Changing Sea levels During the Past 25,000 Years

An Introduction to Changes due to Glaciation and Current Conditions

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More than 25,000 years ago

- Nearly half of North America was covered with glacial ice
- This ice sheet was an expansion of polar ice referred to as the Laurentide ice sheet
- The area now occupied by New York City was covered with ice roughly a mile high about 25,000 years ago

Where did the ice come from?

- Over 100,000 years ago, global temperatures began to fall, dropping by 39-42°F (4-10°C) over thousands of years
- Snow that fell in winters in northern areas did not melt in summer (too cold)
- As the snowpack got heavier, the weight caused the underlying snow to turn into ice
- Eventually the weight of the ice on slopes caused the ice to move slowly (through gravity) forming a glacier
- Then the glacier continued to expand southward forming an enormous continental glacier (or ice sheet)

- The ice sheet moved south of Canada about 25,000 years ago
- Advancing as far south as northern New Jersey and northeastern Pennsylvania
- And there it stayed for roughly 10,000 years
- This process took thousands of years (from 75,000 years before present to about 15,000 years ago when the glacier began to recede)

- With the Earth’s water accumulating in these continental glaciers, there was little seasonal return of water to the oceans in these areas
- This caused a tremendous drop in sea level

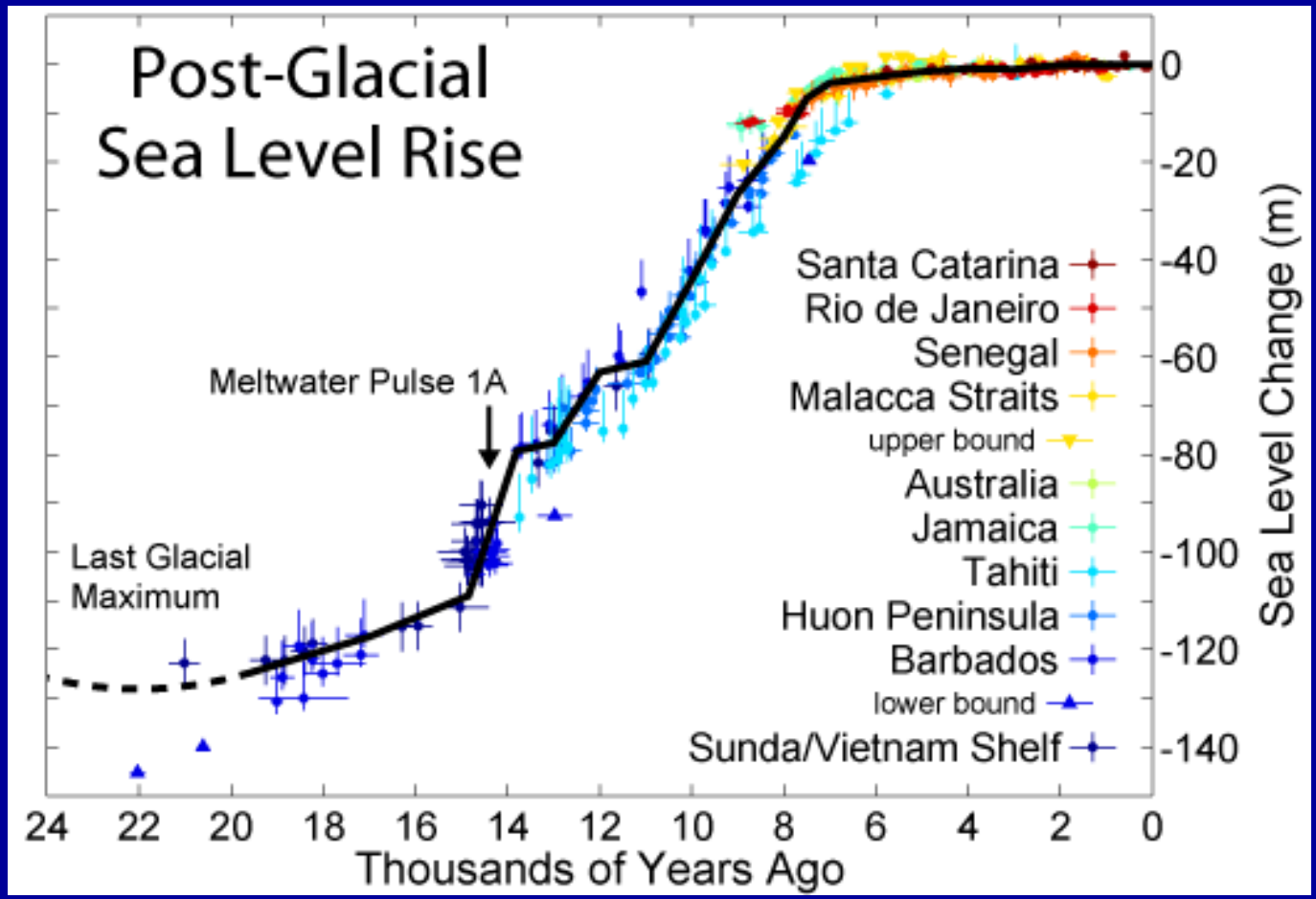
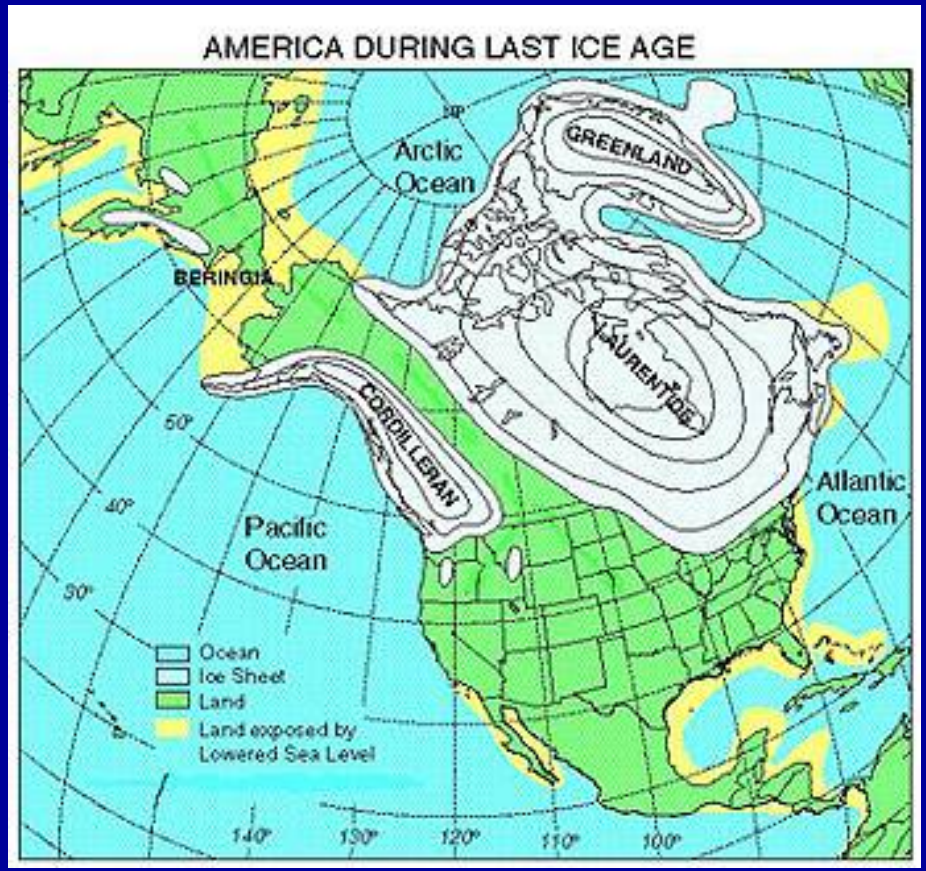


