Mapping Urban Heat with Community Science, Machine Learning, and Remote Sensing

In this webinar, UHI measuring and modeling expert Dr. Vivek Shandas will tease apart the varying approaches to UHI mapping, and will provide an overview of a relatively new machine learning method that incorporates conventional satellite remote sensing data and in situ observations of temperature and humidity from community science urban field campaigns. This presentation will cover the methods applied, results from past campaigns, and lessons learned over the 20 different urban field campaigns conducted since 2015. The presentation will also touch on the emerging plans for 2020 and how outcomes from previous campaigns are helping to inform its design.

Contact Vivek

vs@capastrategies.com www.capastrategies.com

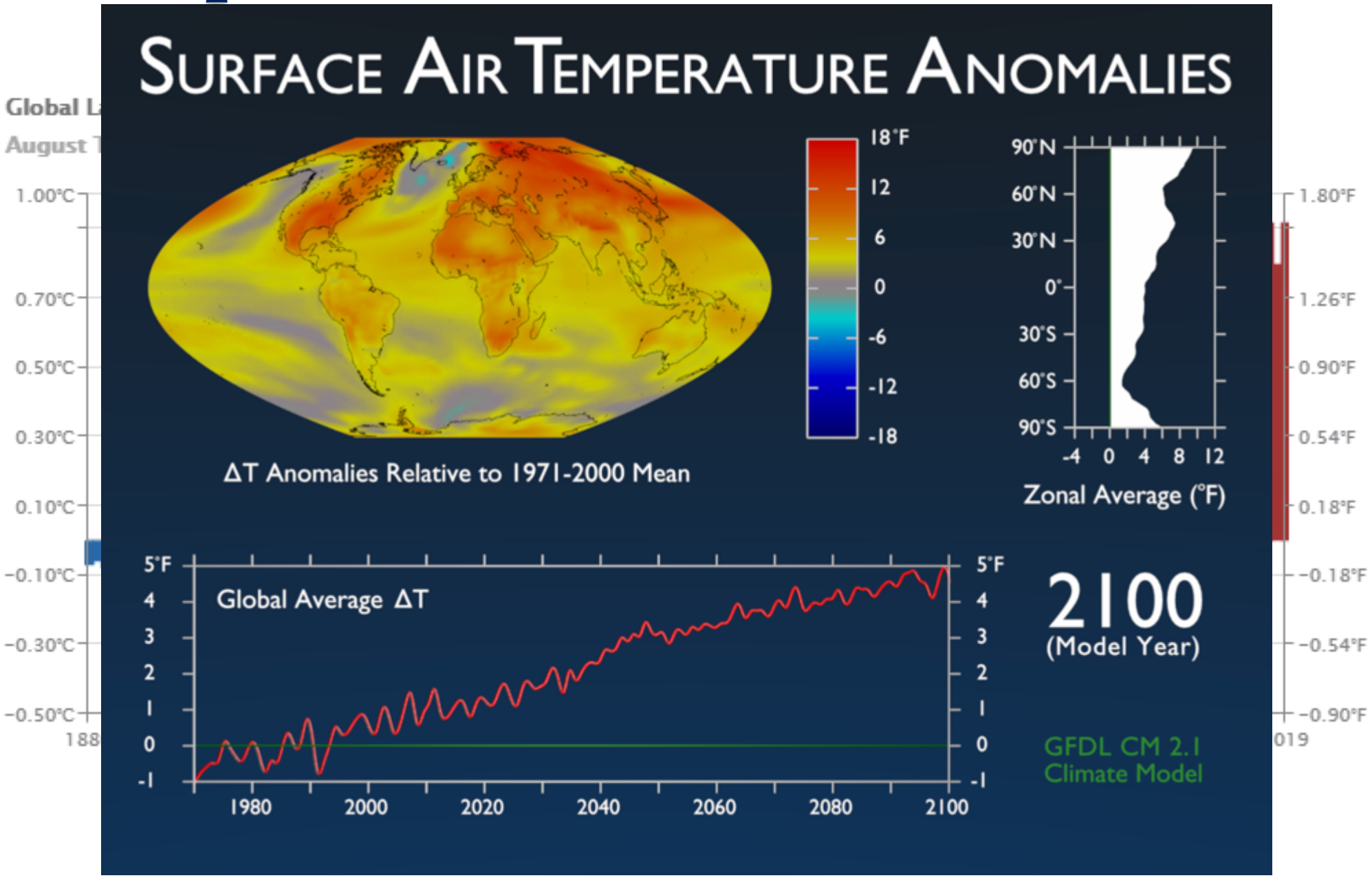
While You Wait

- Read about the 2020 Urban Heat Island City Funding Opportunity and Apply
- See results from previous Urban Heat Island Campaigns.
- Sign up for the Heat Beat newsletter to keep up with the campaigns this summer.

