

Sea Level and Global Change

1. Past Changes in Sea Level
2. Earth's Cryosphere
3. Thermal Expansion of Water
4. Predictions for the Future

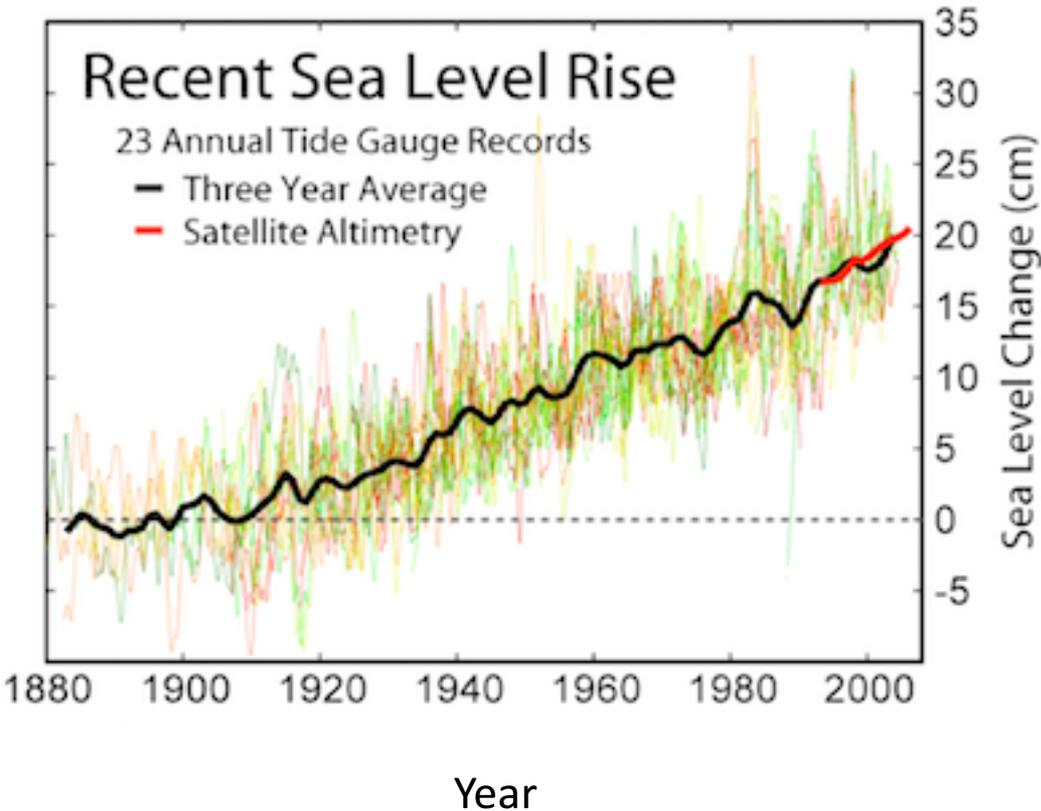
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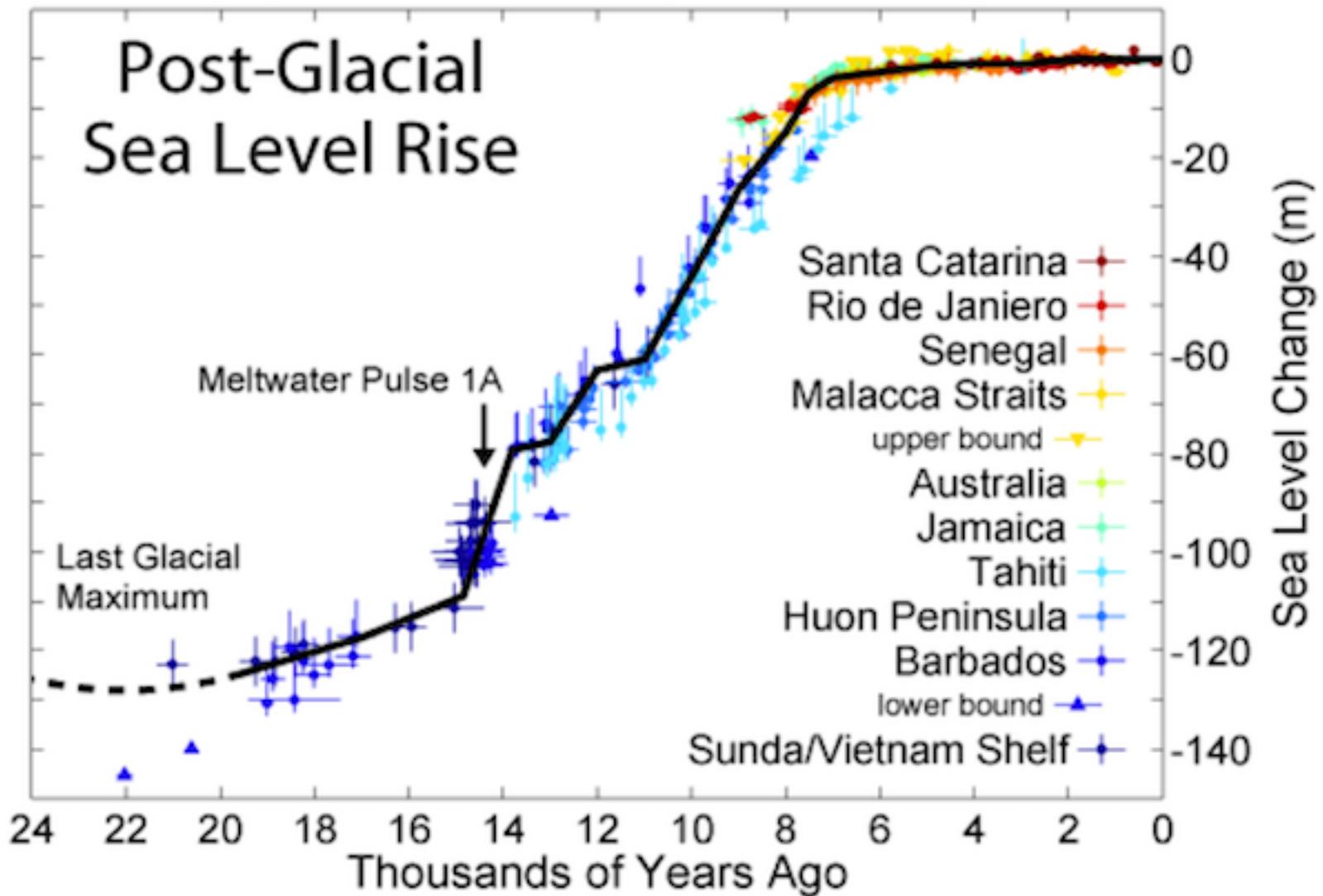


1. Past Changes in Sea Level



Recent data indicate that there has been a steady increase in sea level due to an increase in the volume of water in the Earth's oceans.

