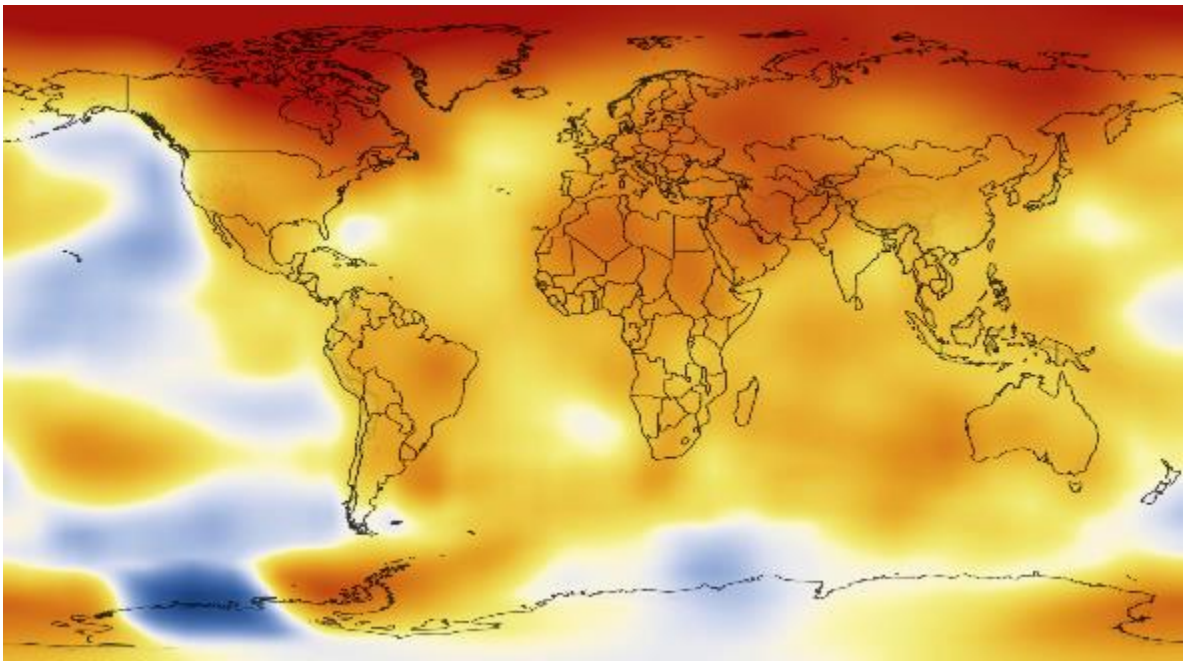
National Aeronautics and Space Administration
Goddard Institute for Space Studies
New York, N.Y.

NASA Goddard Institute for Space Studies (GISS)
Climate Change Research Initiative (CCRI)
Applied Research STEM Curriculum Unit Portfolio

Unit Title: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

NASA STEM Educator / Associate Researcher: Elizabeth Sebastian
NASA PI / Mentor: Dr. Stuart Gaffin, Dr. Reginald Blake, & Dr. Hamidreza Norouzi
NASA GSFC Office of Education – Code 160



I. Executive Summary

The title of this unit "The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions" reflects the main goal of the unit, which is to teach students how to use innovative technology to understand the changing climate in urban areas and create solutions to the ongoing environmental problems in cities. Scientists in the field of urban ecology use tools such as satellites and thermal cameras to understand the effect impervious surfaces have on temperatures in urban areas and to show how implementing green infrastructure (pervious surfaces) can reduce the temperatures in these urban areas.

By the year 2100, Earth's average global temperature is predicted to rise 3-10 degrees Fahrenheit (NASA, 2019). In cities, it could be even worse due to the urban heat island effect. How do we change our current path to make a better future? We start with the younger generations.

Steps are starting to be taken in order to equip the younger generations with the knowledge and skill set to thrive in STEM occupations. New York State recently merged their standards with the Next Generation Science Standards. An entire section of the high school curriculum standards are dedicated solely to understanding climate change and developing innovative ways to combat the effects of climate change. New York Content State Standards states, "Evaluate or refine a technological solution that reduces impacts of human activities on natural systems" (NYSED, 2018). This is one of countless standards in the New York State curriculum dedicated to preparing our younger generations for the future. In an effort to keep the momentum going, it is important that we continue to educate our students on climate change and the steps they can take to understand the changing climate in order to take action on mitigating the effects.

This unit allows the students to learn the innovative technology that is being used to understand the urban heat island effect and how we can use the data collected to support mitigation strategies. Students learn that it requires understanding all aspects of the urban environment (temperature, structure, population, neighborhoods) in order to determine the best solution. Students walk away from this unit with being proficient in the technology used to assess the urban heat island, the process of testing and analyzing the land surface temperatures, and justifying the need for mitigation based on data collected.

II. Introduction Goals and Overview of Unit:

The following unit is designed to engage students in how to use innovative technology to understand the changing climate in urban areas and create solutions to the ongoing environmental problems in cities.

The unit begins with students learning how satellites collect data in order to utilize data to understand a phenomenon (Lesson1). Students will observe NASA GISS Director Gavin Schmidt discuss current impacts of climate change in PBS News Hour. From there, students will work with a partner to extract and analyze data from EOS Worldview and Google Earth to determine if there have been changes in land surface and land surface temperature. Students will then identify patterns within the data to see if there is a correlation between the changing environment and the changing land surface temperature. Students will follow up with learning how satellites are able to collect data and how scientists interpret data based on bands. To finish, students will reflect on how they can use satellite data to understand their area and how scientists can use data to track climate change.

In the second lesson of the unit, students will learn how to “ground truth” satellite data. Students will view a demonstration of measuring a surface temperature from different distances to put into perspective the scales of data retrieval (satellite vs. ground measurements). Students will then venture outside to practice the method of “ground truthing” by using thermal cameras to collect surface temperatures and then compare it to satellite data collected for the same area. Students will learn more about this method of “ground truthing” by viewing a video from NASA GSFC about ground validation. The lesson wraps up with students reflecting back to the opening question of how valid is satellite data.

In the third lesson of the unit, students will learn about urban heat island intensity and how we use data to pinpoint areas of particularly high intensity. Students will select a city in the Explore activity to investigate urban heat island intensity. Students will use Landsat data in coordination with a Google Earth Engine’s Urban Heat Island Intensity data set in order to track the range of intensity year by year for a 14-year time span. Students will then analyze the data to find a correlation between intensity and the changing state of the urban environment. Students will follow up their research with learning about UHI intensity through two sources: NASA’s Urban Heat Islands video from GSFC and an article titled “Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect”. In the Elevate activity, students will then connect the information they gathered with demographic data for the area of study to identify patterns/trends between socio/economic status and UHI intensity.

In the fourth lesson of the unit, students will learn about a mitigation strategy called a bioswale and how it is used to reduce the UHI. Students will explore bioswales locations throughout NYC using Arc GIS to determine patterns/trends of placement of bioswales to determine the purpose behind the locations of the bioswales. Students will then learn more about bioswales in the Explain activity by looking at the structure of bioswales and an Earth Observatory article titled “Vegetation limits city warming effects”. Using the knowledge gained from the Explore and Explain activities, students will use a topographic map to further understand the many purposes of utilizing bioswales for both temperature reduction and rainwater drainage (which both contribute to UHI).

The unit was developed based on New York State Standards and Next Generation Science Standards for high school students. The Common Core State Standards are also included within each lesson to develop reading and mathematical skills required of a high school graduate. Lastly, The NASA System of Engineering Behaviors are used in the design of each lesson for students to learn and use the same behaviors that a NASA scientist experiences every day to develop groundbreaking ideas and solutions.

III. Educator Biography

Elizabeth Sebastian
Head of Science Department
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Elizabeth is the Head of the Science Department at Fusion Academy in Downtown Brooklyn. She is also the technology liaison for the learning management and student information systems for her campus. She teaches a variety of math and science courses to students from 6th-12th grade. During the past couple of summers, Elizabeth has worked with her school to reconstruct and develop science courses. At Fusion Academy, Elizabeth has hosted the annual STEM fair for students to display their projects to parents, teachers, administration, and fellow students. Elizabeth has also created events for students to speak and ask questions with NASA astronaut Paul Richards and Chief Safety & Mission Assurance Officer Mark Hubbard.

Outside of school, Elizabeth is a member of the NASA GISS Climate Change Research Initiative as a teacher and associate researcher where she spends her time studying the urban heat island and the effectiveness of mitigation strategies throughout the city using both satellite data and field campaigns using thermal thermography. Elizabeth also serves on the Education Advisory board for Infiniscope where she creates and reviews online interactive science lessons.

Elizabeth has had several achievements throughout her career. Elizabeth was awarded “Teacher of the Year” at her school for 2016-2017. She was featured in the nationwide quarterly newsletter for Fusion Academy for her accomplishments at Fusion and her participation in the NASA CCRI program. In college, Elizabeth was selected to present at the Maryland Math Teachers Conference on her research of collaborating Art into Math. Elizabeth was inducted into Order of Omega, an institute that recognizes Outstanding Greek Leaders. In her senior year of college, Elizabeth attended the Pre-service Teaching Institute at the National Institute of Aerospace where she learned to incorporate STEM into the classroom.

As a result of her experience in the NASA CCRI program, Elizabeth has gained a new way of teaching that without the program would not have been possible. Elizabeth will incorporate these lessons and ideals into her classroom in the next school year as well as sharing the unit with her fellow teachers at Fusion both locally and nationwide. Elizabeth hopes to build a professional development course for her school utilizing the experiences she has learned through the CCRI program and how teachers can incorporate the experiences into their classroom. Elizabeth has made many connections in the NASA network to help her continue her passion of STEM education. Without these individuals, Elizabeth would not have gained the wonderful experience and knowledge that has transformed her approach to education and continued her passion for science.

Elizabeth currently holds a Bachelor of Science in Elementary Education from Towson University. Elizabeth plans to pursue a masters in Instructional Technology within the next year and then in the future obtain a Doctorate of Education in Science Education.

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**Some of the resources in this lesson require either a Windows, Mac, or Linux computer in order to run properly.*

V. NGSS and Common Core Alignment

Grade Band	9th-12th
Unit Duration	4 lessons & 1 Capstone Project Each lesson: >90 minutes Total Approximate Unit Duration: 2 weeks
Sphere	Atmosphere, Geosphere, Earth as a System
Phenomena	Urban Heat Islands, Air Temperatures, Flow of Energy and Matter, Land surface/Land Use Change, Land Use
NGSS Disciplinary Core Ideas	ESS2D: Weather and Climate ESS3D: Global Climate Change ESS2A: Earth Materials and Systems ETS1.B: Developing Possible Solutions
NGSS Science and Engineering Practices	Engaging in Argument from Evidence Constructing Explanations and Designing Solutions Asking Questions and Defining Problems
NGSS Crosscutting Concepts	Patterns Cause and Effect Science Addresses Questions About the Natural and Material World
Supported NGSS Performance Expectations	(HS-ETS1-3) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
Supported Common Core ELA	CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research. 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4- 4)
Supported Common Core Math	CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

VI. NASA Education Resources Utilized in Unit

a. Data visualization & analysis activity

- **Lesson 1**
  - EOS Worldview
    - Land Surface Temperature
- **Lesson 2**
  - Globe Data Entry
    - Land Surface Temperature
  - EOS Worldview
    - Land Surface Temperature
- **Lesson 3**
  - Urban Heat Island Intensity Map – utilizing MODIS Terra data
- **Lesson 4**
  - Arc GIS DEP Green Infrastructure Program Map
  - Index of USGS Topographic Maps, New York State

b. Other NASA Education Resources Utilized

- **Lesson 1**
  - NASA Peeling back Landsat's Layers of Data video
- **Lesson 2**
  - NASA Scientific Visualization Studio video "Remote Sensing: Observing the Earth"
- **Lesson 3**
  - NASA Images of Change "Urban Expansion in Shanghai China"
  - NASA Urban Heat Islands video
  - NASA "Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect" article
- **Lesson 4**
  - NASA Climate Kids "Offset" Game
  - NASA Earth Observatory "Vegetation Limits City Warming Effects" article

c. NASA Mission Alignment

This unit uses the data from several satellite missions in order to understand the urban heat island effect and its effect on surface and near surface air temperatures. The satellites used are:

- Landsat
- Terra/MODIS

d. NASA 2018 Strategic Objective Alignment

The main goal of the unit plan is to educate students in the missions that NASA conducts to further enrich our understanding of our planet. The unit plan aligns with Strategic Objective 3.3: *Inspire and Engage the Public in Aeronautics, Space, and Science"* as stated in the NASA 2018 Strategic Plan. As Educators, we are continuously striving to "*provide the widest and appropriate understanding*" of activities and missions throughout our science program. This is conducted through a use of STEM principles and activities designed by the NASA Education team. In the unit, students are utilizing missions such as Landsat and Terra to better understand our surfaces and how we can continue to improve our knowledge of the effects of climate change and development of technology to keep our planet in peak physical shape. By creating and implementing unit plans such as the one created here, we are fulfilling the goal of Strategic Objective 2.2 to "*engage the public in science, technology, discovery, and exploration… and providing unique STEM opportunities"* through our classrooms.

VII. Research Opportunity Title and Abstract
Urban Climate Adaptation Research: New Materials, Technology, & Thinking

Urban Heat Islands (UHIs) and Remote Sensing: Combining Data to Characterize Land Surface Temperature (LST)

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Elizabeth Sebastian[2]
Claudia Yanos[3]
Matthew Bilik[4]
Dr. Reginald Blake[5]
Dr. Hamidreza Norouzi[5]

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[3]*The University of Chicago, 5801 S Ellis Ave, Chicago, IL 60637*

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[5]*New York City College of Technology, 300 Jay Street, Brooklyn NY 11201*

The urban heat island effect can magnify the negative consequences of climate change for cities. Most studies of the urban heat island effect rely on satellite data to complete their analysis, but this has some drawbacks. Satellites are often either

spatially or temporally coarse and can only collect data on non-cloudy days. Their usefulness is further limited by their inability to retrieve near-surface air temperature; satellites can only be used to calculate the surface temperature of the land types. In order to facilitate studies of urban heat on the neighborhood scale, ground observations were taken in the Bedford-Stuyvesant neighborhood of New York, and compared to data from the Landsat 8 and MODIS Aqua and MODIS Terra satellites. This involved identifying the hot and cool spots within the neighborhood, according to the Landsat 8 satellite, and traversing an approximately 1 km transect through both “hot” and “cool” spots according to the satellite map. Satellite data was analyzed using the Google Earth Engine tool, and the ground surface temperatures were collected using the FLIR T650 thermal imaging camera. The ground data was shown to identify the same patterns with regard to hot and cool spots within the neighborhood as the Landsat 8 satellite, even though the absolute temperatures differed by up to a few degrees Celsius. In particular, the maximum surface temperatures recorded by the FLIR camera in the sun for all surface types was up to 20 degrees Celsius higher than the maximum surface temperatures recorded by the Landsat 8 satellite.

VIII. Unit Pre-and Post-Standards Based Assessment:

The pre-assessment for this unit helps to gauge students’ prior knowledge about the common terminology and concepts used in climate change. The pre-assessment below contains a series of questions that will provide the instructor with a document of student’s prior knowledge in order to determine the depth needed to be spent on each topic in the following unit. After the conclusion of the Capstone Project, the instructor will give this same pre-assessment to help students see how their knowledge has changed and grown over the unit. This will also be an indicator to the instructor of what the students have learned throughout the unit and if any topics need to be revisited.

The Pre-assessment is composed of two parts. Part 1 is an online interactive assessment that gauges students basic understanding of climate change. The interactive lesson is on a NASA SMD funded site called Infiniscope. The lesson itself was created by the author of this unit, Elizabeth Sebastian. Part 2 consists of general reflection questions in regards to the Urban Heat Island in order to see the prior knowledge that students contain of the phenomenon the urban heat island effect. The assessment is constructed based on the NY State Standards, Next Generation Science Standards (NGSS), and Fusion Academy Environmental Science and Biology standards. Fusion Academy creates their standards based on the requirements of each states Standards, NGSS, and Common Core State Standards. Fusion courses are designed by the Universal Backwards Design (UBD) method. The preassessment reflects the essential questions, course understandings, and performance tasks in the Environmental Science and Biology Fusion Academy courses.

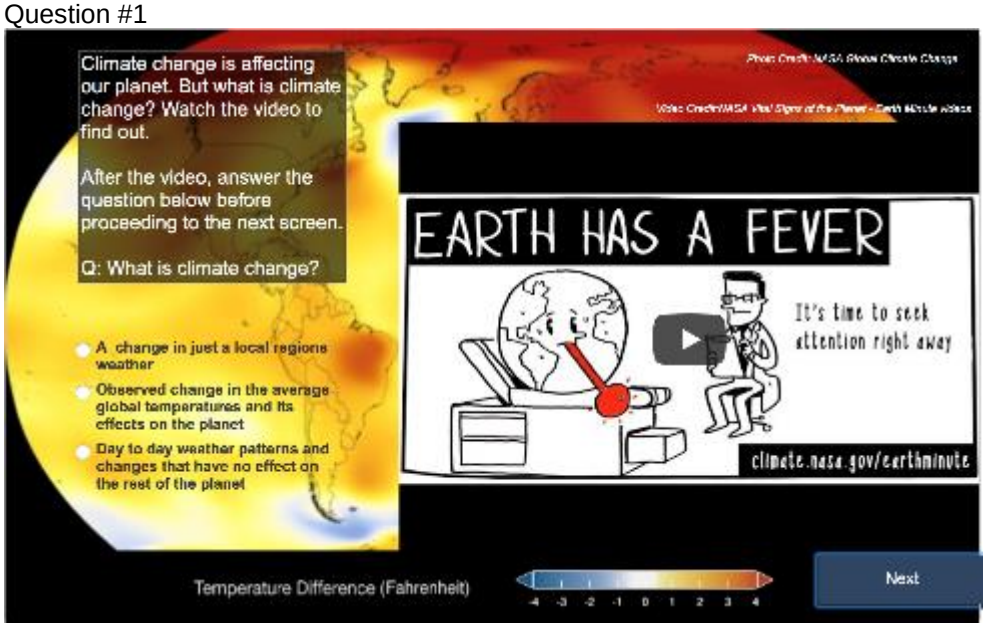
The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions
Pre-Assessment

Part 1

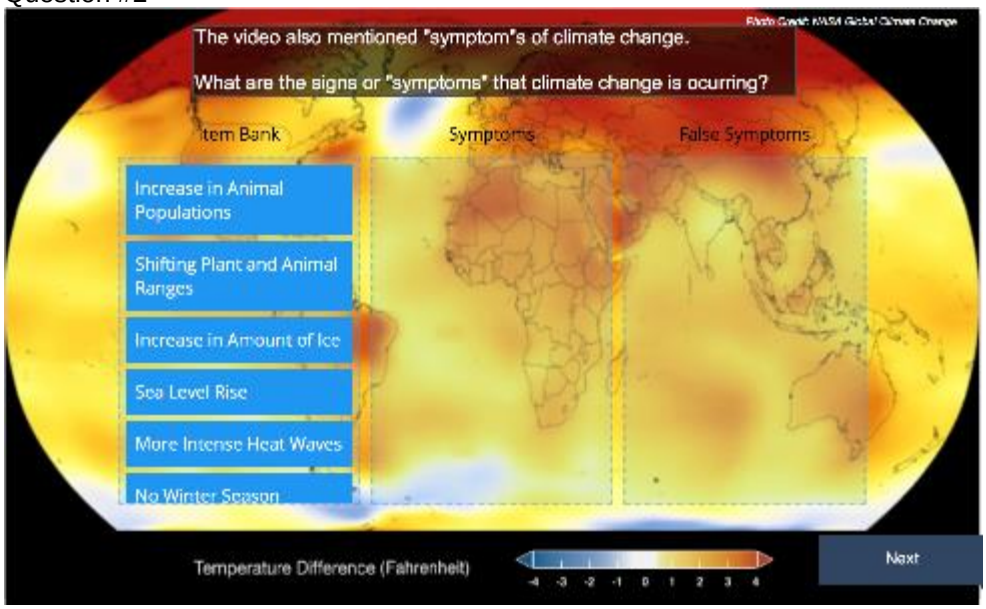
Directions: Go to https://infiniscope.org/. Log in to your account (see teacher if you're having trouble). Scroll to the bottom of the site to the section labeled, "Contributed Content". Click the lesson labeled "Overview of Climate Change". Then click, "Explore Now" to begin.

As you are going through "Overview of Climate Change", you will be asked various questions about climate change. As you answer the questions, write your responses in the designated space below.

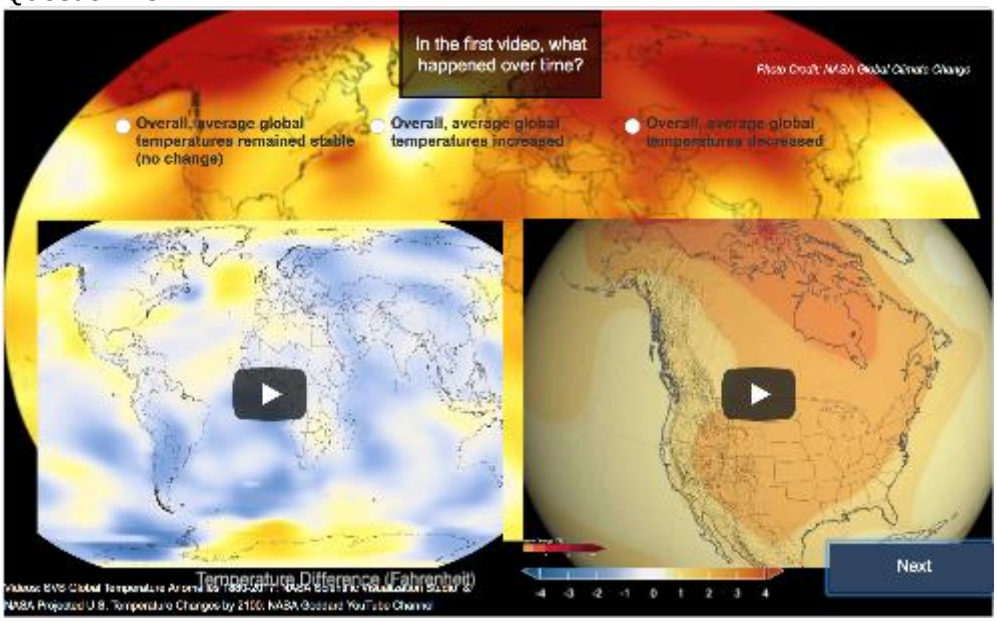
Question #1



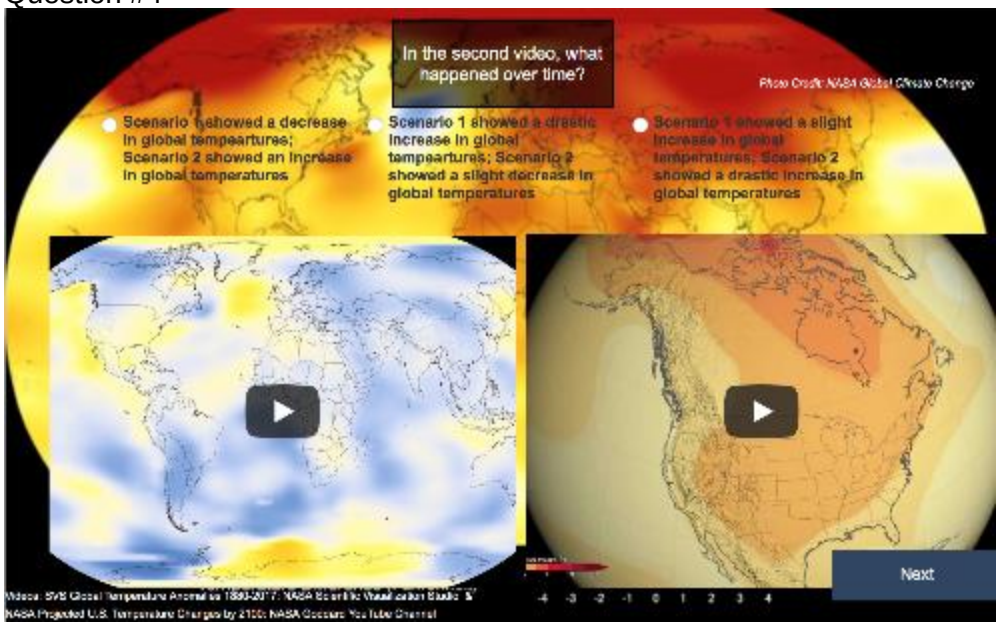
Question #2



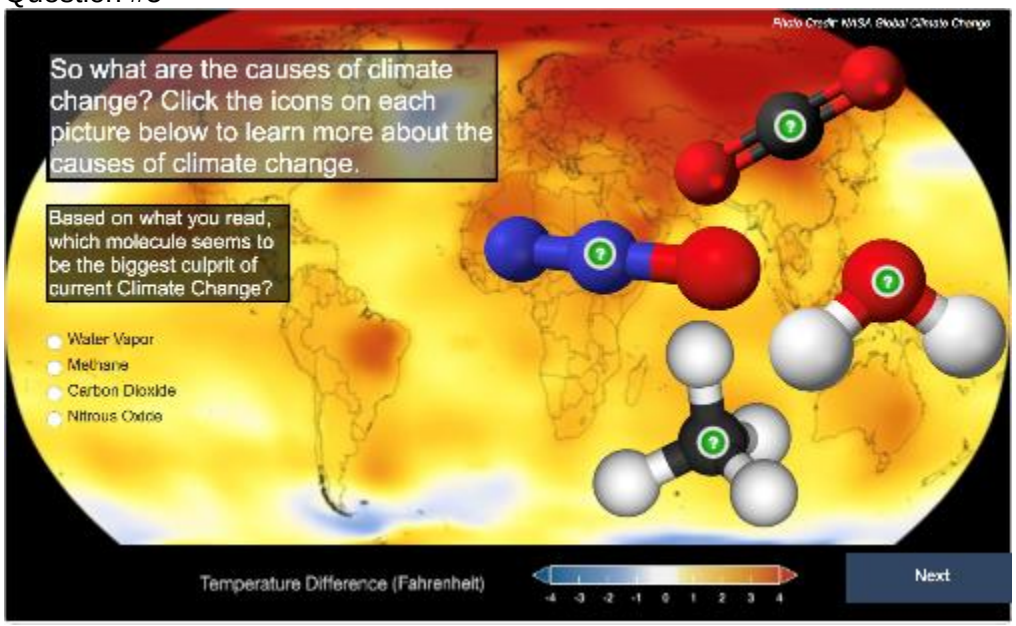
Question #3



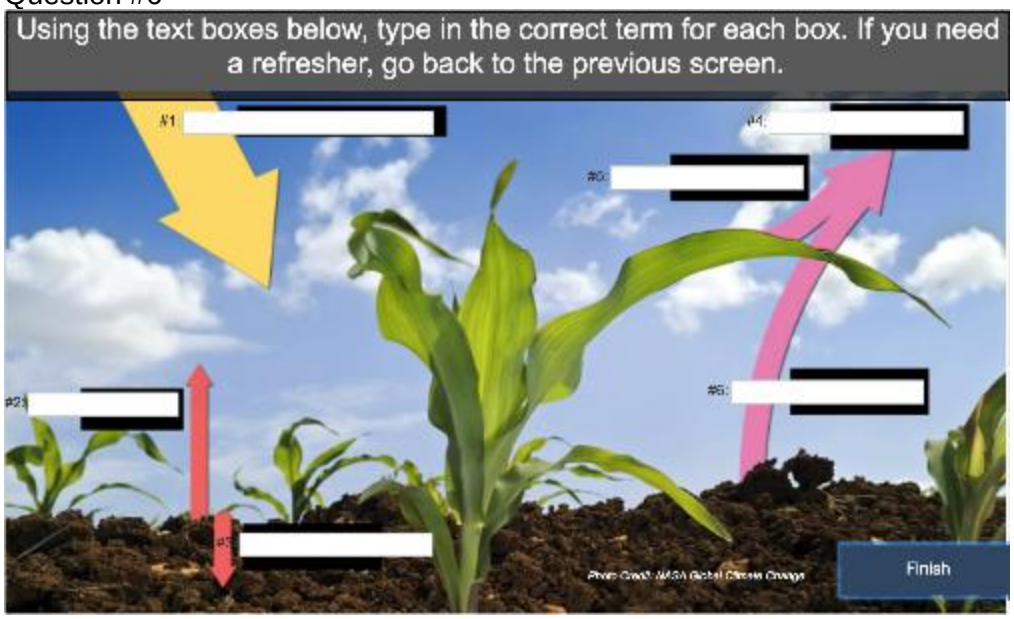
Question #4



Question #5



Question #6



Part 2

Directions: Answer the questions below using your prior knowledge.

1. What is the Urban Heat Island effect and how can we use data to prove that it is occurring?

2. How does the Urban Heat Island effect relate to climate change?

3. How does the Urban Heat Island effect change over time?

4. What are some ways to reduce the effects of the urban heat island effect?

5. How can we measure the changes that mitigation strategies have on the urban heat island effect?

KEY

The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions
Pre-Assessment

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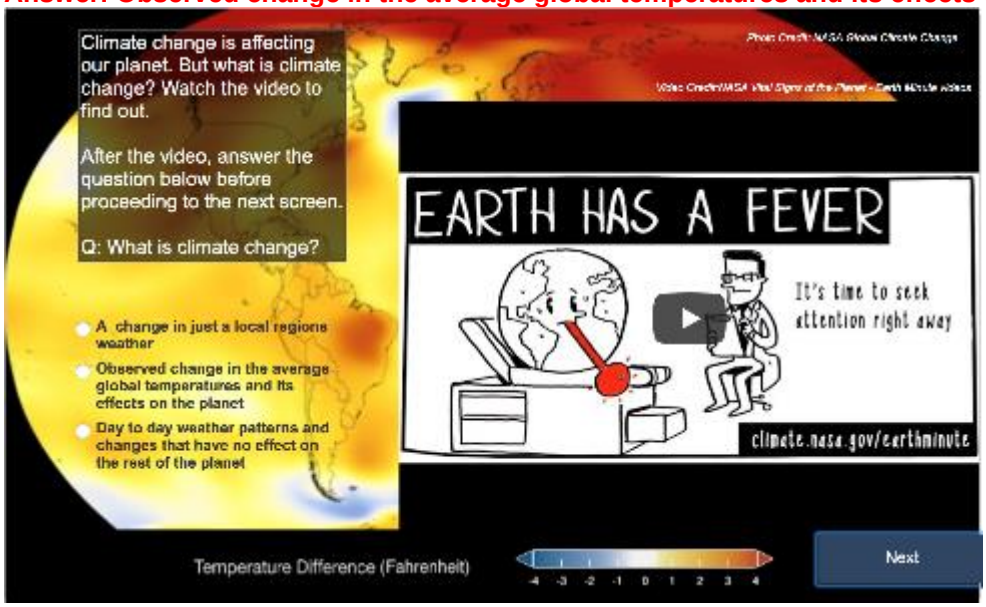
As you are going through "Overview of Climate Change", you will be asked various questions about climate change. As you answer the questions, write your responses in the designated space below.

Question #1

Answer: Observed change in the average global temperatures and its effects on the planet

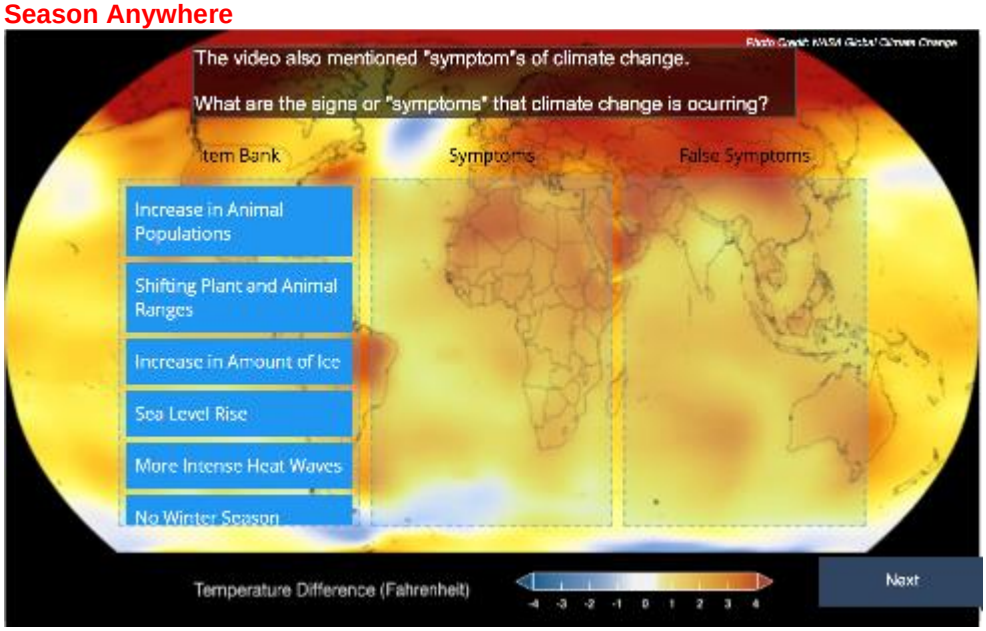


Question #2

Answer:

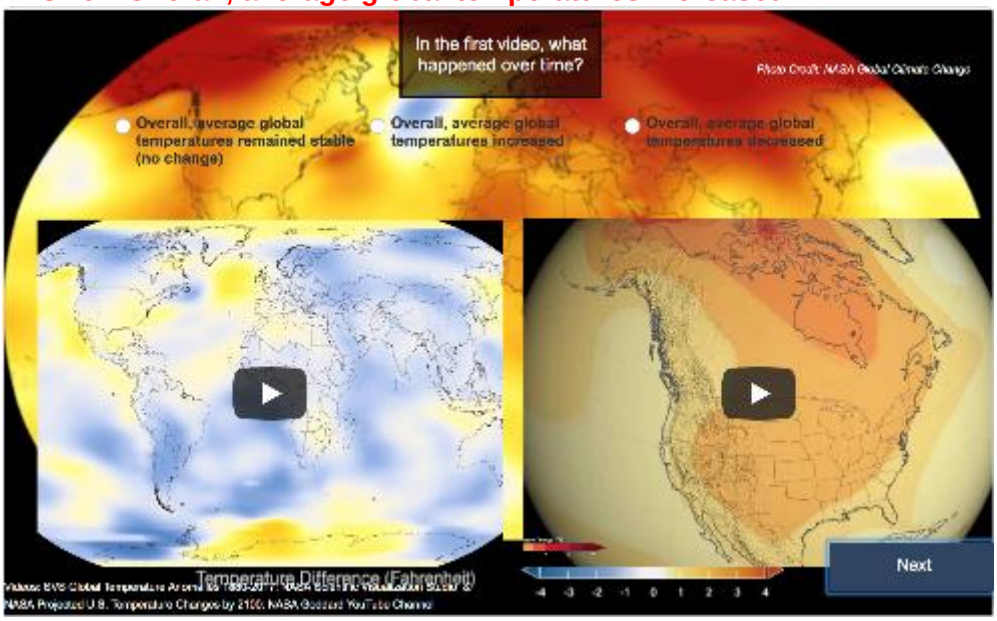
Symptoms: Shifting Plant and Animal Ranges, Sea Level Rise, Shrinking Glaciers, More Intense Heat Waves

False Symptoms: Increase in Animal Populations, Increase in Amount of Ice, No Winter Season Anywhere



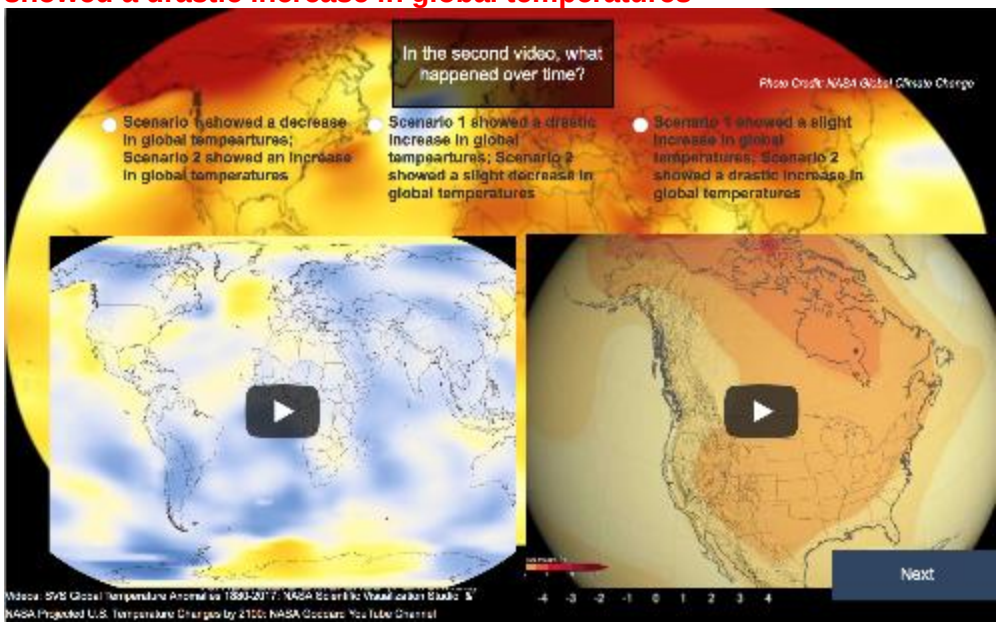
Question #3

Answer: Overall, average global temperatures increased



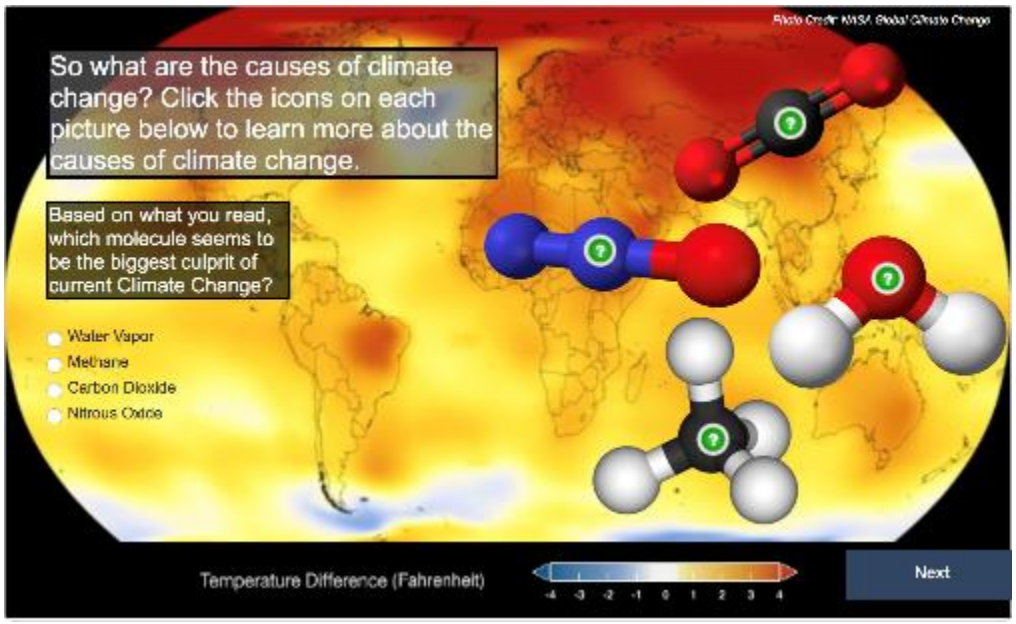
Question #4

Answer: Scenario 1 showed a slight increase in global temperatures; Scenario 2 showed a drastic increase in global temperatures



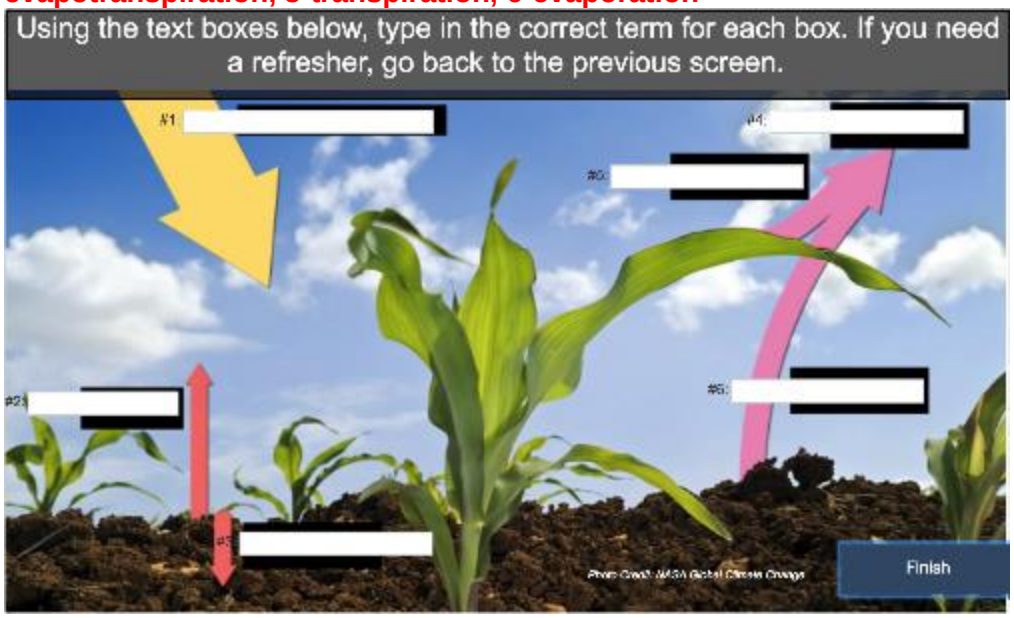
Question #5

Answer: Carbon Dioxide



Question #6

Answers: 1-Incoming (solar) energy, 2-heat to air, 3-heat to ground, 4-evapotranspiration, 5-transpiration, 6-evaporation



Part 2

Directions: Answer the questions below using your prior knowledge.

1. What is the Urban Heat Island effect and how can we use data to prove that it is occurring?
   The urban heat island effect is the phenomena of urban areas having on overall higher average temperature than surround rural areas due to a number of factors such as human activities (transportation, factories), impervious structures (concrete), and lack of vegetation. We can use land surface temperature data, air temperature data, vegetation index and more to prove that this effect is occurring.

2. How does the Urban Heat Island effect relate to climate change?
   The urban heat island effect is one of the contributing factors to overall climate change. Human activities in cities (transportation → co2 emissions), impervious surfaces, and lack of vegetation raise the average temperature of an urban area. Overall, we have seen an increase in average global temperatures with cities being one small factor of the areas affected by rising temperatures.

3. How does the Urban Heat Island effect change over time?
   With current growth in both population and development in urban areas, the urban heat island effect will increase in intensity over time. If changes are made (changing impervious surfaces to vegetated surfaces, reducing carbon emissions), then the urban heat island effect will gradually decrease over time.

4. What are some ways to reduce the effects of the urban heat island effect?
   Changing impervious surfaces like concrete into vegetated surfaces (rain gardens, parks, etc..), reducing the number of cars in urban areas, convert buildings to a "greener" infrastructure (recycling, energy efficient lights, better insulation).

5. How can we measure the changes that mitigation strategies have on the urban heat island effect?
   There are numerous ways to measure the changes that mitigation strategies have on the urban heat island effect. One was is with remote sensing. Satellites can capture land surface temperature and land surface changes over a series of time. Another is to focus more on a micro scale by using handheld thermal cameras to measure different surfaces and their effects on surface temperature.

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Applied Research STEM Curriculum Unit Portfolio

Unit Title: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

Lesson Title: From the Sky to the Ground: Using Satellite Data to understand the Urban Heat Island

NASA STEM Educator / Associate Researcher: Elizabeth Sebastian
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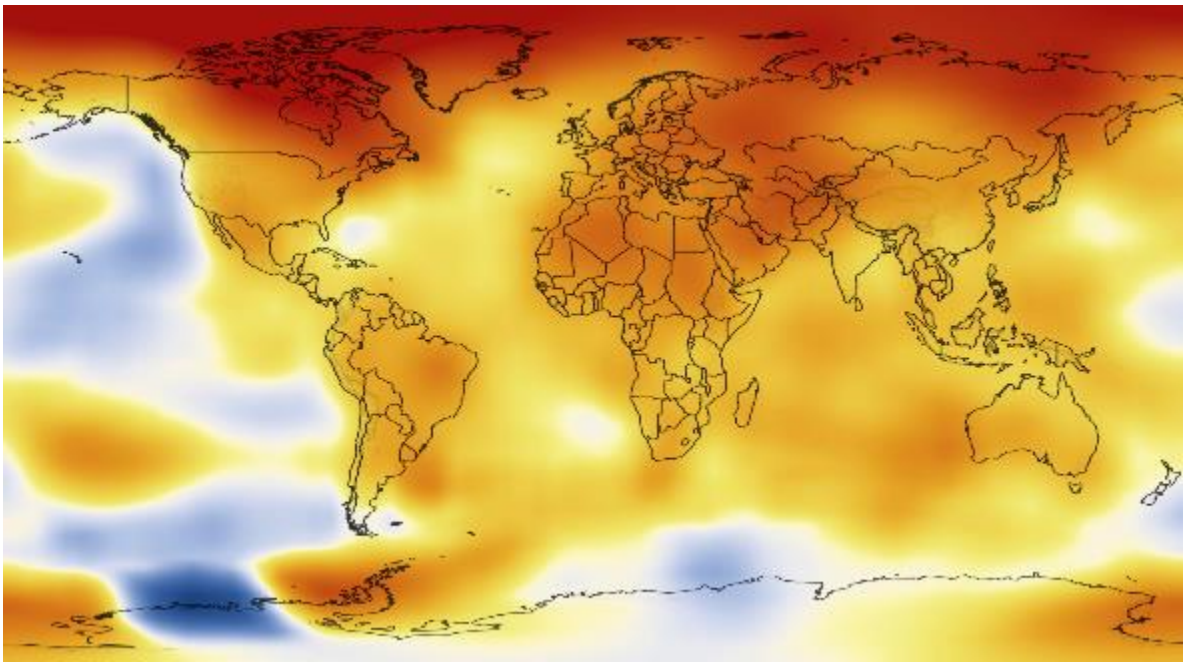

IX. Lesson 1: From the Sky to the Ground: Using Satellite Data to understand the Urban Heat Island Effect

a. Summary and Goals of Lesson

In this lesson, students will learn how satellites collect data in order to utilize data to understand a phenomenon. Students start out with reflecting on what they think of when they hear the term “climate change”. This is set to engage students’ prior knowledge of the concept of climate change. Then, students will observe NASA GISS Director Gavin Schmidt discuss current impacts of climate change in PBS News Hour. From there, students will work with a partner to extract and analyze data from EOS Worldview and Google Earth to determine if there has been changes in land surface and land surface temperature. After data collection and analysis, students will identify patterns within the data to see if there is a correlation between the changing environment and the changing land surface temperature. Students will follow up with learning how satellites are able to collect data and how scientists interpret data based on bands. Students will then compare the specifications of the two satellites to understand why scientists may use more than one satellite to conduct research. To finish, students will reflect on how they can use satellite data to understand their area and how scientists can use data to track climate change. The goals of this lesson are to have students understand how satellites work, how we use the data from satellites, and how we can use it to understand phenomenon such as the urban heat island effect.

b. Table of Contents for lesson

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**Some of the resources in this lesson may require either a Windows, Mac, or Linux computer in order to run properly.*

c. 5 E lesson model template:

Unit: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

Topic: How to use satellite data to understand the Urban Heat Island Effect

Prior Learning: Prior to this lesson, students should have an understanding of the Urban Heat Island Effect. Students should be well versed in the Electromagnetic Spectrum and how to use wavelength values to determine which part of the spectrum they need. Students should also be familiar with how to use a computer.

Do Now (Pre-Assessment): Students will respond to the following prompt: "Climate change is a term we've been hearing for a while now and more the past few years. Below, brainstorm all the terms or phrases that come to mind when you hear the term "climate change".

Aim: How can scientists use satellite data and changes in data to track climate change and reduce the effects of climate change?

New York State Standards (Aligned to Next Generation Science Standards):

- (HS-PS4-2),(HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- (HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).
- (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- (HSPS4-6) Mathematical representations can be used to identify certain patterns.
- (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)

Common Core State Standards:

- CCSS.MATH.CONTENT.HSN.Q.A.2
  Define appropriate quantities for the purpose of descriptive modeling.
- CCSS.MATH.CONTENT.HSN.Q.A.3
  Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- CCSS.ELA-LITERACY.W.9-10.9
  Draw evidence from literary or informational texts to support analysis, reflection, and research.

NASA System of Engineering Behavior:

- *Leadership*
  - Understands the Human Dynamics of a Team
- *Attitudes & Attributes*
  - Seeks Information and Uses the Art of Questioning
- *Systems Thinking*

    - Assimilates, Analyzes, and Synthesizes Data
    - Has the Ability to Find Connections and Patterns Across the System
- *Communications*
    - Communicates Effectively Through Personal Interaction
    - Facilitates an Environment of Open and Honest Communication
- *Technical Acumen*
    - Learns from Successes and Failures

Performance Objective: Students will learn how satellites collect data in order to utilize data to understand a phenomenon.

Materials:
- Lesson 1 worksheet
- Lesson 1 worksheet Answer Key
- Computer (for each student if applicable)
- PBS News Hour Interview https://www.giss.nasa.gov/research/features/201810_unreport/
- EOS Worldview https://worldview.earthdata.nasa.gov/
- Google Earth Desktop Application (downloaded onto computers beforehand)
    - *This application requires Windows, Mac, or a Linux computer
    - **An alternative resource, EOS Worldview, is available for this activity. Instructions are on page 43
- NASA Peeling back Landsat's Layers of Data video https://www.youtube.com/watch?v=YP0et8l_bvY&t=90s
- What are the best Landsat spectral bands to use for my study? Article https://www.usgs.gov/faqs/what-are-best-landsat-spectral-bands-use-my-study?qt-news_science_products=7#qt-news_science_products
- Landsat 8's Overview website https://www.usgs.gov/land-resources/nli/landsat/landsat-8?qt-science_support_page_related_con=0#qt-science_support_page_related_con
- MODIS Terra's Specifications website https://modis.gsfc.nasa.gov/about/specifications.php

Vocabulary: Landsat, spectral bands

Development of Lesson: Two Day Lessons (Approximately two 50-minute periods).

What the Teacher does	What the Student does	Time
Do Now! (Anticipatory Opening) As the students are coming into class and setting up, direct students to complete the *Do Now!* Section of the worksheet. Students will brainstorm terms or phrases that they associate with the term climate change. Students will record the terms in a word cloud in the Do Now! Section of the worksheet. After a few minutes, direct students to turn to a neighbor and share their terms. After 1 minute, bring students back together. Ask students to	Students will complete the Do Now! Section of the worksheet. Students will brainstorm terms or phrases they think of when they hear the term climate change. Students will record their terms in a cloud in the Do Now! Section of their worksheet. When directed, students will then turn and share their thoughts with a neighbor. After 1 minute, students will be redirected back to the teacher to share their	5 minutes

share what they wrote on their worksheet. Students responses will vary but could include terms such as “warmer temperatures”, “rising seas”, and “droughts”. Write the terms in a cloud shape on the board. For repeats, create a tally next to the term to record how often terms appear.	thoughts aloud with the class. The teacher will record the terms on the board. Repeats will be marked with a tally to see how often a term is used.	
Engage After the Do Now! Activity, inform students that they will now watch a short clip from a PBS News hour interview with NASA Goddard Institute for Space Studies Director Gavin Schmidt (see materials for link). Display the video on the board. After watching, direct students to the Engage section of the worksheet. Have students turn to a partner and discuss the quote in the Engage section of the worksheet. After 1-2 minutes, direct students to write down what they discussed about the quote on the lines provided on the worksheet. After 1-2 minutes, ask for a few students to volunteer their responses they wrote down. Student responses will vary, but should mention in some format that action to do something about climate change should take place now. **Assessment Opportunity #1 (Use Worksheet Answer Key & Engage section of rubric to assess).**	Students will watch a short video on the board from PBS News Hour on an interview with NASA Goddard Institute for Space Studies Director Gavin Schmidt. After watching the video, students will turn and discuss their thoughts on the quote on their worksheet in the Engage section that is from the interview. After 1-2 minutes, students will write down what they discussed on the lines provided in the worksheet. Students can then volunteer to share their responses when directed by the teacher.	8 minutes
Explore Students will now complete an exploratory activity in the *Explore* section of the worksheet. Direct students to the *Explore* section of the worksheet. Read aloud the first paragraph which explains the overall activity. After reading the paragraph, have students pick a partner to work with. Inform students that with their partner, they will complete the *Explore* activity. If a larger class, model the activity beforehand. Let students know that you will be walking around if they have questions or need guidance while completing the activity. For the *Explore* activity, students will work in pairs to find land surface changes and land surface temperature changes. The partners will designate who in the pair will look at land surface changes and who will look at land surface temperature changes. Once selected,	Students will now complete an exploratory activity in the *Explore* section of the worksheet. Students will listen as the teacher reads the first paragraph which explains the overall activity. After the teacher reads the paragraph, students will pick a partner to work with. Students will work with their partner to find land surface changes and land surface temperature changes. The partners will designate who in the pair will look at land surface changes and who will look at land surface temperature changes. Once selected, students will then select a time frame to focus on that spans at least 10 years to gather a total of 10 images. Students will then follow the directions for the section they selected. One student will use Google Earth to find land surface images over a	25 minutes

students will then select a time frame to focus on that spans at least 10 years to gather a total of 10 images. One student will use Google Earth to find land surface images over a time span and observe if a city has changed over time. ***If Google Earth is not available for use, there are alternative directions/resources for the students to use for this activity on the last page of the student worksheet.*** The other student will use EOS Worldview Terra satellite to find land surface temperature images over a time span and observe the average temperature of each year. Students will record their images, data, observations, and notes in the table in the *Explore* section of the worksheet. Allow at least 20 minutes for students to complete this part of the activity. While students are completing the activity, walk around the classroom to check that students are on a good pace and to guide any students who may be having difficulty. **Assessment Opportunity #2 (Use Worksheet Answer Key & Explore section of rubric to assess).**	time span and observe if a city has changed over time. . ***If Google Earth is not available for use, there are alternative directions/resources for the students to use for this activity on the last page of the student worksheet.*** The other student will use EOS Worldview MODIS satellite to find land surface temperature images over a time span and observe the average temperature of each year. Students will record their images, data, observations, and notes in the table in the *Explore* section of the worksheet.	
Explain After the *Explore* activity, direct students' attention to the *Explain* section. Give students 5-10 minutes to complete the first part of the *Explain* activity. Part 1 Students will answer a series of questions based on the data collected in the *Explore* activity. For the last question, students will find another pair to discuss their findings. Allow 5-10 minutes for part 1. After all pairs have discussed their findings and recorded their discussion, direct student's attention back to the teacher. Part 2 Read aloud the Part 2's instructions. Inform students they will have 15 minutes to complete this part. Students will first watch a video about how Landsat works. While or after watching the video, students will use on organizer in the *Explain* section to answers questions about Landsat. After the video, they will briefly read a short help page about how Landsat works. Lastly, students will turn to a partner to share their findings and add any new information discussed to their organizer. While students	After the *Explore* activity, students will work independently to complete the *Explain* activity. Part 1 Students will answer a series of questions based on the data collected in the *Explore* activity. For the last question, students will find another pair to discuss their findings. After discussing information about their findings from the *Explore* activity with another pair, record new findings in the provided space. Part 2 Students will first listen to the instructions the teacher reads aloud. Students will first watch a video about how Landsat works. While or after watching the video, students will use on organizer in the *Explain* section to answers questions about Landsat. After the video, students will briefly read a short help page about how Landsat works. Lastly, students will turn to a partner to share their findings and add any new information discussed to their organizer.	25 minutes

are working, walk around the classroom to make sure students stay on task. **Assessment Opportunity #3 (Use Worksheet Answer Key & Explain section of rubric to assess).**		
Elevate After students have finished their discussions from the *Explain* activity, direct students' attention to the *Elevate* section of the worksheet. Independently, students will complete the Elevate section. Part 1 Students will brainstorm ways they can use satellite data to better understand their neighborhood. After brainstorming, students will then try to use the satellites from the *Explore* or *Explain* section to see if the information they stated in the first question can be found/determined with satellites. Students will record their findings in the space provided in the *Elevate* section of the worksheet. While students are working, walk around the classroom to help support students as needed. Give students 8-10 minutes for this section. After the allotted time, bring students attention back and ask a few students to volunteer what they were able to find out in the *Elevate* activity. Record the responses on the board below the cloud from the *Engage* activity. Part 2 Students will now look at two satellites to understand why scientists may use more than one satellite for their research. Students will work with their partner from the *Explore* activity. Students will use two websites (provided in the worksheet) to find the band number, spatial resolution, frequency of flyover, and projected mission duration of Landsat 8 and MODIS Terra. After finding the information about each satellite, they will compare the advantages and disadvantages of using each satellite (see worksheet key for suggested responses of advantages and disadvantages). Allow 10-15 minutes for this section. After the allotted time, bring students back together. Ask the students, "In your research and discussion, what were the advantages/disadvantages of using each satellite?" Suggested responses are located in the worksheet answer key. In the responses,	After students have finished their discussions from the *Explain* activity, students will then complete the *Elevate* section of the worksheet independently. Students will brainstorm ways they can use satellite data to better understand their neighborhood. After brainstorming, students will then try to use the satellites from the *Explore* or *Explain* section to see if the information they stated in the first question. Students will record their findings in the space provided in the *Elevate* section of the worksheet. After the allotted time, students will then volunteer what they were able to find out in the *Elevate* activity. Responses will be recorded by the teacher on the board.	20-25 minutes

students should provide specifications from the satellite to support their response. For example, "The advantage of using MODIS Terra is the number of flyovers. MODIS Terra flies over an area 1-2 times per day where as Landsat 8 only flies over 1 time every 16 days." Record a few responses on the board to display for all students. **Assessment Opportunity #4 (Use Worksheet Answer Key & Elevate section of rubric to assess).**		
Evaluate Direct students to the *Evaluate* section of the worksheet. In the *Evaluate* section of the worksheet, students will work independently to answer the following prompt: "At the beginning of the lesson, we heard from Dr. Gavin Schmidt about how the time for reducing emissions was 25 years ago, but the second-best time is now. How can scientists use Landsat data and changes in data to track climate change and reduce the effects of climate change?" Direct students to record their responses on the lines provided in this section. It is recommended to use this section as a homework. It can also be used as an exit ticket. **Assessment Opportunity #5 (Use Worksheet Answer Key & Evaluate section of rubric to assess).**	In the *Evaluate* section of the worksheet, students will work independently to answer the following prompt: "At the beginning of the lesson, we heard from Dr. Gavin Schmidt about how the time for reducing emissions was 25 years ago, but the second-best time is now. How can scientists use Landsat data and changes in data to track climate change and reduce the effects of climate change?" Students will record their responses on the lines provided in this section.	5 minutes

Summary/Conclusion:

The students will answer the prompt, "At the beginning of the lesson, we heard from Dr. Gavin Schmidt about how the time for reducing emissions was 25 years ago, but the second-best time is now. How can scientists use Landsat data and changes in data to track climate change and reduce the effects of climate change?" Students will respond in the Evaluate section of the worksheet.

