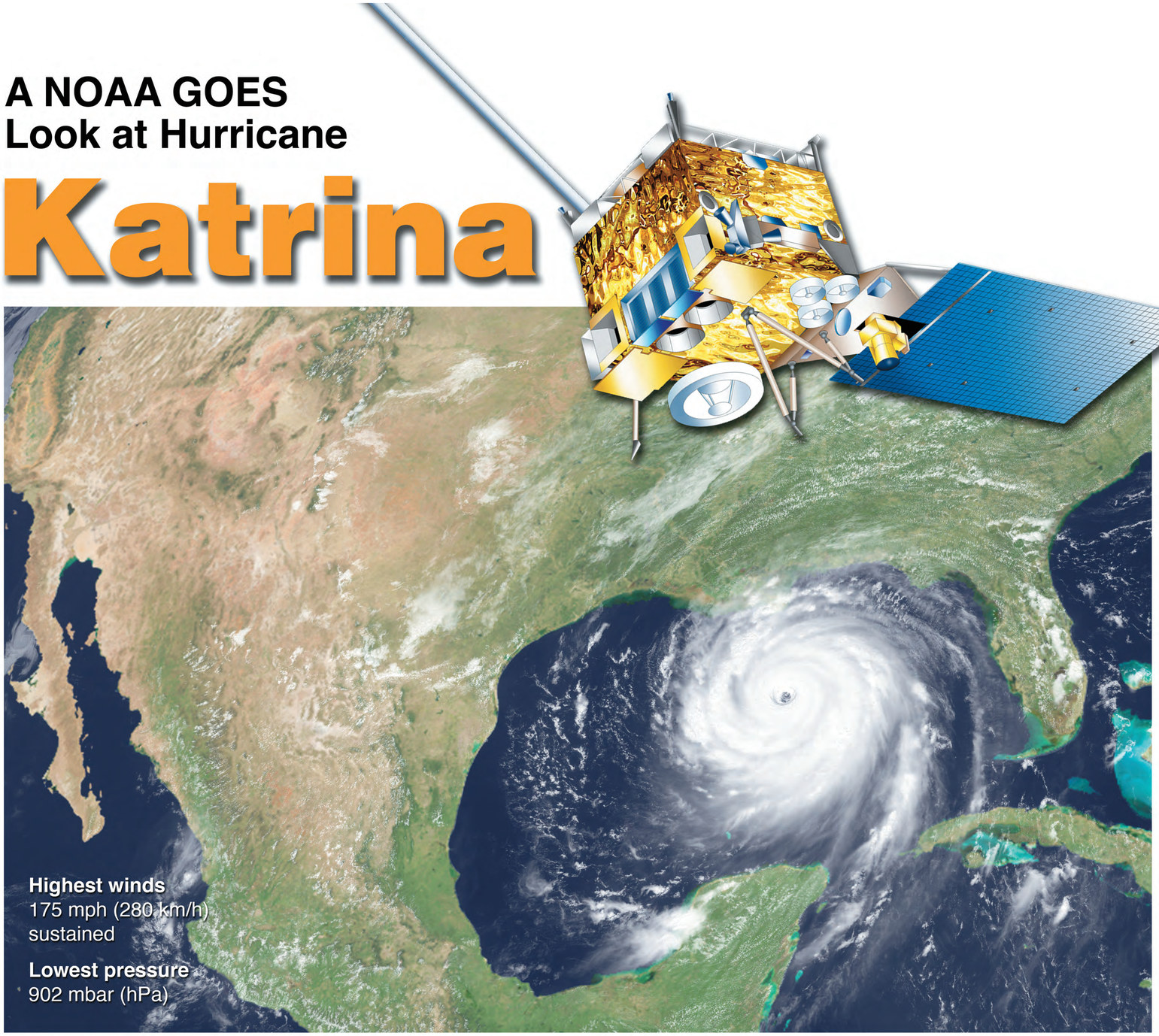
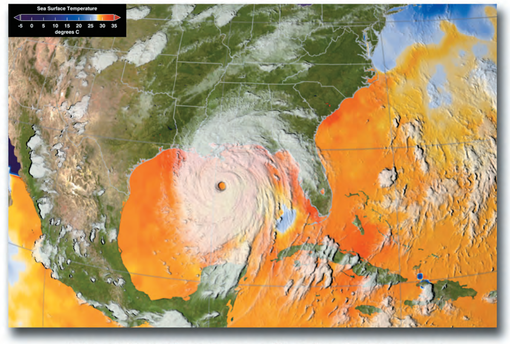
A NOAA GOES Look at Hurricane

