Satellites and Storms: Using Ocean Observing to Investigate Coastal Storms

A Classroom Activity for Ocean Gazing Episodes 8 & 17: The glide of a lifetime: Part II; The prince's predictions: Part I

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Grade Level: 8-12

Lesson Time: 60 min.

Summary

Investigate weather patterns, weather maps and the effects weather has on the ocean, all using real ocean observing system data.

Objectives

- ✓ Describe atmospheric conditions from observing a basic weather map.
- ✓ Identify high and low pressure systems on a weather map based on respective indicators.
- ✓ Forecast conditions based on weather maps and satellite imagery of sea-surface temperature.

Vocabulary

Hurricane, Northeaster, Nor'easter, Low pressure, Wind barb, Coriolis, Fetch

Introduction

Ocean and Atmosphere: Linked Fluids in Motion

The atmosphere and the ocean are both dynamic fluids, ever circulating as they are driven by the uneven heating of the earth and the earth's rotation on its axis. While we often think of the atmosphere and ocean as two separate systems - with weather and wind moving the air, currents and tides affecting the sea - in reality they are two sides of a single air-sea system. The ocean and atmosphere influence and interact with each other in very complex ways. Reflecting this linkage between air and ocean, researchers in the fields of meteorology and oceanography often work together.

We can investigate basic atmosphere-ocean interactions using some of modern oceanography's most valuable tools, satellites. From their orbits high above the earth, ocean observing systems provide global and regional perspectives that reveal the effects that atmosphere and ocean have on one another. Thanks to advancing technology, satellites now collect all sorts of data: ocean temperature; water color (indicating sediment load or phytoplankton density, for example); wind speed and direction; the roughness of the ocean's surface; and more. And we can access this information, plus data from buoys, ships and coastal observing stations, using the internet. In this series of activities, we'll use ocean observing systems to study the formation and impacts of coastal storms.

Coastal Storms

But, first, let's introduce our subjects, coastal storms. Here in Virginia, we get two main types of severe coastal storms: Hurricanes and Nor'easters. They differ in their region of origin, season, and duration of impact.

Hurricanes develop over tropics in late summer and fall. These powerful coastal storms are characterized by high winds, waves and storm surge and heavy rain that results in flooding. They usually migrate quickly, at speeds of 10 to 25 miles/hour.

In contrast, Northeasters, or Nor'easters, are not of tropical origin. They can form right off the North American coast any time during the fall, winter or early spring. They also generate high winds, waves and flooding, but they don't always move very quickly. Although Nor'easter winds are not as intense as those of many hurricanes, they make up for it in duration. Nor'easters may be held in place for days by arctic (Canadian) high pressure systems. As a result, the seas have time to develop to maximum wave size, pounding the coast for prolonged periods.

Data Activities

To investigate these two types of storms, we'll take one step at a time, learning about meteorology and oceanography as we work through **five activities**.

1. What Starts a Coastal Storm? Water Temperature Highs Fuel Air Pressure Lows
2. Thar She Blows!
3. And the Lows Go Round and Round
4. Surf's Up!
5. The Gulf Stream: Storm-Maker

Activity #1: What Starts a Coastal Storm?

Introduction

A "low" is a mass of warmer, lighter air that is rising off the earth's surface . This creates a vacuum (= low pressure) over the land or sea. This vacuum draws air in horizontally from all sides, and this produces wind. We'll come back to talk more about lows and wind later.

What makes the air warm to begin with? Warmed by the sun's greater intensity at low latitudes, the tropical ocean becomes a source of heat for the atmosphere.

Hurricanes develop in the tropics over seawater that is warmer than 28°C (82°F). The seawater warms the air above it. Hot, humid air then rises, until at higher elevations it cools down. When it cools, the moisture condenses, forming massive cumulus clouds, and a storm is born.

Nor'easters develop a bit differently, but also depend on warm water and warm air for their energy. We'll investigate them later.

Data Activity & Discussion: Using SST Daily Composite Imagery

Go to the Rutgers University's COOL site Satellite Images page.

- ✓ Scroll down the page. On the left you'll see "Sea Surface Temperature Composite."
- ✓ Under that heading, select "Eastcoast."

- ✓ Scroll down to the “Most Recent Imagery” section in the center. You’ll see thumbnail images for 10-days of data. The most recent image, the top left, is an analysis of yesterday’s satellite data.
- ✓ Click the most recent image to get a full screen. You’ll see the longitude (X-axis) and latitude (Y -axis). The temperature color legend is on the far right; you may have to use the cursor arrow to scroll over to it.

