UCAR CENTER FOR SCIENCE EDUCATION

TEACHER ANSWER KEY

LEARNING SEQUENCE 3

LESSON 12 — How do storms move around the world?

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

LESSON 14 — How and why does air move in the tropics?

LESSON 15 — When air and storms move, why do they curve?

BSCS SCIENCE LEARNING

NASA

THE GLOBE PROGRAM

Name Period Date

LESSON 12

How do storms move around the world?

STEP 1: How do storms move across North America?

Watch the video of storms moving across North America and draw arrows on the map below to record the patterns of storms you observe.

Draw arrows to indicate the direction that each storm moves through this region.

Storms have a general pattern of arriving from the west and moving across the continent towards the east.

STEP 2: Why is this pattern important?

Explain below why it would it be helpful to understand the patterns of storm movement.

Understanding patterns of storm movement is useful for predicting the weather in your area. People who live in the central or eastern US states can monitor weather in the western states to prepare for storm systems that may be heading their way.

LESSON 12

How do storms move around the world?

STEP 3: Observe precipitation movement around the world.

Watch a video of storms as they move around the world. How do storms move near the equator? In the tropics? In the midlatitudes?

Draw arrows on and write on the map below to record your observations of moving storms from the video.

STEP 4: Discuss your observations.

Discuss the following questions with your peers and record your answers below. Be ready to share your ideas in a whole class discussion.

1. What patterns did you notice about how precipitation moves around the world?

Storms appear to move in predictable patterns around the world. In the mid-latitudes, storms move from the west to the east across the Earth's surface. In the tropics, storms form from the east to the west across the Earth's surface.

Though it wasn't specifically asked for in this question, students might also notice that storms in the tropics are smaller than storms in the mid-latitudes. Mid-latitude storms appear to elongate or stretch out. There are also more storms in the tropics than in the midlatitudes. Though it is hard to see in the video, storms swirl counterclockwise in the Northern Hemisphere, and clockwise in the Southern Hemisphere.

2. What questions do you have about these patterns?

Answers will vary. Students may wonder what causes these patterns of movement, or why the storms move in different directions at certain places on the Earth. They might also wonder how convection, which they learned about in Learning Sequence 1, influences these patterns.

LESSON 12

How do storms move around the world?

STEP 5: Form an initial explanation.

What do you think could be causing these patterns of global storm movement? Draw on your knowledge from Learning Sequences 1 and 2 to answer the questions below.

1. What do you know about what causes rain?

   - *In Learning Sequence 1, students learned that convection causes air and water vapor to rise in the troposphere, and that high altitude air is cooler than air at the surface, which leads to condensation/cloud formation and can lead to precipitation.*
   - *In Learning Sequence 2, students learned that rain happens along a cold front due to the collision of a cold air mass and a warm air mass. The cold, dense air mass forces the warm, moist air mass upwards, which leads to cloud formation and storms.*

2. What do you know about what causes air to move?

   - *In Learning Sequence 1, students learned that as air is heated, the molecules spread further apart, becoming less dense, and rise. When air cools, the molecules move closer together, becoming more dense, and sink.*
   - *In Learning Sequence 2, students learned that air moves from high pressure areas to low pressure areas.*
   - *In Learning Sequence 2, students learned that low pressure air rises and high pressure air sinks.*

3. How could the same processes affect the whole world?

   - *Students may note that some regions of the Earth are warmer or colder than others and connect what they have learned about air movement to how storms move around the world. For example, students may predict that air from warm places on the Earth will rise while air from cold places on Earth will sink. They may predict that warm places on Earth will have lower air pressure, and cold places will have high air pressure.*
   - *In Learning Sequence 2, students learned that rain happens along a cold front when a cold air mass meets a warm air mass. Students may connect this learning to storms across the whole world and predict that the interaction of air masses with different temperatures on a global scale is driving the storm patterns.*

