Worldwide Weather

Why do storms move in predictable patterns around the world?

The purpose of this learning sequence is for students to figure out why storms move the way they do, on a global scale. While the weather can change day-to-day, the investigative phenomenon anchoring this learning sequence is that prevailing winds at different latitudes move moisture in predictable patterns. Students investigate how solar radiation leads to uneven heating of the atmosphere. Students leverage existing Model Ideas from Learning Sequence 1 and new ideas about solar radiation to explain how this uneven heating causes convection on a global scale. They develop a model to explain air movement in the tropics and test their models to see if they can explain precipitation movement patterns near the equator. Students realize their current models only explain the north to south movement of winds. They read and develop understandings about how the Coriolis effect causes winds to curve, accounting for the east to west movement near the equator. Students can then predict the directions storms would travel in various locations around the world. This sequence shifts the spatial scales and focus, as students move from examining what causes storms to form over several days across a region to explaining why storms move in predictable patterns around the world.

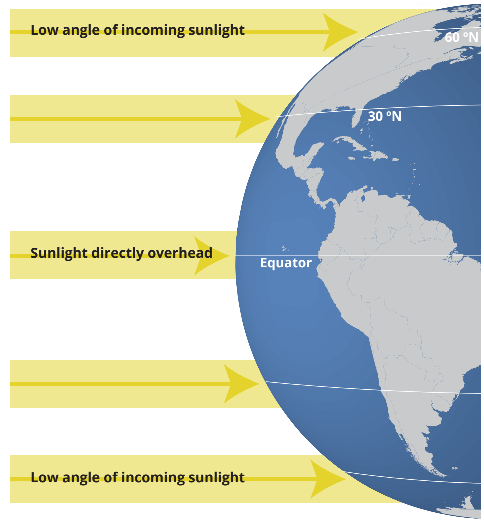
SCIENCE IDEAS

Concentrated sunlight heats the Earth more at the equator than at the poles. This causes warm, moist air to rise near the equator, creating areas of low pressure that lead to clouds and rainfall, releasing water vapor and cooling the air. This air cools more as it is forced away from the equator, sinks at 30˚N and 30˚S and is pulled toward the low pressure area at the equator to replace the rising air. This is convection on a global scale. The Earth's rotation creates three areas of circulation in each hemisphere. In the tropics, winds move across Earth's surface toward the equator—prevailing winds known as the trade winds. The Earth's rotation causes prevailing winds to curve due to the Coriolis effect. In the tropics, prevailing winds move from east to west. In the midlatitudes, they move from west to east, leading to predictable patterns of storm movement around the world.

Background Science Content

THE SUN'S ENERGY AND LATITUDE

The Sun's energy heats the Earth's surface unevenly. Latitudes at or near the equator are warmer overall than places that are far from the equator (towards the North and South Poles), which receive less sunlight per unit of area. This is because the Sun is most directly overhead and most intense near the equator and lower in the sky at higher latitudes where the same amount of energy is spread out over a larger area. As you listen to student ideas about why it is warmer near the equator, note that some students might think that temperatures are warmer near the equator because those places are "closer to Sun," and temperatures are cooler in the midlatitudes because those places are "farther from the equator and therefore farther from the Sun."



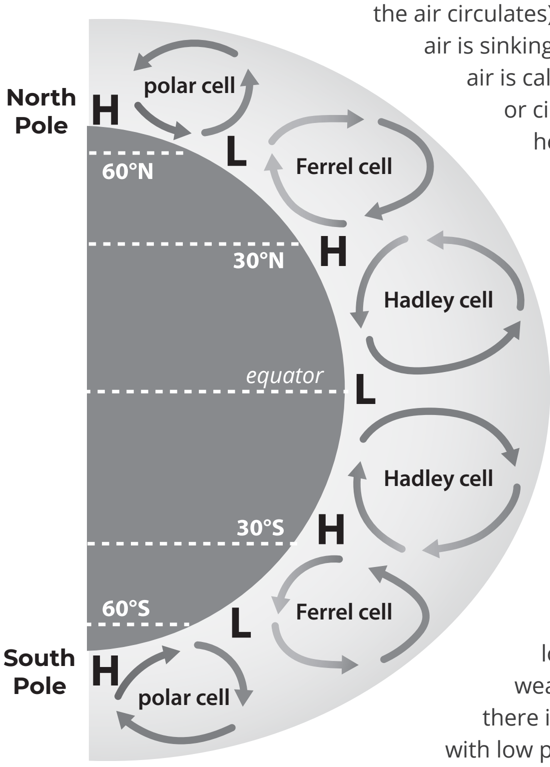
Incoming sunlight at various latitudes (Credit: SA Geography)

Additionally, locations far from the equator have strong seasonal differences in temperature, and locations at or near the equator have little or no seasonal differences in temperature (aside from that caused by storms or other weather phenomena). This occurs because Earth's axis is tilted, so a location far from the equator receives more sunlight at times of year when its hemisphere is tilted towards the Sun and less sunlight at times of year when its hemisphere is tilted away from the Sun.

These variations with latitude are explored in Lesson 13, in which students interpret data that shows general differences in temperature between Earth's poles and the equator.

GLOBAL ATMOSPHERIC CIRCULATION

While weather can change day-to-day, surface winds at different latitudes move in predictable ways. These surface winds are part of a pattern of global atmospheric circulation, which is the result of the Sun heating the Earth more at the equator than at the poles (because there are differences in air temperature around the Earth, the air circulates). In places where warm air is rising, air pressure is low. In places where cool air is sinking, air pressure is high. The systematic rising of warm air and sinking of cool air is called convection and describes the circulation of air in predictable patterns, or circulation cells, around the Earth. There are three circulation cells in each hemisphere: the Hadley cell, Ferrel cell, and polar cell as shown in the image.



The Hadley cells are located between the equator and 30° north and south of the equator. At the equator, warm, moist air rises, creating areas of low pressure that leads to clouds and rainfall, releasing water vapor as air rises to the top of the troposphere (the tropopause). The air, now cooler, is forced north and south of the equator, and it cools even more. At 30° north and south of the equator, the cooler, drier air sinks towards the ground creating high pressure. Some of the sinking air travels north forming the Ferrel cell and rises at about 60° north and south. Some of that rising air moves towards the poles then sinks as part of the polar cell.

High pressure areas are found at 30° north and south. These latitudes have stable weather (warm/dry). Many deserts are located near 30° north and south where high pressure areas are located. Low pressure areas are located at the equator and at 50°-60° north and south and have unstable weather (more clouds and precipitation). In the midlatitudes and at the equator, there is more precipitation especially along the west coast of continents associated with low pressure areas.

THE CORIOLIS EFFECT

Global atmospheric circulation is also affected by the spin of the Earth. The Earth spins from west to east on its axis. Because the Earth is widest at the equator, it rotates faster at the equator than at the poles, and surface winds (or objects) are deflected, or turned, by the Coriolis effect.

