SE MAPS PROJECT

Climate Change Activity #1

(Southeastern Coastal Zone Region)

Climate & Sea-Level Rise

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.

Climate Change & Sea-Level Rise

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

INSTRUCTIONAL FOCUS: Students will recognize the role that climate change is expected to play in future global sea-level rise. Environmental factors (melting ice, thermal expansion, etc.) associated with sea-level rise will be compared in terms of relative impact. Economic and ecological impacts of sea-level rise on the South Carolina coast will be highlighted.

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.7 Construct scientific arguments to support claims of past changes in climate caused by various factors (such as changes in the atmosphere, variations in solar output, Earth's orbit, changes in the orientation of Earth's axis of rotation, or changes in the biosphere).

H.E.5A.8 Analyze scientific arguments regarding the nature of the relationship between human activities and climate change.

Other Curriculum Connections

"SE MAPS (SouthEast Maps and Aerial Photographic Systems) – Regional Study Sites #3D,3E"

PRIOR SKILLS REQUIRED: ability to locate and use map scale and legends to read and interpret topographic maps and their symbols. Also, students should have had experience navigating to different websites and using a variety of search engines (Google™, etc.) to retrieve information.

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 area is needed so students can draw on large maps - students should work in cooperative groups. Internet access is required.

KEY VOCABULARY AND CONCEPTS:

- elevation
- global climate change
- weather
- thermal expansion
- glaciers

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

1. Global sea-level will rise, due to physical environmental changes, as global temperatures rise
   - *If global air temperatures rise, the heat is transferred to the water in the oceans, causing thermal expansion.*
   - *If global air temperatures rise, melting of glacial ice sheets/icecaps will accelerate, adding water to oceans.*
   - *The melting of 'floating' ice will not change sea level; however melting of 'grounded' ice will raise sea level.*
2. Global climate change (sea-level rise) will impact coastal areas in South Carolina and the Southeast
   - *Lower elevations along the coast will be affected the most by sea-level rise.*
   - *'Weather' describes local conditions over a very short period of time (days or weeks); 'climate' describes regional conditions over a much longer period of time (decades or centuries).*
   - *Most coastal areas in the Southeastern United States have very low elevations (close to sea level).*
   - *Most beaches and other Southeastern coastal areas have been heavily developed and are highly populated.*

MATERIALS: internet [Google Earth™] access, 6 @ SE MAPS laminated lithographs ["Map #3E - Political Setting" & "Map #3D - Topography and Climate"]; 6 @ 'wet-erase' marker pens; 6 @ commercial 'volcano boxes' or similar [transparent plastic box with irregular rock or clay 'landmass' placed on inside bottom of box]; access to water source; 2 @ large ice cubes

PROCEDURES:

1. Ask students to construct a working definition of 'sea level'. Ask them if they think sea level always stays the same. Also ask them which natural events might change sea level.
2. Lead a discussion on what factors might cause sea level to rise along the coast of the Southeastern USA. List (project) all answers on the board (screen). Ask students to evaluate which of these factors they think would be major contributors to sea-level rise and which would not.
3. [optional] A good activity showing the relationship between rising water temperature and increase in water volume can be found at <http://cosee.umaine.edu/cfuser/resources/tr_sea_level.pdf>.
4. As a demonstration, set up two 'volcano boxes' and fill each half-full of water. Place one large ice cube in each box, one floating and the other placed completely on the 'land surface'. Mark the original 'sea-level' and let the ice melt. After ice has melted, note any rise in sea level. Discuss which factor (melting ice or thermal expansion) will likely have a greater impact on sea-level rise.
5. Give each student group a commercial 'volcano box' (or equivalent) and follow the instructions listed on Student Work Sheet Part I. [This activity can also be done as a teacher-led demonstration]
6. [optional] If students need help understanding connections between contour lines and land surface topography, many activities use 'volcano box' models to teach those concepts. One good website is <http://www.hinsdalebobcats.org/site/Default.aspx?PageType=6&SiteID=1&SearchString=constructing%20a%20topographic%20map>.
7. Define the word 'elevation' as "land height above sea level" and explain how it is measured. Ask student groups to follow instructions on Student Work Sheet Part I using this website app to find elevations of their school and home: <http://www.freemaptools.com/elevation-finder.htm>.
8. Assign student groups three states to investigate (refer to Student Work Sheet - Part I). Give each group a copy of SE MAPS #3D and #3E and a wet-erase marker pen. Groups should answer the questions on the Work Sheet and be prepared to compare their answers with those of other groups.
9. Ask students to relate potential sea-level rise to shoreline conditions in South Carolina by using the map <http://maps.risingsea.net/coarse/sa_sc.html> and Google Earth™ [see instructions on Student Work Sheet - Part II]. Ask each group to summarize results and identify societal impacts. View images of flooding in Charleston, SC at <http://www.live5news.com/slideshow?widgetid=82659>.
10. Mention to students that the winter of 2014 was unusually cold for South Carolina (snow and ice storms as well as extremely cold temperatures). Ask students how much they think this unusual weather pattern might have affected regional and global climate trends.

