NAME ______________________________

DATE ______________________________

Carolina EcoKits™:
Climate Mechanisms

Introduction

It is easy to take for granted that Arctic and Antarctic regions are cold and that areas near the equator are much hotter. We understand that some regions of the earth experience seasons characterized by fluctuating temperatures and amounts and types of precipitation, while in other regions these environmental conditions remains relatively constant. However, these conditions are the result of numerous factors and influences that collectively determine global climate.

To understand these mechanisms, it is important first to distinguish between weather and climate. "Weather" describes short-term, specific conditions in an area, such as temperature range, wind strength and direction, precipitation type and amount, humidity, and cloud cover in a specific region on a particular day. "Climate" refers to the long-term, collective, cumulative effects of these conditions on the region.

Mechanisms that affect global climate patterns include (1) the tilt of the earth and the rotation of the earth on its axis, (2) uneven heating of the earth's surface due to uneven distribution of radiant solar energy, (3) global air and water circulation and convection currents set in motion by other mechanisms, and (4) the interactions of major air, land, and water masses, including the Coriolis effect. Using a model globe and other materials, your group will explore important aspects of these mechanisms in greater detail over the course of these laboratory activities.

Activity 1: The Earth in Space

Background

The earth rotates from west to east around a north-south axis. The axis upon which the earth spins is tilted at a 23.5° angle relative to the plane in which the planet orbits the sun. The points on the planet that delineate the axis of rotation are named the North Pole and the South Pole. Viewed from space at the North Pole, the earth rotates counterclockwise. The imaginary line drawn perpendicular to the planet's axis of rotation at an equal distance from the North and South poles is called the equator. Over the course of the earth's annual orbit, due to it's tilt and rotation, the planet receives overall more solar radiation nearer the equator than it does at locations closer to the poles.

Distance from the equator is measured in degrees. Imagine measuring the curve of the earth on a protractor, with the equator at the origin (0°). The Tropic of Cancer lies 23.5° north of the equator, and the Tropic of Capricorn lies 23.5° south of the equator. The Arctic Circle lies 66.5° north of the equator, and the Antarctic Circle lies 66.5° south of the equator. The poles are, of course, 90° north and south of the equator.

Consider two points on the earth, one at the North Pole (i.e., at the earth's axis of rotation) and another point at the equator. Over the course of one rotation of the planet, the point at the North Pole would rotate once, moving in an exceedingly small circle. In the same amount of time, however, the point on the equator would have traveled, relative to the point at the pole, in a great circle almost 25,000 miles in circumference at a speed of over 1,000 miles per hour! Thus, the earth is moving faster at the equator than it is at the poles, and its speed is proportionally faster or slower at points between these.

Materials

globe	wet-erase marker
string	ruler

Procedure

1. Assume that the globe is the earth. Use the wet-erase marker to label the following major circles of latitude on the globe: the Arctic Circle, the Antarctic Circle, the Tropic of Cancer, the Tropic of Capricorn, and the equator.
2. Design a method to use the string and ruler to measure the circumference of the globe at the major circles of latitude.
3. Answer the questions for Activity 1.