Higher Order Questions:

1. Based on the changes in land surface temperature and the changes in the land surface of the selected city, what can you conclude about land surface's correlation with land surface temperature?
2. How can scientists use Landsat data and changes in data to track climate change and reduce the effects of climate change?
3. How do different combinations enable scientists to gather data on various items of interest (ex: vegetation cover)?

Differentiated Instruction:

- The students learn the content in a variety of ways. The students learn content through visual formats (images and videos), oral discussion, experimental design, data analysis, and reflection.
- Students use data analysis tools to create models (excel).
- Students use a variety of technology to learn about content (EOS Worldview, Google Earth Desktop App, YouTube)
- Students are provided with a variety of leveled questions (low-high order) to answer questions at their level and elevate their thought processes.
- Students are given the chance to review their understanding through oral discussion in order to confirm or add to their understanding of the content.
- Students are given the opportunity to rewind and review content in a video in order to help their understanding of the content.
- Students will use a graphic organizer to help with their understanding of the content and organize the content in an orderly, easily readable fashion.

Daily Formative Assessment:

Based on what your learned in the *Explore, Explain,* and *Elevate* activities, answer the prompt below.

At the beginning of the lesson, we heard from Dr. Gavin Schmidt about how the time for reducing emissions was 25 years ago, but the second-best time is now. How can scientists use Landsat data and changes in data to track climate change and reduce the effects of climate change?

Next Lesson: The Truth of the Matter: How & Why We Ground Truth Satellite Data

d. Content template:

NGSS Standard & State Science Content Standard: (HS-PS4-2),(HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HSPS4-6) Mathematical representations can be used to identify certain patterns. (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)			Common Core Standard: CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.	NASA Science: Earth Science
Content Area: Earth Science/Environmental Science Grade Level: 9th Grade		Name of Project-Based Activity or Theme: From the Sky to the Ground: Using Satellite Data to understand the Urban Heat Island	Estimated Time Frame to Complete(days/weeks): 2 classes/days	
Overall Investigation Question(s): How can scientists use satellite data and changes in data to track climate change and reduce the effects of climate change?				
Overall Project Description/Activity: Students will learn how satellites collect data in order to utilize data to understand a phenomenon.				
	:			
Materials Needed to Complete Project (put N/A as needed). Lesson 1 Worksheet Lesson 1 Worksheet Answer Key Computer PBS NewsHour Interview with Dr. Gavin Schmidt EOS Worldview Google Earth Desktop Application NASA "Peeling Back Landsat's Layers of Data" video Landsat informational page on spectral bands "What are the best Landsat spectral bands to use for my study?"	Stakeholders: Fusion Academy: Education Team, Administrators, Science Department, Science Teachers, and students	Hyperlinks Used: PBS NewsHour Interview with Dr. Gavin Schmidt: https://www.giss.nasa.gov/research/features/201810_unreport/ EOS Worldview: https://worldview.earthdata.nasa.gov/ NASA "Peeling back Landsat's Layers of Dater" video: https://www.youtube.com/watch?v=YP0et8l_bvY&t=90s Landsat informational page on spectral bands "What are the best Landsat spectral bands to use for my study?": https://www.usgs.gov/faqs/what-are-best-landsat-spectral-bands-use-my-study?qt-news_science_products=7#qt-news_science_products Landsat 8's Overview website https://www.usgs.gov/land-resources/nli/landsat/landsat-8?qt-science_support_page_related_con=0#qt-science_support_page_related_con MODIS Terra's Specifications website https://modis.gsfc.nasa.gov/about/specifications.php	Multimedia/Technology: Computer PBS NewsHour Interview with Dr. Gavin Schmidt EOS Worldview Google Earth Desktop Application NASA "Peeling Back Landsat's Layers of Data" video Landsat informational page on spectral bands "What are the best Landsat spectral bands to use for my study?" Landsat 8's Overview website MODIS Terra's Specifications website	Classroom Equipment: Computer

NASA System Engineering Behaviors (2 behaviors per category)	Category (must have one Technical Acumen)	Activities How will student model engineering behaviors when learning science content? Describe student activities here.	Student Outcomes How will you assess learning for each behavior	Evaluation Describe specific science content students understand as a result of engineering behavior.
Understands the Human Dynamics of a Team	Leadership	Students work in pairs to complete the Explore and Explain activities (interpreting satellite data & understanding how satellites work)	Lesson 1 Rubric – Explore and Explain Categories	Data collection, data analysis, thermal bands, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Seeks Information and Uses the Art of Questioning	Attitudes & Attributes	Students will research information on how satellites work in the Explain activity.	Lesson 1 Rubric – Explain Category	Data collection, data analysis, thermal bands, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Assimilates, Analyzes, and Synthesizes Data	Systems Thinking	Students will obtain satellite data and interpret the data in order to identify a trend/pattern of surface temperatures and land changes to understand the UHI phenomenon in the Explore & Explain activities.	Lesson 1 Rubric – Explore and Explain Categories	Data collection, data analysis, thermal bands, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Has the Ability to Find Connections and Patterns Across the System	Systems Thinking	Students will obtain satellite data and interpret the data in order to identify a trend/pattern of surface temperatures and land changes to understand the UHI phenomenon in the Explore & Explain activities.	Lesson 1 Rubric – Explore and Explain Categories	Data collection, data analysis, thermal bands, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Communicates Effectively Through Personal Interaction	Communications	Students work in pairs to complete the Explore & Explain activities. Must have effective communications in order to be successful in activities.	Lesson 1 Rubric – Explore and Explain Categories	Data collection, data analysis, thermal bands, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon

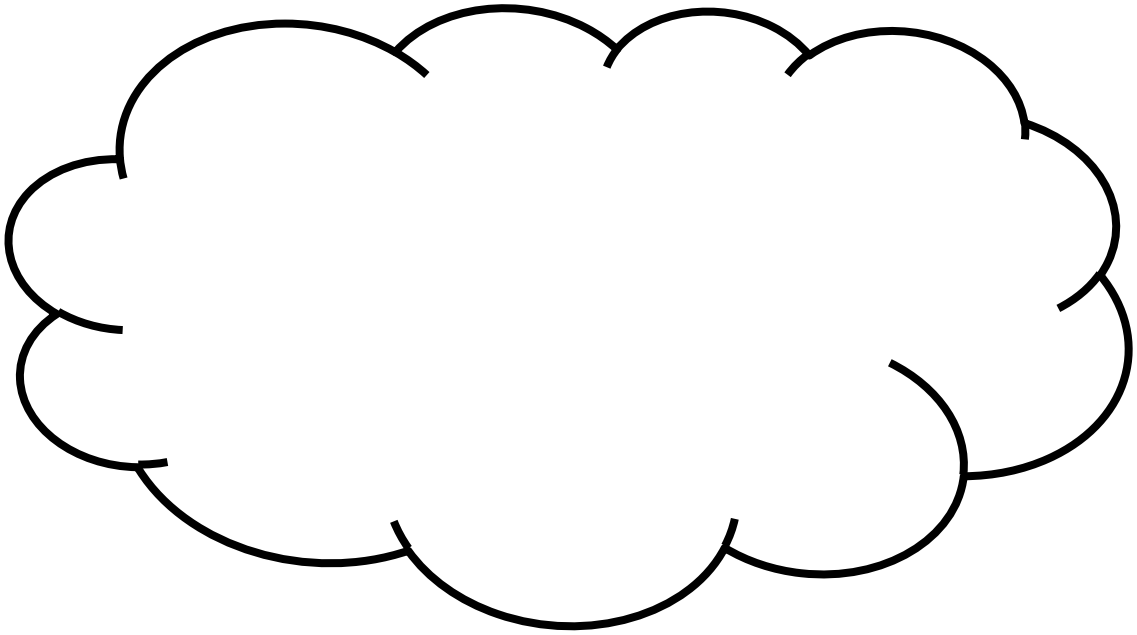
Facilitates an Environment of Open and Honest Communication	Communications	Students work in pairs to complete the Explore & Explain activities. Must have effective communications in order to be successful in activities.	Lesson 1 Rubric – Explain and Explain Categories	Data collection, data analysis, thermal bands, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Learns from Successes and Failures	Technical Acumen	Through all the activities and discussions, students have to be open to both success and failures in order to learn new information.	Lesson 1 Rubric – All Categories	Data collection, data analysis, thermal bands, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
List and attach all supportive documents for instructional activities	Attachments? (circle) Yes or No	List Attached Documents(if any): Lesson 1 Worksheet		
List and attach all rubrics for activity and assessment evaluation	Attachments? (circle) Yes or No	List Attached Rubrics (if any): Lesson 1 Rubric		
Include comments or questions here:				

e. Supporting Documents: (order according to sequence of lesson.)

1. Lesson 1 worksheet

From the Sky to the Ground: Using Satellite Data to understand the Urban Heat Island
Lesson 1 Worksheet

Do Now!
Climate change is a term we've been hearing for a while now and more the past few years. Below, brainstorm all the terms or phrases that come to mind when you hear the term "climate change".



Engage

Watch the video displayed on the board. After watching, turn to a partner and discuss the quote below. Think about what this quote means and how it impacts you. Write down in the space provided what you and your partner discuss.

"The key thing to remember from this report is that it's clear that the best time to have reduced emissions was 25 years ago, but the second best to reduce emissions is right now."

_____

_____

_____

_____

_____

_____

_____

Explore

With a partner, you will use satellite data to find how land surface has changed over a decade. You will then pull land surface temperature data for the same time span and see if there has been a change in land surface temperature for that particular area. Finally, you will compare the land surface changes and land surface temperatures to see if there is a correlation between the changes in both variables. Follow the steps below to complete the activity.

First, designate who will be finding the land surface changes and who will be finding the land surface temperature changes. Once assigned, follow the directions below for your specific topic.

1. Select a city in the US to study.
2. Select a timeframe that spans at least 10 years collecting a total of 10 images. Once the time frame has been selected, make sure there is land surface temperature data for the years you selected.
3. Based on the topic you selected, follow the directions below for how to complete the next part.

Land Surface Changes ***Alternative directions for this activity using EOS Worldview on last page of worksheet*

1. On your desktop, open the Google Earth application.
2. Once opened, in the top left-hand corner, type in the city you and your partner selected, then press search. The map will automatically redirect and zoom into the city you selected.
3. At the top, select View, then click Historical Imagery. This will enable you to look at Google Earth images of the city over time.
4. At the top left, you will see a rectangle with a scroll bar and date range for the city selected. Each city has a different date range based on data Google has in its archives, so double check the date range your team selected. Use the scroll bar to move back in time. When you let go, it will display an aerial image of the city during that year.
5. Move the scroll bar to the earliest year your team has selected.
6. You will now take selected screenshots of the data displayed for each year. Start at your first selected date. In total, you will have 10 images. Depending on the computer you are using follow

the instructions below. After each image you screen shot, save it to a folder on your desktop. You will need all the images to paste into your worksheet.

i. PC Instructions
   1. In the start menu, select the “Snipping Tool”.
   2. Double check you are on your first screen. Then, click “New” in snipping tools. It will give you a + icon. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
   3. A window will then pop up in Snipping Tools showing you what you copied. Right click on the image and click “Save as”. Save the image to a designated folder on the desktop.
   4. Repeat steps 1-3 for every year of the time span you selected.

   Mac Instructions
   1. Double check you are on your first screen. Then press command+shift+4. Your cursor will then turn into a + sign. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
   2. The image captured will save to your desktop automatically.

7. Using the screen shots you just created, you will now divide each image into 9 equal sections. Using either a ruler or Microsoft word, divide each image into 9 equal sections. Paste this image in the “Land Surface Image” column in the table below
8. For each image, you will write down observations of the city in terms of built areas and green space (areas of greenery). Record the observations in the table below in the “Observations of Land Surface” column. Note specific changes by square if applicable. Repeat for each image.

Land Surface Temperature Changes

1. Go to https://worldview.earthdata.nasa.gov/ . If you haven’t been to the site before, it will give you a guided tour of how to use the site (go through this if you haven’t used the site before).
2. On the left side of the screen towards the bottom, click the button that says "+Add Layers”. Click the second tab “Science Disciplines”.
3. Find the category that says “Land Surface” and select the three horizontal dots at the bottom of the category for more options. Find “Land Surface Temperature” and then click the orange arrow next to this option. Then select the box for “Land Surface Temperature (Day)” for Terra/MODIS. This will add the layer of land surface temperature to your map. Then click the X at the top of the pop out box to close the pop out window. You may want to adjust the opacity of the layer so you can see the dimensions of the city when the land surface temperature layer is on. To do this, click the middle icon in the top right hand corner of the Land Surface Temperature layer box. Then, click and drag the circle for Opacity to the desired amount to show about the land surface and land surface temperature. 80% opacity is recommended.
4. In the bottom left hand corner, you will see options to change for different time options. Select “Year”.
5. On the bottom left hand corner, the date currently being shown on the map is displayed. Change the date to the first date you selected. Make sure the month and day stay the same for each year you research. If there is no available data for the exact day, change the day to find the nearest day that has data.
6. Zoom in on the city you selected on the map using the scrolling feature on your mouse or trackpad until you have a zoom of 10 km/5 mi (this is displayed in the lower right part of the screen).
7. You will now take selected screenshots of the data displayed for each year. Start at your first selected date. In total, you will have 10 images. Depending on the computer you are using follow the instructions below. After each image you screen shot, save it to a folder on your desktop. You will need all the images to paste into your worksheet.

   PC Instructions
   1. In the start menu, select the “Snipping Tool”.
   2. Double check you are on your first screen. Then, click “New” in snipping tools. It will give you a + icon. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.

3. A window will then pop up in Snipping Tools showing you what you copied. Right click on the image and click “Save as”. Save the image to a designated folder on the desktop.
4. Repeat steps 1-3 for every year of the time span you selected.

Mac Instructions

1. Double check you are on your first screen. Then press command+shift+4. Your cursor will then turn into a + sign. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
2. The image captured will save to your desktop automatically.

8. Using the screen shots you just created, you will now divide each image into 9 equal sections. Using either a ruler or Microsoft word, divide each image into 9 equal sections. Paste the image into the “Land Surface Temperature Image” column in the table below.
9. For each image, find the temperature of each of the 9 sections. Then, find the average temperature of the image. Record the temperature in the table below in the “Average Temperature of Land Surface” column. Repeat for each image. Make sure your temperatures are in Celsius.

After completing the directions above for your selected topic, you will now discuss with your partner changes in both land surface temperature and the land surface for correlations.

1. Starting with the first year, observe the two images collected. Discuss what you see in each image.
2. In the “Notes” section column in the table, write down any correlations you identify between the land surface temperature image and the land surface image.
3. Repeat steps 1 and 2 for all 10 images.
4. When finished, move on to the *Explain* section to answer questions regarding the information collected in this activity.

Land Surface Changes Table

Year	Land Surface Image	Observations of Land Surface	Land Surface Temperature Image	Average Temperature of Land Surface	Notes

Explain

Part 1

Based on what you found in the *Explore* activity, answer the questions below.

1. Over the years you observed, calculate the overall change in temperature. What was the overall change in temperature? _____ *Make sure you note if it decreased or increased.

2. Over the years you observed, what were the changes in the land surface of the city you selected?
_____
_____
_____
_____

3. Based on the changes in land surface temperature and the changes in the land surface of the selected city, what can you conclude about land surface's correlation with land surface temperature?
_____
_____
_____
_____
_____

4. Turn to another pair and compare your findings. What are the similarities and differences between what your team found and what the other team found in their data collection?
_____
_____
_____
_____
_____

Part 2

Independently, you will now learn about another satellite that collects data about the surface of Earth called Landsat. Follow the directions given below to learn how satellites like the ones used in the *Explore* activity and Landsat collect data.

1. Go to https://www.youtube.com/watch?v=YP0et8l_bvY and watch the video "*NASA: Peeling Back Landsat's Layers of Data".* When finished, answer the questions below in the organizer.

Question	Response	Illustration	Example
How does Landsat create an image?			
How do different combinations enable scientists to gather data on various items of interest (ex: vegetation cover)?			
What are the different wavelengths used with Landsat and what are each of the wavelengths used for?			

2. After answering the questions in the organizer, go to the following website: https://www.usgs.gov/faqs/what-are-best-landsat-spectral-bands-use-my-study?qt-news_science_products=7#qt-news_science_products.

3. After reading through the information page, review the questions in the organizer again and add more information to the organizer. (Hint: this page is particularly helpful for the last question).

4. Once completed, find another student to share discuss what you found in the video and article about Landsat. From your discussion, be sure to add more information to organizer to enhance your understanding of how Landsat is used and how it operates.

Elevate

Part 1: Imagery to understand our neighborhood

Landsat and the images it captures can help scientists understand the surface of our planet in a deeper way. We've seen that Landsat can help us learn about vegetation coverage, changing environments, natural disasters such as flooding, and much more.

But how can you use Landsat data to better understand your neighborhood?

_____
_____
_____
_____
_____
_____

Let's try it out! Given what you stated above, see if you can find out more information using satellite data to better understand your neighborhood. Record your findings below in the space provided below.

Part 2: Why use several satellites for one purpose?

In the Explore and Explain activity, we looked at two satellites: MODIS Terra and Landsat 8. But why are we using two satellites for the same thing? Let's take a look…

1. Let's look at the specifications of each satellite. Go to Landsat 8's Overview page (link below)
   https://www.usgs.gov/land-resources/nli/landsat/landsat-8?qt-science_support_page_related_con=0#qt-science_support_page_related_con
2. Using the provided website, find the Band # (Thermal Infrared band), Spatial Resolution, Frequency of Flyover, and Projected Mission Duration for Landsat 8. In the table below, record the specifications of Landsat 8.
3. Go to MODIS Terra's Specifications page (link below).
   https://modis.gsfc.nasa.gov/about/specifications.php
4. Using the provided website, find the Band # (Surface Temperature band), Spatial Resolution, and Frequency of Flyover for Landsat 8. In the table below, record the specifications of MODIS Terra.

Satellite	**Band #'s (Thermal Infrared or Land Surface Temperature)**	**Spatial Resolution for Band**	**Frequency of Flyover (Repeat Cycle)**
Landsat 8			
MODIS Terra			

5. What are the advantages and disadvantages for using each satellite? Record your responses in the diagram below.

Landsat 8		**MODIS Terra**	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**

6. As you can see by your research, there are advantages and disadvantages to using both Landsat 8 and MODIS Terra. What effect would using one or both of these satellites have on collecting surface temperature data to better understand the Urban Heat Island Effect?

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Evaluate

Based on what your learned in the *Explore, Explain,* and *Elevate* activities, answer the prompt below.

At the beginning of the lesson, we heard from Dr. Gavin Schmidt about how the time for reducing emissions was 25 years ago, but the second-best time is now. How can scientists use Landsat data and changes in data to track climate change and reduce the effects of climate change?

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**Alternative resource, EOS Worldview, for the "Explore" Land Cover activity

Land Surface Changes

1. Go to https://worldview.earthdata.nasa.gov/ . If you haven't been to the site before, it will give you a guided tour of how to use the site (go through this if you haven't used the site before).
2. On the left side of the screen towards the bottom, click the button that says "+Add Layers". Click the second tab "Science Disciplines".
3. Find the category that says "Land Surface" and select the three horizontal dots at the bottom of the category for more options. Find "Land Cover" and then click the orange arrow next to this option. Then select the box for "Land Cover Type (L3, IGBP, Yearly)". This will add the layer of land surface temperature to your map. Then click the X at the top of the pop out box to close the pop out window.
4. In the bottom left hand corner, you will see options to change for different time options. Select "Year".
5. On the bottom left hand corner, the date currently being shown on the map is displayed. Change the date to the first date you selected. Make sure the month and day stay the same for each year you research.
6. Zoom in on the city you selected on the map using the scrolling feature on your mouse or trackpad until you have a zoom of 10 km/5 mi (this is displayed in the lower right part of the screen).
7. You will now take selected screenshots of the data displayed for each year. Start at your first selected date. In total, you will have 10 images. Depending on the computer you are using follow the instructions below. After each image you screen shot, save it to a folder on your desktop. You will need all the images to paste into your worksheet.
    i. PC Instructions
        1. In the start menu, select the "Snipping Tool".
        2. Double check you are on your first screen. Then, click "New" in snipping tools. It will give you a + icon. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
        3. A window will then pop up in Snipping Tools showing you what you copied. Right click on the image and click "Save as". Save the image to a designated folder on the desktop.
        4. Repeat steps 1-3 for every year of the time span you selected.

    Mac Instructions

    3. Double check you are on your first screen. Then press command+shift+4. Your cursor will then turn into a + sign. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
    4. The image captured will save to your desktop automatically.

8. Using the screen shots you just created, you will now divide each image into 9 equal sections. Using either a ruler or Microsoft word, divide each image into 9 equal sections.
9. For each image, you will write down observations of the city in terms of built areas and green space (areas of greenery). Record the observations in the table below. Note specific changes by square if applicable. Repeat for each image.

2. Lesson 1 Worksheet Answer Key

From the Sky to the Ground: Using Satellite Data to understand the Urban Heat Island
Lesson 1 Worksheet

Do Now!
Climate change is a term we've been hearing for a while now and more the past few years. Below, brainstorm all the terms or phrases that come to mind when you hear the term "climate change".

Answers will vary. Examples of responses that may come up:

Warmer temperatures **rising seas**

Intense weather **droughts**

Engage
Watch the video displayed on the board. After watching, turn to a partner and discuss the quote below. Think about what this quote means and how it impacts you. Write down in the space provided what you and your partner discuss.

"The key thing to remember from this report is that it's clear that the best time to have reduced emissions was 25 years ago, but the second best to reduce emissions is right now."

Answers will vary. This question is focused on the impact the video makes on the student. Example response: *"I believe what he is trying to say with the quote is that when we first started seeing the signs of climate change 25 years ago, that was when we should have started pushing for alternative energy sources and tackling the problem of climate change. However, that doesn't*

mean we should not do anything now. We should still try to be active about reducing the effects of climate change today."

Explore

With a partner, you will use satellite data to find how land surface has changed over a decade. You will then pull land surface temperature data for the same time span and see if there has been a change in land surface temperature for that particular area. Finally, you will compare the land surface changes and land surface temperatures to see if there is a correlation between the changes in both variables. Follow the steps below to complete the activity.

First, designate who will be finding the land surface changes and who will be finding the land surface temperature changes. Once assigned, follow the directions below for your specific topic.

1. Select a city in the US to study.
2. Select a timeframe that spans at least 10 years collecting a total of 10 images. Once the time frame has been selected, make sure there is land surface temperature data for the years you selected.
3. Based on the topic you selected, follow the directions below for how to complete the next part.

Land Surface Changes ***Alternative directions for this activity using EOS Worldview on last page of worksheet*

1. On your desktop, open the Google Earth application.
2. Once opened, in the top left-hand corner, type in the city you and your partner selected, then press search. The map will automatically redirect and zoom into the city you selected.
3. At the top, select View, then click Historical Imagery. This will enable you to look at Google Earth images of the city over time.
4. At the top left, you will see a rectangle with a scroll bar and date range for the city selected. Each city has a different date range based on data Google has in its archives, so double check the date range your team selected. Use the scroll bar to move back in time. When you let go, it will display an aerial image of the city during that year.
5. Move the scroll bar to the earliest year your team has selected.
6. You will now take selected screenshots of the data displayed for each year. Start at your first selected date. In total, you will have 10 images. Depending on the computer you are using follow the instructions below. After each image you screen shot, save it to a folder on your desktop. You will need all the images to paste into your worksheet.
   ii. PC Instructions
      1. In the start menu, select the "Snipping Tool".
      2. Double check you are on your first screen. Then, click "New" in snipping tools. It will give you a + icon. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
      3. A window will then pop up in Snipping Tools showing you what you copied. Right click on the image and click "Save as". Save the image to a designated folder on the desktop.
      4. Repeat steps 1-3 for every year of the time span you selected.

   Mac Instructions
   1. Double check you are on your first screen. Then press command+shift+4. Your cursor will then turn into a + sign. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
   2. The image captured will save to your desktop automatically.

7. Using the screen shots you just created, you will now divide each image into 9 equal sections. Using either a ruler or Microsoft word, divide each image into 9 equal sections. Paste this image in the “Land Surface Image” column in the table below.
8. For each image, you will write down observations of the city in terms of built areas and green space (areas of greenery). Record the observations in the table below in the “Observations of Land Surface” column. Note specific changes by square if applicable. Repeat for each image.

Land Surface Temperature Changes

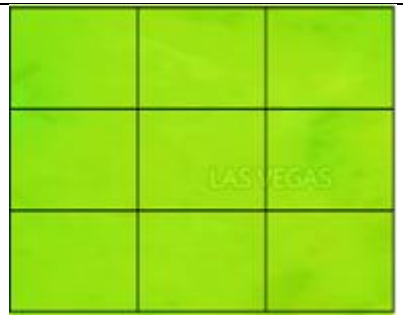
1. Go to https://worldview.earthdata.nasa.gov/ . If you haven’t been to the site before, it will give you a guided tour of how to use the site (go through this if you haven’t used the site before).
2. On the left side of the screen towards the bottom, click the button that says "+Add Layers”. Click the second tab “Science Disciplines”.
3. Find the category that says “Land Surface” and select the three horizontal dots at the bottom of the category for more options. Find “Land Surface Temperature” and then click the orange arrow next to this option. Then select the box for “Land Surface Temperature (Day)” for Terra/MODIS. This will add the layer of land surface temperature to your map. Then click the X at the top of the pop out box to close the pop out window. You may want to adjust the opacity of the layer so you can see the dimensions of the city when the land surface temperature layer is on. To do this, click the middle icon in the top right hand corner of the Land Surface Temperature layer box. Then, click and drag the circle for Opacity to the desired amount to show about the land surface and land surface temperature. 80% opacity is recommended.
4. In the bottom left hand corner, you will see options to change for different time options. Select “Year”.
5. On the bottom left hand corner, the date currently being shown on the map is displayed. Change the date to the first date you selected. Make sure the month and day stay the same for each year you research. If there is no available data for the exact day, change the day to find the nearest day that has data.
6. Zoom in on the city you selected on the map using the scrolling feature on your mouse or trackpad until you have a zoom of 10 km/5 mi (this is displayed in the lower right part of the screen).
7. You will now take selected screenshots of the data displayed for each year. Start at your first selected date. In total, you will have 10 images. Depending on the computer you are using follow the instructions below. After each image you screen shot, save it to a folder on your desktop. You will need all the images to paste into your worksheet.
    . PC Instructions
        1. In the start menu, select the “Snipping Tool”.
        2. Double check you are on your first screen. Then, click “New” in snipping tools. It will give you a + icon. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
        3. A window will then pop up in Snipping Tools showing you what you copied. Right click on the image and click “Save as”. Save the image to a designated folder on the desktop.
        4. Repeat steps 1-3 for every year of the time span you selected.

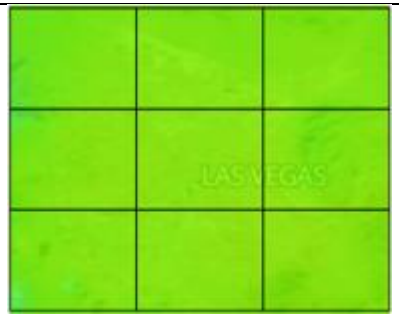
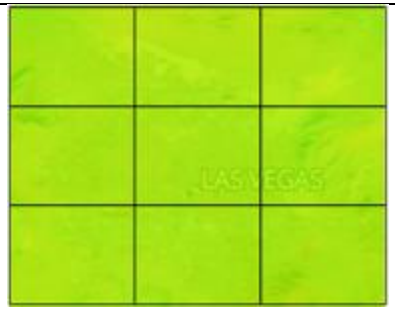
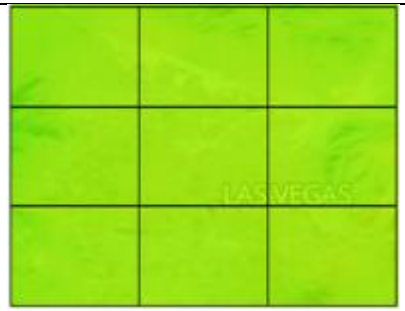
    Mac Instructions
    1. Double check you are on your first screen. Then press command+shift+4. Your cursor will then turn into a + sign. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
    2. The image captured will save to your desktop automatically.
8. Using the screen shots you just created, you will now divide each image into 9 equal sections. Using either a ruler or Microsoft word, divide each image into 9 equal sections. Paste the image into the “Land Surface Temperature Image” column in the table below.
9. For each image, find the temperature of each of the 9 sections. Then, find the average temperature of the image. Record the temperature in the table below in the “Average Temperature of Land Surface” column. Repeat for each image. Make sure your temperatures are in Celsius.

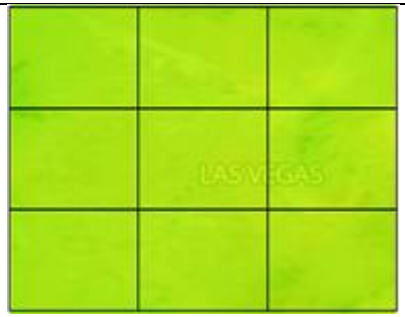
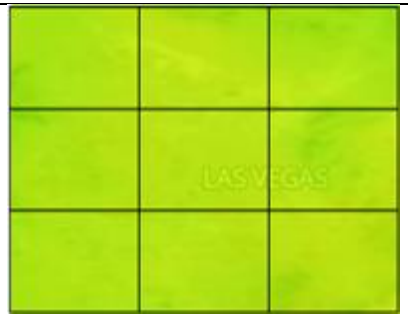
After completing the directions above for your selected topic, you will now discuss with your partner changes in both land surface temperature and the land surface for correlations.

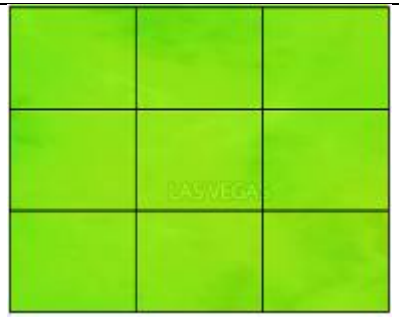
1. Starting with the first year, observe the two images collected. Discuss what you see in each image.
2. In the “Notes” column in the table, write down any correlations you identify between the land surface temperature image and the land surface image.
3. Repeat steps 1 and 2 for all 10 images.
4. When finished, move on to the *Explain* section to answer questions regarding the information collected in this activity.

Land Surface Changes Table **An example of answers are provided in the chart below – City: Las Vegas, NV**

Year	Land Surface Image	Observations of Land Surface	Land Surface Temperature Image	Average Temperature of Land Surface	Notes
2007		Top left: some development at bottom right Top center: development in bottom half Top right: no development Middle left: half developed Middle center: densely built Middle right: small development top left Bottom left: small development top right Bottom center: very developed, left empty Bottom right: scattered developed throughout		283 K = 9.85 C	
2008		Top left: some development at bottom right Top center: development in bottom half Top right: no development Middle left: half developed Middle center: densely built Middle right: small development top left Bottom left: small development top right Bottom center: very developed, left empty Bottom right: scattered developed throughout		285 K = 11.85 C	
2009		Top left: some development at bottom right Top center: development in bottom half Top right: no development Middle left: half developed Middle center: densely built Middle right: small development top left Bottom left: small development top right Bottom center: very developed, left empty Bottom right: scattered developed throughout		286 K = 12.85 C	

2010		Top left: some development at bottom right Top center: development in bottom half Top right: no development Middle left: half developed Middle center: densely built Middle right: small development top left Bottom left: small development top right Bottom center: very developed, left empty Bottom right: scattered developed throughout		280 K = 6.85 C	
2011		Top left: some development at bottom right Top center: development in bottom half Top right: no development Middle left: half developed Middle center: densely built Middle right: small development top left Bottom left: small development top right Bottom center: very developed, left empty Bottom right: scattered developed throughout		285 K = 11.85 C	
2012		Top left: development at bottom right Top center: more development in bottom half Top right: no development Middle left: half developed Middle center: densely built Middle right: small development top left Bottom left: small development top right Bottom center: very developed, some empty spots Bottom right: more developed throughout		284 K = 10.85 C	

2013		Top left: development at bottom right Top center: more development in bottom half Top right: no development Middle left: half developed Middle center: densely built Middle right: small development top left Bottom left: small development top right Bottom center: very developed, some empty spots Bottom right: more developed throughout		288 K = 14.85 C	
2014		Top left: development at bottom right Top center: more development in bottom half Top right: no development Middle left: half developed Middle center: densely built Middle right: small development top left Bottom left: small development top right Bottom center: very developed, some empty spots Bottom right: more developed throughout		290 K = 16.85 C	
2015		Top left: development at bottom right Top center: more development in bottom half Top right: no development Middle left: half developed Middle center: densely built Middle right: small development top left Bottom left: small development top right Bottom center: very developed, some empty spots Bottom right: more developed throughout		284 K = 10.85 C	

2016		Top left: development at bottom right Top center: more development in bottom half Top right: no development Middle left: half developed Middle center: densely built Middle right: small development top left Bottom left: small development top right Bottom center: very developed, some empty spots Bottom right: more developed throughout		283 K = 9.85 C	

Explain

Part 1

Based on what you found in the *Explore* activity, answer the questions below.

1. Over the years you observed, calculate the overall change in temperature. What was the overall change in temperature? **Answers will vary depending on the city. Example: Temperature increased: +3.5 degrees** *Make sure you note if it decreased or increased.

2. Over the years you observed, what were the changes in the land surface of the city you selected?
   Answers will vary depending on the selected city. Example response: Over the years, Las Vegas developed a bit more around the fringes of the city as it was already a very densely built city at the start of the study.

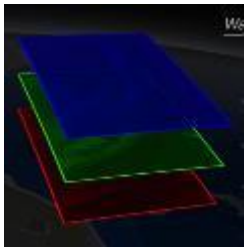
3. Based on the changes in land surface temperature and the changes in the land surface of the selected city, what can you conclude about land surface's correlation with land surface temperature?
   As land surface becomes more developed (more buildings/concrete), the land surface temperature increases.

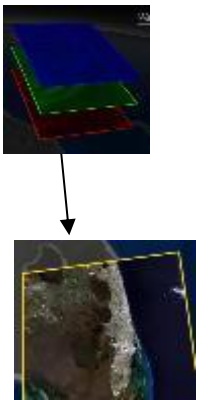
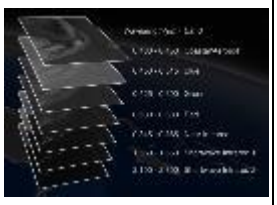
4. Turn to another pair and compare your findings. What are the similarities and differences between what your team found and what the other team found in their data collection?
   Answers will vary depending on the cities selected by each group. Example response: In our teams study, there was very little change in land surface and therefore no overall change in land surface temperature. However, the group we met with had a city where there was major land development and land surface change which led to an increase in overall land surface temperature.

Part 2

Independently, you will now learn about another satellite that collects data about the surface of Earth called Landsat. Follow the directions given below to learn how satellites like the ones used in the *Explore* activity and Landsat collect data.

1. Go to https://www.youtube.com/watch?v=YP0et8l_bvY and watch the video "*NASA: Peeling Back Landsat's Layers of Data".* When finished, answer the questions below in the organizer.

Question	Response	Illustration	Example
How does Landsat create an image?	**The Landsat satellite uses several bands (wavelengths) to create an image. It can combine any three bands to create different depictions of Earth's surface.**	*These can be pictures or actual drawings, drawings are preferred* 	**Combine red, blue, and green bands to create a "natural-color image"**

How do different combinations enable scientists to gather data on various items of interest (ex: vegetation cover)?	**Scientists can combine different bands to create "false-color images" that allow them to see what we can't with the naked eye such as infrared radiation.**		**The combination of the bands green, red, and near infrared allows scientists to see infrared being reflected by surfaces.**
What are the different wavelengths used with Landsat and what are each of the wavelengths used for?	**The ones listed in the video are: 0.433-0.453 Coastal/Aerosol 0.45-0.515 Blue 0.525-0.500 Green 0.630-0.680 Red 0.845-0.885 Near Infrared 1.560-1.660 Shortwave Infrared 1 2.100-2.300 Shortwave Infrared 2 0.50-0.68 Panchromatic 1.36-1.38 Cirrus 10.60-11.19 TIRS 1 11.50-12.51 TIRS 2**		**Answers may vary. Example: 11.50-12.51: 100 meter resolution, improved thermal mapping and estimated soil moisture**

2. After answering the questions in the organizer, go to the following website: https://www.usgs.gov/faqs/what-are-best-landsat-spectral-bands-use-my-study?qt-news_science_products=7#qt-news_science_products.

3. After reading through the information page, review the questions in the organizer again and add more information to the organizer. (Hint: this page is particularly helpful for the last question).

4. Once completed, find another student to share discuss what you found in the video and article about Landsat. From your discussion, be sure to add more information to organizer to enhance your understanding of how Landsat is used and how it operates.

Elevate

Part 1: Imagery to understand our neighborhood

Landsat and the images it captures can help scientists understand the surface of our planet in a deeper way. We've seen that Landsat can help us learn about vegetation coverage, changing environments, natural disasters such as flooding, and much more.

But how can you use Landsat data to better understand your neighborhood?
Answers will vary. Example response: We can use Landsat to see the surface temperature of an area and how it has changed over time.

Let's try it out! Given what you stated above, see if you can find out more information using satellite data to better understand your neighborhood. Record your findings below in the space provided below.
Answers will vary. Example response: With Landsat 8, different band combinations allow us to see different aspects of the land cover. If we combine the blue, red, and green satellite bands we can get a "natural color image" of the area. If we combine green, near infrared, and shortwave infrared 2, we can see more of the greenery (trees, shrubs, marshes), which can help us understand the vegetation coverage of an area that we may not see with the natural color image.

Part 2: Why use several satellites for one purpose?

In the Explore and Explain activity, we looked at two satellites: MODIS Terra and Landsat 8. But why are we using two satellites for the same thing? Let's take a look…

1. Let's look at the specifications of each satellite. Go to Landsat 8's Overview page (link below)
   https://www.usgs.gov/land-resources/nli/landsat/landsat-8?qt-science_support_page_related_con=0#qt-science_support_page_related_con
2. Using the provided website, find the Band # (Thermal Infrared band), Spatial Resolution, and Frequency of Flyover for Landsat 8. In the table below, record the specifications of Landsat 8.
3. Go to MODIS Terra's Specifications page (link below).
   https://modis.gsfc.nasa.gov/about/specifications.php
4. Using the provided website, find the Band # (Surface Temperature band), Spatial Resolution, Frequency of Flyover, and Projected Mission Duration for Landsat 8. In the table below, record the specifications of MODIS Terra.

Satellite	Band #'s (Thermal Infrared or Land Surface Temperature)	Spatial Resolution for Band	Frequency of Flyover (Repeat Cycle)
Landsat 8	**Band 5 Near-Infrared (0.85 - 0.88 µm)**	**30m**	**Once every 16 days**
MODIS Terra	**20-23; 31-32**	**1000m**	**Twice per day**

5. What are the advantages and disadvantages for using each satellite? Record your responses in the diagram below. **Responses will vary. Examples of responses are below.**

Landsat 8		MODIS Terra	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
30 m resolution	**Flyover is only once every 16 days**	**Flyover is twice per day**	**1000m resolution**

6. As you can see by your research, there are advantages and disadvantages to using both Landsat 8 and MODIS Terra. What effect would using one or both of these satellites have on collecting surface temperature data to better understand the Urban Heat Island Effect?
The use of both satellites can help scientists gather more images in a time span, but the image will vary in resolution. Landsat 8 provides high quality images of 30m resolution, but only flies over every 16 days. In between the 16 days, MODIS Terra can provide images twice a day, but the resolution will be much lower than the Landsat 8 images. By using both satellites, we can collect more data and are able to use the data to observe patterns/trends in the urban heat island effect.

Evaluate

Based on what your learned in the *Explore, Explain,* and *Elevate* activities, answer the prompt below.

At the beginning of the lesson, we heard from Dr. Gavin Schmidt about how the time for reducing emissions was 25 years ago, but the second-best time is now. How can scientists use Landsat data and changes in data to track climate change and reduce the effects of climate change?

Answers will vary. Example response: Landsat data provides high quality images of land surface and land surface temperatures over a series of time. The images over a set of time can help scientists identify patterns, trends, and changes in land surface and land surface temperature. For example, if an urban area has drastically developed over the past ten years, the satellite data can show the expansion/development in the area and we can measure the change in land surface temperature with the satellite data. We can use this data to support the need for reducing the urban heat island effect, define the causes of the effect, and therefore support the need for change to urban areas to reduce the effects of climate change.

2. PBS News Hour Interview

https://www.giss.nasa.gov/research/features/201810_unreport/

Research Features

The New UN Climate Report in One Sentence

By Adam Voiland, NASA Earth Observatory — Oct. 19, 2018

In October 2018, the Intergovernmental Panel on Climate Change (IPCC) released yet another sobering report about the planetary disruption happening because of all the carbon human activity puts into the atmosphere.

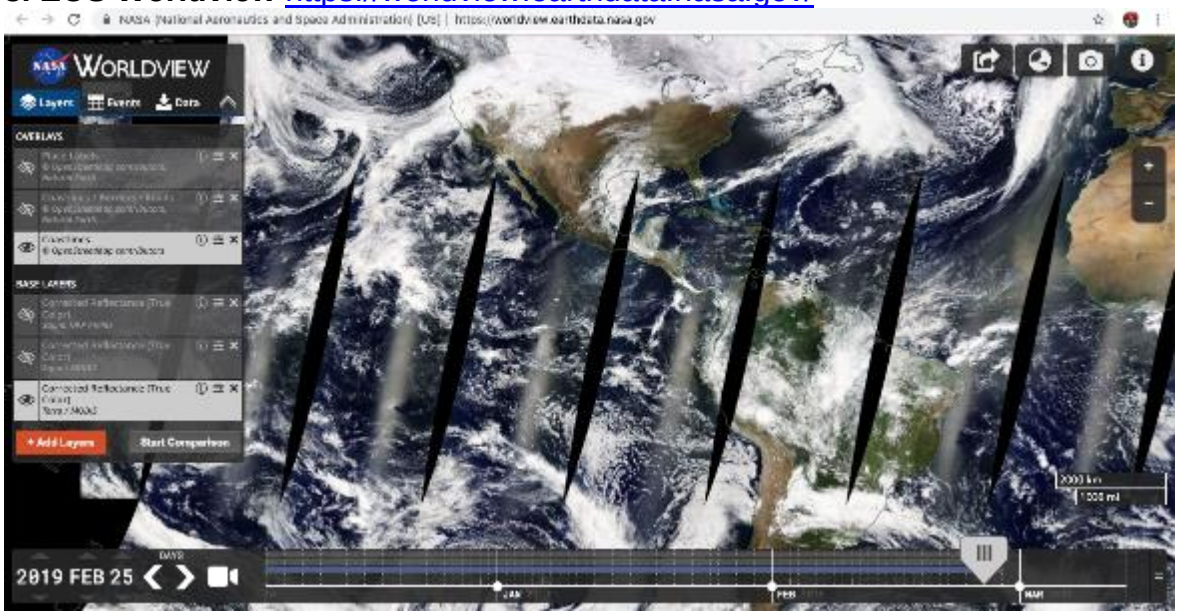
PBS NewsHour
@NewsHour

"The key thing to remember from this report is that it's clear that the best time to have reduced emissions was 25 years ago," @ClimateofGavin of @NASAGoddard/@GISS tells @WmBrangham. "But the second best to reduce emissions is right now."

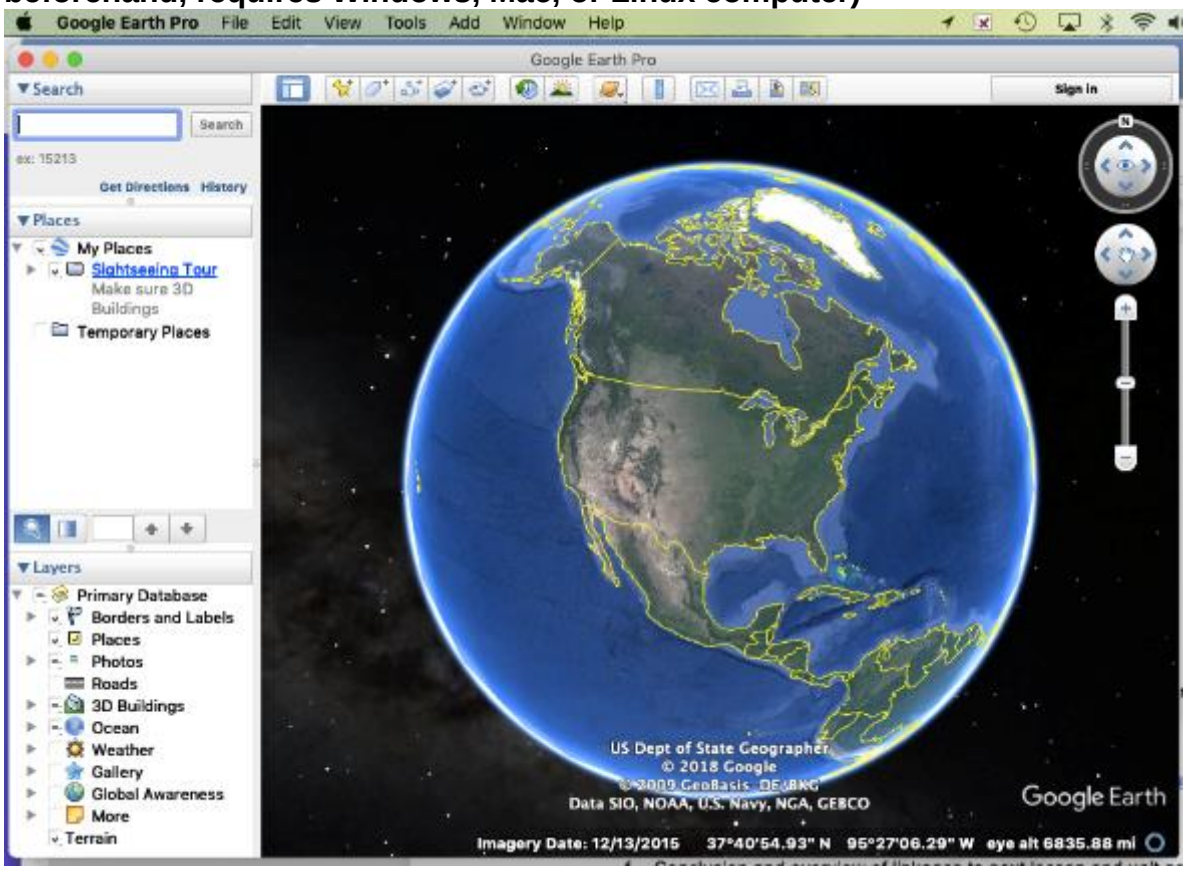
288 5:39 PM - Oct 8, 2018

235 people are talking about this

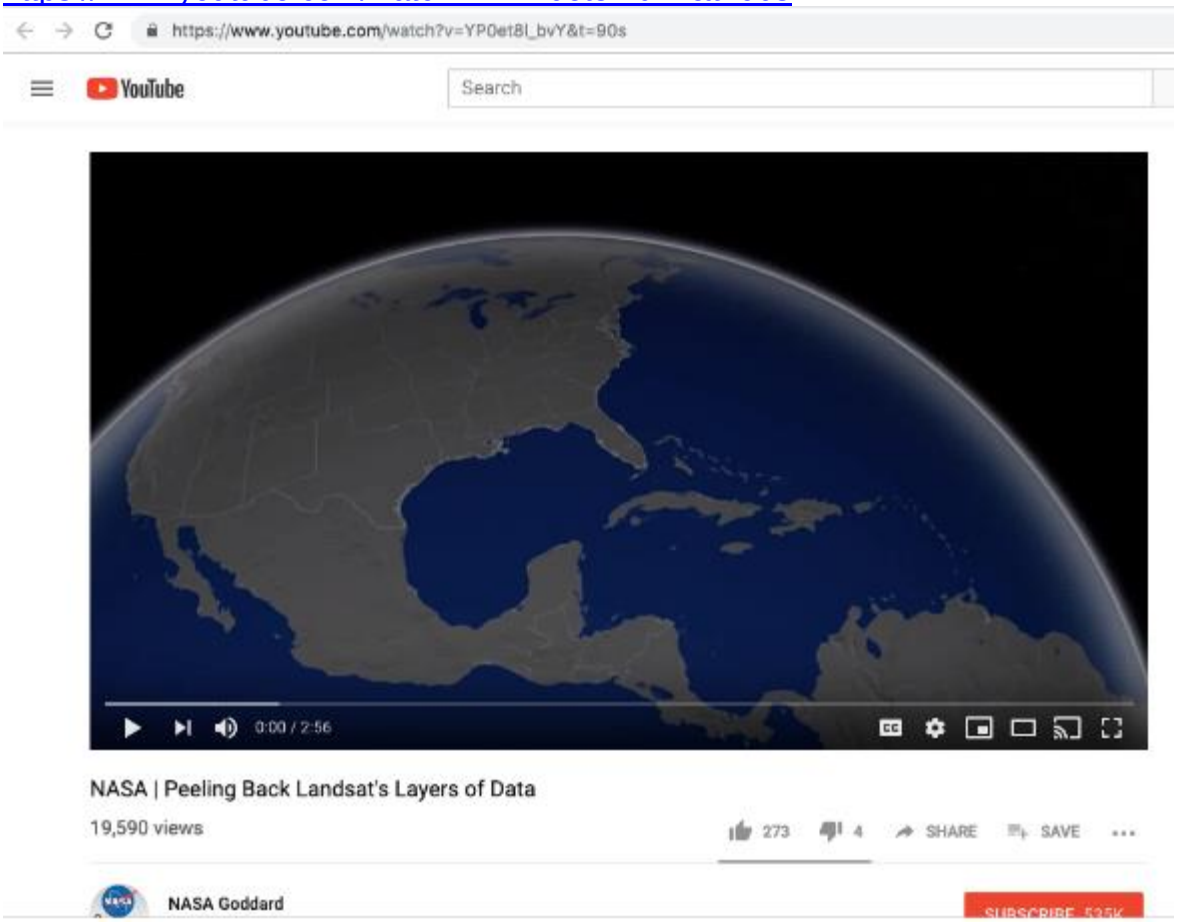
3. EOS Worldview https://worldview.earthdata.nasa.gov/



4. Google Earth Desktop Application (downloaded onto computers beforehand, requires Windows, Mac, or Linux computer)



5. NASA Peeling back Landsat's Layers of Data video
https://www.youtube.com/watch?v=YP0et8l_bvY&t=90s



6. What are the best Landsat spectral bands to use for my study? Article
https://www.usgs.gov/faqs/what-are-best-landsat-spectral-bands-use-my-study?qt-news_science_products=7#qt-news_science_products

https://www.usgs.gov/faqs/what-are-best-landsat-spectral-bands-use-my-study?qt-news_science_products=7#qt-news_science_products

USGS science for a changing world

SCIENCE PRODUCTS NEWS CONNECT ABOUT Search

Mapping, Remote Sensing, and Geospatial Data

What are the best Landsat spectral bands to use for my study?

This is a common question considered by all users of remotely sensed data. The level of detail (spatial resolution) is often the most interesting aspect of viewing a satellite image, but less appreciated is how changes in irradiative energy reflected by different surface materials are used to identify features of interest.

The Spectral Characteristics Viewer is an interactive tool developed by scientists at the USGS Earth Resources Observation and Science (EROS) Center to visualize how the bands, or channels, of different satellite sensors measure the intensity of the many wavelengths (colors) of light. This is also known as the relative spectral response (RSR). By overlaying the spectral curves from different features (spectra), one can determine which bands of the selected sensor will work for the application.

