COASTAL PROCESSES AND HAZARD MITIGATION CURRICULUM FRAMEWORK

Developed in conjunction with the Center for Coastal Studies' Increasing Coastal Resiliency Through Intermunicipal Shoreline Management: CZM Coastal Resiliency Grant 2020-2022

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Increasing Coastal Resiliency Through Intermunicipal Shoreline Management: Coastal Processes and Hazard Mitigation Curriculum

Introduction

The Center for Coastal Studies education program has worked for over four decades to bring relevant science-based education programs to students on Cape Cod and beyond. For the past eleven years, the Center has worked with local area schools developing a robust water quality in-school program at seven area schools. The lessons developed herein are part of the Center's Increasing Coastal Resiliency Through Intermunicipal Shoreline Management: Coastal Resiliency Grant funded project and utilize the scientific expertise and data from the project in development of a curriculum on the topics of coastal processes, coastal storms, sea level rise, climate change and hazard mitigation. The lessons developed herein will be delivered by the Center's education director at two Cape Cod regional middle schools, that the Center currently works with, in year two of the coastal resiliency grant, but are designed so that educators at these middle schools and other schools throughout the Cape can utilize the curriculum in future classes. The lessons herein serve as a framework for teaching students about local coastal process and sea level rise impacts along the towns in Cape Cod Bay, the Atlantic Coast. Each lesson contains an introduction discussion question, to connect the student to coastal changes along Cape Cod. Activities are created to introduce the students to the subject areas of coastal processes, sea level rise, coastal hazards and climate change. Students should have a basic understanding of coastal processes, i.e. weathering, erosion and accretion, so this curriculum is best suited for the part of the year after which those topics have been covered, which is part to the Massachusetts Curriculum Frameworks for 7th grade science. Each lesson incorporates a conclusion activity which ranges from classroom discussions and presentations to projects the students can continue outside of school. These activities, discussion questions and extension activities serve as recommendations for teachers for future years.

7th GRADE LESSON PLANS

Nauset Regional Middle School

Understanding Sediment Movement along Cape Cod Bay

Time 50 min

Standards: 7.MS-ESS2-2. Construct an explanation based on evidence for how Earth's surface has changed over scales that range from local to global in size. Example of changes occurring over small, local spatial scales include earthquakes and seasonal weathering and erosion.

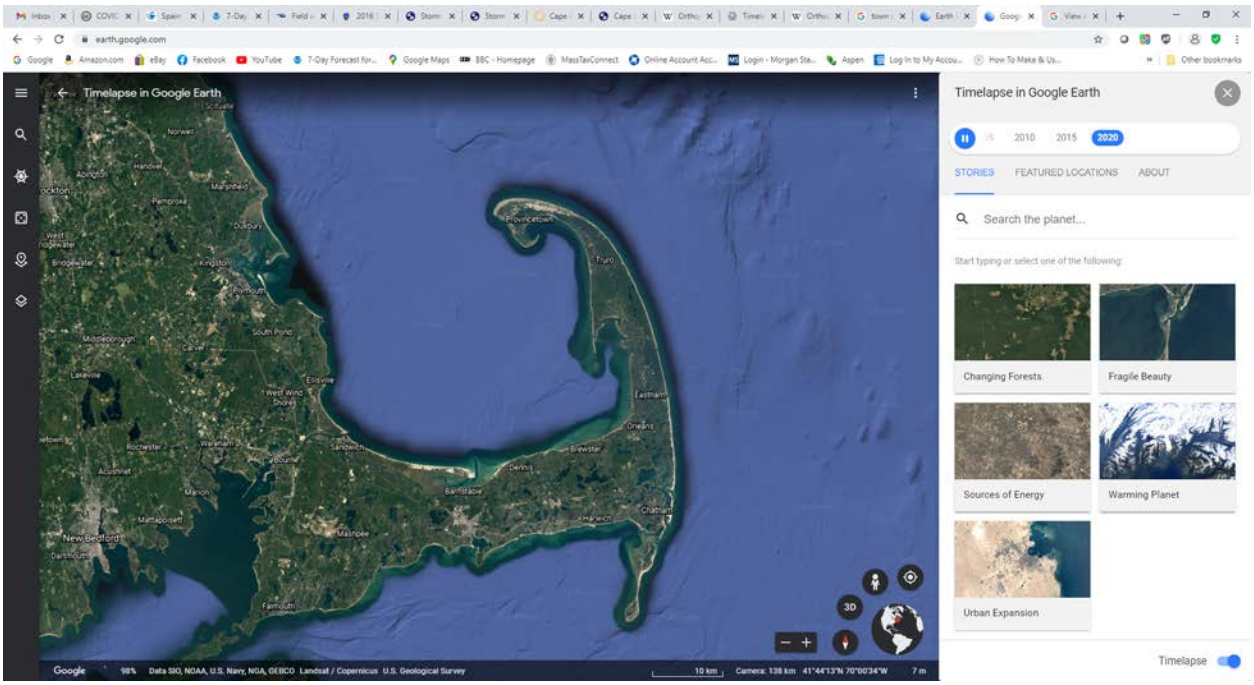
Question: How does sediment along Cape Cod Bay's shoreline from Eastham to Provincetown change over time and how might these changes affect towns located along this area of Cape Cod Bay.

