OH! BUOY!

A data rich lesson about Hurricane Katrina and the NOAA National Data Buoy Center

OBJECTIVE: Students will gain an understanding of the National Data Buoy Center and how the information gathered from these sensors is used to study of hurricanes and ocean science. Students will develop skills in graph interpretation and data analysis.

National Science Content Standards:

Science and Technology Content Standard, Grades 9-12: Abilities of technological design
Science and Technology Content Standard, Grades 9-12: Understandings about science and technology
Science in Personal and Social Perspectives, Grades 9-12: Natural and human-induced hazards
Science in Personal and Social Perspectives, Grades 9-12: Science and technology in local, national, and global challenges
Unifying Concepts and Processes, Grades 9-12: Evidence, models, and explanation
Unifying Concepts and Processes, Grades 9-12: Change, constancy, and measurement

Ocean Literacy Principles:

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

a. The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.
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 7: The ocean is largely unexplored.

d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Alabama Course of Study Science Standards:

Aquascience Elective Core 2, Grades 9-12: Relate geological and hydrological phenomena and fluid dynamics to aquatic systems
Earth and Space Science Elective Core 2, Grades 9-12: Describe effects on weather of energy transfer within and among the atmosphere, hydrosphere, biosphere, and lithosphere.
Earth and Space Science Elective Core 3, Grades 9-12: Explain how weather patterns affect climate.
Geology Elective Core 14, Grades 9-12: Explain the interaction of the continuous processes of waves, tides, and winds with the coastal environment.
Marine Science Elective Core 4, Grades 9-12: Recognize interactions between the atmosphere and the ocean

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BACKGROUND INFORMATION

ABOUT THE NATIONAL DATA BUOY CENTER:

From the NOAA National Data Buoy Center http://www.ndbc.noaa.gov/tour/virtr1.shtml

The National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC) is a part of the National Weather Service (NWS). NDBC designs, develops, operates, and maintains a network of data collecting buoys and coastal stations. NWS forecasters need frequent, high-quality marine observations to examine conditions for forecast preparation and to verify their forecasts after they are produced. Other users rely on the observations and forecasts for commercial and recreational activities. NDBC provides hourly observations from a network of about 90 buoys and 60 Coastal Marine Automated Network (C-MAN) stations to help meet these needs. All stations measure wind speed, direction, and gust; barometric pressure; and air temperature. In addition, all buoy stations, and some C-MAN stations, measure sea surface temperature and wave height and period. Conductivity (used to derive salinity) and water current are measured at selected stations.

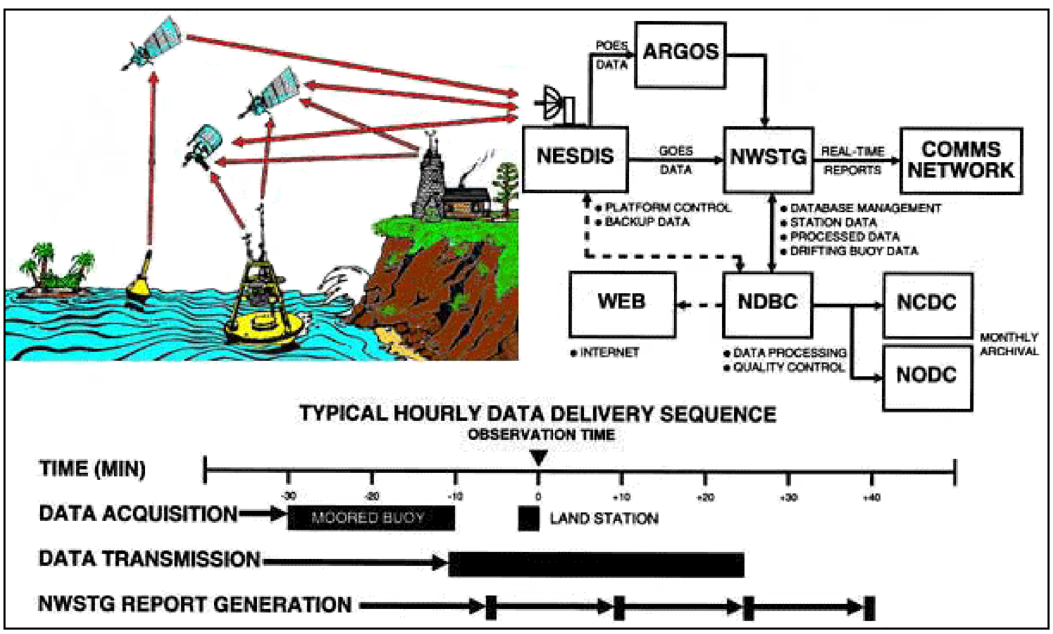
NDBC's main office is located in southern Mississippi at the Stennis Space Center, a National Aeronautics and Space Administration (NASA) facility. This site was chosen because it contains an excellent pre-existing industrial facility which is adjacent to a canal with deep-water access to the Gulf of Mexico. Equipment integration and testing aboard the buoys are accomplished in high bays. Sensors are calibrated in wind tunnels or environmental chambers, and later tested with the onboard station microprocessors, called payloads, on test stands at the outside sensor test facility. Final calibration and testing of the completed buoy systems are accomplished in the onsite canals. Most NDBC stations are located at sites determined by NWS forecast and warning requirements. Some are installed and maintained in areas identified through reimbursable funding agreements with other agencies and private sector institutions. The NDBC web site provides a historical inventory of measurements made at each NDBC station.

