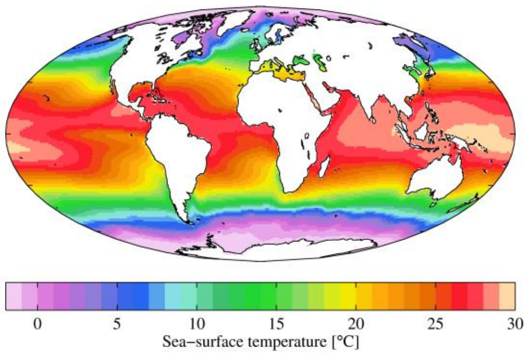
Hurricane Learning Module



Source

Hurricanes are among the largest and most destructive storms on the planet. They can produce winds that exceed 200 mph, storm surge up to 30 feet, massive waves, and torrential rains that can cause deadly flooding. A hurricane is a strong low-pressure system that forms over warm tropical oceans, also called a **tropical cyclone.**

Tropical cyclones require a few things to form:

1. Warm ocean waters (sea surface temperatures ≥ 26.5ºC/80°F)
2. High relative humidity in the troposphere
3. Constant wind speed and direction with height
4. Thunderstorms

Tropical Cyclone Development

Tropical cyclones pass through four distinct stages of development: Tropical Disturbance, Tropical Depression, Tropical Storm and Hurricane. Figure 1 highlights the major features of each stage of development and the essential defining factor in each stage is the sustained wind speed. When a tropical cyclone reaches "Depression" strength, the cyclone is given a number. When it reaches "Tropical Storm" strength, it is assigned a name from the name list in Figure 2. The cyclone will keep this name for the rest of its life.

Figure 1. Stages of development for a tropical cyclone.
Source

Created by Tyra Brown, Nicole Riemer, Eric Snodgrass and Anna Ortiz at the University of Illinois at Urbana-Champaign. 2015-2016. Supported by the National Science Foundation CAREER Grant #1254428.

Hurricane

→large, organized system of intense tropical t-storms circulating around a very deep low-pressure center

→ 74+ mph sustained winds, torrential rains and storm surge 5-30+ feet

Tropical Storm

→Cluster of intense t-storms circulating around a deep low-pressure center with sustained winds of 39 mph – 73 mph

→Assigned a name

Tropical Depression

→Organized cluster of tropical thunderstorms with sustained winds between 22-38 mph

→Surface low-pressure area develops

→Assigned a number

Tropical Disturbance

→Cluster of tropical thunderstorms

→Watched or "investigated" for further development

Saffir-Simpson Scale

If the winds in the tropical cyclone reach 74 mph, it is upgraded to a Category 1 hurricane. Meteorologists use the **Saffir-Simpson scale** (below) to rank a hurricane's strength. This scale is based upon a 1-minute averaged wind speed. To accurately measure the winds, the Hurricane Hunter aircraft will fly into a hurricane and measure its winds with special instruments. To see one of these flights, check out this web page!

Hurricane Hunters

Saffir-Simpson Scale

Category	Wind Speed (mph)
1	74-95
2	96-110
3	111-130
4	131-155
5	>155

Source

Hurricane Names

When a tropical cyclone reaches the "Tropical Storm" stage, the cyclone is named. The name list used to name these storms is given in Figure 2. The name list is recycled over a 7-year period and the names on this list alternate male/female and reflect the geographic region for which the list is created. The names are designed to be short, distinctive and easy to pronounce. There are 21 names on the current name list since the letters Q, U, X, Y and Z are not used. As we learned in 2005, there were 28 named tropical cyclones, which means the name list used that year was completely exhausted! The contingency plan when something like this happens is to use Greek alphabet to name the extra storms. In 2005, we had to name 6 tropical cyclones using the Greek alphabet! The only way a name will come off this list is if it is retired. Hurricane names are only retired if they are so devastating that using that name in the future to name another storm would be insensitive.

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2012	2013	2014	2015	2016	2017
Alberto	Andrea	Arthur	Ana	Alex	Arlene
Beryl	Barry	Bertha	Bill	Bonnie	Bret
Chris	Chantal	Cristobal	Claudette	Colin	Cindy
Debby	Dorian	Dolly	Danny	Danielle	Don
Ernesto	Erin	Edouard	Erika	Earl	Emily
Florence	Fernand	Fay	Fred	Fiona	Franklin
Gordon	Gabrielle	Gonzalo	Grace	Gaston	Gert
Helene	Humberto	Hanna	Henri	Hermine	Harvey
Isaac	Ingrid	Isaias	Ida	Ian	Irma
Joyce	Jerry	Josephine	Joaquin	Julia	Jose
Kirk	Karen	Kyle	Kate	Karl	Katia
Leslie	Lorenzo	Laura	Larry	Lisa	Lee
Michael	Melissa	Marco	Mindy	Matthew	Maria
Nadine	Nestor	Nana	Nicholas	Nicole	Nate
Oscar	Olga	Omar	Odette	Otto	Ophelia
Patty	Pablo	Paulette	Peter	Paula	Philippe
Rafael	Rebekah	Rene	Rose	Richard	Rina
Sandy	Sebastien	Sally	Sam	Shary	Sean
Tony	Tanya	Teddy	Teresa	Tobias	Tammy
Valerie	Van	Vicky	Victor	Virginie	Vince
William	Wendy	Wilfred	Wanda	Walter	Whitney

Figure 2. Atlantic Ocean Basin Hurricane Name List
Source

Tropical Cyclone Tracks

Globally, there are approximately 80 tropical cyclones each year and about 60% of these reach hurricane strength. Figure 3 shows the typical tropical cyclone track for those storms forming in the Atlantic Basin, which includes the Caribbean Sea and Gulf of Mexico. Figure 4 shows all the places on earth where tropical cyclones form and track. One of the most interesting features on this map is that tropical cyclones never form between 5°N and 5°S. In fact, it is impossible for a tropical cyclone to cross the equator! The reason they cannot track between these latitudes or cross the equator is because tropical cyclones rely on the Coriolis force to circulate. The Coriolis force is a force that exists because the earth spins on its axis. It is because of this force that all large-scale low-pressure systems including hurricanes have winds that spin counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. To learn more about the Coriolis force, watch this video! [1]

