

Lab Activity on Global Wind Patterns

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Objectives

When you have completed this lab you should be able to...

1. explain how convection redistributes atmospheric heat energy from the equator to the poles,
2. correctly state whether rising air is characterized by low atmospheric pressure or high atmospheric pressure and why; do the same for sinking air,
3. explain how and why the rotation of the earth deflects the wind from its intended path (the Coriolis effect); describe which way the wind is deflected in each hemisphere (N and S).

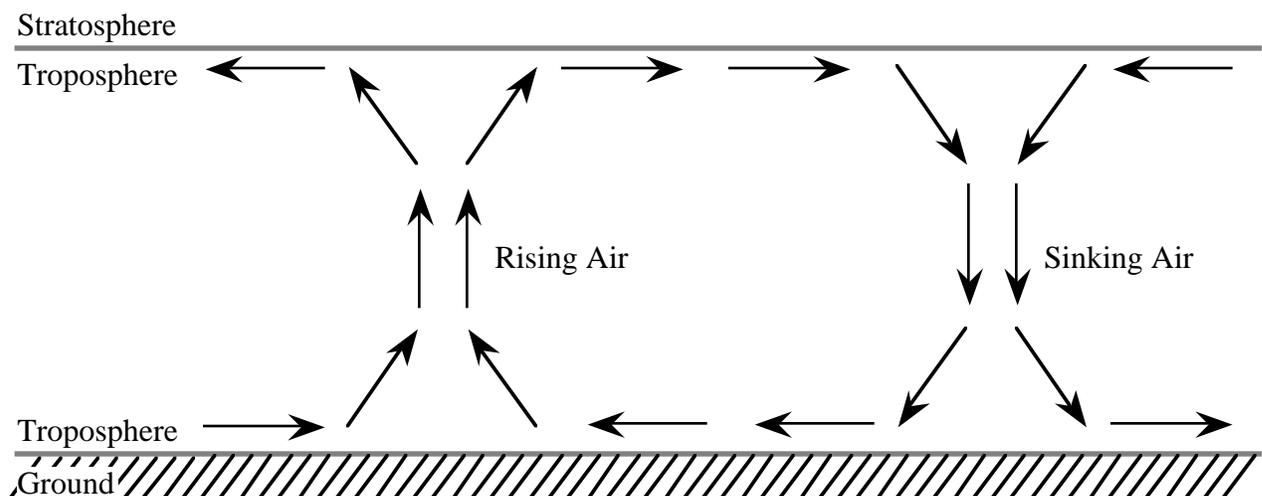
Important Information About the Layering of the Atmosphere

Earth's atmosphere is made of four layers (Figure 14.6 on p. 368 of the textbook shows a diagram of these layers). In this class, we will only concern ourselves with two of these layers:

- (1) The **troposphere** is the lowermost layer of the atmosphere; it is where we live and where most interesting "weather" (clouds, wind, storms, etc.) occurs.
- (2) The **stratosphere** is immediately above the troposphere; it contains the ozone layer.

The boundary between the troposphere and the stratosphere (called the **tropopause**) acts like an almost impenetrable barrier to air; very little air crosses this boundary.¹ Why? Because the bottom of the stratosphere is warmer than the top of the troposphere and you know how effectively that kind of a temperature gradient acts to prevent vertical air circulation (remember—from the lab on convection—the red-clear-and-blue water in the beaker that was heated from above?).

The near impenetrability of the boundary between the troposphere and the stratosphere is very important when it comes to understanding weather. For example, when air rises in the troposphere, it hits the tropopause. It cannot push its way upward into the stratosphere, so it is forced to spread out sideways (see diagram below). Meanwhile, the rising air leaves behind a region of extra-thin (low-density) air near the ground that pulls in air from the surrounding area. When air sinks, the opposite happens (see below). So, in many ways the troposphere behaves like a pan of water (very little water "jumps" up into the air above; very little air penetrates down into the water).



¹Meteorites, jet planes, rockets and weather balloons have no trouble crossing this barrier, but air molecules do.