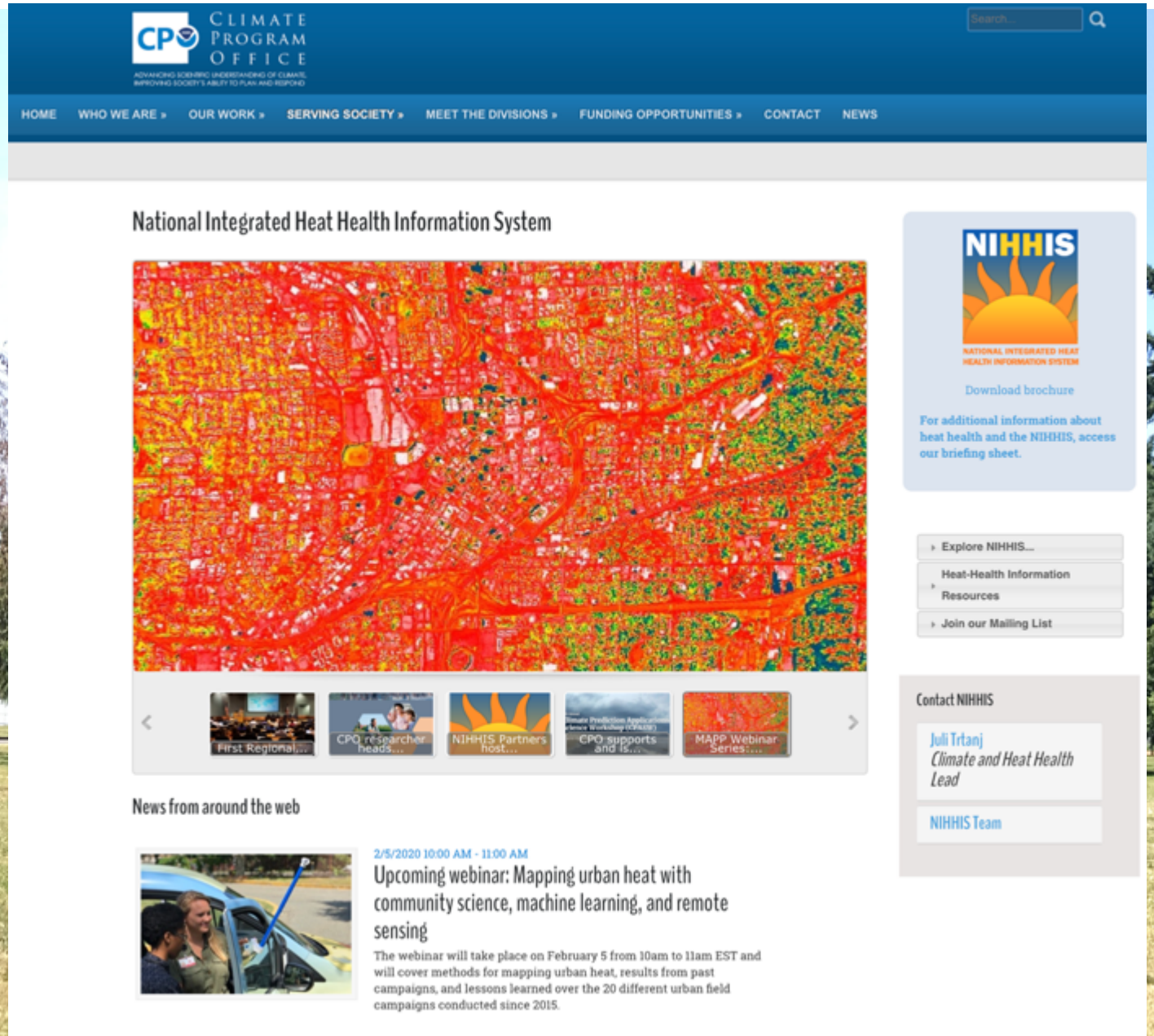
nihhis.cpo.noaa.gov

CAPA HEAT WATCH | NOAA | NIHHIS

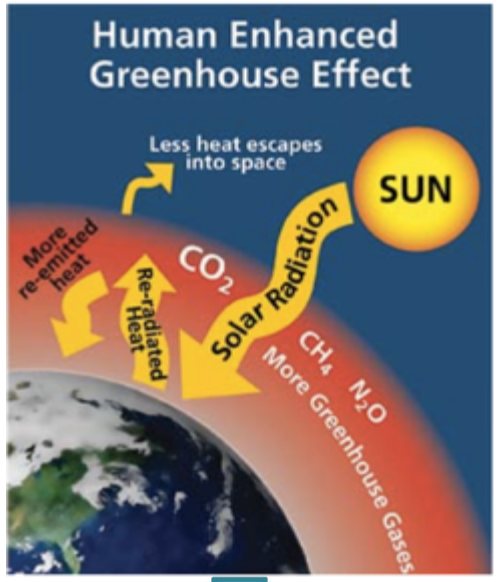
Temperatures and Anomalies on the Rise!



Heat and Local Impacts



Climate Change and Health



REGIONAL WEATHER CHANGES:

Extreme weather

Temperature variability

Precipitation variability

Moderating influences

Exposure levels

Contamination pathways

Transmission dynamics

Adaptation measures

HEALTH EFFECTS

Heat-related illness & death

Flood and storm-related health effects

Air pollution effects

Water- and food borne diseases

Vector-borne and rodent-borne disease

Urban Heat Assessments: A 137 Year History

- Research motivations have changed over time
  i. Historically: Observe differences between city and surrounding areas
  ii. Current: Describe the causes for differences within and across cities

- Measuring progress
  i. Development and use of methodological standards
  ii. Effective application of findings to planning tools, and design guidelines for mitigation
  iii. Opps for climate change adaptation

Author name	Year of publication	Language of publication	City or region studied
L. Howard	1833	English	London (U.K.)
É. Renou	1868	French	Paris (France)
J. Hann	1885	German	Europe, India, USA
M. Moreno	1899	Spanish	Mexico City (Mexico)
W. Hammon & F. Duenckel	1902	English	St. Louis (USA)
W. Schmidt	1927	German	Vienna (Austria)
A. Treibich	1927	German	Berlin (Germany)
A. Peppler	1929	German	Karlsruhe (Germany)
C. Brooks	1931	English	Springfield (USA)
L. Besson	1931	French	Paris (France)
K. Sasakura	1931	Japanese	Tokyo (Japan)
A. Budel & J. Wolf	1933	German	Munich (Germany)
H. Berg & H. Metzler	1934	German	Hanover (Germany)
W. Middleton & F. Millar	1936	English	Toronto (Canada)
E. Fukui & N. Wada	1941	Japanese	Tokyo, Osaka, Nagoya (Japan)
W. Balchin & N. Pye	1947	English	Bath (U.K.)
Å. Sundborg	1951	English	Uppsala (Sweden)
F. Duckworth & J. Sandberg	1954	English	San Francisco (USA)
E. Einarsson & A. Lowe	1955	English	Winnipeg (Canada)
H. Shitara	1957	Japanese	Hiroshima (Japan)
M. Takahashi	1959	Japanese	Ogaki, Kumagaya (Japan)
T. Chandler	1960	English	London (U.K.)
I. Kayane	1960	Japanese	Tokyo (Japan)
T. Sekiguti	1963	Japanese	Ogaki (Japan)
T. Kawamura	1964	Japanese	Kumagaya (Japan)
T. Chandler	1965	English	London (U.K.)
S. Nieuwolt	1966	English	Singapore
K. Nakamura	1966	Japanese	Nairobi (Kenya)
E. Fukui	1968	Japanese	Japan
F. Ludwig	1970	English	Dallas (USA)
Y. Goldreich	1970	English	Johannesburg (South Africa)
S. Sham	1972	English	Kuala Lumpur (Malaysia)
C. Daniel & K. Krishnamurthy	1973	English	Pune, Mumbai (India)
E. Jáuregui	1973	English	Mexico City (Mexico)
T. Oke	1973	English	St. Lawrence Lowland (Canada)
T. Oke & G. Maxwell	1975	English	Vancouver, Montreal (Canada)

Source: Stewart I., 2019. The relevance of history in contemporary urban heat island research. *Urban Climate News*, 74.

Examining the Sun's Heating of Earth

Short Wave Radiation Budget

Warm the Surface

↓

Ground Heat (G)

Warms the Air

↓

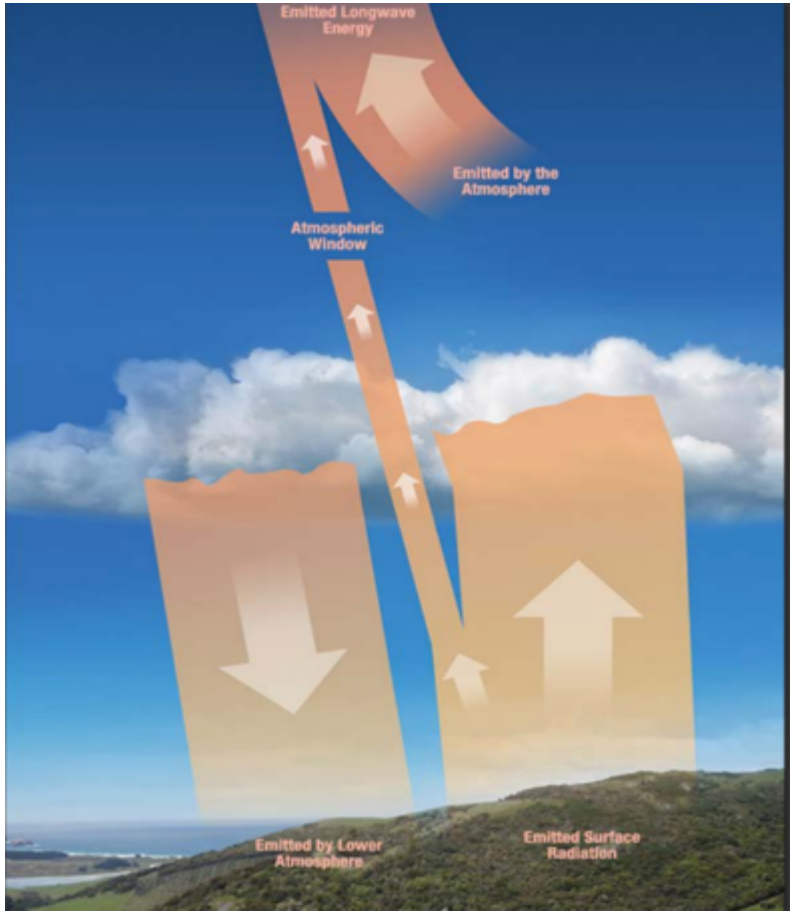
Sensible Heat (H)

