Lesson 3: Why are cities and other regions of the world getting hotter?

HS Climate and Resilience Unit

Previous Lesson….Where we've been: We explored the data and representations from the Climate Central report mentioned in the video and figured out that the average summer temperatures in cities and other regions are increasing, but that cities are warming at a faster rate. We also explored global data and figured out that there are global warming trends even in places where there aren't big cities.

T	**This Lesson….What we are doing now:** This lesson explores how albedo is a contributing factor to why the temperature in some places like cities are increasing at a faster rate; albedo is not the only factor.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
Lesson 3: Why are cities and other regions of the world getting hotter? (2 periods) S *Building toward* ↓ *NGSS PEs: HS-ESS-3-6*	Albedo Indoor Albedo Outdoor Albedo Simulation Calculating Energy Balance and Temperature Earth's Albedo Thought experiment/ HW image global albedo	**Plan and carry out an investigation** that explores what about cities, states, and global regions might be causing them to warm differently.	Last class we figured out that cities are hotter than rural areas. Also, that there are places around the world where temperatures are increasing at a faster rate, so we decided to plan an investigation to figure out why cities are getting hotter faster than states overall. We were wondering why cities warm faster than state according to the data we reviewed in the last lesson. We explore differences in things that are in the city versus the whole state and look for patterns in land surface characteristics. We notice that cities have more buildings, roads and pavement, less green space, more cars and people as well as a lot of construction We also noticed that states have more open space, forests and trees, mountains, some urban areas and that the western half of states is greener than the eastern half. . We decide we want to investigate how different surface materials relate to temperature by conducting an experiment and completing a lab report. We will conclude that dark colored materials heat faster than light colored materials and add "albedo" to our vocabulary. Cities are growing as well as have a lower albedo, this might explain why it is hotter and the temperature is increasing faster. We are still wondering why the temperature of Colorado is increasing, even if at a lesser rate and think that perhaps the albedo of the state is changing. We do a thought experiment with a global map and we figure out that albedo should be higher (meaning more reflective) on places where there is more ice and snow like the polar regions. However, we saw on our map from Lesson 2, that the northern polar region is an anomaly - it's warming at a faster rate than we would expect. That doesn't make sense - it can't just be that urban areas and more people are making cities hotter, there's something missing. What's missing from our thinking? Just using land use and population, we can't explain why the world is getting hotter. We decide we need to figure out if there is something going on. We revisit our Driving Questions Board and add some questions. • Humans are impacting cities at a local level, how are they impacting the world on a global scale since we aren't building in or increasing the population of the Arctic? • Does this have to do with greenhouse gases? I've heard of those. **We decide we need to make a model and figure out where human activity fits in and what this has to do with greenhouse gases.**

Next Lesson….Where we're going: We explore computer simulations to understand the Greenhouse Effect and then develop a model for how this works.

Getting Ready: Materials Preparation

Materials For Each Group

- Students will need graphing calculators for day 2
- Outdoor lab:
  - Infrared heat guns (1 per group)
  - Outdoor Albedo Lab Activity (1 per student)
- Indoor lab:
  - Desk lamp with a 60-watt bulb (1 per group)
  - Black construction paper (1 per group)
  - White construction paper (1 per group)
  - Thermometers (2 for each pair of students)
  - Scissors (1 per group)
  - Stapler (1 per group)
- Albedo Online Simulation:
  - Computer or tablet

Preparation of Materials (15 min.)

- Large paper for saving student ideas/questions posted in classroom
- Day 1: Materials for lab organized for group, set out on lab counter if possible.
- Day 1: Make sure infrared guns or desk lamps are working, replace batteries and bulbs as needed
- Day 1: Google Earth/Google Maps cued on your computer or have students warm up their computers when they arrive to class
- Day 2: Create data table on board for albedo calculations
- Day 2: It's a good idea to have a graphing calculator ready, and have practiced the equation in case you need to check student work

Materials For Each Student

- Student Activity Sheet
- Indoor Albedo or Outdoor Albedo Lab Activity (depending on which you are doing) (1)
- OR Albedo Simulation (computer or tablet)
- Albedo Reading Guide (1)

Safety

- Outdoor lab: Clear expectations about time students return to classroom, where they are allowed to go, and where they cannot go when outside
- Indoor lab: a reminder than desk lamps get hot, don't touch them

Getting Ready: Teacher Preparation

Background Knowledge

ESS3.C from the FRAMEWORK:
By the end of grade 8: Human activities have significantly altered the biosphere sometimes damaging or destroying natural habitats and causing the extinction of many other species. However, changes to Earth's environment can have different impacts (negative and positive) for different living things. Typically, as human populations and per capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

ESS3.D from the FRAMEWORK:
By the end of grade 8: Activities such as the release of Greenhouse Gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior, applying that knowledge wisely, decisions, and activities.

ESS3 from the FRAMEWORK:
"Thus science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences…"

Rate of and region of change matters for understanding climate change. Cities are changing faster because of their characteristics - localized amplification because of things black tops, resulting in heat islands in cities. However, this isn't the entire explanation for climate change. Overall, regionally and globally human activities are increasing CO_2 and Greenhouse Gases, which result in global warming.