Explore More
remote sensing
land surface
land use and lan
land use change
Mapping, Remote
Geospatial Data

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

Band	Wavelength	Useful for mapping
Band 1 – coastal aerosol	0.43-0.45	coastal and aerosol studies
Band 2 – blue	0.45-0.51	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
Band 3 - green	0.53-0.59	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 4 - red	0.64-0.67	Discriminates vegetation slopes
Band 5 - Near Infrared (NIR)	085.-0.88	Emphasizes biomass content and shorelines
Band 6 - Short-wave Infrared (SWIR) 1	1.57-1.65	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 7 - Short-wave Infrared (SWIR) 2	2.11-2.29	Improved moisture content of soil and vegetation and thin cloud penetration
Band 8 - Panchromatic	.50-.68	15 meter resolution, sharper image definition
Band 9 – Cirrus	1.36 -1.38	Improved detection of cirrus cloud contamination
Band 10 – TIRS 1	10.60 – 11.19	100 meter resolution, thermal mapping and estimated soil moisture
Band 11 – TIRS 2	11.5-12.51	100 meter resolution, Improved thermal mapping and estimated soil moisture

gov/media/images/landsat-8-oli-and-tirs-and-their-uses

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), Band wavelengths and band uses (Public domain)

7. MODIS Terra Specifications Overview
https://modis.gsfc.nasa.gov/about/specifications.php

8. Lesson 1 Rubric

	Struggling	Approaching	At Level	Advanced
Engage *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* *11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)* *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.*	The student may/may not have an effective discussion with a partner student in which they focus on discussing the given quote. The student is able to somewhat effectively communicate through writing how the quote impacts them. The student does not use an example from their discussion to support their explanation of what the quote means to them.	The student has an effective discussion with a partner student in which they focus on discussing the given quote. The student is able to effectively communicate through writing how the quote impacts them. The student does not use an example from their discussion to support their explanation of what the quote means to them.	The student has an effective discussion with a partner student in which they focus on discussing the given quote. The student is able to effectively communicate through writing how the quote impacts them. The student uses an example from their discussion to support their explanation of what the quote means to them.	The student has an effective discussion with a partner student in which they focus on discussing the given quote. The student is able to effectively communicate through writing how the quote impacts them. The student uses an example from their discussion to support their explanation of what the quote means to them. The student also uses an example from their personal life to explain their response.
Explore *(HS-PS4-2),(HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.* *(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.*	The student has some difficulty with extracting and analyzing the data according to the directions. The student is able to capture most of the 10 images of the city they selected over a period of time for both land surface and land surface temperature and display the images in the	The student is able to extract and analyze the data according to the directions. The student is able to capture 10 images of the city they selected over a period of time for both land surface and land surface temperature and display the images in the provided organizer. The images are of just the	The student is able to extract and analyze the data according to the directions. The student is able to capture 10 images of the city they selected over a period of time for both land surface and land surface temperature and display the images in the provided organizer. The images are of just the city (no extra	The student is able to extract and analyze the data according to the directions. The student is able to capture 10 images of the city they selected over a period of time for both land surface and land surface temperature and display the images in the provided organizer. The images are of just the

(HSPS4-6) Mathematical representations can be used to identify certain patterns. *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* *CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.* *CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.*	provided organizer. The images are of just the city, but may have extra material in the images. The student has some difficulty in being able to divide each image into 9 equal sections, determining the ratio of built areas versus green space (but their ratio may be off by a little), and/or determining the average temperature of each image (calculations may be off). The student has some trouble communicating their observations in the provided space in the organizer by noting specific changes by square for most images. The student may not be able to correlate that land surface changes in urban areas, and/or may/may not express that it has an effect on land surface temperature.	city, but may have extra material in the images. The student is able to divide each image into 9 equal sections, determine the ratio of built areas versus green space (but their ratio may be off by a little), and determine the average temperature of each image (calculations may be off by a little). The student effectively communicates their observations in the provided space in the organizer by noting specific changes by square for most images. The student is able to correlate that land surface changes in urban areas, but may/may not express that it has an effect on land surface temperature.	material). The student is able to divide each image into 9 equal sections, determine the ratio of built areas versus green space, and determine the average temperature of each image. The student effectively communicates their observations in the provided space in the organizer by noting specific changes by square for each image. The student is able to correlate that land surface changes affect land surface temperature.	city (no extra material). The student is able to divide each image into 9 equal sections, determine the ratio of built areas versus green space, and determine the average temperature of each image. The student effectively communicates their observations in the provided space in the organizer by noting specific changes by square for each image. The student is able to correlate that land surface changes affect land surface temperature. The student uses the data they collected to explain the correlation.
Explain *(HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).*	The student is not able to calculate the overall temperature change of the images they collected in the previous activity. The student is somewhat able to communicate the	The student is able to calculate the overall temperature change of the images they collected in the previous activity but the answer may be slightly off. The student is	The student is able to calculate the overall temperature change of the images they collected in the previous activity. The student is able to effectively communicate	The student is able to calculate the overall temperature change of the images they collected in the previous activity. The student is able to effectively communicate

1-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4) *(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.*	changes in land surface over the selected time period and how it correlates to the land surface temperature changes. The student has an effective discussion with other classmates comparing similarities/differences between their data collections. Student is able to somewhat work independently to complete part 2 of the explain activity. The student is able answer each question and includes but may not include an illustration and an example to support their response. The student somewhat communicates with another student their responses but may not add more information to their organizer based on the discussion.	mostly able to effectively communicate the changes in land surface over the selected time period and how it correlates to the land surface temperature changes. The student has an effective discussion with other classmates comparing similarities/differences between their data collections. Student is able to mostly work independently to complete part 2 of the explain activity. The student is able answer each question but may not include an illustration or example to support their response. The student effectively communicates with another student their responses and adds more information to their organizer based on the discussion.	the changes in land surface over the selected time period and how it correlates to the land surface temperature changes. The student has an effective discussion with other classmates comparing similarities/differences between their data collections. The student is able to work independently to complete part 2 of the explain activity. The student is able answer each question and includes both an illustration and example to support their response. The student effectively communicates with another student their responses and adds more information to their organizer based on the discussion.	the changes in land surface over the selected time period and how it correlates to the land surface temperature changes. The student provides an example using the data from the previous activity to support their answer. The student has an effective discussion with other classmates comparing similarities/differences between their data collections. The student is able to work independently to complete part 2 of the explain activity. The student is able answer each question and includes both an illustration and multiple examples to support their response. The student effectively communicates with another student their responses and adds more information to their organizer based on the discussion.
Elevate	The student is somewhat able to explain how they	The student is able to effectively explain how	The student is able to effectively explain how	The student is able to effectively explain how

(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. *(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.* *CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.* *CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.*	can use Landsat 8 to better understand their neighborhood. The student does not use an example from either the previous activities or from the articles they read to support their answer. The student is able to identify some of the specifications for both Landsat 8 and MODIS Terra. The student provides at least 1 advantage and disadvantage for either of the satellites that are correct. The student is able to construct a somewhat accurate explanation that describes how scientists can use both satellites to better understand the urban heat island effect, but does not provide examples to support their explanation.	they can use Landsat 8 to better understand their neighborhood. The student may use an example from either the previous activities or from the articles they read to support their answer. The student is able to identify most of the specifications for both Landsat 8 and MODIS Terra. The student provides at least 1 advantage and disadvantage for the satellites that are correct. The student is able to construct an accurate explanation that describes how scientists can use both satellites to better understand the urban heat island effect but may not provide examples to support their explanation.	they can use Landsat 8 to better understand their neighborhood. The student uses an example from either the previous activities or from the articles they read to support their answer. The student is able to identify all specifications for both Landsat 8 and MODIS Terra. The student provides at least 2 advantages and disadvantages for the satellites that are correct. The student is able to construct an accurate explanation that describes how scientists can use both satellites to better understand the urban heat island effect. The student provides at least 1 example to support their reasoning.	they can use Landsat 8 to better understand their neighborhood. The student uses an example from both the previous activities or from the articles they read to support their answer. The student is able to identify all specifications for both Landsat 8 and MODIS Terra. The student provides at least 2 advantages and disadvantages for the satellites that are correct. The student is able to construct an accurate explanation that describes how scientists can use both satellites to better understand the urban heat island effect. The student provides at least 2 examples to support their reasoning.
Evaluate *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* *11-12.RST.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video,*	The student is able to mostly describe how scientists can use Landsat data to track climate change. The students does not use examples from the three activities: the explore, explain, or the elevate	The student is able to mostly describe how scientists can use Landsat data to track climate change. The students use examples from 1 of the three activities: the explore, explain, or the elevate	The student is able to effectively describe how scientists can use Landsat data to track climate change. The students use examples from 2 of the three activities: the explore, explain, or the	The student is able to effectively describe how scientists can use Landsat data to track climate change. The students uses examples from all the activities: the explore, explain, and the

multimedia) in order to address a question or solve a problem. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4) *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.*	activities to support their response.	activities to support their response.	elevate activities to support their response.	elevate activities to support their response.

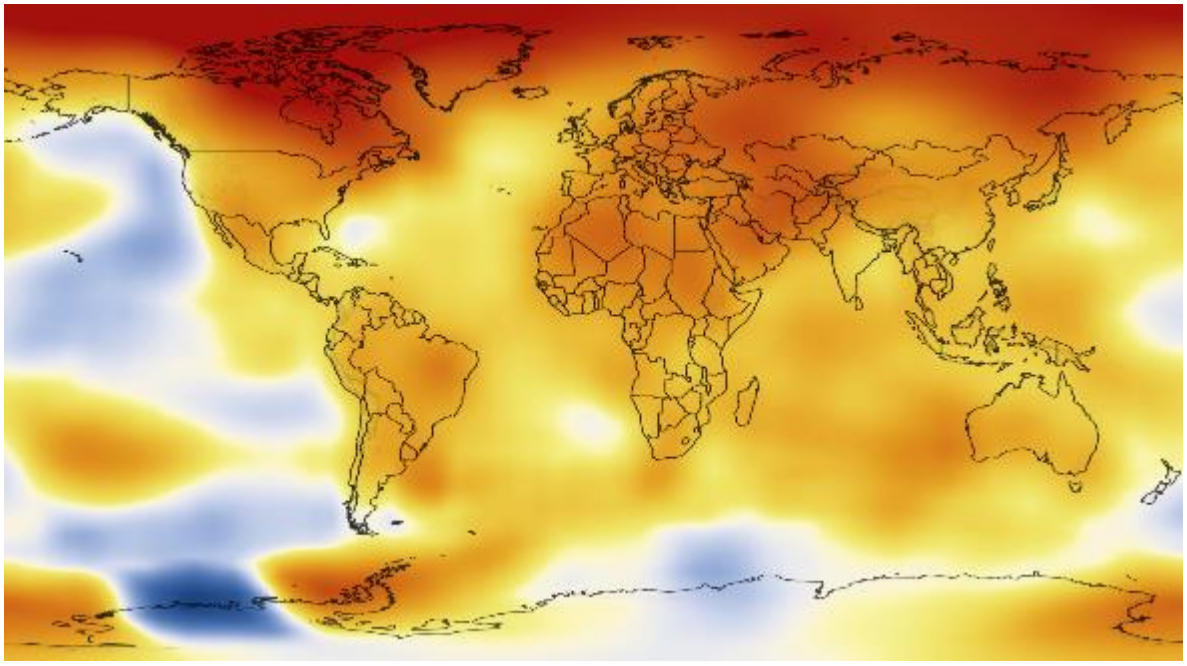
f. Conclusion and overview of linkages to next lesson and unit goals.
In this lesson, students learned about how satellites collect data and how scientists interpret the data to understand phenomena such as the urban heat island. The next lesson focuses on utilizing ground-based data to verify the satellite data in a process called “ground truthing”. With the knowledge gained in this lesson, students will be able to use satellite data efficiently in the next lesson to help understand how we verify the satellite data.

NASA Goddard Institute for Space Studies (GISS)
Climate Change Research Initiative (CCRI)
Applied Research STEM Curriculum Unit Portfolio

Unit Title: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

Lesson Title: The Truth of the Matter: How & Why We Ground Truth Satellite Data

NASA STEM Educator / Associate Researcher: Elizabeth Sebastian
NASA PI / Mentor: Dr. Stuart Gaffin, Dr. Reginald Blake & Dr. Hamidreza Norouzi
NASA GSFC Office of Education – Code 160



X. Lesson 2: The Truth of the Matter: How & Why We Ground Truth Satellite Data

a. Summary and Goals of Lesson

In the second lesson of the unit, students will learn how to "ground truth" satellite data. This is a novel approach to understanding the Urban Heat Island effect that was developed and tested in the summer of 2019. The lesson starts out with students reflecting on how accurate they think satellite data is based on the previous lesson. Students will then view a demonstration of measuring a surface temperature from different distances to put into perspective the scales of data retrieval (satellite vs. ground measurements). Students will first learn how to calibrate the handheld thermal cameras to make sure their instruments are precise before taking measurements. Students will then venture outside to practice the method of "ground truthing" by using thermal cameras to collect surface temperatures and then compare it to satellite data and weather station data collected for the same area. Students will then learn more about this method of "ground truthing" by viewing a video from NASA GSFC about ground validation. After, students will continue learning about how scientists validate data by reviewing instrument specifications, applying atmospheric corrections, and collecting data from all sources for the same date and time. The lesson wraps up with students reflecting back to the opening question of how valid is satellite data. The goals of the lesson are for students to understand the concept and importance of ground validation and how the practice of validation is completed.

b. Table of Contents for lesson

a. Summary and Goals of Lesson……69
b. Table of Contents for Lesson……69
c. 5 E Lesson Model Template……...70
d. Content Template……..81
e. Supporting Documents……...84
f. Conclusion and Linkages to Next Lesson & Unit Goals……..119

**Some of the resources in this lesson may require either a Windows, Mac, or Linux computer in order to run properly.*

c. 5 E lesson model template:

Unit: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

Topic: How & Why we Ground Truth Satellite Data

Prior Learning: Students will have an understanding of how to extract satellite data and interpret satellite data from the previous lesson. Students should also have a familiarity with how to use mobile thermal cameras. Students must have an understanding of thermal absorption of land surfaces (energy budget).

Do Now (Pre-Assessment): Students will answer the following prompt: "In the previous lesson we learned about satellites, how they gather data, and how we can utilize satellite data for scientific research. In your opinion, how accurate do you think data is that is retrieved from satellites? Explain your thoughts."

Aim: How does ground validation methods help to verify the data collected by satellites?

New York State Standards (Aligned to Next Generation Science Standards):

- (HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
- (HS-PS4-2),(HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- (HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).
- (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- (HSPS4-6) Mathematical representations can be used to identify certain patterns.
- (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)

Common Core State Standards:

- CCSS.MATH.CONTENT.HSN.Q.A.2
  Define appropriate quantities for the purpose of descriptive modeling.
- CCSS.MATH.CONTENT.HSN.Q.A.3
  Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- CCSS.ELA-LITERACY.W.9-10.9
  Draw evidence from literary or informational texts to support analysis, reflection, and research.

NASA System of Engineering Behavior:

- *Leadership*
  - Understands the Human Dynamics of a Team
- *Attitudes & Attributes*
  - Seeks Information and Uses the Art of Questioning
- *Systems Thinking*
  - Assimilates, Analyzes, and Synthesizes Data
  - Has the Ability to Find Connections and Patterns Across the System
- *Communications*
  - Communicates Effectively Through Personal Interaction
  - Facilitates an Environment of Open and Honest Communication
- *Technical Acumen*
  - Possesses Technical Competence and Has Comprehensive Previous Experience

Performance Objective: Students will be able to ground validate satellite data in order to understand the verification process of data collection to utilize for research purposes.

Materials:

- Lesson 2 Worksheet
- Lesson 2 Worksheet Answer Key
- Computer
- Thermal Camera
- GLOBE Account for each student (if completing this portion of Explore activity)
- EOS Worldview https://worldview.earthdata.nasa.gov
- NASA Scientific Visualization Studio video "Remote Sensing: Observing the Earth" https://svs.gsfc.nasa.gov/2674
- Thermometer
- Cup (solid color)
- Atmospheric Corrections - University of Bonn website http://fis.uni-bonn.de/en/recherchetools/infobox/professionals/preprocessing/atmospheric-correction

Vocabulary: Ground Truthing

Development of Lesson: Two Day Lessons (Approximately two 50-minute periods).

What the Teacher does	What the Student does	Time
Do Now! (Anticipatory Opening) As the students are coming into class and setting up, direct the student to complete the *Do Now!* Section of the worksheet. Students will reflect on the previous lesson what they learned about satellites, how they gather data, and how we can utilize satellite data for scientific research to determine how accurate satellite data is.	Students will complete the Do Now! Section of the worksheet. Students will reflect on the previous lesson what they learned about satellites, how they gather data, and how we can utilize satellite data for scientific research to determine how accurate satellite data is.	5 minutes

Engage Direct students' attention to the engage section of the worksheet. Have students silently read the prompt. Explain aloud to students that "remote sensing is a great tool to help scientists understand our planet. What we are going to do now is demonstrate taking measurements both near an object (ground observations) and far from an object (remote sensing). Ask for 2 student volunteers to help with the demonstration. After selecting 2 volunteers, have 1 student hold either a thermal camera or air temperature probe at a designated spot (example: in front of a heater/ac unit). Have the second student stand with a thermal camera or air temperature probe 20 feet away from the designated spot. Before reading the temperatures from each spot, have students write down their prediction in the space provided in the Engage section of the worksheet on whether or not the temperature readings will be the same at 1 foot from the designated spot (student 1's probe) versus 20 feet away from the designated spot (student 2's probe). After 1 minute, take a poll on the board of their predictions (yes it will be the same or no it will not). This can be done with simply hand raising or you can use a polling site/app. Then have the student volunteers take the temperature and share aloud with the class the temperature. Students will record the temperatures in the space provided in the Engage section of the worksheet. After writing down the temperatures, have students draw a diagram of the experimental set up in the space provided in the Engage section of the worksheet. After 1-2 minutes, have students turn and share their original predictions and discuss why their predictions were correct/incorrect. After 1-minute, direct students to the last question in the section which reflects back to the Do Now! Question. Give students 1-2 minutes to answer the question and then have a few students volunteer to share their responses aloud to the class. Example responses can be found in the Worksheet Answer Key. Record the responses on the board in order to revisit at the end of the lesson.	**Engage** After the opening question, students will read the prompt in the Engage section of the worksheet. After reading, the teacher will ask for 2 student volunteers to ask for help with a demonstration. Before the student volunteers read the temperatures from each spot, students will observe the set-up of the demonstration and write down their prediction in the space provided in the Engage section of the worksheet on whether or not the temperature readings will be the same at 1 foot from the designated spot (student 1's probe) versus 20 feet away from the designated spot (student 2's probe). After 1 minute, students will partake in a poll on the board of their predictions (yes it will be the same or no it will not). This can be done with simply hand raising or you can use a polling site/app. The student volunteers will then take the temperature and share aloud with the class the temperatures. Students will record the temperatures in the space provided in the Engage section of the worksheet. After writing down the temperatures, students will draw a diagram of the experimental set up in the space provided in the Engage section of the worksheet. After 1-2 minutes, students will turn and share their original predictions and discuss why their predictions were correct/incorrect. After 1 minute, students will then answer the last question in the section which reflects back to the Do Now! Question. After 1-2 minutes, students can volunteer to share their responses aloud to the class.	5-8 minutes

Assessment Opportunity #1 (Use Worksheet Answer Key & Engage section of rubric to assess).		
Explore In the Explore activity, students will practice "ground truthing" satellite data. Prior to this activity and lesson, the teacher will need to determine when the satellite will pass over their location using the following link: https://scool.larc.nasa.gov/GLOBE/globe_overpass-en.html After determining flyover dates/times, select 3 dates for 3 data collections and perform this activity on the date of the flyovers and preferably at the same time frame as the flyover. Also prior to this lesson, you will need to set up a GLOBE account, field site, and student accounts. *Using GLOBE is recommended for this activity but is not required. If you would like to omit the GLOBE part of the activity, ignore/delete the part of the activity that refers to GLOBE. Please explore this link for more information, including a demonstration video: http://www.globe.gov/get-trained/using-the-globe-website/creating-student-accounts After completing the Engage activity, direct student's attention to the Explore section of the worksheet. Inform students that they will be working with a partner (preferably the same partner from the previous lesson) to complete a process called "ground truthing". The teacher should read aloud the opening prompt in the Explore section. After going through the opening prompt, have students meet up with their partner to read through the Thermal Imaging Preparation section. While students are reading through the directions, make sure all materials needed for the experiment are available for each group. After the time allotted, check with students to see if they have any questions about how to do the Thermal Calibration. Allow students 5-10 minutes to calibrate the thermal cameras. Once finished move on to Part 1. Have students read Part 1's instructions prior to going outside. Allow 3-5 minutes for students to read through the instructions thoroughly. After the time allotted, check with students to see if they have any questions about how to do Part 1. After confirming understanding of the directions, take students outside to the pre-determined study site. Students will then follow the instructions for Part 1 which involves collecting thermal images of the	After completing the Engage activity, students will complete the Explore section of the worksheet. Students will be working with a partner (preferably the same partner from the previous lesson) to complete a process called "ground truthing". The teacher will read aloud the opening prompt in the Explore section. After going through the opening prompt, students will meet up with their partner to read through to read through the Thermal Imaging Preparation section. After reading, the students will perform the Thermal Calibration. Allow students 5-10 minutes to calibrate the thermal cameras. Once finished move on to Part 1. Students will read Part 1's instructions prior to going outside. After reading the instructions, students will go outside to the pre-determined study site. Students will then follow the instructions for Part 1 which involves collecting thermal images of the designated study space to collect land surface temperatures (LST). Students will select 9 random locations within the study site and draw in a box in the Explore section their selected sites in order to return to the chosen spots for all three data collection days. Students will then use a thermal camera to take pictures of the surface of the 9 selected spots. After taking thermal pictures, students will then make observations (if following the GLOBE protocol) about the area itself and atmosphere (clouds/sky). They will record the observational data in the table provided in the Explore section of the worksheet.	20-30 minutes over 3 test days

designated study space to collect land surface temperatures (LST). Students will select 9 random locations within the study site and draw in a box in the Explore section their selected sites in order to return to the chosen spots for all three data collection days. Students will then use a thermal camera to take pictures of the surface of the 9 selected spots. When outside, make sure to walk around to the various groups to make sure they collect the data by following the protocol given in Part 1 After taking thermal pictures, students will then make observations (if following the GLOBE protocol) about the area itself and atmosphere (clouds/sky). They will record the observational data in the table provided in the Explore section of the worksheet. After the field work, bring students back to the classroom to analyze the data from the thermal pictures. If using a FLIR thermal camera, students can use the FLIR tools app to find the LST of each picture. Students will record the LST for all nine spots in the table provided. They will then find the average from each day and write the averages in the 2nd data table provided in the Explore section of the worksheet. After completing the 3 days of field work, students will complete Part 2. In part 2, students will use EOS Worldview to find the satellite data for LST using the Terra/MODIS satellite. Students will follow the directions in Part 2 on how to find the data from their field research and add it to the 2nd table in the Explore section of the worksheet. While students are working, walk around the classroom to make sure students are able to successfully complete Part 2. If they have difficulty, guide them through the instructions, but do not complete the task for them. **Assessment Opportunity #2 (Use the Worksheet Answer Key & Explore section of rubric to assess).**	After the field work, students will return back to the classroom to analyze the data from the thermal pictures. If using a FLIR thermal camera, students can use the FLIR tools app to find the LST of each picture. Students will record the LST for all nine spots in the table provided. They will then find the average from each day and write the averages in the 2nd data table provided in the Explore section of the worksheet. After completing the 3 days of field work, students will complete Part 2. In part 2, students will use EOS Worldview to find the satellite data for LST using the Terra/MODIS satellite. Students will follow the directions in Part 2 on how to find the data from their field research and add it to the 2nd table in the Explore section of the worksheet.	
Explain After the Explore activity, direct students' attention to the Explain section of the worksheet. With their partner, students will meet with another pair to debrief and share results from the Explore activity. Allow students 5 minutes to complete the first 8 questions in the Explain section.	After the Explore activity, students will then complete Explain section of the worksheet. With their partner, students will meet with another pair to debrief and share results from the Explore activity.	15 minutes

After 5 minutes, bring students back together and ask “In your discussions with other groups, did you find similar readings? Why do you think you did/did not have similar readings?” have a few groups share aloud what they discussed. Then ask, “How can the method in the Explore activity help scientists determine the accuracy of satellite data?” and have a few groups share aloud what they discussed. Lastly, ask students “Before the activity we calibrated the thermal cameras and then during the activity we used weather station data. Why did we do this for the activity?” and have a few groups share aloud what they discussed. Adding to the previous information from the Engage activity, add the comments to the board to continue building the knowledge of ground truthing. After sharing, direct students to the Ground Truthing section of the Explain section of the worksheet. Students will work independently to learn how scientists use “ground truthing” to verify data. Students will watch the NASA SVS video “Remote Sensing: Observing the Earth” (https://svs.gsfc.nasa.gov/2674). While/after watching the video, students will fill out the “5 Key Points of Ground Truthing” organizer. After watching the video, students will meet up with another student who is not the student they worked with earlier in the Explore activity. Students will discuss the key points they wrote in their organizer. If a student does not have a key point mentioned by the other student, they will write it in the organizer. Example responses are included in the Worksheet Answer Key. Allow students 6-8 minutes to complete this activity. After collaborating, have students return to their seats. Ask students “What additional information did you learn about the concept of ground truthing from the video?” and have the students share aloud some of their key points. Next to the information already written on the board, draw a box to write the key points in. As students share their key points, write the key points in the box. Example responses are included in the Worksheet Answer Key. **Assessment Opportunity #3 (Use the Worksheet Answer Key & Explain section of rubric to assess).**	After sharing, students will complete the Ground Truthing section of the Explain section of the worksheet. Students will work independently to learn how scientists use “ground truthing” to verify data. Students will watch the NASA SVS video “Remote Sensing: Observing the Earth” (https://svs.gsfc.nasa.gov/2674). While/after watching the video, students will fill out the “5 Key Points of Ground Truthing” organizer. After watching the video, students will meet up with another student who is not the student they worked with earlier in the Explore activity. Students will discuss the key points they wrote in their organizer. If a student does not have a key point mentioned by the other student, they will write it in the organizer. After collaborating, students will return to their seats. Students will share aloud some of their key points.	
Elevate After completing the Explain activity, direct students to meet up with their partner from the Explore	After completing the Explain activity, students to meet up with their partner	15-20 minutes

activity. With their partners, students will learn about how scientists check the accuracy of their research. With their partner, students will look at three components that scientists do during research the ensure the validity of their data: review instrument specifications, apply atmospheric corrections, and ensure data is collected at the same time and date for all instruments used. Part 1 Students will learn find the specifications for the handheld thermal imaging. There are links provided for both FLIR One Gen1 and FLIR One Pro. If you use a different thermal camera, please provide the manuals to the students or an online version of the manual to the students. Students will record the resolution of the camera, the degree of accuracy, and the degree range of the thermal camera. They will then discuss with their partner the advantages and disadvantages to using a handheld thermal camera for their study. Allow 3-5 minutes for Part 1. After 5 minutes, ask students "What are some advantages/disadvantages of using a handheld thermal camera in this study?" and have students share aloud with the class their discussed advantages/disadvantages. Write the responses on the board. Example responses are included in the Worksheet Answer Key. Part 2 Students will learn about Atmospheric Corrections and how they are used in research for satellite imagery. Students (with their partner) will read about atmospheric corrections on the University of Bonn's website. Students will then answer two questions about using atmospheric questions in research. Allow 5 minutes for this part. After completion, have at least one student share their response for each question. Part 3 Students will discuss with their partner why it is important to collect data on the same date and time for all instruments used in a research study. Allow students 5 minutes to discuss. After 5 minutes, ask students "What is the purpose of scientists collecting data at the same time and day for all the instruments they use? Why is consistency of data collection important?" Have several students share aloud why it is important for sameness in data acquisition. Write their discussion points on the board. Student should also record the points discussed in the provided space on their worksheet	from the Explore activity. With their partners, students will learn about how scientists check the accuracy of their research. With their partner, students will look at three components that scientists do during research the ensure the validity of their data: review instrument specifications, apply atmospheric corrections, and ensure data is collected at the same time and date for all instruments used. Part 1 Students will learn find the specifications for the handheld thermal imaging. Students will record the resolution of the camera, the degree of accuracy, and the degree range of the thermal camera. They will then discuss with their partner the advantages and disadvantages to using a handheld thermal camera for their study. After 5 minutes, students will share with the class their discussed advantages/disadvantages. Part 2 Students will learn about Atmospheric Corrections and how they are used in research for satellite imagery. Students (with their partner) will read about atmospheric corrections on the University of Bonn's website. Students will then answer two questions about using atmospheric questions in research. After completion, students will share their response for each question. Part 3 Students will discuss with their partner why it is important to collect data on the same date and time for all instruments used in a research study. After 5 minutes, several students will share aloud why it is important for sameness in data acquisition. Student should record the points discussed in the provided space on their worksheet as well.	

as well. Make sure to reinforce to students that it is important to collect data on the same date and time for every instrument to ensure the accuracy of the data across all instruments. **Assessment Opportunity #4 (Use the Worksheet Answer Key & Elevate section of rubric to assess).**		
Evaluate It is recommended to use this section as a homework. It can also be used as an exit ticket. After completing the Elevate activity, students will complete the Evaluate section of the worksheet independently (in class as exit ticket or for homework). Students will revisit the question from the opening (Do Now!) given what they have learned from the Explore, Explain, and Elevate activities. Students will then reflect if their viewpoint has changed/not changed given what they have learned in this lesson. **Assessment Opportunity #5 (Use the Worksheet Answer Key & Evaluate section of rubric to assess).**	After completing the Elevate activity, students will complete the Evaluate section of the worksheet independently (in class as exit ticket or for homework). Students will revisit the question from the opening (Do Now!) given what they have learned from the Explore, Explain, and Elevate activities. Students will then reflect if their viewpoint has changed/not changed given what they have learned in this lesson.	1-3 minutes

Summary/Conclusion:
The students will revisit the question from the opening (Do Now!) and answer the following prompt, “Reflect if your viewpoint has changed/not changed given what you have learned in this lesson.” Students will respond in the Evaluate section of the worksheet.

Higher Order Questions:
1. Based on the data collected, discuss with the other team how the method performed in the Explore activity can help scientists verify the accuracy of satellite data. Why is it important to verify the satellite data?
2. In the previous lesson we learned about satellites, how they gather data, and how we can utilize satellite data for scientific research. In your opinion, how accurate do you think data is that is retrieved from satellites? Explain your thoughts.

Differentiated Instruction:
- The students learn the content in a variety of ways. The students learn content through visual formats (images and videos), oral discussion, experimental design, data analysis, and reflection.
- Students use data analysis tools to create graphs of their final results from the experiment (excel).
- Students use a variety of technology to learn about content (FLIR mobile camera, GLOBE, EOS Worldview, YouTube).
- Students are provided with a variety of leveled questions (low-high order) to answer questions at their level and elevate their thought processes.

- Students are given the chance to review their understanding through oral discussion in order to confirm or add to their understanding of the content.
- Students will use a graphic organizer to help with their understanding of the content and organize the content in an orderly, easily readable fashion.

Daily Formative Assessment:

1. In the previous lesson we learned about satellites, how they gather data, and how we can utilize satellite data for scientific research. In your opinion, how accurate do you think data is that is retrieved from satellites? Explain your thoughts.
2. How has your viewpoint changed from the beginning of the lesson to now in regards to satellite data? Why or why not has you're your viewpoint changed?

Next Lesson: Things are getting tense: A look at Urban Heat Island Intensity

d. Content template:

NGSS Standard & State Science Content Standard: (HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-PS4-2),(HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HSPS4-6) Mathematical representations can be used to identify certain patterns. (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)			Common Core Standard: CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.	NASA Science: Earth Science
Content Area: Earth Science/Environmental Science Grade Level: 9th Grade		Name of Project-Based Activity or Theme: The Truth of the Matter: How & Why We Ground Truth Satellite Data	Estimated Time Frame to Complete(days/weeks): 2 classes/days	
Overall Investigation Question(s): How does ground validation methods help to verify the data collected by satellites?				
Overall Project Description/Activity: Students will be able to ground validate satellite data in order to understand the verification process of data collection to utilize for research purposes.				
	:			
Materials Needed to Complete Project (put N/A as needed). Lesson 2 Worksheet Lesson 2 Worksheet Answer Key Computer Thermal Camera Globe Account for each student (if completing this portion of Explore activity) EOS Worldview NASA Scientific Visualization Studio video "Remote Sensing: Observing the Earth"	Stakeholders: Fusion Academy: Education Team, Administrators, Science Department, Science Teachers, and students	Hyperlinks Used: EOS Worldview https://worldview.earthdata.nasa.gov NASA Scientific Visualization Studio video "Remote Sensing: Observing the Earth" https://svs.gsfc.nasa.gov/2674 Weather weather.gov FLIR One Gen1 https://www.flir-direct.com/product/flir-one-thermal-imager-first-gen1 FLIR One Pro https://www.flir-direct.com/product/flir-onepro-thermal-camera-for-ios Atmospheric Corrections – University of Bonn http://fis.uni-bonn.de/en/recherchetools/infobox/professionals/preprocessing/atmospheric-correction	Multimedia/Technology: Computer Thermal Camera Globe Account for each student (if completing this portion of Explore activity) EOS Worldview NASA Scientific Visualization Studio video "Remote Sensing: Observing the Earth"	Classroom Equipment: Computer Thermal Cameras

Thermometer Cup (solid color) Atmospheric Corrections article from the University of Bonn				
NASA System Engineering Behaviors (2 behaviors per category)	Category (must have one Technical Acumen)	Activities How will student model engineering behaviors when learning science content? Describe student activities here.	Student Outcomes How will you assess learning for each behavior	Evaluation Describe specific science content students understand as a result of engineering behavior.
Understands the Human Dynamics of a Team	Leadership	Students work in pairs to complete the Explore and Explain activities (collecting land surface temperature data using thermal cameras and satellite data)	Lesson 2 Rubric – Explore and Explain Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Seeks Information and Uses the Art of Questioning	Attitudes & Attributes	Students will research information on ground validation of satellite data in the Explain activity.	Lesson 2 Rubric – Explain Category	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the

				environment, using technology to understand phenomenon
Assimilates, Analyzes, and Synthesizes Data	Systems Thinking	Students will obtain land surface temperature data from thermal cameras and satellites. Students will interpret the data in order to verify the data collected by satellites in the Explore & Explain activities.	Lesson 2 Rubric – Explore and Explain Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Has the Ability to Find Connections and Patterns Across the System	Systems Thinking	Students will obtain land surface temperature data from thermal cameras and satellites. Students will interpret the data in order to verify the data collected by satellites in the Explore & Explain activities.	Lesson 2 Rubric – Explore and Explain Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Communicates Effectively Through Personal Interaction	Communications	Students work in pairs to complete the Explore & Explain activities. Must have effective communications in order to be successful in activities.	Lesson 2 Rubric – Explore and Explain Categories	Data collection, data analysis, validation of data, infrared

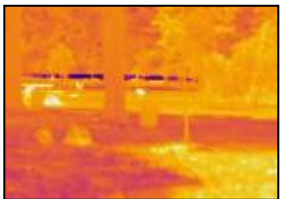
				energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Facilitates an Environment of Open and Honest Communication	Communications	Students work in pairs to complete the Explore & Explain activities. Must have effective communications in order to be successful in activities.	Lesson 2 Rubric – Explain and Explain Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Possesses Technical Competence and Has Comprehensive Previous Experience	Technical Acumen	For the Explore activity, students must have a comprehensive knowledge of retrieving and analyzing satellite data in order to verify the data collected using ground data collection methods.	Lesson 2 Rubric – Explore Category	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon

List and attach all supportive documents for instructional activities	Attachments? (circle) Yes or No	List Attached Documents(if any): Lesson 2 Worksheet		
List and attach all rubrics for activity and assessment evaluation	Attachments? (circle) Yes or No	List Attached Rubrics (if any): Lesson 2 rubric		
Include comments or questions here:				

e. Supporting Documents: (order according to sequence of lesson.)

1. Lesson 2 Worksheet

The Truth of the Matter: How & Why We Ground Truth Satellite Data
Lesson 2 Worksheet



Do Now!
In the previous lesson we learned about satellites, how they gather data, and how we can utilize satellite data for scientific research. In your opinion, how accurate do you think data is that is retrieved from satellites? Explain your thoughts.

_____
_____
_____
_____
_____

Engage
Remote sensing can be a great tool to use for understanding our planet. However, can we rely on the data to be accurate for all questions that may be posed in regards to the Urban Heat Island effect?

Your teacher and a few student volunteers will demonstrate an experiment to understand validity of data collection from afar and data collection from near a study site. Before observing the demonstration, answer the question below.

Will the temperature reading being conducted from a further distance (20 feet) of the study site be the same or different from the temperature reading being conducted directly at the study site (1 foot)? Why or why not?

_____
_____
_____
_____
_____

The teacher and students will now give the demonstration. Observe what happens and record the results below in the spaces provided. Illustrate the set-up of the experiment below in the space provided.

Temperature from 20 feet: _____
Temperature from 1 foot: _____

Diagram of Experimental Set Up

Based on the temperature collected, what can you conclude and infer about the accuracy of satellite data?

_____
_____
_____
_____
_____

Explore

You will now test how accurate satellite data is by conducting an experiment to "ground truth" the data collected. You will work with your partner from the first lesson to complete the activity. Follow the directions below to learn how to "ground truth" satellite data. You will collect data for this activity on three dates selected by your teacher.

Thermal Imaging Preparation – Calibrate

Before we can take thermal images using an infrared camera to measure surface temperatures, we first need to calibrate our tools. Follow the steps below to calibrate your camera.

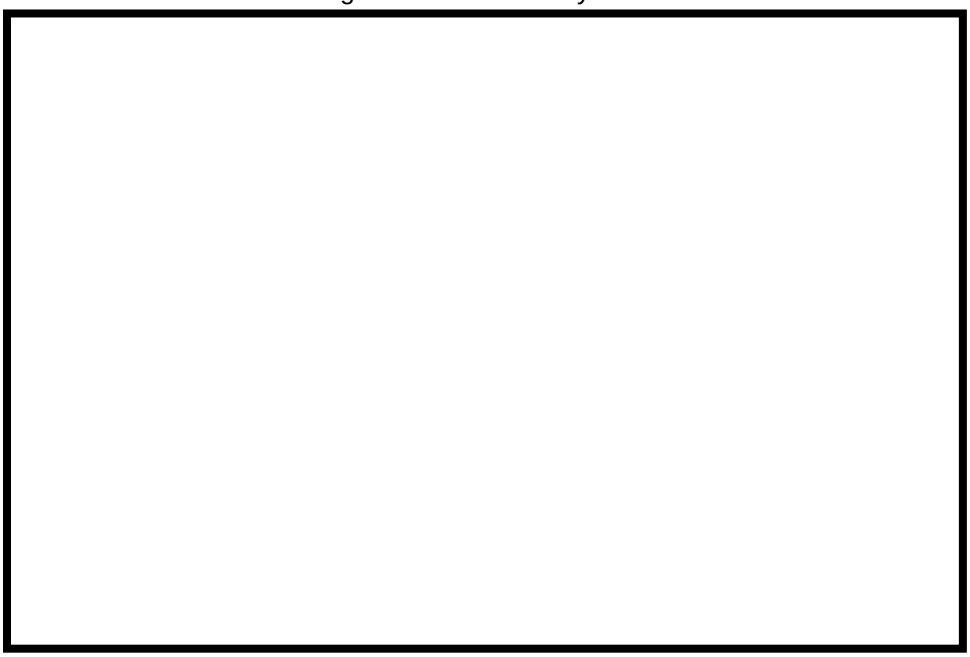
1. Fill a non-shiny cup (preferably a solid colored cup) with hot or cold water. Place a thermometer in the cup of water. Once the temperature on the thermometer stabilizes, proceed to the next step.
2. Attach the FLIR mobile attachment to your phone.
3. Turn on the FLIR mobile camera (refer to manual for how to do this, different for various models).
4. Open the FLIR One mobile app. The app should then give you a walkthrough of how to use the camera and other "tips and tricks".
5. Click the gear wheel on the screen, then tap settings. Tap "Emissivity" and set it to Matte.
   **This is important because emissivity is the measurement of the thermal radiation being emitted by on object. If you are measuring an object that is "shiny" it will not give an accurate measurement if the emissivity value is not set properly.*
6. Go back to the settings screen. Make sure the "save to photos" is on and you have the temperature unit set. It is recommended to have it in Celsius, but you can have it in Fahrenheit and convert to Celsius at a later time. When finished, click done.
7. At the top middle of the screen, tap the point icon (circle with a cross) to enable spot touch temperature analysis. The circle will be filled when it is activated.
8. Face the camera so the cup is in the screen. Pick a spot towards the middle of the cup to use as a point of calibration. Once you have the camera on the point, compare the temperature on the screen with the temperature of the thermometer. If it is +/-5 degrees of the thermometer reading, then your camera is set and ready to go. If it is not, please see your teacher for a different instrument. (+/-5 degrees is the recommended range by GLOBE).

Part 1: Thermal Imaging

On the date given by your teacher, you and your partner will go outside to collect land surface temperature measurements. You will record your data on this worksheet and in an app called "GLOBE Data Entry". This app allows people all over the world to submit their land surface temperature data to compare globally how accurate satellites are and for everyone to have access to data to help them in their research. Follow the directions below to complete part 1.

1. Before starting the activity, make sure your GLOBE account is all set up and ready to go. Check with your teacher if you are encountering issues with logging in/setting up your account.
2. As directed by your teacher, go outside to the designated area of study. Select 9 locations within the designated area of study. In the space provided below, put an "X" for each location selected. You will visit the site a total of 3 times. You will use the diagram to help you relocate the site areas for each day of study.

Designated Area of Study



3. Attach the FLIR mobile attachment to your phone.
4. Turn on the FLIR mobile camera (refer to manual for how to do this, different for various models).
5. Open the FLIR One mobile app. The app should then give you a walkthrough of how to use the camera and other "tips and tricks".
6. Click the gear wheel on the screen, then tap settings. Tap "Emissivity" and set it to Matte.
7. Go back to the settings screen. Make sure the "save to photos" is on and you have the temperature unit set. It is recommended to have it in Celsius, but you can have it in Fahrenheit and convert to Celsius at a later time. When finished, click done.
8. At the top middle of the screen, tap the point icon (circle with a cross) to enable spot touch temperature analysis. The circle will be filled when it is activated.
9. Go to each of the 9 locations and take a picture of the surface using the FLIR camera. Make sure the camera is looking straight down onto the surface. Do not take a picture with a shadow in it. Make sure the area is completely free of all obstacles (feet, trash, etc…).
10. After taking a picture of each of the 9 sites, you will collect cloud and surface condition observations.

a. Cloud Observations: In the row "Cloud Observations" in the table below, record the following items (please reference the GLOBE Clouds Chart to help with identifying the type of clouds: https://www.globe.gov/documents/348614/24331082/GLOBE+Cloud+Chart):
    i. Observability
        1. Are there "no observable clouds/contrails", "clouds/contrails observable", or "clouds/contrails >25% obscured"?
            a. If "no observable clouds/contrails":
                i. what is the sky color? (deep blue, blue, light blue, pale blue, or milky)
                ii. what is the sky visibility? (unusually clear, clear, somewhat hazy, very hazy, extremely hazy)
            b. If "clouds/contrails observable", what percentage of the whole sky is covered by clouds/contrails?
                i. If 1-50% options are selected:
                1. What color is the sky? (deep blue, blue, light blue, pale blue, or milky).
                2. What is the sky visibility? (unusually clear, clear, somewhat hazy, very hazy, extremely hazy). Then go to step iii
                ii. If 50-100% options are selected, go to step iii.
                iii. Which high level clouds/contrails are present? (no high-level clouds observed, cirrus, cirrocumulus, cirrostratus, short lived contrails & #, persistent non-spreading contrails & #, and/or persistent spreading contrails & #)
                1. What percent of high-level sky is covered with clouds/contrails? (0-100%).
                2. What is the visual opacity of the high-level clouds/contrails? (opaque, translucent, or transparent)
                iv. Which mid-level clouds are present? (no mid-level clouds observed, altostratus, or altocumulus)
                1. What percent of high-level sky is covered with clouds/contrails? (0-100%).
                2. What is the visual opacity of the high-level clouds/contrails? (opaque, translucent, or transparent)
                v. Which low level clouds are present? (no low-level clouds observed, fog/stratus, stratocumulus, cumulus, nimbostratus, or cumulonimbus).
                1. What percent of high-level sky is covered with clouds/contrails? (0-100%).
                2. What is the visual opacity of the high-level clouds/contrails? (opaque, translucent, or transparent)
            c. If "clouds/contrails >25% obscured":
                i. Record the types of obscurations (blowing snow, heavy snow, heavy rain, fog/stratus, sand, spray, volcanic ash, smoke, dust, haze)
        2. Record the surface condition (snow/ice, standing water, muddy, dry ground, leaves on trees, raining/snowing).
b. Site's Overall Surface Condition:
    i. Record the overall surface condition (wet, dry, or snow).

11. After recording step 10's data, you will now go back inside as directed by the teacher to write down local weather conditions and find the surface temperature from the pictures.
12. Go to weather.gov. In the top left-hand corner, there should be a text box that says, "Local forecast by 'City, 'St', or ZIP code. Type in your zip code and click GO to find the weather station closest to your study site.
13. In the middle portion of the screen, you will see the current weather conditions. On the right side of the middle section there are links to additional information. Click the third link down titled "3-day history". It will redirect you to a table of the weather information from the past three days.
14. Using the 1st column (Date), locate the dates of your day of study. Then, find the time closest to your time of study (the time is in 24-hour time).
15. Using the 7th column (Air), identify the air temperature for the time of study. Record the temperature in the table below.

Data Collection for Land Surface Temperature (LST)

Site #	Day 1	Day 2	Day 3
1			
2			
3			
4			
5			
6			
7			
8			
9			
Average LST Temperature			
Air Temperature from local NOAA station			
Date & Time of Study			
Site's Overall Surface Condition			

Cloud Observations			

Part 2: Satellite Data
The day after the thermal imaging is collected, you will gather the satellite data. Follow the directions below with your partner from part 1 to collect the data.

1. Go to EOS Worldview: https://worldview.earthdata.nasa.gov/
2. On the left side of the screen towards the bottom, click the button that says "+Add Layers". Click the second tab "Science Disciplines".
3. Find the category that says "Land Surface" and select the three horizontal dots at the bottom of the category for more options. Find "Land Surface Temperature" and then click the orange arrow next to this option. Then select the box for "Land Surface Temperature (Day)" for Terra/MODIS. This will add the layer of land surface temperature to your map. Then click the X at the top of the pop out box to close the pop out window.
4. In the bottom right hand corner, you will see options to change for different time options. Select "Year". On the bottom left hand corner, the date currently being shown on the map is displayed. Change the date to the date of the thermal imaging data collection.
5. Zoom in on the area of study (outside of your school) on the map using the scrolling feature on your mouse or trackpad until you have a zoom of 1000m/5000 ft (this is displayed in the lower right part of the screen).
6. You will now need to move your mouse to the latitude and longitude of your study location. The coordinates should have been determined in Part 1. In the bottom right hand corner of the screen, you will see the latitude and longitude coordinates. Move your mouse until the coordinates match the coordinates from part 1.
7. You will now determine the temperature. At the left-hand side of the screen where it displays the layers, you will see a color scale for the layer of "land surface temperature". The scale will display the temperature of the area your mouse is on in Kelvin. Record the temperature in the data table below in the "Satellite (K)" column.
8. Since the satellite reading is in Kelvin, you will have to convert it to Celsius. To do this, subtract 273.15 from the number in the "Satellite (K)" column. Record the result in the "Satellite (C)" column.

Final Data
Record the data from Parts 1 and 2 in the data table below.

Date	Average Surface Temperature from Thermal Imaging	Surface Temperature from Satellite (K)	Surface Temperature from Satellite (C)	Air temperature from local weather station (C)	Other Observations

Explain
With your partner, meet with another pair to discuss the results from the *Explore* activity. Answer the questions below based on your discussion.

1. Did the other pair have similar results to your team's results? _____
2. If yes to the previous questions, why do you think your team had similar results?_____
_____
_____
_____
_____

3. If no to the first question, why do you think your team had different results?
_____
_____
_____
_____
_____

4. Based on the data collected, discuss with the other team how the method performed in the *Explore* activity can help scientists verify the accuracy of satellite data. Why is it important to verify the satellite data?
_____
_____
_____
_____
_____
_____
_____

5. In the first part of the Explore activity we compared land surface temperatures by using data from satellites and handheld thermal cameras. However, there's a source in every town that we can use to measure temperatures: a weather station.

   a. Why didn't we initially use a weather station to study the surface temperatures?

   _____
   _____
   _____
   _____
   _____

   b. What could we use weather station data for to help further enhance the data we collected in the Explore activity?

   _____
   _____
   _____
   _____
   _____

6. As you may have predicted, weather station data can help us see the average air temperature in an area. In our study, we are looking at the surface temperatures of land cover which is why we use thermal cameras and satellites. However, air temperature data can help us with seeing a correlation between surface temperatures and air temperatures. Let's see how the air temperatures from our study days compare to the surface temperature data.

   a. Describe in your own words the difference between the three temperature measurements recorded in the Explore's final data table and what it may tell us about the UHI effect in that area.

   _____
   _____
   _____
   _____
   _____

7. Before beginning the activity, you were asked to calibrate the thermal camera. Why do we calibrate our tools such as thermal cameras? Is it necessary to calibrate tools before each use?

   _____
   _____
   _____
   _____
   _____
   _____
   _____

8. How can comparing the handheld thermal image data to the weather station data help us with determining errors in the data? What sources could cause the errors in data?

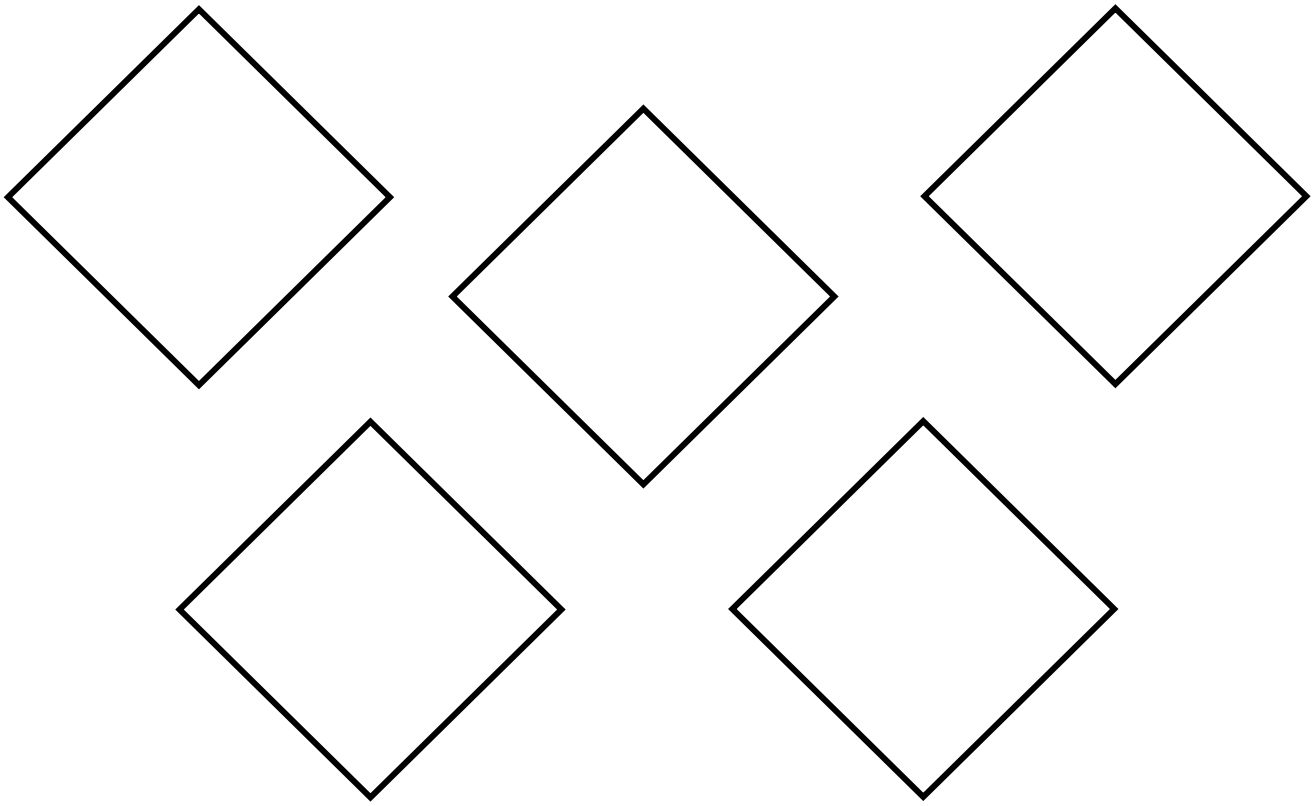
_____
_____
_____
_____
_____
_____

Ground Truthing

The method you performed in the *Explore* activity is called Ground Truthing. Independently, follow the directions below to find out more about ground truthing.

1. Go to https://svs.gsfc.nasa.gov/2674
2. Watch the video on the site. During/after the video, fill out the organizer below about ground truthing. Write in the diamonds below 5 key points of ground truthing.

5 Key Points of Ground Truthing



3. Meet up with a student that is not your partner from the *Explore* activity or the pair you met up with in the beginning of the *Explain* activity. With the student, discuss the 5 key points you wrote down in your organizer. If the other student has key points you don't have, add it to your organizer in the space outside of the diamonds.

Elevate

Accuracy Check
In the Explore & Explain activities, we use satellites and thermal imagery to measure the surface temperatures of land cover. However, how we do know that the data we are getting from the individual measurements is accurate?

There are several things that scientists do to verify the accuracy of satellites and thermal imagery:

1. Review the specifications and error margin of each tool
2. Check or apply atmospheric corrections for imagery
3. Retrieve/collect data on the same date & time for all instruments.

Part 1: Review Specifications
In the previous lesson, we looked at the specifications for the satellites Landsat 8 and MODIS Terra. However, we are using an additional instrument in this lesson's Explore activity, a handheld thermal camera. Let's find out the specifications of the handheld thermal camera.

If you are using a FLIR One Gen1 handheld thermal camera, go to this website to find the specifications. Make sure under to click the specifications tab. https://www.flir-direct.com/product/flir-one-thermal-imager-first-gen1

If you are using a FLIR One Pro handheld thermal camera, go to this website to find the specifications. Make sure to click the specifications tab. https://www.flir-direct.com/product/flir-onepro-thermal-camera-for-ios

If you are using a different handheld thermal camera, please refer to the user manual or search for the user manual online for a list of specifications.

Tool	Resolution	Degree Accuracy or Sensitivity	Degree Range
Handheld Thermal Camera			

What are the advantages and disadvantages for using a handheld thermal camera with satellite data for our study? Record your responses in the diagram below.

Advantages	Disadvantages

Part 2: Atmospheric Corrections
The images that are taken satellites are often not the same images we see or use for our studies. Why is that? Think about where the satellites are and what the satellites images pick up along the way.

Satellites orbit around the planet in different layers of the atmosphere. As the satellites take images, there are particles within the atmosphere that can interfere with the information that the scientists are trying to extract from the image. Because of the particles and other things that may alter the image, scientists will apply "Atmospheric Corrections" to an image while processing the image for data.

Go to this website from the University of Bonn to learn more about Atmospheric Corrections:
http://fis.uni-bonn.de/en/recherchetools/infobox/professionals/preprocessing/atmospheric-correction

Answer the following questions about Atmospheric Corrections:

1. What does it mean to make atmospheric corrections on an image from a satellite?

_____
_____
_____
_____

2. Why do we need to apply atmospheric corrections to satellite images?

_____
_____
_____
_____

Part 3: Retrieve/Collect data on the same date & time for all instruments
As you have seen with the Explore activity, we collected the data from all the instruments for the same time and day.

Discuss with a partner why it is important to always collect data for all devices being used in research at the same time and day.

Write your main discussion points in the space below.

Evaluate

After completing the *Explore, Explain, and Elevate* activities, revisit the questions from the beginning of the lesson below:

In the previous lesson we learned about satellites, how they gather data, and how we can utilize satellite data for scientific research. In your opinion, how accurate do you think data is that is retrieved from satellites? Explain your thoughts.

_____
_____
_____
_____
_____

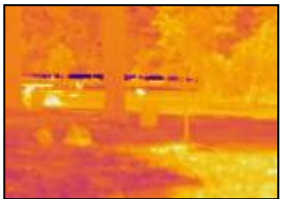
How has your viewpoint changed from the beginning of the lesson to now in regards to satellite data? Why or why not has you're your viewpoint changed?

_____
_____
_____
_____
_____

2. Lesson 2 Worksheet Answer Key

KEY

The Truth of the Matter: How & Why We Ground Truth Satellite Data
Lesson 2 Worksheet



Do Now!

In the previous lesson we learned about satellites, how they gather data, and how we can utilize satellite data for scientific research. In your opinion, how accurate do you think data is that is retrieved from satellites? Explain your thoughts.

Answers will vary. Example response: From what we learned in the previous lesson, I think that satellites can be very accurate. We saw that Landsat 8 has a spatial resolution of 30m. To think that from up in orbit in can capture the land surface at that resolution is amazing. The satellites are in constant motion above our planet taking data non-stop. I don't think necessarily all satellites are highly accurate, but as technology improves (think about the first model of Landsat versus Landsat 8) we will see an improvement in the accuracy of satellite data.

Engage

Remote sensing can be a great tool to use for understanding our planet. However, can we rely on the data to be accurate for all questions that may be posed in regards to the Urban Heat Island effect?

Your teacher and a few student volunteers will demonstrate an experiment to understand validity of data collection from afar and data collection from near a study site. Before observing the demonstration, answer the question below.

Will the temperature reading being conducted from a further distance (20 feet) of the study site be the same or different from the temperature reading being conducted directly at the study site (1 foot)? Why or why not?

Answers will vary. Example response: I think the temperature reading from farther away will be roughly the same, but may not be as highly accurate as the temperature reading that is close to the study site. For example, far reading: 38.2C, near reading: 38.9C. I think it will not be in complete agreement with each other, but more or less close to each other.

The teacher and students will now give the demonstration. Observe what happens and record the results below in the spaces provided. Illustrate the set-up of the experiment below in the space provided.

Example temperature reading

Temperature from 20 feet: ____42.2C_____

Temperature from 1 foot: _____43.5C_____

Diagram of Experimental Set Up

Based on the temperature collected, what can you conclude and infer about the accuracy of satellite data?
Answers will vary. Example response: I think that satellites are for the most part very accurate in their readings, but may be a +/- a few degrees off than if we took readings at the ground level. Overall, what the scientsts are looking to measure will be collected by the scientists, but maybe not to the highest degree of accuracy. EX: satellite reads 37.5 C whereas ground reading says: 38.5789 C

Explore
You will now test how accurate satellite data is by conducting an experiment to "ground truth" the data collected. You will work with your partner from the first lesson to complete the activity. Follow the directions below to learn how to "ground truth" satellite data. You will collect data for this activity on three dates selected by your teacher.

Thermal Imaging Preparation – Calibrate
Before we can take thermal images using an infrared camera to measure surface temperatures, we first need to calibrate our tools. Follow the steps below to calibrate your camera.

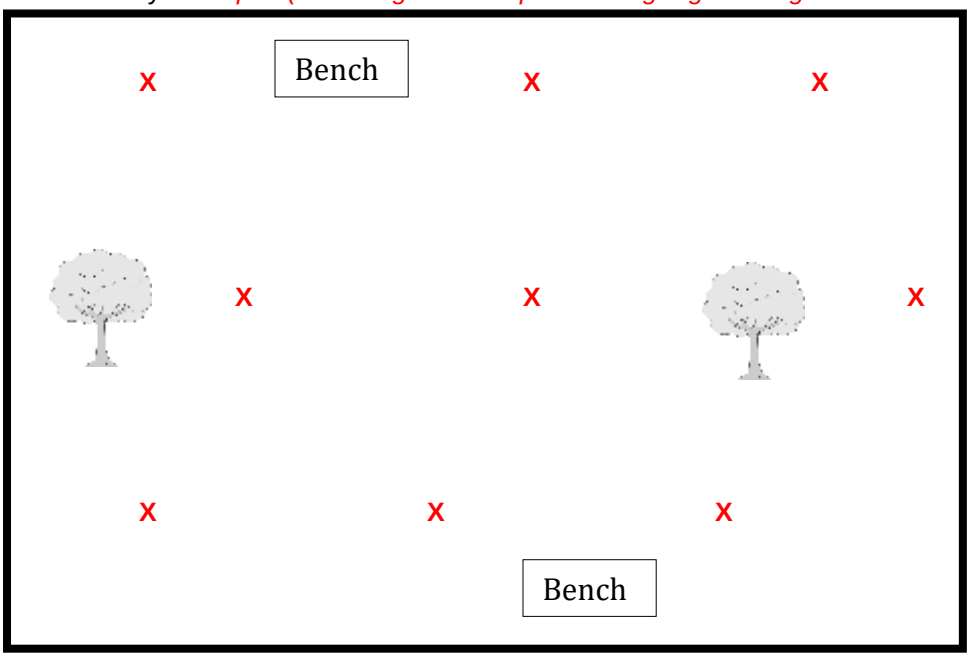
1. Fill a non-shiny cup (preferably a solid colored cup) with hot or cold water. Place a thermometer in the cup of water. Once the temperature on the thermometer stabilizes, proceed to the next step.
2. Attach the FLIR mobile attachment to your phone.
3. Turn on the FLIR mobile camera (refer to manual for how to do this, different for various models).
4. Open the FLIR One mobile app. The app should then give you a walkthrough of how to use the camera and other "tips and tricks".
5. Click the gear wheel on the screen, then tap settings. Tap "Emissivity" and set it to Matte.
   **This is important because emissivity is the measurement of the thermal radiation being emitted by on object. If you are measuring an object that is "shiny" it will not give an accurate measurement if the emissivity value is not set properly.*
6. Go back to the settings screen. Make sure the "save to photos" is on and you have the temperature unit set. It is recommended to have it in Celsius, but you can have it in Fahrenheit and convert to Celsius at a later time. When finished, click done.
7. At the top middle of the screen, tap the point icon (circle with a cross) to enable spot touch temperature analysis. The circle will be filled when it is activated.
8. Face the camera so the cup is in the screen. Pick a spot towards the middle of the cup to use as a point of calibration. Once you have the camera on the point, compare the temperature on the screen with the temperature of the thermometer. If it is +/-5 degrees of the thermometer reading, then your camera is set and ready to go. If it is not, please see your teacher for a different instrument. (+/-5 degrees is the recommended range by GLOBE).