Evaporates Water

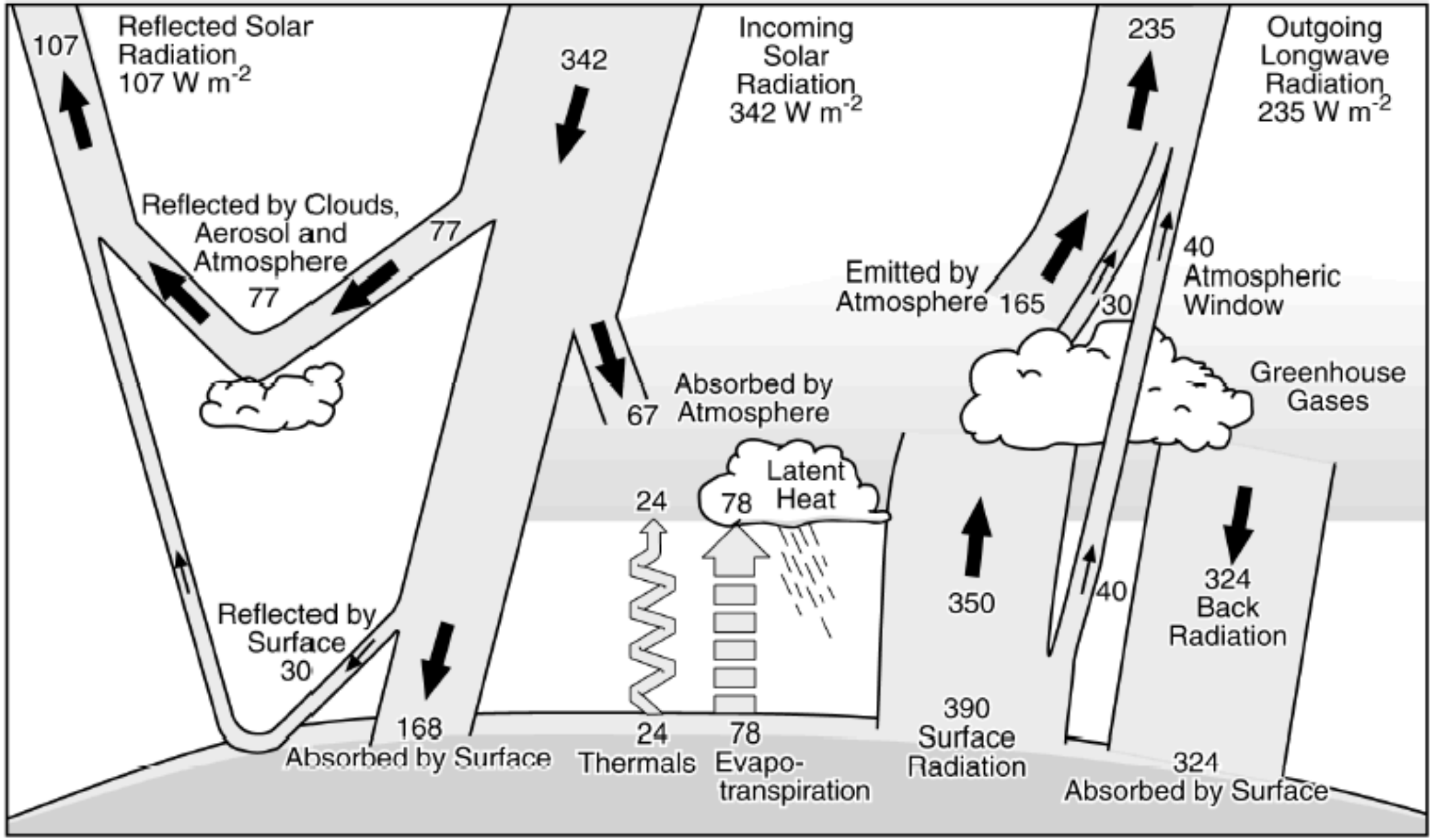
↓

Latent Heat (L)

Long Wave Radiation Budget

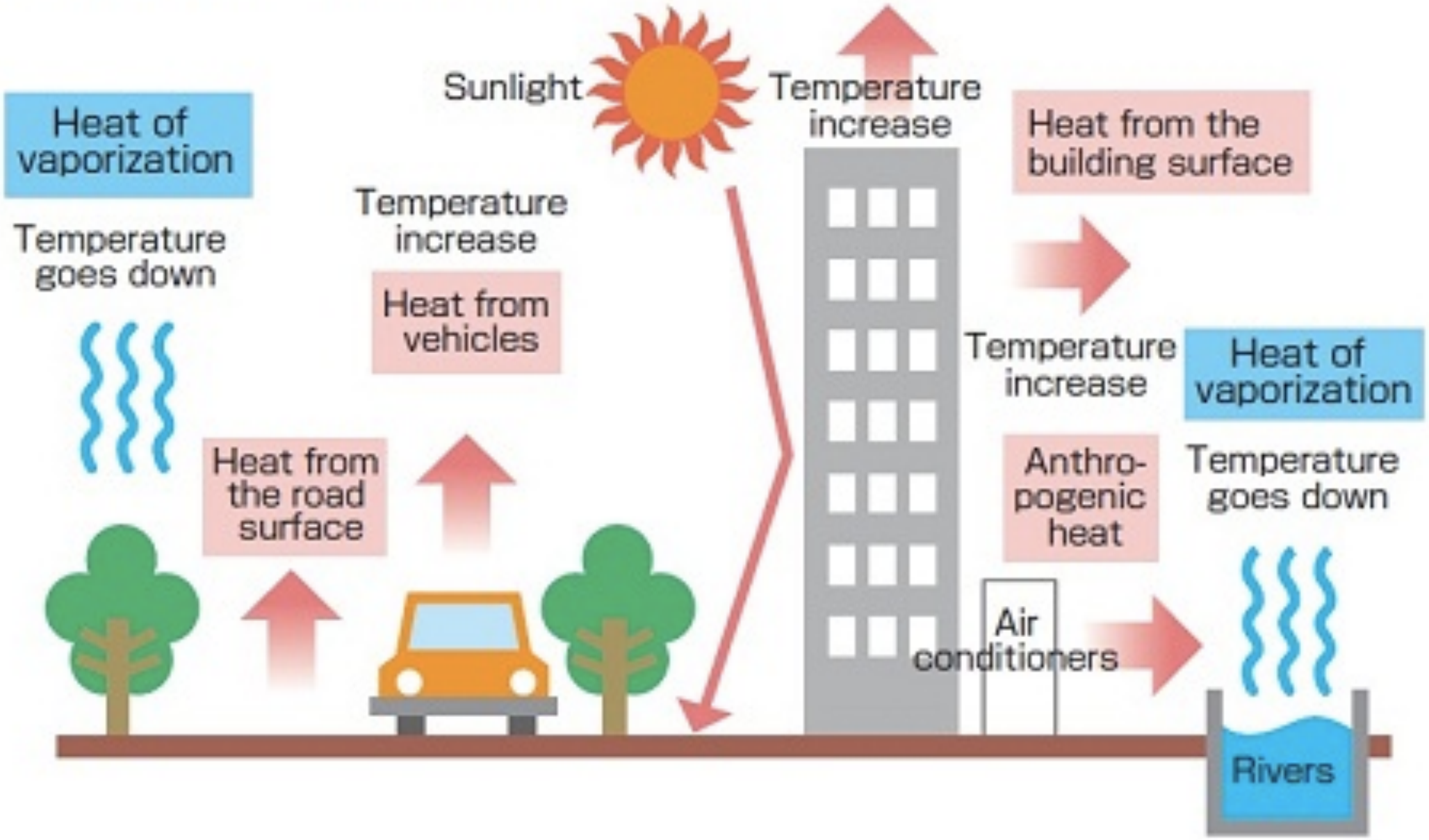


Solar-Earth Interactions



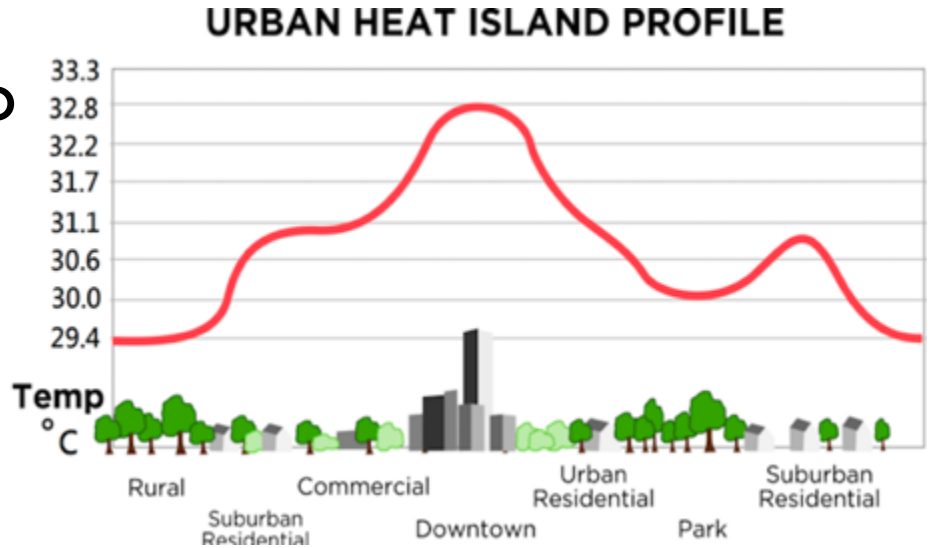
Source: http://stephenschneider.stanford.edu/graphics/EarthsEnergyBalance.png

