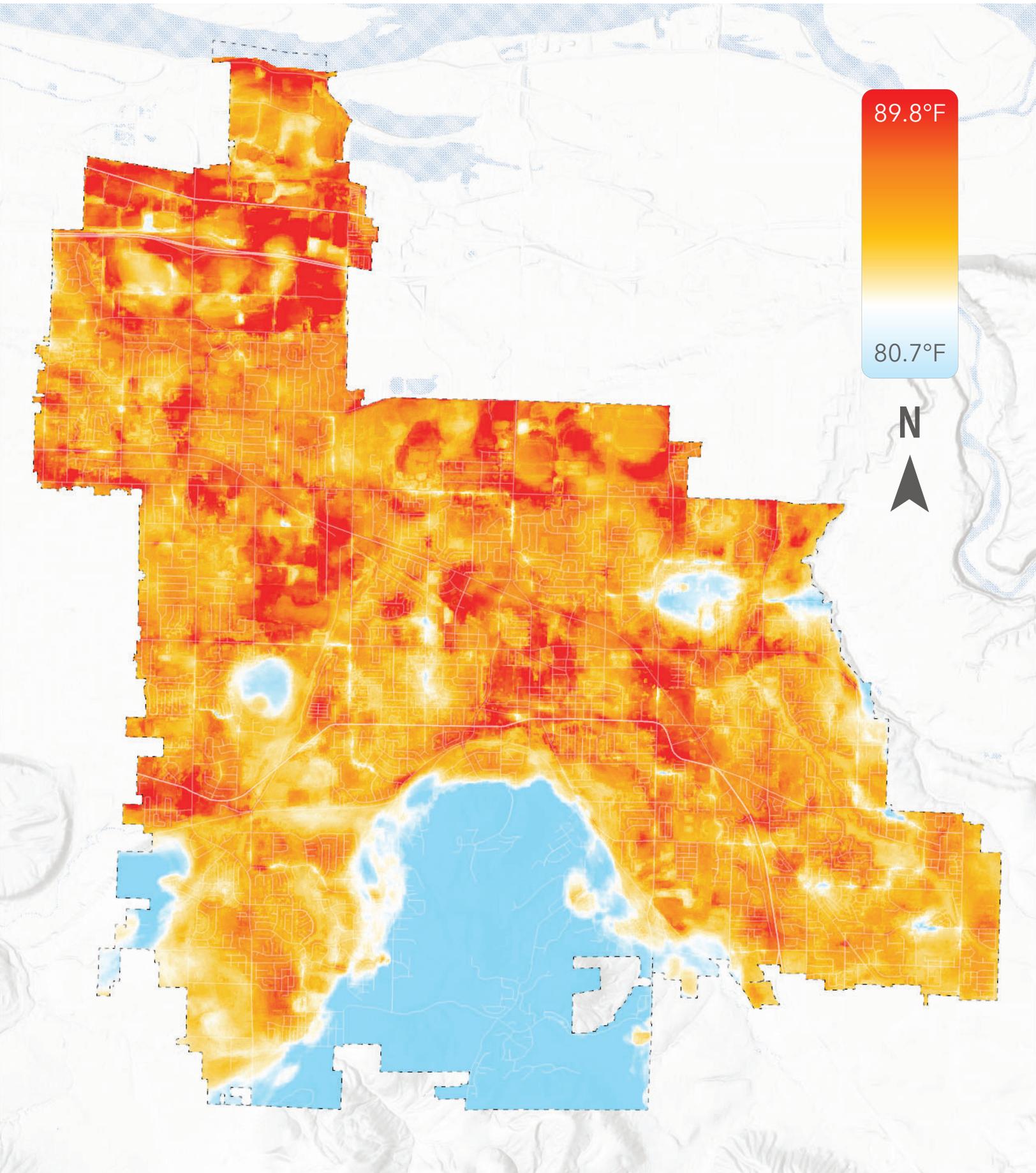
CAPA

HEAT WATCH

89.8°F

80.7°F

N

CAPA

HEAT WATCH

89.4°F

81.9°F

N

90.6°F

83.3°F

N
