

SE MAPS PROJECT

Climate Change Activity #3

(Southeastern Coastal Zone Region)

Climate Impact - Hurricanes



The SE MAPS Project is a NSF-funded project that evolved from a South Carolina model for inquiry-based classroom instructional modules proposed by South Carolina K-12 teachers participating in a series of Professional Development Courses designed to help educators better understand and appreciate the natural environment of their state. Each activity was reviewed by content specialists at Clemson University before final publication. Funding support for the 'Climate Change' series of activities was provided by the NASA REAP program administered by the South Carolina Space Grant Consortium. All SE MAPS lessons and products are available for use only in non-profit educational activities. Any other uses, including activities involving fees for instruction and/or materials, must receive permission from the Clemson University Geology K-12 Outreach Office. Contact Jackie Gourdin, SE MAPS Project Manager, 445 Brackett Hall, Clemson University, Clemson SC 29634-0919; [864-656-1560 (voice) or <jackieg@clemson.edu> (e-mail)] with questions about any SE MAPS materials or programs.

Climate Impact on Hurricanes

Steven Pruitt and John Wagner [based on an activity written by Sarah Disario, Nick Hill, and Alexandra McIntyre]

INSTRUCTIONAL FOCUS: Students will identify and analyze the impact of physical factors [especially temperature, wind, geographic latitude, and atmospheric moisture] that affect the development and severity of hurricanes. Students will also discuss the predicted effect of global climate change on those factors and how that might increase hurricane frequency and intensity.

SUGGESTED TARGET AUDIENCE: high school earth/environmental studies classes

CORRELATION TO SOUTH CAROLINA ACADEMIC SCIENCE STANDARDS (2014):

EARTH'S ATMOSPHERE – WEATHER AND CLIMATE

Standard H.E.5: The student will demonstrate an understanding of the dynamics of Earth's atmosphere.

H.E.5A.3 Analyze and interpret data to predict local and national weather conditions on the basis of the relationship among the movement of air masses, pressure systems, and frontal boundaries.

H.E.5A.5 Construct explanations for the formation of severe weather conditions (including tornadoes, hurricanes, thunderstorms, and blizzards) using evidence from temperature, pressure and moisture conditions.

Other Curriculum Connections

“SE MAPS (SouthEast Maps and Aerial Photographic Systems) – Regional Study Site #3D”

PRIOR SKILLS REQUIRED: ability to read and use map scales, symbols, and legends.

Specifically, students should be familiar with weather maps (high and low pressure centers and frontal boundaries) and the physical characteristics of hurricanes, including the Saffir-Simpson Hurricane Intensity Scale. Also, students should feel comfortable navigating to various websites and using search engines (Google™, etc.) to search for information on different topics.

LOGISTICS: The basic activity is designed for a 50-minute class, but can be extended to several class sessions if supplemental materials are used. Large tables or flat work areas are needed to work with large-format maps - students should work in cooperative groups. Internet access is required.

KEY VOCABULARY AND CONCEPTS:

- African Wave
- Coriolis Effect
- global climate change
- trade winds
- wind shear

CONTENT OVERVIEW: [more detail is provided in the “Teacher Answer Key.”]

1. Hurricane paths are controlled by the relative positions of high and low pressure centers
 - Most hurricanes form over tropical waters and are pushed westward by the equatorial trade winds.
 - Hurricane paths are steered by the clockwise circulation around high-pressure centers (in the northern hemisphere) and counterclockwise circulation around low-pressure centers (in the northern hemisphere).
 - If a hurricane reaches mid-latitudes it may also be pushed by upper-level jet stream winds.
2. Hurricane intensity is affected by several atmospheric and geographic factors
 - The latitude range most conducive to strong Atlantic hurricane development is from 5° to 30° North Latitude.
 - Hurricanes form most easily over ocean waters that have a temperature of at least 30° C [86° F].
 - Higher levels of atmospheric moisture feed the storm and tend to produce stronger hurricanes.
 - Wind shear can disrupt air circulation within the hurricane and cause the storm to weaken.
3. Global climate change may influence future hurricane frequency and storm intensity
 - Recent scientific data predicts that hurricane intensity may increase due to higher sea-surface temperatures.
 - Recent scientific data is inconclusive regarding predictions of changes in number of hurricanes per year.