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Lab Activity #1: The Atmosphere in a Cake Pan

Introduction

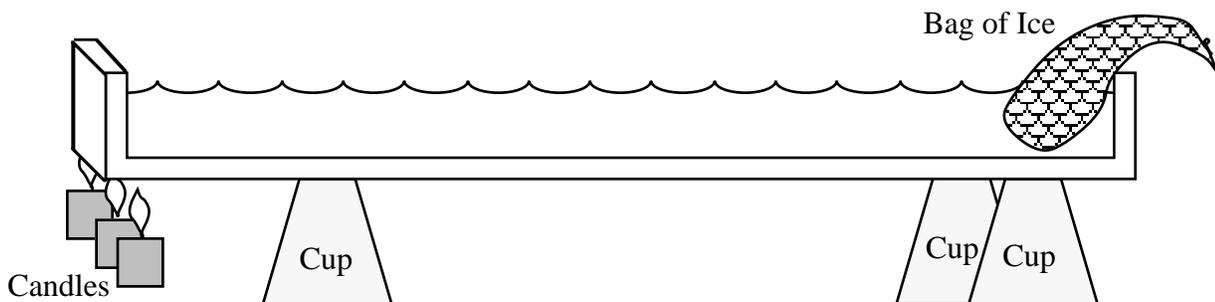
In this activity, we model the air movements that occur when air is cold in one place (for example, at the poles) and hot in another (for example, at the equator). We use water to represent air in the lower part of the atmosphere (i.e. the troposphere) because it's easier to observe the motion of water than it is to observe the motion of air. Keep in mind, however, what each part of the model represents:

Part of Model	Real Thing That it Represents
Bottom of cake pan	The Earth's surface
Water in the cake pan	The lowermost layer of the atmosphere (the troposphere)
Air above the cake pan	The stratosphere (the layer of the atmosphere directly above the troposphere)
Bag of ice	Cold ground near the north (or south) pole
Candles	Warm ground near the equator

Materials: large rectangular clear glass cake pan (15x10x2)
 red and blue food coloring
 2 eye droppers
 3 small candles (the kind that are used to keep food warm)
 box of matches
 three Styrofoam cups
 ice
 gallon-size Ziploc bag
 red and blue colored pencils

Activity

1. Fill the cake pan with water.
2. Place the three Styrofoam cups, upside down on the lab table, forming a triangle that the cake pan can rest on and remain stable. Place the cake pan on the three cups.
3. Light the candles and place them in a line underneath one end of the cake pan. This end of the cake pan represents the warm equatorial regions of the earth.
4. Put some ice in the large Ziploc bag and place the bag of ice in the cake pan on the side opposite the candle. This end of the cake pan represents the cold polar regions of the earth. The set up should look like the diagram below.



Questions

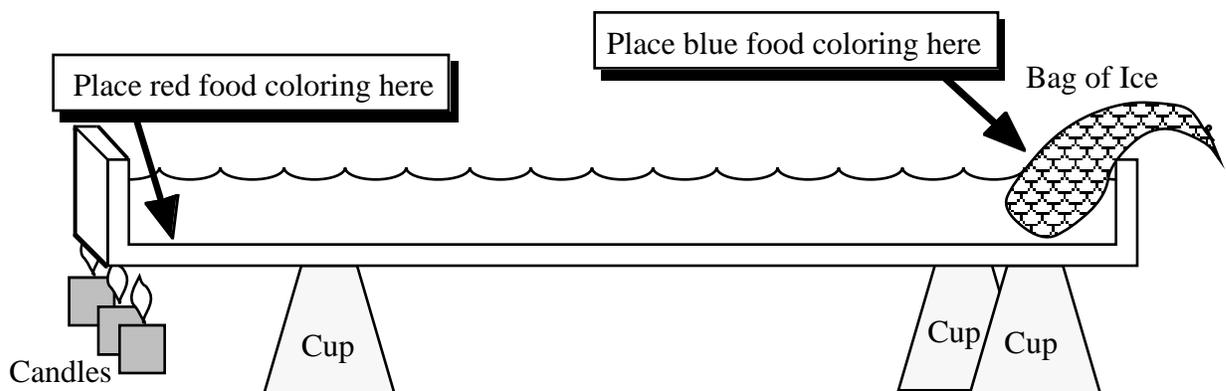
1. On the diagram on the previous page, use arrows to show any (invisible) motion of the water that you think may be occurring, due to the temperature differences across the cake pan.
2. Explain why you think the water is moving this way.