Coriolis Force (6:09)

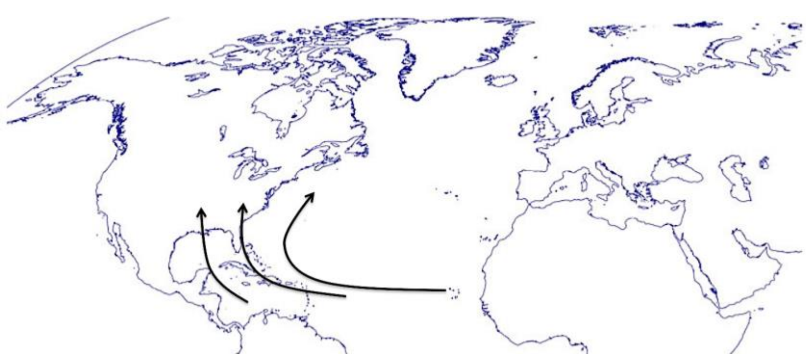

Figure 3. Typical Hurricane Tracks in the Atlantic Ocean Basin

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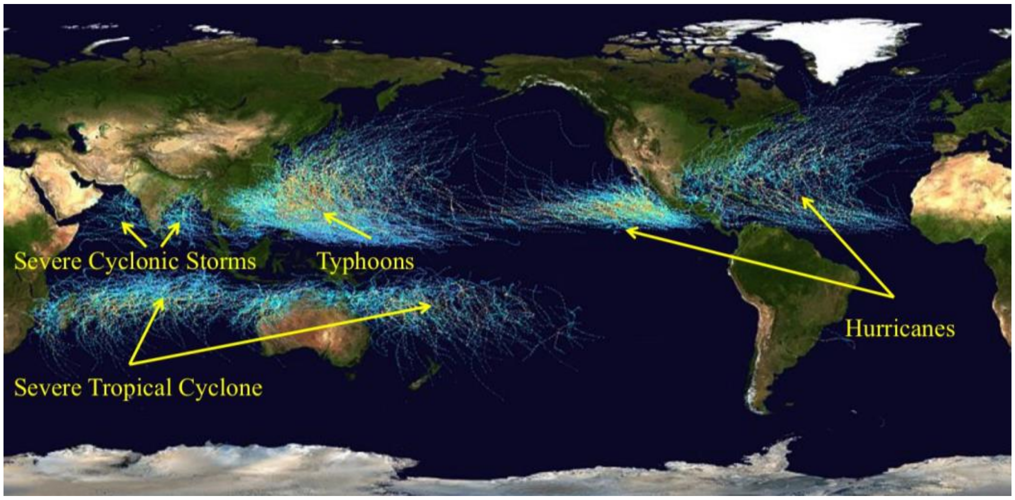

Figure 4. Lines show tropical cyclone tracks and the color shows storm intensity from 1985 – 2006.
Source

Tropical cyclones rarely form north of 30°N or south of 30°S because the waters there are too cold. That is also the reason why the South Atlantic Ocean and the Pacific Ocean near South America do not experience tropical cyclones – the water is too cold to support the development of a tropical cyclone. One last thing to note in Figure 4, tropical cyclones have different names depending on where they form. While we call them hurricanes in the U.S., in Japan they are called typhoons, cyclones in India and Australia. These are just different names for the same type of weather system.

Atlantic Ocean Hurricane Season

A typical hurricane season in the U.S. will include 10 named tropical cyclones, 6 hurricanes and 3 major hurricanes (Category 3+) and cost about $10 billion to clean up. On average, 47 deaths will occur in the U.S. from hurricanes each year, which ranks them as the 4^{th} deadliest weather phenomenon. An important thing to remember is that only 11% of the world's tropical cyclones occur in the Atlantic Basin. As you can see in Figure 4, there are far more tropical cyclones in the Pacific Ocean than in the Atlantic.

Hurricane season in the Atlantic Ocean, Caribbean Sea and Gulf of Mexico starts in June and ends in November (see Figure 5). This season corresponds to the time of year when the sea surface temperatures are warm enough to support hurricane development. A typical hurricane season will reach a peak on September 10 and likely produce several tropical cyclones that will make landfall. Figure 5 highlights those regions that are hit most often by hurricanes as well as the locations in which hurricanes typically form each month of the hurricane season.

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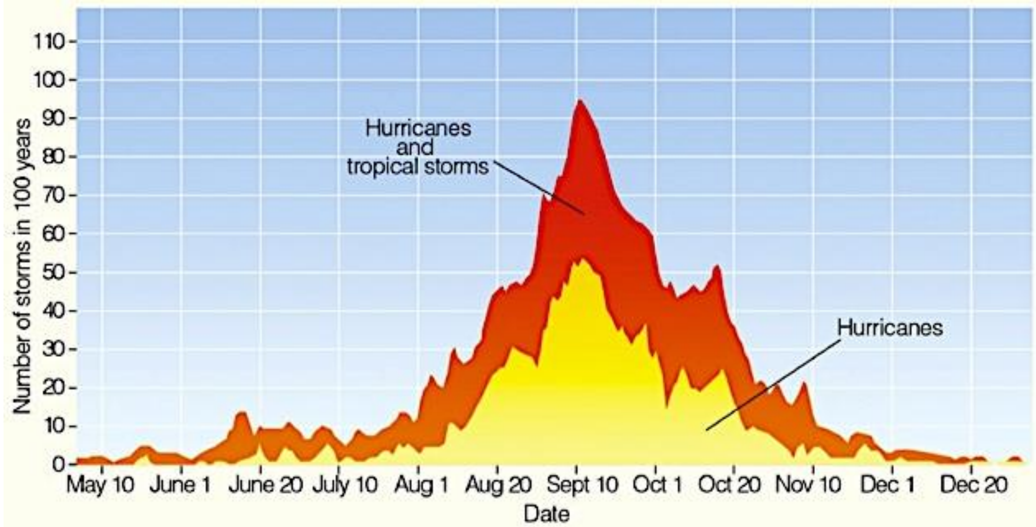

