
[Earth As a System Mini Lesson/Activity Teacher Key](#)

Submitted by stellaxxy on Mon, 08/10/2020 - 18:15

[Analyzing Earth's Energy Imbalance by Latitude and Month](#)

[Analyzing Earth's Energy Imbalance by Latitude and Month](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. Describe the latitude zone/s where you see the biggest range in values? Why do you think this is? *The largest spatial variability in EEI is found between 10° to 30° North throughout the year. Variability is the largest in this area because of the presence of large areas of bright desert areas with few clouds in this latitude zone.*
3. What months do you observe the greatest change by latitude? *Summer months, compared to all other months, show the greatest change and range of values. High values are also seen at both lower and higher latitudes in both hemispheres during respective summer seasons. The high values a result of high insolation and surface properties of the polar regions (cold ice-free ocean versus ice/snow-covered ocean and land).*
4. What zones change the least? Why do you think this is? *Areas around the -50 zone (50 degrees South) show the least amount of change. This may be due to ice-free ocean regions with the lack of large areas of land.*

[Analyzing Historic Ocean Chlorophyll Concentration Data with Maps](#)

[Link to Analyzing Historic Ocean Chlorophyll Concentration Data with Maps](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. Identify what living organisms may be observed using chlorophyll data. *Phytoplankton, plants, etc.*
 - *Recall that phytoplankton are microscopic, floating, plant-like organisms that live in oceans, lakes, and rivers. They use photosynthetic pigments (like chlorophyll) to convert energy from the Sun into organic matter. For this reason, NASA satellites can observe the amount of phytoplankton present in the ocean by measuring chlorophyll concentrations.*
3. Review the color bar scale below. What do the different colors mean as they are

related to phytoplankton? *When phytoplankton populations are large, the color of the water appears greener because of high concentrations of chlorophyll.*

4. Identify each region using the numbers listed on the map. 1. Alaskan Coast, 2. Canadian West Coast, 3. West Coast (U.S.), 4. East Coast (U.S.), 5. Canadian East Coast, 6. Pacific (Hawaii)
5. Analyze the Chlorophyll Concentrations in Surface Ocean Waters [image](#) with each region you listed.
6. Compare the Chlorophyll Concentrations in the coastal areas to the open ocean in the Pacific. What do you observe? *Coastal areas tend to have higher concentrations of chlorophyll than the open ocean.*
7. How do the lower latitudes like those in Florida or Hawaii compare to the higher latitudes like those in Alaska? *There are high concentrations in the higher latitudes than the lower ones.*
8. Compare the West Coast vs. East Coast concentrations. *The higher concentrations are more evident along the west coast of North America*

[Analyzing Seasonal Phytoplankton & Energy Flow](#)

[Link to Analyzing Seasonal Phytoplankton & Energy Flow](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. Analyze the graph displaying Monthly Flow of Energy into Surface by Shortwave Radiation between the years of 2016 and 2018 in the North Atlantic Ocean. Answer the the following questions.
 1. What variable is represented on the x-axis? *Time.?????* What is the range of values? *2016-2018*
 2. What variable is represented on the y-axis? *Watts per square meter, which is the flow of energy spread out over an area.* What is the range of values? *20-240 w/m²*
 3. Describe the pattern that is revealed over the three years. *The shortwave radiation values are sinuous in that the increase in the spring, peak in the summer, decline in the fall through winter and steadily repeat this pattern.*
3. Analyze the graph displaying Monthly Average Chlorophyll Concentration between the years of 2016 and 2018 in the North Atlantic Ocean and then answer the following questions. The units for chlorophyll concentration in this graph is milligrams of chlorophyll per cubic meter of seawater. This is a very small mass unit. To compare, the average mass of a feather from a chicken is about 8 milligrams.
 1. What variable is represented on the x-axis? *Year* What is the range of values? *2016-2018*
 2. What variable is represented on the y-axis? *Chlorophyll concentration*
 3. Describe the pattern that is revealed over the three years. *The chlorophyll values tend to decline around the middle of summer in both 2016 and 2017 but rebound in early fall, only to decline for the remainder of the calendar year.*
 4. Compare the two line graphs. Describe what these graphs have in common? How are they different? *They are both cyclical and highly variable. They both peak in the summer and decline in the winter. How are they different? The*

chlorophyll values tend to decline around the middle of summer in both 2016 and 2017 but rebound in early fall, only to decline for the remainder of the calendar year. On the other hand, the shortwave radiation values are sinuous in that the increase in the spring, peak in the summer, decline in the fall through winter and steadily repeat this pattern.

5. Brainstorm the factors that may contribute to their differences. *Answers will vary.*

An Island Transforms through Erosion and Deposition

[Link to An Island Transforms through Erosion and Deposition Mini Lesson](#)

1. Watch the [The Birth of a New Island](#) video about the formation of the island Hunga Tonga-Hunga Ha'apai and why NASA is interested in studying the island. Check with your instructor on how to submit answers.
2. After the video, answer the following questions.
 1. How did the island form? (From a volcanic eruption.)
 2. Why is NASA interested in studying this island? (It can help NASA learn about how features seen on other planets formed.)
 3. What sort of changes did you notice in the island? (Answers will vary.)
 4. How did the geosphere and hydrosphere interact in the changes of the island? (The geosphere had a newly formed land feature that experienced erosion and deposition. The water in the hydrosphere eroded portions of the island, transported and deposited the sediments.)
 5. Do you think about the timescale involved in these videos is faster or slower than many other areas on Earth? (Much faster than many areas on Earth.)????
 6. How long do you think this island will last? (Answers will vary.)

[Aurora Bracelet](#)

[Link to Aurora Bracelet](#)

See the [handout](#) for a sample result.

[Aurora Chalk Art](#)

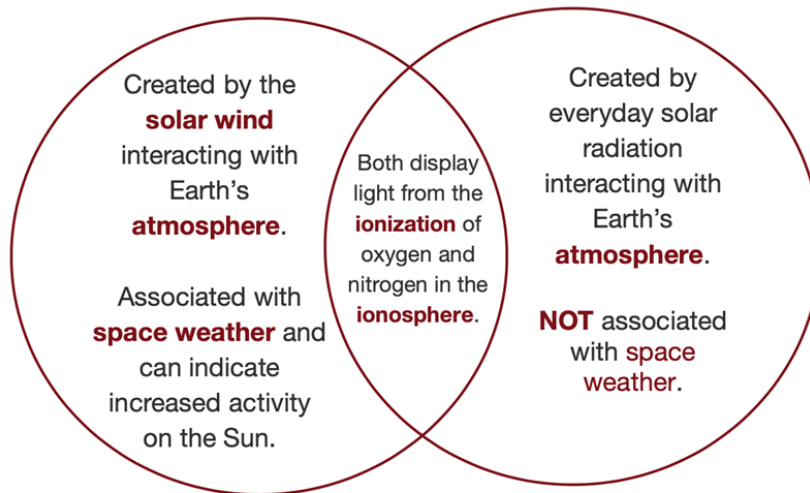
[Link to Aurora Chalk Art](#)

See the [handout](#) for a sample result.

[Aurora vs. Airglow](#)

[Link to Aurora vs. Airglow](#)

Aurora vs. Airglow



Calculating Ratios of an Eclipse

[Link to Calculating Ratios of an Eclipse](#)

The [Calculating Ratios of an Eclipse - Teacher Key](#)

spreadsheet has the answer formulas and numeric answers in the appropriate cells.

Carbon Dioxide Production and Sequestration

[Link to Carbon Dioxide Production and Sequestration](#)

1. Use the [image of forested and deforested land](#) to answer the questions. Check with your instructor on how to submit answers.
 - The picture shows a plot of landscape measuring 1 kilometer on a side.
 - Each box on the image covers 2.5 acres.
 - The land and soil with green trees sequester carbon dioxide at a rate of 1 ton per acre per year. So, a box that is all trees will sequester 2.5 tons of carbon dioxide per year.
 - The deforested land and soil have smaller amounts of vegetation and only sequesters carbon dioxide at a rate of 0.2 tons per acre per year. So, a box that is all deforested, or bare, land will sequester 0.5 tons of carbon dioxide per year.
2. Estimate the size of the forested (dark green) area of the picture in acres. If one box has more than one type of cover, estimate how much is trees and how much is not. How many forested acres are in this picture?
 - Approximately $\frac{2}{3}$ of the picture is covered in green. $2.5 * 100 * .66 = 165$

-
- acres
 - Accept reasonable estimates.
3. Estimate the size of the deforested, bare area of the picture. How many deforested acres are in this picture?
 - Approximately 1/3 of the picture is covered in green. $2.5 * 100 * .33 = 82.5$ acres
 - Accept reasonable estimates.
 4. How much carbon dioxide is sequestered by trees?
 - *(Number of boxes covered by trees X 2.5 tons of carbon dioxide per year)*
 - *Approximately $66 * 2.5 \text{ tons/year} = 165 \text{ tons/year}$*
 - *Accept reasonable estimates*
 5. How much carbon dioxide is sequestered by bare land?
 - *(Number of boxes covered by bare land x 0.5 tons of carbon dioxide per year)*
 - *Approximately $33 * .5 \text{ tons/year} = 16.5 \text{ tons/year}$*
 6. What is the total rate of carbon dioxide sequestration in this particular area in terms of tons per year?
 - *Approximately $165 \text{ tons/year} + 16.5 \text{ tons/year} = 181.5 \text{ tons/year}$*
 7. A typical American home produces about 10 tons of carbon dioxide per year. The image shows one house. What is the overall (or net) sequestration of carbon dioxide in the image including the house?
 - $181.5 \text{ tons/year} - 10 \text{ tons/year} = 171.5 \text{ tons/year}$
 8. Assume someone built 50 more homes on the land in the image. What would the overall (or net) carbon dioxide sequestration be?
 - There are 51 houses total.
 - $181.5 \text{ tons/year} - 51(10 \text{ tons/year}) = 181.5 \text{ tons/year} - 510 \text{ tons/year} = -328.5 \text{ tons/year}$.
 - This means that there is a production of 328.5 tons/year that is NOT sequestered.