More Activity

5. After the cake pan has rested undisturbed for a few minutes, place several drops of blue food coloring in a line along the bag of ice, near where it touches the water (see diagram below).
6. Carefully place several drops of red food coloring into the water in a line along the BOTTOM of the cake pan directly above the candles (see diagram below).
7. Watch the motion of the colored water and answer the following questions.

More Questions

3. On the diagram below, use arrows and colored pencils to show the motion of the red and blue water in the cake pan.



4. Did the motion you observed match your predictions (Question #1 above)? _____
If not, explain why the motion that you DID observe occurred.

5. What can you conclude about the density of the water near the candle as compared to the density of the water near the ice? Where is the water more dense? Why?

For questions 6–13 below, imagine that you are a tiny water-breathing person, usually walking around on the bottom of the cake pan but sometimes “flying” up in the water in an airplane.

6. As you fly around in the “air” (the water in the cake pan), near the top of the troposphere, where do you feel the highest water pressure, near the ice or near the candle? Why? Hint: remember the recent lecture on wind.

7. On the diagram of the cake pan (previous page), place an “H” where the pressure aloft (i.e. near the top of the water) is highest and an “L” where the pressure aloft (i.e. near the top of the water) is lowest.

8. As you walk around on the “ground” (the bottom of the cake pan), where do you feel the highest water pressure, near the ice or near the candle? Why?² Hint: remember the recent lecture on wind.

9. On the diagram of the cake pan (previous page), place an “H” where the surface pressure (i.e. at the “ground”) is highest and an “L” where the surface pressure (i.e. at the “ground”) is lowest.

²In water as well as in air, the pressure you experience is proportional to the weight of the water or air above you. In other words, it is proportional to the number of molecules of air or water above you.

10. When you “fly” (in an airplane) up to the upper part of the water “atmosphere” near the center of the cake pan, which way do you feel the “wind” blow? (circle your answer)
from the pole (ice) to the equator (candle) / from the equator (candle) to the pole (ice)
11. When you stand on the “ground,” at the center of the cake pan, which way do you feel the “wind” blow ? (i.e. which way is water flowing?). Circle your answer.
from the pole (ice) to the equator (candle) / from the equator (candle) to the pole (ice)
12. When you stand on the “ground”, near the “equator,” do you feel much wind? Why or why not? (Hint: remember that “wind” is defined as a horizontal flow of air)
13. When you stand on the “ground”, near the “pole,” do you feel much wind? Why or why not?

