The Sun’s Effect on Climate and Seasons
Lesson 2: Energy Angles

Grade: 5	**Length of lesson: 101 minutes**	**Placement of lesson: 2 of 6 lessons**
Anchoring Phenomenon: Earth’s Northern and Southern Hemispheres experience repeating, predictable seasonal changes in average temperatures.		
Unit Learning Goal: Earth’s curved surface and consistent tilt and its orbit around the Sun result in uneven heating across the planet. This difference in the sunlight’s intensity causes different locations on Earth to experience different seasons at the same time of year as well as varying average yearly temperatures.		
Lesson Main Learning Goal: Because Earth is a sphere, the Sun’s light hits Earth’s curved surface more directly close to the equator and less directly closer to the poles. The difference in the angle of sunlight striking Earth’s surface at different latitudes causes uneven heating. **Science and Engineering Practices:** Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena; Developing and Using Models: Evaluate limitations of a model for a proposed object or tool. **Crosscutting Concepts:** Patterns: Graphs, charts, and images can be used to identify patterns in data; Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural ~~or designed systems~~.		
Unit Central Question: Why are some places on Earth hotter than others at different times of the year?		**Lesson Focus Question:** What causes the average temperatures on Earth near the equator to be higher than the average temperatures on Earth far from the equator?
Science content storyline: Temperatures on Earth are generally higher (warmer) closer to the equator and lower (cooler) toward the poles. The patterns seen on Earth related to varying temperatures are caused by uneven heating of Earth’s surface. Earth’s surface heats unevenly because the Sun’s light (solar radiation and energy) hits different parts of the planet either more directly or less directly. When light hits a surface straight on (or perpendicular to it), the energy is more concentrated over a smaller area. When light hits a surface less directly (at a low angle), the energy is more spread out. The Sun’s light shines most directly near the equator, so it provides more heat per unit area (square on the graph paper). When the Sun’s light hits at a less-direct angle toward the poles, it is more spread out and does not provide as much heat per unit area. Because Earth is a sphere, sunlight hits the curved surface more directly closer to the equator and less directly as you move closer to the poles. Solar radiation is most direct at or close to the equator and thus produces higher average temperatures. As one moves farther from the equator and closer to the poles, the sunlight is less direct. Because of the less-direct angles of sunlight the farther you are from the equator, solar radiation is less intense and therefore the average temperatures are lower. The angle of the Sun’s light affects the heating of Earth’s surface. When the angle of sunlight is direct, the sunlight is more intense and Earth’s surface will get warmer. When sunlight strikes Earth’s surface less directly—when we move from the equator to the poles (increasing latitude)—then the Sun’s light is less concentrated and the surface does not warm as much. Temperatures vary in the Northern and Southern Hemispheres at different times of the year.		
Ideal student response to the Lesson Focus Question: At or near the equator, the Sun’s light strikes Earth’s surface directly and is very concentrated. More-intense sunlight warms the surface more. As you move from the equator to the poles, the sunlight hits Earth less directly, at an angle, so the sunlight is more		

spread out and not as intense. Places near the poles are cooler than places near the equator because the sunlight they receive is more spread out (less concentrated) and, therefore, they do not warm up as much.

Preparation

MATERIALS NEEDED	AHEAD OF TIME
The Sun's Effect on Climate and Seasons PowerPoint (by lesson) **Teacher Resources** • TE2.2 *Tray and Globe Example* • TE2.3 *The Sun's Incoming Energy—Angle Related to Latitude* **Student Handouts** • HO2.1 *Energy Angles* (1 per student) • HO2.4 *Sun's Incoming Energy* (1 per pair of students) **Other Materials** • inflatable globe (1 per pair of students) • cardboard sheet or plastic tray (1 per pair of students) • sheets of graph paper (2 per pair of students) • flashlight (with a concentrated beam) (1 per pair of students) • scissors, ruler, and transparent tape (1 set per pair of students) • Communicating in Scientific Ways chart	• Review the background information on the Sun's energy and Earth's shape found on pages 7-14 of the *Content Background* document. • Prepare handouts. • Prepare a two-column data table on chart paper to post and record student data following Activity 1. Title: Number of Lighted Squares; column headings: "Direct" and "Less direct" (or "Straight on" and "At an angle"). This is also included as a slide in the PowerPoint. • Prepare a two-column data table on chart paper to post and record student data for Activity 2. Title: Number of Light Rays per Latitude; column headings: "Number of Light Rays" and "Latitude." This is also included as a slide in the PowerPoint.

Lesson 2 General Outline

Time	Phase of lesson	How the science content storyline develops
5 min	**Link to Previous Lesson:** Students review the temperature patterns from Lesson 1.	Temperatures on Earth are generally higher (warmer) closer to the equator and lower (cooler) toward the poles.
1 min	**Lesson Focus Question:** Teacher introduces the Lesson Focus Question.	
5 min	**Setup for Activity 1:** The teacher sets up an activity about the intensity of light relative to the angle at which it strikes a surface.	The patterns seen on Earth related to varying temperatures are caused by uneven heating of Earth's surface.
10 min	**Activity 1:** Students shine a flashlight on a flat surface, first perpendicular and then at an angle. They collect and record data from their investigation.	Earth's surface heats unevenly because the Sun's light (solar radiation and energy) hits different parts of the planet either more directly or less directly. When light hits a surface straight on (or perpendicular to it), the energy is more concentrated over a smaller area. When light hits a surface less directly (at a low angle), the energy is more spread out.
35 min	**Follow-up to Activity 1:** Students analyze their data about the angle of light on a flat surface. Then, they compare the angle of light to the curved surface of a globe.	The Sun's light shines most directly near the equator, so it provides more heat per unit area (square on the graph paper). When the Sun's light hits at a less-direct angle toward the poles, it is more spread out and does not provide as much heat per unit area.
5 min	**Setup for Activity 2:** Students examine a new content representation of the Sun's light striking Earth's surface at various latitudes.	
10 min	**Activity 2:** Students count and compare the rays of sunlight striking Earth at different latitudes and record their data.	Because Earth is a sphere, sunlight hits the curved surface more directly closer to the equator and less directly as you move closer to the poles.

Time	Phase of lesson	How the science content storyline develops
12 min	**Follow-up to Activity 2:** Students look for patterns in their data about the concentration of the Sun's light related to latitude.	Solar radiation is most direct at or close to the equator and thus produces warmer temperatures. As one moves farther from the equator and closer to the poles, the sunlight is less direct. Because of the less-direct angles of sunlight the farther one is from the equator, solar radiation is less intense and therefore the average temperatures are lower.
15 min	**Synthesize and Summarize Today's Lesson:** Students compare the data from the two activities and summarize what they learned about the angle of sunlight and temperatures on Earth.	The angle of the Sun's light affects the heating of Earth's surface. When the angle of sunlight is direct, the sunlight is more intense and Earth's surface will get warmer. When sunlight strikes Earth's surface less directly—when one moves from the equator to the poles (increasing latitude)—then the Sun's light is less concentrated, and the surface does not warm as much.
3 min	**Link to Previous and Next Lessons:** Students relate the patterns from Lesson 1's bar graphs to the upcoming lesson.	Temperatures vary in the Northern and Southern Hemispheres at different times of the year.

