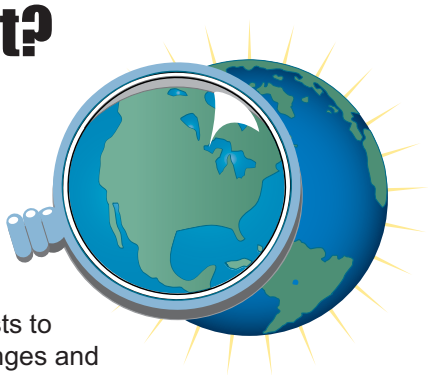
# Why is the city hot?



## Investigation Overview

This investigation examines the formation of urban heat islands. NASA scientists are studying the urban heat island in Atlanta and in other cities. This investigation draws on thermal images and research by NASA scientists to examine causes of environmental changes and actions that might be taken to reduce the harmful effects of those changes.

Time required: Three 45-minute sessions

## Material/Resources

Briefing and Logs 1 and 2 (one copy of each per student)
Color transparencies of:
- Figure 1: Land use 1973
- Figure 2: Land use 1987
- Figure 3: Land use 1997
- Figure 4: Sketch of an urban heat-island profile

Color photocopies of:
- Figure 5: Atlanta, day and night (class set or one per student group)

World atlases
Outline maps of the United States
Road atlas of the United States
Overhead transparencies

## Content Preview

Urban deforestation and urban sprawl lead to the formation of heat islands, areas of higher than normal temperature. Buildings and roads absorb more heat than trees and grass, causing a buildup of heat. Vegetation and trees help keep a city cool.

## Classroom Procedures

### *Beginning the Investigation*

1. Have students develop a list of different topics that NASA scientists are studying. Share the list with the class. Discuss the topics presented and have students identify which of their topics are local issues and which are global issues.

2. Explain to students that NASA scientists are studying land use change in urban areas to find out what happens when forests and vegetation are removed and replaced by buildings and roads. Scientists use aerial photos, satellite images, maps, census data, and other information to examine urban expansion. For example, satellite images of Atlanta show how the city has expanded into farmland and woodlands. Scientists are measuring temperature and rainfall to see what kinds of changes are occurring and how they affect people living in urban areas. This activity introduces students to some of the research conducted by NASA scientists.

## Geography Standards

### *Standard 12: Human Systems*

***The processes, patterns, and functions of human settlement***

- Explain the causes and consequences of urbanization.

### *Standard 14: Environment and Society*

***How human actions modify the physical environment***

- Analyze the environmental consequences of human changes of the physical environment.

### *Standard 18: The Uses of Geography*

***How to apply geography to interpret the present and predict the future.***

- Analyze the interaction between physical and human systems.

### *Geography Skills*

***Skill Set 1: Asking Geographic Questions***

- Identify geographic issues, define geographic problems, and pose geographic questions.

***Skill Set 2: Acquiring Geographic Information***

- Use maps to collect and compile geographic information.

***Skill Set 4: Analyzing Geographic Information***

- Interpret information obtained from maps, aerial photographs, satellite-produced images, and geographic information systems.
- Use statistics and other quantitative techniques to evaluate geographic information.

***Skill Set 5: Answering Geographic Questions***

- Make generalizations and assess their validity.

3. Using a map of the United States have students locate Atlanta and identify the location by latitude and longitude (33°45'N, 84°23'W). Ask students to describe where Atlanta is in relation to their own community. Using the scale given on the map, estimate how far away Atlanta is and how long it would take to get there by automobile.

4. Distribute these population data for Atlanta to illustrate its rapid growth:

   1980—2,138,000
   1998—3,589,000

   Ask students to calculate the change in the number of people (*1,451,000*) and the percentage of population increase (*67.9%*).

   Have students discuss population growth in their own community. Has population been expanding, staying the same, or declining? Why? What is the relationship between population growth and land use change? Have students give some specific examples. Examples may include land clearing for new roads, housing, and shopping areas.

5. Use an overhead transparency of **Figure 1** to explain how to interpret land use in Atlanta. The color legend and map provide the information needed.