Part 1: Thermal Imaging

On the date given by your teacher, you and your partner will go outside to collect land surface temperature measurements. You will record your data on this worksheet and in an app called "GLOBE Data Entry". This app allows people all over the world to submit their land surface temperature data to compare globally how accurate satellites are and for everyone to have access to data to help them in their research. Follow the directions below to complete part 1.

1. Before starting the activity, make sure your GLOBE account is all set up and ready to go. Check with your teacher if you are encountering issues with logging in/setting up your account.
2. As directed by your teacher, go outside to the designated area of study. Select 9 locations within the designated area of study. In the space provided below, put an "X" for each location selected. You will visit the site a total of 3 times. You will use the diagram to help you relocate the site areas for each day of study.

Designated Area of Study *Example (tree image from https://freesvg.org/drawing-of-thin-trunk-tree)*



3. Attach the FLIR mobile attachment to your phone.
4. Turn on the FLIR mobile camera (refer to manual for how to do this, different for various models).
5. Open the FLIR One mobile app. The app should then give you a walkthrough of how to use the camera and other "tips and tricks".
6. Click the gear wheel on the screen, then tap settings. Tap "Emissivity" and set it to Matte.
7. Go back to the settings screen. Make sure the "save to photos" is on and you have the temperature unit set. It is recommended to have it in Celsius, but you can have it in Fahrenheit and convert to Celsius at a later time. When finished, click done.
8. At the top middle of the screen, tap the point icon (circle with a cross) to enable spot touch temperature analysis. The circle will be filled when it is activated.
9. Go to each of the 9 locations and take a picture of the surface using the FLIR camera. Make sure the camera is looking straight down onto the surface. Do not take a picture with a shadow in it. Make sure the area is completely free of all obstacles (feet, trash, etc…).
10. After taking a picture of each of the 9 sites, you will collect cloud and surface condition observations.

a. Cloud Observations: In the row "Cloud Observations" in the table below, record the following items (please reference the GLOBE Clouds Chart to help with identifying the type of clouds: https://www.globe.gov/documents/348614/24331082/GLOBE+Cloud+Chart):
    i. Observability
        1. Are there "no observable clouds/contrails", "clouds/contrails observable", or "clouds/contrails >25% obscured"?
            a. If "no observable clouds/contrails":
                i. what is the sky color? (deep blue, blue, light blue, pale blue, or milky)
                ii. what is the sky visibility? (unusually clear, clear, somewhat hazy, very hazy, extremely hazy)
            b. If "clouds/contrails observable", what percentage of the whole sky is covered by clouds/contrails?
                i. If 1-50% options are selected:
                1. What color is the sky? (deep blue, blue, light blue, pale blue, or milky).
                2. What is the sky visibility? (unusually clear, clear, somewhat hazy, very hazy, extremely hazy). Then go to step iii
                ii. If 50-100% options are selected, go to step iii.
                iii. Which high level clouds/contrails are present? (no high-level clouds observed, cirrus, cirrocumulus, cirrostratus, short lived contrails & #, persistent non-spreading contrails & #, and/or persistent spreading contrails & #)
                1. What percent of high-level sky is covered with clouds/contrails? (0-100%).
                2. What is the visual opacity of the high-level clouds/contrails? (opaque, translucent, or transparent)
                iv. Which mid-level clouds are present? (no mid-level clouds observed, altostratus, or altocumulus)
                1. What percent of high-level sky is covered with clouds/contrails? (0-100%).
                2. What is the visual opacity of the high-level clouds/contrails? (opaque, translucent, or transparent)
                v. Which low level clouds are present? (no low-level clouds observed, fog/stratus, stratocumulus, cumulus, nimbostratus, or cumulonimbus).
                1. What percent of high-level sky is covered with clouds/contrails? (0-100%).
                2. What is the visual opacity of the high-level clouds/contrails? (opaque, translucent, or transparent)
            c. If "clouds/contrails >25% obscured":
                i. Record the types of obscurations (blowing snow, heavy snow, heavy rain, fog/stratus, sand, spray, volcanic ash, smoke, dust, haze)
        2. Record the surface condition (snow/ice, standing water, muddy, dry ground, leaves on trees, raining/snowing).
b. Site's Overall Surface Condition:
    i. Record the overall surface condition (wet, dry, or snow).

11. After recording step 10's data, you will now go back inside as directed by the teacher to write down local weather conditions and find the surface temperature from the pictures.
12. Go to weather.gov. In the top left-hand corner, there should be a text box that says, "Local forecast by 'City, 'St', or ZIP code. Type in your zip code and click GO to find the weather station closest to your study site.
13. In the middle portion of the screen, you will see the current weather conditions. On the right side of the middle section there are links to additional information. Click the third link down titled "3-day history". It will redirect you to a table of the weather information from the past three days.
14. Using the 1st column (Date), locate the dates of your day of study. Then, find the time closest to your time of study (the time is in 24-hour time).
15. Using the 7th column (Air), identify the air temperature for the time of study. Record the temperature in the table below.

Data Collection for Land Surface Temperature (LST)
Example Data Below (*not real figures from these dates*)

Site #	Day 1	Day 2	Day 3
1	38.7 C	35.6 C	37.5 C
2	39.2 C	34.2 C	37.2 C
3	37.4 C	36.5 C	38.1 C
4	28.4 C	28.6 C	27.6 C
5	38.2 C	36.4 C	37.9 C
6	27.6 C	28.4 C	28.2 C
7	38.8 C	35.8 C	37.8 C
8	39.5 C	35.9 C	38.2 C
9	37.1 C	36.7 C	38.0 C
Average LST Temperature	36.1 C	34.2 C	35.6 C
Air Temperature from local NOAA station	29 C	28 C	31 C
Date & Time of Study	June 1st 2:30pm	June 2nd 2:30pm	June 3rd 2:30pm
Site's Overall Surface Condition	The site has natural grass in most areas, with two benches (one in the north side along edge, one	The site has natural grass in most areas, with two benches (one in the north side along edge, one on	The site has natural grass in most areas, with two benches (one in the north side along edge, one on the south

	on the south side along edge). There are two trees (one at middle left edge, one at middle right edge). Leaves on trees. Soil is dry, no rain for a week.	**the south side along edge). There are two trees (one at middle left edge, one at middle right edge). Leaves on trees. Soil is slightly wet, there was light rain overnight.**	**side along edge). There are two trees (one at middle left edge, one at middle right edge). Leaves on trees. Soil is dry, no rain for 24 hours.**
Cloud Observations	**No observable clouds/contrails Deep blue color Clear**	**Clouds/contrails observable >25% Light blue Somewhat hazy Cirrus clouds**	**No observable clouds/contrails Deep blue color Clear**

Part 2: Satellite Data
The day after the thermal imaging is collected, you will gather the satellite data. Follow the directions below with your partner from part 1 to collect the data.

1. Go to EOS Worldview: https://worldview.earthdata.nasa.gov/
2. On the left side of the screen towards the bottom, click the button that says "+Add Layers". Click the second tab "Science Disciplines".
3. Find the category that says "Land Surface" and select the three horizontal dots at the bottom of the category for more options. Find "Land Surface Temperature" and then click the orange arrow next to this option. Then select the box for "Land Surface Temperature (Day)" for Terra/MODIS. This will add the layer of land surface temperature to your map. Then click the X at the top of the pop out box to close the pop out window.
4. In the bottom right hand corner, you will see options to change for different time options. Select "Year". On the bottom left hand corner, the date currently being shown on the map is displayed. Change the date to the date of the thermal imaging data collection.
5. Zoom in on the area of study (outside of your school) on the map using the scrolling feature on your mouse or trackpad until you have a zoom of 1000m/5000 ft (this is displayed in the lower right part of the screen).
6. You will now need to move your mouse to the latitude and longitude of your study location. The coordinates should have been determined in Part 1. In the bottom right hand corner of the screen, you will see the latitude and longitude coordinates. Move your mouse until the coordinates match the coordinates from part 1.
7. You will now determine the temperature. At the left-hand side of the screen where it displays the layers, you will see a color scale for the layer of "land surface temperature".

The scale will display the temperature of the area your mouse is on in Kelvin. Record the temperature in the data table below in the "Satellite (K)" column.

8. Since the satellite reading is in Kelvin, you will have to convert it to Celsius. To do this, subtract 273.15 from the number in the "Satellite (K)" column. Record the result in the "Satellite (C)" column.

Final Data

Record the data from Parts 1 and 2 in the data table below.

Example responses that continue from above sample responses

Date	Average Surface Temperature from Thermal Imaging	Surface Temperature from Satellite (K)	Surface Temperature from Satellite (C)	Air temperature from local weather station (C)	Other Observations
6/1	**36.1 C**	**308 K**	**34.8 C**	**29 C**	**1.2 degree difference between ground and satellite readings**
6/2	**34.2 C**	**307 K**	**33.7 C**	**28 C**	**1.5 degree difference between ground and satellite readings**
6/3	**35.6 C**	**309 K**	**35.8 C**	**31 C**	**0.2 degree difference between ground and satellite readings**

<u>Explain</u>

With your partner, meet with another pair to discuss the results from the *Explore* activity. Answer the questions below based on your discussion.

Answers will vary for this section since it is comparing two groups results. An example of responses is provided below

1. Did the other pair have similar results to your team's results? ___**very similar**____
2. If yes to the previous questions, why do you think your team had similar results?
   Since we were surveying the same piece of land, the perspective from the MODIS satellite will find the average for the plot of land (1000m resolution). When we average our temperatures, our group and the other groups were roughly the same. So from the satellite viewpoint, the results are within an acceptable window for accurate readings.

3. If no to the first question, why do you think your team had different results?
   If a group had different responses
   I think our team had different results because of the 9 locations we selected within our study site. Two of our locations that we picked were underneath a tree, which consistently had much lower temperature readings than the rest of the selected

sites. Because the values were much lower, it pulled the average temperature down. In comparison to the other team, our team's averages were 5-10 degrees lower than theirs.

4. Based on the data collected, discuss with the other team how the method performed in the *Explore* activity can help scientists verify the accuracy of satellite data. Why is it important to verify the satellite data?
Just like with any other data collected, satellite data should be verified in order to ensure its accuracy. It is important to verify data to being collected by instruments in a study, in this case satellites, because the data is what helps scientists identify trends and patterns of an event or phenomena that is occurring, in this case, the urban heat island effect.

5. In the first part of the Explore activity we compared land surface temperatures by using data from satellites and handheld thermal cameras. However, there's a source in every town that we can use to measure temperatures: a weather station.

   a. Why didn't we initially use a weather station to study the surface temperatures?
   We didn't initially use weather station data because we were looking at surface temperatures, not air temperatures. Weather stations have very high precision, but are measuring air temperature, dew point, etc.

   b. What could we use weather station data for to help further enhance the data we collected in the Explore activity?
   We could use weather station data to help us see the correlation between the surface temperature and air temperature of an area. Does a higher surface temperature lead to higher air temperatures?

6. As you may have predicted, weather station data can help us see the average air temperature in an area. In our study, we are looking at the surface temperatures of land cover which is why we use thermal cameras and satellites. However, air temperature data can help us with seeing a correlation between surface temperatures and air temperatures. Let's see how the air temperatures from our study days compare to the surface temperature data.
   a. Describe in your own words the difference between the three temperature measurements recorded in the Explore activities final data table and what it may tell us about the UHI effect in that area.
   According to the data my group collected, the surface temperature was higher than the air temperature. As the air temperature increased, the surface temperature increased. This can help us explain that the UHI effect of higher air temperatures is related to the higher surface temperatures in that area.

7. Before beginning the activity, you were asked to calibrate the thermal camera. Why do we calibrate our tools such as thermal cameras? Is it necessary to calibrate tools before each use?
We calibrate tools such as the thermal camera in order to ensure the data we are about to collect is accurate. It is necessary to calibrate tools before each use to ensure the accuracy of the data that the tool is collecting.

8. How can comparing the handheld thermal image data to the weather station data help us with determining errors in the data? What sources could cause the errors in data?
Comparing the thermal imaging data to the weather station data can help us determine errors by seeing the margin of errors. If the surface temperature is 100 degrees higher than the air temperature, that could be an indication that either the instrument is not

collecting data properly or there is another source unseen to the eye that is causing a much higher reading than the average temperatures. For example, if there is a heat source such as a thermal vent directly underneath the land surface you are measuring that is covered and not visible to us.

Ground Truthing

The method you performed in the *Explore* activity is called Ground Truthing. Independently, follow the directions below to find out more about ground truthing.

1. Go to https://svs.gsfc.nasa.gov/2674
2. Watch the video on the site. During/after the video, fill out the organizer below about ground truthing. Write in the diamonds below 5 key points of ground truthing.

Key points will vary. Examples of points are provided below*

5 Key Points of Ground Truthing

Satellites don't always pick up the finer details, we can use airplanes or ground methods to get these finer details

ground truthing associates ground data with remote sensing data

make corrections to the gathered data by the sensors to get more accurate measurements

Satellites and ground collecting methods are performed at the same time

helps understand global phenomena and understand what is occurring in our area and quickly notice changes

help us studying changes over a long period of time such as El Niños.

3. Meet up with a student that is not your partner from the *Explore* activity or the pair you met up with in the beginning of the *Explain* activity. With the student, discuss the 5 key points you wrote down in your organizer. If the other student has key points you don't have, add it to your organizer in the space outside of the diamonds.

Elevate

Accuracy Check

In the Explore & Explain activities, we use satellites and thermal imagery to measure the surface temperatures of land cover. However, how we do know that the data we are getting from the individual measurements is accurate?

There are several things that scientists do to verify the accuracy of satellites and thermal imagery:

1. Review the specifications and error margin of each tool
2. Check or apply atmospheric corrections for imagery
3. Retrieve/collect data on the same date & time for all instruments.

Part 1: Review Specifications

In the previous lesson, we looked at the specifications for the satellites Landsat 8 and MODIS Terra. However, we are using an additional instrument in this lesson's Explore activity, a handheld thermal camera. Let's find out the specifications of the handheld thermal camera.

If you are using a FLIR One Gen1 handheld thermal camera, go to this website to find the specifications. Make sure under to click the specifications tab. https://www.flir-direct.com/product/flir-one-thermal-imager-first-gen1

If you are using a FLIR One Pro handheld thermal camera, go to this website to find the specifications. Make sure to click the specifications tab. https://www.flir-direct.com/product/flir-onepro-thermal-camera-for-ios

If you are using a different handheld thermal camera, please refer to the user manual or search for the user manual online for a list of specifications.

Example responses here are for the FLIR One Pro camera

Tool	Resolution	Degree Accuracy or Sensitivity	Degree Range
Handheld Thermal Camera	**Thermal resolution 160 x 120**	**+/- 3C**	**-20 C to 400 C**

What are the advantages and disadvantages for using a handheld thermal camera with satellite data for our study? Record your responses in the diagram below.

Advantages	Disadvantages
- Helps verify the land surface temperatures if the readings are within an acceptable range of each other **- Can provide a finer resolution/more data points for the study** **- Provides both a micro and macro view of an area and detect data, patterns, or anomalies that may go unseen with just the use of one instrument**	**- More data to process/time consuming to process data** **- alignment of satellite flyovers may not align with good/decent weather conditions for ground data** **- Can cause a misunderstanding/errors in data if the readings are inaccurate**

Part 2: Atmospheric Corrections
The images that are taken satellites are often not the same images we see or use for our studies. Why is that? Think about where the satellites are and what the satellites images pick up along the way.

Satellites orbit around the planet in different layers of the atmosphere. As the satellites take images, there are particles within the atmosphere that can interfere with the information that the scientists are trying to extract from the image. Because of the particles and other things that may alter the image, scientists will apply "Atmospheric Corrections" to an image while processing the image for data.

Go to this website from the University of Bonn to learn more about Atmospheric Corrections:
http://fis.uni-bonn.de/en/recherchetools/infobox/professionals/preprocessing/atmospheric-correction

Answer the following questions about Atmospheric Corrections:

1. What does it mean to make atmospheric corrections on an image from a satellite?
Making atmospheric corrections to an image from a satellite means removing or "subtracting" reflectance from an image. Reflectance is "the radiation arriving at a sensor as it is influence by the atmosphere". Things can affect the radiance include water drops, aerosols, gas molecules, and other atmospheric particles. Because of these particles, the light that is reflected is not a direct reflection because it encounters particles in the atmosphere that distort the path of the light.

2. Why do we need to apply atmospheric corrections to satellite images?
We apply atmospheric corrections to satellite images because the particles in the atmosphere (wat drops, aerosols, gas molecules) can distort the light being reflected off of the surface of the Earth. The removal of the influence of these particles helps to put together a more accurate image of the light being reflected off of the surface.

Part 3: Retrieve/Collect data on the same date & time for all instruments
As you have seen with the Explore activity, we collected the data from all the instruments for the same time and day.

Discuss with a partner why it is important to always collect data for all devices being used in research at the same time and day.

Write your main discussion points in the space below.

-Consistency with data collection helps validate data (ex: if you collect data at 12pm on one day and 5pm on the next day, you will get different results which leads to inaccurate analysis/conclusion
-Collecting data at the same time every data collection day for all instruments helps to identify trends/patterns at study site.
-Can help with identifying errors with instruments and correct errors

Evaluate

After completing the *Explore, Explain, and Elevate* activities, revisit the questions from the beginning of the lesson below:

In the previous lesson we learned about satellites, how they gather data, and how we can utilize satellite data for scientific research. In your opinion, how accurate do you think data is that is retrieved from satellites? Explain your thoughts.

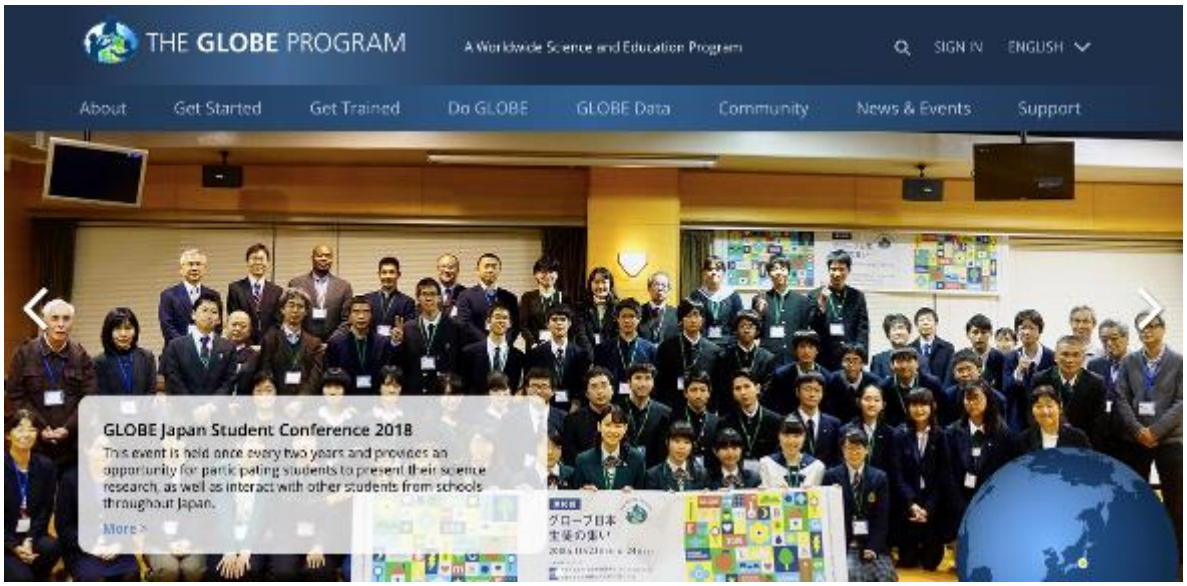
Answers will vary. Example response: I think that data retrieved from satellites is highly accurate. In the explore activity, the temperature collected with the thermal camera was within +/-5 degrees of the satellite data. For example, on day 3 the thermal camera average surface temperature reading was 35.5 C and the satellite average surface temperature reading was 35.8 C. In the explain activity, we learned from the "Ground truthing" video that scientists validate satellite data using both ground measurements via handheld instruments and airplanes with sensors. In the elevate activity, we saw that scientists do a series of tasks to make sure satellite data is accurate such as applying atmospheric corrections to images to get the true reflectance from the surfaces they are measuring. Overall, after completing this lesson I think that satellite data is highly accurate.

How has your viewpoint changed from the beginning of the lesson to now in regards to satellite data? Why or why not has you're your viewpoint changed?

Answer will vary. Example response: My viewpoint has not changed, if anything my viewpoint has been confirmed. At the beginning of the lesson I felt that satellite data was very accurate. In the explore activity, this was verified from the data I collected from both the handheld camera and satellite. On day 3, the readings were very close (35.5 C for the handheld camera, 35.8 C for the satellite). In the explain activity, my viewpoint was further verified through the video we watched which stated that scientists use a two point system (airplane and ground measurements) to validate satellite data in order to make sure the data is accurate. Lastly, in the elevate activity I read about how scientists apply atmospheric corrections to images in order to get the most accurate reading from the surface of the Earth. The information I learned throughout this lesson helped to support my viewpoint that satellite data is highly accurate.

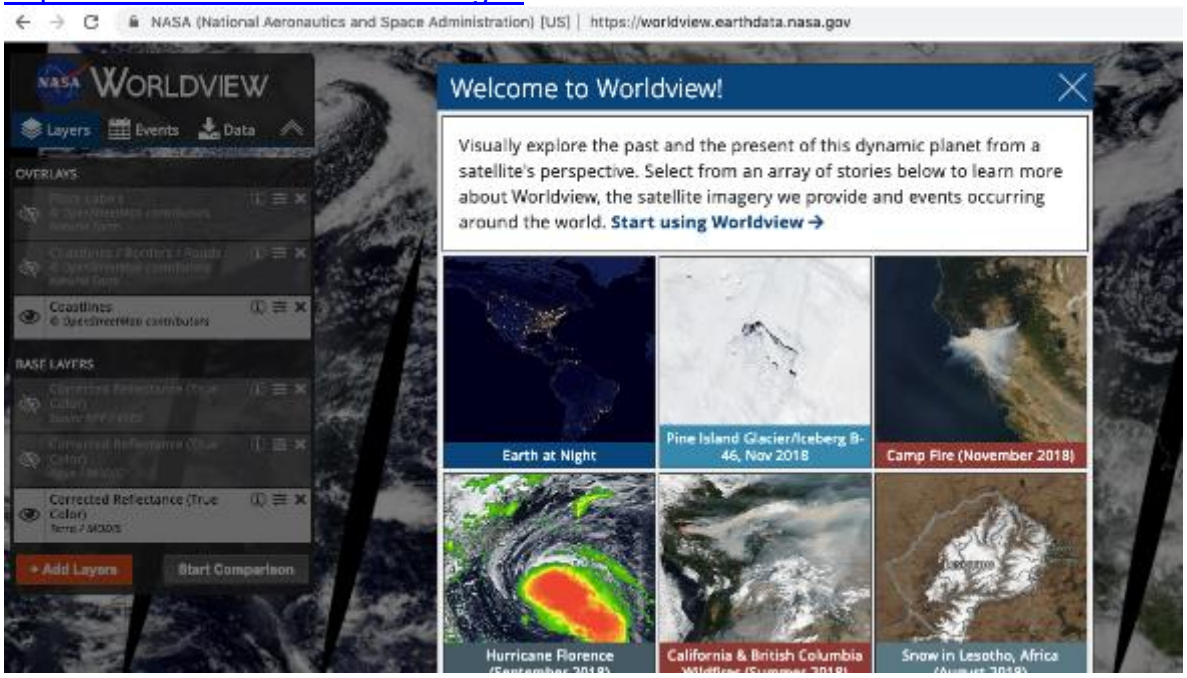
3. Globe Website (where to register and set up student accounts)

https://www.globe.gov



4. EOS Worldview (satellite data collection site)

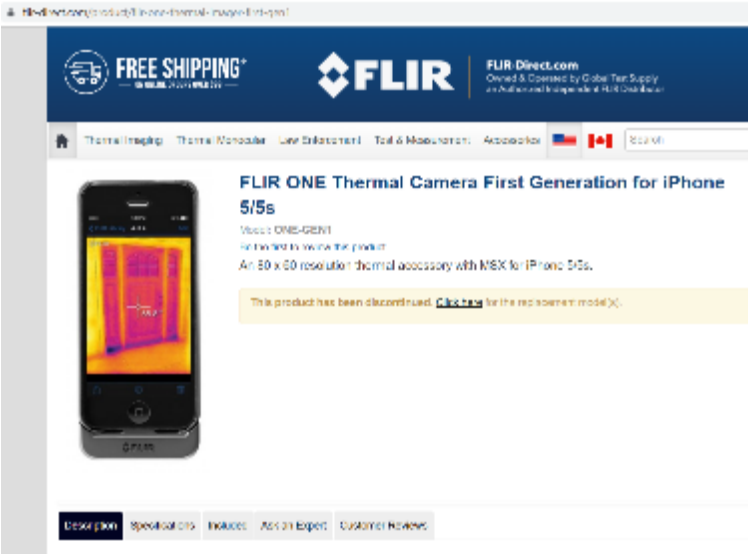
https://worldview.earthdata.nasa.gov



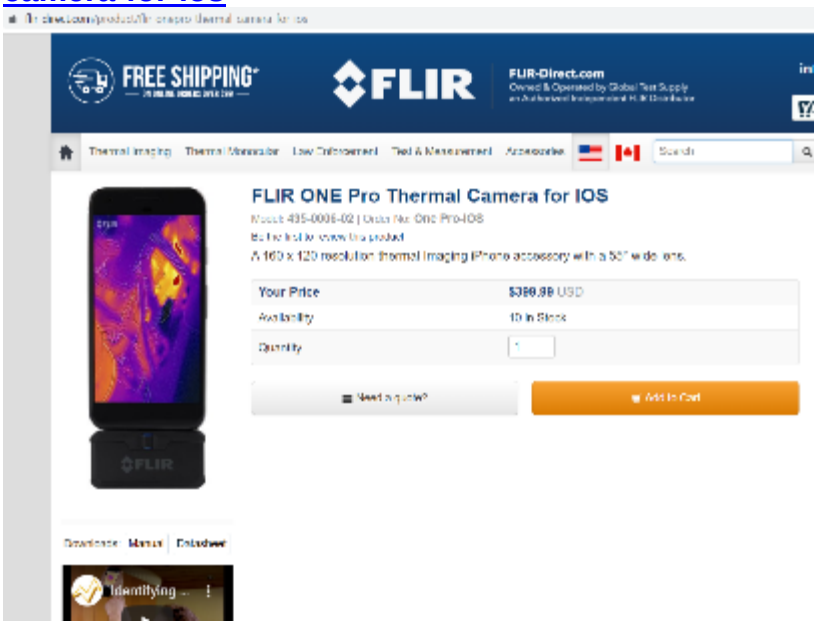
5. NASA Scientific Visualization Studio video "Remote Sensing: Observing the Earth" https://svs.gsfc.nasa.gov/2674

6. Weather at weather.gov

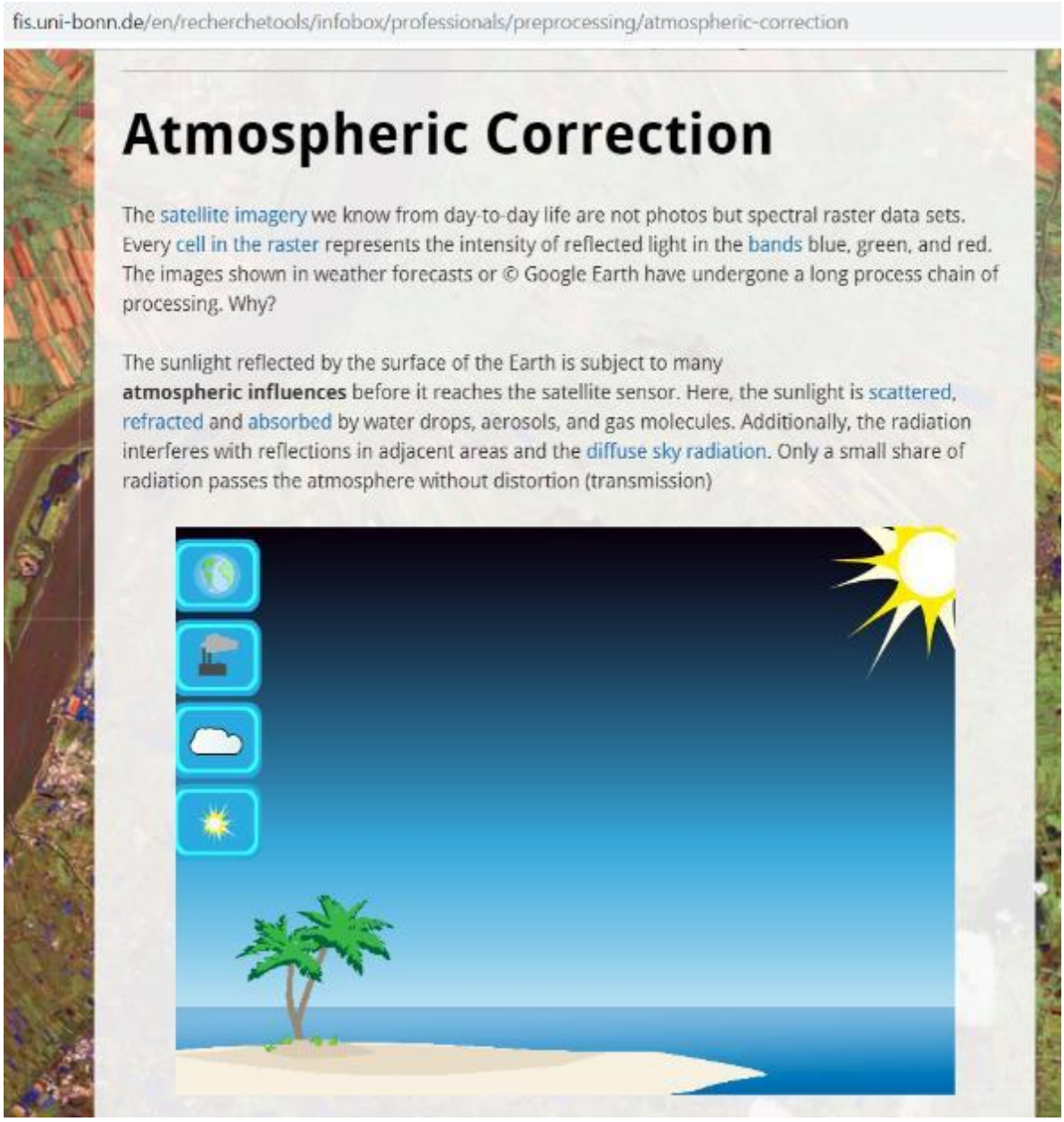
7. FLIR One Gen1 https://www.flir-direct.com/product/flir-one-thermal-imager-first-gen1



8. FLIR One Pro https://www.flir-direct.com/product/flir-onepro-thermal-camera-for-ios



9. Atmospheric Corrections – University of Bonn http://fis.uni-bonn.de/en/recherchetools/infobox/professionals/preprocessing/atmospheric-correction

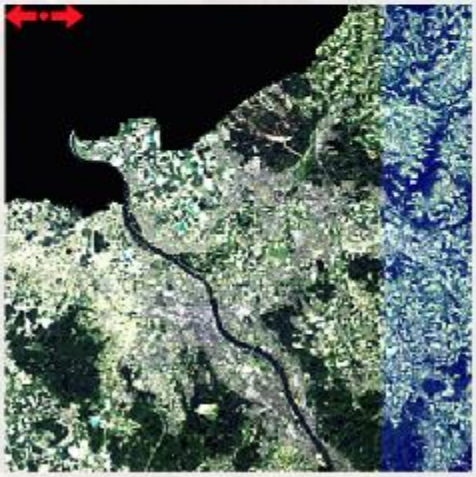


At the touch of a button, various light processes in the atmosphere or on the surface of the Earth can be activated, e.g. the scattering of light due to water drops.

Reflectance, radiance, and digital signals

The light arriving at the satellite sensor is not equal to the light reflected by a body on the surface of the Earth. The pure radiation is called **radiance**. The radiation arriving at the sensor is called **reflectance** as it is influenced by the atmosphere. To draw conclusions about the nature of the Earth's surface the influence of the atmosphere has to be subtracted from the reflectance. This process is called **atmospheric correction** in remote sensing. Atmospheric correction enables us to gauge the spectral fingerprint of an area.

The swipe below shows the product of an atmospheric correction processing. The image before preprocessing has an over-driven blue band. This means that vapour in the atmosphere leads to higher reflection vales in the blue band. Thus, the sensor registers higher values than were reflected on the surface of the Earth.



Spectral image before and after atmospheric correction. The over-drive in the blue band caused by diffuse sky radiation has been subtracted (Images of USGS/NASA Landsat Program).

Conclusion:
The sunlight reflected by the surface of the Earth is influenced by multiple processes in the atmosphere before it reaches the sensor of the satellite. The sunlight is scattered, refracted and absorbed by water drops, aerosols and gas molecules. Because of these processes, not the radiances free of interference but the reflectances are reaching the sensor. These have to be processed in such a manner that the nature of the Earth's surface can be derived. This process is called atmospheric correction.

← Preprocessing Geometric Correction →

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Datenschutzerklärung
Impressum

10. Lesson 2 Rubric

	Struggling	Approaching	At Level	Advanced
Engage *(HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.* *(HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).* *(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.* *(HSPS4-6) Mathematical representations can be used to identify certain patterns.* *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.*	The student is able to make a somewhat clear prediction of what temperatures they think will occur at each study site for the demonstration. The student is not able to describe the reason for their prediction and it is not based off of knowledge from the previous lesson. The student draws a somewhat clear illustration of the experimental set up. The illustration includes some of the labels of each part of the experimental set up. The student is able to draw a somewhat clear conclusion and inference about the accuracy of satellite data. The student includes does not include an example from the demonstration to support their response.	The student is able to make a clear prediction of what temperatures they think will occur at each study site for the demonstration. The student is able to somewhat describe the reason for their prediction but it may not be based off of knowledge from the previous lesson. The student draws a clear illustration of the experimental set up. The illustration includes most of the labels of each part of the experimental set up. The student is able to draw a clear conclusion and inference about the accuracy of satellite data. The student includes does not include an example from the demonstration to support their response.	The student is able to make a clear prediction of what temperatures they think will occur at each study site for the demonstration. The student is able to effectively describe the reason for their prediction based off of knowledge from the previous lesson. The student draws a clear illustration of the experimental set up. The illustration includes clear labels of each part of the experimental set up. The student is able to draw a clear conclusion and inference about the accuracy of satellite data. The student includes at least 1 example from the demonstration to support their response.	The student is able to make a clear prediction of what temperatures they think will occur at each study site for the demonstration. The student is able to effectively describe the reason for their prediction based off of knowledge from the previous lesson and includes at least 1 example to support their response. The student draws a clear illustration of the experimental set up. The illustration includes clear labels of each part of the experimental set up. The labels include a brief description of each part of the illustration. The student is able to draw a clear conclusion and inference about the accuracy of satellite data. The student includes more than 1 example from the demonstration

				to support their response.
Explore *(HS-PS4-2),(HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.* *(HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).* *(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.* *(HSPS4-6) Mathematical representations can be used to identify certain patterns.* *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* *CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.* *CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.*	The student has difficulty following the protocol for the data collection and needs guidance. The student has designated some of the 9 locations within their area of study, but not all. The student draws an illustration of the designated study area and where their 9 locations are within the study area but it is not completely clear. The illustration includes some or none of the labels of the 9 sites. The student records some of the required information in the provided organizer for part 1. Descriptions are somewhat understandable, but are not completely clear. Some of the boxes have been filled in on the organizer and are somewhat accurate. For part 2, the student has difficulty being able to extract and analyze the data according to the	The student is able to mostly follow the protocol for the data collection, but may need some guidance. The student has designated 9 locations within their area of study. The student draws a clear illustration of the designated study area and where their 9 locations are within the study area. The illustration includes most of the labels of the 9 sites. The student records most of the required information in the provided organizer for part 1. Descriptions are understandable, but may be somewhat unclear. Most of the boxes have been filled in on the organizer and are accurate. For part 2, the student is able to extract and analyze the data according to the directions, but may need some guidance. The	The student is able to effectively follow the protocol for the data collection. The student has designated 9 locations within their area of study. The student draws a clear illustration of the designated study area and where their 9 locations are within the study area. The illustration includes clear labels of each of the 9 sites. The student records all required information in the provided organizer for part 1. Descriptions are clear and easy to understand. All boxes have been filled in on the organizer and are accurate. For part 2, the student is able to extract and analyze the data according to the directions. The student has the information recorded on the provided organizer for part 2. The information is clear and easy to read. Calculations are correct.	The student is able to effectively follow the protocol for the data collection. The student has designated 9 locations within their area of study. The student draws a clear illustration of the designated study area and where their 9 locations are within the study area. The illustration includes clear labels of each of the 9 sites. The student records all required information in the provided organizer for part 1. Descriptions are clear and easy to understand. All boxes have been filled in on the organizer and are accurate. Observations include any items that may cause an error with the data results. For part 2, the student is able to extract and analyze the data according to the directions. The student has the information

	directions, and needs guidance. The student has some of the information recorded on the provided organizer for part 2. The information is somewhat readable. Calculations are somewhat or not correct.	student has the information recorded on the provided organizer for part 2. The information is easy to read. Calculations are mostly correct.		recorded on the provided organizer for part 2. The information is clear and easy to read. Calculations are correct.
Explain *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.* *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* *11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)* *(HS-PS4-2),(HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.* *(HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).*	The student has a somewhat effective discussion with other students which involves reviewing and comparing the results of the experiment from the previous activity, but may get distracted. The student is somewhat able to effectively describe why or why not the results were similar. The student does not include at least 1 example from the data in the previous activity to support their explanation. The student is somewhat able to describe how the method performed in the previous activity can help with data verification of satellites. The student does not use at least 1 example from the	The student has a mostly effective discussion with other students which involves reviewing and comparing the results of the experiment from the previous activity, but may get somewhat distracted. The student is able to effectively describe why or why not the results were similar. The student may include at least 1 example from the data in the previous activity to support their explanation. The student is able to mostly effectively describe how the method performed in the previous activity can help with data verification of satellites. The student does not use at least 1 example from the experiment to justify their response.	The student has an effective discussion with other students which involves reviewing and comparing the results of the experiment from the previous activity. The student is able to effectively describe why or why not the results were similar. The student uses at least 1 example from the data in the previous activity to support their explanation. The student is able to effectively describe how the method performed in the previous activity can help with data verification of satellites. The student uses an at least 1 example from the experiment to justify their response. The student is able to independently research ground truthing by	The student has an effective discussion with other students which involves reviewing and comparing the results of the experiment from the previous activity. The student is able to effectively describe why or why not the results were similar. The student uses more than 1 example from the data in the previous activity to support their explanation. The student is able to effectively and clearly describe how the method performed in the previous activity can help with data verification of satellites. The student uses more than 1 example from the experiment to justify their response.

(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. *(HSPS4-6) Mathematical representations can be used to identify certain patterns.*	experiment to justify their response. The student is somewhat able to independently research ground truthing by following the directions given in the activity, but needs guidance with completing the research. The student writes at less than 4 key points from the video. The key points show some evidence that the information is useful for understanding why scientists ground truth satellite data. The student has a somewhat effective discussion with another student to review their key points. The student does not have an additional key point in the organizer to help further enhance their understanding of ground truthing.	The student is able to independently research ground truthing by following the directions given in the activity. The student writes at least 4 key points from the video. The key points show evidence that the information is useful for understanding why scientists ground truth satellite data. The student has a somewhat effective discussion with another student to review their key points. The student does not have an additional key point in the organizer to help further enhance their understanding of ground truthing.	following the directions given in the activity. The student writes 5 clear key points from the video. The key points show evidence that the information is useful for understanding why scientists ground truth satellite data. The student has an effective discussion with another student to review their key points. The student has at least 1-2 additional key points in the organizer to help further enhance their understanding of ground truthing.	The student is able to independently research ground truthing by following the directions given in the activity. The student writes 5 clear key points from the video. The key points show evidence that the information is useful for understanding why scientists ground truth satellite data. The student has an effective discussion with another student to review their key points. The student has at least 2-5 additional key points in the organizer to help further enhance their understanding of ground truthing.
Elevate *(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.*	The student has some difficulty with finding the specifications of the handheld thermal camera. The student's responses in the organizer are somewhat	The student is able to find the specifications of the handheld thermal camera. The student's responses in the organizer are accurate to what the manual specifies	The student is able to effectively find the specifications of the handheld thermal camera. The student's responses in the organizer are accurate to what the manual	The student is able to effectively find the specifications of the handheld thermal camera. The student's responses in the organizer are accurate to

(HSPS4-6) Mathematical representations can be used to identify certain patterns. *CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.* *CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.*	accurate to what the manual specifies for the specifications. The student has 0-2 advantages and disadvantages for using a handheld thermal camera for the research. The advantages and disadvantages are somewhat accurate and demonstrates some understanding of the usage of the thermal camera. The student has some difficulty with accurately answering the questions on what it means to make atmospheric corrections and why we use atmospheric corrections using the information from the article. The student has some difficulty with having an effective discussion with their partner on why it is important to collect data on the same date/time. The student records some of their responses in the designated area of the organizer. The students responses reflect some	for the specifications. The student has 2-3 advantages and disadvantages for using a handheld thermal camera for the research. The advantages and disadvantages are mostly accurate and demonstrate an understanding of the usage of the thermal camera. The student is able to accurately answer the questions on what it means to make atmospheric corrections and why we use atmospheric corrections using the information from the article. The student is able to have an effective discussion with their partner on why it is important to collect data on the same date/time. The student records some of their responses in the designated area of the organizer. The students responses reflect an understanding of the concept of retrieving data on the	specifies for the specifications. The student has at least 3 advantages and disadvantages for using a handheld thermal camera for the research. The advantages and disadvantages are accurate and demonstrate an understanding of the usage of the thermal camera. The student is able to accurately answer the questions on what it means to make atmospheric corrections and why we use atmospheric corrections using the information from the article. The student is able to have an effective discussion with their partner on why it is important to collect data on the same date/time. The student records their responses in the designated area of the organizer. The students responses reflect an understanding of the concept of retrieving data on the same date/time for all instruments.	what the manual specifies for the specifications. The student has at least 3 advantages and disadvantages for using a handheld thermal camera for the research. The advantages and disadvantages are accurate and demonstrate an understanding of the usage of the thermal camera. The student is able to accurately answer the questions on what it means to make atmospheric corrections and why we use atmospheric corrections using the information from the article. The student cites direct quotations properly from the site to support their response. The student is able to have an effective discussion with their partner on why it is important to collect data on the same date/time. The student records their responses in the

	understanding of the concept of retrieving data on the same date/time for all instruments, but is missing important information to fully show understanding.	same date/time for all instruments, but may be missing some important information to fully show understanding.		designated area of the organizer. The students responses reflect an understanding of the concept of retrieving data on the same date/time for all instruments.
Evaluate CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research. (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HSPS4-6) Mathematical representations can be used to identify certain patterns. (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)	The student has some difficulty being able to describe the accuracy of satellite data clearly. The student does not use examples from the lesson to help support their response. The student has some difficulty being able to describe how their viewpoint changed from the beginning of the lesson. The student does not use examples from the lesson to support their response as to why their viewpoint has or has not changed.	The student is mostly able to describe the accuracy of satellite data clearly. The student uses at least 1 example from the lesson to help support their response. The student is mostly able to describe how their viewpoint changed from the beginning of the lesson. The student uses at least 1 example from the lesson to support their response as to why their viewpoint has or has not changed.	The student is able to describe the accuracy of satellite data clearly. The student uses at least 2 examples from the lesson to help support their response. The student is able to describe how their viewpoint changed from the beginning of the lesson. The student uses at least 2 examples from the lesson to support their response as to why their viewpoint has or has not changed.	The student is able to describe the accuracy of satellite data clearly. The student uses at least 3 examples from the lesson to help support their response. The student is able to describe how their viewpoint changed from the beginning of the lesson. The student uses at least 3 examples from the lesson to support their response as to why their viewpoint has or has not changed.

f. Conclusion and Linkages to Next Lesson

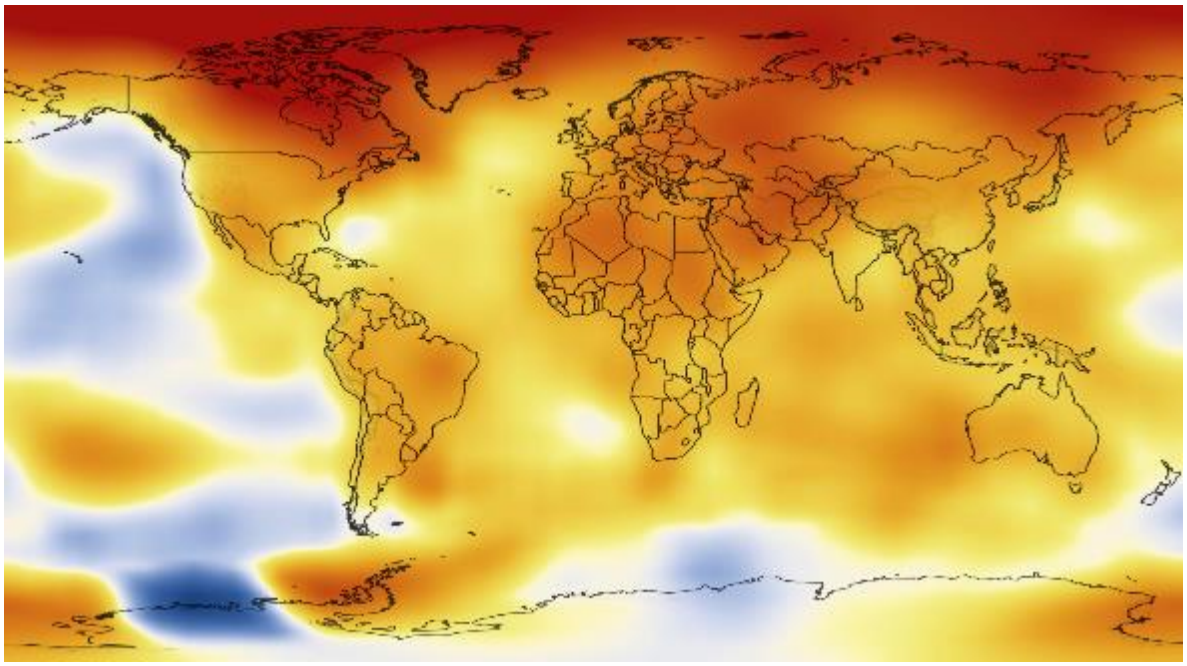
In this lesson, students learned what it means for scientists to perform ground validation to verify the data collected by satellites. Students will use these methods in the next lesson to understand urban heat island intensity and how we can use both ground and satellite data to pinpoint areas of particularly high intensity in urban environments.

NASA Goddard Institute for Space Studies (GISS)
Climate Change Research Initiative (CCRI)
Applied Research STEM Curriculum Unit Portfolio

Unit Title: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

Lesson Title: Things are getting tense: A look at Urban Heat Island Intensity

NASA STEM Educator / Associate Researcher: Elizabeth Sebastian
NASA PI / Mentor: Dr. Stuart Gaffin, Dr. Robert Blake, & Dr. Hamidreza Norouzi
NASA GSFC Office of Education – Code 160



XI. Lesson 3: Things are getting tense: A look at Urban Heat Island Intensity

a. Summary and Goals of Lesson

In the third lesson of the unit, students will learn about urban heat island intensity and how we use data to pinpoint areas of particularly high intensity. The lesson starts out with students viewing an "Image of Change" from the NASA Scientific Visualization studio of Shanghai. The before/after image depicts urban expansion and how it has taken away vegetation. Students will then select a city in the Explore activity to investigate urban heat island intensity. Students will use Landsat data in coordination with a Google Earth Engine's Urban Heat Island Intensity data set in order to track the range of intensity year by year for a 14-year time span. Students will then analyze the data to find a correlation between intensity and the changing state of the urban environment. Students will follow up their research with learning about UHI intensity through two sources: NASA's Urban Heat Islands video from GSFC and an article titled "Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect". In the Elevate activity, students will then connect the information they gathered with demographic data for the area of study to identify patterns/trends between socio/economic status with UHI intensity. The lesson wraps up with students reflecting on how they can use the data collected in the lesson to take steps to reduce the Urban Heat Island Effect. The goal of the lesson is to have students understand all components to determine Urban Heat Island intensity and use the components to develop a plan to change the intensity.

b. Table of Contents for lesson

a. Summary and Goals of Lesson……121
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d. Content Template……129
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**Some of the resources in this lesson may require either a Windows, Mac, or Linux computer in order to run properly.*

c. 5 E lesson model template:

Unit: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

Topic: Urban Heat Island Intensity

Prior Learning: Students must understand the Urban Heat Island concept. Students must be proficient in research methods to gather information to support their data (using valid websites/resources).

Do Now (Pre-Assessment): "In the past few lessons, we have been looking at satellite data, thermal imagery, and other sources to observe land surface temperature (LST). What factors do you think affect the intensity and/or increase of surface temperatures in urban areas?"

Aim: What are the main factors that determine Urban Heat Island Intensity and how can we use this information to reduce the Urban Heat Island Effect?

New York State Standards & Next Generation Science Standards:

- (HS-ESS3-5) Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
- (HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes
- (HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.
- (HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
- (HS-PS4-2), (HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- (HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).
- (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- (HSPS4-6) Mathematical representations can be used to identify certain patterns.
- (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)

Common Core State Standards:

- CCSS.MATH.CONTENT.HSN.Q.A.2
  Define appropriate quantities for the purpose of descriptive modeling.
- CCSS.MATH.CONTENT.HSN.Q.A.3
  Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- CCSS.ELA-LITERACY.W.9-10.9
  Draw evidence from literary or informational texts to support analysis, reflection, and research.

NASA System of Engineering Behavior:

- *Leadership*
  - Understands the Human Dynamics of a Team
- *Attitudes & Attributes*
  - Seeks Information and Uses the Art of Questioning
- *Systems Thinking*
  - Assimilates, Analyzes, and Synthesizes Data
  - Has the Ability to Find Connections and Patterns Across the System
- *Communications*
  - Communicates Effectively Through Personal Interaction
  - Facilitates an Environment of Open and Honest Communication
- *Technical Acumen*
  - Possesses Technical Competence and Has Comprehensive Previous Experience

Performance Objective: Students will be able to research and analyze historical temperature data in order to understand the main factors that determine Urban Heat Island Intensity.

Materials:

- Lesson 3 worksheet
- Computer
- NASA Images of Change "Urban Expansion in Shanghai China" https://climate.nasa.gov/images-of-change?id=603#603-urban-expansion-in-shanghai-china
- Google Earth Desktop Application (downloaded onto computers beforehand)
  - *This application requires Windows, Mac, or a Linux computer
  - **An alternative resource, EOS Worldview, is available for this activity. Instructions are on page 143
- Urban Heat Island Intensity Map https://yceo.users.earthengine.app/view/uhimap
- NASA Urban Heat Islands video https://www.youtube.com/watch?v=lnBO4vX82Fs
- NASA "Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect" article https://www.nasa.gov/mission_pages/terra/news/heat-islands.html
- US Government Census Bureau Interactive Maps https://www.census.gov/programs-surveys/geography/data/interactive-maps.html

Vocabulary: Urban Heat Island Intensity

<u>Development of Lesson:</u> Two Day Lessons (Approximately two 50-minute periods).

What the Teacher does	What the Student does	Time
Do Now! (Anticipatory Opening) As the students are coming into class and setting up, direct students to complete the *Do Now!* Section of the worksheet.	Students will complete the Do Now! Section of the worksheet.	5 minutes
Engage Students will now complete the Engage section of the worksheet. Direct students to pair up with another student (preferably the student they have been previously working with in other lessons). With their partners, students will view a NASA Image of Change of Shanghai. The image shows two pictures of Shanghai before and after urbanization. Students will view the images and then provide an explanation in the organizer provided in the section about what they think occurred in the city and how it might affect the land surface temperature (LST). Allow students 3 minutes to complete this activity. After 3 minutes, ask students, "What did you observe in the two images of Shanghai?" Have students volunteer what they wrote in the organizer. On the board, have the same organizer to write down student responses. Example responses are on the Worksheet Answer Key. **Assessment Opportunity #1 (Use Worksheet Answer Key & Engage section of rubric to assess)**	Students will now complete the Engage section of the worksheet. Students will work with a partner (preferably the student they have been working with in other lessons) to complete the activity. With their partner, students will view a NASA Image of Change of Shanghai. Students can use a variety of tools to view the image (toggle, side by side, separate viewing). Students will then brainstorm with their partner to write down observations of the picture and an explanation of what they think has occurred in the picture in the organizer provided. Students can then volunteer their findings aloud with the class when directed by the teacher.	5 minutes
Explore Students will now complete the Explore section of the worksheet. Students will continue to work with their partner from the previous activity to learn about Urban Heat Island Intensity. Direct students to meet with their partner to complete the Explore activity. Students will work with their partner to select a city of their choice and use a google earth engine Urban Heat Island map to explore UHI intensity over the past 14 years. While students are working, walk around the classroom to make sure students are able to follow the steps and to provide guidance if students need it. Students will record in a table provided the "Summer Daytime UHI", "Summer Nighttime UHI",	Students will now complete the Explore section of the worksheet. Students will continue to work with their partner from the previous activity to learn about Urban Heat Island Intensity. Students will meet with their partner to complete the Explore activity. Students will work with their partner to select a city of their choice and use a google earth engine Urban Heat Island map to explore UHI intensity over the past 14 years. Students will record in a table provided the "Summer Daytime UHI", "Summer Nighttime UHI", "Highest Summer Daytime Intensity", "Lowest Summer	20 minutes

"Highest Summer Daytime Intensity", "Lowest Summer Daytime Intensity", "Range of Intensity", "Picture of the City", and "Observations". Allow 20 minutes for students to complete the activity. **Assessment Opportunity #2 (Use Worksheet Answer Key & Explore section of rubric to assess.)**	Daytime Intensity", "Range of Intensity", "Picture of the City", and "Observations".	
Explain After completing the Explore activity, direct students to complete the Explain activity which is in three parts. Part 1 Students will reflect with their partner on the data collected in the Explore activity. Students will answer three questions that focus on correlations between UHI and land surface and how this data can help determine mitigation strategies. Allow 5 minutes for students to complete this part. Part 2 Students will then complete part 2 with their partner to learn more about UHI intensity. Students will view the NASA Urban Heat Island video and read the article "Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect". While viewing/reading the information, students will first take notes in their organizer provided in this section. They will then discuss with their partner the information they gathered form the video/article. This will take about 10 minutes. Students will then find another pair of students to discuss their findings. Students will record any new findings from the discussion in the table provided. This part will take about 5 minutes. Part 3 Students will then create a "mind map" with their partner and the other pair of students they met with in Part 2 outlining the key concepts of urban heat islands that they have learned throughout this lesson. This will take about 3-5 minutes. While the students are completing parts 1-3, walk around the classroom to provide students with guidance as needed.	After completing the Explore activity, students will complete the Explain activity which is in three parts. Part 1 Students will reflect with their partner on the data collected in the Explore activity. Students will answer three questions that focus on correlations between UHI and land surface and how this data can help determine mitigation strategies. Part 2 Students will then complete part 2 with their partner to learn more about UHI intensity. Students will view the NASA Urban Heat Island video and read the article "Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect". While viewing/reading the information, students will first take notes in their organizer provided in this section. They will then discuss with their partner the information they gathered form the video/article. Students will then find another pair of students to discuss their findings. Students will record any new findings from the discussion in the table provided. Part 3 Students will then create a "mind map" with their partner and the other pair of students they met with in Part 2 outlining the key concepts of urban heat islands that they have learned throughout this lesson. When the teacher draws the mind map on the board, students can volunteer key ideas they wrote on their mind map.	30 minutes

After students have completed part 3, draw a mind map on the board for Urban Heat Island. Ask students, “What are some of your key ideas from your mind map?” Have students volunteer key ideas they wrote on their mind map. Write the response on the board. With students, refer back to the organizer created at the beginning of the lesson. Brainstorm aloud with students similarities/differences in the two organizers and how it helps us understand UHI. This will take about 5-7 minutes. **Assessment Opportunity #3 (Use the Worksheet Answer Key & Explain section of rubric to assess.)**		
Elevate Direct students to the Elevate activity. Students will work with their partner from the previous activities to find the demographics of the city from the Explore activity. Before working, have a volunteer student (or a few) read aloud the directions. After reading the directions, open the census website on the board to show students where they can find the two types of demographic maps mentioned in the instructions. After showing students the maps, provide 5-10 minutes for students to complete the demographic data collection. While students are completing the data collection, walk around the classroom to help students as needed. Students will record their findings in an organizer provided in the Elevate section of the worksheet. After completing the research, students will answer two questions about their findings: are there trends/patterns and is there a correlation within the data. Allow an additional 3-5 minutes for students to answer these questions. After students have completed the questions, draw a box on the board below the two organizers already on the board. Ask students, “What trends/patterns did you identify within the data?” Have students volunteer their responses to the two questions. Write their responses in the box on the board. Then ask, “Are there correlations within the data?” Write their responses in the box on the board. Lastly ask, “What is the connection we see between the three organizers of information?” Have	Students will now complete the Elevate activity. Students will work with their partner from the previous activities to find the demographics of the city from the Explore activity. Before working, a volunteer student (or a few) will read aloud the directions. After reading the directions, the teacher will show how to navigate the census website to collect data for the activity. Students will then complete the demographic data collection activity. Students will record their findings in an organizer provided in the Elevate section of the worksheet. After completing the research, students will answer two questions about their findings: are there trends/patterns and is there a correlation within the data. After students have completed the questions, students can volunteer their responses to the two questions. The teacher will then ask aloud, “What is the connection we see between the three organizers of information?” Students can brainstorm aloud their thoughts (this will help them with the Evaluate questions).	15-20 minutes

students brainstorm aloud their thoughts (this will help them with the Evaluate questions). **Assessment Opportunity #4 (Use the Worksheet Answer Key & Elevate section of rubric to assess.)**		
Evaluate It is recommended to use this section as a homework. It can also be used as an exit ticket. Students will independently complete the Evaluate section of the worksheet. Students will answer two questions based on the Explore, Explain, and Elevate activities: "Based on the information gained during Explore, Explain, and Elevate activities, what would be some next steps that scientists could take to reduce the Urban Heat Island effect? Use the data/information from the activities to support your reasoning." And "What are the main factors that determine Urban Heat Island intensity? Use the data/information from the activities to support your answer." **Assessment Opportunity #5 (Use the Worksheet Answer Key & Evaluate section of rubric to assess.)**	For homework or an exit ticket, students will independently complete the Evaluate section of the worksheet. Students will answer two questions based on the Explore, Explain, and Elevate activities: "Based on the information gained during Explore, Explain, and Elevate activities, what would be some next steps that scientists could take to reduce the Urban Heat Island effect? Use the data/information from the activities to support your reasoning." And "What are the main factors that determine Urban Heat Island intensity? Use the data/information from the activities to support your answer."	5 minutes

Summary/Conclusion:

The students will answer two questions based on the activities: "What would be some next steps that scientists could take to reduce the Urban Heat Island effect?" And "What are the main factors that determine Urban Heat Island intensity? Use the data/information from the activities to support your answer." The students will answer the questions in the Evaluate section of the worksheet.