Time	Phase of lesson and how the science content storyline develops	STeLLA strategy	Teacher talk and questions	Possible student and teacher dialogue
5 min	**Link to Previous Lesson** Synopsis: Students review the temperature patterns from Lesson 1. Main Science Idea: Temperatures on Earth are generally higher (warmer) closer to the equator and lower (cooler) toward the poles.	Highlight key science ideas and focus question throughout.	To begin today's lesson, let's review the patterns we found in temperatures around the world from our last lesson. ***NOTE TO TEACHER:*** *Refer to the summary of science ideas from the end of Lesson 1.* In your notebook, summarize your current thinking by completing these sentence frames: *Average temperatures on Earth …* *One pattern in our data that supports this is …* *An example from our data is ...* Who will share your response? Who agrees with this response, but said it a little differently or can add to it? Who disagrees with the response and will share why and what you wrote? Who has a different pattern to share? ***NOTE TO TEACHER:*** *Allow students to use the inflatable globe to describe the patterns of temperatures they observed in Lesson 1. Use this opportunity to reinforce the use of academic vocabulary, including* equator*,* latitude*,* Northern Hemisphere*, and* Southern Hemisphere.	Average temperatures on Earth are higher near the equator and lower near the poles. **What do you mean by …?** One pattern in our data that supports this is the average temperatures on the world map in January and July--both are higher near the equator and lower near the poles. **Can someone else provide another example?** **Can you point to those locations?** An example from our data is the average temperature of Nome,

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		Summarize key science ideas.	So, to summarize, one thing we observed was that average temperatures are not the same everywhere in the world, even at the same time of year. We also observed the pattern that average temperatures are higher closer to the equator and the opposite pattern that they are lower the farther you are from the equator.	AK, (near the North Pole), which is 5°F in January and 52°F in July, which are both lower than the average temperatures of Lagos, Nigeria, (near the equator)—80°F in January and 77°F in July. **Can you use the globe to show us what you mean?**
1 min	**Lesson Focus Question** Synopsis: Teacher introduces the Lesson Focus Question: *What causes the average temperatures on Earth near the equator to be higher than the average temperatures on Earth far from the equator?*	Set the purpose with a focus question.	Today we're going to find out more about the patterns we identified to answer our Lesson Focus Question: *What causes the average temperatures on Earth near the equator to be higher than the average temperatures on Earth far from the equator?* ***NOTE TO TEACHER:** Add the Lesson Focus Question to your list of Lesson Focus Questions, which are posted so you and the students can refer to them throughout the lessons.* Before we begin to think about our focus question together, please record it in your science notebook. Notice that we aren't looking for patterns like last time, but instead we're	

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			wondering why the patterns we noticed occur. What causes them? Take a minute to record any ideas you have about our focus question.	
5 min	**Setup for Activity 1** <u>Synopsis</u>: The teacher sets up an activity about the intensity of light relative to the angle at which it strikes a surface. <u>Main Science Idea</u>: The patterns seen on Earth related to varying temperatures are caused by uneven heating of Earth's surface.	Engage students in communicating in scientific ways. Make explicit links between science ideas and activities (before the activity).	Just as we will do every day in science, use the Communicating in Scientific Ways sentence stems when talking with your partner or sharing your ideas in class. Take a minute to look over numbers 2, 3, 6, 7, and 11. We're going to use a flashlight to represent the Sun and its light. We will use a tray with graph paper to represent the surface of Earth. ***NOTE TO TEACHER:*** *At this time, organize students into pairs and distribute student materials. Be explicit with the link between the model and the real world. This will help students complete the Analogy Map in the Follow-up to Activity 1. If you've used the Analogy Map before, you could invite students to use it at this time instead of afterwards.* After we finish this activity, we'll think about whether light striking a flat surface, like our tray, is similar to light striking a curved surface, like the surface of Earth. ***NOTE TO TEACHER:*** *Show students the setup with the tray and graph paper. Distribute the handout,* Energy Angles, *and review the directions for parts 1 and 2 of the activity. Invite one pair of students to demonstrate how far and*	

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		Ask questions to elicit student ideas and predictions.	*in what orientation (horizontal) they should hold the flashlight from the tray (do not turn on the light!) and remind them to talk about the discussion questions in step 4 of the first part.* ***Remind students that at this time they will complete parts 1 and 2, then stop.*** *Before they begin, elicit students' ideas about what they think will happen with the image of the light.* Will the image of the light change in any way when you tilt the tray? ***NOTE TO TEACHER:*** *Before beginning the activity, have students turn to their partner and make predictions using these sentence stems:* *I think when the tray is perpendicular or straight up and down, the image of light …* *When the tray is at an angle or tilted, the image of light ...* OK. Let's begin.	No. There will be a circle of light on the paper. The light might get bigger. **What do you mean by "bigger"?** There might be less light. **Say more about "less light." Do you mean less light from the flashlight?**
10 min	**Activity 1** <u>Synopsis</u>: Students shine a flashlight on a flat surface, first perpendicular and then at an angle. They collect and record data from their investigation.	Make explicit links between science ideas and activities (during the activity).	***NOTE TO TEACHER:*** *As students work through the activity, encourage them to use the CSW sentence stems to talk about their observations and ideas about what happens to the light energy when it strikes the surface at an angle versus directly (straight on). As partners finish counting the number of squares in their two graph paper cutouts, have them record their data on the Number of Lighted Squares data*	

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	Main Science Ideas: Earth's surface heats unevenly because the Sun's light (solar radiation and energy) hits different parts of the planet either more directly or less directly. When light hits a surface straight on (or perpendicular to it), the energy is more concentrated over a smaller area. When light hits a surface less directly (at a low angle), the energy is more spread out.		*table at the front of the classroom. (See* Ahead of Time *on page 2.)* *Have them tape their cutouts to the data table to provide a visual image to go along with their numerical data. Be sure to have students place their cutout and number of squares side-by-side in the appropriate column, so that they can easily compare across the two columns.* *These cutouts will be referred to and used in Lessons 3 and 4; therefore, have procedure for students to identify and reclaim their own cutouts.*	
35 min	**Follow-up to Activity 1** Synopsis: Students analyze their data about the angle of light on a flat surface. Then, they compare the angle of light to the curved surface of a globe. Main Science Idea: The Sun's light shines most	Engage students in using content representations and models.	We just used a model to represent and begin to understand something in our real world. Let's compare our model to the real-life happening. Please turn to your Analogy Map. ***NOTE TO TEACHER:*** *Have one set of partners come to the front of the room and show the model setup. Also, display the Analogy Map so students can follow along.* First, what are the components, or parts, of our model?	Flashlight, tray, graph paper.