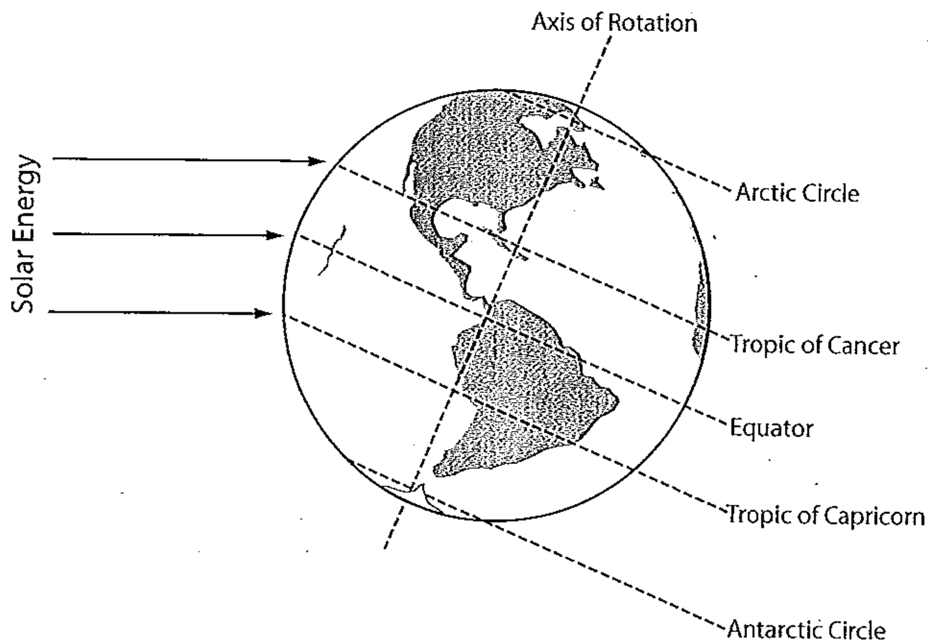
Activity 2: Solar Energy Distribution

Background

The sun gives off vast amounts of energy, including light and heat, and some of this energy reaches the earth as it orbits the sun. Some of the solar energy is reflected by the ozone layer in the earth's upper atmosphere. The ozone layer's reflective properties help prevent solar rays from damaging and destroying living organisms on the earth's surface. Some solar energy is absorbed by greenhouse gases, such as carbon dioxide, in the earth's atmosphere. Greenhouse gases help warm the atmosphere, and certain amounts of these gases can be beneficial to life. Some solar energy passes through the atmosphere and reaches the earth's surface. Some of the heat is absorbed and some is reflected off the earth's surface back into the atmosphere, where it can be absorbed by greenhouse gases. The amount of solar energy that any particular region on Earth receives is based on the mostly spherical shape of the earth, the tilt of the earth's axis, and the angle of the sun's rays.

Regions close to the equator receive the most solar energy overall because these areas remain closer to the sun over the course of earth's orbit, while the regions near the North and South poles receive less solar energy over the course of a year because these regions remain farther from the sun.

Annual seasonal changes can be attributed to the tilt of the earth. On June 21st, the northern portion of the earth's axis tilts toward the sun, and the regions at the Tropic of Cancer receive the most direct sunlight. Regions of the Northern Hemisphere experience the summer solstice, or the most daylight hours of the year. Conversely, regions of the Southern Hemisphere experience the fewest daylight hours of the year. On this day, the Antarctic Circle receives no sunlight. The opposite occurs on December 21st. On this day, the Tropic of Capricorn receives the most sunlight, and regions of the Southern Hemisphere experience the summer solstice, while regions of the Northern Hemisphere experience winter solstice. On December 21st, the Arctic Circle receives no sunlight.



Winter in the Northern Hemisphere, summer in the Southern Hemisphere

Materials

- inflatable globe
- flashlight

Procedure

1. Hold the inflatable globe upright, with the North Pole facing directly upward and the South Pole facing downward.
2. Have one person hold a flashlight and point the light at the equator of the globe.
3. Observe how the light from the flashlight is distributed across the globe.
4. Tilt the earth slightly. Consult the preceding figure to get an idea of the tilt of the earth's axis.
5. Have one person hold the globe and (without blocking the light) move in a circle around the person holding the flashlight. This represents the orbit of the earth around the sun.
6. a. Shine the flashlight perpendicular to the globe, directly at the equator. As the globe orbits the flashlight, turn the flashlight so that it is always shining on the globe.

   b. As you do so, observe how the light is distributed across the globe at different points of the globe's rotation. Note the amount of "sunlight" received at the equator, at the poles, at the Tropic of Capricorn, and at the Tropic of Cancer, and consider how the amount ot solar energy received would affect each region's climate.
7. Answer the questions for Activity 2.

