GLOBE Educator One-Week Pacing Guide: *Urban Heat Islands*

Phenomenon: Urban Heat Island **Grade Level:** 6-12	**Guiding Question:** What environmental conditions influence surface temperature?	**Contact:** Reach out to Dr. Kevin Czajkowski, (kevin.czajkowski@utoledo.edu) if you have questions.
Further Investigation: GLOBE Mission Earth Urban Heat Island Effect / Surface Temperature Field Study		
Optional: Become a GLOBE Trained Teacher: GLOBE Atmosphere Protocol Training		
Access GLOBE Pacing Guides: https://www.globe.gov/web/nasa-langley-research-center/home/resources		
Revision Date: 7-2-2025		

Standards - These standards are supported by the activities in this guide but not completely covered.		
Middle	**Performance Expectations:** • MS-ESS2-1 Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. • MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. • MS-ESS3-4 Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. • MS-PS1-4 Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.	**Disciplinary Core Ideas:** • ESS2.A Earth's Materials and Systems • ESS3-C Human Impacts on Earth Systems • PS1.A Structure and Properties of Matter • PS3.A Definitions of Energy • PS3.B Conservation of Energy and Energy Transfer

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	● MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. *(Testing surfaces)*	
	Science and Engineering Practices: ● Developing and Using Models ● Constructing Explanations and Designing Solutions ● Developing and Using Models ● Engaging in Argument from Evidence	**Crosscutting Concepts:** ● Stability and Change ● Energy and Matter ● Cause and Effect
High School	**Performance Expectations:** ● HS-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. ● ESS3.C Human Impacts on Earth Systems the sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.	**Disciplinary Core Ideas:** ● ESS3.D Global Climate change
	Science and Engineering Practices: ● Using Math and Computational Thinking	**Crosscutting Concepts:** ● Systems and System Models

Background Information and NASA Connection
What Are Urban Heat Islands? An *urban heat island* is a phenomenon that is best described when a city experiences much warmer temperatures than in nearby rural areas. The Sun's heat and light reach the city and the country in the same way. The difference in temperature between urban and less-developed rural areas has to do with how well the surfaces in each environment absorb and hold heat. Sometimes the urban areas can be cooler if there are a lot of trees in the area and it is surrounded by barren or desert areas. Again, this is due to the differences in surfaces, or land cover.

What is Albedo and How is it Related to Surface Temperature?

Part of the reason for differences in surface temperature over different types of surfaces comes from differences in **Albedo**. Some materials reflect more sunlight than others. This has a lot to do with the color of the surface. Have you ever noticed that you get hotter outside in the summer when you wear black and you feel cooler when you wear white? This is the effect of Albedo. **Albedo** indicates what percentage of the incoming solar radiation (sunlight) is **reflected** by a surface. The less albedo a surface has, the more energy contained in solar radiation (sunlight) is getting **absorbed**. So if a surface has an albedo of 6%, that means 6% of the incoming solar energy that reaches that surface is reflected and the other 94% of the energy is absorbed by the surface.

How do Plants Affect Urban Heat Islands?

Plants take up water from the ground through their roots. Then, they store the water in their stems and leaves. The water eventually travels to small holes on the underside of leaves. There, the liquid water turns into water vapor and is released into the air. This process is called **transpiration**. By releasing water, plants cool themselves and the surrounding environment. Like how sweat cools the human body, energy is absorbed and transported away from a warm object by the evaporation of water. Also, over a forest canopy or a vast expanse of grassland, large amounts of transpiration can greatly increase water vapor in the atmosphere, causing more precipitation and cloud cover in an area. The additional cloud cover often reinforces the cooling by blocking sunlight.