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	directly near the equator so it provides more heat per unit area (square on the graph paper). When the Sun's light hits at a less-direct angle toward the poles, it is more spread out and does not provide as much heat per unit area.		Let's discuss what each component represents in the real world. Now, let's discuss the last two columns in our Analogy Map. ***NOTE TO TEACHER:*** *Guide students through this discussion, asking probe questions when necessary. The purpose of the Analogy Map is for students to clearly understand what they are modeling, what the parts of the model are, and how they relate to the actual phenomenon. With this understanding, they will be able to apply the data from their model to answer the Lesson Focus Question.*	**What does the flashlight represent?** The Sun. **What about the tray? What do others think?** Planet Earth. **What do the squares on our graph paper cutouts represent?** The part of the surface of Earth that gets the light.
		Engage students in analyzing and interpreting data and observations.	Now that we understand our model, let's talk as a whole class about our observations and the data we collected. First, let's look up here at our Number of Lighted Squares data table and our graph paper cutouts. Who can remind us of what each column represents?	The surface area covered by the light when the tray was straight on versus at an angle. **What pattern do you see between the two columns?** **What do you notice about the number of squares that are lit when the tray is straight on versus at an angle?** The pattern I see is that the at-an-angle number of squares is higher than the straight-on number.

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				What do you notice about the patterns in the cutouts? The direct light was more like a circle. **What was more circular? Can you come and point to what you mean?** **What about in the "At an angle" column? What shape are you seeing there?** That shape is more oval and looks bigger.
		Make explicit links between science ideas and activities (after the activity).	That was a great job of summarizing what you *see or observe* in the data. Now, let's talk about what it *means*. Let's remind ourselves--What does the flashlight represent in the real world? The tray? When you held the tray in the two different positions, was there any difference in the *amount* of light coming from the flashlight? Did the *amount of light* change or stay the same? ***NOTE TO TEACHER:*** *Model the use of the tray and the flashlight to help them answer these questions. Probe to help them recognize that the amount of light did not change, rather, the position of the tray, and therefore the area of the surface it covered, changed.*	The Sun. Earth. When we tilted the tray, the light was different. **Explain "different".** **Was the flashlight different? Did you hold it at a constant distance from the tray?** It wasn't as bright on the paper, so there's something different about it.

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				But, was the light from the flashlight different? The amount of light coming out of the flashlight is the same, that didn't change.
		Engage students in using content representations and models.	Look at the model up here. The amount of light coming from this flashlight (the Sun) did not change. What changed was the angle of the tray (Earth's surface). Therefore, something *did* change about the light when you tipped or tilted the tray. Think through our observations of our graph paper cutouts and what they represent. Turn to your partner and summarize what those two columns of data tell us about light striking Earth at an angle versus straight on. You have about two minutes. Who will share?	More area is hit in the at-an-angle shapes and less area is hit for the straight-on shapes. When the light shines straight on, the circle is smaller (fewer squares), and when the light shines at an angle, it shines on a bigger area (more squares).
		Highlight key science ideas and <u>focus</u>	Now, let's think more deeply about what this difference in area covered—the number of squares—means about the light energy hitting Earth's surface either directly or at an angle.	

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		question throughout.	Imagine that you are standing on Earth on one of the squares of the graph paper from the "Straight on" column and then from the "At an angle" column and the light is coming from the Sun, not from a flashlight. Write in your notebook your answers to these questions, and then we'll discuss them. ***NOTE TO TEACHER:*** *In the PowerPoint, these questions are on two consecutive slides. Display the first slide and allow time for student recording before moving to the second slide.*	
		Ask questions to elicit student ideas and predictions.	• On which piece of graph paper would you feel the most heat? Why do you think so?	It would be hotter on the small circle because there is more light in a smaller area.
			• On which piece of graph paper would you not feel as much heat? Why?	It wouldn't be as hot when the light is spread out more because the same amount of light is in a larger area. So, the oval piece would be less hot.
			• Would each square on the graph paper in the "At an angle" column have more or less light energy than the ones in the "Straight on" column?	The "At an angle" column squares have less light energy. **What evidence do you have that to indicate there is less light energy?** **Can you go to our chart and point to a specific example?**

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			• When is light energy *more* concentrated—when it shines *straight on* or when it shines *at an angle*? What is your evidence for this cause-effect relationship?	It's more concentrated when it's shining straight on because it covers fewer squares. **Do you agree with [student]? Why or why not?**
		Highlight key science ideas and <u>focus question</u> throughout.	Let's think about what we observed in our data and what it means as it relates to today's focus question, *What causes the average temperatures on Earth near the equator to be higher than the average temperatures on Earth far from the equator?* Now, instead of our flat tray, I will distribute one inflatable globe for each pair to use to represent Earth and the flashlight will still represent the Sun.	
			If we shined the flashlight horizontally toward the middle of the globe, where do you think the light will shine most directly?	The light will shine straight on at the equator—in the middle of the globe. **Do you agree with [student]? Why or why not?**
		Link science ideas to other science ideas.	Are there parts of the globe where the light will strike the surface less directly, like when you tilted the tray?	The globe isn't flat like our trays. I don't think it's the same kind of angle. **What do you mean by "the same kind of angle"?**

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				Do you agree with [student]? Why or why not?
		Select content representations and models matched to the learning goal.	Now, let's turn on the flashlights and see if our predictions are correct. Think back to your graph paper and about the shape of the light you expect to see when it shines directly onto the globe. Think about the shape of the light you expect to see when it strikes the globe at an angle. ***NOTE TO TEACHER:*** *In pairs, have students hold the flashlight horizontally about 12 inches from the globe. If necessary, students can raise and lower the flashlight to shine on different parts of the globe, but they should not tilt the light—they should keep the light pointing toward the globe and parallel to the floor. Depending on your classroom, students will be able to see the circles of light better if you dim the classroom lights. Ask for student volunteers to record on the board answers to the following questions.*	
		Make explicit links between science ideas and activities (after the activity).	What images of light do you see on the surface of the globe?	The light shines in a circle at the equator. **How does that relate to your graph paper images?**
			Where is the light more spread out?	When we moved the flashlight above or below the equator, the

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				circle got bigger. Like on our trays, the light is more spread out. **Can anyone add to [student's] ideas?** **How does your idea relate to what we did with the graph paper and flashlight?** **And, how does the area of light above and below the equator on your globe compare?**
			Where is the light most concentrated? Explain your thinking by including what we learned about the amount of light and the amount of area.	Sunlight is most concentrated when it shines straight on at the equator. It covers a smaller area of Earth. **What do others think?**
		Engage students in using content representations and models.	Those are good observations. We can see that the light shines directly at the equator and is more spread out as the light moves toward the poles. When the light is more spread out, we know from our experience with the trays and graph paper that it strikes Earth at an angle. Let me show you another model we can use to visualize the Sun's light energy hitting Earth straight on and at an angle.	

