UCAR CENTER FOR SCIENCE EDUCATION

TEACHER GUIDE

TEACHER GUIDE

LEARNING SEQUENCE 3

ENGAGE	LESSON 12	**STORMS ON THE MOVE**
EXPLORE	LESSON 13	**HEATING UP**
EXPLAIN	LESSON 14	**AIR MOVEMENT IN THE TROPICS**
ELABORATE	LESSON 15	**A CURVEBALL**

BSCS SCIENCE LEARNING

NASA

THE GLOBE PROGRAM

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.

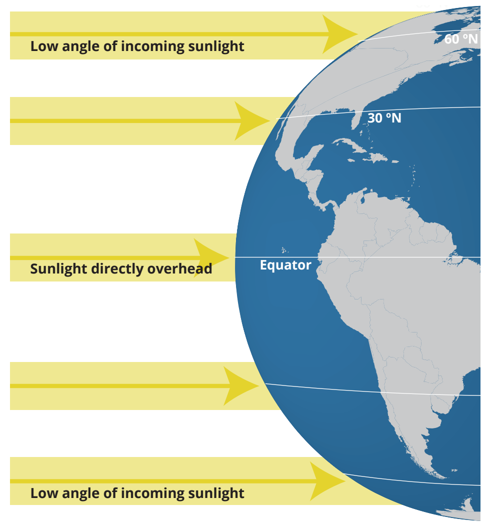
SCIENCE IDEAS

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."



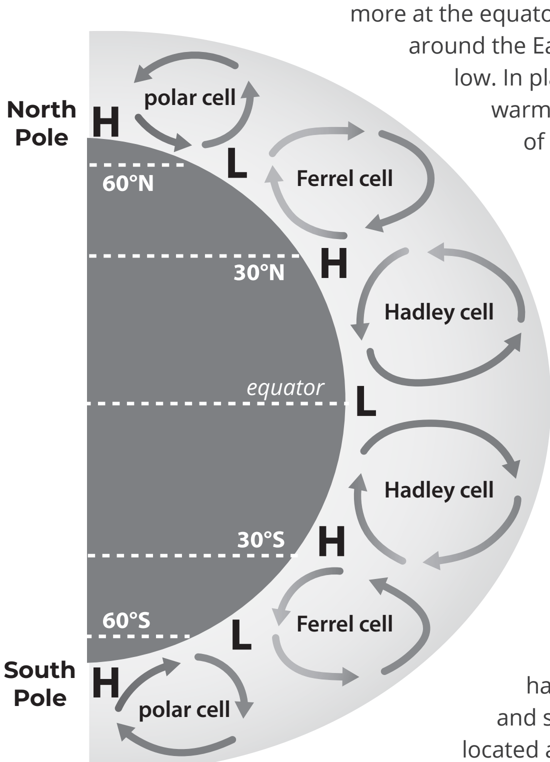
Incoming sunlight at various latitudes
(Credit: SA Geography)

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 to higher latitudes, forming the Ferrel cell, and rises at about 60° north and south latitude. 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.

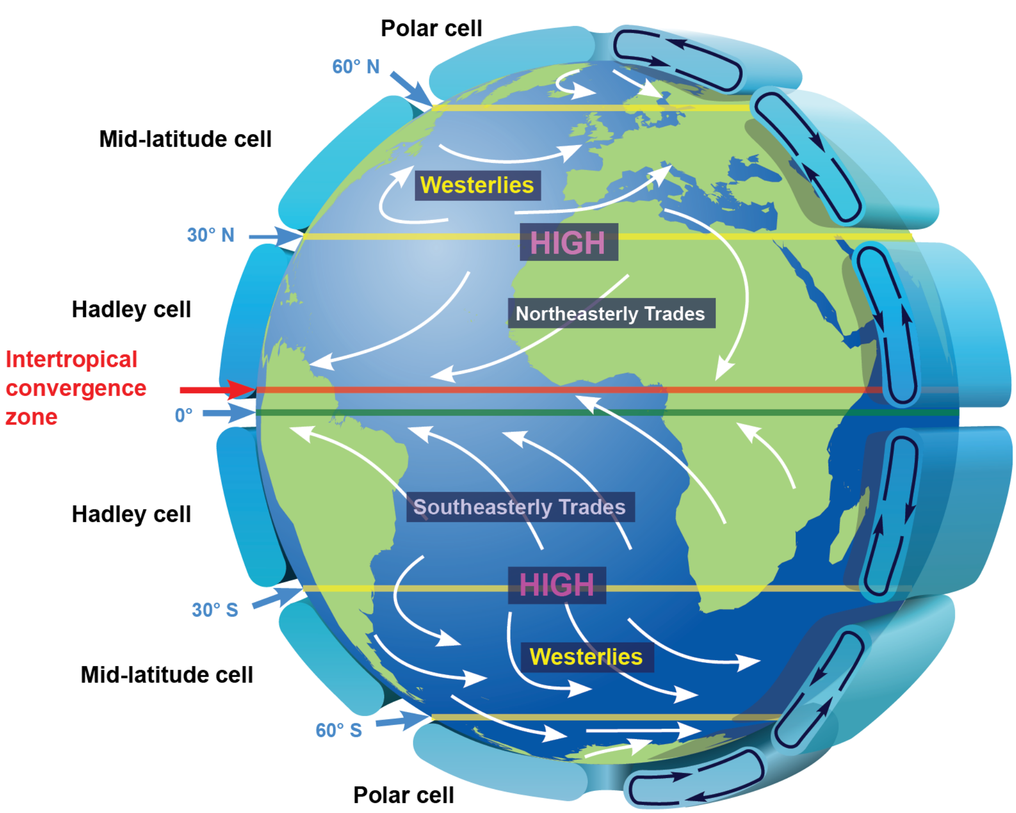
The Coriolis effect is zero at the equator and then increases in magnitude towards the poles. The Coriolis effect is the apparent acceleration of a moving body as a result of the Earth's rotation (deflecting the direction of the north-south air). If the Earth didn't spin, there would be just one large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



Credit: Kaidor
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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:** Seasons and Why the Equator is Warmer than the Poles (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:** What Causes the Seasons? (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:** Heat from the Earth's interior does not control climate (https://www.skepticalscience.com/heatflow.html)

LESSON 12

STORMS ON THE MOVE

How do storms move around the world?

ENGAGE · EXPLORE · EXPLAIN · ELABORATE

AT A GLANCE

ACTIVITY DESCRIPTION	MATERIALS
(50 minutes)	
Global Precipitation Patterns Students watch a video and record observations of precipitation movement patterns first in North America and then globally. They share observed patterns and generate questions in small groups, followed by a whole class discussion. Students add new questions to the Driving Question Board.	**Lesson 12: Student Activity Sheet** LESSON 12 North America storm movement time-lapse video NASA rainfall and snowfall video Whiteboard, smart board, or chart paper and markers (to make the Driving Question Board)
Develop Initial Explanations Students develop initial ideas to explain these patterns in global precipitation movement, drawing on prior experience and Model Ideas from Learning Sequences 1 and 2.	

LESSON 12

STORMS ON THE MOVE

How do storms move around the world?

NGSS Sensemaking

Students observe patterns of storm movement across North America and around the world to identify the phenomenon anchoring Learning Sequence 3: there are predictable patterns of precipitation movement around the world, and patterns are different in the tropics and midlatitudes. Students generate questions about what is causing these patterns. Students develop initial explanations, drawing on their understanding about how temperature and pressure cause water vapor movement from Learning Sequences 1 and 2.

PERFORMANCE OUTCOME

- Make observations to describe the large-scale motion of water in the atmosphere.
- Describe patterns of how water moves through the atmosphere around the world.

