COAST

Written by Howard Walters

On the cutting edge…
On average, every three years approximately five hurricanes strike the United States coastline, killing from 50 to 100 people from Maine to Texas, Hawaii, and Caribbean and tropical territories. Massive in scale, the winds and rains associated with a hurricane can extend as far as 400 miles from the calm center or eye of the storm. A single hurricane making landfall on a southern coast of the continental United States can impact the lives of tens of millions of people, and wreck havoc resulting in billions of dollars in property damage. Scientists are striving to understand the meteorological phenomena which guide the formation and strength of hurricanes to better predict the path of these killer storms to save lives and reduce property loss.

Coastal Hazards: Hurricanes

Lesson Objectives: Students will be able to do the following:
- Describe how and where hurricanes form
- Discuss the negative impacts of hurricanes on coastal communities
- Indicate appropriate preparation action when at-risk from an approaching storm

Key Concepts: latitude and longitude, sustained winds, low pressure zone, Coriolis effect, Saffir-Simpson Scale, Federal Emergency Management Agency, mitigation.

What is a Hurricane?

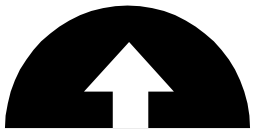
Hurricanes are widely considered the most destructive storm systems on our planet. A hurricane is a tropical storm with winds that have reached a sustained speed of 74 miles per hour. **Sustained winds** are defined as a 1-minute average wind measured at approximately 33 feet (10 meters) above the surface of the ocean.

All hurricanes—even the most catastrophic—begin over warm oceanic waters where atmospheric conditions result in low-pressure zones. These generally form in the tropical zones of the planet and are accompanied by severe thunderstorms, heavy rainfall, and—in the northern hemisphere—a counterclockwise circulation pattern around the low pressure "**eye**" of the storm. This rotation results in an uneven distribution of storm damage due to coastal waters being pushed onshore on the east side of the

storm, but offshore on the west side of the storm. Further, this rotation results in a difference in the speed of the winds in a storm due to rotational force with the winds being strongest on the east side of a storm (assumed to be moving due north) and slightly weaker on the west side of the storm.

In the northern hemisphere, the winds in a hurricane rotate counter-clockwise due to the **Coriolis effect**. When a low pressure **front** starts in the northern hemisphere, the surface winds will flow inward trying to fill the low pressure and will be deflected to the right as a result of the rotation of the earth. This results in the counter-clockwise rotation. The opposite deflection occurs south of the equator where storms rotate clockwise.

Hurricanes contain tremendous energy obtained from the warmth of the tropical waters over which they form. As the warm, humid air rises, it cools, releasing heat energy. This heat warms the surrounding air causing it to rise. Rising warm air is replaced in the lower atmosphere by cooler air that rushes in to replace it as previously described. This cooler air is warmed by the ocean and the cycle continues. The heat from the warm ocean is the "fuel" for the hurricane; hence the association of a hurricane "season" with the seasons of the year when the oceanic waters are warmest.



Due to the tremendous potential for loss of human life and property, hurricanes are tracked by the National Oceanic and Atmospheric Administration (NOAA) through satellite imagery and in cooperation with the United States Air Force 53rd Weather Reconnaissance Squadron, known as the Hurricane Hunters. These men and women fly specially equipped aircraft through the tropical storms and record meteorological data. These data have allowed scientists to enhance their capabilities to accurately forecast the track of these storms, which has resulted in more effective and efficient community response plans to preserve life and property.

What are the Impacts of Hurricanes?

The United States classifies hurricanes according to the strength of their winds using the **Saffir-Simpson Hurricane Scale**. This scale estimates the potential damage associated with wind speed, storm surge, and flooding for coastal governments and property owners and is highly variable depending on factors including:

- Does the storm make landfall during high or low tides;
- What is the average elevation above sea level of the area impacted; and
- Is the area of impact on the east or west side of the storm?

The Saffir-Simpson Scale includes five categories of storms from level 1, with sustained winds from 74-95 mph, to level 5, with sustained winds in excess of 156 mph. Damage from hurricanes ranges on this scale from, at the weakest level, primarily to shrubbery, trees, and unanchored structures. Poorly constructed signs and garages can be impacted. Additionally, low-lying coastal roads can be flooded, piers can be damaged and small crafts in exposed anchorage can be torn from their moorings. At the extreme end of the scale, a level 5 or catastrophic storm results in shrubs and trees being uprooted, broken, or blown down; considerable damage to roofs of buildings; and all signs blown down. Further, severe and extensive damage to windows and doors and complete failure of roofs on many buildings occurs. Small buildings are completely overturned or blown away and many mobile homes are destroyed. From the storm surge, major damage occurs to the lower floors of all structures less than 15 feet above sea level within 500 yards from the shore.