Higher Order Questions:

1. How can the data you collected be used to understand the urban heat island effect?
2. Is there a correlation between the "hot spots" of the city and the socio/economic status of the population in the city? If so, what is it? Why do you think this correlation may exist?
3. Based on the information gained during Explore, Explain, and Elevate activities, what would be some next steps that scientists could take to reduce the Urban Heat Island effect?

Differentiated Instruction:

- The students learn the content in a variety of ways. The students learn content through visual formats (images and videos), oral discussion, experimental design, data analysis, and reflection.
- Students use data analysis tools to create graphs of their final results from the experiment.
- Students use a variety of technology to learn about content (Google Earth Pro Desktop App, YouTube).
- Students are provided with a variety of leveled questions (low-high order) to answer questions at their level and elevate their thought processes.
- Students are given the chance to review their understanding through oral discussion in order to confirm or add to their understanding of the content.
- Students will use a graphic organizer to help with their understanding of the content and organize the content in an orderly, easily readable fashion.

Daily Formative Assessment:

1. Based on the information gained during Explore, Explain, and Elevate activities, what would be some next steps that scientists could take to reduce the Urban Heat Island effect? Use the data/information from the activities to support your reasoning.
2. What are the main factors that determine Urban Heat Island intensity? Use the data/information from the activities to support your answer.

Next Lesson: Bioswales, Topography, and Urban Heat, Oh My!: Understanding the Mitigation Strategy Bioswales

d. Content template:

NGSS Standard & State Science Content Standard: (HS-ESS3-5) Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes (HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-PS4-2),(HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HSPS4-6) Mathematical representations can be used to identify certain patterns. (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)			Common Core Standard: CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.	NASA Science: Earth Science
Content Area: Earth Science/Environmental Science Grade Level: 9th Grade		Name of Project-Based Activity or Theme: Things are getting tense: A look at Urban Heat Island Intensity	Estimated Time Frame to Complete(days/weeks): 2 classes/days	
Overall Investigation Question(s): What are the main factors that determine Urban Heat Island Intensity and how can we use this information to reduce the Urban Heat Island Effect?				
Overall Project Description/Activity: Students will be able to research and analyze historical temperature data in order to understand the main factors that determine Urban Heat Island Intensity.				
	:			
Materials Needed to Complete Project (put N/A as needed). Lesson 3 worksheet Computer NASA Images of Change "Urban Expansion in Shanghai China" Google Earth Pro Desktop App	Stakeholders: Fusion Academy: Education Team, Administrators, Science Department, Science Teachers, and students	Hyperlinks Used: NASA Images of Change "Urban Expansion in Shanghai China" https://climate.nasa.gov/images-of-change?id=603#603-urban-expansion-in-shanghai-china Urban Heat Island Intensity Map https://yceo.users.earthengine.app/view/uhimap NASA Urban Heat Islands video https://www.youtube.com/watch?v=lnBO4vX82Fs NASA "Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect" article	Multimedia/Technology: Computer NASA Images of Change "Urban Expansion in Shanghai China" Google Earth Pro Desktop App Urban Heat Island Intensity Map NASA Urban Heat Islands video NASA "Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect" article	Classroom Equipment: Computer

Urban Heat Island Intensity Map NASA Urban Heat Islands video NASA "Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect" article US Government Census Bureau Interactive Maps		https://www.nasa.gov/mission_pages/terra/news/heat-islands.html US Government Census Bureau Interactive Maps https://www.census.gov/programs-surveys/geography/data/interactive-maps.html	US Government Census Bureau Interactive Maps	
NASA System Engineering Behaviors (2 behaviors per category)	Category (must have one Technical Acumen)	Activities How will student model engineering behaviors when learning science content? Describe student activities here.	Student Outcomes How will you assess learning for each behavior	Evaluation Describe specific science content students understand as a result of engineering behavior.
Understands the Human Dynamics of a Team	Leadership	Students work in pairs to complete the Explore and Explain activities (collecting data on urban heat island intensity using various sources of information)	Lesson 3 Rubric – Explore and Explain Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Seeks Information and Uses the Art of Questioning	Attitudes & Attributes	Students will research information on urban heat island intensity in the Explain activity.	Lesson 3 Rubric – Explain Category	Data collection, data analysis, validation of data, infrared

				energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Assimilates, Analyzes, and Synthesizes Data	Systems Thinking	Students will obtain urban heat island intensity information from a variety of sources. Students will interpret the data in order to identify the areas of most intense UHI and the factors that cause the UHI in the Explore, Explain, and Elevate activities.	Lesson 3 Rubric – Explore, Explain, and Elevate Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Has the Ability to Find Connections and Patterns Across the System	Systems Thinking	Students will obtain urban heat island intensity information from a variety of sources. Students will interpret the data in order to identify the areas of most intense UHI and the factors that cause the UHI in the Explore, Explain, and Elevate activities.	Lesson 3 Rubric – Explore, Explain, and Elevate Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon

Communicates Effectively Through Personal Interaction	Communications	Students work in pairs to complete the Explore & Explain activities. Must have effective communications in order to be successful in activities.	Lesson 3 Rubric – Explore and Explain Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Facilitates an Environment of Open and Honest Communication	Communications	Students work in pairs to complete the Explore & Explain activities. Must have effective communications in order to be successful in activities.	Lesson 3 Rubric – Explain and Explain Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Possesses Technical Competence and Has Comprehensive Previous Experience	Technical Acumen	For the Explore activity, students must have a comprehensive knowledge of retrieving and analyzing data from a variety of sources in order to determine UHI intensity.	Lesson 3 Rubric – Explore Category	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment,

				using technology to understand phenomenon
List and attach all supportive documents for instructional activities	Attachments? (circle) Yes or No	List Attached Documents(if any): Lesson 3 Worksheet		
List and attach all rubrics for activity and assessment evaluation	Attachments? (circle) Yes or No	List Attached Rubrics (if any): Lesson 3 rubric		
Include comments or questions here:				

e. Supporting Documents: (order according to sequence of lesson.)

1. Lesson 3 worksheet

"Things are getting tense"

A look at Urban Heat Island Intensity

Do Now!

In the past few lessons we have been looking at satellite data, thermal imagery, and other sources to observe land surface temperature (LST). What factors do you think affect the intensity and/or increase of surface temperatures in urban areas?

_____
_____
_____
_____

Engage

With a partner, go to the NASA Visualization Studio and observe the image of Shanghai. Use the variety of toggles at the bottom right of the image to view the two images from different perspectives. In the space provided below, write down your observations of what you notice in the two images of Shanghai.

Beneath your observations, provide an explanation as to what occurred in the city and how it might affect LST.

Go to: https://climate.nasa.gov/images-of-change?id=603#603-urban-expansion-in-shanghai-china

Observations:

Explanation:

Explore

Continuing to work with your partner, you will now observe a concept called Urban Heat Island intensity. Follow the directions below to explore more about this concept.

1. Select a city from the list below to study in this activity. Write the selected city on the space provided.

Available Cities to Study:

- New York City	- Pittsburgh	- Phoenix
- Philadelphia	- Columbus	- Los Angeles
- Providence	- Atlanta	- San Francisco
- Washington DC	- Houston	- Sacramento
- Detroit	- Dallas	- Portland
- Chicago	- Minneapolis	- Seattle

City of Study: _____

2. Once you have selected your city, go to: https://yceo.users.earthengine.app/view/uhimap
3. In the search bar at the top, type in your city. Suggestions will start popping up underneath the search bar. Click your city. The map will then redirect and zoom you in on your city. At the top left of the screen you will see a scroll bar to change the year. You will need to use this for the data collection below.
4. Click on an area in the city. Make sure the area you click on has data for that particular location (has a colored pixel over top of it).
5. On the bottom left side of the screen, there is a key to indicate the color of different intensities. There is also a drop-down menu to change the view of the intensities. Click the drop-down menu and select “Summer Day”. This will overlay the data of UHI intensity for an average summer day in your city.
6. On the right side of the screen you will see data for the drop down you selected. You will use this area for the next step.
7. Observe the Summer Daytime UHI. Write this value in the table below in the “Summer Daytime UHI” column. Repeat for “Summer Nighttime UHI”.
8. You will now determine the Highest Summer Daytime Intensity and Lowest Summer Daytime Intensity. Using the key at the left of the screen, determine which value is the highest value shown in the data on your screen. Record the intensity in the column “Highest Summer Daytime Intensity”. Repeat this process for the “Lowest Summer Daytime Intensity”.
9. Calculate the range of intensity by subtracting the “Lowest Summer Daytime Intensity” from the “Highest Summer Daytime Intensity”. Record the value in the “Range of Intensity” column in the table below.
10. In order to keep track of changes in both temperature and city structure, you will take 2 images of the city for each year.
    a. First, select screen shot the city. Make sure to include the key in your image as a reference point.
    b. Go to Google Earth Pro desktop app. Type in your city into the search bar at the top left of the screen and hit “search”. Once the screen has automatically zoomed into your city, go to the top of the screen and click “view” and select “historical imagery”. At the top left you will see a scroll bar that will allow you to change the years. Place the tool at the year being observed. Once set, take a selected screen shot of the city. Make sure it is encompassing the same area as the image you collected in the previous step. ***An alternative source, EOS Worldview, is provided at the end of the worksheet if you are unable to use Google Earth Pro*.
11. In the last column, write any observations you noticed with the data collection for that year.

12. Repeat steps 7-10 for all the years listed in the table.
13. Once all data has been collected, you will then complete the last row of the table. The last row is to calculate/identify changes over the time span.
    a. For columns “Summer Daytime UHI”, “Summer Nighttime UHI”, Highest Summer Daytime Intensity”, “Lowest Summer Daytime Intensity”, and “Range of Intensity”, calculate the change of temperatures over the years. This may turn out to be either a positive or negative value.
    b. For columns “Picture of City” and “Observations”, you will identify the overall changes that have occurred during the time span of data collection.

Urban Heat Island Intensity Table

Year	Summer Daytime UHI	Summer Nighttime UHI	Highest Summer Daytime Intensity	Lowest Summer Daytime Intensity	Range of Intensity	Picture of City	Observations
2003							
2004							
2005							
2006							
2007							
2008							
2009							
2010							
2011							
2012							
2013							
2014							
2015							
2016							
2017							
Change							

Explain

Part 1

With your partner, answer the following questions below in regards to the *Explore* activity.

1. Based on your data, is there a correlation between UHI intensity and changes in land surface temperature? Why?

_____
_____
_____
_____
_____
_____
_____

2. How can the data you collected be used to understand the urban heat island effect?

_____
_____
_____
_____
_____
_____

3. How could you use the data to determine mitigation strategies in an urban area?

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_____

Part 2

You've looked at the land surface temperature, intensity of the urban heat island, and changes in surfaces in urban areas. What is the point in collecting all of this data? What are we trying to understand? In the activity below, you will learn about the reasoning behind collecting LST, UHI intensity, and surface changes. With your partner from the *Explore* activity, complete the task below.

1. Go to https://www.youtube.com/watch?v=lnBO4vX82Fs and watch the video "NASA Urban Heat Islands". While watching, use the organizer below to write down notes.
2. After watching the video, discuss with your partner the information from the video. Write down additional notes/discussion points in the organizer below.
3. Go to https://www.nasa.gov/mission_pages/terra/news/heat-islands.html and read the article "Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect". While reading, use the organizer below to write down notes.
4. After reading the article, discuss with your partner the information from the article. Write down additional notes/discussion points in the organizer below.
5. After reading/viewing the article and video, with your partner, find another pair of students. With the pair, discuss what you and your partner found in the video and article. Write down any new/additional findings from the discussion in the last column of the organizer below.

Resource	Notes	Discussion with Partner Notes	Discussion with Other Students Notes
NASA Urban Heat Islands Video			
Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect article			

Part 3

With your partner and the other pair of students, you will now create a mind map of the important points from both the video/article. Use the space below to create a mind map of the Urban Heat Island.

Elevate

We've looked at cities in regards to LST and surface coverage. However, with the Urban Heat Island, a large component that can be overlooked when analyzing UHI is the population living in these areas. In the activity below, you will find out the demographics of the city you selected to see how the "hot spots" of the city correlate with the demographics in these areas.

With your partner, follow the directions below.

1. Go to https://www.census.gov/programs-surveys/geography/data/interactive-maps.html
2. On this site, you will find a variety of interactive maps that uses the US census data. You can use either the "Census Data Mapper" and/or the "Metro/Micro Thematic Map Viewer". First browse through both to get a better idea of which would better suit your research needs.
3. After browsing through both maps, use one or both maps, research the demographics and record research findings below. It is suggested to draw a rough outline of the city with the "hot spots" (areas of higher/highest temperatures) to help with correlating data. After researching, answer the questions below the organizer.

Demographics Data Collection

Questions to keep in mind while researching:

- *In the "hot spot" areas of the city:*
    - *What is the majority age range?*
    - *What is the economic status?*
    - *What is the population concentration?*
    - *Are there more families or single households?*
    - *What is the main type of housing?*
    - *What is the main race?*

Questions:

1. Are there any trends/patterns in the data you collected? Explain.

_____
_____
_____
_____
_____

2. Is there a correlation between the "hot spots" of the city and the socio/economic status of the population in the city? If so, what is it? Why do you think this correlation may exist?

_____
_____
_____
_____
_____
_____
_____

Evaluate

Independently, answer the questions below.

1. Based on the information gained during *Explore, Explain, and Elevate* activities, what would be some next steps that scientists could take to reduce the Urban Heat Island effect? Use the data/information from the activities to support your reasoning.

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_____
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2. What are the main factors that determine Urban Heat Island intensity? Use the data/information from the activities to support your answer.

_____
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**Alternative resource, EOS Worldview, for the "Explore" activity

b. Go to Google Earth Pro desktop app. Type in your city into the search bar at the top left of the screen and hit "search". Once the screen has automatically zoomed into your city, go to the top of the screen and click "view" and select "historical imagery". At the top left you will see a scroll bar that will allow you to change the years. Place the tool at the year being observed. Once set, take a selected screen shot of the city. Make sure it is encompassing the same area as the image you collected in the previous step. You will now take selected screenshots of the data displayed for each year. Start at your first selected date. In total, you will have 10 images. Depending on the computer you are using follow the instructions below. After each image you screen shot, save it to a folder on your desktop. You will need all the images to paste into your worksheet.

2. Lesson 3 worksheet Answer Key

"Things are getting tense"

A look at Urban Heat Island Intensity

Do Now!

In the past few lessons we have been looking at satellite data, thermal imagery, and other sources to observe land surface temperature (LST). What factors do you think affect the intensity and/or increase of surface temperatures in urban areas?

Answers will vary. Example response: In the first lesson we saw that as a city expanded in size, the average surface temperatures increased. This could be in part due to the increase in impervious surfaces such as concrete and asphalt and the reduction of vegetated surfaces.

Engage

With a partner, go to the NASA Visualization Studio and observe the image of Shanghai. Use the variety of toggles at the bottom right of the image to view the two images from different perspectives. In the space provided below, write down your observations of what you notice in the two images of Shanghai.

Beneath your observations, provide an explanation as to what occurred in the city and how it might affect LST.

Go to: https://climate.nasa.gov/images-of-change?id=603#603-urban-expansion-in-shanghai-china

Observations:

- **The first image has a lot of vegetation**
- **The first image has a small built area in comparison to the second image**
- **The second image has drastically more built area**
- **There is very little vegetated area below the sand/beach area.**

Explanation:

From the time the first image was taken to the time the second image was taken, Shanghai's population grew which in turn required more buildings to support the population growth. Therefore, the vegetated area was converted into buildings to accommodate the population growth.

Explore ***For this activity, an example set of responses are given for an example study**

Continuing to work with your partner, you will now observe a concept called Urban Heat Island intensity. Follow the directions below to explore more about this concept.

1. Select a city from the list below to study in this activity. Write the selected city on the space provided.

Available Cities to Study:

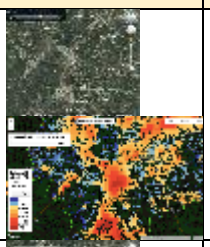
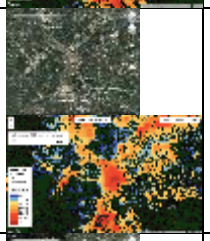
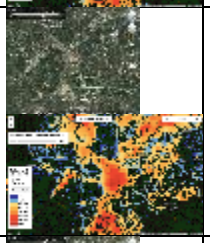
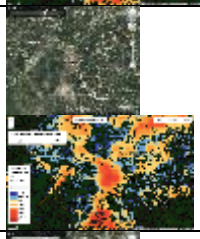
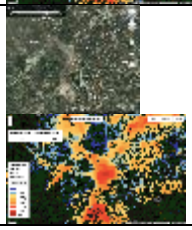
- New York City	- Pittsburgh	- Phoenix
- Philadelphia	- Columbus	- Los Angeles
- Providence	- Atlanta	- San Francisco
- Washington DC	- Houston	- Sacramento
- Detroit	- Dallas	- Portland
- Chicago	- Minneapolis	- Seattle

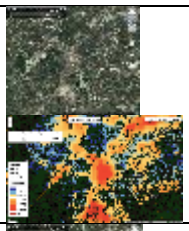
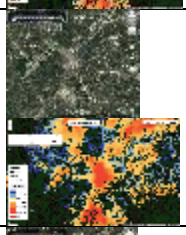
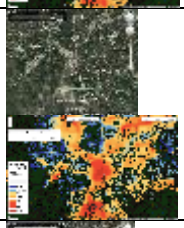
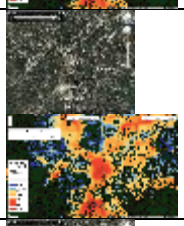
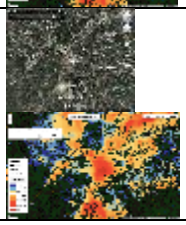
City of Study: _____**Atlanta**_____

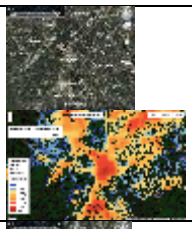
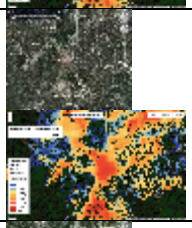
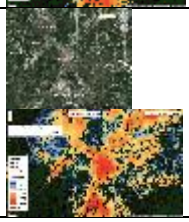
2. Once you have selected your city, go to: https://yceo.users.earthengine.app/view/uhimap
3. In the search bar at the top, type in your city. Suggestions will start popping up underneath the search bar. Click your city. The map will then redirect and zoom you in on your city. At the top left of the screen you will see a scroll bar to change the year. You will need to use this for the data collection below.
4. Click on an area in the city. Make sure the area you click on has data for that particular location (has a colored pixel over top of it).
5. On the bottom left side of the screen, there is a key to indicate the color of different intensities. There is also a drop-down menu to change the view of the intensities. Click the drop-down menu and select “Summer Day”. This will overlay the data of UHI intensity for an average summer day in your city.
6. On the right side of the screen you will see data for the drop down you selected. You will use this area for the next step.
7. Observe the Summer Daytime UHI. Write this value in the table below in the “Summer Daytime UHI” column. Repeat for “Summer Nighttime UHI”.
8. You will now determine the Highest Summer Daytime Intensity and Lowest Summer Daytime Intensity. Using the key at the left of the screen, determine which value is the highest value shown in the data on your screen. Record the intensity in the column “Highest Summer Daytime Intensity”. Repeat this process for the “Lowest Summer Daytime Intensity”.
9. Calculate the range of intensity by subtracting the “Lowest Summer Daytime Intensity” from the “Highest Summer Daytime Intensity”. Record the value in the “Range of Intensity” column in the table below.
10. In order to keep track of changes in both temperature and city structure, you will take 2 images of the city for each year.
    a. First, select screen shot the city. Make sure to include the key in your image as a reference point.
    b. Go to Google Earth Pro desktop app. Type in your city into the search bar at the top left of the screen and hit “search”. Once the screen has automatically zoomed into your city, go to the top of the screen and click “view” and select “historical imagery”. At the top left you will see a scroll bar that will allow you to change the years. Place the tool at the year being observed. Once set, take a selected screen shot of the city. Make sure it is encompassing the same area as the image you collected in the previous step. ***An alternative source, EOS Worldview, is provided at the end of the worksheet if you are unable to use Google Earth Pro*.

11. In the last column, write any observations you noticed with the data collection for that year.
12. Repeat steps 7-10 for all the years listed in the table.
13. Once all data has been collected, you will then complete the last row of the table. The last row is to calculate/identify changes over the time span.
    a. For columns “Summer Daytime UHI”, “Summer Nighttime UHI”, Highest Summer Daytime Intensity”, “Lowest Summer Daytime Intensity”, and “Range of Intensity”, calculate the change of temperatures over the years. This may turn out to be either a positive or negative value.
    b. For columns “Picture of City” and “Observations”, you will identify the overall changes that have occurred during the time span of data collection.

Urban Heat Island Intensity Table

Year	Summer Daytime UHI	Summer Night-time UHI	Highest Summer Daytime Intensity	Lowest Summer Daytime Intensity	Range of Intensity	Picture of City	Observations
2003	1.42 C	0.39 C	>7.5 C	<-1.5 C	9.0 C		
2004	1.42 C	0.39 C	>7.5 C	<-1.5 C	9.0 C		
2005	1.42 C	0.39 C	>7.5 C	<-1.5 C	9.0 C		
2006	1.42 C	0.39 C	>7.5 C	<-1.5 C	9.0 C		
2007	1.42 C	0.39 C	>7.5 C	<-1.5 C	9.0 C		

2008	**1.42 C**	**0.39 C**	**>7.5 C**	**<-1.5 C**	**9.0 C**		
2009	**1.42 C**	**0.39 C**	**>7.5 C**	**<-1.5 C**	**9.0 C**		
2010	**1.42 C**	**0.39 C**	**>7.5 C**	**<-1.5 C**	**9.0 C**		
2011	**1.42 C**	**0.39 C**	**>7.5 C**	**<-1.5 C**	**9.0 C**		
2012	**1.42 C**	**0.39 C**	**>7.5 C**	**<-1.5 C**	**9.0 C**		
2013	**1.42 C**	**0.39 C**	**>7.5 C**	**<-1.5 C**	**9.0 C**		
2014	**1.42 C**	**0.39 C**	**>7.5 C**	**<-1.5 C**	**9.0 C**		

2015	**1.42 C**	**0.39 C**	**>7.5 C**	**<-1.5 C**	**9.0 C**		
2016	**1.42 C**	**0.39 C**	**>7.5 C**	**<-1.5 C**	**9.0 C**		
2017	**1.42 C**	**0.39 C**	**>7.5 C**	**<-1.5 C**	**9.0 C**		
Change	**None**	**None**	**None**	**None**	**None**		

Explain

Part 1 Answers will vary. Example responses below are based off of the example responses from the Explore activity sample set

With your partner, answer the following questions below in regards to the *Explore* activity.

1. Based on your data, is there a correlation between UHI intensity and changes in land surface temperature? Why?

It was difficult to distinguish in our study city of UHI intensity and changes in land surface temperature are correlated because the city itself did not change noticeably enough (in terms of impervious surfaces) to have an effect on UHI (at least from our study city.

2. How can the data you collected be used to understand the urban heat island effect?

In terms of the urban heat island effect, we can use the intensity map with the historical imagery of the land surface of the city from the same year to see where the higher intensity of heat is in urban environments. For example, we can see in the center of Atlanta it is very built up and has a high UHI intensity.

3. How could you use the data to determine mitigation strategies in an urban area?

Both images collected in the Explore activity can help us identify the areas that UHI effect is having the largest effect. By identifying these areas where UHI intensity is the greatest, we can develop mitigation strategies that first target these areas to reduce the UHI effect.

Part 2 Answers in this section will vary based on discussion. Example responses are provided below.

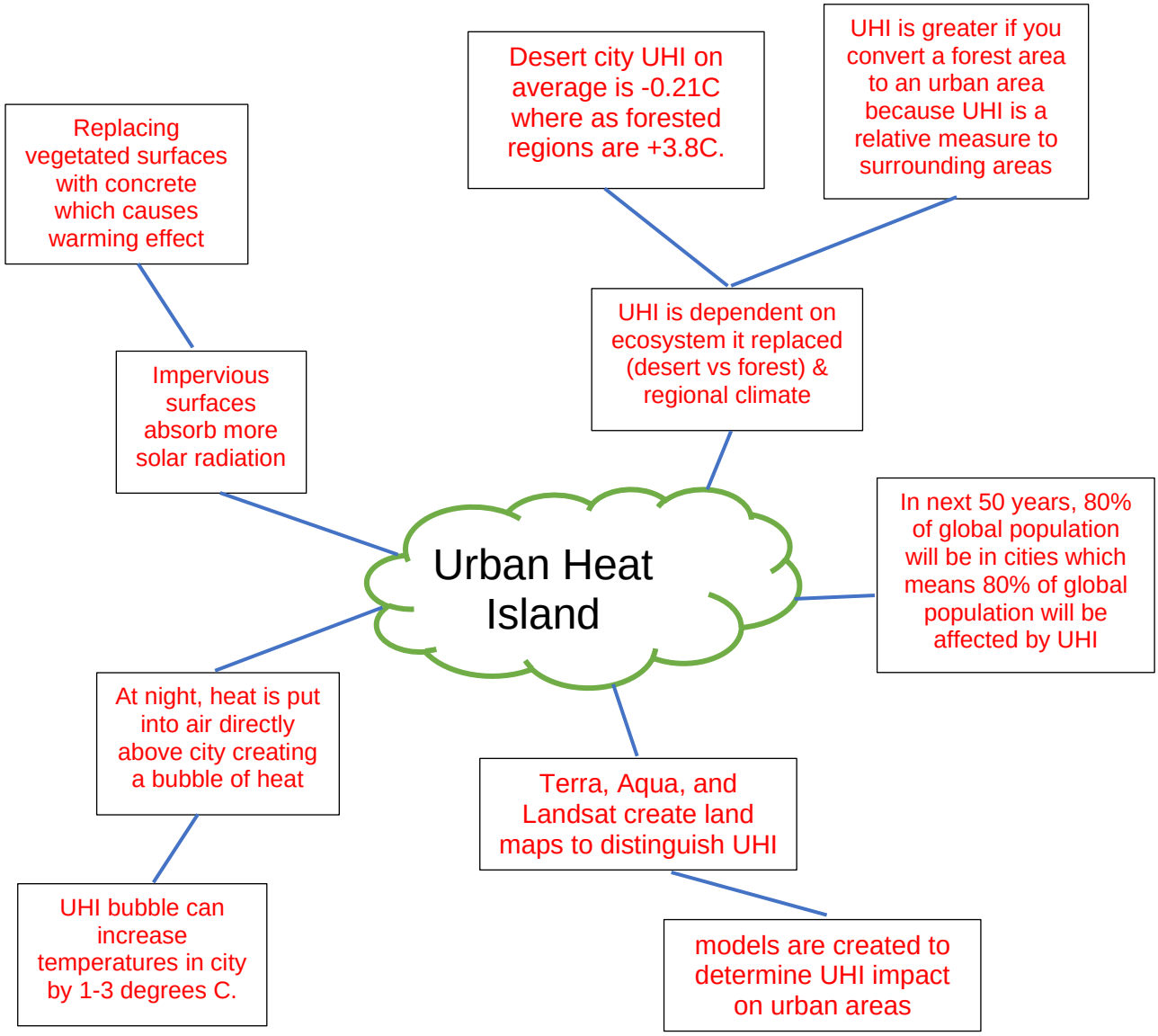
You've looked at the land surface temperature, intensity of the urban heat island, and changes in surfaces in urban areas. What is the point in collecting all of this data? What are we trying to understand? In the activity below, you will learn about the reasoning behind collecting LST, UHI intensity, and surface changes. With your partner from the *Explore* activity, complete the task below.

1. Go to https://www.youtube.com/watch?v=lnBO4vX82Fs and watch the video "NASA Urban Heat Islands". While watching, use the organizer below to write down notes.
2. After watching the video, discuss with your partner the information from the video. Write down additional notes/discussion points in the organizer below.
3. Go to https://www.nasa.gov/mission_pages/terra/news/heat-islands.html and read the article "Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect". While reading, use the organizer below to write down notes.
4. After reading the article, discuss with your partner the information from the article. Write down additional notes/discussion points in the organizer below.
5. After reading/viewing the article and video, with your partner, find another pair of students. With the pair, discuss what you and your partner found in the video and article. Write down any new/additional findings from the discussion in the last column of the organizer below.

Resource	Notes	Discussion with Partner Notes	Discussion with Other Students Notes
NASA Urban Heat Islands Video	-replacing vegetated surfaces with concrete which causes warming effect - factors that affect UHI: surrounding areas, size of city, shape of city, development patterns of city - urban areas by forests experience more intense UHI because surrounding area is much cooler than for example a city that is surrounded by desert	-NASA uses MODIS and Landsat to help determine UHI -UHI is greater if you convert a forest area to an urban area because UHI is a relative measure to surrounding areas -UHI affects health, how much heating/ac we need to heat/cool living spaces	-impervious surface data tells us how much building material is on the land -in next 50 years, 80% of global population will be in cities which means 80% of global population will be affected by UHI
Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect article	-UHI is dependent on ecosystem it replaced (desert vs forest) & regional climate -impervious surfaces absorb more solar radiation -UHI bubble can increase temperatures in city by 1-3 degrees C. -Terra, Aqua, and Landsat create land maps to distinguish UHI	-placement and structure of cities matters for UHI -at night, heat is put into air directly above city creating a bubble of heat -desert city UHI on average is -0.21C where as forested regions are +3.8C.	-UHI is affected by amount of vegetation in urban area -impervious surfaces creates faster runoff = less cooling effect by water through evaporation

	-models are created to determine UHI impact on urban areas		

Part 3
With your partner and the other pair of students, you will now create a mind map of the important points from both the video/article. Use the space below to create a mind map of the Urban Heat Island.



Elevate

We've looked at cities in regards to LST and surface coverage. However, with the Urban Heat Island, a large component that can be overlooked when analyzing UHI is the population living in these areas. In the activity below, you will find out the demographics of the city you selected to see how the "hot spots" of the city correlate with the demographics in these areas.

With your partner, follow the directions below.

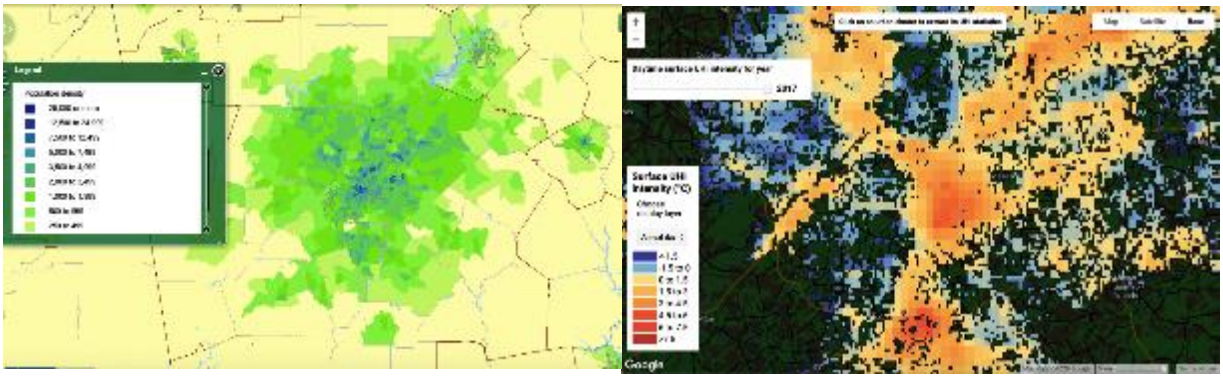
1. Go to https://www.census.gov/programs-surveys/geography/data/interactive-maps.html
2. On this site, you will find a variety of interactive maps that uses the US census data. You can use either the "Census Data Mapper" and/or the "Metro/Micro Thematic Map Viewer". First browse through both to get a better idea of which would better suit your research needs.
3. After browsing through both maps, use one or both maps, research the demographics and record research findings below. It is suggested to draw a rough outline of the city with the "hot spots" (areas of higher/highest temperatures) to help with correlating data. After researching, answer the questions below the organizer.

Demographics Data Collection

Questions to keep in mind while researching:

- *In the "hot spot" areas of the city:*
    - *What is the majority age range?*
    - *What is the economic status?*
    - *What is the population concentration?*
    - *Are there more families or single households?*
    - *What is the main type of housing?*
    - *What is the main race?*

Majority Age Range: 21.9-36.4
Economic Status: 12-14% in poverty
Population concentration: 7,500-12,499 (image on below)
Families or Single household: 35-81% are single household
Type of Housing: Single household
Main race: Black or African American



Questions:

1. Are there any trends/patterns in the data you collected? Explain.

Yes, in the two images and the data collected in the box above you can see that the hot spots on the image on the right are the same areas where we see the densest population.

2. Is there a correlation between the "hot spots" of the city and the socio/economic status of the population in the city? If so, what is it? Why do you think this correlation may exist?

Based on the available data it was hard to distinguish the socio/economic status of areas within the city as the data was shown as a county. The counties that do make up Atlanta, do show that the average income is 40K and the poverty rate is 12-14%. While not particularly low income, the city average income is not is not as high as other cities such as New York County (Manhattan) which is 81K.

Evaluate

Independently, answer the questions below.

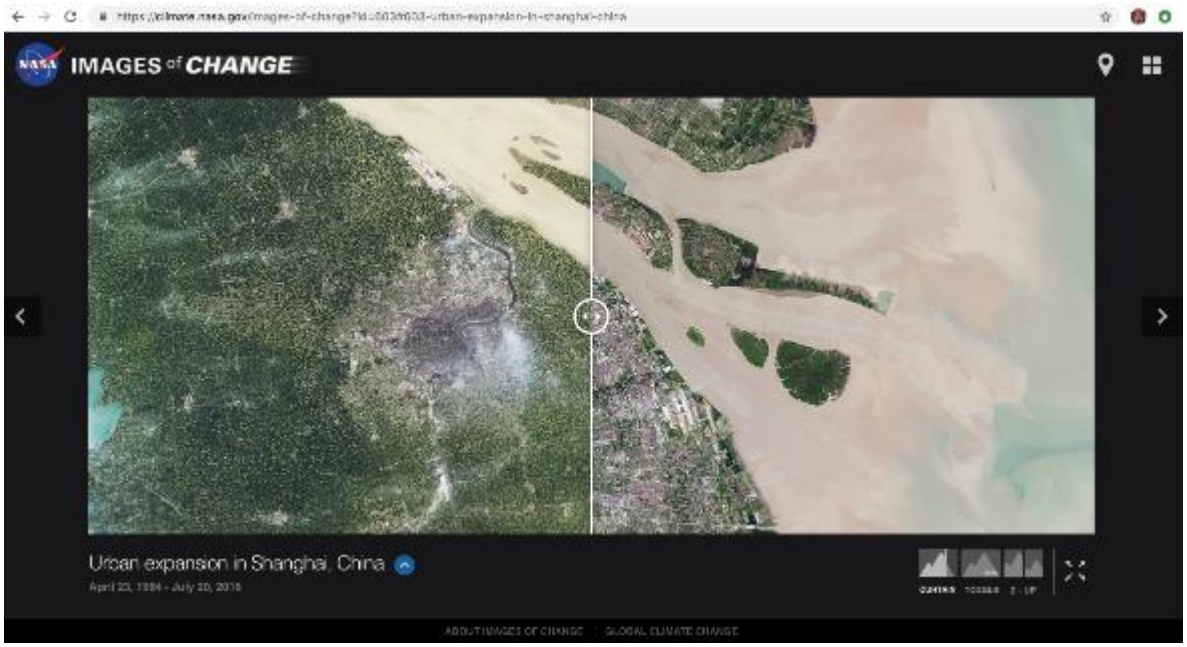
1. Based on the information gained during *Explore, Explain, and Elevate* activities, what would be some next steps that scientists could take to reduce the Urban Heat Island effect? Use the data/information from the activities to support your reasoning.

Based on what I learned in the activities, urban areas contain more impervious areas than their surrounding areas. Because of the higher amount of impervious areas, we see that the urban area has an average higher surface temperature than the surrounding suburban/rural areas. For example, in the Explore activity, the highest surface temperatures for Atlanta are where we see the most impervious/built areas. According to the information we learned in the Explain activity, more vegetation would decrease the land surface temperatures. Based on this information, scientists could begin reducing the urban heat island effect by turning some of the impervious surfaces into vegetated surfaces.

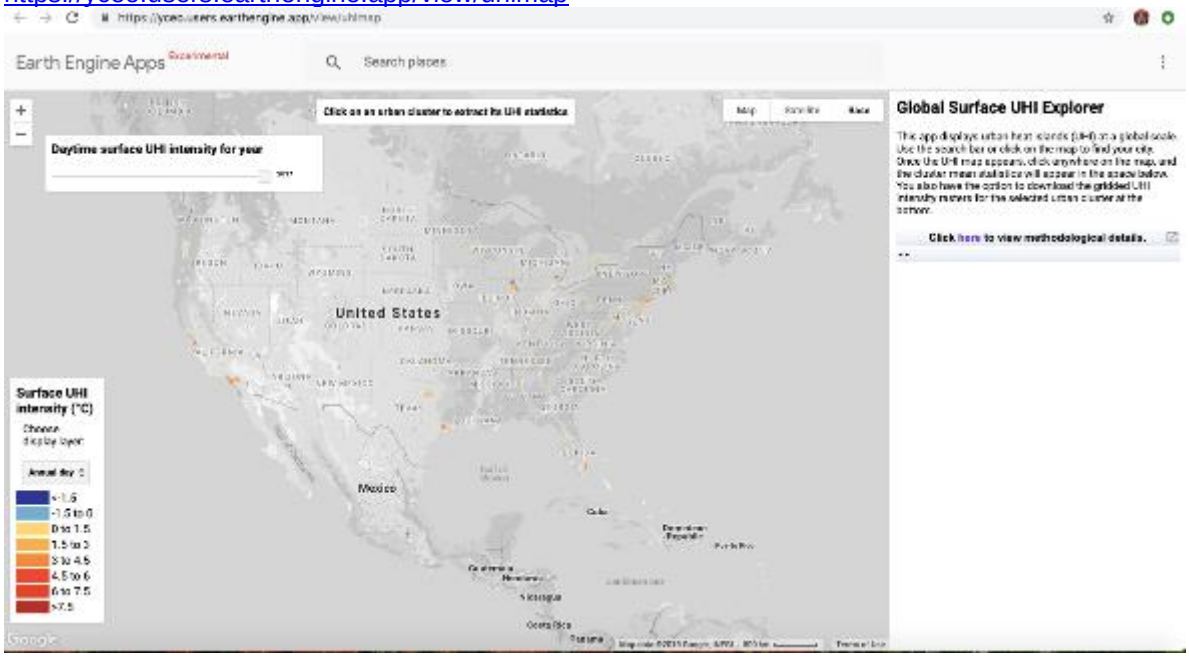
2. What are the main factors that determine Urban Heat Island intensity? Use the data/information from the activities to support your answer.

The main factors that determine UHI intensity are amount of impervious surfaces, surrounding area type, and population density. As we saw in our data for the Explore activity, the areas that had more impervious surfaces had the higher UHI intensity. In the explain activity, we learned that the surrounding ecosystem can impact how intense UHI is for an urban area. For example, if a city is surrounded by desert, the UHI intensity of the city is less than a city that is surrounded by forests. Lastly, we saw in the Elevate activity that the areas that had higher UHI intensity had higher populations. If we compare these higher populated areas in Atlanta to the Google Earth image showing the land surface type, the areas of higher populations are in the areas that have a higher amount of impervious surfaces.

2. NASA Images of Change, Urban Expansion in Shanghai China
https://climate.nasa.gov/images-of-change?id=603#603-urban-expansion-in-shanghai-china



3. Google Earth Engine Urban Heat Island Intensity Interactive Map
https://yceo.users.earthengine.app/view/uhimap

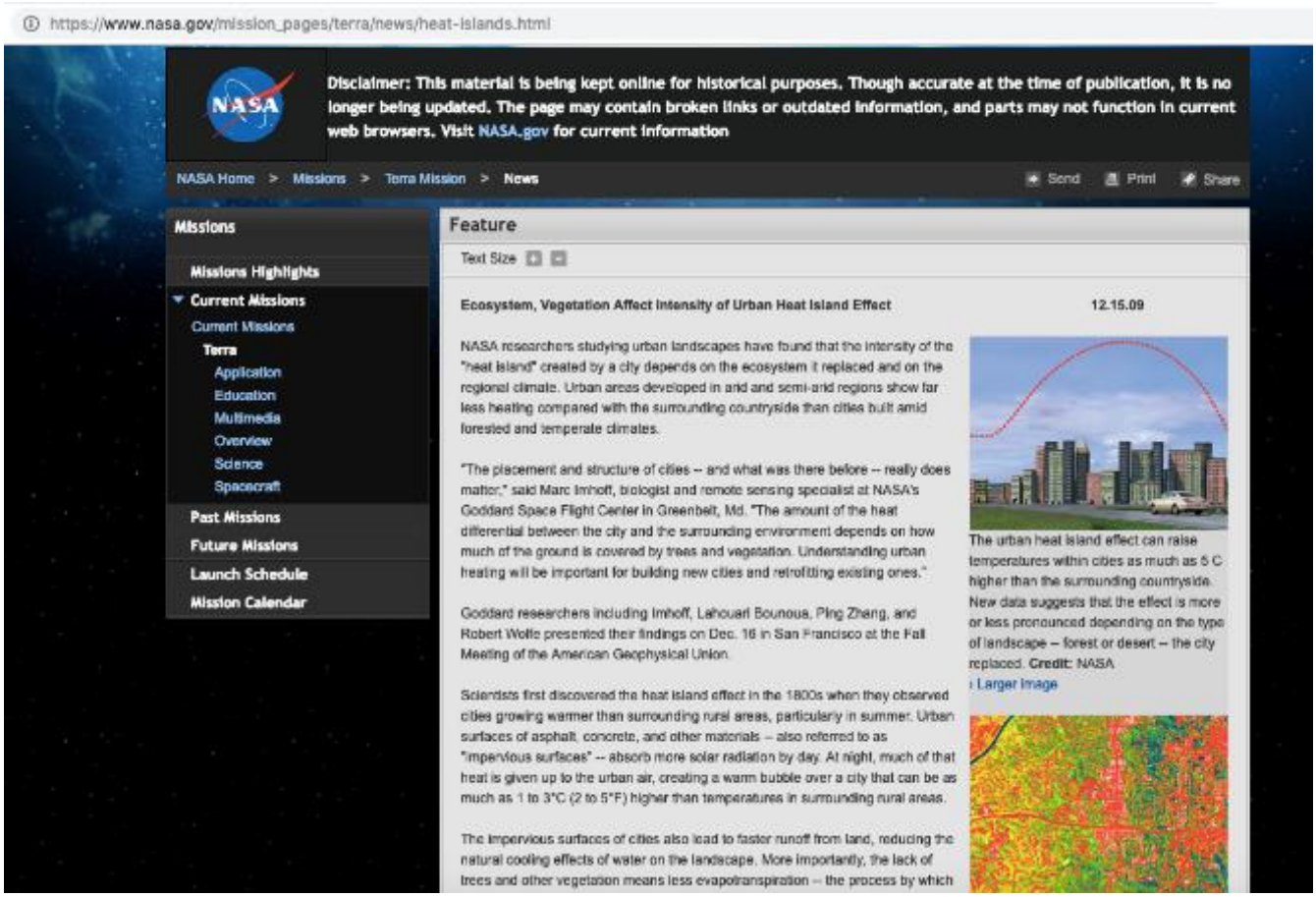


4. NASA Urban Heat Islands Video

https://www.youtube.com/watch?v=lnBO4vX82Fs

5. NASA Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect" Article

https://www.nasa.gov/mission_pages/terra/news/heat-islands.html



https://www.nasa.gov/mission_pages/terra/news/heat-islands.html

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Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect 12.15.09

NASA researchers studying urban landscapes have found that the intensity of the "heat island" created by a city depends on the ecosystem it replaced and on the regional climate. Urban areas developed in arid and semi-arid regions show far less heating compared with the surrounding countryside than cities built amid forested and temperate climates.

"The placement and structure of cities -- and what was there before -- really does matter," said Marc Imhoff, biologist and remote sensing specialist at NASA's Goddard Space Flight Center in Greenbelt, Md. "The amount of the heat differential between the city and the surrounding environment depends on how much of the ground is covered by trees and vegetation. Understanding urban heating will be important for building new cities and retrofitting existing ones."

Goddard researchers including Imhoff, Lahouari Bounoua, Ping Zhang, and Robert Wolfe presented their findings on Dec. 16 in San Francisco at the Fall Meeting of the American Geophysical Union.

Scientists first discovered the heat island effect in the 1800s when they observed cities growing warmer than surrounding rural areas, particularly in summer. Urban surfaces of asphalt, concrete, and other materials -- also referred to as "impervious surfaces" -- absorb more solar radiation by day. At night, much of that heat is given up to the urban air, creating a warm bubble over a city that can be as much as 1 to 3°C (2 to 5°F) higher than temperatures in surrounding rural areas.

The impervious surfaces of cities also lead to faster runoff from land, reducing the natural cooling effects of water on the landscape. More importantly, the lack of trees and other vegetation means less evapotranspiration -- the process by which

The urban heat island effect can raise temperatures within cities as much as 5 C higher than the surrounding countryside. New data suggests that the effect is more or less pronounced depending on the type of landscape -- forest or desert -- the city replaced. **Credit:** NASA

Larger Image

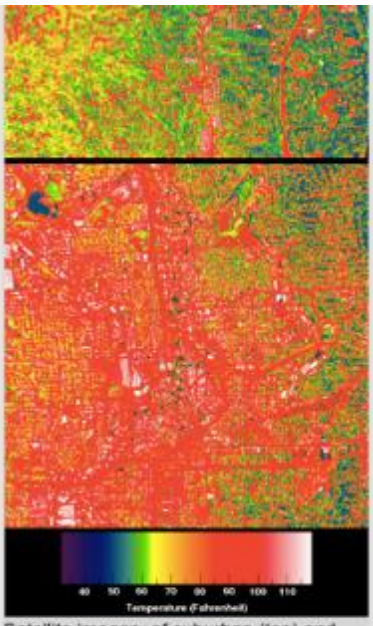
trees and other vegetation means less evapotranspiration -- the process by which trees "exhale" water. Trees also provide shade, a secondary cooling effect in urban landscapes.

Using instruments from NASA's Terra and Aqua satellites, as well as the joint U.S. Geological Survey-NASA satellite Landsat, researchers created land-use maps distinguishing urban surfaces from vegetation. The team then used computer models to assess the impact of urbanized land on energy, water, and carbon balances at Earth's surface.

When examining cities in arid and semi-arid regions -- such as North Africa and the American Southwest -- scientists found that they are only slightly warmer than surrounding areas in summer and sometimes cooler than surrounding areas in winter. In the U.S., the summertime urban heat island (UHI) for desert cities like Las Vegas was 0.46°C lower than surrounding areas, compared to 10°C higher for cities like Baltimore. Globally, the differences were not as large, with a summertime UHI of -0.21°C for desert cities compared to +3.8°C for cities in forested regions.

In a quirk of surface heating, the suburban areas around desert cities are actually cooler than both the city center and the outer rural areas because the irrigation of lawns and small farms leads to more moisture in the air from plants that would not naturally grow in the region.

"If you build a city in an area that is naturally forested -- such as Atlanta or Baltimore -- you are making a much deeper alteration of the ecosystem," said Imhoff. "In semi-arid areas with less vegetation -- like Las Vegas or Phoenix -- you are making less of a change in the energy balance of the landscape."



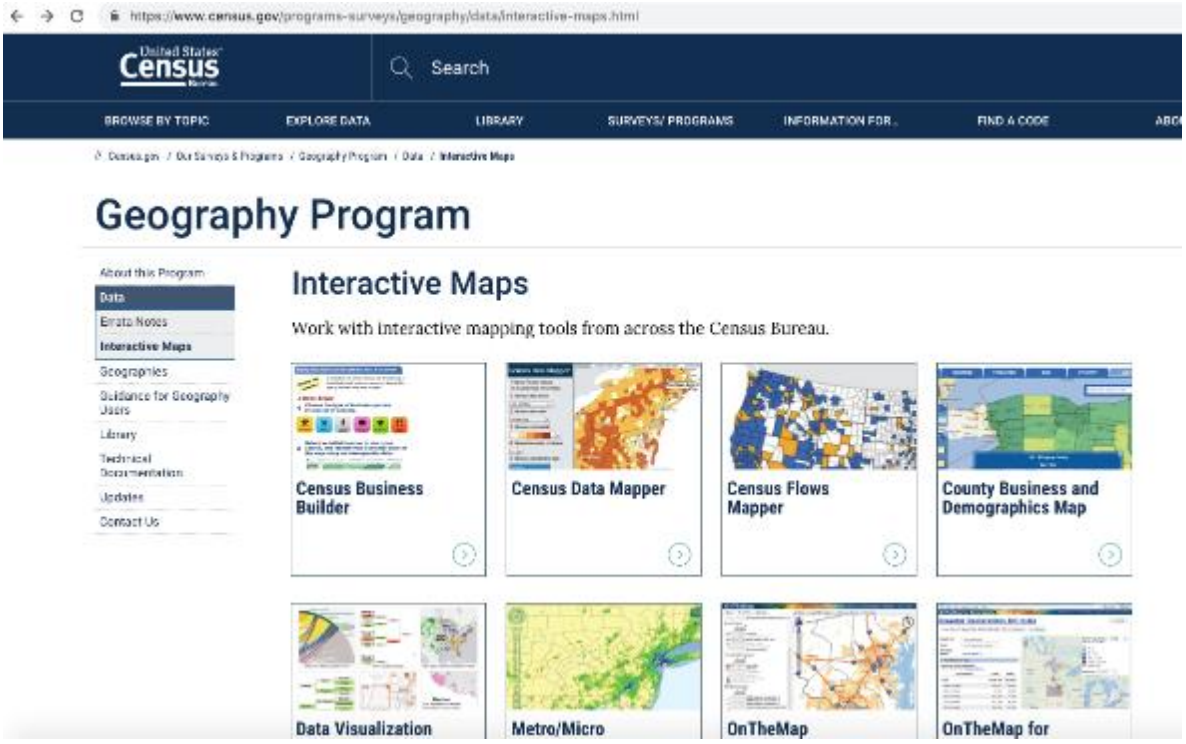
Satellite imagery of suburban (top) and urban Atlanta shows the differences in daytime heating, as caused by the urban heat island effect. **Credit:** NASA Goddard's Scientific Visualization Studio
› Larger image (suburban)
› Larger image (urban)

"The open question is: do changes in land cover and urbanization affect global temperatures and climate?" Imhoff added. "Urbanization is perceived as a relatively small effect, and most climate models focus on how the oceans and atmosphere store and balance heat. Urban heat islands are a lot of small, local changes, but do they add up? Studies of the land input are still in early stages."