   After presenting the 1973 map, show the 1973 and **Figure 2** 1987 maps simultaneously and ask students to identify changes that have occurred. Discuss reasons why the changes occurred, such as migration of people to Atlanta and the development of new businesses and roads. On the 1973 map, point out that development is concentrated in the central area of the city and along major roads. Historically, some development was also located along rivers for access to water and water transportation. Later development grew toward the airport, which was once on the outskirts of the city. Most of the growth since 1973 is related to the accessibility provided by transportation routes. Also, growth tended to occur near already built-up areas.

6. Distribute **Log 1** containing the 1987 map divided into quadrants with an alphanumeric grid. Provide a brief explanation of quadrants and an alphanumeric grid system.

   On **Log 1,** students predict where expansion took place between 1987 and 1997 (**Figure 3**) by identifying grid units where they believe that the expansion occurred. After completing the **Log,** use a road atlas of the United States to have students look at the road network and other features in the Atlanta region. Identify and describe the locations of the interstate highways in and around the city. (*Examples: Interstates 20, 85, and 75.*)

## *Developing the Investigation*

7. Show students **Figure 4**, and discuss how an urban heat island is measured. Sometimes remote-sensing devices on planes or satellites are used to detect temperature differences on Earth's surface. Urban heat islands are measured by observing temperatures in different locations across the city at different hours of the day and in different seasons. Temperatures are recorded for individual buildings, roads, parking lots, and vegetated areas. The high temperatures of individual features combine to raise the overall temperature of the city by 4.5-5.5°C (8-10°F). Areas that lose vegetation by adding concrete and asphalt structures experience the greatest increases in temperature.

8. Distribute copies of **Figure 5**. Each image has an alphanumeric grid overlay to allow precise comparison of parts of the city. The focus is on the cooling process and how it affects the thermal appearance of the city. The city cools faster in areas with more vegetation and more slowly in areas with less vegetation. Individual features stand out more clearly on the night image. This is due to the greater variation in temperature across the city during the night. See the temperature scale on **Figure 4** for image interpretation.

   Using a specially outfitted Lear Jet, NASA researchers collected thermal data for the Atlanta metro area. As shown in **Figure 5**, aircraft data are lined up with a larger image, taken from the orbiting Landsat 5 satellite. Notice how the buildings themselves help keep small areas cool, casting shadows across the pavement and walls of surrounding structures. Using the same color scale, you can see how much heat remains locked in the developed areas of the city at night.

9. **Log 2** asks students to compare the same pre-selected grid cells on both images. The objective is to have students see the differences in how clearly individual features such as major roads, the downtown area, or large housing subdivisions appear on the images. The night image provides finer detail and allows students to more readily identify features.

### *Concluding the Investigation*

10. On **Log 2** ask students to create an equation that describes the relationships that lead to urban heat islands using the following terms and symbols:

| | |
|---|---|
| urban heat island | ↑ (increase) |
| urban development | + (plus) |
| forests | = (equals) |
| | ↓ (decrease) |

Students should be able to develop the following equation:

↑ urban development + ↓ forests = urban heat island

Have students write a sentence describing the relationships shown in the equation. A possible sentence might be: Increasing urban development and decreasing forests cause urban heat islands.

## Background

**Urban Sprawl, Urban Heat Islands, and Urban Deforestation**

During the last few decades many cities in the south, southwest, and west experienced dramatic population growth. Atlanta, Georgia, was among the fastest growing cities in the United States during the '90s. The population of the city of Atlanta dropped from 495,039 in 1970 to 394,017 in 1990, but the suburban population in the surrounding 20 counties skyrocketed from 1.8 million to 3 million. The population of the city of Atlanta was 416,474 in 2000. The metropolitan area expanded so much that it is considered to have four central business districts rather than one. Rapid growth that spreads far from the center of a city and uses a lot of land is usually called urban sprawl. When heat builds up in a city it creates a hot spot within an area of cooler countryside. This hot spot is called an urban heat island.

Urban areas display higher temperatures than the more rural surrounding areas. The Sun's heat is absorbed by buildings and pavement, causing surface temperatures to rise. The gradual loss of vegetation and the increase of built-up and paved areas cause the formation of hot spots and urban heat islands. Stored-up heat is released at night and causes a dome of high temperature over the city compared to the cooler countryside. Heat islands or hot spots may be found even on the outskirts of an urban area such as at airports which have large areas of pavement.