Name Period Date

LESSON 13

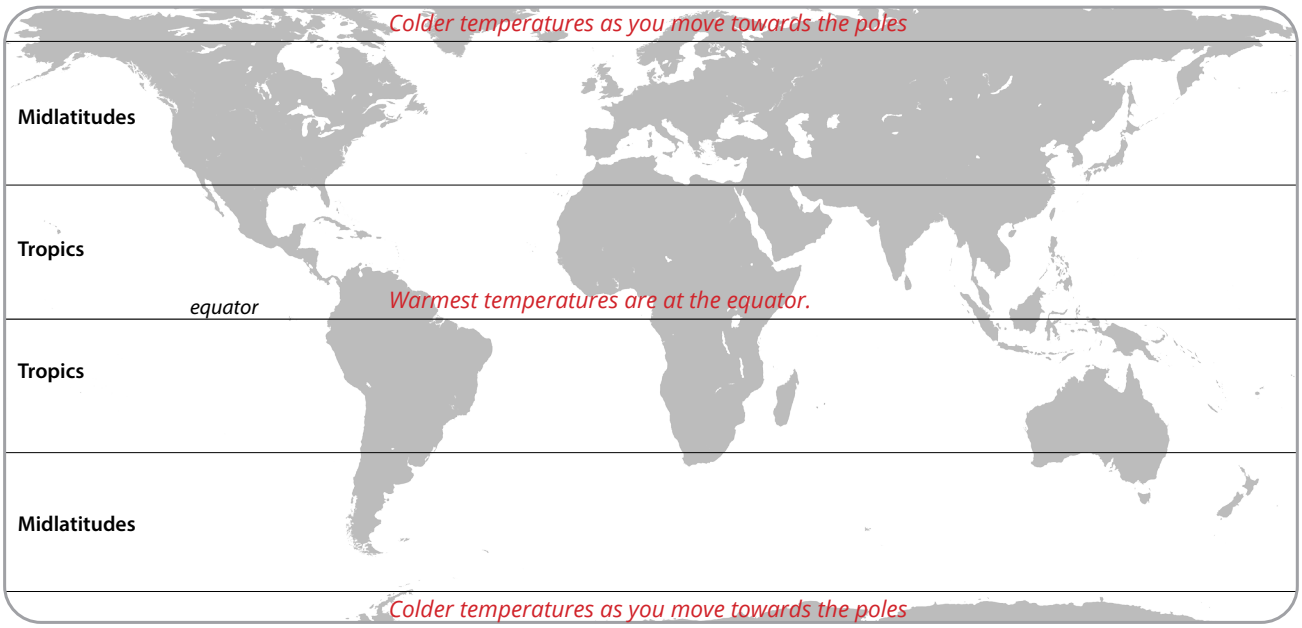
Why is it hotter at the equator than other places on Earth?

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.

Students should draw or write on the map to show the pattern of decreasing temperatures as the distance from the equator increases.



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

Answers will vary. Use student responses to pre-assess their understanding of the uneven heating of the Earth. Look for answers that explain the connection between the amount of sunlight received and temperature. The equator is hotter than other places because it receives more direct sunlight than other places on the Earth.

LESSON 13

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?

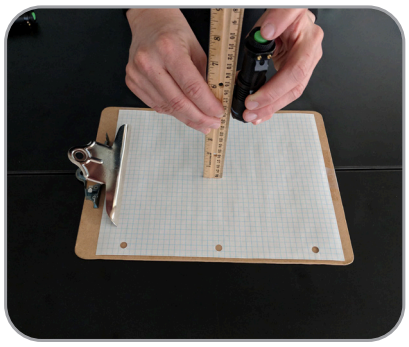
sunlight

What does the clipboard represent in this investigation?

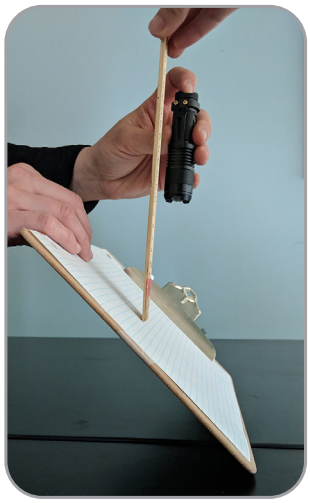
the surface of the Earth

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. *The area of illumination increases as the angle increases.*
- Do you observe any difference in the brightness of the light? *Brightness might decrease as the light spreads out, depending on the flashlight and lighting conditions in your room.*
- 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?

