GIS Workflows For Urban Heat Mapping

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Webinar Objectives

How can GIS be efficiently and effectively used in identifying and analyzing urban extreme heat? What are some workflows, data sources, and tools that can be used?

Where does extreme heat occur, how does tree cover affect heat, who are the vulnerable populations affected?

Audience: University students, GIS professionals, Urban planners/designers (key stakeholders in a city), others.
Very Happy to be Collaborating!

• First of a series of Webinars, leading to a Workshop at GIS Pro (Portland, Maine)
Our World
Is Now Being Challenged

- Steep Decline in Biodiversity
- Pollution
- Population Growth
- Water Crises
- Natural Disasters
- Wildfires
- Social Conflict
- Food Shortages
- CO₂ Levels 1960–2020
- Loss of Nature
- Ecological Instability
- Pollution
- Unconstrained Development

Humans Are Living Recklessly . . . Beyond Our Means . . . Unsustainably

- Ocean Warming
- Severe Droughts
- Human-Induced Climate Changes
- Unconstrained Development
Climate Mapping for Resilience and Adaptation (CMRA)
Extreme Heat
A concern we all share…

- Affects Agriculture
- Affects Public Health
- Affects Economic Productivity

Europe’s first chief heat officer warns our cities are not prepared for what’s coming

From painting apartment blocks in light colours to reusing wastewater, Athens’ former heat guru Eleni Myrivill explains how cities can adapt to rising temperatures.

Excessive Heat Will Hit Resource-strapped Cities and the Urban Poor the Hardest

Cities with the least resources to adapt will be among the hardest hit by higher levels of warming.

While cities on average will experience 29 more extremely hot days under 3 degrees C of warming vs. 1.5 degrees C, the difference is greater for cities in less developed and lower-income regions. In South Asia, it’s 40 days; Sub-Saharan Africa, 38 days; Latin America and Caribbean, 34 days. For cities in lower-middle-income countries, 38 days; low-income countries, 34 days. These are often cities that are also growing rapidly and lack the fiscal and institutional capacity to adapt.

Days per year that max temperature exceeds 35° C (95° F), by city

Using global scale IPCC projections
The affected cities are ‘creeping North’ (and South)
Extreme Heat Plans
How to prioritize efforts; Data-driven decisions; Storytelling

GOAL 3: Cool our neighborhoods. Reduce the excessive heat burden in urban areas by expanding the tree canopy and vegetation, improving access to water features and shade structures, and cooling our surfaces.

12. INCORPORATE EXTREME HEAT IN COUNTYWIDE RESILIANCE HUB PLAN.

13. CREATE A BOLD TREE PLAN.

14. COOL OUR COMMUTES.

15. COOL OUR SCHOOLS.

16. EXPAND ACCESS TO WATER AND SHADE.

17. PLANT AND PROTECT TREES ON COUNTY LAND.

18. PILOT AND SCALE COOL PAVEMENTS.

19. RAMP UP ENGAGEMENT AND CITIZEN SCIENCE.

Arizona 2024

Miami 2022
ArcGIS can contribute to Extreme Heat Plans
For data-driven decisions

• WHERE (and When) is there Extreme Heat?
  - Advanced step: WHERE might it be in the future?

• WHERE are there nature-based solutions/aids?
  - Tree canopy cover, Water, Green spaces, Shadows/Shade, …

• WHERE are the Populations affected?
  - Raw population, Vulnerable populations
  - Census and other survey data, Satellite-based pop estimates

• WHERE is Remedial Action possible/optimal
  - Mobile Cooling Centers, Landuse Changes, Transportation Changes,…
Web GIS is the Key

• Discover valuable data sets, in government portals (Hubs)
  - And on the Living Atlas of the World

• Publish your own data layers and apps:
  - On ArcGIS Online
  - In ArcGIS Hubs
  - Also contribute to the Living Atlas

• The Value of the Web increases through Contributions!
Analysis, then Tell your Story
A form of Climate Action

• StoryMaps
• Apps
• Dashboards
Urban Heat Equity

Urban heat and equity

These conditions also disproportionately affect low-income neighborhoods and communities of color where green spaces, tree cover, and access to cooling infrastructure may be limited or absent due to historic underinvestment. When overlaid with historical weathering data, these patterns of disinvestment are put into a temporal context that can be handed back to future generations.

Shade Equity Analysis

Improving cities through green infrastructure
Basic Workflow

A. Identify heat (surface temperature)
B. Identify tree cover
C. Identify population affected
D. Create and map (a weighted) index of the three variables

• Other variables can be added for deeper investigations. These deeper investigations will be explored in upcoming curricular materials and webinars.
Similar workflow in Pro and Online (CAPA data)
ArcGIS Living Atlas apps

Drought Aware, Water Balance, Land Cover Change, Landsat Explorer

In the current map display, the most recent and most cloud free scenes from the Landsat archive are prioritized and dynamically fused into a single mosaicked image layer. As you explore, the map continues to dynamically fetch and render the best available scenes.