Objective: Students will use orthoimagery to describe how the shoreline has changed along Cape Cod Bay through time, make inferences on why these changes occur and what that means for the towns located in the area.

Background: Students should have a basic understanding of coastal processes (i.e. accretion/erosion) and how these processes can shape the environment on a regional and local scale.

Materials: Google Earth Timelapse Cape Cod

Introduction: The towns of Eastham, Wellfleet, Truro and Provincetown have dynamic coastlines. Historically, towns have managed their coastlines individually, not taking into account the dynamic nature of sediment flow throughout Cape Cod Bay. Managing their coastal development by town and not by region, makes it harder for town officials to have sufficient and sustainable long-term plans, which can lead to higher costs, placement of infrastructure at importune locations, and projects that may benefit one town, but negatively impact another. Students will first become familiar with the coastline and observe how the coastline has changed using aerial time lapse satellite imagery, and then answer questions about why managing these changes would be beneficial for towns to work collectively.



Main Lesson:

The students will now use historical maps and aerial photos to observe how Cape Cod Bay's Shoreline has changed over time. Aerial photos are a type of ortho-photo that is taken of the earth's surface from aircraft such as planes, helicopters or even drones. Orthophotos can also be taken by satellites placed in earth's orbit. Aerial photography taken through time can aid a viewer in describing how local landforms have changed over time. First begin with a discussion question about the local resource that they may be familiar with.

Discussion Question:

1. Describe changes that you see at Bay beaches in your towns?

   Ex. Some towns add sand to beaches during the winter months.

Using Google Earth Timelapse:

Google Earth Timelapse is a mapping platform that is free to download to any device and is useful in becoming more acquainted to any geography in the world. Google Earth is useful in learning local roads, important local places and even the elevation and terrain characteristics of a locale. Google Earth Timelapse imagery is fine resolution and provides the benefit of looking at historical imagery annually over a thirty-seven year time frame. You can also utilize Google Earth Pro Time Lapse, which quickly runs through the thirty-seven year period, but with Google Earth Timelapse, you can slowly click through each year.

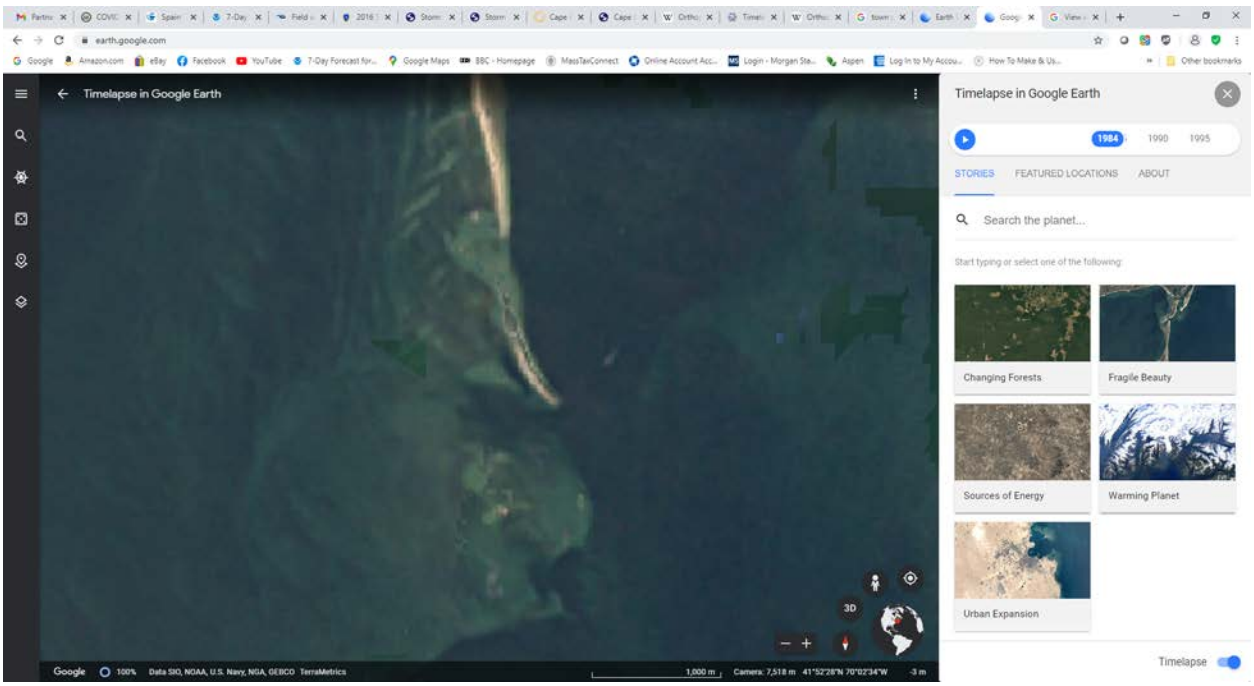
To access the time lapse function of Google Timelapse, simple, enter the web address or click on link and scroll the map to the area of Cape Cod you would like to view. Located along the bottom of the map is a timeline beginning in 1984 and running to 2020. You can press the play button to watch this run automatically, or you can click on each individual year to see the changes slowly. You can click on the play tab to run automatically or you can pause during any one year, and click year to year to see changes.