NGSS DIMENSIONS (GRADES 6-8)

- Ask questions that arise from careful observation of phenomena to seek additional information.
- Develop a model to describe unobservable mechanisms.
- Apply scientific ideas to construct an explanation for real-world phenomena.
- Images can be used to identify patterns in data.
- The complex patterns of the changes and the movement of water in the atmosphere are major determinants of local weather patterns.

Teacher Procedures

Global Precipitation Patterns

1. **Navigate from the previous lesson.** At the end of the previous lesson, students followed one storm moving across the United States. Help the class think about how that is a very long way for moisture to travel.

   Pose the questions:
   - *Where do you think the storm was a day before? Where was it two days before?*
   - *Where do you think the moisture for that storm came from?*

   Tell students that in this activity they are going to investigate the global pattern of storm movement.

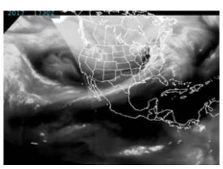
   Note: Prior experience with world maps and the global view of Earth will allow the remaining activities to go more smoothly. Introduce world maps, a globe, and/or Google Earth if needed.

Storyline Link
Continuing a discussion of storm movement is a critical link to maintain coherence as students move from Learning Sequence 2 to Learning Sequence 3.

2. **Observe storm movement patterns across North America.** Tell students that one way to identify regular patterns in storm movement is to look at weather patterns from a satellite point of view from above instead of from locations on the ground. Introduce students to the North America Storm Movement video context (see below). Tell students they will make observations from the video:
   - While students watch the video for the first time, have them make observations without taking notes. Point out a cold front over the central U.S. to connect with what students learned in Learning Sequence 2.
   - Watch the video a second time, and now have students take notes and draw the path of the storms on their student activity sheets *(Lesson 12: Step 1).* Focus students on monitoring the direction that storms travel.

LESSON 12
STEP 1

Patterns in Data
Students identify patterns in storm movement across North America.



NORTH AMERICA STORM MOVEMENT TIME-LAPSE VIDEO
Time-lapse video of storm movement across North America from March to April 2017
(https://www.youtube.com/watch?v=jC3H2k8lONU&feature=youtu.be)

In this video, the white areas are places with more water vapor (moisture) in the air, which indicates where precipitation is happening. The date appears in the upper left. Students are seeing the curvature of Earth in this video because the satellite is so far away, so due east is in the upper right and due west is in the upper left.

Two cold fronts pass though this video:
- The best option is March 6–8
- A second option is March 29–31

If students would like to see if the same pattern is visible at another time of year, have them watch: the time-lapse video from January to February:
(https://www.youtube.com/watch?v=ntC070Sh9t0&feature=youtu.be)

3. **Discuss observations as a class.** Draw out ideas around the west to east pattern across North America. Patterns students might notice are as follows:
   - Air with water vapor in it generally travels west to east across North America.
   - Air with water vapor in it travels in squiggly, curling, and/or spinning lines.
   - Certain areas have repeated patterns in cloud cover (e.g., the West Coast gets a lot of water vapor from the Pacific Ocean, and some areas, like Mexico, have a "pulsing pattern" in water vapor).

Patterns in Data
Students identify patterns in storm movement globally.

LESSON 12 STEP 2

4. **Have students think about why it's important to understand why storms move in predictable patterns.** In *Lesson 12: Step 2,* have students record ideas about why understanding storm movement patterns might be helpful to people and their communities.

   Have students share some of these ideas.

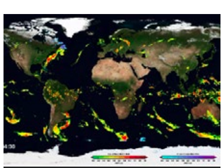
SUGGESTED PROMPTS	SAMPLE STUDENT RESPONSES
How could understanding patterns of storm movement be helpful to people and communities?	For people, it's helpful to prepare for rain (e.g., like knowing what to wear). For communities, it's helpful to know when an event is going to happen (e.g., so that people can prepare and stay safe).

5. **Consider how air moves around the world.** Ask students if they think there are similar patterns in other parts of the world and prepare them to look for that in the next video.

6. **Observe precipitation movement patterns around the world.** Introduce students to the NASA rainfall and snowfall video context (see below). Tell students they will make observations from the video. Play the video and mute the sound.
   - The first time students watch the video, have them make visual observations without taking notes. Discuss their initial observations of storm movement patterns across North America.
   - Watch the video a second time, now taking notes and drawing on the map in *Lesson 12: Step 3.* You may want to show the video multiple times or pause the video to allow for note taking.

LESSON 12 STEP 3

Storyline Link
The patterns in the NASA global rainfall and snowfall video are the phenomena anchoring Learning Sequence 3. Students will return to these patterns several times.



NASA GLOBAL RAINFALL AND SNOWFALL VIDEO
Satellite measurements of global precipitation from April to September 2014.
(https://pmm.nasa.gov/education/videos/gpms-first-global-rainfall-and-snowfall-map)

This two-minute video shows how precipitation moves globally from April to September 2014, with data collected just below the clouds. The green-yellow-red colors indicate rainfall and the blue-purple colors indicate snowfall, which students may not notice in the video. The voiceover explains how the data was collected and some patterns students might notice, so we suggest muting. The video provides a global view and zooms in on the United States (0:25), South America (0:50), and the Atlantic Ocean (1:25).

LESSON 12 STEP 4

7. **Share observations and generate questions in small groups.** Have students discuss their observations and generate questions about those observations in small groups or pairs.

Question prompts for discussion are in *Lesson 12: Step 4.*

- *What patterns do you notice about how precipitation moves around the world?*
- *What questions do you have about those patterns?*

8. **Conduct a whole class discussion.** Discuss the guiding question: *"How does precipitation move around the world in predictable patterns?"* Draw out students' ideas working toward the following key patterns:

KEY PATTERN: Precipitation near the equator moves from east to west.
KEY PATTERN: Precipitation in the midlatitudes moves from west to east.

9. **Generate questions to investigate in Learning Sequence 3.** Have students share their questions about the observed patterns. Add these questions to the Driving Question Board to reference throughout the learning sequence. Focus students on causal questions and elicit responses to the following key questions:

- *Why do storms move in predictable patterns around the world?*
- *Why do storms in the tropics move in different directions than the midlatitudes?*
- *Why do storms move from east to west near the equator in the Northern Hemisphere?*
- *Why do storms move from west to east in the midlatitudes in the Northern Hemisphere?*

Develop Initial Explanations

1. **Navigate from the previous lesson.** Tell students that they'll try to answer the following questions in Learning Sequence 3:

- *Why do storms move in predictable patterns around the world?*
- *Why do storms move in different directions in the tropics and midlatitudes?*

LESSON 12 STEP 5

2. **Form initial ideas about causes of precipitation movement patterns, based on what we already know.** Have students answer the questions in *Lesson 12: Step 5* of their student activity sheets to begin to explain what could be causing the patterns of storm movement. Pull out the Model Idea Tracker and encourage them to use what they learned from Learning Sequences 1 and 2. As students work, circulate and prompt students who are stuck:

- *What do you already know about what causes rain?*
- *What do you already know about what causes air to move?*
- *What would cause storms to move?*
- *How could the same processes affect the whole world?*

Model Ideas that might help students:

- Hot air rises as part of convection (Learning Sequence 1).
- Cool air sinks as part of convection (Learning Sequence 1).
- Air moves from areas of high to low pressure (Learning Sequence 2).

Asking Questions
Students generate questions based on observed patterns of worldwide precipitation movement.

Storyline Link
These questions set the stage for what students will investigate in Learning Sequence 3.

Storyline Link
These questions guide student investigations in Learning Sequence 3.

Cause-Effect
Students start thinking about what could be causing precipitation movement patterns.

3. **Facilitate a whole class discussion about students' initial explanations.** Have students share their initial explanations (answers to *Lesson 12: Step 5:* Question 3). Consider recording multiple and conflicting student ideas in a public place to be revised later (e.g., chart paper, PowerPoint, smart board). If students have conflicting ideas, pull out the important Model Ideas they are drawing on.

