COASTAL AREAS AND MARINE RESOURCES

KEY ISSUES

- **Shoreline Erosion and Human Communities**
- **Threats to Estuarine Health**
- **Coastal Wetland Survival**
- **Coral Reef Die-offs**
- **Stresses on Marine Fisheries**

The US has over 95,000 miles of coastline and over 3.4 million square miles of ocean within its territorial waters.These areas provide a wide range of essential goods and services to society. Some 53% of the total US population live on the 17% of land in the coastal zone,and these areas become more crowded every year. Because of this growth,as well as increased wealth and affluence,demands on coastal and marine resources for both aesthetic enjoyment and economic benefits are rapidly increasing.

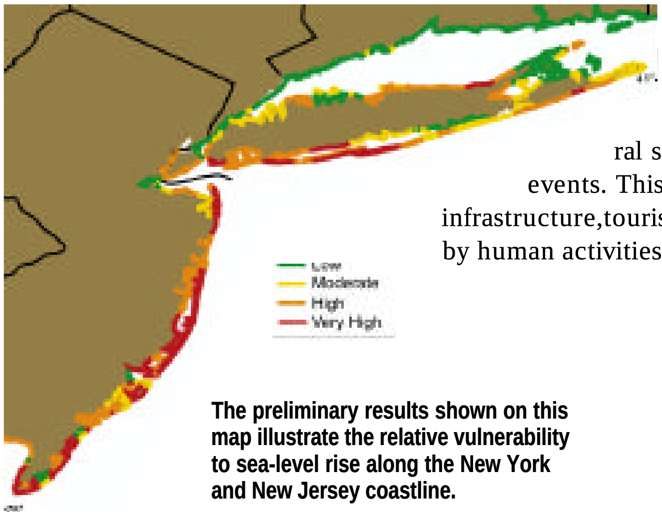
Coastal and marine environments are intrinsically linked to climate in many ways. The ocean is an important distributor of the planet's heat,with major ocean currents moving heat toward the poles from the equator. There is some chance that this distribution of heat through the ocean's "conveyor belt" circulation would be strongly influenced by the changes projected in many global climate models. Sea-level rise is another climate-related phenomenon with a major influence on coastlines. Global sea level has already risen by 4 to 8 inches (10-20 cm) in the past century and models suggest this rise is very likely to accelerate. The best estimate is that sea level will rise by an additional 19 inches (48 cm) by 2100,with an uncertainty range of 5 to 37 inches (13-95 cm). Geological forces (such as subsidence,in which the land falls relative to sea level) play a prominent role in regional sea-level change. Accelerated global sea-level rise is expected to have dramatic impacts in those regions where subsidence and erosion problems already exist.

Key Issue: Shoreline Erosion and Human Communities

Coastal erosion is already a widespread problem in much of the country and has significant impacts on undeveloped shorelines as well as on coastal development and infrastructure. Along the Pacific Coast,cycles of beach and cliff erosion have been linked to El Niño events that raise average sea levels over the short term and alter storm tracks that affect the coastline. For example,during the 1982-83 El Niño and the 1997-98 El Niño,erosion damage was widespread along the Pacific Coastline. If increases in the frequency or intensity of El Niño events occur, they would likely combine with long-term sea-level rise to exacerbate these impacts.

Atlantic and Gulf Coast shorelines are especially vulnerable to long term sea-level rise as well as any increase in the frequency of storm surges or hurricanes. Most erosion events on these coasts are the result of storms,and the slope of these areas is so gentle that a small rise in sea level produces a large inland shift of the shoreline. When buildings, roads,and seawalls block this natural shift,the beaches and shorelines erode,especially during storm events. This increases the threats to coastal development,transportation infrastructure,tourism,freshwater aquifers,and fisheries (which are already stressed by human activities). Coastal cities and towns,especially those in storm-prone

Coastal Vulnerabilty

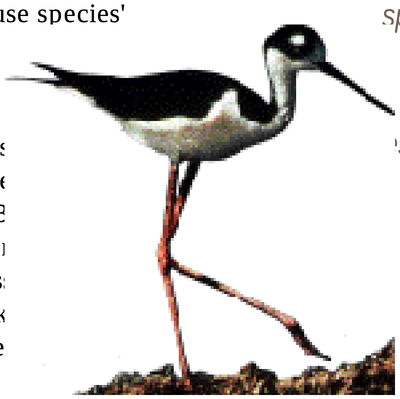


The preliminary results shown on this map illustrate the relative vulnerability to sea-level rise along the New York and New Jersey coastline.

regions such as the Southeast,are particularly vulnerable to extreme events. Intensive residential and commercial development in such regions puts life and property at risk.