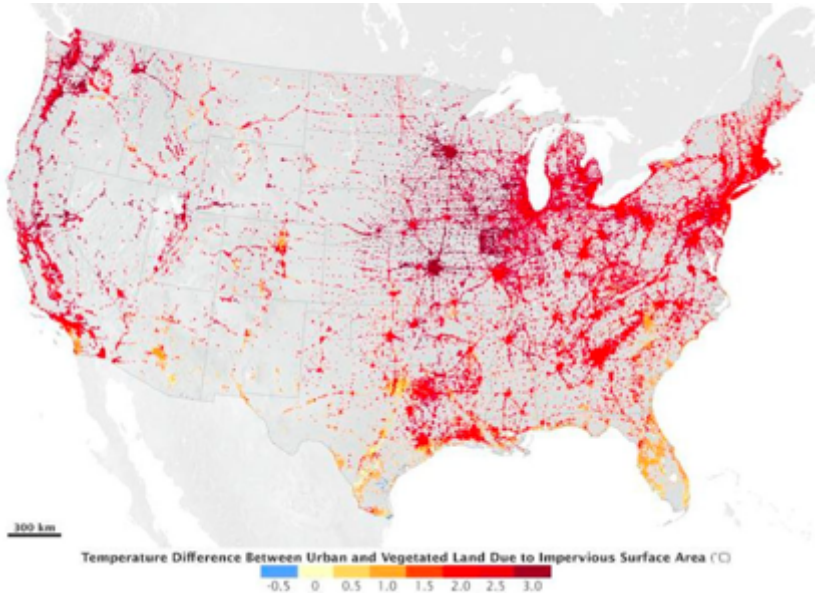
Solar-City Interactions



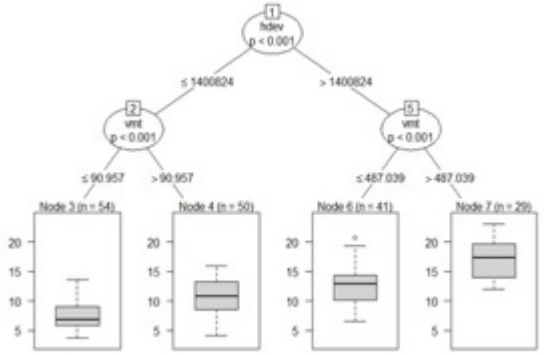
Common Descriptions of the UHI

1. Traditional use of a ‘reference site’ to assess urban temps (Chandler, 1965; Landsberg, 1979)
   1. Use of weather stations (spatial)
   2. Nighttime differences (temporal)
2. Satellite description of the land surface temperature (LST)
   1. Atmospheric brightness & emissivity
3. Integrating satellite with ground-based measurements
   i. Aim of developing a predictive model for air temperatures





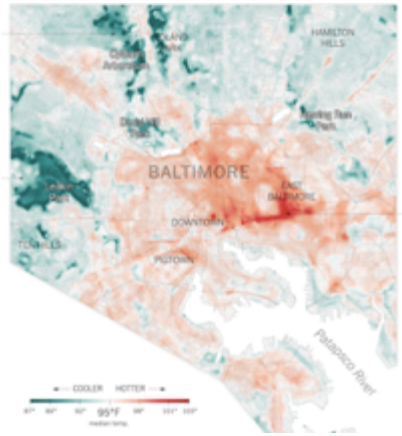
Community-Based Heat Assessments



Community Engagement

Field Campaign & Data Science

Climate Resiliency Planning



Preparation → Execution → Interpretation

- City Organizer recruits 20-40 volunteers
- Organizer/volunteer designs driving route for each study area
- CAPA trains volunteers on equipment usage & driving/biking route

CAPA HEAT WATCH

brought to you by CAPA Strategies

Feeling the heat in your region?

Climate is changing, and **our planet is getting warmer**. Urban areas are especially prone to high temperatures due to a combination of hard surfaces (buildings, roads), limited vegetation, and heat-producing factors like car use and industrial activity. Heat can create issues for **human health, urban infrastructure, and quality of life**. Climate change is a global problem, but **there are steps you can take** to plan for and combat rising temperatures in your region.

Seeking volunteers

The CAPA Heat Watch program measures **distribution and intensity of temperature** where you live. Your region has decided to participate in a CAPA heat campaign and **we need your help!** As a volunteer, you'll play a key role in collecting temperature data. Using specialized equipment, you'll drive around the region logging thousands of temperature data points. After the campaign, we will **process, analyze and visualize the data** you've collected. This information can help your region plan for the future, and direct needed relief to the hottest parts of the region. It is also a great opportunity to share your concerns regarding urban heat and climate change with supportive organizations.

What you'll do

As a volunteer, you will be asked to participate in two key activities:

1. Attend a training session webinar with the CAPA team (1.5 hours)

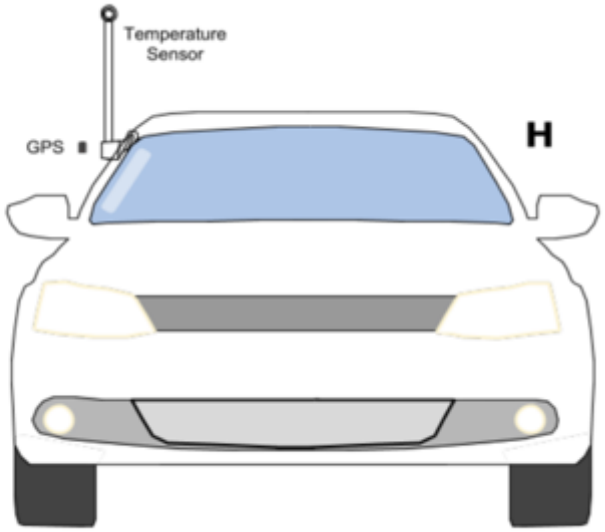
2. Drive a pre-determined route through the city 3 times on the day of the campaign (each outing will take 1 hour; these will occur at 6 a.m., 3 p.m., and 7 p.m.)

Drivers will need a valid driver's license, access to a vehicle and auto insurance. Don't have those things? No problem! You may be able to participate as an in-car navigator and give directions. Volunteers will be compensated with a $50 stipend per trip.

To learn more about the CAPA Heat Watch Program or to sign up as a volunteer, contact your local campaign organizer Grey Kolevzon Tel. 510-776-5556 Email greyloom@gmail.com or fill out the Sign-Up Sheet here: https://forms.gle/rVKw5KswWHh9MDVd8