Chlorophyll Concentration and Incoming Shortwave Radiation Interactive Model

Link to [Chlorophyll Concentration and Incoming Shortwave Radiation](#)

Link to [Chlorophyll Concentration and Incoming Shortwave Radiation Teacher Key](#)

[Clouds & Earth's Climate with Dr. Patrick Taylor Video](#)

[Link to Clouds & Earth's Climate with Dr. Patrick Taylor Video](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. How much has Earth's mean surface temperature warmed over the last 130 years? ***More than 1? Celsius or more than 1.8? Fahrenheit.***
3. How does the CERES (Clouds and the Earth's Radiant Energy System) project produce global climate data records of Earth's energy budget and clouds over many decades? ***Over decades, from space, with six different instruments on four different satellites. The instruments are the CERES and MODIS instruments.***
4. Why is Earth's energy budget important for climate? ***The difference between the***

amount of sunlight absorbed by Earth and the amount of infrared energy emitted to space controls Earth's temperature.

5. If less sunlight is absorbed than infrared energy is emitted to space, what will the effect be on Earth's temperature? ***It will cool Earth's temperature.***
6. If more sunlight is absorbed than infrared energy is emitted to space, what will the effect be on Earth's temperature? ***It will warm Earth's temperature.***
7. According to the animation of CERES data showing where Earth cools by losing infrared energy to space, which regions lose the **most** energy to space? ***In the warmest places, especially desert regions of Earth.***
8. Where is the **least** infrared energy lost to space? ***Cold regions such as the Arctic and Antarctic and places with a lot of clouds like the Amazon, Central Africa, and the tropical western Pacific regions.***
9. According to the animation showing CERES observations of reflected sunlight from Earth, where are the areas with the **least** reflected sunlight? ***Oceans.***
10. According to the animation showing CERES observations of reflected sunlight from Earth, where are the areas with the **most** reflected sunlight? ***Polar regions covered by ice and snow as well as some places in the Tropics with lots of clouds***
11. What are two possible effects that clouds have on the energy budget? ***Cooling and warming. Teacher Note: Some reflect more sunlight for a cooling effect. Others reduce the amount of infrared radiation lost to space resulting in warming. It depends on the height of the clouds and the amount of water vapor they contain. High-level clouds tend to have a warming effect. Low-level clouds tend to have a cooling effect. The effects are also different across Earth with more cooling over the oceans and warming over the land and the poles. The total overall effect is a cooling effect.***
12. Why does NASA study clouds and their role in Earth's energy budget? ***How clouds change and the impact on the Earth's energy budget will influence how climate changes including how hot and dry summers will be, the frequency of extreme weather events, where it rains, when it rains, and how hard it rains.***

Comparing Earth and Space Weather StoryMap

[Link to Comparing Earth and Space Weather StoryMap](#)

[Link to Teacher Key](#)

[Creating and Interpreting Images as Models](#)

[Link](#)

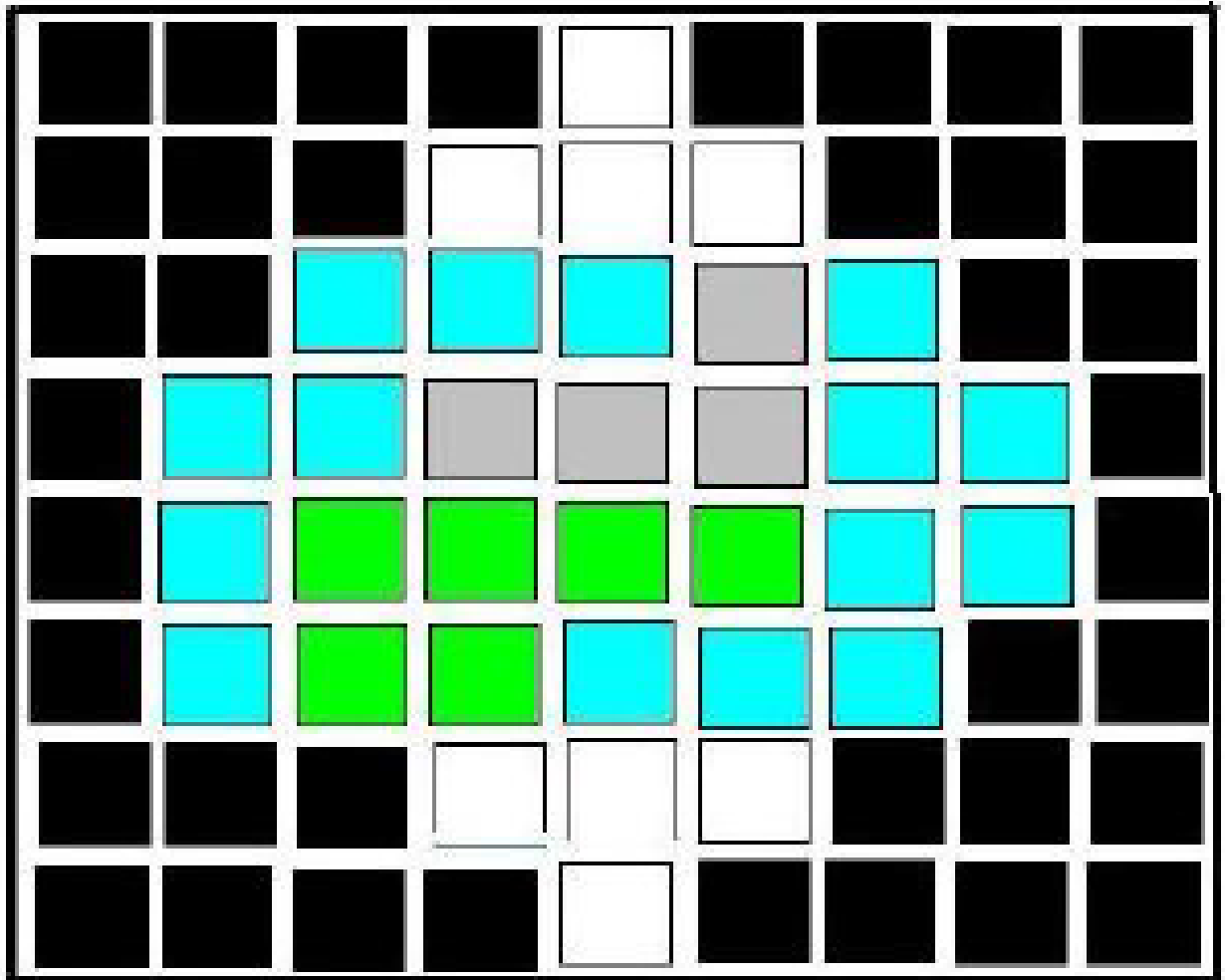
Array tables to be created:

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Combined Array Table:

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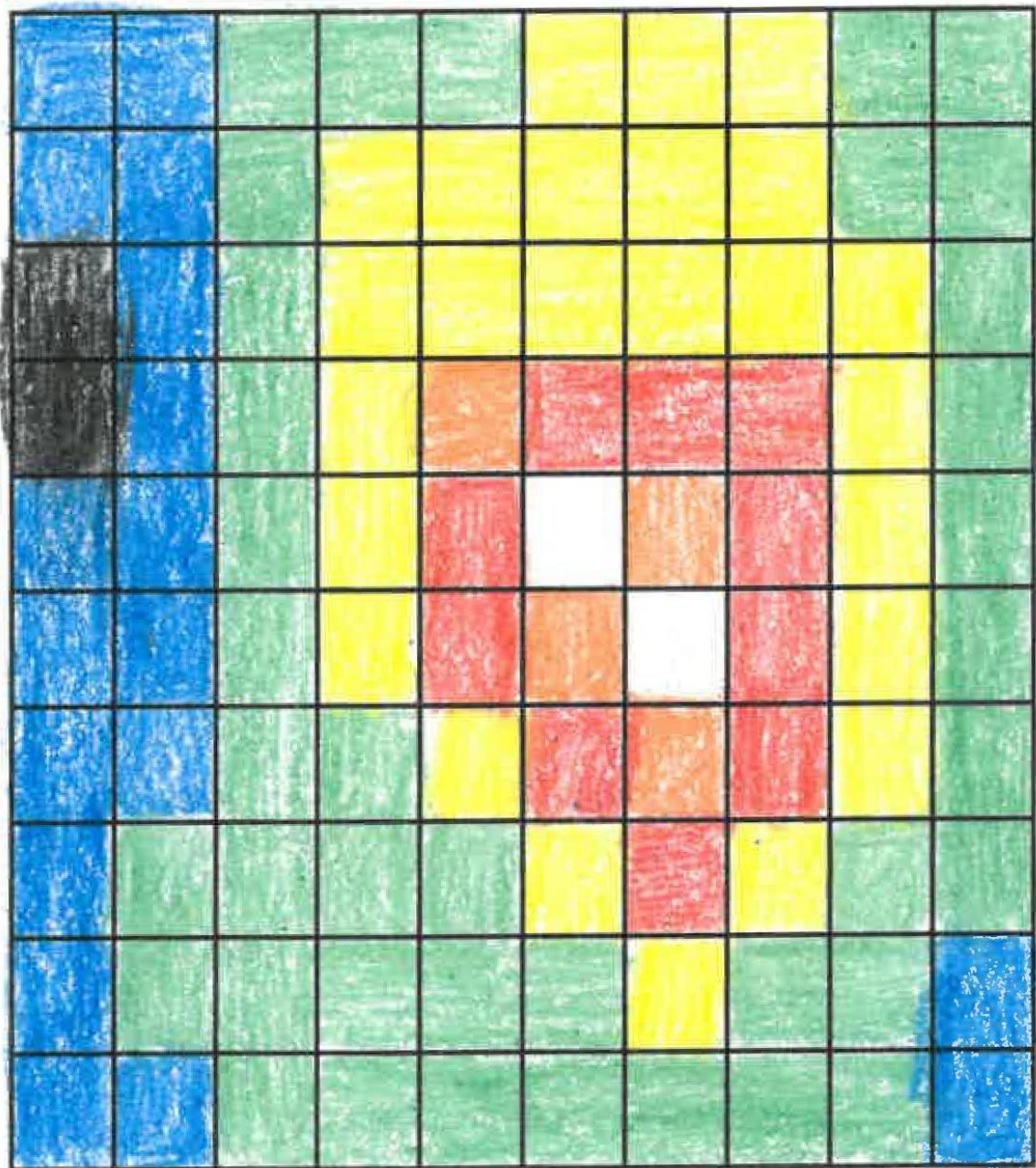
Pixel Grid:



6. Where is the ice represented in the image? *In the center of top and bottom. This could be representative of poles on a planet.*

[Creating Images from Numbers: Student Activity](#)

[Link to Creating Images from Numbers](#)



Creating

Images from Numbers sample answer using assigned colors. The answers will vary if students select other colors.