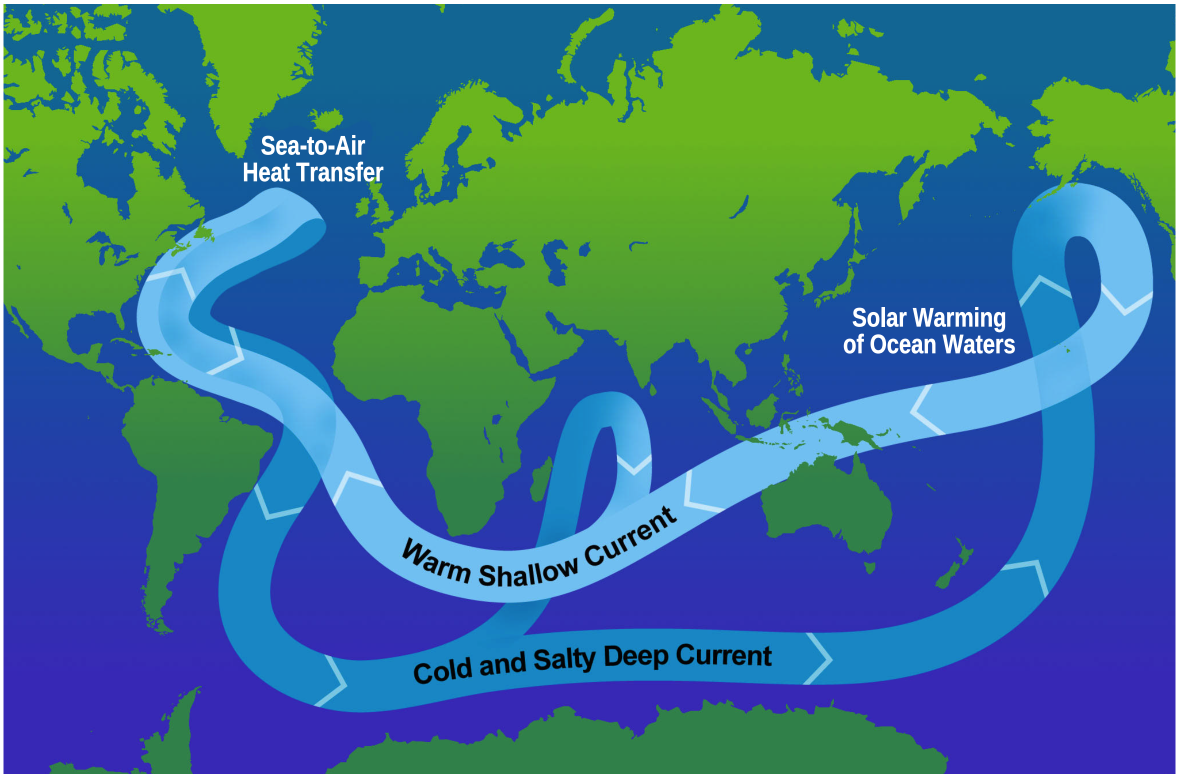
Key Issue: Threats to Estuarine Health

Estuaries are extremely productive ecosystems that are affected in numerous ways by climate. Winter temperatures are projected to continue to increase more than summer temperatures, resulting in a narrowing of the annual water temperature range of many estuaries. This is likely to cause species' ranges to shift and increase the vulnerability of some estuaries to non-native invasive species. Either increases or decreases in runoff would very likely create impacts to estuaries. Increased runoff would likely deliver increased amounts of nutrients such as nitrogen and phosphorous to estuaries,while simultaneously incre the stratification between freshwater runoff and marine waters. B ent additions and increased stratification would increase the poten blooms of algae that deplete the water of oxygen,increasing stress grasses, fish,shellfish,and other living things on the bottom of lak and oceans. Decreased runoff would likely reduce flushing,decre of estuarine nursery zones,and allow predators and pathogens of penetrate further into the estuary.