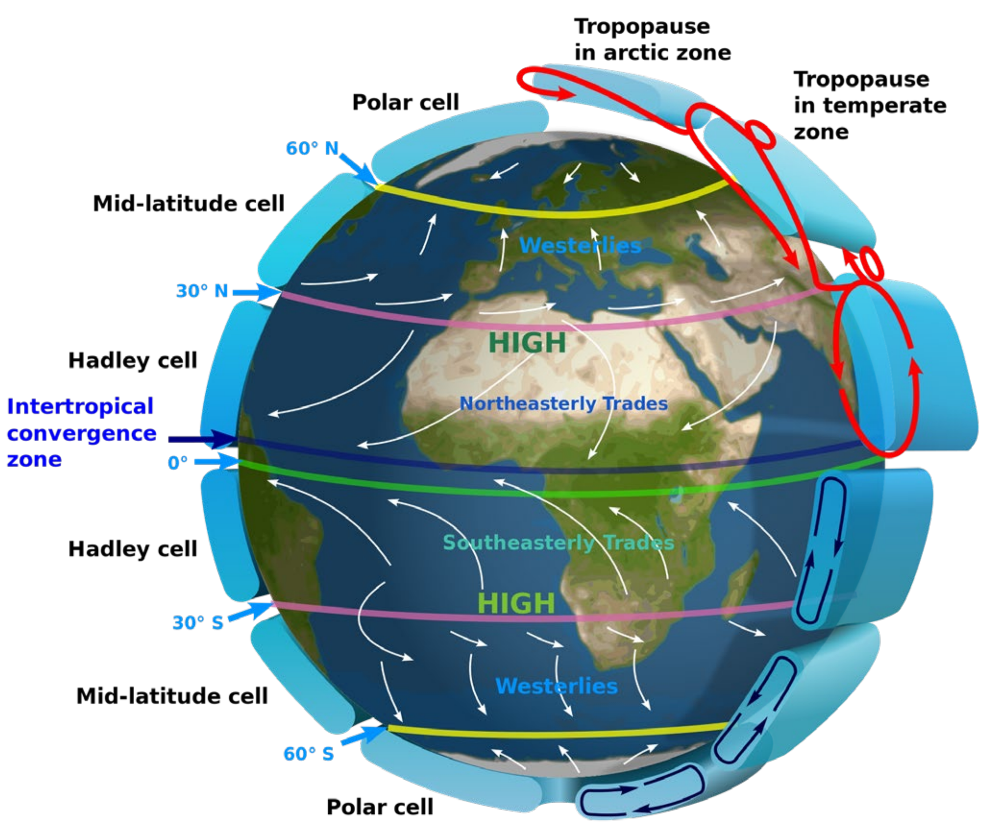
The Coriolis effect is zero at the equator and then increases in magnitude towards the poles. The Coriolis effect is the apparent acceleration of a moving body as a result of the Earth's rotation (deflecting the direction of the north-south air). If the Earth didn't spin, there would be just one large convection cell between the equator and poles. The deflecting winds split the one cell into three convection cells.

- The NOAA SciJinks website (https://scijinks.gov/coriolis/) provides an explanation about the Coriolis effect that may be helpful for students.

The Coriolis effect greatly impacts the prevailing wind direction on a global scale (see image below).

The prevailing winds at the Earth's surface, caused by convection, are deflected by Earth's rotation, causing them to curve to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. The (surface) trade winds in the tropics are associated with the Hadley cells and move towards the equator, southwest in the Northern Hemisphere and northwest in the Southern Hemisphere. In the midlatitudes, where the Ferrel cells are located, warmer surface air moving poleward is deflected east by the Coriolis effect, which leads to prevailing westerly surface winds (west to east) in both hemispheres. At the higher latitudes, where the polar cells are located, the prevailing surface winds are easterly (east to west) in both hemispheres.

In addition, on a smaller scale, air moving toward an area of low pressure and away from high pressure is also influenced by the Coriolis effect. Air moves counterclockwise around low pressure in the Northern Hemisphere and clockwise around low pressure in the Southern Hemisphere. This is why storms in the Northern Hemisphere rotate counterclockwise, while storms in the Southern Hemisphere rotate clockwise.



COMMON MISCONCEPTIONS:

The following science misconceptions were identified by *GLOBE Weather* field test teachers. Watch out for them as your students are learning about weather.

MISCONCEPTION	CORRECT EXPLANATION
It is warmer at the equator because it is closer to the Sun.	While it is true that the Earth "bulges" at the equator, there is no significant difference in the distance to the Sun, whether measuring from the equator or from the poles. The reasoning for warmer temperatures at the equator is because of the angle of the Sun; at the equator the Sun is directly overhead, providing more heat, while areas further from the equator receive less direct sunlight and thus less heat. **For more information, visit:** https://serc.carleton.edu/sp/library/guided_discovery/examples/seasons.html
Summer occurs when the Earth is closest to the Sun and winter when the Earth is farthest from the Sun.	Similar to the reasoning in the misconception above, it is not the distance between the Sun and the Earth that causes the extreme changes in latitudinal and seasonal temperatures (In fact, the Earth is closest to the Sun in January, which is winter for the Northern Hemisphere, and farthest from the Sun in July, when the Northern Hemisphere is experiencing summer). The reason for the seasons is the 23.5° tilt of the Earth on its axis, which means that each hemisphere experiences warm seasons when it is pointed more directly at the Sun and cold seasons when it is pointed away from the Sun. **For more information, visit:** https://spaceplace.nasa.gov/seasons/en/
Heat from the Earth's core is responsible for heat at the Earth's surface.	While it is true that the Earth's core and mantle are extremely hot (the source of this heat is the decaying of radioactive elements within the Earth as well as residual heat from when the Earth formed), as students discovered in Learning Sequence 1, Earth's surface temperature is a result of incoming radiation from the Sun. The amount of heat energy flowing to the surface from the Earth's interior is only about 1/10,000th of the amount of energy flow from the Sun to the Earth's surface. **For more information, visit:** https://www.skepticalscience.com/heatflow.html

LESSON 13

HEATING UP

Why is it hotter at the equator than other places on Earth?

ENGAGE · EXPLORE · EXPLAIN · ELABORATE

AT A GLANCE

ACTIVITY DESCRIPTION	MATERIALS
(90 minutes)	
Latitudinal Patterns of Temperature Have students revisit the patterns of moving air (Lesson 12) and think about how heat may be involved. Students explore patterns in average annual temperatures worldwide and notice that heat is concentrated at the equator. This leads to the question: Why is it hotter at the equator than other locations around the world?	**Lesson 13: Student Activity Sheet** LESSON 13
Energy Angles Students investigate different angles of light to think about how the surface of Earth is curved, causing incoming solar radiation to hit more directly at the equator and spread out toward the poles.	Inflatable globe Clipboard Flashlight Ruler Graph paper Colored pencils
Temperature Data Investigation Using GLOBE temperature data for five locations at different latitudes, students use what they have learned about uneven heating at different latitudes to explain the patterns in the five locations.	GLOBE Temperature and Latitude Data card sets (see pages 128-131 of this Learning Sequence)
Model Idea Tracker Students revisit their Model Ideas about uneven heating patterns on Earth and revisit the lesson question: "Why does air move in different ways around Earth?" They think about how uneven heating might help them answer part of this question.	Whiteboard, smart board, or chart paper and markers (to make the Model Idea Tracker)

LESSON 13

HEATING UP

Why is it hotter at the equator than other places on Earth?