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			NOTE TO TEACHER: *Now display the slide showing the image,* The Sun's Incoming Energy—Angle Related to Latitude. Turn to part 3 of your investigation handout. Compare the model in step 1 to your flashlight-and-tray model and label the parts. Notice the straight lines along Earth by each arrow on this slid. Can you compare that to the tray-flashlight model?	Are they like our trays? **What do others think?**
		Engage students in communicating in scientific ways.	***NOTE TO TEACHER:*** *Now display the slide with the image,* Tray and Globe Example. Look at this image. Do we agree that both models are showing us the same thing, just in different ways? ***NOTE TO TEACHER:*** *Once students are clear on the similarities, again display the slide showing the image,* The Sun's Incoming Energy—Angle Related to Latitude. Now going back to our first image, what do you notice about the angle at which the Sun's energy (the solar radiation) strikes the surface of Earth a. at the equator?	I notice that it shines directly at the equator. **Come up and point to the place where you are looking.**

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			b. near the latitudes of the United States?	There's an angle. **What do you mean by "angle"? Please show us.**
			c. near the North Pole?	I see it's almost flat. **Show us what you mean by "flat."** **What is "flat"?**
			c. near the South Pole?	I see that it's the same as at the North Pole.
			Now, look carefully at the rays of the Sun—the arrows of solar radiation. Notice that the rays from the Sun are always straight on when they strike Earth's surface. However, what do you notice about the surface of Earth—is it also straight?	No, Earth's surface is curved. **Good observation. How did we represent this curve with our tray-and-flashlight model?** We tipped or slanted the tray.
			Earth's curved surface is what causes the Sun's light to strike the surface at an angle in places above and below the equator. How is this model like our flashlight-and-tray model?	The flashlight represented the Sun, and we never tipped the flashlight. The light was always straight on.

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			How is it different? ***NOTE TO TEACHER:*** *To make this diagram even more visual for students, have them place their graph paper cutouts on the globe in positions that mirror the angles shown on this content representation to see where the light would be more direct and where it would be more at an angle.* *Continue to ask questions similar to the following until you are confident that students understand what is meant by solar radiation striking Earth's surface at an angle.* ● Where would the light energy be more concentrated or less spread out? ● Where would the light be less intense and more spread out?	**Yes, that's an important point you are making. Does anyone want to add to [student's] ideas?** The tray is flat, but Earth isn't flat. I guess that's why we tipped the tray so it would hit at an angle. **Say more about why we tipped the tray. How does that help us understand what happens along Earth's curved surface?**

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			● Where do you think it would be warmer? Where would it be cooler? Why do you think so?  Listen to students' ideas. What is visible about student thinking? *The visual image from this content representation should help students in the next activity.*	
5 min	**Setup for Activity 2** Synopsis: Students examine a new content representation of the Sun's light striking Earth's surface at various latitudes.	Select content representations and models matched to the learning goal.	I'm going to give you yet another way to picture how the Sun's energy strikes Earth at different locations. ***NOTE TO TEACHER:*** *Distribute the handout,* Sun's Incoming Energy, *one for each pair of students.* Point to the Sun in this representation. Now, point to Earth. What do the lines between the Sun and Earth represent?	They show the sunlight traveling through space. The Sun's rays. Solar radiation. The Sun's energy. Light rays.

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		Link science ideas to other science ideas.	Remember the latitude lines on our *World Map Record Pages* from Lesson 1? In this next activity, you will work with your partner to count and record the number of light rays that strike Earth's surface at different latitudes. Refer to part 3 of your investigation handout for directions. Then, we will discuss how the data you collect and record relate to our focus question.	
10 min	**Activity 2** <u>Synopsis</u>: Students count and compare the rays of sunlight striking Earth at different latitudes and record their data. <u>Main Science Idea</u>: Because Earth is a sphere, sunlight hits the curved surface more directly closer to the equator and less directly as you move closer to the poles.	Select content representations and models matched to the learning goal.	How many light rays hit Earth's surface at latitudes closest to the equator? Write the number in the appropriate space on your handout. Select two more sections between latitude lines and count the number of light rays. Record the latitudes and the data on your handout. Complete as many segments of latitude as you can in the time allowed. ***NOTE TO TEACHER:*** *Display the slide showing the image from the handout,* Sun's Incoming Energy. *As pairs complete the activity, record the data on the chart Number of Light Rays per Latitude for each segment of latitude, for example, from 0° N to 15° N, from 30° S to 45° S, and so on.*	

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12 min	**Follow-up to Activity 2** <u>Synopsis</u>: Students look for patterns in their data about the concentration of the Sun's light related to latitude. <u>Main Science Idea:</u> Solar radiation is most direct at or close to the equator and thus produces warmer temperatures. As one moves farther from the equator and closer to the poles, the sunlight is less direct. Because of the less-direct angles of sunlight the farther you are from the equator, solar radiation is less intense and therefore the average temperatures are lower.	Engage students in analyzing and interpreting data and observations.	Now, let's see if we can find a pattern in our data that relates to our experience with the flashlight and graph paper. ***NOTE TO TEACHER:*** *Give students time to review the data and have them note where there are more and fewer light rays according to latitude.* First of all, can we really count the number of the Sun's rays that reach Earth? No, of course not. However, our simplified diagram of the Sun's rays helps us see that the curve of Earth changes how the sunlight hits the planet's surface and either spreads out or doesn't. ***NOTE TO TEACHER:*** *Be sure that students understand that rays cannot be counted in the real world, but the image of them can be used to illustrate how the Sun's energy heats Earth unevenly.* What pattern can you describe from this model? Consider the number of rays and latitudes.	I see that the number of light rays decreases as the latitude increases on both sides of the equator. **Does anyone have another way of saying this?** **Does anyone disagree with [student]?**

Time	Phase of lesson and how the science content storyline develops	STeLLA strategy	Teacher talk and questions	Possible student and teacher dialogue
			So based on this pattern, where is the Sun's light energy more concentrated? What is your evidence? Where is the Sun's energy more spread out? What is your evidence? STOP Listen to students' ideas. What is visible about student thinking? Notice that in our diagram the Sun's rays are evenly spaced as they come from the Sun. But, according to our data, not as many of the Sun's rays strike Earth at higher latitudes. Our data show that the Sun's energy is more spread out as we go north and south from the equator—along the curve of Earth's surface. The angle that the Sun's light hits Earth changes as we move away from the equator.	Closest to the equator because it is hit by more rays of sunlight. **Can you think of examples in your life when something is more concentrated or it is stronger or warmer or more intense?** **That's an interesting idea. How much farther do you think the Sun's rays have to travel to the poles? How do you think that compares with the distance from the Sun to Earth?**
15 min	**Synthesize and Summarize Today's Lesson** Synopsis: Students compare the data from the two activities and summarize what they learned about the	Highlight key science ideas and focus question throughout. Engage students in making	Let's revisit today's Lesson Focus Question: *What causes the average temperatures on Earth near the equator to be higher than the average temperatures on Earth far from the equator?* We used two different models today to try to figure out why the average temperature is higher closer to the equator and lower farther away from the equator.	