Winter temperatures are projected to continue to increase more than summer temperatures, resulting in a narrowing of the annual water temperature range of many estuaries. This is likely to cause species' ranges to shift and increase the vulnerability of some estuaries to non-native invasive species.

Ocean Circulation Conveyor Belt



The ocean plays a major role in the distribution of the planet's heat through deep sea circulation. This simplified illustration shows this "conveyor belt" circulation which is driven by differences in heat and salinity. Records of past climate suggest that there is some chance that this circulation could be altered by the changes projected in many climate models, with impacts to climate throughout lands bordering the North Atlantic.

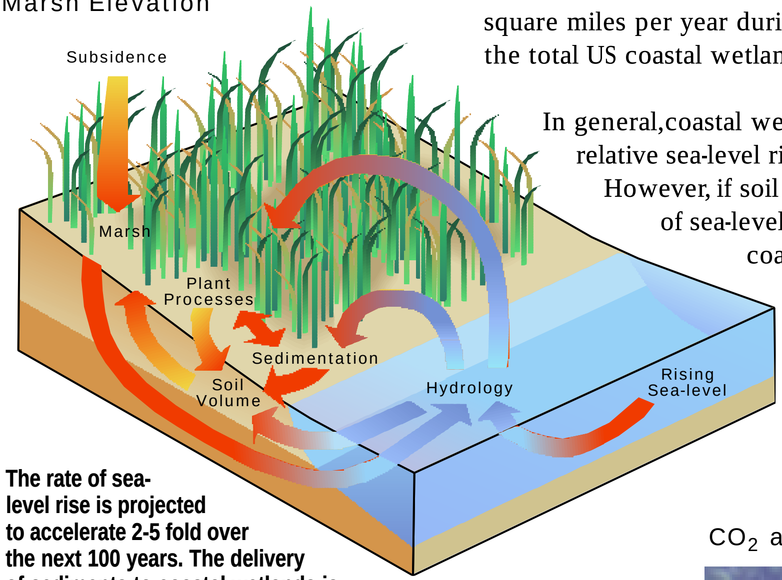
COASTAL AREAS AND MARINE RESOURCES KEY ISSUES

Coastal Wetland Survival

Coastal wetlands (marshes and mangroves) are highly productive ecosystems that are strongly linked to fisheries productivity. They provide important nursery and habitat functions to many commercially important fish and shellfish populations. Dramatic losses of coastal wetlands have already occurred on the Gulf Coast due to subsidence, changes caused by dams and levees that alter flow and reduce sediment supply, dredge and fill activities, and sea-level rise. Louisiana alone has been losing land at rates between 24 and 40 square miles per year during the last 40 years, accounting for as much as 80% of the total US coastal wetland loss.

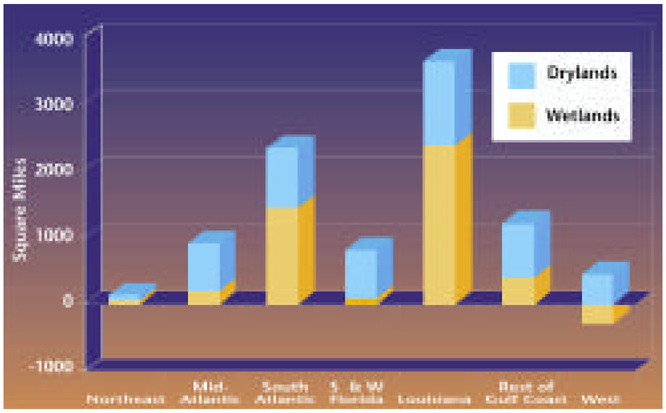
In general, coastal wetlands will survive if soil buildup equals the rate of relative sea-level rise or if the wetland is able to migrate inland. However, if soil accumulation is unable to keep pace with high rates of sea-level rise, or if wetland migration is blocked by bluffs, coastal development, or shoreline protective structures (such as dikes, sea walls, and jetties), the wetland will be excessively inundated and eventually lost. The projected increase in the current rate of sea-level rise will very likely exacerbate coastal wetland losses nationwide, although the extent of impacts will vary among regions.