Katrina

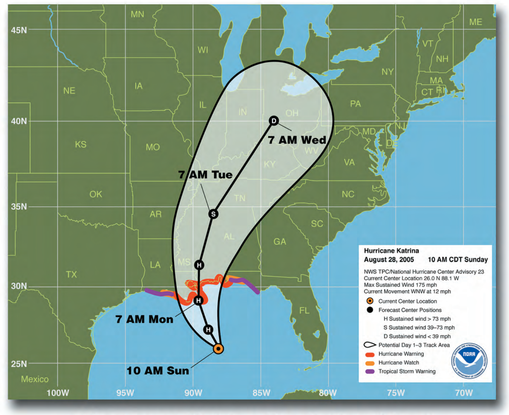




Tracking Hurricane Katrina's Energy

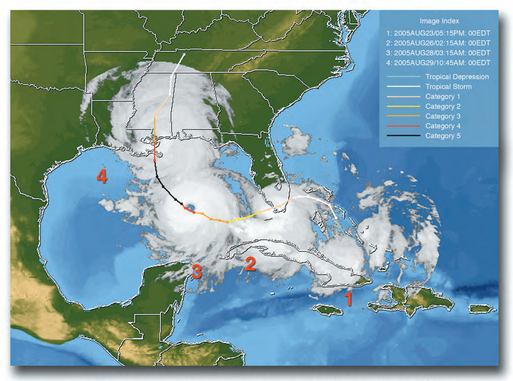
This satellite image is from the Advanced Microwave Scanning Radiometer (AMSR-E) instrument on the Aqua satellite. The cloud imagery is from GOES-12. Hurricanes form over tropical waters (between 8° and 20° latitude) in areas of high humidity, light winds, and warm sea surface temperatures, as indicated in orange, typically 80 degrees Fahrenheit (F) or greater. Temperatures of 80° F or above act as fuel for hurricanes. http://earthobservatory.nasa.gov/Library/Hurricanes/

Image Credit: NASA



Hurricane Katrina Prediction Chart

Image Credit: NOAA's National Hurricane Center/ Tropical Prediction Center



Montage of Hurricane Katrina's Path Over a 4-Day Period

Image Credit: University of Wisconsin-Madison Space Science and Engineering Center Cooperative Institute for Meteorological Satellite Studies

Hurricanes and other severe weather events cause tremendous human and economic impacts worldwide. A hurricane path can be predicted more accurately than ever before with Geostationary Operational Environmental Satellite (GOES) tracking data, aiding emergency personnel to quickly identify and evacuate areas directly in the predicted path of the storm. Advances in GOES capabilities will allow us to continue this vital effort in the decades ahead, thereby reducing the loss of life and damage to property.

36"x24"

National Oceanic and Atmospheric Administration (NOAA)'s GOES

NOAA's Geostationary Operational Environmental Satellites (GOES) continuously observe and measure meteorological phenomena in real time, providing the meteorological community and the atmospheric scientist observational and measurement data of the Western Hemisphere. Forecasting the approach of severe storms, the GOES system of weather satellites provides timely environmental information to meteorologists and their audiences alike—graphically displaying the intensity, path, and size of storms. In addition to short-term weather forecasting, GOES data is used to support atmospheric science research, numerical weather prediction models, and environmental sensor design and development.

GOES environmental satellites are key in helping meteorologists observe, predict, and monitor dust storms, volcanic eruptions, and forest fires. Early warning of impending severe weather enhances the public's ability to retreat to safety and protect their property. GOES also monitors the space and solar environments for solar events that can disrupt communications and electric power transmission, which could have adverse effects on astronaut safety, high altitude aircraft, and spacecraft.

In addition to the very important infrared and visible images that GOES delivers, there are a number of other products derived from the GOES measurements. Winds are estimated by tracking cloud and water vapor features in sequential satellite images. The GOES winds are used in numerical weather prediction models to steer the path of a hurricane. GOES infrared window radiances are also used to automatically estimate tropical cyclone intensity; this is especially important in regions that are not accessed by hurricane-hunting aircraft. Sea surface temperatures are also derived from GOES infrared measurements; tropical cyclone intensity is strongly related to sea surface temperature. Infrared radiances are also used to quantitatively estimate rain rates.

The impressive imagery of cloud cover produced by the GOES spacecraft, as viewed from orbit high above the Earth, has become a highlight and staple of television weather forecasts for more than 30 years. With El Niño and La Niña affecting people worldwide, GOES images have been featured on the covers of the international press, appearing in *National Geographic*, *Der Spiegel*, and *Life* magazines.

