Teacher’s Guide

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Mission:
The National Aeronautics and Space Administration (NASA) awarded the Association of American Geographers (AAG) a one-year $92,834 grant to develop Geo-Spatial Thinking Activities and Resources for Teachers (GeoSTART) as a pilot project to enhance the teaching of geography and earth science. Teachers using the GeoSTART materials will learn state-of-the-art approaches to teaching geography, earth science, and spatial thinking skills using NASA Earth Observing Missions remote sensing imagery and related data.

Acknowledgements:
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Introduction: Using Different Modes of Spatial Thinking to Look at Hurricanes

This packet contains eight sample student activities. Each one is designed to engage one of the eight major modes of spatial thinking listed in the learning scaffold that is the primary focus of this NASA-funded curriculum project.

As written, the activities contain all of the background information, instructions, satellite imagery, and other materials needed to support a very short but tightly-focused inquiry. This inquiry could fit into a larger curricular unit on hurricanes in many ways. By following the suggestions listed in the Extension section of the activity, however, a teacher could turn any activity into a standalone inquiry lesson. In most cases, that larger lesson will require high-speed Internet access to obtain additional satellite images, maps, and other information. Under a teacher’s guidance, students should select a location for that inquiry that fits with other aspects of the curriculum.

In short, these lessons should be seen as miniature models of how to pose questions that can engage various modes of spatial thinking in order to solve a geographic problem. The durability of learning, however, will depend on whether students are motivated to apply those thinking skills to address a problem they see as important enough to warrant independent, self-directed inquiry.

These lessons are based on three extremely important conclusions from recent brain research:

1) Different modes of spatial thinking make use of different brain structures that operate in parallel – that is, simultaneously rather than sequentially. In other words, there is no “natural” sequence that students should follow in applying spatial-thinking skills to a specific problem, such as the origin, movement, and effects of a hurricane.

2) The brain structures for complex spatial thinking are fully functional by age four, although people can continue to improve in competence throughout their lives.

3) There are significant individual differences among students in their predisposition to use particular modes of spatial thinking to address a problem.

One purpose of this packet of activities, and indeed of the entire learning-scaffold project, is to provide teachers with both background and materials that allow them to “deploy” different modes of spatial thinking at different times. Teachers should do this for four reasons:

1) to enhance the full range of thinking skills in their students,

2) to equip students with tools that are suited to address different questions,

3) to accommodate individual differences among students, and

4) to provide variety and still maintain a coherent focus on a worthwhile problem, such as trying to understand and cope with hurricanes.

In that spirit, here are the titles of the eight activities in this packet; the featured mode of spatial thinking is underlined in each title (remember, they do not have to be done in this order!):

1. Hurricane Shapes: Spatial Patterns on Satellite Images

2. Hurricane Frequency: Identifying Regions with Similar Numbers of Hurricanes

3. Hurricane Paths: Comparing Places with Different Prevailing Winds

4. Hurricane Stories: Analogous Locations in Different Hemispheres

5. Hurricane Winds: A Spatial Hierarchy of Processes at Different Scales

6. Hurricane Strength: Spatial Association of Wind Speed and Water Temperature

7. Hurricane Influence: Landfall Probabilities and Wind Speed

8. Hurricane Impact: Storm Surges and Elevation Transitions
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<th>Grade Levels 4-6</th>
<th>Grade Levels 7-8</th>
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<tr>
<td><strong>Comparison</strong></td>
<td>Given images of a coastal area before and after a hurricane, describe the changes that you observe and speculate about the reasons for those changes.</td>
<td>Given wind roses for some east coast locations (NYC, DC, Norfolk, Miami) and Caribbean islands, write a verbal comparison of the wind pattern at each place.</td>
<td>Given past and present images of a coastal area, generalize about how vulnerability to hurricanes seems to be changing through time.</td>
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<tr>
<td><strong>Aura (Buffer)</strong></td>
<td>Given a set of wind observations on a day when a hurricane is nearby, choose a likely direction for the eye of the hurricane. Compare your prediction with a satellite image.</td>
<td>Given a map of probable landfall of a hurricane, identify the likelihood that a given location nearby will experience onshore winds and higher waves as opposed to offshore winds and lower waves.</td>
<td>Given an image of a coastal urban area, identify the nodes (e.g., city, industry) that seem to &quot;attract&quot; settlement (have an influence that leads to higher population densities nearby).</td>
</tr>
<tr>
<td><strong>Region</strong></td>
<td>Given a map that shows hurricane tracks for a period of time (e.g., 2000-2006), shade in the region of the ocean that had hurricanes.</td>
<td>Given a set of observed sea surface temperatures, color the region that had temperatures higher than a specified temperature (e.g., 28°C).</td>
<td>Given a topographic map and a SLOSH-model estimate of maximum storm surge, identify the at-risk region and color it in a distinctive way.</td>
</tr>
<tr>
<td><strong>Transition (Gradient)</strong></td>
<td>Given a map of hurricane tracks in the Atlantic and an east-west row of grid cells, make a table that shows the number of hurricanes in each grid cell. Then make a graph about this row of grid cells.</td>
<td>Given spot elevations or a topographic map of the land along a hurricane-prone shore, make a side profile of the land and indicate how far inland a storm surge is likely to reach.</td>
<td>Given a map of spot depths of the water near the shore in a hurricane-prone area, make a side profile of the water depth to use as input for an analysis of storm surge waves.</td>
</tr>
<tr>
<td><strong>Hierarchy (Enclosure)</strong></td>
<td>Describe the hierarchy of water bodies in an ocean (e.g., the Gulf of Honduras is part of the Caribbean Sea, which in turn is part of the Atlantic Ocean).</td>
<td>Local gusts blowing in different directions are part of the counterclockwise circulation around the eye of a hurricane. The hurricane, in turn, moves as part of larger global wind system.</td>
<td>Given part of the NOAA data base about particular hurricanes, note that segments are individually identified but also are part of an overall path.</td>
</tr>
<tr>
<td><strong>Analogy</strong></td>
<td>Compare short readings about living through a hurricane in the southern United States, a snowstorm in the northern United States, and similar storms in southern and northern Japan.</td>
<td>Given climographs for places in East Asia, identify the ones that are analogous to selected locations in North America (e.g. NY-Seoul, Miami-Hong Kong, Charleston-Shanghai, Salt Lake City-Kashgar).</td>
<td>Given a latitude-longitude location in East Asia, select an analogous location in the United States by applying information about climate, elevation, and land cover from satellite image.</td>
</tr>
<tr>
<td><strong>Pattern</strong></td>
<td>Given several remotely-sensed images that show clouds with different patterns, pick the one that shows a classic hurricane, and explain.</td>
<td>Given a set of images of hurricanes, classify them into classic spirals, blobs, and other shapes, and write generalizations about the clouds and winds.</td>
<td>Given maps of settlement near hurricane-prone shorelines, describe the patterns that you see (string or cluster patterns, even distribution, etc.)</td>
</tr>
<tr>
<td><strong>Association (Correlation)</strong></td>
<td>Given a basic map of prevailing winds (easterly trade winds and mid-latitude westerlies) explain why hurricanes often move westward across the Atlantic.</td>
<td>Given a hurricane path and a map of sea surface temperatures on the same day, predict whether the hurricane is likely to get stronger or weaker.</td>
<td>Given an image of settlement, oil refineries, etc., describe the association of features with elevation, transportation, etc. as seen on other maps.</td>
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</tbody>
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Hurricane Shapes: Spatial Patterns on Satellite Images

Overview – the “Big Idea”

This lesson is about visual shape, which is one aspect of the idea of spatial pattern. In order to communicate ideas about shape, people have to learn a common vocabulary.