Related Links

NASA's American Geophysical Union homepage
› www.nasa.gov/topics/earth/agu/index.html
Related story: New Results from a Terra-ific Decade in Orbit
› www.nasa.gov/mission_pages/terra/news/decade-orbit.html

6. US Government Census Bureau Demographics Interactives Website



7. Lesson 3 rubric

	Struggling	Approaching	At Level	Advanced
Engage *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system* *(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.*	The student has some difficulty working with a partner to observe an image of change. The student records none or 1 observation in the space provided in the organizer. The student provides a somewhat effective explanation as to what occurred in the city and how it might affect LST. The student may/may not refer to one of their observations in the explanation.	The student is able to effectively work with a partner to observe an image of change. The student records at least 1-2 observations in the space provided in the organizer. The student provides an effective explanation as to what occurred in the city and how it might affect LST. The student may/may not refer to one of their observations in the explanation.	The student is able to effectively work with a partner to observe an image of change. The student records at least 2-3 observations in the space provided in the organizer. The student provides an effective explanation as to what occurred in the city and how it might affect LST. The student refers their one of their observations in the explanation.	The student is able to effectively work with a partner to observe an image of change. The student records more than 3 observations in the space provided in the organizer. The student provides a thorough explanation as to what occurred in the city and how it might affect LST. The student refers to more than one of their observations in the explanation.
Explore *(HS-ESS3-5) Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.* *(HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes* *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.*	The student is able to follow the directions for the activity but needs near consistent guidance from the teacher. The student records some of the data required for the table from the Urban Heat Island intensity site. The student has some difficulty calculating the range of intensity and may have several errors. The student includes a picture	The student is able to follow the directions for the activity with some guidance from the teacher. The student records most of the data required for the table from the Urban Heat Island intensity site. The student is able to calculate the range of intensity with few errors. The student includes a picture of the city for each year. The image is mostly	The student is able to follow the directions for the activity with little guidance from the teacher. The student records all the data required for the table from the Urban Heat Island intensity site. There are no missing values. The student is able to calculate the range of intensity with no errors. The student includes a picture of the city for each year. The image is clear and easy to	The student is able to follow the directions for the activity with no guidance from the teacher. The student records all the data required for the table from the Urban Heat Island intensity site. There are no missing values. The student is able to calculate the range of intensity with no errors. The student includes a picture of the

(HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. *(HS-PS4-2), (HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.* *(HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).* *(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.* *(HSPS4-6) Mathematical representations can be used to identify certain patterns.*	of the city for most of the years. The image is somewhat clear. The student records their observations in the provided space in the table. Observations add some insightful knowledge to the already collected data.	clear and easy to see. The student records their observations in the provided space in the table. Observations are clear and add some insightful knowledge to the already collected data.	see. The student records their observations in the provided space in the table. Observations are clear and add insightful knowledge to the already collected data.	city for each year. The image is clear and easy to see. The student records their observations in the provided space in the table. Observations are clear and add insightful knowledge to the already collected data.
Explain *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* *11-12.RST.7 Integrate and evaluate multiple sources of information presented in diverse formats and*	The student has some difficulty distinguishing a correlation between UHI intensity and changes in land surface temperature. The student does not provide an effective explanation that includes at least 1 example from	The student is able to distinguish a correlation between UHI intensity and changes in land surface temperature. The student may provide an effective explanation that includes at least 1 example from the activity	The student is able to distinguish a correlation between UHI intensity and changes in land surface temperature. The student provides an effective explanation that includes at least 1 example from	The student is able to distinguish a correlation between UHI intensity and changes in land surface temperature. The student provides an effective explanation that includes more than 2 examples from the

media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4) *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.* *(HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes* *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.* *(HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.*	the activity to support their explanation. The student is able to somewhat explain how the data collected can be used to understand the UHI effect. The student does not use an example from the previous activity to support their explanation. The student is able to somewhat explain how the data can be used to determine mitigation strategies in urban areas. The student writes less than 3 pieces of relevant and important information from the video and article in the provided organizer. The student records the notes from the discussions with both their partner and other students. There are at least 1 point of discussion in each discussion box. The student creates a somewhat clear, easy to read mind map utilizing the data from the previous activity, the information from the article and video, and	to support their explanation. The student is able to explain how the data collected can be used to understand the UHI effect. The student uses at least 1 example from the previous activity to support their explanation. The student is able to explain how the data can be used to determine mitigation strategies in urban areas. The student is able to write down at least 4 pieces of relevant and important information from the video and article in the provided organizer. The student records the notes from the discussions with both their partner and other students. There are at least 2 points of discussion in each discussion box. The student creates a clear, easy to read mind map utilizing the data from the previous activity, the information from the article and video, and	the activity to support their explanation. The student is able to explain how the data collected can be used to understand the UHI effect. The student uses at least 1 example from the previous activity to support their explanation. The student is able to explain how the data can be used to determine mitigation strategies in urban areas. The student is able to write down at least 5 pieces of relevant and important information from the video and article in the provided organizer. The student records the notes from the discussions with both their partner and other students. There are at least two points of discussion in each discussion box. The student creates a clear, easy to read mind map utilizing the data from the previous activity, the information from the article and video, and information from the discussions. The student has at least 5 key	activity to support their explanation. The student is able to explain how the data collected can be used to understand the UHI effect. The student uses more than 2 examples from the previous activity to support their explanation. The student is able to explain how the data can be used to determine mitigation strategies in urban areas. The student is able to write down more than 5 pieces of relevant and important information from the video and article in the provided organizer. The student records the notes from the discussions with both their partner and other students. There are at least 3 points of discussion in each discussion box. The student creates a clear, easy to read mind map utilizing the data from the previous activity, the information from the article and

	information from the discussions. The student has less than 3 key points from the middle cloud and at least 1 point from each of the secondary clouds. The information is directly connected to urban heat islands and demonstrates an understanding of the UHI effect.	information from the discussions. The student has at least 4 key points from the middle cloud and at least 1 point from each of the secondary clouds. The information is directly connected to urban heat islands and demonstrates an understanding of the UHI effect.	points from the middle cloud and at least 2 points from each of the secondary clouds. The information is directly connected to urban heat islands and demonstrates an understanding of the UHI effect.	video, and information from the discussions. The student has more than 5 key points from the middle cloud and at least 3 points from each of the secondary clouds. The information is directly connected to urban heat islands and demonstrates an understanding of the UHI effect.
Elevate *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.* *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.*	The student is able to effectively research the demographic data but needs almost constant guidance from the teacher. The student has some difficulty being able to identify in a somewhat clear illustration the “hot spots” within the city. The student records some of the following information for the hot spots: age range, economic status, population, household type, type of population (family or single), and race. All information collected is in a somewhat readable format in the provided organizer.	The student is able to effectively research the demographic data with their partner with some guidance from the teacher. The student is able to identify in a mostly clear illustration the “hot spots” within the city. The student records most of the following information for the hot spots: age range, economic status, population, household type, type of population (family or single), and race. All information collected is in a readable format in the provided organizer.	The student is able to effectively research the demographic data with their partner with little guidance from the teacher. The student is able to identify in a clear illustration the “hot spots” within the city. The student records the following information for the hot spots: age range, economic status, population, household type, type of population (family or single), and race. All information collected is in a readable format in the provided organizer. The student is able to identify trends/patterns	The student is able to effectively research the demographic data with their partner with no guidance from the teacher. The student is able to identify in a clear illustration the “hot spots” within the city. The student records the following information for the hot spots: age range, economic status, population, household type, type of population (family or single), and race. All information collected is in a readable format in the provided organizer.

	The student is able to identify trends/patterns from the data they collected. The student may use at least 1 example from the data collected to support their explanation. The student is able to identify a correlation between the hot spots and the socio/economic status of the hot spots. The student does not use an example from the data they collected to support their explanation.	The student is able to identify trends/patterns from the data they collected. The student may use at least 1 example from the data collected to support their explanation. The student is able to identify a correlation between the hot spots and the socio/economic status of the hot spots. The student does not use an example from the data they collected to support their explanation.	from the data they collected. The student uses at least 1 example from the data collected to support their explanation. The student is able to identify a correlation between the hot spots and the socio/economic status of the hot spots. The student uses at least 1 example from the data they collected to support their explanation.	The student is able to identify trends/patterns from the data they collected. The student uses more than 1 example from the data collected to support their explanation. The student is able to identify a correlation between the hot spots and the socio/economic status of the hot spots. The student uses more than 1 example from the data they collected to support their explanation.
Evaluate *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.* *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* *11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)*	The student is able to somewhat effectively describe how scientists can take steps to reduce the UHI effect. The student does not use an example from either the explore or explain activity to support their response. The student is able to somewhat identify the main factors that determine UHI intensity. The student does use an example from either the explore or explain	The student is able to effectively describe how scientists can take steps to reduce the UHI effect. The student uses an example from either the explore or explain activity to support their response. The student is able to identify the main factors that determine UHI intensity. The student uses an example from either the explore or explain activities to support their explanation.	The student is able to effectively describe how scientists can take steps to reduce the UHI effect. The student uses an example from at least the explore and explain activities to support their response. The student is able to identify the main factors that determine UHI intensity. The student uses examples from at least the explore and explain activities to support their explanation.	The student is able to effectively describe how scientists can take steps to reduce the UHI effect. The student uses examples from the explore, explain, and elevate activities to support their response. The student is able to identify the main factors that determine UHI intensity. The student uses examples from the explore, explain, and elevate activities to support their explanation.

(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.*	activities to support their explanation.			

f. Conclusion and overview of linkages to next lesson and unit goals.

In this lesson, students learned about the main factors that cause urban heat island intensity. Students utilized a variety of sources to determine areas of high UHI intensity and the socio/economic status of those areas to see if demographics correlated with areas of high intensity. The next lesson focuses on mitigation strategies to reduce UHI intensity. Students will utilize the information from this lesson and the previous lessons to determine how mitigation solutions can reduce UHI.

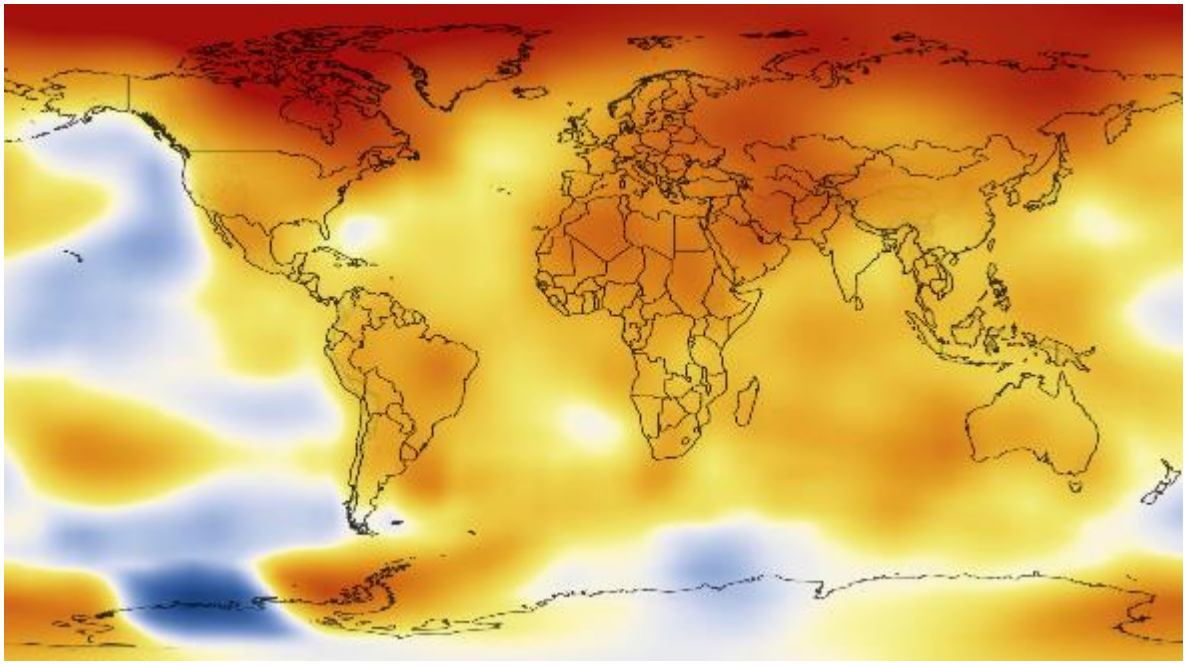
National Aeronautics and Space Administration
Goddard Institute for Space Studies
New York, N.Y.

NASA Goddard Institute for Space Studies (GISS)
Climate Change Research Initiative (CCRI)
Applied Research STEM Curriculum Unit Portfolio

Unit Title: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

Lesson Title: Bioswales, Topography, and Urban Heat, Oh My!: Understanding the Mitigation Strategy Bioswales

NASA STEM Educator / Associate Researcher: Elizabeth Sebastian
NASA PI / Mentor: Dr. Stuart Gaffin, Dr. Robert Blake, & Dr. Hamidreza Norouzi
NASA GSFC Office of Education – Code 160



XII. Lesson 4: Bioswales, Topography, and Urban Heat, Oh My!: Understanding the Mitigation Strategy Bioswales

a. Summary and Goals of Lesson

In the fourth lesson of the unit, students will learn about a mitigation strategy called a bioswale and how they are used to reduce the UHI. First, students will reflect back on previous lessons and brainstorm the next steps to reducing UHI. After the opening, students will play a game called "Offset" from the Jet Propulsion Laboratory. Through the game, students will learn about mitigation strategies such as planting trees and the effect it has on both carbon dioxide levels in the atmosphere and the temperature in the atmosphere. Students will then explore bioswales locations throughout NYC using Arc GIS to determine patterns/trends of placement of bioswales to determine the purpose behind the locations of the bioswales. Students will then learn more about bioswales in the Explain activity by looking at the structure of bioswales and an Earth Observatory article titled "Vegetation limits city warming effects". Using the knowledge gained from the explore and explain activities, students will use a topographic map to further understand the many purposes of utilizing bioswales for both temperature reduction and rain water drainage (which both contribute to UHI). To end the lesson, students will reflect on how mitigation strategies such as bioswales help with reducing the UHI effect and how we can utilize the data from the previous lessons to identify areas of UHI intensity and how mitigation strategies can help the areas of high intensity. The goal of the lessons is for students to learn and understand how a mitigation strategy such as bioswales can be used to reduce the effects of UHI.

b. Table of Contents for lesson

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**Some of the resources in this lesson may require either a Windows, Mac, or Linux computer in order to run properly.*

c. 5 E lesson model template:

Unit: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

Topic: Bioswales as a Mitigation Strategy to reduce Urban Heat Island Effect

Prior Learning: Students must have an understanding of UHI. Students must be proficient in analyzing data in order to identify patterns/trends.

Do Now (Pre-Assessment): Students will respond to the following prompt: "In the past three lessons, we've looked at how we can evaluate the Urban Heat Island and how to determine the impact/intensity of UHI. Now that we have all of this information, what are the next steps to reducing UHI?"

Aim: How do mitigation strategies such as bioswales help with reducing the urban heat island effect? Why is it important to implement mitigation strategies?

New York State Standards & Next Generation Science Standards:

- (HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- (secondary to HS-ESS3-2),(secondary to HS-ESS3-4) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.
- (HS-ETS1-3) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
- (HS-ETS1-1) Analyze complex real-world problems by specifying criteria and constraints for successful solutions.
- (HS-ETS1-4) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.
- (HS-ESS3-5) Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
- (HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.
- (HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
- (HS-PS4-2), (HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- (HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).

- (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- (HSPS4-6) Mathematical representations can be used to identify certain patterns.
- (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)

Common Core State Standards:

- CCSS.MATH.CONTENT.HSN.Q.A.2
  Define appropriate quantities for the purpose of descriptive modeling.
- CCSS.MATH.CONTENT.HSN.Q.A.3
  Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- CCSS.ELA-LITERACY.W.9-10.9
  Draw evidence from literary or informational texts to support analysis, reflection, and research.

NASA System of Engineering Behavior:

- *Leadership*
  - Understands the Human Dynamics of a Team
- *Attitudes & Attributes*
  - Seeks Information and Uses the Art of Questioning
- *Systems Thinking*
  - Assimilates, Analyzes, and Synthesizes Data
  - Has the Ability to Find Connections and Patterns Across the System
- *Communications*
  - Communicates Effectively Through Personal Interaction
  - Facilitates an Environment of Open and Honest Communication
- *Technical Acumen*
  - Possesses Technical Competence and Has Comprehensive Previous Experience

Performance Objective: Students will be able identify patterns within placement of mitigation strategies in order to determine the effect of mitigation strategies such as bioswales on UHI.

Materials:

- Lesson 4 worksheet
- Lesson 4 worksheet answer key
- Computer
- NASA Climate Kids Offset Game https://climatekids.nasa.gov/offset/
- Arc GIS DEP Green Infrastructure Program Map
  - http://www.arcgis.com/home/webmap/viewer.html?webmap=a3763a30d4ae459199dd01d4521d9939&extent=-74.3899,40.497,-73.3757,40.9523
- NYC Department of Environmental Protection Rain Gardens article
  - https://www1.nyc.gov/html/dep/html/stormwater/rain-gardens.shtml

- NASA Earth Observatory Vegetation Limits City Warming Effects article
  - https://earthobservatory.nasa.gov/images/86440/vegetation-limits-city-warming-effects
- Index of USGS Topographic Maps, New York State website
  - https://cugir.library.cornell.edu/catalog/cugir-009001?id=92

Vocabulary: bioswales, mitigation

Development of Lesson: Two Day Lessons (Approximately two 50-minute periods).

What the Teacher does	What the Student does	Time
Do Now! (Anticipatory Opening) As the students are coming into class and setting up, direct students to complete the *Do Now!* Section of the worksheet. Students will answer the question, "In the past three lessons, we've looked at how we can evaluate the Urban Heat Island and how to determine the impact/intensity of UHI. Now that we have all of this information, what are the next steps to reducing UHI?"	Students will complete the Do Now! Section of the worksheet. Students will answer the question, "In the past three lessons, we've looked at how we can evaluate the Urban Heat Island and how to determine the impact/intensity of UHI. Now that we have all of this information, what are the next steps to reducing UHI?"	5 minutes
Engage Direct students will now complete the Engage section of the worksheet. Direct student attention to the Engage section of the worksheet. Have a student read aloud the initial instructions. Students will play the climate game "Offset". The game entails keeping CO2 from going into the upper parts of the atmosphere, while at the same time mitigating the environment. Students will play at least 1 round of "Offset". After completing 1 round of the game, they will record on their worksheet the number of upgrades and final score. While students are playing, walk around the classroom to ensure students understand how to play the game. The instructions for the game are on the website. After students play the game, direct students to turn to a partner (does not have to be a partner from previous lessons) to discuss the following questions: "In 'Offset', what was the goal of the game?", "How were you able to score more points?", and "How does this game apply to what we have been learning about the Urban Heat Island and Climate Change?". After discussing with their partner, students will	Students will now complete the Engage section of the worksheet. A student will volunteer to read aloud the initial instructions. Students will play the climate game "Offset". The game entails keeping CO2 from going into the upper parts of the atmosphere, while at the same time mitigating the environment. Students will play at least 1 round of "Offset". After completing 1 round of the game, students will record on their worksheet the number of upgrades and final score. After students play the game, they will then turn to a partner (does not have to be a partner from previous lessons) to discuss the following questions: "In 'Offset', what was the goal of the game?", "How were you able to score more points?", and "How does this game apply to what we have been learning about the Urban Heat Island and Climate Change?". After discussing with their partner, students will write down their thoughts on the lines provided in the Engage section of the worksheet.	5-8 minutes

write down their thoughts on the lines provided in the Engage section of the worksheet. While students are working, continue to walk around to make sure students stay on topic. Allow 5-8 minutes for this activity. **Assessment Opportunity #1 (Use the Worksheet Answer Key & Engage section of rubric to assess.)**		
Explore Students will now complete the Explore section of the worksheet. Students will work with their partner from the previous lessons to complete this activity. Students will be learning about bioswales and placement of bioswales. Direct students to meet with their partner to complete the Explore activity. Students will work with their partner to explore the Arc GIS DEP Green Infrastructure Program Map. The map has all the locations of planned, in construction, and built bioswales. Students will select a particular watershed to focus on for the first part of the activity. Once selected, students will zoom in on the watershed to determine number of bioswales. Students will also observe the location of these bioswales to see if there is a pattern/purpose to the placement of the bioswales. Students will repeat this for 2 more watersheds. While students are working, walk around to help students as needed with the activity. Allow 15-20 minutes to complete. **Assessment Opportunity #2 (Use the Worksheet Answer Key & Explore section of rubric to assess.)**	Students will now complete the Explore section of the worksheet. Students will work with their partner from the previous lessons to complete this activity. Students will be learning about bioswales and placement of bioswales. Students will work with their partner to explore the Arc GIS DEP Green Infrastructure Program Map. The map has all the locations of planned, in construction, and built bioswales. Students will select a particular watershed to focus on for the first part of the activity. Once selected, students will zoom in on the watershed to determine number of bioswales. Students will also observe the location of these bioswales to see if there is a pattern/purpose to the placement of the bioswales. Students will repeat this for 2 more watersheds. .	15-20 minutes
Explain After completing the Explore portion of the worksheet, students will go directly into the Explain worksheet. Part 1 After finishing the explore activity, students will complete part 1 of the explain activity in which they discuss the following questions in relation to what they found in the previous activity: “Is there a pattern/trend with the placement of bioswales throughout all the watersheds?”, “If yes, why do you think the city planners	After completing the Explore portion of the worksheet, students will go directly into the Explain worksheet. Part 1 After finishing the explore activity, students will complete part 1 of the explain activity in which they discuss the following questions in relation to what they found in the previous activity: “Is there a pattern/trend with the placement of bioswales throughout all the	15-20 minutes

selected the placement of the bioswales to follow this pattern/trend?", and "If no, explain your reasoning based on the data collected in the explore activity." This should take at most 5 minutes. While students are discussing, walk around the class to keep students on track and for any questions students may have. Part 2 In part 2, students will learn about the structure of bioswales and why green infrastructure such as bioswales (rain gardens) are used in urban areas. Students will continue to work with their partner from the previous activities. Students will first visit the NYC Department of Environmental Protection's website to learn about the parts of bioswales (rain gardens). Students will record in a table the part and purpose of each part. Once completed, students will answer two questions: "What is the purpose of installing rain gardens in an urban area?" and "Why would this be an effective strategy in an urban environment versus a suburban environment?" Students will then go the NASA Earth Observatory to read the article "Vegetation Limits City Warming Effects". Use the cloud organizer provided in this section, students will write down key ideas from the article. Students will then discuss their key ideas with their partner and add any additional ideas discovered through discussion. They will then answer the question, "How does the rain garden tie in with what you read about vegetation in urban areas from the article?" This will link together the two pieces of information the students have read. Both parts should take about 10-15 minutes to complete. While students are working, walk around the classroom to act as a guide to answer any questions that students may have. Make sure not to give them the answer, but to guide them to where they can find the answer or "think aloud" to have them reach the answer. After students have finished, have them return to their seats. Draw an organizer on the board (cloud, circle, rectangle, any shape will do). Ask students, "What were the main findings you found in the explore activity?" Have	watersheds?", "If yes, why do you think the city planners selected the placement of the bioswales to follow this pattern/trend?", and "If no, explain your reasoning based on the data collected in the explore activity." Part 2 In part 2, students will learn about the structure of bioswales and why green infrastructure such as bioswales (rain gardens) are used in urban areas. Students will continue to work with their partner from the previous activities. Students will first visit the NYC Department of Environmental Protection's website to learn about the parts of bioswales (rain gardens). Students will record in a table the part and purpose of each part. Once completed, students will answer two questions: "What is the purpose of installing rain gardens in an urban area?" and "Why would this be an effective strategy in an urban environment versus a suburban environment?" Students will then go the NASA Earth Observatory to read the article "Vegetation Limits City Warming Effects". Use the cloud organizer provided in this section, students will write down key ideas from the article. Students will then discuss their key ideas with their partner and add any additional ideas discovered through discussion. They will then answer the question, "How does the rain garden tie in with what you read about vegetation in urban areas from the article?" This will link together the two pieces of information the students have read. After students have finished, they will return to their seats. Students will be asked by the teacher, "What were the main findings you found in the explore activity?" Students can volunteer their responses. Students will then be asked, "How does the explain activity help with understanding the purpose of bioswales?" Before sharing responses, students will "think, pair, and share" with a neighbor. After the "think, pair, and	

students volunteer their responses and record the responses on the board. Then ask students, “How does the explain activity help with understanding the purpose of bioswales?” Before sharing responses, have students “think, pair, and share” with a neighbor. After the “think, pair, and share”, have students volunteer responses and record the responses on the board. **Assessment Opportunity #3 (Use the Worksheet Answer Key & Explain section of rubric to assess.)**	share”, students can volunteer responses.	
Elevate Explain that in the Explore activity, we see the bioswales are placed in strategic locations for the purpose of providing more vegetation in “hot spot” areas to reduce the urban heat island effect. However, is there another purpose to these bioswales that can help the areas they are planted in? Have students “think, pair, and share” before volunteering responses aloud. After hearing the students’ responses, direct students’ attention to the Elevate activity. Have a student volunteer(s) read through the directions for this activity. Students will work with their partner from the previous activity to download a topographic map, locate the first watershed from the Explore activity, and to determine the reasoning for the placement of the bioswales in the watershed based off of topography. Students will collect the following information and record it in their “Topographic Data Table”: watershed name, picture of watershed from Arc GIS, picture of watershed from Topographic map, and observations of placement of bioswales with topographic features. Once students have collected the information, they will then answer the question: “Based on the observations and pictures, is there a pattern of the placement of the bioswales? Use the data from the table to justify your response.” Before starting, let students know that if they have trouble finding their watershed, to reference their map from the Explore activity to help them find it on the topographic map. Allow students 10-15 minutes to complete the activity.	The teacher will ask students, “However, is there another purpose to these bioswales that can help the areas they are planted in?” Students will “think, pair, and share” before volunteering responses aloud. After hearing the students’ responses, students’ attention will be directed to the Elevate activity. A student will volunteer(s) to read through the directions for this activity. Students will work with their partner from the previous activity to download a topographic map, locate the first watershed from the Explore activity, and to determine the reasoning for the placement of the bioswales in the watershed based off of topography. Students will collect the following information and record it in their “Topographic Data Table”: watershed name, picture of watershed from Arc GIS, picture of watershed from Topographic map, and observations of placement of bioswales with topographic features. Once students have collected the information, they will then answer the question: “Based on the observations and pictures, is there a pattern of the placement of the bioswales? Use the data from the table to justify your response.”	15-20 minutes

Assessment Opportunity #4 (Use the Worksheet Answer Key & Elevate section of rubric to assess.)		
Evaluate It is recommended to use this section as a homework. It can also be used as an exit ticket. Students will then complete the Evaluate section of the worksheet. Students will answer 4 questions in regard to bioswales, how it ties in with mitigation and the urban heat island, and why mitigation is useful. The questions are: "How do mitigation strategies such as bioswales help with reducing the urban heat island effect?" "Why is it important to implement mitigation strategies? Why can't we just use adaptation strategies?" "Using what you learned in prior lessons, how can we determine the effectiveness of mitigation strategies such as bioswales?" "Why is it important to have data and identify patterns/trends within the data when suggesting a mitigation strategy?" **Assessment Opportunity #5 (Use the Worksheet Answer Key & Evaluate section of rubric to assess.)**	Students will complete the Evaluate section of the worksheet as either an exit ticket or for homework. Students will answer 4 questions in regard to bioswales, how it ties in with mitigation and the urban heat island, and why mitigation is useful. The questions are: "How do mitigation strategies such as bioswales help with reducing the urban heat island effect?" "Why is it important to implement mitigation strategies? Why can't we just use adaptation strategies?" "Using what you learned in prior lessons, how can we determine the effectiveness of mitigation strategies such as bioswales?" "Why is it important to have data and identify patterns/trends within the data when suggesting a mitigation strategy?"	5-7 minutes

Summary/Conclusion:

The students will answer the following questions in the Evaluate section of the worksheet: How do mitigation strategies such as bioswales help with reducing the urban heat island effect? Why is it important to implement mitigation strategies? Why can't we just use adaptation strategies? Using what you learned in prior lessons, how can we determine the effectiveness of mitigation strategies such as bioswales? Why is it important to have data and identify patterns/trends within the data when suggesting a mitigation strategy?

Higher Order Questions:

1. Why do you think the city planners selected the placement of the bioswales to follow this trend/pattern?
2. Why is it important to implement mitigation strategies? Why can't we just use adaptation strategies?
3. Why is it important to have data and identify patterns/trends within the data when suggesting a mitigation strategy?

Differentiated Instruction:

- The students learn the content in a variety of ways. The students learn content through visual formats (images and videos), oral discussion, experimental design, data analysis, and reflection.
- Students use data analysis tools to create graphs of their final results from the experiment.
- Students use a variety of technology to learn about content.
- Students are provided with a variety of leveled questions (low-high order) to answer questions at their level and elevate their thought processes.
- Students are given the chance to review their understanding through oral discussion in order to confirm or add to their understanding of the content.
- Students will use a graphic organizer to help with their understanding of the content and organize the content in an orderly, easily readable fashion.

Daily Formative Assessment:

Using what you learned in the Explore, Explain, and Elevate activities, independently answer the questions below.

1. How do mitigation strategies such as bioswales help with reducing the urban heat island effect?
2. Why is it important to implement mitigation strategies? Why can't we just use adaptation strategies?
3. Using what you learned in prior lessons, how can we determine the effectiveness of mitigation strategies such as bioswales?
4. Why is it important to have data and identify patterns/trends within the data when suggesting a mitigation strategy?

Next Lesson: Back to a Green Future: Using data of the past to change the future Capstone Project

d. Content template:

NGSS Standard & State Science Content Standard: (HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (secondary to HS-ESS3-2),(secondary to HS-ESS3-4) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-1) Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-4) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ESS3-5) Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-PS4-2),(HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HSPS4-6) Mathematical representations can be used to identify certain patterns. (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)			Common Core Standard: CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.	NASA Science: Earth Science
Content Area: Earth Science/Environmental Science Grade Level: 9th Grade		Name of Project-Based Activity or Theme: Topography, and Urban Heat, Oh My!: Understanding the Mitigation Strategy Bioswales	Estimated Time Frame to Complete(days/weeks): 2 classes/days	
Overall Investigation Question(s): How do mitigation strategies such as bioswales help with reducing the urban heat island effect? Why is it important to implement mitigation strategies?				

Overall Project Description/Activity: Students will be able identify patterns within placement of mitigation strategies in order to determine the effect of mitigation strategies such as bioswales on UHI.				
	:			
Materials Needed to Complete Project (put N/A as needed). Lesson 4 worksheet Computer NASA Climate Kids Offset Game Arc GIS DEP Green Infrastructure Program Map NYC Department of Environmental Protection Rain Gardens article NASA Earth Observatory Vegetation Limits City Warming Effects article Index of USGS Topographic Maps, New York State website	Stakeholders: Fusion Academy: Education Team, Administrators, Science Department, Science Teachers, and students	Hyperlinks Used: NASA Climate Kids Offset Game https://climatekids.nasa.gov/offset/ Arc GIS DEP Green Infrastructure Program Map http://www.arcgis.com/home/webmap/viewer.html?webmap=a3763a30d4ae459199dd01d4521d9939&extent=-74.3899,40.497,-73.3757,40.9523 NYC Department of Environmental Protection Rain Gardens article https://www1.nyc.gov/html/dep/html/stormwater/rain-gardens.shtml NASA Earth Observatory Vegetation Limits City Warming Effects article https://earthobservatory.nasa.gov/images/86440/vegetation-limits-city-warming-effects Index of USGS Topographic Maps, New York State website https://cugir.library.cornell.edu/catalog/cugir-009001?id=92	Multimedia/Technology: Computer NASA Climate Kids Offset Game Arc GIS DEP Green Infrastructure Program Map NYC Department of Environmental Protection Rain Gardens article NASA Earth Observatory Vegetation Limits City Warming Effects article Index of USGS Topographic Maps, New York State website	Classroom Equipment: Computer
NASA System Engineering Behaviors (2 behaviors per category)	Category (must have one Technical Acumen)	Activities How will student model engineering behaviors when learning science content? Describe student activities here.	Student Outcomes How will you assess learning for each behavior	Evaluation Describe specific science content students understand as a result of engineering behavior.
Understands the Human Dynamics of a Team	Leadership	Students work in pairs to complete the Explore and Explain activities (collecting information on location of bioswales and the purpose of bioswales)	Lesson 4 Rubric – Explore and Explain Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon

Seeks Information and Uses the Art of Questioning	Attitudes & Attributes	Students will research information the purpose of Bioswales in the Explain activity.	Lesson 4 Rubric – Explain Category	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Assimilates, Analyzes, and Synthesizes Data	Systems Thinking	Students will obtain information on the location of bioswales using Arc GIS. Students will interpret the data in order to identify the areas in order to determine the pattern of the placement of bioswales in areas around the city.	Lesson 4 Rubric – Explore, Explain, and Elevate Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Has the Ability to Find Connections and Patterns Across the System	Systems Thinking	Students will obtain information on the location of bioswales using Arc GIS. Students will interpret the data in order to identify the areas in order to determine the pattern of the placement of bioswales in areas around the city.	Lesson 4 Rubric – Explore, Explain, and Elevate Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Communicates Effectively Through Personal Interaction	Communications	Students work in pairs to complete the Explore & Explain activities. Must have effective communications in order to be successful in activities.	Lesson 4 Rubric – Explore and Explain Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Facilitates an Environment of Open and Honest Communication	Communications	Students work in pairs to complete the Explore & Explain activities. Must have effective communications in order to be successful in activities.	Lesson 4 Rubric – Explain and Explain Categories	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon

Possesses Technical Competence and Has Comprehensive Previous Experience	Technical Acumen	For the Explore activity, students must have a comprehensive knowledge of retrieving and analyzing data from a variety of sources in order to reasoning for location of bioswales.	Lesson 4 Rubric – Explore Category	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
List and attach all supportive documents for instructional activities	Attachments? (circle) Yes or No	List Attached Documents(if any): Lesson 4 Worksheet		
List and attach all rubrics for activity and assessment evaluation	Attachments? (circle) Yes or No	List Attached Rubrics (if any): Lesson 4 rubric		
Include comments or questions here:				

e. Supporting Documents: (order according to sequence of lesson.)

1. Lesson 4 worksheet

Bioswales, Topography, and Urban Heat, Oh My!: Understanding the Mitigation Strategy Bioswales Lesson 4 Worksheet

Do Now!
In the past three lessons, we've looked at how we can evaluate the Urban Heat Island and how to determine the impact/intensity of UHI. Now that we have all of this information, what are the next steps to reducing UHI?

_____
_____
_____
_____

Engage
On your computer, go to https://climatekids.nasa.gov/offset/ to play the game "Offset". Before pressing "play game", read the directions on the site on how to play the game. Once you are ready, click "play game".

After playing 1 round, record below your upgrades and final score
Number of upgrades:_____
Final score: _____

Turn to a partner and discuss the following:
- In "Offset", what was the goal of the game?
- How were you able to score more points?
- How does this game apply to what we have been learning?

Record your thoughts below.

_____
_____
_____
_____
_____
_____

Explore

With your partner from the previous activities, you will learn more about a type of mitigation strategy called a bioswale. Follow the directions below to learn about bioswales.

1. Go to the Arc GIS DEP Green Infrastructure Program Map http://www.arcgis.com/home/webmap/viewer.html?webmap=a3763a30d4ae459199dd01d4521d9939&extent=-74.3899,40.497,-73.3757,40.9523
2. On the left-hand side of the screen will be an area with different pieces of information: "About", "Content", and "Legend". Go to content and make sure the only two boxes checked are "DEP GI Assets Public" and "Combined Sewer Watersheds".
3. On the left-hand side, you will see a color-coded key for "Combined Sewer Watersheds". Select a watershed to study. Write the name on the line provided below.
    a. Watershed: _____
4. Zoom in are on the area that is designated as your selected watershed. As you zoom in, a new key will pop up on the left-hand side of the screen, "DEP_GI_Assets_Public". This designates whether a bioswale is constructed (completed), in construction, or in the final design phase.
5. Once you have zoomed in to the point where the watershed takes up most of the screen, take a screenshot of the watershed and paste it in the table below.
6. Identify all the bioswales in this watershed. Note in the table below how many are constructed, in construction, and in final design.
7. Observe the location of the bioswales. With your partner, discuss the trend/pattern of the locations of the bioswales. Record your discussion in the table below.
8. Repeat steps 3-7 for two more watersheds. Record data in the table below.

Bioswale Data Table

Watershed Name	Picture of Watershed	Number of Constructed bioswales	Number of In Construction bioswales	Number of Final Design bioswales	Observation of trends/patterns of bioswale placement

Explain

Part 1

Discuss with your partner the questions below. Record your responses on the lines provided.

1. After observing three watersheds, is there a pattern/trend with the placement of bioswales throughout all the watersheds? _____

2. If yes, what is the trend/pattern? Why do you think the city planners selected the placement of the bioswales to follow this trend/pattern?
   _____
   _____
   _____
   _____

3. If no, explain your reasoning based on the data collected in the Explore activity.
   _____
   _____
   _____
   _____

Part 2

Continuing to work with your partner, you will now look at two sources of information to learn more about bioswales and the reasoning behind implementing bioswales into urban areas. Follow the directions below.

1. Go to: https://www1.nyc.gov/html/dep/html/stormwater/rain-gardens.shtml
2. Read through the short informational page about "Rain Gardens" (aka bioswales!).
3. Once you have read through the page, complete the diagram below. Make sure to include the purpose of each part below the diagram.

Photo Credit: NYC Department of Environmental Protection

Number on Diagram	Part	Purpose
1		
2		
3		
4		
5		
6		
7		

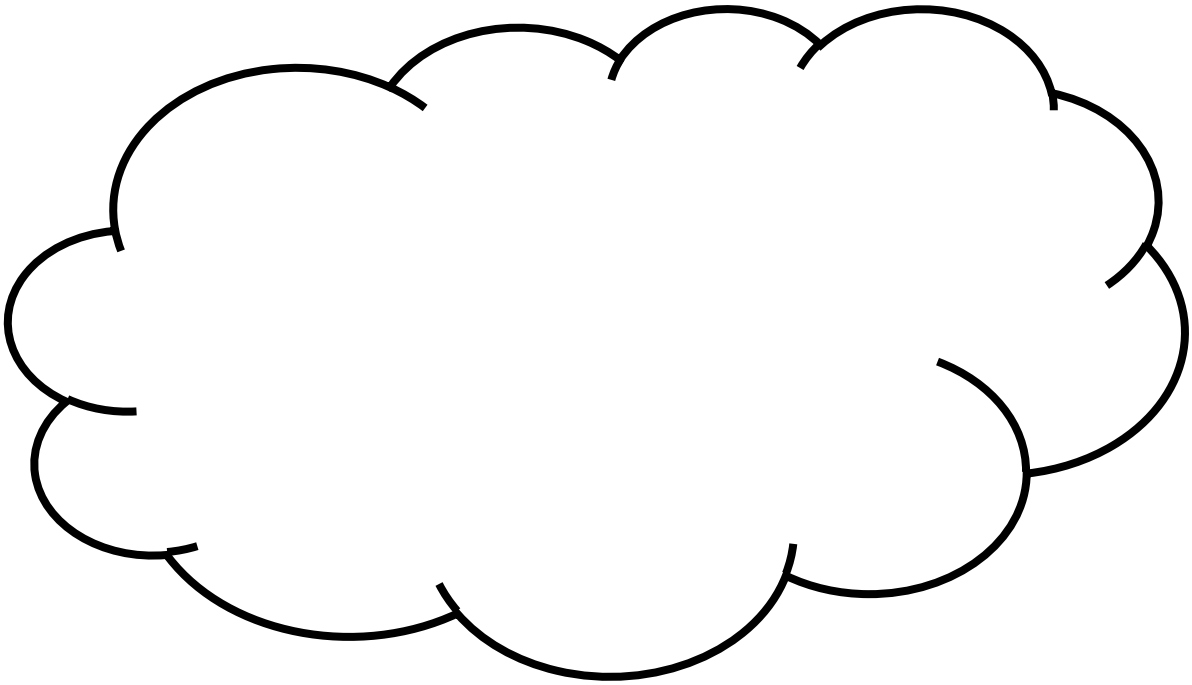
What is the purpose of installing rain gardens (bioswales) in an urban area? Explain.

_____
_____
_____
_____

Why would this be an effective strategy in an urban environment versus a suburban environment?

_____
_____
_____
_____

4. Go to: https://earthobservatory.nasa.gov/images/86440/vegetation-limits-city-warming-effects
5. Use the cloud below to write down key ideas from the article.



6. Discuss with your partner the key ideas you wrote down from the article. Add any additional key ideas discussed to your organizer.

How does the rain garden tie in with what you read about vegetation in urban areas from the article? Explain.

_____
_____
_____
_____
_____

Elevate

In the Explore and Explain activities, we looked at bioswales and why they are used in urban areas. However, the bioswales are not randomly place throughout the city. To learn about the reasoning behind the placement of bioswales, let us take a look at a topographic map of New York City.

1. Go to: https://cugir.library.cornell.edu/catalog/cugir-009001?id=92
2. Zoom in on the area of the city where your first water shed was located. Then click on the area of the watershed. Once you click, an option will pop up to the right of the image to download the picture. Click the link to download the image.
3. Once downloaded, open the file. Zoom in on different areas of the watershed. As you zoom in, you will start to notice “wavy” lines. These “wavy” lines represent the topography of the area. The closer together the lines, the steeper the slope. The topography lines are placed over the road map of the area. Using the roads as a guide, Complete the table below to see how the placement of the bioswales lines up with the topographic features and the local bodies of water the watersheds deposit into.

Topographic Data Table

Watershed Name	Picture of Watershed from Arc GIS	Picture of Watershed from Topographic Map	Observations of placement of bioswales with topographic features

Based on the observations and pictures, is there a pattern of the placement of the bioswales? Use the data from the table to justify your response.

_____
_____
_____
_____
_____

Evaluate

Using what you learned in the Explore, Explain, and Elevate activities, independently answer the questions below.

1. How do mitigation strategies such as bioswales help with reducing the urban heat island effect?

_____
_____
_____
_____

2. Why is it important to implement mitigation strategies? Why can't we just use adaptation strategies?

_____
_____
_____
_____
_____

3. Using what you learned in prior lessons, how can we determine the effectiveness of mitigation strategies such as bioswales?

_____
_____
_____
_____

4. Why is it important to have data and identify patterns/trends within the data when suggesting a mitigation strategy?

_____
_____
_____
_____

2. Lesson 4 Worksheet Answer Key

Bioswales, Topography, and Urban Heat, Oh My!: Understanding the Mitigation Strategy Bioswales Lesson 4 Worksheet

Do Now!
In the past three lessons, we've looked at how we can evaluate the Urban Heat Island and how to determine the impact/intensity of UHI. Now that we have all of this information, what are the next steps to reducing UHI?
Answers will vary. Example response: Based on what we learned in the previous lessons, impervious surfaces have a large impact on the land surface temperature and UHI. Some next steps we can take to reduce UHI are reducing the amount of impervious surfaces, adding more vegetated surfaces, and creating more "eco/green" infrastructures.

Engage **Scores and Answers may vary. Example responses below.**
On your computer, go to https://climatekids.nasa.gov/offset/ to play the game "Offset". Before pressing "play game", read the directions on the site on how to play the game. Once you are ready, click "play game".

After playing 1 round, record below your upgrades and final score
Number of upgrades:____**12 x 100 = 1200**_____
Final score: _____**1637**_____

Turn to a partner and discuss the following:
- In "Offset", what was the goal of the game?
- How were you able to score more points?
- How does this game apply to what we have been learning?

Record your thoughts below.
The goal of the game was to reduce CO2 emissions by upgrading existing infrastructure to more environmentally friendly infrastructure and to keep air temperature from rising. I was able to score more points by upgrading the existing infrastructure to more eco friendly infrastructure, by keeping the CO2 from entering the upper parts of the atmosphere, and keeping the air temperature down for as long as possible.

Explore **Answers will vary depending on the site selected for study. A sample set of responses are provided below. The numbers show may not be the exact numbers.**
With your partner from the previous activities, you will learn more about a type of mitigation strategy called a bioswale. Follow the directions below to learn about bioswales.

1. Go to the Arc GIS DEP Green Infrastructure Program Map http://www.arcgis.com/home/webmap/viewer.html?webmap=a3763a30d4ae459199dd01d4521d9939&extent=-74.3899,40.497,-73.3757,40.9523
2. On the left-hand side of the screen will be an area with different pieces of information: "About", "Content", and "Legend". Go to content and make sure the only two boxes checked are "DEP GI Assets Public" and "Combined Sewer Watersheds".

3. On the left-hand side, you will see a color-coded key for “Combined Sewer Watersheds”. Select a watershed to study. Write the name on the line provided below.
    a. Watershed: ____**Gowanus Canal**_____
4. Zoom in are on the area that is designated as your selected watershed. As you zoom in, a new key will pop up on the left-hand side of the screen, “DEP_GI_Assets_Public”. This designates whether a bioswale is constructed (completed), in construction, or in the final design phase.
5. Once you have zoomed in to the point where the watershed takes up most of the screen, take a screenshot of the watershed and paste it in the table below.
6. Identify all the bioswales in this watershed. Note in the table below how many are constructed, in construction, and in final design.
7. Observe the location of the bioswales. With your partner, discuss the trend/pattern of the locations of the bioswales. Record your discussion in the table below.
8. Repeat steps 3-7 for two more watersheds. Record data in the table below.

Bioswale Data Table

Watershed Name	Picture of Watershed	Number of Constructed bioswales	Number of In Construction bioswales	Number of Final Design bioswales	Observation of trends/patterns of bioswale placement
Gowanus Canal		102	9	8	Most bioswales are clustered together, none in southern portion of watershed.
Coney Island Creek		0	0	0	No watersheds have been built, are in construction, or being planned for construction.
City wide or open waters		81	205	175	Most of the bioswales in construction are around areas that are around the water or close by water.

<u>Explain</u>
Part 1
Discuss with your partner the questions below. Record your responses on the lines provided.

1. After observing three watersheds, is there a pattern/trend with the placement of bioswales throughout all the watersheds? _____**Yes**_____

2. If yes, what is the trend/pattern? Why do you think the city planners selected the placement of the bioswales to follow this trend/pattern?
Answers will vary depending on the watersheds students studied in the Explore activity. Example Response: In the watersheds I studied, there was a noticeable pattern of

placement of bioswales. In the open water/city wide watershed, the area that had the most in construction and built bioswales where in the area of Brooklyn that s close to the water. The rest of the watersheds were sporadically placed about it seemed and were far apart from each other. From the placement of the ones in Brooklyn, there must be a reason as to why they are so many in construction/built in one part of the neighborhood and not more spread out.

If no, explain your reasoning based on the data collected in the Explore activity.
Answers will vary depending on the watersheds students studied in the Explore activity. Example response: In the watersheds I studied, there wasn't enough of a noticeable pattern of placement of bioswales for me to come to the conclusion that there is a trend/pattern of the placement of bioswales. For example, in the Gowanus canal watershed, the bioswales that are in construction or already built seem to be just spread about randomly throughout the area. I couldn't find a large enough pattern to confidently say there is a trend.

Part 2
Continuing to work with your partner, you will now look at two sources of information to learn more about bioswales and the reasoning behind implementing bioswales into urban areas. Follow the directions below.

1. Go to: https://www1.nyc.gov/html/dep/html/stormwater/rain-gardens.shtml
2. Read through the short informational page about "Rain Gardens" (aka bioswales!).
3. Once you have read through the page, complete the diagram below. Make sure to include the purpose of each part below the diagram.

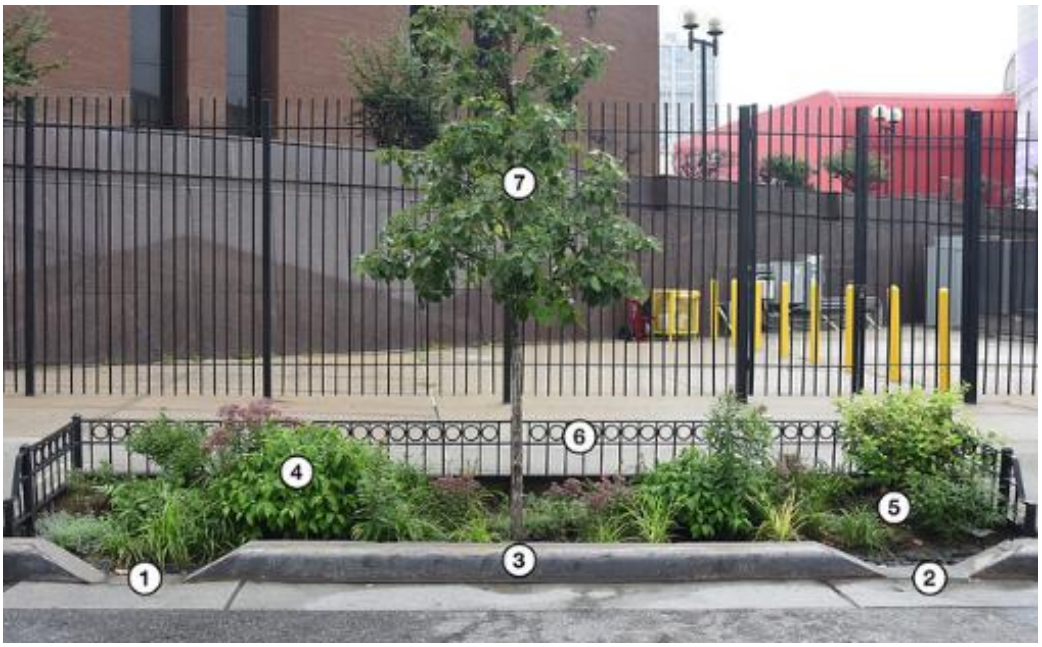


Photo Credit: NYC Department of Environmental Protection

Number on Diagram	Part	Purpose
1	Curb inlet	Allows water to flow into rain garden as it flows down the curb toward the catch basin
2	Outlet	(only larger rain gardens have this) If bioswale fills to capacity, water can exit through the outlet and continue into the catch basin on the street corner
3	Stone Strip	Allows people to step out of their cars without damaging the plants
4	Plants	Plants and grasses that have been carefully selected to ensure they survive busy NYC streets. *outright purpose isn't stated, but based on evapotranspiration, we can assume they are put in to reduce surface temperatures and reduce stormwater runoff through evaporation.
5	Soil	Soil is graded so water ponds in the center of the rain garden
6	Tree Guard	Protects the plants and keeps people and animals from walking inside of the rain garden.
7	Tree	Lowers temperatures in hotter months, improves air quality, and provides habitat for birds and butterflies

What is the purpose of installing rain gardens (bioswales) in an urban area? Explain.
There are several reasons for installing a rain garden. One, the greenery (vegeation) such as the trees and plants in raingardens can help lower temperatures in the hotter months. Another purpose is to help with stormwater runoff (soil, plants, tree) by redirecting stormwater runoff, absorbing some of the runoff, and evaporating the water back into the atmosphere. Lastly, the bioswales provide a habitat for birds and butterflies.

Why would this be an effective strategy in an urban environment versus a suburban environment?
As we saw in the Explore activity and in previous lessons, areas that have higher amounts of impervious surfaces tend to have higher land surface temperatures. We've seen in this lesson and previous lessons that the surrounding areas around a city tend to have more vegetation and lower surface temperatures than the urban areas. Since these areas already have a higher amount of vegetation, it won't impact the surface temperature as much as with an urban environment that has numerous amounts of concrete and asphalt (impervious surfaces).

4. Go to: https://earthobservatory.nasa.gov/images/86440/vegetation-limits-city-warming-effects
5. Use the cloud below to write down key ideas from the article.

UHI raises city temperatures by 1-3C compared to neighboring rural and semi rural areas.

Rise is due to asphalt, concrete, stone, steel, and other impervious surfaces (these surfaces absorb heat and disrupt natural cooling system by vegetation)

Scarcity of vegetation is essential factor in UHI.

Satellite data modeled urban areas that are covered in impervious surfaces are on average 1.9C higher in summer than surrounding rural areas

Plants in urban areas can regulate UHI effect

1C can raise energy demands for AC from 5-20% in US

Amount & type of vegetation plays a large role in how urbanization changes temperatures

UHI effect occurs primarily during the day where impervious surfaces absorb more sunlight than surrounding vegetated areas

Models show that when impervious surfaces surpass 35% coverage, temperatures began increasing

These models and studies can help urban planners with designing cities with mitigation factors

6. Discuss with your partner the key ideas you wrote down from the article. Add any additional key ideas discussed to your organizer.

How does the rain garden tie in with what you read about vegetation in urban areas from the article? Explain.

The rain garden is one of the ways that cities can use to implement vegetation to the cities to reduce the UHI effect. The article mentioned how with impervious surfaces you do not get the evapotranspiration effect that plants and soil provide for cooling. In the rain garden activity, we saw that one of the reasons that trees, plants, and soil are in bioswales is to increase the amount of evapotranspiration in urban areas which will hopefully lead to a reduction in surface and air temperatures.

Elevate

In the Explore and Explain activities, we looked at bioswales and why they are used in urban areas. However, the bioswales are not randomly place throughout the city. To learn about the reasoning behind the placement of bioswales, let us take a look at a topographic map of New York City.

1. Go to: https://cugir.library.cornell.edu/catalog/cugir-009001?id=92
2. Zoom in on the area of the city where your first water shed was located. Then click on the area of the watershed. Once you click, an option will pop up to the right of the image to download the picture. Click the link to download the image.

3. Once downloaded, open the file. Zoom in on different areas of the watershed. As you zoom in, you will start to notice “wavy” lines. These “wavy” lines represent the topography of the area. The closer together the lines, the steeper the slope. The topography lines are placed over the road map of the area. Using the roads as a guide, Complete the table below to see how the placement of the bioswales lines up with the topographic features and the local bodies of water the watersheds deposit into.

Topographic Data Table

Watershed Name	Picture of Watershed from Arc GIS	Picture of Watershed from Topographic Map	Observations of placement of bioswales with topographic features
Gowanus Canal			The largest amount of bioswales are in the area designated as Park Slope. The contour lines in this area are very close together running N/S. This indicates a steeper incline/decline of land that feeds to the Gowanus Canal
Coney Island Creek			For the most part in this area, the contour lines are far apart which indicates little incline/decline in the land of the area.
City wide or open waters			The area with the most bioswales (Brooklyn area by the navy yard), there are various hills/slopes indicated by closer together contour lines that are angled in a way that shows the hills are aligned to have runoff go to the East River

Based on the observations and pictures, is there a pattern of the placement of the bioswales? Use the data from the table to justify your response.

Answers will vary. Example response: Yes, there is a pattern with the data. Based on the topographic map activity, the bioswales in the watersheds seem to be placed around areas of the city where there is a change in elevation (hills, slopes, etc…). For example, in the Gowanus Canal watershed, the bioswales in the upper right region (where we see a decent amount of bioswales clustered together), there is steep elevation (the contour lines are close together.

Evaluate

Using what you learned in the Explore, Explain, and Elevate activities, independently answer the questions below.

1. How do mitigation strategies such as bioswales help with reducing the urban heat island effect?

Answers will vary. Example response: Mitigation strategies such as bioswales help with reducing the urban heat island effect in a number of ways. Bioswales contain vegetation such as tress, plants, and bushes. The vegetation can help reduce surface temperature of an area. We saw in the Explain activity that vegetation has lower surface temperatures than impervious surfaces such as concrete which overall can help reduce the higher surface temperatures associated with UHI's. The vegetation of bioswales cen help with storm water runoff by absorbing the water. Storm water runoff can increase UHI because the water is not absorbed by surfaces like concrete. Therefore, the cooling effects of evapotranspiration can't occur. With bioswales vegetation, evapotranspiration can occur once again and cool the surfaces and air temperatures.

2. Why is it important to implement mitigation strategies? Why can't we just use adaptation strategies?

Answers will vary. Example response: It is important to implement mitigation strategies because in order to have a long-term reduction of UHI, we can't just adapt to the changes. Adaptation can help short term with dealing with current UHI effects, but in order to reduce the effects implementation strategies such as bioswales need to be built in cities. We learned in the Explain activity that incorporating more vegetation in urban areas will reduce surface temperatures. If we are thinking long term in reducing global average temperatures, we need to incorporate this long term thinking in urban areas planning. Populations in urban areas are increasing and by 2050, 80% of the world's population could be living in urban areas. We can't just adapt, we also need to mitigate the effects in order to live in these urban environments.

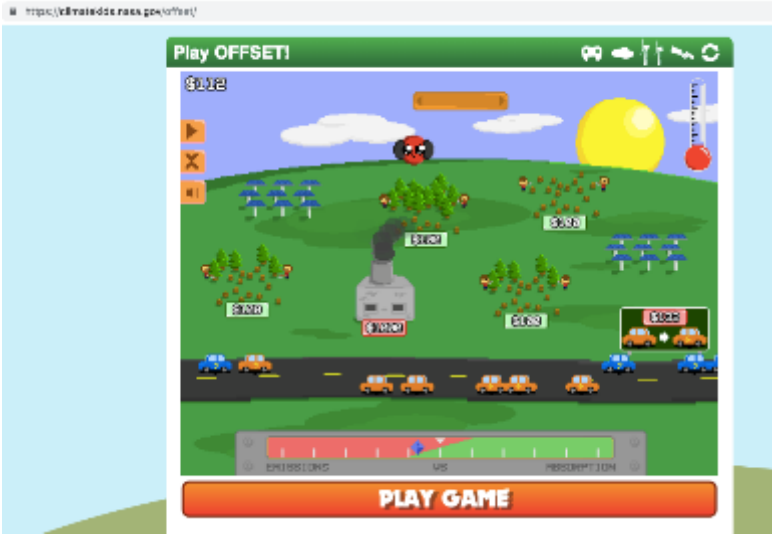
3. Using what you learned in prior lessons, how can we determine the effectiveness of mitigation strategies such as bioswales?

Answers will vary. Example response: We can test the effectiveness of mitigation strategies using the methods we used in the Explore activity in the second lesson. We can use handheld thermal cameras to measure the temperatures of both impervious surfaces and vegetated surfaces in an urban area. In order to demonstrate how effective bioswales are, we would need to conduct the study for a series of days and weather conditions, ideally when it is warmer outside.

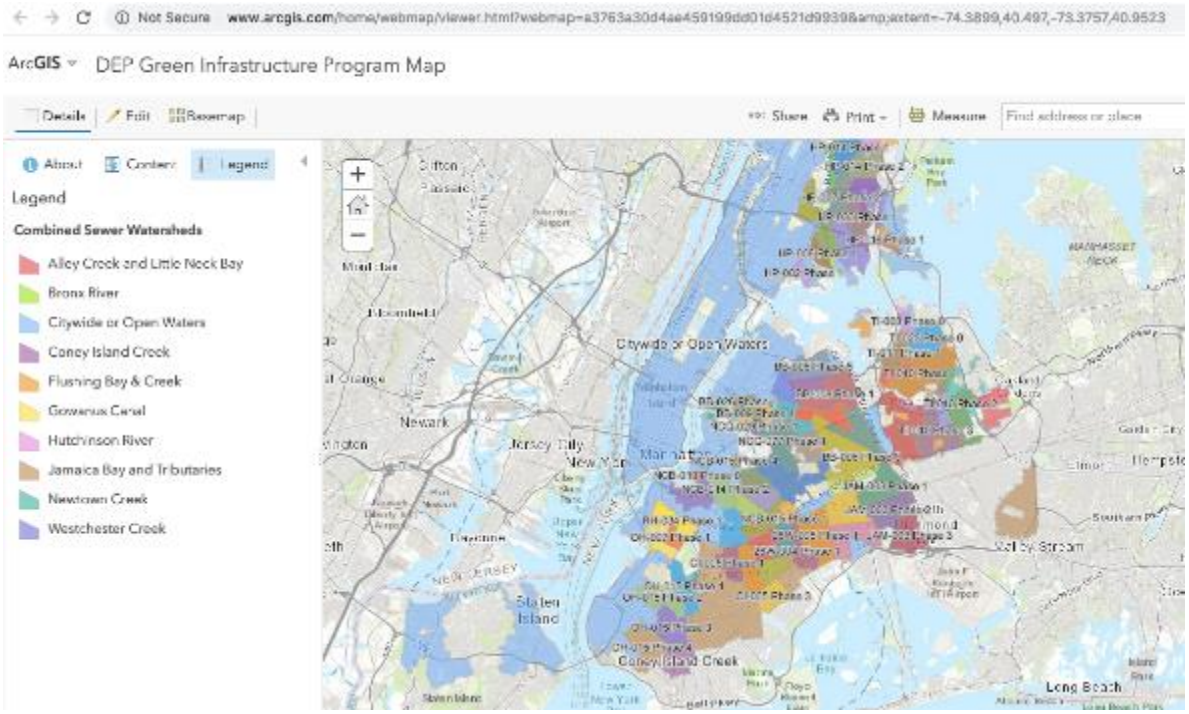
4. Why is it important to have data and identify patterns/trends within the data when suggesting a mitigation strategy?