Processes Affecting Marsh Elevation



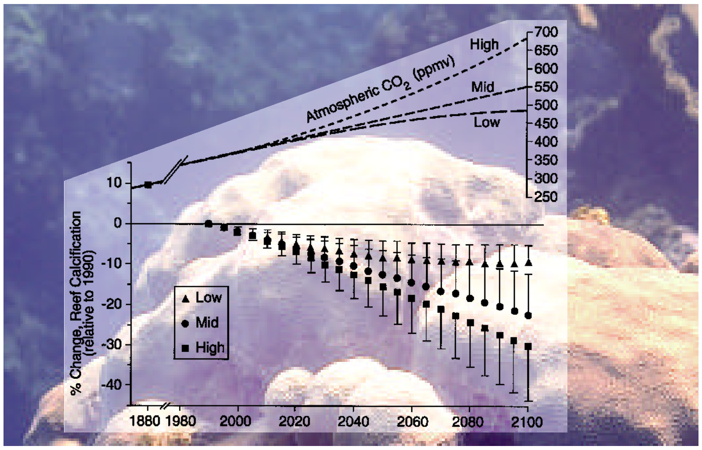
The rate of sea-level rise is projected to accelerate 2-5 fold over the next 100 years. The delivery of sediments to coastal wetlands is extremely important in determining the potential of these systems to maintain themselves in the face of current and future sea-level changes.

US Coastal Lands at Risk from a 20-inch Sea-Level Rise



These bars show the square miles of coastal land at risk from a 20-inch rise in sea level, for seven areas of the US. Coastal wetlands projected to be inundated are shown in yellow while drylands projected to be inundated are shown in blue.

CO_2 and Temperature Stresses on Coral Reefs



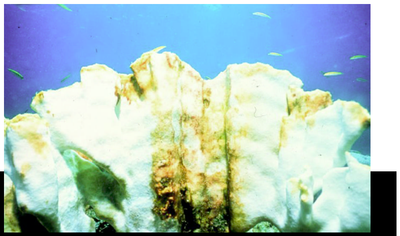
This graph shows a simulation of the effect of increased atmospheric CO_2 on percent change in coral reef calcification. Rising atmospheric CO_2 harms coral directly by making surface waters less alkaline, reducing corals' calcification and making their skeletons smaller and weaker. Warmer ocean temperatures will be another significant added stress, causing corals to expel the algae that live inside them and are crucial to their survival. Because these algae also give coral its color, this process is called "coral bleaching." Coral can recover after a short episode of warmer water, but if the warming persists the coral die. Under these combined stresses in addition to the existing stresses posed by human activities, corals may not survive in many areas.

