

How to use and analyze geospatial data for climate research and teaching

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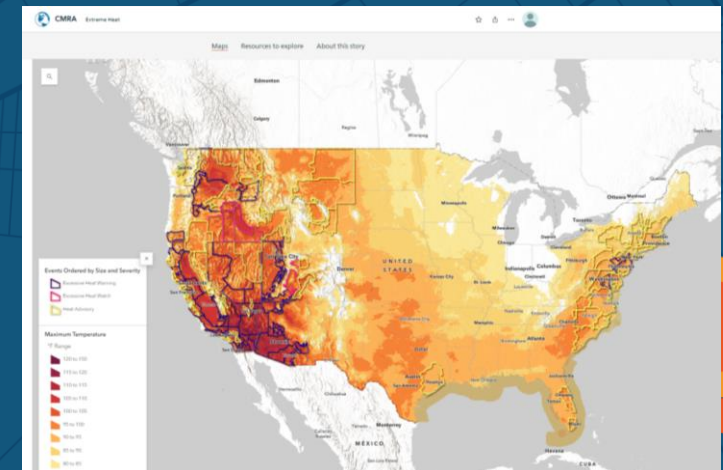
Objectives

--Build skills in effectively finding, using, and analyzing climate data in a geospatial context to enhance research and instruction

--Foster critical thinking skills about data, including ethical considerations in mapping

--Foster skills and confidence in modern GIS methods: data as streaming services, analytics in the cloud, real-time feeds, sharing, web maps and apps

--Give confidence to pursuing your future learning



Our World

Is Now Being Challenged



Population Growth

Human-Induced Climate Changes

Loss of Nature

Ecological Instability

Pollution

CO₂ Levels
1960-2020

Unconstrained Development

Social Conflict

Steep Decline in Biodiversity

Wildfires

Food Shortages

Severe Droughts

Water Crises

Extreme Heat

Ocean Warming

Natural Disasters

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

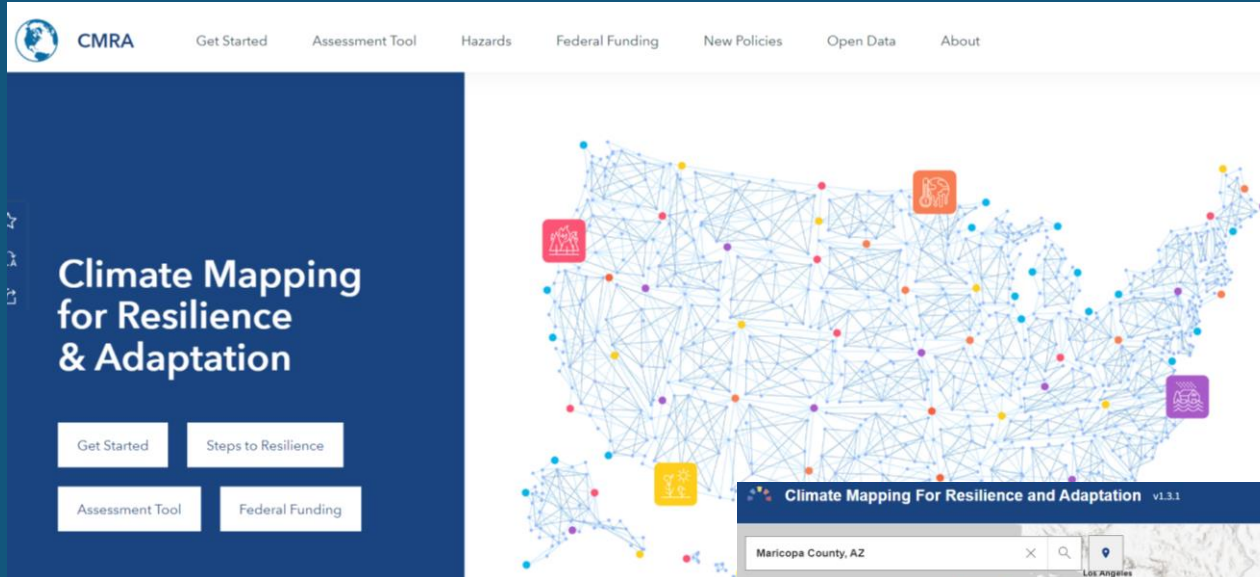
Decision-makers do use these approaches and data



Software products	→	Platforms and APIs
2D	→	2D/3D/4D AR/VR
Client/server	→	Web Services and apps
Standalone desktop	→	Connected devices
Printed maps	→	Web maps, dashboards, other apps
Static data	→	Data services, live streams, big data
Custom applications	→	Interoperable packages, libraries
Single, all-purpose application	→	Focused apps
Proprietary data	→	Open Data & Shared Services
Using data created by others	→	Combining others' data with our own
Limited sharing	→	Many ways to share
Niche technology	→	Ties to larger IT community: GitHub
Some attention to societal concerns	→	Much attention to societal concerns
Mapping department	→	Integrated across the business

...GIS has changed.

Climate Mapping for Resilience and Adaptation (CMRA)



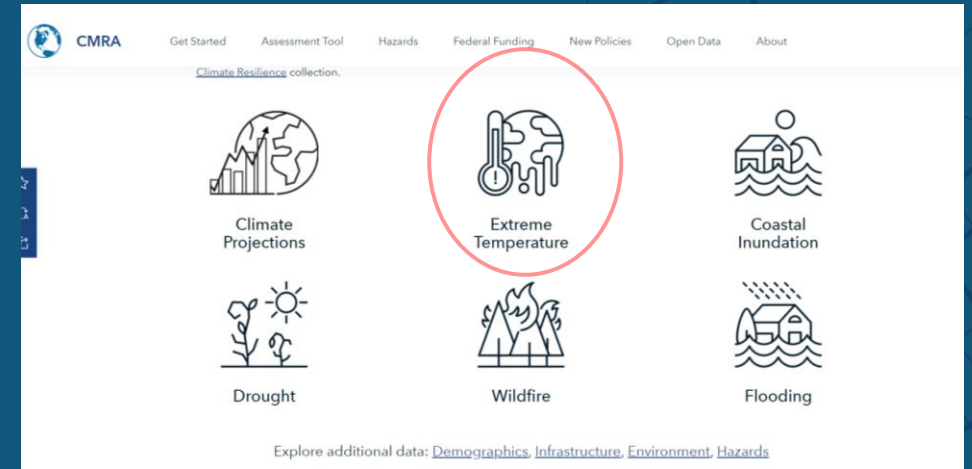
CMRA navigation menu: Get Started, Assessment Tool, Hazards, Federal Funding, New Policies, Open Data, About.

Climate Mapping for Resilience & Adaptation

Get Started | Steps to Resilience

Assessment Tool | Federal Funding

A network map of the United States with various colored nodes and icons representing different climate resilience and adaptation topics.

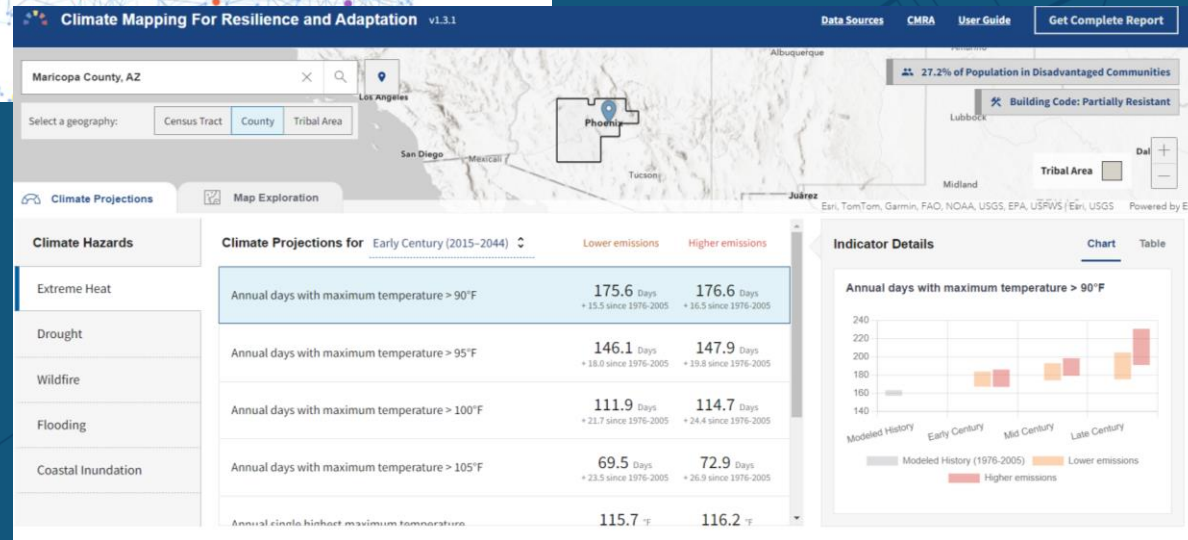


CMRA navigation menu: Get Started, Assessment Tool, Hazards, Federal Funding, New Policies, Open Data, About.

Climate Resilience collection.

- Climate Projections
- Extreme Temperature (highlighted with a red circle)
- Coastal Inundation
- Drought
- Wildfire
- Flooding

Explore additional data: [Demographics](#), [Infrastructure](#), [Environment](#), [Hazards](#)



Climate Mapping For Resilience and Adaptation v1.3.1

Maricopa County, AZ

Select a geography: Census Tract County Tribal Area

27.2% of Population in Disadvantaged Communities

Building Code: Partially Resistant

Climate Projections | Map Exploration

Climate Hazards	Climate Projections for Early Century (2015-2044)	
	Lower emissions	Higher emissions
Extreme Heat	Annual days with maximum temperature > 90°F: 175.6 Days (+15.5 since 1976-2005)	176.6 Days (+16.5 since 1976-2005)
Drought	Annual days with maximum temperature > 95°F: 146.1 Days (+18.0 since 1976-2005)	147.9 Days (+19.8 since 1976-2005)
Wildfire	Annual days with maximum temperature > 100°F: 111.9 Days (+21.7 since 1976-2005)	114.7 Days (+24.4 since 1976-2005)
Flooding	Annual days with maximum temperature > 105°F: 69.5 Days (+23.9 since 1976-2005)	72.9 Days (+26.9 since 1976-2005)
Coastal Inundation	Annual single highest maximum temperature: 115.7°F	116.2°F

Indicator Details: Annual days with maximum temperature > 90°F

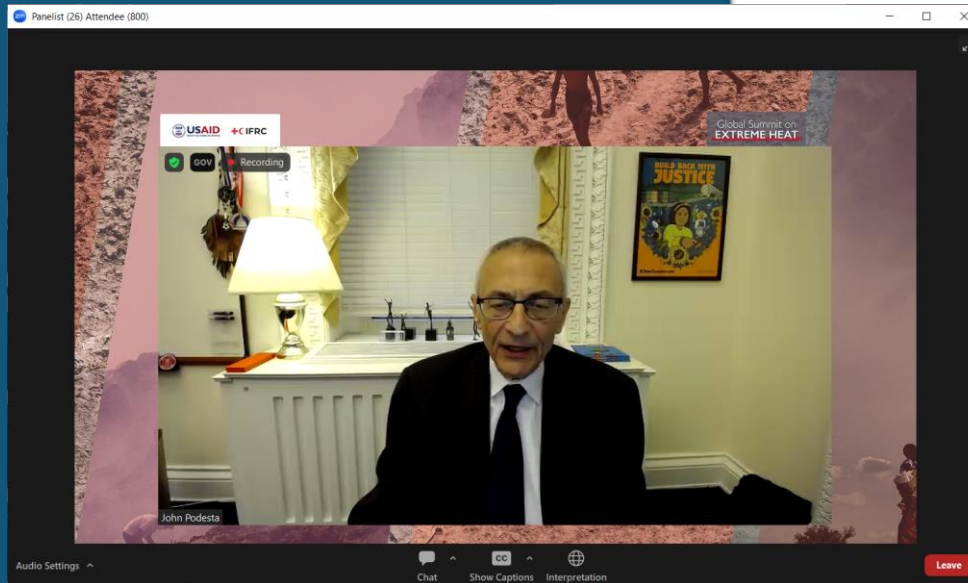
Chart showing Modeled History (1976-2005) and projections for Early, Mid, and Late Century under Lower emissions and Higher emissions scenarios.



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 Myrivili explains how cities can adapt to rising temperatures



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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



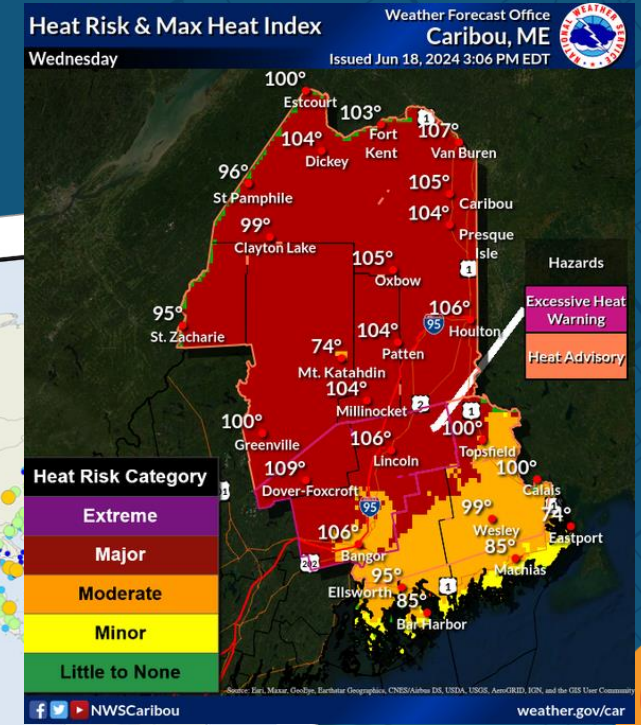
The affected cities are 'creeping North' (and South)

C40 CITIES WHO WE ARE ▾ WHAT WE DO ▾ OUR CITIES LATEST ▾ Q

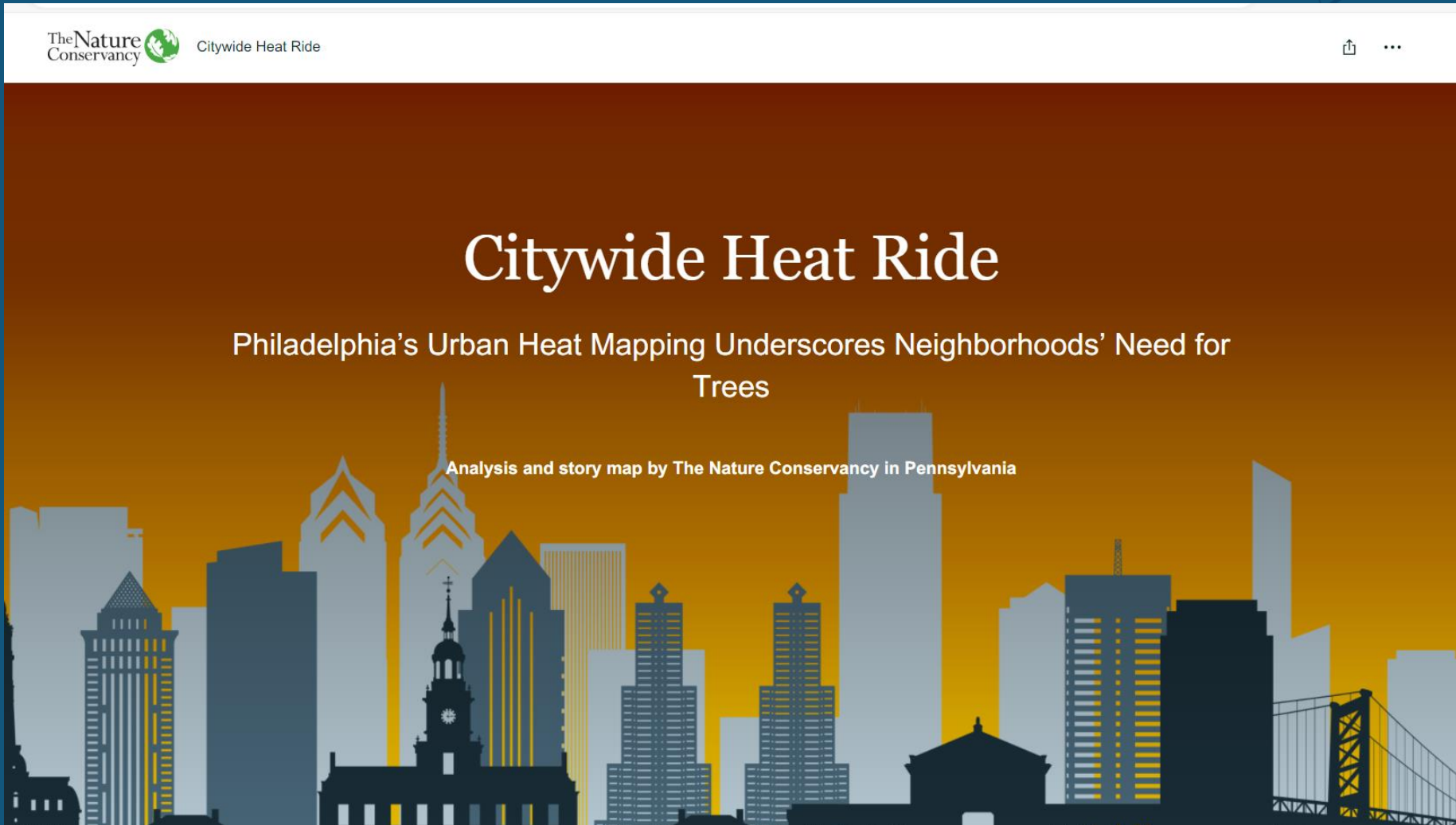
Heat Extremes

A summary of [The Future We Don't Want](#) research on the dangers of increasing urban heat.