NGSS Sensemaking

Students identify patterns in average annual temperatures worldwide and figure out the equatorial region is much warmer consistently throughout the year and the midlatitudes have, on average, generally cooler temperatures (although there is seasonal variation). Students then conduct an investigation using a model to explore the causal mechanisms for these temperature differences by latitude and figure out that they are caused by uneven heating of a spherical earth. Students apply this new understanding to explain patterns in temperature in five cities around the world. They will also use this knowledge to help explain global convection in Lesson 14.

PERFORMANCE OUTCOME

- Analyze a model to describe latitudinal variations in the concentration of sunlight and to explain variations in temperature.
- Analyze data to describe global patterns in average annual temperatures.

NGSS DIMENSIONS (GRADES 6-8)

- Use a model to generate data to test ideas about phenomena in natural systems, including those at unobservable scales.
- Analyze and interpret graphical displays of data to identify relationships.
- Construct an explanation using models or representations.
- Construct a scientific explanation based on valid and reliable evidence obtained from students' own experiments.
- Graphs, charts, and images can be used to identify patterns in data.
- Weather and climate are influenced by interactions involving sunlight. These interactions vary with latitude.

Teacher Procedures

Latitudinal Patterns of Temperature

1. **Navigate from the previous lesson.** At the end of the previous lesson, students discussed what they noticed about the movement of weather in North America and globally. Remind students that they have been thinking about how heating can cause air to move and that heating can also cause pressure differences.

   The question they are trying to answer now is:

   - *How might temperature cause air to move in different ways on a global scale?*

Storyline Link
Revisit the question posed at the end of Lesson 12 to remind students of the focus of this lesson.

2. **Ask students: "What are some ideas we have about how temperature affects air movement?"** Encourage students to use models and rules of thumb from Learning Sequences 1 and 2 as well as prior knowledge that might help them explain why air would move. Track student thinking on the board. Students will likely say something about hot or cold air (based on what they learned in Learning Sequence 1). Use this idea to link to the next step.

LESSON 13 STEP 1

3. **Show students a global map of average annual temperatures** (*Lesson 13: Step 1*). Ask students to study the map and write down patterns they notice. Then, as a whole class, ask students to share the temperature patterns they noticed. Most students will notice that it is much warmer at the equator then the poles, and there is a gradient between. They may also point out the parallel pattern between the northern and southern hemispheres.

   - **KEY PATTERN:** Temperatures are warmer at the equator and cooler at the poles.
   - **KEY PATTERN:** Temperature follows a pattern of warmer bands in the middle (and around the equator) and cooler bands toward the poles.

Patterns in Data
Students identify patterns in annual average global temperatures.

4. **Ask students: "Why is it hotter at the equator than other places on Earth?"** Give students time to think about this and write down some initial ideas below the map in *Lesson 13: Step 1* of their activity sheets. Ask students to share their thinking with the class. (Note: Students might say, "The equator is hotter because it's closer to the Sun." This is a common student misconception, which should be cleared up by the Energy Angles activity below. If students have this misconception, make sure to address it directly after the Energy Angles activity.) Tell students that in the next activity, they will use a model to explore why it's hottest at the equator.

Going Deeper
Try this additional activity to help students understand the relative size of Earth and the Sun and the distance between them: sunearthday.nasa.gov/2007/materials/solar_pizza.pdf

Energy Angles

1. **Set up the Energy Angles activity.** Tell students: "We are going to use a flashlight, clipboard, and graph paper to study what happens when sunlight strikes Earth's surface." Prior to starting, ask students to explain what the following parts of the set-up represent:

   - *What does the flashlight represent? [Sunlight]*
   - *What does the clipboard represent? [The Earth's surface]*

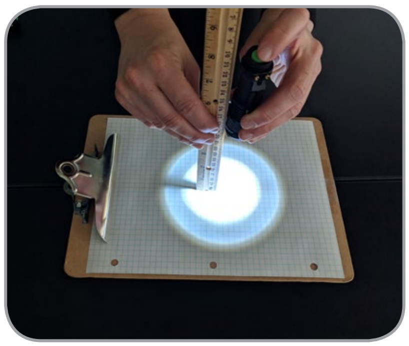
Developing & Using Models
Students use a model to think about how the Sun's incoming energy affects temperatures on Earth.

LESSON 13
STEP 2

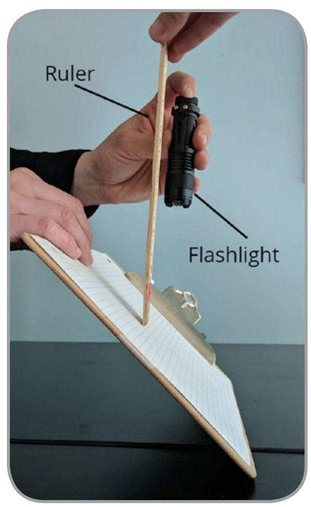
2. **Give students about 10 minutes to complete the activity.** Use *Lesson 13: Step 2* in the student activity sheet.

NOTES:

- This activity works best in groups of three: one student to hold the clipboard (the surface of the Earth), one student to hold the flashlight and ruler (the Sun), and one student to trace where the light falls on the graph paper (the recorder).
- If possible, darken your classroom or move to a room without windows.
- Students will shine their flashlights down on the paper from straight above while the clipboard is lying flat on the table and again when the clipboard is tilted at an angle (with one edge resting on the table). When creating the angled set-up, tilt the clipboard to about 45˚ or more.
- Both times the recorder will outline the area that the flashlight lights up. Consider having students use different colors and overlap the images (e.g., shine the light in approximately the same spot both times) to accentuate the differences.
- The distance between the flashlight and the paper will vary depending on how bright your flashlight is. Students will want to choose a distance that allows the entire image to fit on the paper with ample space around the borders. The investigation works best when the flashlight is fairly close to the paper, at a distance of less than 5 cm.
- It is important that the distance between the flashlight and the clipboard stay the same the whole time, but also equally important that the flashlight remain pointing straight down towards the table, even when the clipboard is titled at an angle. If it helps, point out to students that the Sun is not changing position, but rather we are changing where we are on the Earth; when the Earth's surface is flat we are at the equator, and when the Earth's surface is tilted we have moved far from the equator. Use a globe to point out hypothetical locations on the Earth where we might be "standing."



STRAIGHT ON



TILTED

To do this activity as a demonstration instead, shine a flashlight straight above onto the ceiling of a darkened room and then angled at the ceiling.

Data Analysis & Interpretation
Students analyze and interpret data from their graph paper to think about where solar radiation is more concentrated and more spread out on Earth.

Going Deeper
To collect more data, you can tilt a small photovoltaic cell that is connected to a small motor or voltmeter. Have students measure the amount of tilt and record the amount of energy.

3. **Make sense of the data.** As a whole class, ask students to share their findings from the investigation. Ask students: "When did the light cover more of the paper, straight on or tilted?" Consider asking if any of the groups counted the number of squares illuminated, and if so, which way lighted more squares. Students will notice that there were more squares lit when the clipboard was tilted.