Coral Reef Die-offs

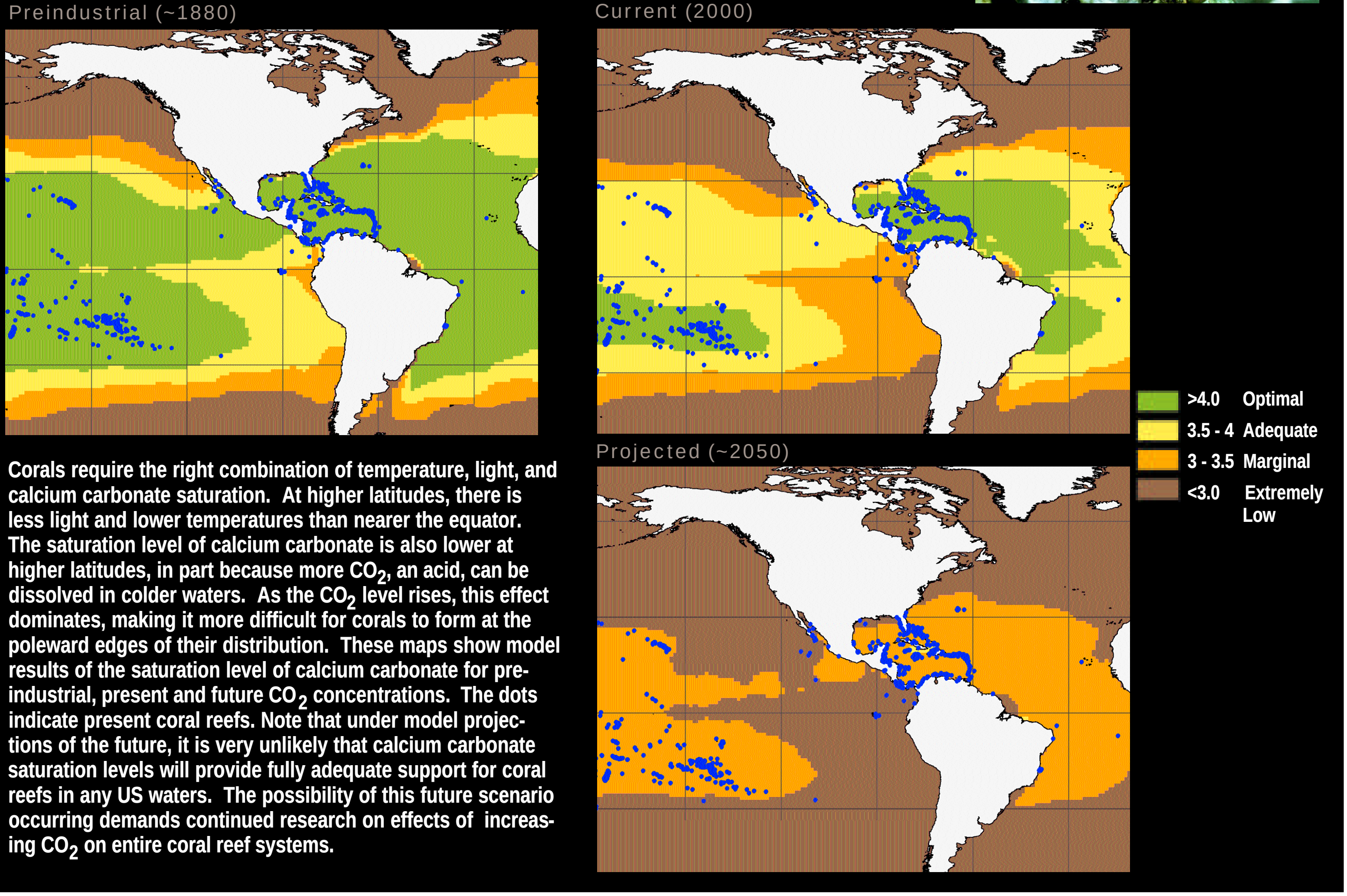
Coral reefs play a major role in the environment and economies of two states (Florida and Hawaii) as well as most US territories in the Caribbean and Pacific. Coral reefs are valuable economic resources for fisheries, recreation, tourism, and coastal protection. In addition, reefs are one of the largest global storehouses of marine biodiversity, with untapped genetic resources. Some estimates of the global cost of losing coral reefs run in the hundreds of billions of dollars each year. The demise or continued deterioration of reefs could have profound implications for the US.

The last few years have seen unprecedented declines in the health of coral reefs. The 1998 El Niño was associated with record sea-surface temperatures and associated coral bleaching (when coral expel the algae that live within them and are necessary to their survival); in some regions, as much as 70% of the coral may have died in a single season. There has also been an upsurge in the variety, incidence, and virulence of coral diseases in recent years, with major die-offs in Florida and much of the Caribbean region. In addition, increasing atmospheric CO_2 concentrations could possibly decrease the calcification rates of the reef-building corals, resulting in weaker skeletons, reduced growth rates and increased vulnerability to erosion. Model results suggest that these effects would likely be most severe at the current margins of coral reef distribution.