GOES spacecraft operate as a two-satellite constellation in geosynchronous orbit above the equator and observe 60 percent of the Earth. They measure the Earth's atmosphere, its surface, cloud cover, and the solar and geosynchronous space environment using Imagers, Sounders, Solar X-Ray Imagers, and space environment monitoring instruments. The GOES system also supports search and rescue operations by providing instantaneous relay of distress signals from people, aircraft, or marine vessels to the search and rescue ground stations. The system also supports land- and ocean-based Data Collection Platforms, transmits Low Rate Information Transmission/Weather Facsimile and imaging and sounding data between Earth terminals and relays Emergency Managers Weather Information Network broadcasts.

Since 1983, the National Aeronautics and Space Administration (NASA) and NOAA actively engaged in a cooperative program to develop and perfect the GOES system. NOAA manages the overall GOES Program and establishes requirements, provides funding, distributes environmental data for the U.S., and determines the need for satellite replacement. NASA teams with NOAA to acquire and manage the study, design, and development of each of the GOES spacecraft and the ground system needed to acquire, process, and disseminate the data.

The NOAA satellites help to carry forth the U.S. commitment to systematic global weather observation by providing data supporting requirements of 140 nations. All nations can access NOAA spacecraft data and for many, NOAA data is their sole weather forecasting reference.

Hurricane Katrina 23–30 August 2005—Tropical Cyclone Report

Richard D. Knabb, Jamie R. Rhome, and Daniel P. Brown
National Hurricane Center, 20 December 2005

Katrina was an extraordinarily powerful and deadly hurricane that carved a wide swath of catastrophic damage and inflicted large loss of life. It was the costliest and one of the five deadliest hurricanes to ever strike the United States. Katrina first caused fatalities and damage in southern Florida as a Category 1 hurricane on the Saffir-Simpson Hurricane Scale. After reaching Category 5 intensity over the central Gulf of Mexico, Katrina weakened to Category 3 before making landfall on the northern Gulf coast. Even so, the damage and loss of life inflicted by this massive hurricane in Louisiana and Mississippi were staggering, with significant effects extending into the Florida panhandle, Georgia, and Alabama. Considering the scope of its impacts, Katrina was one of the most devastating natural disasters in United States history.
http://www.nhc.noaa.gov/ms-word/TCR-AL122005_Katrina.doc

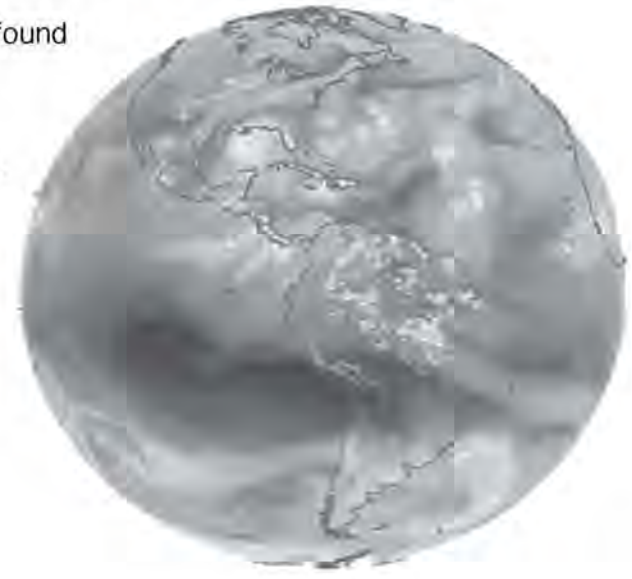
How Was This Hurricane Katrina Image Created?

The image of Hurricane Katrina on the front of this poster was created using data collected from the Imager instrument on NOAA's GOES-12 satellite and from the MODIS instrument on NASA's Terra satellite. The colors and realistic "look" of this image are the end result of a lot of computer processing. GOES provided approximately 716 images of Hurricane Katrina, from August 26–August 30, once every five minutes. Hurricane Katrina marked the first time GOES data was available onboard a NOAA P-3 hurricane hunter airplane.

A digital image processing program was used to overlay the GOES cloud image on top of the MODIS background color image. The GOES satellite's grayscale image of the hurricane was computer-enhanced to increase the contrast in the shadows of the cloud tops. The background image shows the colors of the land and the ocean. It was created using archive data from the MODIS instrument corresponding to the red, green, and blue primary colors used in a color TV.

By overlaying the digital data from the two instruments, this hurricane image shows what we would see if we could look at a hurricane using a color TV camera with a big zoom lens from way out in space.

Many other colorful hurricane images and movies can be found online in the image catalogs listed at **http://goes.gsfc.nasa.gov**.