   Use the following questions to guide a discussion to make sense of what this means:

   - *Was there any difference in the amount of light coming from the flashlight? Did it change or stay the same?"* [The amount did not change.]
   - *So what happened when you tilted the clipboard?* [The area got bigger; the light spread out.]
   - *If you were standing in one of the squares on the clipboard, within which one do you think you would feel the most heat? Why?* [Help students realize that it would be hotter in the circle where the heat is more concentrated and cooler in the circle where the heat is more spread out.]

   Now, let's think about what this means for Earth. Demonstrate shining the flashlight directly at the equator of the inflatable globe, holding the flashlight horizontally. Then, keeping the flashlight horizontal, shine the light toward the poles. If students need support relating their clipboard model to the Earth, have a student hold their clipboard at the equator (so that it is vertical) and then at a high latitude location (so that it's at an angle). Have them make connections between where the light is more concentrated (the smaller circle on the graph paper) and where the light is more spread out. (Alternatively, project the "What does this mean for Earth's surface?" slide with the image of the Earth instead of using the physical model.)

Storyline Link
Revisit where students are in Lesson 13 if this lesson is taught across multiple class periods.

LESSON 13 STEP 3

4. **Have students apply these ideas to diagrams of what this means for uneven heating on Earth.** Say: "We are going use what we just did with the flashlights and clipboards to think about what this would look like on Earth's surface." Direct them to *Lesson 13: Step 3*. Ask, "What do you notice about this image?" Students should notice that the "clipboard" from *Lesson 13: Step 2* is now placed at certain points on Earth (e.g., the slanted clipboard could be the Earth's surface at midlatitudes and the non-slanted clipboard could be the Earth's surface at the equator). Students should think about where solar radiation is more concentrated and where it is more spread out (less concentrated) as they answer the questions.

5. **What did this activity help us figure out related to our question: Why is it hotter at the equator than other places on Earth?** Ask students to summarize what they learned from the Energy Angles activity.

   Write these ideas on the Model Idea Tracker.

   - Sunlight (solar radiation) is more concentrated at the equator because incoming sunlight shines directly on the equator, concentrating it in a smaller area.
   - Sunlight (solar radiation) is more spread out toward the poles because incoming sunlight hits the surface at an angle, spreading the light out over a larger area.
   - The amount of concentrated solar radiation that warms the land influences air temperatures just above the land. More concentrated solar radiation causes higher air temperatures. More spread out solar radiation causes cooler air temperatures.

Note: This is where you can end the lesson for the first day.

Temperature Data Investigation

1. **Tell students they are going to look closer at temperature data by latitude.** If you split this lesson across two days of class time, begin day two by asking students to describe general differences in temperature between Earth's poles and the equator and why they believe there are different temperatures. Revisit the Model Idea Tracker as needed to remind students where they are in the investigation of uneven heating between the equator and the poles.

2. **Divide students into groups and preview the GLOBE Temperature and Latitude data graph cards, location cards, and maximum/minimum temperature cards to orient students to the activity.** Pass out a card set to each group. Ask students what they notice about the graphs. Students may notice the following:

   - The x-axis is time and this data was collected over several years.
   - The data in different places was not collected over the same time period.
   - Some graphs have strong shifts in temperature over seasons, and some locations have little variation.

   Tell students that GLOBE students in five locations around the world took measurements of maximum daily temperature (the warmest temperature each day) and that these are the graphs of that data. Their task is to figure out the location of the data based on what they understand about how temperatures vary by latitude. (Note: The graphs introduce seasonal shifts in temperature, which is NOT part of this unit. If you have already taught seasons in your class, this is a good place to have students make connections. If you have not taught seasons in your class, ask students to focus on the range of temperatures, focusing on where warmer and cooler temperatures are and not the seasonal shifts within the year.)

   GLOBE Locations:
   - *Juuan Lukio/Poikolan Koulu, Finland*
   - *WANAKA Field Station, Vermont, USA*
   - *Many Farms High School, Arizona, USA*
   - *Hamzah Bin Abdulmutalib Secondary School at Jeddah, Saudi Arabia*
   - *Wp/Minu/D S Senanayake College, Sri Lanka*

3. **Allow students time to match the graphs/temps/locations for each of the five locations.** Have the groups share their initial matches with another group and discuss any differences before they begin to record them on the student activity sheet.

LESSON 13 STEP 4

4. **In *Lesson 13: Step 4*, have students complete their explanations of locations based on the temperature and latitude data.** Using the clues below, students can revisit their matches and then write down their final best guesses.

   CLUE 1: Seasonal differences (fluctuations from cold to warmer temperatures) are stronger at higher latitude (further from the equator). At or near the equator, there is usually no seasonal difference in temperature.

   CLUE 2: Temperatures are warmer at low latitude (close to the equator) than at high latitude (far from the equator).

CORRECT MATCHES

Location	Graph	High/Low
Finland	B	I
Vermont	E	J
Arizona	A	H
Saudi Arabia	C	F
Sri Lanka	D	G

Data Analysis & Interpretation
Students analyze and interpret temperature data and latitude for five GLOBE locations.

Model Idea Tracker

1. **Revisit the Model Idea Tracker to summarize Model Ideas about uneven heating.** Summarize the Model Ideas from this lesson.
   - Sunlight (solar radiation) is more concentrated at the equator because incoming sunlight shines directly on the equator, concentrating it in a smaller area.
   - Sunlight (solar radiation) is more spread out toward the poles because incoming sunlight hits the surface at an angle, spreading the light out over a larger area.
   - The amount of concentrated solar radiation influences air temperatures; more concentrated solar radiation causes higher air temperatures and more spread out solar radiation causes cooler air temperatures.

   Then ask students: "So we know that Earth is heated unevenly by the Sun. Some places have more direct solar radiation; other places have more spread out solar radiation. That causes temperature differences on Earth. But how does that have anything to do with how air moves?"

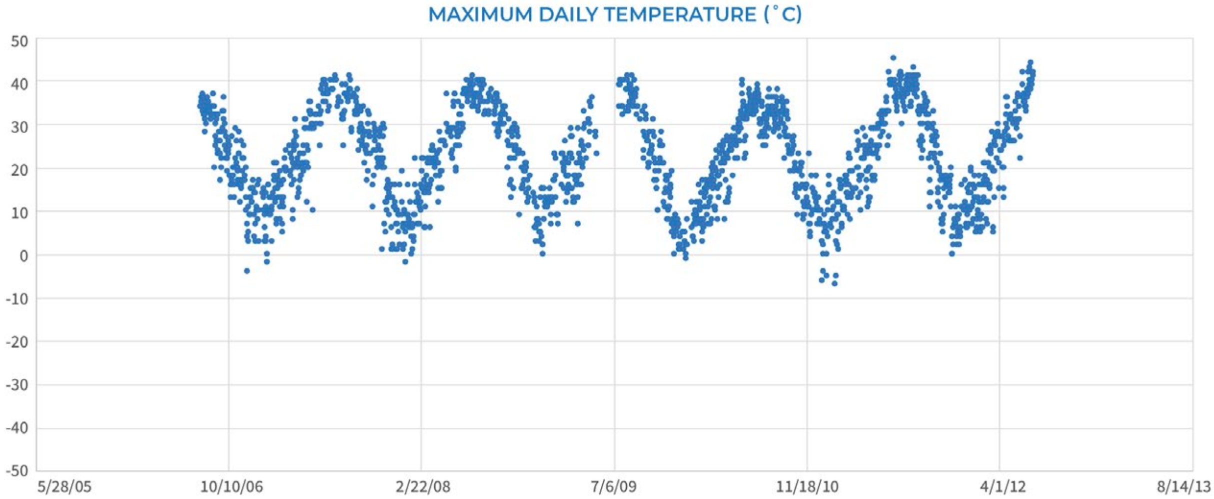
   Give students a few minutes to ponder this question. Ask if they can pull from the Model Idea Tracker, particularly as it relates to pressure differences and air temperatures. Some students may say something about different air temperatures being related to convection. Push them to explain how temperature difference might cause convection. Build on this idea by telling students that they will think about temperature differences and how they cause air to move in the next lesson.

