Weather & Climate

Forecasting severe weather: Hurricanes and GPS

Students will learn about the relationship between water vapor in the atmosphere and severe weather.

13-16 schools

Math, Earth Science

Water vapor, GPS, Hurricane, Severe weather, Julian day

1 hour

TEACHER GUIDELINES

Students will learn about the relationship between water vapor in the atmosphere and severe weather. Then they will use water vapor data from GPS systems and other meteorological variables to predict and track Hurricane Georges. Significant understanding of background material, especially the relationship between water vapor and severe weather, is helpful.

MATERIALS

- 1 copy of the table of data for students
- 1 blank sheet of paper and pencil per student for graphing exercise
- 1 copy of Hurricane George satellite imagery

LEARNING OBJECTIVES/ STANDARDS

1. Graph actual water vapor and pressure data during a hurricane. (Reproducing)
2. Understand the relationship between water vapor and severe weather. (Understanding)
3. Explain graph trends and results compared to satellite imagery of the hurricane. (Creating)

BACKGROUND INFORMATION

Meteorologists, researchers, and forecasters work to improve weather forecasts, especially forecasts of severe weather. One factor limiting timely forecasts is a lack of information about water vapor in the atmosphere. The amount of water vapor in the atmosphere varies greatly over short distances and short periods of time. For example, some people have experienced watching rain in one location while standing in the sun, or watching clouds drift by with lots of water but no precipitation. Most of us have experienced a brief rain shower, only to find the sun shining within a few minutes.

Water travels rapidly through the atmosphere. Billions of gallons of water exist in the atmosphere. Like fuel in an engine, water vapor provides energy in the form of convection. In convection, water evaporates (taking up heat), expands in the atmosphere, then cools, and condenses. When vapor condenses, it gives off heat. This heat is like high-octane fuel, providing the energy for thunderstorms, tornados, and hurricanes. During a hurricane, for example, water vapor comes from the warm ocean water. Once the hurricane reaches land, its "fuel" supply disappears and the hurricane rapidly fades away. Not only does water vapor affect weather events, it also plays a critical role in the global climate system. For example, water vapor is a greenhouse gas, and it influences air pollution. Water vapor also refracts (slows-down and bends) radio waves, including GPS (global positioning system) signals. When this happens, the apparent distance between a GPS satellite and a receiver on the ground is a little longer than it would be if the air were completely dry. This means that your GPS position may be a little less accurate when the sky is cloudy than when it is clear.

The slowing of the GPS signals mostly come from local changes in atmospheric water vapor. GPS meteorology is an inexpensive and effective ground-based meteorological observing system. Existing GPS sites can be equipped with a thermometer and barometer to receive measurements for the total amount of water vapor above a GPS antenna. Scientists call this water "precipitable" water vapor.

CREATED BY:

Leah Tai, TAHMO

In this activity, you will use the amount of precipitable water vapor measured in centimeters and surface air pressure measured in millibars to follow the development of Hurricanes Georges.

1. First, have students demonstrate their understanding of precipitable water vapor. Imagine a cylinder where the base sits on the ground and the sides reach up to the top of the atmosphere. Precipitable water vapor is the amount of water that would form if all of the water vapor in the cyclinder were condensed or precipitated. Ask students to draw a representation.

2. Look at actual data from researchers at the National Oceanic and Atmospheric Administration Forecast Systems Laboratory, in Colorado, USA and create a graph of changes to precipitable water and surface pressure over time.
a. Sometimes researchers find it convenient to use a calendar that simply counts days in numerical order beginning with the first day of a new year, this is called a Julian Calendar. Using Table 1, convert the Julian Calendar dates to Gregorian Calendar dates by filling in the columns for your calculations and calculation-derived values for day and time, in hours and minutes.

> 1. To convert days: The Julian Calendar in this table begins with day 1 of 1998 and numbers each successive day – day 1, day 2, day 3, etc. For example, Day 268 is September 25, 1998 and Day 269 is September 26, etc. Furthermore, each day used in these data is divided into decimal fractions.
> 2. To convert hours: Simply multiply 24 hours times the decimal part of the date (from Column 1 – Table 1). Round your result to the nearest one hundredth and record your result in the "Hours Calculation" column of Table 1.
> 3. To convert hours to minutes: Simply multiply 60 minutes times the decimal part of the hour results. Round your result to the nearest whole number and record your result in the "Minutes Calculation" column of Table 1.
> 4. Complete the column for the "Gregorian Calendar Time". Remember to label "AM" and "PM".
> 5. Using Table 1, round off each precipitable water vapor reading to the nearest tenth. Record your results in the appropriate column of Table 1. Using Table 1, round off surface air pressure to the nearest whole number. Record your results in the appropriate column of Table 1.
> 6. Use the data from Table 1 to create a graph of precipitable water vapor (cm) and surface pressure (mb) over time.

RESULT

Students will create a graph of precipitable water vapor and surface pressure over several days. This data was taken during an actual hurricane, Hurricane Georges.