MATERIALS: internet access, 6 @ SE MAPS laminated lithographs [“Map #3E - Political Setting”] (or similar map of Southeast USA), 6 @ ‘wet-erase’ markers, world map (hardcopy or online), optional video [Engineering Nature: Engineering Hurricanes”], world globe

PROCEDURES:

1. Review general information about hurricane categories (Saffir-Simpson Hurricane Scale) and the types of damage hurricanes can cause, especially to coastal areas. Review the stages of hurricane formation and the physical characteristics of a typical storm (air pressure, wind circulation, etc.).
2. [optional] Show students the second half of the video “Engineering Nature: Engineering Hurricanes”.
3. Ask students where they think most hurricanes form and what paths these storms might take. Have students share their answers by referring to a world map and justifying their pathway predictions. Show students some historical data of major storm paths <<http://www.csc.noaa.gov/hurricanes/#>> and ask why they think there is so much variability. Show students on a world globe where hurricanes usually form. Tell students that the next activity will provide answers to these questions.
4. Pass out Map #3E and a wet-erase marker to each group. Ask each student group to access the website <<http://www.nhc.noaa.gov/outreach/games/movncane.htm>> and follow the instructions on the Student Work Sheet. When students have finished, have groups summarize their results.
5. Ask students to predict what atmospheric conditions will generate the strongest hurricanes. List (project) all answers on the board (screen). Discuss each item on the list and analyze how that item might influence the strength of the storm. Rank items from most important to least important.
6. Ask each student group to access <<http://www.nhc.noaa.gov/outreach/games/canelab.htm>> and follow the instructions on the Student Work Sheet. When students have finished, have groups share their answers to the questions and evaluate the accuracy of the list generated in the previous step.
7. Ask student groups to consider various ways that global climate change might influence some of the factors that affect hurricane path and intensity. Have each group write down their results and report their predictions (and justifications) to the entire class. Have groups access several climate change websites [listed on “Student Work Sheet”] to verify the accuracy of their predictions. Also assign groups one or more additional website(s) to research and prepare a report to share with the class.

SAMPLE CULMINATING ASSESSMENT:

- MULTIPLE-CHOICE QUESTION ON EXAM:

What is the most important factor that ‘steers’ a hurricane along its path?

- a. distance of the storm from the equator
- b. position relative to low/high pressure centers
- c. the wind speed around the ‘eye’ of the storm
- d. the elevation of the land the storm passes over

- Ask students to write a 100 word essay identifying the four main factors that impact the development and severity of a hurricane and describing the specific effects that each factor has on the storm.

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STUDENT WORK SHEET

Part I – ‘Aim a Hurricane’

- a. Access the website <<http://www.nhc.noaa.gov/outreach/games/movncane.htm>>. Experiment (using the various options offered at this website) to create the conditions necessary for a hurricane to hit your assigned coastal region. Once you have successfully steered your hurricane into your assigned region, use the wet-erase marker to plot the locations of the high and low pressure steering systems [use circled ‘L’ for “low” and circled ‘H’ for “high”] on MAP 3E (“Political Setting”) and draw a line on the map showing the projected path of the hurricane. Be prepared to share your map with the class and explain how the pressure centers effectively ‘steer’ the hurricane into your target.

GROUP ‘A’ ASSIGNMENT

Southeast North Carolina (near Wilmington)

GROUP ‘B’ ASSIGNMENT

Louisiana Coast (near New Orleans)

Part II – ‘Predict a Hurricane’

- a. Discuss the various factors (atmospheric and geographic) that you think favor the strengthening of a hurricane and those you think favor the weakening of a hurricane. List at least five (5) factors in order of importance. The most important factor, sea-surface temperature, is shown as an example.

FACTORS THAT STRENGTHEN

1. *higher sea-surface temperature*
- 2.
- 3.
- 4.
- 5.

FACTORS THAT WEAKEN

1. *lower sea-surface temperature*
- 2.
- 3.
- 4.
- 5.