All buoys and many C-MAN stations located in offshore areas operate on marine batteries which are charged by solar cells. Data collection, averaging, and formatting for satellite transmissions are controlled by a payload computer system. On buoys, the payloads and batteries are located inside the hull; on C-MAN stations, they are located at the base of the tower.

NDBC uses commercially available sensors such as anemometers to measure wind speed and direction and barometers to measure atmospheric pressure. On the buoys, wave data are collected using an accelerometer which measures the vertical acceleration every 2/3 of a second for 20 minutes. Wave heights and periods are mathematically calculated from these time-series accelerations.

Offshore servicing relies primarily on support from the United States Coast Guard. Stations are serviced as required to repair damaged or degraded equipment. In addition, all buoys are serviced about every 2 years for routine maintenance and to install newly calibrated sensors. The Great Lakes buoys are retrieved every fall because of potential damage by ice. Moorings are designed for a 6-year life span, but often last up to 10 years. The type of mooring used depends on the hull type, location, and water depth.

The observations from moored buoys and C-MAN stations are transmitted hourly through NOAA Geostationary Operational Environmental Satellites (GOES) to a ground receiving facility at Wallops Island, VA, operated by the NOAA National Environmental Satellite, Data, and Information Service (NESDIS). Some stations report via commercial low earth orbiting satellites. The satellite reports are immediately relayed to the NWS Telecommunications Gateway (NWSTG) in Silver Spring, MD.



NDBC also serves as a data assembly center for receiving, quality controlling, and disseminating measurement data from other stations owned and maintained by non-federal regional ocean observing systems, members of the U.S. Integrated Ocean Observing System (IOOS).

At the NWSTG, NDBC systems perform automated quality control on the reports. Data analysts at NDBC monitor the data and adjust the controls to release only good quality data. From the NWSTG, the data are transmitted via various communications networks to NDBC and NWS offices. Private meteorologists receive the reports via the NWS Family of Services. The general public receives them via the Internet, via Dial-A-Buoy, and via NOAA Weather Radio. After additional quality analysis, NDBC data are transmitted to NOAA's archive centers, the National Oceanographic Data Center, NODC, and the National Climatic Data Center, NCDC.