Be patient while this downloads. The colorful image of ocean temperature you’ll see is made available by oceanographers at Rutgers University in New Jersey. The images are from the NOAA AVHRR (Advanced Very High Resolution Radiometer) satellites. The white areas are cold temperatures caused by clouds.

Tracking the factors that fuel coastal storms

1. Find today’s approximate sea surface temperature (SST) at 25°N latitude and between 60-65°W longitude. If the map is white, that means there are clouds in the way of the satellite’s sensors; look through earlier dates for a better view of the sea surface.

   Hurricanes develop in the tropics over seawater that is warmer than 28°C (82°F). Are the waters down in the tropical Atlantic (at 25°N latitude, for example) warm enough at this time of year to produce a hurricane?

2. For comparison, review the approximate SST in this same location between the dates of August 15-28, 2005, right before Hurricane Katrina struck the Gulf Coast on August 29. Report the sea surface temperature at 25°N latitude and 65°W longitude.

   (To do this, scroll back up to the “Sort by: date” box and enter the August dates. Then, hit “Select” and review the new images. Hurricane Katrina appears as a white area in the first image, scroll down to the image of August 15 and click for a larger view.)

Activity #2: Thar She Blows

Introduction

Go to Oceanweather, Inc. This site uses satellites to relay real-time meteorological data collected from different sources: buoys, ships and coastal stations.

- ✓ On the left, click on North Atlantic, “Southern Region,” then
- ✓ Click the “Marine Observations” icon at the top of the page, This is a real time image of today’s weather systems, annotated with various symbols.

The “flags” scattered around the map are wind barbs that indicate wind velocity and direction. Red flags represent data collected by weather buoys, blue indicates information collected by ships.

Data Activity & Discussion: Reading Wind Barbs

1. Find wind barbs indicating wind speeds of: 0-5 kt; 10-20 kt; 30-40 kt, 50+ kt.
2. What direction are winds blowing off the SE coast of the US (south of Cape Hatteras)?
3. What direction are winds blowing off the NE coast of the US (north of Cape Cod)?
4. Is there a pattern to the wind directions in the middle of the North Atlantic? How is this pattern related to ocean surface currents in the North Atlantic? Could this circulation pattern influence the path that hurricanes often follow?

Activity #3: And the Lows Go Round and Round

Introduction

North Atlantic low pressure systems always rotate counterclockwise. Why? The rotation stems from the Coriolis Force, which is caused by the rotation of the earth on its axis. As the warm, wet air in a low pressure system rises, it draws air toward its center. The Coriolis Force deflects wind to the right, resulting in a counterclockwise pattern of windstreams around the low.

Identifying Lows

Go to an example weather map. Look at the isobars, the solid lines that form curving patterns on the map. They are usually measured in millibars (mb) of pressure. Where the isobars close around a low value, you have a Low. Where they close around a high value, it's a High.

> High values = greater than 1001 mb, e.g. 1012 in this example.
>
> Low values = lower than 1000 mb, e.g. less than 996 in this example.

See another example weather map.

Data Activity & Discussion: Identifying Lows

Go to Oceanweather, Inc. On the left, click on North Atlantic, "Southern Region," then click the "Marine Observations" icon at the top of the page.

Note: On Oceanweather.com Marine Observations images, the first 2 digits of the isobar reading are dropped as part of the meteorologist's shorthand. So a high reading might appear as "26" (meaning 1026), while a low might look like "89" (meaning 989).

1. Search for Lows -- possible storm centers -- in the Atlantic. If there are no lows in the Southern region, try the view of the Northern region. If you find a low(s), record the latitude and longitude.
2. What direction do the wind vectors point around the low?

Activity #4: Surf's Up!

Introduction

How do lows and their winds affect the ocean? As the wind shears across the water, it rubs against the sea surface, transferring energy and creating wind-driven waves. The stronger the wind is, the longer it blows, and the greater the fetch, or the distance over which it blows, all contribute to generating big waves. To see the impact of wind speed on waves we'll use a view of real-time wave data provided by Oceanweather Inc.

Data Activity & Discussion: Linking Winds and Waves

Go to Oceanweather, Inc.

- Click on **Global View** at the left
- Then, click **Wave Graphics**

Note: The arrows on this chart indicate wave direction (not wind) and the colors indicate the size of the waves. Use the color-coded scale at the bottom of the webpage to interpret.