4. **Look forward to the next lesson.** Allow multiple explanations to linger. Tell students that there are a few things to investigate. In the next lesson, they'll start by investigating temperature:
   - *How might temperature cause air to move on a global scale?*

Developing Explanations
Students develop initial explanations for the observed patterns.

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** Global map of average annual temperatures (http://scied.ucar.edu/sites/default/files/media/images/annual_mean_temperature_graphic_ls3.jpg)
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 128-132 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 than 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
Solar Pizza: Size and Scale Model of the Sun-Earth System: https://sdo.gsfc.nasa.gov/assets/docs/solar_pizza_museum.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:

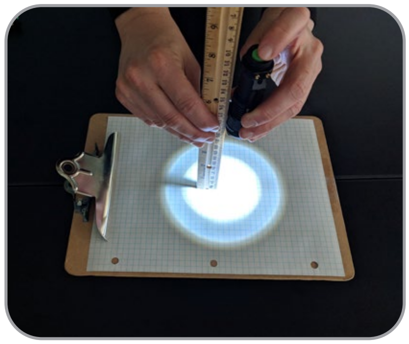
   - *What does the flashlight represent? [Sunlight]*
   - *What does the clipboard represent? [The Earth's surface]*

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

LESSON 13
STEP 2

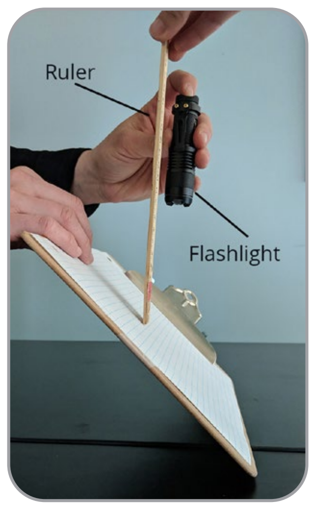
2. **Give students about 10 minutes to complete the activity.** Use *Lesson 13: Step 2* in the student activity sheet.

NOTES:



STRAIGHT ON

- 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 degrees 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.



TILTED

- 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 tilted 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."

****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 to 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?*

LESSON 14

AIR MOVEMENT IN THE TROPICS

How and why does air move in the tropics?

ENGAGE · EXPLORE · **EXPLAIN** · ELABORATE

AT A GLANCE

ACTIVITY DESCRIPTION	MATERIALS
(90 minutes)	
Develop a Working Model Students pull their ideas together from Learning Sequences 1, 2, and 3 to develop an initial model to explain how and why air moves in the atmosphere in the tropics.	**Lesson 14: Student Activity Sheet** LESSON 14 Optional: NASA rainfall and snowfall video
Convection Demonstration Students observe convection in a class demonstration. Students figure out that winds move toward the equator in global convection. Students then add these ideas to the Model Idea Tracker.	Clear tub Cold water Red and blue food coloring Two pipettes Kettle and near boiling water Five insulated cups Optional: Device for time-lapse/ slow-motion video
Global Air Circulation Diagram Students review a diagram of global air circulation and record observations, initial explanations, and questions. In a whole class discussion, students discuss how convection happens on a global scale and add additional Model Ideas to the Model Idea Tracker.	Whiteboard, smart board, or chart paper and markers (to make the Model Idea Tracker)
Consensus Model: Air Movement in the Tropics Students use the Model Idea Tracker to develop a Consensus Model for explaining how and why air moves in the tropics. Students develop models in small groups and then share their models with the class and come to consensus.	Whiteboard, smart board, or chart paper and markers (to make the Consensus Model)

LESSON 14

AIR MOVEMENT IN THE TROPICS

How and why does air move in the tropics?

NGSS Sensemaking

Students develop a model to explain how and why air moves in large-scale convection in the tropics. Students develop an initial model drawing on understandings from Learning Sequences 1, 2, and 3. Students gather evidence about how air moves in global convection from critical review of a diagram and a convection demonstration. Students revise models in small groups and develop a class Consensus Model.

PERFORMANCE OUTCOME

- Develop a model to show how air is circulating through the atmosphere in the tropics and midlatitudes.

NGSS DIMENSIONS (GRADES 6-8)

- Develop a model to describe unobservable mechanisms.
- Construct an explanation using models or representations.
- Weather and climate are influenced by interactions involving sunlight and the atmosphere. These interactions vary with latitude, which can affect atmospheric flow patterns.

Teacher Procedures

Develop a Working Model

1. **Revisit the Learning Sequence 3 phenomenon and question: Why do storms move in predictable patterns around the world?** Remind students that the class is investigating how air moves on a global scale because air movement is related to patterns in storm movement. (Optional: Show the NASA global rainfall and snowfall video from Lesson 12 to remind students of the precipitation movement pattern in the tropics.)

2. **Navigate from the previous lesson.** At the end of the previous lesson, students figured out that solar radiation causes uneven heating of Earth, which leads to air temperature differences. Students figured out that air at the equator will be warmer than air in the midlatitudes. Remind students of the next question to investigate:
   - *How does uneven heating relate to air movement in the tropics?*

3. **Prepare students to develop a Working Model.** Tell students they will develop a Working Model to explain how and why air moves in the tropics. Have students review the Model Idea Tracker to draw on ideas from lessons 1 to 13. Tell students that not all ideas will be helpful, but some might.
   - Encourage students to draw on ideas from the previous lesson about solar radiation as well as ideas from Learning Sequence 1 about how temperature relates to air movement and ideas from Learning Sequence 2 about how pressure relates to air movement.
   - Remind students that the purpose is for them to try to draw on their existing knowledge to start developing an explanation. They don't need to be certain about their models at this point.

LESSON 14 STEP 1

4. **Orient students to the illustration of the Earth's atmosphere in *Lesson 14: Step 1* of the student activity sheet.** Show the cross section of Earth's atmosphere (slide: Layers of the Atmosphere) and relate it to the illustration on their activity sheets. While the atmosphere does have four distinct layers, the illustration on their activity sheets is focusing just on the Earth's surface and the troposphere layer of the atmosphere, because this is where all weather occurs.

5. **Students record an initial Working Model.** In *Lesson 14: Step 1* of their student activity sheets, students record a model that explains how air movement in the tropics relates to latitude. Encourage students to share their working models with others as they finish.

Use the following prompts to guide students as you circulate the class:

- *Where might air be rising from Earth's surface to the atmosphere and why?*
- *Where might air be sinking from the atmosphere to Earth's surface and why?*

Storyline Link
Students remember that they're exploring air movement because precipitation is moisture in the air, and they are trying to explain patterns in global storm movement.

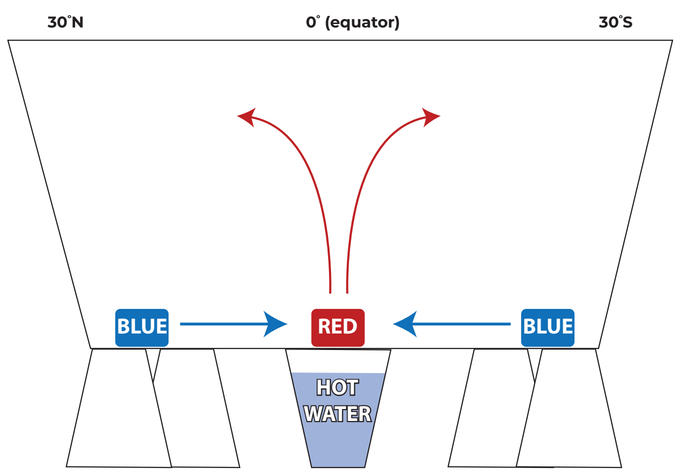
Developing & Using Models
Students draw on Model Ideas from Learning Sequences 1, 2, and 3 to develop a Working Model to explain how air moves in the tropics.