Specific Learner Outcomes. After doing this lesson, students should be able to:
1. Recognize typical hurricane shapes on satellite images.
2. Classify hurricanes into conventional shape categories.
3. Recognize that category terms for shapes and other spatial patterns are somewhat arbitrary. They are established by discussion, revision, and eventual adoption of conventional terms.

Procedures.
1. Discuss the idea of remote sensing – looking at the world from an airplane or satellite. Ask students about advantages of this way of viewing the world.
2. Have students examine the satellite images and try to classify hurricanes according to their shape.
3. If desired, conduct a discussion about the process of deciding about shape categories. Ask students to comment about categories that are easy to recognize, and ones that are hard to separate. You might even ask them to invent a new category to make it easier to communicate about a shape.

Clues that a teacher might mention at appropriate times in the discussion:
- As hurricanes become more powerful, they are more likely to develop classic spiral shapes with very distinct eyes. This fact provides one justification for going through the process of classifying storms according to shape.
- The winds on opposite sides of a hurricane’s eye tend to blow in opposite directions. This explains why places that are directly in the path of a hurricane can have especially severe damage, because they are battered by winds from opposite directions at different times.

Answers. See attached answer key.

Differentiation: One way to simplify the activity is to reduce the number of categories. The simplest version has only two categories – spirals with clearly defined eyes, and other shapes.

Extension: To explain how a hurricane can form an eye, have 5-7 students stand in a circle about ten feet in diameter (roughly at arm’s length). Tell them that the low pressure at the center is pulling them in toward the middle, but that every object that moves across the surface of the earth in the northern hemisphere is pulled to the right. If they ask, explain that it has to do with being an object in motion on the curved surface of a globe that is spinning; as a result, the surface is also moving eastward at 800-900 miles an hour in the latitudes where hurricanes are common. By the time a wind moves a hundred miles, the motion of the earth has pulled it strongly to the right (in the northern hemisphere – the pull is to the left in the southern hemisphere). To simulate this process, have the students take a step with their left feet toward the middle, but also turn toward the right, take a step with their right feet, and follow the person ahead of them. Eventually, the rightward pull (caused by the spinning earth) is balanced by a leftward pull (toward the low pressure in the center), and the winds just follow each other around and around the middle (they actually rise and cause clouds and rain, the famous “wall” around the eye).

Caveat: The balance of forces around a hurricane eye is one of those topics that students often find baffling right up the moment they suddenly “get it,” and then they wonder why anyone else still seems to have trouble with it.

To find other storm images, click the keyword “hurricanes” at the NASA or NOAA website:
- http://visibleearth.nasa.gov/
or
- http://www.osei.noaa.gov/events/Tropical/Atlantic

The following pages contain the web addresses for the images used in the activity.
Lenny 1999
NASA Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=1075

Irene 1999
NASA Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=1104

Issac 2000
NASA Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=1250

Andrew 2002
NASA Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=3612

Elena 1985
NOAA National Weather Service Forecast Office Jackson, MS
http://www.srh.noaa.gov/jan/hrcn18.php

Wilma 2005
Nasa Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=20342

Gordon 2000
NOAA Mariners Weather Log April 2007
www.vos.noaa.gov/MWL/apr_07/atlanhurricane.shtml

Kate 2003
NASA Visible Earth
ftp://disc2.nascom.nasa.gov/data/TRMM/Gridded/Hurricane_Maps/Archive/2003/Kate/MODIS/2003Kate_Terra_03Oct_1340.jpg

Felix 2001
Nasa Vis. Earth
http://visibleearth.nasa.gov/view_rec.php?id=2125

Rita 2005
NASA Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=7957

Frances 2004
Nasa Goddard Earth Sciences and Information Portal
Charley 2004
NASA Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=14232

Keith 2000
NOAA News
www.noaanews.noaa.gov/stories/s534.htm

Fabian 2003
NASA Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=5739

Bonnie 1998
www.ngdc.noaa.gov/dmsp/hurricanes/atlantic98.html

Katrina 2005
Nasa Goddard Earth Sciences and Information Portal

Isabel 2003
NASA Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=5862

Mitch 1998
Nasa Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=8670

Georges 1998
Nasa Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=8654

Humberto 2001
NASA Visible Earth
http://visibleearth.nasa.gov/view_rec.php?id=2127
Hurricane Frequency: Identifying Regions with Similar Numbers of Hurricanes

Overview – the “Big Idea”

This lesson is about the idea of spatial regions – groups of areas that are close to each other and similar to each other according to some criterion, and therefore can be put together into a single visual entity on a map. In order to identify a region and show it on a map, a person has to decide which places have similar conditions, and then choose a color or other graphic means to depict them.

Specific Learner Outcomes. After doing this lesson, students should be able to:

1. Classify areas on a map according to specific criteria – in this case, the presence or absence of a coastline, and whether the number of hurricanes that cross the area in a given year exceeds a designated threshold.
2. Examine a map of hurricane tracks and color all of the areas that meet specific criteria.
3. Write a generalization about the difference between two regional maps.
4. Recognize that the criteria for grouping areas into regions are somewhat arbitrary, although some criteria make more intuitive sense and/or make more coherent maps.

Procedures.

1. Hand out the maps, the response forms, and colored pencil or markers.
2. If desired, have students make a “reconnaissance survey” of the maps and decide how many hurricanes in a grid cell they think would be appropriate to describe as “many,” as opposed to “few.” Selecting the criterion can be done individually (with different map/response outcomes) or as a class. If you have your students use the suggested number of 5 as the criterion, you should emphasize that criteria selection is an essential part of the process of making any regional map – whether the topic is soil, vegetation, language, or political votes. NOTE: Answer keys provided are based on 5 as the criterion.
3. Have students color their maps according to the criterion they decided to use (or you assigned).
4. Conduct a discussion about differences in the pattern of hurricanes in the two years. An increase is obvious – but the cause is controversial. One likely component is a cyclical pattern of sea surface temperature that is related to multi-year cycles such as the Southern Oscillation (“El Nino”) and the North Atlantic Oscillation. Added to these well-established cycles is a possible upward trend in water temperature as a result of the global warming that is caused by the increase in carbon dioxide and other greenhouse gases.

Answers. See attached answer key and colored maps.

Differentiation: One way to simplify the activity is to reduce the number of categories. The simplest version has only two categories – areas with five or more hurricanes, and areas with fewer than five. One can also have different students or groups do different rows of cells and then combine the results.

Additional fact that a teacher might mention at an appropriate time in the discussion:

The task of classifying and coloring areas in this activity is simplified by the fact that the grid cells are the same size and shape. The basic process, however, would be the same if we were making regional maps based on data for individual states in a country, counties in a state, or census tracts in a city.

Extension: Assign groups of students different criteria for classifying sectors as having “frequent” hurricanes. The resulting maps will be different, which provides an opportunity for students to compare their maps with others who used a different criterion.

Hurricane tracks for other years can be obtained from the Historical Hurricane Tracks database at the NOAA Coastal Services Center website:

http://maps.csc.noaa.gov/hurricanes/download.html
Hurricane Paths: Comparing Places with Different Prevailing Winds

Overview – the “Big Idea”

This lesson is about the idea of spatial comparison, using a graphic summary of wind records to compare conditions in different places and draw inferences about the role of prevailing winds in guiding ocean currents and the movement of hurricanes.

Specific Learner Outcomes. After doing this lesson, students should be able to:

1. Read a standard wind-rose graph and make valid generalizations about wind speed and direction.
2. Make a generalization about prevailing winds in the latitudes of the Trade Winds (roughly 10-20 degrees north and south of the Equator) and the mid-latitude Westerlies (roughly 40-60 degrees of latitude North and South).
3. Given a wind rose, describe the net zonal flow as a positive or negative number.
4. Describe the role of prevailing winds in guiding the movement of a typical hurricane.

