Lecture 24: Sea Level Rise

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Sea level rise is a topic of considerable scientific interest because it is closely linked to climate change and has major social and economic importance due to its potential to increase disastrous flooding and vulnerability to severe storms in coastal regions, where many of the world's megacities with ever-increasing human populations live.

About 20,000 years ago at the peak of last glacial age, global-averaged sea level was more than 100 m lower than it is today as the northern European and American ice sheets formed. Estimates of rates of global-averaged sea level rise prior to the 20th century are less than 0.2 mm/yr, base on historical land records and geological evidence from the late Holocene. However, tide-gauge records and satellite altimetry data indicate that the rates of global-averaged sea level rise today is more than 10 times higher than that of the past thousand years. Rate of sea level rise has been nearly about 1.7 mm/yr since the 20th century, and evidence suggests that it is accelerating. During the 21st century, sea levels is forecast to continue to rise with rates increased by 2-5 times over present rates under projected global warming. It is projected in the IPCC Fourth Assessment Report that global sea level will continue to rise by up to ~60 cm by 2100 in response to ocean warming and glaciers melting.

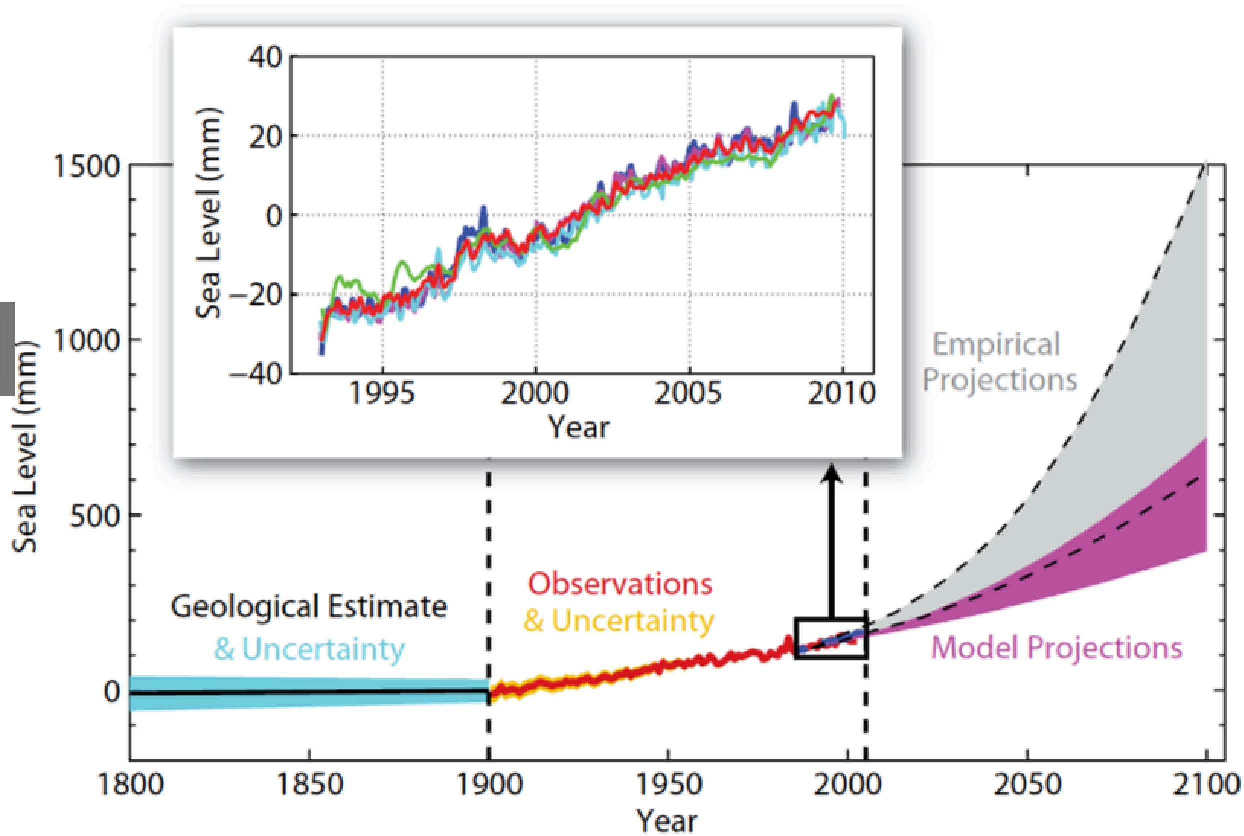

Figure 1. Estimated, observed, and projected global-averaged sea level rise from 1800 to 2100. Figure from Willis et al. 2010. Oceanography, 23(4), 26-35.