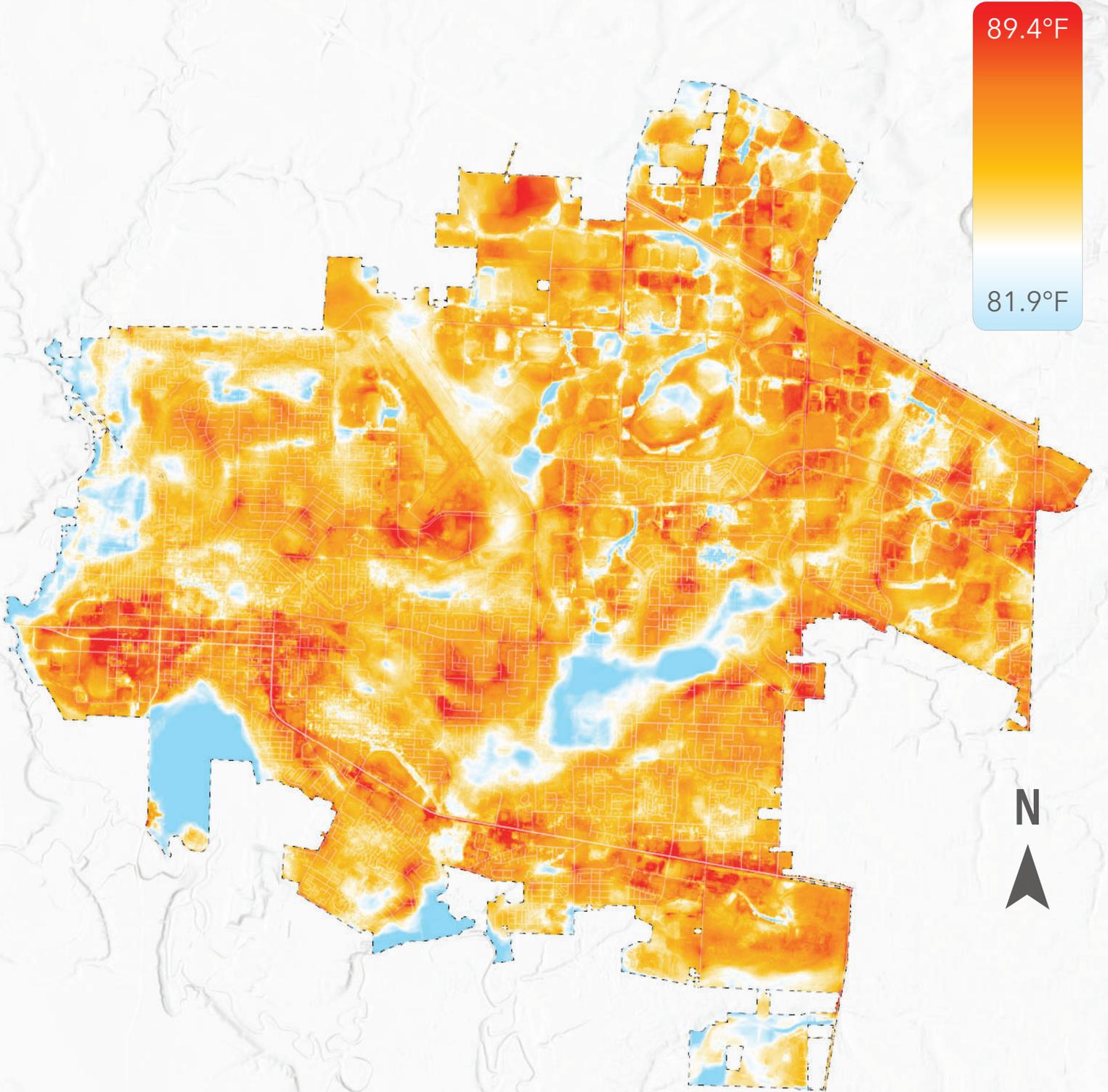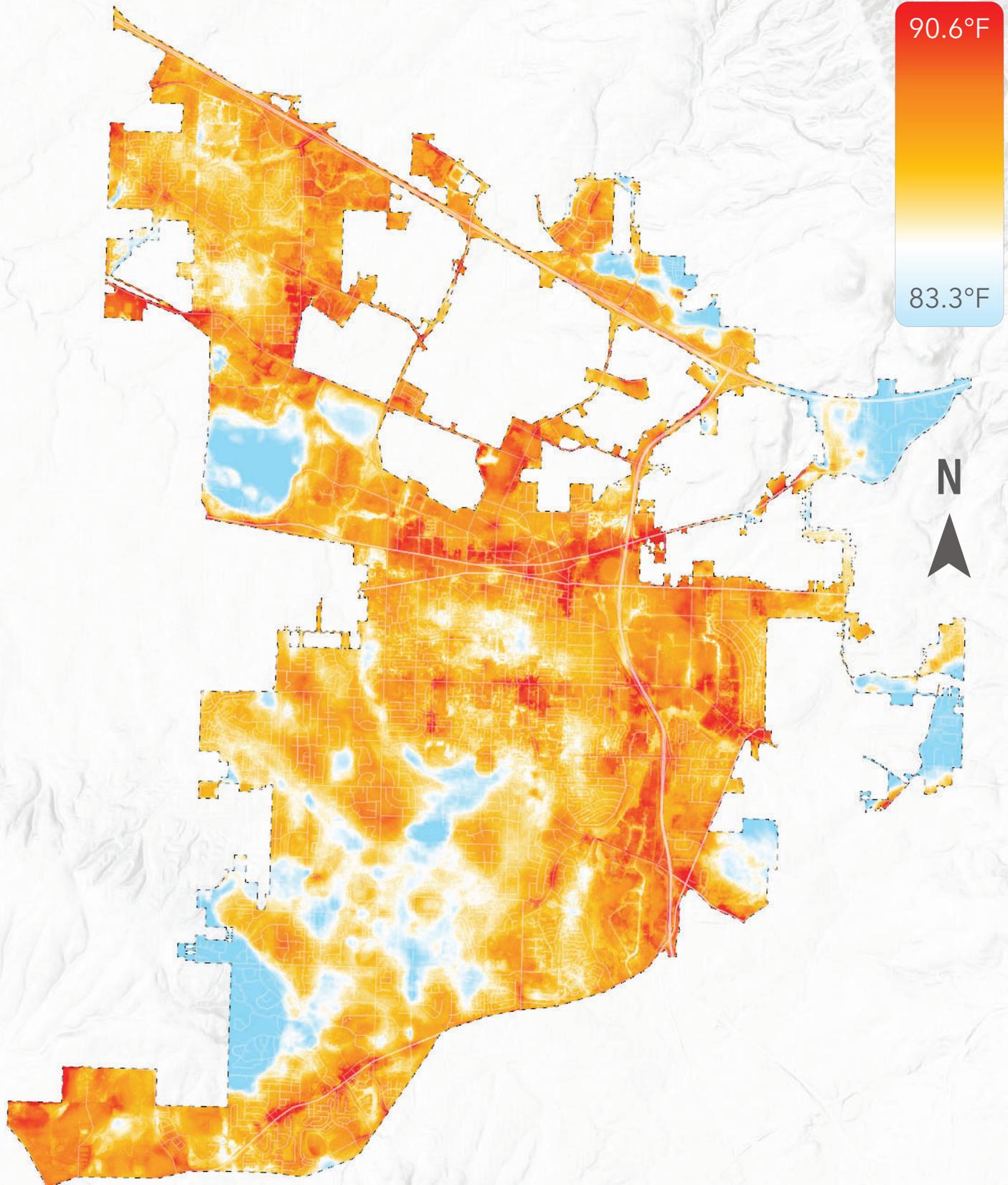
Tigard
Afternoon Area-Wide Model
Temperature (3 - 4 pm)