HURRICANES

FROM HTTP://WWW.NHC.NOAA.GOV/CLIMO/ AND HTTP://ENVIRONMENT.NATIONALGEOGRAPHIC.COM

Hurricanes are a type of tropical cyclone. A tropical cyclone is a rotating, organized system of clouds and thunderstorms that originates over tropical or subtropical waters and has a closed low-level circulation. Tropical cyclones rotate counterclockwise in the Northern Hemisphere. They are classified as follows:

- **Tropical Depression:** A tropical cyclone with maximum sustained winds of 38 mph (33 knots) or less.
- **Tropical Storm:** A tropical cyclone with maximum sustained winds of 39 to 73 mph (34 to 63 knots). When a cyclone becomes a tropical storm, it is given a name by the World Meteorological Organization. (To see a current list of cyclone names for the next 6 years, visit http://www.nhc.noaa.gov/aboutnames.shtml)
- **Hurricane:** A tropical cyclone with maximum sustained winds of 74 mph (64 knots) or higher. In the western North Pacific, hurricanes are called typhoons; similar storms in the Indian Ocean and South Pacific Ocean are called cyclones.
- **Major Hurricane:** A tropical cyclone with maximum sustained winds of 111 mph (96 knots) or higher, corresponding to a Category 3, 4 or 5 on the Saffir-Simpson Hurricane Wind Scale. Retired storm names: http://www.nhc.noaa.gov/aboutnames_history.shtml

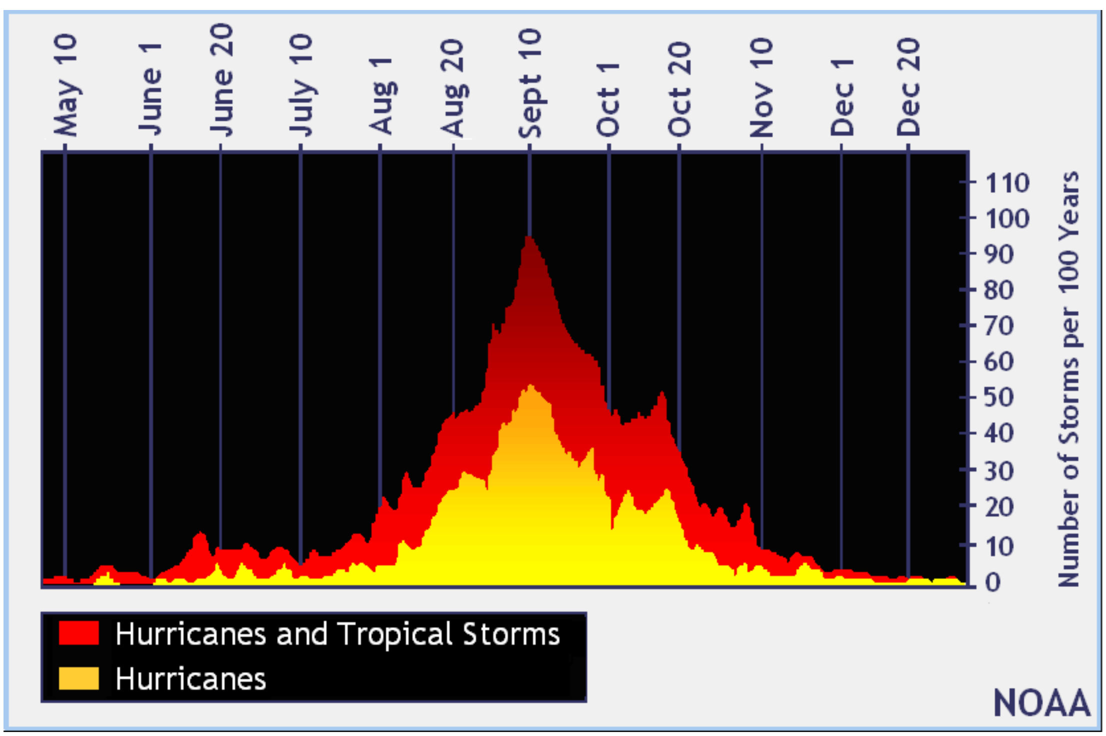
Category	Sustained Winds	Types of Damage Due to Hurricane Winds
1	74-95 mph	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3	111-129 mph (major)	Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4	130-156 mph (major)	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5	157 mph or higher (major)	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Hurricanes are low pressure systems that can pack wind speeds of over 160 miles (257 kilometers) an hour and unleash more than 2.4 trillion gallons (9 trillion liters) of rain a day. Hurricanes begin as tropical disturbances in warm ocean waters with surface temperatures of at least 80 degrees Fahrenheit (26.5 degrees Celsius). These low pressure systems are fed by energy from the warm seas. Hurricanes are enormous heat engines that generate energy on a staggering scale. They draw heat from warm, moist ocean air and release it through condensation of water vapor in thunderstorms. Hurricanes spin around a low-pressure center known as the “eye.” Sinking air makes this 20- to 30-mile-wide (32- to 48-kilometer-wide) area notoriously calm. But the eye is surrounded by a circular “eye wall” that hosts the storm’s strongest winds and rain.