Our understanding of sea level rise has been revolutionized by cutting edge satellite technology. These satellites allow continuous and reliable estimates of global mean sea level to be possible. One thing that these high tech observations have shown is that sea level rise isn't the same everywhere. Watch **this video (https://www.youtube.com/watch?v=GTBWjDUkTzI&t=118s)**

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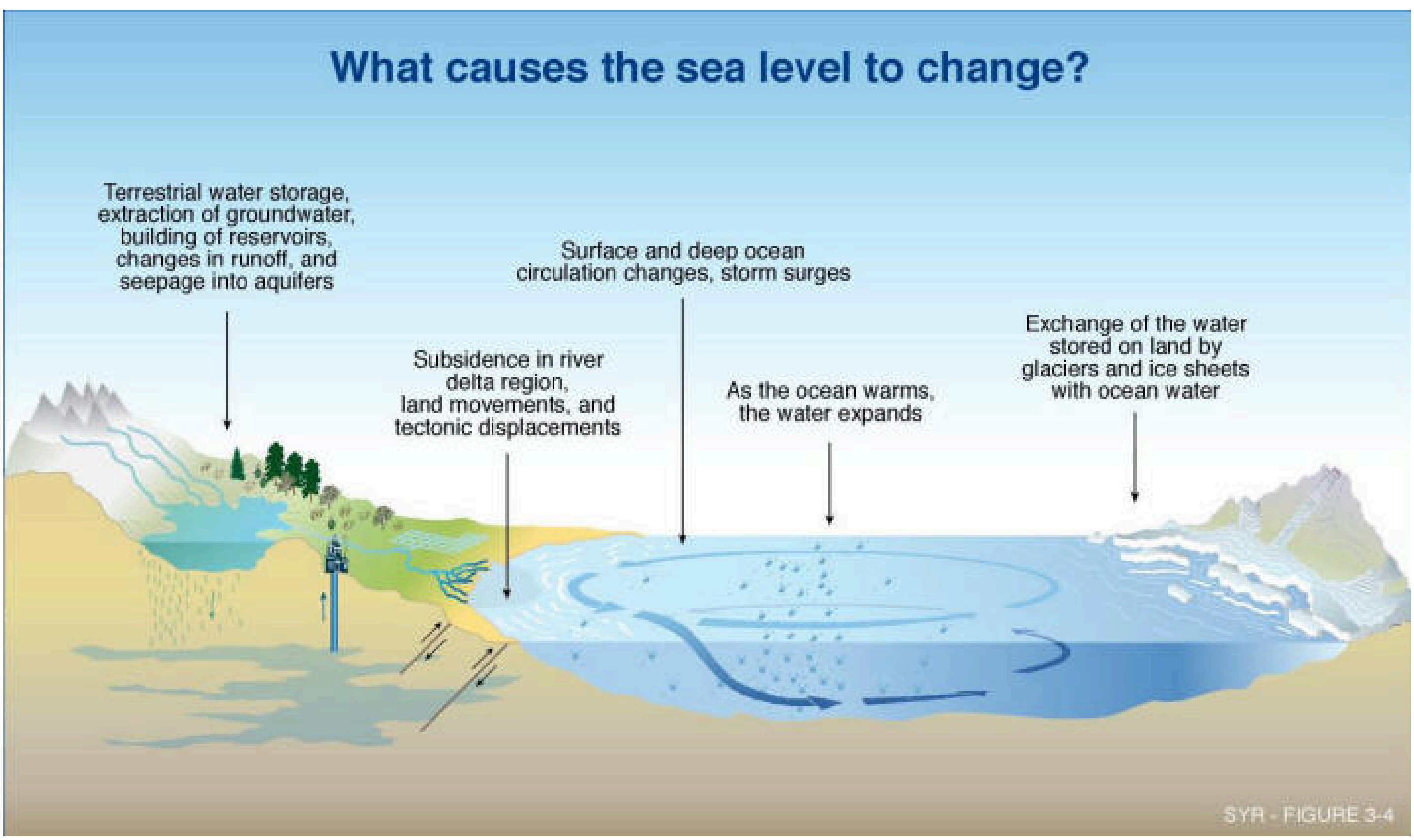
for details about how NASA and satellites are helping us better understand rising global oceans.