Figure 5. Atlantic Hurricane Season

Figure 6. Hurricane Landfall Frequency Along the U.S. Coastline
[Source]

Figure 7 on the next page shows the tracks of all the named tropical cyclones of the 2005 season in the Atlantic Ocean. 2005 ranks as the most active hurricane season on record with 28 named storms (on average, 10 named storms). During this season, the U.S. dealt with many land-falling hurricanes, the worst of which was Katrina. To watch a satellite animation of Katrina, check out this link!

Hurricane Katrina (Satellite) (1:38)

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Figure 7. Tracks of the Tropical Cyclones from 2005 Hurricane Season
[Source]

Hurricane Structure

In this section, we will define the major structural features of the hurricane. On average, a hurricane is approximately 500 miles wide with a clearly defined eye in the center that may have a diameter of 10 - 50 miles (see Figure 8). Most hurricanes last for 2 - 7 days, although some have been known to last for 2 or more weeks! When viewed from space or on Doppler radar, most well developed hurricanes have three distinct features – an eye, eyewall, and spiral rainbands. Figure 8 shows each of these three features on satellite and radar. Starting from the outside, the **spiral rainbands** are bands of intense rainfall that circulate around the center of the hurricane. These rainbands can produce rainfall rates that exceed 2 inches an hour at times and are responsible for much of the flooding associated with hurricanes. The most intense part of the hurricane is the **eyewall**. Here are the hurricane's most intense storms, fastest winds, and heaviest rains. Just inside the eyewall is the hurricane eye. The **eye** is typically calm and clear and it is in this part of the storm where we measure the lowest air pressure. Surrounding the eye are thunderstorms that can be 12 miles tall that orbit around the eye at speeds approaching 200 mph! Figure 10 is a picture from within Hurricane Katrina's eye. [2, 3]

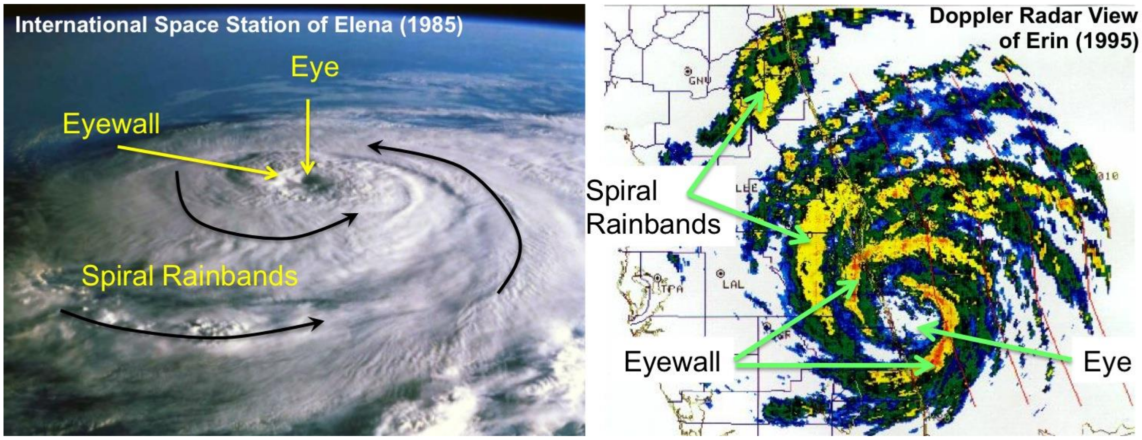

Figure 8. Hurricane Structure

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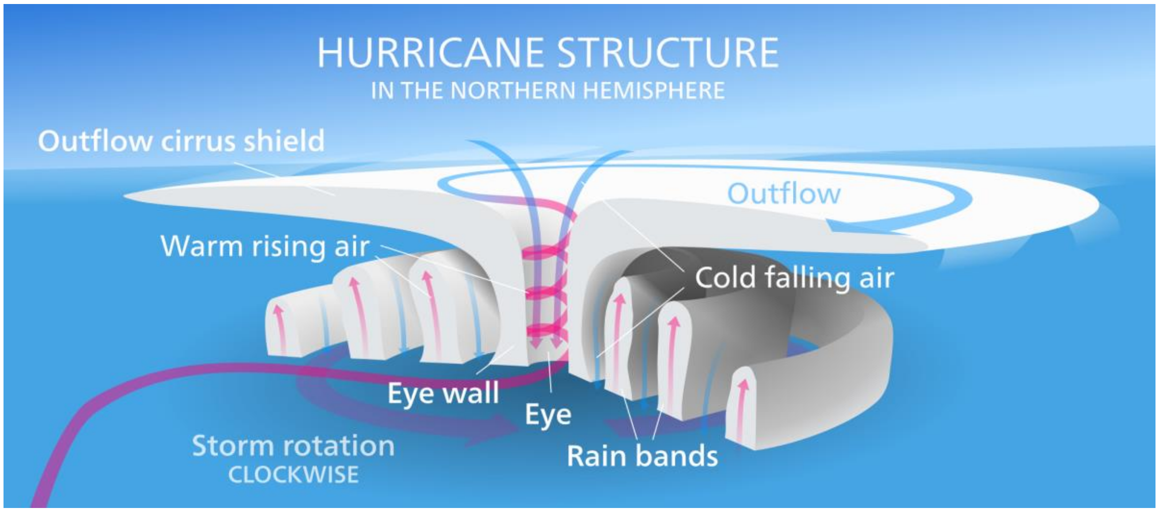