90.6°F
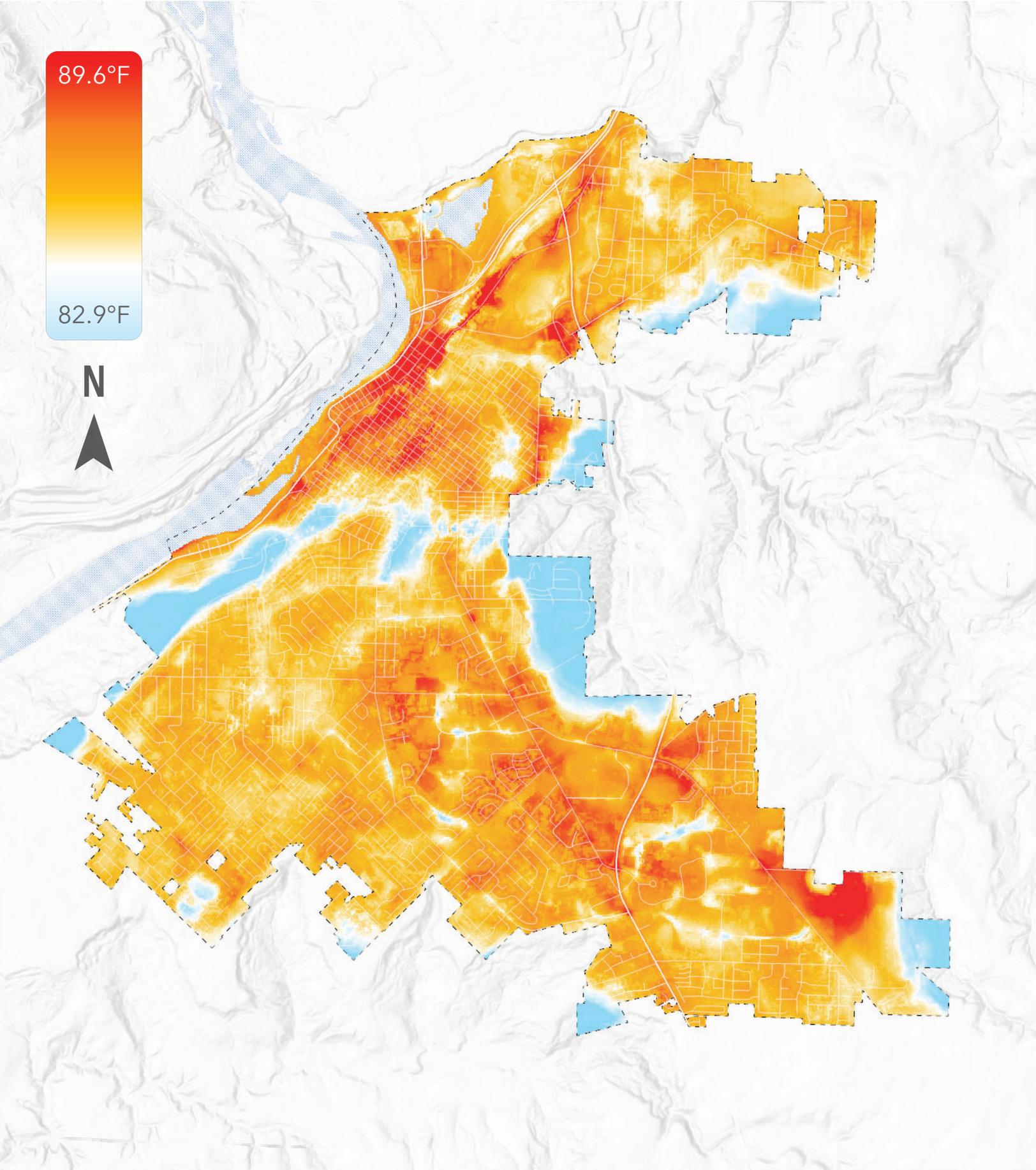
83.5°F

N
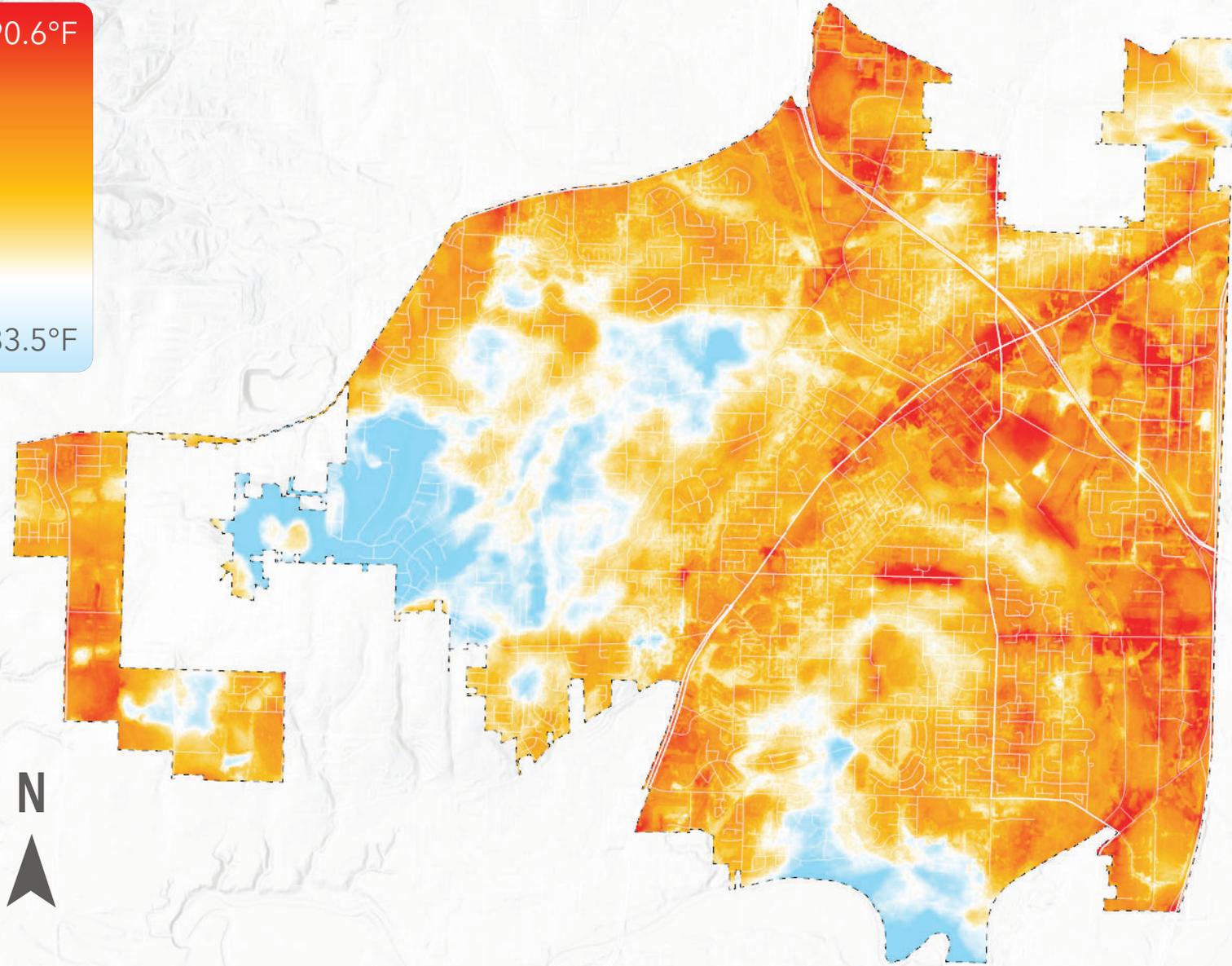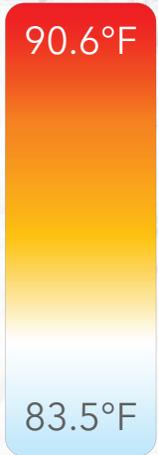
Lake Oswego
Afternoon Area-Wide Model
Temperature (3 - 4 pm)