Inland, rainfall from thunderstorms can accumulate excessively. On June 11, 2001, **Tropical Storm** Allison dropped over 30 inches of rain on Houston, Texas in a 24-hour period. Such rain amounts are typical and result in flooding of low elevation roadways and properties, and torrential flows in otherwise serene streams and rivers. River levels can rise a dozen feet in a matter of hours overflowing their banks and flooding entire communities. Mudslides in the Appalachian Mountain areas of the United States associated with rains from Hurricane Camille in 1969 took over one hundred lives and destroyed entire towns.

After storms pass, communities must manage the significant tasks of clean-up and debris disposal, and the restoration of infrastructure and utility services in the face of downed electrical and telephone lines, contaminated water lines, and roads and bridges "washed out" by flooding. Additionally, food shortages, damaged or destroyed housing, and maintaining hygiene during water and electricity outages pose the threat of disease and emotional debilitation.

How Do Communities Prepare for Hurricanes?

Hurricanes can result in the loss of human life and serious damage to personal and community properties. Consequently, it is important for people who live in areas at-risk from these storms to understand how to prepare for the impact to reduce the risks described in the previous section. The Federal Emergency Management Agency (FEMA**)** has prepared recommendations for people living in these coastal communities that are widely disseminated by local media at the beginning of the hurricane "season," i.e. June 1 through November 30 each year, and also when storms are pending.

Of primary importance, individuals should identify evacuation routes, the conditions under which they should or must evacuate, and the preparatory steps to secure their property before leaving. Coastal communities identify—generally by elevation above sea level—mandatory evacuation areas—from which citizens are required to exit before storms make **landfall**. Many injuries and deaths associated with storms are from people who fail to evacuate early enough and are trapped on road-ways by rising waters, downed electrical lines, or fallen trees.

FEMA recommends a route leading from 20 to 50 miles inland to an approved storm shelter.

For individuals who are not required to evacuate, disaster supplies should be on hand assuming a loss of electricity and a safe supply of drinking water after the storm. Additionally, FEMA recommends the following items be acquired:

- Flashlight and extra batteries,
- Portable, battery-operated radio,
- First aid kit and manual,
- Emergency food and water,
- Non-electric can opener,
- Essential medicines,
- Cash and credit cards, and
- Sturdy shoes.

Additionally, all family members should know how to respond after a hurricane. Children should know how and when to call 911, police, or fire departments, and how to operate radios. All family members should know how to turn off gas supplies, electricity, and water.

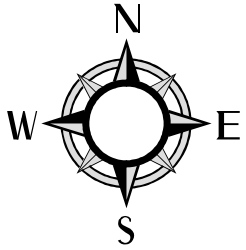
Finally, families should develop an emergency communications plan. In case families are separated from one another during a hurricane, they need a location and timetable for re-establishing contact with one another.

Recent research into storm impacts has resulted in numerous mitigation techniques to lesson the damaging effects of storms. Investing in steps such as strengthening non-reinforced masonry wall, installing wind straps on roof truss systems, raising foundations above flood zones, and installing shutters on all windows reduces hurricane damage significantly.

Activity: Hurricane Georges Web Quest

A single hurricane making landfall on a southern coast of the continental United States can impact the lives of tens of millions of people, and wreck havoc resulting in billions of dollars in property damage. Scientists are striving to understand the meteorological phenomena that guide the formation and strength of hurricanes to better predict the path of these killer storms to save lives and reduce property loss.

Objectives: Students will be able to do the following:
- Describe how and where hurricanes form.
- Discuss the negative impacts of hurricanes on coastal communities.
- Indicate appropriate preparation activities when at-risk from an approaching storm.



Materials:
- Internet capable computer and printer
- Paper and colored pencils
- 3-pronged notebook for project

Procedure: Using the following web sites and related web links, answer the following questions or complete the activities.

Web Sites:
- <www.haznet.org>
- <www.nhc.noaa.gov>

1. Print a Hurricane Tracking Chart.
2. Plot the storm track of Hurricane Georges through the Caribbean. Label each point with its date, wind speed in knots, and pressure in millibars (mB). Draw a line connecting these points, and compare your answer to the "Georges Storm Path Map" web site. (The teacher should review longitude and latitude with students not familiar with these terms.)

