Teacher Guide

Lesson 6: Sea Level Rise

SKILLS:

Lesson question: How will sea level rise affect our coast in the future?

Learning objectives:

- Students learn from a video how global sea sea level rise is caused by climate warming.
- Students analyze a map to learn that sea level rise is not the same along every coast because of changes in the level of the land along the coast.
- Students use an interactive map as a model to learn how their local coastline will likely be affected by sea level rise over the next hundred years.

Timing: One class period

Materials:

- Classroom computer, projector, and Internet access
- Sea Level Rise video from the NOAA National Ocean Service (access at scied.ucar.edu/HurricaneResilience)
- NOAA map of Sea Level Trends (tidesandcurrents.noaa.gov/sltrends/sltrends.html)
- NOAA Digital Coast Sea Level Rise Viewer (coast.noaa.gov/slr)
- Paper and pencil for exit ticket question

Preparation:

- Preview the video, the Sea Level Trends map, and the NOAA Digital Coast Sea Level Rise Viewer.

Directions

Introduction

- Remind students that in the last lesson, they learned that climate warming is causing hurricanes to change and stronger storms to become more common. In this lesson, students are going to take a look at another effect of climate change that is making our coast more vulnerable: sea level rise.
- Tell students that today we will be looking at why sea level rise is happening, look at data about the amount of sea level rise that's occurring, and then investigate how this will likely affect our coast in the future.
- Remind students that they learned how hurricanes and tropical storms cause storm surge, which is a temporary increase in sea level. In this investigation, they will be focusing on sea level rise that is long-term, not just during a storm.

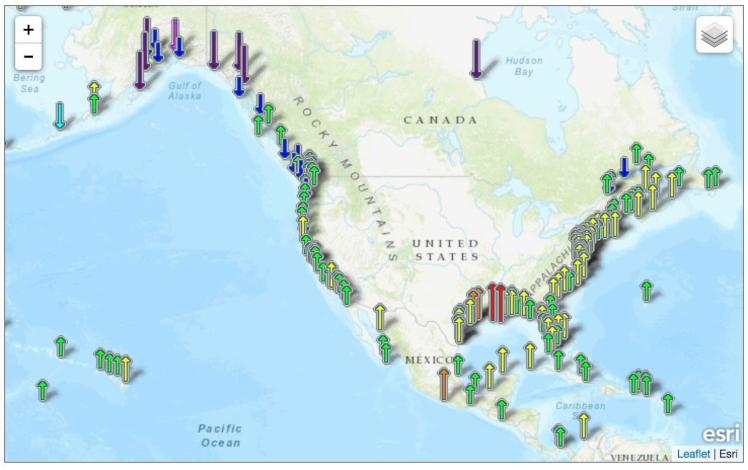
Explain how climate warming causes global sea level rise.

- Watch from minute 7:43 to 18:36 of the Sea Level Rise video from the NOAA National Ocean Service. Before you play the video, provide students with the following guiding questions to consider as they watch.
  - How much of the sea level has risen in the past century? *(On average over the past century, rise has been 1.5 mm/yr, but the rate of rise is increasing. It was 1.1 mm/yr early in the century and 2.79 mm/yr rise recently.)*
  - How do we know? *(measurements from tide gauges and satellites)*
  - What are the two reasons for the increase in global sea level? *(melting of glaciers and other ice on land, and thermal expansion of seawater)*
  - How do increases in air temperature (global warming) cause sea level to rise? *(The ocean is absorbing most of the extra heat, expanding water, and is causing ice on land to melt and add water to the ocean.)*

  - Why is the air temperature warming? *(Because there are extra greenhouse gases in the atmosphere from fossil fuel emissions.)*
- Note: Pauses for discussion are embedded within the video, which you can use to review the guiding questions.
- Ensure that students understand the two reasons for sea level rise that they learned about in the video: (1) seawater expands with heat, and (2) water is added to the ocean as land-ice melts.
- Ask students why these two processes are happening now. (*Because of climate warming*)

Explain how changes in the land along a coast contribute to change in sea level, too.