Preparation → **Execution** → Interpretation

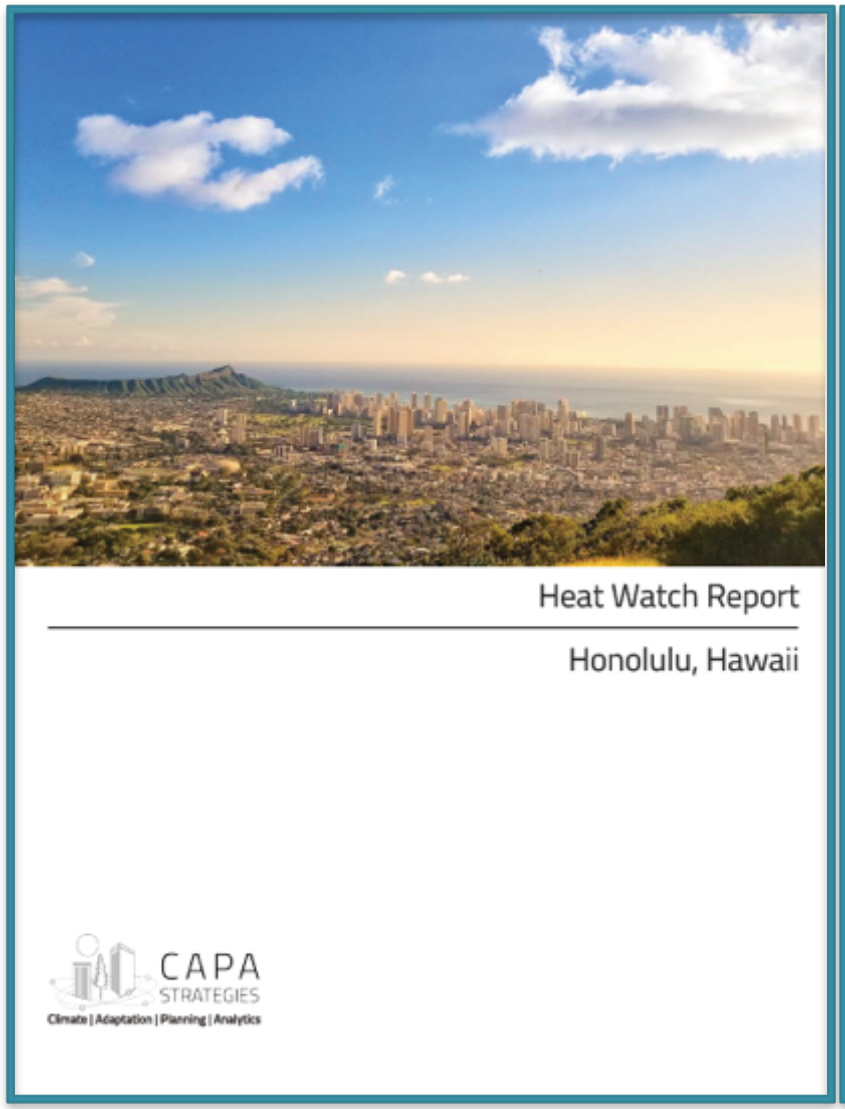
- Volunteers drive/bike at 6am, 3pm, 7pm
- Navigators direct driving turns and operate equipment (on/off)
- Volunteers return equipment and debrief

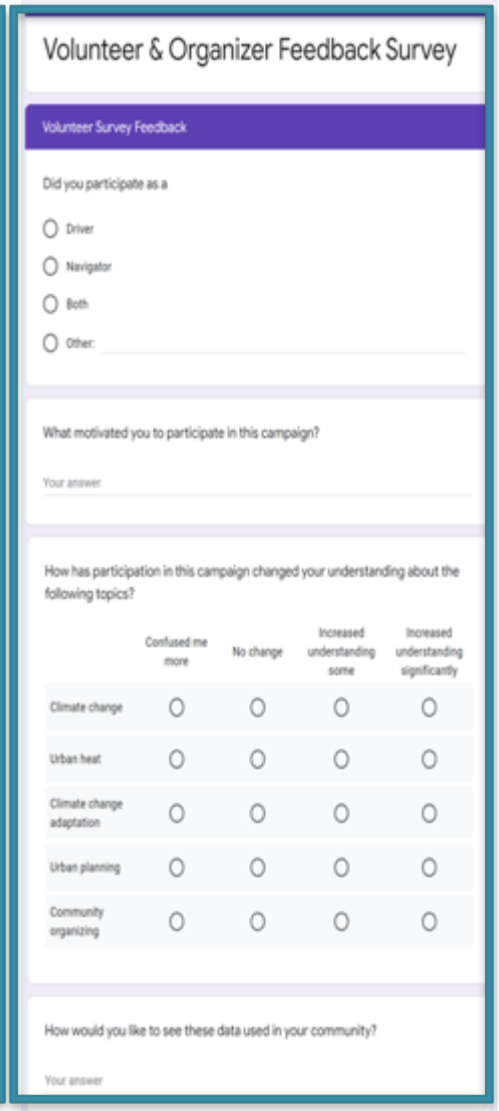


SCIENCE IN PROGRESS
Learn more at CAPAstrategies.com

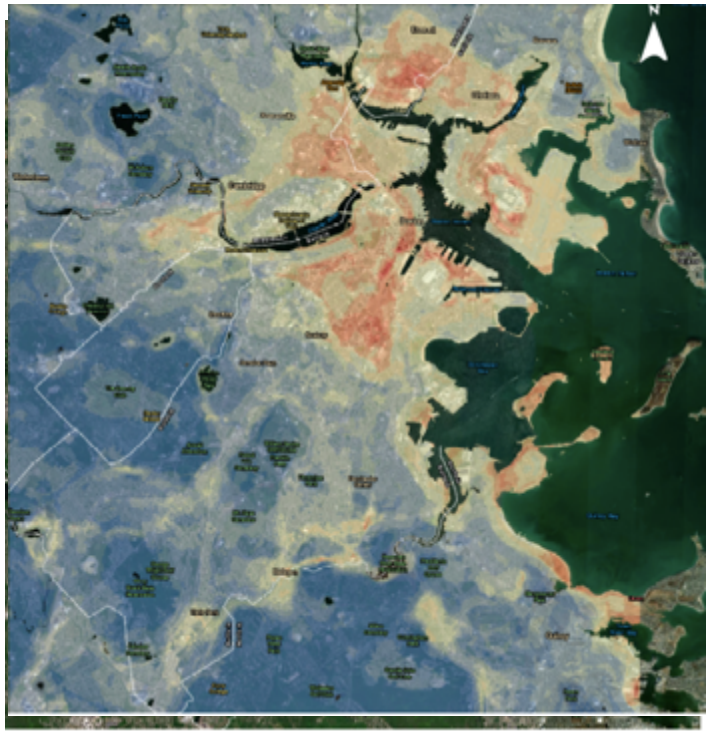
Preparation → Execution → **Interpretation**

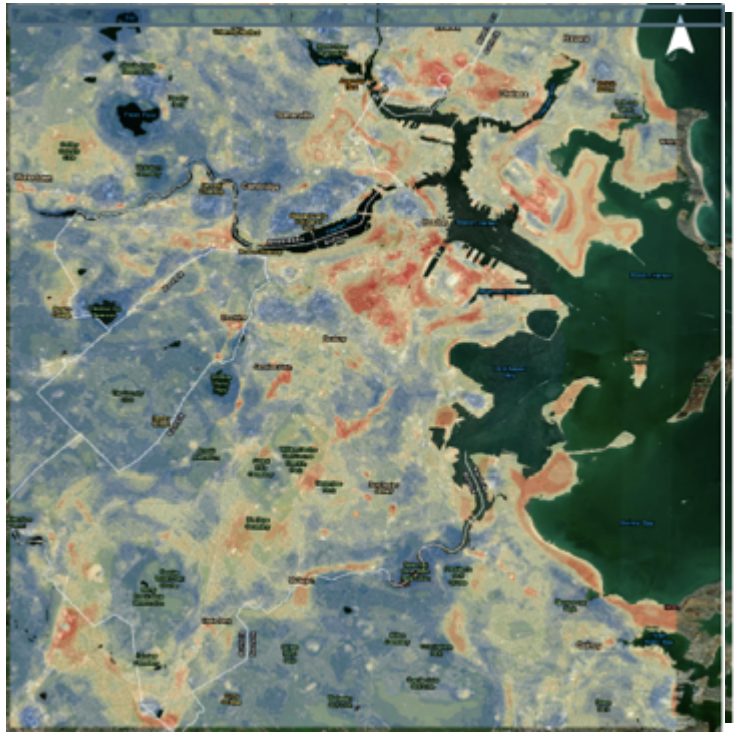
- Report sent, and community interpretation of results
- Follow-up survey: participant experience & interest in climate issues
- Potential for additional services/studies

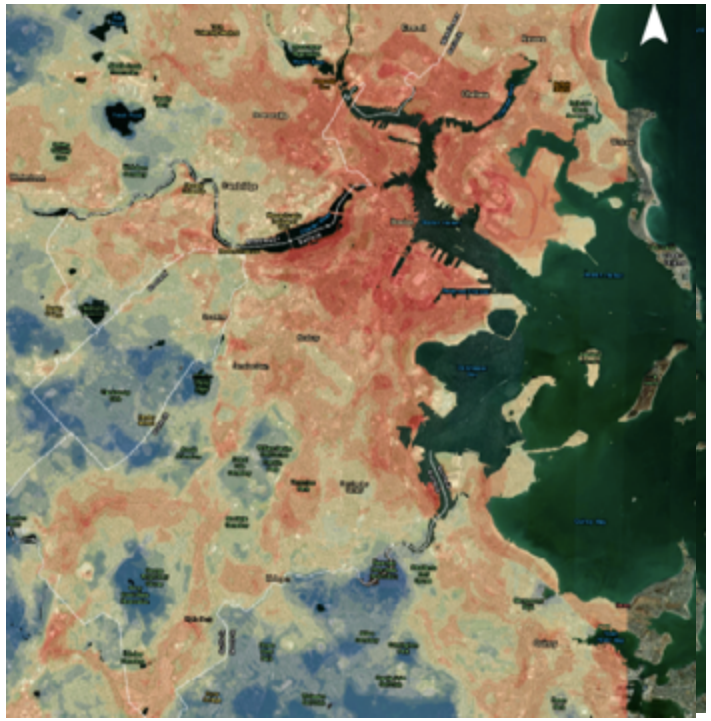




Outputs: City of Boston (MA, 2019)