<https://mynasadata.larc.nasa.gov/sites/default/files/inline-images/creating%20images%20from%20numbers.jpg>

1. Answer the following questions if the data are **wind speed** in km per hour.
 1. What color is the fastest? *white* Slowest? *black*
 2. Where is the wind between 21-25 km per hour? *red squares or the color chosen*
2. Answer the following questions if the numbers are **elevation** in meters above sea level.
 1. What color is the lowest? *black* Highest? *white*
 2. Where is the elevation between 31 and 35 meters above sea level? *white squares*
3. Do you notice any pattern in the image? *Accept reasonable responses. The highest values are in the center. Numbers decrease the farther they are from the center. Learners are likely not to think the red color would be the highest, which is not the*

case.

4. How does the size of the grids in the grid paper affect the image that you created? *Accept reasonable responses. Smaller grids can have different values which can provide more detail. Larger grids will provide less detail.*
5. Which do you think would be more realistic, larger grid sizes or smaller? Why? *Accept reasonable responses. Smaller grids will provide more detail, which can be more realistic.*

Creation of Urban Heat Islands StoryMap

Link to [Creation of Urban Heat Islands StoryMap](#)

Link to [Creation of Urban Heat Islands StoryMap Teacher Key](#)

Describing Radiation in Earth's Energy Budget

[Link to Describing Radiation in Earth's Energy Budget](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. Identify the three distinct classifications of radiation (forms of electromagnetic energy) shown in the infographic. *Ultraviolet, Visible and Infrared Radiation.*
3. Identify the measured value for each type of radiation. What units are used? *Unit of length (nanometer, nm or micrometer, μm) used to measure the wavelength.*
4. Explain why it is important to not simply compare the numerical values when comparing the measurements of each classification. *The unit scales for wavelength are different. 1 micrometer = 1,000 nanometers.*
5. Describe the range of radiation characterized as "shortwave radiation."
 - *Longer ultraviolet (UV-A, UVB and only a the longest wavelengths of UV-C) range*
 - *Entire visible range - the peak amounts are 500nm which is the Blue part of visible range*
 - *Shortest infrared range 700nm - 5000nm*
6. Describe the range of radiation characterized as "longwave radiation." *Mid and upper infrared range 5000nm - 1 million nm (5 μm - 1000 μm).*
7. Discuss how the energy associated with shortwave radiation compares to the energy associated with longwave radiation. *The shorter the wavelength the greater the energy associated with that electromagnetic radiation. Therefore, "shortwaves" transfer a greater amount of energy than do "longwaves". This is described in using the mathematical equations $c = \lambda f$ that describes all electromagnetic travels at the same speed (c = speed of light). Therefore the wavelength and frequency are inversely related. $E = hf$ is then applied to reveal that energy of a particle of light (E), called a photon, is proportional to its frequency (f), by a constant factor (h).*
8. Identify the source of "shortwave radiation." *The Sun is the source of shortwave radiation.*
9. Identify the source of "longwave radiation." *The Earth's geosphere and the Earth's atmosphere is the source of longwave radiation. This longwave radiation was a result of shortwave radiation being absorbed and not reflected.*

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10. Describe how the Earth's energy budget model distinguishes between shortwave and longwave radiation. *The model uses a yellow color and straight arrows to reveal the interactions of shortwave radiation.*
 11. Look closely at the model and describe the different interactions clouds have with shortwave radiation and longwave radiation. *The model uses a red color and curved arrows to reveal the interactions of longwave radiation.*
 12. Identify the heat illustrated in the model that is NOT characterized by either shortwave or longwave radiation.

The purple arrows are neither longwave, nor shortwave radiation.

Note: These purple arrows are used to describe sensible and latent heat. Sensible heat (the curved purple arrow) is described as the "thermals" which is both includes both conduction and convection. These types of heat create weather systems. Latent heat (The broken purple arrow) is the energy that accounts for phase change. In this case evapotranspiration in the driving phase change the feeds Earth's weather systems.

Earth System Energy Travels

[Link to Earth System Energy Travels Mini Lesson](#)

1. What can happen to the energy as it travels through the Earth system? *It can be reflected or absorbed.*
2. Where does the largest percentage of energy go in the Earth system? *It is absorbed by land and oceans.*
3. What kinds of ways is the energy used once it enters the Earth system (i.e., Hydrosphere, Atmosphere, Biosphere, etc.)? *Accept reasonable responses. Energy that is absorbed can heat the surface and land (geosphere), atmosphere, and oceans (hydrosphere). Energy can also be used by plants for photosynthesis (biosphere).*
4. What is the role of the atmosphere (including clouds) as it relates to Earth's energy? *The energy can be both reflected and absorbed by the atmosphere and by clouds.*

Earth's Energy Budget StoryMap

Link to [Earth's Energy Budget StoryMap](#)

Link to [Earth's Energy Budget StoryMap Teacher Key](#)

Earth's Energy: Shortwave Radiation

[Link to Mini Lesson](#)

1. What is albedo? *Albedo is the ratio of reflected-to incoming energy. A higher albedo means that more incoming energy is reflected.*

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2. What colors represent areas where the most energy is being reflected back out to space? *brighter, whiter regions show where more sunlight is reflected* Least energy? *blue*
 3. What are the units of these measurements? *Watts per square meter*
 4. What drives Earth's climate engine? *The Sun's radiant energy*
 5. What system of the Earth system is constantly adjusting to maintain a balance between the energy that reaches the Earth from the Sun and the energy that flows from the Earth back out to space? *Atmosphere*
 6. What parts of the aforementioned system reflect energy back to space? *clouds, aerosols, bright surfaces*
 7. Predict what might happen if Earth's cloud cover decreases over time? *The albedo would decrease. There would be less shortwave radiation reflected back to space. More energy would be absorbed leading to warming.*

[Earth's Heating Imbalance](#)

[Link to Earth's Heating Imbalance](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. Analyze the graph.
 1. Describe the energy received at the Equator. *At the equator (gray line), the peak energy changes very little throughout the year and it is where the energy is concentrated the most.*
 2. How does it change over the year? *The peak energy at the equator lowers slightly during the summer months of June and July, then raises during the fall and spring seasons.*
 3. What do the blue lines (23.5 degrees N, 45 degrees N, 60 degrees N) represent? *Latitudes in the northern Hemisphere.*
 4. What do the green lines (23.5 degrees S, 45 degrees S, 60 degrees S) represent? *Latitudes in the Southern Hemisphere*
 5. Describe the relationship among the blue and green lines and the cause of these values/patterns. *The northern latitudes that are furthest away from the equator have the highest peak energy during the summer months while the southern latitudes that are furthest away have the lowest, depicting the cooler periods the southern hemisphere experiences during that time of year. This pattern is reversed as the months go from fall to winter.*

[Energy and Matter: Dust Transport \(Student Activity\)](#)

[Link to Mini Lesson](#)

The Sahara Desert is a near-uninterrupted brown band of sand and scrub across the northern third of Africa. The Amazon rain forest is a dense green mass of humid jungle that covers northeast South America. These two very different ecosystems are connected across the Atlantic Ocean by atmospheric circulation. After strong winds sweep across the Sahara, a cloud of dust rises in the air and stretches between the continents. When the dust settles in the Amazon, it deposits phosphorus, an essential nutrient that acts like a fertilizer. NASA's CALIPSO satellite has quantified in three dimensions how much dust makes this trans-

Atlantic journey. The study is part of a bigger research effort to understand the role of dust and aerosols in the environment.

Watch the [Video Interview \(2015\)](#) with visualizer Kel Elkins for a guided walk through of this visualization, starting at 0:54.

1. Review the following questions with students prior to showing the video so that students are prompted for the content they are to identify.

Where does the dust originate or come from? *Africa* What is special about the location of where the dust originates? *Sahara Desert* Where does the dust travel to? *South America* What is special about this location? *Amazon rain forest* How does the dust get from one place to the other? *in the wind across the Atlantic Ocean* What NASA satellite collects the data? *CALIPSO*

2. Play the video at least once.

3. If you have enough time, play the [Video Interview \(2015\)](#) with visualizer Kel Elkins for a guided walk through of this visualization, starting at 0:54 and stopping at 1:23.

- What is special about the way that the data are collected and displayed by this satellite? *Shows the altitude of the dust in the air column*
- How are the geosphere and the biosphere connected in this example? *The geosphere's dust provides much needed nutrients to the forested areas of South America.*

[Energy and Matter: Exploring Ocean Salinity](#)

[Link to Energy and Matter: Exploring Ocean Salinity Mini Lesson](#)

1. Review the [NASA Video of sea surface salinity observations](#) (September 2011-September 2014) from the Aquarius/SAC-D mission, a collaboration between NASA and the Space Agency of Argentina. The data is shown on a spinning globe.
2. Answer the following questions. Check with your instructor on how to submit your answers.
 1. What is salinity? *concentration of dissolved salt*
 2. Why is salinity important in the water cycle and in ocean circulation? *Salinity is key to studying the water cycle and ocean circulation, both of which are related to climate. Over decades, the amount of salt in ocean basins has been fairly stable. The water cycle operates on much faster time scales, however, causing changes in salinity patterns.*
 3. In the video, what color represents high salinity values? *Red* Low? *Blue*
 4. Where do you see the greatest concentrations of low salinity values? *Polar regions, equatorial region, some coast lines.* High salinity values? *The saltiest areas in the global ocean are the locations where evaporation is high or in large bodies of water where there is no outlet into the ocean.*
 5. Based on what you know about the water cycle, what causes changes in the salinity values? *Changes in sea surface salinity, provide a fingerprint of Earth's freshwater cycle. Salinity decreases when freshwater enters the ocean from*

rivers, melting ice, rain and snow. Processes that cause freshwater to exit the ocean such as evaporation and formation of sea ice raise salinity. Differences in dissolved salt content also play a major role in moving seawater, and the heat it carries, around the globe.