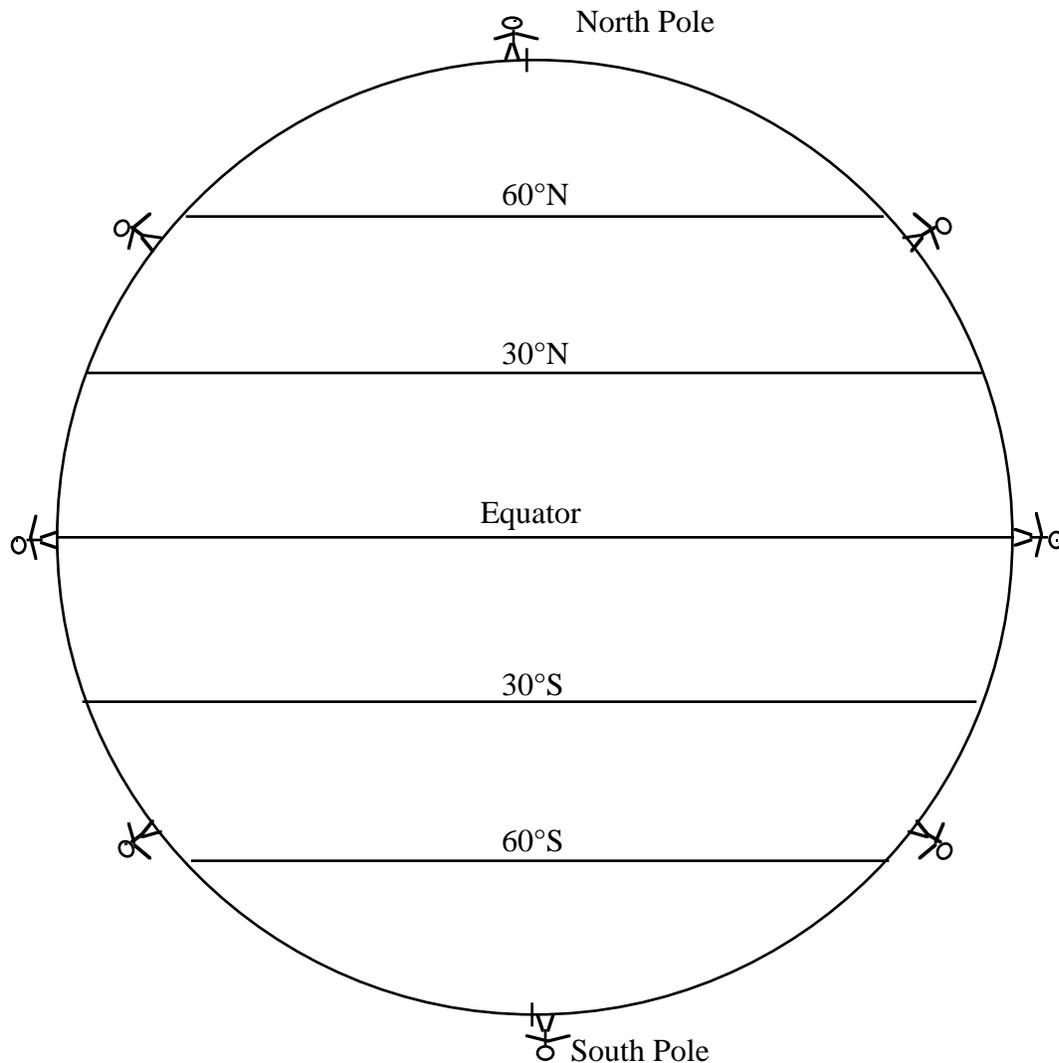
Questions 14–18 below ask you to apply what you've learned from the behavior of the water in the cake pan experiment to an analysis of the behavior of the air in the **upper part of** the troposphere.

14. Where the air is rising, the air pressure aloft is higher / lower than it is at the same level wherever air is not rising.
15. Where the air is sinking, the air pressure aloft is higher / lower than it is at the same level wherever air is not sinking.
16. The polar regions are characterized by relatively high / low atmospheric pressure aloft.
17. The equator is characterized by relatively high / low atmospheric pressure aloft.
18. Winds aloft tend to blow from the pole to the equator / from the equator to the pole.

Questions 19–23 below ask you to apply what you've learned from the behavior of the water in the cake pan experiment to an analysis of the behavior of the air in the troposphere **as experienced by people living on the Earth's surface**.

19. Where the air is rising, the surface air pressure is higher / lower than it is where air is not rising.
20. Where the air is sinking, the surface air pressure is higher / lower than it is where air is not sinking.
21. The polar regions are characterized by relatively high / low atmospheric pressure at the surface.
22. The equator is characterized by relatively high / low atmospheric pressure at the surface.
23. Winds near the ground tend to blow from the pole to the equator / from the equator to the pole.

24. On the model earth below, use arrows to show the air movement (i.e. atmospheric convection) that you think would result from the contrast in air temperatures between the equator and the poles. To keep things simple, show the air movement just on the outside “edges” of the earth--where the “people” are shown. Mark each region of low pressure with an “L” and each region of high pressure with an “H.”



