



Lesson 3: Why are growing cities hotter?

MS Climate Change Unit

Previous Lesson....Where we've been: We explored reasons why temperatures in particular Colorado cities are rising.

 This Lesson....What we are doing now: This lesson explores what changes in land use are happening and how changes in surface color affects temperatures in cities.			
Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), <i>New Questions</i> and <i>Next Steps</i>
L3: Why are growing cities hotter? (2.5-3 periods)  <i>Building toward</i> ↓ <u>NGSS</u> <u>PEs:</u> <u>MS-</u> <u>ESS3-4</u>	Before/after images of urban growth True color and infrared urban images: Baton Rouge, Sacramento, and Salt Lake City true color and infrared thermal images Albedo investigation	Plan and conduct an investigation ... and in the design, identify independent and dependent variables and controls, what tools are needed, how measurements will be recorded, and how much data is needed to support a claim about how the expansion of cities impacts the surface of the Earth and how these changes relate to temperature.	<p>Yesterday we decided that population growth could be a reason why these cities are getting hotter than others.</p> <p>We look at some pictures of an area that has grown a lot in the last 30 years. We have some initial ideas about growing cities that would matter that we could look at. With more people, there's more energy used, more cars. We see the land is going from crops and prairie to pavement, buildings, and parks.</p> <p><i>We wonder:</i></p> <ul style="list-style-type: none"> <i>How might these changes to the landscape be affecting temperature in these cities?</i> <p>We learn that infrared images show how hot things are. We look at some infrared images of areas and compare them to true-color images from space, and we see it's consistently warmer in areas with buildings and pavement. The dark parts of the map are hotter within the city, but that the green parts tend to be cooler when we look across the maps. We think this might have to do with why it's hotter.</p> <p>We think about the t-shirts we wear in the summertime. We think lighter color t-shirts keep us cooler than darker color in the summer. We think this is what might be going on with the planet's surface, too. Lighter colors might keep the surface cooler, darker ones hotter.</p> <p><i>We decide that we need to conduct an experiment to test out how color affects temperature.</i></p> <p>We plan and conduct an investigation to explore what might be the effect of different colored surfaces on temperature. Focus on the color of the surfaces, since we noticed in the images that cities have different colored surfaces from the surrounding areas. We have some materials to work with, and each of us comes up with a plan to investigate what we think is going on.</p> <p>As part of our investigation plan, we consider: (1) what each type of material we choose represents, in terms of a model of the Earth's surface, (2) how to measure temperature, and (3) how to aggregate data from our different groups and use the results of the investigation to help us explain why cities might be hotter than surrounding areas.</p> <p><i>We figure out that color is related to heat. Darker colors are hotter than lighter ones, but the material seems to matter.</i></p> <p><i>We're wondering</i></p> <ul style="list-style-type: none"> <i>If changes in land use are causing a change in albedo and making cities in Colorado hotter, is this happening in other parts of the country?</i> <i>If changes in albedo are causing cities to get hotter, is albedo changing in other parts of the world?</i> <i>Could changing albedo affect temperatures elsewhere?</i> <i>What has the average temperature of the world been in the past and has it changed?</i> <p><i>We decide we need to look at albedo and temperatures in other places.</i></p>

Next Lesson....Where we're going: We are wanting to know if other parts of the world are also changing and getting hotter.



Getting Ready: Materials Preparation

Materials For Each Group

- Dark colored construction paper or cloth (1)
- Light colored construction paper or cloth (1)
- Green colored construction paper or plant-patterned cloth (1)
- Ice cube (3)
- Stopwatch or timer (1)
- Light source (indoors: desk lamp or sunny windowsill, outdoors: sunshine)
- Thermometer

Preparation of Materials (25 min.)

- Class copies of student activity sheet
- Create a set of materials for each group of 3 students in advance.
- Post "Notice and Wonderings" chart from previous lesson.
- Prepare printed copies of the "then and now" comparison and infrared images for students who may be absent.

Materials For Each Student

- Student Activity Sheet (1)

Safety

- Remind students to recycle the construction paper and wipe off their lab surface when done.
- Use care when using thermometers.





Getting Ready: Teacher Preparation

Background Knowledge

From 4th Grade:

- PS3: Conservation of Energy and Energy Transfer**
 “Light also transfers energy from place to place. For example, energy radiated from the sun is transferred to Earth by light.”
 Energy can be transferred from one place to another.
 The sun’s light heats up the earth.
 There’s a relationship between temperature and energy.

From 5th Grade:

- ESS3C. Human Impacts on Earth Systems**
 “Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space.”
 One way that humans alter the biosphere is through the activity of changing the landscape.
 Examples of changes to the landscape include to build cities and grow crops.