6. Create a narration script that describes your observations over the course of this 30 second video. *Answers will vary. Higher salinity areas are shown in red. These regions of high evaporation are sometimes called "ocean deserts." Blue colors represent lower salinities, resulting from freshwater inputs into the ocean. These include Amazon River outflow that appears as a ribbon-like feature in the tropical Atlantic, a zone of persistent rainfall that spans the tropical Pacific, and melting ice near Earth's poles.*

[Energy and Matter: Longwave Radiation \(Student Activity\)](#)

[Link to Mini Lesson](#)

Review the video and text below and answer the questions that follow.

1. What is longwave radiation? *Generally refers to the electromagnetic radiation in infrared and near-infrared wavelengths (longer than 4 micrometers) – i.e., wavelengths where most of Earth's radiative energy is concentrated.*
2. What time period does this video show longwave radiation on Earth? *from January 26 and 27, 2012*
3. What colors represent areas where the most energy is being emitted out to space? *Yellow*
Least energy? *White*
4. What are the units of these measurements? *Watts per square meter*
5. Where do you expect to find the warmest temperatures? *brightest-yellow areas*
Coldest? *the dark blue and bright white areas (clouds) are much colder, emitting the least energy*
6. What drives Earth's climate engine? *The Sun's radiant energy*
7. What system of the Earth system is constantly adjusting to maintain balance between the energy that reaches the Earth from the Sun and the energy that flows from the Earth back out to space? *Atmosphere*
8. What parts of the aforementioned system reflects energy back to space? *clouds, aerosols, bright surfaces*

[Energy and Matter: Shortwave Radiation](#)

[Link to Energy and Matter: Shortwave Radiation Mini Lesson](#)

1. What time period does this video show shortwave radiation on Earth? *from January 26 and 27, 2012*

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2. What colors represent areas where the most energy is being reflected back out to space? *brighter, whiter regions show where more sunlight is reflected* Least energy? *blue*
 3. What are the units of these measurements? *Watts per square meter*
 4. What drives Earth's climate engine? *The Sun's radiant energy*
 5. What part of the Earth system is always adjusting to maintain a balance between Earth's incoming and outgoing energy? *Atmosphere*
 6. What parts of this system reflect energy back to space? *clouds, aerosols, bright surfaces*

[Energy and Matter: Water Cycle & The Ocean's Temperature](#)

[Link to Energy and Matter: Water Cycle & The Ocean's Temperature](#)

1. Review the NASA Scientific Visualization Studio video, [The Water Cycle: Heating the Ocean on Youtube](#).
2. Answer the following questions. Check with your instructor on how to submit your answers.
 1. What is the water cycle? *The water cycle is a never-ending global process of water circulation from clouds to land, to the ocean, and back to the clouds.*
 2. What drives the movement of air and water in the Earth System? *The Earth acts as a giant engine that uses solar power to move air in the atmosphere and water in the ocean.*
 3. Where does this visualization begin in the water cycle? *In this visualization series, the cycle begins when the top of the ocean absorbs sunlight.*
 4. Describe what happens to the Sun's heat as you progress through the video. *The Sun's heat is dispersed in the upper ocean by waves and currents.*
 5. How does the Sun and the Hydrosphere's oceans interact in this video? *Water has a high heat capacity and the ocean can absorb a lot of heat without much change in temperature.*
 6. Describe what happens in the night to the ocean with respect to energy. *The ocean cools off very little at night.*
 7. Describe what happens to the land's temperature over the course of the day and night. *Materials forming the land surface such as rocks and soil, however, have lower heat capacity. Thus land temperature changes rapidly, even from night to day.*

[Estimating Biomass Loss from a Large Fire: Student Activity](#)

[Link to Estimating Biomass from a Large Fire Mini Lesson](#)

1. Use a paper copy of the image to complete this activity. Check with your instructor on how to submit answers.
2. Using a metric ruler, and the conversion 1 mile = 1.61 kilometers, what is the scale of the image in meters per millimeter? *The legend on the lower right indicates that 12 miles = 12 millimeters, so in kilometers, this becomes $19.4 \text{ km}/12 \text{ mm} = 1.6 \text{ km/mm}$.*
3. About what is the total area, in square kilometers, of this photo of Greece and its surroundings? *The field on the right measures $78 \text{ mm} \times 98 \text{ mm} = 125 \text{ km} \times 127 \text{ km} = 19,700 \text{ km}^2$.*
4. About what was the land area, in square kilometers, that was burned? (Burned areas

show up in red in the image on the right.) To estimate the area of irregular regions, divide the image into a suitable number of smaller squares, for example, 5mm on a side (= 8 km on a side or an area of 64 km²) as shown in the figure below. The full area has 13 squares across and 19 squares vertically, for a total of 247 cells and a total area of 16,000 km². Because the drawn cells are slightly irregular, we can recalculate their average area as 19,700 km²/247 cells = 80 km². The land area is covered by 173 cells for a total area of 173 x 80 km² = 13,800 km². The red areas that were burned total about 30 cells or 2,400 km². Student answers will vary depending on how they counted the cells. Students may combine their counts and average the to get a more accurate estimate.

5. What percentage of the total area was lost to the fires? $100\% \times 2400\text{km}^2 / 13,800\text{km}^2 = 17\%$.
6. Suppose that a typical forest in this region contains about 5.0 kilograms of biomass per square meter. How many metric tons of biomass were lost during the fires? $5.0 \text{ kg/m}^2 \times (1,000,000 \text{ m}^2/\text{km}^2) \times 2,400 \text{ km}^2 = 12,000,000,000 \text{ kg}$ or 12,000,000 metric tons.

Evaluating Natural and Human Activities Effects on Earth's Climate

[Link to Evaluating Natural and Human Activities Effects on Earth's Climate](#)

1. Review the chart above and answer the following questions. Check with your instructor on how to submit answers.
 1. What is the net total value of radiative forcing (in watts per square meter) of natural activities? Anthropogenic (human) activities? *Natural approximately 0.05 - 0.1 watts per square meter. Anthropogenic approximately 2.5 watts per square meter*
 2. Of the anthropogenic activities, which factor has the greatest value? What category does this belong to? *Carbon dioxide belongs to long-lived greenhouse gases.*
 3. Which of the factors have both a cooling and warming effect on climate? *Halogenated gases, some short-lived gases that create ozone or destroy other green house gases, and aerosols.*
 4. Why is the year 1750 selected as a baseline? *It is prior to the industrial revolution.*
 5. What are three questions that you can ask of this chart? *Accept reasonable responses.*

[Examining a Simplified Model of Clouds Effects on Earth's Energy Budget](#)

Link to [Examining a Simplified Model of Clouds Effects on Earth's Energy Budget](#)

Steps:

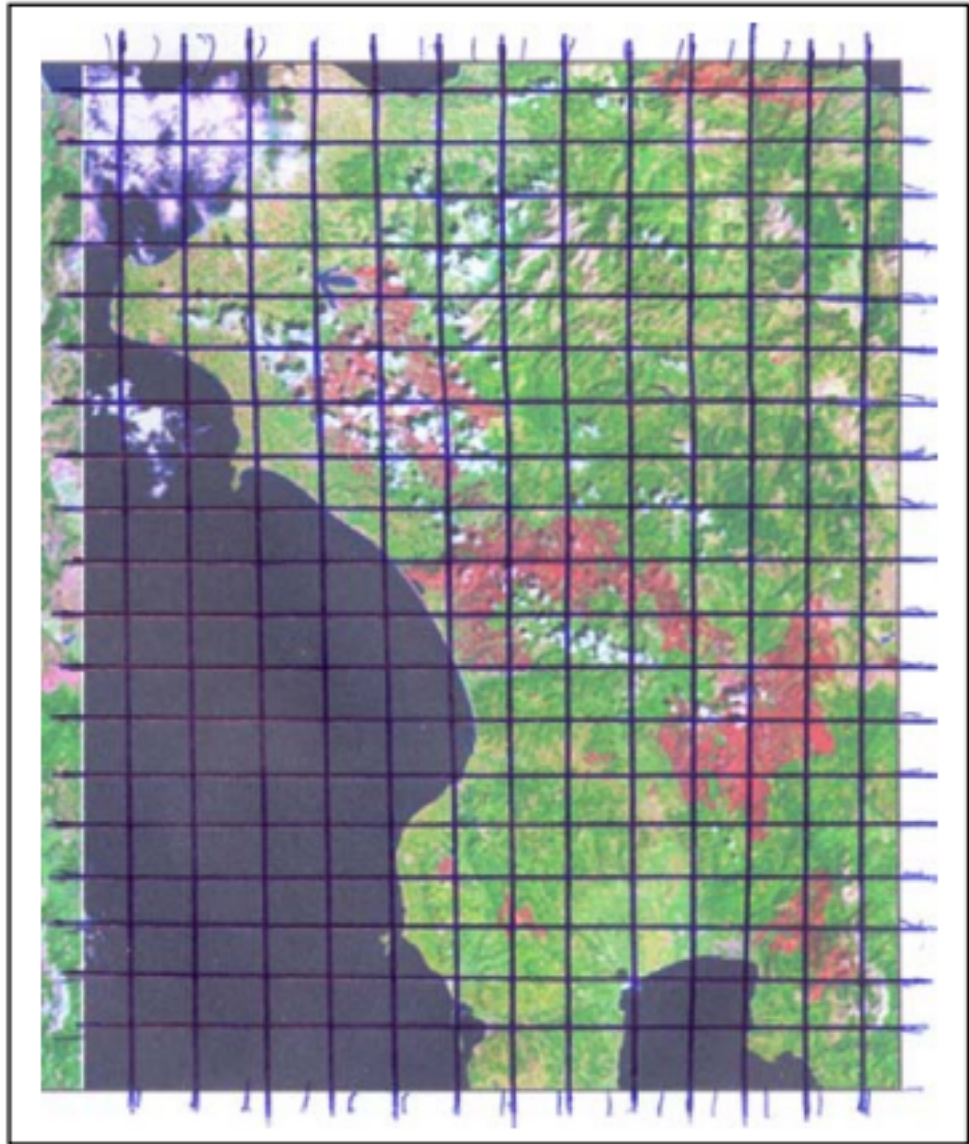
1. Check with your instructor on how to submit your answers.
2. Examine the yellow arrows showing incoming shortwave radiation. What is the difference between the amount of incoming shortwave radiation transmitted through high-level clouds and low-level clouds? *High-level clouds transmit more shortwave radiation to Earth's surface than low-level clouds.*