- Project the NOAA map of Sea Level Trends for the class and explain that this map shows how water levels are changing along coasts according to tide gauge data.
- Have students focus on coastal sea level measurements over large areas, such as the U.S. east and Gulf coasts. Students should notice that the amount of sea level rise is not the same everywhere.
- Explain that these variations in the rate of sea level rise are due to differences in the *subsidence and uplift* of coastal land in different locations. Provide the following examples:
  - Navigate the map to coastal Louisiana. Students will notice that the arrows indicate that sea level is rising at a much faster rate than in other places. Explain that this is because the land is sinking lower, a process called *subsidence*, which compounds the amount of sea level rise.
  - Navigate the map to the coast of southern Alaska. Students will notice that the arrows indicate that sea level is decreasing. Explain that this is happening because the land is rising, a process called *uplift*. (If students are familiar with plate tectonics and isostatic rebound, mention that these are the reasons that land is rising up.) The rate of land rising is greater than the rate of global sea level rise due to climate change, which makes sea level decrease along the coast in this location.
  - Navigate the map to the U.S. East Coast. In this region, land is not sinking or rising much. Students should notice that the arrows indicate a modest level of sea level rise. This is the effect of global sea level rise without any other change to the elevation of the land surface.
- Post the question: How has sea level in our local area been changing?
  - As a class, zoom into the map to find the arrow closest to your local area.
  - Note the color of the arrow and look at the key to see how much sea level rise the arrow represents. The sea level trends in the key are described in mm/year, which the tide gauges measure, and also in feet/century, which is extrapolated based on the data.)
  - Locate the number of feet/century that corresponds with the arrow closest to your coast. You will need this number for the next part of the lesson.

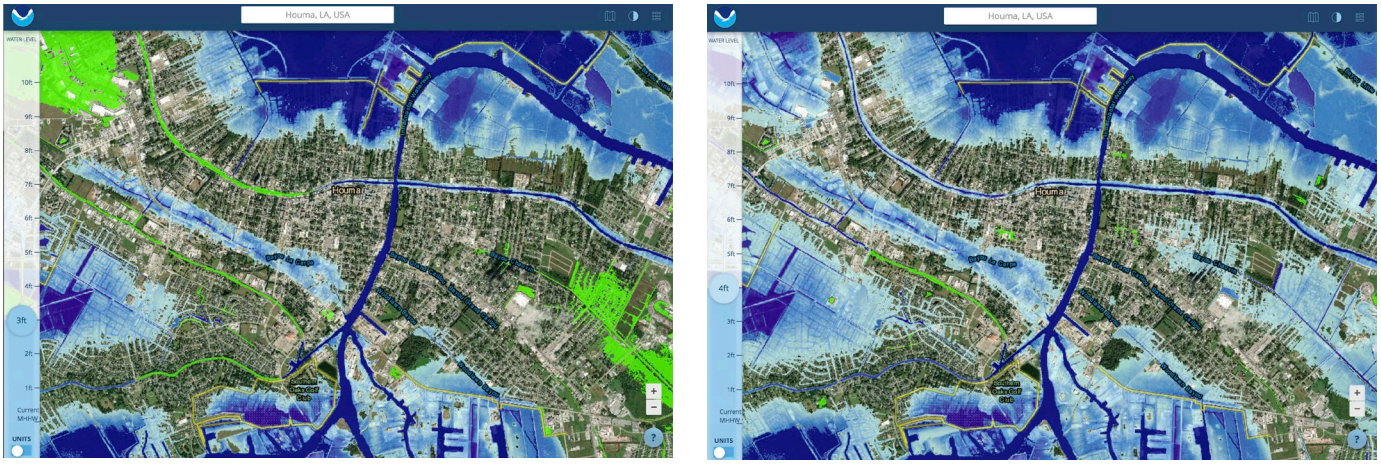


NOAA map of relative sea level change in North American coastal locations

Investigate a map that shows the future of sea level rise.

- Project the Sea Level Rise Viewer from NOAA Digital Coast for the class and explain:
  - While the previous map showed recent changes in sea level, this map will let us see what sea level may look like along our coast in the future.
  - We'll be using the map as a model. Models are used in earth and environmental science to simulate real conditions so that we can predict how environments will be affected when there is a change.