The number of cities exposed to extreme temperatures will nearly triple by 2050



Citywide Heat Ride (arcgis.com)



Extreme Heat Plans

How to prioritize efforts; Data-driven decisions; Storytelling



Huang et al 2024

OFFICE OF THE GOVERNOR
KATIE HOBBS

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but last year and continuing this year, state employees may start cooling centers with pay.

Extreme Heat Preparedness Long-Term Recommendations focus on the following categories:

- Safe, Affordable Housing
- Adapting and updating emergency response
- Cooling Center Network improvements and support recommendations
- Data sets, knowledge, and workforce development

Read the full Extreme Heat Preparedness Plan [HERE](#)

Read Extreme Heat Preparedness Plan FAQs [HERE](#)

Read the Governor's LIHEAP Letter [HERE](#)

Governor Hobbs

Offices of the Governor

News

Priorities

Connect

12. INCORPORATE EXTREME HEAT IN COUNTYWIDE RESILIENCE HUB PLAN.

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.

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

GIS 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 (that have emissions reduction co-benefits?)
 - 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, Land use Changes, Transportation Changes, ...

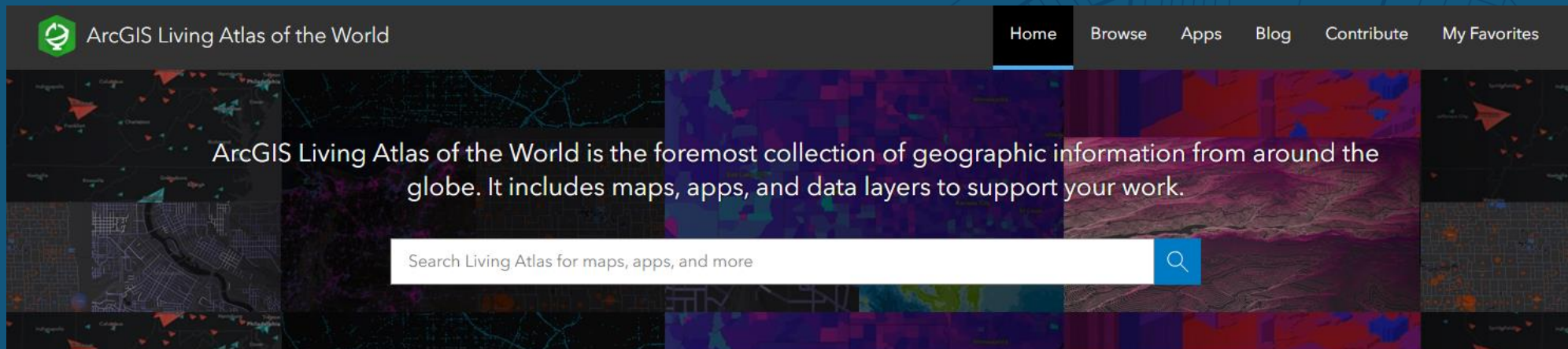


LA Times



Web GIS can enable understanding

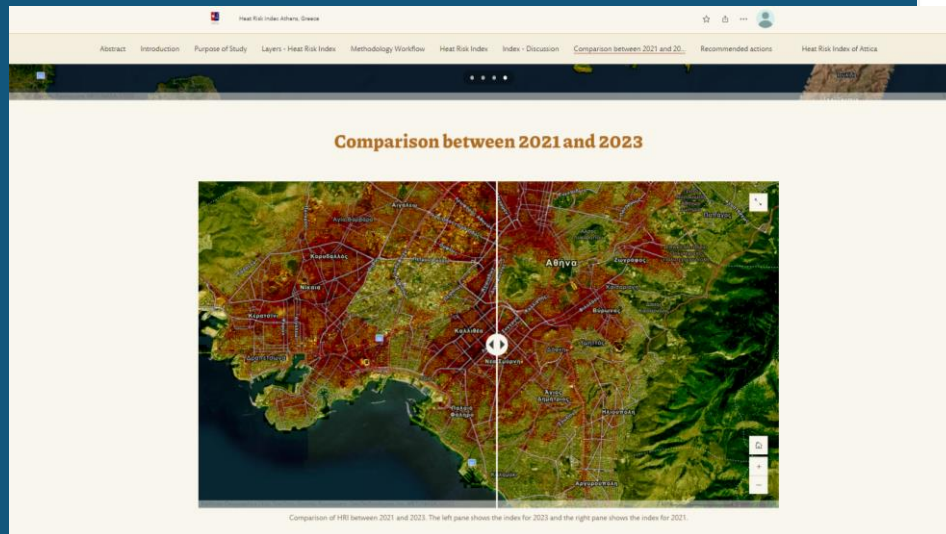
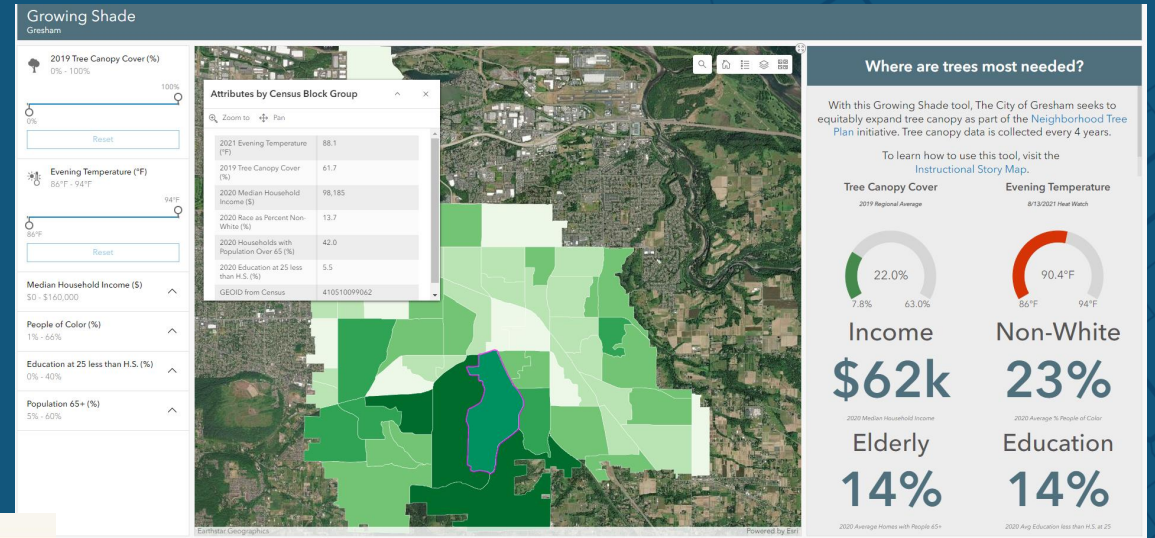
- Discover valuable data sets, in government portals (Hub sites, other libraries)
 - And on the ArcGIS **Living Atlas of the World**
- Publish your own data layers and apps:
 - On ArcGIS Online
 - In ArcGIS Hubs
 - Also **contribute** to the Living Atlas
- Then, to dig deeper > ArcGIS Pro, and the ArcGIS Pro <> R Bridge.



Map, analyze, then Tell your Story

A form of Climate Action

- StoryMaps
- Instant apps
- Infographics
- Dashboards



A Story Map

San Francisco Vulnerability to the Health Impacts of Extreme Heat

Climate change is one of the greatest public health threats of the 21st century. It is expected to cause more variable weather: heat waves, heavy precipitation events, flooding, droughts, sea level rise, wildfires and air pollution. These events have significant and cascading impacts on public health.

This interactive story map illustrates a recent assessment conducted by the San Francisco Department of Public Health that examines how extreme heat impacts public health.

This story will begin with a brief introduction to extreme heat in San Francisco and then pivot to examine the different communities most likely to be impacted.

Urban Heat Equity

Citywide Heat Ride:


<https://storymaps.arcgis.com/stories/1a131b1d4dd74143a47ae556809c72b3>

ArcGIS Blog Overview

including older individuals and those with pre-existing health conditions such as diabetes.

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 redlining data, these patterns of disinvestment are put into a temporal context that can be traced back over generations.



Shade Equity Analysis



Shade Equity Analysis

Improving cities through green infrastructure

Ross Donihue
January 24, 2022

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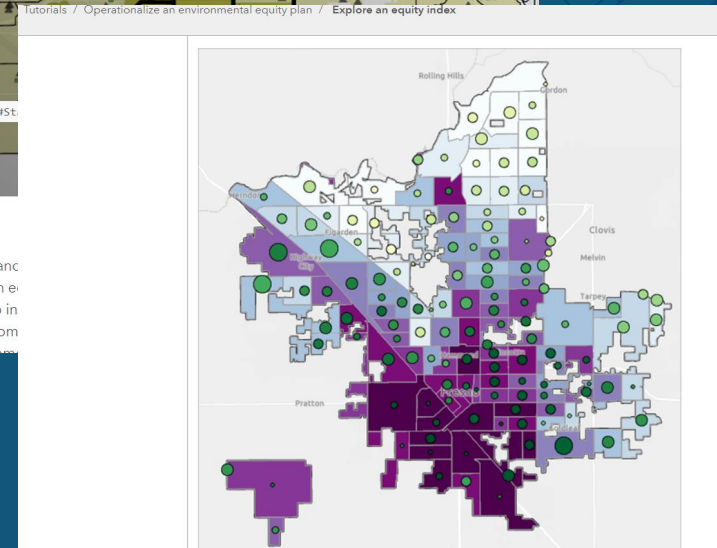
Operationalize an environmental equity plan

Use an environmental justice index to create a compelling and interactive map to apply for a bikeway funding opportunity.

Authors: Walker Wieland and Niki Wong
Duration: 1hr(s) Difficulty: Intermediate

Tags: Spatial Analysis & Data Science, #Health & Human Services, #Racial Equity and Social Justice, #St Development

Government agencies and community-based, nonprofit organizations are increasingly creating and allocate resources, programs, and funding to improve health and well-being outcomes based on an effective way to combine several factors or indicators an organization and community want to in should focus. Many indices have been made available at various levels of municipalities. It is recom available and to customize an index for your particular project goals, unique experiences and dom



Selected Studies

Flathead Reservation, Montana: Understanding climate change:

<https://www.esri.com/en-us/industries/blog/articles/understanding-climate-change-on-the-flathead-reservation/>

Athens, Greece:

<https://storymaps.arcgis.com/stories/b37837ed9b544bf3b2e881171626dedf>

These use ArcGIS story maps to tell the story.



Activity 1: Explore Data Sources and Strategies

Libraries and databases, including those powered by ArcGIS Hub
Examine this book and blog about how to find spatial data, how to assess its quality, and societal issues surrounding spatial data:

<https://spatialreserves.wordpress.com>

Including 10 exercises: finding, loading, and analyzing spatial data in ArcGIS Pro.

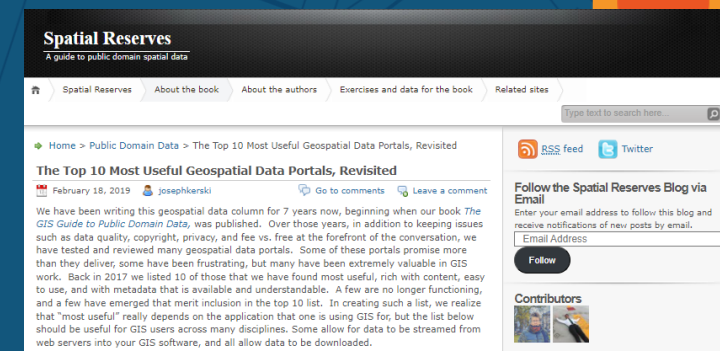
Examine these top 10 most useful geospatial data portals:

<https://spatialreserves.wordpress.com/2019/02/18/the-top-10-most-useful-geospatial-data-portals-revisited/>

Examine this Modern Strategies for finding geospatial data:

<https://spatialreserves.wordpress.com/2024/01/22/modern-strategies-for-finding-geospatial-data-updated/>

Examine ethics, location privacy, copyright, and other societal issues, such as [these case studies](#) and [this on location privacy](#).



The screenshot shows the homepage of the 'Spatial Reserves' website. The header includes the site name 'Spatial Reserves' and the tagline 'A guide to public domain spatial data'. Below the header is a navigation menu with links for 'Spatial Reserves', 'About the book', 'About the authors', 'Exercises and data for the book', and 'Related sites'. A search bar is located on the right side of the navigation menu. The main content area features a blog post titled 'The Top 10 Most Useful Geospatial Data Portals, Revisited' by Joseph Kierski, dated February 18, 2019. The post text discusses the author's experience writing a geospatial data column for 7 years and lists 10 of the most useful portals. The right sidebar contains social media links for RSS feed and Twitter, an email subscription form, and a 'Contributors' section.

Activity 2: Focused Data Examination

Go to the ArcGIS Living Atlas of the World: <https://livingatlas.arcgis.com>

Examine Weather and Climate layers:

<https://livingatlas.arcgis.com/en/browse/#d=2&categories=Weather+and+Climate>

Example: World Terrestrial Ecosystems.

Examine 18 new hosted feature layer items for building community science resilience, focused on extreme heat, wildfire, inland flooding, and sea level rise:

<https://www.esri.com/arcgis-blog/products/arcgis-living-atlas/announcements/tools-for-building-community-climate-resilience/>

The screenshot displays the ArcGIS Living Atlas of the World web application. The top navigation bar includes the logo and the text 'ArcGIS Living Atlas of the World', along with menu items for Home, Browse, Apps, Blog, Contribute, and My Favorites. A search bar is positioned below the navigation, with the placeholder text 'Search Living Atlas for maps, apps, and more'. Below the search bar, there are several category icons: All, Trending, Basemaps, Imagery, Boundaries, People, Infrastructure, and Environment. The main content area shows search filters for 'All content types', 'All time', 'All regions', 'Esri-only content', and 'Authoritative-only content'. The search results are sorted by 'Relevance' and show '10,000+ Results'. Two featured items are visible: 'Sentinel-2 Views' and 'Active Hurricanes, Cyclones and Typhoons'. The 'Active Hurricanes, Cyclones and Typhoons' item is highlighted and includes a description: 'This layer describes the observed path, forecast track, and intensity of tropical cyclone activity (hurricanes, typhoons, cyclones) from the National Hurricane Center (NHC) and Joint Typhoon Warning Center (JTWC)'. Both items are marked as 'Authoritative'.