Time	Phase of lesson and how the science content storyline develops	STeLLA strategy	Teacher talk and questions	Possible student and teacher dialogue
	angle of sunlight and temperatures on Earth. Main Science Ideas: The angle of the Sun's light affects the heating of Earth's surface. When the angle of sunlight is direct, the sunlight is more intense and Earth's surface will get warmer. When sunlight strikes Earth's surface less directly—when we move from the equator to the poles (increasing latitude)—then the Sun's light is less concentrated and the surface does not warm as much.	connections by synthesizing and summarizing key science ideas.	Using the data from our two models, talk with your partner and come up with the best explanation for why you think the average temperature is lower as you move toward the poles. ***NOTE TO TEACHER:*** *Point to the two class data tables, Number of Lighted Squares Number of Light Rays per Latitude so students know what you mean by "using data." As student pairs discuss, move around the room to listen to student thinking. Ask questions when needed.*	It's higher closer to the equator because more sunlight hits there. The rays of sunlight are closer together or more concentrated. **Can you tell me more about that?** **How do the Sun's rays relate to how warm it is?** The data I have to support this idea is the number of lines (of sunlight) I counted was higher closer to the equator. **Is the amount of energy different if you are above or below the equator?** It's colder farther from the equator because the sunlight is more spread out so any given spot doesn't get as much energy. The data I have to support this idea is that the flashlight was dimmer when it hit at an angle. It covered bigger space, so the light was more spread out. **Where on Earth would you say was like the flashlight shining on the angled tray? Let's revisit your cutouts up here on the *Number of Lighted Squares* data table. If you were to put your two cut-out pieces of graph paper at different**

Time	Phase of lesson and how the science content storyline develops	STeLLA strategy	Teacher talk and questions	Possible student and teacher dialogue
				places on the globe, where would they go based on the amount of energy hitting them? How do their positions compare to
		Summarize key science ideas.	Now, you will capture your own thinking in your science notebook by completing the following sentences:	
		Engage students in communicating in scientific ways.	*Sunlight strikes Earth directly at …* *Therefore, the light is …* *This causes …* *My evidence is ...* *However, sunlight strikes Earth indirectly, or at an angle, at ...* *This results in the light …* *Which causes …* *My evidence is ...*	
		Engage students in using content representations and models.	In today's lesson, we used models to focus on what happens to the angle at which the Sun's light strikes our curved Earth. We used our data to explain that when sunlight directly hits Earth, the sunlight is more intense and Earth's surface will get warmer. When sunlight strikes Earth's surface at an angle—when we move from the equator to the poles—then the Sun's light is less concentrated and the surface does not warm as much.	

Time	Phase of lesson and how the science content storyline develops	STeLLA strategy	Teacher talk and questions	Possible student and teacher dialogue
		Highlight <u>key science ideas</u> and focus question throughout.	Now, let's revisit your initial response to our focus question: *What causes the average temperatures on Earth near the equator to be higher than the average temperatures on Earth far from the equator?* Please record your thinking now under your initial response and include a labeled model as part of your explanation.	
3 min	**Link to the Previous and Next Lessons** <u>Synopsis</u>: Students relate the patterns from Lesson 1's bar graphs to the upcoming lesson. <u>Main Science Idea</u>: Temperatures vary in the Northern and Southern Hemispheres at different times of the year.	Link science ideas to other science ideas. Engage students in communicating	Let's look at the temperature bar graphs from Lesson 1. What do you observe? Yes, these graphs show that average temperatures are higher closer to the equator and lower closer to the poles. Today we learned one reason why: The Sun's rays hit directly at the equator, which causes the light energy to be more intense and, therefore, the average temperatures to be higher. The sunlight hits Earth less directly, or at an angle, near the poles, causing the energy to be more spread out or less intense. Therefore, the average temperatures are lower. Check the model and response you just wrote to see if your ideas are the same. Add any edits or changes with a different color if you need to.	It's cooler farther from the equator both above and below the equator, and the temperatures are about the same going north and south of the equator.

Time	Phase of lesson and how the science content storyline develops	STeLLA strategy	Teacher talk and questions	Possible student and teacher dialogue
		in scientific ways.	Now, let's revisit our Driving Question Board. • Have we answered any questions on our Driving Question Board? • What part of the lesson helped you answer the question? What is your answer? • What new questions do you have to add? *Ask a question related to CSW 11: Let your ideas change and grow.* • Who changed their mind about something we talked about so far today? Today's learning doesn't help us explain why the Southern Hemisphere locations have their higher average temperatures at a different time of year than the Northern Hemisphere locations. Next time, we will talk about why the temperatures on our bar graphs are different in the Northern and Southern Hemispheres at different times of year.	The average temperature at the equator is higher because the sunlight is more direct. The circles compared to the ovals. **What do you mean? Can you come up to our class charts and show us an example?** **What idea changed? What helped you change your mind?**

BSCS SCIENCE LEARNING
Transforming Science Education Through Research-Driven Innovation

Lesson 2
The Sun's Effect on Climate and Seasons

1

Unit Central Question

Why are some places on Earth hotter than others at different times of the year?

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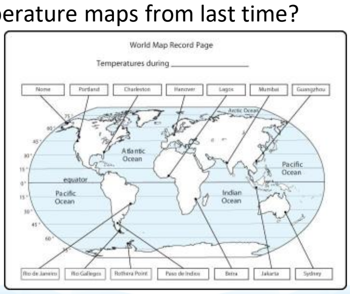
2

Link to Previous Lesson

What were some patterns we noticed in the temperature maps from last time?



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3

Lesson 2 Focus Question

What causes the average temperatures on Earth near the equator to be higher than the average temperatures on Earth far from the equator?

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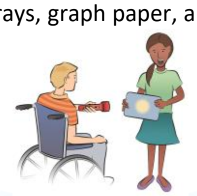
4

Investigation 1: Energy Angles

Today we will conduct an investigation to learn about angles of sunlight and Earth's surface.

We will use trays, graph paper, and flashlights.



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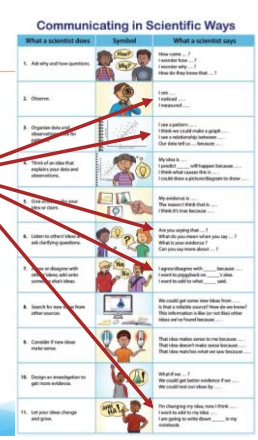
We will use these sentence starters today.



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Investigation 1: Energy Angles

Before we begin, what do you think will happen to the image of light on the graph paper if the light shines straight at the tray?

Will the image of the light change in any way when you tilt the tray?

I predict the light will / won't change because I think ________________________.

7

Analogy Map: Energy Angles Investigation

Part of the model		Part of the real world	They are alike because	They are different because
	... is/are like ...			

8

Investigation 1: Energy Angles

What pattern do you see between the two columns?

Number of Lighted Squares

Straight on	At an angle

9

Investigation 1: Energy Angles

In your science notebook, answer these questions:

- On which piece of graph paper would you feel the most heat? Why do you think so?
- On which piece of graph paper would you not feel as much heat? Why?

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Investigation 1: Energy Angles

Let's think about these questions:

- Would each square on the graph paper in Column 2 have more or less light energy than the ones in column 1?
- When is light energy *more* concentrated—when it shines straight on or when it shines at an angle? What is your evidence for this cause-effect relationship?

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Investigation 1: Energy Angles and Earth

Now, let's try it with our inflatable globes and flashlights. Think about these questions:

1) If we shined the flashlight horizontally on the globe, where do you think the light will shine most directly?
2) Are there parts of the globe where the light will strike the surface less directly, like when you tilted the tray?