Figure 9. Hurricane Structure
Source

Key Features

Eye: Very low central pressure, clear and calm conditions

Eyewall: Most intense part of the hurricane, just outside of the eye, heaviest rain and fastest wind speeds

Spiral Rainbands: Heavy rain, circulates around the hurricane

Figure 10. Hurricane Katrina's Eye and Eyewall
Source

Destructive Forces

There are three main destructive forces of strong hurricanes that can kill people and destroy property. First is **storm surge**, which is defined as a build up of ocean water and intense waves. Many think that storm surge is like a tsunami, but in reality, they are quite different. Tsunamis occur because of earthquakes that cause one large breaking wave that rushes onshore and sweeps away everything at once. Storm surge is much different in that instead of one massive wave, hurricane storm surge is created by many smaller waves that build on top of one another with time. As the hurricane approaches, the wind-blown water can pile up 30 feet along the coastal areas! To see what storm surge looks like, check out these two links and see Figure 11.

Hurricane Katrina Storm Surge (13:38)

NHC Surge Simulation

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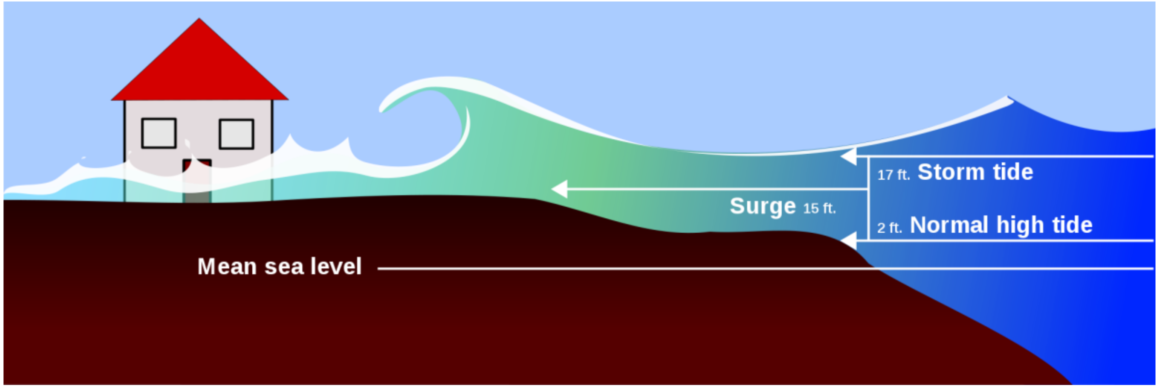

Figure 10. Hurricane Katrina's Eye and Eyewall
Source

The second major destructive force are the **hurricane force winds** powered by the intense low-pressure found in the center of the storm. They can last for several hours and relentlessly batter a coastal city. Figure 12 shows how the winds circulate around a hurricane. In the Northern Hemisphere, the winds circulate counterclockwise (clockwise in the Southern Hemisphere) around tropical cyclones.

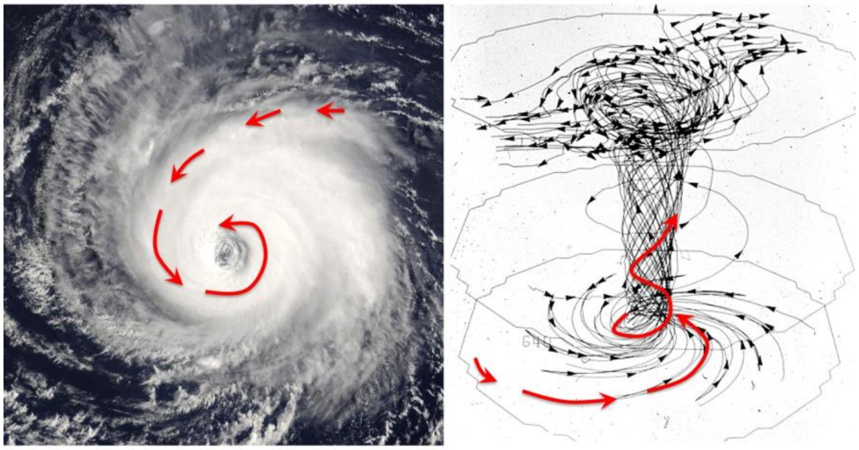

Figure 12. Hurricane Winds
Source

In general, the fastest wind speeds are found in the eyewall on the right side of tropical cyclones. The cyclone's motion (forward speed) contributes to the counterclockwise wind speed. When the winds are in the same direction as the storm motion, the storm wind speed is added to the forward speed. When the winds are moving in the opposite direction, the forward speed is subtracted from the storm wind speed **5**. This can increase the destruction in areas that are on the right side of the storm, during landfall especially. To see the destruction caused by these intense winds, check out the videos below!

Hurricane Winds (2:09)

Hurricane Destruction (0:39)

Hurricane Wilma (3:38)

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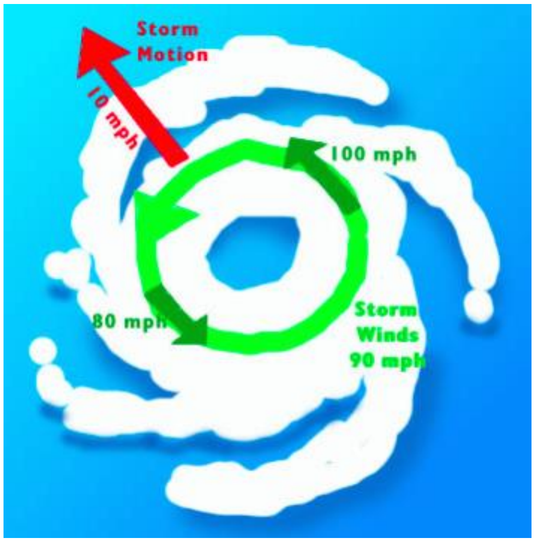

The third and by far most deadly aspect of a hurricane is **inland flooding**. Figure 13 reveals how a hurricane's destructive forces, particularly freshwater flooding, kill people. Hurricanes can easily drop 10 to 20 inches of rain in a couple of days, which for some locations can be as much as half a year's worth of precipitation! Furthermore, the situation worsens if a hurricane slows down and remains over one area for several days. Hurricane Mitch (1998) did just that and stalled over the mountains of Central America. Some locations saw 50 inches of rain in two days, which caused extreme flooding that killed 18,000 people! To see how bad floodwaters be, check out these pictures!