Image created by Robert A. Rohde / Global Warming Art

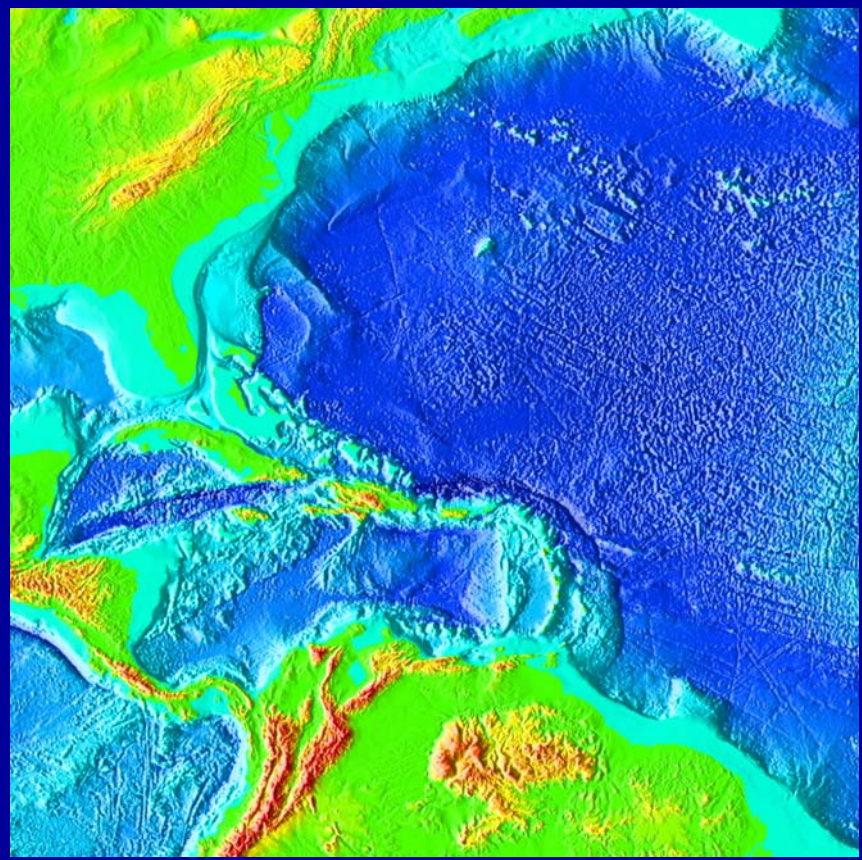
Globally, sea level fell to about 400 feet (120m) below current levels

- This drop in sea level exposed new areas of “land” (yellow areas)



Where was the coast about 25,000 years ago?

- Near the edge of what today is our "Continent Shelf" (light blue areas)
- About 50 miles off the coast of New Jersey
- During the last glaciation, this area was the "Coastal Plain"



- The “new” coastal plain was miles offshore of the present-day coastline (to 280 miles at the mouth of the Amazon River)
- It consisted of a combination of dryland, wetland, and rivers
- The climate, of course, was much colder than today

- Temperatures were cold enough that in the Northeast, the vegetation of the coastal plain was not like today's but instead was much like the boreal forest

- The ocean’s temperature was also colder as evidence of fossil remains of arctic marine mammals: walruses, sea lions, bearded seals in the Gulf of Maine, for example (they don’t occur there today)

Evidence of Life on the Continental Shelf

- Offshore dredgers have hauled in fossils, mastodon teeth (teeth in upper figure were dredged from Gulf of Maine)
- The remains of trees also have also been uncovered on the shelf