Water vapor and surface pressure during Hurricane Georges
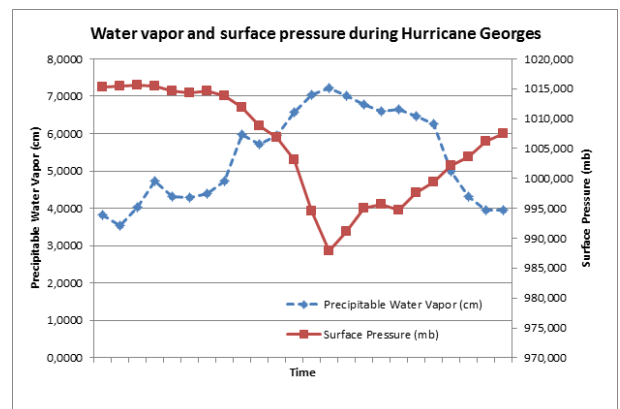
DISCUSSION

Students should then examine their graphs and satellite images to compare results to figures 1 and 2.

Discussion questions:

a. According to the Gregorian Calendar, on what day and at what time did the highest amount of precipitable water occur? (September 28, 1998, 06:15 AM)

b. According to the Gregorian Calendar, on what day and at what time did the lowest surface air pressure occur? (September 28, 1998, 06:15 AM)

c. What is the relationship between the amount of precipitable water and surface air pressure over time? (The amount of precipitable water increases as surface air pressure decreases.)

d. Why is information about the amount of water vapor in the atmosphere important to forecasters? (Improves short term forecasts, especially for severe weather. Knowing that more water vapor is present, means that a storm is more likely.)

e. Using your graph for precipitable water vapor and Figure 2 of Hurricane Georges, explain why there is a slight jump (spike) in the amount of precipitable water vapor on the graph just before the peak for the amount of precipitable water vapor from the full force of the hurricane. (The spike represents a visible "arm" of Hurricane Georges that reaches land before the full force of the hurricane.)

f. Why does the graph for precipitable water slope steeply on one side and not the other? (Hurricane Georges gains power as it slowly builds up over water. It loses power quickly once it reaches land because there is no water to fuel it.)

g. Using Figure 2, the diagram for the track of Hurricane Georges, explain the changes in wind speed. (Hurricanes Georges increases in power, therefore in wind speed, as it gets its energy from the ocean, convection), over which it travels, then loses its source of energy as it travels over land, and therefore decreases wind speed.)

Table 1

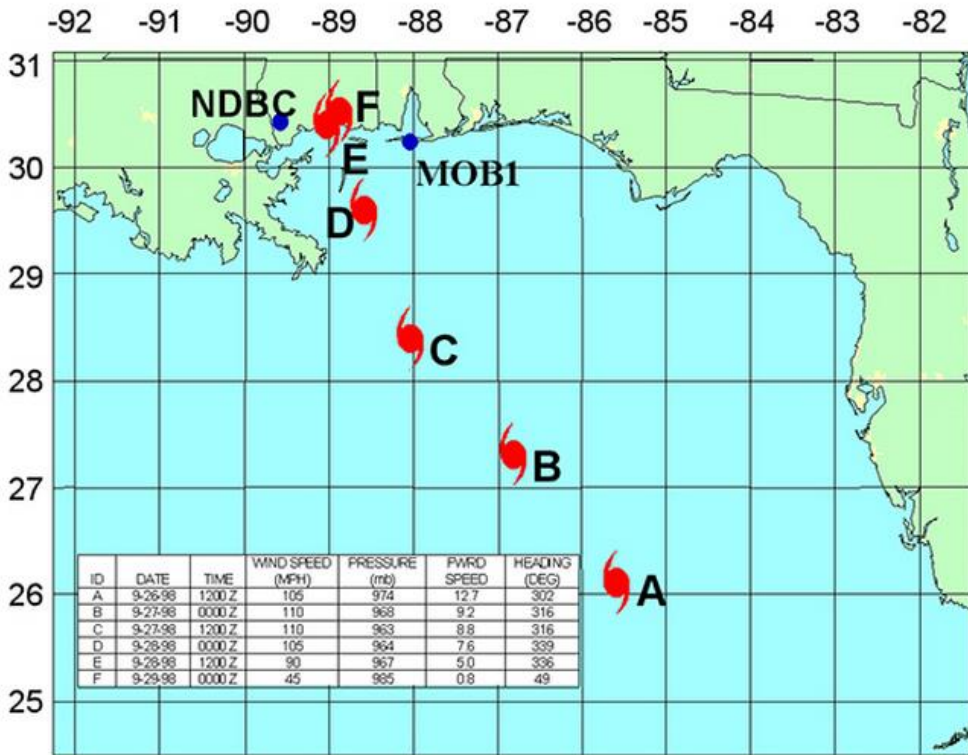| Julian Calendar (Day and Time)	Gregorian Calendar (Day)	Hours Calculation	Minutes Calculation	Gregorian Calendar Time (00:00)	Precipitable Water Vapor (cm)	Precipitable Water Vapor – rounded (cm)	Surface Pressure (mb)	Surface Pressure – rounded (mb)
268.0104	9/25/1998	0.25	15	12:15 AM	3.8140		1015.230	
268.2604	9/25/1998	6.25	15	6:15 AM	3.5430		1015.380	
268.5104	9/25/1998				4.0350		1015.630	
268.7604	9/25/1998				4.7340		1015.400	
269.0104	9/26/1998				4.3250		1014.580	
269.2604					4.2870		1014.230	
269.5104					4.4000		1014.600	
269.7604					4.7270		1013.880	
270.0104					5.9840		1011.950	
270.2604					5.7020		1008.800	
270.5104					5.9600		1006.780	
270.7604					6.5670		1003.200	
271.0104					7.0260		994.580	
271.2604					7.2260		987.900	
271.5104					7.0090		991.100	
271.7604					6.7900		995.030	
272.0104					6.6000		995.650	
272.2604					6.6580		994.675	
272.5104					6.4770		997.650	
272.7604					6.2680		999.450	
273.0104					4.9840		1002.150	
273.2604					4.3130		1003.575	
273.5104					3.9580		1006.275	
273.7604					3.9470		1007.475	

