Examining Sea Level Rise and Differential Shoreline Response

DESCRIPTION

Global climate change used to be something we associated with the distant future, but is now a part of our present lives. The 2014 *National Climate Assessment* states that "precipitation patterns are changing, sea level is rising, the oceans are becoming more acidic, and the frequency and intensity of some extreme weather events are increasing." How we respond to these changes will impact future generations. According to projections from the 2013 IPCC report, a sea level rise between 10 and 32 inches is expected by the end of this century, but not necessarily uniformly from region to region. **To truly gain a better understanding of these sea level rise projections and to critically evaluate various coastal adaptation strategies to prepare for rising seas, students will make and manipulate physical shoreline models in this lesson**. North Carolina is especially vulnerable to sea level rise because it has the third largest low-lying region in the United States, the nation's second largest estuary system, as well as numerous barrier islands. Students will be asked to consider the relationship of sea level rise to climate change as well as the consequences of sea level rise on North Carolina's citizens, the environment, and the economy.

KEYWORDS

sea level rise, shoreline, erosion, estuaries, barrier islands, jetties, sea walls, freshwater, saltwater, ocean, climate, weather, economy, adaptations, glacier, salt water intrusion, salinity

EXTENSION KEYWORDS

infrastructure, storm surge, force, hurricane, energy

LEARNING OUTCOMES

During this lesson students will:

- construct physical models of shorelines to examine how various shorelines--both natural and altered--will respond to sea level rise;
- collaborate in small groups to assess the effect of sea level rise on their shoreline model;
- compare their observations to current data available from NASA and the USGS;
- manipulate online tools to observe worldwide trends in sea level rise; and,
- communicate their findings to the class.

CURRICULUM ALIGNMENT

2010 North Carolina Essential Standards for Earth/Environmental Science

EEn.2.1.3 Explain how natural actions such as weathering, erosion (wind, water and gravity), and soil formation affect Earth's surface.

EEn.2.3.1 Explain how water is an energy agent (currents and heat transfer).

EEn.2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.

EEn.2.5.4 Predict the weather using available weather maps and data (including surface, upper atmospheric winds, and satellite imagery).

EEn.2.6.1 Differentiate between weather and climate.

EEn.2.6.2 Explain changes in global climate due to natural processes.

EEn.2.6.3 Analyze the impacts that human activities have on global climate change (such as burning hydrocarbons, greenhouse effect, and deforestation).

Next Generation Science Standards

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).

Develop a model based on evidence to illustrate the relationships between systems or between components of a system. ***(HS-ESS2-3), (HS-ESS2-6)***

Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

· Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. ***(HS-ESS2-5)***

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

·Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. ***(HS-ESS2-2)***

ESS2.C: The Roles of Water in Earth's Surface Processes

· The abundance of liquid water on Earth’s surface and its unique combination of physical and chemical properties are central to the planet’s dynamics. These properties include water’s exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. ***(HS-ESS2-5)***

ESS2.D: Weather and Climate

· The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space. ***(HS-ESS2-2)***

· Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. ***(HS-ESS2-6), (HS-ESS2-7)***

· Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. ***(HS-ESS2-6)***

Climate Literacy Framework

Principle 2	Climate is regulated by complex interactions among components of the Earth’s system
Principle 5	Our understanding of the climate system is improved through observations, theoretical studies, and modeling
Principle 6	Human activities are impacting the climate system
Principle 7	Climate change will have consequences for the Earth System and human lives

Background Information for Teacher

According to the U.S. Climate Change Science Program 2009 report, *Coastal Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region*, "most coastal regions are currently managed under the premise that sea-level rise is not significant and that shorelines are static or can be fixed in place by engineering structures. The new reality of sea-level rise due to climate change requires new considerations in managing areas to protect resources and reduce risk to humans. Long-term climate change impact data are essential for adaptation plans to climate change and coastal zone plans are most useful if they have the premise that coasts are dynamic and highly variable." Many climate models based on satellite data and observations have shown that sea level rise is not uniform, and this is partly due to the lack of uniformity of Earth's surface. Some regions surpass the global mean, while in other areas, it is falling. This is more than likely due to the fact that Earth's temperature changes are not uniform, nor are salinity changes which impact ocean circulation. Additionally, the nature of a shoreline along with other factors will influence local sea level and how shorelines respond to rising seas. The 2014 *National Climate Assessment* states that "in coastal areas, sea level rise may act in parallel with inland climate changes to intensify water-use impacts and challenges" such as flooding. Factors that influence local sea levels include:

- land subsidence and/or land uplift
- heavier runoff from inland areas
- patterns of precipitation changes
- erosion and sediment migration
- wave action
- storm activity

TIME REQUIRED:

90 MINUTE BLOCK or 2, 50-60 MINUTE CLASS PERIODS

20 minute introduction
60 minutes for lab activity and small group collaboration
10 minutes for daily assessment and discussion

MATERIALS

Per group of 4-5 students

- Transparent container* for shoreline model (**for comparison purposes all groups should have the same kind of container:* Sterilite© container, stream table, clear takeout container, etc.
- Beaker or cup for holding a set volume of water
- Gravel (could include different sized gravels) and/or clay to model jetties and sea walls
- Sand (fine, coarse, mixed) to model beach, sand dunes, and barrier islands
- Paper towels
- Water
- Sponges (could include different types of sponges) to model estuaries, marshes, etc.
- (*optional*) Monopoly homes, Lego blocks, straws, lincoln logs, toothpicks, popsicle sticks, cardboard, toy cars, etc.
- (*optional*) Block of wood/hair dryer (multiple speed) for *Storm Surge Extension Activity*
- Markers
- Ruler (mm)
- Paper for drawing shoreline representations (optional)
- Colored pencils/wax pencils for drawing shoreline representations (optional)
- Scissors for cutting sponges

- *Student Activity Sheet*, one per student

TECHNOLOGY ACCESS

Students will need access to computers, smartphones, iPads or other approved electronic device for viewing the online resources & tools to complete the *Student Activity Sheet.*

STUDENT PREPARATION FOR ACTIVITY

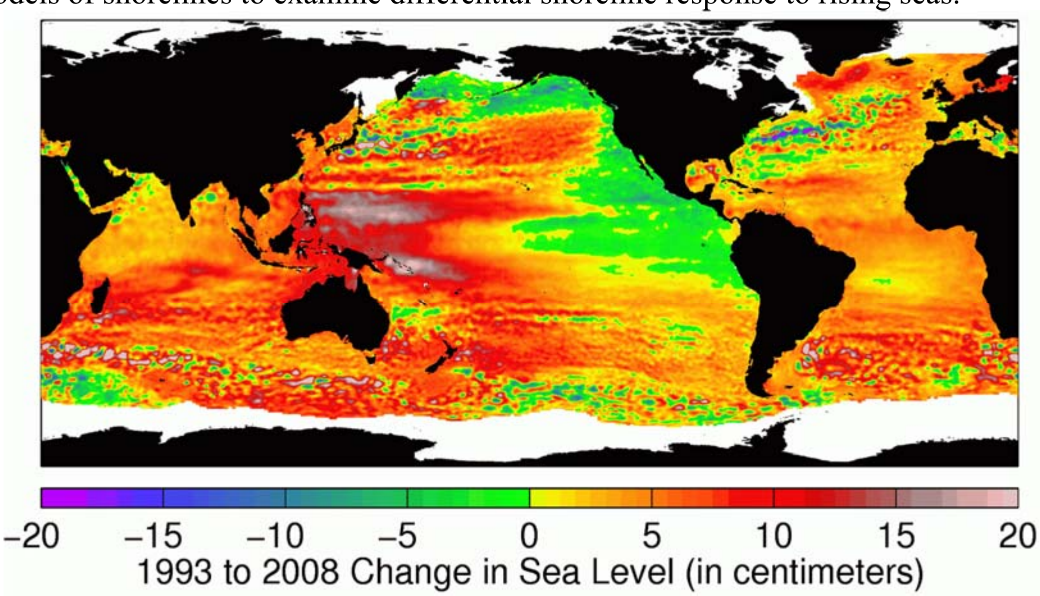
Students should have knowledge of the following **prior to completing this activity**:

a. an understanding that thermal expansion of water, melting glaciers and loss of ice from the Greenland and Antarctic ice sheets can contribute to rising sea level;
b. an understanding that physical, geological and human forces shape shorelines;
c. a general understanding of NC's coastal ecology and geography. A nice overview can be found in Chapter 1 of North Carolina National Estuarine Research Reserve's *A Field Guide to the North Carolina National Estuarine Research Reserve*.
d. awareness of the different types of shorelines, especially those along the NC coast. This could be done by showing students images of different shorelines (photo examples of 15 major shoreline types from NOAA can be found here) and/or letting them look for/explore different shorelines using Google Earth.