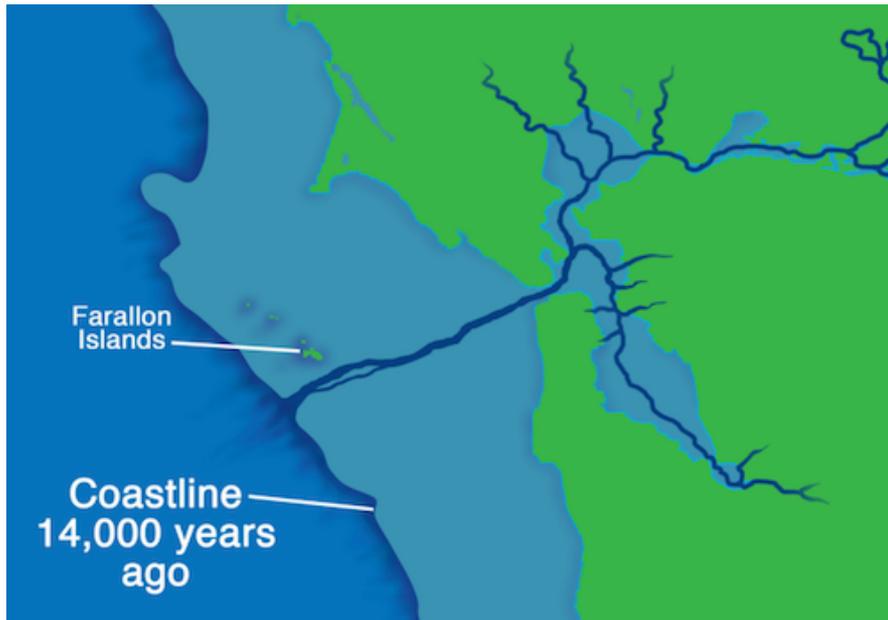
Although the mean sea level is increasing, the amount of increase of sea level in different regions differs due to local effects such as tides, currents, etc.



Sea level has changed dramatically over geological time.

Since the last ice age (~20,000 years ago), mean sea level has increased by ~125 m.

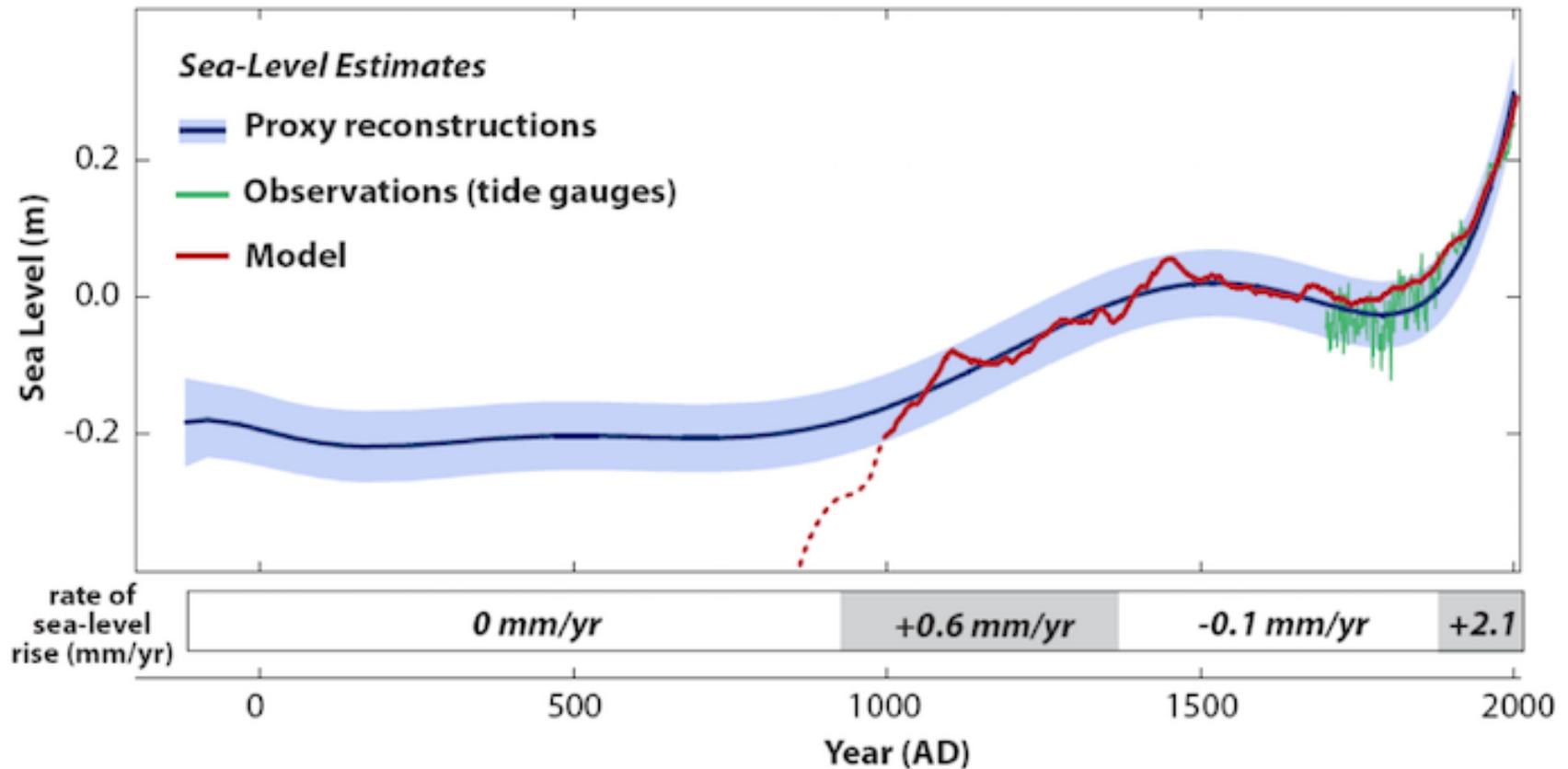
This map shows a reconstruction of the shoreline for the Florida peninsula during the last ice age.