Flood Damage

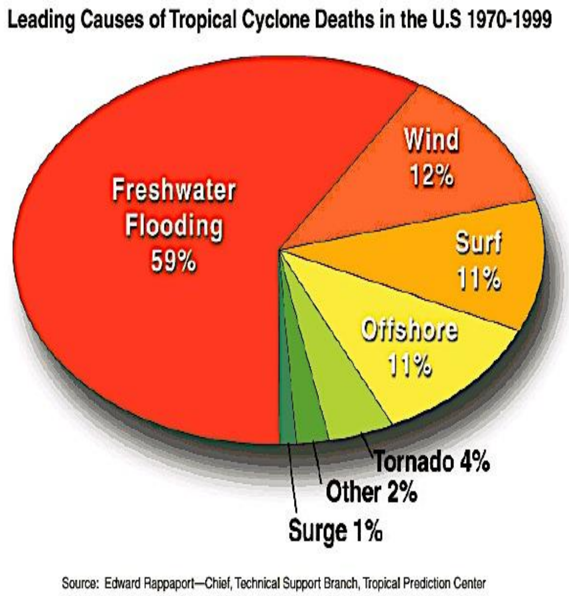

Figure 13. Leading Causes of Tropical Cyclone Deaths in the U.S.

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Hurricane Safety

If hurricane conditions are expected within 48 hours for a location, the National Hurricane Center (NHC) will issue a hurricane watch. If hurricane conditions are expected within 36 hours for a location, the NHC will issue a hurricane warning. Figure 14 is a map of a typical hurricane watch/warning. If a hurricane warning has been issued for your location, evacuate immediately if the evacuation order is given. Many who have stayed behind to "ride out" the hurricane have lost their lives in addition to their property. For example, when Hurricane Ike (2008) was headed toward Galveston, TX, many decided to stay in their homes rather than evacuate. For those that stayed in their beach houses seen in Figure 15 many died as the storm surge wiped all the houses off the shore except one. To learn more about preparing for weather hazards such as hurricanes, visit this link from the NHC.

Hurricane Preparedness

Figure 14. Hurricane Advisory Map
Source

Figure 15. Beachfront Property Destroyed during Hurricane Ike (2008)
Source

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Pre-Class Activity 4

Instructions: Before teaching about hurricanes, have the students answer the questions below, followed by the scenario question for in-class discussion between you and your students.

1. How many categories of hurricanes are there?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 10

2. Which of the following is not another name for a hurricane?
   a. Typhoon
   b. Tsunami
   c. Tropical Cyclone
   d. Cyclone

3. What is the most destructive force associated with hurricanes?
   a. Winds
   b. Waves
   c. Storm surge
   d. Thunderstorms
   e. Flooding
   f. Tornados

4. What is the most deadly force associated with hurricanes?
   a. Winds
   b. Waves
   c. Storm surge
   d. Thunderstorms
   e. Flooding
   f. Tornados

5. Hurricane intensity is categorized by
   a. Rainfall rate
   b. Storm surge
   c. Sustained wind speed
   d. Wind gusts
   e. Pressure

Discussion Question: You are living in Orlando, FL and a Hurricane Watch has been issued for your town, but your friend that lives in Miami, FL calls you saying that a Hurricane Warning has been issued for his/her area and wants to know the difference. Using your best judgment, what would you tell him/her?

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In-Class Activity

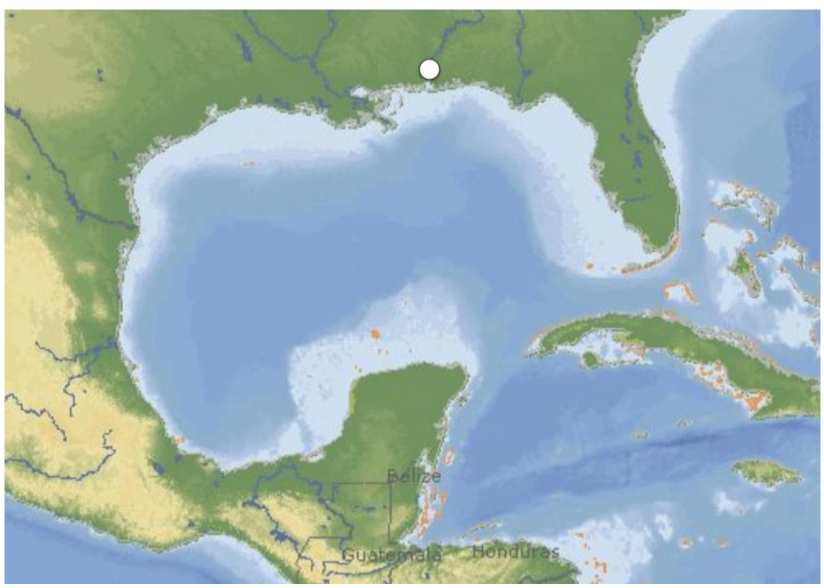
Weather Situation: Hurricane

In this project, your group will forecast and prepare for a landfalling hurricane in the U.S. Each group member will choose one of the following roles and complete the tasks written at the end of each section.