Alternative Student Conceptions

Students may conclude from the investigation that urban growth itself is the cause of climate change. While cities are hotter than surrounding areas typically, city development by itself can’t explain why the climate is hotter in surrounding areas as well. Subsequent lessons will problematize this conclusion, but also provide a foundation for students to explore ways that albedo is related to climate change. [Data show](#) that albedo shows little change overall and has a limited effect relative to cloud cover on global warming. .

Linking Our Understanding to Scientific Terminology

- Infrared
- Albedo Thermal energy (heat)
- Absorption
- Reflection





Learning Plan: Why are growing cities hotter? (125 min)

1. (15 min) Begin with a Consensus Building Discussion ¹ to help reorient students in the storyline. Use the following prompts to help students articulate what they figured out in the last lesson.

Suggested Prompts:

- During our last class, we looked at different types of information about the cities that are getting hotter. What things did we decide are NOT causing temperatures to increase? What things did we decide ARE causing temperatures to increase?
- What did we decide we need to figure out?

Listen for *student responses* ² that refer to what we figured out last time, such as:

- *We decided that the amount of sun is not causing temperatures to increase.*
 - Ask: What evidence showed us this?
- *We decided that the amount of precipitation is not causing temperatures to increase.*
 - Ask: What evidence showed us this?
- *We decided that increased population is causing the temperature to increase.*
 - Ask: What evidence showed us this?
- *We decided that when there are more people in an area, the people would replace areas that used to be full of plants with buildings, parking lots, and other human-made structures.*
 - Ask: What evidence showed us this?
- *We decided we needed to investigate some cities that have grown a lot in the past few years to see if we can find a pattern here that helps us answer this question.*
 - Ask: What kind of a pattern should we look for? What will this tell us?
 - What if we do not see this pattern? What else could we look for?

2. (35 min) Picture comparisons: Show students pairs of pictures of areas that have increased in population over the last 30 or so years.

Ask students:

- What looks different between the two pictures?
- What are your ideas about what caused these changes?
- Why did these changes happen?
- How might those things affect temperatures? Why do you think that?



Teacher Supports & Notes



Strategies for this Consensus Building Discussion

1: The goal of this discussion is to put students in the driver's seat. Use the prompts to help students recall and restate what we as a class figured out in the last lesson. Their ideas should motivate what we are going to need to do next, in this lesson.



Additional Guidance

2: If students struggle to recall the previous lesson, prompt them to consider what phenomena they examined or what activities they engaged in.

Possible lesson extensions:

[Evapotranspiration lab](#)

Earth's Energy Cycle: Albedo Activity:
<http://cleanet.org/resources/41824.html>



Listen for:

- Earlier picture: more grass/vegetation
- Later picture: more buildings/roads/parking lots
- More people would need more buildings to live, work, and go to school in
- More people would need more roads for more cars
- Buildings might produce heat that warms up the air, or they might absorb more heat from the sun. We're not really sure, we have different ideas about it.

Show students infrared and true-color images of an area.

https://science.nasa.gov/science-news/science-at-nasa/1998/essd20nov98_1/

Explain that infrared pictures show the temperatures of different things, represented with colors. (Many students will be able to make a connection with TV shows that use infrared cameras to find people inside of buildings or for night vision goggles.)

Ask students:

- Which areas are the warmest? What types of surfaces do these areas have?
- Which areas are the coolest? What types of surfaces do these areas have?
- What might cause the different surfaces to be warmer or cooler?
- Do these give us new ideas about what growing cities might mean for temperatures?

Listen for:

- The warmest areas are where there are buildings and roads.
 - ◆ This might be because they are made by people, or because of the materials they are made from, or because this is where people and cars are going to be the most.
- The coolest areas are where there are trees or other plants.
 - ◆ This might be because they are made of natural materials, or because these areas don't have as many people or cars, or because of something that the plants do to make the air cooler.
- Sometimes darker surfaces are warmer and lighter surfaces are cooler.
 - ◆ This might be because dark surfaces absorb more heat from the sun than lighter surfaces.
 - ◆ We think that the information suggests that changing the surface will matter for temperatures, and so we need to test it somehow.
 - ◆ We think that in general, we see higher temperatures in the city where the surfaces are concrete.

Ask students to consider some initial ideas for planning an investigation to measure the temperature of different surfaces.

Ask students:

- How can we tell which areas are warmer?
- How can we tell which areas are cooler?
- How can we measure the temperature of different surfaces?



3. (50 minutes) Student Activity Sheet (Color and Temperature Parts A & B): Suggest to students that we try to replicate these connections in the lab. If we can, we have clearer evidence about what causes the differences in temperatures.³

Investigation Part A, ask students:

- How does the color of a surface affect how much it warms up in the sun?
- Students then individually write their hypothesis on the activity sheet.
- Next, share hypotheses as a class.