CAPA

HEAT WATCH

90.1°F

80.1°F

N
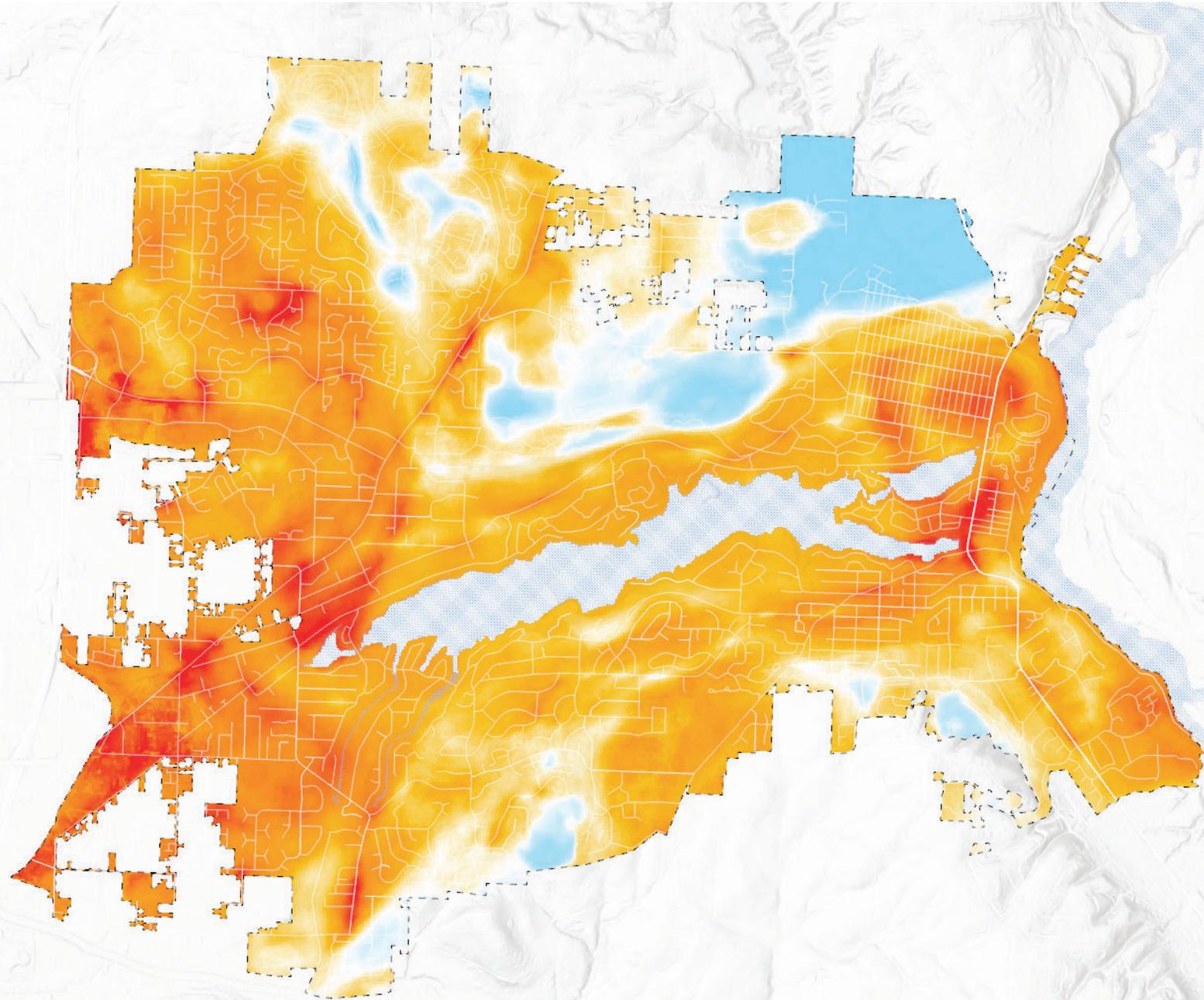
Oregon City
Afternoon Area-Wide Model
Temperature (3 -4 pm)

CAPA

HEAT WATCH

89.6°F

82.9°F

N

Tualatin
Afternoon Area-Wide Model
Temperature (3 - 4 pm)