Alternative Student Conceptions

Cities have trees/green space, states have cities and infrastructure in them but our goal is to identify what the majority of the land surfaces in states are composed of… we can acknowledge those green spaces in cities using an albedo measurement, but what type of surface does most of the energy coming from the sun encounter?

Students might want to jump to emissions/gases. Need to use the Driving Questions Board to table this discussion for next lesson and focus on surfaces/ albedo.

Linking Our Understanding to Scientific Terminology

- Albedo
- Absorption
- Reflection
- Infrared heat
- Urban
- Rural
- Urban heat island effect

Learning Plan: Why are cities and other regions of the world getting hotter? (2-55 min class periods)

1. (5 min) Begin with a Do Now to orient the students to the storyline and remind them of what they decided they wanted to investigate.

Suggested Prompts:

- ➔ Yesterday we decided that we would plan an investigation to figure out why cities are getting hotter faster than states overall.
- ➔ What are some basic differences between the regions we call cities, versus the regions we call states. Try to get at least 5 different characteristics listed in this time.

Ask students to share their ideas and create a class list of things we know about landscapes categorized as cities versus landscapes categorized as states.

Listen for and capture student responses, such as:

- ➔ *Cities are smaller in area, state are larger.*
- ➔ *People are more concentrated in cities, less dense in states.*
- ➔ *Cities and states both have buildings; cities have more dense buildings.*
- ➔ *Cities and states both have green spaces/trees, states have a greater percentage of trees than buildings*
- ➔ *Cities have factories and/or cars.*
- ➔ *States have farms.*

2. (10 min) Share with students that these are just our assumptions about cities and states without taking an in depth look. What resources could allow us to enrich our list of similarities and differences between cities and states? Students should arrive at a "map" or satellite image of these two regions and be able to deduce how we can access this resource in the classroom[A]. Once students have suggested looking at satellite imagery (such as that from Google Earth,) instruct them to work with a partner to use the resources to observe satellite images of Colorado (cities as well as rural areas and the state overall) and make note of their observations[B].

Teacher Supports & Notes

Additional Guidance

A: Students might start at "traveling" to these regions, but can be redirected by the time and logistical constraints of this idea. They may also propose "pictures" which can be extended to maps and satellite imagery

Differentiation Strategies and Alternate Activities

B: If students have their own computers - teachers can instruct them to open up to Google Earth or to Google Maps (if using Google Maps students will need to click the "imagery" layer in the lower right hand corner (green color).

You can also project images that you pull up on your computer if you want to save time, work as a whole class or don't have access to computers for everyone.

Suggested Prompts:

- What resources could allow us to better explore differences in cities and states?
- What would allow us to visually compare the land of a city such as Denver and a state such as Colorado side by side?
- How can we access satellite imagery from our classroom?
- What similarities and differences did you notice between city land features and state land features?
- What did you figure out related to the question prompts?
  - List what features/objects you find on this landscape
  - Describe what makes up the majority of the land use.
  - Describe what colors are dominant on this landscape.
  - What patterns do you notice?
  - What usual things did you notice?
  - What else was notable in your observations?

Listen for student responses and capture the new ideas (adding to original list) for everyone to see:

- *There are green spaces in cities, some trees and parks but not dominant.*
- *There are small bodies of water in the cities.*
- *There are many cars in the cities.*
- *The western half of the state of Colorado is greener than the eastern half.*
- *State open space is brown and green.*
- *Cities are mostly grey and paved.*
- *Denver appears to be growing, a lot of construction.*

3. (5 min) Ask students what questions we have about what we are observing in cities and the state overall that we need to add to the Driving Questions Board.

Suggested Prompts:

- What questions should we add to our Driving Questions Board? Which ones should we prioritize now?

Listen for student questions:

- *How do plants affect temperature, what about photosynthesis?*
- *How to the mountains affect temperature?*
- *How does having an open space affect temperature?*
- *How does the kind of plant affect temperature (large trees vs brush)?*
- *How do other surfaces affect temperature?*
- *How does a city growing affect temperature?*

Strategies for this Consensus Building Discussion

C: Be transparent about the constraints of this investigation. For example, if the weather is too cold to go outside or the school rules do not allow it, share this with the class to guide them towards an indoor investigation.

4. (15 mins) Instruct students to circle which materials listed on their charts are accessible here on campus. Then, in pairs, write a scientific procedure for how we could investigate those materials in relation to temperature (on their Student Activity Sheet)[C]

Suggested Prompts:

- ➔ Which of these materials would we able to investigate here at school
- ➔ How would we conduct this investigation?

5. (10 min) Ask students to share their procedure ideas and use students' responses to push them towards agreeing to the investigation you have chosen to use today (either the outdoor or the indoor investigation). Write the procedure down on a large paper as students agree/edit each of the steps. Be sure to identity potential sources of error, what constants are involved in the procedure.

Suggested Prompts:

- ➔ Outdoor:
  - ◆ What tool would we use to measure the temperature of different surfaces around campus?
  - ◆ What types of surfaces are most important to measure?
  - ◆ How can we avoid error in our investigation as student scientists?
- ➔ Indoor:
  - ◆ How can we simulate solar heating in the classroom?
  - ◆ How can we simulate different land surfaces in the classroom?
  - ◆ How can we avoid error in our investigation as student scientists?