SAMPLE CULMINATING ASSESSMENT:

- Ask the students to evaluate the impact of sea level rise in South Carolina (high, moderate, low) as compared to the other states in the southeast. Have students write a 100 word essay backing up their assessment and using examples from their work with the maps.

Climate Change & Sea-Level Rise

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STUDENT WORK SHEET – Part I

Part I – Changing Sea Level and Shoreline Consequences

a. Write down your best definition of 'sea-level' based on the class discussion.

_____

b. List at least two natural events that you think might be able to change the elevation of 'sea-level'.

_____

c. Which factor (thermal expansion or ice-melt) do you predict would have the greatest impact on global sea-level rise. Explain your answer. _____

_____

d. Fill the 'volcano box' about one-fourth full of water. Determine a way to mark the position of 'sea-level' on the 'landform' model. Add enough water to raise the water level at least 2 cm (~ 1 inch) in the box. Determine the new position of 'sea-level' on the 'landform' model and describe how the new 'shoreline' is different from the original 'shoreline'.

_____

e. Access the following website app <http://www.freemaptools.com/elevation-finder.htm>. Use this app to determine the elevation of your home and your school.

   i. *Zoom and pan the map to find the desired location.*
   ii. *Click on the map to place a marker at the desired location. You will see the estimated elevation displayed below the map.*
   iii. *Now locate other desired locations.*
   iv. *You can return to the original location, or any other marker that has been placed, by hovering over the marker with your mouse.*

   Elevation of home = _____ elevation of school = _____

f. Select three states from the list below and use the 'elevation-finder' app to determine the elevation of the cities that are listed for each state. Using MAP #3E as a reference, mark the approximate location of each city on MAP #3D with a wet-erase marker, and also write on this map (#3D) the elevation of each city that you mark.

GROUP 1	**GROUP 2**
Alabama: Birmingham & Mobile	*North Carolina: Charlotte & Wilmington*
Florida: Miami & Orlando	*Louisiana: New Orleans & Baton Rouge*
Georgia: Atlanta & Savannah	*Tennessee: Nashville & Memphis*

   Compare elevation differences between cities in each state and review the relative elevation information displayed on MAP #3D to infer which state(s) would likely suffer the greatest consequences from a potentially significant sea-level rise. Be prepared to defend your answer in a class discussion. Based on MAP #3D, where would you expect South Carolina fall on your list.

   State(s) likely to suffer most consequences = _____

   Position of South Carolina on 'consequences' list = _____

g. Based on the results of the 'melting ice-cube' demonstration, which factor do you now think is most important in causing the greatest amount of sea-level rise? _____