Identifying Heat

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

An official website of the United States government [Here's how you know](#)

USGS
science for a changing world

SCIENCE PRODUCTS NEWS CONNECT ABOUT

Latest Earthquakes |

LANDSAT MISSIONS

Landsat Collection 2 Surface Temperature

By [Landsat Missions](#)

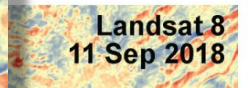
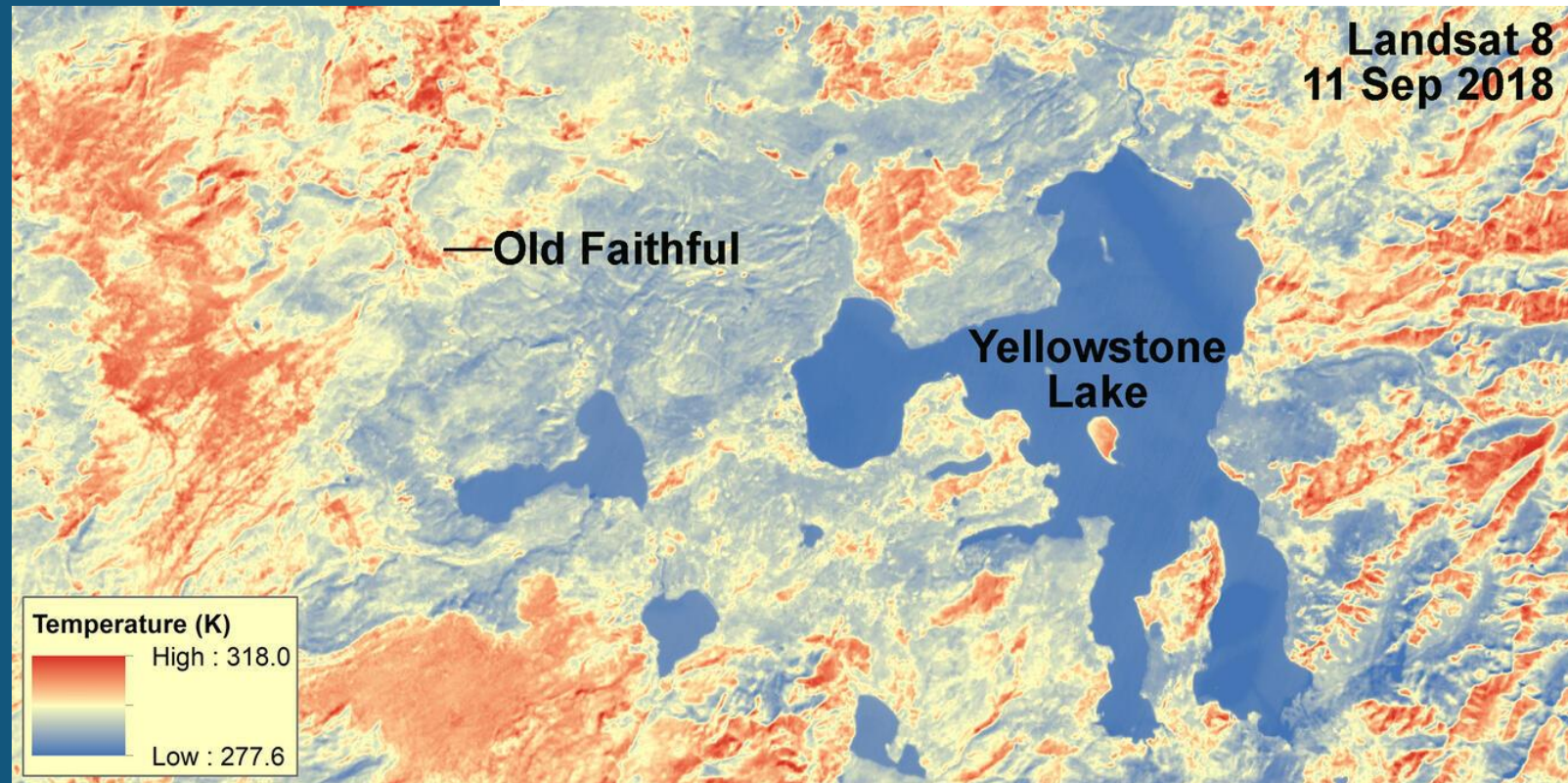
HOME

LANDSAT MISSIONS

SCIENCE

PRODUCT INFORMATION

Landsat surface temperature measures the Earth's surface temperature in Kelvin and is an important geophysical parameter in global energy balance studies and hydrologic modeling. Surface temperature data are also useful for monitoring crop and vegetation health, and extreme heat events such as natural disasters (e.g., volcanic eruptions, wildfires), and urban heat island effects.



Heat.gov

Built on ArcGIS Hub



HEAT.gov

National Integrated Heat Health Information System

- Home
- News & Events
- Learn
- Urban Heat Islands
- Tools & Information
- At Risk Groups
- Planning & Preparing
- Funding Opportunities
- About



Afternoon Heat Index in Cities - Urban Heat Islands



NOAA VizLab
NOAA GeoPlatform

[View Data](#)

[Download](#)

[More](#)

Summary

Afternoon Heat Index for U.S. cities for use in urban heat island mapping. Source: NOAA/CAPA Strategies.

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 increase over time.

Details



Imagery Dataset
Image Service

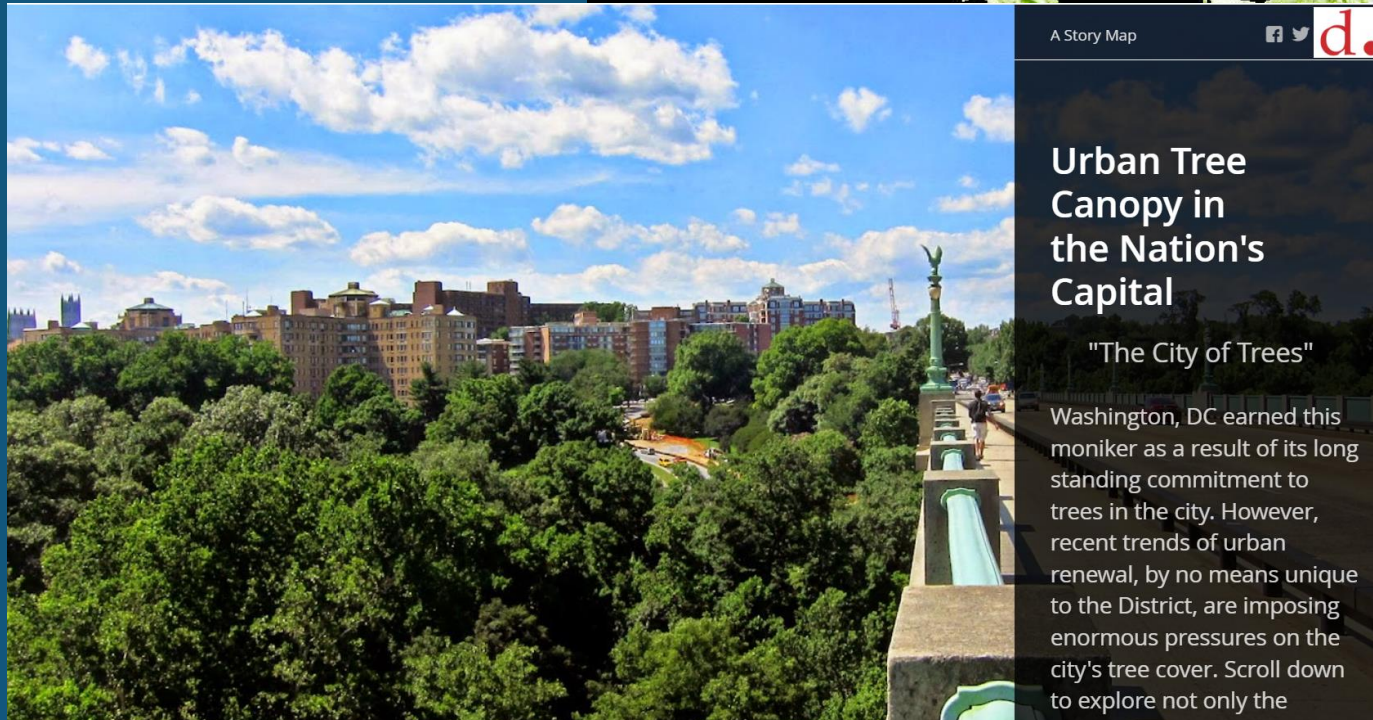
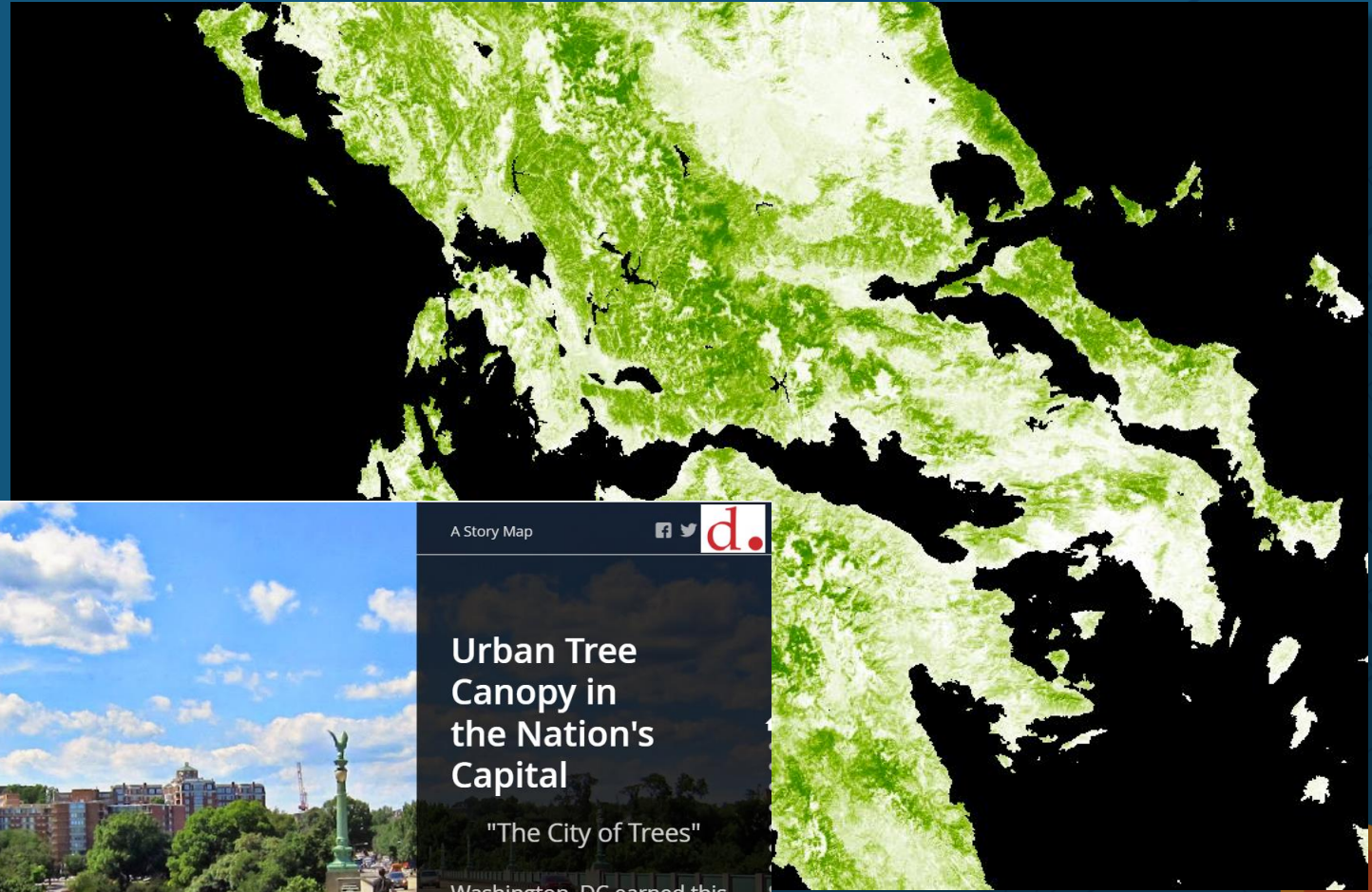


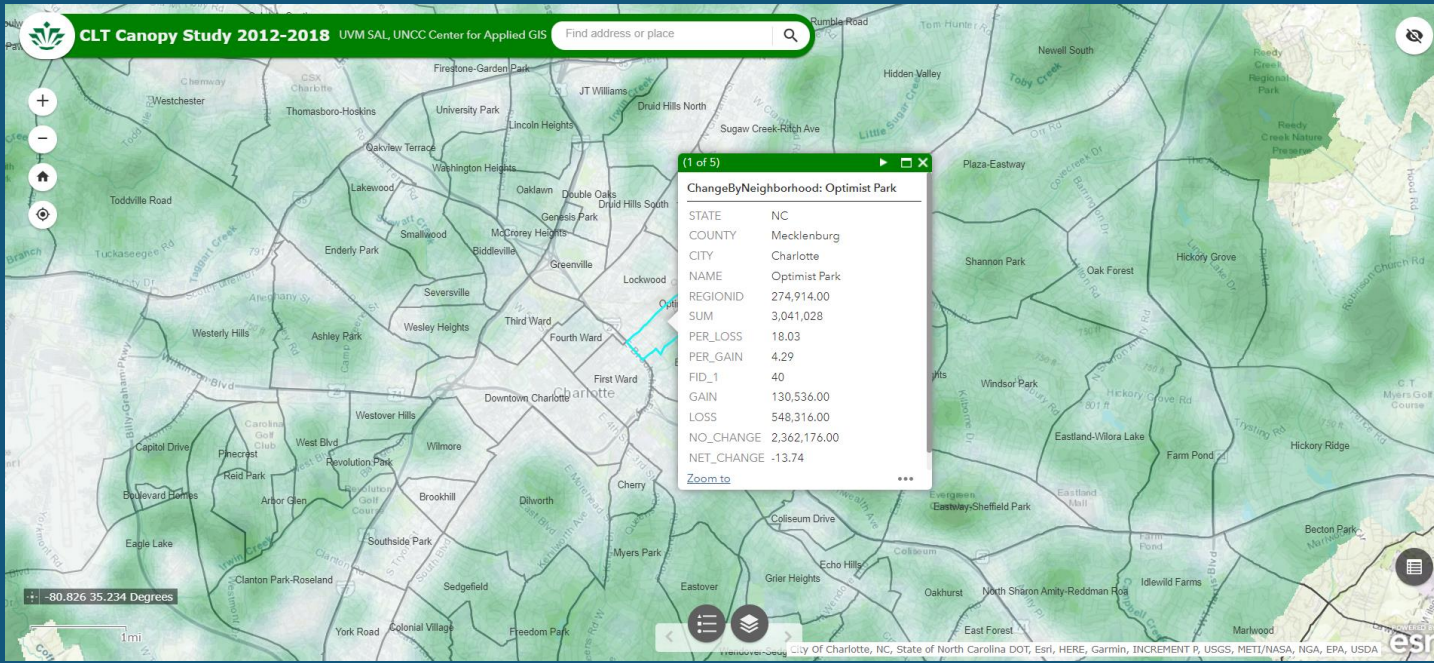
August 2, 2023
Info Updated

August 2, 2023

Identifying Tree Cover

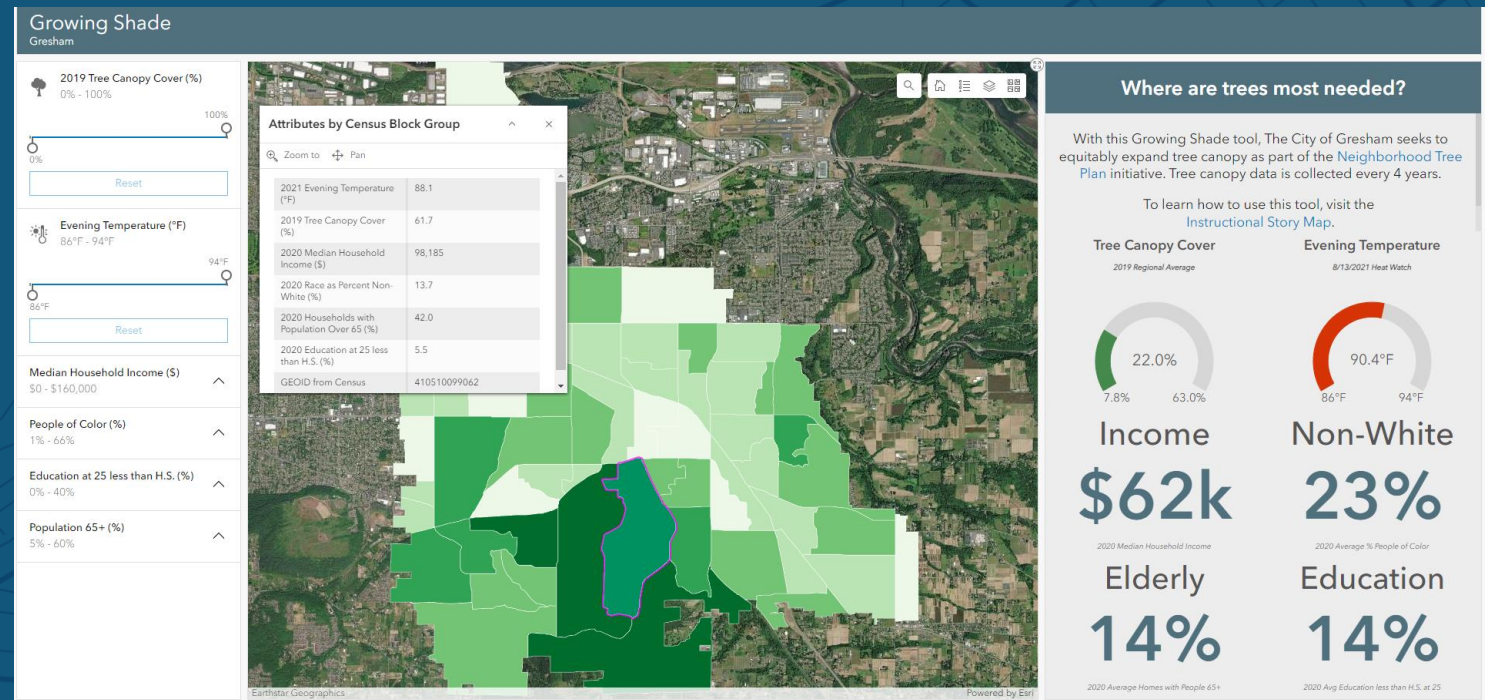
- Classified landcover images
- NAIP and other imagery
- NDVI
- UAVs





