**Hurricane Winds**

**Hurricanes: Science and Society**

**www.hurricanescience.org**

**Inquiry Questions:**

How strong are the winds in a hurricane?

What causes the wind to blow?

What is the pressure in a hurricane?

**Introduction:**

Hurricanes are among the most powerful natural hazards known to humankind. During a hurricane, residential, commercial, and public buildings, as well as critical infrastructure such as transportation, water, energy, and communication systems may be damaged or destroyed by several of the impacts associated with hurricanes. Wind is one of the major perils associated with hurricanes and can be tremendously destructive and deadly.

**Objectives:**

To understand the relationship between wind and pressure.

To understand hurricane circulation.

**Materials:**

* Graph paper
* Transparencies or sheet protectors
* Markers

**Procedure:**

1. Write down your predictions about wind speed.
2. Make a graph of the hurricane wind speed vs. time on graph paper using the data table provided. Note that for most hurricane reports, there will be data points each day, every six hours.
3. Clip a piece of graph paper behind a transparency (or put the paper in a sheet protector).
4. On the transparency/sheet protector, make a graph of the hurricane pressure vs. time. Size your graph to match the axis of the wind speed graph.
5. Overlay the wind speed and the pressure graph.
6. Based on the two graphs, what conclusions can you make about wind speed and pressure in a hurricane?

**Discussion Questions:**

1. What do you observe about the relationship between wind speed and pressure in a hurricane?
2. Why are wind speed and pressure related?
3. How did you overly your graphs? Why?
4. What other hurricane measurements could you graph or plot to better understand hurricane intensity?

**Vocabulary:**

Cyclone

An atmospheric closed circulation rotating counter-clockwise in the Northern Hemisphere.

Hurricane

A tropical cyclone with maximum sustained winds of 119 km/h (74 mph) or greater. The term "hurricane" is used for Northern Hemisphere tropical cyclones east of the International Dateline to the Greenwich Meridian. The term "typhoon" is used for Pacific tropical cyclones north of the equator, west of the International Dateline.

Pressure

In this case, we are generally talking about atmospheric pressure. Pressure is a force per unit area.

Pressure Gradient

If the pressure is different in two parts of the atmosphere next to each other, there will be a greater force on one side. The part with a greater pressure will exert a force on the other part and this is called the pressure gradient force.

Tropical Cyclone

A warm-core non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters, with organized deep convection and a closed surface wind circulation about a well-defined center.

Tropical Depression

A tropical cyclone in which the maximum sustained surface wind speed is 62 km/h (38 mph) or less.

Tropical Storm

A tropical cyclone in which the maximum sustained surface wind speed ranges from 63 km/h (39 mph) to 118 km/h (73 mph).

Additional glossary words can be found on the Hurricanes: Science and Society site: http://www.hurricanescience.org/glossary/

**TEACHER STRATEGIES**

**Approximate Time Required:**

The activity takes 1 class period. The activity is designed as an introduction to hurricanes.

**Instructional Strategies:**

The basic concept is that by graphing wind speed and pressure data from a hurricane, the student will gain an understanding of the relationship between pressure and wind speed in a hurricane. Starting from the pressure-wind speed relationship should allow for a discussion of how the winds in a hurricane work and what drives a hurricane. Overlaying the graphs allows different graphic orientations to be explored without making a new graph. Students can do this in groups of two where each student makes one graph. They will need to work together to get the scale the same.

Any hurricane can be chosen for this activity. Hurricane reports can be found on the National Hurricane Center website in the seasons archive - http://www.nhc.noaa.gov/pastall.shtml. The reports are in the first item on the page - **Hurricane Season Tropical Cyclone Reports.** Choose a year and then you should see a list of hurricanes . Every hurricane report has a best track data table, and often has nice graphs and images as well.

**Extensions:**

1) Use a hurricane tracking chart to plot the locations of the hurricane as a first activity (tracking charts available at http://www.nhc.noaa.gov/tracking\_charts.shtml). Relate the pressure and wind graphs to the track of the hurricane. Particular areas to look at are regions of warm water that year and approaches to land.

2) Plot additional information such as sea surface temperature, vertical sheer, wave heights, or storm surge height. This data, or links to this data, can be found on the Hurricanes: Science and Society website - www.hurricanescience.org - and the National Hurricane Center website - http://www.nhc.noaa.gov/.

**Standards Addressed:**

**Ocean Literacy: Essential Principles and Fundamental Concepts**

Essential Principle 3: The ocean is a major influence on weather and climate.

b**.** The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.

Essential Principle 6: The ocean and humans are inextricably interconnected.