Note: This is a useful model, but it is not correct.

First, as air flows aloft from the equator toward the pole, it loses a lot of heat. By the time it gets near 30° N and 30° S latitude, a great deal of that air has cooled enough that it becomes too dense to stay aloft--thus it sinks there--most doesn't make it all the way to the pole.

Second, Earth rotates on its axis, modifying the direction that the wind blows (at least from the perspective of any one place on earth. We will now modify the model to take Earth's rotation about its axis into account.

Lab Activity #2: The Coriolis Effect on a Flat Spinning Earth

Introduction

In this activity, we begin to study the Coriolis effect, the effect that Earth's rotation has on the motion (from the viewpoint of an observer on Earth) of flying objects, including air molecules.

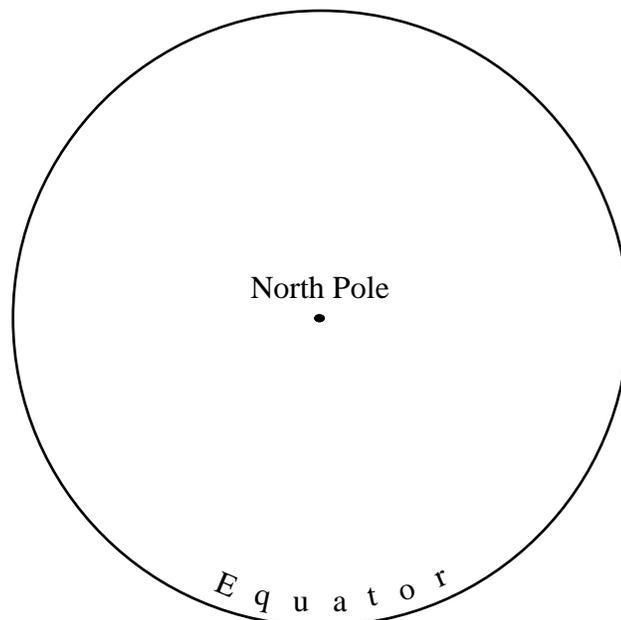
Materials: spinning lab stool
large piece of paper
felt-tip pen
yardstick

Activity

1. Choose a stool that spins easily. Cut out a paper circle that just fits the seat of the stool; tape the paper circle to the stool.
2. Make a mark in the center of the circle to represent the north pole; the edge of the stool represents the equator.
3. Using the yardstick as a guide, draw a path from the north pole to the equator. It should be a straight line. This is the path of an object (such as a missile) that is flying in a straight line from north to south on a NONROTATING Earth.
4. Figure out which way Earth spins, clockwise or counterclockwise, when looking down at the north pole.
5. Repeat step #3, but this time spin the stool (model Earth) in the appropriate direction at a slow constant rate while guiding the pen along the yardstick. This is the path of an object that is flying in a straight line from north to south on a ROTATING Earth.

Questions

1. On the circle below, show the two paths that you drew on the large circle of paper.



2. When you drew the line while rotating the seat of the stool, in which direction (to the right or to the left) was the pen deflected from the intended path (imagine yourself traveling with the pen tip, looking forward)?
3. The experiment you did modeled the situation for the northern hemisphere. Would objects be deflected in the same direction in the southern hemisphere? Explain why or why not.

Lab Activity #3: Coriolis Effect on a Spherical Spinning Earth

Introduction

In this activity, we continue to study the Coriolis effect. This time, we make it a bit more realistic by using a spherical Earth instead of a flat earth.