1. Meteorologist
2. Homeowner in Galveston, TX
3. Mayor of Galveston, TX
4. General Manager of "The Home Depot" in Galveston, TX

Real World Application: Meteorologist [4]

Task #1 Below is a map of the Gulf of Mexico and Caribbean Sea. The white circle indicates the location of Mobile Bay, AL – a city that is especially vulnerable to hurricanes. Your task is to draw an arrow that represents a typical track a hurricane would take if it started in Jamaica and tracked between the Yucatan Peninsula and Cuba and eventually hit Mobile Bay, AL. In the blank space below the map, draw your best representation of a hurricane as viewed from a Doppler radar. Be sure to draw the spiral rainbands, eyewall and eye.



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<u>Task #2</u> As a meteorologist, it is important that you learn to properly convey weather information to the general public. Your task is to create a 5-minute weather broadcast, like you might see on the Weather Channel, about hurricanes. Remember that your classmates will not know much about what you have just learned so be sure to address the following topics in your broadcast:

1. Convey statistics about hurricanes in the U.S. (fatalities, frequency, etc.)

2. Discuss the Atlantic Hurricane Season and the Hurricane Name list

3. Show the Saffir-Simpson Scale

4. Explain the stages of development of a tropical cyclone

5. Discuss hurricane structure and each of the three main destructive forces

6. Talk about hurricane watches, warnings and safety

Build this weather broadcast using presentation software (like PowerPoint) and be sure to include pictures and videos to supplement what you discuss. Your teacher has access to several videos and pictures of hurricanes, so make sure to use your teacher as a resource as well as the Internet. Be sure to be both informative and entertaining!

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Real World Application: Homeowner

It is September 2008 and you and your family have just moved to Galveston, TX. Since you are from Illinois, you have no experience with hurricanes. On September 10, the National Weather Service issued a Hurricane Warning as Hurricane Ike is expected to directly hit Galveston in 2 days as a Category 4 hurricane. The Texas governor has just issued a mandatory evacuation for Galveston! You have a spouse, three children and a dog.

1. How do you use the next 24-48 hours to prepare for this evacuation and protect your home from damage?

2. What supplies will you need?

3. Where will you find information about Galveston's evacuation plan and route?

4. What will you bring with you when you evacuate?

5. Where will you stay during your evacuation?

The next day, you begin packing and preparing for your evacuation when your neighbor comes over for a friendly chat. She mentions that she and her husband have decided not to leave because there is a major football game on TV in two days and she says, "those silly weathermen are never right anyways…"

1. Why do you think some people choose not to evacuate?

2. How would you respond to your neighbor?

TASK Set up a mock interview where one student assumes the role of the homeowner (described above) and the other a TV reporter. In this interview, ask the questions above about how to prepare to evacuate. Then, have your group put on a skit where two students pretend to be the neighbors who don't want to evacuate and the other two students pretend to be the family that has chosen to evacuate. In the skit, the neighbors are supposed to play the "devil's advocate" and give all their reasons why they are staying. The other two students have to try to convince them to evacuate!

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Real World Application: Mayor of Galveston, TX

You are the newly elected mayor of Galveston, TX and your job involves keeping your citizens and community safe during hurricane season. Hurricanes frequently hit the Texas coastline and to best prepare for the hurricane season you hold a meeting with other city officials to answer the following questions.

1. Before a hurricane hits, what actions should we take to get prepared? (Think about setting up shelters and getting fresh water, food, and other supplies to your citizens)

The mayor must always be prepared to lead citizens to safety if/when the hurricane hits.

2. What type of planning can you do during the hurricane off-season to ensure that you will be prepared to keep your citizens safe when hurricane season arrives?

3. Create a city evacuation plan brochure to share with the rest of the class. Consider important components such as escape routes, carpool systems for citizens who do not have cars, and ways to keep your citizens informed as the evacuation is taking place.

In September 2008, Hurricane Ike destroyed much of Galveston.

4. What actions would you take as mayor to restore your city back to what it was before the hurricane?

5. How would you assist your citizens in the recovery effort (money, resources, equipment, etc.)?

6. How will you disperse information about the clean up effort?

7. How will keep your city safe from looting?

8. How will you deal with the additional need for emergency personnel?

Task Stage a mock interview where you play the role of the mayor. Have the interviewer ask the questions written above and either perform the interview in front of the class or record it so your classmates can see the your responses.

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Real World Application: General Manager of "The Home Depot" in Galveston, TX

You are the General Manager of "The Home Depot" in Galveston, TX and you just received word that Hurricane Ike is expected to make landfall in Galveston in 3 days. Your job is to prepare your store for this hurricane and make some crucial decisions, as you will see in the questions below.

1. In preparation for this hurricane, how would you prepare your store's inventory to be in the best position to meet the demand of your customers?

2. What items should you overstock knowing they will be purchased because of this hurricane?

As a manager, you have to make the decision to keep the store open during the hurricane or close it down.

3. What are some of the benefits and drawbacks of keeping the store open? What about closing it down?

4. If you decide to close the store, when should you make the final decision?

5. What will you do to prepare the storm for the hurricane?

6. How will you protect your inventory from being destroyed?

7. If you decide to keep the store open, how will you handle your employees that don't want to come to work because of the storm?

8. How will you keep those employees, that do make it to work, safe in the event that the hurricane causes damage to the building?

9. If your store is partially destroyed by Hurricane Ike, how will your prepare for reopening? How will you prevent looting?

10. How will you replace lost merchandise? (Remember that hurricanes cause widespread destruction and many nearby stores will be damaged, too)

11. Do you take advantage of the opportunity to make extra profit on items citizens will need to rebuild, like lumber, generators, and other building construction materials, or do you reduce prices to help the community rebuild and hope that you sell large enough quantities that the company will make a profit?