NASA scientists are studying the relationship between tree removal and urban heat islands in Atlanta, Georgia. Scientists estimate that Atlanta's vegetation and tree cover have declined by 65 percent between 1973 and 1993. The area of tree loss equals 153,781 hectares. The trees were removed to make way for new urban growth.

**Excerpt from NASA Research**

http://wwwghcc.msfc.nasa.gov/overview/urban.html
Rapid population growth in the last 25 years (27 percent between 1970-80, and 33 percent in 1980-90) has made Atlanta one of the fastest growing metropolitan areas in the United States. This rapid growth has translated into an approximately 17 percent decline in forest land in the Atlanta metropolitan region between 1973 and 1992. Atlanta is also a model for what is in store for other cities, especially in developing nations where the industrial revolution is taking off and threatens large areas of forest or jungle. This enormous transformation of land from forest and agriculture to an urban landscape causes changes in land-atmosphere energy balance relationships.

The amount and location of urban forest are very important to how cool or how hot temperatures become in different parts of the city. Trees contain a lot of water and release that water into the atmosphere to keep themselves cool. Water absorbs a large amount of heat before showing significant rises in temperature. Also, trees absorb a lot of heat and release it slowly, which moderates temperatures of urban heat islands.

**Excerpt from a satellite's view of urban sprawl by Richard L. Hill, *The Oregonian*, March 8, 2000**

Two geographers at the University of Maryland are using the nation's Landsat satellite system to analyze and compare the growth of cities. Jeffrey G. Masek and Francis E. Lindsay say that understanding how urban areas expand is important because half of the world's six billion people live in cities, an increase of more than one billion in the past 30 years. They say that a better understanding of urban growth patterns can answer such questions as how the spreading populations affect the landscape, how best to use limited space, and which social, economic, and environmental factors influence population expansion.

Sensor-loaded spacecraft are a valuable scientific tool in examining natural environments such as oceans, forests and mountains. Now, researchers are using the spacecraft to take a look at a less attractive aspect of our planet: urban sprawl.

The sensors aboard Landsat satellites are able to distinguish between vegetated and nonvegetated areas. With the aid of computers, the researchers can determine whether vegetation has changed during a period of time. "We basically say that urban growth is where we see vegetation at an earlier time and don't see it at the later time."

"We have data from these satellites going back for more than 20 years, so they provide us with a tremendous look at change," Lindsay said. "And that's going to be especially important because we can look at what change has happened in the past and make predictions about future growth in the world's urban centers."

***Becoming a Cool Community***

What can be done to reduce the negative consequences of an urban heat island? One step to reduce heat buildup is to increase all forms of vegetation in the city. Some scientists believe that a city should contain 40 percent park land, forest, and green spaces. (Atlanta has only 27 percent). This can be accomplished by limiting the number of trees cut when building, and planting trees wherever possible, planting shrubs and grasses in bare ground areas, and planting trees in median strips along roads and in parking lots. Other specific steps include planting more trees to shade sidewalks, parking lots, and buildings and replacing old roofs with new reflective roofing material.

## Evaluation

***Log 1***

1. Change from 1973 to 1987

| Quadrant | # of changed units | Rank |
|---|---|---|
| Northeast | 14 | High |
| Northwest | 13 | High |
| Southwest | 13 | High |
| Southeast | 10 | High |

4. Growth occurred along major highways, near the airport and expanded outward from the city center. Land near roads and developed areas tends to be more accessible to new development.

***Log 2***

1. The night image allows more precise identification of land uses.
2. During the day, roads, pavement, and buildings absorb much heat, and so on the day image they appear red. At night, as the temperature drops, the city becomes cooler and there is more color variation between buildings and roads and vegetation.
3. Pavement absorbs more heat than trees and cools at a slower rate, so roads appear orange or yellow on the image.
4. Areas along roads are often cooler because of the presence of trees and vegetation.