This map shows a reconstruction of the coastline in the San Francisco area during the last ice age. Note that 14,000 years ago, the Farallon islands would have been short mountains or hills near the ancient shoreline.

This figure shows that the rate of increase in mean sea level has been accelerating since around 1800.

Note that the increase in mean sea level coincides with the Industrial Revolution and the dramatic increase in the CO₂-content of the Earth's atmosphere.



What could be causing the recent rise in sea level?

2. Introduction to Cryosphere

What's the first thing that you notice about our planet when you see this image?

The Earth is composed of several integrated parts (spheres) that interact with one another:

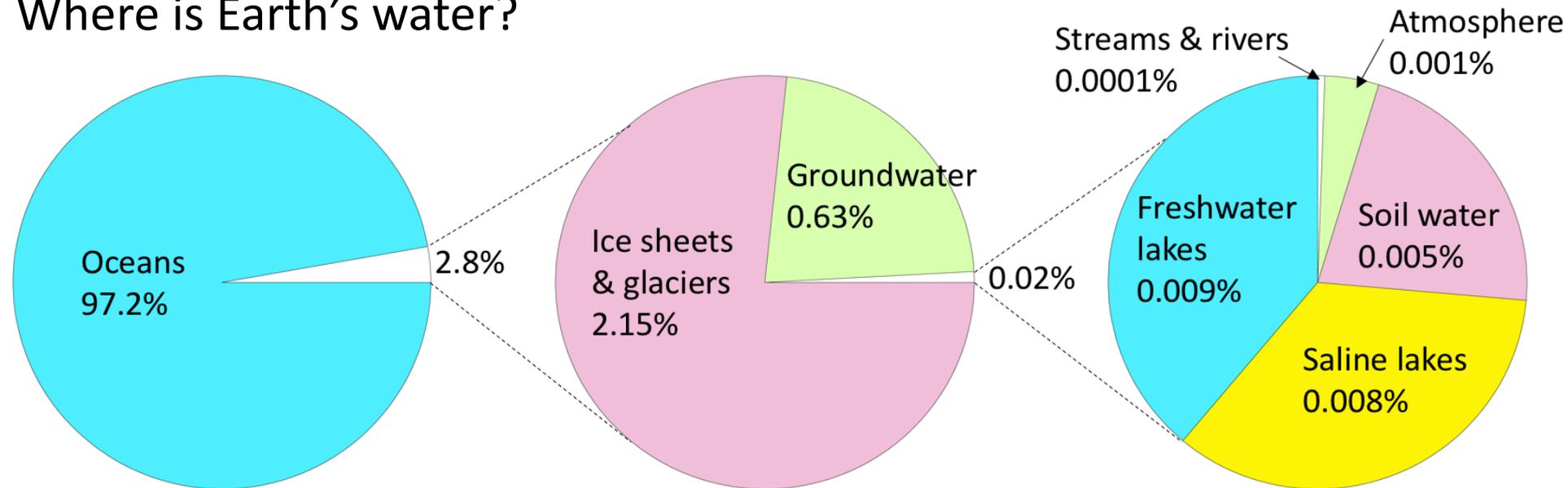
- atmosphere
- hydrosphere
- geosphere (lithosphere)
- biosphere
- cryosphere



The cryosphere are the portions of the Earth the are composed of water ice and are an integral part of the Earth system.

The cryosphere is a portion of the *Earth's water cycle*.

Where is Earth's water?



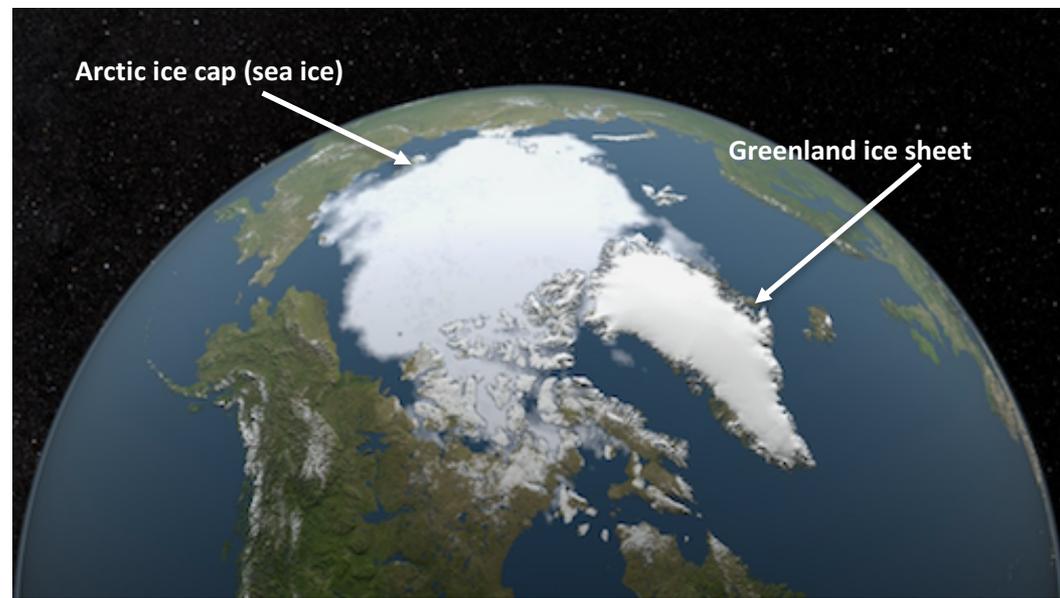
About 97% of the Earth's water is found in the oceans.

Only ~2.5% of the Earth's water is freshwater.

Most of the Earth's freshwater is locked up ice (glaciers) and groundwater.