Task Write a short report that you would give to your regional manager with your responses to these questions. Make an argument for why you would chose to take a certain course of action and present your answers to these questions to the class. Be sure to solicit comments and questions from your classmates as you present.

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Take Home Assignment

Part 1. Hurricane Patricia (2015) [2, 6]

Hurricane Patricia formed off the western coast of Mexico from a low-pressure system on October 20, 2015. Patricia strengthened from a tropical storm to a Category 5 hurricane in 24 hours! The storm peaked in strength on the 23rd with maximum sustained winds of 200 mph and a central minimum pressure of 879 mb, as measured by NOAA's Hurricane Hunters. Check out the video below to see the extreme turbulence experienced by the Hurricane Hunters to get these measurements! Patricia was the most intense tropical cyclone recorded in terms of barometric pressure in the Western Hemisphere.

Hurricane Hunters - Patricia 2015

Instructions: The table below provides Hurricane Patricia's minimum central pressure and maximum sustained wind speeds (data obtained from the National Hurricane Center). Using this information, determine the strength of the tropical cyclone during its lifecycle. Fill in the last column in Table 1 with Tropical Depression (**TD**), Tropical Storm (**TS**), or Hurricane (**H**). If it is hurricane strength, be sure to include the category (see Table 2 for example).

Table 1. Before Landfall

Date/Time	Minimum Pressure (mb)	Sustained Wind Speed (mph)	Strength
Oct. 20 at 10 a.m.	1006 mb	35 mph	
Oct. 20 at 10 p.m.	1004 mb	40 mph	
Oct. 22 at 1 a.m.	987 mb	75 mph	
Oct. 22 at 10 a.m.	973 mb	100 mph	
Oct. 22 at 1 p.m.	958 mb	130 mph	
Oct. 22 at 10 p.m.	924 mb	160 mph	

Questions

1. Briefly explain how you determined the strength of Patricia from October 20 – 22.

2. Patricia was slow to strengthen over the open waters of the Pacific, but favorable environmental conditions led to a rapid intensification on October 22. List the environmental conditions necessary for hurricane development.

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Patricia made landfall near Cuixmala, Mexico late on October 23. At landfall Patricia had weakened with winds of 165 mph, still a Category 5 storm. Patricia's damage was remarkably limited to no fatalities. The largest impact was agriculture losses. As Patricia moved inland it quickly weakened to a remnant low on the 24th after interacting with high terrain in western Mexico. Over the next few days the remnant low moved into the southern U.S. where significant flooding was observed across Texas and the Gulf Coast.

Table 2. During/After Landfall

Date/Time	Minimum Pressure (mb)	Sustained Wind Speed (mph)	Strength
Oct. 23 at 1 p.m.	879 mb	200 mph	H Cat 5
Oct. 23 at 10 p.m.	946 mb	130 mph	H Cat 4
Oct. 24 at 1 a.m.	970 mb	100 mph	H Cat 2
Oct. 24 at 4 a.m.	986 mb	75 mph	H Cat 1
Oct. 24 at 7 a.m.	998 mb	50 mph	TS
Oct. 24 at 10 p.m.	1002 mb	35 mph	TD

Questions

3. Estimate the date and time of Patricia's landfall (Use information from Table 2 and underlined sentence above). How did you come to this conclusion?

4. After landfall, Patricia's pressure increased and wind speed rapidly decreased. What do you think caused Patricia to weaken?

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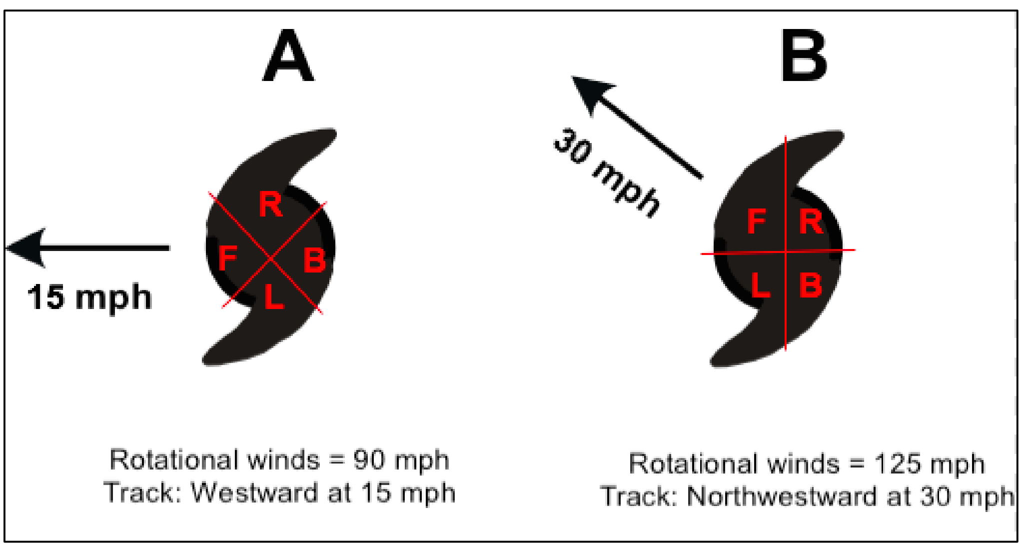
Part 2. Wind Speed Calculation 5, 6

Instructions: Information about the rotational wind speeds and forward movement of two hurricanes is provided in the sketches below. Four quadrants in each storm are defined relative to the direction the storm is moving. Use the information to evaluate the winds in the eyewall in the four quadrants of the storm (Right, Left, Front, and Back). Wind speeds for Hurricane Abby have been completed for you as an example.

1. Draw the counterclockwise winds you would expect to see circulating around a low-pressure system for A and B.

2. Using the given rotational wind speeds, calculate the actual wind speed in each quadrant of the hurricane. Remember the rotational winds will ADD to the forward movement of the hurricane on one side where the winds are in the same direction as the storm motion and will be SUBTRACTED from the other.