You may choose to show the NASA video *Melting Ice, Rising Seas* (4min 31seconds) prior to starting this lesson: http://pmm.nasa.gov/education/videos/melting-ice-rising-seas

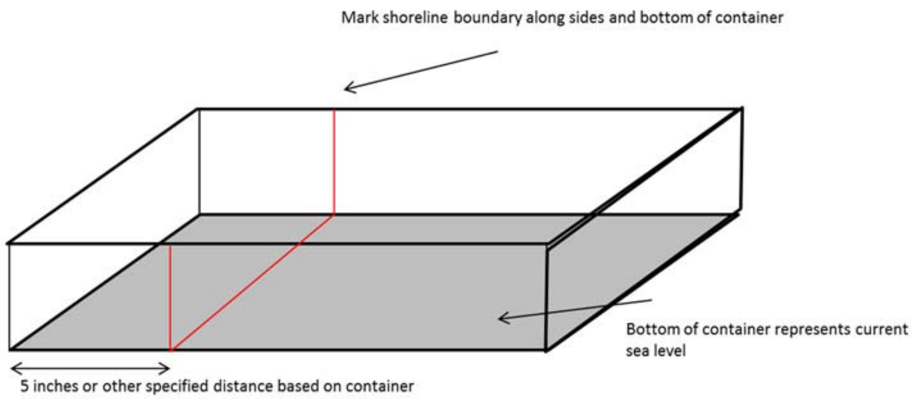
Engagement activity

1. Project an image at the front of the room that **illustrates that sea level rise is not uniform across the globe – there is regional variation**. Use the image available from NASA's Sea Level Rise Viewer or use the one below (available at http://climate.nasa.gov/blog/239). In the figure below, yellow, orange and red colors indicate rising sea level, while green and blue colors indicate falling sea level. White indicates data is not available during parts of the year. Ask students to *explain* why sea level rise is not uniform.
2. Next, tell students that in addition to the regional variation seen across the globa, different types of shorelines will also experience sea level rise differently. They will create physical models of shorelines to examine differential shoreline response to rising seas.



PROCEDURE | Model Construction

1. Set up materials for student construction of shoreline models and divide class into groups of 3-4 students each; each group should have an empty container in which they will construct their shoreline with available materials. ***All containers should be identical and should have the same shoreline boundary designated with a marker. *** All shorelines need to extend the same distance (e.g., 5”) into the container; a line needs to be drawn along the bottom and sides of the container (e.g., 5” from the edge of the container) indicating that students will build their shorelines within this area (see red line below). The bottom of the container will represent the *current sea level*.



2. Tell students that they are going to build a physical model of a shoreline out of sand, gravel, clay and sponges in order to predict and then observe the effect of sea level rise (SLR) on their shoreline. You could provide them with a description of a shoreline to build or let them design their own.

Example shoreline descriptions students could model are included below:

Coastline #1: Barrier Island: Your shoreline consists of a sandy beach on the ocean side and a sound side wetland. Using sand and sponges and/or paper towels model this in the container provided.

Coastline #2: Your shoreline consists of a sandy beach and as a result of coastal protection measures also includes a jetty (gravel) and/or a sea wall (clay). Use sand, gravel, and clay to model this shoreline in the container provided.

Coastline #3: Your shoreline is a wetland located in an estuary where a river meets the sea. Using paper towels and/or sponges model this coastline in the container provided.

Coastline #4: Resilient shoreline - students create what they feel will be the safest (least vulnerable to sea level rise) shoreline with same materials as listed above.

3. Instruct students to follow the instructions on their activity sheet and construct their models; you will need to provide each group with the *****same volume***** of water so that groups can compare their results.

Figure 1 (left). Student pours specified volume of water to witness how "rising seas" will impact shoreline model. Figure 1 (right). Student measures height of water to quantify the amount of sea level rise observed.