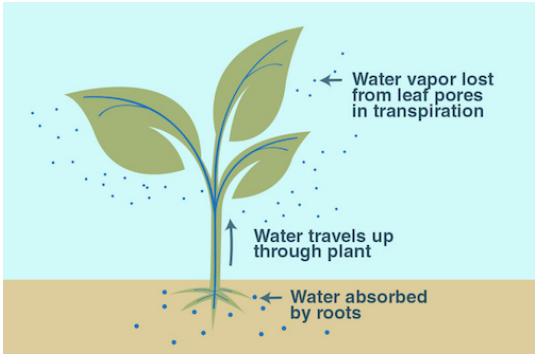
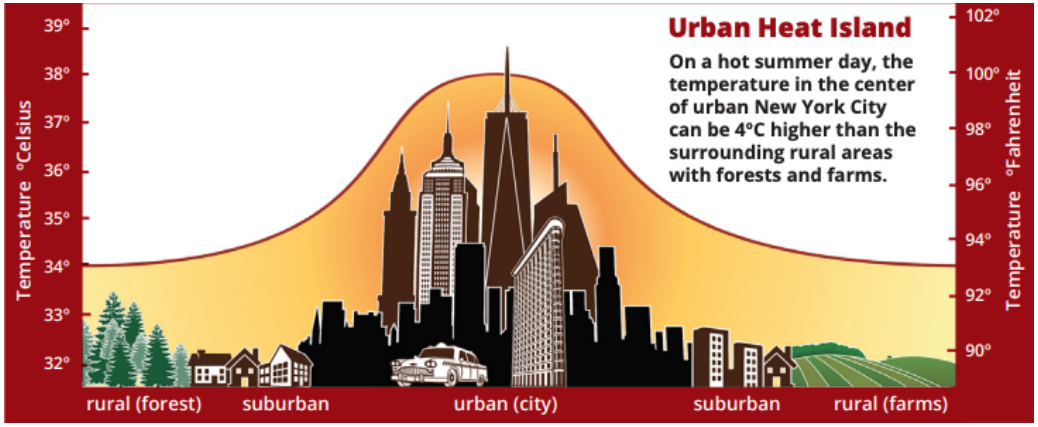


Image: An illustration of the process of transpiration
Credit: NASA JPL/Caltech



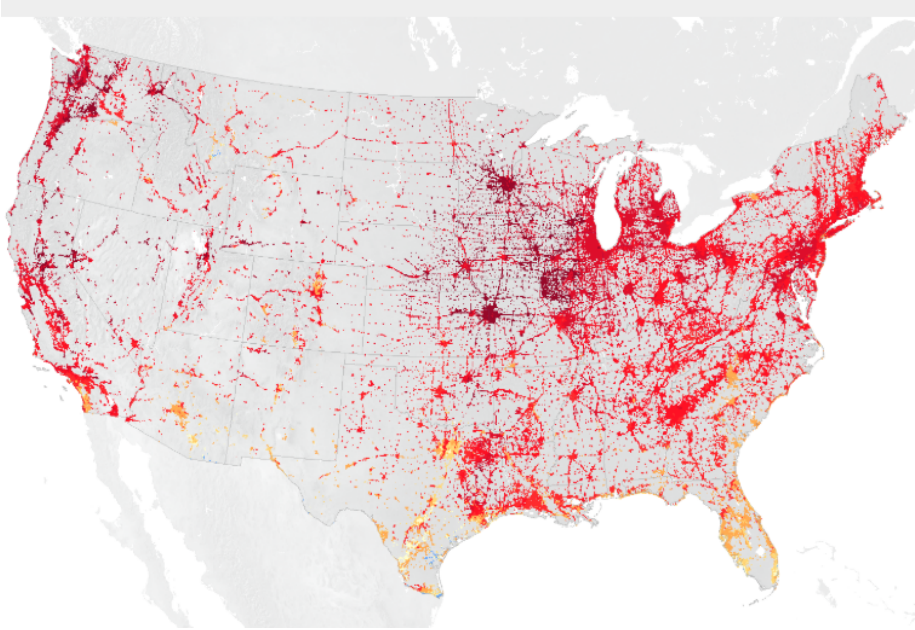
Credit: NASA

Where Do Urban Heat Islands Form?

The hottest places on Earth have a few traits in common. They are full of rock and stone. They do not have a lot of water, plants, or trees, and they are full of dark colors. Cities are full of these rocky surfaces — asphalt, brick, and concrete — that absorb heat by day and release it at night. These materials are used to make the sidewalks, parking lots, roads, and basketball courts of urban areas. Urban heat islands form because humans replace cooler surfaces with rocky surfaces.

These hard and dark-colored surfaces contribute to the urban heat island effect in two ways. First, these surfaces have a low albedo, which increases the amount of energy from solar radiation they absorb. Second, these surfaces do not contain much water to evaporate, meaning that less of the absorbed energy evaporates water, and more goes into warming the surface and releasing energy by conduction, convection, or radiation. The combination of these factors means that cities and other highly developed areas are hotter than the plant-covered countryside.

Urban areas often see temperatures rise 6°C (10°F) hotter than the surrounding suburbs and rural areas. Cities tend to be hotter than their surrounding areas at all times of the day and at all times of the year. However, a variety of factors influence the urban heat island. Bigger cities tend to have stronger heat-trapping capacities than smaller cities. Cities surrounded by forest have more pronounced heat islands than do cities in arid environments. This is because replacing forests with paved surfaces leads to a greater warming effect than replacing dry sand and rock with pavement.