## Resources

NASA, Global Hydrology and Climate Center, Huntsville, Alabama http://www.ghcc.msfc.nasa.gov

NASA, Spacelink, an aeronautics and space resource for educators http://spacelink.nasa.gov/

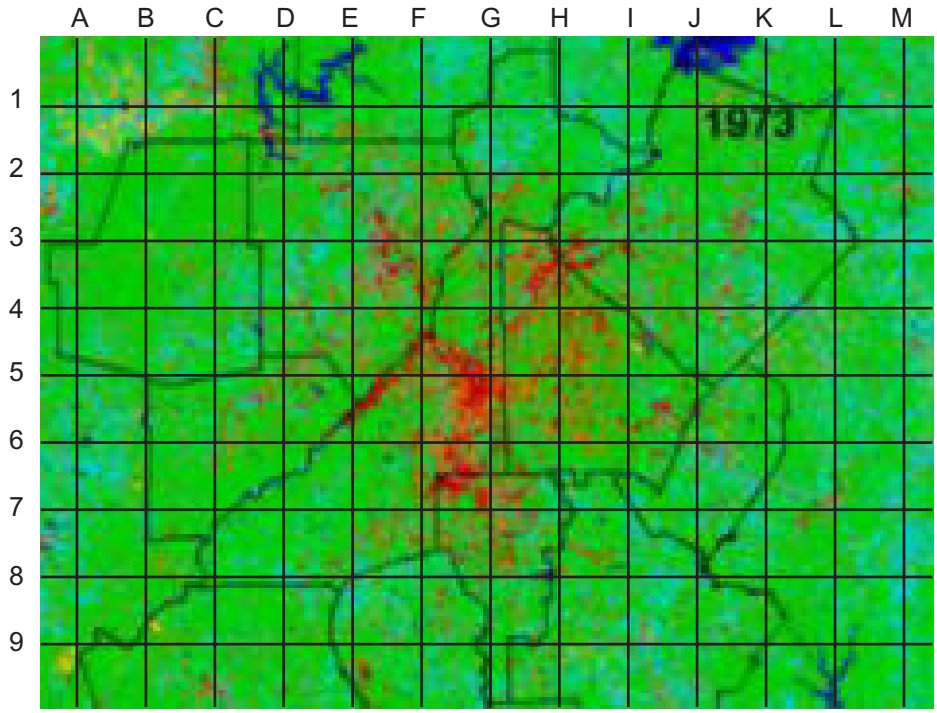
Science @NASA article: Atlanta's urban heat alters weather patterns http://science.nasa.gov/newhome/headlines/essd26apr99_1.htm

American forests, Washington, D.C. (information on tree planting) http://www.amfor.org

Environmental Protection Agency, Washington, D.C. (information on tree planting, reflective roofing and paving) http://www.epa.govhttp://www.energystar.gov

Lawrence Berkeley National Laboratory, Berkeley, California (information on urban heat-island research, tree planting, reflective roofing and paving) http://www.lbl.gov and http://EETD.LBL.gov