4. Once students have witnessed the impact of sea level rise on their shoreline model, invite them to move around the room and observe other models to determine the features that make a shoreline more resilient to sea level rise (e.g., which model resulted in the least amount of sea level rise (smallest depth of water?)). Alternatively (*time permitting*), ask each group to take into consideration how they answered question 10 and repeat their experiment to see if they can reconstruct a shoreline that is less vulnerable to sea level rise.
5. Summarize current thinking about sea level rise for the class. Tell them, in general, rising seas will inundate wetlands and other low-lying lands, erode beaches, intensify flooding, and increase the salinity of rivers, bays, and groundwater tables. IPCC 2014 states, "Sea level rise will not be uniform. By the end of the 21st century, it is very likely that sea level will rise in more than about 95% of the ocean area. About 70% of the coastlines worldwide are projected to experience sea level change within 20% of the global mean sea level change." This means that some areas will experience sea level rise greater than the projected mean and other areas will experience less.
6. Conclude this activity by asking the following questions and having students record their responses on the back of their worksheet:

   A. How will a rising sea impact people?
   - *loss of towns/developments*
   - *loss of coastal cropland*
   - *creates refugees (displaces people from low-lying areas)*
   - *salt water intrusion/groundwater supplies/municipal water supplies*

   B. How will a rising sea impact coastal infrastructure?
   - *salt water intrusion*
   - *loss of septic/sewage*
   - *loss of roads, power lines, etc.*

   C. How will a rising sea impact coastal ecosystems? (*barrier island migration, breaching, segmentation)*
   - *loss of coastal habitats and wetlands by inundation of low-lying lands or erosion*
   - *wetland accretion and migration;*
   - *expansion of wetlands*
   - *saltwater intrusion*

   D. How will a rising sea impact coastal storms?
   - *increased storm waves/surges*
   - *flooding*

E. How can coastal communities prepare for rising seas?

- *develop resilient shorelines and infrastructure*
- *address homes and buildings in low-lying areas*
- *educate citizens on individual and collective actions to help community adapt to higher seas*

F. What role do local, state and federal policymakers play in helping communities prepare?

- *answers will vary but may include policies related to development, preservation, etc.*

7. Ask students to reflect on their model and describe how it behaved like an actual shoreline? How was it different?

Their models looked at sea level rise in isolation from other factors when in fact shorelines are dynamic and shaped by physical, geological, and human factors. Discuss the value of constructing physical models. How could they supplement their model data with real data?

Assessment

- Student presentations of their shorelines and response to rising seas
- Completion of *Student Activity Sheet*

Differentiation

Students with Special Needs

- Place students in mixed ability partners for activity completion; provide additional time for model construction.

AIG

- Invite students to work individually to design and construct models.
- Conduct one or more of the extension activities below.
- Ask students to summarize their predictions and observations writing.
- Ask students to investigate one or more NC coastal communities and research what the community is doing to prepare for sea level rise; students can compare community adaptation strategies.

AIG STUDENT EXTENSION ACTIVITIES

PROCEDURE | *Storm Surge Investigation*

1. Using the shoreline model they have already developed, track the destruction a tropical storm can cause. The students will track Haiyan Tropical Storm that devastated the Philippines in 2013. They will use the following site and replicate the strength of the storm:
 http://www.nasa.gov/content/goddard/haiyan-northwestern-pacific-ocean/#.VH8yVclNeSp

 They will use the hair dryer/wood block to replicate a storm surge by using the Saffir-Simpson Hurricane Wind Scale. http://www.nhc.noaa.gov/aboutsshws.php

 Use wood block to softly tap surface of water - 1
 Use wood block to make more forceful waves, submerging shoreline quickly - 2
 Use hair dryer on low speed to direct water toward shoreline- 3
 Use hair dryer on medium speed to direct water toward shoreline - 4
 Use hair dryer on high speed and use wood block to create forceful waves - 5
2. Next ask students to describe their observations and evaluate damages to their shoreline model either orally or in writing.

PROCEDURE | *Resilient Shoreline Investigation*

1. Invite students to research building designs and building materials that can be used for constructing resilient shorelines and resilient infrastructure.
2. Allow students to revisit their shoreline model and use various materials/designs to construct a more resilient shoreline.
3. Perform the storm surge activity and make observations, estimate economic impact, environmental impact, social impact, etc.