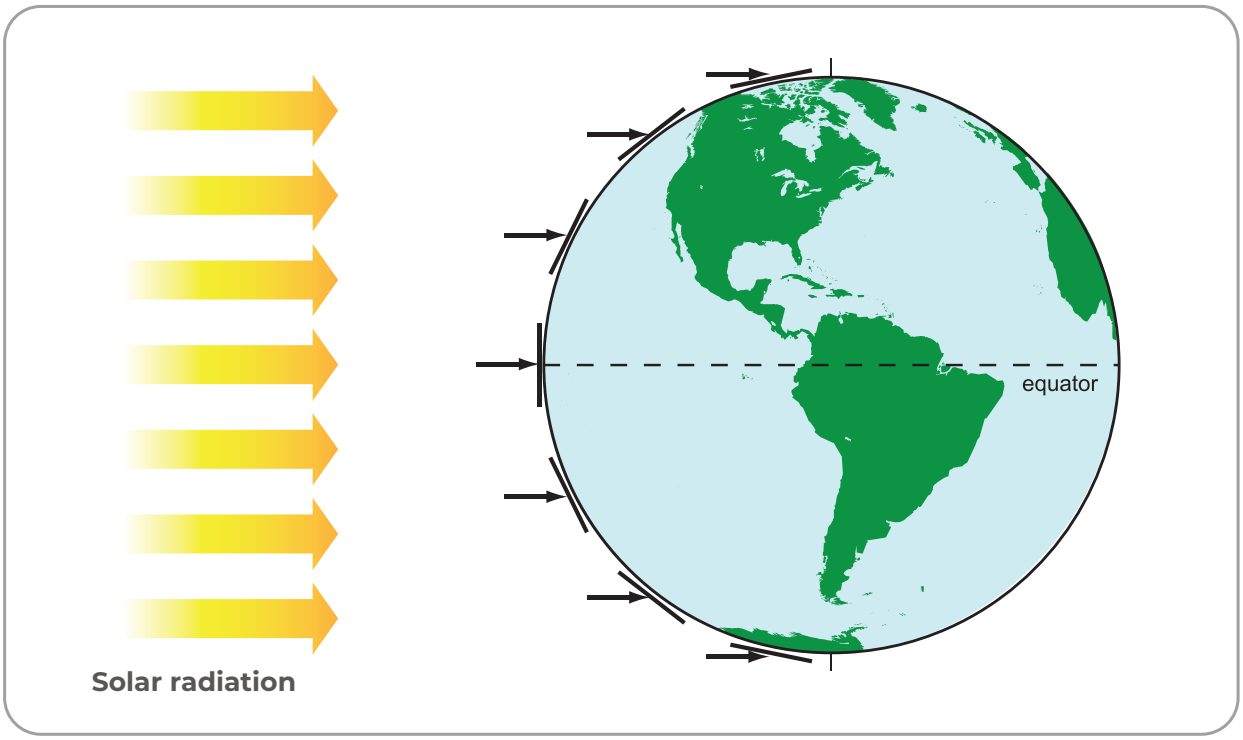
  Light energy is most concentrated when the clipboard is flat. As you change the angle, the light energy is more spread out, and less energy reaches each square on the graph paper.

LESSON 13

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?

The equator receives more concentrated sunlight. The Sun is directly overhead at the equator, which means that energy from the Sun strikes the surface with the smallest angle (about 90 degrees). Sunlight is most concentrated here, just as it was in the energy angle experiment when the clipboard was flat.

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

All locations as you move north or south from the equator receive less concentrated sunlight than at the equator itself. The poles receive the least concentrated sunlight. Energy from the Sun strikes the surface with increasingly larger angles the further you move from the equator. Sunlight is less concentrated as the angle increases, just as it was in the energy angle experiment when the clipboard was held at an angle.

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

There is a direct relationship between temperature and concentration of sunlight: temperature increases as the concentration of sunlight increases. Hotter areas have more concentrated sunlight (the tropics, which is the region surrounding the equator). Colder areas have less concentrated sunlight (the polar regions; the Arctic in the north and the Antarctic in the south). The temperate zone inbetween experiences more moderate temperatures but also significant seasonal variation.

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	*B*	*-30° C*	*30° C*	*60° C*
This is why I think Finland matches this graph:	*Answers will vary. Graph B shows the lowest maximum temperature and the greatest difference in temperature throughout the year, which matches with Finland's location, which is the furthest from the equator.*			
Vermont, US	*E*	*-22° C*	*35° C*	*57° C*
This is why I think Vermont matches this graph:	*Answers will vary. Graph E also shows a lot of difference in temperature throughout the year, but doesn't get quite as cold as Finland (Graph B), which matches with Vermont's location, which is the second furthest from the equator.*			
Arizona, US	*A*	*-7 °C*	*44° C*	*51° C*
This is why I think Arizona matches this graph:	*Answers will vary. Graph A is similar to Graph E, both have over 50° C of difference in temperature throughout the year, but overall temperatures are warmer in Arizona than in Vermont because Arizona is closer to the equator.*			
Saudi Arabia	*C*	*24° C*	*49° C*	*25° C*
This is why I think Saudi Arabia matches this graph:	*Answers will vary. Graph C shows considerably less difference in temperature throughout the year but does still show some seasonal fluctuation. Temperatures are overall quite warm, which matches with Saudi Arabia's location, which is the second closest to the equator.*			
Sri Lanka	*D*	*27° C*	*41° C*	*14° C*
This is why I think Sri Lanka matches this graph:	*Answers will vary. Graph D shows very little difference in temperature throughout the year, with overall warm temperatures, which matches with Sri Lanka's location, which is the closest to the equator.*			

Name Period Date

LESSON 14

How and why does air move in the tropics?

STEP 1: Develop a model.