CAPA

HEAT WATCH

92.1°F

83.5°F

N
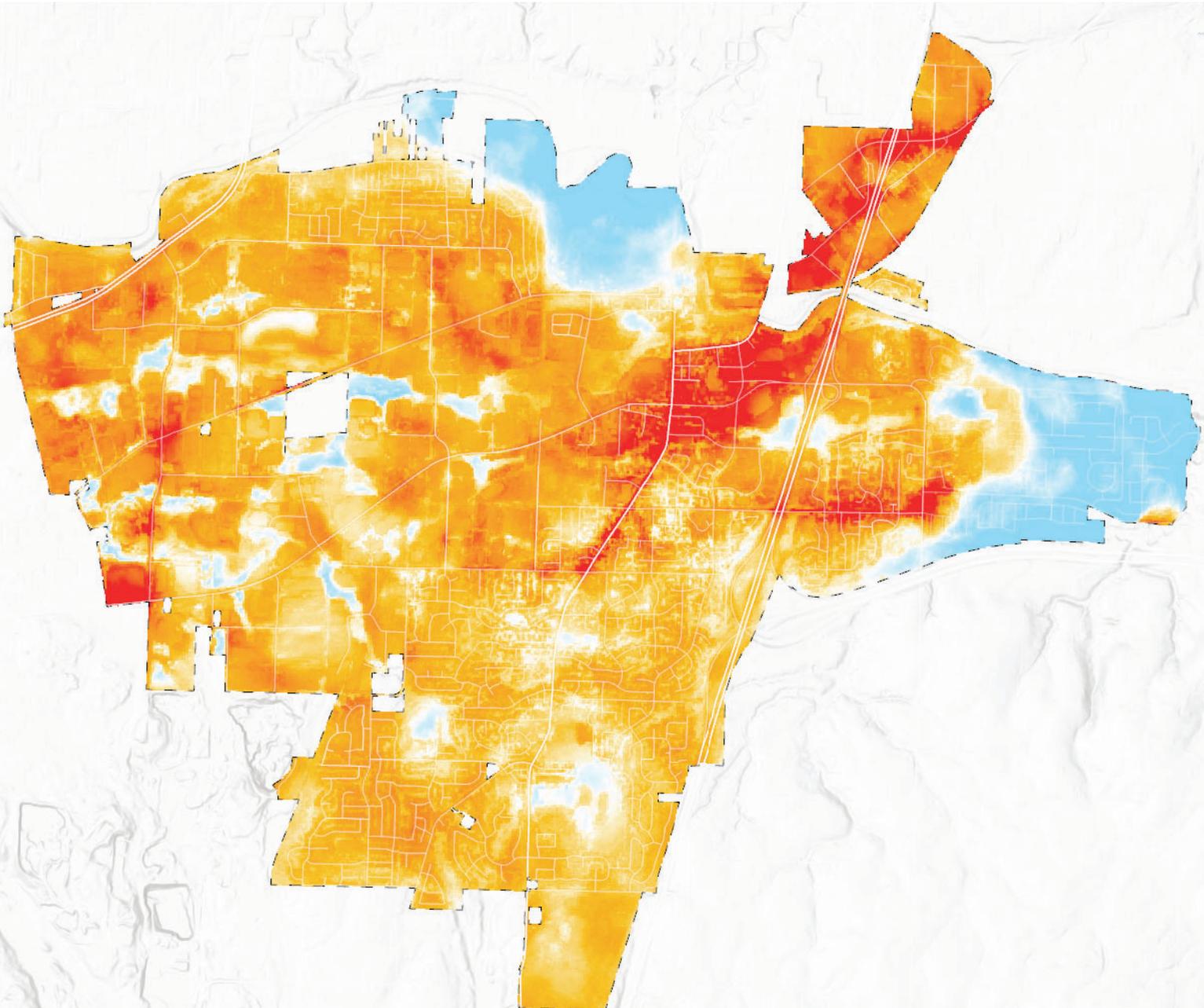
West Linn
Afternoon Area-Wide Model
Temperature (3 -4 pm)