Date (at 5:00AM)	Latitude	Longitude	Wind Speed in knots	Pressure in millibars
9-18-98	12.9	45.2	80	978
9-19-98	14.4	51.3	90	970
9-20-98	16.1	57.1	130	939
9-21-98	17.4	63.1	95	967
9-22-98	18.1	68	95	970
9-23-98	19.5	73.3	65	986
9-24-98	21.1	76.7	65	992
9-25-98	23.8	80.7	90	974
9-26-98	25.5	84.5	90	974

3. What day did Hurricane Georges hit Puerto Rico? Write at least three sentences describing the effects of Hurricane Georges on the people of Puerto Rico. Locate, print and include at least two photographs showing the damage caused by this storm.
4. What are the characteristics of a category 5 hurricane (refer to the Safir Simpson scale)? Attach a copy of the Saffir-Simpson Scale to your report.
5. What is GMT (Greenwich Mean Time)? Refer to www.goes.noaa.gov/pr1.html for a live satellite image of Puerto Rico, with current GMT time. If it is 1915Z, what time is it here? Attach a copy of this satellite image to your report.
6. What months of the year do most hurricanes form in the Atlantic Ocean (refer to the FEMA-Atlantic Tropical Storm Formation 1885-1996 page, and attach a copy of this graph to your report)?
7. What is a hurricane and briefly describe how one forms. Attach a copy of a diagram of a hurricane and a satellite photograph/image of a hurricane to your report.
8. Review the Federal Emergency Management Plan for Hurricane Preparation. Print a copy of this Fact Sheet for your report.
9. What aircraft and airborne equipment do the Hurricane Hunters use for airborne weather reconnaissance? Include a diagram of this airplane in your report.
10. Collate all of the above documents or answers into a notebook and submit to your instructor for a grade.

Possible Extensions:

1. Using elevation maps of their local communities, students can identify areas most prone to flooding from storm surges or excess rainfall. Students can contact government planning offices for copies of disaster and flood response plans.
2. Students can research the history of their own communities relative to storm impacts and natural coastal hazards using records located at the web sites indicated above.
3. Teachers can contact the public affairs office of local U.S. Air Force Bases—if available—for classroom speakers on the role of the military in disaster response. State National Guard units can also fulfill this activity.
4. Using the Sea Grant Haznet web site referenced above, students can research other natural coastal hazards and compare disaster response plans from communities at risk for these disasters, i.e. compare southern California earthquake response plans to Gulf of Mexico states' hurricane response plans.

Student Information: Hurricanes

Hurricanes are widely considered the most destructive storm systems on our planet. A hurricane is a tropical storm with winds that have reached a sustained speed of 74 miles per hour.

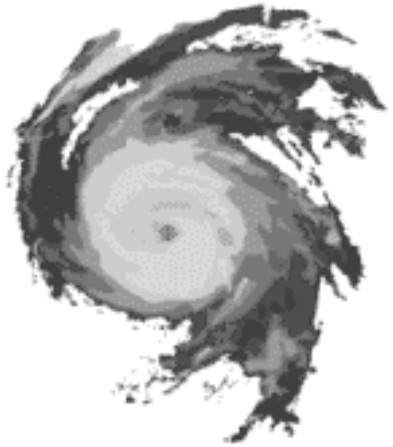
The winds in a hurricane blow in a spiral around a low-pressure center or **eye**. Due to the effects of the Earth's rotation, the winds rotate counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere. This effect is termed the **Coriolis force** or effect.

Hurricanes can be massive, and winds are often seen extending as far as four hundred miles out from the center of the storm. As the higher pressure and cooler air from outside the storm moves to the center of the storm, it contacts the warmer ocean waters and begins to heat. As the air heats, it rises–carrying moisture from the surface to the upper atmosphere. As the air rises, it cools and the moisture condenses forming massive, rain-laden thunderstorms. The released heat energy drives the storm's circular pattern as it moves toward land.

As a hurricane moves onto land, the winds and rain from the storm can produce catastrophic damage. Hurricanes are ranked on the **Saffir-Simpson Scale** from one to five, with five being a catastrophic storm in which entire buildings are blown away. The storm also drives ocean water forward in a **storm surge**. This surge can inundate coastal areas with low elevations and destroy beachfront development. Massive erosion is seen in the wake of these storms.

Moving onto land, the water in the clouds condenses to rain, which has been observed falling in amounts exceeding 24 inches per day. Such rainfall produces flooding in low lying areas, and is generally followed by secondary flooding as rivers and streams overflow their banks, swallowing entire communities under muddy water.

Following the storm, communities are left to clean mountains of debris, including drowned livestock in agricultural regions, flooded homes and businesses, and broken trees and shrubbery. Frequently, electricity and water supplies are interrupted for a period ranging from days to over a week, as utility services are taxed by the width of destruction.



Hurricane Vocabulary

Advisory-official information issued by tropical cyclone warning centers describing all tropical cyclone watches and warnings in effect along with details concerning tropical cyclone locations, intensity and movement, and precautions that should be taken; Advisories are also issued to describe: (a) tropical cyclones prior to issuance of watches and warnings and (b) subtropical cyclones.