These storms bring destruction ashore in many different ways. When a hurricane makes landfall it often produces a devastating storm surge that can reach over 20 feet (6 meters) high and extend nearly 100 miles (161 kilometers). Ninety percent of all hurricane deaths result from storm surges. A hurricane’s high winds are also destructive and may spawn tornadoes. Torrential rains cause further damage by spawning floods and landslides, which may occur many miles inland.

The best defense against a hurricane is an accurate forecast that gives people time to get out of its way. The National Hurricane Center issues hurricane watches for storms that may endanger communities, and hurricane warnings for storms that will make landfall within 24 hours.

The Atlantic hurricane season runs from June 1st to November 30th but peaks from mid-August to late October and averages five to six hurricanes per year. The Atlantic basin includes the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico.



NDBC Data Uses

Surveys of meteorologists have shown about 40 percent of NWS marine warnings and advisories are based, at least in part, on NDBC's meteorological data. In addition to this critical purpose, the observations are used by meteorologists who need to adjust flight level wind speeds reported by hurricane reconnaissance aircraft to surface winds; by geophysicists who use our sea surface temperature, wind, and wave reports to help calibrate remotely sensed measurements from spacecraft; and by engineers who obtain directional wave measurements to study beach erosion and shore protection. Surfers, fishermen, and boaters acquire the reports via the Internet to help them determine if they want to venture offshore.

FOR THIS ACTIVITY

This lesson can be done without the use of a student computer lab.

Discuss the National Data Buoy Center with your students. If the teacher has internet access, visit http://www.ndbc.noaa.gov/ and visit several buoy sites in the Gulf of Mexico and around the world. Discuss the ongoing real-time data that is collected by the buoys and show several examples such as the information found at the Gulf of Mexico station 42003. (http://www.ndbc.noaa.gov/station_page.php?station=42003)

Students will need a basic understanding of how to read scientific data from graphs prior to doing this exercise, including x-axis versus y-axis, dependent and independent variables, and interpretting data trends.

This lesson assumes a general knowledge of hurricanes and the parts of a wave (period, wave height, and wave length).

Expand it!