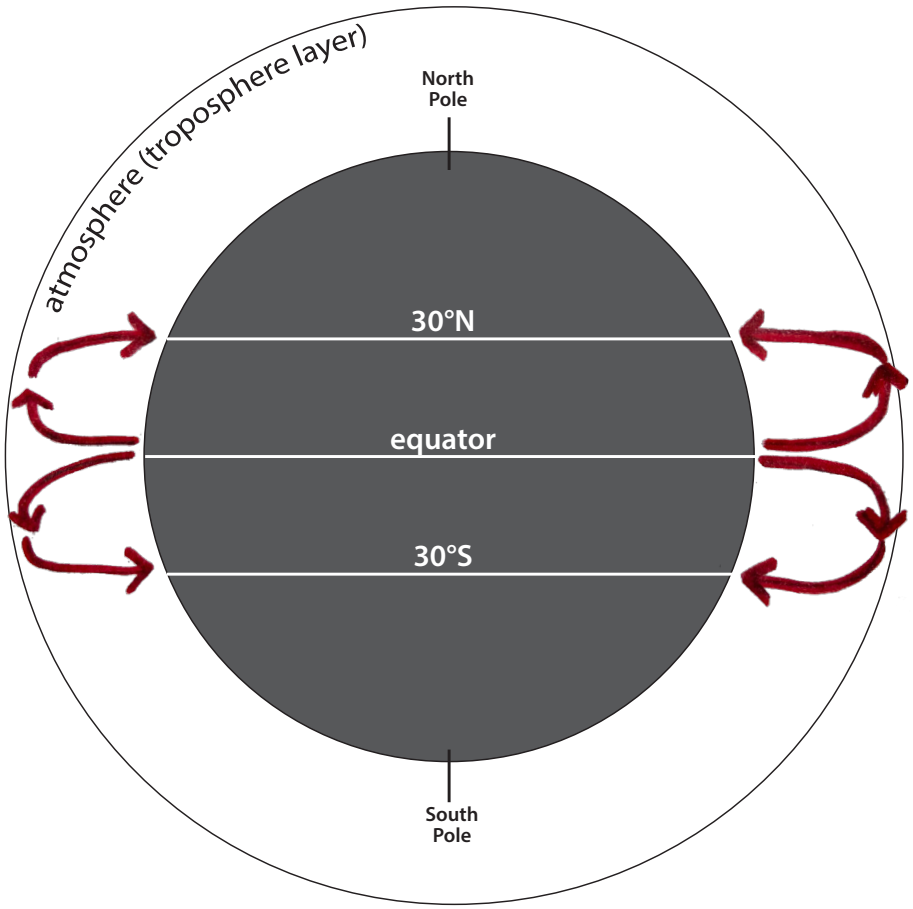
How do you think air is moving in the tropics between 30°N and 30°S? Why? Record your initial ideas on the image below.

Temperature differences cause air to move around the world.

- In some places, warm temperatures cause air to rise from the Earth's surface to higher in the atmosphere.
- In other places, cooler temperatures cause air to sink from higher in the atmosphere to the Earth's surface.

Translate those ideas to the illustration of Earth's atmosphere below. In the illustration, the atmosphere is exaggerated.

1. **Draw arrows in the troposphere layer of the atmosphere** to indicate where air is rising. Remember that warm air rises.
2. Air can't rise forever. **Draw arrows** to indicate where you think the rising air goes when it gets to the top of the troposphere.
3. At 30°N and 30°S latitude, air is cooler than it is at the equator. **Draw arrows** in the atmosphere to indicate what happens to the cooler air.



How and why does air move in the tropics?

STEP 2: Investigate air movement across Earth's surface.