- Enter your location into the search. (You may need to zoom the map in or out so that the class can see the entire coastline.)
- Orient students to the map.
  - The map legend, which is visible when you click the button in the upper right. Green indicates low-lying areas, blue indicates water, and levees are shown as yellow lines.
  - On the left side of the map is the water level indicator. The blue circle indicates the water level compared to today. (MHHW means "Mean Higher High Water," which is the average height of the highest tide recorded each day during the recording period).
- Raise the water level indicator to the number of feet per century that you found as the rate of sea level rise using the NOAA map of Sea Level Trends. Have students observe what areas of their local coastline become flooded (changing to light or dark blue on the map).
  - If the number of feet/century for your area is listed as a range (such as 1 to 2 feet) in the Sea Level Trends map, move the water level indicator to the minimum value of the range and have students make observations. Then move the water level to the higher end of the range and have students again make observations.
  - If your location has the highest rate of sea level rise (above 3 feet/century), no upper limit is given on the map of sea level trends. In coastal Louisiana, the only U.S. location in that category, local measurements have found sea level rise of 4.2 feet over the next century, which can be used as the upper limit.
- With the Sea Level Rise Viewer map of your local area projected, have students note what locations look vulnerable to flooding in the future and which locations look like they will stay dry. Ask students to describe why certain locations are more or less vulnerable to flooding. List the areas on the board.
- Discuss the Sea Level Rise Viewer as a model. How does it accurately simulate real conditions? How is it simplified? Students may mention the following:
  - The model includes information about the elevation of the land surface, which is what allows it to identify what areas might flood in the future.
  - The model does not include predictions of areas where sediments may accumulate in the future or how floodgates and human-built levees could change the outcome.



The Sea Level Rise viewer showing Houma, Louisiana, with a 3 foot (left) and 4 foot (right) rise in sea level.

Connecting Future Sea Level and Hurricanes

- Help students consider prior knowledge about coastal flooding during hurricanes.
  - Remind students that through Storm Stories (Lesson 3), they heard about the hazards of flooding during hurricanes.
  - Remind students that when they analyzed data about hurricane characteristics (Lesson 4), they learned about how much flooding occurred during different tropical storms and hurricanes.
- As an exit ticket, have students answer the question: How will sea level rise affect the way that hurricanes impact our coast in the future?

Opportunities for Assessment

- Ensure that students can name the two reasons that a warmer climate causes sea level rise: (1) melting glaciers and ice sheets and (2) expansion of sea water as it warms.
- During the sensemaking discussion, listen to the reasons why students think certain locations will be vulnerable to flooding in the future and why other regions might be more protected. As students move into Part 3 of the curriculum, they will gain more experience with the idea that vulnerability and risk are not evenly distributed.
- With the exit ticket, note whether students are combining what they have learned about the impacts of hurricanes with the impacts of sea level, particularly whether they recognize that the chances of flooding compound when sea level rise is combined with storm surge. Additionally, students may recognize that sea level rise will change the shape of the coast or flood wetlands, which serve as a buffer (depending on the location). These types of changes would cause a landfalling hurricane to affect different locations and to have more severe impacts.

Teacher Notes:

- For more information and educational resources related to the NOAA Sea Level Rise Video, visit oceanservice.noaa.gov/education/sea-level-rise
- The Sea Level Rise Viewer does not account for future engineering adaptations developed to help prevent flooding. Raising this point with students can start a productive conversation about how engineering can help improve resilience, which they will be moving towards in the third part of the curriculum. Note that some coastal engineering can cause benefits in one area while causing problems in another area. For example, jetties along a coast can cause beaches to widen on one side of the jetty, protecting the community, while sand erodes from the other side of the jetty.
- There is some uncertainty in future sea level rise projections. Over this century, global sea level will rise an average of 1.7-4.0 feet (0.5-1.2 m) due to climate warming. If large parts of ice sheets slip into the ocean, that number will be higher. This is an area of active research. See the background content at the beginning of this curriculum for more information about sea level rise.
- In places where land is subsiding, like coastal Louisiana, there will be more sea level rise because land subsidence adds to the sea level rise caused by climate warming. In places where land is uplifting, like southern Alaska, sea level rise will have less impact over this century along the coast.