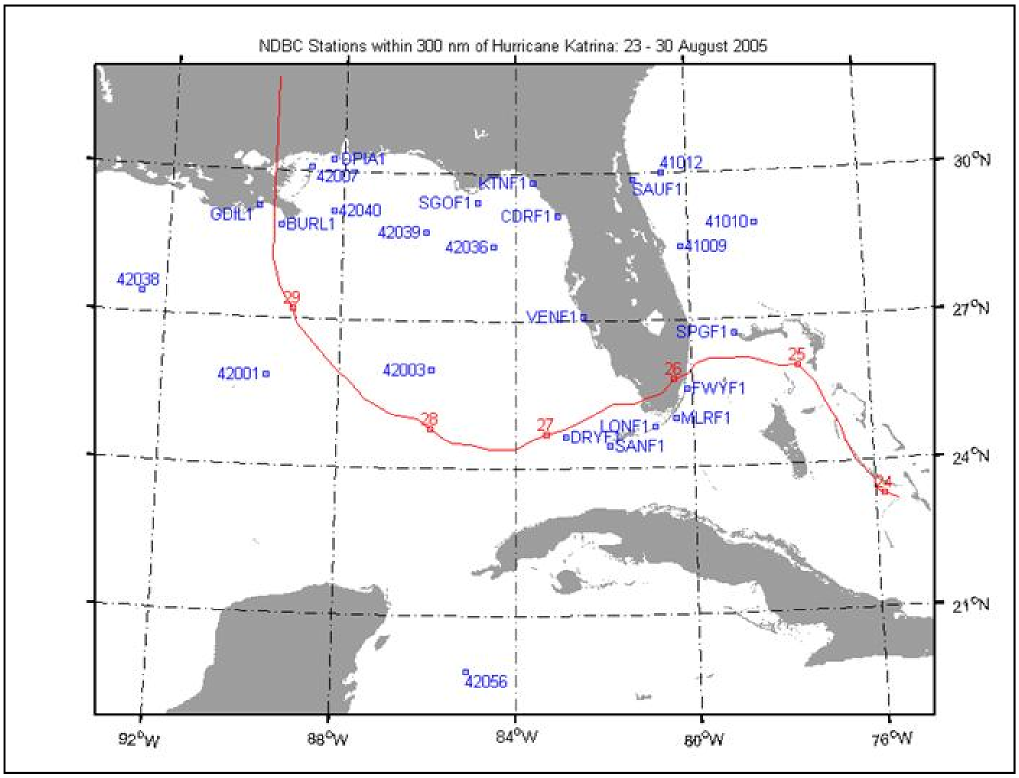
In a computer lab, have your students visit the NDBC website and locate NDBC sation 42040. Compare this week's data to the data during hurricane Katrina. Compare and contrast the maximum sustained wave heights, maximum wind gusts, wind speed, air pressure and atmospheric pressure. To the left of each current measurement, students can click on the graph icon to see time series plots of the data from the past five days.

<u>OH! BUOY!</u>

STUDENT WORKSHEET • TEACHER KEY

Hurricane Katrina was a Category 4 tropical cyclone when it struck land in 2005. The hurricane's intensity reached a maximum wind speed of 175mph making it the second strongest hurricane ever recorded in the Gulf of Mexico. National Data Buoy Center information was gathered throughout the Atlantic Ocean and Gulf of Mexico as the storm traveled its path.

Using the figure and graphs, answer the questions about Hurricane Katrina and NDBC ocean science data. Don't forget to include the correct unit of measurement in your answers!



<u>FIGURE 1:</u> The track of Hurricane Katrina's eye from August 24- August 29, 2005.

The start of each day is numbered. National Data Buoy locations are designated by squares and labeled with the station numbers.

Locate NDBC station 42040.