CAPA

HEAT WATCH
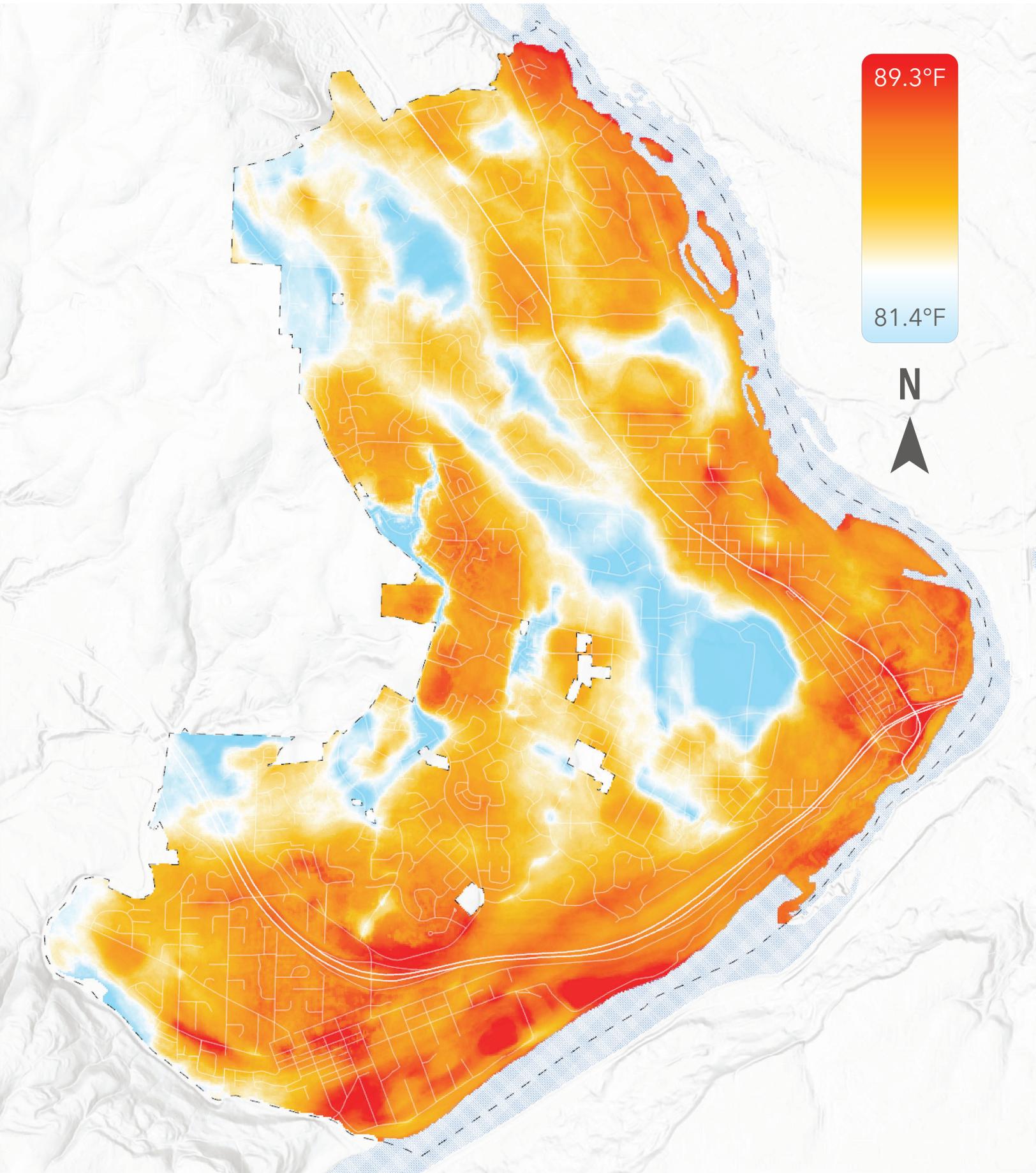
89.3°F

81.4°F

N

Forest Grove
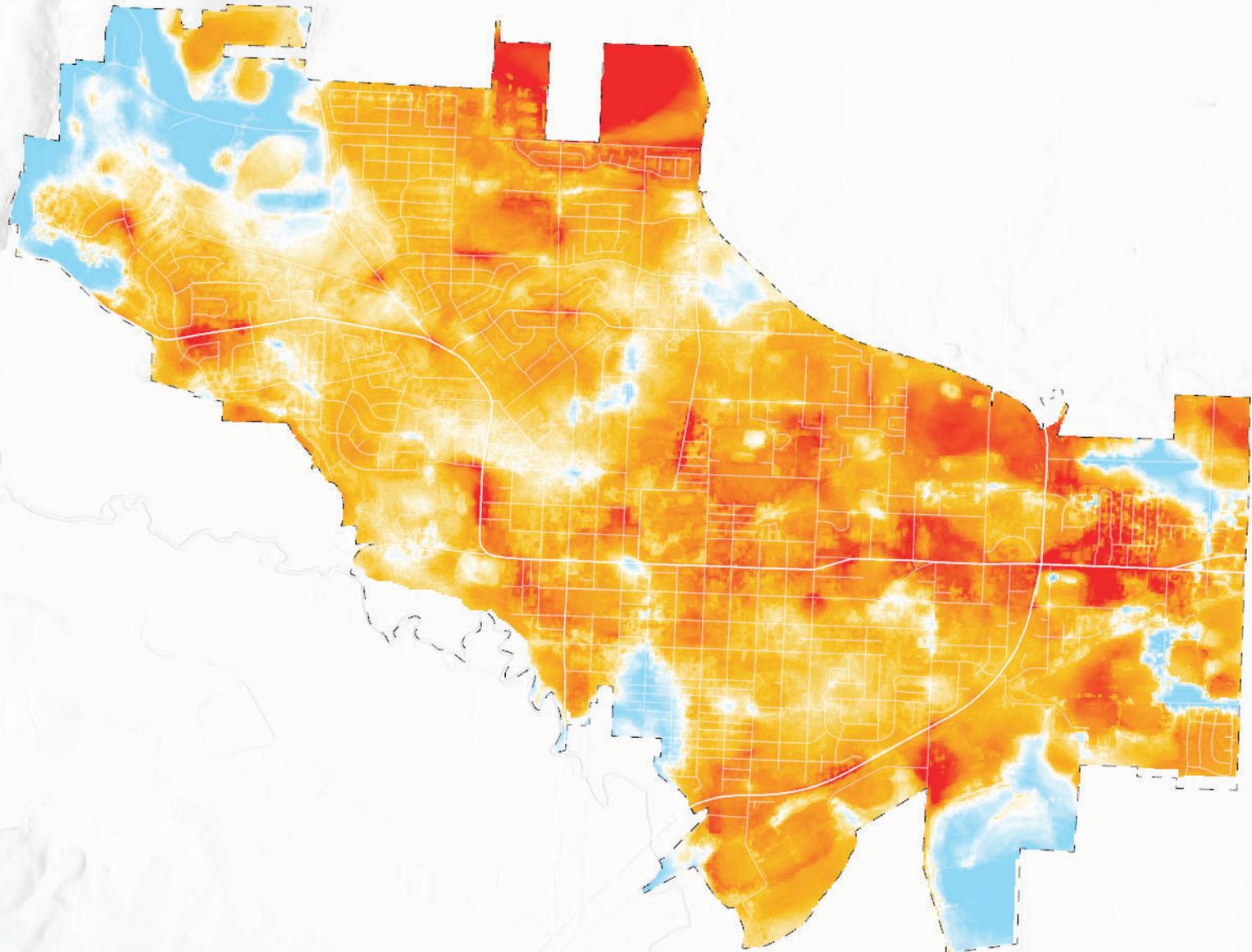## Afternoon Area-Wide Model
Temperature (3 - 4 pm)