6. (30 mins) Have students complete the investigation about surface heating using one of the two investigations below[D]. There are two options to choose from, based on class constraints.

1. **Option 1: (need appropriate time of year to go outside AND infrared thermometer) Outdoor Albedo modified from NGSS. Students will use an infrared thermometer to find the temperature of different types of ground coverings. Students will test black asphalt, white concrete, grass, and one other surface of their choice. Surfaces should not be in shadow.**
   - **a. Instruct students to first collect data working in pairs or small lab groups based on how many thermometers are available**
   - **b. Students return to the classroom to compile data from their trials. Students will then calculate the average temperature of each type of ground covering. Next, they will work with their lab partner to analyze their data, and write out their analysis and conclusion on their lab report.**
   - **c. With 5 minutes left, have students switch out one partner with a group near them so they have a new partner. New partners will then take a few moments to share their findings, and their conclusion. Afterwards, students can move back into their original partner pairings, and make any modifications to their conclusions that they feel is necessary.**

Alternate Activity

D: If you would prefer to use a computer simulation instead of a hands-on investigation, you can access this online simulation to understand albedo. This could also be used for students who are absent or need additional reinforcement of the ideas.

2. **Option 2: (during winter months, if you cannot go outside, or if you only have regular thermometers) Indoor Albedo Lab. Use this investigation adapted from CLEAN Understanding Albedo.**

7. (10 mins) Have students complete the Albedo Reading Guide and questions on their own or with a partner to reinforce the idea of albedo.

8. (5 mins) Engage students in a Buildings Understandings Discussion using the "Day 2 Making Sense Questions" from their Student Activity Sheet. At this point, name the Urban Heat Island effect. Students should scribe final thoughts for the day on their Student Activity Sheets.

Suggested Prompts:
- ➔ Why are average city temperatures hotter than average state temperatures? Let's name this Urban Heat Island Effect.
- ➔ Why are city temperatures increasing at a faster rate than state temperatures?

Listen for student responses:
- ➔ *Cities have more surfaces with lower albedo than states, such as pavement.*
- ➔ *Cities have fewer trees.*
- ➔ *Cities are growing, so that is creating more, low albedo (dark) surfaces causing more absorption of heat and increasing temperatures.*

9. (10 min) As a thought experiment or for homework, have students complete the last section of the Student Activity Sheet. At the end of this lesson or the beginning of the next lesson, have a Consensus Building Discussion about the contradiction between what we would expect to see given the investigation results (greater warming in places with low albedo) and what we saw in the map data in lesson 2 (greater warming in places with high albedo like snow and ice in the arctic).

Suggested Prompts:
- ➔ Where do you expect low albedo areas to be on the world map? What about high albedo areas?
- ➔ What effect does albedo have on temperature? Based on albedo alone, where do we expect the largest temperature increases? What about the smallest temperature increases?
- ➔ When you compared the albedo world map with the temperature anomaly world map, what did you notice?

Listen for student responses:
- ➔ *We would expect low albedo areas to be developed areas where there are many people like areas in the US with big cities.*
- ➔ *We would expect high albedo areas to have a lot of reflective land cover like ice and snow. For example, the Arctic.*

Further References

E: For students that are ahead and have questions, link to the following report: "ClimateChangeCO_CWCB_ExtraReading". Website is http://wwa.colorado.edu/climate/co2014report/index.html

If you would like access to more data to run different analyses, a good website is: https://www.ncdc.noaa.gov/cag/ There, you can make regional, statewide, global, etc. plots of different things, like temperature, precipitations, anomalies, etc.

- ➔ *In urban heat islands, the low albedo areas have high temperatures and the high albedo areas have lower temperatures. However, in the global trend data, the temperatures are increasing the most in the Arctic. What's going on? Why is this happening? What's missing from our explanation?*
- ➔ *Why do small (microscale) systems follow the trend we expect but large (macrsocale) systems do not? What does this mean about what's happening? Answer: it tells us that there are very large scale effects that do not matter on the small time/space scales, but do matter on the large time/space scales.)*

10. Engage students in a next steps discussion to prepare students for the next lesson.

Suggested Prompts:

- ➔ What did we figure out today?
- ➔ What new questions do you have?
- ➔ What should we investigate next?

Listen for student responses[E]:

- ➔ *We figured out that albedo could be part of an explanation for why cities are getting hotter than rural areas.*
- ➔ *We are wondering what explains the increase in temperature in places like the Arctic that reflect back most light as they shouldn't be warming as fast as the global trends data suggests they are.*
- ➔ *We have heard of Greenhouse Gases and have decided we need to make a model and figure out where human activity fits in and what this has to do with Greenhouse Gases.*

Alignment With Standards

Building Toward Target NGSS PE

- **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.

Building Toward Common Core Standard(s)

- **RST.11-12.2:** Determine the central ideas or conclusions of a test; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms
- **RST.11-12.7:** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem
- **WHST.9-12.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.