Share the image from Google Earth Timelapse of an area of Cape Cod Bay. Since there are students representing the four towns in the study area, students from each town will look at their own specific towns. Students from other towns, not in the study area, will choose a town to view or be given a town if no students from one of the four towns are in class.

Students will then use these aerial platforms to complete the lesson. Students first identify key geographic locations in their selected town i.e. beaches, islands, town landings, piers, etc, and then they use the following worksheet to answer questions of historical changes.

2. While looking at the earliest available time lapse satellite photo, 1984, describe coastal features for your town. Note the width of the beach, sand deposit offshore, degree of development along shoreline.

   Ex. Note the position of Jeremy Island in Wellfleet and the among of sand surrounding the island.



3. While looking at the time lapse satellite imagery of your respective town, fill out the table below to describe how the coastline has changed through time, and how sediment moves in and out of the system.

Year Comparison 1984-2020	Describe the changes you see
Ex. 1990-1996	Salt marsh vegetation was exposed in 1995-1995, but not in earlier years.

5. Describe the processes that are happening in your town.

Ex. There are years with more sediment along the coast and extent of salt marshes has changed.

6. Where do you think the sediment from your town travels to and comes from?

Ex. Sand travels from Race Point in Provincetown along beach and is deposited at Long Point.

7. Why would it be beneficial for towns to manage their shorelines together rather than individually?

Conclusion:

After the students have completed the table and questions, students can volunteer to share some of their identified changes through time guided by the display of the satellite photos on a big screen.

Scientific Terms:

Orthoimagery—is an aerial photograph or satellite imagery geometrically corrected ("orthorectified") such that the scale is uniform: the photo or image follows a given map projection. Unlike an uncorrected aerial photograph, an orthophoto can be used to measure true distances, because it is an accurate representation of the Earth's surface, having been adjusted for topographic relief,[1] lens distortion, and camera tilt.

Accretion—the process of growth or increase, typically by the gradual accumulation of additional layers or matter.

Erosion--- the process of eroding or being eroded by wind, water, or other natural agents.

Sediment transport—the movement of solid particles (sediment), typically due to a combination of gravity acting on the sediment, and/or the movement of the fluid in which the sediment is entrained.

7th GRADE LESSON PLANS

Nauset Regional Middle School

Hazard Mitigation from the Impacts of Storms and Sea Level Rise

Time: 50 min.

Standard: 7.MS-ESS3-2. Obtain and communicate information on how data from past geologic events are analyzed for patterns and used to forecast the location and likelihood of future catastrophic events. Examples of data typically analyzed can include the locations, magnitudes, and frequencies of the natural hazards.

Question: How can using sea level rise data combined with the Center's Storm Tide Pathways App, predict coastal flooding and how could towns use this app to mitigate future coastal hazards.

Background: Students should have a basic understanding of storms, coastal inundation and sea level rise.