1. Where in the world are the largest waves today?
2. Compare this view of Global Wave Graphics with the Global view of Marine Observations.

Now that you know how to find lows and read wind barbs: Do you see any relationship between the position and strength of a low, the wind speed and the occurrence of large waves?

Activity #5: The Gulf Stream – Storm-Maker

Introduction

Now, we come full circle to study sea surface temperatures again. This time, we'll concentrate our observations along the Atlantic coast, looking at the Gulf Stream. This famous current forms the western boundary of the North Atlantic Gyre's clockwise circulation. Flowing from south to north, the Gulf Stream moves warm water from subtropics to temperate latitudes and is the East Coast's powerful storm maker. It can carry hurricanes up the Eastern seaboard during summer and early fall, fueling the storms' strength with warm, wet air. And, since it carries some warm water year-round, the Gulf Stream also plays a role in promoting Nor'easters from fall through spring.

Moving currents of air and ocean interact to create these dangerous storms. Nor'easters usually develop off the coast of North Carolina or Virginia when the cold Labrador Current coming down from the North meets the warm Gulf Stream coming up from the South. The contrast in the air temperatures above these currents help form a low pressure system. At the same time over Canada, winds circulate in a clockwise motion around a high pressure system. These cold winds dip deeply into the United States, colliding with the warmer air mass sitting above the sea. Since warm air is lighter, it rapidly rises over the arctic air, drawing moisture with it. The pressure then plummets and a wet, violent tempest takes shape.

Data Activity & Discussion: Tracking the Gulf Stream

Look for the Gulf Stream at the Cool Room website.

- ✓ On the Satellite Images page, scroll down the page until you see on the left "Sea Surface Temperature Composite."
- ✓ Under taht heading, select "Eastcoast."
- ✓ Scroll down to the "Most Recent Imagery" section in the center. You'll see thumbnail images for 10-days of data. The image at top left is an analysis of yesterday's satellite data.
- ✓ Click the most recent image to get a full screen. You'll see the longitude (X-axis) and latitude (Y-axis). The temperature color legend is on the far right; you may have to use the cursor arrow to scroll over to it.

Look again at the water temperatures off the Atlantic Coast.

- ✓ Can you discern the Gulf Stream as it travels up the southeast coast of the U.S.?
- ✓ How warm was the water in the Gulf Stream off Cape Hatteras, 35°N latitude, 75°W longitude, last summer? Look at August 15, 2006.
- ✓ What about in mid-winter? Can the Gulf Stream carry any warmth up the coast in January?
- ✓ Look at January 15, 2007.

Extensions

Tracking the factors that fuel coastal storms

1. SST in a record hurricane year. To see how tropical sea surface temperature varied through the seasons of 2005, sample SST at 25ºN latitude and between 60-65ºW longitude on or about the 15th of each month (bracket several days to be sure there's at least one day with SST readings for that site). Record the SST and plot this as a line graph with month on the X-axis and SST on the Y-axis. Does this help you understand why NOAA Weather Service defines Hurricane Season as June to

November of each year? Why does Hurricane Season extend so far into the autumn months? What special property of water holds the key? How do temperatures at this location compare with surrounding waters?

2. A year of SST on the Gulf Stream. To see how Gulf Stream temperature varies through the seasons, we'll sample the SST off Cape Hatteras at approximately 35°N latitude, 75°W longitude on or about the 15th of each month (bracket several days to be sure there's at least one day with SST readings for that site). Record the SST and plot this as a line graph with month on the X-axis and SST on the Y-axis. Does this help you see how the Gulf Stream can fuel storms even in the cooler winter months? How do Gulf Stream temperatures normally compare with surrounding waters?

3. What made the Perfect Storm? One of the most notorious Nor'easters is "The Perfect Storm" of October 31, 1991, which caused damage from the Carolinas to Maine. It has been immortalized in books, movies and TV specials. You can read more about the formation of Nor'easters at the NASA-sponsored Storm-E Weather Simulation web page, and about the Perfect Storm. In this famous example, you'll see that a failed late-season hurricane actually contributed to the unusual severity of this Nor'easter!

Related Resources

Physical oceanography, Climate & Atmosphere

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Extensions

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Sources

To access an online version of this activity, you can go to the following URL: http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive1007.html

The related podcast episode for this activity can be found by going to the podcast section of www.oceangazing.org