Charlotte NC

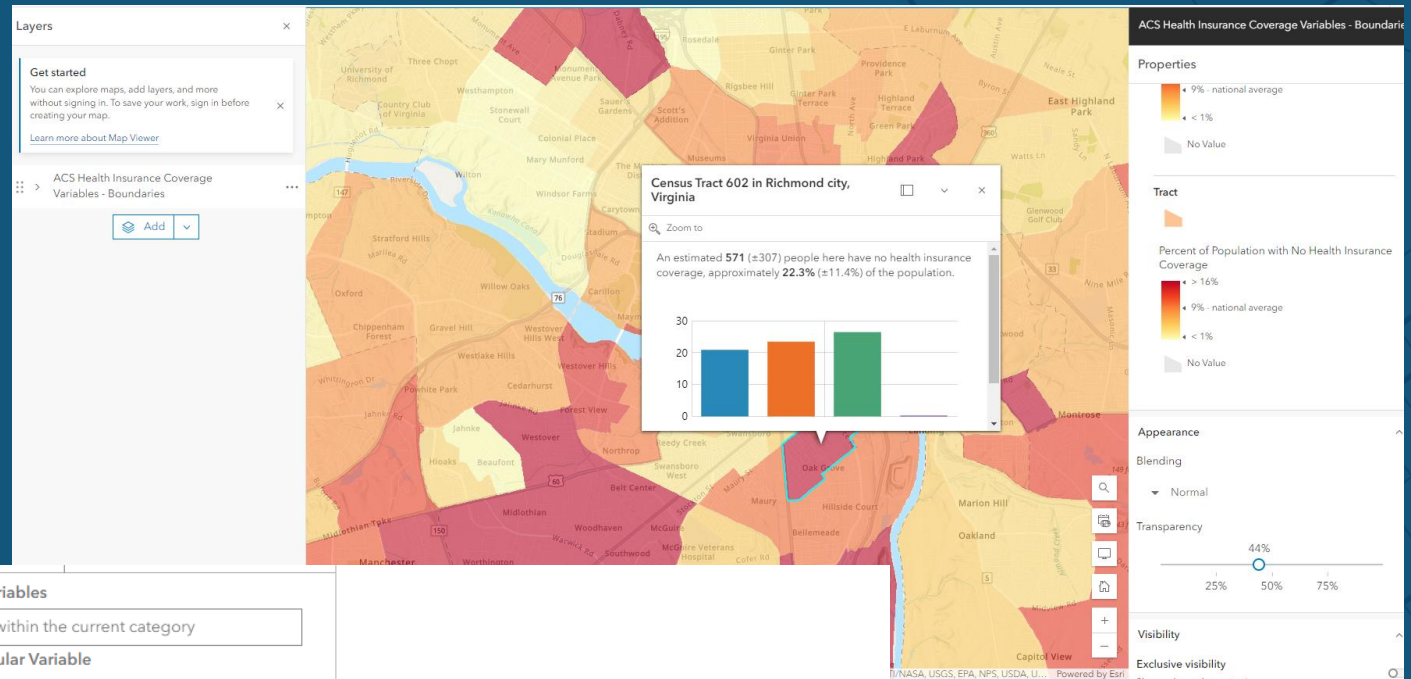
Gresham OR



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



Population Variables

Search within the current category

Choose a Popular Variable

- 2023 Population Density (Pop per Square Mile) (Esri)
- 2023 Total Population (Esri)

Next, you will add variables related to vulnerable populations. People who do not have access to a vehicle or have incomes below will have fewer resources to cope with potential extreme heat events.

Click the **Back** button. In the search bar, type `no vehicle` and press Enter.

Custom Search: no vehicle

'no vehicle' variables (12)

- 2017-2021 Vehicles Available (ACS)
 - 2021 Owner Households with No Vehicles (ACS 5-Yr)
 - 2021 Renter Households with No Vehicles (ACS 5-Yr)

Expand 2017-2021 Vehicles Available (ACS) and check the box for 2021 Renter Households with No Vehicles (ACS 5-Yr).

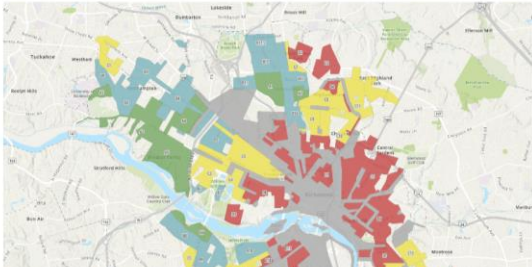
Urban Heat Equity

ArcGIS Blog Overview

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Urban heat and equity

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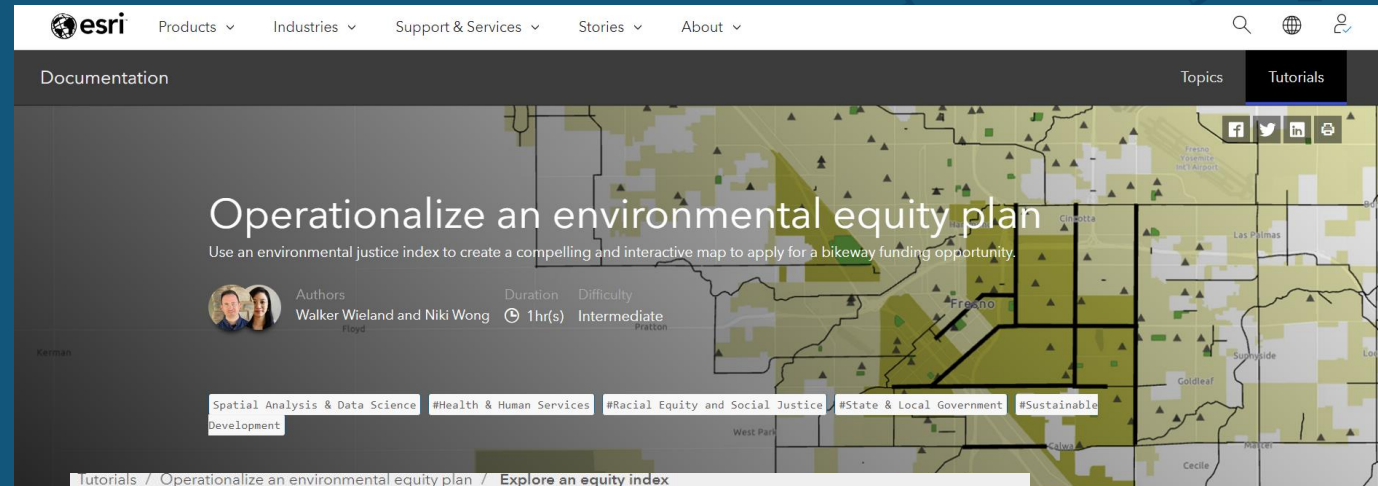
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Tags: #Spatial Analysis & Data Science #Health & Human Services #Racial Equity and Social Justice #State & Local Government #Sustainable Development

Tutorials / Operationalize an environmental equity plan / Explore an equity index

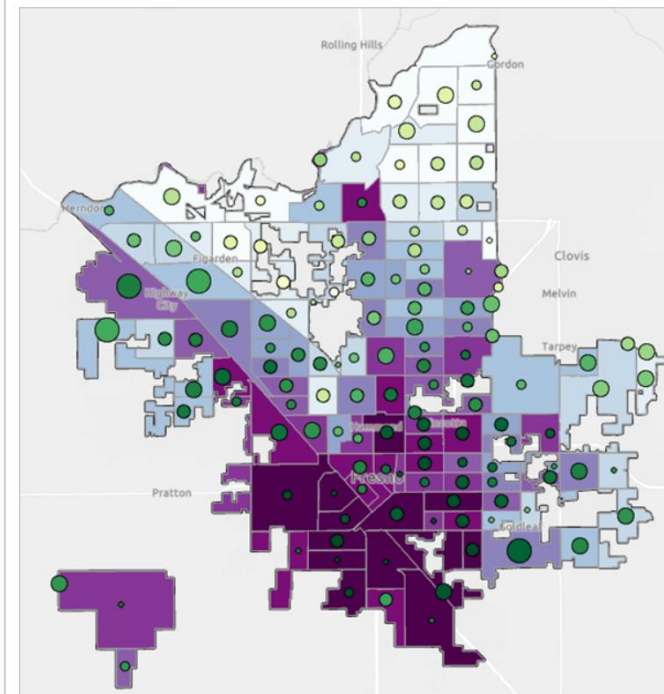
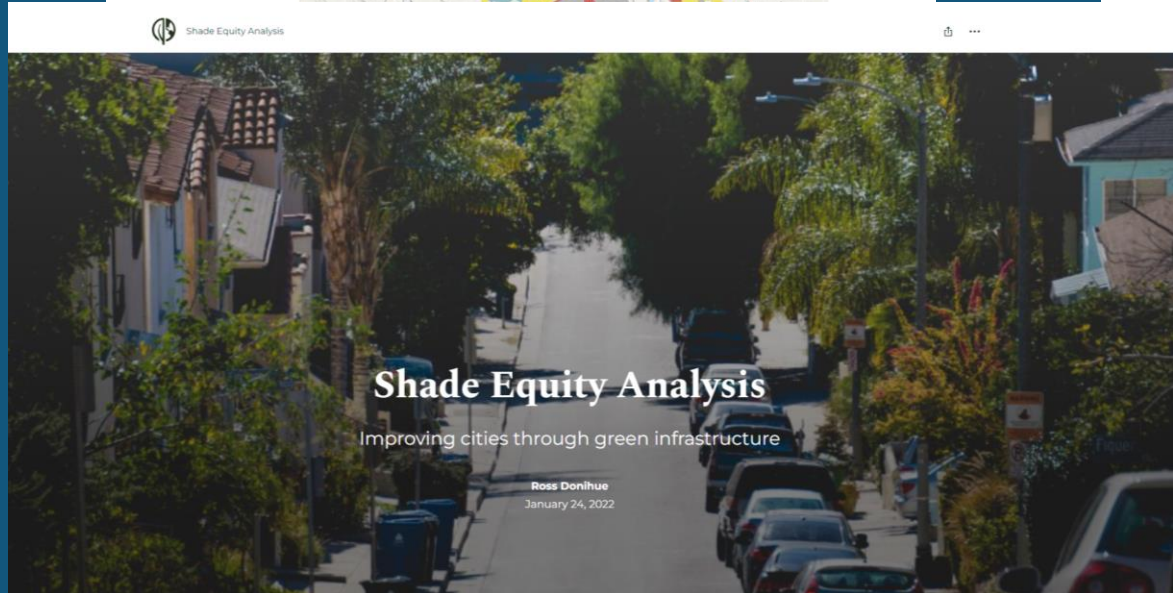


Shade Equity Analysis

Shade Equity Analysis

Improving cities through green infrastructure

Ross Donihue
January 24, 2022



etermine where to best
directives. Indices are
e an intervention
ocal level of data as
operationalize an



Surface Temp: From Landsat Level-2

- Thermal (TIR) Bands 10,11
- Resampled at 30m
- Land Surface Temp (LST)
 - 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 can assist

The screenshot shows a map interface with a thermal imagery overlay. A pop-up window titled "OLI_TIRS Level-2" displays the following metadata:

Name	LC09_L2SP_015034_20230730_20230802_02_T1
Acquisition Date	Jul 30, 2023
Category	Primary
Product Name	L2SP
Sun Azimuth	128.14
Sun Elevation	62.77
Surface Temperature (Fahrenheit)	106.788

The right sidebar shows the "Landsat Level-2" image collection explorer with a list of images. The first image is selected:

Ov_L0A_0
name: Ov_L0A_0
acquisitiondate: null
best: null

Below it are other images with their names, acquisition dates, and best values.

National Climate Assessment

<https://toolkit.climate.gov/>

<https://toolkit.climate.gov/#tools>

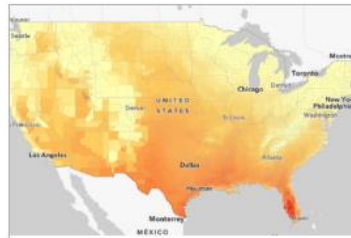
<https://toolkit.climate.gov/tool/nca-interactive-atlas>



NCA5 Atlas Global Warming Level 1.5 deg C

This layer provides county summaries from the 5th Natio...

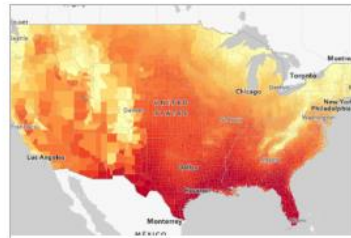
Access Data



NCA5 Atlas Global Warming Level 2 deg C

This layer provides county summaries from the 5th Natio...

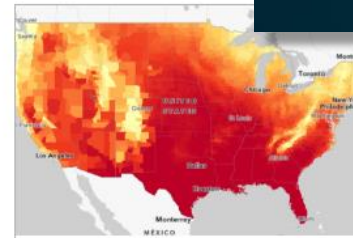
Access Data



NCA5 Atlas Global Warming Level 3 deg C

This layer provides county summaries from the 5th Natio...

Access Data



NCA5 Atlas Global Warming Level 4 deg C

This layer provides county summaries from the 5th Natio...

Access Data

Share this card



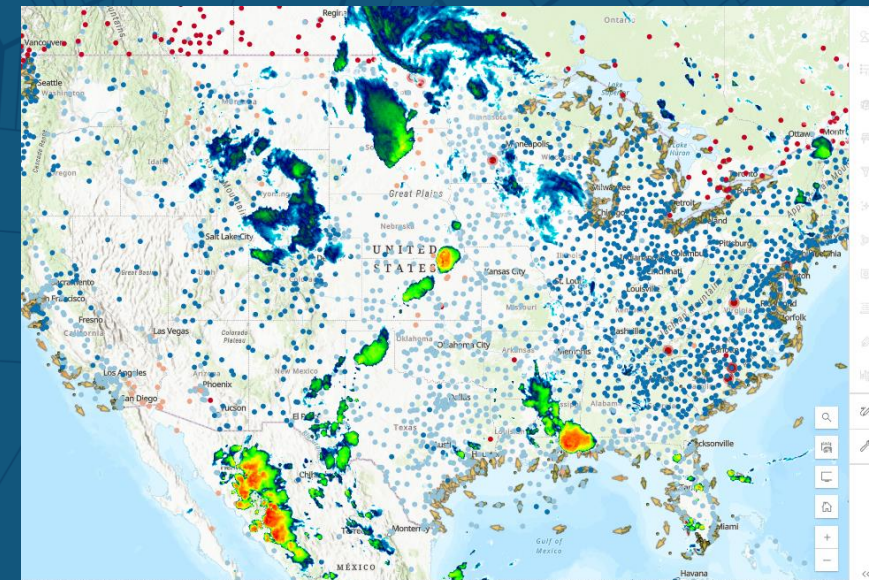
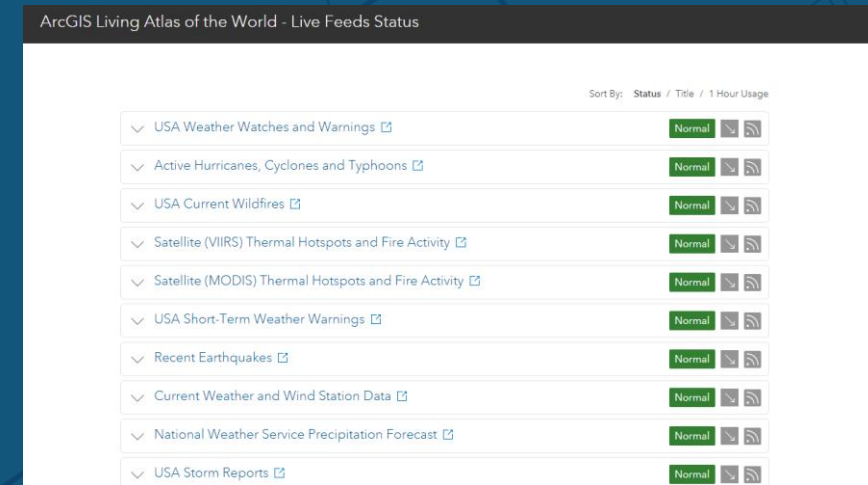
Activity 3: Explore the ArcGIS Living Atlas apps

Drought Aware, Water Balance, Sentinel-2 Cover Change, Landsat Explorer

The screenshot displays the Esri Landsat Explorer application interface. At the top left, the title bar reads "Esri | Landsat Explorer". The main map area shows a satellite view of a coastal region with various labels such as "SALALAH AIRPORT", "Al Wersh Industrial Area", "Al Wadi", "New Salalah", "Al Qawf", "Al Rubat", "Al Saadah South", "Al Dahariz North", "Al Dahariz South", "Awqad North", "Al Sultan Qaboos Hospital", "Salalah West", "Al Haffah", "Al Hafa", "Awqad South", and "Awqad". A search bar at the top right contains the text "Find address or place" and a search icon. A popup window titled "Landsat 9 | Mar 18, 2024" displays the following data: "Surface Temp: 96°F / 36°C", "NDVI: 0.660 MNDWI: -0.417", and coordinates "x 54.118 y 17.015". The bottom of the interface features a navigation panel with buttons for "EXPLORE", "DYNAMIC", "SWIPE", "ANIMATE", and "ANALYZE". The "DYNAMIC" section is active, showing "DYNAMIC VIEW" and "INTERESTING PLACES". The "DYNAMIC VIEW" section contains text: "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." The "INTERESTING PLACES" section displays a grid of 12 thumbnail images with labels: "Ganges Delta", "Grand Canyon", "Lake Mackay", "Richat", "Kalahari Dunes", "Kuiseb Canyon", "Quelccaya", "Gosses Bluff", "Three Gorges", "Dasht-e Kevir", "Ouarkiz", and "Etosha Pan". The "RENDERER" section shows a grid of 9 thumbnail images with labels: "Natural Color", "Color IR", "Short-wave IR", "Agriculture", "Bathymetric", "Urban", "NDVI Colorized", "Surface Temp", and "MNDWI".