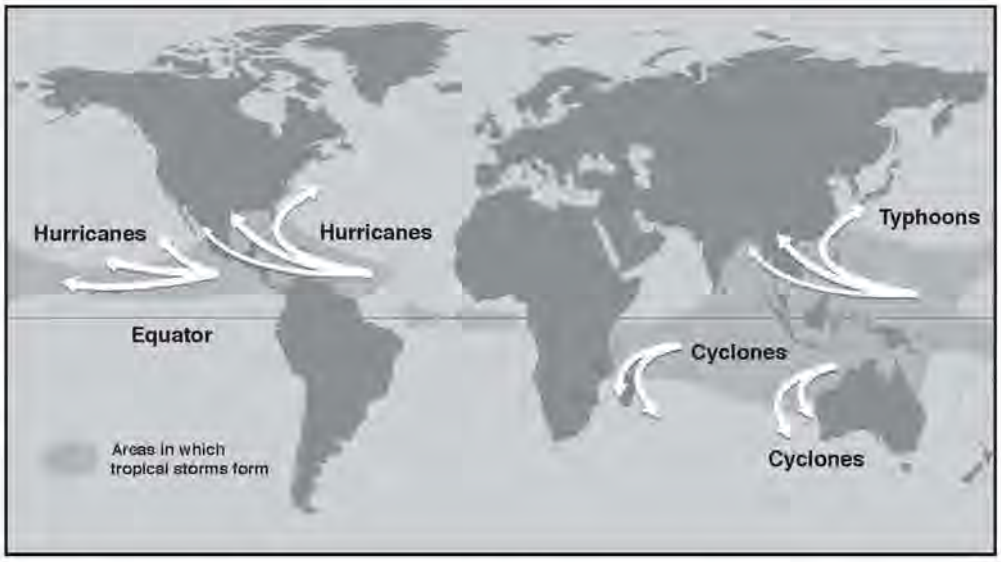


This is a full disk "water vapor" image acquired by GOES-12 on the afternoon of August 28, 2005. The image displays the water vapor concentration in the middle and upper parts of the troposphere, a key region for storm development and growth. Clouds appear white, while the dark regions denote drier air or "jet streaks." Note the location of Hurricane Katrina—with the warm (dark) "eye" off the Gulf Coast.

How Does A Hurricane Form?

Hurricanes are the most awesome, violent storms on Earth. They form over warm ocean waters. Actually, the term "hurricane" is used only for the large storms that form over the Atlantic Ocean or eastern Pacific Ocean.

The generic, scientific term for these storms, wherever they occur, is tropical cyclone. Depending on where in the world they are born, other names for these storms are typhoons, cyclones, severe tropical cyclones, or severe cyclonic storms. Whatever they are called, the same forces and conditions are at work in forming these giant storms, which all can cause damage or devastation when they hit land.



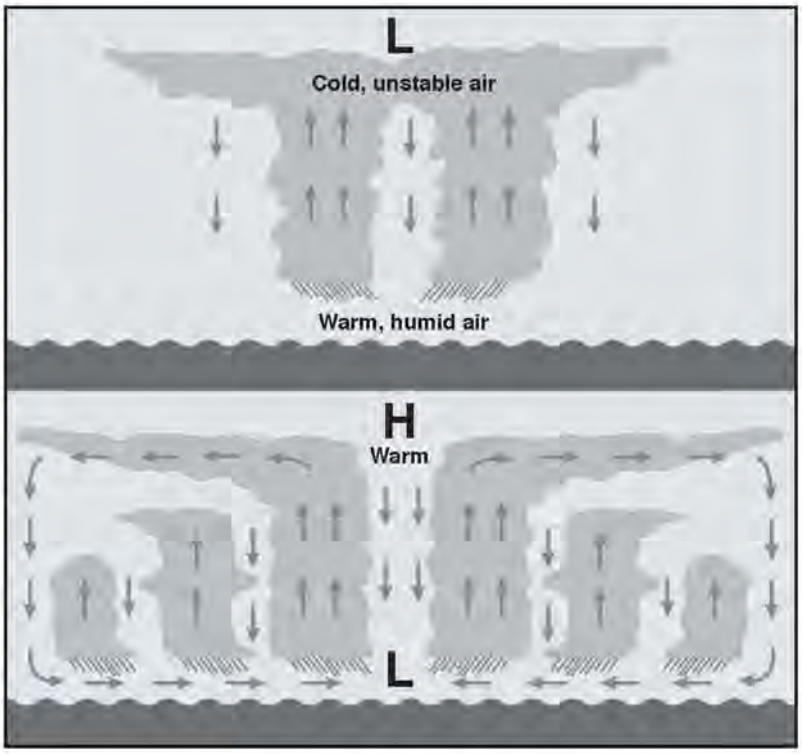
Tropical cyclones are like engines that require warm, moist air as fuel, so the first ingredient needed for a tropical cyclone is warm ocean water. That is why tropical cyclones form only in tropical regions where the ocean is at least 80° F for at least the top 50 meters (about 165 feet) below the surface.