Part A: Plan the steps of your group's investigation to test which color of paper gets the warmest using the following materials:

- Various colors of construction paper (black, white plus green, yellow, red, orange, blue, etc.)
- 3 thermometers
- Stopwatch or timer
- Light source (indoors: desk lamp or sunny windowsill, outdoors: sunshine)

Part A: Plan the procedure:

- In teams of 2-4 students, write your ideas for an investigation on temperature on chart paper before doing the investigation.
- Next, have a class discussion to get feedback on which plan is likely to work best for investigating surface temperatures.
- Then, revise the investigation as a class and implement the plan in teams.

Part A: Conduct the investigation and record observations:

After testing, ask:

- Which color paper had the warmest temperature?
- Which color paper had the coolest temperature?
- Was your hypothesis supported by your observations? Why or why not?

Part B: Plan the steps of your group's investigation to test which color of paper melts an ice cube the fastest using the following materials:

- Various colors of construction paper (black, white plus green, yellow, red, orange, blue, etc.)
- 3 ice cubes
- Stopwatch or timer
- Light source (indoors: desk lamp or sunny windowsill, outdoors: sunshine)

Part B: Plan the procedure:

- In teams of 2-4 students, write your ideas for an investigation on temperature on chart paper before doing the investigation.
- Next, have a class discussion to get feedback on which plan is likely to work best for investigating surface temperatures.
- Then, revise the investigation as a class and implement the plan in teams.



**Strategies for this
Initial Ideas Discussion**

3: In this discussion, students should lay out the path for the activities they will engage in today. Use the prompts to ensure that students do this heavy lifting to generate ideas.



Before testing, ask:

- If darker surfaces absorb more heat from the sun, what will happen to the temperature and the ice cube on the dark paper? What will happen to the temperature and the ice cube on the light paper? What will happen to the temperature and the ice cube on the green paper?

Listen for:

- *The ice cube will melt faster on the darker paper than on the lighter paper.*

Part B: Conduct the investigation and record observations:**After testing, ask:**

- On which color paper did the ice cube melt the fastest?
- On which color paper did ice cube melt the slowest?
- What does this information tell us about why temperatures in cities are warming?

Discuss Part A & B Conclusions:

- (1) Aggregate data from different student groups;
- (2) Discuss patterns in data
- (3) Draw conclusions from data
- (4) Revise model to reflect data

Investigation Reflection:

- What types of land surfaces does the dark color represent?
- What types of land surfaces does the light color represent?
- What does our data tell us about the color of a surface and its temperature?

Listen for:

- *The dark colors represent dark surfaces, like asphalt or black roofs of buildings.*
- *The light colors represent light surfaces, like cement or light gray roofs of buildings.*
- *The plant colors (i.e. green or yellow) represent vegetation, like trees, grasses, flowers or crops.*
- *The ice cubes melt more quickly on the darker papers than on the lighter papers.*
- *The darker papers got warmer faster than the lighter papers.*
- *In the sun, darker surfaces will get warmer than lighter surfaces.*

4. (15 min) Have students reflect on what we have figured out about temperatures and growing cities. Use the following prompts to guide this Consensus Building Discussion.



Suggested Prompts:

- How does the presence of many plants (forest, field) affect the temperature of a place compared to a place without those plants?
- How do different colors of surfaces affect the temperatures of places?
- What does this tell us about cities that are increasing in population and their temperatures?
- At the end of the discussion, introduce “albedo” as the scientific term to describe the phenomenon that darker colors reflect less light energy and lighter colored surfaces reflect more light energy.

Listen for student responses such as:

- *It seems like places with plants do not get as hot as places with plants, so people moving to a city and changing farmland, fields, and forests into streets and buildings will make the temperature go up.*
- *More buildings or streets with dark colors will make the temperature go up even faster.*

5. (10 min) Ask student to brainstorm what our next steps should be in our investigations.⁴

Suggested Prompts:

- What do we need to investigate next time we meet for science?

Listen for student responses such as:

- *We should look at data from different areas, including places where population is growing versus staying the same, and see if the same increase in temperature is happening for both types of areas.*



Formative Assessment Opportunities

4: Ask students to complete an exit slip restating what they figured out in this lesson and/or what they think we should do in the next lesson.



Alignment With Standards

Building Toward Target NGSS PE

- **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.

Building Toward Common Core Standard(s)

ELA/Literacy -

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts. (MS-ESS3-4)

WHST.6-8.1: Write arguments focused on discipline content. (MS-ESS3-4)

WHST.6-8.9: Draw evidence from informational texts to support analysis, reflection, and research. (MS-ESS3-4)

Mathematics -

6.RP.A.1: Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-ESS3-4)

7.RP.A.2: Recognize and represent proportional relationships between quantities. (MS-ESS3-4)

6.EE.B.6: Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. (MS-ESS3-4)

7.EE.B.4: Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (MS-ESS3-4)