Procedures.

1. If needed, explain how to construct and interpret a wind rose. The length of each line on a wind rose represents the average percentage of time the wind blows from that specific direction. The wind roses on pages 2 and 3 add information about velocity that is not needed for this activity.
2. Hand out the worksheet and graphs. Ask students to examine the graphs and answer the questions.
3. Discuss how prevailing winds tend to push hurricanes toward the west at low latitudes (e.g., near San Juan, Puerto Rico) and back toward the east at higher latitudes.
4. If desired, make connections between the prevailing winds and historic patterns of trade, especially the Triangle Trade that brought African slaves to the colonial Americas.

Additional facts that a teacher might mention at appropriate times in the discussion:

The trade winds (easterlies) are more consistent in direction than the mid-latitude westerlies. All of the major wind zones shift north and south with the seasons, because they are all ultimately driven by the surplus of solar energy near the Equator. As a rule of thumb, the core of the trade winds will shift about 5-10 degrees of latitude north of their “average” position in summer. A place at a latitude of 20 degrees north, therefore, can have strong trade winds in summer and autumn and nearly calm, desert-like conditions in winter.

Answers: 1) 18 2) west 3) +61% for Boston -100% for San Juan 4) clockwise 5) warm

Differentiation: It is possible to simulate the global wind circulation by having students move between desks that are strategically placed in a classroom to simulate continents. What is not known, however, is whether students really grasp the idea better as a result of this seemingly obvious kinesthetic activity. It is true that the relatively simple circulation of wind around the eye of a hurricane can easily be simulated in a classroom, as explained in the module on Hurricane Shapes. The global wind system, however, is much more complex and varied, with more exceptions due to elevation, continent placement, etc., and therefore it is more difficult to simulate accurately in a classroom.

Extension: Wind roses for other places can be generated by using the NOAA Air Resources Laboratory Web Server tool at http://www.arl.noaa.gov/ready.htm At this website, users can choose a variety of variables, including wind speed and air pressure, and explore them with real-time or archived data.

Pages 4 and 5 show another way to represent wind speed and direction. These resources are not needed to complete the activity, but might be helpful to students in putting the prevailing winds at Boston and San Juan into a broader context.

Caveat: The “steering effect” of prevailing wind is only one of the factors that influence the movement of a hurricane. Other factors include local air pressure fields, sea surface temperatures, and the heat-transfer effects of precipitation. One important attitudinal outcome, therefore, is an appreciation of the complexity of the global wind system and the associated fact that a hurricane-landfall prediction is at best a statistical possibility, not a certainty.
Hurricane Stories: Analogous Locations in Different Hemispheres

Overview – the “Big Idea”

This lesson is about the idea of analogous locations – places that may be far apart but have locations that are similar in some way, which in turn can produce similar conditions. By critical reading, students try to identify the places that have similar weather conditions in Japan and the United States.

Specific Learner Outcomes. After doing this lesson, students should be able to:

1. Use critical reading to classify stories according to different criteria. For example, they might use the names of people to classify stories according to their country of origin. They can also use details about storms to separate places that are experiencing a mid-latitude winter storm from places that are going through a tropical hurricane.

Procedures.

Have students read each story and make notes about the main points. Explain that the purpose of their notes is to help them answer two questions:

1. Did this story happen in the United States or Japan?
2. Did this story happen in a cold place in the northern part of the country, or did it happen in a warm place in the southern part of the country?

Conduct a discussion to clarify the idea of an analogous location (see above).

Clues that a teacher might mention at appropriate times in the discussion:

- Latitude: as you go farther from the Equator, the average temperature gets lower; hurricanes become rare, and snow becomes more common
- Longitude: you can get a clue from the names of people. Names like Sanchez, Peterson, and O’Neill are more likely in the United States, whereas Iwamizami, Miyazaki, and Noburo are Japanese names. It is true that some people with Japanese names live in the United States, but they are less common in the eastern part of the country.

Answers and more facts about each place (so that you can add a little “cultural capital” to the lesson):

Place A – southern Japan, close to Nagasaki, where the second atomic bomb was dropped.
Place B – southern U.S., close to Lake Placid, NY, the site of the 1932 and 1980 Winter Olympics.
Place C – northern Japan, close to Sapporo, the site of the 1972 Winter Olympics.
Place D – southern U.S., near Beaufort Island, a famous resort area between two historic coastal cities: Charleston, South Carolina, and Savannah, Georgia.

Differentiation: One way to simplify the activity is to tell students at the outset which stories are in Japan and focus their critical reading on the question of climate differences. Or conduct a prior discussion about clues. Ask students to list some features of hurricanes and snowstorms. Discuss the country of origin of names like Miyazaki, Noburo, O’Neill, Peterson, Sanchez.

Extension: Have students draw a picture or write a poem (perhaps a haiku?) about their story. The question at the end of each story affords an opportunity for another writing extension to help reinforce the main point about geographic analogies: places that are in similar positions (in this case, place C in northern Japan and place B in northern New York) tend to have similar conditions. Likewise, conditions at place A in southern Japan are similar to place D in southeastern U.S., not place C in northern Japan.

One useful analogy is with parts of the human body: point out that one child’s knee looks more like another child’s knee than either knee looks like a head or a hand.

An optional world map (page 5) shows that many hurricanes occur in similar positions near the southeastern “corners” of North America and Eurasia. Satellite images of storms in both places tend to look quite similar (page 6). To find other images for comparison, go to http://visibleearth.nasa.gov/

Caveat: You do not need to use the term “analogous location” to get the main idea across. The world has many analogous locations: Miami and Hong Kong, Minneapolis and Moscow, Los Angeles and Casablanca, Utah and Uzbekistan, etc. Becoming aware of these similarities is a powerful way of organizing knowledge about the world (and thus remembering geographic facts better).
Hurricane Winds: A Spatial Hierarchy of Processes at Different Scales

Overview – the “Big Idea”

This lesson is about the idea of spatial hierarchy – the fact that a geographic feature often has smaller features within it and at the same time is part of a large feature. One obvious example is political: states have smaller counties within them and are part of a larger country.

Specific Learner Outcomes. After doing this lesson, students should be able to:

1. Recognize that the wind that is measured at a particular place and time is the result of a complicated hierarchy of influences that reflect the position of the place with respect to local gusts, regional circulation, and global wind patterns.

2. Read a standard wind rose and make valid generalizations about wind direction.

3. Suggest a plausible location for a specific wind rose on a map that shows a typical hurricane in the North Atlantic Ocean.

4. Estimate the relative speed of the wind at a specific place in a typical hurricane, given a description of wind speed in another location within the same storm.

Procedures.

1. Use local examples to illustrate the idea of a spatial hierarchy. In New York one might say that Brooklyn is part of a larger entity called New York City and also has smaller neighborhoods inside. In Nebraska, one might note that many small streams empty into the Platte River, which in turn is part of the larger Missouri River drainage system.

2. If necessary, explain how to construct and interpret a wind rose. (See Prevailing Winds Module)

3. Hand out the worksheet and have students answer the questions. They can work alone, in small groups, or as a whole class.

4. Discuss some implications of the fact that the wind at any given instant in time actually reflects forces that operate on different scales. One obvious consequence is that a longer record is usually necessary in order to make generalizations that are valid for the larger system. This principle also applies to many other processes, such as global warming, animal migrations, and even the trend of the Dow Jones Industrial Average.