Materials: Center for Coastal Studies Storm Tide Pathway App, NOAA Sea Level Rise Viewer, NOAA Tides and Currents

Introduction: Cape Cod's geography and low-lying coasts make it vulnerable to coastal flooding during storm events. During the winter months Cape Cod's coastline is routinely affected by Nor'easters and other winter storm events. Cape Cod is generally not impacted directly by tropical hurricanes, yet coastal erosion from hurricanes has and does occur. Storm intensity, both winter storms and hurricanes are thought to be increasing due to global climate change, and thus the impacts from those storms on the coast. In addition, sea level rise caused by thermal expansion of the ocean place more coastal structures at risk now and into the future.

Main Lesson:

Have a brief discussion on storm events that students remember and the impacts on their town/towns. In March 2018, there were three major storm events that affected Cape Cod, that students may recall. In addition, in January 2018, there was a major storm event that flooded parts of Provincetown and major roadways in low lying areas in towns along Cape Cod Bay that students may recall.

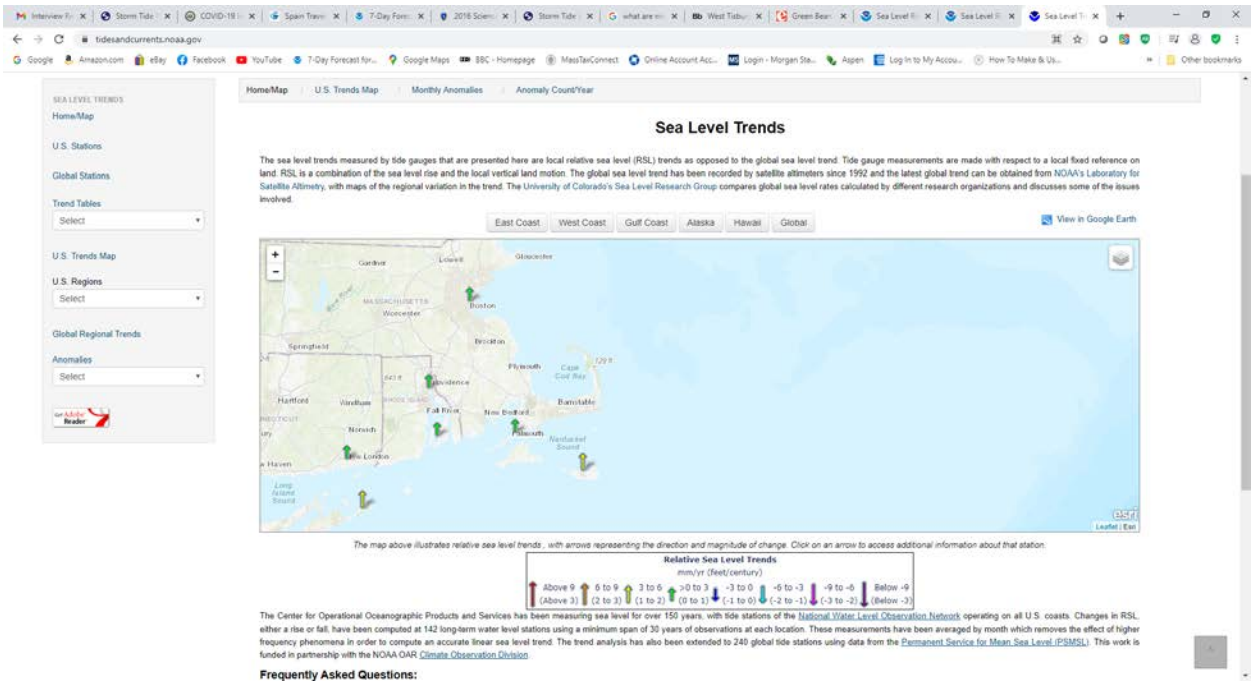
Discussion Questions:

1. Do you recall major storm events in your town?

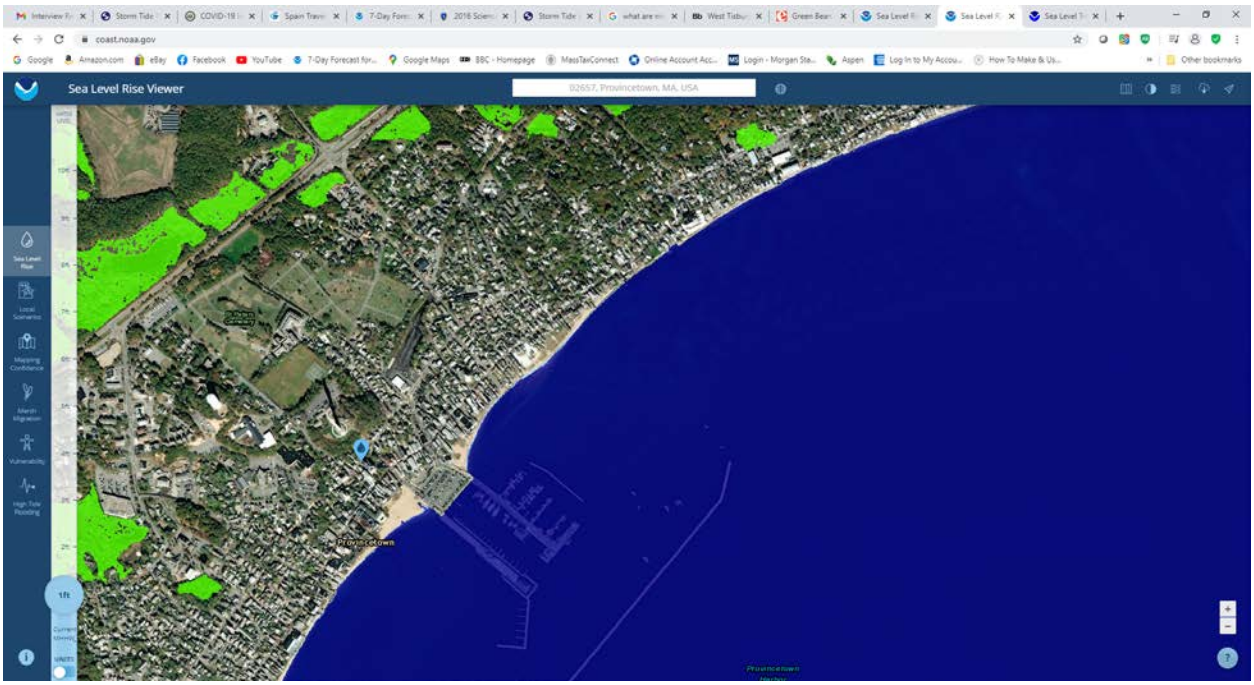
   Ex. March 2018 series of three Nor'easters.

2. If so, do you recall what damage was caused during those storms i.e. to roads, beaches, buildings, etc?

Next the students will be introduced to sea level rise using NOAA's tide and current webpage looking at current trends in sea level rise. Relative sea level rise is measured by tidal gauges located at coastal locations around the world. Sea level is not rising uniformly around the globe. Students will be presented with the relative pace of sea level rise for Cape Cod. Also, it is important to make the distinction here of long-term sea level rise, which is caused by factors such as thermal expansion of the oceans, and short-term sea level rise associated with storm events.



Using NOAA's Sea Level Rise Viewer, using Provincetown as an example, illustrate what happens to surrounding areas as sea level rises. NOAA's Sea Level Rise Viewer is a web mapping tool to visualize community-level impacts from coastal flooding or sea level rise (up to 10 feet above average high tides). Photo simulations of how future flooding might impact local landmarks are also provided, as well as data related to water depth, connectivity, flood frequency, socio-economic vulnerability, wetland loss and migration, and mapping confidence. Explain to students that gradual sea level rise is a natural process but during storm events sea level can be much higher than the normal high tide mean water. Using the Sea Level Rise Viewer, focus in on Provincetown Harbor and see where flooding occurs as sea level rises.



3. Which locations are most vulnerable to sea level rise?

   Ex. The center of town near the piers.