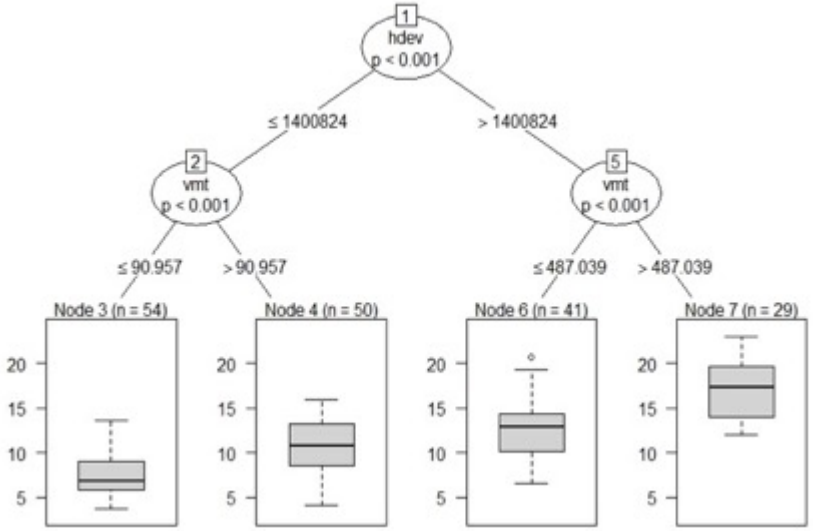
On July 29th and 30th, 2019, volunteers traversed ten study areas across Boston, Cambridge, and Brookline. The maximum heat measured during the traverses was 102.3 degrees Fahrenheit (near Boston Harbor), with a highest concurrent heat differential of 15 degrees.

Temperature and Heat Index Stats

Traverse	Temperature			Heat Index		
	MIN	MAX	MEAN	MIN	MAX	MEAN
6 - 7 am	71.8 F	82.7 F	74.5 F	73.0 F	87.7 F	75.8 F
3 - 4 pm	87.3 F	102.3 F	90.8 F	91.0 F	108.9 F	96.1 F
7 - 8 pm	78.7 F	91.1 F	84.0 F	80.5 F	97.7 F	88.9 F

Machine Learning: Random Forest

- Integrate ground-based measurements with satellite imagery
  i. Satellite bands provide descriptions about land cover
  ii. Diversity of land covers provide variation in temperature measurements
- Identify best predictors of temperatures across all land covers
  i. Use predictors to develop temperature surfaces
  ii. Temperature estimation is based on land covers traversed
- Advantages over geospatial interpolation
  - Takes into account what is on the ground, as opposed to directly statistical estimation



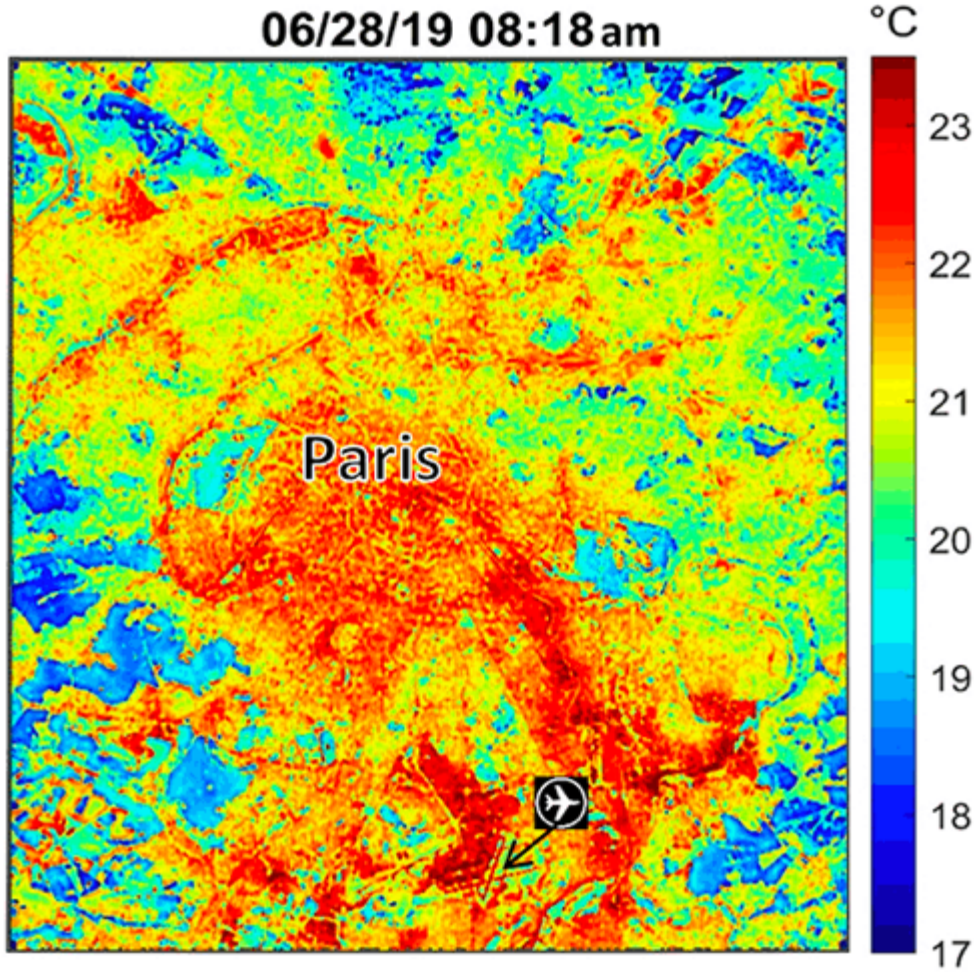
Satellite-Based Measurements

Strengths

1. Freely available across the world
2. Seasonal availability
3. Intra-urban variation detectable
4. Extensive literature and research
5. Potential connections to land use

Weaknesses

1. Exaggerates temperature ranges
2. Coarse pixel size (30m, 90m, 1km…)
3. Rooftops as opposed to street-level
4. Discrete differences between land covers
5. Translation to policy remains unclear