Resources

Introduction Video (4min 31seconds): *Melting Ice, Rising Seas*
http://pmm.nasa.gov/education/videos/melting-ice-rising-seas

Interactive Maps
Sea Level Rise Analysis by Climate Central
http://sealevel.climatecentral.org/

Global Sea Level Rise Map
http://geology.com/sea-level-rise/

Sea Level Viewer - Global Effects (post lesson)
http://climate.nasa.gov/interactives/sea_level_viewer

Current Sea Level Data from NASA
http://climate.nasa.gov/vital-signs/sea-level/

Author Information

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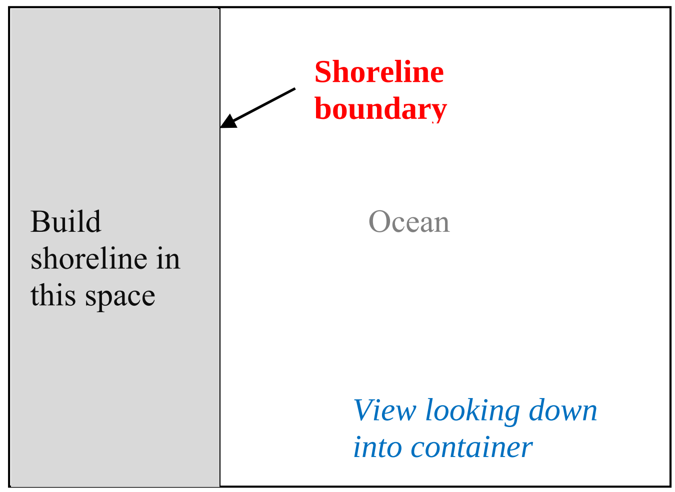
Examining Sea Level Rise and Differential Shoreline Response | *Student Activity Sheet*

Your name:____
Group members: ____________________________________

Part I. Shoreline Model

1. Obtain a transparent container from your teacher and with a marker ***mark the shoreline boundary*** (with a solid line) on the side and bottom of the container according to your teacher's instructions. Your teacher may have already marked the container.

2. Notice that the shoreline boundary line divides your container into two sections. Within the smaller section (see shaded area in drawing to the right), use available materials (sand, gravel, sponges, clay, etc.) to create a shoreline- you get to decide the elevation and slope of your coastal structures. Alternatively, your teacher may tell you which materials you are allowed to use. You may also choose to construct one or more barrier islands opposite the shoreline using sand and/or gravel and/or one or more man-made structures such as a jetty or sea wall using clay or gravel.



3. Next, use a marker to draw the profile of your shoreline on the sides of the container so that you can monitor how your shoreline responds once you add water to the container.

4. Draw a representative picture of your shoreline on the diagram above (or on another sheet of paper) and, using labels, indicate what each material represents. You may also choose to draw a cross-section of your shoreline, especially if you layered materials when constructing.

5. ***Imagine that the bottom of the container represents the *current sea level*.*** Predict what will happen to your shoreline features if sea level rises.

6. On a scale of 1 to 10, with 10 being most vulnerable, ***predict* the vulnerability** of your shoreline to sea level rise.

   1 2 3 4 5 6 7 8 9 10

7. Now, pour a set volume of water (as determined by your teacher) into the empty section ("ocean") of the container, pouring the water slowly so as to not disrupt any of your structures.

8. Then, use a ruler to measure the depth of the water (in mm). *Depending on the materials you used, it might take a few minutes for the water to infiltrate your shoreline.*

   Record depth of water here ___________. This represents the amount of sea level rise.

9. Shade the portions of your shoreline drawing (Step 4 above) that are now underwater as a result of this increase in sea level and describe your observations in the space below.

10. By completing the table below, indicate which coastal features were affected by this increase in sea level.

Coastal Feature	Sea Level Rise Impact	Economic Costs of Impact	Environmental Cost
i.e. Beach/Sand	*Erosion*	*Loss of beach front property, tourism*	*Loss of dunes; habitats for plants and animals*

11. On a scale of 1 to 10, with 10 being most vulnerable, estimate the ***observed vulnerability*** of your coastline to sea level rise.

1 2 3 4 5 6 7 8 9 10

12. How could your shoreline be altered to be less vulnerable to sea level rise?

13. On a notecard, write the depth of the water in mm and place next to your tray so others can evaluate the resulting sea level rise observed in your shoreline model.