4. What happens between 3 feet and 4 feet of sea level rise?

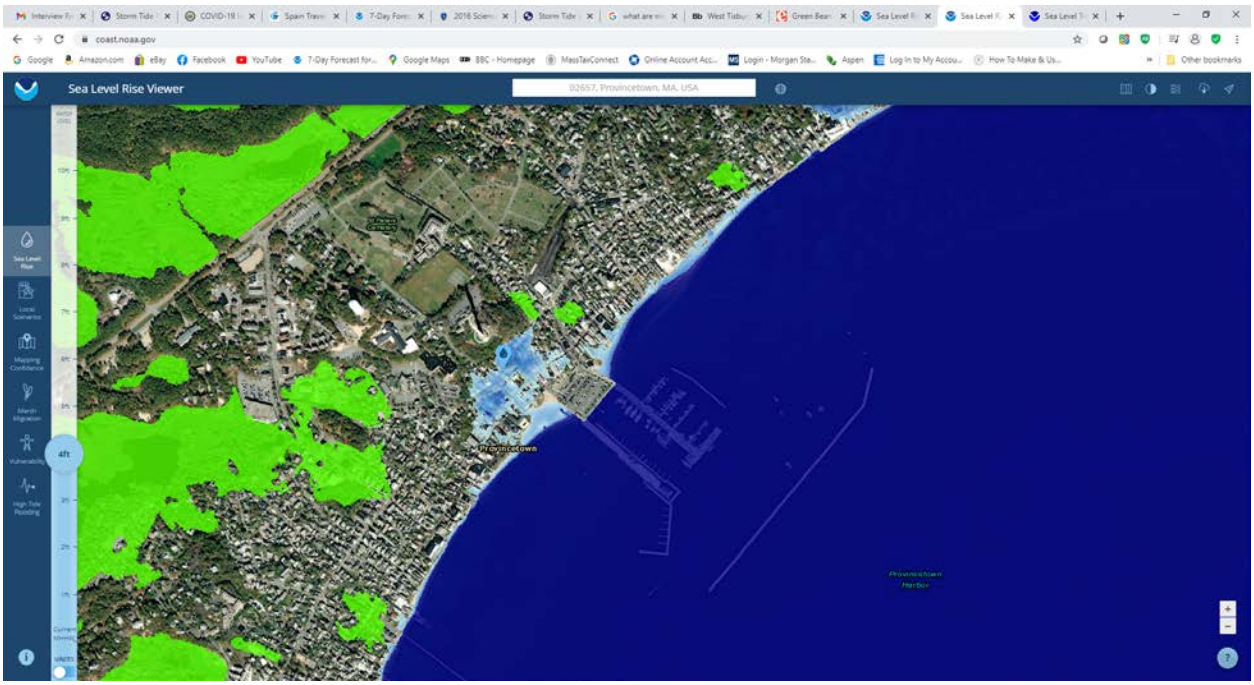
   Ex. At 3 feet flooding is contained to beach areas, at 4 feet sea level rise the center of downtown becomes flooded.

5. How would the town be able to mitigate flooding during rises of 5 feet or more, potentially during winter storms?

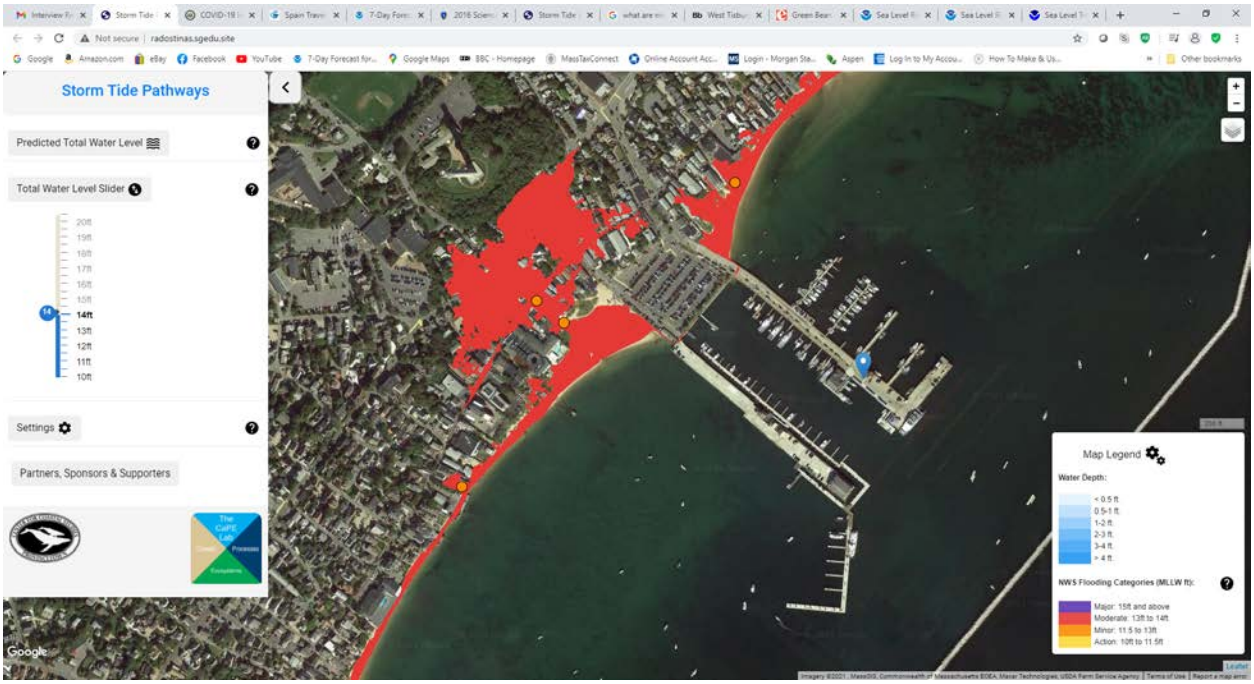
   Ex. Perhaps building structures, but where would you put them.