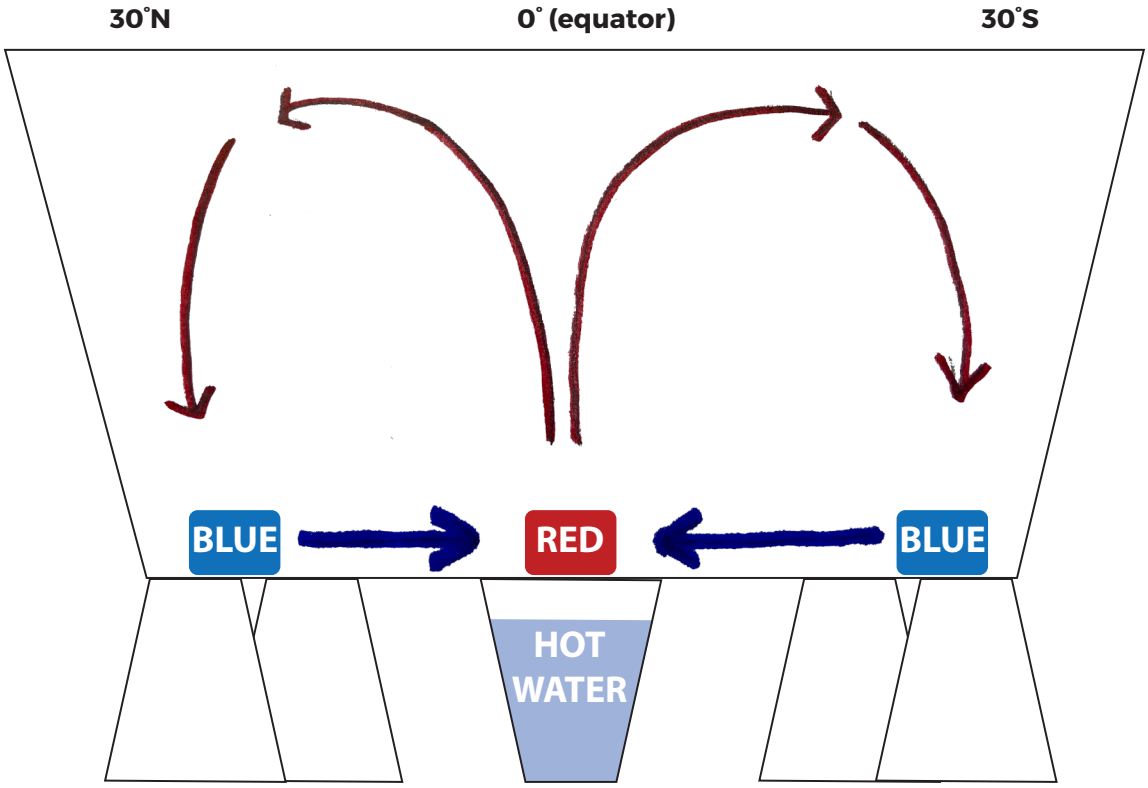
With a partner, write a statement that connects the water tank demonstration to the real world and explains why they are alike. The first part of the model is completed for you as an example.

PART OF THE MODEL		PART OF THE REAL WORLD		WHY ARE THEY ALIKE?
The water in the tank	*is like*	*the atmosphere*	*because*	*the water in the clear plastic tub represents the air in the tropics (between 30°N and 30°S latitude). Air and water are both fluids, so they behave similarly.*
Red food coloring	*is like*	*warmed air*	*because*	*warm air rises up into the atmosphere. The air is heated because the surface has absorbed energy from the Sun, creating low pressure.*
Blue food coloring	*is like*	*cool air*	*because*	*it is located further from the equator and is pulled towards an area of low pressure, rushing in to fill the space left by rising warm air.*
The cup of boiling hot water	*is like*	*solar energy/sunlight*	*because*	*it is the source of heat.*
The bottom of the clear plastic water tub	*is like*	*the Earth's surface*	*because*	*the surface absorbs energy from the Sun, and then transfers heat to the air, causing it to rise. The bottom of the tub is warmed by the cup of boiling hot water (sunlight), which transfers heat to the red food coloring (air) and causes it to rise.*

How and why does air move in the tropics?

STEP 3: Record observations of the water movement.

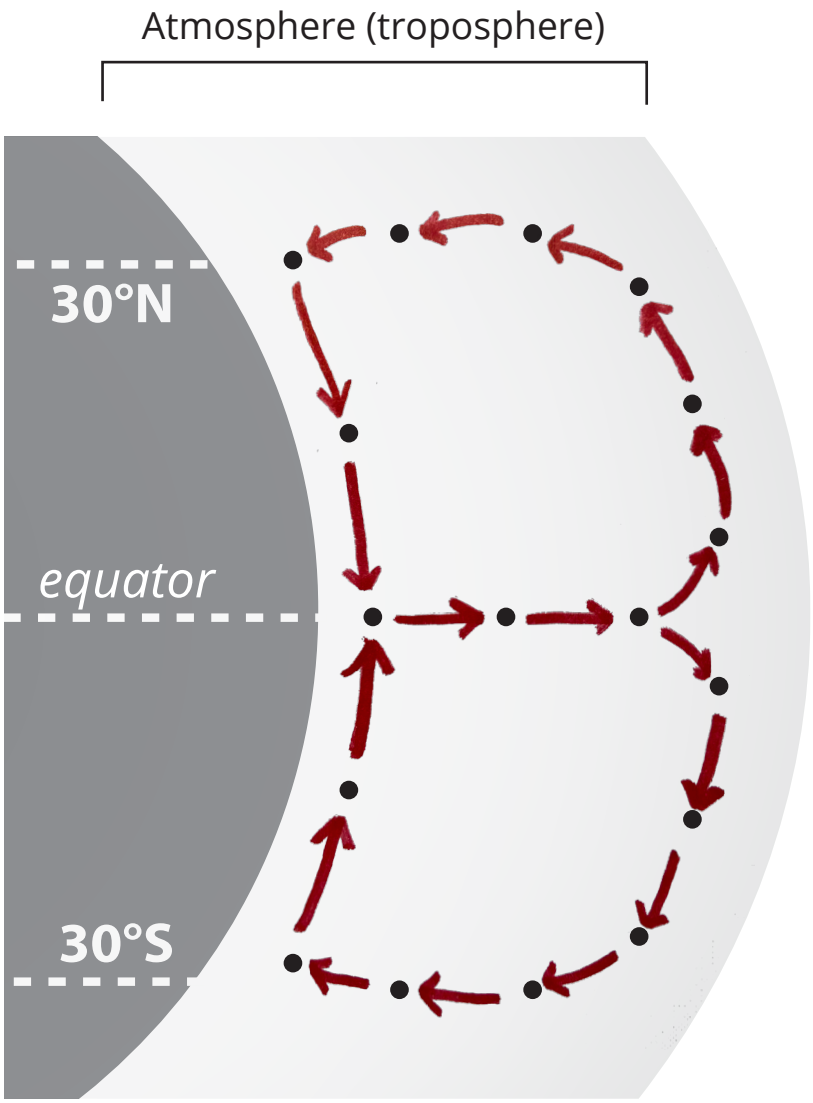
Draw how the water moves through the tank.