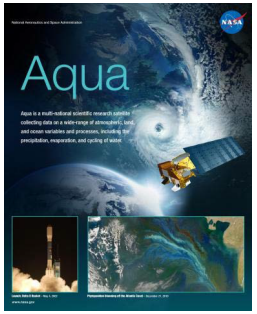


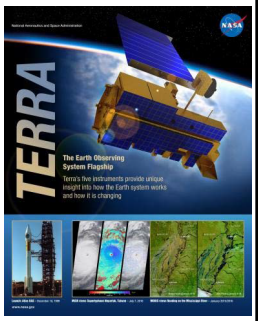
Temperature Difference Between Urban and Vegetated Land Due to Impervious Surface Area
Credit: NASA Earth Observatory image by Joshua Stevens, using data from Bounoa, et al. (2015)

Why Does NASA Study the Urban Heat Island Effect?
According to the United States Global Change Research Program, heat waves (periods of abnormally hot and/or humid weather lasting a few days to weeks at a time) are occurring more frequently in major cities across the U.S. These events can have detrimental impacts on public health. Urban heat islands play a role in these extreme heat events, as the buildings and impervious surfaces (such as roads and sidewalks) of cities and developed areas tend to retain heat and have higher temperatures than rural areas.

Some measures can mitigate the urban heat island. Painting roads and rooftops white instead of black enables those surfaces to reflect more sunlight and absorb less heat. Planting vegetation on rooftops and elsewhere also reduces surface temperatures.

How Does NASA Study Urban Heat Islands?





NASA's newest method for comparing cities involves the use of maps of impervious surface area produced by a United States Geological Survey-operated Landsat satellite, and land surface temperature data from the Moderate-resolution Imaging Spectroradiometer (MODIS), an instrument aboard NASA's Aqua and Terra satellites. Data from NASA's ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) mission provide detailed measurements of vegetation temperature, which is an indication of plant stress. Plants with sufficient water are able to maintain their temperature; plants that are stressed by insufficient water caused by drought, extreme heat, and other factors show a temperature rise.

By analyzing data from thousands of settlements around the world, the NASA team has pinpointed key characteristics of cities that drive the development of heat islands. The largest cities usually have the strongest heat islands. Cities located in forested regions, such as the northeastern United States, also have stronger heat islands than cities situated in grassy or desert environments.

While the satellites deployed by NASA and worldwide space agencies give us a big picture of what's happening on Earth, they struggle at times to provide a detailed analysis of what's happening in specific locations. That's why it's so crucial for researchers to have ground truth data gathered from the Earth's surface. The GLOBE Program is NASA's largest and longest lasting citizen science program about the Earth. Through the program's GLOBE Observer app, you can contribute to our current state of scientific knowledge by submitting land cover observations and photographing what you see. If you are GLOBE trained, you can also use the app to submit surface temperature data. These data help form a complete picture of the data.

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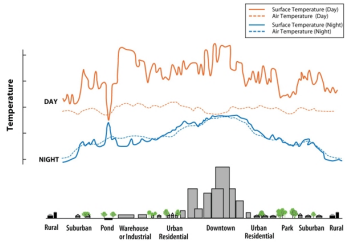
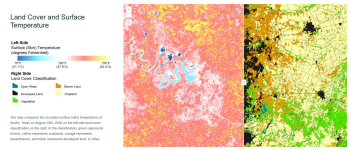
Activities		Assessment Options
Day 1: • Watch the Climate Bits: Urban Heat Island Video • Complete the Analyze Graphs of Surface Temperature Throughout the Day activity **Materials:** Online activity		• Evaluate student answers to questions ***Connection to guiding question:*** *Why do you think the air and surface temperatures are higher in the cities?* ***Answer:*** *The cities have more surfaces that absorb incoming energy from the Sun.*
Day 2: A Mini Urban Heat Island **Materials:** Listed in activity including Infrared Thermometer. (Analyzing Surface Temperature Differences is an online version of this activity)		• Data table and conclusions ***Connection to guiding question:*** *Which surface material(s) would make your area cooler?* ***Answer:*** *Surfaces such as grass or water or lighter colored surfaces are cooler than dark surfaces.*
Day 3: Patterns in Earth's Surface Temperature Interactive Model **Materials:** Online activity		• Evaluate student answers to questions ***Connection to guiding question:*** *Where do you think the most developed land is located?* ***Answer:*** *In urban areas or cities.*

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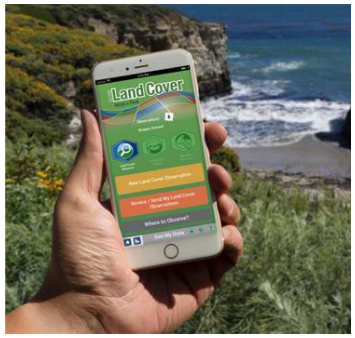
<table>
<tr><th colspan="2">Activities</th><th>Assessment Options</th></tr>
<tr><td colspan="2">Day 4: GLOBE Observer Land Cover or Tree Height Observation