Discuss that while this tool is important for looking at where flooding would occur due to certain sea level heights, whether due to storm events or over time, it is not fine scale enough to indicate which "pathways" the waters would use to flood.

Students will now be introduced to the Center's Storm Tide Pathway App, a web-based app that pinpoints pathways for flooding. The App uses the same flooding data from NOAA's Sea Level Rise Viewer, but at a finer scale which pinpoints exact locations or "pathways" the flood waters would take.



NOAA's Sea Level Rise Viewer with 4feet above mean high tide sea level.



The Center's Storm Tide Pathways App using same data, but at a finer scale and pinpointing locations (orange circles) where flooding would occur.

6. While using the Storm Tide Pathways App, list the number of locations where flooding will occur at different sea levels. The average mean high water is 10 feet, so above 10 feet indicates extreme high tide events or storm events.

Sea Level Height	Number of Flooding Pathways
10’	
10.5’	
11’	
11.5’	
12’	
12.5’	
13’	
13.5’	
14’	
14.5’	
15’	
15.5’	
16’	
16.5’	

Critical Thinking Questions:

7. What could the town do to prevent flooding with relative low levels of sea level rise due to storm events 3 to 4 feet?

   Ex. Identify the pathways and perhaps provide barriers, natural or constructed at those locations?

8. At what level of sea level rise would it be impossible to stop flooding?

Conclusion:

After the students have completed the table and questions they will share out their results. Teacher will share what Provincetown did after the March 2018 storms where downtown Provincetown was flooded and after they had the Storm Tide Pathways App data i.e. they built a small dune on a beach where the pathway occurred. Students can identify hazard mitigation protocols in their own town, based on the new Storm Tide Pathway App.

Extension Activities:

Students can use the app to highlight areas in their own town that are vulnerable to coastal flooding, and what mitigations their towns have taken to address these pathways.

Scientific Terms:

Sea Level Rise—is the average long-term global rise of the ocean surface measured from the center of the Earth, as derived from satellite observations. Relative sea level rise refers to long-term average sea-level rise relative to the local land level, as derived from coastal tide gauges.

Storm surge—a rising of the sea as a result of atmospheric pressure changes and wind associated with a storm.

Flooding—the covering or submerging of normally dry land with a large amount of water.

Natural Hazards—all the atmospheric, hydrologic, geologic (especially seismic and volcanic), and wildfire phenomena that, because of their location, severity, and frequency, have the potential to affect humans, their structures, or their activities adversely.

7th GRADE LESSON PLANS

Monomoy Regional Middle School

Understanding Coastal Changes along Chatham's Shoreline

Time 50 min

Standards: 7.MS-ESS2-2. Construct an explanation based on evidence for how Earth's surface has changed over scales that range from local to global in size. Example of changes occurring over small, local spatial scales include earthquakes and seasonal weathering and erosion.

Question: How does sediment along Chatham's Atlantic shoreline change over time and how might these changes affect the town and resources within?

Objective: Students will use orthoimagery to describe how the shoreline has changed along Cape Cod Bay through time, make inferences on why these changes occur and what that means for the towns located in the area.

Background: Students should have a basic understanding of coastal processes (i.e. accretion/erosion) and how these processes can shape the environment on a regional and local scale.

Materials: Google Earth Pro Timelapse Cape Cod

Introduction: Chatham, MA, located at the elbow of Cape Cod is the most geologically dynamic area of the region. The shifting sands on Chatham's Atlantic Coast are in constant flux, affecting boating and navigation, land-based structures and coastal development. Students will first become familiar with the coastline and observe how the coastline has changed using aerial time lapse satellite imagery, and then answer questions about how different thoughts on managing this unique and ever-evolving coastal shoreline.

Main Lesson:

The students will now use historical maps and aerial photos to observe how Chatham's Shoreline has changed over time. Aerial photos are a type of ortho-photo that is taken of the earth's surface from aircraft such as planes, helicopters or even drones. Orthophotos can also be taken by satellites placed in earth's orbit. Aerial photography taken through

time can aid a viewer in describing how local landforms have changed over time. First begin with a discussion question about the local resource that they may be familiar with.

Discussion Question:

1. Who remembers the last break through at the Outer beach in Chatham?
   Ex. It occurred in 2017.

Students will then be shown historical maps of Chatham from the 1880s through to the early 1980s.

2. What patterns do you recognize happening from the 1880s to the 1980s?
   Ex. The outer beach breaks open, then new beach is formed and moves South, where it will then break open.