Materials: “chalk board” globe (we have only two of these, so the groups will have to take turns)
piece of chalk

Activity

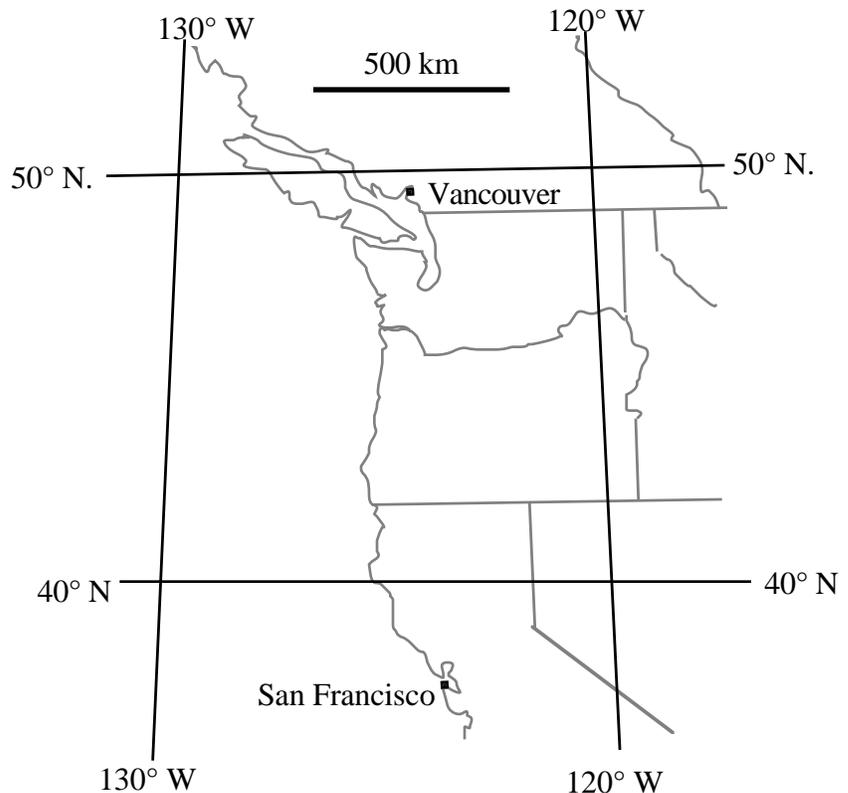
1. Without spinning the globe and using the metal arch around the globe as a guide, draw a straight line from the north pole to the equator.
2. Repeat step #1, but this time spin the globe slowly and steadily in the appropriate direction.
3. Repeat steps 1 and 2 but draw your line from the south pole to the equator.

Question: Does the spherical globe display a Coriolis effect similar to the flat lab stool? _____

Lab Activity #4: The Coriolis Effect on Objects “Launched” from Somewhere Other than the Poles

Introduction: We will now study how the Coriolis effect works if the object is “launched” from somewhere other than the North or South Pole. This makes things a bit more complicated and almost impossible to model physically. So, we will explore this issue by solving a couple of math “word problems.”

1. Imagine a war between Canada and the United States (fortunately, this is a highly unlikely scenario) in which the Canadians shoot a missile from Vancouver, aiming straight south toward San Francisco. Here is some important information:
 - The distance between the two cities is 1300 km.
 - The missile travels toward the south at a speed of 1300 km/hour.
 - Because the missile was launched from Vancouver, it also travels toward the east at the same speed that Vancouver is traveling eastward.
 - As the earth revolves around its axis...
 - Vancouver is constantly circling eastward at a speed of 1100 km/hour
 - San Francisco is constantly circling eastward at a speed of 1300 km/hour
- a. Why is San Francisco circling eastward faster than Vancouver is?
 - b. **Problem to solve:** Where will the missile actually land and why?



2. Even though the missile did not hit San Francisco, the United States is angry about the attempted missile attack and wants to shoot a missile from San Francisco so that it will hit Vancouver. But, like the Canadians, the Americans do not take the Coriolis effect into account. Where will their missile land and why?