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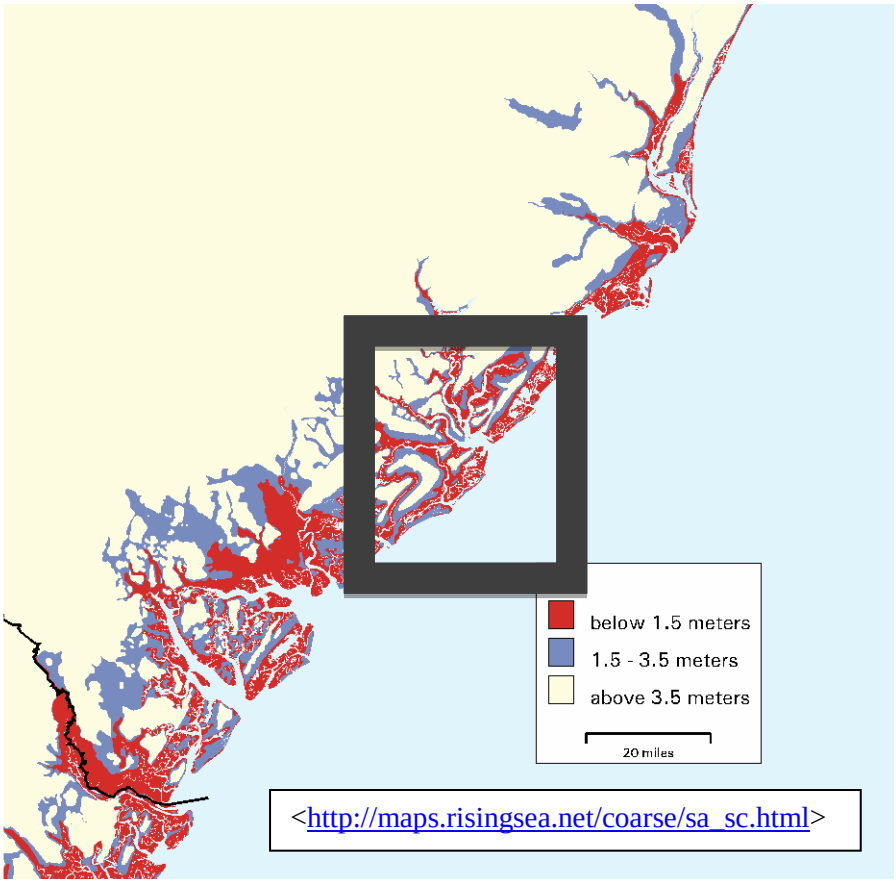
STUDENT WORK SHEET – Part II

Part II – Implications for Sea-Level Rise in South Carolina

a. Examine the map below (portion of coastline of South Carolina). Pay special attention to the area in the marked rectangle (Folly Beach and Isle of Palms).

What percentage of this areas would be under water if the sea level rose 1.5 meters? _____
Explain in detail how you calculated this percentage.



<http://maps.risingsea.net/coarse/sa_sc.html>

b. Find the same region on Google Earth™ (Folly Beach/Charleston area) and examine the land use in this area. Predict the human impact in this area if sea level were to rise 1.5 meters.

_____

_____

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TEACHER ANSWER KEY

KEY VOCABULARY AND CONCEPTS:

- elevation = the height (or altitude) of a specific location above sea level
- climate = the average pattern of variation in atmospheric conditions (temperature, precipitation, wind speed, etc.) in a particular region over long periods of time
- weather = the description of day-to-day atmospheric conditions (temperature, precipitation, wind speed, etc.) for a specific location on the earth
- thermal expansion = the increase in volume of a substance caused by the heating of that substance
- glaciers = slow-moving masses of ice found on land (some may extend into ocean waters)

PROCEDURES:

1. Ask students to construct a working definition of 'sea level'; whether sea-level stays the same; what natural events might change sea level.

Answers may vary, but any definition should recognize that sea-level is in fact a 'contour line' of elevation = 0. A typical definition might be "the contour line defined by the ocean shoreline at the current time".

True Sea Level varies moment by moment and even day by day due to ocean wave activity and tidal fluctuations. In some parts of the world (Bay of Fundy in Canada for example) daily fluctuations can exceed 12 meters (~40 feet). What we call 'sea level' is really an average position of the shoreline over longer time intervals (months or years). Longer term sea-level changes (over centuries or millenia) have occurred in the past and could happen again.

Answers may vary, but the two most important factors would be 'adding water to the oceans' (through melting of ice for example) and thermal expansion of water due to heating of the oceans. A longer-term factor is the changing shape of the ocean basins due to plate-tectonic activity, but those types of changes require many thousands of years to become significant factors in sea-level rise or fall.

2. Lead a discussion on what factors might cause sea level to rise along the Southeastern coast.

The major factors are thermal expansion of seawater and melting of glacial ice (grounded ice only - the melting of floating ice will not raise sea level - see procedures #3 and #4 below). Any other factors that students may mention are either temporary (downpours from hurricanes - evaporation will remove whatever water was added) or insignificant (sediment entering ocean through rivers will displace minor amounts of water - not measurable).

3. [optional] Note relationship between water temperature and water volume from 'cosee' website.

This website <http://cosee.umaine.edu/cfuser/resources/tr_sea_level.pdf> has suggestions for good class activities or demonstrations that document the relationship between temperature and water volume.

4. Set up 'volcano box' demonstration. In one 'box', ice cube should float; in second 'box', ice cube should be put on 'land'. Discuss which scenario actually adds water to the 'ocean' and why.