Clues that a teacher might mention at appropriate times in the discussion:

The actual circulation of air around the eye of a hurricane reflects two major forces – an air-pressure pull toward the center of the hurricane, and the Coriolis deflection (the tendency of objects in motion on the curving surface of the globe to be deflected from an apparent straight line; this deflection is toward the right in the northern hemisphere and toward the left in the southern). The two “forces” are always in rough balance – if the pressure pull somehow got stronger, the wind would speed up, which would make the Coriolis pull stronger and turn the wind toward the right. If the rightward deflection somehow got stronger, the air would move away from the eye, which would cause it to slow down, and the deflection would get weaker.

Answers: 1) c and d 2) middle diagram 3) last set, CDE 4) B 5) a-B, b-A, c-C, maybe D

Differentiation: One way to simplify the activity is to have students draw a single arrow that shows the major wind direction shown by a wind rose.

Extension: As written, this is a quick and simple activity. To increase the difficulty level (or especially if you want to make it more applicable to local conditions), have students examine the wind field around other hurricanes or even ordinary daily weather maps. To find other storm images, click the keyword “hurricanes” at the NASA website: http://visibleearth.nasa.gov/

To find a weather map for a given day:

http://docs.lib.noaa.gov/rescue/dwm/data_rescue_daily_weather_maps.html
Hurricane Strength: Spatial Association of Wind Speed and Water Temperature

Overview – the “Big Idea”

This lesson is about the idea of spatial association – the tendency for things that are causes and effects also tend to have similar geographic patterns – like Anopheles mosquitoes and malaria, they occur in the same places and are both absent in other places.

Specific Learner Outcomes. After doing this lesson, students should be able to:

1. Explain a plausible causal relationship between sea surface temperature and hurricane intensity – hurricanes tend to get stronger if the temperature of the sea surface is greater than about 27°C (81°F).
2. Examine a map of sea surface temperatures and make a valid generalization about the temperatures under the future path of a specified hurricane.
3. Explain why hurricanes tend to weaken rapidly when they pass from the ocean onto land – such a hurricane is deprived of the energy provided by water evaporating from a warm ocean surface.

Procedures.

1. Decide whether you want the students to proceed deductively or inductively – in other words, do you intend to explain how a warm ocean surface adds energy to a hurricane, and have students explore the consequences of that idea, or do you want students to infer the principle by examining the path and intensity of a specified hurricane?
2. Hand out the map and worksheet and have students answer the questions. They can work singly, in small groups, or as a whole class.
3. Discuss the possible implications of global warming for sea surface temperatures and, indirectly, for hurricane intensity.

Clues that a teacher might mention at appropriate times in the discussion:

Sea surface temperatures used to be very difficult to map, because it was hard to gather information from a large area. Satellite sensors have changed that dramatically – it is now possible to make a very accurate map in a few seconds. Problem: some satellite sensors are not able to “see” through clouds, and therefore they cannot record the water temperature in the most critical area, the ocean directly underneath an active hurricane!

Answers. 1) West 2) Increase 3) Cooler 4) The hurricane passing over stirs up the ocean surface and cools the water at the surface. Rainfall also cools the surface water.

Differentiation: As presented, this activity is very simple and straightforward; downloading a current image makes it more realistic and often much more challenging.

Extension: Page 4 is an optional, additional map of sea surface temperatures for May 10, 2005. Compare this map to the September map to understand why stronger storms are more likely to occur in autumn rather than spring. Sea surface temperatures for other dates may be viewed at:

http://marine.rutgers.edu/mrs/sat_data/?product=sst&region=eastcoast&nothumbs=0

Caveat: The relationship between sea surface temperature and hurricane intensity is complicated by two kinds of vertical motion – the motion of air within the hurricane, which carries energy upward and often results in heavy rain and lightning, and the vertical motion of water within the ocean, which can sometimes be mixed and cooled quite rapidly by wind and rain.
Hurricane Influence: Landfall Probabilities and Wind Speed

Overview – the “Big Idea”

This lesson is about the idea of spatial aura – the zone of influence around a geographic feature such as a factory smokestack, airport, unstable dictator, hurricane, even a dead skunk. The aura tends to be bigger for large objects, and the influence usually decreases as you go farther away from the object. The primary influences of a hurricane are the wind and the storm surge. Both of these tend to be higher just to the right of the eye of the hurricane. CAUTION: when a weather analyst says “to the right” of a hurricane path, it means “to the right” as viewed from behind the hurricane – it is to the left of the eye when you look from the shore at a hurricane approaching you from the ocean. Obviously, it is very important that people do not get the perspectives mixed when interpreting a storm warning!

Specific Learner Outcomes. After doing this lesson, students should be able to:

1. Estimate the speed of a wind at a given point within a hurricane, by noting the category of the storm, the distance of the place from the eye, and the direction and speed of movement of the hurricane as a whole.

2. Examine a map of landfall probabilities and generalize about the chances of the hurricane striking a given section of coast.

3. Combine information about storm category, storm motion, and landfall probability to estimate the likelihood of winds that exceed a particular speed at a particular place on the shore.

Procedures.

1. Review the general pattern of circulation around the eye of a hurricane.

2. Hand out the worksheet. If necessary, run a discussion to make sure that every student understands the meaning of the numbers, letters, and category table. Then have students answer the questions on the worksheet. They can work singly, in small groups, or as a whole class.

3. Check whether they have drawn the correct inference by asking which side of a hurricane’s path usually has the fastest winds and highest storm surge – the right side or the left side?

Clues that a teacher might mention at appropriate times in the discussion:

Storms in the North Atlantic are often more violent than one might infer from their category designation, because a hurricane near Washington or New York can move as fast as 40 miles per hour. This can make a category 2 hurricane with 100mph winds feel like a category 4 (100+40 = 140, a middle category 4 speed on the right side of the eye).

The storm surge is usually much higher on the right side of a hurricane’s path – in fact, the water may actually be unusually low on the left side, depending on the arrangement of hills, islands, and other shore features. For this reason, a hurricane that turns to the left can surprise some people and cause more damage than one that turns to the right, where people were expecting a fairly big storm surge anyway.

Answers. 1) 120 mph  2) 110 mph (120 minus 10)  3) 70 mph (120 / 2 + 10)

4) 10 p.m. (100 miles @ 10 mph = 10 hours)  5) 20 percent  6) 30 percent (10 + 20)

7) 120 mph if the eye crosses the shore just to the west of place C

Differentiation: Ask students to estimate the wind speed just the left of the hurricane’s path and just to the right – check to make sure that they understand why the hurricane speed should be added to the wind speed on the right side of the path and subtracted on the left side.

Extension: Have students examine the wind field around other hurricanes or even ordinary daily weather maps. To find other storm images, click the keyword “hurricanes” at the NASA website:

http://visibleearth.nasa.gov/
Hurricane Impact: Storm Surges and Elevation Transitions

Overview – the “Big Idea”

This lesson is about the idea of spatial transition – the change in some feature, such as elevation, as you go from one place to another. The side profile of a coast (the transition in elevation as you go inland from the shore) has an important influence on the amount of land that is vulnerable to hurricane damage. If a shore is a cliff, the damage from a storm surge is likely to be confined to a small area at the bottom of the cliff. If the land near the shore is a nearly flat plain, the storm surge can reach quite far inland.

Specific Learner Outcomes. After doing this lesson, students should be able to:

1. Examine a topographic map and make generalizations about how fast the land rises as you go inland from the shore.
2. Optional extension: Make a side profile of land by transferring information from a topographic map to a graph of elevation.
3. Add information about likely water depth during a hurricane to a topographic map or side profile.
4. Combine information about elevation, storm surge depth, and building location to predict whether a particular building is likely to be hit by a storm surge from a hurricane of a given category.