Activity 4: Examine ArcGIS Living Atlas Real Time Feeds

- 1) Go to the Living Atlas:
<https://livingatlas.arcgis.com/en/home/> > Browse > Search on Live Feeds > Open the Live Feeds Status Page > View.
- 2) Click on Live Stream Gauges > Examine metadata > open in Map Viewer. This will open the contents in the www.arcgis.com ArcGIS Online Map Viewer.
- 3) Observe global pattern. Zoom to USA > select a gauge > observe popup. Edit popup > Remove organization. Add media to popup > Bar chart > on field Flow (cfs) > Make horizontal orientation > Done > test popup.
- 4) Filter on > Status is Major Flood. Observe patterns.
- 5) Add data from ArcGIS Online > Base reflectivity Radar time enabled: Compare to flooding gauges. Add data from URL: This [URL](https://mapservices.weather.noaa.gov/eventdriven/rest/services/radar/radar_base_reflectivity/MapServer) for radar base reflectivity:
https://mapservices.weather.noaa.gov/eventdriven/rest/services/radar/radar_base_reflectivity/MapServer

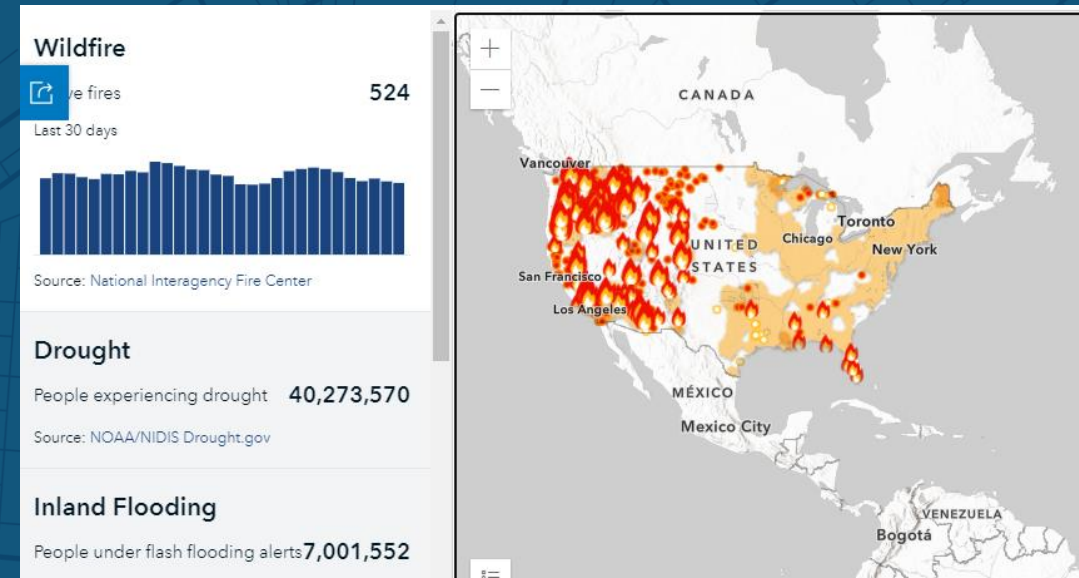


Activity 5: Identify Climate Hazards with a Web Mapping App

- 1) Go to this mapping app and scroll down to Identify Climate Hazards:

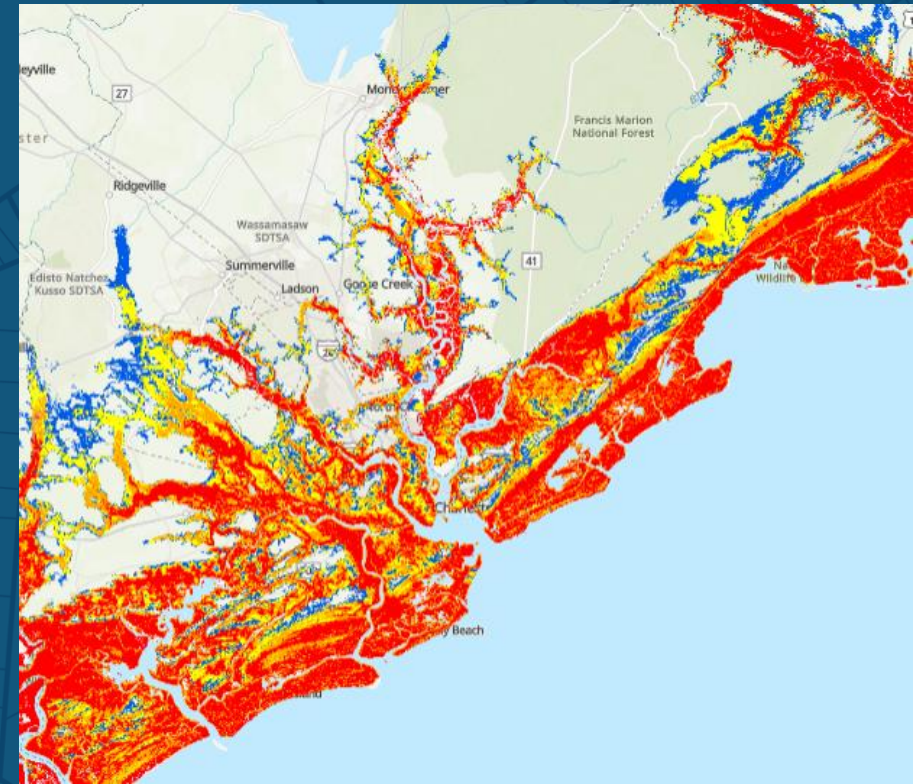
<https://gis-for-climate-resilience-learn.org/hub.arcgis.com/pages/community-action>

- 2) Answer these questions: Which of these 5 climate hazards is currently affecting the most people? Are there any hazards currently affecting your community, region, or state?
- 3) Which hazard poses the greatest threat to your community, region, or state? Note: Conditions vary seasonally. Consider how all four seasons might affect hazards like wildfire, extreme heat, and flooding.
- 4) How could you make your own web mapping applications? Instant apps, dashboards, story maps, Experience Builder apps.



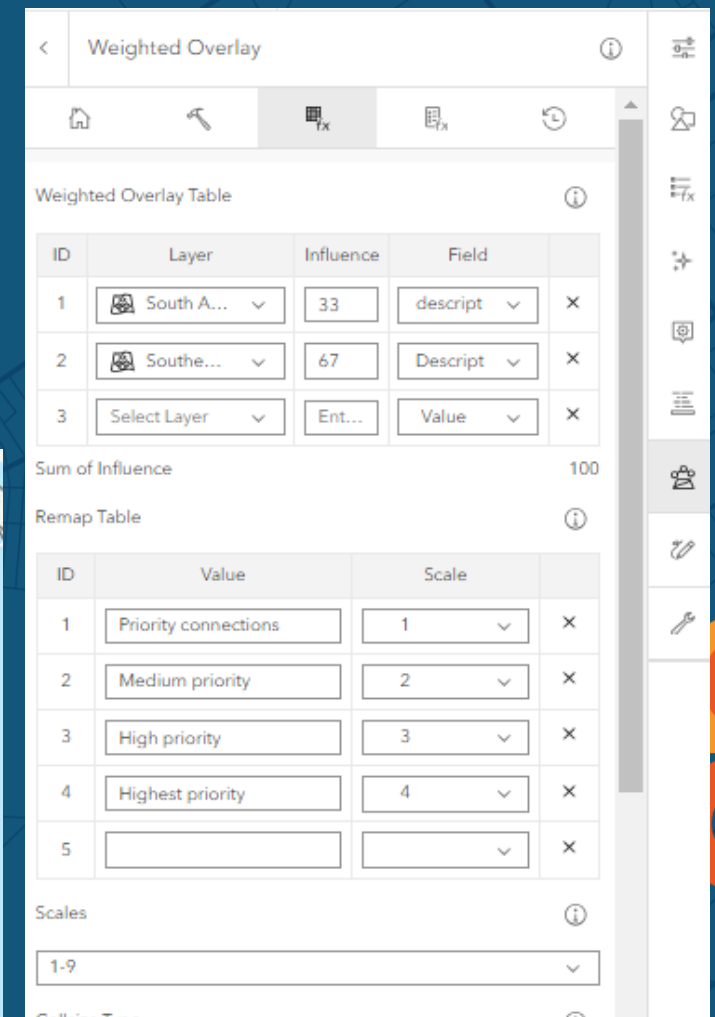
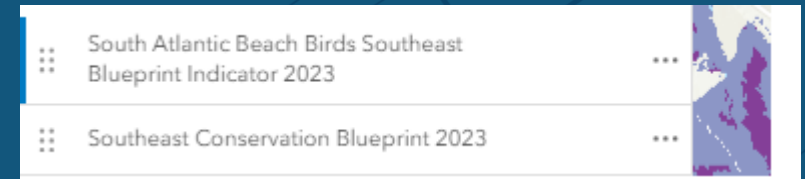
Activity 6 Part 1: Analyze Coastal Hazards and Habitat in ArcGIS Online

- 1) Open this map in ArcGIS Online: [Map Viewer \(arcgis.com\)](https://www.arcgis.com/apps/mapviewer/index.html?webmap=4cd40122c95c4fed9266cf28a30d2abe) :
<https://www.arcgis.com/apps/mapviewer/index.html?webmap=4cd40122c95c4fed9266cf28a30d2abe>
- 2) Explore the map via the 3 bookmarks and the 2 vector layers (schools and OSM buildings) and 3 raster layers (storm surge and hábitat). The storm surge data is based on the National Weather Service SLOSH model maximum for Category 2 and 3 hurricanes. The OSM is a crowdsourced layer from the Open Street Map initiative. Can you determine some spatial relationships between buildings, habitat, the coastline, and the SLOSH data?



Activity 6 Part 2: Analyze Coastal Hazards and Habitat in ArcGIS Online

- Using the raster tool “weighted overlay”, you could determine the areas that are high priority for Southeast Conservation blueprint **and** are high priority for the South Atlantic Beach Birds, using the parameters at right and weighting the conservation layer at 33% and the birds layer at 67%.
- This tool takes awhile to run, so to just see the results, examine this final map, [here](#).

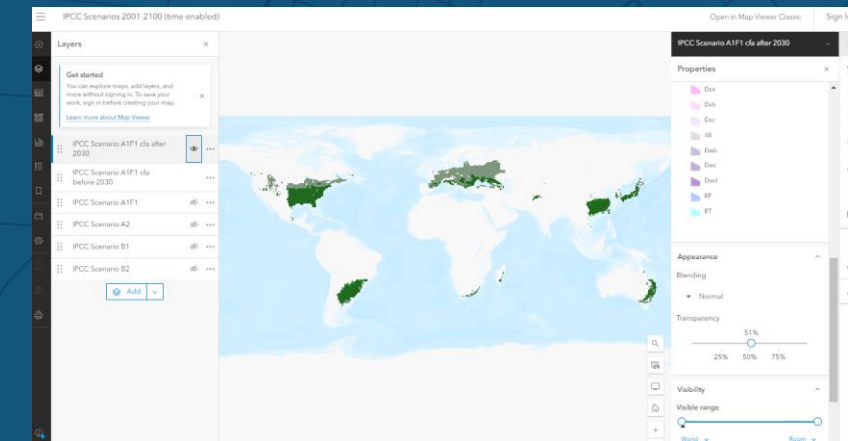
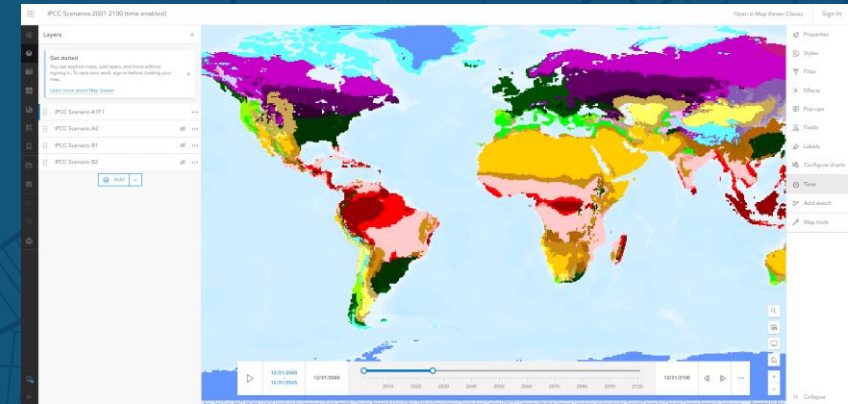


Activity 7 Part 1: Analyzing IPCC Scenarios 2001-2100

Open the following map in ArcGIS Online Map Viewer:

<https://www.arcgis.com/apps/mapviewer/index.html?webmap=24bdf1aedb1b41b9a5ddf02f54f9ad1c>

- (1) Examine the metadata for the map and layers.
- (2) Play time tool and observe patterns. Select each scenario layer (A1F1, A2, B1, B2), play time tool, and observe patterns over time and across different models. What difference(s) do you note?
- (3) Focus on A1F1: Note expansion of cfa (Warm temperate, fully humid, hot summer) in eastern North America and Europe but not in China. Which other climate zones are predicted to expand? Which are predicted to contract? Why?
- (4) Search for Ottawa Canada and add to new sketch. Add text to this point that says “Ottawa” Play timeline for 4 IPCC scenarios. Observe global patterns. Observe scenario for Ottawa through 2100. Zoom in to Ottawa and create a bookmark called “Ottawa”
- (5) Repeat step 4 for another city of interest. Then turn off “time” tool. Then zoom to world and create a bookmark called “World”.