Activity 3: Convection

Background

An air mass is a body of air that is characterized by a particular temperature and humidity. Air masses usually cover hundreds of thousands of square miles and have temperatures and humidities similar to the area where they originate. Polar air masses are those originating between the Arctic Circle and the North Pole or between the Antarctic Circle and the South Pole; they are characteristically cold. Tropical air masses are those originating between the Tropic of Cancer and the Tropic of Capricorn; they are warm air masses. Maritime air masses form over the ocean; they are very moist. Continental air masses, as their name implies, form over land; they tend to contain less moisture than maritime air masses. There are, therefore, four basic types of air masses. Their names, abbreviations, and traits are as follows:

continental polar (cP): a cold, dry air mass

continental tropical (cT): a warm, dry air mass

maritime polar (mP): a cold, moist air mass

maritime tropical (mT): a warm, moist air mass

As air molecules are heated, they gain energy and move apart from one another, increasing the volume of the air mass and decreasing its density. As its density decreases, the air mass rises. When air molecules cool, they move closer together, increasing in density. A convection current forms in the atmosphere when cool, dense air moves toward a source of heat, becomes warmer and less dense, then rises and moves away from the heat source, and then cools and sinks again. The differing density of air masses leads to convection currents in the atmosphere.

Materials

- pipet
- vial and cap
- convection fluid
- food coloring
- paper towels
- hot plate

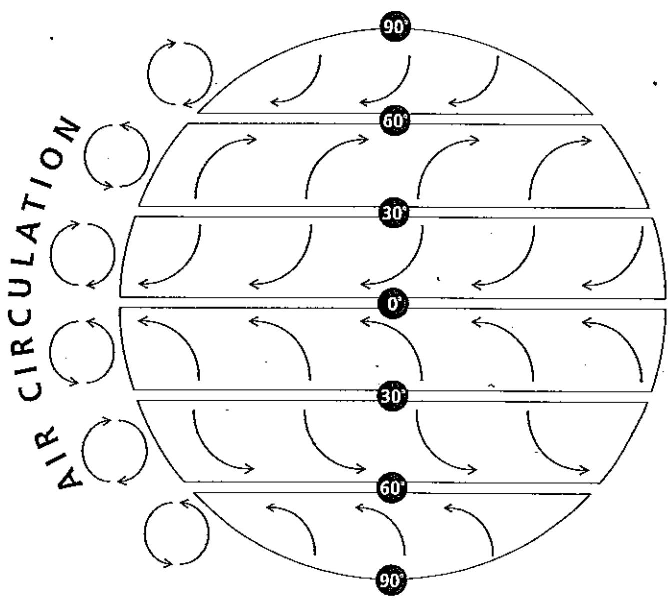
Procedure

1. Use a pipet to fill the vial with convection fluid.
2. Add 1 drop of food coloring to the convection fluid.
3. Tightly cap the vial, and invert the vial several times to evenly distribute the food coloring.
4. Place the vial on a hot plate set on its lowest heat setting.
5. As the convection fluid heats up, observe the currents in the fluid.
6. Answer the questions for Activity 3.

Activity 4: The Coriolis Effect

Background

The Coriolis effect is the name given to the phenomenon that objects (including air masses) moving in a straight path on an object rotating at a constant speed appear to be deflected to one side of their path when viewed from the frame of reference of the rotating object, due to differences in relative velocity and the turning of the frame of reference. The amount of deflection is determined by both the speed and latitude of the moving object. The greater the speed, the greater the deflection force exerted on the object. This force is named in recognition of the French mathematician and engineer Gaspard Gustave Coriolis (1792–1843), a pioneer in the physics of work, energy, and the forces that affect rotating systems.

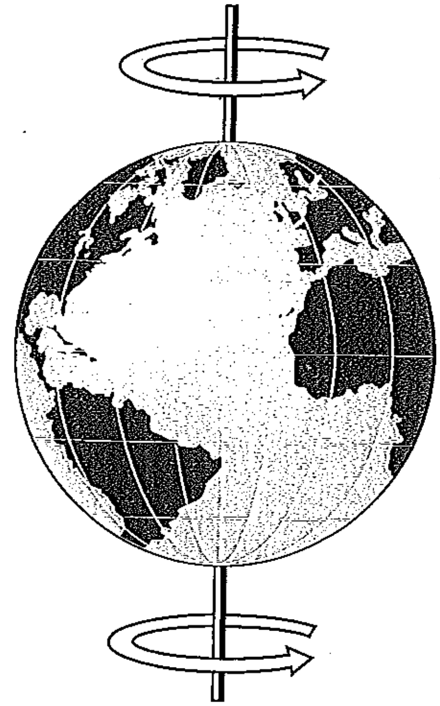


How does this force relate to the other mechanisms that affect global climate? Consider that, in the absence of other forces, wind moving in a straight line at a certain speed will continue to do so. However, as you know, many forces are at work. In addition to pressure gradients, convection currents, and other factors, the movement of air masses across the earth's surface is affected by the earth's rotation. Because the earth's surface moves more quickly at the equator than it does at the poles, winds in the Northern Hemisphere are deflected to the right, and winds in the Southern Hemisphere are deflected to the left. The Coriolis force not only affects the path of large air masses, it also affects the rotation of large storm systems including hurricanes and typhoons, as well as the movement of ocean currents.