   Tell students: "We saw different patterns of storm movement in the tropics and the midlatitudes. Next time, we'll start by thinking solely about the tropics and how uneven heating and air movement relate in that region."

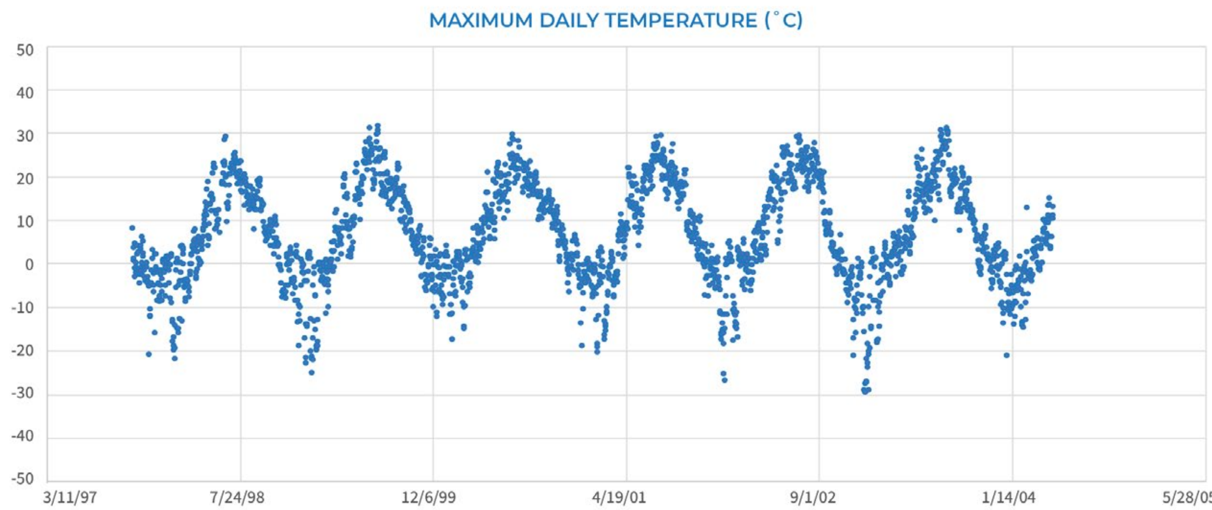
   - *How does uneven heating relate to air movement in the tropics?*

NOTE: Cut apart the graphs and maps on the following four pages for each student group. (Use the highest/lowest temperature cards if students need support to interpret graphs.)