Procedures.

1. Ask students what we would need to know to predict how far the storm waves from a hurricane might reach inland from the shoreline. Continue the discussion until they realize that they need information about both the storm (its size and speed) and the shore (its change in elevation and the pattern of buildings and other features on the shore).
2. Hand out one version of the elevation transitions worksheet (page 2 is a version with contour elevations marked; page 3 is a large version with fewer questions) and answer the questions. Hand out page 4 (map and form for constructing a side profile – a graph of elevation vs. distance), and have students construct the graph and add the storm surge line. They can work singly, in small groups, or as a whole class. Finally, ask students to compare their completed work with the information about roads and hurricane evacuation zones on page 5.
3. Make sure that they understand that the average depth of storm surges listed in the table are just indications of the hurricane-induced change in average sea level – the normal tides and wind-driven waves of a hurricane are added to that level.

Clues that a teacher might mention at appropriate times in the discussion: A storm surge is a general increase in water level due to circulation of wind around a hurricane. The storm surge is usually much higher on the right side of a hurricane’s path – in fact, the water may actually be unusually low on the left side, depending on the arrangement of hills, islands, and other shore features. For this reason, a hurricane that turns to the left can surprise some people and cause more damage than one that turns to the right, where people were expecting a fairly big storm surge anyway.

Answers. 1) 20 feet 2) 15 feet 3) place E 4) place E 5) 15 feet 6) places A, B, and C

Note: Answers will vary if using the short version on page 3.

Differentiation: To simplify the activity, use an alternative map on pages 2 or 3, or put several dots on the graph before handing it out – the students’ task is then to finish a graph that has already been started.

Extension: Topographic maps for nearly any place in the U.S. can be downloaded from several sites http://terraserver-usa.com/ http://www.topozone.com/

For example, http://terraserver-usa.com/image.aspx?T=2&S=14&Z=17&X=238&Y=1173&W=1 will get a detailed map of a very vulnerable town called Long Beach, near Cape Fear, North Carolina. This activity can generate a lot of interest if students make and compare profiles for places near specific cities of interest, such as Apalachicola, Florida; Cape Canaveral, Florida; Charleston, South Carolina; Biloxi, Mississippi; New Orleans, Louisiana; Savannah, Georgia; or even New York City. The ultimate goal is for students to become proficient enough in visualizing terrain that they no longer need to make an actual side profile. They could look at a topographic map and build a mental image of the shore.
# Hurricane Shapes: Spatial Patterns on Satellite Images

The accompanying pages show selected images of hurricanes that occurred in the Atlantic Ocean between 1985 and 2006. Satellites as well as space shuttle missions can capture different types of images of hurricanes. As you can see, hurricanes have a wide variety of sizes and shapes. To make it easier to talk about them, it helps to have a kind of standard “language” to describe the overall shape of a hurricane.

1) Listed below are some suggested hurricane shape categories. Read the descriptions of the shape categories, and then review the attached images. Match or classify each of the hurricane images to a description below by writing the hurricane name in the “Hurricane Examples” column in the table. Finally, if there is an image that does not seem to match any of the listed categories, suggest a new category for that hurricane and write a short description to explain the new category.

<table>
<thead>
<tr>
<th>Shape</th>
<th>Description</th>
<th>Hurricane Examples</th>
</tr>
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<tbody>
<tr>
<td>A. Classic</td>
<td>spiral shape (like a whirlpool), evenly centered (symmetrical) around a cloudless central “eye”</td>
<td>Rita</td>
</tr>
<tr>
<td>B. Spiral</td>
<td>spiral around a clearly defined eye, but the shape of the spiral is NOT symmetrical, some of the cloud “arms” are longer than others</td>
<td></td>
</tr>
<tr>
<td>C. Eyeless Spiral</td>
<td>spiral shape but no clear eye in the cloud formation</td>
<td></td>
</tr>
<tr>
<td>D. Square</td>
<td>squarish shape rather than round, no clear eye</td>
<td></td>
</tr>
<tr>
<td>E. Blob</td>
<td>shapeless mass of clouds, no clear eye</td>
<td></td>
</tr>
<tr>
<td>F. Half</td>
<td>only half of a spiral with or without a clear eye</td>
<td></td>
</tr>
<tr>
<td>Other shapes:</td>
<td>Write a description for the suggested shape:</td>
<td>List examples for the shape:</td>
</tr>
<tr>
<td>G.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) Do you think there is a shape category that is not useful and should be deleted? ______
If so, which one(s)?

3) Hurricanes can be classified by other criteria than shape. For example, the Saffir-Simpson Hurricane scale is a 1-5 rating based on the hurricane’s present intensity. Wind speed is the determining factor in the scale. It is just one more example of how hurricanes might be classified into categories. Based on the satellite images, look again at the images of the hurricanes, what other criteria might be observed by scientists (in addition to shape or wind speed) to classify and communicate about hurricanes?

4) A satellite image captures a hurricane at one moment in time. What other information could be observed from an entire series of satellite images covering a longer time span in the life of a hurricane?
Selected Atlantic Hurricanes 1985 - 2006

Rita 2005
Fabian 2003
Andrew 1992
Lenny 1999
Kate 2003
Gordon 2000
Bonnie 1998
Isaac 2006
Isabel 2003
Felix 2001
Selected Atlantic Hurricanes 1985 - 2006

- Elena 1985
- Georges 1998
- Wilma 2005
- Charley 2004
- Mitch 1998
- Humberto 2001
- Irene 1999
- Danielle 2004
Selected Atlantic Hurricanes 1985 - 2006

Francis 2004

Katrina 2005

Keith 2000
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<td>List examples for the shape:</td>
</tr>
<tr>
<td>G. Comma</td>
<td>comma shaped cloud with tail</td>
<td>Humberto, Irene</td>
</tr>
<tr>
<td>H.</td>
<td></td>
<td></td>
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</table>

2) Do you think there is a shape category that is not useful and should be deleted? Yes
If so, which one(s)? Half. It might be better to call Felix long and skinny.

3) Hurricanes can be classified by other criteria than shape. For example, the Saffir-Simpson Hurricane scale is a 1-5 rating based on the hurricane’s present intensity. Wind speed is the determining factor in the scale. It is just one more example of how hurricanes might be classified into categories. Based on the satellite images, look again at the images of the hurricanes, what other criteria might be observed by scientists (in addition to shape or wind speed) to classify and communicate about hurricanes?

- size of the storm
- location
- latitude and longitude

4) A satellite image captures a hurricane at one moment in time. What other information could be observed from an entire series of satellite images covering a longer time span in the life of a hurricane?

- direction of the path
- how fast it is moving
- change in the size of the eye
- other changes in the storm over time
Hurricane Frequency: Identifying Regions with Similar Numbers of Hurricanes

The first step in assessing the hurricane hazard in a particular place is to see where hurricanes have occurred in the past. Making a map of hurricane regions for several time periods can help us decide if the hazard is increasing, staying the same, or decreasing.

The maps on pages 2 and 3 show the tracks of hurricanes that occurred during two different time periods. Page 2 shows the location of hurricane tracks from 1980-1982. Page 3 shows the location of hurricane tracks from 2003-2005. Your job is to classify each rectangular sector (e.g., A1) into one of six categories: land, shoreline with frequent hurricanes, ocean with frequent hurricanes, shoreline with few hurricanes, ocean with few hurricanes, and areas with no hurricanes.

Use the maps on pages 2 and 3 to complete the following activities.