RECORD YOUR OBSERVATIONS *I notice...*	RECORD IDEAS FOR WHY *I think...*	RECORD YOUR QUESTIONS *I wonder...*
Observations will vary, but may include: • *The red food coloring rises until it reaches a certain height, and then it spreads out and sinks back down.* • *The blue food coloring is pulled along the bottom of the tub towards the heated area (where the cup of hot water is).* • *After a while, the rising and sinking seem to stop, and the colors mix within the water.*	*Ideas will vary, but look for an understanding of convection:* • *Warmed (red) water becomes less dense and rises until it cools and becomes more dense, and sinks.* • *Cooler water from along the surface (blue) is pulled towards the heat to replace the rising warm (red) water.* • *There is not enough heat to continue convection, the water temperature is equalizing, and the food coloring is diluted by the water.*	*Questions will vary. Look for students wondering about the processes involved, and how they relate to weather.*

How and why does air move in the tropics?

STEP 4: Describe how and why air moves in the tropics.
Focus on how air is moving in the tropics (between 30°N and 30°S of the equator). Draw arrows to connect the dots and show how air is moving in the atmosphere, just as the water moved in the water tank model.



Write a caption to describe air movement in the model above.

Warmed air at the equator rises and then cools and sinks back towards 30°N and 30°S latitude. Cool air along the surface is pulled towards the warm, rising air at the equator.

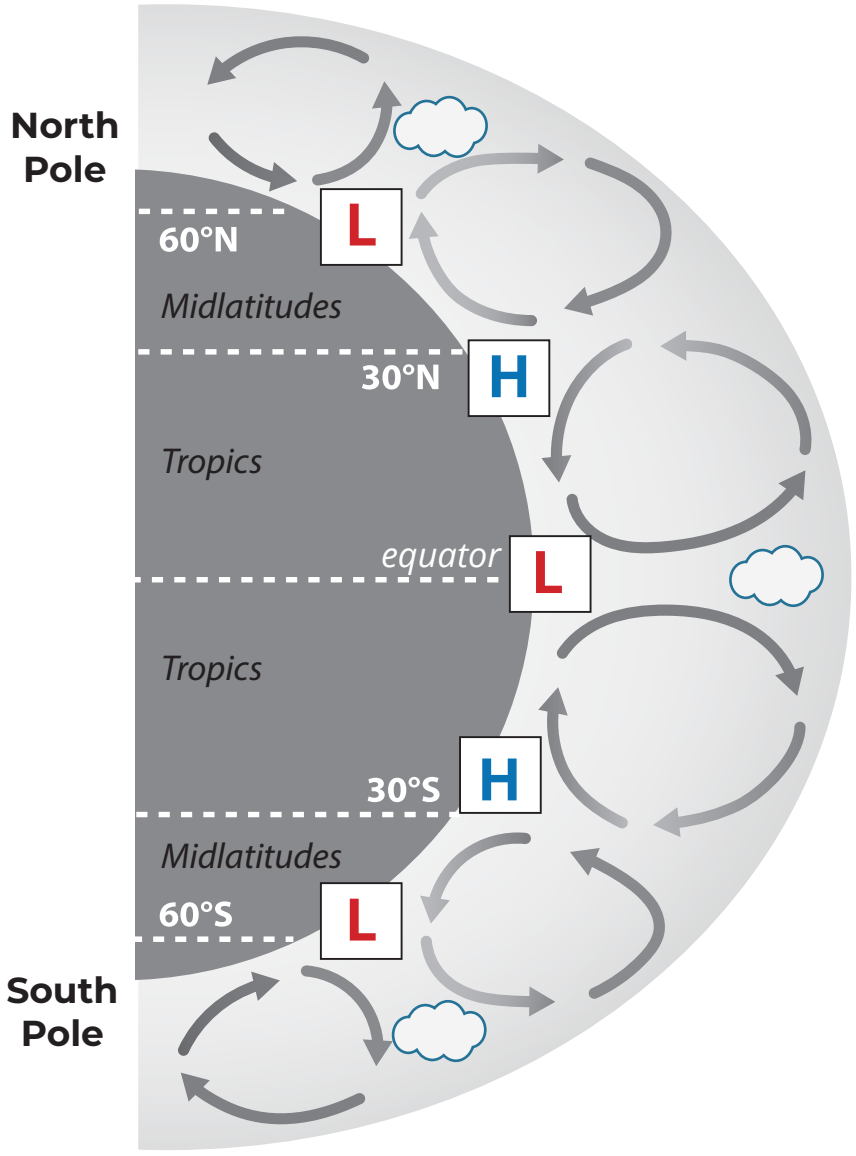
LESSON 14 How and why does air move in the tropics?