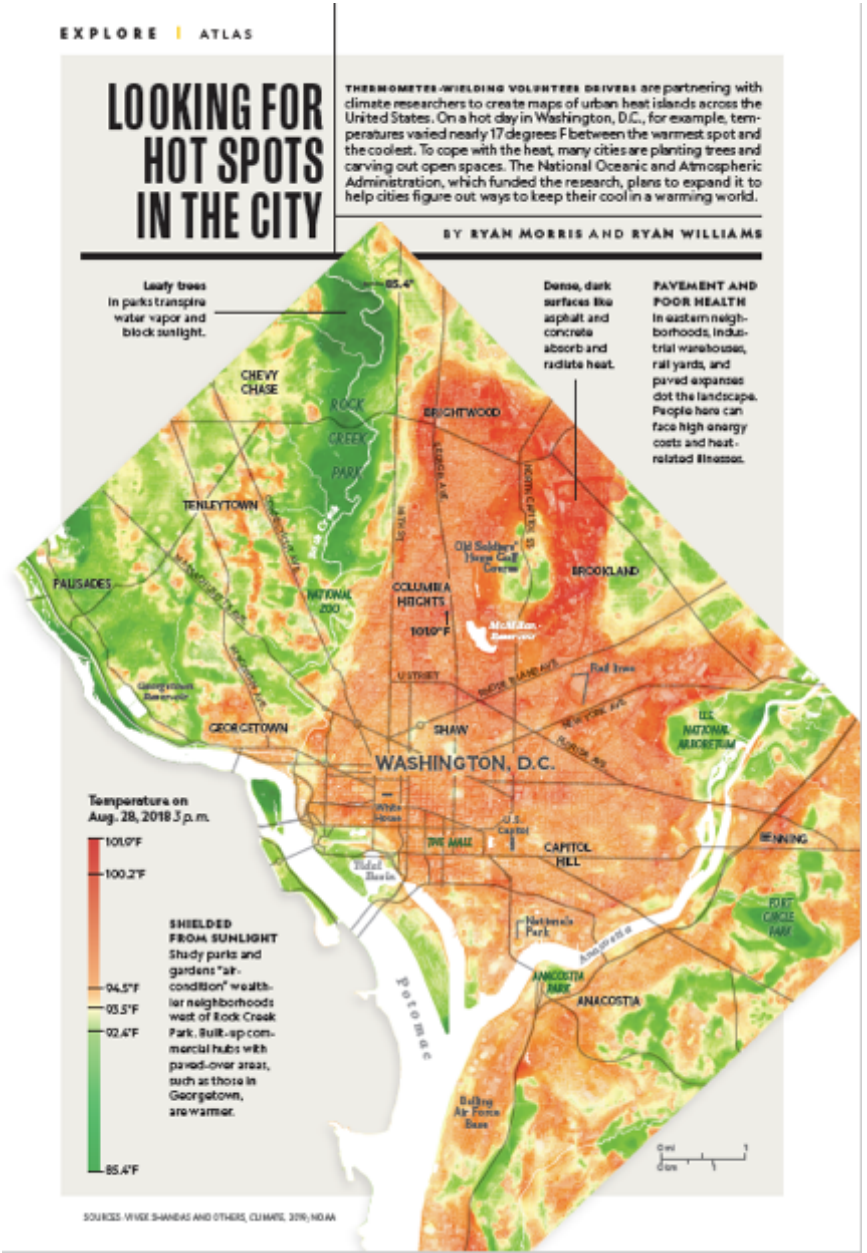
Ground-Based Measurements

Strengths

1. Engages community in their place
2. Established 'civic legitimacy' of scientific process and results
3. High resolution outputs (1m, 10m)
4. Diurnal profile of air temperatures
5. Policy applications are evident

Weaknesses

1. Coordination of local community groups requires time and strategy
2. Not free due to engagement and analysis
3. Seasonal differences not [yet] available
4. Clouds or rain can create delays
5. Generalizable models are still forthcoming



Richmond (VA): Heat Vulnerability

Sustainability & Resiliency

Preparing and responding to a changing climate

Community Greenhouse Gas emissions have decreased by 15%.

From 2008 to 2015, community GHG emissions decreased by 15%. The City's goal is to decrease community-wide Greenhouse Gas (GHG) emissions by 80% by 2050 using 2008 as the baseline year. *RVAgreen 2050* is Richmond's planning process to develop a roadmap of actions to achieve Richmond's 80% reduction by 2050.

63% of GHG emissions are from the residential and commercial sectors.

In 2015, 40% of community GHG emissions were from commercial buildings, 24% from the transportation sector, 23% from residential buildings, and 11% from industrial facilities. 50% of community GHG emissions in 2015 resulted from the use of electricity, 24% from gasoline/diesel and 22% from natural gas. Overall energy consumption in Richmond decreased by 2% between 2008 and 2015.

Renewable energy is changing the Richmond landscape

In 2017, Richmond achieved SolSmart[1] Silver designation for its efforts to provide resources and reduce barriers to make it faster, easier and less expensive for the community to go solar. While only accounting for 0.08% of the total energy supply, the production of solar energy has increased by nearly 450 times between 2008 and 2015. Analysis by VCU's Center for Urban and Regional Analysis shows great potential for rooftop solar panels to produce up to 12% of the city's energy demand; however, the electricity distribution and energy storage infrastructure would need to be significantly upgraded to accommodate that much solar energy.

There has been a slight increase in vehicle miles traveled since 2008.

Vehicle miles traveled (VMT) is an indicator that policy makers track to understand how much people are driving and estimate how many greenhouse gases are produced by vehicles. Total VMT increased from 2008 to 2015 by 0.2%.

The number of days over 95° is likely to increase by 30 days annually.

According to the Science Museum of Virginia, the city already experiences 9 more days above 90 degrees annually than surrounding rural areas. Climate models predict that Richmond could experience nearly 30 more days above 95 degrees annually. Per the Science Museum of Virginia, "As extreme summertime temperatures in the City of Richmond have been linked with urban heat vulnerability and visits to urgent care centers and emergency departments for heat-related illnesses in 2016, the urban heat island effect is not only an infrastructural challenge and an environmental equity issue, but also an important public health issue."

Major rain events are expected to increase by more than 25%.

According to the Science Museum of Virginia, from 1948 to 2011, "Virginia saw a 33% increase in the frequency of extreme rainfall events and an 11% increase in the amount of rain falling in its largest annual storms." The number of extreme rain events is expected to increase by two and a half times. Given the environmental constraints and large amount of paved surface in Richmond, planning for increased intensity and frequency of rain events is critical.

Richmonders are very vulnerable to urban heat.

Urban heat vulnerability is a term used to describe an area's conditions that make it more or less sensitive to heat. Currently, 21.5% of Richmonders live in Census tracts designated as "highest" in terms of urban heat vulnerability, while 19.6% live in Census tracts designated as "high". These areas correspond with some of the densest areas of the city.

Heat-related illness is highly concentrated.

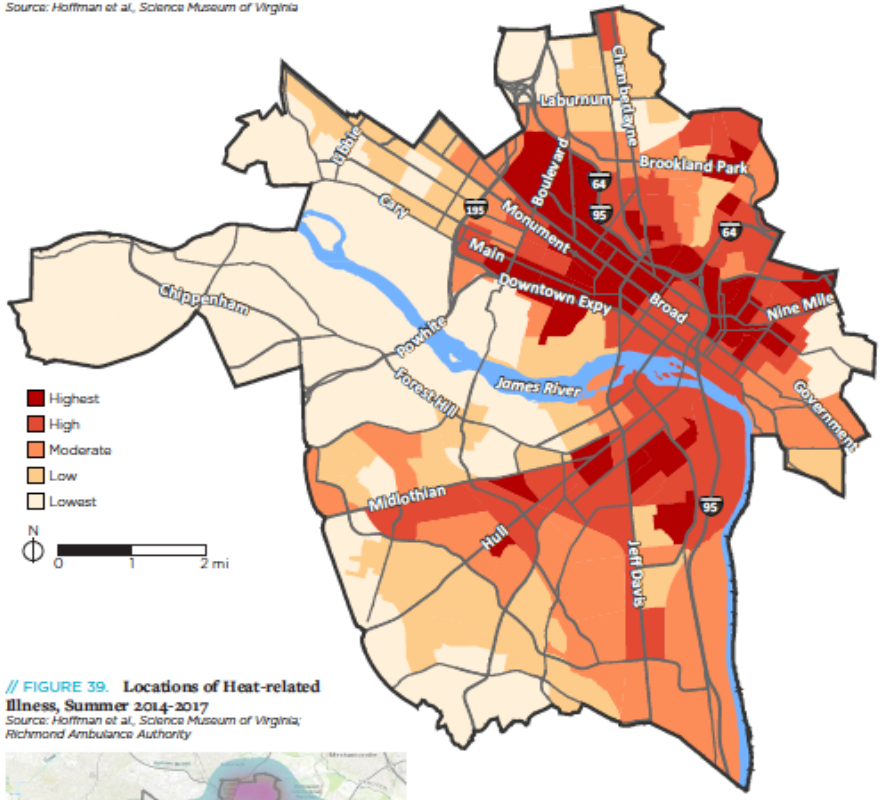
Heat-related illness in the summer is highly concentrated in areas with "high" and "highest" urban heat vulnerability and areas that are poor.

1 *SolSmart is a program of the Department of Energy and National League of Cities.*

// FIGURE 38. **Urban Heat Vulnerability, 2017**

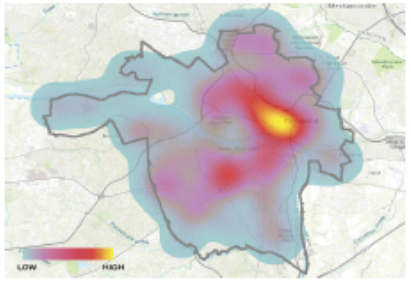
Urban heat vulnerability is a term used to describe an area's conditions that make it heat sensitive using a combination of % tree canopy, % impervious surfaces, % families in poverty, and the amount of afternoon warming during a heat event.