14. When prompted by your teacher, move around the room to view other shoreline models and the extent of sea level rise in each and determine which shoreline was least vulnerable to sea level rise. What feature(s) did the least vulnerable shorelines have in common? What strategies should coastal communities use to best prepare for sea level rise? Describe your observations below:

15. How did your model behave like an actual coastline? How was it different?

16. In your own words, define what is meant by the phrase differential sea level rise.

Part II. Impact of Sea Level Rise

1. Use an approved electronic device with Internet access to open the interactive map, *Sea Level Rise Analysis* by Climate Central available at http://sealevel.climatecentral.org/

2. Pick any coastal county of NC and predict the impact that sea level rise will have on North Carolina's citizens, the environment, and the economy based on your observations. Record your predictions in the chart below.

County:

Impact on citizens	
Environmental Impact	
Economic Impact	

3. Predict the various consequences that sea level rise will have on a global scale. Choose a country other than the United States and use the interactive map available at **http://geology.com/sea-level-rise/** to examine how a sea level increase between 4-10 meters will impact that country. To determine environmental and economic impact, use the following link to help you brainstorm predicted impacts:
http://climate.nasa.gov/interactives/sea_level_viewer

Country:

Impact on citizens	
Environmental Impact	
Economic Impact	

Part III. Sea Level Data Analysis

1. Go to **http://climate.nasa.gov/key_indicators/#seaLevel** and observe the graphical data presented.

2. Describe the trend in sea level observed as you view both satellite data and ground data using coastal tide gauge records.

3. List the two ways that global warming contributes to sea level to rise.
   a.

   b.

4. Click on *Arctic Sea Ice Minimum* and *Land Ice* and observe the graphical data presented for each.
   a. Are there data to support your answers to question #3 above? Yes or no? Explain your answer.

   b. Describe the trend(s) observed for each indicator. Describe how each indicator is connected to sea level rise.

5. Look at all of the graphs on NASA's *Climate Change: Vital Signs* webpage. Create a flow chart on a separate sheet of paper to illustrate how the following key indicators are connected to global climate change:

   Carbon Dioxide
   Global Temperature
   Arctic Sea Ice Minimum
   Land Ice
   Sea Level
   Forest Cover

Critical Thinking Essay

If sea level continues to rise, how will this impact the globe? Are there ways to prevent this trend or slow down its effects? (Be creative, think outside the box) What can you envision as a possible solution(s) to preventing a worldwide disaster?

Examining Sea Level Rise and Differential Shoreline Response ANSWER KEY

10. By completing the table below, indicate which coastal features were affected by this increase in sea level.
Answers will vary depending upon shoreline features modeled.

Coastal Feature	Sea Level Rise Impact	Economic Costs of Impact	Environmental Cost
i.e. Beach/Sand	*Erosion*	*Loss of beach front property, tourism*	*Loss of dunes; habitats for plants and animals*
Wetland/Sponge	Increased salinity and potential loss of wetland; aquatic freshwater habitats could be replaced by saltwater habitats	Impact on fisheries and freshwater aquatic vegetation	Loss of wetlands and the ecosystem services they provide
Sea walls or jetties/ Gravel or Clay	Erosion North or South of the sea walls/jetties.	Continued beach remediation; upkeep of jetties/sea wall; tourism communities (i.e., surfing, wakeboarding, fishing); Water transport	Changing of intertidal zones, dune formation, reshaping native communities (i.e., turtle nesting/migration, sea grasses, shrimp etc.)
Homes, buildings and roads / development	Flooding, destruction of homes and buildings, road damage	Loss of homes, home insurance rates increase, saltwater damage. Loss of life, careers, etc.	Pollution, non-potable water, sewage treatment;

11. On a scale of 1 to 10, with 10 being most vulnerable, estimate the *observed vulnerability* of your shoreline to sea level rise.

1 2 3 4 5 6 7 8 9 10

12. How could your shoreline be altered to be less vulnerable to sea level rise?
Answers will vary: More wetland = more sponges; keep natural sea grasses/dune vegetation intact; maintain natural maritime forests; do not build homes on shorelines.

13. On a notecard, write the depth of the water in mm and place next to your tray so others can evaluate the resulting sea level rise observed in your shoreline model.