1. What is the approximate latitude and longitude of NDBC station 42040? **29^oN 88.5^oW**

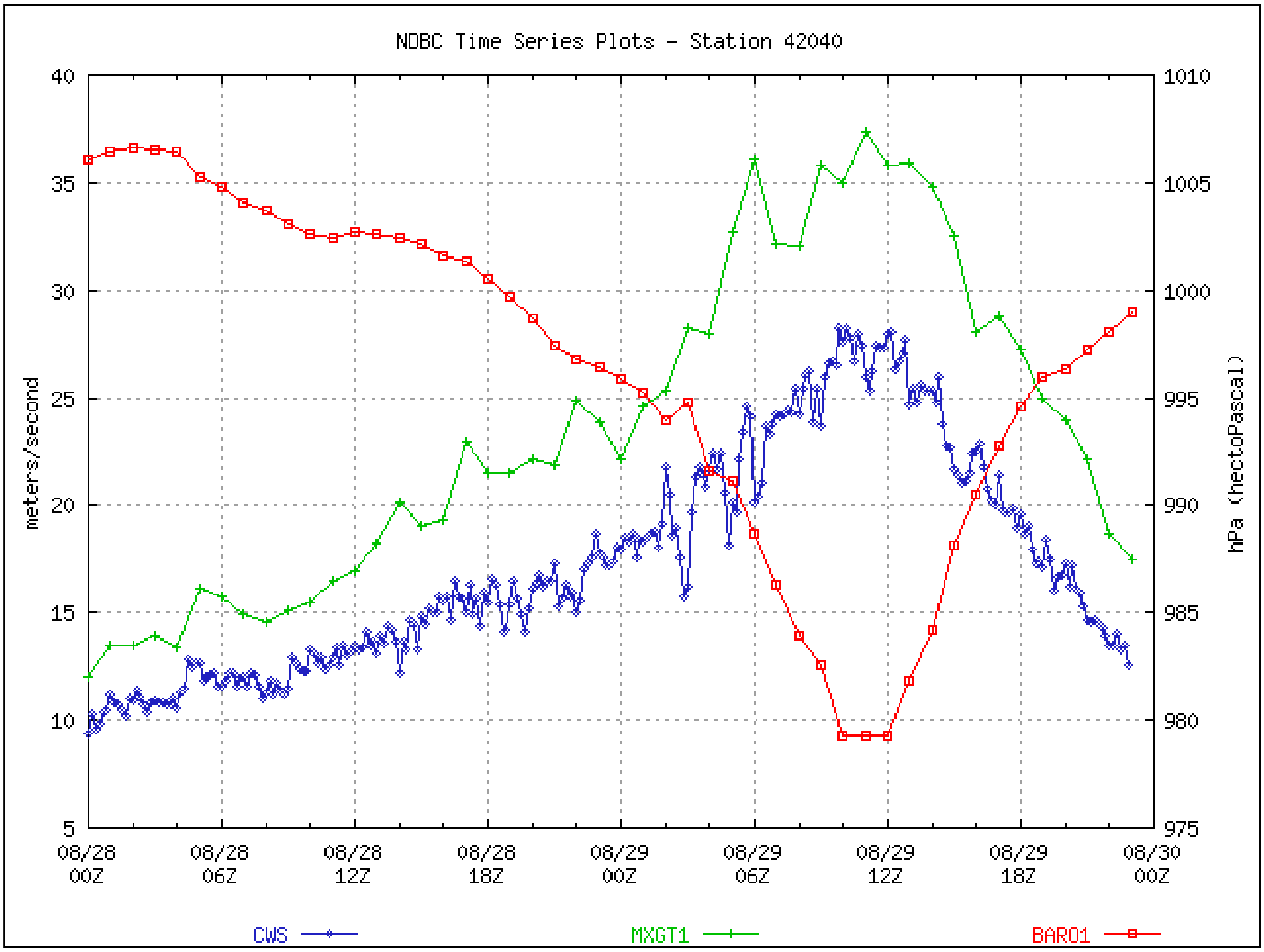
2. What day did the eye of Hurricane Katrina pass NDBC station 42040? **AUGUST 29, 2005**

3. Where is buoy 42040 located in respect to Katrina's path? **APPROXIMATELY 1.5^o EAST OF THE STORM EYE**

   If 1^o longitude at 30^oN equals approximately 59.95 miles, how far away was station 42040 from the eye's center? **APPROXIMATELY 89.9 MILES**

4. How did the path of Hurricane Katrina change between August 28 and August 29? **8-28 TRAVELED NORTHWEST, 8-29 DIRECTION SHIFTED TO THE NORTH**

GRAPH 1



Graph 1: Wind and pressure data collected from Station 42040 during Hurricane Katrina August 2005.

<u>CWS</u>: The average wind speed over 10 minute periods at a height of 5m. Measured in meters/second on the left-hand y-axis.

<u>MXGT1</u>: Peak 5-second gust during the previous hour at a height of 5m. Measured in meters/second on the left hand y-axis.

<u>BAR01</u>: Sea-level pressure averaged over 8 minutes. Measured in hectopascals (hPa) on the right-hand y-axis.