The Earth's cryosphere is composed of snow, lake and river ice, permafrost, sea ice, glaciers and continental ice sheets.

Glaciers and ice sheets are the largest reservoirs and are ice masses that rest on solid land. ~77% of all fresh water resides in glaciers and continental ice sheets. Antarctica is by far the largest reservoir of water in glaciers and ice sheets.



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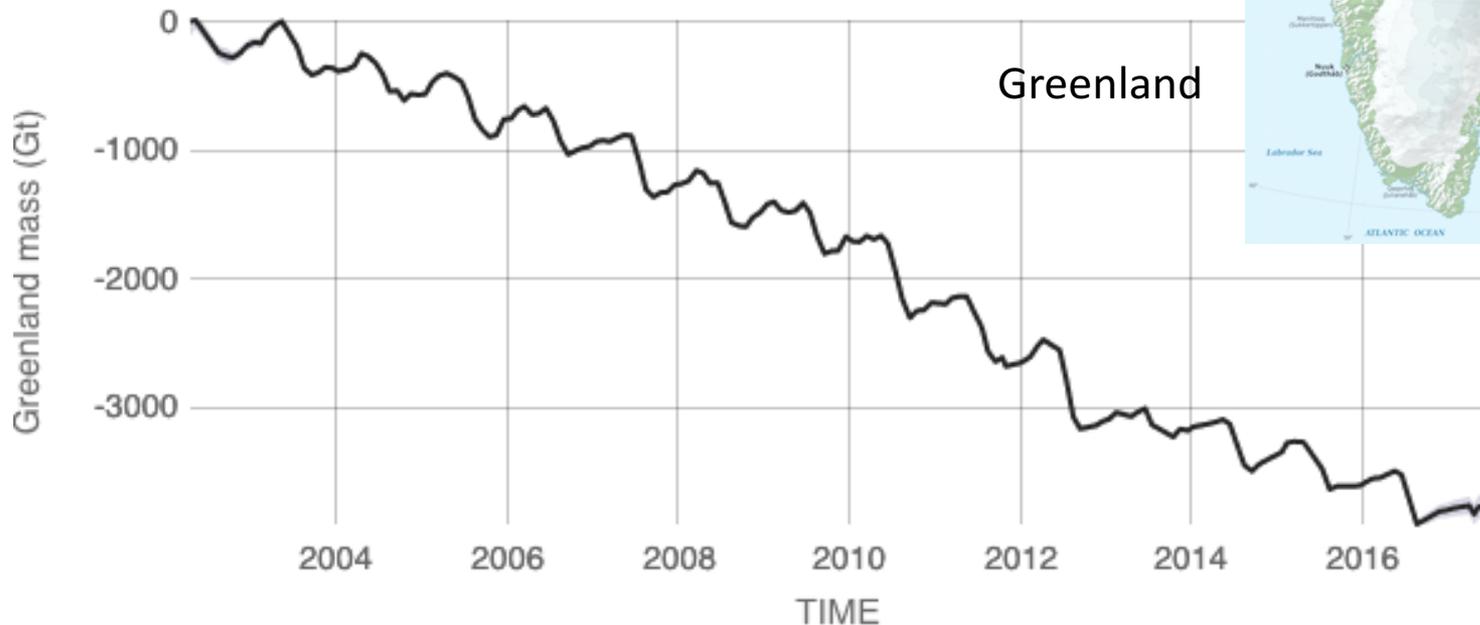
Sea ice forms from the freezing of sea water; the ice is composed of fresh water leaving the sea water more saline.

Sea ice forms in polar regions and the amount of ice varies greatly by season.

Ice Sheets and Glaciers

The total amount of water in ice sheets and glaciers is equivalent to ~ 80 m sea level equivalent. Antarctica accounts for $\sim 90\%$ of the continental ice and Greenland for most of the remaining 10%.

80% of Greenland is covered by an ice sheet. The figure below shows that the annual rate of reduction in the mass of ice has been increasing since 2002 when data were first collected.



Source: climate.nasa.gov

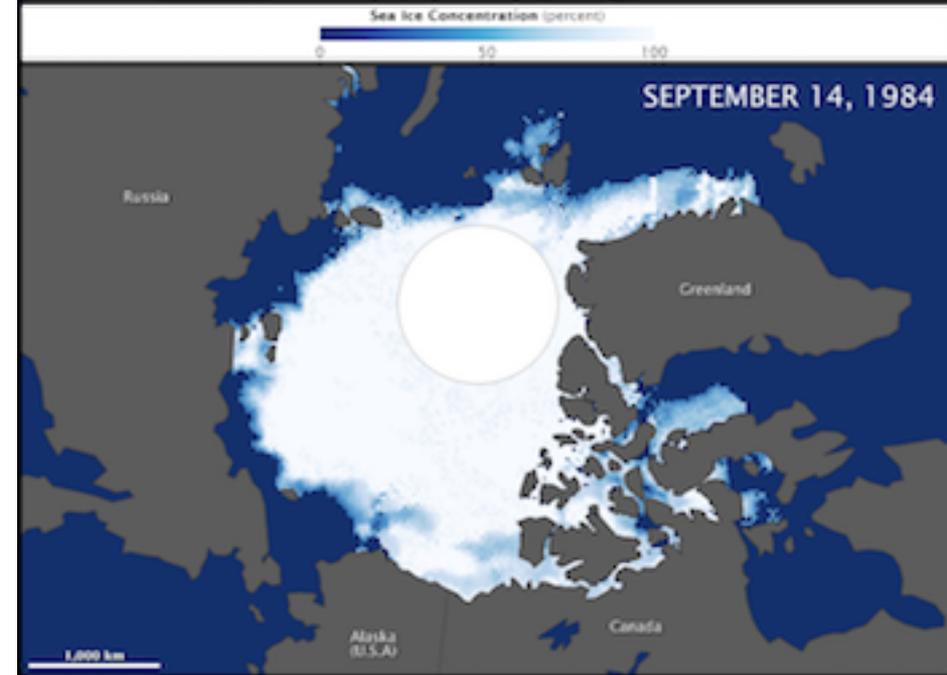
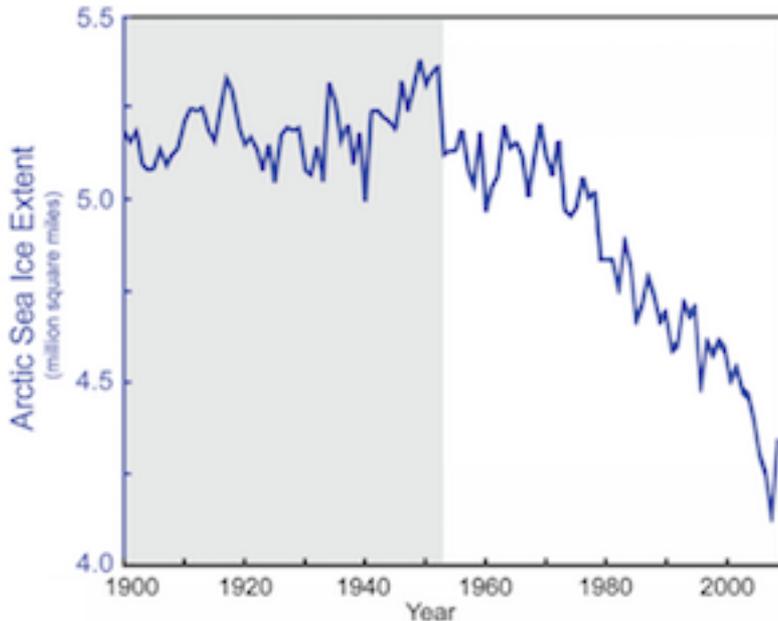
There are similar losses in ice mass for Antarctica.