A



B



F

lowest max temperature **24˚C**

highest max temperature **49˚C**

G

lowest max temperature **27˚C**

highest max temperature **41˚C**

H

lowest max temperature **-7˚C**

highest max temperature **44˚C**

I

lowest max temperature **-30˚C**

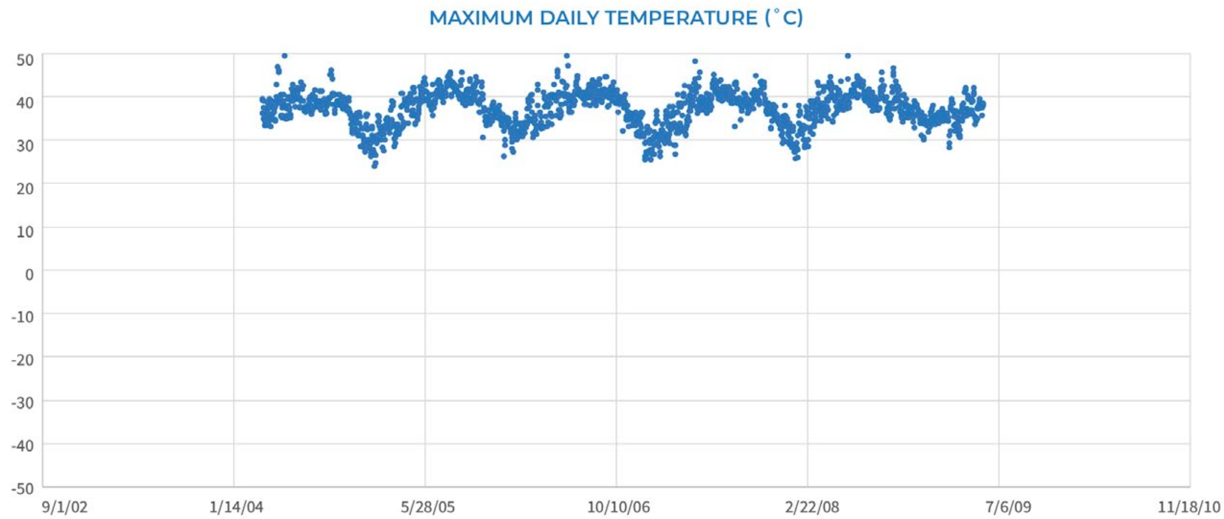
highest max temperature **30˚C**

J

lowest max temperature **-22˚C**

highest max temperature **35˚C**

C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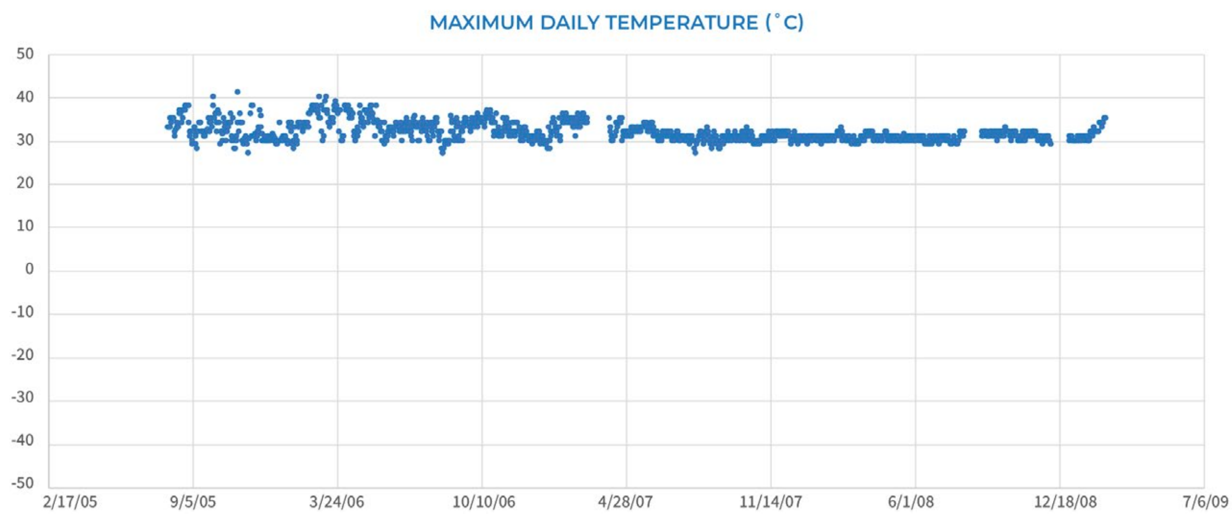
D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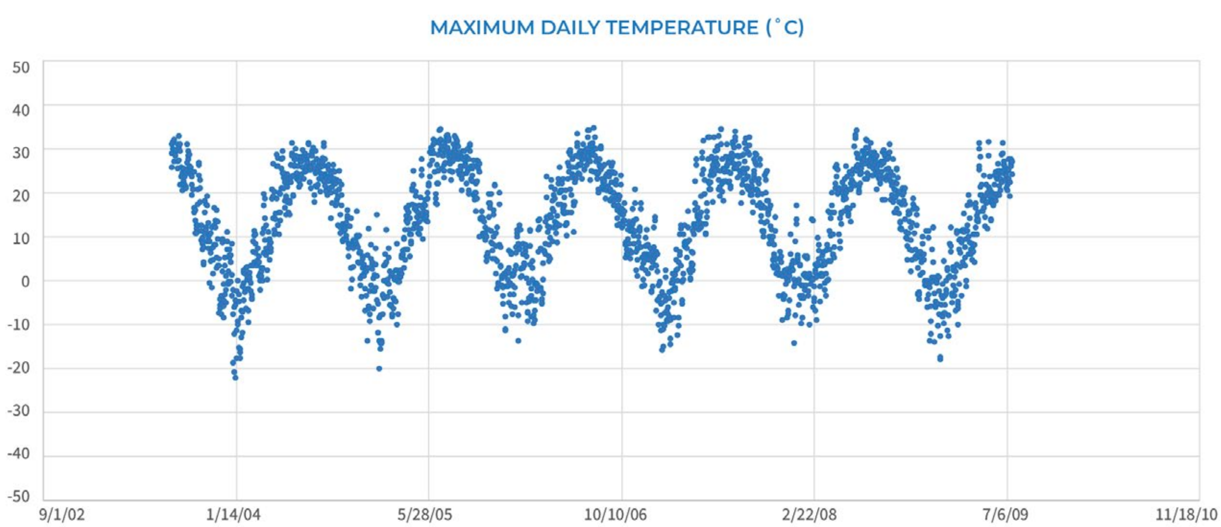
E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-40
-50
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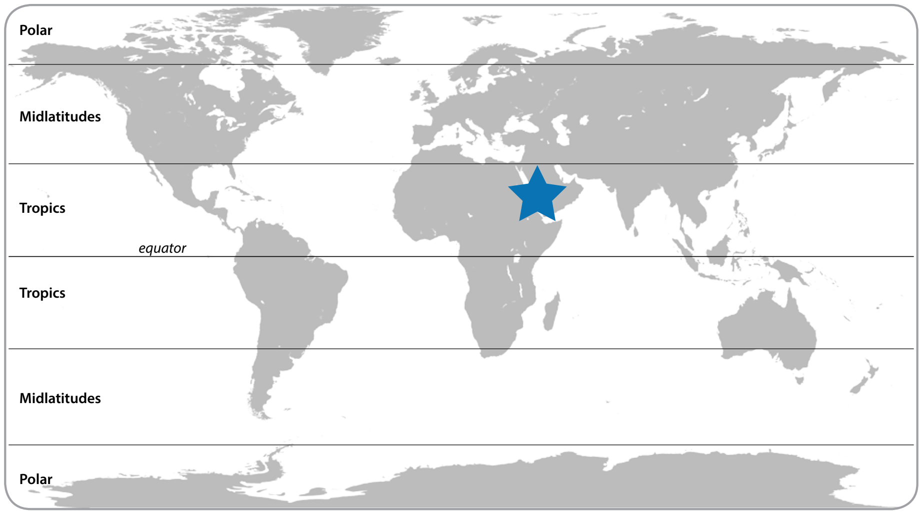
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10