● The GLOBE Program's GLOBE Observer Land Cover and/or Tree Height Tools
● If you are not using the GLOBE Observer tools, you may use the following protocols.
○ Land Cover Classification
○ Biometry Including Tree Height

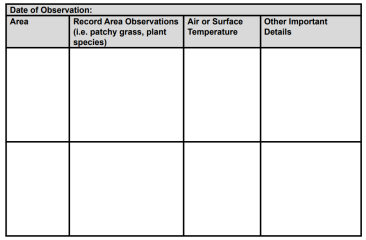
Materials: Online activity

Only make observations if you can do so safely and legally.</td><td> 
</td><td>● Within groups, develop consensus on observations using evidence and submit observations.

Connection to guiding question:
How might land cover affect the surface temperatures?

Answer: Different land covers absorb different amounts of energy. Developed land tends to absorb more energy. Deserts also absorb a lot of energy.</td></tr>
<tr><td colspan="2"></td><td>Optional Instructional Videos:
● GLOBE Observer: Land Cover - Getting Started
● GLOBE Observer Trees Introduction
● How to Take a NASA GO Tree Observation</td></tr>
<tr><td colspan="2">Day 5: Microclimates activity using surface temperature

Make predictions about two different locations.

Materials: notebook, calibration or infrared thermometer</td><td> 
<table>
<tr><td colspan="4">Date of Observation:</td></tr>
<tr><td>Area</td><td>Record Area Observations (i.e. patchy grass, plant species)</td><td>Air or Surface Temperature</td><td>Other Important Details</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table></td><td>● Predication and results
● Complete Claim - Evidence - Reasoning document

Connection to guiding question:
What evidence did you find to support the Urban Heat Island Effect? If none, why?

Answer: Different locations had different temperatures. If none, not enough variety in surfaces.</td></tr>
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Activities		Assessment Options
Day 5: (Continued)		***Connection to NASA:*** *How and why does NASA study urban heat islands?* ***Answer:*** *NASA uses satellites to observe land cover type, vegetation, and surface temperatures. They study urban heat islands because the effects can be dangerous, especially in the summer. There are ways to lessen the effects when they are detected. This includes changing surfaces and introducing more plants and trees.*

Additional Resources		
Online Activities	Audience	Description
My NASA Data Creation of Urban Heat Islands StoryMap	Grades 6-12	By interacting with various visualizations (i.e., images, charts, and graphs), students explore the *urban heat island effect* using land surface temperature and vegetation data. Students will investigate the processes that create differences in surface temperatures, as well as how human activities have led to the creation of urban heat islands.
My NASA Data Human Impact and the Creation of Urban Heat Islands Interactive Model	Grades 6-12	Using interactive maps, students will identify and describe the relationship between land cover classification and surface temperature as it relates to the urban heat island effect. Students will also identify patterns between population density and the locations of urban heat islands in order to describe how urbanization has contributed to the urban heat island effect.

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Additional Resources		
Online Activities	Audience	Description
My NASA Data Relationship Between Surface Temperature and Vegetation	Grades 6-12	Analyze Landsat images of Atlanta, Georgia to explore the relationship between surface temperature and vegetation.
What is an Urban Heat Island? (Climate Kids)	Upper Elementary	NASA Climate Kids webpage to explore the concept of urban heat islands.
My NASA Data Analyzing Surface Temperature Differences	Grades 6-12	Students observe the surface temperatures of a variety of surface types found in a suburban environment.
Hands-On Activities	Audience	Description
Heating Things Up	Grades 6-12	Investigate the different rates of heating and cooling of certain materials on earth in order to understand the heating dynamics that takes place in the Earth's atmosphere.
Videos and Reading	Audience	Description
Urban Heat Islands	Grades 6-12	At the 2010 American Geophysical Union (AGU) conference in San Francisco, Dr. Ping Zhang presented her findings on the Urban Heat Island effect. The data collected spans from 1995 to 2005 and will give scientists an idea of why cities are warmer than their surrounding areas, as well as what effect this will have on the planet. *Credit: NASA Goddard*

Additional Resources		
Videos and Reading	Audience	Description
NASA EO Kids Urban Heat Islands: Hot Times in the City	Ages 9-14	What makes an urban heat island? Why is New York City a "hot" town? Where are the hottest places on Earth? How can NASA scientists help city planners turn down the heat? Read this and more in this issue of EO for Kids.

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