1) Make sure you know how to read and use the maps accurately.
   How many hurricanes went through sector F5 between 1980-1982? ______
   How many hurricanes went through sector H4 between 1980-1982? ______

2) It is necessary to decide how many hurricanes should pass through a sector to classify the hazard as “frequent” in that location. One possibility is to classify the hazard in a sector as frequent if at least 5 hurricanes passed through the sector on the map. In determining a rule to use, study both maps. Selecting a number that is too low will result in most sectors being classified as “frequent” hazard sectors. Selecting a number that is too high will result in few sectors being classified as “frequent” hazard sectors. Write the number you plan to use to classify the “frequent” hazard sectors. ______

3) To analyze the data, a blank grid for each map is provided on page 4. Color each sector on the blank grid using the legend below. Please refer back to the rule above to classify the data as to whether it will be in the “frequent” or “few” hazard categories.

   | Dark blue = Ocean sectors with frequent hurricanes |
   | Light blue = Ocean sectors with few hurricanes   |
   | Red = Shoreline sectors with frequent hurricanes |
   | Orange = Shoreline sectors with few hurricanes   |
   | Yellow = Land sectors without ocean shoreline    |
   | White = Ocean or shoreline sectors with no hurricanes |

Compare your two colored grids to answer the following questions.
4) Do you think hurricane hazards increased or decreased between 1980-82 and 2003-05?

5) Put a zero on each sector of the 2003-05 map that did not change color from the 1980-82 map.
   How many zeroes did you put on orange sectors? ______
   How many zeroes did you put on light blue sectors? ______

6) Describe the pattern of the orange and light blue sectors with zeroes. For example, are they spread across the map or clustered together in one particular region of the map?
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Use the maps on pages 2 and 3 to complete the following activities.

1) Make sure you know how to read and use the maps accurately.
   How many hurricanes went through sector F5 between 1980-1982? 3
   How many hurricanes went through sector H4 between 1980-1982? 1

2) It is necessary to decide how many hurricanes should pass through a sector to classify the hazard as “frequent” in that location. One possibility is to classify the hazard in a sector as frequent if at least 5 hurricanes passed through the sector on the map. In determining a rule to use, study both maps. Selecting a number that is too low will result in most sectors being classified as “frequent” hazard sectors. Selecting a number that is too high will result in few sectors being classified as “frequent” hazard sectors. Write the number you plan to use to classify the “frequent” hazard sectors. _____

Note: The answer key maps provided are based on the suggested criterion of 5. Choosing a different number will change the number of sectors of each color on the student maps.

3) To analyze the data, a blank grid for each map is provided on page 4. Color each sector on the blank grid using the legend below. Please refer back to the rule above to classify the data as to whether it will be in the “frequent” or “few” hazard categories. See attached maps.

   Dark blue = Ocean sectors with frequent hurricanes
   Light blue = Ocean sectors with few hurricanes
   Red = Shoreline sectors with frequent hurricanes
   Orange = Shoreline sectors with few hurricanes
   Yellow = Land sectors without ocean shoreline
   White = Ocean or shoreline sectors with no hurricanes

Compare your two colored grids to answer the following questions.

4) Do you think hurricane hazards increased or decreased between 1980-82 and 2003-05?
   Increased

5) Put a zero on each sector of the 2003-05 map that did not change color from the 1980-82 map.
   How many zeroes did you put on orange sectors? 5
   How many zeroes did you put on light blue sectors? 3

6) Describe the pattern of the orange and light blue sectors with zeroes. For example, are they spread across the map or clustered together in one particular region of the map?
   Most of these sectors are located in the southeast corner of the map

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Atlantic Hurricanes 1980 - 1982

Atlantic Hurricanes 2003 - 2005
Hurricane Paths: Comparing Places with Different Prevailing Winds

To understand where hurricanes usually start and what direction they usually move, it helps to have a clear mental image of the pattern of prevailing winds in the world. One way to get this image is to make a careful comparison of wind observations in several places.

The diagrams on the right are examples of a special kind of graph called a wind rose. The number in the center indicates the percentage of time the air is calm (no wind). Each of the eight lines radiating away from the center shows the percentage of time the wind blows FROM that direction. Repeat: The lines point to the direction the wind is blowing FROM.

Please answer the following questions.

1) According to the map above, Boston has calm air about 12% of the time; the percentage of time San Juan, Puerto Rico, has calm air is _____.

2) In San Juan, the wind blows the largest percentage of time from the northeast; in Boston, the wind blows from the ________ more often than from any other direction.

3) Use the wind rose graphs on pages 2 and 3. To get an idea about the net zonal flow of air in each location, add up the total percentage of time the wind blows from the southwest, west, and northwest, and subtract the total percentage from the southeast, east, and northeast total percentage. The result is the net westerly component - it is a positive number if the flow is mainly westerly (from the west), and a negative number if the flow is easterly (from the east).
What is the zonal net flow at Boston? __________   At San Juan? __________

4) The prevailing winds push surface ocean water, creating ocean currents that are very important for heat transfer. Unlike winds, however, the ocean currents cannot continue over the continents. If the water “piles up” against the continent, it has to move north or south to replace water that was pushed away from the land by the wind. The result is a giant gyre, a roughly circular flow of water around the center of the ocean. Does this flow go clockwise or counter clockwise in the North Atlantic Ocean? ________________

5) Ocean currents that move toward the pole tend to carry warmer water; those that move toward the Equator carry cold water. Is the current near the east coast of the United States warm or cool? ________________
Wind Rose for San Juan

fnl.nh.aug06.002 Wind Rose
Latitude: 18.43 Longitude: -66.00
Level: 10 m

DATA INITIAL TIME: 16 AUG 2006 00Z
CALCULATION STARTED AT: 16 AUG 2006 00Z
CALCULATION ENDED AT: 23 AUG 2006 00Z

NOAA AIR RESOURCES LABORATORY
READY Web Server
Wind Speed and Directions for Puerto Rico
(locate the island of Puerto Rico to interpret the graph data)

The arrows in the graphic above indicate wind flow direction (vectors).
The numbered, dashed contour lines indicate wind speed measured in knots.
Blue lines show strong winds. Red lines are weaker winds.
The arrows in the graphic above indicate wind flow direction (vectors). The numbered, dashed contour lines indicate wind speed measured in knots. Blue lines show strong winds. Red lines are weaker winds.
"It’s time to move our boats,” Mr. Miyazaki said. “I don’t like the look of the clouds.” My Father, my older brother, and Mr. Miyazaki put on their rain coats and went down to the bay. Mother said, “They are going to move the boats into the river. Then they will tie ropes from each boat to some trees on both sides of the river. That way, the boats won’t move very far when the wind blows.”

When Father got back, we all went to the school. When we got there, it seemed like everybody we knew was already there. There was a radio on a table, and the men were listening carefully and whispering.

Then the wind started to blow. I never heard it so loud. Then all of a sudden the front door broke, and the wind blew into the room. Some men pushed a table in front of the door and leaned against it.

Then suddenly everything seemed to get quiet. Three of the men quickly went outside, but two women stood by the door and wouldn’t let any of us children out. They said, “You can’t go out, because the second half of the storm will be here in a few minutes.”

The men carried the front door around to the back and nailed it across the door opening. Then they came back in and moved the table across the open front door. “Don’t worry,” they said, “the wind will come from the other way next time.”

They were right. It suddenly got very dark, and the wind started blowing again. So we just waited and waited, and eventually it got quiet. The men got their tools and went out; our teacher told us to stay in the school and listen to the radio.

What do you think the radio said about this storm?
You should look outside," My friend Teresa called me on phone last night. So I got my sister and we went out on the porch. The first thing we noticed was all the snowflakes.