-
3. Examine the red arrows showing outgoing longwave radiation. What is the difference between the amount of outgoing longwave radiation transmitted through high-level clouds and low-level clouds? *High-level clouds allow less longwave radiation to escape to space.*
 4. Compare the yellow arrow reflected by the high cloud to the red arrow leaving the base of the high cloud and pointing toward the surface. Overall, what effect do high-level clouds have on the atmosphere? *Overall, high-level clouds reflect less shortwave radiation than redirect longwave radiation back toward the surface. High clouds have a warming effect. This is shown in the diagram as the yellow arrow directed toward space from the low cloud is smaller than the red arrow directed from the low cloud to the surface.*
 5. Compare the yellow arrow reflected by the low cloud to the red arrow leaving the base of the low cloud and pointing toward the surface. Overall, what effect do low-level clouds have on the atmosphere? *Overall, low-level clouds reflect more sunlight than redirect longwave radiation back toward the surface. Low clouds have a cooling effect. This is shown in the diagram as the yellow arrow directed toward space from the high cloud is smaller than the red arrow directed from the high cloud to the surface.*
 6. As global temperatures rise, how do you think this will effect clouds? *Accept reasonable responses. Rising temperatures may cause the cloud base to rise, causing a reduction in cloud layer thickness due to the drier air on the surface of the Earth. Higher-level clouds tend to warm the Earth.*

Explore Albedo

[Link to Explore Albedo](#)

1. Review the [NASA Climate Bits: Albedo](#) video and answer the following questions. (Check with your instructor on how to submit your answers.)
 1. What is albedo? *The fraction of the incoming Sun's energy that is reflected.*
 2. What do the colors represent in the weekly maps of reflected solar radiation for the past 10 years? *Lighter colors show more reflection, or higher albedo, and darker colors show less reflection, or lower albedo.*
 3. Why is albedo important for Earth's climate? *Incoming solar energy must equal outgoing energy. The amount of energy absorbed and reflected can impact this balance.*
 4. What pattern did you notice? *More reflected energy where there are persistent clouds, dust, smoke and pollution and snow and ice. Also, albedo increases at the poles during their respective fall and winter seasons and decrease in their respected summer months. Missing data peaks at the poles in their respective summers. Deserts have a higher albedo than areas with a lot of vegetation.*
 5. Why do you think there are missing data at the poles during their winter seasons? *There is little to no sunlight arriving at the poles during these times. Therefore, there is no sunlight to reflect.*
6. How can humans impact albedo? *Contrail and ship trails can temporarily raise albedo. Land use change and burning can also change albedo.*



Sample

Grid

Source: NASA Earth Math Educator Guide

<https://mydasdata.larc.nasa.gov/sites/default/files/inline-images/Estimating%20Biomass%20from%20a%20Large%20Fire.PNG>

Source:

Dunbar, Brian. "Earth Math Educator Guide." NASA, NASA, 30 May 2013, <https://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/...>

[Exploring Cryosphere's Seasonal Thaw](#)

[Link to Exploring Cryosphere's Seasonal Thaw](#)

Observing Changes in Land's Surfaces

1. Check with your instructor on how to submit your answers.
2. Watch this animation and answer the questions below:

-
1. Which latitudes in the Northern Hemisphere (i.e., Arctic, Northern Mid Latitudes, or Tropics) experience the most change in snow and ice extent over the course of a year? *Northern Mid Latitudes*
 2. During what months do you predict to have the largest amount of frozen soil conditions in the Northern Mid Latitudes? *Nov-Jan* Thawing soil conditions in the Northern Mid Latitudes? *March - August*

Describing the Arctic's Land Surfaces

3. Analyze the maps below to orient yourself to the geographic region being analyzed in the blue and red maps that follow. Answer the following questions.

1. What is the location that the map is focused on? *We are looking at the Arctic in the northern hemisphere*
2. What variable is being analyzed? *The state of H₂O in the soil changing from solid to liquid during spring thawing, based on the temperature of the soil.*
3. Describe what the shades of **red** indicate about soil conditions mean? *Water within the soil is in the thaw (liquid) state. **White**? The ratio of the frozen soil to thawed soil equals 0.5. **Blue**? Water within the soil is in the frozen (solid) state.*
4. What two dates are being compared? *April 1st, 2015 and April 13, 2015*
5. The two maps are 12 days apart. What do you predict would happen in 12 more days? Why? *There would be more thawing even closer to the North Pole. The hours of daylight increases as we move from winter to spring and the illumination of solar energy increases at the poles, the bright white snow and sea ice reflect a significant portion of the incoming light, reducing the potential for solar heating.*
6. When the surface changes from blue to red, what happens to the environment of that area? *Rapid warming releases liquid water. As liquid water becomes more readily available, plant and animal activity are energized. The land greens up, and animals return to graze.*

Explore Earth's Energy Budget Diagram Interactive Model

Link to [Explore Earth's Energy Budget Diagram Interactive Model](#)

Link to [Explore Earth's Energy Budget Diagram Teacher Key](#)

Explore Solar Eclipses

[Link to Explore Solar Eclipses](#)

[Explore Solar Eclipses Teacher Key Slides](#)

[Exploring Energy and Matter with Chlorophyll Data](#)

[Link to Exploring Energy and Matter with Chlorophyll Data Mini Lesson](#)

The following video, [NASA SeaWiFS Biosphere Data over the North Atlantic](#), shows satellite data as an animation, displaying 10 years of phytoplankton growth. This animation begins

with Earth's rotation until it reaches the North Atlantic.

Review the video and then answer the following questions.

Steps:

1. Check with your instructor on how to submit your answers.
2. Describe how can you tell what season is showing in the video. Identify the indicators of seasonal change? *By observing the land cover, changing vegetation becomes evident as seasons change. For example, land vegetation appears in the northern hemisphere during summer.*
3. Describe what the dark blue areas of the ocean represent? *These are areas where phytoplankton are scarce, often due to the lack of nutrients.*
4. Describe what the greens and reds in the ocean indicate? *They indicate an abundance of phytoplankton, which often correlates with nutrient-rich areas. These can include coastal regions where cold water rises from the seafloor and near the mouths of rivers.*
5. Compare the Chlorophyll Concentrations in the coastal areas to the open ocean in the Pacific. What do you observe? *Coastal areas tend to have higher concentrations of chlorophyll than the open ocean.*
6. Compare the Chlorophyll Concentrations of the North Atlantic. What differences do you in the summertime versus the wintertime? *Chlorophyll concentrations surge during the wintertime months and fall back during the summertime months.*

Exploring the Tradeoffs of Surface Temperature Models

Link to [Exploring the Tradeoffs of Surface Temperature Models](#)

Link to [Exploring the Tradeoffs of Surface Temperature Models Teacher Key](#)

Extreme July 2022 Temperatures

[Link to Extreme July 2022 Temperatures](#)

Steps:

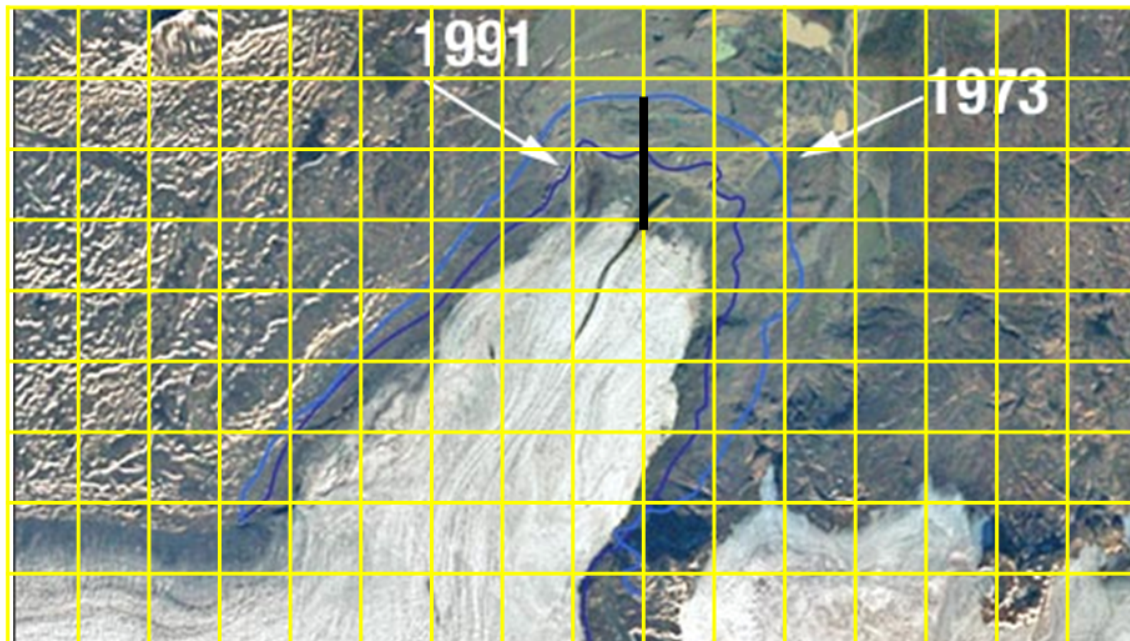
1. Check with your instructor on how to submit your answers.
2. Describe the daily maximum air temperature in the continental United States during the month of July in 2022. *During July 2022, most of the United States daily air temperatures above 30°C with some locations in the mid-west and south displaying temperatures higher than 40°C.*
3. Identify evidence provided in the animation that supports the claim that the July 2022 air temperatures in the United States were extreme and out of normal expected temperature ranges. *Temperature ranges in the United States show values similar to Saharan Desert in northern Africa. (Note the temperature scale has an upper limit of >40°C therefore it is unknown how much higher the air temperatures were modeled to be.)*
4. Describe one impact excessive heat has on your local community. *Answers vary. Example answers may include impact on human life, opening cooling centers,*

limits time outdoors, increase electric costs for air conditioning, etc.