Source: Hoffman et al., Science Museum of Virginia



// FIGURE 39. **Locations of Heat-related Illness, Summer 2014-2017**

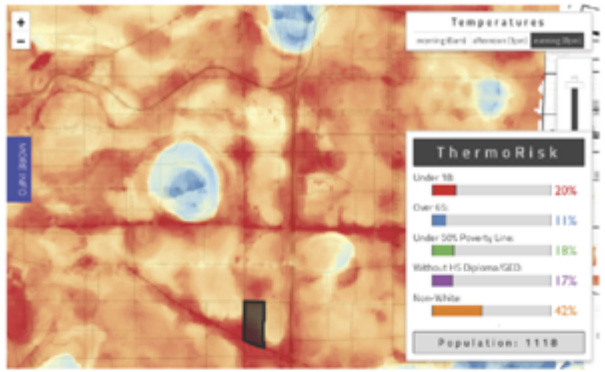
Source: Hoffman et al., Science Museum of Virginia; Richmond Ambulance Authority



Consider this:

- How can we prepare for the effects of climate change?
- How do we ensure the most vulnerable populations are included in creating solutions to mitigate the effects of climate change?

Development of Decision Support Tools

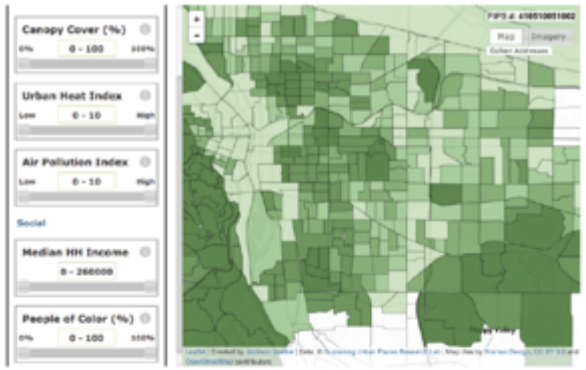


Social Vulnerability

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.

Scenarios of Changing the Built Environment

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 up to an entire city.

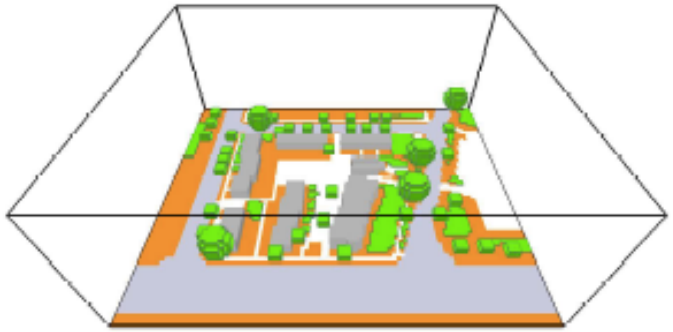


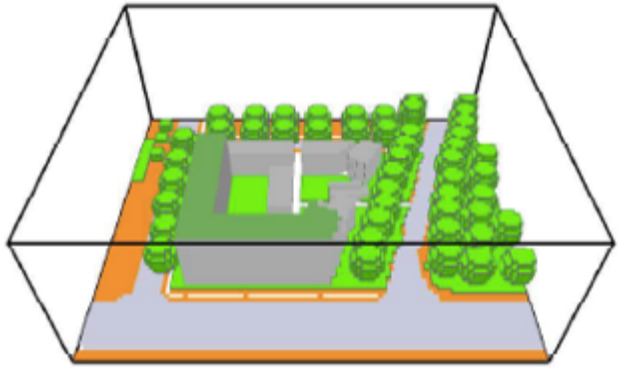
Branch Out

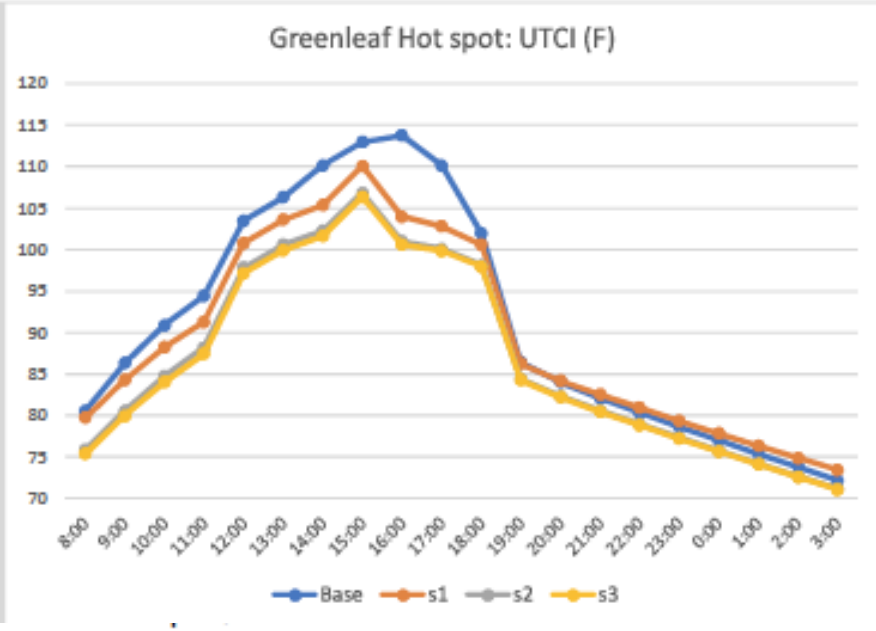
This tool serves as a planting map to identify areas where expanding tree canopy will have direct benefit to social and environmental conditions. By using publicly available data along with socio-demographics, land use, and other datasets, each neighborhood is described in terms of the potential plantable locations.

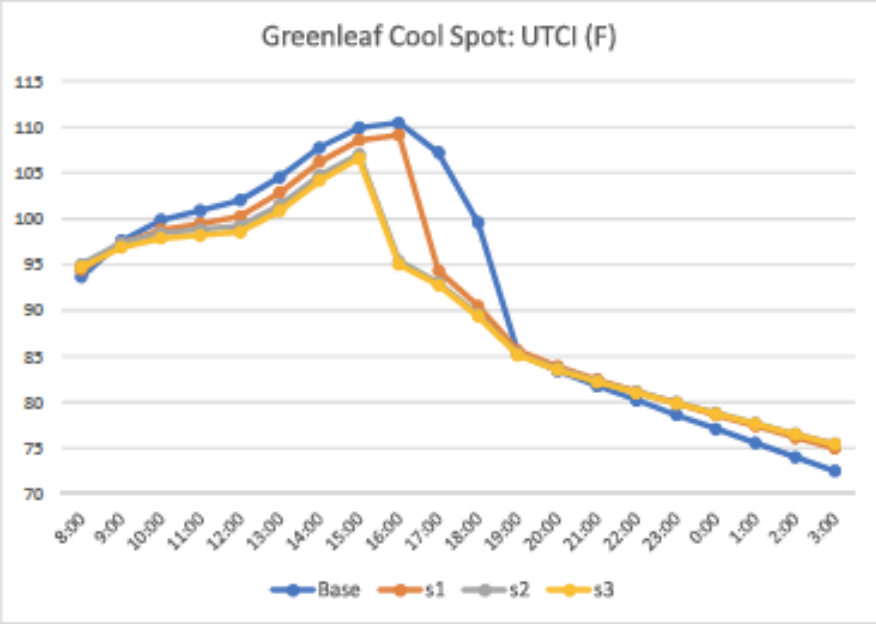
www.capainsights.com/branchout

District of Columbia Extensions: Land Use Change









Climate Adaptation Planning & Analytics (CAPA)

URBAN HEAT WATCH

Engage communities in describing and localizing climate-induced hazards

URBAN INSIGHTS

Develop analytical tools for examining scenarios of adaption actions

GROWING CAPACITY

Support capacity building efforts through engaging decision makers and community groups

Mapping Urban Heat with Community Science, Machine Learning, and Remote Sensing

Contact

vs@capastrategies.com

www.capastrategies.com

Remember to….

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