Then Mom came out and told us to look at the color of the sky – it was a funny kind of yellow. Mom said that was because the clouds were really low, and the lights of the city made them look yellow.

The snow was really quiet at first. Then it seemed to change to rain and made little popping noises on the windows. It kept doing that even after I went to bed. When I woke up the next morning, the rain had stopped and the wind was blowing. All of a sudden I heard a cracking sound, and then another one. Dad said we should stay inside, but we could look out the window.

It was like everything was covered with diamonds. The sun made sparkles where it was shining on the trees and telephone wires. It looked really beautiful. Then I noticed some tree branches in the street. Dad said it was because the snow and ice was too heavy. Those branches couldn't take all the extra weight and they just broke.

Then a car came along. It was really funny. The driver tried to go around the tree branches, but the wheels kept spinning on the ice. Finally the car just kind of slid sideways. My dad and Mr. O'Neill went over to push it back into the middle of the street.

That's when we decided it would be fun to try to slide down the hill on some cardboard. When we got back, all wet and snowy, the electricity was back on, and Mom was listening to the radio.

What do you think they said about the storm on the news?

Name ___________________________

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“Watch this,” Father said, as he turned into our driveway. He aimed the car lights out across the low wall at the end of our parking place. The lights hit the top of the tree next to Mr. Iwamizawa’s house. In between, it was like a million little specks of light. The car lights were shining on snowflakes, millions of them, all coming down like little parachutes.

We ran out of the car, climbed over the wall, and jumped onto the ground. There, we could lie on the hillside and watch the snowflakes coming down. The car lights were making them glow. When Father turned the lights off, we climbed up to the top of the hill, and then we ran and slid all the way down. We did that again and again, until we were all out of breath.

We were really tired when we went to bed that night. Next morning, the snow was really deep.

“I remember a day like this when I was a child like you,” Mother said. “It was the year they had the Olympics here. Everyone was pretending they were Olympic skiers sliding down the hill. Would you like to learn how to slide?”

Skiing is a lot harder than it looks! We stood on a piece of cardboard and tried to slide down the hill. At first, it wouldn’t move, and then it slid really fast and we fell off. But then our neighbor Noburo came over with real skis. We watched him slide across the snow. It was like magic, how far he could go with each step.

The snow made everything quiet. Mother asked if we knew why. She said it was because no one could make their car go anywhere – the snow was too deep.

What do you think the TV news said about this storm?
“SSHhhh” my father said, “We need to listen.” The radio announcer was using words like “landfall” and “category 3,” which didn’t make much sense to me. But Daddy was definitely worried. He said, “I’m going to the store to get some more wood.”

When he got back, he and Mr. Sanchez started nailing boards on the outside of our windows. Weird! Mom told us to go outside and bring all our toys and even our bicycles under the porch. Double weird!

Then it got windy, and Daddy said we should all go into the bedroom. We brought the radio in with us, but we could hardly hear it. The wind got louder and louder. It seemed like the whole house shook. The noise was like a hundred jet planes at the same time.

Then suddenly it got real quiet. I got up and started to go toward the door, but Daddy yelled, “Don’t go out now. It’s way too dangerous.” I asked why, but all he said was “wait.” Then the wind started again. It sounded even louder than before. Then I heard an awful cracking noise, and some glass breaking. Then the lights went out and the radio stopped. Mom turned on a flashlight and told us to get under the bed.

Finally, the wind died down. After awhile we went out on the porch. You couldn’t believe it! There were leaves and branches and boards and junk all over the place. The whole tree across the street had fallen down. One branch landed on Mr. Peterson’s garage. Part of the roof was gone from the house next door. An ambulance went by with its siren on. It took a long time before they fixed the electricity so we could watch TV.

What do you think the TV announcer said about the storm?
Hurricanes with Winds of More Than 110 Miles Per Hour, 2001-2005

Cyclone tracks (categories 3, 4, and 5)

carol.gersmehl@hunter.cuny.edu, 2007
This Robinson Projection shows shapes and relative sizes of land areas fairly accurately. Any map that tries to show the globe on a flat piece of paper is imperfect in some way. This projection distorts distance and direction, especially near the edges.
Hurricane Winds: A Spatial Hierarchy of Processes at Different Scales

Some people say that a hurricane is basically a giant wind machine. That's a good description, but there is an even better way to think about it. A hurricane is really just a fairly small but very important part of an even bigger wind machine, the global atmospheric circulation. Within that huge system, the “job” of a hurricane is to take some heat from a warm tropical ocean and carry it toward the cold pole.

At the same time, each individual wind within a hurricane has a smaller job to do as part of the circulation of air around the eye of the hurricane. In short, wind can be viewed at different scales: local, intermediate, and global. Viewing a hurricane as a hierarchy of air movements makes it easier to understand some of the individual motions that occur at specific places and times.

The “wind rose” diagram shows the directional pattern of winds at a single point. The length of each line indicates how often the wind blew FROM that direction in the previous hour. The wind rose in the margin here is a copy of a wind rose for a point in an actual hurricane. The map on page 2 shows the wind rose on top of a satellite image of Hurricane Isabel.

Please use the information on the map on page 2 to answer the following questions.

1) At a local scale, individual gusts of wind can come from any direction. Which two statements below are accurate summaries of the wind shown on the wind rose above and on the map on page 2?
   a. It blew all of the time from the northwest or north.
   b. It blew most of the time from the south or southeast.
   c. It blew from every direction, but more than half of the time from the north or northwest.
   d. It blew most often toward the southeast.

2) At an intermediate scale, the wind circulates around the eye of the hurricane. Circle the wind rose diagram below that best represents the wind direction at location “C” on the map on page 2?

3) The wind tends to be stronger close to the eye of the hurricane. Circle the letter sequence below that best represents the rank order of strongest to weakest wind at the corresponding locations on the map on page 2.
   ABC   BCD   CDE

4) At a global scale, the entire hurricane also moves along a path. If this hurricane is moving toward the northwest at 20 miles per hour, circle the location that is likely to have stronger wind 12 hours from now.
   A  B  C  D

5) Match the following predictions with the A, B, C, or D locations on the map on page 2.
   ___ a. Strong wind from the NE, then calm, then strong SW wind.
   ___ b. Wind shifting from northwesterly (from the NW) to westerly.
   ___ c. Strong SE wind, then weakening and shifting more southerly.
Hurricane Strength: Spatial Association of Wind Speed and Water Temperature

The characteristics of a hurricane depend on the environment it passes through. There are some well-known geographical associations between features such as prevailing winds, sea surface temperatures, and the strength and path of a hurricane.

Hurricanes tend to move in an easterly direction following the path of the “easterlies” or trade winds. The trade winds tend to blow northeasterly in the northern hemisphere and southeasterly in the southern hemisphere in a zone between the Equator (0 degrees latitude) and approximately 30 degrees north or south latitude. These zones are named because of their prevailing winds and were very important when ships used sails for power (i.e., before the invention of steam or diesel engines).

Sea surface temperatures affect the strength of a hurricane. If a hurricane moves over warm water, it tends to get stronger. If a hurricane moves over cooler water or land, it usually gets weaker.

Compare the satellite image of Hurricane Rita with sea surface temperature data for the same day, September 21, 2005 (Hint: Find the outline of Florida on both images first). Clouds from the hurricane block the satellite’s ability to measure surface temperature. Therefore, the map shows those areas in white (no data). Comparing the two images helps illustrate the relationship between the location of the storm and the missing sea surface temperature data. To examine the relationship between ocean temperature and wind speed, we can look at data from a few days before and after this date.