Part III – ‘Create a Hurricane’

- a. Access the website <<http://www.nhc.noaa.gov/outreach/games/canelab.htm>>. Use the animation tools on the screens to manipulate the winds, latitude range, atmospheric moisture, and sea-surface temperature to achieve the maximum score of ‘80’ for this section.
- b. Once you have reached a score of ‘80’, you can add a condition to trigger the formation of a new tropical depression (typically referred to as an ‘African Wave’) in the Atlantic Ocean. Continue to follow the website instructions and answer the following questions.

1. What is the most favorable range of latitudes for Atlantic Ocean Hurricane formation?

2. What is the normal minimum sea-surface temperature needed to generate a hurricane?

3. What effect does wind shear have on a developing hurricane?

4. What effect does the atmospheric moisture content have on a developing hurricane?

Part IV – Effect of Climate Change on Hurricanes

- a. Discuss in your group how global climate change might affect the various factors influencing hurricane formation. For each factor listed in the table below (add additional factors if you can), predict what changes are likely and how those changes are expected to affect hurricanes.

FACTOR	PREDICTED CHANGE	EFFECT ON HURRICANES
Sea-surface temperature		
Air temperature		
Moisture level in atmosphere		
Atmospheric wind circulation		
Jet-stream wind position		

- b. Access the following websites to review predicted environmental changes due to the effects of global climate change. Compare those hurricane predictions to your own predictions in the table above.
- i. <<http://c0402442.cdn.cloudfiles.rackspacecloud.com/static/ttcms/1.0.0.42/us/documents/NAWP-July08.pdf>>
 - ii. <http://www.awi.de/en/news/background/climate_change/how_will_climate_change_affect_the_world/>
 - iii. <http://earthobservatory.nasa.gov/Features/RisingCost/rising_cost5.php>
 - iv. <<http://www.pbs.org/wgbh/nova/earth/hurricanes-climate.html>>
- c. Access one or more of the following websites to review more environmental changes that might be attributed to effects of global climate change. Prepare a report summarizing your research findings from your chosen website emphasizing the effect on future hurricane strengths and frequencies.

NOAA - Geophysical Fluid Dynamics Laboratory

<<http://www.gfdl.noaa.gov/global-warming-and-hurricanes>>

Union of Concerned Scientists -

<http://www.ucsusa.org/global_warming/science_and_impacts/impacts/hurricanes-and-climate-change.html>

NOVA -

<<http://www.pbs.org/wgbh/nova/earth/hurricanes-climate.html>>

NOAA - National Hurricane Center -

<<http://www.nhc.noaa.gov/?atlc>>

Center for Ocean Solutions -

<<http://centerforoceansolutions.org/climate/impacts/cumulative-impacts/storm-intensity/>>

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TEACHER ANSWER KEY

KEY VOCABULARY AND CONCEPTS:

- African Wave = a tropical depression in the Atlantic Ocean usually formed off the western coastline of Africa; generally moves westward and can intensify into a hurricane under the right conditions.
- Coriolis Effect = a deflective force arising from the rotation of the earth that affects global wind patterns (wind direction deflects towards right in Northern Hemisphere (opposite in Southern).
- global climate change = systemic, non-random changes in atmospheric/hydrologic environmental conditions throughout the earth over long periods of time (decades or centuries).
- trade winds = global wind pattern generally blowing from east to west in the tropics (between 30° South Latitude and 30° North Latitude).
- wind shear = condition produced by a change in wind velocity (speed and/or direction) with height

PROCEDURES:

1. Review general information about hurricane categories, damage, stages of formation, and physical characteristics of typical storms.

Be sure students understand that hurricanes operate the same way as any other Low-Pressure System, only on a larger scale. The lowest atmospheric pressure is found at the center of the storm, where air is rising rapidly, and the winds circulate around the center in a counter-clockwise pattern (in the northern hemisphere).

Hurricanes usually begin forming over an ocean as a small tropical low-pressure zone of clouds, rain showers, and thunderstorms. The chart below details the stages of hurricane formation.