The second ingredient for a tropical cyclone is wind. In the case of hurricanes that form in the Atlantic Ocean, the wind blowing westward across the Atlantic from Africa provides the necessary ingredient. As the wind passes over the ocean's surface, water evaporates (turns into water vapor) and rises. As it rises, the water vapor cools, and condenses back into large water droplets, forming large cumulonimbus clouds. These clouds are just the beginning.

Meteorologists have divided the development of a tropical cyclone into four stages: Tropical disturbance, tropical depression, tropical storm, and full-fledged tropical cyclone.

1. **Tropical Disturbance**
   When the water vapor from the warm ocean condenses to form clouds, it releases its heat to the air. The warmed air rises and is pulled into the column of clouds. Evaporation and condensation continue, building the cloud columns higher and larger. A pattern develops, with the wind circulating around a center (like water going down a drain). As the moving column of air encounters more clouds, it becomes a cluster of thunderstorm clouds, called a tropical disturbance.

2. **Tropical Depression**
   As the thunderstorm grows higher and larger, the air at the top of the cloud column is cooling and becoming unstable. As the heat energy is released from the cooling water vapor, the air at the top of the clouds becomes warmer, making the air pressure higher and causing winds to move outward away from the high pressure area. This movement and warming causes pressures at the surface to drop. Then air at the surface moves toward the lower pressure area, rises, and creates more thunderstorms. Winds in the storm cloud column spin faster and faster, whipping around in a circular motion. When the winds reach between 25 and 38 mph, the storm is called a tropical depression.



3. **Tropical Storm**
When the wind speeds reach 39 mph, the tropical depression becomes a tropical storm. This is also when the storm gets a name. The winds blow faster and begin twisting and turning around the eye, or calm center, of the storm. Wind direction is counterclockwise (west to east) in the Northern Hemisphere and clockwise (east to west) in the Southern Hemisphere. This phenomenon is known as the Coriolis effect.

4. **Tropical Cyclone**
When the wind speeds reach 74 mph, the storm is officially a hurricane or typhoon. The storm is at least 50,000 feet high and around 125 miles across. The eye is around 5 to 30 miles wide. The trade winds (which blow from east to west) push the tropical cyclone toward the west—that is, toward the Caribbean, the Gulf of Mexico, or the southeastern coast of the U.S. The winds and the low air pressure also cause a huge mound of ocean water to pile up near the eye of the tropical cyclone, which can cause monster storm surges when all this water reaches land.

Tropical cyclones usually weaken when they hit land, because they are no longer being "fed" by the energy from the warm ocean waters. However, they often move far inland, dumping many inches of rain and causing lots of wind damage before they die out completely.

Tropical Cyclone Categories

Category	Wind Speed (mph)	Damage at Landfall	Typical Storm Surge (feet)
1	74–95	Minimal	4–5
2	96–110	Moderate	6–8
3	111–130	Extensive	9–12
4	131–155	Extreme	13–18
5	Over 155	Catastrophic	19+

Hurricane Season—*Be Prepared—Be Safe!*

Be prepared to be safe during hurricane season by following these tips and directions from the National Hurricane Center Web site: **http://www.nhc.noaa.gov**

Before Hurricane Season Starts: Make sure that all family members know how to respond after a hurricane.

- Protect your property
- Prepare a family evacuation plan, learn safe evacuation routes inland
- Assemble an Evacuation Kit
- Make arrangements for pets

Protect Your Property: Prepare for high winds.

- Install hurricane shutters or prepare 1/2" outdoor plywood boards for each window of your home. Install anchors for the plywood and pre-drill holes in the plywood so that you can put it up quickly.
- Make trees more wind resistant by removing diseased and damaged limbs, then strategically removing branches so that wind can blow through.

Prepare a Family Evacuation Plan:

- Choose several friends that your family members can contact and places to meet in case you have to evacuate. Ensure family members have all the appropriate names and telephone numbers.
- Plan an evacuation route and keep a map of your locality handy in case you have to take an alternative or unfamiliar route.
- Be sure that all family members know the locations of the nearest designated public shelters.
- Listen to NOAA Weather Radio or local radio or TV stations for evacuation instructions and evacuate immediately when advised.

Evacuation Supply Kit: Take these items with you when evacuating.