3. Using the maximum wind speed for each hurricane, determine the Saffir-Simpson rating.



	Wind in Each Quadrant				Saffir-Simpson
Hurricane Abby	**N: 105**	**S: 75**	**E: 90**	**W: 90**	_________
Hurricane Benny	**NE:** _____	**SW:** _____	**NW:** _____	**SE:** _____	_________

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Questions

1. Now that you have completed this exercise, on which side of a hurricane (Northern Hemisphere) will the fastest winds be located and therefore, greatest storm surge, be located relative to the storm motion: left or right?

2. If the same hurricanes were in the Southern Hemisphere, how would these calculations be different? Briefly explain why.

Part 3. True/False (Circle One) 7

1.	It is impossible for tropical cyclones to form within 5^{o} of the equator.	T	F
2.	The U.S. hurricane season peaks in September.	T	F
3.	Hurricane Katrina is the most powerful hurricane on record.	T	F
4.	Every hurricane makes landfall at least once.	T	F
5.	Hurricanes can produce deadly tornados when they make landfall.	T	F

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Student Evaluation [8]

Instructions: After completing the lesson on hurricanes, please have the students answer the following questions below.

1. What is a tropical storm?
   a. A tropical cyclone that has not reached hurricane strength yet
   b. A tropical cyclone that has surpassed hurricane strength
   c. A tropical cyclone that has already made landfall
   d. An extremely weak tropical cyclone with winds 20 – 30 mph

2. What is the name of the scale that is used to categorize the strength of a hurricane?
   a. Enhanced Fujita Scale
   b. Fujita Scale
   c. Barometer Scale
   d. Saffir-Simpson Scale
   e. Cyclone Scale

3. Which of the following is necessary for hurricanes to form?
   a. Warm ocean waters
   b. Thunderstorms
   c. A low-pressure system
   d. High relative humidity in the Troposphere
   e. All of the above

4. Hurricane season in the United States
   a. begins in June
   b. ends in September
   c. is all year long
   d. only occurs every 3 years

5. A typhoon
   a. is the same as a tsunami.
   b. is a weaker hurricane.
   c. is a tropical cyclone that occurs in the western Pacific Ocean.
   d. causes more damage than hurricanes.

6. Winds circulate ____________ around tropical cyclones in _________________.
   a. clockwise, the Northern Hemisphere
   b. counterclockwise, the Northern Hemisphere
   c. clockwise, the Southern Hemisphere
   d. counterclockwise, both hemispheres

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7. Where are the heaviest rain and fastest winds found in a hurricane?
    a. Within the eye
    b. Just outside of the rainbands
    c. In the eyewall
    d. Toward the top of the hurricane

8. Which of the following is <u>not</u> a destructive force associated with hurricanes?
    a. Tornados
    b. Flooding
    c. Hurricane force winds
    d. Extreme cold temperatures
    e. Storm surge

9. Why do tropical cyclones rarely form north of 30^{o}N or south of 30^{o}S? Briefly explain.

10. Calculate the Coriolis force at 15^{o}N using the following equation. Make sure your calculator is in degrees!

Coriolis = 2 x Ω x sin Θ

where $\Omega = 7.292 \times 10^{-5}$/second and Θ is the latitude in degrees.

    a. Coriolis = 0/sec
    b. Coriolis = 0.0000948/sec
    c. Coriolis = 0.0000377/sec
    d. Coriolis = 474,189.89/sec
    e. Coriolis = 948,379.79/sec

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Common Core State Standards (CCSS) Initiative
To learn more, visit http://www.corestandards.org

Next Generation Science Standards (NGSS)
To learn more, visit http://www.nextgenscience.org

The following standards are met in this learning module:

1. **NGSS.MS-PS1-5**

MS-PS1-5. Chemical Reactions (Connections to Nature of Science)
Laws are regularities or mathematical descriptions of natural phenomena.
Lecture: Tropical Cyclone Tracks: Coriolis Force

2. **NGSS.MS-ESS2.5**

MS-ESS2-5. Weather and Climate
Provide evidence for air pressure systems and resulting weather conditions.
Lecture: Hurricane Structure; Take Home Assignment: Part 1

3. **NGSS.MS-PS2.2**

MS-PS2.2. Forces and Interactions
Emphasis on balanced and unbalanced forces in a system and an object's motion (F = ma). This includes a specification of units.
Lecture: Hurricane Structure

4. **CCSS.ELA-LITERACY.RST.6-8.4**

Grade 6-8: Science and Technical Subjects
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific science or technical context relevant to grades 6-8 texts and topics.
Lectures: Bolded text; Pre-Class Activity; In-Class Activity: The Meteorologist

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5. **[CCSS.MATH.CONTENT.7.NS.A.1.C]**

Grade 7: The Number System
Understand subtraction of rational numbers as adding the additive inverse, and apply this principle in real-world contexts.
Lectures: Destructive Forces; Take Home Assignment: Part 2

6. **[CCSS.ELA-LITERACY.RST.6-8.3]**

Grade 6-8: Science and Technical Subjects
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
Take Home Activity: Parts 1 & 2

7. **[CCSS.ELA-LITERACY.RST.6-8.8]**

Grade 8: Science and Technical Subjects
Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
Take Home Activity: Part 3

8. **[CCSS.MATH.CONTENT.8.EE.A.4]**

Grade 8: Expressions and Equations
Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Interpret scientific notation that has been generated by technology.
Student Evaluation

9. **[CCSS.ELA-LITERACY.RST.6-8.9]**

Grade 6-8: Science and Technical Subjects
Compare and contrast the information gained from experiments, simulations, video or multimedia sources that gained from reading a text on the same topic.
Video lectures

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10. [CCSS.ELA-LITERACY.RST.6-8.7]

Grade 6-8: Science and Technical Subjects
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
Video lectures

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