Stage	Definition
Tropical disturbance	a discrete system of clouds, showers, and thunderstorms that originates in the tropics and remains intact for 24 hours or more.
Tropical depression	when a tropical disturbance develops a closed circulation (for example, counter-clockwise winds blowing around a center of low pressure). It contains maximum sustained one-minute winds of 38 mph or less, at an elevation of 10 meters.
Tropical Storm	maximum sustained one-minute winds of 39-73 mph, at an elevation of 10 meters.
Hurricane	have sustained one-minute winds of at least 74 mph, at an elevation of 10 meters.

Hurricanes are typically categorized according to the Saffir-Simpson Hurricane Wind Scale (see chart below).

Alternatively, you may access the chart on the NOAA website <<http://www.nhc.noaa.gov/aboutshws.php>>.

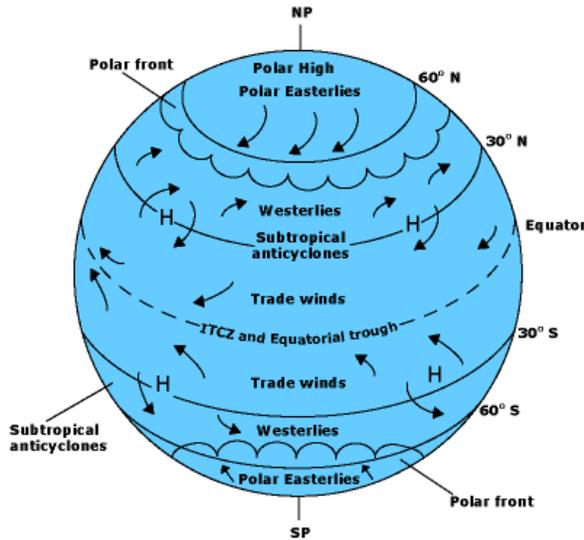
Category	Sustained Wind Speed (mph)	Extent of Damage at Landfall
1	74-95	minimal
2	96-110	moderate
3	111-130	extensive
4	131-155	extreme
5	Over 155	catastrophic

2. [optional] Show second half of video “Engineering Nature: Engineering Hurricanes”.

The second half builds on the introduction by showing how hurricane scientists take measurements of atmospheric readings (wind speed, barometric pressure, etc.) and use this information to predict future strength of the storm.

3. Ask students where hurricanes form and what path they take, and show historical storm-path data.

Hurricanes are first and foremost tropical storms. Therefore they must form in the tropics (between 30°N and 30°S latitude). All storm paths are guided by global prevailing wind patterns. In the tropics, the trade winds blow predominately from east to west; therefore hurricanes would be expected to move from east to west. Some Atlantic hurricanes form off the western coast of Africa; others form in the Caribbean Sea or even the Gulf of Mexico. It may be helpful to refer to a map of global circulation patterns (see below) and review global weather.



Trade winds tend to push hurricanes westward. But, if a hurricane moves far enough away from the equator, it falls under the influence of the Westerlies, winds that then push the hurricane eastward. Hurricane paths are also guided by localized high and low pressure systems. The diagram to the left is copied from the website:

<http://www.hurricanescience.org/science/science/hurricane/movement/>

Image provided by the National Snow and Ice Data Center

Answers will vary regarding where hurricanes form. There are actually several correct answers. Focus the discussion on why hurricanes form in these areas (must have warm air and warm water available for growth). Project a world map on a screen or have students access a world map to identify areas of hurricane formation and also predict the path of a hurricane. A world globe may also be useful. Student answers will vary regarding the direction of movement of hurricanes. Make a list of answers; but do not mark them as 'right' or 'wrong' yet.

Next, project on a screen some historical data of major storm paths from <http://www.csc.noaa.gov/hurricanes/#>. The best approach is to select "Ocean Basin" in the 'Search' box and then pick "West Atlantic" in the 'Select a Basin' box. Then click on the 'GO' box. When the 'warning' box pops up, click "OK". Use the sliding scale on the right side of the screen to zoom in until you can see individual storm paths. [See a screen shot from this site on the second page of website listings at the end of the 'Teacher Answer Key' section.] The purpose of viewing this site is to recognize that there is no 'typical' storm path. There are almost as many different paths as there are storms. Don't worry about identifying the path of any particular hurricane, just make sure students recognize the complexity and variability within the historical record. Students will come up with many different answers to account for the variability. Make a list of these answers, but do not mark them as 'right' or 'wrong' yet.