Depending on available class time, you may need to use a heat lamp or hair dryer to speed up the melting of the ice cube. Make sure the ice cube is large enough to add a significant amount of water to the 'box' when it melts (a good amount of ice for the typical 'volcano box' can be achieved by filling two 500 ml containers with water ahead of time and freezing them). A grease pencil or non-soluble marker can be used to mark original 'sea-level' position in the 'box'. After melting, the water level in the 'box' where the ice was floating should be unchanged. This is a consequence of Archimedes' principle of buoyancy. The mass of floating ice (above and below water both)

is identical to the mass of the water displaced. If the ice melts into water, its density decreases but is mass is the same, and water level is unchanged. However the water level in the 'box' where the ice was grounded should be measurably higher as this represents a true increase in the volume of water.

In discussing which factor (melting ice or thermal expansion) has a greater impact on sea-level rise, note that the actual amount of grounded ice (glaciers and ice-caps) on earth is extremely small compared to the total volume of seawater on earth (nowhere near the percentage implied by the 'volcano box' demonstration). Even so, if every glacier and ice-cap on earth melted completely, there would be a significant rise in sea level. Nevertheless, the impact of thermal expansion is still of greater significance. Global warming is a concern because the oceans absorb heat from the atmosphere and therefore when the atmosphere warms, the oceans warm also, causing both thermal expansion and the melting of grounded ice. <http://cosee.umaine.edu/cfuser/resources/tr_sea_level.pdf>

5. Give 'volcano box' to each group; follow instructions on Student Work Sheet Part I.

If this activity is done as a teacher-led class demonstration, make sure that the changes to the 'shoreline' as a result of sea-level rise are clearly documented. Note that not only are major areas of 'land' now under water, but the actual configuration of the shoreline has changed due to irregularities in the original 'land' topography.

If student groups each perform this activity, be sure they document that lower-elevation areas are more susceptible to flooding. Students should also draw 'before' and 'after' maps showing the changing shoreline configuration.

6. [optional] Other activities using 'volcano box' to define contour lines are available on website.

Other activities are posted on various educational websites (find with online search), but one good site is: <http://www.hinsdalebobcats.org/site/Default.aspx?PageType=6&SiteID=1&SearchString=constructing%20a%20topographic%20map>

7. Define 'elevation' and explain how it is measured; use website app to find home/school elevation.

Define 'elevation' as "land height above sea level". Note that when topographic maps are made, the contour line numbers are based on the sea level datum measured during a specific year (this information is usually printed in the lower margin of the topographic map). Various surveying methods and more recently GPS technology have been used to determine elevations at specific locations.

Answers will vary depending on what school and home sites are selected. Locating these sites of personal interest will help familiarize students with how to use the website app <http://www.freemaptools.com/elevation-finder.htm>.

8. Assign states to student groups; answer questions on Student Work Sheet Part I.

The two cities selected for each state represent a 'coastal' city and a city close to the center of the state. The idea is to determine how quickly elevation rises from the coastline to the center of each state. Tennessee is an exception as it does not have an ocean coastline. South Carolina is not used in this section of the activity because students are asked in a follow-up question to use their map data to predict the relative impact of sea-level rise on that state.

Elevations for each city (in feet) are listed below.

GROUP 1	**GROUP 2**
*AL: Birmingham [**615**] & Mobile [**16**]*	*NC: Charlotte [**745**] & Wilmington [**30**]*
*FL: Miami [**8**] & Orlando [**125**]*	*LA: New Orleans [**2**] & Baton Rouge [**49**]*
*GA: Atlanta [**1016**] & Savannah [**10**]*	*TN: Nashville [**422**] & Memphis [**249**]*

Based on the map data and the city elevation data, the states that will probably suffer the most land loss from major sea-level rise are (in decreasing order): Louisiana, Florida, Alabama, North Carolina, Georgia, and Tennessee. Note that Tennessee is least likely to suffer from rising sea level (even though the elevation difference between cities is less than 200 feet) because no part of that state borders the ocean and the lowest point in the state is still more than 200 feet above sea level.

South Carolina will probably rank between Florida and Alabama in terms of predicted land loss. Columbia, SC, at the center of the state, lies at an elevation of approximately 325 feet above sea level.

9. Examine the South Carolina shoreline map <http://maps.risingsea.net/coarse/sa_sc.html> and Google Earth to assess the potential societal impact of sea-level rise in this area.

The percentage of this area that would be under water if sea level rose 1.5 meters is approximately 50%.