Location:
Saudi Arabia

Latitude:
21.3725

Distance from the equator:
2,372 km

N

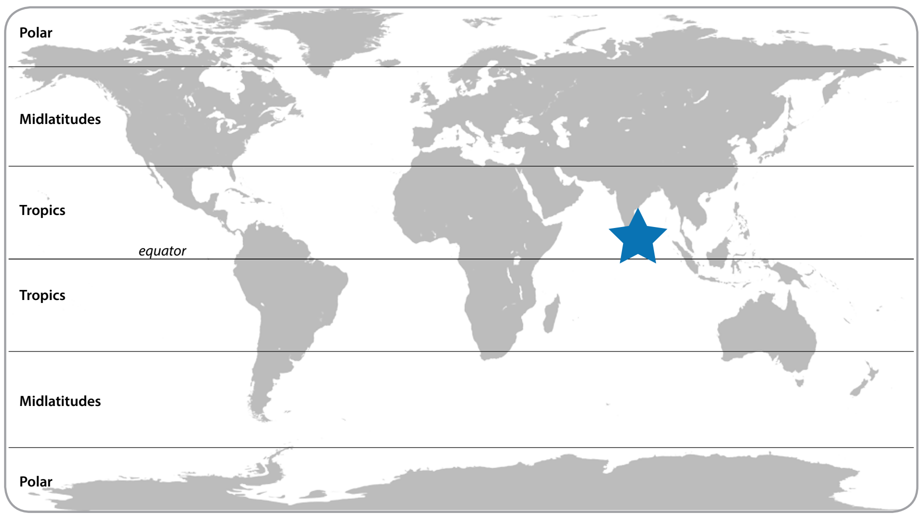


Location:
Sri Lanka

Latitude:
7.1438

Distance from the equator:
793 km

O

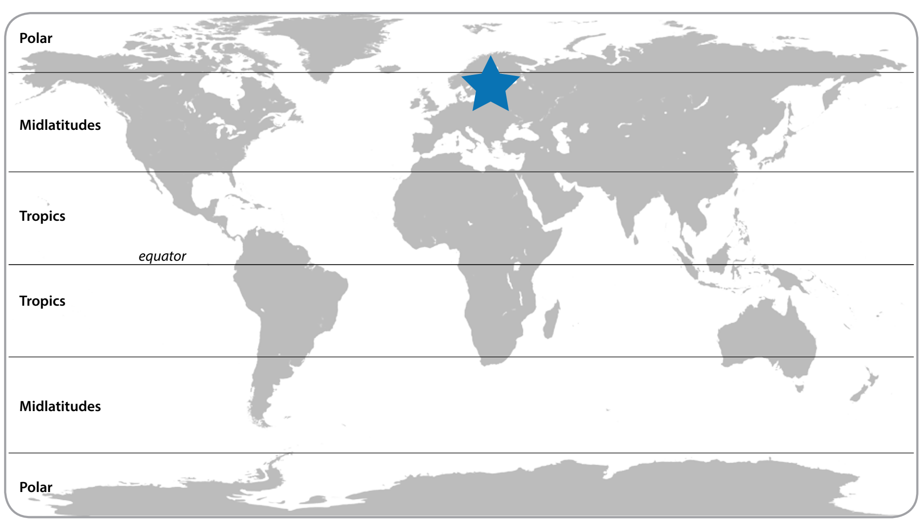


Location:
Finland

Latitude:
63.2377

Distance from the equator:
7,020 km

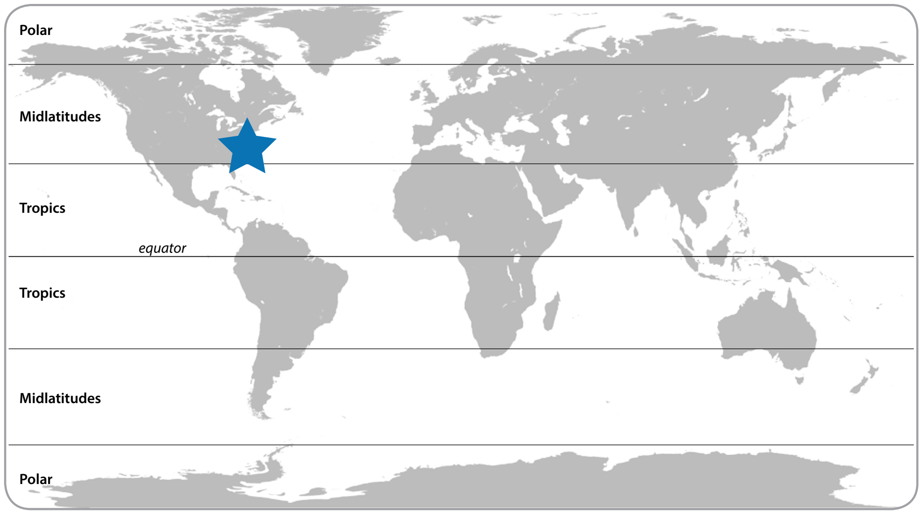
K



Location:
Vermont, US

Latitude:
44.675

Distance from the equator:
4,959 km

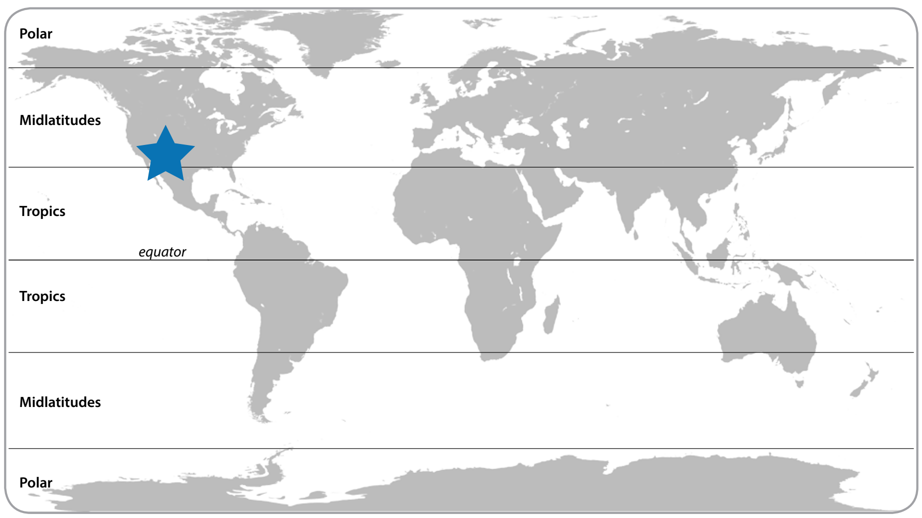


L

Location:
Arizona, US

Latitude:
36.4493

Distance from the equator:
4,046 km



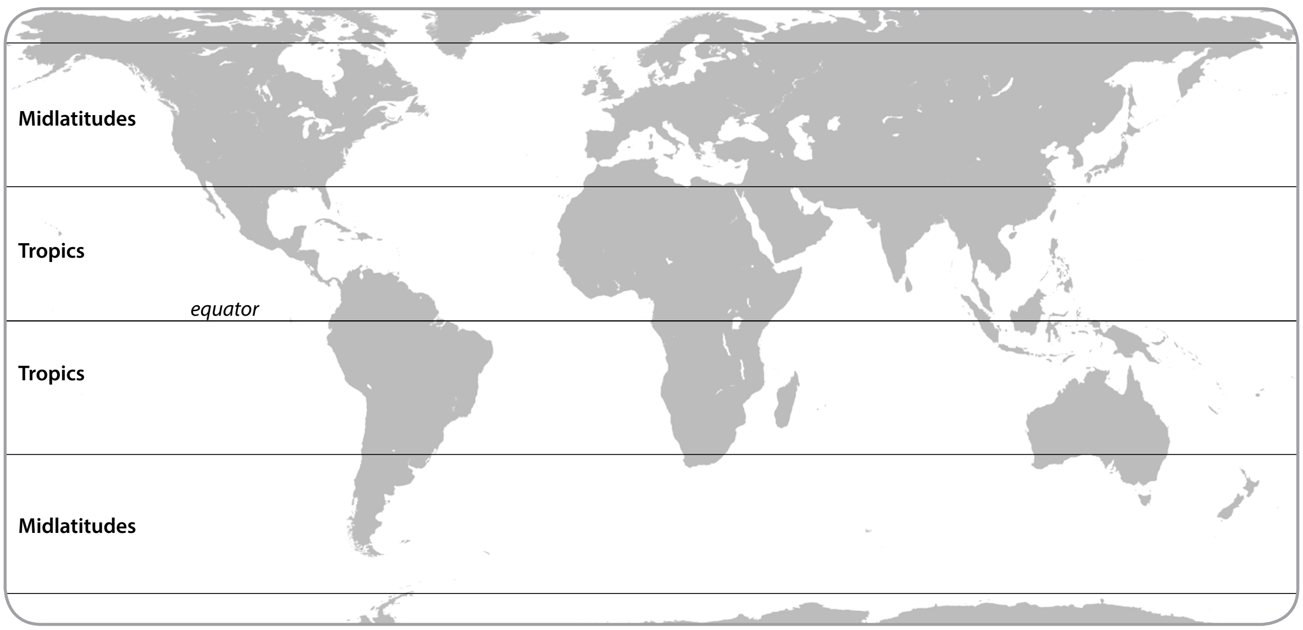
M

LESSON 13 Why is it hotter at the equator than other places on Earth?

STEP 1: Observe patterns in average annual temperatures.
Look closely at the World Average Temperatures slide.

1. Where are temperatures cooler?
2. Where are they warmer?
3. What patterns do you notice?

Draw and write your answers to the questions above on the map below.



Record your ideas about why it's hotter at the equator than other places on Earth.