Other Evidence – Offshore Oil and Gas Deposits

- Rich oil and gas deposits offshore are the remains of prehistoric swamps

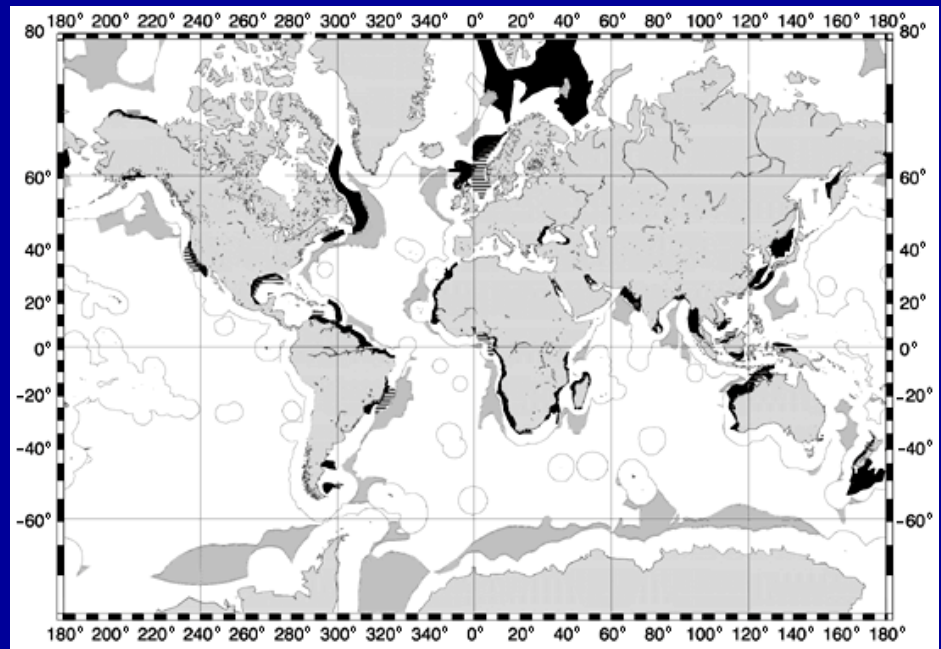


Figure 8 - Oil and Gas provinces of the world (in black - after Klett *et al.*,1997) and the main offshore areas where oil and gas are produced (striped - after IEA, 1996 and references therein) with reference to ELCS regions (in grey) and EEZ areas (outlined by thin curved grey lines).

About 15,000 years ago

- The glacier began to retreat
- Left the US about 10,000 years ago
- Where did the water from the melting ice sheet go?

Answer: Back to the Ocean

- The graph on right shows
  - The rapid fall in sea level as the Laurentide ice sheet built up and
  - The rapid rise in sea level when the glacier retreated,
  - Slowing of the rise about 10,000 years ago
  - Further slowing about 3,000 years ago when near present-day levels were reached (most coastal wetlands formed since this time)