- Prescription medications, medical supplies, and a first aid kit
- Special items for infants, elderly, or disabled family members
- At least three gallons of bottled water per person
- Canned food, dry food and a can opener
- Clothing and all weather gear
- Bedding including sleeping bags and pillows
- Battery-operated radio, flashlight, and extra batteries
- Documents for each family member, including drivers license, Social Security card, proof of residence, insurance policies, wills, deeds, birth and marriage certificates, tax records, etc.
- Written instructions on how to turn off electricity, gas, and water if authorities advise you to do so.

Arrangements for Pets: In the case of an evacuation you may not be able to take your pets.

- Be sure that all pets have current vaccinations and have identification tags with telephone numbers of family or friends
- Know the telephone numbers of area veterinarians and animal shelters
- Determine what the evacuation policies are for pets in your locality

HURRICANE WATCH: A Hurricane Watch is issued when there is a threat of hurricane conditions within 24–36 hours.

Single flag:
Storm/whole gale warning
Wind Speed is 55–73 mph

- Listen to a NOAA Weather Radio or local radio or television for hurricane progress reports
- Review evacuation plan with family
- Gather emergency supplies and evacuation kit
- Fuel vehicles
- Bring in outdoor objects and anchor objects that cannot be brought inside
- Secure buildings by closing and boarding up windows
- Store drinking water in clean bathtubs, jugs, bottles, and cooking utensils
- Store valuables and personal papers in a waterproof container on the highest level of your home so that they may be removed quickly in case of evacuation

HURRICANE WARNING: A Hurricane Warning is issued when hurricane conditions, winds of 74 miles per hour or greater, or dangerously high water and rough seas, are expected in 24 hours or less.

Double flag:
Hurricane warning
Wind Speed is 74+ mph

- Listen constantly to a battery-operated NOAA Weather Radio or local radio or television for hurricane progress reports
- If in a mobile home, check tie-downs and evacuate immediately
- Stay inside, away from windows, skylights, and glass doors
- Keep a supply of flashlights and extra batteries handy
- Avoid open flames, such as candles and kerosene lamps, as a source of light
- If power is lost, turn off major appliances to reduce power "surge" when electricity is restored

If Directed to Evacuate: If officials indicate evacuation is necessary, then

- Leave as soon as possible. Avoid flooded roads and watch for washed-out bridges.
- Secure your home by unplugging appliances and turning off electricity and the main water valve.
- Tell someone outside of the storm area where you are going. If time permits, and you live in an identified surge zone, elevate furniture to protect it from flooding or better yet, move it to a higher floor.
- Take pre-assembled emergency supplies, protective clothing, blankets, and sleeping bags to shelter.
- Lock up home and leave.

Know What to Do After a Hurricane Is Over: Be aware that the calm "eye" is deceptive; the storm is not over. The worst part of the storm will happen once the eye passes over and the winds blow from the opposite direction. Trees, shrubs, buildings, and other objects damaged by the first winds can be broken or destroyed by the second winds.

- Be alert for tornadoes. Tornadoes can happen during a hurricane and after it passes over. Remain indoors, in the center of your home, in a closet or bathroom without windows. Stay away from floodwaters. If you come upon a flooded road, turn around and go another way. If you are caught on a flooded road and waters are rising rapidly around you, get out of the car and climb to higher ground.
- Keep listening to NOAA Weather Radio or local radio or TV stations for instructions.
- If you evacuated, return home when local officials tell you it is safe to do so.
- Inspect your home for damage.
- Use flashlights in the dark; do not use candles.

All Hazards NOAA Weather Radio
NOAA National Weather Service

Informational Web Sites

http://scijinks.gov
http://www.noaa.gov
http://www.nhc.noaa.gov
http://cimss.ssec.wisc.edu/
http://www.nasa.gov/goes-n
http://goespoes.gsfc.nasa.gov
http://www.nasa.gov/hurricane
http://www.spaceplace.nasa.gov
http://www.aoml.noaa.gov/hrd/tcfaq
http://cimss.ssec.wisc.edu/tropic
http://www.nws.noaa.gov/stormready/
http://www.fema.gov/plan/index.shtm
http://www.osd.noaa.gov/GOES/goes_n.htm
http://www.esri.com/hazards/makemap.html
http://www.redcross.org/services/disaster/0,1082,0_319_,00.html
http://www.redcross.org/services/disaster/0,1082,0_587_,00.html
http://www.nhc.noaa.gov/pastdead.html *(most deadly hurricanes for U.S.)*
http://www.nhc.noaa.gov/pastint.shtml *(most intense hurricanes for U.S.)*
http://www.nhc.noaa.gov/pastcost.shtml *(most expensive hurricanes for U.S.)*

Tracking A Monster Storm

Student Actvity

Objective:

1. Students will map the track of hurricane Katrina.
2. Students will compare the actual track of the hurricane to the path predicted by NOAA and comment on the accuracy of the predictions.