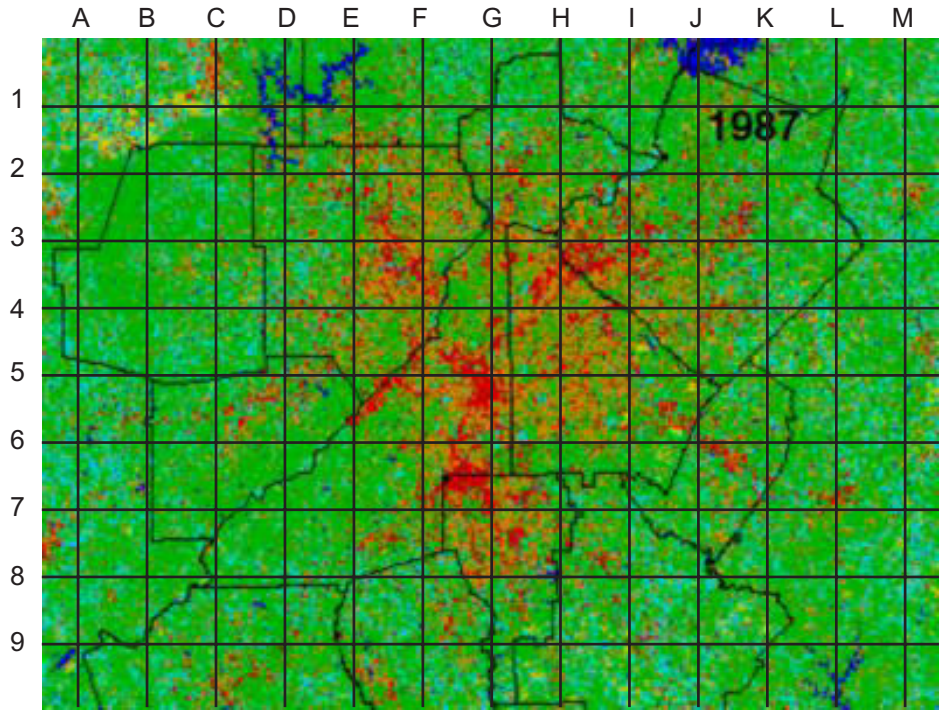
## Figure 1: Land use 1973




Source: http://svs.gsfc.nasa.gov/search/Keywords/Atlanta.html — click on link for Atlanta Land Use.

Dense Urban, Forest, Exposed, Sparse Urban, Water, Cropland

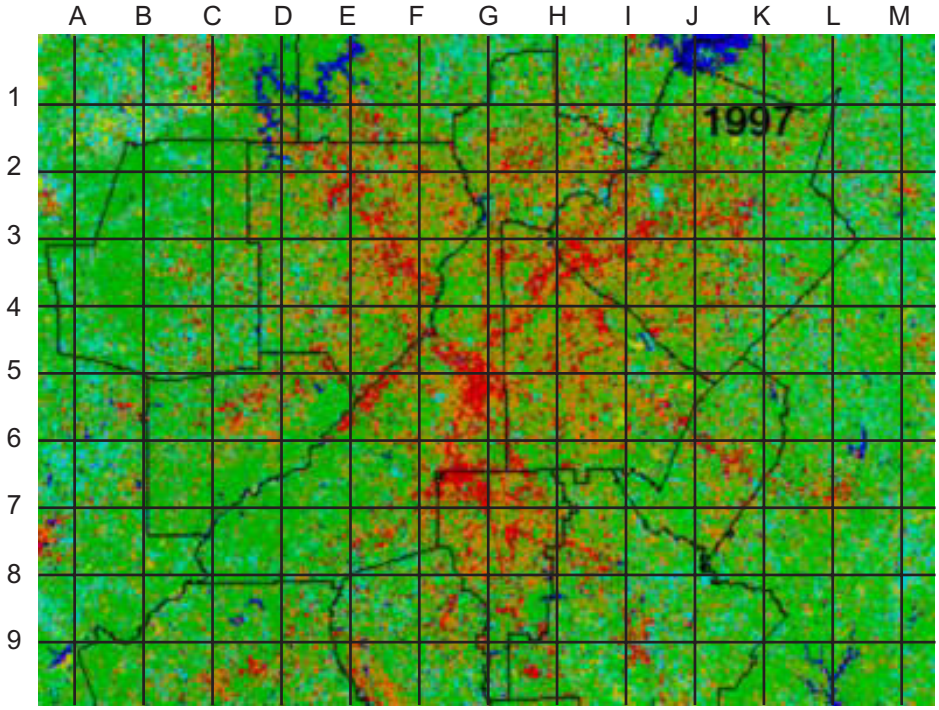
## Figure 2: Land use 1987




Source: http://svs.gsfc.nasa.gov/search/Keywords/Atlanta.html — click on link for Atlanta Land Use.

Dense Urban | Forest | Exposed
Sparse Urban | Water | Cropland

## Figure 3: Land use 1997




Source: http://svs.gsfc.nasa.gov/search/Keywords/Atlanta.html — click on link for Atlanta Land Use.