<u>Independent Variable-Date and time</u>: Month/day above time of day in military time

Graph 1 Questions:

5. According to graph 1, what day and time did the atmospheric pressure begin to drop as Hurricane Katrina approached Station 42040? **AUGUST 28, 2AM**

6. What was the highest atmospheric pressure before it began to fall? **APPROXIMATELY 1006.5 hPa**

7. What was the lowest pressure recorded at station 42040? **APPOXIMATELY 979 hPa**

8. What day and times was the lowest pressure recorded at station 42040? **AUGUST 29, 10:00AM-12:00PM**

9. What was the highest recorded average wind speed during Katrina at Station 42040? **APPROX 28 m/sec**

10. Convert the highest recorded average wind speed to miles per hour. (1 m/sec = 2.2369 miles per hour) **62.6mph**

11. What was the highest recorded wind gust during Katrina at Station 42040? **APPROXIMATELY 37.5 m/sec**

12. Convert the highest recorded wind gust to miles per hour. (1 m/sec = 2.2369 miles per hour) **83.9 mph**

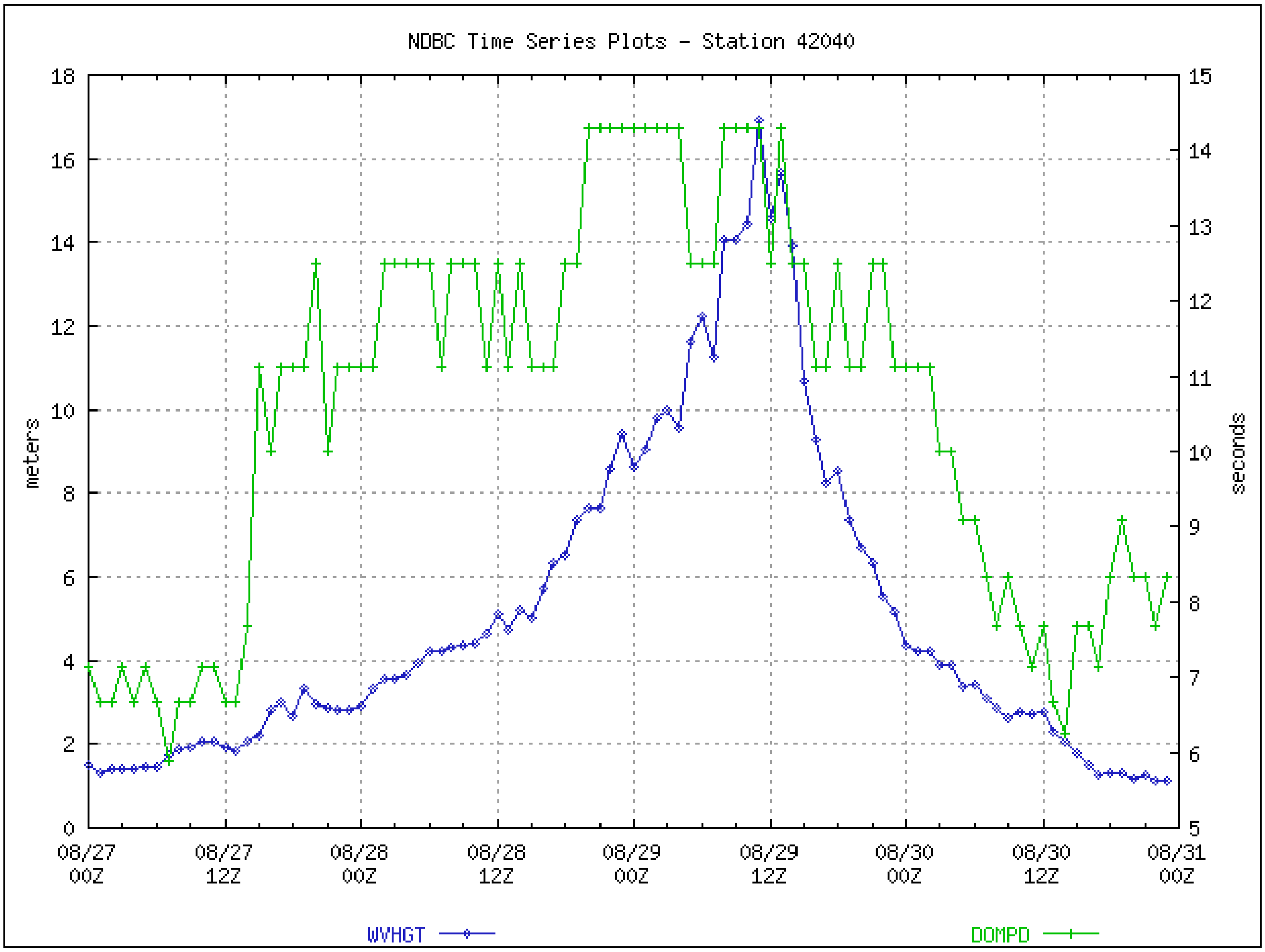
13. Based on what you know about hurricanes, when did hurricane Katrina start to move away from station 42040? **NOON ON AUGUST 29**