> *There has also been an upsurge in the variety, incidence, and virulence of coral diseases in recent years, with major die-offs in Florida and much of the Caribbean region. In addition, increasing atmospheric CO_2 concentrations could possibly decrease the calcification rates of the reef-building corals, resulting in weaker skeletons, reduced growth rates and increased vulnerability to erosion.*



Calcium Carbonate Saturation in Ocean Surface Waters



Corals require the right combination of temperature, light, and calcium carbonate saturation. At higher latitudes, there is less light and lower temperatures than nearer the equator. The saturation level of calcium carbonate is also lower at higher latitudes, in part because more CO_2, an acid, can be dissolved in colder waters. As the CO_2 level rises, this effect dominates, making it more difficult for corals to form at the poleward edges of their distribution. These maps show model results of the saturation level of calcium carbonate for pre-industrial, present and future CO_2 concentrations. The dots indicate present coral reefs. Note that under model projections of the future, it is very unlikely that calcium carbonate saturation levels will provide fully adequate support for coral reefs in any US waters. The possibility of this future scenario occurring demands continued research on effects of increasing CO_2 on entire coral reef systems.

COASTAL AREAS AND MARINE RESOURCES KEY ISSUES

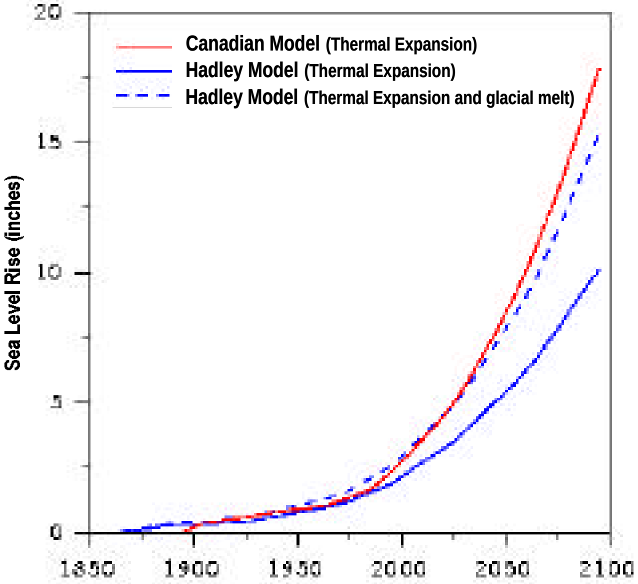
Stresses on Marine Fisheries

In the US,the total economic contribution of recreational and commercial fishing has been estimated at approximately $40 billion per year, with total marine landings averaging about 4.5 million metric tons over the last decade. Climate change is very likely to substantially alter the distribution and abundance of major fish stocks, and have important implications for marine populations and ecosystems.Changes over the long term are likely to include poleward shifts in distribution of marine populations.With changing ocean temperatures and conditions,shifts in the distribution of commercially important species are likely. For example,models suggest that several species of Pacific salmon are likely to have reduced distribution and productivity, while species that thrive in warmer waters,such as Pacific sardine and Atlantic menheden,are likely to have increased distribution.

Along the Pacific Coast,impacts to fisheries related to the El Niño/Southern Oscillation illustrate how climate directly affects marine fisheries on short time scales. For example,elevated sea-surface temperatures associated with the 1997-98 El Niño had a tremendous impact on the distribution and abundance of market squid,California’s largest fishery by volume. Landings fell to less than 1,000 metric tons in the 1997-98 season,down from a record-breaking 110,000 tons in the 1996-97 season. Many other unusual events occurred during this same El Niño as a result of elevated sea-surface temperatures. Examples include widespread sea lion pup deaths in California,catches of warm-water marlin in the usually frigid waters off Washington State,and poor salmon returns in Bristol Bay, Alaska.