Dense Urban, Forest, Exposed, Sparse Urban, Water, Cropland

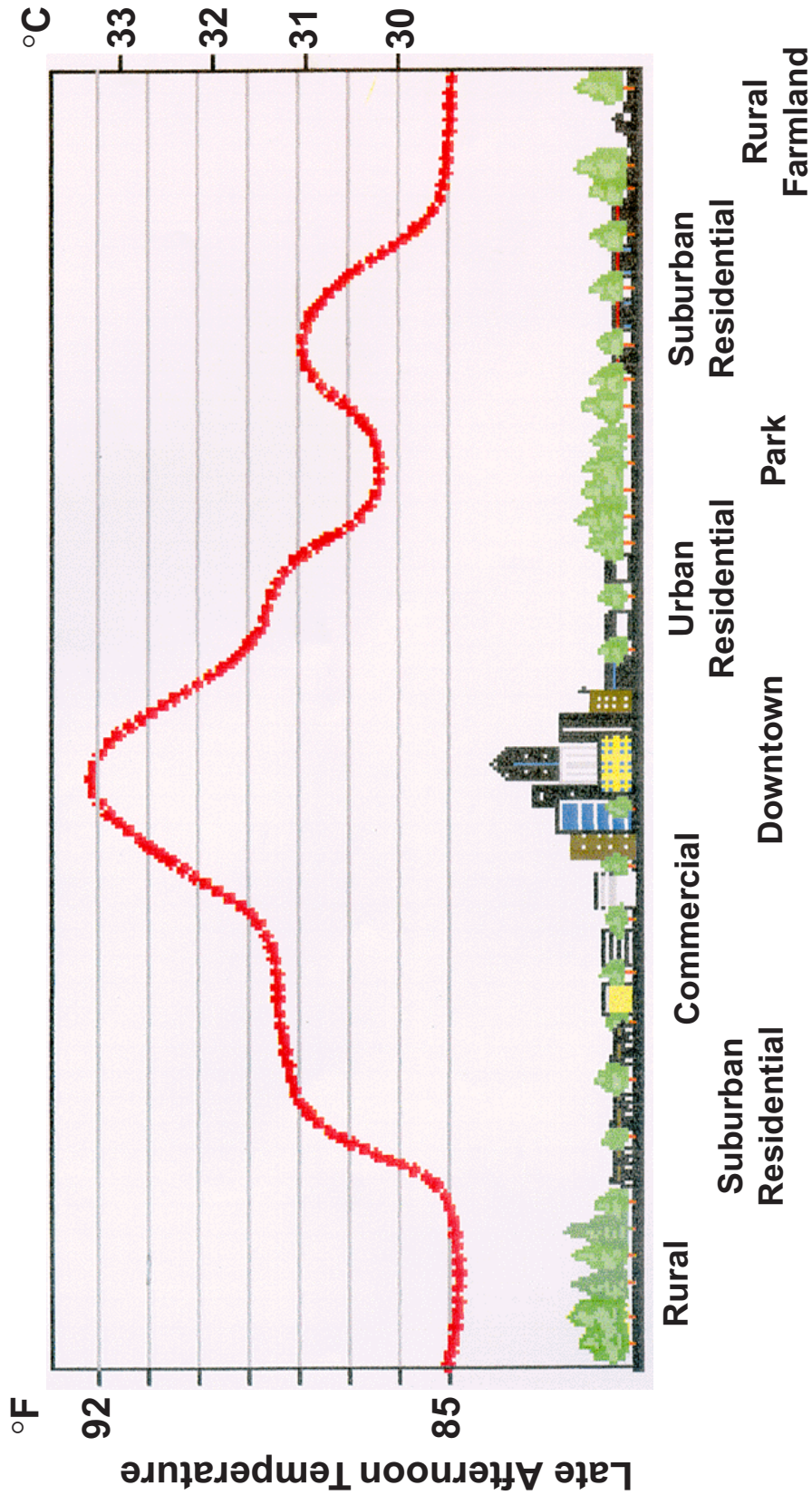



Figure 4: Sketch of an urban heat-island profile

# Module 3, Investigation 3: Briefing

## Why is the city hot?

### Background

On a hot, sunny day if we wear dark clothes, we feel warm. Dark colors absorb more heat than light colors. We experience rising heated air when we walk across a paved parking lot on a sunny, summer day. The heat stored in the pavement warms the air and radiates to our bodies. On the other hand, when we sit under a tree, we feel cool. The moisture in trees and the shade they provide cools the area around them.