Convection Demonstration

1. **Introduce the goal of the Convection Demonstration.** Tell students that the goal of this demonstration is to help them think about how and why air moves across the Earth's surface in global convection near the equator. Students can also make observations about the rest of the convection cycle.

Storyline Link
In this activity, students think about how air would move across Earth's surface in global convection, which would cause patterns in storm movement.

CONVECTION DEMONSTRATION



MATERIALS:

- Clear tub (about the size of a shoebox)
- Cold water (enough to fill the clear tub ¾ full)
- Red and blue food coloring
- Two pipettes
- Hot water
- Device to heat water (e.g., kettle)
- Five cups of the same height (four to hold up the tub and one for hot water)

PREPARATION:

- Fill the clear tub with cold water and place the tub on top of four cups. Let the water settle. Place the tub in front of a light-colored background.

TO BE DONE WITH STUDENTS IN CLASS:

1. Heat water using a kettle and fill an insulated cup.
2. Use a pipette to carefully place a large drop of red food coloring at the bottom of the center of the tub.
3. Use a pipette to carefully place two large drops of blue food coloring at the bottom of each side of the tub.
4. Place the cup with hot water underneath the red drop of food coloring at the center of the tub.

Video showing this demonstration
(https://scied.ucar.edu/video/convection-demonstration)

LESSON 14 STEP 2

2. **Discuss what each part of the tank represents.** Orient students to the demonstration set-up and discuss what each part represents. Students can fill in the middle column ("Part of the real world") in *Lesson 14: Step 2* as you discuss.
    - The water in the tank represents air. This model uses water to simulate air because both air and water are fluids, so they behave similarly, but water can be seen.
    - The red food coloring represents air at the equator.
    - The blue food coloring represents air at 30°N and 30°S.
    - The cup full of hot water represents solar radiation.
    - The bottom of the tank represents Earth's surface.

    Have students work with a partner to fill out the third column ("Why are they alike?") of the analogy map in *Lesson 14: Step 2*. Students should come up with reasoning to explain why the analogy works (e.g., Why is red coloring a good choice to represent air at the equator?).

3. **Prepare for observations.** Students may wish to make a video or take photos. They might sketch or write about the changes. Explain that having several ways to document what is happening is a good idea because different types of data can be used together to help us understand what is happening. Have students plan how they will document what happens in the tank.

4. **Set-up the demonstration.** Explain how the demonstration will be completed. The key idea here is that students watch what is happening along the bottom of the tank, as it represents air movement, or winds, across Earth's surface. Ask students to predict what will happen when the cup of hot water is added. Put the red and blue food coloring drops at the base of the tank. Heat the water, add it to the cup, and place the cup with hot water under the red food coloring in the tank. It will take about one minute for the red dye to start rising and convection to start. The blue dots should also slowly begin to pull towards the center of the tank (towards the red dot).

LESSON 14 STEP 3

5. **Make observations.** Have students draw what they notice happening in the tank in *Lesson 14: Step 3* of their activity sheets. Students should observe that the red food coloring rises and the blue food coloring is pulled in from the sides of the tank to the middle of the tank. Have students record their ideas about what they see, why they think it is happening, and what they wonder about in the boxes below their drawings.

LESSON 14 STEP 4

6. **Relate the convection demonstration to how and why air moves in the tropics.** Orient students to the model, pointing out that we are focusing only on the convection cells near the equator. Have students develop a model in *Lesson 14: Step 4,* using their observations of the tank to describe how air is moving in the tropics (between 30°N and 30°S of the equator). Students should be able to explain why air is rising and sinking.

7. **Share observations and lead a discussion of the demonstration.** Have students explain what they observed and why it happened. Use the following questions to guide this discussion:

SUGGESTED PROMPTS	SAMPLE STUDENT RESPONSES
What happened to air at the surface of the Earth when it received direct heat?	The air near the equator heated up from the Sun and rose.
What happened to the pressure where the warm air rose?	The warm rising air caused an area of low pressure.
Why would the air move from the cool location to the warm location?	As the warm air rises, it creates an area of low pressure. Cool air moved toward the area of low pressure across the Earth. That's the wind we would feel.

Students may need support to understand why the cool air is pulled across Earth's surface toward the equator. This is a good time to remind students what they know about pressure and how air moves from high to low pressure. Students may also not realize that this horizontal movement represents winds. Have them think about what they would feel if they stood at the bottom of the tank. Remind them that the bottom of the tank represents the Earth's surface.

8. **Revisit the Model Idea Tracker to summarize Model Ideas about air movement.** Summarize the new Model Ideas from this lesson and record them on the Model Idea Tracker.

Model Ideas:

- As warm air rises at the equator, it creates an area of low pressure.
- Cooler air with higher pressure moves across Earth's surface toward the area of low pressure to replace the rising warm air.
- Horizontal movement of air across Earth's surface is wind.

Global Air Circulation Diagram

Note: Do not hand out *Lesson 14: Step 5* until students get to this point, as the previous steps involve students discovering the pattern of convection cells that is provided here.

LESSON 14 STEP 5

1. **Introduce the Global Air Circulation Diagram in *Lesson 14: Step 5*.** Orient students to this diagram and point out that it shows how air moves around the whole world, not just in the tropics.

2. **Have students create a model of air pressure and humidity.** Annotating the illustration in *Lesson 14: Step 5*, students should create a model locating the areas of low and high atmospheric pressure and the locations that are likely to be cloudy because air is rising. Use the arrows indicating air movement as clues.

3. **Lead a class discussion about the diagram.** Focus students on convection near the equator and encourage students to draw on their understanding of convection from Learning Sequence 1 and high and low pressure from Learning Sequence 2 to explain air movement in tropical convection. The one important thing for students to notice in the midlatitudes at this point is that convection moves in the opposite direction. This will be revisited in Lesson 15. Use the prompts below to guide your discussion.

Disciplinary Core Idea
Students deepen their conceptual understanding about how temperature and pressure causes air movement in convection. Students expand their understanding that convection also happens on a global scale.

SUGGESTED PROMPTS	SAMPLE STUDENT RESPONSES
Where is air rising from Earth's surface into the atmosphere and why?	Warm air is rising at the equator because there is more concentrated sunlight (solar radiation) there. Warm air is also rising at the top of the midlatitudes.
Worldwide, where is air sinking from the atmosphere to Earth's surface and why?	Cool air is sinking at 30°N and 30°S. Cool air is also sinking at the poles.
How is air moving across Earth's surface and why?	We're not sure, but the arrows are pointing toward the equator, so it looks like air is moving toward the equator.
Where do you think there are areas of high and low pressure and why?	We think there's low pressure at the equator where the warm air is rising, like the isolated storm. There's probably high pressure around 30°N and 30°S where cool air is sinking.

4. **Document new Model Ideas on the Model Idea Tracker at the end of the discussion.**

   Students figure out the following:
   - Warm air is rising at the equator because of concentrated sunlight (solar radiation), which heats air, causing it to rise. An area with rising air has low pressure.
   - Cool air is sinking at 30°N and 30°S, which is an area of high pressure.
   - Convection happens on a global scale.

5. **Ask students what we would experience on the surface of the Earth.** Have students wonder about what the air movement would be like if we were standing at the surface of the Earth near the equator. Tell students that air movement across Earth's surface is what we experience as wind. It's okay if students are not sure about this yet.
   - *If you stood just north of the equator, where would you feel winds coming from?*
   - *If you stood just south of the equator, where would you feel winds coming from?*

Consensus Model: Air Movement in the Tropics

1. **Revisit the Learning Sequence 3 phenomenon and question:** Why do storms move in predictable patterns around the world? Remind students that the class is investigating air movement patterns because precipitation is moisture in the air. Remind students that we're focusing only on air movement in the tropics for now. Review the question that the Consensus Model will help us answer:
   - *How and why does air move in the tropics?*

Assessment
Use this discussion to formatively assess student learning about global convection.