4. Use website to 'Aim a Hurricane', and have students summarize their results.

Students will experiment on the website <http://www.nhc.noaa.gov/outreach/games/movncane.htm> to create conditions that steer hurricanes in certain directions. One way [there are several other possible configurations] to aim a hurricane to hit the Southeast North Carolina coast (near Wilmington) is to place the 'blue H' in the upper right corner of the screen, place the 'red L' in the lower right corner of the screen, and place the hurricane in the bottom position. To aim a hurricane towards the Louisiana coast (through New Orleans), one possible configuration is to place the 'blue H' in the lower left corner of the screen, place the 'red L' in the upper left corner of the screen, and place the hurricane in the lower position.

After marking the high and low pressure centers on their maps, students should be able to explain how the wind circulation around Low Pressure Centers (counter-clockwise in the northern hemisphere) and High Pressure Centers (clockwise in the northern hemisphere) helps to steer their hurricane. Drawing wind-direction arrows on their maps may help students visualize the steering effect.

5. Ask students to predict conditions generating stronger hurricanes; discuss.

Answers will vary. The most important conditions (others could be added) are listed below in order of importance:

FACTORS THAT STRENGTHEN

1. higher sea-surface temperature
2. higher levels of moisture in the atmosphere
3. lower wind shear affects upper levels of storm
4. latitude range between 10° and 30° N
5. steering winds all blowing in same direction

FACTORS THAT WEAKEN

1. lower sea-surface temperature
2. lower levels of moisture in the atmosphere
3. higher wind shear affects upper levels of storm
4. latitude below 10° or above 30° N
5. steering winds blowing from different directions

Higher sea-surface temperatures sustain the storm by releasing latent heat (energy) from seawater evaporation and subsequent condensation (rainfall). If a hurricane passes over colder ocean water, or land, it will lose energy.

Higher levels of moisture in the atmosphere foster the growth of clouds and rain bands that help generate energy. A hurricane that moves into a region of drier air will produce less rainfall and effectively 'starve' itself.

Higher wind shear in the upper levels of the storm can literally tear the storm apart by interfering with the circulation of cloud bands and disturbing the 'lift forces' that sustain the hurricane. Without strong counter-clockwise (in Northern Hemisphere) circulation, the storm cannot sustain its low-pressure center. Lack of wind shear allows circulation to continue uninterrupted and wind speeds and pressure differentials within the storm to intensify.

Latitudes between 10° and 30° N are tropical enough to sustain the warm ocean temperatures and atmospheric moisture levels required for hurricane development but also have a sufficiently strong Coriolis Force to permit strong wind circulation around the low-pressure storm center. Latitudes above 20° N generally have cooler seawater temperatures and less atmospheric moisture. Latitudes below 10° N have such a weak Coriolis Force that cyclonic (counter-clockwise in Northern Hemisphere) storm wind circulation is difficult to maintain.

Steering winds are related to global atmospheric circulation patterns (air moves from regions of higher pressure towards regions of lower pressure). The 'Trade Winds' are formed when air near the 30° N latitude high-pressure region moves towards the equatorial low-pressure region and is simultaneously deflected to the right (westward) due to the Coriolis Force. As long as the hurricane is under the influence of only the Trade Winds, it can strengthen. If other winds, such as the Jet Stream, interfere, the hurricane can be pushed in different directions and lose energy.

6. Use website to 'Create-A-Hurricane', and have students summarize their results.

Students will experiment on the website <<http://www.nhc.noaa.gov/outreach/games/canelab.htm>> using the animation tools on the screen to try to achieve the maximum score of '80'. To achieve a score of '80', make the sea temperature in the top 50 meters of the ocean as high as it will go (26.5°C [~80°F]); set the latitude range between 10°N and 30°N; make the middle and lower atmospheric layers very moist; and set the three winds at 'light intensity' and 'all in the same direction'.

Students will follow website instructions to generate 'African Waves' and use the results to answer these questions.

1. What is the most favorable range of latitudes for Atlantic Ocean Hurricane formation?

The most favorable hurricane formation range in the Atlantic Ocean is between 5° N and 30° N latitude.