Temperatures are not uniform across a city. The amount of vegetation and colors of materials affect temperatures. Generally the denser and darker the building materials, the higher the temperatures. Masses of brick and asphalt absorb huge amounts of heat and then re-radiate the heat into the surrounding air. Color is a very important factor in heat gain. Dark colored materials such as slate or asphalt absorb more heat from the Sun than materials with lighter colors such as white roofing shingles or cement. Lighter colors reflect the rays of the Sun back into the atmosphere, and less heat is built up.

When heat builds up in a city, it creates a hot spot compared to the cooler countryside. This hot spot is called an urban heat island.

NASA scientists are studying temperatures in Atlanta, Georgia, because many trees were cut as the city grew. Tree removal contributes to forming urban heat islands. Trees were removed to make way for new houses, roads, parking lots, office buildings, and shopping centers. Scientists estimate that Atlanta's vegetation and tree cover decreased by 65 percent between 1973 and 1993. The area of tree loss equals 153,781 hectares (380,000 acres).

### Objectives

In this investigation you will

- describe features on thermal images,
- identify change in land use and population changes leading to urban heat islands,
- explain how urban heat islands form,
- describe examples of environmental changes caused by urban heat islands, and
- offer ways to remedy some of the negative consequences of urban heat islands.

### Procedures for the Investigation

Using Atlanta as a case study, you consider several aspects of urban expansion and its consequences for people and natural environments. To accomplish this you will examine land use maps and thermal images gathered by NASA. You will complete Logs distributed by your teacher.

### References


NASA, Global Hydrology and Climate Center, Huntsville, Alabama http://www.ghcc.msfc.nasa.gov

NASA, Spacelink, an aeronautics and space resource for educators http://spacelink.nasa.gov/

Unit Converter: Online conversion of English and metric units
http://www.webcom.com/legacysy/convert2/convert2.html

Excerpt from NASA research
http://www.ghcc.msfc.nasa.gov/overview/urban.html

Images of Atlanta and information about heat islands
http://science.msfc.nasa.gov/newhome/headlines/images/atlanta.jpg
http://science.msfc.nasa.gov/newhome/essd/urban_heat/urban_heatisland_atl2.htm
http://svs.gsfc.nasa.gov/imagewall/aaas.html
http://svs.gsfc.nasa.gov/imagewall/AAAS/atlanta.html

Population of Atlanta
http://demographia.com/dm-atlpor.htm

Excerpt from *The Oregonian*, March 8, 2000
"A satellite's view of urban sprawl" by Richard L. Hill of *The Oregonian* staff

# Module 3, Investigation 3: Log 1

## Why is the city hot?

You have viewed the 1973 and 1987 land use maps showing changes in Atlanta resulting from urban expansion. More people moving into the city means that more trees have been removed and more roads built and buildings erected. This process is clearly revealed on the maps.

The 1987 map on page 3 is divided by lines G and 5 into four parts or quarters called quadrants. The set of lines placed over the map is called a grid. A number and letter correspond to each section or unit on the grid. This intersecting set of lines labeled with letters and numbers is called an alphanumeric grid.

1. Look at each quadrant and estimate the amount of land use change from 1973 to 1987.
   Rank your choices in the following way:
   - Noticeable change in 1-4 units is ranked low
   - Noticeable change in 5-8 units is ranked moderate
   - Noticeable change in 9 and above units is ranked high

   The quarters or quadrants are:

   Northeast Number of changed units _____ Rank _____

   Northwest Number of changed units _____ Rank _____

   Southwest Number of changed units _____ Rank _____

   Southeast Number of changed units _____ Rank _____

2. Now identify the sections (units) in each quadrant where you think expansion of the built-up area continued to occur between 1987 and 1997. The numbers may vary from person to person.

   Northeast Number of changed units _____

   Northwest Number of changed units _____

   Southwest Number of changed units _____

   Southeast Number of changed units _____

   Why did you make those predictions?