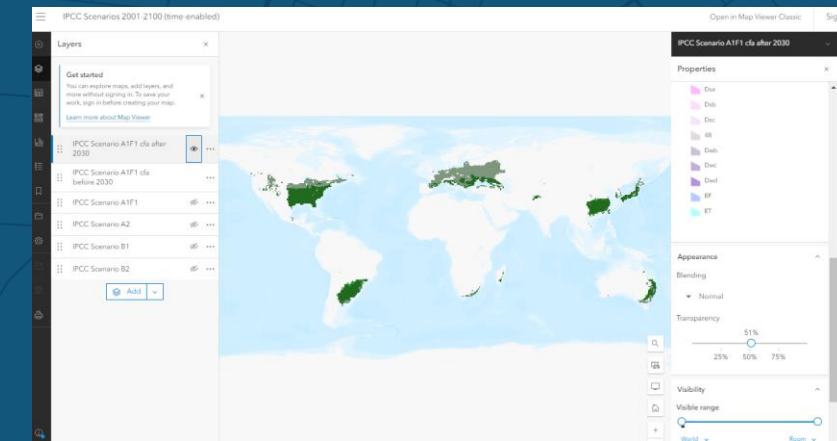
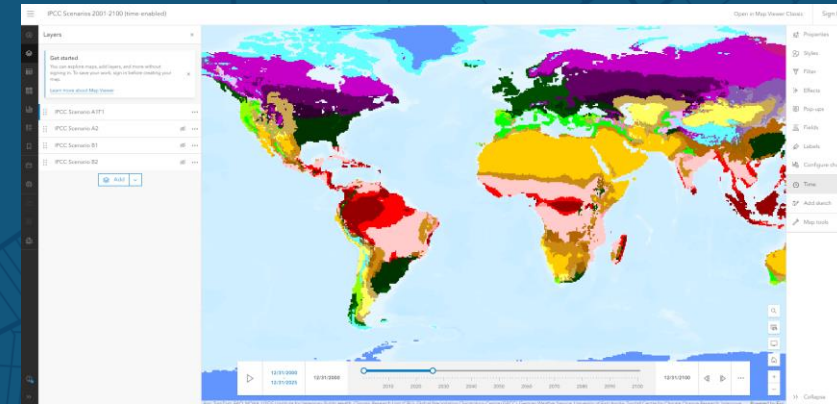


Activity 7 Part 2: Analyzing IPCC Scenarios 2001-2100

Open the following map in ArcGIS Online Map Viewer:

<https://www.arcgis.com/apps/mapviewer/index.html?webmap=24bdf1aedb1b41b9a5ddf02f54f9ad1c>

- 6) Make IPCC A1F1 the active layer > Filter on All of the following are true: GRIDCODE is Cfa and End_Year is before 8/1/2030 > Save. Observe pattern. Duplicate layer and name duplicate IPCC A1F1 cfa before 2030. Filter IPCC Scenario A1F1 > All true: GRIDCODE is Cfa and End_year is **after 8/1/2030**. Duplicate layer and name it IPCC A1F1 cfa after 2030. Drag the “before” layer below the “after” layer.
- 7) Use Styles > Style options > change color of cfa after 2030 to a different color. Toggle and compare cfa time snapshots. Use Properties > Transparency and make “after” layer semi-transparent. Compare. For example map, click [here](#).



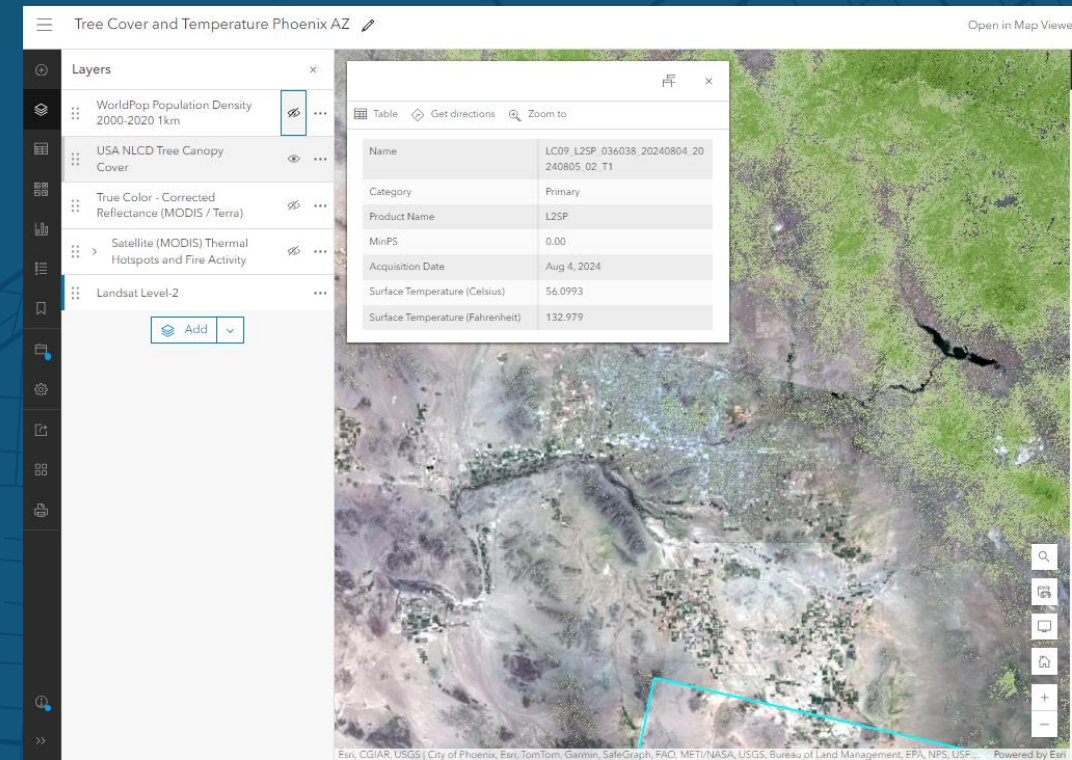
Activity 8: Explore and render raster data in ArcGIS Online

(1) Start ArcGIS Online (www.arcgis.com) > Sign In > Search for and zoom to Phoenix AZ.

(2) Add 3 layers from the Living Atlas: [A] Landsat Level-2. [B] USA NLCD Tree Canopy Cover. [C] WorldPop Population Density.

(3) Configure popups for Landsat to indicate Surface Temperature in C and F, Click here for [sample map](#) (you'll need to sign in to view it). Popups > Disable “display topmost image only”.

Examine relationships and patterns. Experiment with transparency settings.



The screenshot displays the ArcGIS Online interface for a map titled "Tree Cover and Temperature Phoenix AZ". The map shows a satellite view of a landscape with a cyan polygon highlighting a specific area. A popup window is open over this area, displaying the following data:

Name	LC09_L2SP_036038_20240804_20240805_02_T1
Category	Primary
Product Name	L2SP
MinPS	0.00
Acquisition Date	Aug 4, 2024
Surface Temperature (Celsius)	56.0993
Surface Temperature (Fahrenheit)	132.979

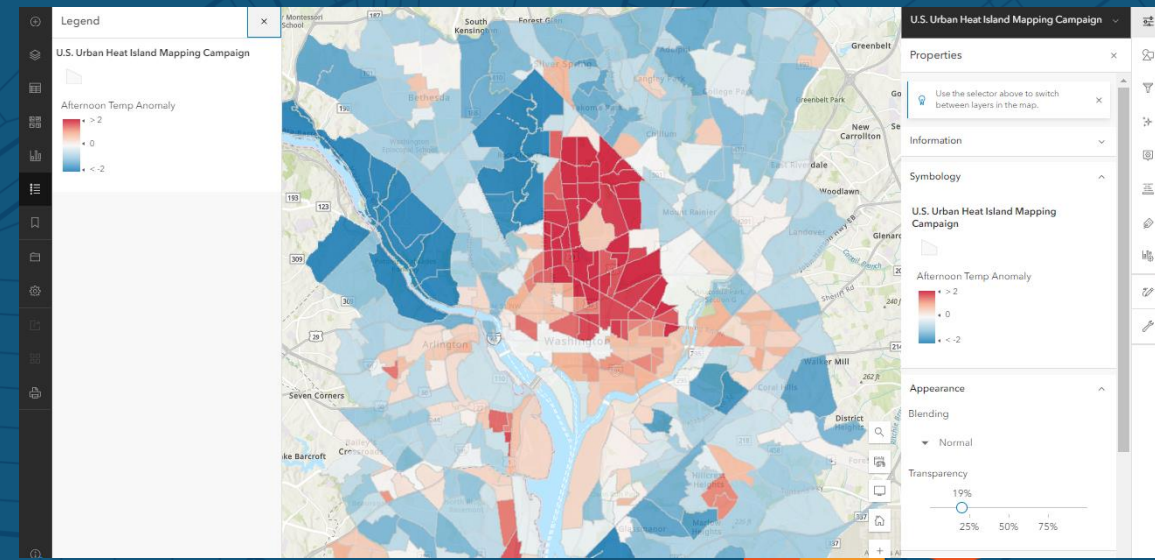
The interface also shows a "Layers" panel on the left with the following layers listed:

- WorldPop Population Density 2000-2020 1km
- USA NLCD Tree Canopy Cover
- True Color - Corrected Reflectance (MODIS / Terra)
- Satellite (MODIS) Thermal Hotspots and Fire Activity
- Landsat Level-2

At the bottom of the page, there is a footer with the text: "Esri, CGIAR, USGS | City of Phoenix, Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USF... Powered by Esri".

Activity 9 Part 1: Examining heat using the composite index tool

- 1) Examine the metadata for the US Urban Heat Island mapping campaign (temperature, enviro, demographic information):
<https://www.arcgis.com/home/item.html?id=777502ece2b343f7b3ec54170f0d972e> and then open it in the ArcGIS Online map viewer.
- 2) Sign in to ArcGIS Online and save your map.
- 3) Zoom to Washington DC and note how neighborhood temperature compares to the city-wide temperature. Since climate and weather don't vary much over short distances, the temperature anomalies across the city are due to differences in the landscape, such as the amount of tree cover or development.



Activity 9 Part 2: Examining heat using the composite index tool

- 4) Analysis > Calculate composite index > Input features: Urban heat islands campaign.
- 5) In Input variables, select these 3 variables – one that indicates exposure to heat, and two that indicate vulnerability to heat:

Afternoon Temp Anomaly, with a Weight of 2. The weight of this variable is 2 x more important than the others as it's a critical factor in determining the risk of high heat events > Add > Poverty %, with a Weight of 1 > Add > 65 and older %, with a Weight of 1.

- 6) In Index settings, combine scaled values (mean) > change the Minimum to 0 and the Maximum to 100: Output will be rescaled to make the minimum value 0 and the maximum value 100, to be more interpretable. Use defaults for the rest of the parameters. Output: Provide an appropriate name such as Urban Heat Risk Index Wash DC.
- 7) Analyze results: Darkest purple color where the aft temperature anomaly is higher, and where a higher % of people are in poverty and a higher % of people are over 65+.



Activity 9 Part 3: Examining heat using the composite index tool

- 8) Run results of index through Find Outliers tool to gain insights on spatial patterns: Find Outliers > Use Index – Mean field as the analysis field > Use defaults for other parameters. Result layer: Provide meaningful name such as Find Outliers Urban Heat Index Wash DC
- 9) The output of this tool shows different types of clusters and outliers in the index: Pink locations are hot spots where the index results are high. The pale blue locations are cold spots where the index results are low. The dark blue locations are low high outliers – the index result is low relative to the neighboring census tracts. The red locations are high low outliers – the index result is high relative to the neighboring census tracts.

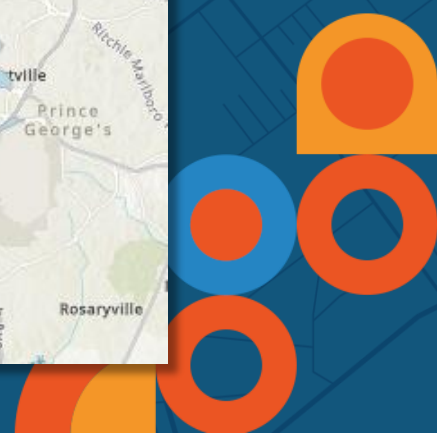
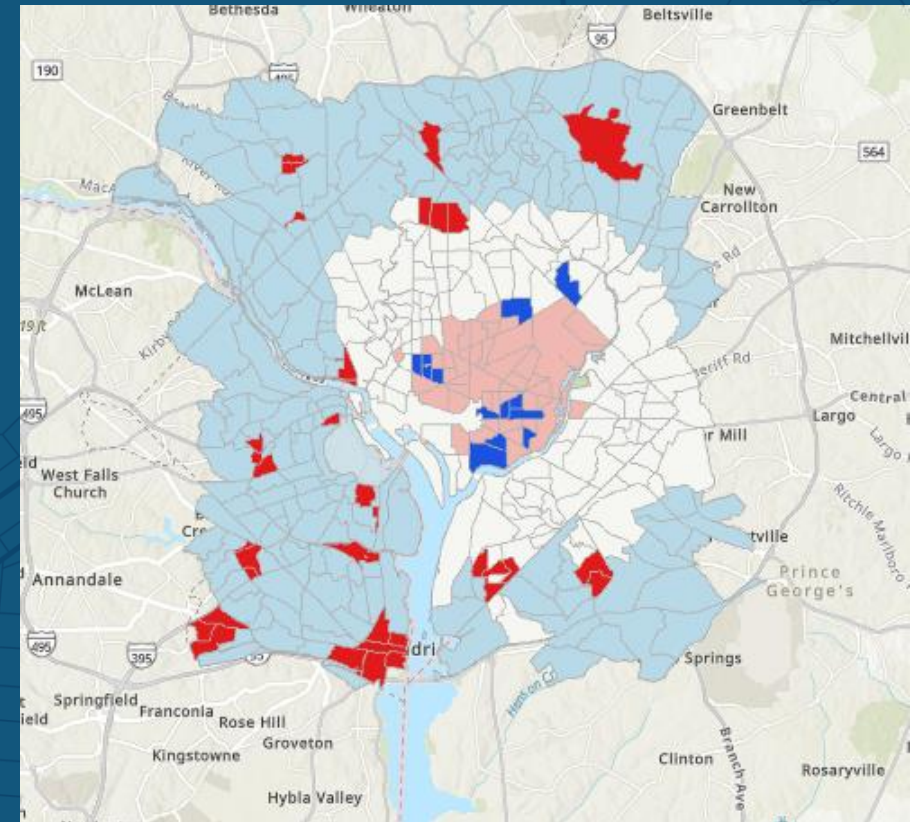
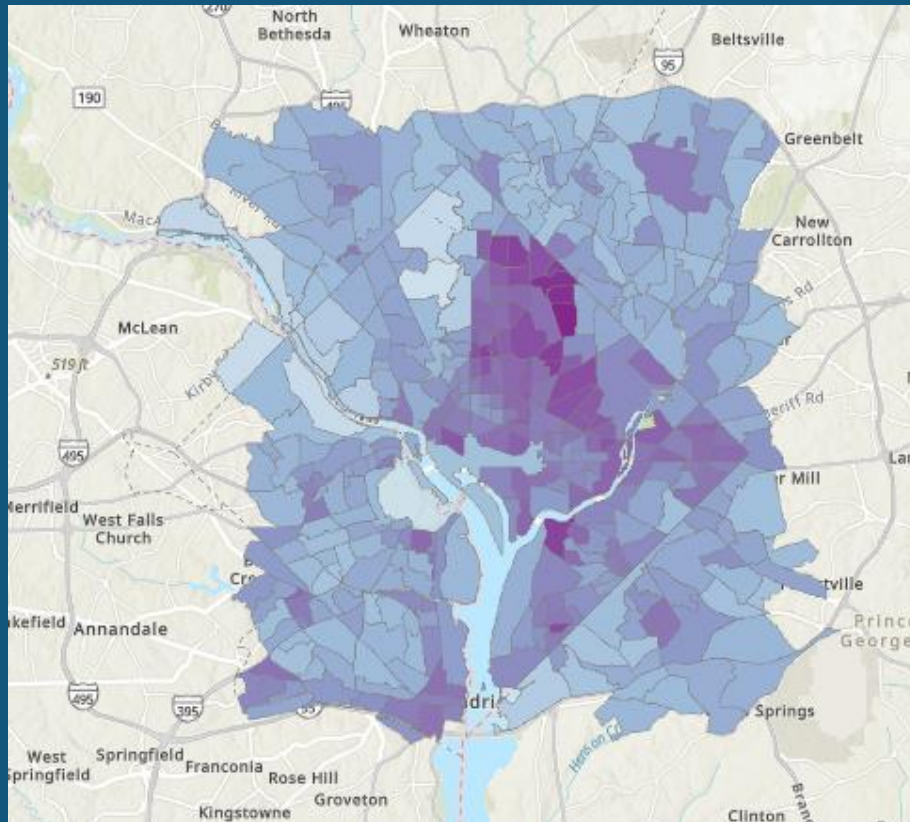
How could this inform action? For example, we might decide that the pale blue areas have less need for cooling centers, but any cooling centers we do add in the city should be in the red locations as these have higher risk relative to their surroundings.