STEP 5: Create a model to describe air pressure and clouds at different latitudes.
Review the following diagram of how air moves around the world.

L **Put an "L"** in the white boxes where there would be low pressure.

H **Put an "H"** in the white boxes where there would be high pressure.

Draw in clouds at locations of low pressure, where they are likely to form.



Name Period Date

LESSON 15

When air and storms move, why do they curve?

STEP 1: Compare storm movement with your model.

Watch the *Global Rainfall and Snowfall* video from Lesson 12 again, this time focusing your observations on the movement of storms in the tropics. Below, compare the movement you see in the video to how you might predict storms to move based on your model about air movement in the tropics (from the end of Lesson 14).

1. What kind of movement did you observe in the video that isn't explained by your model?

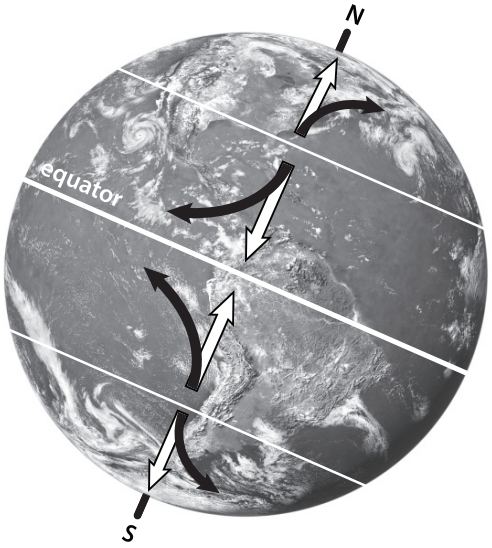
In the video, all of the storms appear to move either from west to east or from east to west. According to our model, warm air should be rising from the equator towards the midlatitudes, and then sinking back down towards the equator as it cools, which would cause air at the Earth's surface to move either from north to south or from south to north.

LESSON 15

When air and storms move, why do they curve?

STEP 2: Learn about the Coriolis effect.

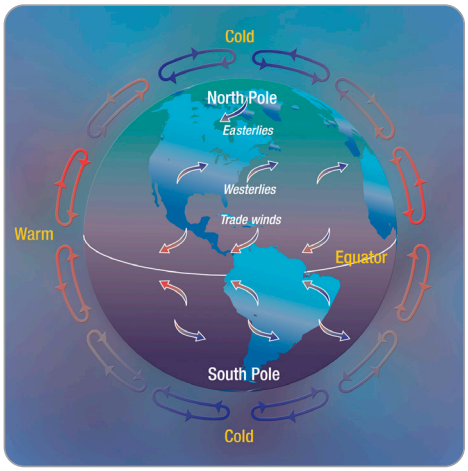
Because Earth is spinning, air does not travel in a straight line above the surface (like the white arrows on the picture to the right). Instead, air has a curved path (like the black arrows). Air north of the equator turns to the right as it moves. Air south of the equator turns to the left as it moves. This is called the **Coriolis effect.**



STOP AND DO

Make a model of the Coriolis effect.

1. Make a model of the Earth.
   - **Inflate** the balloon.
   - **Draw** an equator around the widest point.
   - **Draw** lines around the balloon where 30˚N latitude and 30˚S latitude lines would be.
2. Simulate how air in the tropics would move if the Earth didn't spin.
   - *Student 1:* **hold the balloon** in front of you so that the equator and latitude lines are parallel to the floor.
   - *Student 2:* **draw an arrow** starting at 30˚N latitude going toward the equator.
3. Simulate how air moves with Earth's spin.
   - *Student 1:* **slowly rotate** the balloon counterclockwise to model the Earth spinning on its axis. (Look at the balloon from above to determine which direction is counterclockwise.)
   - *Student 2:* **draw another arrow**, starting from the same point as before and trying to get to the equator.