5. Describe one action you should take during times of excessive heat other than to simply moving indoors into climate-controlled conditions. *Answers vary. Example answers may be found at <https://www.heat.gov/pages/planning-and-preparing>*
6. Describe how the daily maximum air temperatures on the West Coast of the continental United States differs from the air temperatures immediately offshore over the Pacific Ocean. *Air temperatures on the continental West Coast were generally over 30°C while immediately offshore, the air temperatures were dramatically different ranging between 10°C and 20°C.*
7. Use your knowledge of heat transfer to explain why the air temperatures over land are different than the air temperatures over nearby large bodies of waters. *Heat is transferred to the air both by directly absorbing shortwave solar radiation as well as absorbing longwave radiation that is emitted from Earth's surface. The dramatic difference in temperature is a result of a large difference in surface temperatures. Since ocean waters in that region are much cooler as a result of the California current, the air immediately above the ocean surface is cooler since the ocean serves as an energy sink in that region.*
8. Identify a localized area/region in the continental United States where the air temperatures remained relatively cooler in July. *Answers vary. Example response may include that a cooler region of air was experienced over the Rocky Mountain range in Colorado.*

[Glacier Retreat: Student Activity](#)

[Link back to Glacier Retreat Mini Lesson](#)



[Eyjabakkajökull Glacier](#)

[Image Credit: NASA](#)

<https://mydasdata.larc.nasa.gov/sites/default/files/inline-images/glacier%20retreat%20cropped.png>

Steps

Refer to the image to answer the questions. Check with your instructor on how to submit your answers.

1. Each box on the image represents 1 km^2 . Using the conversion $1 \text{ kilometer} = 0.62137 \text{ miles}$, what is the area of each box in square miles? $1 \text{ km}^2 * 0.62127 \text{ miles/km} * 0.62137 \text{ miles/km} = 0.3861 \text{ miles}^2$
2. The change in shape is not the same everywhere. Use the locations shown by the black line on the image to estimate the answer to the question.
 - How many meters did the glacier retreat between 1973 and 1991? 1991 and 2000? *Since this is an estimate, accept reasonable responses.*
 - For 1973 to 1991 - Approximately 0.8 to 0.9 km or 800 to 900 meters
 - For 1991 to 2000 - Approximately 1.1 km or 1100 meters.
3. From your answers to Problem 2:
 - What is the average rate of retreat in meters per year between 1973-1991 and 1991 to 2000?
 - 1973-1991 example: $900 \text{ meters} / 18 \text{ years} = 50 \text{ meters/year}$
 - 1991-2000 example $1100 \text{ meters} / 9 \text{ years} = 122.2 \text{ meters/year}$
4. Is the retreat of the glacier speeding up or slowing down? *speeding up because the rate was higher for 1991-2000*
5. What possible explanation do you have for your answer to question 4? *accept reasonable responses*

Global Phytoplankton Distribution Interactive Model

Link to [Global Phytoplankton Distribution Interactive Model](#)

Link to [Global Phytoplankton Distribution Interactive Model Teacher Key](#)

Global Phytoplankton Distribution StoryMap

Link to [Global Phytoplankton Distribution StoryMap](#)

Link to [Global Phytoplankton Distribution StoryMap Teacher Key](#)

[How are Phytoplankton and Sea Surface Temperatures Related?](#)

[Link to How are Phytoplankton and Sea Surface Temperatures Related? Mini Lesson](#)

Steps:

Check with your instructor on how to submit your answers. Analyze the Chlorophyll Concentrations color bar provided with the map.

1. Describe what you think the color bar legend represents. *When phytoplankton populations are large, the color of the water appears greener because of high concentrations of chlorophyll.*

-
2. Describe where do you observe the highest concentrations? Lowest? *Highest concentrations are located at the higher latitudes and coastal waters. Lowest? Lowest concentrations are located at the lower latitudes.*
 3. What factors do you think control where phytoplankton are distributed? *Access to sunlight and nutrients*

Now, analyze the Sea Surface Temperature mapped image, paying specific attention to the color bar provided and answer the following questions.

1. Where do you observe the highest concentrations? Lowest? *The highest concentrations are located at the higher latitudes and coastal waters, while the lowest concentrations are located at the lower latitudes.*

Review following video visualizing Chlorophyll & Sea Surface Temperature from 2002 to 2019. Answer the following questions:

1. Where are the highest concentrations of chlorophyll generally located? Do the trends that you observed in the Northern Atlantic also occur in the Southern Hemisphere? *Cold, polar waters in both hemispheres (and places where ocean currents bring cold water to the surface, such as around the equator and along the continents) experience high levels of chlorophyll.*
2. How do the values of chlorophyll change over the seasons? *In the hemisphere experiencing summer, we can see the biggest differences between the equatorial regions and polar regions.*
3. Why do you think that the polar regions experience these changes during the spring/summer seasons? *Day length increases so phytoplankton flourish with more sunlight.*

How Do We Receive Energy From the Sun? Interactive Model

Link to [How Do We Receive Energy From the Sun? Interactive Model](#)

Link to [How Do We Receive Energy From the Sun? Teacher Key](#)

How does a Solar Eclipse Affect Air Temperature?

[Link to How does a Solar Eclipse Affect Air Temperature?](#)

Analyze:

1. **Examine:** (no questions in this section)
2. **Watch:** (no questions in this section)
3. Approximately how many degrees does air temperature drop during the eclipse? Hint: look at the legend for the temperatures for the colors.
 1. In the penumbra? *Approximately 2-4 degrees in many locations. Not all locations are the same, and with careful examination, you may find some locations with temperature increases.*
 2. In the umbra? *Approximately 1-3 degrees in many locations. Not all locations are the same, and with careful examination, you may find some locations with*

temperature increases.

4. Do locations experiencing the total solar eclipse have greater temperature variations than locations experiencing the partial solar eclipse? *Most locations in the umbra have a greater temperature variation.*
5. Aside from the Moon's shadow, what other variables would affect the air temperature during this four-hour period? *Other factors can include time of day, elevation, topography, and weather.*

Make a prediction: How do you think plants and animals would behave during a total solar eclipse? *Accept reasonable responses including that they may behave like it is night.*

[How does the Cryosphere Change over the Seasons?](#)

[Link to How does the Cryosphere Change over the Seasons?](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. Describe the phenomenon you observe. *This video shows snow and sea ice in the Northern and Southern Hemispheres pulse at exact times of the year from 2011 - 2012.*
3. Identify the patterns you see in this model. *This model shows the extent in change at the poles. The northern hemisphere shows a growth of snow and sea ice during the months of November 2011 thru March 2012. The southern hemisphere shows the opposite, showing growth during the winter Months of April 2012 thru August 2012.*
4. What are the limits of this model? *This model is depicting the pulse in growth and recession of snow and sea ice at the end of 2011 and all of 2012. It does not show other years to fully compare overall changes that may be occurring at the poles.*
5. What evidence of Earth System interaction (among Atmosphere, Hydrosphere, Biosphere, Cryosphere, Geosphere) do you see? *The water cycle is an important aspect of snow and sea ice. This involves the interaction of all of the spheres. The hydrosphere and atmosphere interact with evaporation and condensation. The volume of water in the hydrosphere increases with the melting of ice in the cryosphere. The geosphere and biosphere are affected by changes in season, changing Earth surface conditions, vegetation, and water supply.*

How will different locations in the US experience the 2023 solar eclipse?

[Link to How will different locations in the US experience the 2023 solar eclipse](#)

1. Examine the map of the United States that shows how each location will experience the April 8, 2024 solar eclipse.
2. Examine the data table that accompanies the data from the map. For example, if you live in Dallas, TX:
 - The **partial eclipse begins at 12:23 pm** Central Daylight Time (CDT). The Moon's shadow will start to cover the Sun.
 - The Sun will become more and more obscured until **totality begins at 1:40 pm** CDT.
 - As you experience totality, the sky gets darker and darker until **1:42 pm** CDT,

at the **maximum totality**, which is the moment that you would experience the most darkness.

- **Totality ends at 1:44 pm** CDT, when the Moon's shadow moves away from you.
- You would then experience a partial solar eclipse until the **partial ends at 3:02 pm** CDT.
- **Safety Reminder!** Only viewers in the path of totality will be able to remove their solar eclipse glasses, and only during totality, which only lasts for about 4 minutes in most locations. The rest of the time observers will have to wear their solar eclipse glasses to view the partial eclipse.

3. Answer the following questions on the [Google Form](#).

1. What location Which location(s) on the path of totality will experience the longest duration of totality? *Cleveland, OH (5 minutes)*
2. What location Which location(s) on the path of totality will experience the shortest duration of totality? *Little Rock, AR; Paducah, KY; Burlington, VT; Caribou, ME will only experience 1 minute of totality.*
3. Where is your location? What will you see at that location on April 8, 2024? For how long will you be able to see it? *Answers will vary. Remind students that they can approximate their location and that the yellow crescents on the border of the map tell them the percentage of the Sun that will be blocked by the Moon at that location.*
4. Make a prediction: how does NASA predict the duration of totality in different locations for future solar eclipses? *Answers will vary. Remind students that predictions are based on background knowledge. A common guess is that NASA uses past eclipse data to predict future eclipse data.*
4. Watch the [video](#) on *Tracing the 2017 Solar Eclipse* to learn more about how NASA uses data from past eclipses to predict the locations and times of future solar eclipses.
5. Answer the following questions about the video.