Developing & Using Models
Use the Model Idea Tracker to document new rules students figured out about air circulation in the tropics. Remember these are general rules of thumb that will be helpful for explaining global storm movement patterns.

Storyline Link
Students remember that they're exploring air movement because precipitation is moisture in the air, and they are trying to explain patterns in global storm movement.

2. **Take stock of ideas from the Model Idea Tracker that will help answer this question.** Have students nominate ideas from the Model Idea Tracker that they think will be helpful for answering this question. All of the ideas from Learning Sequence 3 will be helpful as well as some ideas from Learning Sequences 1 and 2 about warm air rising, cool air sinking, and air moving from high to low pressure.

3. **Develop a class Consensus Model.** Have small groups consider ideas from the models they created in *Lesson 14: Step 4 and Step 5* and the ideas from the Model Idea Tracker. Have each group present which ideas they propose including in the Consensus Model. As small groups present, have students discuss if they agree or disagree with the ideas in each groups' model. Come to consensus about what should be in the model and document a Consensus Model in a public space that reflects agreed upon ideas.

KEY MODEL IDEAS THAT SHOULD BE REPRESENTED IN THE CONSENSUS MODEL

- As warm air rises at the equator, it creates an area of low pressure.
- 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 warmer air temperatures and more spread out solar radiation causes cooler air temperatures.
- There are more areas where warm air is rising near the equator and more areas where cool air is sinking at 30°N and 30°S.
- Cooler air moves along the surface of the Earth toward the area of low pressure to replace the rising warm air.
- Horizontal movement of air along the surface of the Earth is wind, which causes storms to move.

Developing & Using Models
Students use ideas from the Model Idea Tracker to develop a class Consensus Model to explain how and why air moves in the tropics. As students work in groups, they do not need to agree on all parts of the model. They contribute questions to the Consensus Model discussion. Have the Model Idea Tracker and evidence from previous activities ready to revisit during the consensus discussion to help resolve disagreements.

Assessment
Students' small group models may serve as tools for formative assessment.

LESSON 15

A CURVEBALL

When air and storms move, why do they curve?

ENGAGE · EXPLORE · EXPLAIN · **ELABORATE**

AT A GLANCE

ACTIVITY DESCRIPTION	MATERIALS
(55 minutes)	
Use the Consensus Model Students use the Consensus Model to predict how air moves across Earth's surface in the tropics. Students review observed storm movement patterns in the tropics and realize that the model doesn't explain why precipitation at the equator moves from east to west.	**Lesson 15: Student Activity Sheet** LESSON 15
Coriolis Effect Reading Students gather evidence from an article that explains the Coriolis effect and how Earth's rotation causes air to curve. Students discuss the Coriolis effect in a whole class discussion and add new ideas to the Model Idea Tracker.	Round balloons, markers
Explaining Storm Movement Students use their global air circulation models and new ideas about the Coriolis effect to explain where precipitation would travel in the Philippines and where they live.	

LESSON 15

A CURVEBALL

When air and storms move, why do they curve?

NGSS Sensemaking

Students use the Consensus Model to explain precipitation movement patterns near the equator and realize their model does not account fully for the phenomenon. Students critically read a scientific text to gather information about how the rotation of Earth causes winds to curve, the Coriolis effect. Students use their Consensus Model and new ideas about the Coriolis effect to explain patterns of storm movement in two new locations.

PERFORMANCE OUTCOME

- Use knowledge of surface wind patterns to make a prediction about the movement of a storm.

NGSS DIMENSIONS (GRADES 6-8)

- Use a model to predict phenomena.
- Evaluate limitations of a model for a proposed tool.
- Critically read scientific texts adapted for classroom use to obtain scientific information to describe evidence about the natural world.
- Weather and climate are influenced by interactions involving sunlight and the atmosphere. These interactions vary with latitude, which can affect atmospheric flow patterns.
- Phenomena may have more than one cause.

NGSS DIMENSIONS (GRADES 3-5) (REINFORCING)

- Patterns of change can be used to make predictions.

Teacher Procedures

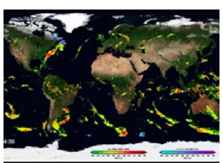
Use the Consensus Model

1. **Navigate from the previous lesson.** Remind students that they just developed a Consensus Model to explain air movement in the tropics. Remind students of the Learning Sequence 3 question and how it connects to air movement.
   - *Why do storms move in predictable patterns around the world?*

2. **Use the model to predict how storms move in the tropics.** Have students use their Air Movement in the Tropics Consensus Model to predict how air or wind moves across Earth's surface in the tropics. Orient students to where storms would occur in their model (at the bottom of the atmosphere). Students should deduce that, because of convection, storms would move towards the equator in the tropics.
   - *Based on what you know about air movement in the tropics, predict storm movement in the tropics.*

LESSON 15 STEP 1

3. **Compare predictions to observed storm movement patterns.** Re-watch the NASA global rainfall and snowfall video from Lesson 12: Step 3 and focus students on storm movement in the tropics. After watching the video, students record the answer to the question below in *Lesson 15: Step 1* of their student activity sheets. Students should notice very obvious patterns of storms moving from east to west that our model doesn't explain.
   - *What kind of movement do you see that isn't explained by the model for air movement in the tropics that you made at the end of Lesson 14?*



NASA Global Rainfall and Snowfall Video
(https://pmm.nasa.gov/education/videos/gpms-first-global-rainfall-and-snowfall-map)

The video shows how precipitation moves globally from April to September 2014, with data collected just below the clouds. The green-yellow-red colors indicate rainfall and the blue-purple colors indicate snowfall, which students may not notice in the video. The voiceover explains how the data was collected and some patterns students might notice, so we suggest muting. The video provides a global view and zooms in on the United States (0:25), South America (0:50), and the Atlantic Ocean (1:25).

4. **Discuss the limitations of the model.** Remind students that all models need to be revised and tested and revised again. This model is not yet helping us fully explain observed patterns of precipitation movement at the equator, nor is it addressing questions about precipitation movement generated in Lesson 12 that are on the Driving Question Board:
   - *Why does precipitation move from east to west near the equator?*
   - *Why does precipitation move from west to east in the midlatitudes?*
   - *Why does precipitation move in different directions in the tropics and midlatitudes?*

Storyline Link
Students review the phenomenon and remember that they're exploring air movement because precipitation is moisture in the air, and they are trying to explain patterns in global storm movement.

Developing & Using Models
Students realize the limitations of their model and that their model does not yet fully help them explain the observed phenomenon.

CORIOLIS EFFECT READING

1. **Navigate from the previous activity.** Tell students that the model they developed explains the north-south aspect of storm movement in the tropics but not the east-west movement.

LESSON 15 STEP 2

2. **Read the first paragraph in *Lesson 15: Step 2* about the Coriolis effect.** Read this aloud with your students to introduce the new idea that the spinning of the Earth deflects winds.

3. **Observe the Coriolis effect with a quick activity:** Provide pairs of students with a round balloon and marker. Instruct students to inflate the balloon and draw an equator around the widest point in the center of the balloon. Also draw on the balloon "about" where the 30˚N latitude and 30˚S latitude lines would be. Tell students that this is a simple model of the Earth. Have one student hold the balloon at chest height (they should be able to look down at the top of the balloon) while the other draws an arrow starting at 30˚N going toward the equator. Then have the student holding the balloon slowly rotate it counterclockwise (to model the Earth spinning on its axis) as their partner draws another arrow, starting again from the same point on their balloon. Students should notice that when their model of Earth was turning, the arrow curved, but when their model wasn't spinning, it did not.