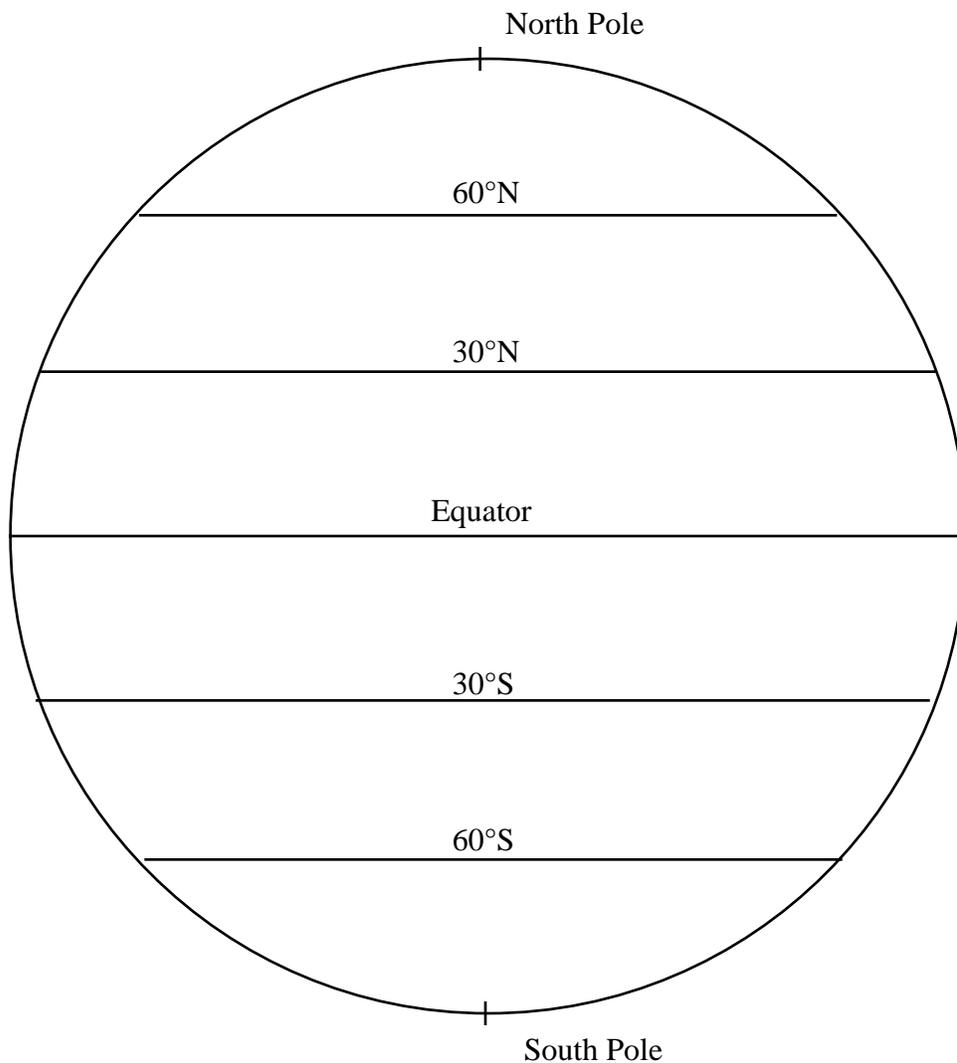
Lab Activity #5: Adding the Coriolis Effect to the Convection Model--Surface Winds

Introduction: It is now time to modify the convection model that you constructed in Activity #1 to take the Coriolis effect into account.

In this model, we will focus on the regions between 30° N and 30° S latitudes--where the trade winds blow. At higher latitudes the wind direction isn't nearly as consistent, partly because the Coriolis effect is so strong (the higher the latitude, the stronger the Coriolis effect).

In this model, we will also focus on the direction of the surface winds, i.e. **the winds near the ground**. We will not worry about the winds aloft yet--we will in the next activity.