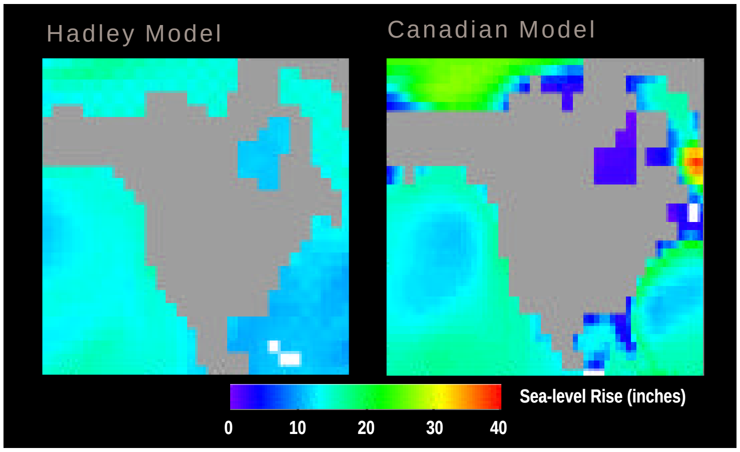
Atlantic and Gulf Coast shorelines are especially vulnerable to long term sea-level rise as well as any increase in the frequency of storm surges or hurricanes. Most erosion events on these coasts are the result of storms and extreme events, and the slope of these areas is so gentle that a small rise in sea level produces a large inland shift of the shoreline.

Sea-level Rise Projections



Historic and projected changes in sea level based on the Canadian and Hadley model simulations. The Canadian model projection includes only the effects of thermal expansion of warming ocean waters. The Hadley projection includes both thermal expansion and the additional sea-level rise projected due to melting of land-based glaciers. Neither model includes consideration of possible sea-level changes due to polar ice melting or accumulation of snow on Greenland and Antarctica.

Sea-level Rise Projections - 2080-2099



The Hadley model projects that ocean warming and melting of mountain glaciers will cause between 8 to 12 inches (20 to 30 cm) of sea-level rise by 2100 for much of the Atlantic and Gulf coasts of the US, depending on changes in winds and ocean current patterns. Projections for the Northeast US and the Pacific coast range from 13 to 16 inches (32 to 40 cm). Any effects of the rising or sinking of the coastal lands must be added to these numbers.

The Canadian model projects a more complex pattern of sea-level rise by 2100. Because of its larger warming estimate, sea level is projected to rise 20 to 24 inches (50 to 60 cm) along parts of the US Atlantic and Pacific coastlines. The orange peak in the Labrador Sea is the result of shifts in the location and intensity of ocean currents.

Adaptation Strategies

It is difficult to assess the potential effects of climate change over the next few decades on coastal and marine resources,especially as climate variability is a dominant factor in shaping coastal and marine systems. The effects of future change will vary greatly in the diverse coastal regions of the nation. Additionally, human-induced disturbances also influence coastal and marine systems,often reducing the ability of systems to adapt,so that systems that might ordinarily be capable of responding to variability and change are less able to do so. In this context, climate change is likely to add to the cumulative impact of both natural and human-caused stresses on ecological systems and resources. This makes devising adaptation strategies particularly challenging.

With few exceptions,the potential consequences of climate change are not yet being considered in coastal management. It is especially urgent to begin adaptation now with regard to development of land in the coastal zone. In areas where beaches or wetlands must migrate inland to survive,it has been shown that implementing protection or retreat strategies for coastal developments can substantially reduce the economic impacts of inundation and shoreline movement. For example,coastal management programs in Maine,Rhode Island, South Carolina,and Massachusetts have implemented various forms of "rolling easement" policies to ensure that wetlands and beaches can migrate inland as sea level rises,and coastal landowners and conservation agencies can purchase the required easements. However, some regulatory programs continue to permit structures that may block the inland shift of wetlands and beaches. Additionally, allowing for such shoreline movement is only feasible in some locations due to the high degree of development on many coastlines.

> *With few exceptions, the potential consequences of climate change are not yet being considered in coastal management. It is especially urgent to begin adaptation now with regard to development of land in the coastal zone.*

This map is a preliminary classification of annual shoreline erosion throughout the US, in coarse detail and resolution. The areas most vulnerable to future sea-level change are those with low relief which are already experiencing rapid erosion rates, such as the Southeast and Gulf Coast.