4. **Finish Reading about the Coriolis effect in *Lesson 15: Step 2.*** Set the purpose of reading an article as a method to help students gather evidence to explain the east-west storm movement they observed in the video as well as additional evidence to explain the west-east storm movement in the midlatitudes. Students can read individually or as a whole group. Prompt students to *Stop and Think* as they encounter questions in the text. These questions are to help students make connections between the information they read and their previous observations.

5. **Discuss the Coriolis effect.** Lead a whole class discussion about the Coriolis effect. The big ideas students should walk away with are that the winds do move north and south, caused by convection, and they also move east and west, caused by the Earth's rotation.

   The unit thus far focused on explaining the north-south movement of air in tropical convection. Students may struggle to see how air moves across Earth's surface toward the poles in midlatitude convection. You can help students see that convection in the midlatitudes travels in the opposite direction.

SUGGESTED PROMPTS	SAMPLE STUDENT RESPONSES
Why does the air in the tropics curve east to west?	The Earth rotates so air that was moving toward the equator curves and moves to the west.
How does air move across Earth's surface in midlatitude convection?	Air moves toward the poles. This is the opposite direction as in the tropics.
Why does the air in the midlatitudes move west to east?	The Earth rotates so air that was moving towards the poles curves and moves to the east.

Storyline Link
Students are motivated to gather more evidence to explain the phenomenon.

Literacy Connection
Students read non-fiction texts and are prompted to make connections and to synthesize ideas.

Going Deeper
Have students blow up a balloon and use a marker to draw an equator. Make the knot the South Pole and the top of the balloon the North Pole. Have one partner rotate the balloon left to right, simulating Earth's rotation, while the other partner slowly tries to draw a straight line from the North Pole to the equator. Next, the partner with the marker will draw a straight line from the South Pole to the equator. Students see how the movement "curves" in opposite directions in the northern and southern hemispheres.

6. **Add new ideas to the Model Idea Tracker.** Summarize the new model ideas developed out of this discussion and add them to the Model Idea Tracker.

Model Ideas

- In the tropics, air moves across Earth's surface towards the equator due to convection.
- In the tropics, air moves across Earth's surface east to west due to the Earth's rotation.
- In the midlatitudes, air moves across Earth's surface toward the poles due to convection.
- In the midlatitudes, air moves across Earth's surface west to east due to the Earth's rotation.

Storyline Link
Students are motivated to gather more evidence to explain the phenomenon.

EXPLAINING STORM MOVEMENT

1. **Navigate from the previous activity.** Tell students that with their new ideas about the Coriolis effect, they are now prepared to explain more of the patterns in storm movement they observed in the tropics and the midlatitudes.

LESSON 15 STEP 3

2. **Record a final explanation.** In *Lesson 15: Step 3*, have students use their model and new ideas about the Coriolis effect to record an explanation that describes where it is likely that storms will originate in the Philippines and where they live.

3. **Lead a whole class discussion.** Have students share their explanations for where weather comes from where they live and why this understanding is important for their daily lives. Have them connect back to their responses from Lesson 12.
   - *Where is it likely that storms originate where we live?*
   - *Why is being able to anticipate where storms come from important for communities?*
   - *How can we use our understanding of weather to prepare for the impacts of storms?*

Assessment
This final individually written explanation can serve as one of the summative assessments for this learning sequence.

LOOK BACK
LESSON 11 STEP 2

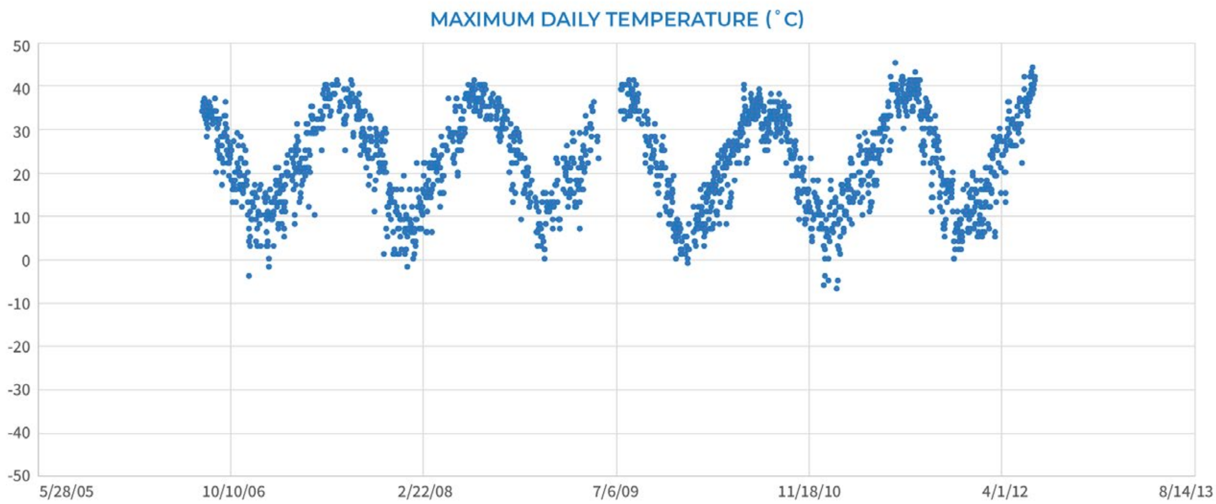
4. **Connect back to the Anchor.** Have students look back at their Lesson 11 weather map model. On a world map, globe, or Google Earth, indicate the location of Colorado. Ask students to identify what direction storms are likely to travel based on its latitude. (Students should recognize that it is in the midlatitudes so storms will tend to move from west to east.) Have students add an arrow to their weather map models to indicate the direction that the storm is trying to move. Ask students what stopped the storm from moving (high pressure to the east, north, and south).

END OF SEQUENCE ASSESSMENT

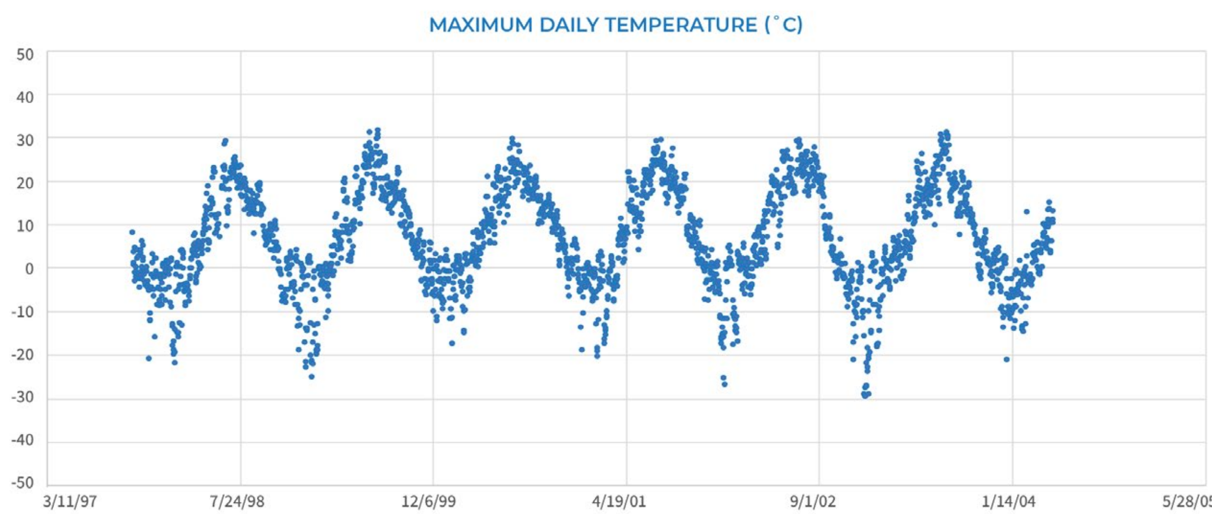
Assess student learning with the Learning Sequence 3 assessment. You can find the assessment item bank and rubric in the Assessments section of *GLOBE Weather.*