Why is it hotter at the equator than other places on Earth?

STEP 2: Observe energy angles.

Work in groups of three to investigate what happens to light when it shines on graph paper at different angles. Be prepared to share your ideas.

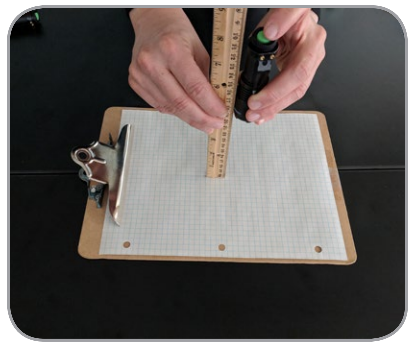
Materials: A clipboard or flat surface, flashlight, ruler, one sheet of graph paper, pencil

What does the flashlight represent in this investigation?

What does the clipboard represent in this investigation?

INSTRUCTIONS:

1. Decide who will hold the flashlight and ruler, who will hold the clipboard, and who will record.
2. Put a piece of graph paper on your clipboard and lay it flat on the table.
3. To investigate what happens to light that shines at different angles onto a surface, follow these steps:
   a. Turn on the flashlight and hold it directly above the clipboard.
   b. Adjust the distance between the flashlight and the clipboard so that the light shines entirely on the graph paper, with lots of space around the edges. Use your ruler to measure the distance. *Note: This distance will vary depending on how bright your flashlight is, but try about 4-5 cm and move closer or further away as needed.*
   c. The recorder will trace the edges of the light pattern onto the graph paper. Be sure that the flashlight is pointed straight down when you take this measurement!
   d. Label this image "straight on."
   e. Next, tip the clipboard so that the light shines on graph paper at an angle, as shown in the picture at the right. Remember to hold the flashlight the same distance from the clipboard as you did when taking the "straight on" measurement (Use your ruler!). Again, be sure that the flashlight is pointing straight down towards the table like it was when you made the "straight on" measurement.
   f. The recorder should trace the new pattern of light on the graph paper.
   g. Label the new image "tilted."
   h. Now, tip the clipboard 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) versus more of a slant (a greater angle).



STRAIGHT ON

TILTED

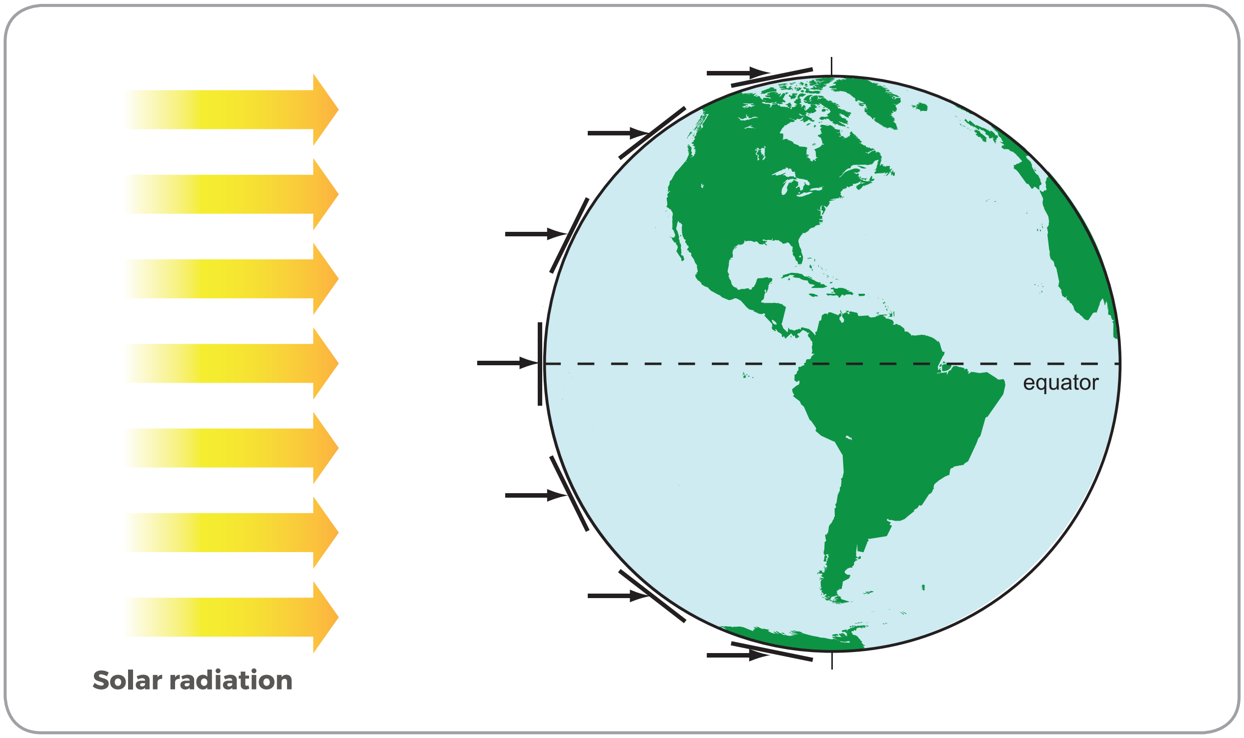
DISCUSS WITH YOUR GROUP:

- Describe how the pattern of light changes when the clipboard changes from flat to angled.
- Do you observe any difference in the brightness of the light?
- Think about the amount of light energy from the flashlight that reaches any particular square on the graph paper. How does this change when you change the angle of the clipboard?

Why is it hotter at the equator than other places on Earth?

STEP 3: Think about the Sun's incoming energy.
Use the image below to think about where solar radiation (sunlight) is more direct and where it is more spread out on Earth's surface. Then answer the questions below.

THE SUN'S INCOMING ENERGY - ANGLE RELATED TO LATITUDE



1. Which area receives more concentrated sunlight? What is your evidence?

2. Which area receives less concentrated sunlight? What is your evidence?

3. How does the concentration of sunlight affect temperatures? Which areas are hotter? Which areas are colder?

LESSON 13 Why is it hotter at the equator than other places on Earth?

STEP 4: Analyze temperature and latitude.

Your teacher will provide you with graphs of daily maximum temperature. Students at schools in Finland, Vermont (US), Arizona (US), Saudi Arabia, and Sri Lanka collected these data. Work with your group to match the graphs with the location where you think that data was collected. Use the clues below to help you decide how graphs and locations match:

CLUE 1: Seasonal differences are stronger at higher latitude (further from the equator). At or near the equator there is usually no seasonal difference in temperature.

CLUE 2: Temperatures are warmer at low latitude (close to the equator) than at high latitude (far from the equator).

	GRAPH (letter)	LOWEST MAXIMUM TEMPERATURE	HIGHEST MAXIMUM TEMPERATURE	DIFFERENCE IN TEMPERATURE (highest minus lowest)
Finland				
This is why I think Finland matches this graph:				
Vermont, US				
This is why I think Vermont matches this graph:				
Arizona, US				
This is why I think Arizona matches this graph:				
Saudi Arabia				
This is why I think Saudi Arabia matches this graph:				
Sri Lanka				
This is why I think Sri Lanka matches this graph:				