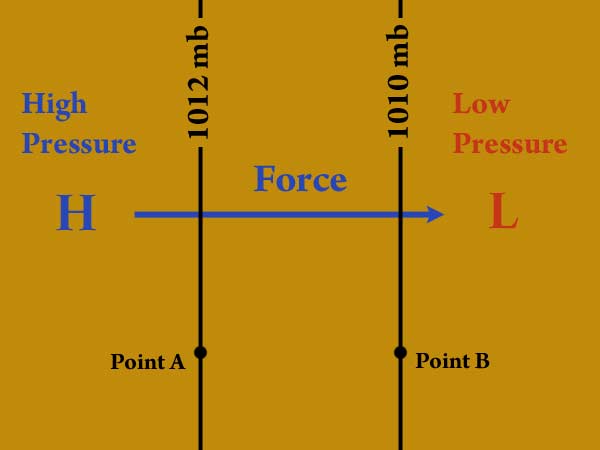
f. Coastal regions are susceptible to natural hazards (tsunamis, hurricanes, cyclones, sea level change, and storm surges).

**Background Information:**

Material from *Hurricanes: Science and Society* - www.hurricanescience.org.

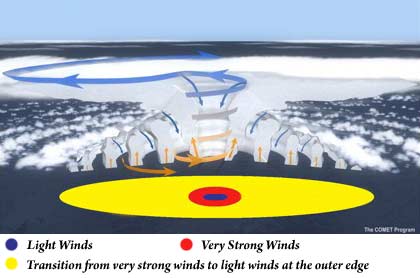
**Pressure Gradient:**

http://www.hurricanescience.org/science/basic/pressure/

Pressure is a force per unit area. In this case, we are generally talking about atmospheric pressure or water pressure and we use units of millibars (mb). Atmospheric pressure at the Earth's surface is the result of the weight of the air above the surface. If the pressure is different in two parts of the atmosphere next to each other, there will be a greater force on one side. The part with a greater pressure will exert a force on the other part and this is called the pressure gradient force. If there are no other forces, then air will flow from the higher pressure to the lower pressure creating wind. Pressure gradients in the atmosphere are typically caused by air of different temperatures.

**Hurricane Structure:** http://www.hurricanescience.org/science/science/hurricanestructure/

A mature hurricane is nearly circular in shape. The winds of a hurricane are very light in the center of the storm (blue circle in the image below) but increase rapidly to a maximum 10-50 km (6-31 miles) from the center (red) and then fall off slowly toward the outer extent of the storm (yellow).



The size of a hurricane's wind field is usually a few hundred miles across, although the size of the hurricane-force wind field (with wind speed > 117.5 km/h [73 mph]) is typically much smaller, averaging about 161 km (100 miles) across. The area over which tropical storm-force winds occur is greater, ranging as far out as almost 500km (300 miles) from the eye of a large hurricane.

In mature hurricanes, strong surface winds move inward towards the center of the storm and encircle a column of relatively calm air. This nearly cloud-free area of light winds is called the eye of a hurricane and is generally 20-50 km (12-30 miles) in diameter. From the ground, looking up through the eye, skies may be so clear that you might see the stars at night or the sun during the day. Surrounding the eye is a violent, stormy eyewall, formed as inward-moving, warm air turns upward into the storm. Usually, the strongest winds and heaviest precipitation are found in this area.

**Primary Circulation**

http://www.hurricanescience.org/science/science/primarycirculation/

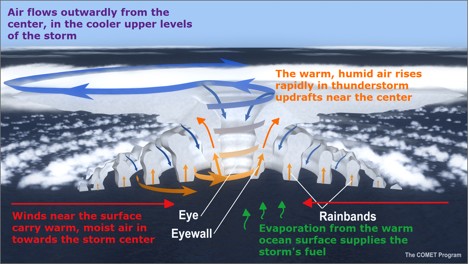
A hurricane’s primary circulation involves four main forces: the pressure gradient force, the Coriolis force, the centrifugal force, and friction. The pressure gradient force always tries to move air from areas of higher pressure to areas of lower pressure. Since the center (eye) of a hurricane contains the lowest atmospheric pressure found in the storm, the pressure gradient force tries to pull air towards the center of the hurricane. In the Northern Hemisphere, air that is being pulled towards the center of the hurricane is deflected towards the right because of the Coriolis force, which is a result of the Earth’s own rotation.

**Hurricane Secondary Circulation**

http://www.hurricanescience.org/science/science/development/

In the lower troposphere, air parcels carry heat energy obtained from the ocean. These air parcels spiral inward towards the center of the developing hurricane. Once an air parcel reaches the hurricane’s eyewall, it turns upward and rises due to a process called convection. The added heat from the ocean causes the air rising in the eyewall to be warmer than the surrounding environment, allowing it to continue to rise.

Once the air parcel reaches the tropopause, the boundary between the troposphere and the stratosphere, it begins to spiral outward. As the air parcel spirals outward, it loses heat to outer space by long wave radiation. At some point far away from the center of the hurricane, the cooled air parcel begins to sink back towards the lower troposphere. Then, this cycle, which is known as a hurricane’s secondary circulation, is complete.