To select a scene for a specific date, try the FIND A SCENE mode.
Build A Heat Risk Index for Local Climate Planning: Part 1 of 3
Build a Heat Risk Index for Local Climate Planning: Part 2 of 3

Imagery & Remote Sensing
December 12, 2022

Mark Gilbert
Build a Heat Risk Index for Local Climate Planning: Part 3 of 3

Imagery & Remote Sensing
December 14, 2022

Mark Gilbert
Identifying Heat

- Thermal infrared bands of satellite imagery
  - Landsat, ASTER
- And/or in situ sensors…
  - CAPA is 10m res.
Surface Temp: From Landsat

- Thermal (TIR) Bands 10,11
- Resampled at 30m
- Land Surface Temp (LST)
  - Hot to the touch
  - Not ambient temp
  - But a good global proxy
- Landsat Level 2 imagery available on the Living Atlas of the World
- Which image to use?
  - Landsat Explorer!
NOAA Urban Heat Island Campaign data

So-called CAPA data

NOAA Urban Heat Island campaign to map temperatures has been summarized by neighborhood and includes environmental and demographic information.

Description

Cities in the U.S. are getting hotter, and that is causing significant health risks, especially to minorities, the elderly, and impoverished. There is significant spatial variation in temperature across a city due to changes in the landscape (elevation, tree cover, development, etc).

NOAA has been engaged in a nationwide effort with CAPA Strategies to use a combination of Sentinel-2 satellite data along with temperature readings recorded from car- and bike-mounted sensors to generate detailed maps of the urban areas most impacted by heat. These measurements have been combined into single raster layers for morning, afternoon, and evening temperatures. As of 2020, 27 cities (26 in the U.S) have been mapped; a total of 50 cities will be mapped by the end of 2021.

This layer shows the census tract (neighborhood) averages for those temperatures, along with additional information calculated for each neighborhood including:
Map and analyze the urban heat island effect

Visualize the urban heat island effect in Richmond, Virginia, using analysis tools in ArcGIS Online and share your results using ArcGIS Dashboards.

Authors: Chris Messerich, Jess Altamira, and Phoebe Gelbard  
Difficulty: Intermediate
Afternoon Heat Index in Cities - Urban Heat Islands

Summary


Urban heat islands are small areas where temperatures are unnaturally high - usually due to dense buildings, expansive hard surfaces, or a lack of tree cover or greenspace. People living in these communities are exposed to more dangerous conditions, especially as daytime high and nighttime low temperatures rise.

Details

- Imagery Dataset
- Image Service
- August 2, 2023
- Info Updated August 2, 2023
Identifying Tree Cover

- Classified landcover images
- NAIP and other imagery
- UAVs
Population Data

Who is affected by extreme heat?

- Raw population
- And specific cohorts
- ACS in the US
- Esri demographic data
  - “Enrichment”
- Michael Bauer data
- WorldPop global data
Athens case (graduate students)
Customize a climate resilience index

Use the Composite Index tool to create an index showing where extreme heat mitigation is needed.

Extreme heat is just one of many hazards exacerbated by climate change. High temperatures can cause or worsen health conditions, including heat exhaustion, and the hazard is especially intensified in urban areas due to the urban
Composite Indices
Several learning resources created

• Technical Paper PDF (Feb 2023)
• Blogs by Lynne Buie (product engineer)
What Next?

GIS is more than just mapping…

- Clever GIS people can imagine a host of analysis options
- Automate the processing of LST each day/week…for updated heat maps
- Walk-time or Drive-time analyses
  - Who lives within a 15-minute walk to cooling stations or shady parks?
- Where to locate new (or mobile) cooling centers? (Is there wifi coverage?)
- Extract features (DL) such as mobile homes, pools and fountains,…
- Resource allocation: how to cover 80% of the vulnerable population with cooling solutions
- Analysis of commuting options: bus stops, car parking, etc.
- More detailed demographic and shopping behavior analysis
Learning Resources: Climate Action MOOC

Starting May 1. Includes a heat mapping section.
Learn to Apply GIS to Climate

There are many resources available for learning how to apply GIS to climate science, many of which can be done in short blocks of time. We have gathered a variety of these materials from Learn ArcGIS Lessons, to conference and webinar demos, to ArcGIS Blogs.

Learn ArcGIS Tutorials

GIS for Climate Resilience
An ArcGIS Tutorial Project

Apply the geographic approach for climate resilience planning. This site contains hands-on tutorials to enhance the geospatial capacity of stakeholders seeking to prepare their cities to withstand weather and climate-related hazards. By promoting training and technical expertise in innovative technology, through the connection of maps, apps, data and people, GIS professionals will be better equipped to make more informed policy decisions.

GET STARTED
How to teach about these topics?
Additional Teaching Resources

Climate Education

Resources for your climate change curriculum

Climate change affects local communities. These tools and teaching resources support environmental and sustainability education.

A complete system for climate change curriculum

Climate change affects everyone and is a key factor in many course topics. Geographic information system (GIS) technology allows you to quantify and communicate climate.
Upcoming Events

- MOOCs
  - Cartography April 3-May 15
  - Climate Action May 1-Jun 12
- Intermountain GIS Conf, May 12-16
- Imagery Summit, May 22.
- Esri Education Summit, July 13-16
- Esri UC, July 15-19
- GIS Pro, October 7-10
- Ongoing: Esri Higher Education Monthly Chats
Take-Aways
First of a series of Webinars and Workshop

• Perfect time for taking action on Urban Extreme Heat
• ArcGIS can help. Many possible, related workflows
• Many relevant Data Sets available (Living Atlas of the World)
• Many relevant Best Practice examples out there
• Many Learning Resources for moving ahead
• Future meetings: more on Imagery, Composite Indices, Demographics

• Thank you to URISA colleagues, and to you all for joining us!!

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