_____

_____

_____

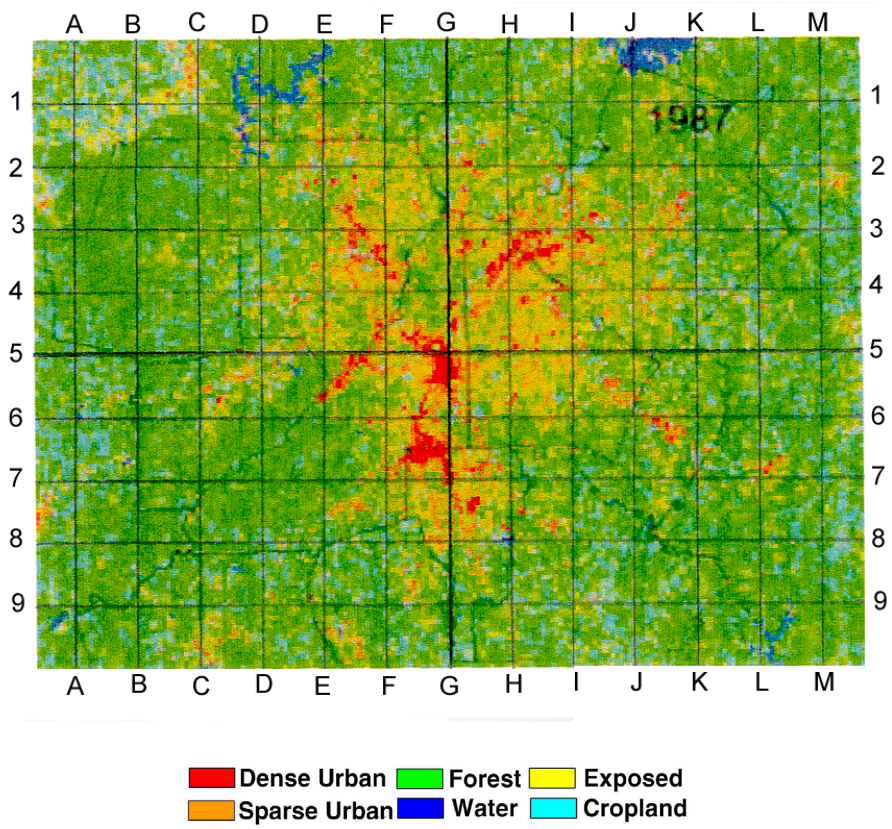
_____

_____

# Module 3, Investigation 3: Log 1

## Why is the city hot?

**Atlanta land use map 1987**



# Module 3, Investigation 3: Log 1

## Why is the city hot?

3. After your teacher shows you the 1997 land use map, make a comparison between the grid units you identified and where areas were actually built up. Is your set of grid units a good match for what happened? Explain.

4. Using a road atlas of the United States, do a visual comparison of the land use map and the highway system in Atlanta. What are your conclusions concerning where and why growth occurred?

# Module 3, Investigation 3: Log 2

## Why is the city hot?

You will use the day and night thermal images of Atlanta to identify features in the area. An alphanumeric grid is overlaid on each image to allow precise comparison of the two images. Use the day image first and identify the land uses in the following set of grid units.

Set One: B6, B7, B8, and B9
Set Two: E2 and I8
Set Three: D5 and E5

Now use the night image and look at the same sets of units.

1. Which image allows you to make more precise identifications of land uses?

   _____

2. Why do temperature differences affect the way that land uses appear on the night image as compared to the day image?

   _____

   _____

   _____

3. Why do temperatures of roads remain warm at night and therefore very noticeable on the night image?

   _____

   _____

   _____

4. At the same time that the roads remain warm, what happens to areas nearby (for example in portions of grid units B6, B7, B8, B9)? What factors contribute to these cooler temperatures?

   _____

   _____

   _____

### Concluding the Investigation

Using the following terms and symbols, create an equation that describes the relationships that lead to urban heat islands.

| | | |
|---|---|---|
| urban heat island | ↑ (increase) | = (equals) |
| land use development | + (plus) | ↓ (decrease) |
| forests | | |

_____

_____

# Module 3, Investigation 3: Figure 5

## Atlanta, day and night