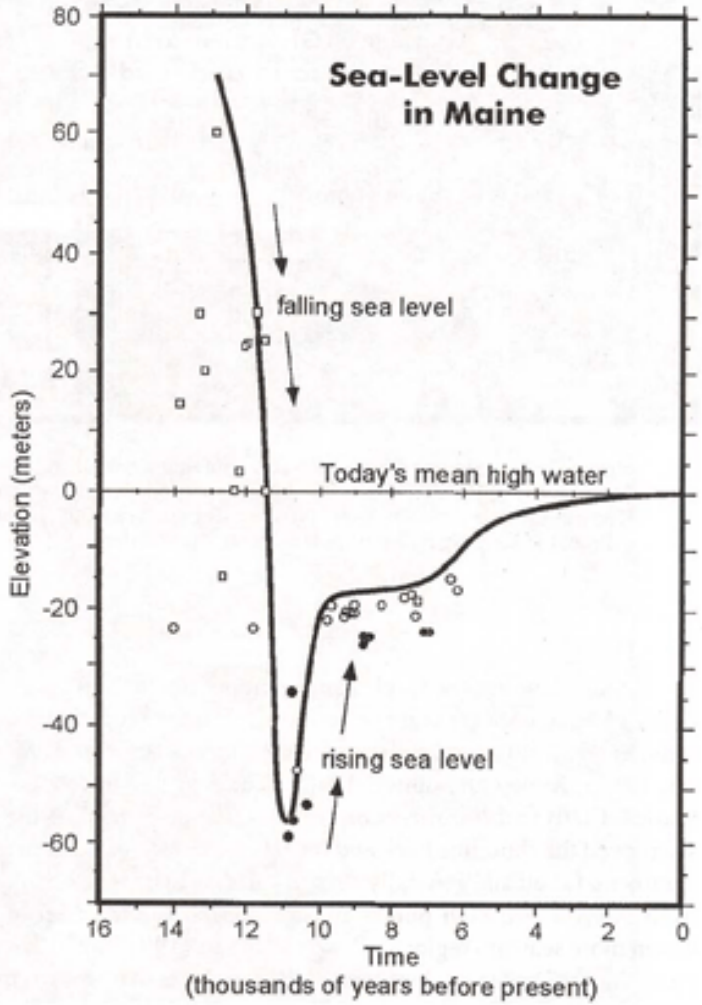


Figure 2. History of sea level change in Maine. Dots represent radiocarbon dates. From *The Sea Floor Revealed* (6).

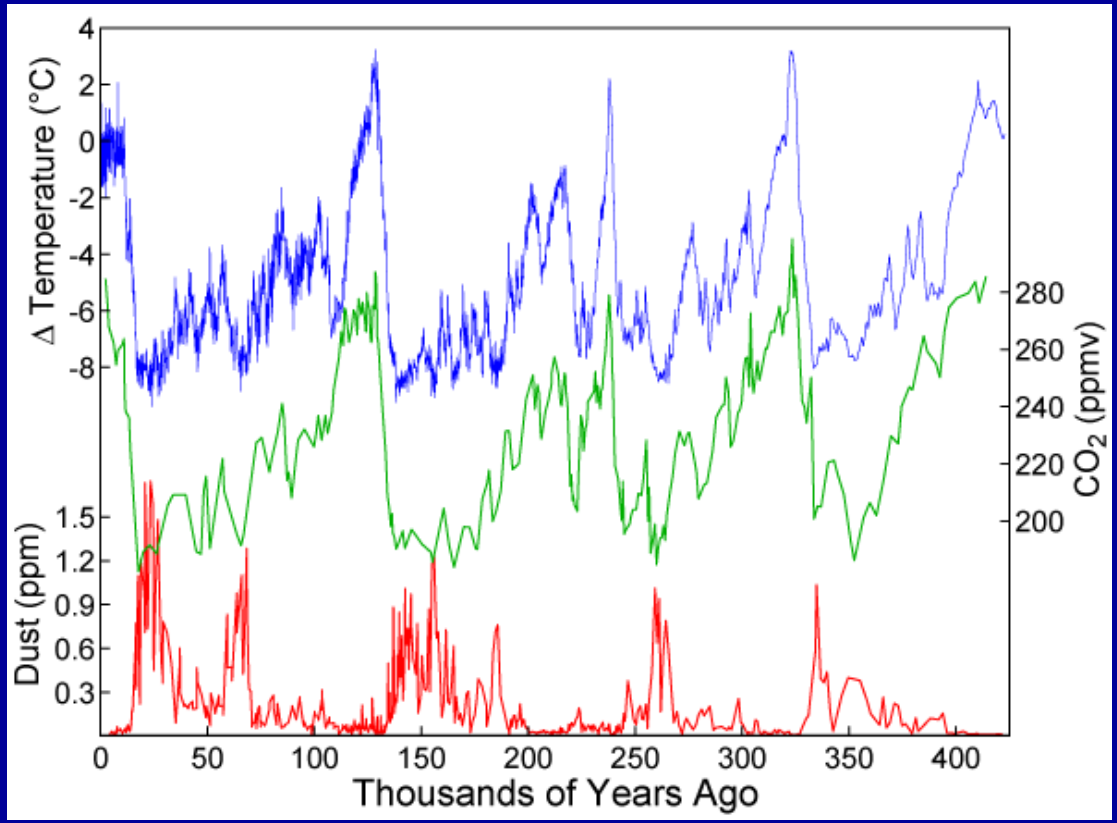
Sea levels and Global Temperature Change