Sea Ice

There are losses in the amount of sea ice in recent years.

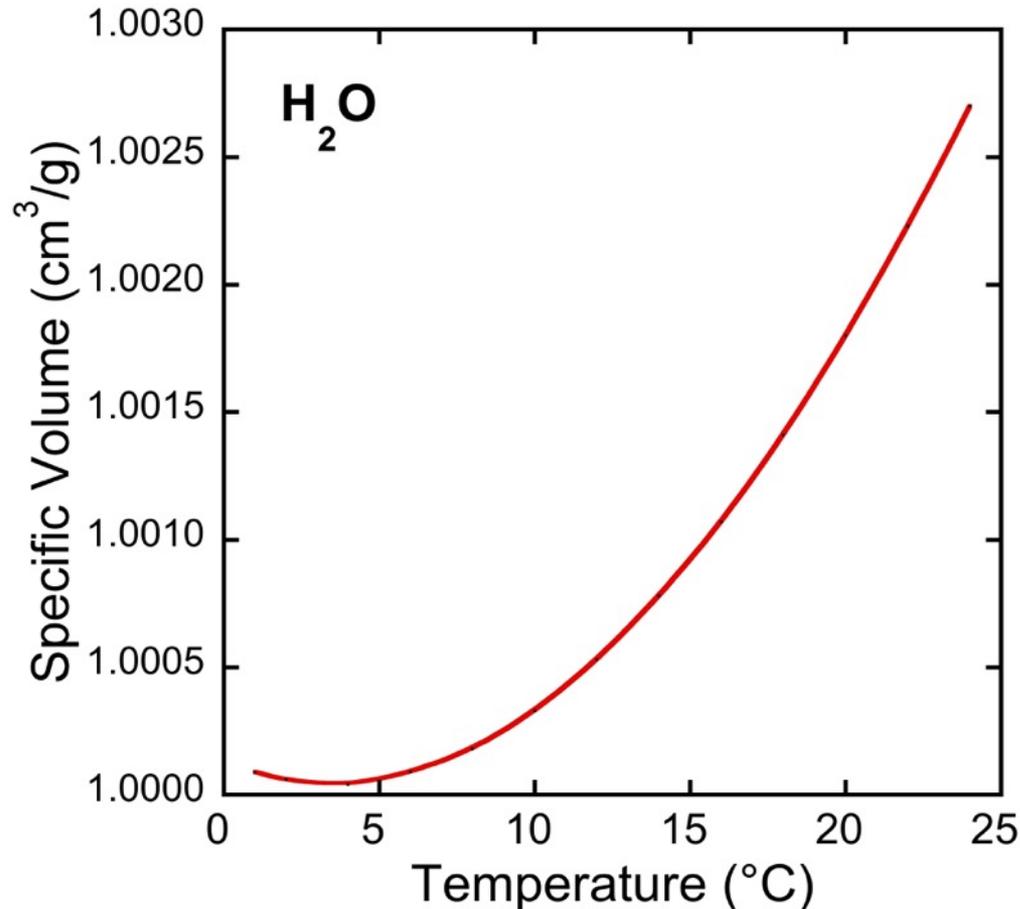
The maps compare the Arctic ice minimum for 2012 and 1984. In 2012, the minimum ice extent is about half of the average from 1979 to 2000.

The graph shows the annual average Arctic sea ice extent for the period 1900 to 2008. The gray shading indicates less confidence in the data before 1953.



3. Thermal Expansion of Water

Matter has a tendency to expand in volume as temperature increases. As temperature increases, the kinetic energy in the molecules of the substance increases, resulting in a greater average distance between them.