14. A. Look at Graph 1 on August 29 at 6am. What do you notice about the wind speed and wind gusts during this time? **THERE IS A PEAK IN WIND GUST, BUT A LULL IN AVG WIND SPEED AT THE SAME TIME**

B. Does this happen anywhere else on Graph 1 as Katrina moved past Station 42040? **YES, 8/29 11AM;**

15. Are the trends for this graph for wind speeds and pressure what you would expect for a typical hurricane approaching a stationary point? Explain your answer. **YES- AS HURRICANES APPROACH A STATIONARY POINT, THE WIND SPEED AND WIND GUSTS WILL INCREASE AS THE EYE APPROACHES AND DECREASES AS THE STORM RECEEDS. THE ATMOSPHERIC PRESSURE FOR THE STORM WILL DROP UNTIL THE STORM PASSES**

GRAPH 2



Graph 2: Wave data collected from Station 42040 during Hurricane Katrina August 2005

<u>WVHGT</u>: Average of the highest 1/3 of waves during the sampling period. Measured in meters on the left-hand y-axis

<u>DOMPD:</u> The wave period (time between consecutive passes of the wave crests) of the waves with the most energy. Measured in seconds on the right hand y-axis

<u>Independent Variable-Date and time</u>: Month/day above time of day in military time

Graph 2 Questions:

16. What was the maximum significant wave height recorded by station 42040 during Hurricane Katrina? **APPROX 17m**

17. Convert the maximum significant wave height from meters to feet. (1 meter = 3.28 feet) **APPROX 55.76 FEET**

18. When (day and time) was the maximum significant wave height recorded? **8-29, 11:00AM**

19. What was the length (time) of the greatest wave period recorded by station 42040 during Hurricane Katrina? **14.5 SECONDS**

20. Did the dominant wave period and significant wave height follow similar trends as Hurricane Katrina approached station 42040? Explain your answer.
BOTH THE DOMINANT PERIOD AND SIGNIFICANT WAVE HEIGHT INCREASED AS KATRINA APPROACHED THE STATION. THE AMOUNT OF TIME THE DOMINANT PERIOD WAS SUSTAINED INCREASED AS THE STORM APPROACHED. THE WAVE HEIGHT INCREASED AT A MORE CONSISTANT RATE THAN THE DOMINANT PERIOD.

WAVE DIMENSIONS:
Wave steepness is the slope determined by the ratio between wave height and wave length. Wave steepness can be inferred from buoy measurements of wave height and period. When wave heights and periods are close to the same value (e.g., six foot seas every six seconds) wave steepness is severe.

21. Given the information about wave dimensions above and using Graph 2, look at the waves on August 28. Give the corresponding wave height and dominant period for August 28 at midnight, noon, and 9:00PM. During these time periods, was the wave steepness severe? Explain your answer.

8-28, MIDNIGHT, WAVE HEIGHT = 3M, DOMINANT PERIOD = 11 SEC
8-28, NOON, WAVE HEIGHT = 5M, DOMINANT PERIOD = 12.5 SEC
8-28, 9:00PM , WAVE HEIGHT = 7.5M, DOMINANT PERIOD = 14.5 SEC

ON AUGUST 28, THE WAVE HEIGHTS RANGED FROM 3M – 10M. THE DOMINANT WAVE PERIOD RANGED FROM 11SEC - 14.5SEC. THE MEASUREMENTS WERE NEVER NUMERICALLY EQUAL OR CLOSE- AS THE WAVE HEIGHT INCREASED THE DOMINANT PERIOD INCREASED.

Graphs used in this exercise from: http://www.ndbc.noaa.gov/hurricanes/2005/katrina/