Answers will vary. Example response: It is important to have data and identify patterns/trends within the data in order to validate the effectiveness the mitigation strategy. For example, in the previous question it was discussed how we can determine effectives of mitigation strategies such as bioswales. Once we have the data to show the effectiveness of the strategy we can use that data to support the reason for suggesting the mitigation strategy.

3. NASA Climate Kids Offset Game
https://climatekids.nasa.gov/offset/

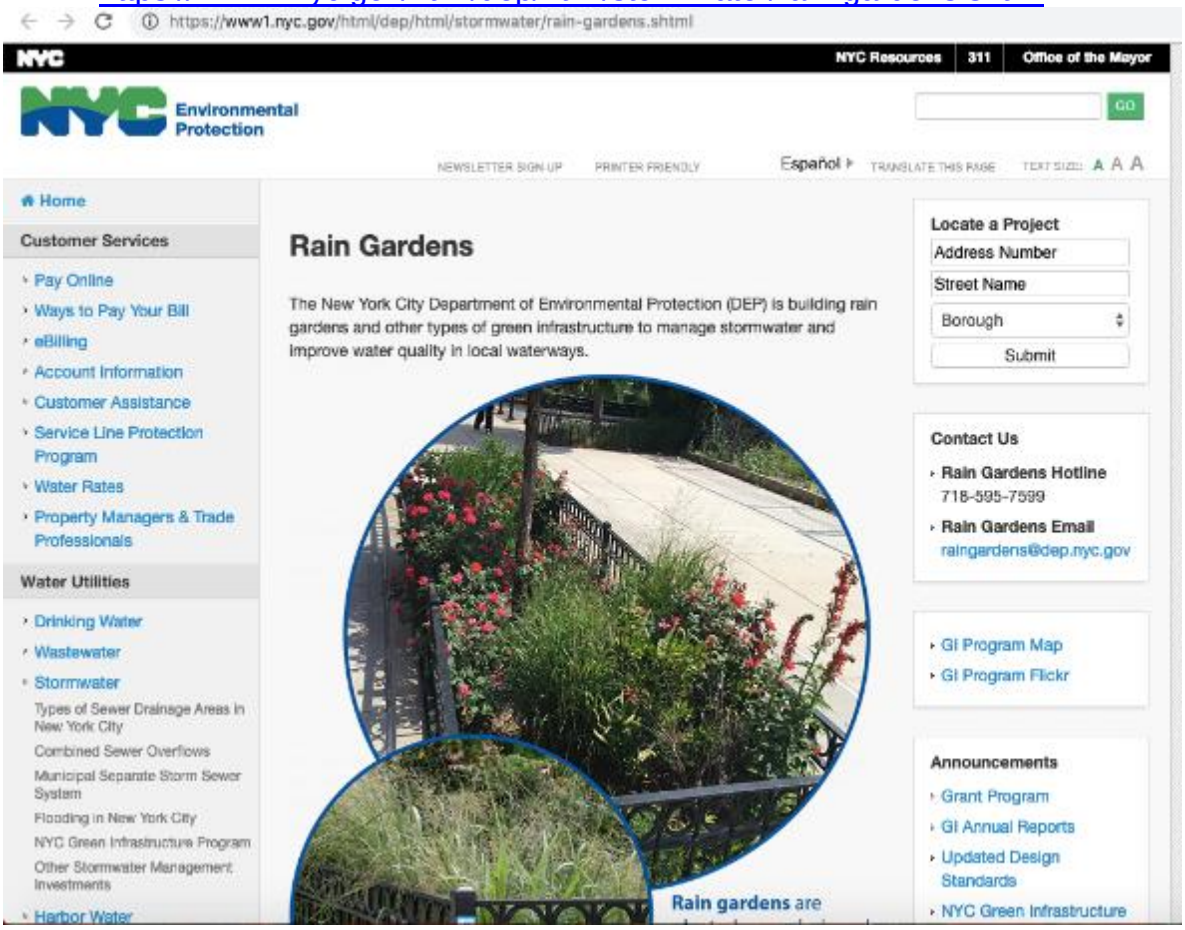


4. Arc GIS DEP Green Infrastructure Program Map
http://www.arcgis.com/home/webmap/viewer.html?webmap=a3763a30d4ae459199dd01d4521d9939&extent=-74.3899,40.497,-73.3757,40.9523



5. NYC Environmental Protection Rain Garden Article

https://www1.nyc.gov/html/dep/html/stormwater/rain-gardens.shtml



Rain gardens are planted areas designed to collect and manage stormwater that runs off the streets and sidewalks when it rains.

- NYC Green Infrastructure Video

Green infrastructure is a cost-effective way to help create a sustainable New York City

- Beautifies neighborhoods.
- Purifies air.
- Reduces temperature during hot weather.
- Improves street drainage.
- Reduces puddles and ponds.

How Rain Gardens Work

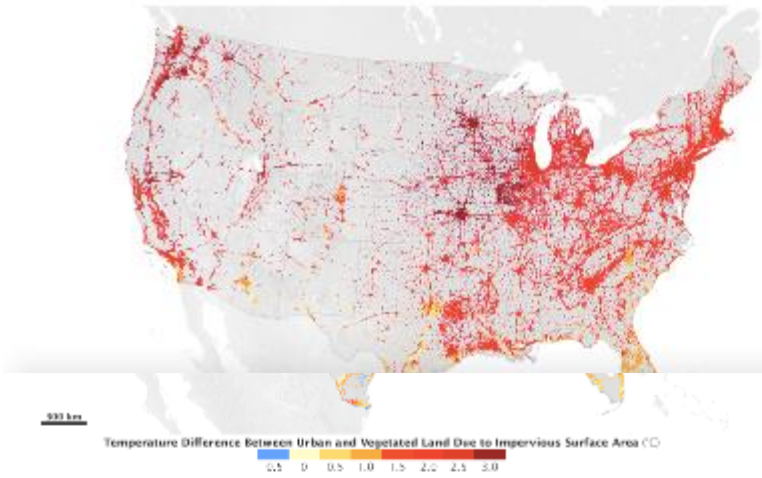
A rain garden may look similar to a street tree pit or a small garden, but there are some key differences. Here's how you can tell the difference:

1. **Curb inlet** - The inlet allows water to flow into the rain garden as it flows down the curb toward the catch basin.
2. **Outlet** - Larger rain gardens also have an outlet. If the rain garden fills to capacity, water can exit through the outlet and continue into the catch basin on the street corner.
3. **Stone Strip** - The stone strip allows people to step out of their cars without damaging the plants.
4. **Plants** - All rain gardens have plants and grasses which have been carefully selected to ensure they can survive on busy New York City streets.
5. **Soil** - The soil is graded so that water ponds in the center of the rain garden.
6. **Tree Guard** - All rain gardens have tree guards around them that protect the plants and keep people and dogs from walking inside of it.
7. **Tree** - DEP plants trees in rain gardens as often as possible. Trees benefit neighborhoods by lowering temperatures in hot summer months, improving air quality, and providing habitat for birds and butterflies.

6. NASA Earth Observatory Vegetation Limits City Warming Effects article

https://earthobservatory.nasa.gov/images/86440/vegetation-limits-city-warming-effects

Vegetation Limits City Warming Effects



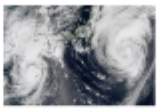
New research quantifies how plants along urban roads, in parks, and in wooded neighborhoods can regulate the warming effects of urbanization.

Image of the Day for August 26, 2015

Instruments:
Landsat 7
Model
Terra — MODIS

Image of the Day | Heat | Human Presence | Remote Sensing

View more Images of the Day:


Aug 25, 2015

Aug 27, 2015

Cities are well-known hot spots—literally. The urban heat island effect has been observed to raise the temperature of cities by 1 to 3°C (2 to 5 °F) compared to neighboring rural and semi-rural areas. The rise is due to the presence of asphalt, concrete, stone, steel, and other impervious surfaces that absorb heat and disrupt the natural cooling effect provided by vegetation.

According to a new NASA study, the presence or scarcity of vegetation is an essential factor in urban heating. Using data from multiple satellites, the researchers modeled urban areas and their surroundings and found that areas covered in part by impervious surfaces—be they city centers, suburbs, or interstate highways—had an average summer temperature 1.9°C higher than surrounding rural areas. In winter, the temperature difference was 1.5 °C higher.

"This has nothing to do with greenhouse gas emissions or with anything anthropogenic. It's in addition to the greenhouse gas effect," said Lahouari Bounoua, a climate scientist at NASA's Goddard Space Flight Center and lead author of the study published in *Environmental Research Letters*. Bounoua and colleagues also quantified how plants within urban areas—along roads, in parks, and in wooded neighborhoods—can regulate the urban heating effect.

"Everybody thinks, 'urban heat island, things heat up," said co-author Kurtis Thome, also from Goddard. "But it's not as simple as that. The amount and type of vegetation plays a big role in how much the urbanization changes the temperature."

The urban heat island effect occurs primarily during the day, when urban impervious surfaces absorb more sunlight than the surrounding vegetated areas. Trees, grasses, and other vegetation naturally cool the air as a by-product of photosynthesis. They release water back into to the atmosphere in a process called evapotranspiration, which cools the local surface temperature in much the same way that sweat cools a person's skin as it evaporates. Trees with broad leaves, like those found in many deciduous forests on the U.S. East Coast, have more pores to exchange water than trees with needles, and so have more of a cooling effect.

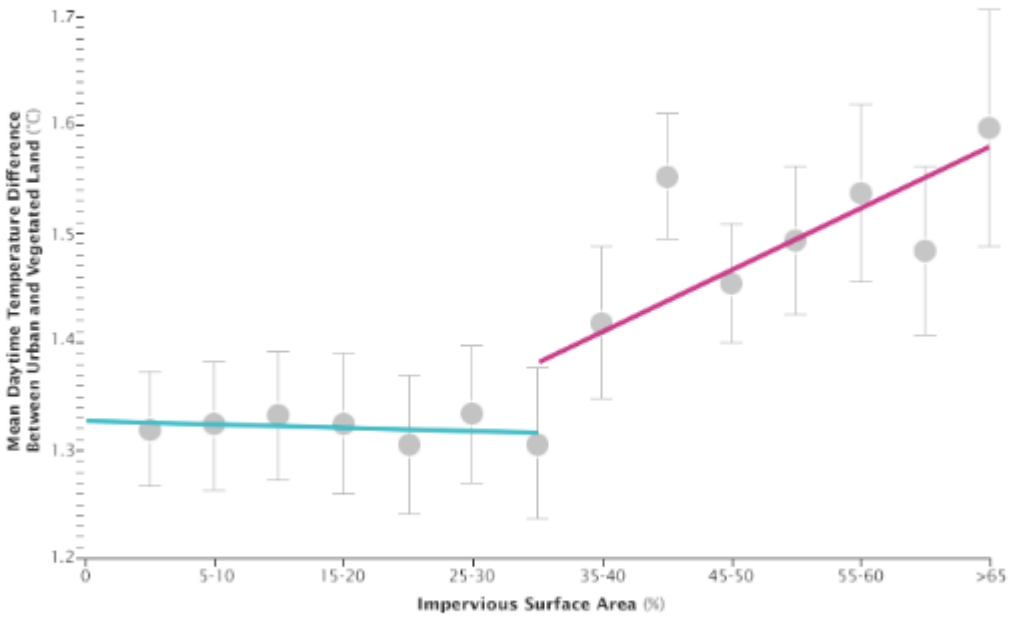
Data from the Enhanced Thematic Mapper Plus (EMT+) on Landsat 7, as well NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on the Terra and Aqua satellites, were combined with NASA's Simple Biosphere model to recreate the interaction between vegetation, urbanization, and the atmosphere at five-kilometer resolution and at half-hour time steps across the continental United States. The temperatures associated with urban heat islands range within a couple degrees, even within a city, with temperatures peaking in the central, often tree-free downtown and tapering out over tree-rich neighborhoods often found in the suburbs.

The highest urban temperatures relative to surrounding rural areas showed up along the Interstate-95 corridor from Boston to Washington, around Atlanta and I-85 corridor in the Southeast, and near the major cities and roads of the Midwest and West Coast. Smaller cities had less pronounced increases in temperature compared to the surrounding areas. In cities built in the desert, such as Phoenix, the urban area was actually cooler because irrigated lawns and trees provide cooling that dry, rocky areas do not.

Bounoua and his colleagues used the model environment to simulate what the temperature would be for a city if all the impervious surfaces were replaced with vegetation. Then they slowly reintroduced impervious surfaces into their model landscape by one percentage point at a time. What they found was unexpected.

When the impervious surfaces were at one percent, the corresponding rise in temperature

When the impervious surfaces were at one percent, the corresponding rise in temperature was about 1.3°C. That temperature difference then held steady at about 1.3° even as impervious surfaces increased to 35 percent. But as soon as the impervious surfaces surpassed 35 percent of land area, temperatures began increasing, reaching 1.6°C warmer by 65 percent urbanization. The chart below shows those differences in mean daytime temperature between urban and vegetated land.



2001

At the human level, a rise of 1°C can raise energy demands for air conditioning in the summer from 5 to 20 percent in the United States, according the Environmental Protection Agency. So even though 0.3 °C may seem like a small difference, it still may have impact

on energy use, said Bounoua, especially when urban heat island effects are exacerbated by global temperature rises due to climate change.

"Understanding the tradeoffs between urban surfaces and vegetation may help city planners in the future mitigate some of the heating effects," said Thome.

"Urbanization is a good thing," Bounoua added. "It brings a lot of people together in a small area. Share the road, share the work, share the building. But we could probably do it a little bit better."

Further Reading

NASA (2006, Aug 1) Ecosystem, Vegetation Affect Intensity of Urban Heat Island Effect. Accessed August 25, 2015.
NASA Earth Observatory (2010, December 14) Urban Heat Islands.
NASA Earth Observatory (2006, December 8) Urban Rain.
NASA Earth Observatory (2006, Aug 1) Beating the Heat.

NASA Earth Observatory images by Joshua Stevens, using data from Bounoua, et al. (2015). Caption by Ellen Gray, NASA Earth Science News Team.

7. Index of USGS Topographic Maps, New York State

https://cugir.library.cornell.edu/catalog/cugir-009001?id=92

https://cugir.library.cornell.edu/catalog/cugir-009001?id=92

7.5 minute quadrangle maps (Digital Raster Graphics) circa 2000. The images form a set of seamless tiles, 5,000 m on a side, from which the map collar information was removed. Images are GeoTIFF files in NAD83, UTM zone 18. A DRG is useful as a source or background layer in a GIS, as a means to perform quality assurance on other digital products, and as a source for the collection and revision of DLG data.

Place:	New York
Category:	basemaps and index map
Subject:	Digital Raster Graphic, basemaps, topographic maps, topo maps, and index map
Year:	1942-2000
File Size:	0.20 MB
More Details:	Metadata

Attribute	Value
Click on map to inspect values	

8. Lesson 4 Rubric

	Struggling	Approaching	At Level	Advanced
Engage *(HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.* *(secondary to HS-ESS3-2),(secondary to HS-ESS3-4) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.* *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.* *(HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.* *(HS-ETS1-4) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of*	The student is able to effectively follow the directions for the Offset game but with almost consistent guidance from the teacher. The student records either their number of upgrades or final score in the provided space on the worksheet. The student has a somewhat effective discussion with another student about the goal of the game and how it applies to what they have been learning but may get a bit distracted. The student records some of the key points from the discussion but does not include an example from the game to support their explanation of the goal of the game, how they were able to score more points, and how the game applies to what they've been learning.	The student is able to effectively follow the directions for the Offset game with some guidance from the teacher. The student records their number of upgrades and final score in the provided space on the worksheet. The student has an effective discussion with another student about the goal of the game and how it applies to what they have been learning but may get a bit distracted. The student records the key points from the discussion but may/may not include an example from the game to support their explanation of the goal of the game, how they were able to score more points, and how the game applies to what they've been learning.	The student is able to effectively follow the directions for the Offset game with little guidance from the teacher. The student records their number of upgrades and final score in the provided space on the worksheet. The student has an effective discussion with another student about the goal of the game and how it applies to what they have been learning. The student records the key points from the discussion. The student includes at least 1 example from the game to support their explanation of the goal of the game, how they were able to score more points, and how the game applies to what they've been learning.	The student is able to effectively follow the directions for the Offset game with little guidance from the teacher. The student records their number of upgrades and final score in the provided space on the worksheet. The student has an effective discussion with another student about the goal of the game and how it applies to what they have been learning. The student records the key points from the discussion. The student includes at least 1 example from the game to support their explanation of the goal of the game, how they were able to score more points, and how the game applies to what they've been learning.

solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs				
Explore *(secondary to HS-ESS3-2),(secondary to HS-ESS3-4) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.* *(HS-PS4-2), (HS PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.* *(HSPS4-6) Mathematical representations can be used to identify certain patterns.* *CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.* *CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.*	The student is able to effectively follow the directions for the explore activity, but requires almost consistent guidance from the teacher. The student works well with their partner, but may get distracted at some points. The student is able to collect most of the required information for the organizer. The name of the watershed is identified, the picture of the watershed is mostly clear, the number of bioswales in their various states are mostly/close to correct, and the observations of trends/patterns of bioswale placement shows evidence of identifying a trend/pattern linked to the bioswales they've identified, but may be excess in wording.	The student is able to effectively follow the directions for the explore activity, but may requires some guidance from the teacher. The student works well with their partner, but may get distracted at some points. The student is able to collect all of the required information for the organizer. The name of the watershed is identified, the picture of the watershed is clear, the number of bioswales in their various states are mostly/close to correct, and the observations of trends/patterns of bioswale placement shows evidence of identifying a trend/pattern linked to the bioswales they've identified, but may be excess in wording.	The student is able to effectively follow the directions for the explore activity, but may require a little guidance from the teacher. The student works well with their partner. The student is able to collect all of the required information for the organizer. The name of the watershed is identified, the picture of the watershed is clear, the number of bioswales in their various states are correct, and the observations of trends/patterns of bioswale placement is concise but shows evidence of identifying a trend/pattern linked to the bioswales they've identified.	The student is able to effectively follow the directions for the explore activity and does not require guidance from the teacher. The student works well with their partner. The student is able to collect all of the required information for the organizer. The name of the watershed is identified, the picture of the watershed is clear, the number of bioswales in their various states are correct, and the observations of trends/patterns of bioswale placement is concise but shows evidence of identifying a trend/pattern linked to the bioswales they've identified. The student includes at least 1 example from the activity in their observation to support their observation.

Explain *(HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.* *(HS-ETS1-3) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.* *(HS-ETS1-1) Analyze complex real-world problems by specifying criteria and constraints for successful solutions.* *(HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.* *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.* *(HS-PS4-4) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).* *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or*	The student has a somewhat effective discussion with their partner, but may be distracted at times. The student is able to identify a pattern/trend of the placement of bioswales. The student does not use an example from the previous activity to support their explanation for the trend/pattern. The student is able to explain why city planners selected the placement of the bioswales but does not use an example from the previous activity to support their reasoning. The student is able to identify most parts of the bioswale. The student includes a write up of the purpose of most of the parts of the bioswale but it may not be concise. The student is able to identify the purpose of installing bioswales but does not use an example from the activity or previous activity to support their explanation. The student is able to provide an effective explanation of why the	The student has an effective discussion with their partner, but may be distracted at times. The student is able to identify a pattern/trend of the placement of bioswales. The student may use at least 1 example from the previous activity to support their explanation for the trend/pattern. The student is able to explain why city planners selected the placement of the bioswales and may use at least 1 example from the previous activity to support their reasoning. The student is able to identify all parts of the bioswale. The student includes a write up of the purpose of each part of the bioswale but it may not be concise. The student is able to identify the purpose of installing bioswales and may use at least 1 example from the activity or previous activity to support their explanation. The student is able to provide an effective explanation of why the strategy would	The student has an effective discussion with their partner. The student is able to identify a pattern/trend of the placement of bioswales. The student uses at least 1 example from the previous activity to support their explanation for the trend/pattern. The student is able to explain why city planners selected the placement of the bioswales and uses at least 1 example from the previous activity to support their reasoning. The student is able to identify all parts of the bioswale. The student includes a concise write up of the purpose of each part of the bioswale. The student is able to identify the purpose of installing bioswales and uses at least 1 example from the activity or previous activity to support their explanation. The student is able to provide an effective explanation of why the strategy would be effective in urban	The student has an effective discussion with their partner. The student is able to identify a pattern/trend of the placement of bioswales. The student uses more than 1 example from the previous activity to support their explanation for the trend/pattern. The student is able to explain why city planners selected the placement of the bioswales and uses more than 1 example from the previous activity to support their reasoning. The student is able to identify all parts of the bioswale. The student includes a concise write up of the purpose of each part of the bioswale. The student is able to identify the purpose of installing bioswales and uses more than 1 example from the activity and previous activity to support their explanation. The student is able to provide an effective explanation of why the strategy would be effective in urban

solutions to determine the merits of arguments. *11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)* *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.*	strategy would be effective in urban environments but does not use an example from this activity or the previous activity to support their explanation. The student records less than 3 key ideas from the article in the space provided in the organizer. The student has an effective discussion with their partner but may/may not add at least 2 more key ideas from the discussion (5 total key ideas). The student is able to provide an effective explanation of how the rain garden ties in with what they read about vegetation in urban areas in the article. The student does not use an example to support their explanation.	be effective in urban environments and may use at least 1 example from this activity or the previous activity to support their explanation. The student records at least 3 key ideas from the article in the space provided in the organizer. The student has an effective discussion with their partner and adds at least 2 more key ideas from the discussion (5 total key ideas). The student is able to provide an effective explanation of how the rain garden ties in with what they read about vegetation in urban areas in the article. The student may use at least 1 example to support their explanation.	environments and uses at least 1 example from this activity or the previous activity to support their explanation. The student records at least 5 key ideas from the article in the space provided in the organizer. The student has an effective discussion with their partner and adds at least 2 more key ideas from the discussion (7 total key ideas). The student is able to provide an effective explanation of how the rain garden ties in with what they read about vegetation in urban areas in the article. The student uses at least 1 example to support their explanation.	environments and uses more than 1 example from this activity and the previous activity to support their explanation. The student records at least 7 key ideas from the article in the space provided in the organizer. The student has an effective discussion with their partner and adds at least 2 more key ideas from the discussion (9 total key ideas). The student is able to provide an effective explanation of how the rain garden ties in with what they read about vegetation in urban areas in the article. The student uses more than 1 example to support their explanation.
Elevate *(secondary to HS-ESS3-2),(secondary to HS-ESS3-4) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.*	The student is able to effectively follow the directions for the activity with almost consistent guidance from the teacher. The student is able to record most of the data	The student is able to effectively follow the directions for the activity with some guidance from the teacher. The student is able to record all the data needed for the table:	The student is able to effectively follow the directions for the activity with little guidance from the teacher. The student is able to record all the data needed for the table:	The student is able to effectively follow the directions for the activity with little guidance from the teacher. The student is able to record all the data needed for the table:

(HS-ETS1-1) Analyze complex real-world problems by specifying criteria and constraints for successful solutions. *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.* *(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.*	needed for the table: watershed name, a somewhat clear picture of the watershed, a somewhat clear picture of the watershed from the topographic map, and an observation of the placement of the bioswales but it may not be concise. The student is able to identify a pattern to the placement of the bioswales. The student does not use an example from the activity to justify their response.	watershed name, a mostly clear picture of the watershed, a mostly clear picture of the watershed from the topographic map, and an informative observation of the placement of the bioswales but it may not be concise. The student is able to identify a pattern to the placement of the bioswales. The student may use at least 1 example from the activity to justify their response.	watershed name, a clear picture of the watershed, a clear picture of the watershed from the topographic map, and concise but informative observations of the placement of the bioswales. The student is able to identify a pattern to the placement of the bioswales. The student uses at least 1 example from the activity to justify their response.	watershed name, a clear picture of the watershed, a clear picture of the watershed from the topographic map, and concise but informative observations of the placement of the bioswales. The student is able to identify a pattern to the placement of the bioswales. The student uses at least 1 example from the activity to justify their response.
Evaluate *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research* *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* *11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)* *(HS-PS4-6) Different patterns may be observed at each of the scales at*	The student is able to somewhat explain how mitigation strategies such as bioswales help reduce the UHI effect. The student does not use an example from the explore, explain, and/or elevate activity to support their explanation. The student is able to identify why it is important to implement mitigation strategies. The student does not use an example from any of the activities	The student is able to explain how mitigation strategies such as bioswales help reduce the UHI effect. The student may use an example from the explore, explain, and/or elevate activity to support their explanation. The student is able to identify why it is important to implement mitigation strategies. The student may use an example from any of the activities	The student is able to explain how mitigation strategies such as bioswales help reduce the UHI effect. The student uses an example from the explore, explain, and elevate activity to support their explanation (3 total). The student is able to identify why it is important to implement mitigation strategies. The student uses an example from any of the	The student is able to explain how mitigation strategies such as bioswales help reduce the UHI effect. The student uses an example from the explore, explain, and elevate activity to support their explanation (3 total). The student is able to identify why it is important to implement mitigation strategies. The student uses several examples from any of the

which a system is studied and can provide evidence for causality in explanations of phenomena. *(HS-ETS1-1) Analyze complex real-world problems by specifying criteria and constraints for successful solutions.* *(HS-ESS3-5) Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.* *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.*	to support their explanation. The student as able to explain how we can determine effectiveness of mitigation strategies. The student does not use an example from this lesson and a previous lesson to support their explanation. The student is able to explain how identifying patterns/rends is important when suggesting a mitigation strategy. The student does not use an example from the lesson to support their explanation.	to support their explanation. The student as able to explain how we can determine effectiveness of mitigation strategies. The student may use an example from this lesson and a previous lesson to support their explanation. The student is able to explain how identifying patterns/rends is important when suggesting a mitigation strategy. The student may use an example from the lesson to support their explanation.	activities to support their explanation. The student as able to explain how we can determine effectiveness of mitigation strategies. The student uses an example from this lesson and a previous lesson to support their explanation. The student is able to explain how identifying patterns/rends is important when suggesting a mitigation strategy. The student uses at least 1 example from the lesson to support their explanation.	activities to support their explanation. The student as able to explain how we can determine effectiveness of mitigation strategies. The student uses several examples from this lesson and a previous lesson to support their explanation. The student is able to explain how identifying patterns/rends is important when suggesting a mitigation strategy. The student uses more than 1 example from the lesson to support their explanation. The student also includes an example from a previous lesson to support their explanation.

f. Conclusion and overview of linkages to next lesson and unit goals. In this lesson, students learned about bioswales, the reasoning behind the placement of bioswales, and how bioswales can help mitigate the effects of UHI. The next and last lesson of the unit (Capstone Project), will utilize the information learned in this lesson and all prior lessons to research a cities UHI and propose a way to mitigate UHI in that particular city.

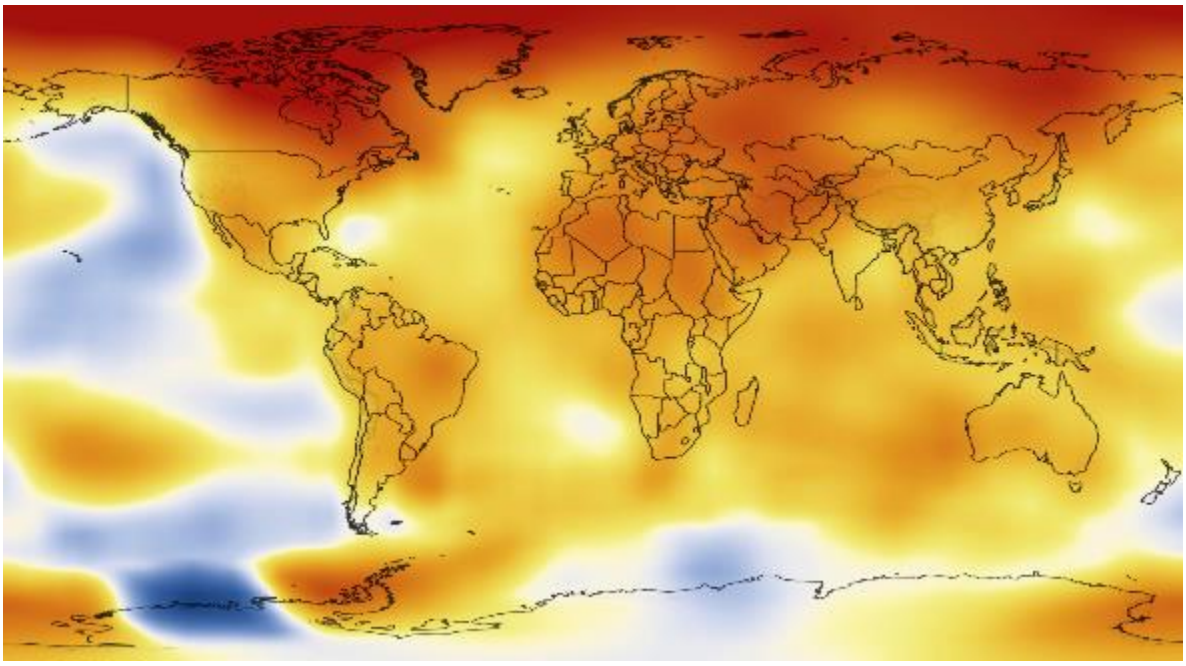
NASA Goddard Institute for Space Studies (GISS)
Climate Change Research Initiative (CCRI)
Applied Research STEM Curriculum Unit Portfolio

Unit Title: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

Lesson Title: Back to a Green Future: Using data of the past to change the future

Capstone Project

NASA STEM Educator / Associate Researcher: Elizabeth Sebastian
NASA PI / Mentor: Dr. Stuart Gaffin, Dr. Reginald Blake, & Dr. Hamidreza Norouzi
NASA GSFC Office of Education – Code 160



XIII. Lesson 5: Back to a Green Future: Using data of the past to change the future Capstone Project - Capstone Project

a. Summary and Goals of Lesson

The final lesson of the unit focuses on the capstone project, which students have been slowly developing and gathering information for throughout the unit. Students will start by viewing a video interview with NASA GISS Director Dr. Gavin Schmidt comparing a doctor's visit to understanding climate change. Then, students will work with a partner to conduct a research study of a specific city to determine how it has been impacted by the Urban Heat Island Effect (UHI). After in depth information using all the techniques from lessons 1-4, students will create an infographic poster to argue how UHI has impacted the city that includes proposed changes the city can take to improve conditions. Students will need to utilize concepts and terms learned within the previous four lessons in order to fully develop their infographic poster. The project requirements reflect how scientists develop, research, and communicate their findings. Students will then present their projects at a poster session where students share their projects in the same fashion as a scientific poster session. The goal of this project is to have students simulate the actions climate scientists would take to develop, test, and propose new ideas to a community, whether that community is their local town government or NASA leadership.

b. Table of Contents for lesson

a. Summary and Goals of Lesson……208
b. Table of Contents for Lesson……208
c. 5 E Lesson Model Template……211
d. Content Template……215
e. Supporting Documents……219
f. Conclusion……262

**Some of the resources in this lesson may require either a Windows, Mac, or Linux computer in order to run properly.*

c. 5 E lesson model template:

Unit: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

Topic: Research a specific city to develop an infographic poster to propose mitigation changes.

Prior Learning: Prior to this lesson, students should have a complete understanding of the Urban Heat Island Effect, how to use both satellite and ground data to understand the UHI effect, and know at least one type of mitigation strategy to reduce the UHI effect.

Do Now (Pre-Assessment): Students will use the knowledge they have gained over the unit to answer the prompt, "Looking towards the future, how can we use what we have learned in this unit to determine and possibly change the future?".

Aim: Conduct a research study of a city to determine how it has been impacted by the Urban Heat Island Effect (UHI) and create an infographic poster to argue how UHI has impacted the city that includes proposed changes the city can take to improve conditions

New York State Standards (Aligned to Next Generation Science Standards):

- (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- (HSPS4-6) Mathematical representations can be used to identify certain patterns.
- (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)
- (HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
- (HS-ESS3-5) Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
- (HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes
- (HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.
- (secondary to HS-ESS3-2),(secondary to HS-ESS3-4) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.
- (HS-ETS1-3) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
- (HS-ETS1-1) Analyze complex real-world problems by specifying criteria and constraints for successful solutions.

- (HS-ETS1-4) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.
- Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-2)

Common Core State Standards:

- CCSS.MATH.CONTENT.HSN.Q.A.2
  Define appropriate quantities for the purpose of descriptive modeling.
- CCSS.MATH.CONTENT.HSN.Q.A.3
  Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- CCSS.ELA-LITERACY.W.9-10.9
  Draw evidence from literary or informational texts to support analysis, reflection, and research.

NASA System of Engineering Behavior:

- *Leadership*
  - Understands the Human Dynamics of a Team
- *Attitudes & Attributes*
  - Seeks Information and Uses the Art of Questioning
- *Systems Thinking*
  - Assimilates, Analyzes, and Synthesizes Data
  - Has the Ability to Find Connections and Patterns Across the System
- *Communications*
  - Communicates Effectively Through Personal Interaction
  - Facilitates an Environment of Open and Honest Communication
- *Technical Acumen*
  - Learns from Successes and Failures
  - Possesses Technical Competence and Has Comprehensive Previous Experience

Performance Objective: Students will be able to create an infographic poster in order to argue why a city needs mitigation due to the Urban Heat Island effect.

Materials:

- Lesson 5 worksheet
- Computer
- Google Earth Pro Desktop App
  - *requires Windows, Mac, or Linux computer to run properly)
  - **An alternative resource, EOS Worldview, is available for this activity. Instructions are on page 242
- Urban Heat Island Intensity Map https://yceo.users.earthengine.app/view/uhimap
- US Government Census Bureau Interactive Maps https://www.census.gov/programs-surveys/geography/data/interactive-maps.html

- EOS Worldview https://worldview.earthdata.nasa.gov/
- Google Earth Desktop Application (downloaded onto computers beforehand)
- Thermal Camera
- GLOBE Account for each student (if completing this portion of Explore activity)
- Visionmaker NYC https://visionmaker.us/nyc/

Development of Lesson: Three Day Lesson (Approximately three 50-minute periods).

What the Teacher does	What the Student does	Time
Do Now! (Anticipatory Opening) As the students are coming into class and setting up, they will complete the *Do Now!* Section of the worksheet. Students will use the knowledge they have gained over the unit to answer the prompt, "Looking towards the future, how can we use what we have learned in this unit to determine and possibly change the future?".	Students will complete the Do Now! Section of the worksheet. Students will use the knowledge they have gained over the unit to answer the prompt, "Looking towards the future, how can we use what we have learned in this unit to determine and possibly change the future?".	5 minutes
Engage Direct the attention to the board. On the board/projector, the video "*HOT Unit 1: The Big Climate Experiment, Lecture 1"* featuring NASA scientist and director Dr. Gavin Schmidt, should be displayed. Instruct students that they will watch this video that compares the changing climate to a visit to a doctor. Instruct students that they will use the organizer provided in the Engage section of the worksheet to write down notes from the video. The organizer has a column for "What it means in a doctor's office" and "What it means if we are looking at the changing climate". Each row goes through the different steps that can occur during a doctor's visit. While watching the video, students will write their notes in the appropriate column/row in the organizer. After watching the video, allow an additional 2-3 minutes for students to finish writing their notes from the video. After, have students turn and share with another student what they wrote down. After 1 minute of sharing, redirect student's attention to the board. Have a copy of the organizer up on the board. Have students volunteer to come up and write their notes in one of the boxes in the organizer. After filling out the organizer, discuss the students why we would use an	Students will watch the video "*HOT Unit 1: The Big Climate Experiment, Lecture 1"* featuring NASA scientist and director Dr. Gavin Schmidt" that compares the changing climate to a visit to a doctor. Students will use the organizer provided in the Engage section of the worksheet to write down notes from the video. The organizer has a column for "What it means in a doctor's office" and "What it means if we are looking at the changing climate". Each row goes through the different steps that can occur during a doctor's visit. While watching the video, students will write their notes in the appropriate column/row in the organizer. After watching the video, student will have an additional 2-3 minutes to finish writing their notes from the video. After, students will turn and share with another student what they wrote down. After 1 minute of sharing, students will volunteer to come up and write their notes in one of the boxes in the organizer.	10 minutes

analogy to help understand the changing climate. **Assessment Opportunity #1 (Use Engage section of rubric to assess.)**		
Explain Direct student's attention to the Explore/Develop part of the worksheet. This section outlines the Capstone project and how to complete the Capstone project. In order to make sure all students understand the project, read the section aloud as a class taking turns to read different parts of the instructions/guidelines. Based on the previous lessons, students will work with a partner to conduct a research study of a city to determine how it has been impacted by the Urban Heat Island Effect (UHI). They will research the following information about the city: "How the city's infrastructure has changed over a set time (think urban expansion)", "How the change of the city's infrastructure has affected land surface temperatures (LST) in the city", "Where are the "hot spots" of the city". "What are the demographics and structure of the hot spot areas", and "How has the city's UHI intensity changed over a set time". Once students have collected this information, they will create an infographic poster to argue how UHI has impacted the city. They will also include proposed changes the city can take to improve conditions on the poster.	Students will direct their attention to the Explore/Develop section of the packet. Taking turns, students will read aloud the instructions/guidelines of the Capstone project. Students are encouraged to ask questions for clarification to help understand the aspects of the project.	10-20 minutes
Explore/Develop Provide students the rest of the class to meet with their partner to start the development/research of their Capstone Project. It is suggested to give students at least 3 full classes to continue development and develop the Capstone Project in order to facilitate guidance as needed from the instructor. If more time is needed, you may continue project in additional classes or assign students to work on project outside class with a set deadline. If outside of class, it is suggested to give students at least 3 weeks to finish the project.	Using the instructions, requirements, rubric, and guided outline, students will work in a pair with another student to complete the Capstone Project. If students need any guidance or assistance, first ask your peers. If they are not able to assist the student, students may seek out the guidance of the teacher.	At least 2-3 classes and possibly 2 weeks outside of class

Assessment Opportunity #2 (Use Explore/Develop section of rubric to assess.)		
Elevate After students have completed 2 peer reviews and a final self-check of their posters, students will send a copy of the poster PowerPoint file to the teacher (teacher must provide a way for students to submit poster, it is suggested to have students email the file). The teacher will then need to print out the poster. The size of printed out poster will depend on the school's printing capabilities. An alternative is to display the poster on the board/projector if the appropriate printing capabilities are not available. Students will then present their poster aloud to the class. Students will use their argument developed in Step 6 to help them with the verbal part of the presentation to the class. For grading the posters, it is suggested the teacher use the rubric attached at the end of this lesson to grade the poster both during the presentation and looking at the poster afterwards. If printing posters out, it is suggested to display the posters along the classroom walls during presentations and in the hallway after presentations to display the great work students have completed. **Assessment Opportunity #3 (Use Elevate section of rubric to assess.)**	After students have completed 2 peer reviews and a final self-check of their posters, students will send a copy of the poster PowerPoint file to the teacher (teacher must provide a way for students to submit poster, it is suggested to have students email the file). Students will then present their poster aloud to the class. Students will use their argument developed in Step 6 to help them with the verbal part of the presentation to the class.	Presentation times will vary. Student presentations should last no more than 10 minutes each.
Closing After presentations have concluded, students will complete two tasks: 1. A reflection of the project/unit, 2. A post assessment (the pre-assessment from the beginning of the unit). Once the student has finished the post-assessment, hand them back their pre-assessment from the beginning of the unit. Students will compare their responses from the first time they took the pre-assessment to the one they completed at the conclusion of the unit to see how much they have learned about Urban Heat Islands.	Students will complete the post-assessment for the unit. Once students have completed the post-assessment, they will receive the pre-assessment. Students will compare their answers from the pre and post assessments to see how their responses have changed since the beginning of the unit. Students will then complete the reflection that is at the end of the lesson 5 worksheet. Once the reflection is completed, students will turn in the	30 minutes

Students will then complete the reflection that is at the end of the lesson 5 worksheet. Once the reflection is completed, have students turn in the lesson 5 worksheet, the pre-assessment, and the post-assessment. **Assessment Opportunity #4 (Use Closing section of rubric to assess.)**	lesson 5 worksheet, the pre-assessment, and the post-assessment.	

Summary/Conclusion:
Students will present their infographic poster to the class. Students will then complete a reflection and post-assessment.

Higher Order Actions/Activities:
1. Develop a statement of support to explain the importance of mitigation in urban areas using the data collected in the research portion of the activity.
2. Propose a plan for change for the city that includes a prediction of what the city might be like in the future because of the changes implemented.
3. Design an infographic poster to display the research findings, proposed changes, and possible future outcome of proposed changes.

Differentiated Instruction:
- The students learn the content in a variety of ways. The students learn content through visual formats (images and videos), oral discussion, experimental design, data analysis, and reflection.
- Students use data analysis tools to create graphs of their final results from the experiment.
- Students use a variety of technology to learn about content.
- Students are provided with a variety of leveled questions (low-high order) to answer questions at their level and elevate their thought processes.
- Students are given the chance to review their understanding through oral discussion in order to confirm or add to their understanding of the content.
- Students will use a graphic organizer to help with their understanding of the content and organize the content in an orderly, easily readable fashion.

Daily Formative Assessment:
Students will complete a reflection and the post-assessment (pre-assessment) to finalize their understanding of the topics throughout the unit.

d. Content template:

NGSS Standard & State Science Content Standard: (HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HSPS4-6) Mathematical representations can be used to identify certain patterns. (HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. 11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4) (HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS3-5) Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes (HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (secondary to HS-ESS3-2),(secondary to HS-ESS3-4) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-1) Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-4) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-2)			Common Core Standard: CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.	NASA Science: Earth Science
Content Area: Earth Science/Environmental Science Grade Level: 9th Grade		Name of Project-Based Activity or Theme: Back to a Green Future: Using data of the past to change the future	Estimated Time Frame to Complete(days/weeks): 3 classes/days	
Overall Investigation Question(s): How does understanding the past climate history of a city help us to determine the effect of mitigation strategies to reduce the urban heat island effect in a city?				
Overall Project Description/Activity: Students will be able to create an infographic poster in order to argue why a city needs mitigation due to the Urban Heat Island effect.				
	:			

Materials Needed to Complete Project (put N/A as needed). -Lesson 5 worksheet -Computer - Google Earth Pro Desktop App - Urban Heat Island Intensity Map https://yceo.users.earthengine.app/view/uhimap - US Government Census Bureau Interactive Maps https://www.census.gov/programs-surveys/geography/data/interactive-maps.html - EOS Worldview https://worldview.earthdata.nasa.gov/ - Google Earth Desktop Application (downloaded onto computers beforehand) - Thermal Camera - GLOBE Account for each student (if completing this portion of Explore activity) - Visionmaker NYC https://visionmaker.us/nyc/	Stakeholders: Fusion Academy: Education Team, Administrators, Science Department, Science Teachers, and students	Hyperlinks Used: ● Urban Heat Island Intensity Map https://yceo.users.earthengine.app/view/uhimap ● US Government Census Bureau Interactive Maps https://www.census.gov/programs-surveys/geography/data/interactive-maps.html ● EOS Worldview https://worldview.earthdata.nasa.gov/ ● Visionmaker NYC https://visionmaker.us/nyc/	Multimedia/Technology: Computer ● Urban Heat Island Intensity Map ● US Government Census Bureau Interactive Maps ● EOS Worldview ● Google Earth Desktop Application (downloaded onto computers beforehand) ● Thermal Camera ● GLOBE Account for each student (if completing this portion of Explore activity) ● Visionmaker NYC	Classroom Equipment: Computer
NASA System Engineering Behaviors (2 behaviors per category)	Category (must have one Technical Acumen)	Activities How will student model engineering behaviors when learning science content? Describe student activities here.	Student Outcomes How will you assess learning for each behavior	Evaluation Describe specific science content students understand as a result of engineering behavior.

Understands the Human Dynamics of a Team	Leadership	Students work in pairs to complete the Explore/Develop activities (researching UHI effect for a specific city, developing an infographic poster, peer reviewing other posters, presenting the poster)	Lesson 5 Rubric	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Seeks Information and Uses the Art of Questioning	Attitudes & Attributes	Students will research information stated in the project guidelines in the in order to develop an infographic poster.	Lesson 5 Rubric	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Assimilates, Analyzes, and Synthesizes Data	Systems Thinking	Students will obtain satellite data and interpret the data in order to identify a trend/pattern of surface temperatures and land changes to understand the UHI phenomenon in the Explore & Explain activities. Students will obtain land surface temperature data from thermal cameras and satellites. Students will interpret the data in order to verify the data collected by satellites. Students will interpret the data in order to identify the areas of most intense UHI and the factors that cause the UHI.	Lesson 5 Rubric	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Has the Ability to Find Connections and Patterns Across the System	Systems Thinking	Students will obtain satellite data and interpret the data in order to identify a trend/pattern of surface temperatures and land changes to understand the UHI phenomenon in the Explore & Explain activities. Students will obtain land surface temperature data from thermal cameras and satellites. Students will interpret the data in order to verify the data collected by satellites. Students will interpret the data in order to identify the areas of most intense UHI and the factors that cause the UHI.	Lesson 5 Rubric	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Communicates Effectively Through Personal Interaction	Communications	Students work in pairs to complete the capstone project. Must have effective communications in order to be successful in activities.	Lesson 5 Rubric	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon

Facilitates an Environment of Open and Honest Communication	Communications	Students work in pairs to complete the capstone project. Must have effective communications in order to be successful in activities.	Lesson 5 Rubric	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Possesses Technical Competence and Has Comprehensive Previous Experience	Technical Acumen	For the Explore activity, students must have a comprehensive knowledge of retrieving and analyzing data from a variety of sources in order to verify the data collected using ground data collection methods, determine UHI intensity, and test their mitigation solutions.	Lesson 5 rubric	Data collection, data analysis, validation of data, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
Learns from Successes and Failures	Technical Acumen	Through all the activities and discussions, students have to be open to both success and failures in order to learn new information.	Lesson 5 rubric	Data collection, data analysis, thermal bands, infrared energy, absorption, changes in land & its effect on the environment, using technology to understand phenomenon
List and attach all supportive documents for instructional activities	Attachments? (circle) Yes or No	List Attached Documents(if any): Lesson 5 Worksheet		
List and attach all rubrics for activity and assessment evaluation	Attachments? (circle) Yes or No	List Attached Rubrics (if any): Lesson 5 rubric		
Include comments or questions here:				

e. Supporting Documents: (order according to sequence of lesson)

1. Lesson 5 Capstone Worksheet

Back to a Green Future:
Using data of the past to change the future
Lesson 5 Worksheet – Capstone Project

Do Now!
This past unit, we have learned about how we can use satellites to learn about the Urban Heat Island, the accuracy of satellite data versus data collected at the ground level, how UHI intensity changes over time and the factors that change the intensity, and some mitigation strategies such as bioswales to help cool down urban areas.

Looking towards the future, how can we use what we have learned in this unit to determine and possibly change the future?

_____
_____
_____
_____
_____
_____

Engage
You will now watch a video where Dr. Gavin Schmidt, Director of NASA Goddard Institute for Space Studies, will compare the changing climate to a visit to a doctor. Using the organizer below, describe how a visit to the doctor is similar to our changing climate.

Video:
https://www.youtube.com/watch?v=N6VJZ6N34XM&list=PLcHlZavTgnuoM47UShbcokqIqkZMluF8t&index=3&t=0s

Phases	What it means in a Doctor's Office	What it means if we are looking at the changing climate
Initial Symptoms		
Diagnosis		

Prognosis		
Treatment		

Explore/Develop

Utilizing what you have learned in this unit, you will work with a partner to conduct a research study of a city to determine how it has been impacted by the Urban Heat Island Effect (UHI). You will research the following information about the city:

- How the city's infrastructure has changed over a set time (think urban expansion)
- How the change of the city's infrastructure has affected land surface temperatures (LST) in the city
- Where are the "hot spots" of the city. What are the demographics and structure of the hot spot areas
- How has the city's UHI intensity changed over a set time?

Once you've collected this information, you will create an infographic poster to argue how UHI has impacted the city. You will also include proposed changes the city can take to improve conditions. Follow the steps below to collect all the information needed for the poster.

Step 1: Determine City of Study

With your partner, select a city to research for this project. Below is a list of suggested cities. You may choose one of the cities in the list or select a different city with approval from your teacher. Once you select your city, write it on the line provided below.

Suggested Cities:

New York City	Tokyo	Mexico City	Melbourne	Buenos Aires
Atlanta	Moscow	Lima	Sydney	Toronto
Shanghai	Paris	Nairobi	Johannesburg	Houston
London	Hamburg	Seoul	Berlin	Rome
Seattle	Mumbai	Bogota	Madrid	Chicago
Las Vegas	Cairo	Singapore	Barcelona	
Bucharest				

City Selected: _____

Step 2: View Historical Data of the City using Google Earth & Worldview

In lesson 1, you viewed historical data of a city and observed how the infrastructure/sprawl and land surface temperature of the city changed over a span of time. You will follow the same process with the city you selected in the previous step. The time span you observe is up to you, but it is suggested to look for at least the past 10 years. You will take images of the time span for each year to help you track the changes. Place the images in the table provided below. Follow the directions below to complete step 2.

Land Surface Changes ***Alternative directions for this activity using EOS Worldview on last page of worksheet*

1. On your desktop, open the Google Earth application.
2. Once opened, in the top left-hand corner, type in the city you and your partner selected, then press search. The map will automatically redirect and zoom into the city you selected.
3. At the top, select View, then click Historical Imagery. This will enable you to look at Google Earth images of the city over time.
4. At the top left, you will see a rectangle with a scroll bar and date range for the city selected. Each city has a different date range based on data Google has in its archives, so double check the date range your team selected. Use the scroll bar to move back in time. When you let go, it will display an aerial image of the city during that year.
5. Move the scroll bar to the earliest year your team has selected.
6. You will now take selected screenshots of the data displayed for each year. Start at your first selected date. In total, you will have 10 images. Depending on the computer you are using follow the instructions below. After each image you screen shot, save it to a folder on your desktop. You will need all the images to paste into your worksheet.
    a. PC Instructions
        i. In the start menu, select the “Snipping Tool”.
        ii. Double check you are on your first screen. Then, click “New” in snipping tools. It will give you a + icon. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
        iii. A window will then pop up in Snipping Tools showing you what you copied. Right click on the image and click “Save as”. Save the image to a designated folder on the desktop.
        iv. Repeat steps 1-3 for every year of the time span you selected.

    Mac Instructions

    3. Double check you are on your first screen. Then press command+shift+4. Your cursor will then turn into a + sign. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
    4. The image captured will save to your desktop automatically.
9. Using the screen shots you just created, you will now divide each image into 9 equal sections. Using either a ruler or Microsoft word, divide each image into 9 equal sections.
10. For each image, you will write down observations of the city in terms of built areas and green space (areas of greenery). Record the observations in the table below. Note specific changes by square if applicable. Repeat for each image.

Land Surface Temperature Changes

1. Go to https://worldview.earthdata.nasa.gov/ . If you haven’t been to the site before, it will give you a guided tour of how to use the site (go through this if you haven’t used the site before).
2. On the left side of the screen towards the bottom, click the button that says "+Add Layers”. Click the second tab “Science Disciplines”.
3. Find the category that says “Land Surface” and select the three horizontal dots at the bottom of the category for more options. Find “Land Surface Temperature” and then click the orange arrow next to this option. Then select the box for “Land Surface Temperature (Day)” for Terra/MODIS. This will add the layer of land surface temperature to your map. Then click the X at the top of the pop out box to close the pop out window.
4. In the bottom left hand corner, you will see options to change for different time options. Select “Year”.

5. On the bottom left hand corner, the date currently being shown on the map is displayed. Change the date to the first date you selected. Make sure the month and day stay the same for each year you research.
6. Zoom in on the city you selected on the map using the scrolling feature on your mouse or trackpad until you have a zoom of 10 km/5 mi (this is displayed in the lower right part of the screen).
7. You will now take selected screenshots of the data displayed for each year. Start at your first selected date. In total, you will have 10 images. Depending on the computer you are using follow the instructions below. After each image you screen shot, save it to a folder on your desktop. You will need all the images to paste into your worksheet.
    a. PC Instructions
        i. In the start menu, select the “Snipping Tool”.
        ii. Double check you are on your first screen. Then, click “New” in snipping tools. It will give you a + icon. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
        iii. A window will then pop up in Snipping Tools showing you what you copied. Right click on the image and click “Save as”. Save the image to a designated folder on the desktop.
        iv. Repeat steps 1-3 for every year of the time span you selected.

    Mac Instructions

    5. Double check you are on your first screen. Then press command+shift+4. Your cursor will then turn into a + sign. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
    6. The image captured will save to your desktop automatically.
8. Using the screen shots you just created, you will now divide each image into 9 equal sections. Using either a ruler or Microsoft word, divide each image into 9 equal sections.
9. For each image, find the temperature of each of the 9 sections. Then, find the average temperature of the image. Record the temperature in the table below. Repeat for each image. Make sure your temperatures are in Celsius.

After completing the directions above for your selected topic, you will now discuss with your partner changes in both land surface temperature and the land surface for correlations.

i. Starting with the first year, observe the two images collected. Discuss what you see in each image.
ii. In the notes section column in the table, write down any correlations you identify between the land surface temperature image and the land surface image.
iii. Repeat steps 1 and 2 for all 10 images.
iv. When finished, move on to the *Explain* section to answer questions regarding the information collected in this activity.

Land Surface Changes Table

Year	Land Surface Image	Observations of Land Surface	Land Surface Temperature Image	Average Temperature of Land Surface	Notes

Step 3: Determining Urban Heat Island Intensity over the years

In lesson 3 of the unit, you looked at how UHI intensity changed in a city over a span of time using a Google Earth Engine site. Using the same site, you will determine the intensity of your selected city. Make sure you are looking at the same amount of time (if applicable) that you did for the previous step. Follow the steps below to complete step 3.

1. Go to: https://yceo.users.earthengine.app/view/uhimap
2. In the search bar at the top, type in your city. Suggestions will start popping up underneath the search bar. Click your city. The map will then redirect and zoom you in on your city. At the top left of the screen you will see a scroll bar to change the year. You will need to use this for the data collection below.
3. Click on an area in the city. Make sure the area you click on has data for that particular location (has a colored pixel over top of it).
4. On the bottom left side of the screen, there is a key to indicate the color of different intensities. There is also a drop-down menu to change the view of the intensities. Click the drop-down menu and select “Summer Day”. This will overlay the data of UHI intensity for an average summer day in your city.
5. On the right side of the screen you will see data for the drop down you selected. You will use this area for the next step.
6. Observe the Summer Daytime UHI. Write this value in the table below in the “Summer Daytime UHI” column. Repeat for “Summer Nighttime UHI”.
7. You will now determine the Highest Summer Daytime Intensity and Lowest Summer Daytime Intensity. Using the key at the left of the screen, determine which value is the highest value shown in the data on your screen. Record the intensity in the column “Highest Summer Daytime Intensity”. Repeat this process for the “Lowest Summer Daytime Intensity”.
8. Calculate the range of intensity by subtracting the “Lowest Summer Daytime Intensity” from the “Highest Summer Daytime Intensity”. Record the value in the “Range of Intensity” column in the table below.
9. In order to keep track of changes in both temperature and city structure, you will take 2 images of the city for each year.
    a. First, select screen shot the city. Make sure to include the key in your image as a reference point.
    b. Go to Google Earth Pro desktop app. Type in your city into the search bar at the top left of the screen and hit “search”. Once the screen has automatically zoomed into your city, go to the top of the screen and click “view” and select “historical imagery”. At the top left you will see a scroll bar that will allow you to change the years. Place the tool at the year being observed. Once set, take a selected screen shot of the city. Make sure it is encompassing the same area as the image you collected in the previous step.
10. In the last column, write any observations you noticed with the data collection for that year.
11. Repeat steps 7-10 for all the years listed in the table.
12. Once all data has been collected, you will then complete the last row of the table. The last row is to calculate/identify changes over the time span.
    a. For columns “Summer Daytime UHI”, “Summer Nighttime UHI”, Highest Summer Daytime Intensity”, “Lowest Summer Daytime Intensity”, and “Range of Intensity”, calculate the change of temperatures over the years. This may turn out to be either a positive or negative value.
    b. For columns “Picture of City” and “Observations”, you will identify the overall changes that have occurred during the time span of data collection.

Urban Heat Island Intensity Table

Year	Summer Daytime UHI	Summer Nighttime UHI	Highest Summer Daytime Intensity	Lowest Summer Daytime Intensity	Range of Intensity	Picture of City	Observations
2003							
2004							
2005							
2006							
2007							
2008							
2009							
2010							
2011							
2012							
2013							
2014							
2015							
2016							
2017							
Change							

Step 4: Determining Demographics of Hot Spots of the City
Using the information you've collected in the previous steps, determine the areas that are considered the "hot spots" of the city (areas where LST is higher than most parts of the city). You will determine the demographics/infrastructure of these hot spot areas. This will help later on with your proposed changes section. Follow the steps below to complete step 4.