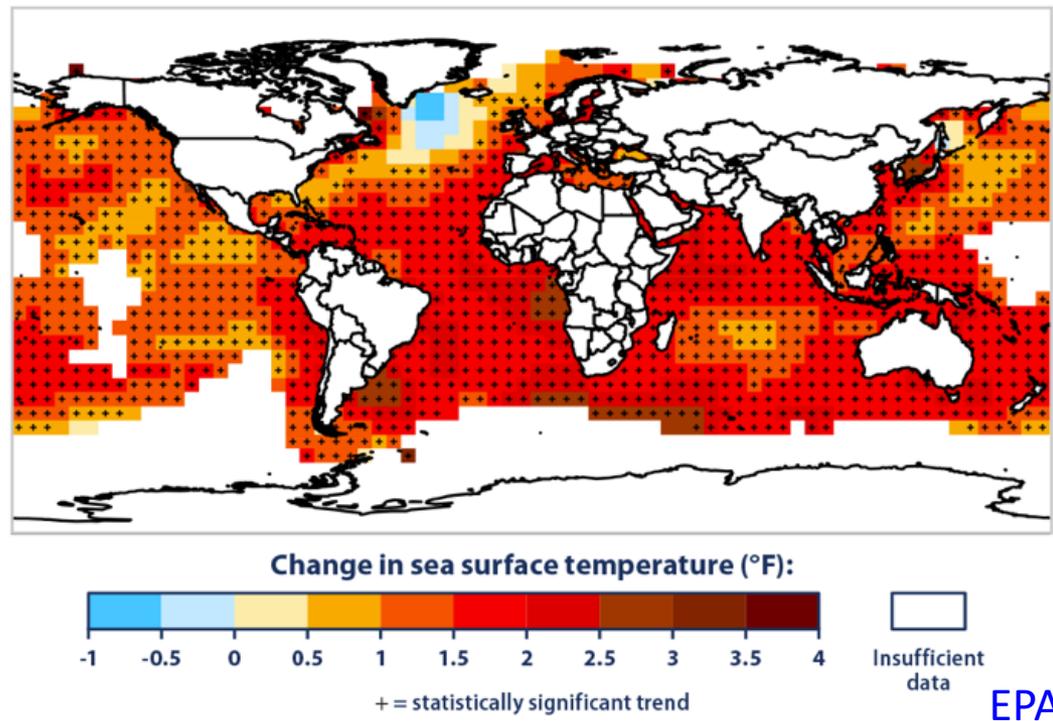
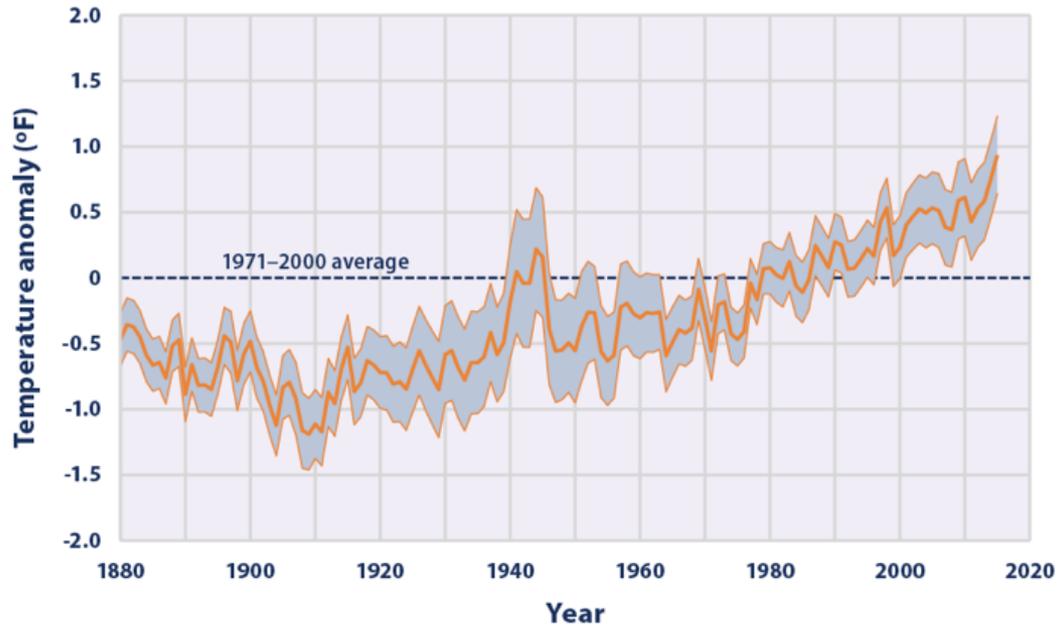


The plot shows the volume of water as a function of temperature. At 20°C, the volume of water increases by ~0.02% for each degree increase in temperature.

The graph and the map show how the average surface temperature of the world's oceans have changed since 1880 (using the 1971-2000 average as the baseline).

Since 1901, temperature rose at an average rate of 0.13°F (0.072°C) per decade.

Although adding melt water to the oceans will result in a rise in sea level, the thermal expansion of water is also a contributor to the volume of water as the oceans warm.

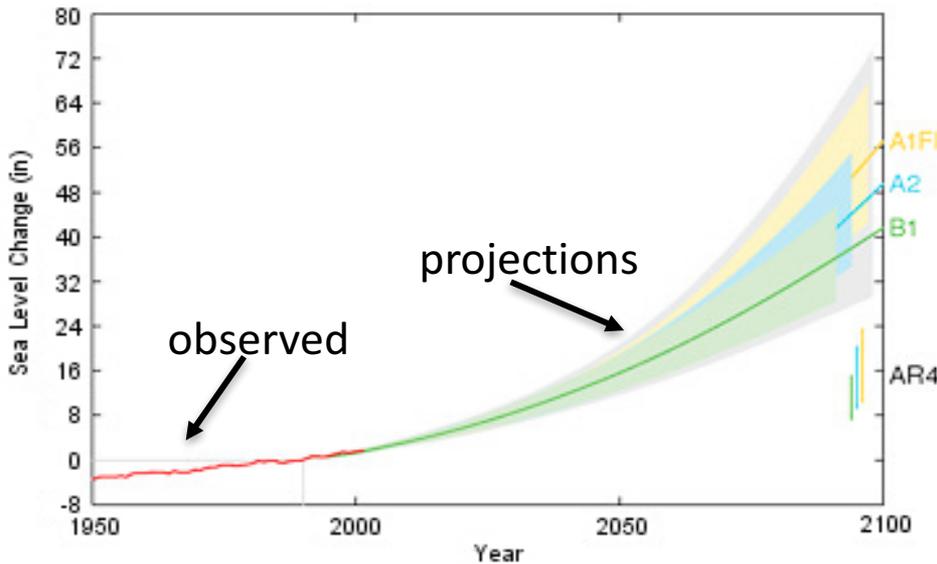
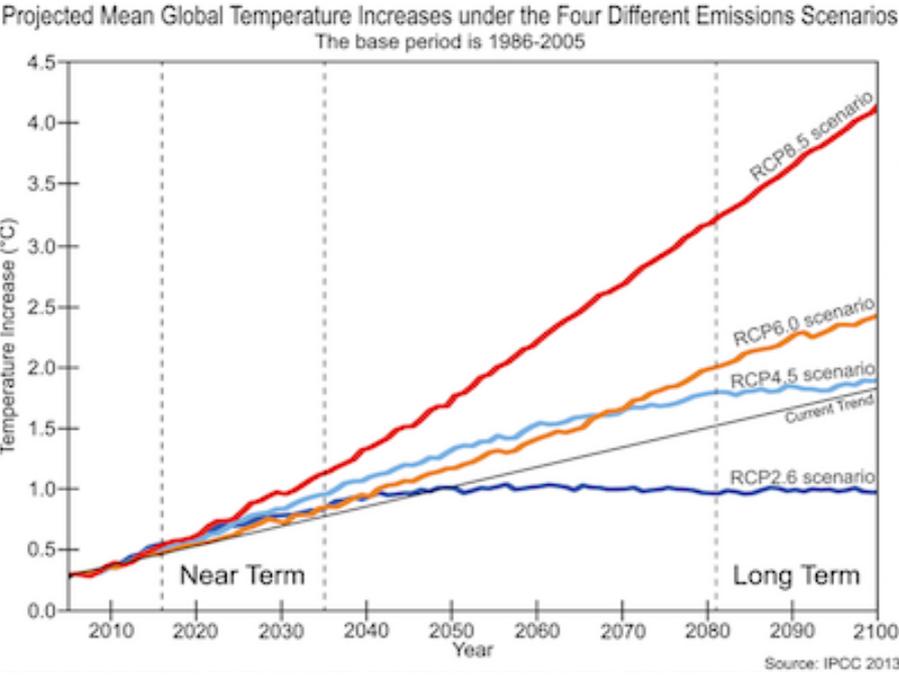