There are several ways to calculate this area mathematically, but all are rather complex and such detail is unnecessary. Based on the map legend and simple inspection of the area within the square, it should be apparent that about half of the land area is below 1.5 meters in elevation; therefore about half the land area would be flooded.

The Google Earth TM view of this area indicates extensive development in the coastal area. Businesses and homes, along with highways and other necessary infrastructure are vulnerable to flooding if sea level rises in the future. Many resort areas and natural areas (state parks, etc) along the coast would be under water – Isle of Palms, Folly Beach state park, Sullivans Island, etc. This would also impact many historical sights – Fort Sumter, Fort Moultrie, Old Customs House, etc. Besides loss of tourism due to these factors, many negative economic impacts would be felt by businesses and companies in downtown Charleston. There would be significant impact to the Northeastern side of the peninsula that includes the SC aquarium, Carnival cruise ship docking station, the BMW exporting docks, etc. Many residents would have to abandon their homes and relocate further inland. By showing the class the photos of flooding in Charleston <http://www.live5news.com/slideshow?widgetid=82659>, some of these impacts will become even more obvious.

10. Discuss the severe winter of 2014 in South Carolina and how this event might affect long-term climate.

Summarize the findings of the activity through a class discussion. Re-emphasize the difference between climate and weather: Weather is a measure of atmospheric conditions over a short period of time while climate describes atmospheric conditions over much longer periods of time. Therefore, even though South Carolina had cold weather during the winter of 2014, the overall affect on South Carolina's climate would be negligible. For a significant change in climate to occur in this region, South Carolina would have to experience abnormal conditions for an extended period of time. Current trends indicate that average global temperatures have been increasing over the past few decades, which, if it continues, could contribute to a significant rise in sea level and coastal flooding.

SAMPLE CULMINATING ASSESSMENT:

- Ask the students to evaluate the impact of sea level rise in South Carolina (high, moderate, low) as compared to the other states in the southeast. Have students write a 100-word essay backing up their assessment and using examples from their work with the maps.

As South Carolina's coastline is highly developed, major societal impact could be expected from any sea-level rise. The key factor is elevation above sea level. Many areas along the coast of South Carolina are low lying areas and will be at great risk of being inundated by the rising sea levels. Students should support their risk ranking with data that they collected from other states in the Southeast during the lesson. The comparison with other states is based on how quickly the elevation rises once you leave the coastal region. Some states (Florida and Louisiana for example) continue to have elevations very near sea level even far inland from the coast and therefore will have a larger land area affected by rising sea level. Students should include information about the worldwide melting of glaciers and thermal expansions of the seas and the subsequent impact of each. A sample 100-word essay is included below:

The coast of South Carolina would be listed in a moderate category in terms of land lost due to sea level rise as compared to other states in the Southeastern United States. The exact impact of this rise will be scattered across coastal South Carolina with the most low-lying areas impacted the greatest. This rise in sea level will be due to melting of glaciers (and other land based ice) and the thermal expansion of seawater due to increases in water temperature, both factors influenced by warming temperatures associated with global climate change. South Carolina could be at great risk economically with several tourist destinations (Downtown Charleston, Isle of Palms, Folly Beach, Sullivan's Island, etc.) being heavily affected by sea level rise.

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Websites Used - Climate/Sea-Level Rise Activity

1. **General Information on Thermal Expansion of Water due to Heating**
   <*http://cosee.umaine.edu/cfuser/resources/tr_sea_level.pdf*>.
   - explanation of thermal expansion process
   - class activity / demonstration showing effects of thermal expansion
2. **One Good Example of Using 'Volcano Box' Models to Define Contour Lines**
   <http://www.hinsdalebobcats.org/site/Default.aspx?PageType=6&SiteID=1&SearchString=constructing%20a%20topographic%20map>
   - shows how contour line elevations relate to sea level
3. **Website App to Find Elevation of Any Location on the Earth**
   <http://www.freemaptools.com/elevation-finder.htm>
   - click on location to see elevation information for that point
4. **Greenhouse Effect and Sea-Level Rise: America Starts to Prepare**
   <http://maps.risingsea.net/coarse/sa_sc.html>
   - several maps showing lands vulnerable to sea-level rise
5. **One Example of Results of Coastal Flooding**
   <http://www.live5news.com/slideshow?widgetid=82659>
   - shows flooding from large rain event on city of Charleston SC due to low elevation
6. **Example of Google Earth™ view of South Carolina shoreline SW of Charleston**