With your partner, follow the directions below.

1. Go to https://www.census.gov/programs-surveys/geography/data/interactive-maps.html
2. On this site, you will find a variety of interactive maps that uses the US census data. You can use either the "Census Data Mapper" and/or the "Metro/Micro Thematic Map Viewer". First browse through both to get a better idea of which would better suit your research needs.
3. After browsing through both maps, use one or both maps, research the demographics and record research findings below. It is suggested to draw a rough outline of the city with the "hot spots" (areas of higher/highest temperatures) to help with correlating data. After researching, answer the questions below the organizer.

In the "hot spot" areas of the city:

What is the majority age range?

What is the economic status?

What is the population concentration?

Are there more families or single households?

What is the main type of housing?

What is the main race?

What type of infrastructure are in these areas?

Step 5: Predicting the Future of the City

Based on the information you collected in the previous steps, you will now make a prediction of what you think will happen in your city in terms of LST and climate. Write your prediction in the space below. You may include illustrations to enhance your prediction. Make sure in your prediction you use the information you collected to support your prediction.

Step 6: Create a well-developed argument for change
Using everything you have collected in the previous steps, you will develop an argument for why change needs to occur in the city you are studying.

Use the space below to mind map your argument using the information you have collected.

Now that you have mapped out your argument, let's turn the notes into a formal statement. Use the lines provided below to construct your argument. Think of the statement as your "script" for when you present your infographic poster. Make sure your argument includes statistics/facts you found during your research phase.

Step 7: Propose a plan for change to improve the city
Using the information collected in all of the previous steps, you will now create a well-structures proposal for how you plan to improve the city and decrease the UHI effect.

First, we will start with brainstorming and researching mitigation strategies that would reduce the UHI effect. Think back to lesson 4 where we learned about bioswales. Bioswales are one type of mitigation strategy, but there are several more!

Using the space below, research other mitigation strategies that would help reduce the UHI effect in your city. Be sure to include information about the mitigation strategy and why it would help the city.

Now that you have your list of mitigation strategies to improve your city, we have to make sure they are indeed effective. There are 2 steps we will use to determine if the strategies proposed are effective. Read through the two steps below. Then use the strategies to test your suggestions.

*Make sure to write down your findings in the space provided below. You will need the information from the testing to give validation for your proposal on the poster.

Part 1:
Using the mobile thermal cameras, you will go with your partner (and a teacher) outside to test the land surface temperature (LST) of the various mitigation strategies you proposed. This will help you collected data to support your proposed changes.

Use the space below to draw a table to record your findings. The number of rows/columns depends on the number of surfaces you test. Make sure to test the LST several times the more repeated tests, the more you can confirm your findings.

Make sure to also take pictures of your mitigation strategies. Visualizations are very helpful on infographic posters to help convey your message.

Part 2:
You will now use a site called “NYC Visionmaker” to test how your mitigation strategies might perform in the future.

First, you will need to select a part of New York City that best represents the majority of the structure of your city. Use a satellite map to view NYC to help you determine the section of NYC to use.

Then, go to https://visionmaker.us/nyc/. Once on the site, click the middle button “Learn More”. Go through all the steps of the tutorial to learn how to use the site.

After completing the tutorial, click “sign up” to create an account in order to develop and save your visions. You only need 1 account in your group.

As you develop and test your “vision”, make sure you take screen shots of the development and the results of testing. Use the space below to record your images and findings.

Additional space for notes:

Step 8: Create an Infographic Poster

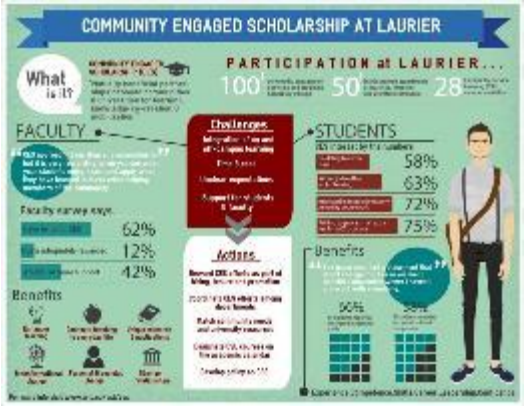
Now that you have all the information need to support your research/argument for your selected city, you will develop an infographic poster.

The poster should include the following information:

- How the city's infrastructure has changed over a set time (think urban expansion) (Step 2)
- How the change of the city's infrastructure has affected land surface temperatures (LST) in the city (Step 3 & 4)
- Where are the "hot spots" of the city. (Steps 3)
- What are the demographics and structure of the hot spot areas (Step 4)
- How has the city's UHI intensity changed over a set time (Step 4)?
- Prediction of the Future of the City (Step 5)
- Why the city needs to change (Step 6)
- Proposed mitigation strategies for the city (Step 7)
- Data to support mitigation strategies (Step 7)

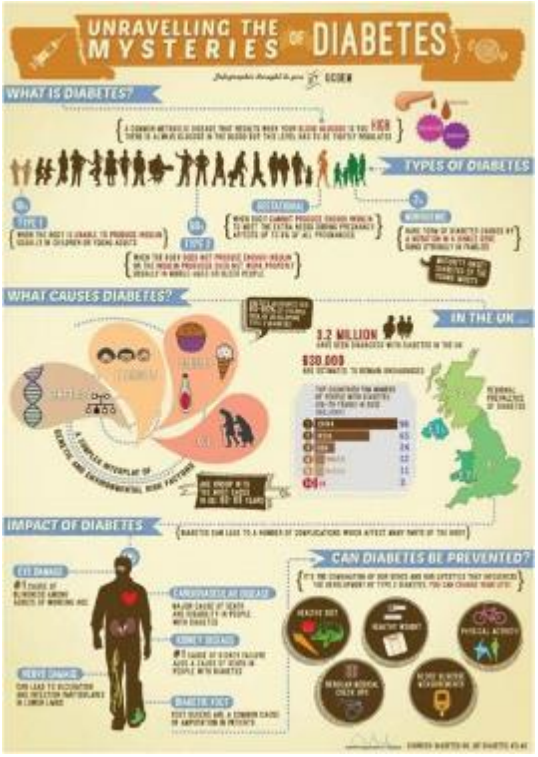
Your poster should be clear, concise, and convey your message in a readable format. Do not create a "wall of text". You want to be able to convey your message in a way that if someone was walking by, they could understand your poster within 1-3 minutes.

Below are examples of various infographic posters (some are scientific, some are not). For more examples, google "scientific infographic poster example". There are plenty of examples in the "images" section that will help you format a design.



Source: http://www.higher-education-marketing.com/uploads/Laurier-CES.jpg

Source: http://pcs.ieee.org/2014-ieee-pcs-conference-student-poster-competition-winners/



Source: http://blogs.it.ox.ac.uk/oxtalent/files/2014/06/Ng-Poster.jpg

To start developing your poster design, use the space below to sketch out how you want to present your information.

Now that you have sketched out a design of your poster, use PowerPoint to create your infographic poster.

Below is a link to help you with designing your infographic poster:
https://www.youtube.com/watch?v=66fnRMbYXsE

Once you have finished designing your poster, you will need 2 other groups to read through your poster to check for understanding and spelling/grammar errors. The groups will use the rubric attached at the end of the worksheet to review your poster. Have the groups provide feedback in the space below. Once feedback is provided, the groups will need to sign off on the lines provided below.

Group 1 Feedback:

Group 1 Check: _____

Group 2 Feedback:

Group 2 Check: _____

After the peer check, conduct one more check of your poster by having you and your partner review the poster using the rubric at the end of the worksheet.

Once you have the final version of your poster ready to go, send the poster to your teacher. The teacher will print out your poster to display. You will also need to paste a copy of the poster in the space provided below.

Now that you have completed your poster, you will present your poster to the class. Hang your poster on a spot on the wall. Once your teacher directs you, you and your partner will go up to your poster and present it to the class. Remember, you can use the script you developed in Step 6 for your presentation.

After presenting, complete the reflection below:

Reflection

1. What have you learned about the Urban Heat Island effect throughout the unit and the Capstone Project?

   _____
   _____
   _____
   _____
   _____
   _____

2. How has completing this unit helped you to understand Urban Heat Islands and the changing climate?

   _____
   _____
   _____
   _____
   _____
   _____
   _____

3. How did creating/developing the infographic poster help you to understand Urban Heat Islands and the changing climate?

   _____
   _____
   _____
   _____
   _____
   _____
   _____

4. After this completion of this unit/project, how do you plan to help our changing climate?

   _____
   _____
   _____
   _____
   _____
   _____

5. After completing this unit, is there anything that you wished you had learned about Urban Heat Islands to help with your understanding of the concept?

   _____
   _____
   _____
   _____
   _____
   _____

**Alternative resource, EOS Worldview, for the "Explore" Land Cover activity

Land Surface Changes

7. Go to https://worldview.earthdata.nasa.gov/ . If you haven't been to the site before, it will give you a guided tour of how to use the site (go through this if you haven't used the site before).
8. On the left side of the screen towards the bottom, click the button that says "+Add Layers". Click the second tab "Science Disciplines".
9. Find the category that says "Land Surface" and select the three horizontal dots at the bottom of the category for more options. Find "Land Cover" and then click the orange arrow next to this option. Then select the box for "Land Cover Type (L3, IGBP, Yearly)". This will add the layer of land surface temperature to your map. Then click the X at the top of the pop out box to close the pop out window.
10. In the bottom left hand corner, you will see options to change for different time options. Select "Year".
11. On the bottom left hand corner, the date currently being shown on the map is displayed. Change the date to the first date you selected. Make sure the month and day stay the same for each year you research.
12. Zoom in on the city you selected on the map using the scrolling feature on your mouse or trackpad until you have a zoom of 10 km/5 mi (this is displayed in the lower right part of the screen).
13. You will now take selected screenshots of the data displayed for each year. Start at your first selected date. In total, you will have 10 images. Depending on the computer you are using follow the instructions below. After each image you screen shot, save it to a folder on your desktop. You will need all the images to paste into your worksheet.
    b. PC Instructions
        i. In the start menu, select the "Snipping Tool".
        ii. Double check you are on your first screen. Then, click "New" in snipping tools. It will give you a + icon. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
        iii. A window will then pop up in Snipping Tools showing you what you copied. Right click on the image and click "Save as". Save the image to a designated folder on the desktop.
        iv. Repeat steps 1-3 for every year of the time span you selected.

    Mac Instructions

    7. Double check you are on your first screen. Then press command+shift+4. Your cursor will then turn into a + sign. You will click and drag the portion of the screen showing only the data. When you have the screen desired, let go of the click.
    8. The image captured will save to your desktop automatically.
10. Using the screen shots you just created, you will now divide each image into 9 equal sections. Using either a ruler or Microsoft word, divide each image into 9 equal sections.
11. For each image, you will write down observations of the city in terms of built areas and green space (areas of greenery). Record the observations in the table below. Note specific changes by square if applicable. Repeat for each image.

2. Lesson 5 Capstone Worksheet Answer Key

Back to a Green Future:
Using data of the past to change the future
Lesson 5 Worksheet – Capstone Project

Do Now!
This past unit, we have learned about how we can use satellites to learn about the Urban Heat Island, the accuracy of satellite data versus data collected at the ground level, how UHI intensity changes over time and the factors that change the intensity, and some mitigation strategies such as bioswales to help cool down urban areas.

Looking towards the future, how can we use what we have learned in this unit to determine and possibly change the future?

Answers will vary. Example response: We can use what we learned in this unit to determine and change the future in numerous ways. First of all, we can use remote sensing data to determine how a city has changed over time (urban expansion). We can then use remote sensing data from satellites like MODIS Terra to determine the land surface temperature and how it has changed over time based on the urban expansion. We can then gather socio/economic status of the city to see what populations are being the most impacted by UHI. Lastly, we can use all of this information develop and test mitigation strategies to reduce the UHI effect and change the future.

Engage
You will now watch a video where Dr. Gavin Schmidt, Director of NASA Goddard Institute for Space Studies, will compare the changing climate to a visit to a doctor. Using the organizer below, describe how a visit to the doctor is similar to our changing climate.

Video:
https://www.youtube.com/watch?v=N6VJZ6N34XM&list=PLcHlZavTgnuoM47UShbcokqIqkZMluF8t&index=3&t=0s

Phases	What it means in a Doctor's Office	What it means if we are looking at the changing climate
Initial Symptoms	**The initial signs that someone is ill. Example: running nose, fever, coughing, sore throat**	**The initial signs that climate is changing. Example: increase in average global temperatures, rising sea levels, ice sheets melting**
Diagnosis	**The doctor identifies the cause of the symptoms. Example: Bacterial infection**	**Scientists identify the cause of the symptoms. Example: climate change**
Prognosis	**The doctor describes what can happen if the illness goes untreated. Example: If left untreated, a bacterial infection can get worse and cause loss of limb or even death.**	**The scientists describe what can happen if we continue "business as usual" and don't implement mitigation strategies. Example: if we don't reduce the amount of CO2 in the atmosphere, the global average temperature will continue to**

		rise, melting more ice and cause increase of sea levels which can flood coastal cities permanently.
Treatment	**The doctor prescribes a strategy, routine, or medication to get rid of the illness. Example: antibiotics to get rid of the bacterial infection.**	**Scientists recommend strategies to reduce the symptoms of climate change and start to reverse the effects of climate change. Citizens then implement the strategies. Example: adding vegetation to cities where high amounts of impervious surfaces currently reside.**

Explore/Develop

Utilizing what you have learned in this unit, you will work with a partner to conduct a research study of a city to determine how it has been impacted by the Urban Heat Island Effect (UHI). You will research the following information about the city:

- How the city's infrastructure has changed over a set time (think urban expansion)
- How the change of the city's infrastructure has affected land surface temperatures (LST) in the city
- Where are the "hot spots" of the city. What are the demographics and structure of the hot spot areas
- How has the city's UHI intensity changed over a set time?

Once you've collected this information, you will create an infographic poster to argue how UHI has impacted the city. You will also include proposed changes the city can take to improve conditions. Follow the steps below to collect all the information needed for the poster.

Step 1: Determine City of Study

With your partner, select a city to research for this project. Below is a list of suggested cities. You may choose one of the cities in the list or select a different city with approval from your teacher. Once you select your city, write it on the line provided below.

Suggested Cities:

New York City	Tokyo	Mexico City	Melbourne	Buenos Aires
Atlanta	Moscow	Lima	Sydney	Toronto
Shanghai	Paris	Nairobi	Johannesburg	Houston
London	Hamburg	Seoul	Berlin	Rome
Seattle	Mumbai	Bogota	Madrid	Chicago
Las Vegas	Cairo	Singapore	Barcelona	
Bucharest				

City Selected: _____

Step 2: View Historical Data of the City using Google Earth & Worldview

See Lesson 1 Worksheet Answer Key → Explore Activity for examples of this step.

Step 3: Determining Urban Heat Island Intensity over the years
See Lesson 3 Worksheet Answer Key → Explore Activity for examples of this step.

Step 4: Determining Demographics of Hot Spots of the City
See Lesson 3 Worksheet Answer Key → Elevate Activity for examples of this step.

Step 5: Predicting the Future of the City
Based on the information you collected in the previous steps, you will now make a prediction of what you think will happen in your city in terms of LST and climate. Write your prediction in the space below. You may include illustrations to enhance your prediction. Make sure in your prediction you use the information you collected to support your prediction.

Responses will vary. Predictions should be clear and use examples from Steps 2, 3, and 4 to support the prediction.

Example: Based on the information we gathered, we predict that the city of Shanghai's LST will increase. In Step 1, we saw that Shanghai rapidly expanded between 2003-2017. The city first had a small city center made of impervious surface and the rest of the area was heavily vegetated. However, as the city grew, the amount of impervious surfaces increased greatly. By 2017, most of the same aerial image of Shanghai was mostly covered by impervious surfaces. Looking at historical temperature day and UHI intensity in steps 2 and 3, we saw the land surface temperatures increase which lead to an increase in UHI intensity. Lastly, we saw that based on the population growth and where the densest populations are located, a large number of citizens in Shanghai will be impacted by the effects of increased surface and air temperatures.

Step 6: Create a well-developed argument for change
Using everything you have collected in the previous steps, you will develop an argument for why change needs to occur in the city you are studying.

Use the space below to mind map your argument using the information you have collected.

Maps will vary depending on the data collected. An example of an UHI mind map can be found in Lesson 3 worksheet Answer Key → Explain activity.

Now that you have mapped out your argument, let's turn the notes into a formal statement. Use the lines provided below to construct your argument. Think of the statement as your "script" for when you present your infographic poster. Make sure your argument includes statistics/facts you found during your research phase.

Answers will vary. See lesson 5 rubric for what the formal statement should include.

Step 7: Propose a plan for change to improve the city
Using the information collected in all of the previous steps, you will now create a well-structures proposal for how you plan to improve the city and decrease the UHI effect.

First, we will start with brainstorming and researching mitigation strategies that would reduce the UHI effect. Think back to lesson 4 where we learned about bioswales. Bioswales are one type of mitigation strategy, but there are several more!

Using the space below, research other mitigation strategies that would help reduce the UHI effect in your city. Be sure to include information about the mitigation strategy and why it would help the city.

Answers will vary. See lesson 5 rubric for what the formal statement should include.

Now that you have your list of mitigation strategies to improve your city, we have to make sure they are indeed effective. There are 2 steps we will use to determine if the strategies proposed are effective. Read through the two steps below. Then use the strategies to test your suggestions.

*Make sure to write down your findings in the space provided below. You will need the information from the testing to give validation for your proposal on the poster.

Part 1:
Using the mobile thermal cameras, you will go with your partner (and a teacher) outside to test the land surface temperature (LST) of the various mitigation strategies you proposed. This will help you collected data to support your proposed changes.

Use the space below to draw a table to record your findings. The number of rows/columns depends on the number of surfaces you test. Make sure to test the LST several times the more repeated tests, the more you can confirm your findings.

Make sure to also take pictures of your mitigation strategies. Visualizations are very helpful on infographic posters to help convey your message.

Part 2:
You will now use a site called “NYC Visionmaker” to test how your mitigation strategies might perform in the future.

First, you will need to select a part of New York City that best represents the majority of the structure of your city. Use a satellite map to view NYC to help you determine the section of NYC to use.

Then, go to https://visionmaker.us/nyc/. Once on the site, click the middle button “Learn More”. Go through all the steps of the tutorial to learn how to use the site.

After completing the tutorial, click “sign up” to create an account in order to develop and save your visions. You only need 1 account in your group.

As you develop and test your “vision”, make sure you take screen shots of the development and the results of testing. Use the space below to record your images and findings.

Visions will vary. An example of a vision that currently exists on the site is provided below (Author: yingzhang)

Step 8: Create an Infographic Poster

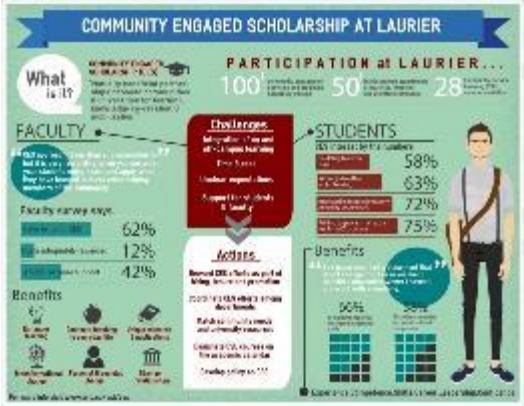
Now that you have all the information need to support your research/argument for your selected city, you will develop an infographic poster.

The poster should include the following information:

- How the city's infrastructure has changed over a set time (think urban expansion) (Step 2)
- How the change of the city's infrastructure has affected land surface temperatures (LST) in the city (Step 3 & 4)
- Where are the "hot spots" of the city. (Steps 3)
- What are the demographics and structure of the hot spot areas (Step 4)
- How has the city's UHI intensity changed over a set time (Step 4)?
- Prediction of the Future of the City (Step 5)
- Why the city needs to change (Step 6)
- Proposed mitigation strategies for the city (Step 7)
- Data to support mitigation strategies (Step 7)

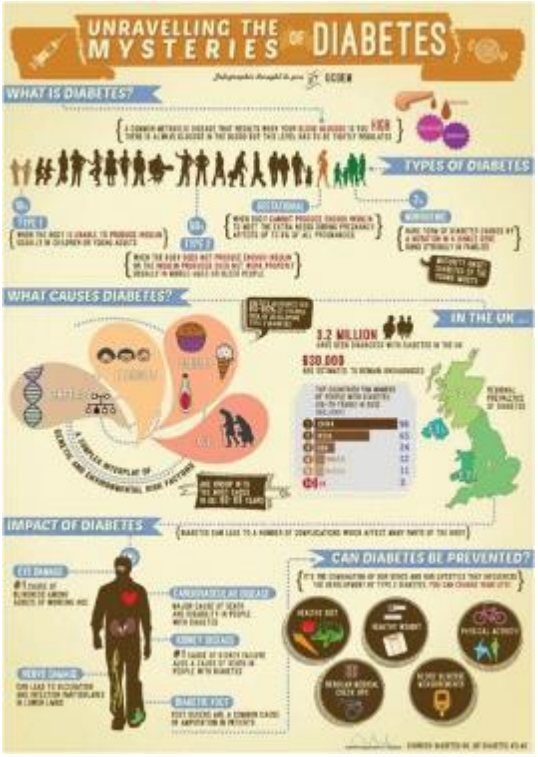
Your poster should be clear, concise, and convey your message in a readable format. Do not create a "wall of text". You want to be able to convey your message in a way that if someone was walking by, they could understand your poster within 1-3 minutes.

Below are examples of various infographic posters (some are scientific, some are not). For more examples, google "scientific infographic poster example". There are plenty of examples in the "images" section that will help you format a design.



Source: http://www.higher-education-marketing.com/uploads/Laurier-CES.jpg

Source: http://pcs.ieee.org/2014-ieee-pcs-conference-student-poster-competition-winners/



Source: http://blogs.it.ox.ac.uk/oxtalent/files/2014/06/Ng-Poster.jpg

Now that you have sketched out a design of your poster, use PowerPoint to create your infographic poster.

Below is a link to help you with designing your infographic poster:
https://www.youtube.com/watch?v=66fnRMbYXsE

Once you have finished designing your poster, you will need 2 other groups to read through your poster to check for understanding and spelling/grammar errors. The groups will use the rubric attached at the end of the worksheet to review your poster. Have the groups provide feedback in the space below. Once feedback is provided, the groups will need to sign off on the lines provided below.

Group 1 Feedback:

Group 1 Check: _____

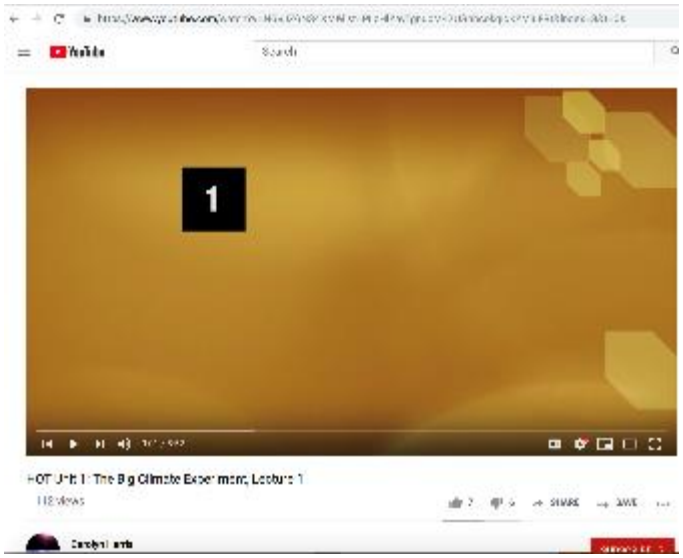
Group 2 Feedback:

Group 2 Check: _____

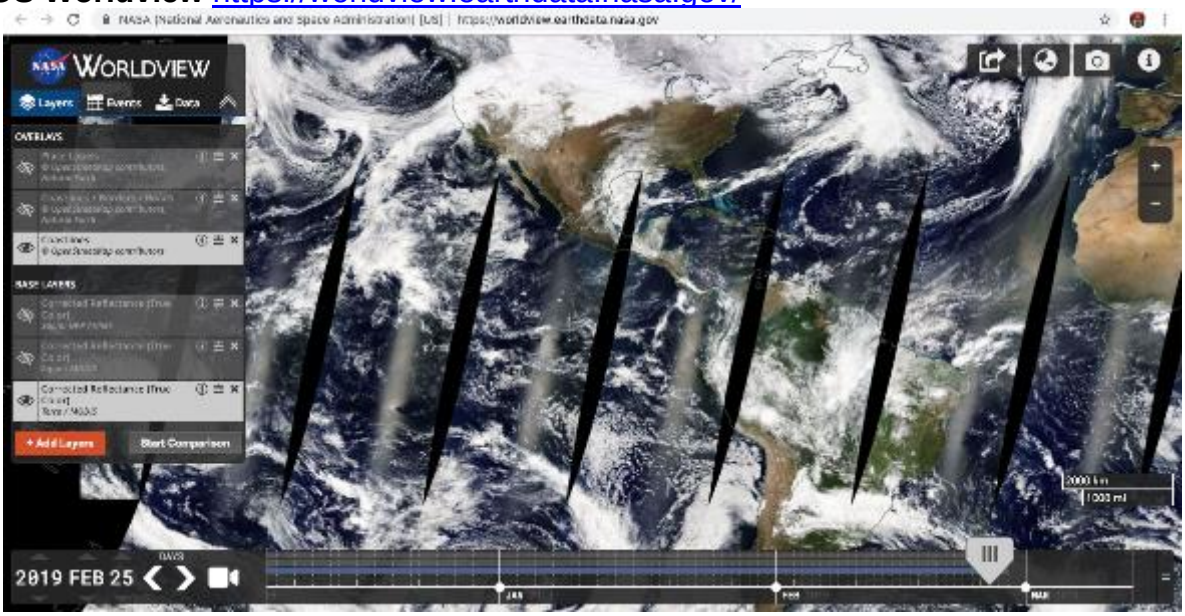
After the peer check, conduct one more check of your poster by having you and your partner review the poster using the rubric at the end of the worksheet.

Once you have the final version of your poster ready to go, send the poster to your teacher. The teacher will print out your poster to display. You will also need to paste a copy of the poster in the space provided below.

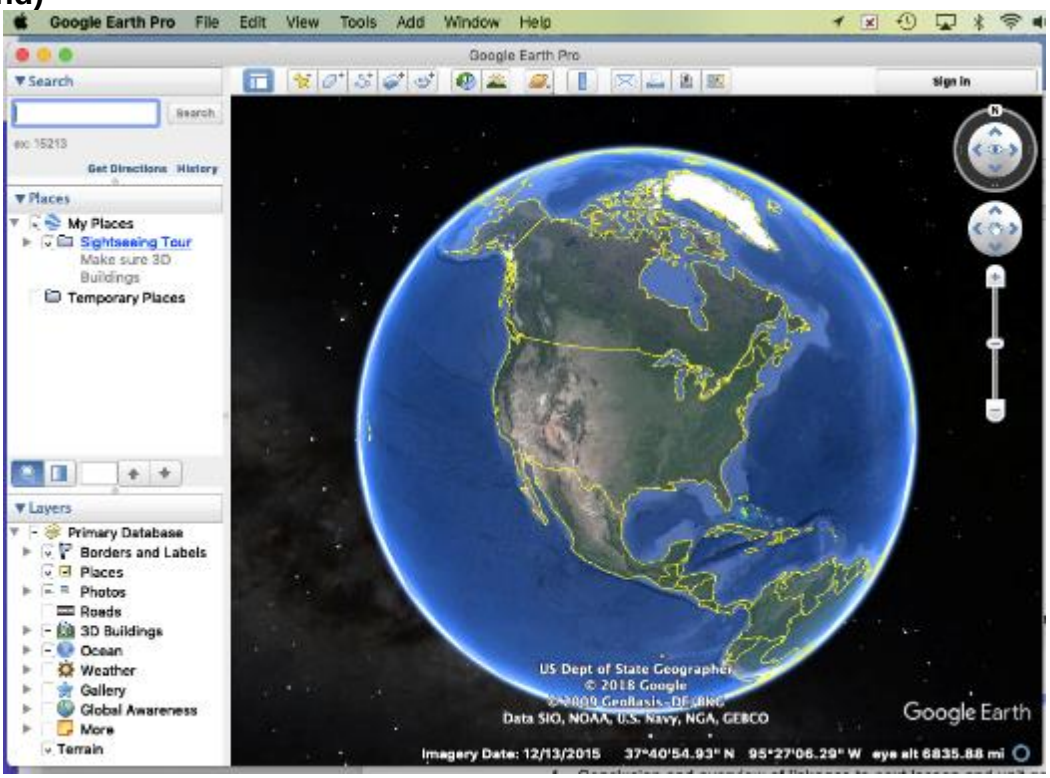
3. ***"Hot Unit 1: The Big Climate Experiment, Lecture 1"***
   https://www.youtube.com/watch?v=N6VJZ6N34XM&list=PLcHlZavTgnuoM47UShbcokqIqkZMluF8t&index=3&t=0s



4. **EOS Worldview** https://worldview.earthdata.nasa.gov/

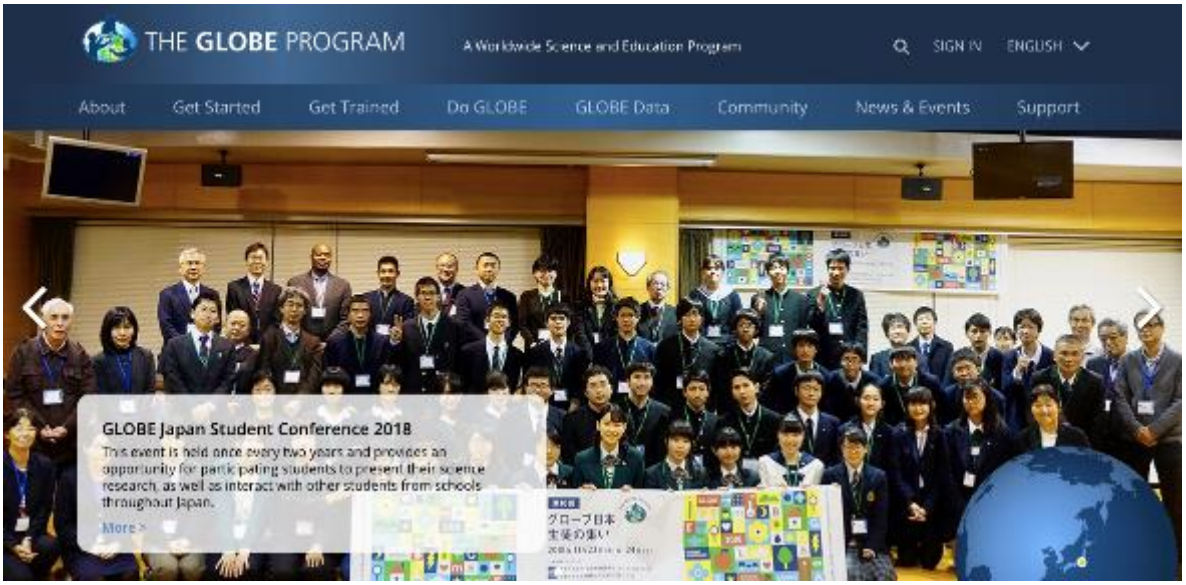


5. Google Earth Desktop Application (downloaded onto computers beforehand)



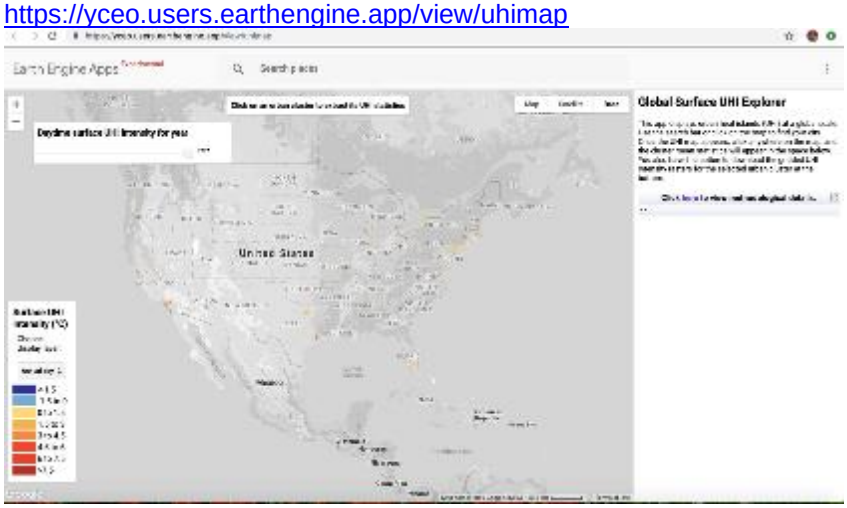
6. Globe Website (where to register and set up student accounts)

https://www.globe.gov



7. Google Earth Engine Urban Heat Island Intensity Interactive Map

https://yceo.users.earthengine.app/view/uhimap



8. US Government Census Bureau Demographics Interactives Website

https://www.census.gov/programs-surveys/geography/data/interactive-maps.html

9. Visionmaker NYC

https://visionmaker.us/nyc/

10. Lesson 5 Rubric

	Struggling	Approaching	At Level	Advanced
Engage *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.*	The student completes most of the organizer. The student effectively describes each part of a "doctor's visit" in terms of both what it means in a doctor's office and what it means when we are looking at the changing climate. For each part, the student includes a description (but may not be concise), but does not include an example from the video to support their description.	The student completes the entire organizer. The student effectively describes each part of a "doctor's visit" in terms of both what it means in a doctor's office and what it means when we are looking at the changing climate. For each part, the student includes a concise description and may have an example from the video to support their description in some of the parts of the organizer.	The student completes the entire organizer. The student effectively describes each part of a "doctor's visit" in terms of both what it means in a doctor's office and what it means when we are looking at the changing climate. For each part, the student includes a concise description and 1 example from the video to support their description.	The student completes the entire organizer. The student effectively describes each part of a "doctor's visit" in terms of both what it means in a doctor's office and what it means when we are looking at the changing climate. For each part, the student includes a concise description more than 1 example from the video to support their description.
Explore/Develop *(HS-PS4-6) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.* *(HSPS4-6) Mathematical representations can be used to identify certain patterns.* *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.*	The student works effectively with their partner with no complications. **Step 1:** The student selects an appropriate city either from the list or a city that is approved by the teacher. **Step 2:** The student has some difficulty with extracting and analyzing	The student works effectively with their partner with no complications. **Step 1:** The student selects an appropriate city either from the list or a city that is approved by the teacher. **Step 2:** The student is able to extract and analyze	The student works effectively with their partner with no complications. **Step 1:** The student selects an appropriate city either from the list or a city that is approved by the teacher. **Step 2:** The student is able to extract and analyze the data	The student works effectively with their partner with no complications. **Step 1:** The student selects an appropriate city either from the list or a city that is approved by the teacher. **Step 2:** The student is able to extract and analyze

11-12.RST.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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4) *(HS-ESS2-4),(secondary to HS-ESS2-2) The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.* *(HS-ESS3-5) Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.* *(HS-ESS2-2) Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes* *(HS-PS4-4) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.* *(secondary to HS-ESS3-2),(secondary to HS-ESS3-4) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.*	the data according to the directions. The student is able to capture most of the 10 images of the city they selected over a period of time for both land surface and land surface temperature and display the images in the provided organizer. The images are of just the city, but may have extra material in the images. The student has some difficulty in being able to divide each image into 9 equal sections, determining the ratio of built areas versus green space (but their ratio may be off by a little), and/or determining the average temperature of each image (calculations may be off). The student has some trouble communicating their observations in the provided space in the organizer by noting specific changes by square for most images. The student may not be able to correlate that land surface changes in urban areas, and/or may/may	the data according to the directions. The student is able to capture 10 images of the city they selected over a period of time for both land surface and land surface temperature and display the images in the provided organizer. The images are of just the city, but may have extra material in the images. The student is able to divide each image into 9 equal sections, determine the ratio of built areas versus green space (but their ratio may be off by a little), and determine the average temperature of each image (calculations may be off by a little). The student effectively communicates their observations in the provided space in the organizer by noting specific changes by square for most images. The student is able to correlate that land surface changes in urban areas, but may/may not express that it has an effect on land surface temperature.	according to the directions. The student is able to capture 10 images of the city they selected over a period of time for both land surface and land surface temperature and display the images in the provided organizer. The images are of just the city (no extra material). The student is able to divide each image into 9 equal sections, determine the ratio of built areas versus green space, and determine the average temperature of each image. The student effectively communicates their observations in the provided space in the organizer by noting specific changes by square for each image. The student is able to correlate that land surface changes affect land surface temperature. **Step 3:** The student is able to follow the directions for the activity	the data according to the directions. The student is able to capture 10 images of the city they selected over a period of time for both land surface and land surface temperature and display the images in the provided organizer. The images are of just the city (no extra material). The student is able to divide each image into 9 equal sections, determine the ratio of built areas versus green space, and determine the average temperature of each image. The student effectively communicates their observations in the provided space in the organizer by noting specific changes by square for each image. The student is able to correlate that land surface changes affect land surface temperature. The student uses the data they collected to explain the correlation. **Step 3:** The student is able to follow the

(HS-ETS1-3) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. *(HS-ETS1-1) Analyze complex real-world problems by specifying criteria and constraints for successful solutions.* *(HS-ETS1-4) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.* *CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.* *CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.* *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research*	not express that it has an effect on land surface temperature. **Step 3:** The student is able to follow the directions for the activity but needs near consistent guidance from the teacher. The student records some of the data required for the table from the Urban Heat Island intensity site. The student has some difficulty calculating the range of intensity and may have several errors. The student includes a picture of the city for most of the years. The image is somewhat clear. The student records their observations in the provided space in the table. Observations add some insightful knowledge to the already collected data. **Step 4:** The student is able to effectively research the demographic data but needs almost constant	**Step 3:** The student is able to follow the directions for the activity with some guidance from the teacher. The student records most of the data required for the table from the Urban Heat Island intensity site. The student is able to calculate the range of intensity with few errors. The student includes a picture of the city for each year. The image is mostly clear and easy to see. The student records their observations in the provided space in the table. Observations are clear and add some insightful knowledge to the already collected data. **Step 4:** The student is able to effectively research the demographic data with their partner with some guidance from the teacher. The student is able to identify in a mostly clear illustration the “hot spots”	with little guidance from the teacher. The student records all the data required for the table from the Urban Heat Island intensity site. There are no missing values. The student is able to calculate the range of intensity with no errors. The student includes a picture of the city for each year. The image is clear and easy to see. The student records their observations in the provided space in the table. Observations are clear and add insightful knowledge to the already collected data. **Step 4:** The student is able to effectively research the demographic data with their partner with little guidance from the teacher. The student is able to identify in a clear illustration the “hot spots” within the city. The student records the following information for	directions for the activity with no guidance from the teacher. The student records all the data required for the table from the Urban Heat Island intensity site. There are no missing values. The student is able to calculate the range of intensity with no errors. The student includes a picture of the city for each year. The image is clear and easy to see. The student records their observations in the provided space in the table. Observations are clear and add insightful knowledge to the already collected data. **Step 4:** The student is able to effectively research the demographic data with their partner with no guidance from the teacher. The student is able to identify in a clear illustration the “hot spots” within the city. The student records the

	guidance from the teacher. The student has some difficulty being able to identify in a somewhat clear illustration the “hot spots” within the city. The student records some of the following information for the hot spots: age range, economic status, population, household type, type of population (family or single), and race. All information collected is in a somewhat readable format in the provided organizer. The student is able to identify trends/patterns from the data they collected. The student may use at least 1 example from the data collected to support their explanation. The student is able to identify a correlation between the hot spots and the socio/economic status of the hot spots. The student does not use an example from the data they collected to support their explanation.	within the city. The student records most of the following information for the hot spots: age range, economic status, population, household type, type of population (family or single), and race. All information collected is in a readable format in the provided organizer. The student is able to identify trends/patterns from the data they collected. The student may use at least 1 example from the data collected to support their explanation. The student is able to identify a correlation between the hot spots and the socio/economic status of the hot spots. The student does not use an example from the data they collected to support their explanation. **Step 5:** The student is able to write an effective prediction of what will happen in the future for their city based off of the research conducted in the previous steps. The	the hot spots: age range, economic status, population, household type, type of population (family or single), and race. All information collected is in a readable format in the provided organizer. The student is able to identify trends/patterns from the data they collected. The student uses at least 1 example from the data collected to support their explanation. The student is able to identify a correlation between the hot spots and the socio/economic status of the hot spots. The student uses at least 1 example from the data they collected to support their explanation. **Step 5:** The student is able to write an effective prediction of what will happen in the future for their city based off of the research conducted in the previous steps. The student uses at least 4 examples of data/information from the	following information for the hot spots: age range, economic status, population, household type, type of population (family or single), and race. All information collected is in a readable format in the provided organizer. The student is able to identify trends/patterns from the data they collected. The student uses more than 1 example from the data collected to support their explanation. The student is able to identify a correlation between the hot spots and the socio/economic status of the hot spots. The student uses more than 1 example from the data they collected to support their explanation. **Step 5:** The student is able to write an effective prediction of what will happen in the future for their city based off of the research conducted in the previous steps. The student uses more than 4 examples of

	Step 5: The student is able to write a somewhat effective prediction of what will happen in the future for their city based off of the research conducted in the previous steps. The student uses none or at least 1 example of data/information from the previous steps to support their prediction. The student includes some illustrations to depict their prediction. The illustration includes some labels. **Step 6:** The student outlines an argument for change in their city by using a mind map. The mind map includes some key information to support their argument. The map includes at less than 3 main key points (first row of thoughts) and less than 2 sub key points for each main point. The student takes the main/sub key points outlined in the mind map and uses the information to develop a mostly well-constructed argument for proposing changes to a city. The	student uses at least 3 examples of data/information from the previous steps to support their prediction. The student includes illustrations to clearly depict their prediction. The illustration includes clear labels. **Step 6:** The student outlines an argument for change in their city by using a mind map. The mind map includes relevant key information to support their argument. The map includes at least 3-4 main key points (first row of thoughts) and at least 2 sub key points for each main point. The student takes the main/sub key points outlined in the mind map and uses the information to develop a mostly well-constructed argument for proposing changes to a city. The argument contains at least 3-4 examples from the previous steps to support their reasoning. **Step 7:** The student is able to research other	previous steps to support their prediction. The student includes illustrations to clearly depict their prediction. The illustration includes clear labels. **Step 6:** The student outlines an argument for change in their city by using a mind map. The mind map includes relevant key information to support their argument. The map includes at least 5 main key points (first row of thoughts) and at least 2 sub key points for each main point (10 total sub key points). The student takes the main/sub key points outlined in the mind map and uses the information to develop a well-constructed argument for proposing changes to a city. The argument contains at least 5 examples from the previous steps to support their reasoning. **Step 7:** The student is able to research other mitigation strategies that will help with reducing	data/information from the previous steps to support their prediction. The student includes illustrations to clearly depict their prediction. The illustration includes clear labels. **Step 6:** The student outlines an argument for change in their city by using a mind map. The mind map includes relevant key information to support their argument. The map includes at least 6 main key points (first row of thoughts) and at least 2 sub key points for each main point (12 total sub key points). The student takes the main/sub key points outlined in the mind map and uses the information to develop a well-constructed argument for proposing changes to a city. The argument contains at least 5 examples from the previous steps to support their reasoning and includes examples from the previous lessons to support their reasoning.

	argument contains less than 3 examples or no examples from the previous steps to support their reasoning. **Step 7:** The student is able to research other mitigation strategies that will help with reducing UHI but may need some guidance from the teacher, but needs almost consistent guidance from the teacher. The student records some of the key information in the organizer provided. The student includes some illustrations of the mitigation strategies with some labels. The student includes information about the mitigation strategy and why it would help the city. The information is somewhat important, but may contain some unnecessary information. The student is able to effectively follow the protocol for the data collection but may need almost consistent guidance from the teacher. The student	mitigation strategies that will help with reducing UHI but may need some guidance from the teacher. The student records the key information in the organizer provided. The student includes an illustration of the mitigation strategies with clear labels. The student includes information about the mitigation strategy and why it would help the city. The information is important, but may not be concise. The student is able to effectively follow the protocol for the data collection but may need some guidance from the teacher. The student draws an illustration of the mitigation strategy being studied but it may be somewhat unclear. The illustration includes most of the labels. The student records most of the required information in the provided organizer for part 1. Descriptions are easy to understand. The student is able to extract and analyze the	UHI. The student records the key information in the organizer provided. The student includes an illustration of the mitigation strategies with clear labels. The student includes information about the mitigation strategy and why it would help the city. The information is concise, but important. The student is able to effectively follow the protocol for the data collection. The student draws a clear illustration of the mitigation strategy being studied. The illustration includes clear labels. The student records all required information in the provided organizer for part 1. Descriptions are clear and easy to understand. The student is able to extract and analyze the data. The student has the information recorded on the provided organizer for part 1. The information is clear and	**Step 7:** The student is able to research other mitigation strategies that will help with reducing UHI. The student records the key information in the organizer provided. The student includes an illustration of the mitigation strategies with clear labels. The student includes information about the mitigation strategy and why it would help the city. The information is concise, but important. The student is able to effectively follow the protocol for the data collection. The student draws a clear illustration of the mitigation strategy being studied. The illustration includes clear labels. The student records all required information in the provided organizer for part 1. Descriptions are clear and easy to understand. The student is able to extract and analyze the data. The student has the information recorded on

	draws an illustration of the mitigation strategy being studied but it is unclear. The illustration includes some of the labels. The student records some of the required information in the provided organizer for part 1. Descriptions are somewhat easy to understand. The student is able to extract and analyze the data with help from the teacher. The student has the information recorded on the provided organizer for part 1. The information is easy to read, but may be somewhat unclear. Calculations are mostly correct. The student is able to use NYC Visionmaker effectively with almost consistent guidance from the teacher. The student may include before/after screen shots of the area they are testing their mitigation strategy in. With the images, the student includes some notes to describe key points for each image to support their research,	data. The student has the information recorded on the provided organizer for part 1. The information is easy to read, but may be somewhat unclear. Calculations are correct. The student is able to use NYC Visionmaker effectively with little guidance from the teacher. The student includes before/after screen shots of the area they are testing their mitigation strategy in. With the images, the student includes notes to describe key points for each image to support their research, but some notes may be irrelevant (not support their findings). **Step 8:** The poster is easy to read (but some parts may be somewhat unclear), and appealing to the eye. The text is easily readable from a 5-foot distance. The poster mostly has a good flow of information and pictures/illustrations to support their research, proposed changes, and	easy to read. Calculations are correct. The student is able to use NYC Visionmaker effectively with little guidance from the teacher. The student includes before/after screen shots of the area they are testing their mitigation strategy in. With the images, the student includes notes to describe key points for each image to support their research. **Step 8:** The poster is clear, easy to read, and appealing to the eye. The text is easily readable from a 5-foot distance. The poster has a good flow of information and pictures/illustrations to support their research, proposed changes, and possible future outcomes. There are no spelling/grammar errors. The authors have a clear title at the top of the poster that is easy to read. The authors include in text/in picture citations. The students	the provided organizer for part 1. The information is clear and easy to read. Calculations are correct. The student is able to use NYC Visionmaker effectively with little guidance from the teacher. The student includes before/after screen shots of the area they are testing their mitigation strategy in. With the images, the student includes notes to describe key points for each image to support their research. **Step 8:** The poster is clear, easy to read, and appealing to the eye. The text is easily readable from a 5-foot distance. The poster has a good flow of information and pictures/illustrations to support their research, proposed changes, and possible future outcomes. There are no spelling/grammar errors. The authors have a clear title at the top of the poster that is easy to read. The authors

	but some notes may be irrelevant (not support their findings). **Step 8:** The poster is easy to read (but some parts may be somewhat unclear), and appealing to the eye. The text is not easily readable from a 5-foot distance. The poster does not have a good flow of information and pictures/illustrations to support their research, proposed changes, and possible future outcomes. There are numerous spelling/grammar errors. The authors have a vague title at the top of the poster that is easy to read. The authors include no/few in text/in picture citations. The students include their name on the poster. The poster includes some of the following information and at least 1 example with most of the points: How the city's infrastructure has changed over a set time (think urban expansion) (Step 2) - How the change of the city's infrastructure has	possible future outcomes. There are few spelling/grammar errors. The authors have a clear title at the top of the poster that is easy to read. The authors include some in text/in picture citations. The students include their name on the poster. The poster includes most or all of the following information and at least 1 example with most of the points: How the city's infrastructure has changed over a set time (think urban expansion) (Step 2) - How the change of the city's infrastructure has affected land surface temperatures (LST) in the city (Step 3 & 4) - Where are the "hot spots" of the city. (Steps 3) - What are the demographics and structure of the hot spot areas (Step 4) - How has the city's UHI intensity changed	include their name on the poster. The poster includes all of the following information and at least 1 example for each point: How the city's infrastructure has changed over a set time (think urban expansion) (Step 2) - How the change of the city's infrastructure has affected land surface temperatures (LST) in the city (Step 3 & 4) - Where are the "hot spots" of the city. (Steps 3) - What are the demographics and structure of the hot spot areas (Step 4) - How has the city's UHI intensity changed over a set time (Step 4)? - Prediction of the Future of the City (Step 5) - Why the city needs to change (Step 6)	include in text/in picture citations. The students include their name on the poster. The poster includes all of the following information and at least 2 examples for each point: How the city's infrastructure has changed over a set time (think urban expansion) (Step 2) - How the change of the city's infrastructure has affected land surface temperatures (LST) in the city (Step 3 & 4) - Where are the "hot spots" of the city. (Steps 3) - What are the demographics and structure of the hot spot areas (Step 4) - How has the city's UHI intensity changed over a set time (Step 4)? - Prediction of the Future of the City (Step 5)

	affected land surface temperatures (LST) in the city (Step 3 & 4) - Where are the "hot spots" of the city. (Steps 3) - What are the demographics and structure of the hot spot areas (Step 4) - How has the city's UHI intensity changed over a set time (Step 4)? - Prediction of the Future of the City (Step 5) - Why the city needs to change (Step 6) - Proposed mitigation strategies for the city (Step 7) - Data to support mitigation strategies (Step 7)	over a set time (Step 4)? - Prediction of the Future of the City (Step 5) - Why the city needs to change (Step 6) - Proposed mitigation strategies for the city (Step 7) - Data to support mitigation strategies (Step 7)	- Proposed mitigation strategies for the city (Step 7) - Data to support mitigation strategies (Step 7)	- Why the city needs to change (Step 6) - Proposed mitigation strategies for the city (Step 7) - Data to support mitigation strategies (Step 7)
Elevate *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.*	The student presents the poster in a clear, projecting voice that is heard by some of the students. The student	The student presents the poster in a clear, projecting voice that is easily heard by most students. The student	The student presents the poster in a clear, projecting voice that is easily heard by all students. The student	The student presents the poster in a clear, projecting voice that is easily heard by all students. The student

(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. *(HS-ETS1-3) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.* *(HS-ETS1-1) Analyze complex real-world problems by specifying criteria and constraints for successful solutions.*	goes over most parts of the poster but consistently reads the text off of the poster. The student does not point to the information on the poster that they are speaking about to direct attention to the relevant sections/illustrations. The student is able to give the presentation in more than 8 minutes.	goes over each part of the poster but may read some of the text off of the poster. The student points to the information on the poster that they are speaking about to direct attention to the relevant sections/illustrations. The student is able to give the presentation in 5-8 minutes.	goes over each part of the poster but is not reading the text off of the poster. The student points to the information on the poster that they are speaking about to direct attention to the relevant sections/illustrations. The student is able to give the presentation in 3-5 minutes.	goes over each part of the poster but is not reading the text off of the poster. The student points to the information on the poster that they are speaking about to direct attention to the relevant sections/illustrations. The student is concise and provides numerous examples to support their explanation. The student is able to give the presentation in 3-5 minutes.
Closing *CCSS.ELA-LITERACY.W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.* *(HS-PS4-3) Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* *(HS-ETS1-3) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.* *(HS-ETS1-1) Analyze complex real-world problems by specifying criteria and constraints for successful solutions.*	The student completes the entire post-assessment. The student is somewhat able to compare their responses from the pre and post assessments to see how their learning has progressed but needs some guidance from the teacher. The student completes part of the reflection. The student's responses are clear, concise, but does not use examples from the unit to support their responses.	The student completes the entire post-assessment. The student is able to compare their responses from the pre and post assessments to see how their learning has progressed. The student completes the entire reflection. The student's responses are clear, concise, and uses few examples from the unit to support their responses.	The student completes the entire post-assessment. The student is able to compare their responses from the pre and post assessments to see how their learning has progressed. The student completes the entire reflection. The student's responses are clear, concise, and uses some examples from the unit to support their responses.	The student completes the entire post-assessment. The student is able to compare their responses from the pre and post assessments to see how their learning has progressed. The student completes the entire reflection. The student's responses are clear, concise, and uses several examples from the unit to support their responses.

f. Conclusion and overview of linkages to next lesson and unit goals.
In this lesson, students researched a city impacted by the Urban Heat Island effect, proposed a way to improve the city in terms of reducing the Urban Heat Island Effect, and developed an infographic poster to show their research and proposed changes. Students utilized information from the entire unit to create their proposal.

XIV: Glossary

Bioswale: also known as a rain garden, are a form of green infrastructure that are designed to redirect storm water runoff using vegetation (shrubs, trees, plants), soil, and built in channels.

Ground Truthing: the process of collecting data at the surface (ground) level of a study location to add information to a remote sensing study or verify satellite data.

Landsat: a remote sensing program developed and run by NASA/USGS of a series of satellites that study Earth.

Mitigation: the process of implementing strategies that aim to reduce the severity of an event.

Spectral Bands: in remote sensing, it is the set of wavelengths used to measure/capture an image of an area of study in satellites.

Urban Heat Island Intensity: the measurement of the difference in average temperatures between an urban area and surrounding rural/suburban areas.

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NASA Goddard Institute for Space Studies (GISS)
Climate Change Research Initiative (CCRI)
Applied Research STEM Curriculum Unit Portfolio

Unit Title: The Heat is On: Urban Heat Islands, detection strategies, and mitigation solutions

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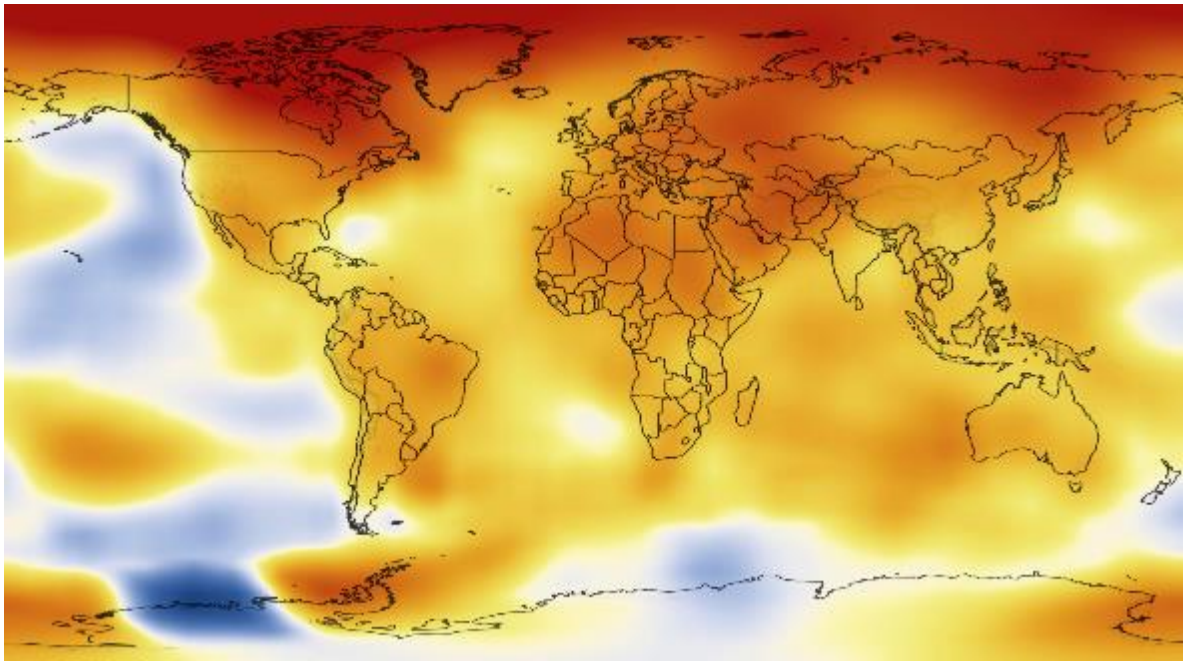
NASA GSFC Office of Education – Code 160



Acknowledgements:

Special thanks to the following for support in development of this unit portfolio:

- Dr. Gavin Schmidt, Director of NASA Goddard Institute for Space Studies
- Matthew Pearce, Education Program Specialist, NASA Goddard Space Flight Center Office of Education
- Dr. Reginald Blake & Dr. Hamidreza Norouzi, New York City College of Technology
- Dean Kern, Deputy Director, NASA Goddard Space Flight Center Office of Education
- Dr. Allison Leidner, Science Mission Directorate
- Sarah Hagens, Head of School, Fusion Academy Brooklyn
- The student scientists of Fusion Academy Brooklyn

This Unit Plan is dedicated to my former mentor Dr. Stuart Gaffin.