Why does air move in different directions in the tropics and in the midlatitudes?

Earth is always on the move. Earth rotates, or spins, making one full turn every 24 hours. If Earth did not spin, air would rise at the equator and sink at the poles. But because Earth spins, there are three areas of convection north of the equator and three south of the equator. Convection causes winds to move across Earth's surface toward the equator in the tropics, away from the equator in the mid-latitudes, and toward the equator around each pole. These winds are called **prevailing winds**. Prevailing winds curve because of the Coriolis effect. Winds in the midlatitudes curve, moving west to east. Winds in the tropics generally move from east to west.

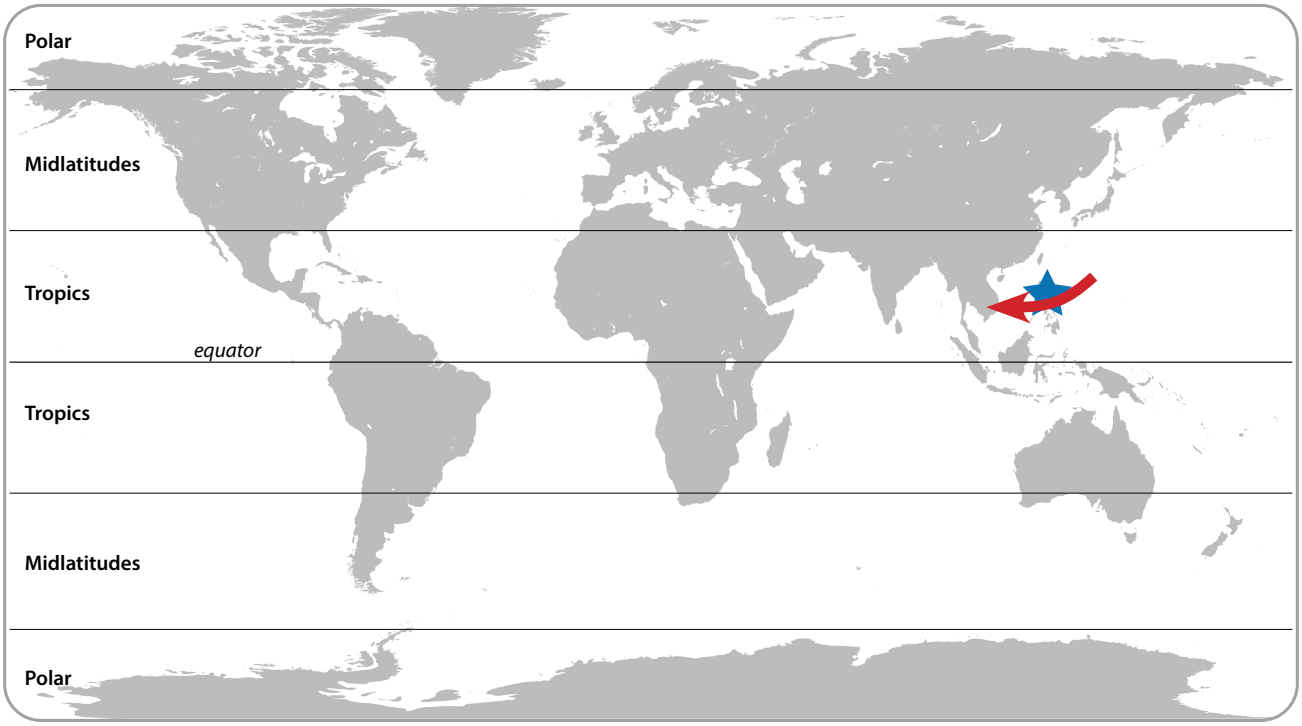
When air and storms move, why do they curve?

STEP 3: Record an explanation.

Use the model of air movement in the tropics you developed and what you learned about the Coriolis effect to explain the direction that storms will likely move through the Philippines (indicated with a star below) and where you live.

- **Draw an arrow** on the map to indicate the direction that storms in the Philippines (starred location) usually travel.
- **Draw a different symbol** on the map that shows where you live. Then, **draw an arrow** to indicate the direction that storms usually travel where you live.

Answers will vary. Look for a correct understanding of which direction storms should travel from your location according to global circulation and the Coriolis effect.



1. Explain why you think storms move through the Philippines in a particular direction.

   Storms in the Philippines usually move from east to west because this location is in the tropics, where air moving towards the equator is deflected to the right (in the Northern Hemisphere) due to the Coriolis effect.

2. Explain why you think storms will come from a particular direction where you live.

   Answers will vary. Look for a correct understanding of which direction storms should travel from your location according to the Coriolis effect and global circulation patterns learned in lesson 14.