Center-the vertical axis or core of a tropical cyclone; It is usually determined by cloud patterns, wind, and/or pressure distributions.

Coriolis Effect-the deflection of air or water bodies, relative to the solid earth beneath, as a result of the earth's eastward rotation

Cyclone-an atmospheric closed circulation rotating counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere

The National Hurricane Center-in Miami, FL is responsible for tracking tropical cyclones in this region.

Eye-the relatively calm center of the tropical cyclone that is more than one half surrounded by a wall cloud

Eye Wall/Wall Cloud-an organized band of clouds immediately surrounding the center of a tropical cyclone; Eye wall and wall cloud are used interchangeably.

Front-the place where air masses meet

Gale Warning-a warning of one-minute sustained surface winds in the range 34 kt (39 mph or 63 km/hr) to 47 kt (54 mph or 87 km/hr) inclusive, either predicted or occurring not directly associated with tropical cyclones

Hurricane/Typhoon-a warm-core tropical cyclone in which the maximum sustained surface wind (using the U.S. 1-minute average) is 64 kt (74 mph or 119 km/hr) or more; The term hurricane is used for Northern Hemisphere cyclones east of the International Dateline to the Greenwich Meridian. The term typhoon is used for Pacific cyclones north of the Equator west of the International Dateline.

Hurricane Local Statement-a public release prepared by local National Weather Service offices in or near a threatened area giving specific details for its county/parish warning area on (1) weather conditions, (2) evacuation decisions made by local officials, and (3) other precautions necessary to protect life and property

Hurricane Season-the portion of the year having a relatively high incidence of hurricanes; The hurricane season in the Atlantic, Caribbean, and Gulf of Mexico extends from June 1 to November 30. The hurricane season in the Eastern Pacific basin extends from May 15 to November 30. The hurricane season in the Central Pacific basin extends from June 1 to November 30.

Hurricane Warning-a warning that sustained winds 64 kt (74 mph or 119 km/hr) or higher associated with a hurricane are expected in a specified coastal area in 24 hours or less; A hurricane warning can remain in effect when dangerously high water or a combination of dangerously high water and exceptionally high waves continue, even though winds may be less than hurricane force.

Hurricane Watch-an announcement of specific coastal areas that a hurricane or a potential hurricane condition poses a possible threat, generally within 36 hours

Landfall- coming ashore

Saffir-Simpson Hurricane Scale-a numbering sequence developed to describe the type of destruction that could be expected from a particular storm

Sustained Winds-1-minute average wind measured at approximately 10 meters above the surface of the ocean

Storm Surge-an abnormal rise in sea level accompanying a hurricane or other intense storm and whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone; Storm surge is usually estimated by subtracting the normal or extreme high tide from the observed storm tide.

Storm Tide-the actual level of seawater resulting from the extreme tide combined with the storm surge

Tropical Cyclone-a warm-core, nonfrontal low-pressure system of synoptic scale that develops over tropical or subtropical waters and has a definite organized surface circulation

Tropical Depression-a tropical cyclone in which the maximum sustained surface wind speed (using the U.S. one-minute average) is 33 kt (38 mph or 62 km/hr) or less

Tropical Disturbance-a discrete tropical weather system of apparently organized convection--generally 100 to 300 nautical miles (nmi) in diameter---originating in the tropics or subtropics, having a nonfrontal migratory character, and maintaining its identity for 24 hours or more; It may or may not be associated with a detectable disturbance of the wind field.

Tropical Storm-a tropical cyclone in which the maximum sustained surface wind speed (using the U.S. one-minute average) ranges from 34 kt (39 mph or 63 km/hr) to 63 kt (73 mph or 118 km/hr)

Tropical Storm Warning-a warning for tropical storm conditions including sustained winds within the range of 34 to 63 kt (39 to 73 mph or 63 to 118 km/hr) that are expected in a specified coastal area within 24 hours or less

Tropical Storm Watch-an announcement that a tropical storm poses or tropical storm conditions pose a threat to coastal areas generally within 36 hours; A tropical storm watch should normally not be issued if the system is forecast to attain hurricane strength.

Hurricane References

Federal Emergency Management Agency (1998). *Fact Sheet: Hurricanes*. The United States Government, <www.fema.gov/library/hurricaf.htm>.

Smith, P. Sean and Brent A. Ford (1999). *Project Earth Science: Meteorology, Second Edition*. The National Science Teachers Association, 227 pp.

Walker, Sharon H. and Howard D. Walters (2000). *Sea Grant Haznet Web Site: K-12 Educational Materials and Resources*. <www.haznet.org>. A project of the National Sea Grant College Program and the Mississippi-Alabama Sea Grant College Program funded through The University of Southern Mississippi College of Marine Sciences.