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.
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Major thanks to all of the participants and organizers of the Urban Heat Watch program in Clark County, NV. 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 August 13th, 2022.

According to the National Weather Service, August 13th was the coolest day of August in 2022 with an observed high of 90°F at the Harry Reid International Airport. The normal historical high for August 13th is 103°F. Brought on by thunderstorms the night prior that occurred around (but not in) the Las Vegas valley, unexpected heavy cloud cover formed across the region at levels between 80 to 100% in the morning and 60 to 80% throughout the rest of the day.

Because the amount of direct solar radiation influences the degree of urban heat island (UHI) effect, we expect that the heavy cloud cover may have dampened the range of temperatures typically experienced on a hot day across Clark County. The results herein provide valuable insight into areas that experience relatively greater and lesser UHI effect, though should be presented and interpreted in the context of these less-than-ideal heat mapping conditions.
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 13th, 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.

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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.

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\(^1\) The most relevant and recent publications to the Heat Watch campaign process include:


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, undeveloped land) 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.

Areas with large amounts of dark, low reflectance surfaces (like asphalt roadways) seem to concentrate heat.

Residential neighborhoods with all-white rooftops appear to reflect away solar radiation and heat.

The GIS tool "Dynamic Range Adjustment" is helpful for more closely viewing differences in heat between areas.
Over 56,000 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 those 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)
Over 37,000 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 those 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)
Over 43,000 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

To learn more about the analytical processes used in Heat Watch, visit the research publications below:


Accuracy Assessment

<table>
<thead>
<tr>
<th>Accuracy Assessment*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traverse</td>
</tr>
<tr>
<td>6 - 7 am</td>
</tr>
<tr>
<td>3 - 4 pm</td>
</tr>
<tr>
<td>7 - 8 pm</td>
</tr>
</tbody>
</table>

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 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 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. We suggest caution when interpreting area wide values that extend far beyond the traversed areas.

*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.
Community Outreach & Participation

Media

RTC is helping Nevadans beat the heat this summer

Volunteers help map ‘urban heat islands’ in Las Vegas Valley

RTC organizing ‘heat island’ mapping project, and looking for volunteers

@capastrategies  www.capastrategies.com
On another hot day, separate from the campaign day, volunteers investigated heat around downtown Las Vegas using a different set of tools: FLIR thermal imagery cameras and their intuitions about people, place, and heat. The FLIR One camera (right) provides a thermal snapshot and estimation of surface temperatures within view, as pictured below.

Using the FLIR cameras, volunteers explored several locations around the County to capture images of heat present in various landscapes. The selected results below show landscapes and their thermal image equivalent.

For context, the images were captured between 12:55 and 1:15pm on August 17th, with conditions at 99°F, 26% humidity, and 0 mph wind speed.
(Source: Weather Underground).

Trees along Grand Central Parkway.

Entrance to the Regional Transportation of Southern Nevada (RTC) and Regional Flood Control District (RFCD).
Transit amenities at a bus stop outside the Clark County Government Center.

Artificial turf and walkway near Lou Ruvo Center.

Transit amenities at a bus stop outside the Clark County Government Center.
Several weeks prior to campaign day, local organizers installed a set of HOBO stationary sensors in targeted locations across the county’s urbanized area. The sensors recorded temperature and humidity measurements every fifteen 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.

To provide a sampling approach, the sensors are distributed across the diverse geography of Clark County and located at a range of land use and land cover types, such as near parking lots as well as a forested area. All sensors were placed at RTC transit locations approximately 10 feet off the ground.
Stationary Sensor Analysis
Temporal Analysis

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 ten HOBO sensors over a one-month period and on the single campaign day. In other words we ask, is sensor #1 warmer or cooler than the average of all ten sensors over one month, 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 15-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-sensor 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)

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

<table>
<thead>
<tr>
<th>HOBO Sensor ID #</th>
<th>Morning</th>
<th></th>
<th></th>
<th>Afternoon</th>
<th></th>
<th></th>
<th>Evening</th>
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<td>Difference from area mean</td>
<td>6am campaign day average</td>
<td>Difference from area mean</td>
<td>3pm 1-month average</td>
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</table>

Note: Sensor IDs 1-10 correspond sequentially with HOBO sensors 11-20.
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. Data points that are closer to the dashed line indicate a closer match between the HOBO sensor and CAPA’s models.

### Stationary Sensor Measurements vs. Modeled Temperature (10m)

#### Table: CAPA Model vs. HOBO Mean (°F) Differences

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<th>CAPA Model (°F)</th>
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<th>CAPA - HOBO Differences (°F)</th>
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</tbody>
</table>

Note: Sensor IDs 1-10 correspond sequentially with HOBO sensors 11-20.
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?

Heat Watch + Supplemental Data ➔ Stakeholder Discussions ➔ Data Discovery & Analysis ➔ Decision Making Support

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

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 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.

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.

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