4. Predictions for the Future

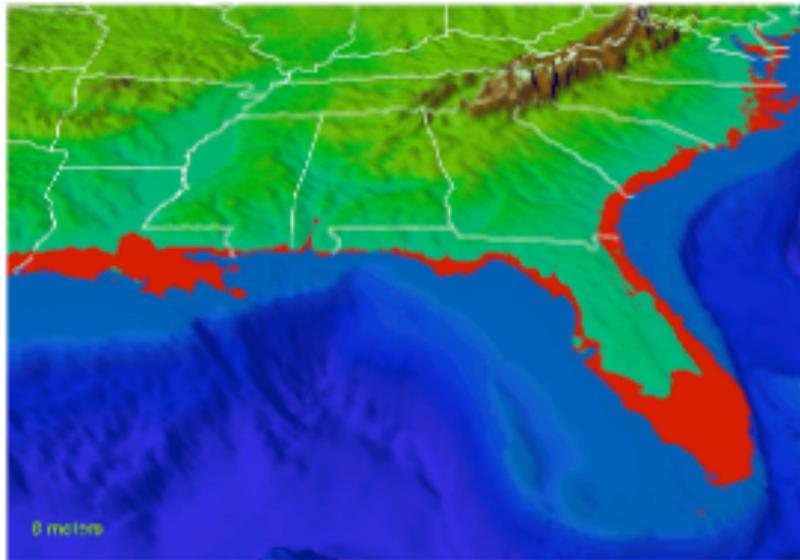
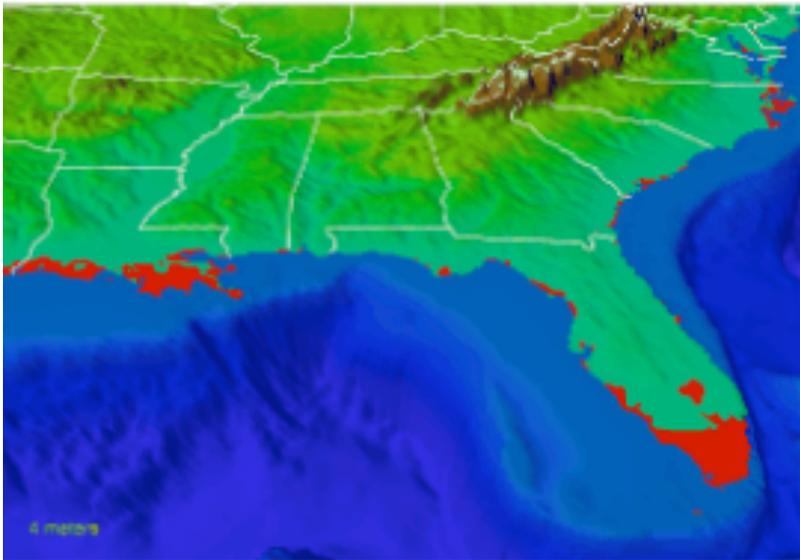
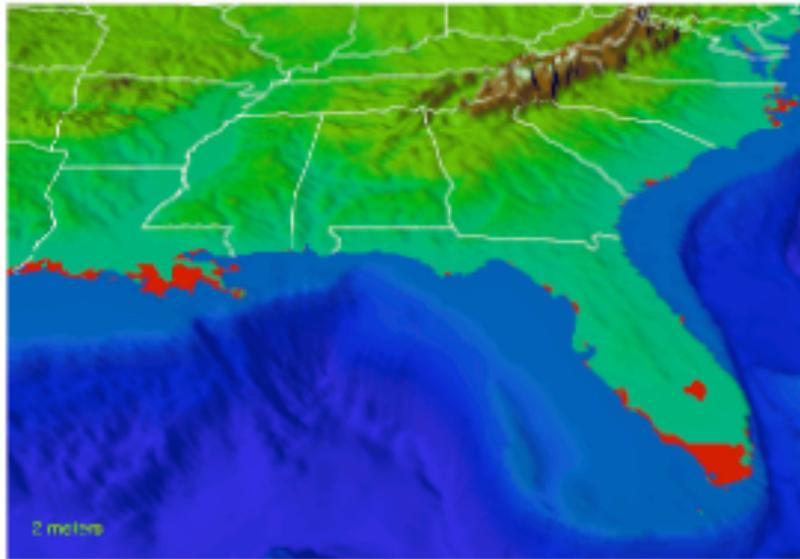
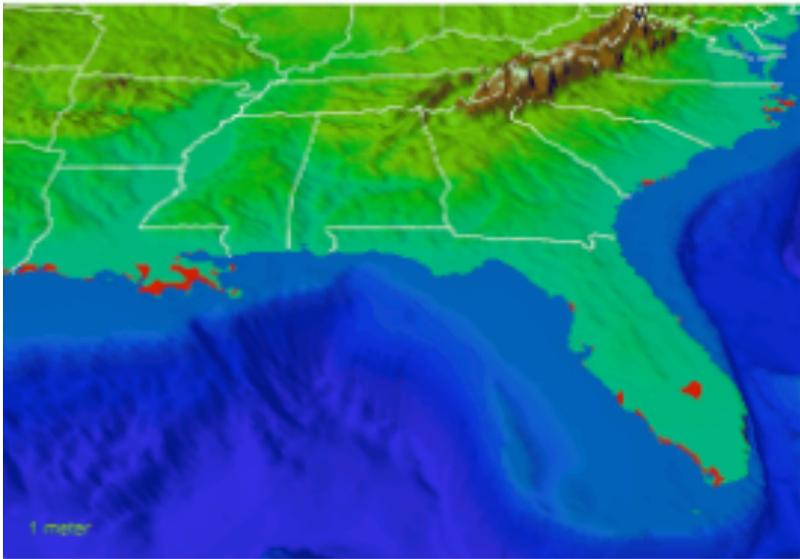
The top figure shows projected changes in the Earth's temperature using several different climate models.