Since the conversion of heat energy to mechanical energy drives the hurricane’s secondary circulation, a hurricane can be treated as a heat engine. For the engine to continue working, air must flow into the system (the hurricane) at a higher temperature than it exits the system. As long as the air parcels can rise in the eyewall and then spiral outward at the tropopause faster than other air parcels can spiral inward towards the eyewall in the lower troposphere, the central pressure in the developing hurricane will fall. A falling central pressure is one way to measure how much a hurricane is intensifying. Increasing winds increase the transfer of heat from the ocean, creating a positive feedback. When the central pressure falls, air parcels begin to spiral inward towards the eyewall faster to fill the vacuum. If the air parcels spiral inward faster, then the maximum wind speed will increase. Increasing maximum wind speed is another way to measure how much a hurricane is intensifying (more intense hurricanes have faster maximum sustained wind s). Eventually, a hurricane may reach a near steady state (in theory), where the heat energy coming in from the ocean is balanced by the energy lost to frictional dissipation in the atmosphere. In this “quasi-steady state”, neither the hurricane’s central pressure nor its maximum wind speed changes much over time. In reality, though, a hurricane rarely remains in quasi-steady state for an extended period of time because changes in the surrounding atmosphere, the underlying ocean, or the hurricane’s internal structure can cause the hurricane’s intensity to change.

Table 1. Best track for Hurricane Wilma, 15-25 October 2005. Extracted from the NHC Tropical Cyclone Report for Hurricane Wilma, published January 2006.

| Date/Time  (UTC) | Latitude  (°N) | Longitude  (°W) | Pressure  (mb) | Wind Speed  (kt) | Stage |
| --- | --- | --- | --- | --- | --- |
| 15 / 1800 | 17.6 | 78.5 | 1004 | 25 | tropical depression |
| 16 / 0000 | 17.6 | 78.8 | 1004 | 25 | " |
| 16 / 0600 | 17.5 | 79.0 | 1003 | 30 | " |
| 16 / 1200 | 17.5 | 79.2 | 1003 | 30 | " |
| 16 / 1800 | 17.5 | 79.4 | 1002 | 30 | " |
| 17 / 0000 | 17.4 | 79.6 | 1001 | 30 | " |
| 17 / 0600 | 16.9 | 79.6 | 1000 | 35 | tropical storm |
| 17 / 1200 | 16.3 | 79.7 | 999 | 40 | " |
| 17 / 1800 | 16.0 | 79.8 | 997 | 45 | " |
| 18 / 0000 | 15.8 | 79.9 | 988 | 55 | " |
| 18 / 0600 | 15.7 | 79.9 | 982 | 60 | " |
| 18 / 1200 | 16.2 | 80.3 | 979 | 65 | hurricane |
| 18 / 1800 | 16.6 | 81.1 | 975 | 75 | " |
| 19 / 0000 | 16.6 | 81.8 | 946 | 130 | " |
| 19 / 0600 | 17.0 | 82.2 | 892 | 150 | " |
| 19 / 1200 | 17.3 | 82.8 | 882 | 160 | " |
| 19 / 1800 | 17.4 | 83.4 | 892 | 140 | " |
| 20 / 0000 | 17.9 | 84.0 | 892 | 135 | " |
| 20 / 0600 | 18.1 | 84.7 | 901 | 130 | " |
| 20 / 1200 | 18.3 | 85.2 | 910 | 130 | " |
| 20 / 1800 | 18.6 | 85.5 | 917 | 130 | " |
| 21 / 0000 | 19.1 | 85.8 | 924 | 130 | " |
| 21 / 0600 | 19.5 | 86.1 | 930 | 130 | " |
| 21 / 1200 | 20.1 | 86.4 | 929 | 125 | " |
| 21 / 1800 | 20.3 | 86.7 | 926 | 120 | " |
| 22 / 0000 | 20.6 | 86.8 | 930 | 120 | " |
| 22 / 0600 | 20.8 | 87.0 | 935 | 110 | " |
| 22 / 1200 | 21.0 | 87.1 | 947 | 100 | " |
| 22 / 1800 | 21.3 | 87.1 | 958 | 85 | " |
| 23 / 0000 | 21.6 | 87.0 | 960 | 85 | " |
| 23 / 0600 | 21.8 | 86.8 | 962 | 85 | " |
| 23 / 1200 | 22.4 | 86.1 | 961 | 85 | " |
| 23 / 1800 | 23.1 | 85.4 | 963 | 90 | " |
| 24 / 0000 | 24.0 | 84.3 | 958 | 95 | " |
| 24 / 0600 | 25.0 | 83.1 | 953 | 110 | " |
| 24 / 1200 | 26.2 | 81.0 | 950 | 95 | " |
| 24 / 1800 | 28.0 | 78.8 | 955 | 105 | " |
| 25 / 0000 | 30.1 | 76.0 | 955 | 110 | " |
| 25 / 0600 | 33.3 | 72.0 | 963 | 100 | " |
| 25 / 1200 | 36.8 | 67.9 | 970 | 90 | " |
| 25 / 1800 | 40.5 | 63.5 | 976 | 75 | hurricane |
| 26 / 0000 | 42.5 | 60.0 | 978 | 60 | extratropical |
| 26 / 0600 | 44.0 | 57.5 | 982 | 55 | " |
| 26 / 1200 | 45.0 | 55.0 | 986 | 50 | " |
| 26 / 1800 | 45.5 | 52.0 | 990 | 40 | " |
| 27 / 0000 |  |  |  |  | merged with low |