Activity 9 Summary: Examining heat using the composite index tool

For more, see best practices on creating composite indices:

<https://www.esri.com/content/dam/esrisites/en-us/media/technical-papers/creating-composite-indices-using-arcgis.pdf>



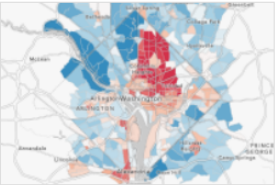
NOAA Urban Heat Island Campaign data

Often referred to as CAPA data (Produced by CAPA Solutions and NOAA)

Overview Pricing Map Scene Help

U.S. Urban Heat Island Mapping Campaign

Overview Data Visualization



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

Feature layer from Esri
Managed by esri_environment

Item created: Jul 15, 2021 Item updated: Oct 13, 2023 View count: 34,695

Authoritative Living Atlas

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:

Open in Map Viewer

Open in Scene Viewer

Open in ArcGIS Desktop

Details

Source: [Feature Service](#)
Data updated: Jul 16, 2021, 4:38 PM
Schema updated: Jul 16, 2021, 4:38 PM
Size: 0 KB
ID: 777502ece2b343f7b3ec54170f0d972e

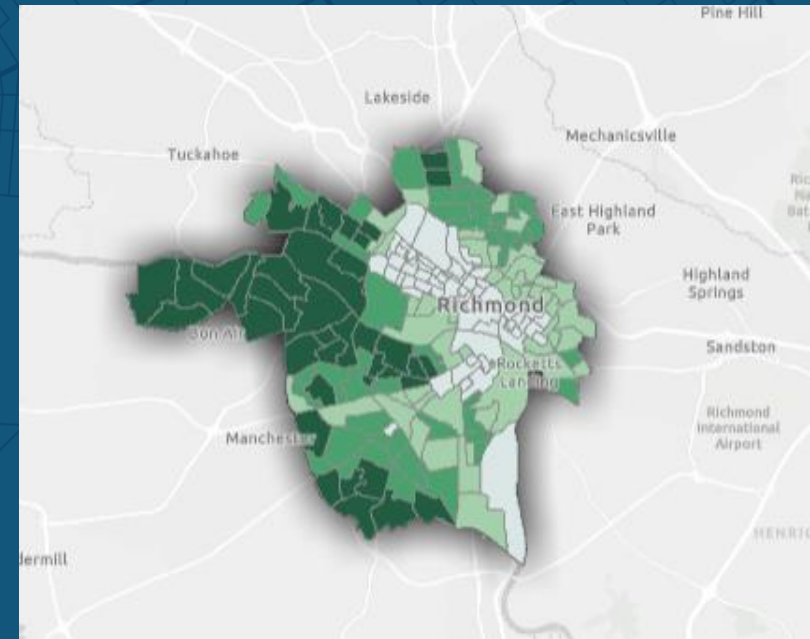
★★★★☆

[Facebook](#) [Twitter](#) [Share](#)



Activity 10 Part 1: Analyzing the urban heat effect

- 1) Open the Richmond urban heat islands map:
<https://www.arcgis.com/apps/mapviewer/index.html?webmap=3ef53b0b8a194b2c913a13497f7fe0c4> Sign in to ArcGIS Online > save map > view the map's layers.
- 2) First, calculate the maximum evening air temperature for each census block group. The Zonal Statistics as Table tool will allow for extracting the values from the air temperature layer, which contains raster data, and summarize this information to each census block group to understand how air temperature changes by neighborhood: Analysis > Tools > type "zonal" to find and choose Zonal Statistics as Table > For Input zone raster or features, choose Census Block Groups - For Zone field, choose GEOID - For Input value raster, choose Evening Temperature - Under Statistical analysis settings, for Statistic type, choose Maximum – for output table name: EveningTemp_BG (for block group) > Run.




Activity 10 Part 2: Analyzing the urban heat effect

- 3) You should now have a new table in the map: Go to Contents > Tables > open your new table. This table shows maximum evening air temp for each block group in degrees F. Note the range of temperatures across block groups. Later, you will use the Join Features tool to join this table to the Census Block Groups layer.
- 4) Next, determine a baseline value of evening air temperature by calculating the mean value for the whole city: Again access Zonal Statistics as Table tool > For Input zone raster or features, choose City Boundary – For zone field: OBJECTID - For Input value raster, confirm it is set to Evening Temperature - Under the Statistical analysis settings, for Statistic type, choose Mean – Output Table name: EveningTemp_Mean_<your initials> > Run.
- 5) Open your new “mean” table – this contains evening air mean temperature for single day of collection across the city: 87.63 deg F. You can now compare this median value to max temps within each block group and determine if a particular block group is warmer or cooler than the rest of the city.



Activity 10 Part 3: Analyzing the urban heat effect

- 6) Impervious surfaces are present in developed spaces and absorb and retain heat, contributing to the urban heat island effect. Using the Zonal Statistics as Table tool, you will now calculate mean percent of impervious surfaces within each census block group. You can later calculate the percentage of impervious surfaces in each census block group. Use the tool Zonal Statistics as Table again > For Input zone raster or features, choose Census Block Groups - For Zone field, choose GEOID - For Input value raster, choose Impervious Surfaces – Under statistical analysis settings: Statistic type: Mean – Output Table name: ImperviousSurfaces_BG_<your initials> > Run.
- 7) Open new ImperviousSurfaces_BG table and note the mean, which is the mean % of impervious surface in the block group.



...	COUNT_	...	ZONE_AREA	...	MEAN	...
	390.00		1,345,148.41		21.77	
	136.00		469,077.39		28.71	
	526.00		1,814,225.80		15.67	
	176.00		607,041.33		32.32	

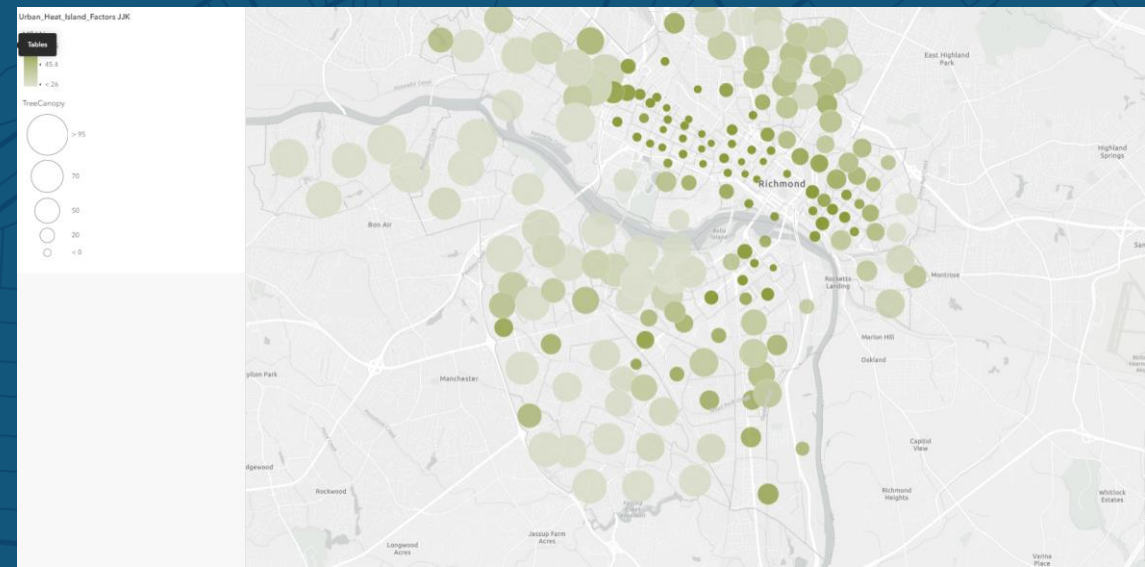
Activity 10 Part 4: Analyzing the urban heat effect

- 8) Now that you've summarized air temperature and impervious surfaces by census block group, you will join the analysis results into a single layer showing where potential heat islands are located across the city: Analysis > Search for and open the Join Features tool > In the Join Features tool pane, for Target layer, choose Census Block Groups. For Join layer, choose Evening Temp BG – zonal statistics table. Join settings: For Target field and Join Field, choose GEOID. Leave the other default settings as they are. Result layer: Output Name: BG_Temp_<your initials> > Run. When done, observe your new layer.
- 9) Now you will join the data from the impervious surface table to the BG_Temp layer. In the Join Features tool pane, enter the following: For Target layer, choose BG_Temp - For Join layer, choose ImperviousSurfacesBG- your zonal stats table - Under the Join settings section, for Target field and Join field, choose GEOID. Leave the other defaults as they are - For Output name: BG_Temp_Surfaces _ < your initials> > Run.
- 10) The BG_Temp_Surfaces layer now contains data for the max evening temp **and** mean impervious surface value for each block group.



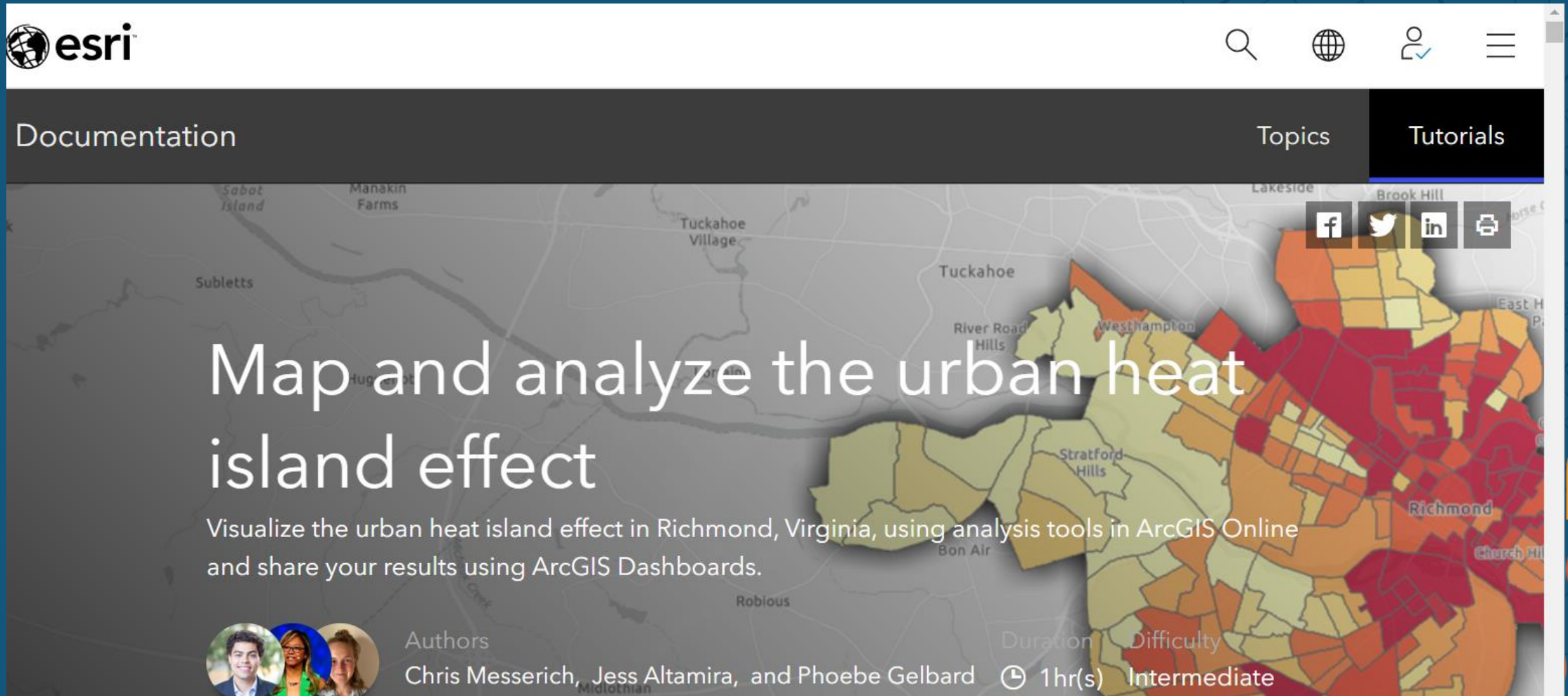
Activity 10 Part 5: Analyzing the urban heat effect

- 11) For the final join, you will join tree canopy data to the BG_Temp_Surface layer: Join Features tool: Target layer: BG_Temp_Surfaces. For Join Layer: Percent Tree Canopy. Join Settings: Use Attribute Relationship: Target Field and Join Field: GEOID. Output Layer: Urban_Heat_Island_Factors_<your initials> > Run.
- 12) Observe your final urban heat island factors map. You now have a layer that can visualize the urban heat island effect factors by census block groups.
- 13) Change style on your final map on “MEAN” as a choropleth map. Then, style > add field TreeCanopy to make a bivariate map. What patterns do you notice?
- 14) For a sample final map, click [here](#).



For more detail, see this lesson:

<https://learn.arcgis.com/en/projects/map-and-analyze-the-urban-heat-island-effect/>



The screenshot shows the ArcGIS Online interface. At the top left is the Esri logo. On the right side of the top navigation bar are icons for search, globe, user profile, and a menu. Below the navigation bar, there are tabs for 'Documentation', 'Topics', and 'Tutorials', with 'Tutorials' being the active tab. The main content area features a map of Richmond, Virginia, with a color-coded overlay representing the urban heat island effect. The colors range from light yellow (cooler) to dark red (warmer), with the highest concentrations in the dense urban core. Overlaid on the map is the title 'Map and analyze the urban heat island effect' in large white text. Below the title is a subtitle: 'Visualize the urban heat island effect in Richmond, Virginia, using analysis tools in ArcGIS Online and share your results using ArcGIS Dashboards.' At the bottom left, there are three circular profile pictures of the authors. To their right, the text 'Authors' is followed by the names 'Chris Messerich, Jess Altamira, and Phoebe Gelbard'. Further right, there are two columns of metadata: 'Duration' with a clock icon and '1hr(s)', and 'Difficulty' with 'Intermediate'. On the right side of the map, there are social media sharing icons for Facebook, Twitter, LinkedIn, and Print. The background of the entire slide is a dark blue grid pattern.

Perfecting the Resilience Model

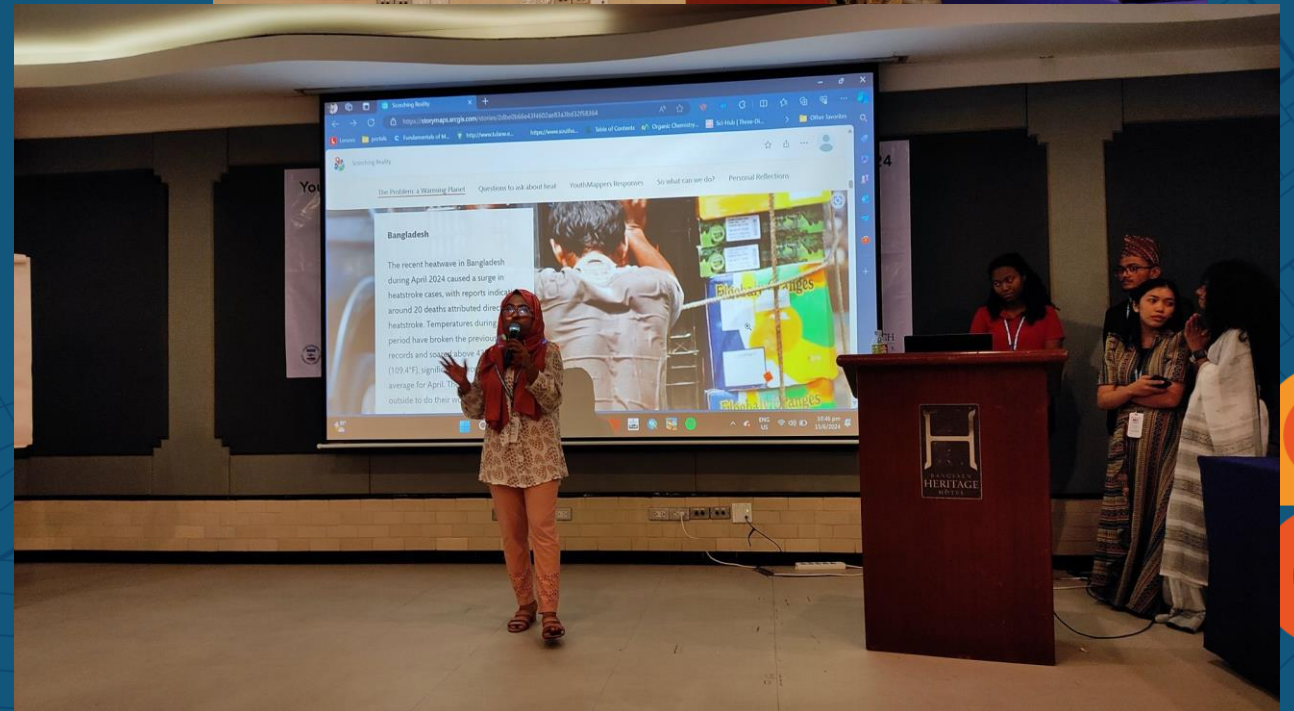
GIS is more than just mapping...