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
highest max temperature 49˚C
lowest max temperature 24˚C

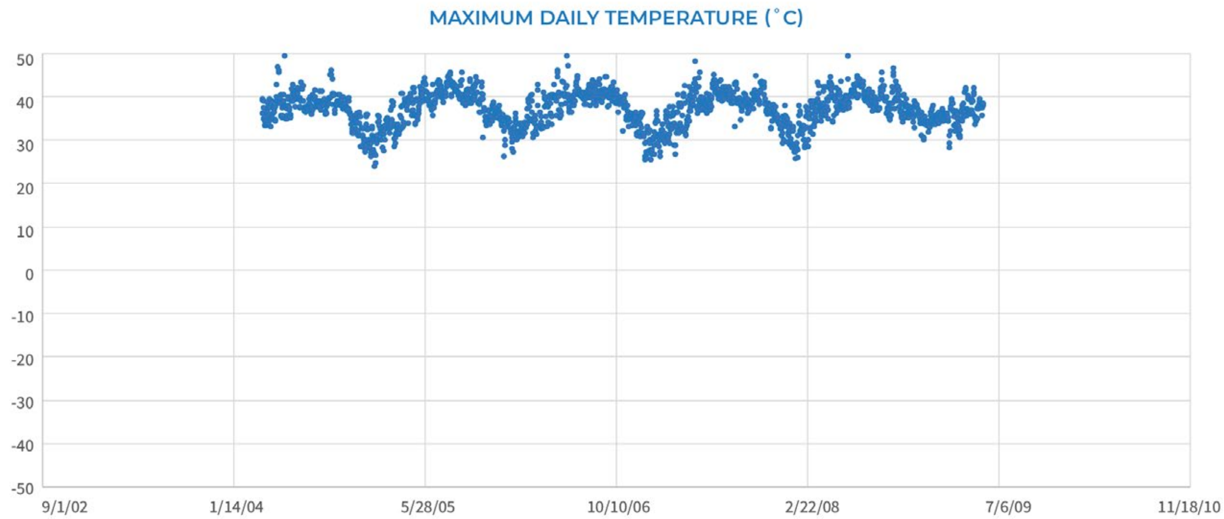
G
highest max temperature 41˚C
lowest max temperature 27˚C

H
highest max temperature 44˚C
lowest max temperature -7˚C

I
highest max temperature 30˚C
lowest max temperature -30˚C

J
highest max temperature 35˚C
lowest max temperature -22˚C

C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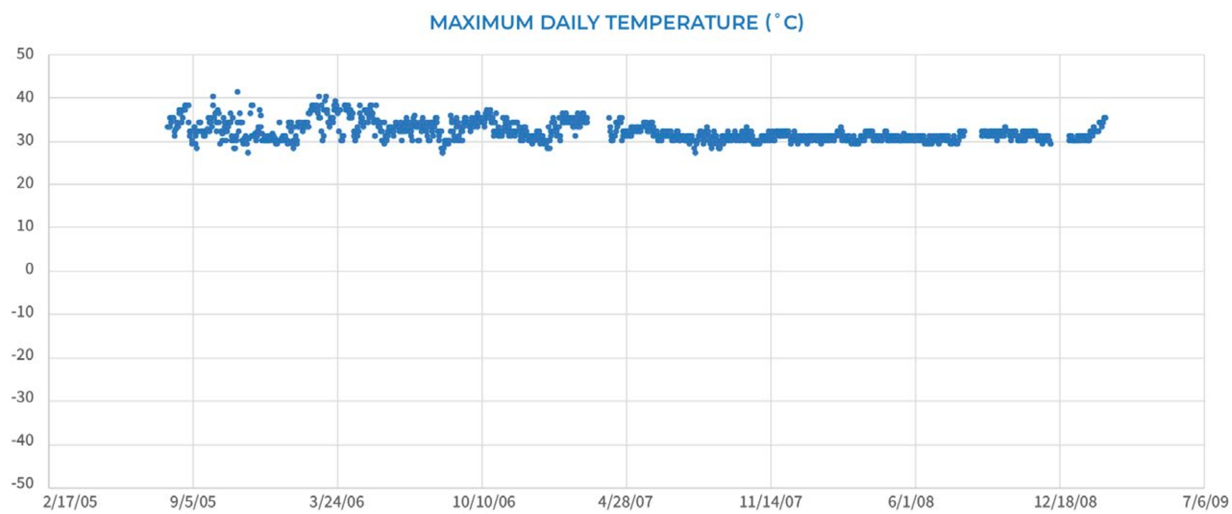
40
30
20
10
0
-10
-20
-30
-40
-50
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10

D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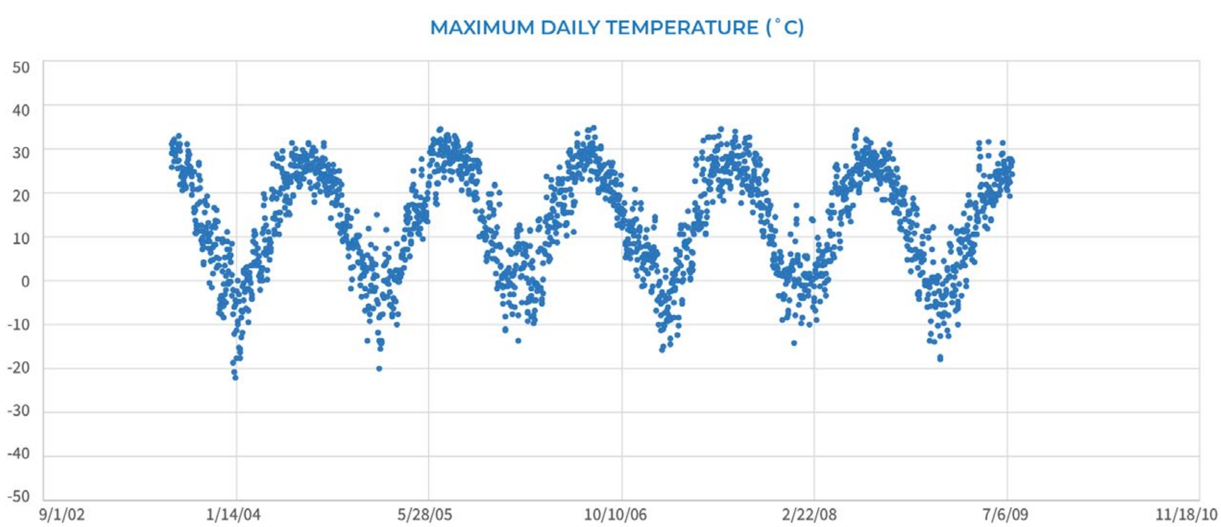
40
30
20
10
0
-10
-20
-30
-40
-50
2/17/05
9/5/05
3/24/06
10/10/06
4/28/07
11/14/07
6/1/08
12/18/08
7/6/09