1. What features of this visualization are driven by data? *All features are driven by data: the color of the ground, the path of totality, the lighting from the Sun, the Sun angle, etc.*
 - *Data on Moon topography was collected from the NASA Lunar Reconnaissance Orbiter (LRO)*
 - *NASA Shuttle Radar Topography Mission (SRTM) Data for Earth topography*
 - *NASA Jet Propulsion Laboratory Orbits & Ephemerides data for a tabulation of the Sun, Earth, and Moon positions*
2. How does Moon topography (mountains and valleys) affect the duration of totality? *Moon topography affects the shape of the edge of the shadow. This could mean that some observers may get a longer or shorter duration of totality depending on if they are located on the edge of the shadow.*
3. What other variables affect the way an observer views a total solar eclipse from different locations on Earth?
 - *Elevation of the observer (Earth topography)*
 - *Local weather (clouds may block the view)*

Human Impact and the Creation of Urban Heat Islands Interactive Model

Link to [Human Impact and the Creation of Urban Heat Islands Interactive Model](#)

Link to [Human Impact and the Creation of Urban Heat Islands Interactive Model Teacher Key](#)

Hurricanes as Heat Engines StoryMap

Link to [Hurricanes as Heat Engines StoryMap](#)

Link to [Hurricanes as Heat Engines StoryMap Teacher Key](#)

[Identifying Changes in Land Use](#)

[Link to Identifying Changes in Land Use](#)

1. Check with your instructor on how to submit your answers.
2. Clear Cut:
 1. Identify the trend in the Pacific Northwest before the clear cut. *The trend was stable at around 825 on the vegetation index before around 1999.*
 2. When did the clear cut in the Pacific Northwest occur? *Before 1999*
 3. Explain the impact of the forest after the clear cut. *The soil gets covered with grasses and then continues to recovering vegetation.*
3. Bark Beetle
 1. Identify the trend in the forest before the Bark Beetle epidemic. *The trend was stable at around 250 on the vegetation index.*
 2. When was the Bark Beetle epidemic? *It began around 2004.*
 3. Explain the impact of the forest after the Bark Beetle epidemic. *The events after the epidemic include a large decrease in the forest's needles and the satellite's instruments collected a much different lower of NDVI as compared to before the beetle infestation.*
4. Western Spruce Budworm
 1. Identify the trend in the forest before the Western Spruce Budworm infestation. *Stable forest, around 700 NDVI*
 2. When was the Western Spruce Budworm infestation? *Around 2000*
 3. Explain the impact of the forest after the Western Spruce Budworm infestation. *Changed the type of vegetation to a shrub instead of a forest.*
5. How might these problems influence human activity? *Answers may vary.*
6. Explain the differences between what the visualization shows and what the graph shows. *The graphs and visualizations use the same data. The graphs can show how a particular area changes over time. These are useful for making quick assessments. Visualizations show large volumes of data and help provide scientists tools. They help to reveal trends and patterns over a large area. Both are useful for analyzing, interpreting, and communicating a scientific story.*

Interpreting a Graph of Surface Temperature of Urban Areas

[Link to Interpreting a Graph of Surface Temperature of Urban Areas Mini Lesson](#)

Review the [Urban Heat Island Profile graph](#) below showing surface temperatures taken from different types of communities.

1. Answer the questions. Check with your instructor on how to submit answers.

1. What is the highest temperature in Celsius on the graph? *38 degrees Celsius*
2. What is the highest temperature in Fahrenheit on the graph? *100 degrees Fahrenheit*
3. Identify which community (rural, suburban, urban) has the highest surface temperatures and explain why. *Urban environments will have the highest surface temperatures because cities are full of these rocky surfaces — asphalt, brick, and concrete — that absorb heat by day and release it at night. These materials are used to make the sidewalks, parking lots, roads, and basketball courts of urban areas.*
4. Identify which community (rural, suburban, urban) has the lowest surface temperatures and explain why. *Rural environments will have the lowest surface temperatures because they have more vegetation. Plants take up water from the ground through their roots. Then, they store the water in their stems and leaves. The water eventually travels to small holes on the underside of leaves. There, the liquid water turns into water vapor and is released into the air. This process is called transpiration. By releasing water, plants cool themselves and the surrounding environment. Like how sweat cools the human body, energy is absorbed and transported away from a warm object by the evaporation of water.*
5. What kind of community do you live in? Describe the surface temperature of your neighborhood by comparing it with other parts of your community. *Answers will vary.*

Learning From Stars and Solar Eclipses StoryMap

Link to [Learning From Stars and Solar Eclipses StoryMap](#)

Link to [Learning From Stars and Solar Eclipses StoryMap Teacher Key](#)

[Modeling the Heliosphere](#)

[Link to Modeling the Heliosphere](#)

Examine:

The Heliosphere Graphic image was created from a 3D model of the heliosphere using actual data collected by the IBEX mission. Colors are meant to enhance features and show structure. The solar wind is represented by the greenish, wavy lines coming out from the Sun. The heliopause is the outermost boundary of the heliosphere. Beyond the heliopause is interstellar space. The termination shock is the innermost boundary of the heliosphere, where the solar wind begins to interact with interstellar space. The termination shock is still inside the heliosphere. The heliosphere creates a bow wave because the Sun is moving through

interstellar space, as it orbits the center of the Milky Way galaxy. Just like how a bow wave is created as a boat moves through the water.

- What do you notice about the boundary? **Accept reasonable responses.**
- What shape is it? **Accept reasonable responses.**

Share Results

Record your results. Include drawings and diagrams and note any modifications you made in order to perfect the model, perhaps adjusting the water pressure or the position of the image, for example.

Answer the following questions:

- How does this model help us learn about the properties (characteristics) of the solar wind and the heliosphere boundary? *The model really helped me understand that the boundary of the heliosphere is not a defined, static line, but a fluid boundary that changes with the output of the solar wind. Just like the puddle of water on the handout changed its shape depending on the outflow of water from the faucet.*
- Why would a soap bubble not be an appropriate model for the heliosphere? *It is not a perfect sphere.*

Nitrogen Cycle Game

Link to the [The Nitrogen Cycle Game](#)- Interactive Model

Link to [The Nitrogen Cycle Game](#)- Teacher Key

Observing the Sun During a Total Solar Eclipse

[Link to Observing the Sun During a Total Solar Eclipse Interactive](#)

[Observing the Sun During a Total Solar Eclipse Teacher Key Slides](#)

Ocean Circulation Patterns: Garbage Patches StoryMap

Link to [Ocean Circulation Patterns: Garbage Patches StoryMap](#)

Link to [Ocean Circulation Patterns: Garbage Patches StoryMap Teacher Key](#)

Patterns in Earth's Surface Temperatures Interactive Model

Link to [Patterns in Earth's Surface Temperatures Interactive Model](#)

Link to [Patterns in Earth's Surface Temperatures Interactive Model Teacher Key](#)

Phytoplankton Distribution and Watersheds Interactive Model

Link to [Phytoplankton Distribution and Watersheds Interactive Model](#)

Link to [Phytoplankton Distribution and Watersheds Interactive Model Teacher Key](#)

Safely Observing the Sun

[Link to Safely Observing the Sun Interactive.](#)

[Safely Observing the Sun Teacher Key Slides](#)

[Scale, Proportion, and Quantity: Ice Flow Model](#)

[Link to Scale, Proportion, and Quantity: Ice Flow Model](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. Answer the Exit Ticket Question:
 1. How do visualizations (which show phenomena on a different time scale) help scientists understand what is happening?

Harsh snows have blanketed Antarctica for so long that the continent has built up an ice sheet a mile thick from bedrock to surface in most places. Despite the ice cap's grip on the rocky landmass below, friction can only hold back the ice so much. This map from NASA reveals icy Antarctica as a landscape of constant movement. NASA scientists at the Jet Propulsion Laboratory and University of California, Irvine have charted this movement for the first time, using Canadian, Japanese and European satellite data to create a record of the speed and direction of ice flow across the entire continent. The map reveals glaciers and tributaries in patterned flows stretching hundreds of miles inland, like a system of rivers and creeks. Slow-moving flows found in largely unexplored East Antarctica defied previous understanding of ice migration. And scientists discovered a ridge that splits Antarctica from east to west.

- *In the first video, slow, interior flows have been sped up to make them more visible. The colors represent the real flow velocity magnitude.*
- *In the second video, all flows are shown at the same scale. At this scale, only the fastest flows are visible.*
- *In the third video, velocity magnitude colors have been removed and the direction of glacial flow stands out clearly against the icy background.*

Sea Ice and the Earth System StoryMap

Link to [Sea Ice and the Earth System StoryMap](#)

Link to [Sea Ice and the Earth System StoryMap Teacher Key](#)

Shaconage: Blue Smoke

[Link to Shaconage: Blue Smoke](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. Describe the conditions that contribute to “blue smoke.” *High humidity and rainfall, along with volatile organic compounds from plants affect the blue wavelength of light, creating a blue hue to the clouds.*
3. Explain how the conditions that create the “blue smoke” of this area are different from conditions that cause other aerosol pollutants. *Most other pollutants are related to combustion of fossil fuels and manufacturing and do not cause the blue hues in clouds.*
4. Identify the first people who lived in the area described? Where did they go? *The Cherokee Indians lived in this area until they were forced out, and on to reservations in another location.*
5. Explain the unintended consequences that occurred when European settlers moved in. *The settlers brought pigs that mated with wild boars, creating the problem of invasive wild pigs.*
6. Where would you go to experience “blue smoke” and this location? *A trip to the Great Smoky Mountains; Great Smoky Mountains National Park.*

[Space Weather Maps](#)

[Link to Space Weather Maps](#)

[Link to teacher slides.](#)

[Space Weather StoryMap](#)

[Link to Space Weather StoryMap](#)

[Link to teacher key.](#)

[Systems and System Models: Megadroughts in our future?](#)

[Link to System and System Models: Megadroughts in our future?](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. Describe the phenomenon you observe. *This video shows megadrought across the United States from 1950 through present and then shows projected drought in the US through 2095.*
3. What are the limits of this model? *This model shows a projection. Since this may not be accurate, it could be clearer where the model transitions from past data to projection. Additionally, the model is focused on North America so the scale could be changed to make it easier to look at smaller or larger regions. Since this visualization is a video, it moves very quickly, making it difficult to really analyze the data*

presented. Having fewer frames per second in the visualization could give students more time to view and interpret the data.