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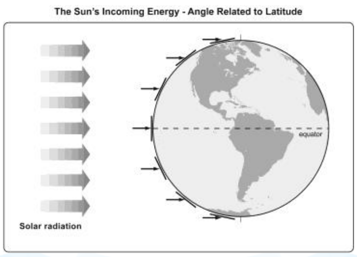
Making Connections

How does our flashlight-and-tray model relate to this model?



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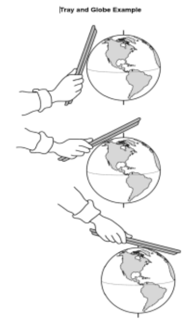
Making Connections

What similarities do you notice with this model and the previous diagram model?
What about the flashlight and tray model?



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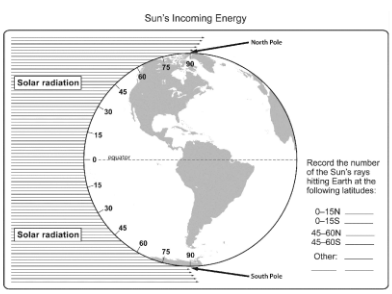
Investigation 2: Concentration of Solar Radiation



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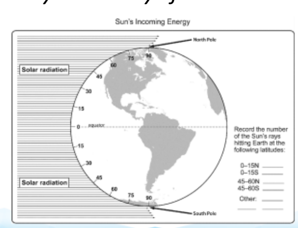
Investigation 2: Concentration of Solar Radiation

Now that you have counted the rays, let's discuss:

Can we really count rays from the Sun?



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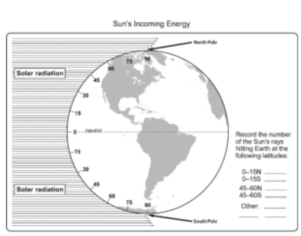
Investigation 2: Concentration of Solar Radiation

Did you find any patterns in your data?

- Where is the Sun's light energy more concentrated? What is your evidence?
- Where is the Sun's energy more spread out? What is your evidence?



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Lesson Summary: Focus Question

Let's revisit today's Lesson Focus Question:

What causes the average temperatures on Earth near the equator to be higher than the average temperatures on Earth far from the equator?

With your partner …

Come up with the best explanation for why you think it is hotter closer to the equator and cooler as you move toward the poles.

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Lesson Summary: Key Science Ideas

We focused on the angle of the Sun's light.

- We used two different models to focus on what happens to the angle at which the Sun's light strikes our curved Earth.
- We used our data to explain that when sunlight directly hits Earth, the sunlight is more intense and Earth's surface will get warmer.
- When sunlight strikes Earth's surface at an angle—when we move from the equator to the poles—then the Sun's light is less concentrated and the surface does not warm as much.

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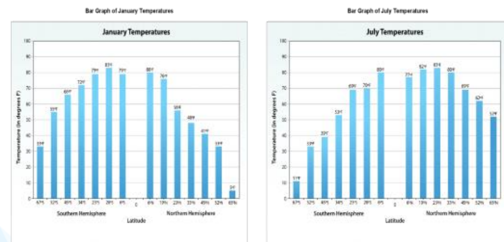
Link to Previous Lesson

Let's look back at the bar graphs from Lesson 1: What do you observe?



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Driving Question Board (DQB)

21

In the next lesson, you will think about ...

Why is it summer in the United States (Northern Hemisphere) when it is winter in Argentina (Southern Hemisphere)?

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Energy Angles

Purpose

This activity will help us answer our Unit Central Question:

- Why are some places on Earth hotter than others at different times of the year?

Team Task

Investigate the scientific question:

- What causes the average temperatures on Earth near the equator to be higher than the average temperatures on Earth far from the equator?

During the investigation, describe what happens to light when it shines on graph paper at different angles. Be prepared to share your ideas.

Materials

1 tray	1 pair of scissors
2 pieces of graph paper	tape
1 flashlight	1 pencil
1 ruler	your science notebooks

Directions

Part 1

1. Tape one piece of graph paper to the tray.
2. Decide who will hold the flashlight and who will hold the tray.
3. To investigate what happens to light that shines at different angles onto a surface, do these things:
    a. Hold the flashlight so the light is about one foot from the tray that is held by your partner. (Use your ruler to check the distance.)
    b. Point the flashlight horizontally and directly toward the graph paper. Hold the tray straight up and down, directly in front of and perpendicular to the flashlight.

c. Turn on the flashlight. Observe the shape and size of the light image and describe it to your partner.

d. Trace around the pattern of light. (The person holding the tray should trace the pattern without moving the position of the tray. Take your time!)

e. Cut out the pattern shape image and label it “straight on.” (Write the label on the back of the cutout image.)

f. Next, tape a new piece of graph paper to the tray.

g. Then, tip the tray **down** so the light shines on the graph paper at an angle or a slant. Remember to hold the flashlight horizontally about one foot from the tray at all times. (Use your ruler to check the distance.)

h. Observe the shape and size of the light image and describe it to your partner.

i. Trace the new pattern of the light. (Remember to take your time to be as accurate as possible.)

j. Cut out this pattern shape image and label it “at an angle.” (Write the label on the back of the cutout image.)

k. Now, tip the tray at different angles and observe what happens to the light. (You do not need to record these images. Just notice what happens to the light when you have less of a slant—less of an angle—and more of a slant—a greater angle.)

4. Talk about these questions with your partner.

   a. How does the image of the light on the paper change when you tip the tray?

   b. Do you observe any difference in the brightness of the light coming from the flashlight? Describe your observations.

   c. Do you observe any difference in the brightness of light hitting the surface of the paper? Describe your observations.

Part 2

1. Set the images side by side and compare them.
    a. Which image is bigger: "straight on" or "at an angle"?
    b. Which one is smaller: "straight on" or "at an angle"?
2. Now, count the number of squares on each of the images.
    a. On each image, write the number of squares that the light covered. (Do not count any partial squares, only whole squares.)
    b. Which image covers the most squares?
3. Put away all your supplies except for the two images of the light patterns on graph paper.
4. Let your teacher know that you are ready to post the images you cut from the graph paper.
5. Begin your Analogy Map to help you connect the Energy Angles activity to the real world. How is the model we used like the real world, and how is it different?