1) The map on page 2 shows the sea surface temperatures on September 16, 2005, a few days before the map displayed above. In which direction did Rita move? _________________

2) Based on the temperature data and the direction in which Rita was moving, do you think the storm was more likely to increase or decrease in strength? _________________

3) The map on page 3 shows the sea surface temperatures on September 25, 2005, a few days after Hurricane Rita. Describe the change in sea surface temperature in the Gulf of Mexico.

4) Explain what you think might have caused this change?
Use the color temperature scale on the right to interpret the sea surface temperatures represented on the map below. The grey area is the land form of the eastern coast of the United States and Canada. White spots in the water area indicate missing or incomplete data (possibly due to cloud interference in the satellite data). Latitude is labeled on the left side of the image. Longitude is labeled along the bottom. Temperature is displayed in both degrees Fahrenheit and Celsius.
Hurricane Influence: Landfall Probabilities and Wind Speed

This map shows a prediction of hurricane landfall. Each number near the coast shows the percentage chance that the center (eye) of the hurricane will cross onto the land in that stretch of coast.

<table>
<thead>
<tr>
<th>Category</th>
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<th>Surge Ft.</th>
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<td>131-155</td>
<td>13-18</td>
</tr>
<tr>
<td>5</td>
<td>156+</td>
<td>19+</td>
</tr>
</tbody>
</table>

Please answer the following questions.

1) If this hurricane is expected to be a middle category 3 when it hits land, what is a reasonable estimate of its average wind speed around the eye at that time?
   60 mph      90 mph     120 mph    150 mph

2. If the hurricane is moving northwest at roughly 10 miles per hour, what actual wind speed is likely at point X next to the eye of the hurricane?
   70 mph   90 mph         110 mph        130 mph     150 mph

3. If the hurricane is moving northwest at roughly 10 miles per hour, what actual wind speed is likely at point Y within the hurricane?
   30 mph      50 mph       70 mph  90 mph

4. If it is noon and the hurricane continues to move at ten miles per hour, about what time will the eye of the hurricane reach the coast?
   2 p.m.      6 p.m.      10 p.m.      2 a.m.

5. What is the chance that the hurricane will hit between points C and D?
   10%  20%  30%  70%  80%

6 What is the chance that the hurricane will hit southwest of point B?
   10%  20%  30%  70%  80%

7. What is the maximum wind speed that is likely at point C on the coast?
   90 mph   110 mph   130 mph   150 mph   170 mph
One reason why people are often hurt or killed by a hurricane is that they are not aware of the danger at a particular place. It helps to compare the predicted height of the storm surge with the transition in elevation - a map or graph that shows how fast the land rises as you go inland from the water's edge.

This map uses contour lines to show the elevation of the land above mean sea level. Each line traces a particular elevation; it separates areas that are higher than that elevation from areas that are lower. The lines on this map are ten feet apart; that means that the line that is closest to the shore indicates ten feet above sea level. The next line going inland shows 20 feet above sea level, and so forth (unless the ten-foot line curves around a hill and shows that you are going back down across the ten-foot level).

Please answer the following questions.

1) What is a reasonable estimate of the elevation of place D on the map?
   5 feet      10 feet       15 feet     20 feet     25 feet

2) What is a reasonable estimate of the elevation of place C on the map?
   5 feet      10 feet       15 feet     20 feet     25 feet

3) Which of these places on the map is higher above sea level?
   place B        place D        place E

4) Where does the land go uphill faster?
   from the shore to place C  from the shore to place E

5) If a category-4 hurricane hit this area, what does the table above shows as the approximate height of the storm surge (the increase in sea level due to the hurricane winds)?
   5 feet  10 feet  15 feet  20 feet

6) Which places on the map might be flooded by this storm surge (circle all that apply)?
   place A       place B       place C       place D       place E

Show this on the map by using a blue marker to shade all the areas that might be flooded.
One reason why people are often hurt or killed by a hurricane is that they are not aware of the danger at a particular place. It helps to compare the predicted height of the storm surge with the transition in elevation - a map or graph that shows how fast the land rises as you go inland from the water’s edge.

### Hurricane Impact: Storm Surges and Elevation Transitions

This map uses contour lines to show the elevation of the land above mean sea level. Each line traces a particular elevation; it separates areas that are higher than that elevation from areas that are lower. The lines on this map are ten feet apart; that means that the line that is closest to the shore indicates ten feet above sea level. The next line going inland shows 20 feet above sea level, and so forth (unless the ten-foot line curves around a hill and shows that you are going back down across the ten-foot level).

Please answer the following questions.

1) What is a reasonable estimate of the elevation of place D on the map?
   - 5 feet  
   - 10 feet  
   - 15 feet  
   - 20 feet  
   - 25 feet

2) What is a reasonable estimate of the elevation of place C on the map?
   - 5 feet  
   - 10 feet  
   - 15 feet  
   - 20 feet  
   - 25 feet

3) Which of these places on the map is higher above sea level?
   - place B  
   - place D  
   - place E

4) Where does the land go uphill faster?
   - from the shore to place C  
   - from the shore to place E

5) If a category-4 hurricane hit this area, what does the table above shows as the approximate height of the storm surge (the increase in sea level due to the hurricane winds)?
   - 5 feet  
   - 10 feet  
   - 15 feet  
   - 20 feet

6) Which places on the map might be flooded by this storm surge (circle all that apply)?
   - place A  
   - place B  
   - place C  
   - place D  
   - place E

Show this on the map by using a blue marker to shade all the areas that might be flooded.
This map uses contour lines to show the elevation of the land above mean sea level. Each line traces a particular elevation; it separates areas that are higher than that elevation from areas that are lower. The lines on this map are ten feet apart; that means that the line that is closest to the shore indicates ten feet above sea level. The next line going inland shows 20 feet above sea level, and so forth (unless the ten-foot line curves around a hill and shows that you are going back down across the ten-foot level).

1) Which place has the fastest increase in elevation as you go inland from the shore?
   from shore to place A  from shore to place D  from shore to place E

2) Which places on the map might be flooded by the storm surge and waves of a category-3 hurricane (the estimated storm surge is 10 feet above mean sea level; waves might go another five feet higher)
   Circle all that might be flooded:  place A  place B  place C  place D  place E

Show this on the map by using a blue marker to shade all the areas that might be flooded.
Making a Side Profile of the Land

This map uses contour lines to show the shape of the land. The numbers on the contours indicate elevation in feet above mean sea level.

1) Choose and draw an interesting transect (a straight line that runs inland from a point on the shore) on the map above.

2) Measure the distance along your transect from the shore to a place where the elevation is known (such as where the transect crosses a contour line).

3) Put a dot on the graph at the appropriate elevation and distance from shore to represent the point on your transect.

4) Repeat this process for every place where your transect crosses a contour line.

5) Connect the dots with a line; this line shows the general shape of the land as seen from the side.

6) Finally, draw a horizontal line to show the height of the water during a hurricane storm surge.

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Hurricane Impact: Storm Surges and Elevation Transitions

This map includes the present-day streets, according to a modern map. The pattern of streets is different on maps from different sources. That is a common problem when you download maps from various web sources. Some maps are based on satellite images. Others are based on maps or records from the Census Bureau.

Regardless of the source, one thing is clear: some streets have been built on land that is subject to flooding during even a moderate hurricane.

The Office of Emergency Management of New York City has a website that shows officially defined hurricane evacuation zones. The dark color indicates areas that city officials expect will be flooded by any hurricane; lighter colors show areas flooded by more intense Category 2 and 3 hurricanes.

[Map image]

www.nyc.gov/oem/html/home/home.shtml and click Hurricane Zone Finder