Materials:

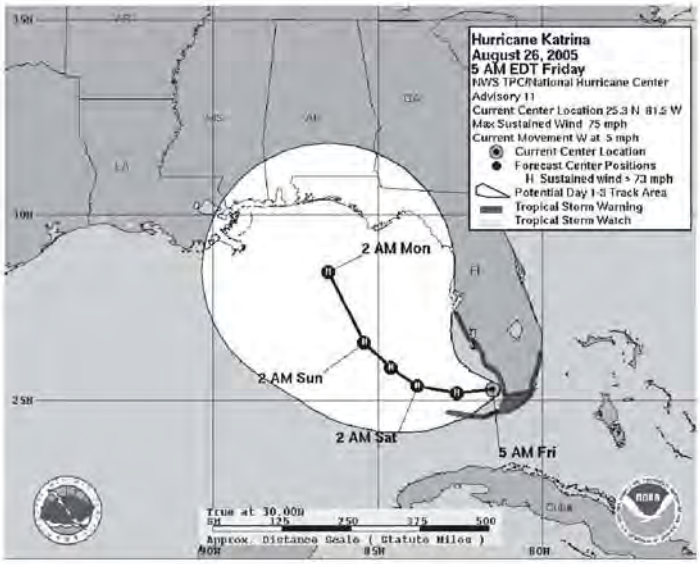
- Print out of the tracking map found at **http://www.nhc.noaa.gov/index.shtml** (near bottom of page)
- Tracking Data from **http://www.wunderground.com/hurricane/at200512.asp** (This data should be copied and pasted from the site—cutting back on total number of tracks is also suggested.)
- Photocopy the hurricane prediction panel from the back of this poster

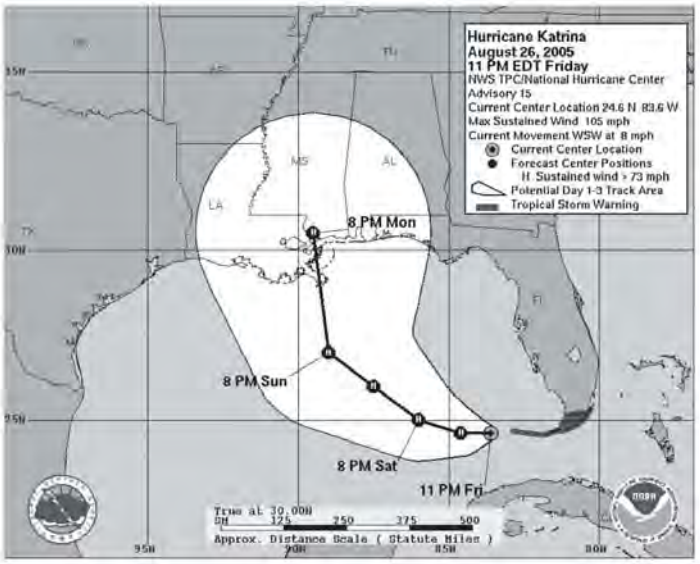
Lesson:

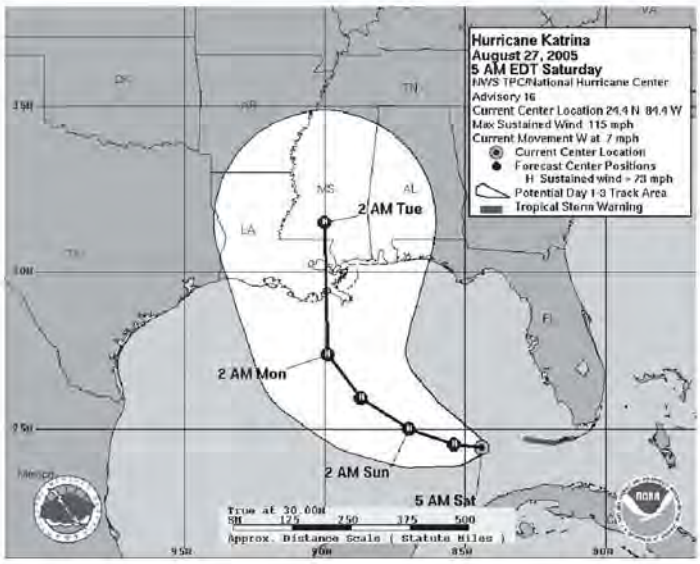
1. Hand out the hurricane tracking map and tracking data for hurricane Katrina.
2. Demonstrate to the students how to track the data for Katrina and have them complete the map.
3. After they are finished with the map, hand out the NOAA Predicted Path and Warning page to each student or group of students.
4. The students should write a response to the question, "Were NOAA predictions accurate and timely?" Students should be sure to include information about the following.
   a. The date of the map with the earliest predicted path that shows Katrina possibly making landfall in New Orleans.
   b. The date of the map on which warnings were given to the area where Katrina actually made landfall.
   c. Whether the predictions and warnings were given in time to be helpful to those making plans to help people living in the path of Katrina.
   d. How a NOAA Weather Radio could have been helpful to residents of the area where Katrina made landfall.