- Clever GIS people can imagine a host of analysis options
- Automate the processing of Land Surface Temperature each day/week
- 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



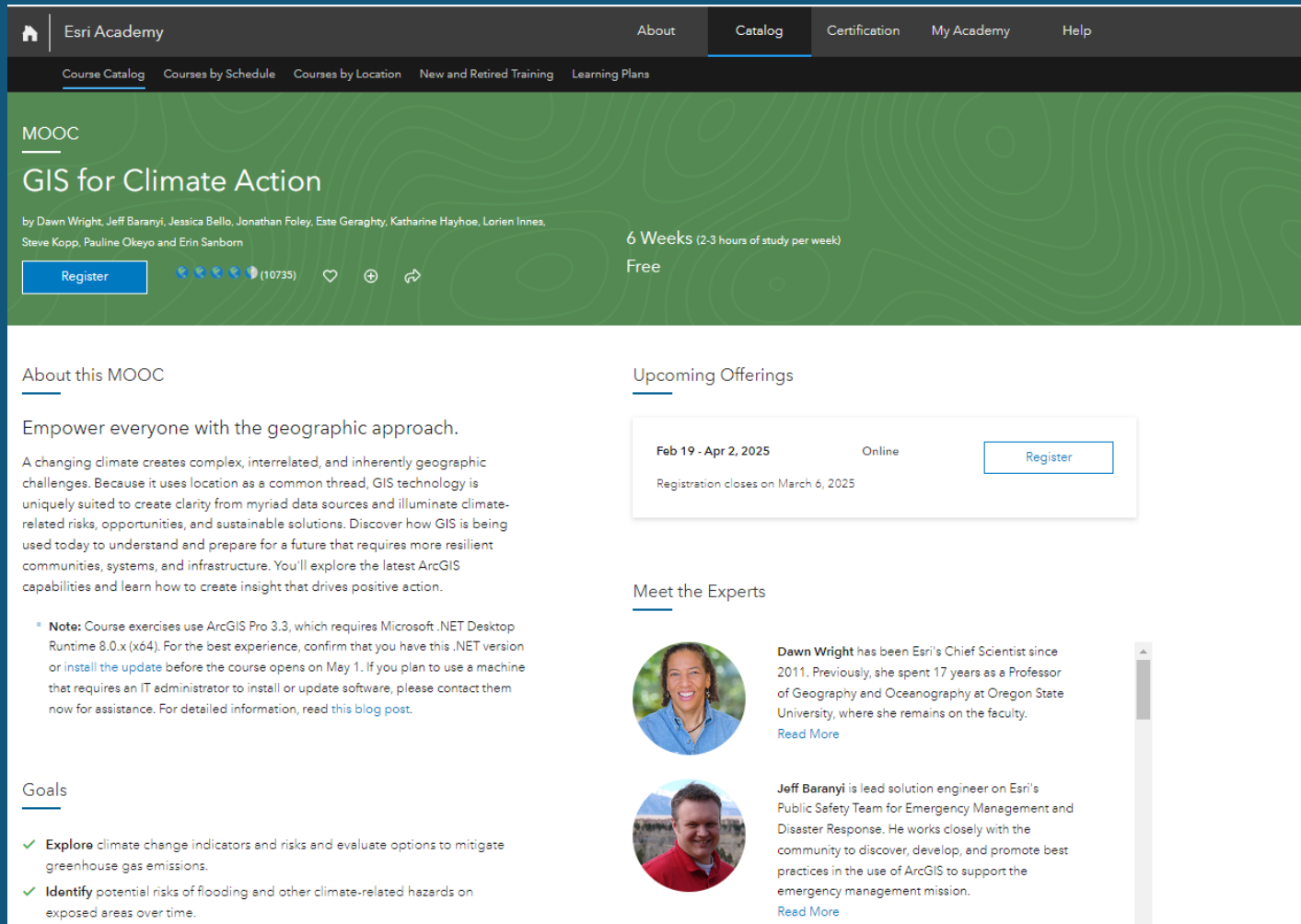
YouthMappers

- >400 university chapters
- OSM plus other mapping
- Pictured: June leadership training Bangkok
- SDG13 team worked on extreme heat mapping



Learning Resources: Climate Action MOOC

3rd offering: February 2025. Includes a heat mapping section and much more.



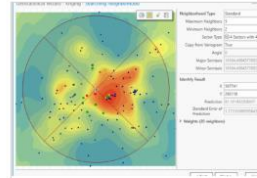
The screenshot shows the Esri Academy website interface. At the top, there is a navigation bar with 'Esri Academy' on the left and 'About', 'Catalog', 'Certification', 'My Academy', and 'Help' on the right. Below this is a secondary navigation bar with 'Course Catalog', 'Courses by Schedule', 'Courses by Location', 'New and Retired Training', and 'Learning Plans'. The main content area has a green background with a topographic map pattern. It features the title 'MOOC GIS for Climate Action' and lists the instructors: Dawn Wright, Jeff Baranyi, Jessica Bello, Jonathan Foley, Este Geraghty, Katharine Hayhoe, Lorien Innes, Steve Kopp, Pauline Okeyo, and Erin Sanborn. A 'Register' button is prominent, along with social media icons and a 'Free' label. The course duration is '6 Weeks (2-3 hours of study per week)'. Below the main header, there are sections for 'About this MOOC', 'Upcoming Offerings', and 'Meet the Experts'. The 'About this MOOC' section describes the course's focus on geographic challenges and climate change. The 'Upcoming Offerings' section shows a course running from Feb 19 to Apr 2, 2025, online, with a 'Register' button and a note that registration closes on March 6, 2025. The 'Meet the Experts' section features two experts: Dawn Wright, Chief Scientist at Esri, and Jeff Baranyi, lead solution engineer on Esri's Public Safety Team. The bottom of the page has a 'Goals' section with two bullet points: 'Explore climate change indicators and risks and evaluate options to mitigate greenhouse gas emissions' and 'Identify potential risks of flooding and other climate-related hazards on exposed areas over time.'

Tutorials on <https://learn.arcgis.com>

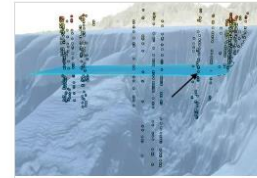
Learn to Apply GIS to Climate

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.

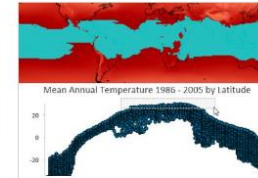
Learn ArcGIS Tutorials



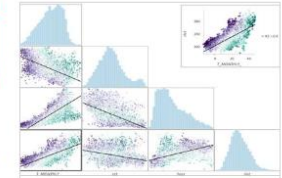
Analyze urban heat using kriging



Interpolate 3D oxygen measurements in...



Explore future climate projections



Downscale climate data with machine learning

esri | GIS for Climate Resilience

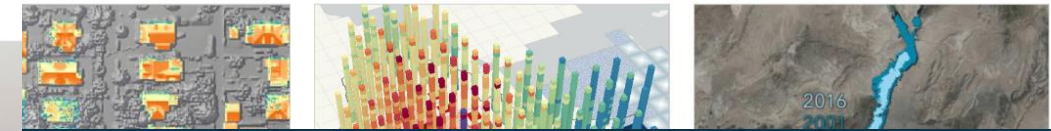
GETTING STARTED • LEARNING PATHWAYS • ADDITIONAL RESOURCES • PROVIDE FEEDBACK

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 preparing 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 and learn about these topics?

<https://community.esri.com/t5/education-blog/using-webgis-to-teach-climate-resilience/ba-p/1266780>

Mike Gould, Joseph Kerski



The screenshot shows the Esri Community website interface. At the top, there is a navigation bar with the Esri logo, 'Community', and links for 'All Communities', 'ArcGIS Ideas', 'GIS Life', 'Community Resources', a search icon, and 'Sign In'. Below this is a purple header banner. The main content area has a breadcrumb trail: 'Home > All Communities > Industries > Education > Education Blog > Using WebGIS to Teach Climate Resilience'. The article title 'Using WebGIS to Teach Climate Resilience' is prominently displayed. Below the title, it shows 2785 views, 0 comments, and a date of 03-13-2023 09:59 AM. There are two labels: 'Curriculum-Learning Resources' and 'Higher Education'. A 'Subscribe' button is located to the right. The author information shows a profile picture of Michael Gould, an Esri Contributor, with a 'Post Options' dropdown. A note states: 'Note: Although these articles take one author name by default, my colleague @JosephKerski co-authored this one. Thanks Joseph!'. The article text begins with 'Climate change and its effects increasingly are part of the general public discourse and is being taught at all levels of education. Related effects are adaptation and resilience, or the capacity of a system to cope with a'. To the right, there is a section titled 'About the Author' with a bio: 'I am an education manager at Esri and I work mostly on projects outside of North America, supporting 80-plus Esri offices and more than 10000 universities. PhD from (SUNY) University at Buffalo. I am based in Spain and am part-'. The bottom right corner of the image features decorative orange and blue circular graphics.

Additional Instructional Resources

<https://www.esri.com/en-us/industries/higher-education/climate-education>

esri Products ▾ Industries ▾ Support & Services ▾ Stories ▾ About ▾

Climate Education

Resources for your climate change curriculum

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

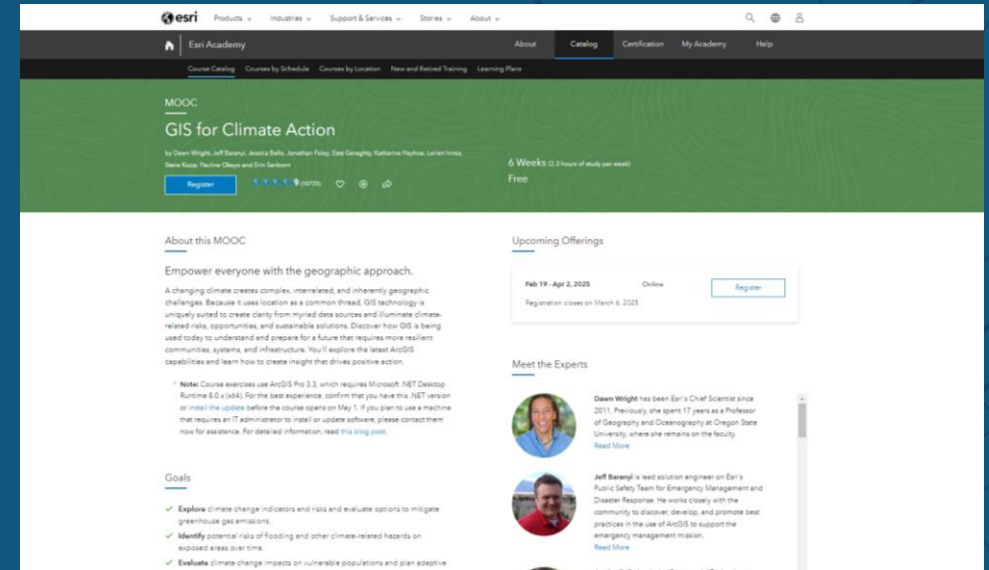
+ STAY UPDATED

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

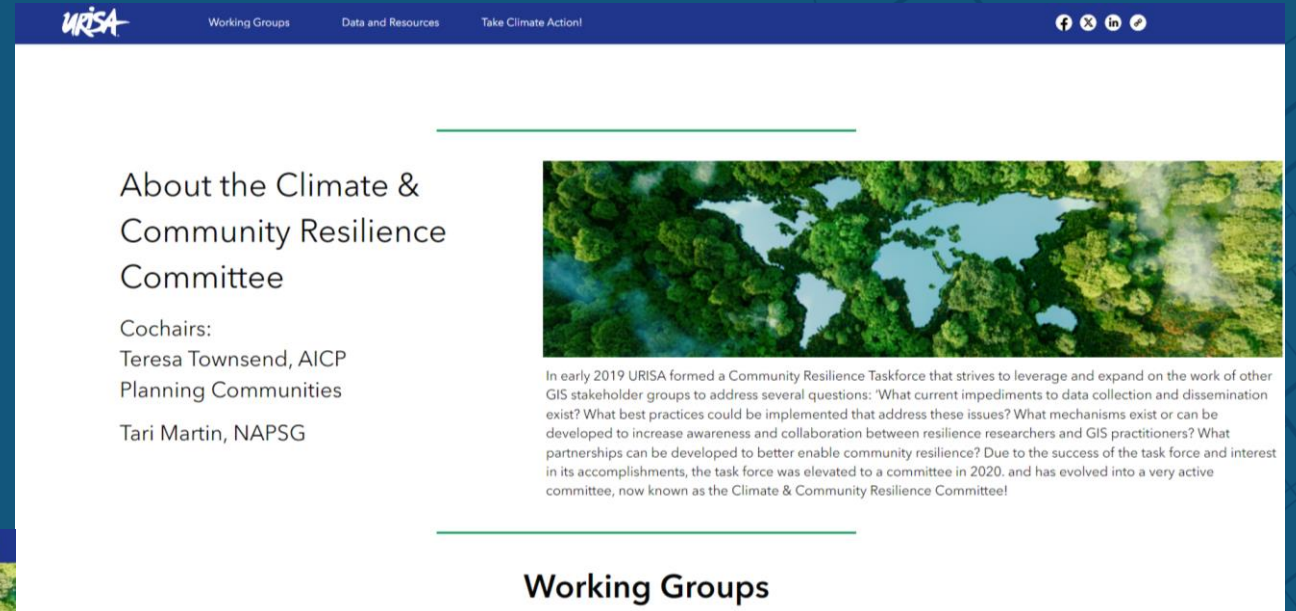
Upcoming Events

- Climate Action MOOC (Feb 2025)
- Esri Education Summit, July 2025
- Esri UC, July 2025
- **Innovate4Cities** (GCOM, UN-Habitat), Montreal 10-12 September
- **URISA GIS Pro**, October 7-10
- **UN Data Forum**, 12-15 Nov
- Ongoing: Esri Higher Education chats, 1st Tue of every month.
- Ongoing: Esri Education blog space.



Organizations to partner with

- URISA
- AASHE
- Esri
- UCAR



The screenshot shows the URISA website's navigation bar with links for 'Working Groups', 'Data and Resources', and 'Take Climate Action!'. The main content area is titled 'About the Climate & Community Resilience Committee' and lists co-chairs Teresa Townsend (AICP Planning Communities) and Tari Martin (NAPSG). A large image of a forest with a stream is featured. Below the image, a paragraph describes the formation of the Community Resilience Taskforce in early 2019, its goals, and its evolution into the Climate & Community Resilience Committee in 2020. A 'Working Groups' section is partially visible at the bottom.

URISA Working Groups Data and Resources Take Climate Action! f x in e

About the Climate & Community Resilience Committee

Cochairs:
Teresa Townsend, AICP
Planning Communities
Tari Martin, NAPSG

In early 2019 URISA formed a Community Resilience Taskforce that strives to leverage and expand on the work of other GIS stakeholder groups to address several questions: 'What current impediments to data collection and dissemination exist? What best practices could be implemented that address these issues? What mechanisms exist or can be developed to increase awareness and collaboration between resilience researchers and GIS practitioners? What partnerships can be developed to better enable community resilience? Due to the success of the task force and interest in its accomplishments, the task force was elevated to a committee in 2020, and has evolved into a very active committee, now known as the Climate & Community Resilience Committee!

Working Groups



The screenshot shows the URISA website's home page. The navigation bar includes links for 'Home', 'Climate Change & Climate Equity', 'Data and Resources Hub', 'Reduce Your Footprint', 'Take Climate Action!', and 'Other Resources'. A large banner image of a forest with a stream features the text 'URISA is TAKING ACTION for Climate and Community Resilience!'. Below the banner, a photo of two people at a tree-planting event is shown next to a text block.

URISA Home Climate Change & Climate Equity Data and Resources Hub Reduce Your Footprint Take Climate Action! Other Resources

URISA is TAKING ACTION for Climate and Community Resilience!

Last year, the URISA community participated in an impactful tree planting event, planting **1014** trees to commemorate our 60th Anniversary. As we head to **GIS-Pro Columbus 2023** and gear up for our **2024 Climate and Community Resilience URISA Challenge**, we're amplifying our commitment, our trees, reducing



Take-Aways

Teaching and learning about climate with GIS

- Perfect time for teaching and researching climate with GIS
- Perfect time for taking action on climate related topics such as Urban Extreme Heat
- ArcGIS can be a valuable tool and approach: Many possible, related workflows
- Many relevant Data Sets available (Living Atlas of the World)
- Many relevant Best Practice examples to tap into the collective wisdom
- Many Learning Resources exist for moving ahead