Using Google Earth Timelapse:

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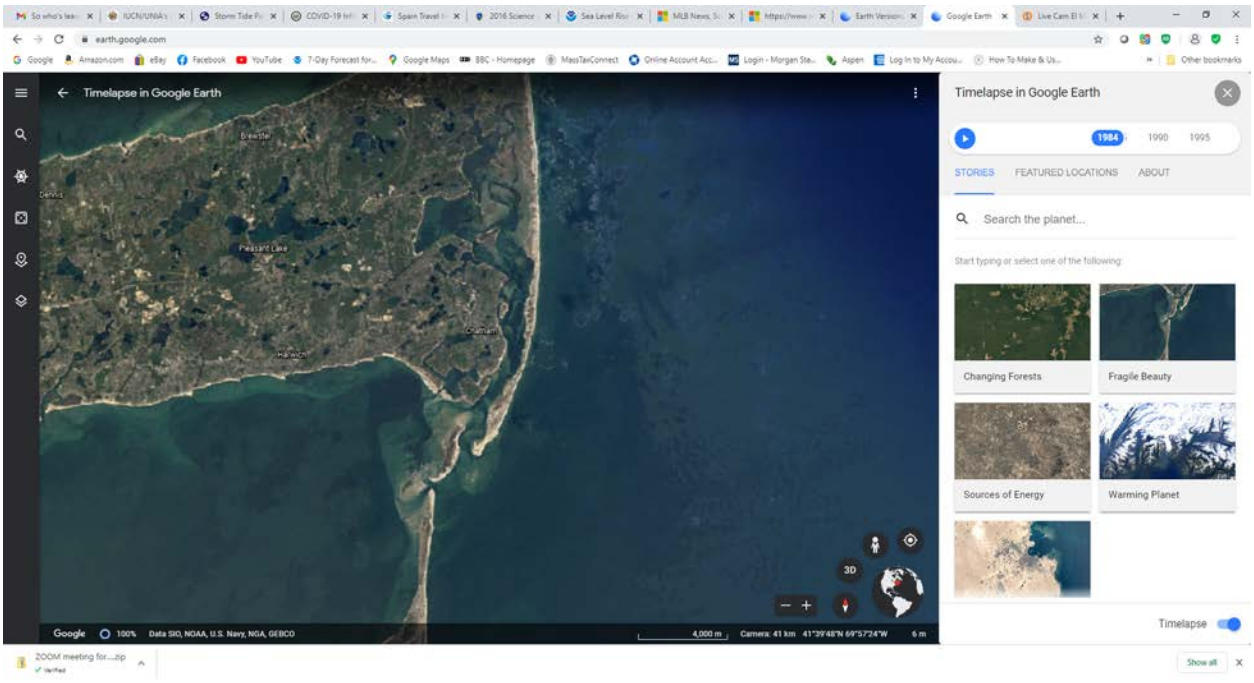
Share the image from Google Earth Timelapse of Chatham.



Students will then use these aerial platforms to complete the lesson. Students first identify key geographic locations in town i.e. beaches, islands, town landings, piers, etc, and then they use the following worksheet to answer questions of historical changes.

3. While looking at the earliest available time lapse satellite photo, 1984, describe coastal features for your town. Note the width of the beach, sand deposit offshore, degree of development along shoreline.

   Ex. Note the outer beach stretches completely from North to South—It will break open in 1986.

4. While looking at the time lapse satellite imagery of your respective town, fill out the table below to describe how the coastline has changed through time, and how sediment moves in and out of the system.

Year Comparison 1984-2020	Describe the changes you see
Ex. 1984-1990	1. Outer barrier beach is intact 2. Breach opens in beach in 1987

	3. Opening widens in1988, while in 1990 barrier almost connects to shoreline

5. Describe the processes that are happening in Chatham?
   Ex. The outer barrier breaks apart and moves over a cycle.

6. How does the shifting sand affect pieces of infrastructure in town i.e. Lighthouse beach, and fish pier?
   Ex. Beach has fast moving currents and dangerous to swim at.

7. How does the change since 1984 compare to historical change?
   Ex. The change is slowing because sediment transport has slowed.

Conclusion:

After the students have completed the table and questions, students can volunteer to share some of their identified changes through time guided by the display of the satellite photos on a big screen.

Scientific Terms:

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Erosion--- the process of eroding or being eroded by wind, water, or other natural agents.

Sediment transport—the movement of solid particles (sediment), typically due to a combination of gravity acting on the sediment, and/or the movement of the fluid in which the sediment is entrained.