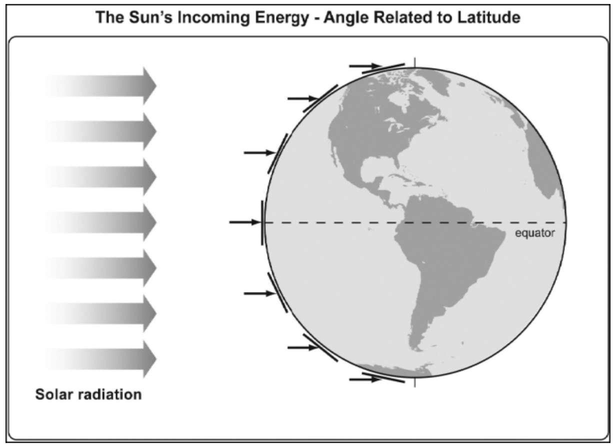
Analogy Map

Part of the model	... is/are like ...	Part of the real world	They are alike because	They are different because

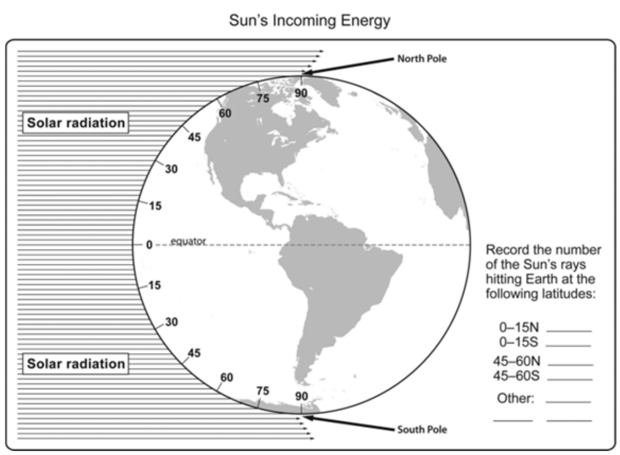
WAIT FOR INSTRUCTIONS TO GO ON TO PART 3

Part 3

1. With your partner, review the Sun's Incoming Energy—Angle Related to Latitude diagram. Use your Analogy Map to make connections between this diagram and your flashlight-tray model. On the diagram below, label the model parts.



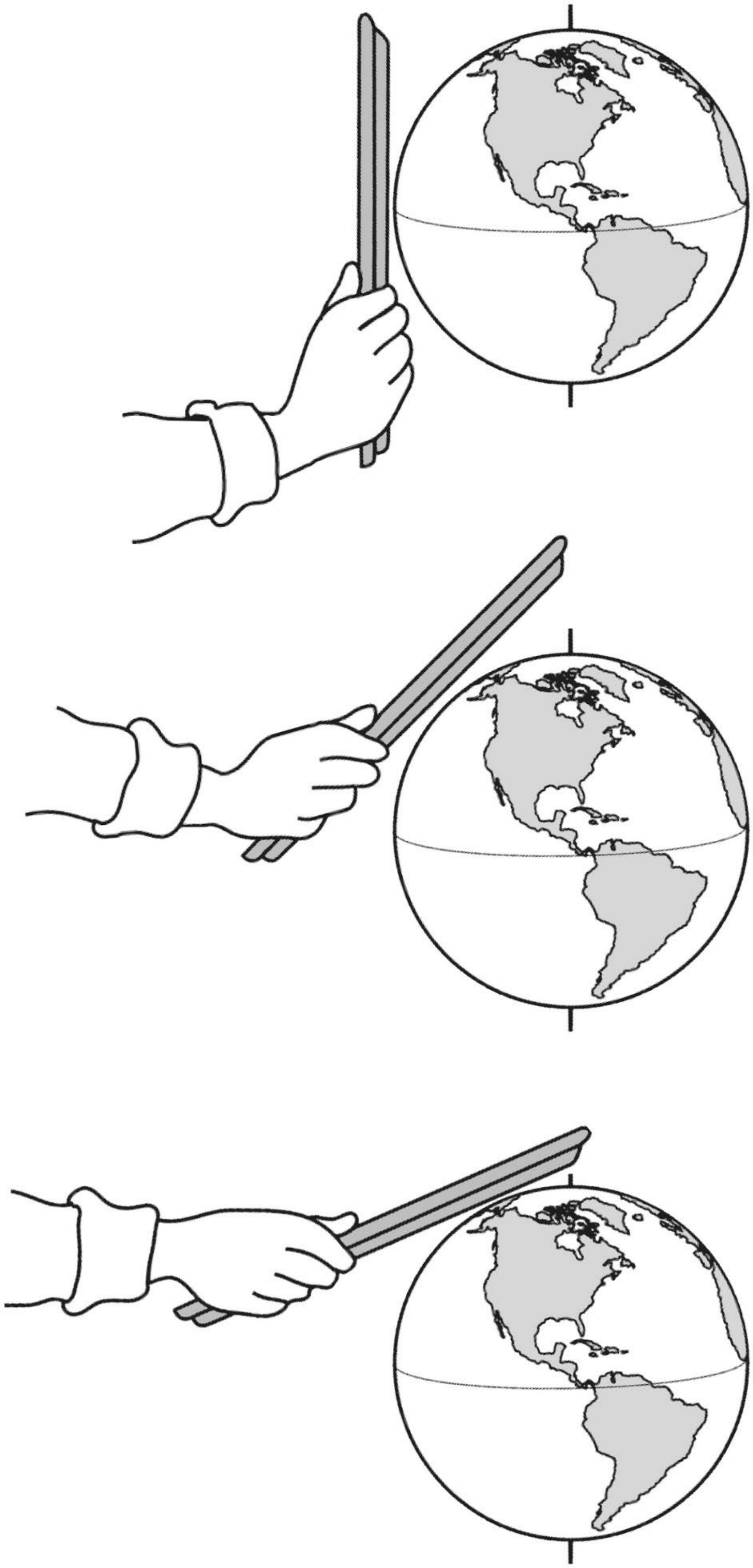
2. With your partner, review the *Sun's Incoming Energy* handout. The numbers along the edge of the diagram of Earth represent lines of latitude. The lines of latitude between the equator and the North Pole are north latitudes, and the lines of latitude between the equator and the South Pole are south latitudes.
    a. How many light rays hit Earth's surface at the latitudes closest to the equator? Write the number in the space on your handout.
    b. Count the number of light rays hitting Earth's surface at the other latitudes and record the latitude and number on the space on your handout.