CAPA

HEAT WATCH

88.4°F

83.7°F

N
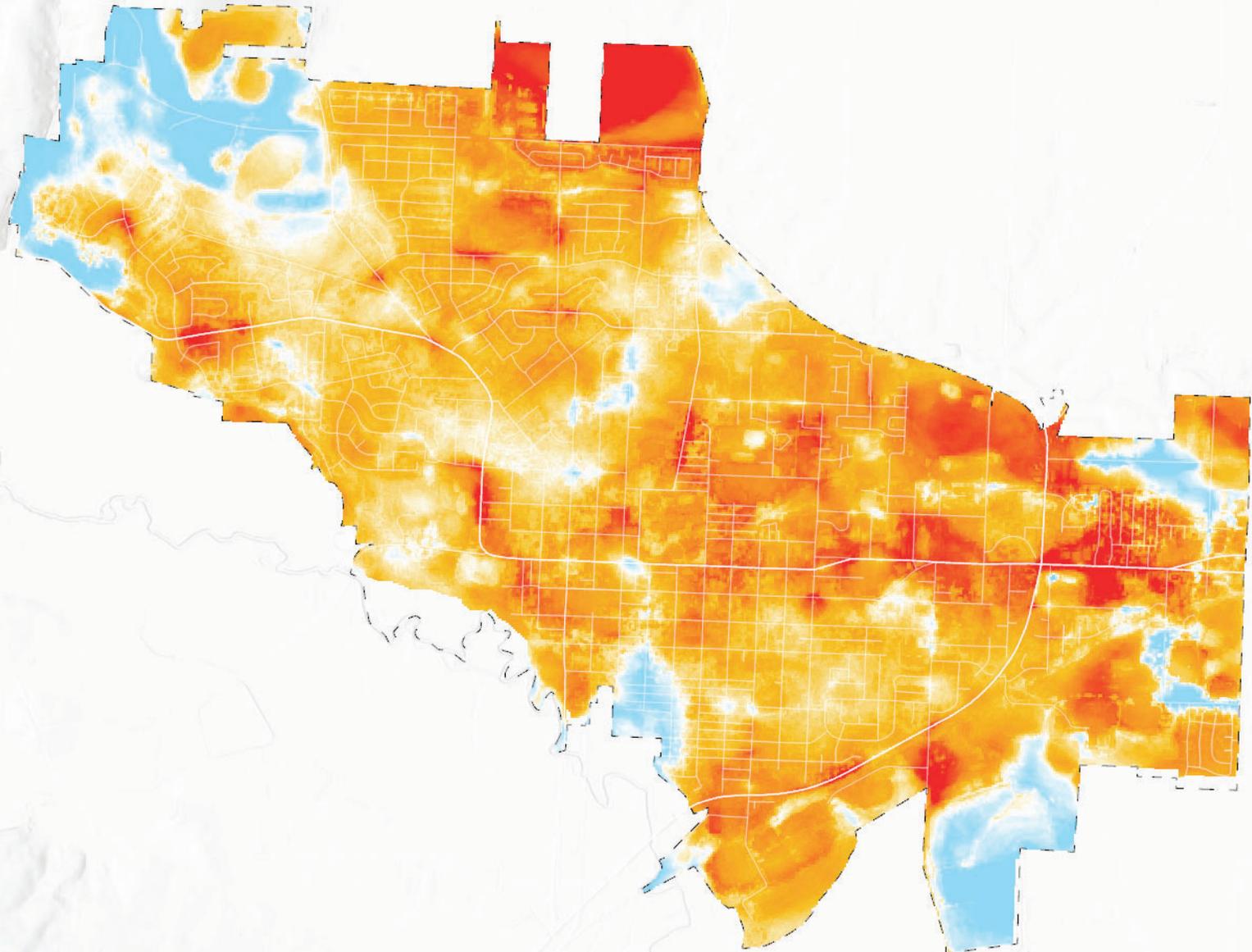
Wilsonville
Afternoon Area-Wide Model
Temperature (3 -4 pm)

CAPA

HEAT WATCH

91.1°F

84.0°F

N
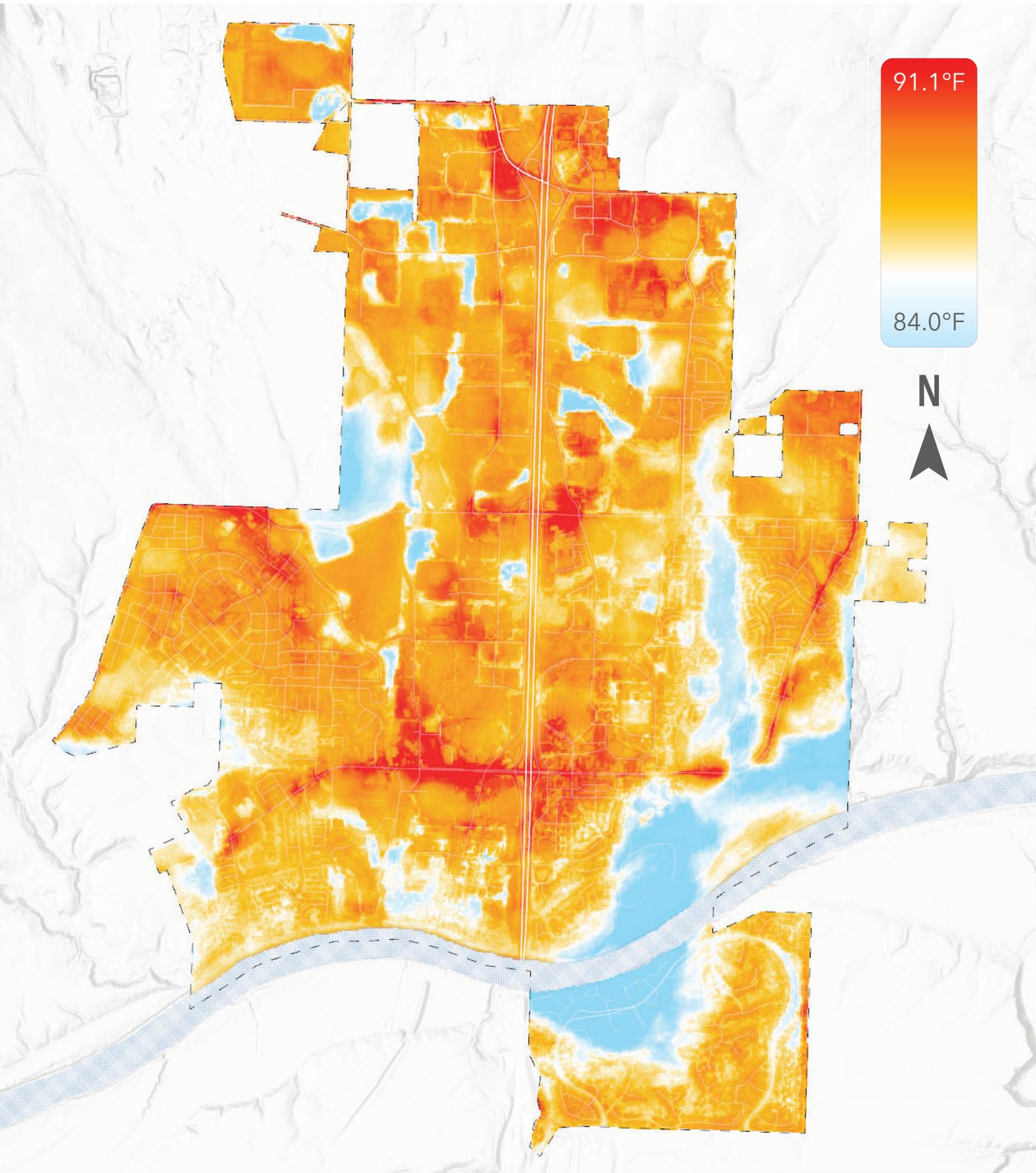
Happy Valley
Afternoon Area-Wide Model
Temperature (3 - 4 pm)