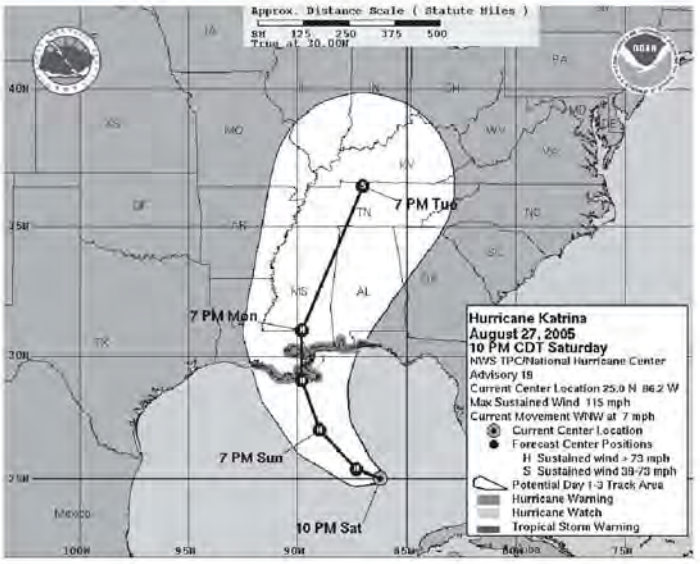
To learn more about the NOAA Weather Radio, go to: **http://www.weather.gov/nwr/**

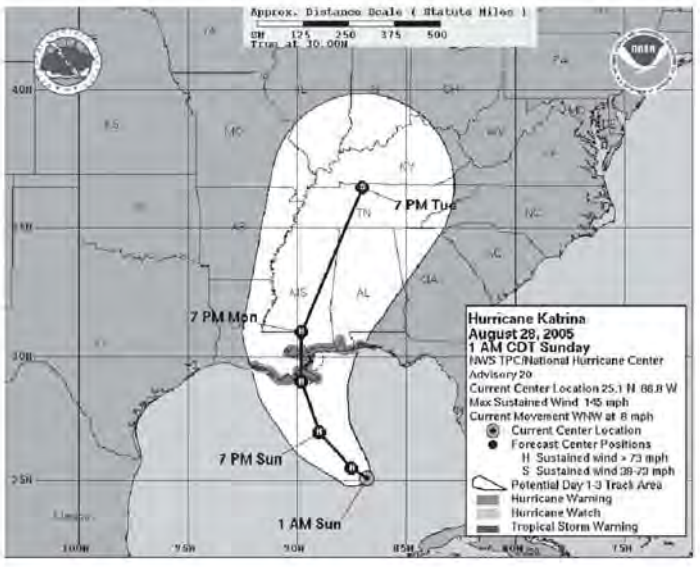
NOAA's Tracking and Predicted Tracking of Hurricane Katrina

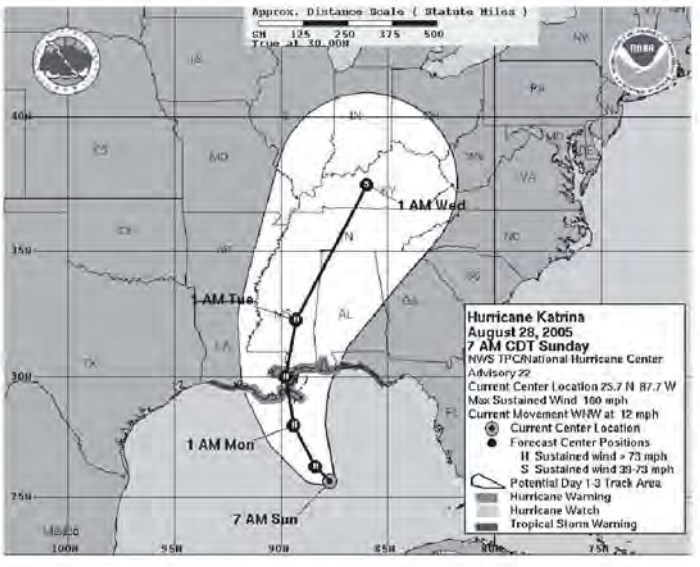












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