There is a growing consensus that water mass input from melting glaciers and ice sheets is causing the level of the ocean to rise. Fill a glass half full, then draw a line where the top of the water is. Add a big ice cube and note where the top of the water is when the ice goes in (ice still frozen), then wait for the ice to melt and make another mark. What you will see, is that when glaciers and ice sheets break off into the ocean, there is a certain amount of rise in the level of water, and then when they melt, you see another rise (bigger this time).

Another important contributor to sea level rise is thermal expansion due to ocean warming. Recall back in our lecture on about the amazing properties of water. One of those properties is that it expands (occupies more volume) as it warms up. So as the ocean warms, it will also expand, and as it expands it has nowhere to go but up – the sea level rises. These two factors – ice melt and thermal expansion - account for possibly half of the apparent increase of global sea level during the past 100 years. Another contributor is changes in land water storage – these are things like underground water mining, irrigation, urbanization, and deforestation. Factors that also affect the level of the ocean are surface and deep ocean circulation changes and subsidence in river delta regions and tectonic movements.



Above is a schematic diagram illustrating factors that causes the sea level changes. Photo source: https://www.lenntech.com/images/sealevelrise.jpg

Impacts of Sea Level Rise

Compared to other geophysical phenomena like earthquakes, volcanoes, and hurricanes, the rate of long-term sea level rise may at first seem benign. However, it has a wide range of impacts on natural and human systems. The physical effects of sea level rise include (1) inundation, flooding, and storm damage, (2) wetland loss and change, (3) erosion, (4) saltwater intrusion into surface and groundwater, and (5) rising water tables. Flooding/submergence and saltwater intrusion are immediate effects that result from higher water levels. While wetland loss and change, erosion of beaches and soft cliffs and saltwater intrusion are longer-term impacts from sea level rise. These physical effects as well as interaction among them have overwhelmingly negative socioeconomic impacts. For example, flooding destroys coastal infrastructure, agricultural lands, billions of dollars in damage to freshwater resources. In some cases, such as Superstorm Sandy in 2012, it can result in loss of life (recall that Sandy hit New York during high tide, which because of sea level rise meant that the storm surge inundated subways and destroyed masses of infrastructure). Such destructive coastal storm flooding events are likely to continue as sea level rises and have a greater impact as the population of the coastal zone increases.
Watch this video (https://www.youtube.com/watch?v=G-fZnIR_IJ0)

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to see the scale of the growing impacts of tidal flooding and sea level rise in the US east coast.

The image below shows an ice stream (summer surface melting) on the western slope of Greenland Ice Sheet in August, 2007 (photo credit: Koni Steffen), which is melting at an unprecedented rate. Over recent decades, the rate of global sea level rise has accelerated, which increases the frequency of extreme water levels and raises tendency for coast erosion. It is also suggested that the retreating rate of shorelines is 50-100 times the rate of local sea-level rise (known as the Bruun Rule). Future impacts of sea level rise are projected to be more apparent in low-elevation coastal areas and islands, e.g. South and Southeast Asia, Africa, Pacific and Indian Ocean islands, and Caribbean islands. In fact, entire island nations are already at risk or in the process of being lost. Imagine an entire country going underwater - that is already happening, and is anticipated to create the world's first climate change refugees as these inhabitants are displaced from their homes.

Responses to Sea Level Rise

Responses to sea level rise can be divided into two categories - mitigation and adaption. Mitigation slows and stabilizes the global sea level rise and reduce its impacts, e.g. reducing greenhouse gas emission, which operates at a global scale. While adaptation is about reducing the impacts of sea level rise through behavioral changes, which is often a local to national activity. Adaptation includes three generic approaches: retreat, accommodation, and protection.

In response to shoreline erosions, living shoreline has been considered as an effective shoreline stabilization option recently. Living shoreline is not one particular technique, but it includes a range of shoreline stabilization techniques, as shown in the figure below. Advantages of living shoreline include reducing damage and erosion, maintaining continuity of the natural land-water interface, and enhancing coastal resilience.
[Here is a video (https://www.youtube.com/watch?v=aQtnU7Rz3yI)](https://www.youtube.com/watch?v=aQtnU7Rz3yI)

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from the area of New Jersey where my lab is located about how Rutgers scientists are helping develop living shoreline techniques to aid farming and fishing communities along New Jersey’s Delaware Bayshore. Along the shores of the Delaware Bay in New Jersey, we see the impacts of sea level rise regularly, often timing our commute to and from work based on tides and rainfall to avoid roads like this.