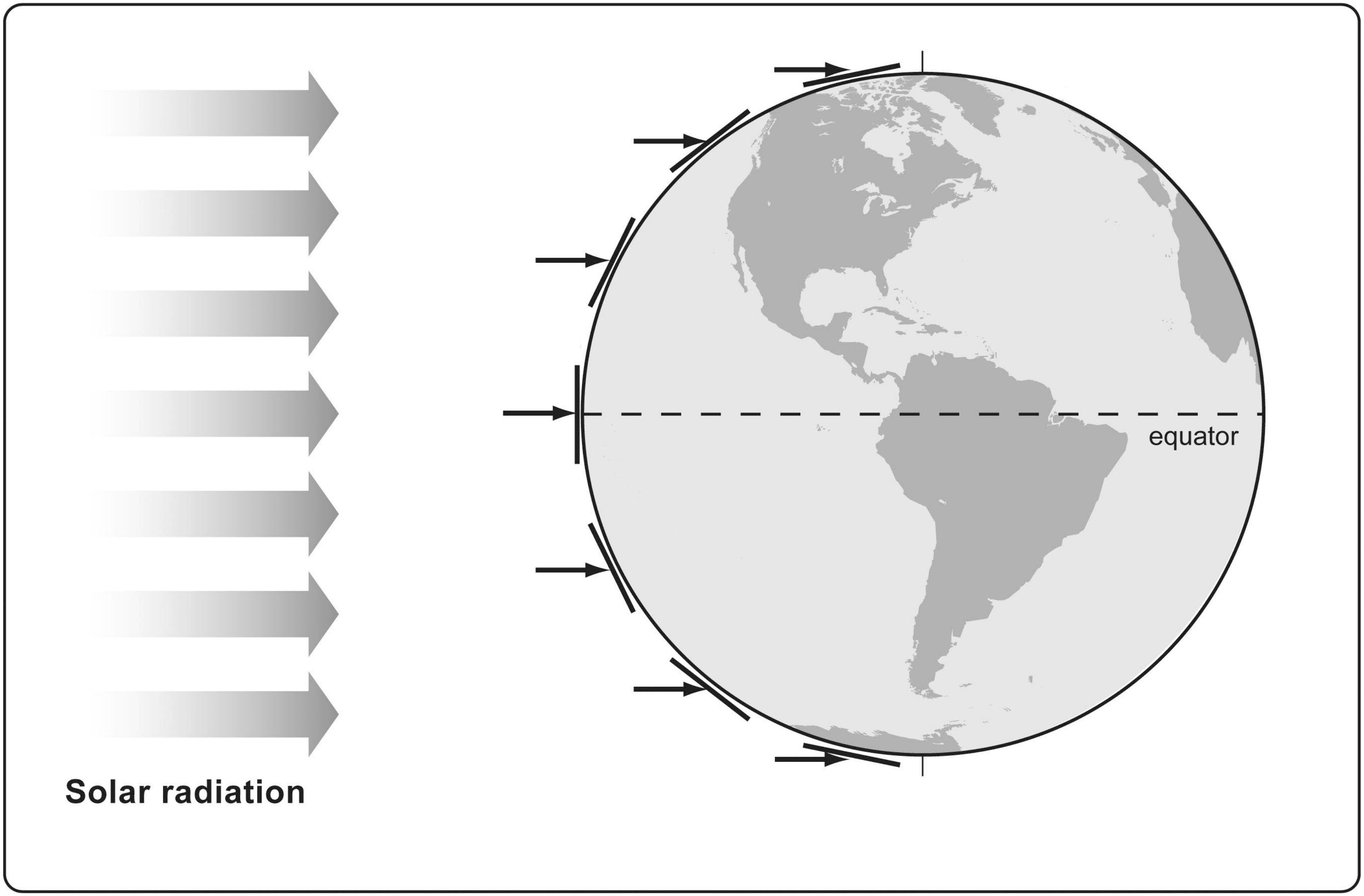
3. What pattern do you notice in the numbers you have recorded? Where on Earth is the Sun's light energy more concentrated? What is your evidence? Where on Earth is the Sun's energy more spread out? What is your evidence?
4. Think about this question: How does the number of the Sun's rays hitting Earth's surface connect to the activity you did with the flashlight? Use what you learned from these activities to answer the Lesson Focus Question: What causes the average temperatures on Earth near the equator to be higher than the average temperatures on Earth far from the equator?

Activity adapted from BSCS. (1999). *Investigating Weather Systems*. Dubuque, IA: Kendall/Hunt Publishing.

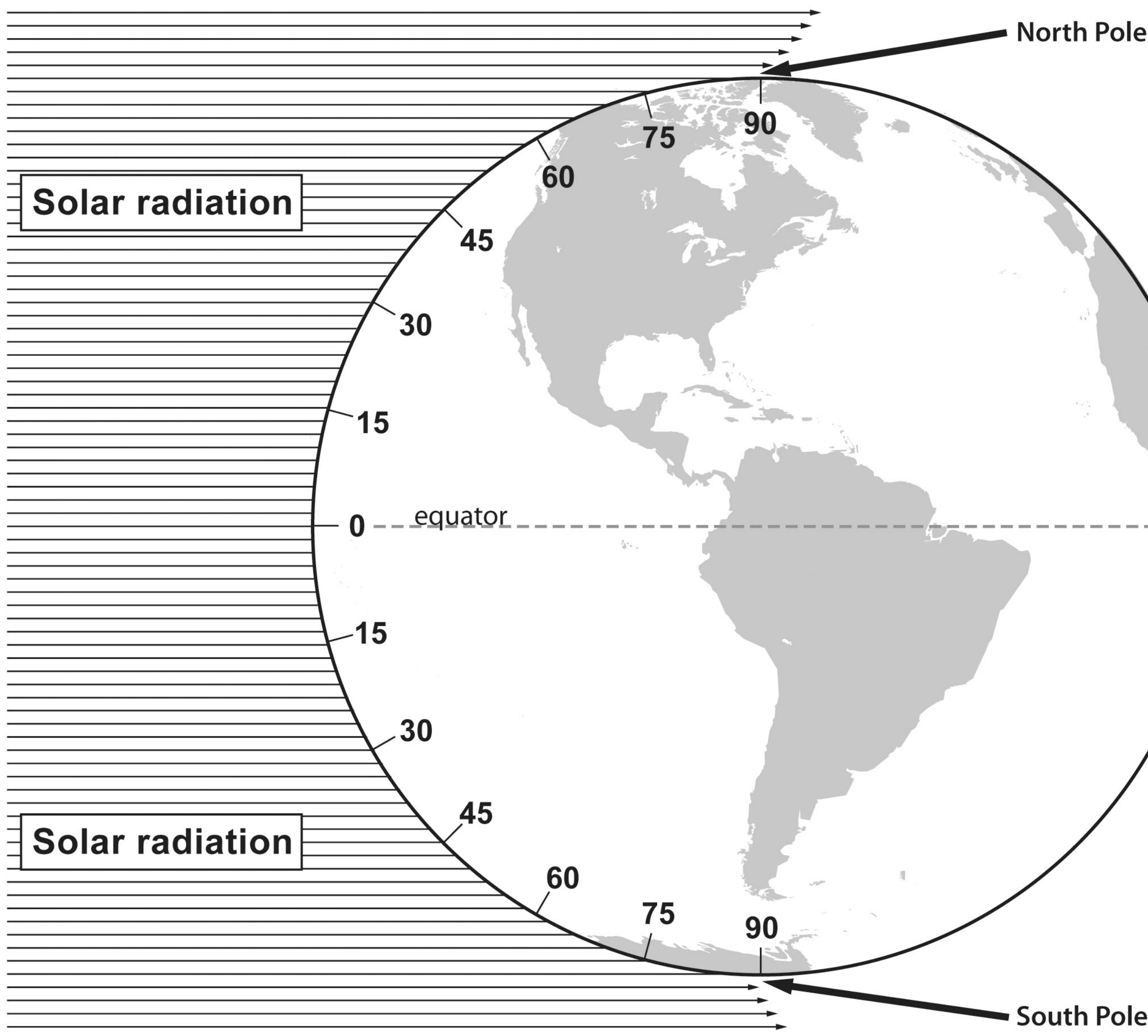
Tray and Globe Example



The Sun's Incoming Energy - Angle Related to Latitude



Sun's Incoming Energy



Record the number of the Sun's rays hitting Earth at the following latitudes:

0–15N ________
0–15S ________
45–60N ________
45–60S ________
Other: ________
________ ________

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