- For millions of years, sea level has fluctuated with changes in the Earth's climate
- During glacial periods, much of the Earth's water is trapped in glacial ice, with this water released back to the sea during interglacial periods

Examination of Ice Cores

- Arctic, Antarctic, and other glacial ice contain a historical record of the Earth's climate based on the content of air bubbles trapped in the ice.
- These bubbles contain atmospheric gases including carbon dioxide, methane, and other greenhouse gases from the time that they became trapped in ice.
- Climate can be traced back 800,000 years using these cores.

- Using this information, scientists have found that the Earth experiences glaciation on a cyclical basis, roughly every 100,000 years
- Graph: temperature (blue), carbon dioxide (green), and dust (red)
  - High points in blue represent interglacial (warming) periods and low points indicate glacial periods



- We are living during the latest interglacial period
- Sea level has been rising since the last glaciation
- Recent evidence of this can be observed by the presence of tree stumps in salt marshes or dead trees at the margins of marshes

- By examining aerial photographs, researchers can detect changes from salt marsh to tidal flats or open water, and track the migration of salt marshes into low-lying forests (converting the latter to the former), for example
- Other scientists have developed landscape-change models to predict these types of interactions into the future
  - What rates of sea-level rise do modelers use?

Factors Affecting Sea-level Rise Today

- Melting polar and glacial ice
- Warming of the ocean (thermal expansion)
- Coastal subsidence
- Post-glacial rebound (rising land after the weight of the ice is removed = “isostatic adjustment”)
- Tectonics (mountain-building, volcanic activity, earthquakes)

Sea-level Rise Predictions

- Intergovernmental Panel on Climate Change (IPCC) has been studying this issue and making predictions re: global temperature increase and sea-level rise since the 1990s.
- Over time, technology and data continue to improve as more research is conducted on this important topic, so predictions change accordingly

IPCC 2007 Predictions

- By 2100, global temperatures may rise between 2.0° and 11.5°F
- This may cause further melting of the Greenland ice sheet and other glaciers and warm the oceans resulting in a rise in sea level
- Predicted sea-level rise by 2100 is between 0.6 feet and 1.9 feet (lower than their earlier estimate of 0.3-2.9 feet)
- This has been viewed as a conservative estimate

2009 Predictions

- European scientists have examined additional information in their assessment of sea-level rise, including an analysis of tree growth rings and correlated that with past global temperatures
- Their estimate of sea-level rise for 2100 ranges from about 3.0-4.3 feet which is much higher than the IPCC estimate.

So what rate should we use for coastal zone planning?

- Many scientists are predicting a rise of 3.3 feet (1 meter) as the average change over the next 100 years
- It, therefore, seems prudent to use this rate as general guidance for coastal zone planning
  - Planners will, however, consult local experts for local variations in sea-level rise rates

Concluding Remarks

- Today the rate of sea-level rise is increasing due to climate change
- Globally, a rise between 0.6-4.3 feet is predicted by 2100
- Actual sea-level rise may exceed or be lower than these predictions due to local conditions (e.g., subsidence, post-glacial rebound or tectonic activity)

- Scientists are using these estimates in models designed to predict the impact of sea-level rise on the coastal zone
- The models will be improved with time
- These models are intended to serve as guides to help government agencies and others plan for the future and are not intended to cause alarm
- In the U.S., we expect a significant increase in sea level that will have a substantial impact on coastal resources, especially fish and wildlife and their habitats