The bottom figure shows predictions using several different models and indicate an increase of 1 meter or more in sea level by 2100.

Currently the contribution from the melting of land ice is 68% of the observed increase in sea level. The contribution of the melting has increased during the last 100 years as the melting of land ice has accelerated.

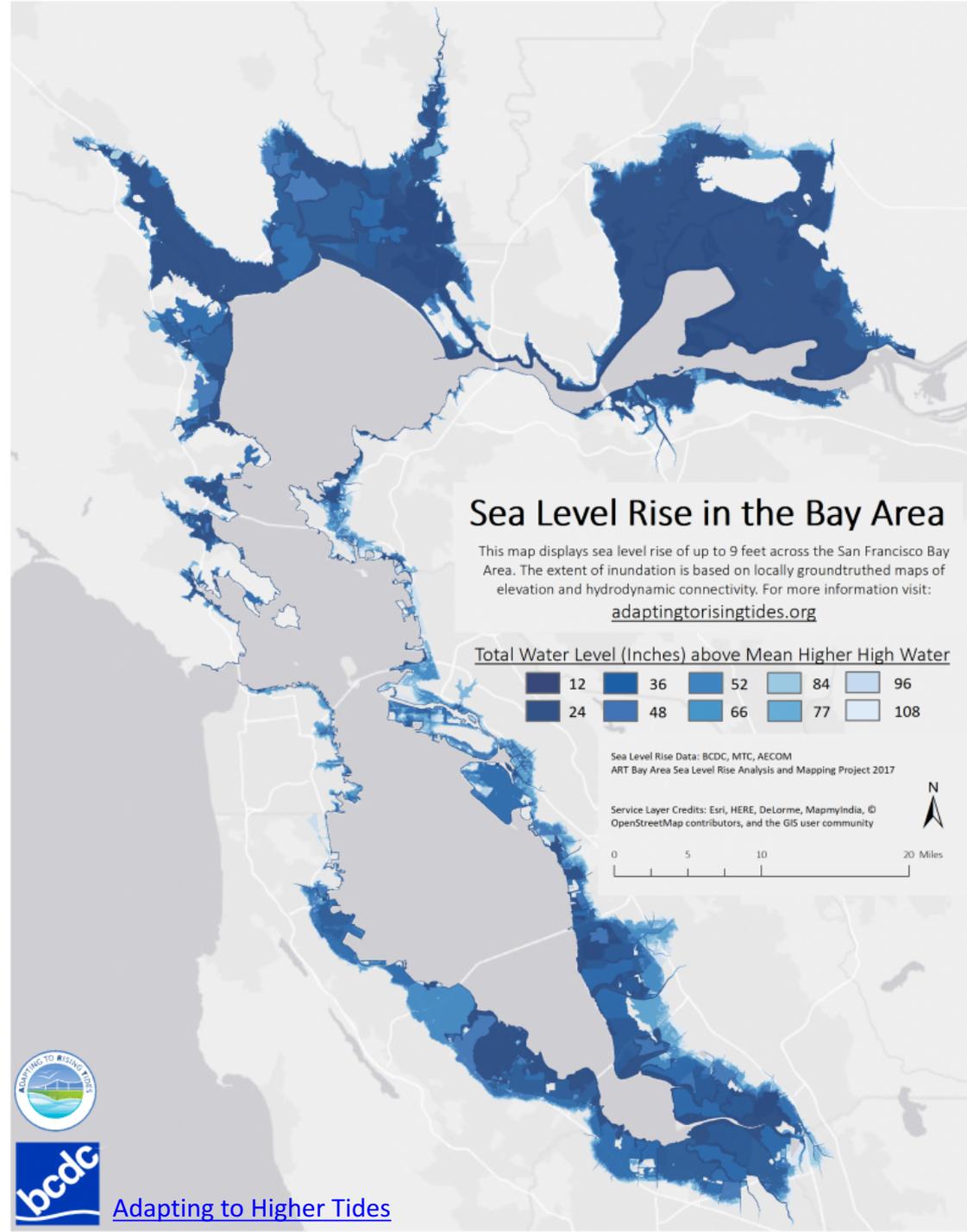


The maps show the inundation of the oceans along the east and gulf coasts (red) if sea level rises of 2, 4, 6 and 8 meters.



This map shows inundation due to sea level rise ranging from 12-108 inches.

Shaded regions indicate locations where flooding is likely during tidal and storm surges.



Consequences of Rising Sea Levels

1. Water quality – many coastal communities rely on groundwater. Rising sea levels can result in the intrusion of saltwater into fresh water aquifers resulting in contamination of drinking water and water used in agriculture.
2. Coastal erosion – higher sea levels result in erosion of the coastline and inundation of seawater onto land.
3. Coastal flooding– higher mean sea levels result in higher storm surges and king tides.
4. Loss of coastal habitats – higher sea levels flood sensitive coastal environments such as coastal wetlands.
5. Loss of island nations – this is especially a problem for small nations such as Tuvalu and Maldives.