Materials

- inflatable globe
- wet-erase marker

Procedure



Note: Move the pen across the surface of the globe at the same speed in each step of this activity.

1. Have one partner hold the globe while another partner uses the marker to draw a line on the globe from the North Pole to the equator.
2. Have one partner hold the globe and rotate it counterclockwise as viewed from the North Pole, as shown in the figure. While the globe is rotating, have another partner use the wet-erase marker to draw a single line from the North Pole to the Arctic Circle, then back from the Arctic Circle to the North Pole.
3. Continue to rotate the globe counterclockwise while one partner draws a single line from the Arctic Circle to the Tropic of Cancer, then back to the Arctic Circle.
4. Continue to rotate the globe counterclockwise while one partner draws a single line from the Tropic of Cancer to the equator, then back to the Tropic of Cancer.
5. Continue to rotate the globe counterclockwise while one partner draws a single line from the equator to the Tropic of Capricorn, then back to the equator.
6. Continue to rotate the globe counterclockwise while one partner draws a single line from the Tropic of Capricorn to the Antarctic Circle, then back to the Tropic of Capricorn.
7. Continue to rotate the globe counterclockwise while one partner draws a single line from the Antarctic Circle to the South Pole, then back to the Antarctic Circle.
8. Study the lines drawn on the globe, and then answer the questions for Activity 4.

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Pre-laboratory Questions

1. Briefly describe the climate where you live. Provide details about the temperature and the amount and type of precipitation received in your region. Describe any seasonal variations.

2. What factors do you think might influence the climate of your particular region?

Questions

Activity 1: The Earth in Space

1. Describe the method you used to measure the globe in Activity 1. Provide measurements for these major circles of latitude.
   a. Arctic Circle ________
   b. Tropic of Cancer ________
   c. Equator ________
   d. Tropic of Capricorn ________
   e. Antarctic Circle ________
2. How many times greater is the distance around the equator than the Arctic Circle? During a full rotation of the earth, a point on the equator travels at a velocity of 465.1 meters per second. Use your measurements to determine the velocity of the earth at a point on the Arctic Circle.

3. How do local differences in the rotational velocity of the earth affect the speed of air masses?

Activity 2: Solar Energy Distribution

1. Which regions received the most light? Which regions received the least light?

2. How does June in the Northern Hemisphere compare with June in the Southern Hemisphere?

3. How does the amount of sunlight that a particular region receives influence the climate?

Activity 3: Convection

1. What happens to the convection fluid as it heats up? How might this relate to masses of heated air?

2. What do you expect will occur as air masses move over cold locations? Hot locations? How does this movement of air masses influence climate?

3. What type or types of air masses originate from near the equator? From near the North Pole and South Pole? How do the qualities of these air masses differ depending on whether they form over land or over an ocean?

4. What climate would regions where air masses from the equator and the poles collide probably have? Where would you expect to find these regions?

5. Carbon dioxide is a greenhouse gas that causes excess solar energy to be trapped in the form of heat in the atmosphere. How do you think carbon dioxide affects convection currents?

Activity 4: The Coriolis Effect

1. As the globe rotated counterclockwise, what happened to the line that was being drawn, observed from a point above the North Pole?

2. Based on your observations, how does the earth's clockwise rotation affect the movement of air masses in the atmosphere?

3. Why is the globe an imperfect model of the earth?

4. Although it is near the Atlantic Ocean, the northwest coast of Africa is characterized by hot, dry deserts. However, the Caribbean, at approximately the same latitude, possesses a hot, moist climate and even supports rainforests. Using your knowledge of the Coriolis effect, explain why this is true.