2. What is the normal minimum sea-surface temperature needed to generate a hurricane?

Sea-surface temperatures need to be at least 25°C [~77°F] for hurricanes to form.

3. What effect does wind shear have on a developing hurricane?

The sudden change in wind direction or speed with height can separate cloud tops from their bases and disrupt the entire circulation pattern of the hurricane, causing the storm to weaken or even disintegrate.

4. What effect does the atmospheric moisture content have on a developing hurricane?

Hurricanes derive their energy from latent heat released when water vapor condenses into raindrops. If the air does not contain sufficient moisture, not enough water will condense and the storm will be starved of energy.

Students should review their predictions from the previous section based on their experience with the 'Create-A-Hurricane' website activity. This is a good opportunity to correct any misconceptions that might be present.

7. Consider ways that global climate change might influence factors affecting hurricanes.

Answers in table may vary, but some possible answers are shown below:

FACTOR	PREDICTED CHANGE	EFFECT ON HURRICANES
Sea-surface temperature	temperatures will increase	will become stronger and larger
Air temperature	temperature will increase	will become stronger and larger
Moisture level in atmosphere	moisture levels will increase	will become stronger and larger
Atmospheric wind circulation	more hot/cold contrast, strong wind	storms might travel further north
Jet-stream wind position	position may shift towards poles	less interference with hurricanes
sea-level	sea levels will rise	minimal effect; storm surge increase
ice caps, glaciers, snowfields	massive melting of ice/snow cover	minimal effect; might travel further

The first set of websites provides direct evidence for expected changes in factors affecting hurricanes:

i. <<http://c0402442.cdn.cloudfiles.rackspacecloud.com/static/ttcms/1.0.0.42/us/documents/NAWP-July08.pdf>> Details the predicted impact on wind circulation patterns, including long-term changes in the large-scale atmospheric circulation, such as a poleward shift and strengthening of the westerly winds. Also indicates that jet streams have risen in altitude and their paths have moved poleward in both hemispheres.

ii. <http://www.awi.de/en/news/background/climate_change/how_will_climate_change_affect_the_world/> Areas located near the poles receive less sunlight than places near the equator. Climate change is likely to be more pronounced in higher latitudes because when snow and ice-covered surfaces melt, darker areas become exposed and absorb more of the sun's energy instead of reflecting it. These areas then rise in temperature, causing even more ice and snow melt. This feedback effect is most likely the reason for the observed temperature rise in the Arctic over the past 50 years, which was twice as fast as the increase of the global average temperature. Because hurricanes form at low latitudes, the impact would be minimal, except for the expected effects of global temperature rise.

iii. <http://earthobservatory.nasa.gov/Features/RisingCost/rising_cost5.php> Details how warmer global temperatures are expected to increase the total amount of water vapor that enters the atmosphere, generating a hotter more humid environment. Also, increases in the average global temperature can affect storm formation by decreasing the temperature difference between the poles and the equator. This temperature difference fuels the mid-latitude storms, which affect the Earth's most populated regions, and can also affect hurricanes.

iv. <<http://www.pbs.org/wgbh/nova/earth/hurricanes-climate.html>> Sea surface temperatures will likely increase as average global temperatures rises. Increasing the amount of heat and water vapor (through increased evaporation) in the atmosphere, can provide more 'fuel' to increase the size and wind speed of tropical storms.

The second set of websites provides an opportunity for students to do further research. Implications of global climate change may be investigated in the classroom by small groups, or research reports may be assigned as homework.

SAMPLE CULMINATING ASSESSMENT:

- MULTIPLE-CHOICE QUESTION ON EXAM:

What is the most important factor that 'steers' a hurricane along its path? [answer in bold]

- a. distance of the storm from the equator
- b. **position relative to low/high pressure centers**
- c. the wind speed around the 'eye' of the storm
- d. the elevation of the land the storm passes over

- Ask students to write a 100 word essay identifying four main factors that impact development and severity of a hurricane and describing the specific effects each factor has on the storm.

