Teacher's Guide

Project GeoSTART:

Geo-Spatial Thinking Activities and Resources for Teachers of Geography and Earth Science

ASSOCIATION *of* AMERICAN GEOGRAPHERS

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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.

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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 <u>not</u> have to be done in this order!):

1. Hurricane Shapes: Spatial <u>Patterns</u> on Satellite Images
2. Hurricane Frequency: Identifying <u>Regions</u> with Similar Numbers of Hurricanes
3. Hurricane Paths: <u>Comparing</u> Places with Different Prevailing Winds
4. Hurricane Stories: <u>Analogous</u> Locations in Different Hemispheres
5. Hurricane Winds: A Spatial <u>Hierarchy</u> of Processes at Different Scales
6. Hurricane Strength: Spatial <u>Association</u> of Wind Speed and Water Temperature
7. Hurricane <u>Influence</u>: Landfall Probabilities and Wind Speed
8. Hurricane Impact: Storm Surges and Elevation <u>Transitions</u>

Scaffold of Spatial-Thinking Activities Related to Hurricanes (January 2008)

Spatial-Thinking Skill	Grade Levels 4-6	Grade Levels 7-8	Grade Levels 9-12
Comparison	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	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.	Given past and present images of a coastal area, generalize about how vulnerability to hurricanes seems to be changing through time.
Aura (Buffer)	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.	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.	Given an image of a coastal urban area, identify the nodes (e.g., city, industry) that seem to "attract" settlement (have an influence that leads to higher population densities nearby).
Region	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.	Given a set of observed sea surface temperatures, color the region that had temperatures higher than a specified temperature (e.g., 28°C).	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.
Transition (Gradient)	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.	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.	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.
Hierarchy (Enclosure)	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).	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.	Given part of the NOAA data base about particular hurricanes, note that segments are individually identified but also are part of an overall path.
Analogy	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.	Given climagraphs 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).	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.
Pattern	Given several remotely-sensed images that show clouds with different patterns, pick the one that shows a classic hurricane, and explain.	Given a set of images of hurricanes, classify them into classic spirals, blobs, and other shapes, and write generalizations about the clouds and winds.	Given maps of settlement near hurricane-prone shorelines, describe the patterns that you see (string or cluster patterns, even distribution, etc.)
Association (Correlation)	Given a basic map of prevailing winds (easterly trade winds and mid-latitude westerlies) explain why hurricanes often move westward across the Atlantic.	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.	Given an image of settlement, oil refineries, etc., describe the association of features with elevation, transportation, etc. as seen on other maps.

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
ftp://disc2.nascom.nasa.gov/data/TRMM/Gridded/Hurricane_Maps/Archive/2004/Frances/MODIS/2004Frances_Aqua_03Sep_1830.jpg

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
ftp://disc2.nascom.nasa.gov/data/TRMM/Gridded/Hurricane_Maps/Archive/2005/Katrina/MODIS/2005Katrina_Terra_28Aug_1705.jpg

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 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.