4. Identify the patterns you see in this model? *Drier areas, such as deserts, are focal points of drought, though the dry conditions eventually spread across the US. Dry conditions tend to worsen over time in this projection.*
5. What evidence of Earth System interaction (among Atmosphere, Hydrosphere, Biosphere, Cryosphere, Geosphere) do you see? *The water cycle is an important aspect of drought. This involves the interaction of all of the spheres. The hydrosphere and atmosphere interact with evaporation and condensation. The volume of water in the hydrosphere increases with the melting of ice in the cryosphere. The geosphere and biosphere are affected by drought, changing Earth surface conditions, vegetation, and water supply.*

[Systems and System Models: Observing Carbon Dioxide in the Atmosphere](#)

[Link to Systems and System Models: Observing Carbon Dioxide in the Atmosphere](#)

1. Check with your instructor on how to submit your answers.
2. Describe the phenomenon you observe in the video. *Carbon dioxide and carbon monoxide cycle in production, concentration, and location across the globe across the seasons.*
3. Identify the patterns you see in this model. *Answers will vary.*
4. What are the limits of this model? *This model only shows one year of data. Since it shows the whole world, it can be hard to focus in on one place to determine the cyclical patterns of a certain continent or country. With a larger data set, we could analyze the changing patterns over a longer period of time to see the effect on climate change. With a different scale, we could focus on emission areas or other areas of interest.*
5. What evidence of Earth System interaction (among Atmosphere, Hydrosphere, Biosphere, Cryosphere, Geosphere) do you see? *The atmosphere interacts with the biosphere directly as plants use up atmospheric carbon dioxide in spring and summer months. The hydrosphere interacts with the atmosphere as well, as ocean reservoirs absorb some of the carbon dioxide in the atmosphere. The geosphere also interacts with the atmosphere as fire plumes contribute to atmospheric carbon monoxide levels.*

[Systems and System Models: Observing Our Planet on Fire](#)

[Link to Systems and System Models: Observing Our Planet on Fire Mini Lesson](#)

Accept reasonable responses for all questions. Some possible answers are outlined below.

1. Describe the phenomenon you observe. *Global impact of smoke from fires*
2. What patterns do you see in this model?
 - *From South America smoke is carried far into the Atlantic.*
 - *Smoke from Southern Africa is also carried into Atlantic.*
 - *Fires in Northeast India produce thick smoke which is trapped by the Himalayas.*
 - *Unusually large human set fires in Indonesia create haze and reduce air quality and visibility.*
 - *Australian fires mostly ignited by lightning burn on eastern and southern*

coasts, and the smoke is sucked into the constant swirl of storms around Antarctica and mixed with sea salt.

- Africa is home to 70% of world's fires and smoke merges with dust from Sahara and travels across the Atlantic.
 - Fires are common in dry season in South America and Southern Mexico.
 - Fires in North America are more rare and occur in the Southeast and Mississippi River Valley.
 - Southeast Asia fires extend 1000s of miles and reach distant lands.
3. What are some limits of this model? *The entire Earth cannot be seen at once. Specific events may not be included.*
 4. How is this model precise? *It does capture some specific events such as the volcano. It shows the different types of aerosols in the atmosphere such as smoke, sea salt and dust. It shows wind patterns.*
 5. What benefits are there in using this model? *It may help predict the impact of large fires in different parts of the world.*
 6. Predict the future of the phenomenon based on the model you've observed. *Fires in different parts of the world are likely to follow similar patterns of smoke transport.*
 7. What evidence of Earth System interaction (among Atmosphere, Hydrosphere, Biosphere, Cryosphere, Geosphere) do you see?
 - *Biosphere is burning and impacting atmosphere with smoke.*
 - *Farmers ignite fires to clear fields for new crops (biosphere) which impacts atmosphere.*
 - *Smoke from Australian fires is sucked into storms formed around Antarctica (cryosphere) and mixed with sea salt from the Hydrosphere.*
 - *Volcanic eruptions (geosphere) can emit smoke into the atmosphere as well.*

The Role of Earth's Features in Earth's Energy Budget Interactive Model

Link to [The Role of Earth's Features in Earth's Energy Budget Interactive Model](#)

Link to [The Role of Earth's Features in Earth's Energy Budget Teacher Key](#)

Using Graphs: Identify and Interpret

[Link to Using Graphs: Identify and Interpret](#)

[Link to Using Graphs: Identify and Interpret Answer Key PDF](#)

[Using Models to Explore Chlorophyll and Radiation Data](#)

[Link to Using Models to Explore Chlorophyll and Radiation Data](#)

Steps:

1. Check with your instructor on how to submit your answers.
2. Review the color bar scale for net radiation. What do the colors mean? *The color bar shows changes in the balance of incoming and outgoing energy on Earth. Places where more energy was coming in than going out (energy surplus) are orange. Places*

where less energy was coming in than going out (energy deficit) are purple. Places where the amounts of incoming and outgoing energy were in balance are white.

Net Radiation



3. Review the color bar scale for chlorophyll concentration. What do the colors mean? *The color bar shows changes in chlorophyll values. Places where chlorophyll amounts are very low, indicating very low numbers of phytoplankton, are blue. Places where chlorophyll concentrations were high, meaning many phytoplankton were growing, are dark green. The observations come from the MODIS sensor on NASA's Aqua satellite. Land is dark gray, and places where MODIS could not collect data (reasons include sea ice, polar darkness, or clouds) are light gray.*

Chlorophyll



4. Describe the values for net radiation during the spring and fall in the Northern Hemisphere. *In the Northern Hemisphere, net radiation during the spring and fall is closest to zero. There are areas that are more positive or negative, but their difference is less extreme compared to the summer and winter.*
5. List the value of net radiation in the Northern Hemisphere during the summer, then list the value of net radiation in the Northern Hemisphere during winter. What do you notice? *In the Northern Hemisphere during the summer, the value of net radiation is high at 180 Watts per square meter. In the Northern Hemisphere during the winter, the value of net radiation is very low at -180 Watts per square meter. The Northern Hemisphere can experience an extremely large range in net radiation.*
6. Describe the patterns you observe between net radiation and chlorophyll concentration? *Chlorophyll concentration shifts north or south throughout the year in the same manner as positive net radiation. For example, in the summer when net radiation is high throughout the Northern Hemisphere, the chlorophyll concentration is also high. In the winter, when net radiation is low throughout the Northern Hemisphere and high throughout the Southern Hemisphere, chlorophyll concentration also decreases in the Northern Hemisphere and increases in the Southern Hemisphere.*
7. Observe the contrast between the Northern Hemisphere and the Southern Hemisphere in net radiation values. Explain which two seasons experience a greater difference? Fall and spring or summer and winter? Explain. *Summer and winter experience the greater difference in net radiation values. There is a stark contrast between the northern and southern hemispheres during the summer and winter. During these seasons, one hemisphere of the Earth will experience high net radiation and the other hemisphere will experience low net radiation. There is little difference in the fall and spring seasons. Both fall and spring experience more uniform net radiation, that is not extremely high or extremely low.*

Volcanic Eruptions StoryMap

Link to [Volcanic Eruptions StoryMap](#)

What is Albedo?

[Link to What is Albedo? Mini Lesson](#)

1. What is albedo? *The fraction of the incoming Sun's energy that is reflected.*
2. What do the colors represent in the weekly maps of reflected solar radiation for the past 10 years? *Lighter colors show more reflection and darker colors show less reflection.*
3. How do these colors relate to albedo? *Lighter colors represent a higher albedo than darker colors.*
4. Why is albedo important for Earth's climate? *Incoming solar energy must equal outgoing energy. The amount of energy absorbed and reflected can impact this balance.*
5. What pattern did you notice? *More reflected energy where there are persistent clouds, dust, smoke and pollution and snow and ice. Also, albedo increases at the poles during their respective fall and winter seasons and decrease in their respected summer months. Missing data peaks at the poles in their respective summers. Deserts have a higher albedo than areas with a lot of vegetation.*

What Elements are in Your Body?

[Link to What Elements are in Your Body? Interactive](#)

[What Elements are in Your Body? Teacher Key Slides](#)

What is a Solar Eclipse?

[Link to What is a Solar Eclipse?](#)

1. View an animation of a total solar eclipse. Animations are used to help explain phenomena that are hard to view. A total solar eclipse is visible only on a small portion of Earth, so this type of animation can make this phenomenon accessible to people who are unable to view a total solar eclipse in their location. Answer the following questions about the animation.
 1. What objects are in the animation? *The Sun and the Moon.*
 2. Estimate the size and distance of those objects. *The Sun is much bigger than the Moon and is much farther away from Earth.*
 3. Describe the motion of those objects. *The Moon is moving across the Sun.*
 4. Where is the observation being made from? *Earth or maybe a satellite between Earth and the Moon.*
2. View imagery of the 2017 total solar eclipse captured from space by NASA's Earth Polychromatic Imaging Camera (EPIC) onboard NOAA's Deep Space Climate Observatory (DSCOVR). Answer the following questions about the imagery.
 1. What objects are in the video? *Earth and the Moon's shadow.*

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2. Estimate the size and distance of those objects. *The Moon is much smaller than Earth.*
 3. Describe the motion of those objects. *The Moon's shadow is moving across Earth.*
 4. Where is the observation being made from? *A satellite orbiting Earth (EPIC/DSCOVR).*
3. Using what you learned from the two perspectives presented by the animation and the imagery, answer the following questions.
1. How would you describe a solar eclipse? *Accept reasonable responses such as: A solar eclipse occurs when the Moon's shadow crosses Earth. The Sun, Moon, and Earth all must be lined up. From observers on Earth, the Moon blocks the disk of the Sun.*
 2. What is your evidence for your explanation? *Accept reasonable responses such as: My evidence is imagery from NASA's EPIC instrument, showing the Moon's shadow move across Earth in 2017; and the animation shows the perspective from Earth, with the Moon blocking the disk of the Sun.*

What is Space Weather?

[Link to What is Space Weather Interactive.](#)

[What is Space Weather Teacher Key Slides](#)

What is the Difference between a Solar Eclipse and a Lunar Eclipse?

[Link to What is the Difference between a Solar Eclipse and a Lunar Eclipse?](#)

Link to [Teacher Key for "What is the Difference between a Solar Eclipse and a Lunar Eclipse?"](#)

What is the Sun's Corona?

[Link to What is the Sun's Corona?](#)

[Link to What is the Sun's Corona? Teacher Key](#)