Students should demonstrate a firm understanding of the four main factors. A sample 100-word essay follows:

The four main factors include winds, latitude change, moisture, and sea-surface temperatures. The absence of wind shear allows circulation of the storm to continue uninterrupted and wind speeds and pressure differentials within the storm to intensify. If the storm moves into latitudes between 10° and 30° N, these are tropical enough to sustain the warm ocean temperatures and atmospheric moisture levels required for hurricane development, in addition to having a sufficiently strong Coriolis Force to permit strong wind circulation around the low-pressure storm center. Higher levels of moisture in the atmosphere also foster the growth of clouds and rain bands that help generate energy to increase the strength of a storm. Higher sea-surface temperatures sustain the storm by releasing latent heat (energy) from seawater evaporation and subsequent condensation (rainfall).

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Websites Used - Climate & Hurricanes Activity

1. Saffir-Simpson Hurricane Wind Scale

<<http://www.nhc.noaa.gov/aboutsshws.php>>

- describes five categories of hurricanes with animation correlating wind speed to damage

2. Movement of Hurricanes

<<http://www.hurricanescience.org/science/science/hurricanemovement/>>

- explains what causes hurricanes to move
- describes factors that influence the path of a hurricane

3. Interactive Hurricane Websites – NOAA

<<http://www.csc.noaa.gov/hurricanes/#>> [*see second page of website listing]

- displays path data for all hurricanes in the NOAA database

<<http://www.nhc.noaa.gov/outreach/games/movncane.htm>>

- ‘Aim-A-Hurricane’ activity shows how prevailing wind patterns steer hurricanes

<<http://www.nhc.noaa.gov/outreach/games/canelab.htm>>

- ‘Create-A-Hurricane’ activity shows what conditions are required to strengthen a storm

4. Science Websites Documenting Global Climate Change Predictions re: Hurricanes

<http://c0402442.cdn.cloudfiles.rackspacecloud.com/static/ttcms/1.0.0.42/us/documents/N_AWP-July08.pdf>

- displays path data for all hurricanes in the NOAA database

<http://www.awi.de/en/news/background/climate_change/how_will_climate_change_affect_the_world/>

- ‘Aim-A-Hurricane’ activity shows how prevailing wind patterns steer hurricanes

<http://earthobservatory.nasa.gov/Features/RisingCost/rising_cost5.php>

- ‘Create-A-Hurricane’ activity shows what conditions are required to strengthen a storm

<<http://www.pbs.org/wgbh/nova/earth/hurricanes-climate.html>>

- ‘Create-A-Hurricane’ activity shows what conditions are required to strengthen a storm

5. Other Websites Discussing Connections Between Climate Change and Hurricanes

<<http://www.gfdl.noaa.gov/global-warming-and-hurricanes>>

- NOAA Geophysical Fluid Dynamics Laboratory (provides an overview of current scientific data showing connections between climate change and hurricanes)

<http://www.ucsusa.org/global_warming/science_and_impacts/impacts/hurricanes-and-climate-change.html>

- Union of Concerned Scientists (briefly describes hurricane behavior and implications of global warming on this process)

<<http://www.pbs.org/wgbh/nova/earth/hurricanes-climate.html>>

- NOVA (describes some of the difficulties scientists have in understanding the systematic relationships between climate, oceans, and hurricanes)

<<http://www.nhc.noaa.gov/?atlc>>

- NOAA - National Hurricane Center (provides current data on hurricanes, tropical storms, etc. in the Atlantic and Eastern Pacific Oceans)

<<http://centerforoceansolutions.org/climate/impacts/cumulative-impacts/storm-intensity/>>

- Center for Ocean Solutions (briefly describes factors that impact the storm intensity of hurricanes/tropical storms, also provides predictions of global warming's impact on future events by the Intergovernmental Panel on Climate Change [IPCC])

6. Video = Engineering Nature: Engineering Hurricanes [Discovery, 2009]

<<http://store.discoveryeducation.com/product/show/91342>>

- this site has ordering information if you want to purchase the video

<<http://scetv.org/education/streamlinesc/index.cfm>>

- South Carolina teachers can download this video free of charge from this SCETV site.

INTERACTIVE NOAA WEBSITE SHOWING HISTORIC HURRICANE PATHS – SCREEN SHOT

<<http://www.csc.noaa.gov/hurricanes/#>>

- displays path data for all hurricanes in the NOAA database