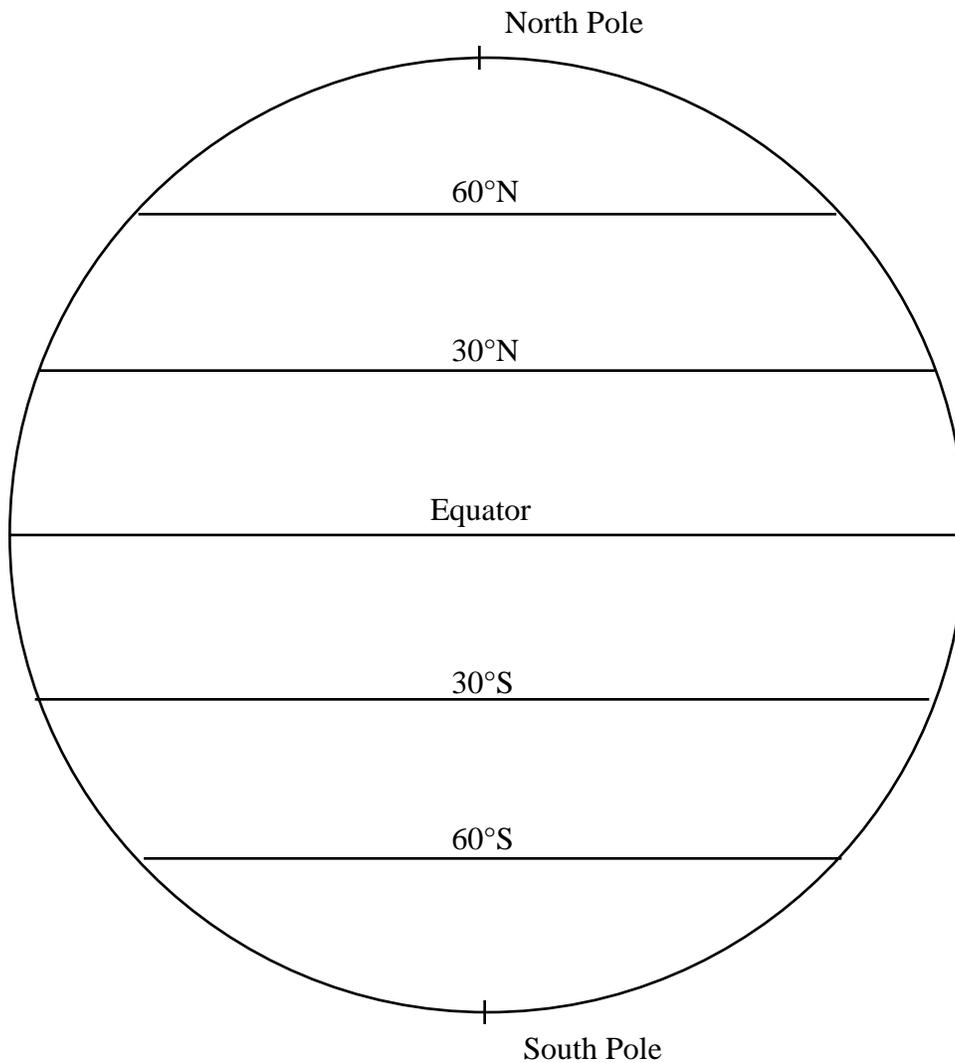
Activity: Look at your model from Activity #1 to see which way the surface winds want to blow in each hemisphere. Figure out which way the wind is deflected and show the direction of the wind, using a curved line with an arrow at the end. Draw these lines all across the globe between 0° and 30° N and between 0° and 30° S (the lines should be different in the northern and southern hemispheres).



1. Are the trade winds in the northern hemisphere easterly (out of the east) or westerly (out of the west)? Why?
2. Are the trade winds in the southern hemisphere easterly (out of the east) or westerly (out of the west)? Why?

Lab Activity #6: Adding the Coriolis Effect to the Convection Model--Winds Aloft

Activity: Look at your model from Activity #1 to see which way the winds aloft want to blow in each hemisphere. Figure out which way the wind is deflected and show the direction of the wind, using a curved line with an arrow at the end. Draw these lines all across the globe



Questions

1. Which way do the winds aloft tend to blow? _____
Why?
2. The jet stream is a narrow band of extra-fast wind aloft. Which way do the jet-stream winds blow? Why?
3. Mid-latitude storms (the kind we get during the winter rainy season) are often caused by diverging winds of the jet stream. These storms are always pushed along by the jet stream. Which direction do these storms tend to migrate? Why?