CAPA

HEAT WATCH
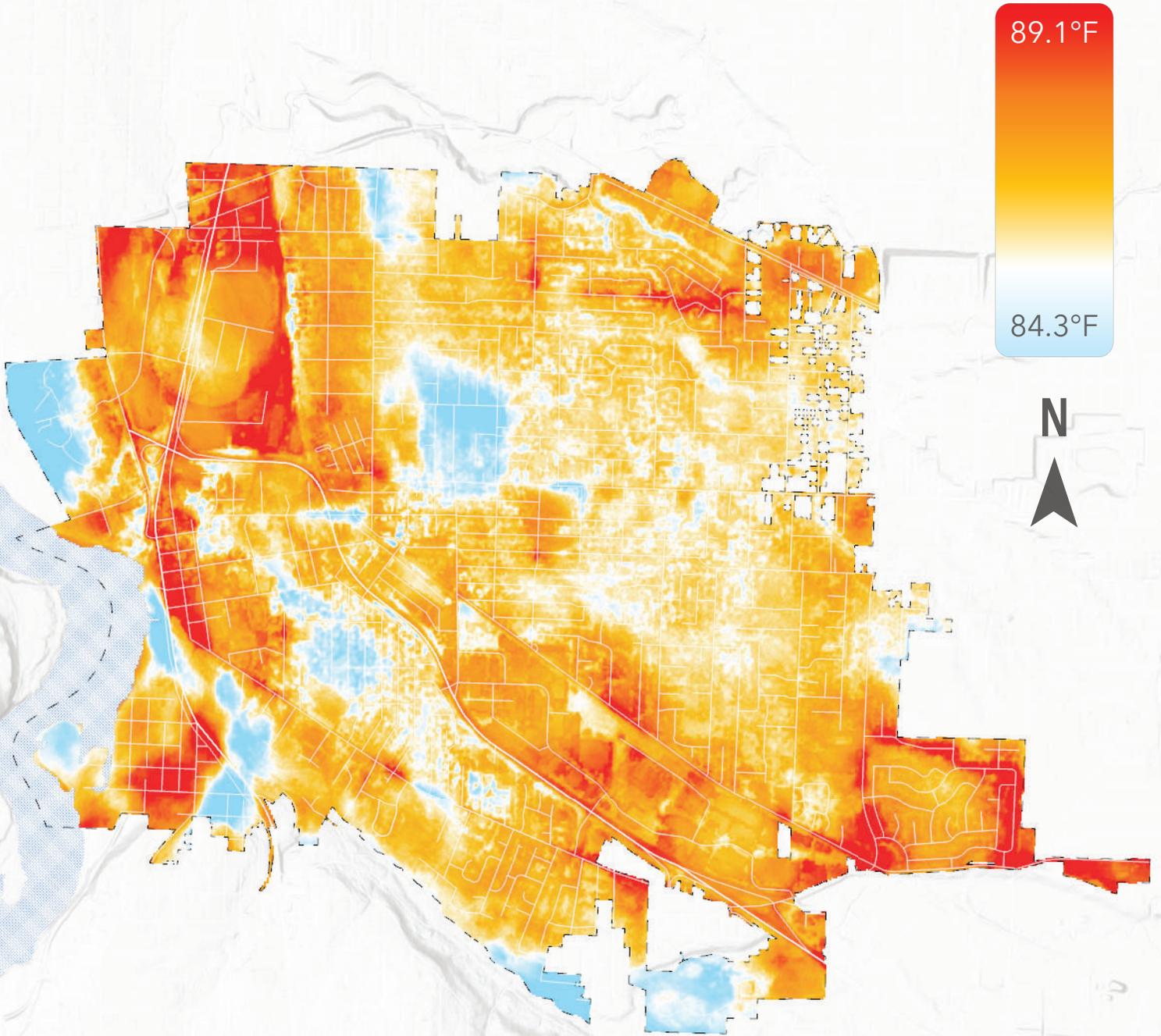
89.0°F

81.9°F

N

Milwaukie
Afternoon Area-Wide Model
Temperature (3 -4 pm)

89.1°F

84.3°F

N

Sherwood
Afternoon Area-Wide Model
Temperature (3 - 4 pm)

CAPA

HEAT WATCH

91.1°F

85.0°F

N