E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40
30
20
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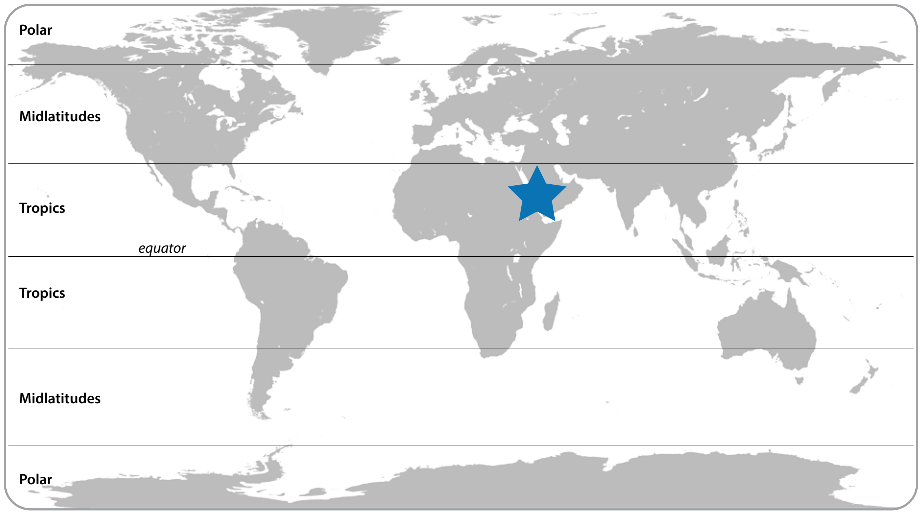
0
-10
-20
-30
-40
-50
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10

Location:
Saudi Arabia

Latitude:
21.3725

Distance from the equator:
2,372 km

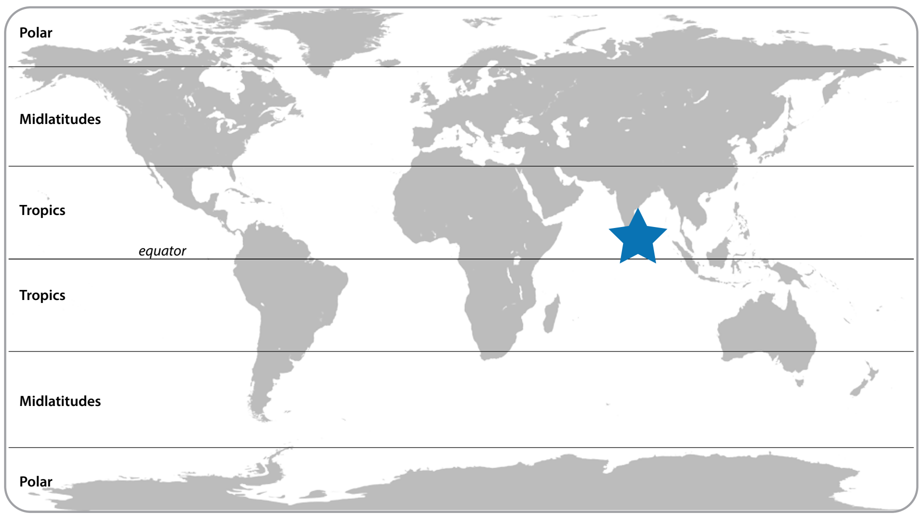


N

Location:
Sri Lanka

Latitude:
7.1438

Distance from the equator:
793 km

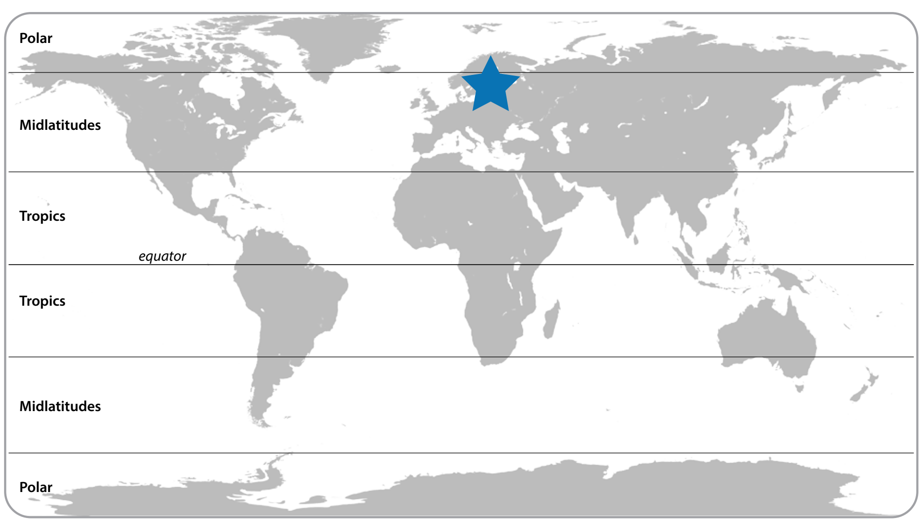


O

Location:
Finland

Latitude:
63.2377

Distance from the equator:
7,020 km

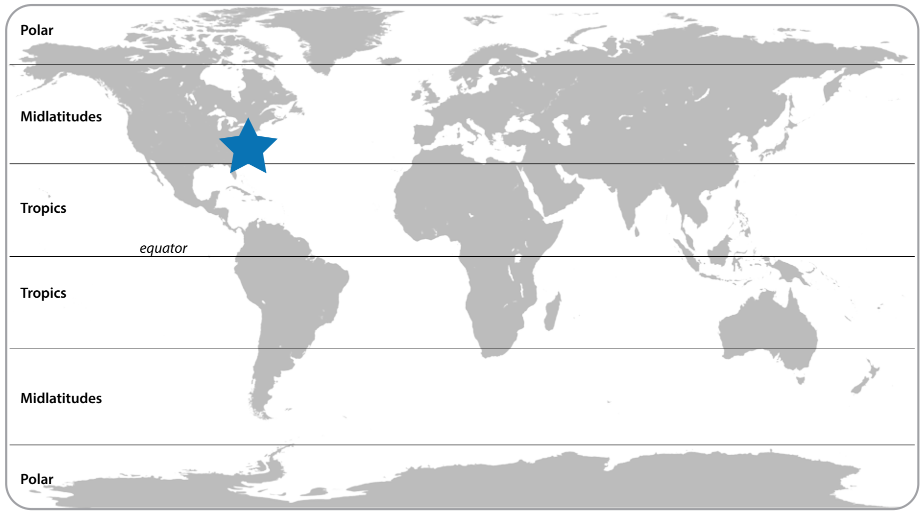


K

Location:
Vermont, US

Latitude:
44.675

Distance from the equator:
4,959 km

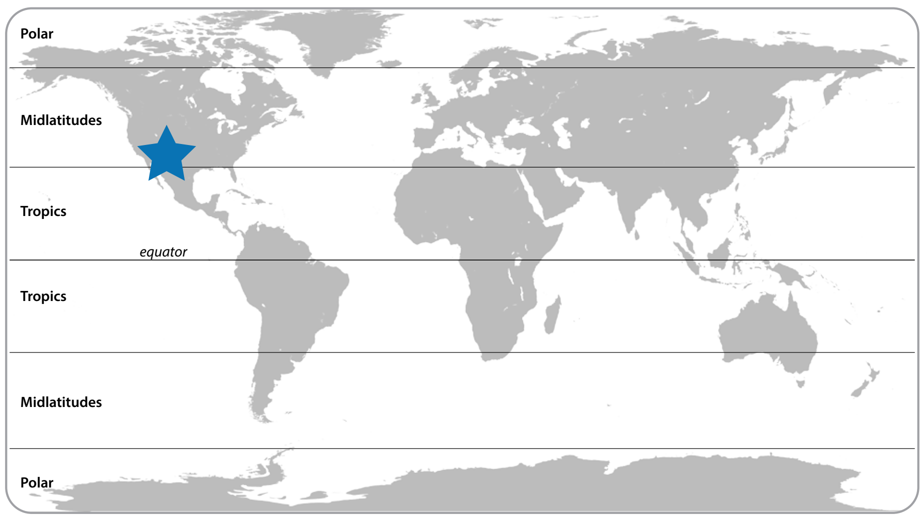


L

Location:
Arizona, US

Latitude:
36.4493

Distance from the equator:
4,046 km



M