14. When prompted, move around the room to view other shoreline models and the extent of sea level rise in each and determine which shoreline was least vulnerable to sea level rise.

a. What feature(s) did the least vulnerable shorelines have in common? Describe your observations.
Students should describe their observations but will likely observe that shorelines with sponges, sand, and minimal hardened structures (gravel, clay, etc.,) were more resilient.

b. What strategies should coastal communities use to best prepare for sea level rise?
Answers will vary but may include wetland restoration, living shorelines, dune preservation, etc.

15. How did your shoreline model behave like an actual coastline? How was it different?
Answers will vary but students should address the limitations of a model…

16. In your own words, define what is meant by the phrase differential sea level rise.
Answers will vary but should include the concept that sea level rise will not be uniform across the globe; some areas will experience more sea level rise than others due to factors such as land subsidence and/or land uplift, heavier runoff from inland areas, patterns of precipitation changes, erosion and sediment migration, wave

action and storm activity.

Part II. Impact of Sea Level Rise

1. Use an approved electronic device with Internet access to open the interactive map, *Sea Level Rise Analysis* by Climate Central available at http://sealevel.climatecentral.org/

2. Pick any coastal county of NC and predict the impact that sea level rise will have on North Carolina's citizens, the environment, and the economy based on your observations. Record your predictions in the chart below.

Impact on citizens	Answers will vary but are likely to include the following….. • loss of jobs, decreased beach access, increased flash flooding during storm surge, increase damage to commercial and personal property
Environmental Impact	Answers will vary but are likely to include the following….. • loss of estuarine habitats in the interim of change (need time to be reconstructed); extinction of coastal species during competition for land
Economic Impact	Answers will vary but are likely to include the following….. • increased taxes to pay for damages, increased flood insurance rates, loss of jobs, loss of small business economy along coastal areas, loss of vital wetland habitat for fisheries

3. Predict the various consequences that sea level rise will have on a global scale. Choose a country other than the United States and use the interactive map available at **http://geology.com/sea-level-rise/** to examine how a sea level increase between 4-10 meters will impact that country. To determine environmental and economic impact, use the following link to help you brainstorm predicted impacts:
http://climate.nasa.gov/interactives/sea_level_viewer

Country: ______________________________

Impact on citizens	Answers will vary
Environmental Impact	Answers will vary
Economic Impact	Answers will vary

Part III. Sea Level Data Analysis

1. Go to **http://climate.nasa.gov/key_indicators/#seaLevel** and observe the graphical data presented.

2. Describe the trend in sea level observed as you view both satellite data and ground data using coastal tide gauge records.

Sea level is increasing.

3. List the two ways that global warming contributes to sea level to rise.

a. Added water of melting glaciers and land ice (not sea ice)

b. Thermal expansion of water as it warms

4. Click on *Arctic Sea Ice Minimum* and *Land Ice* and observe the graphical data presented for each.

a. Are there data to support your answers to question #3 above? Yes or no? YES

b. Describe the trend(s) observed for each indicator. Describe how each indicator is connected to sea level rise.

Land ice is decreasing which increases the amount of water in the oceans, causing sea levels to rise. **Arctic Sea Ice** is also decreasing and while this doesn't contribute to sea level rise, it indicates a warming ocean (thermal expansion).

5. Look at NASA's *Climate Change: Vital Signs* webpage. Create a flow chart on a separate sheet of paper to illustrate how the following "vital signs" are connected to global climate change:

Carbon Dioxide
Global Temperature
Arctic Sea Ice Minimum
Land Ice
Sea Level

Increases in carbon dioxide concentration → increases global surface temperatures → decreases arctic sea ice extent (warming oceans) & decreases land ice→ sea levels increasing

Critical Thinking Essay

If sea level continues to rise, how will this impact the world? Are there ways to prevent this trend or slow down its effects? (Be creative, think outside the box) What can you envision as a possible solution(s) to preventing a worldwide disaster?

Answers may include: coastal habits will flood, saltwater will push further up the river and aquatic freshwater habitats would be replaced by aquatic saltwater habitats, saltwater intrusion into freshwater aquifers, loss of beaches as we currently know them, greater impact from storm surge during hurricanes due to higher seas.

Look for creativity when grading this. Answers can include anything from increased government funding on cleaner fuel sources; mandates for the government on car companies to reduce emissions; mandatory scrubbers on any incineration device; prescribed brown-outs for metropolitan areas…