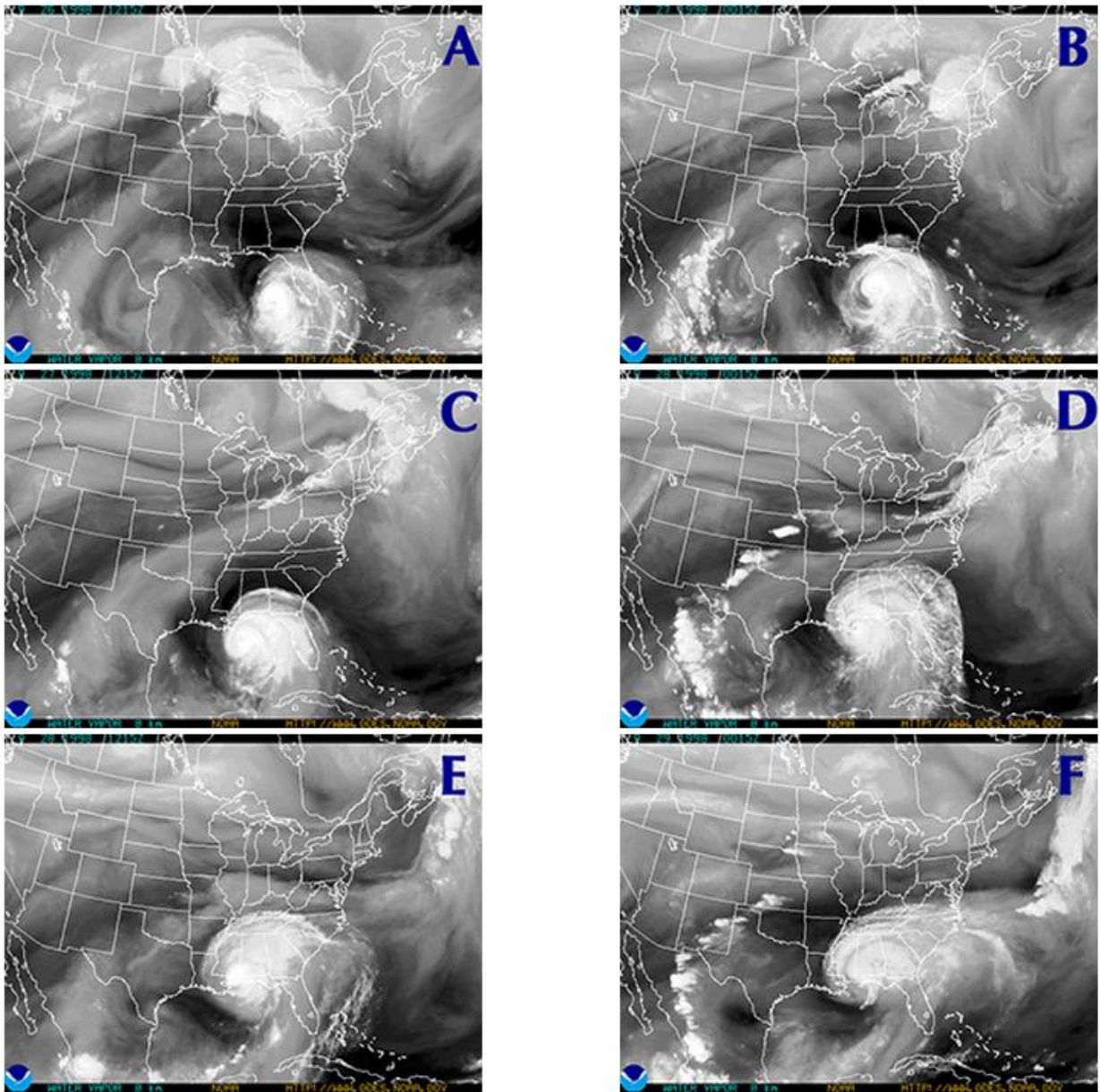Figure 1: Track of Hurricane Georges from 9/25/98 to 9/29/98 (letters correspond to images on figure 2)

Figure 2: Water vapor satellite imagery of Hurricane Georges