NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

INCORPORATING SEA LEVEL CHANGE SCENARIOS AT THE LOCAL LEVEL

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About Sea Level Change

Global sea level change is usually caused by two processes:

1. the melting of land-based ice that increases the volume of ocean water, and
2. thermal expansion—as water warms, it expands.

Basin changes, such as the process of seafloor spreading, can also play an important role, but these changes usually occur on a protracted time scale of as much as 100,000 or more years.

Global sea level change measurements are usually made using satellite altimetry. While these measurements and projections are important, local measurements and projections are needed for realistic local planning efforts.

Local sea level change rates reflect a variety of local factors, including vertical land motion (subsidence or uplift) and changes in estuarine and shelf hydrodynamics, regional oceanographic circulation patterns, and hydrologic cycles (river flow). Local data can be found on NOAA's Sea Levels Online website (*www.tidesandcurrents.noaa.gov/sltrends*). Each tide station represented on this site provides historical sea level change information. Some stations have records that cover 100 years.

To calculate projections, communities add to (or in some cases subtract from) global projections, since local rates vary greatly along the U.S. coastline. High rates of relative sea level rise, for instance, are found in the northern Gulf of Mexico because of regional and local land subsidence. High rates of relative sea level fall are found in the Gulf of Alaska from the loss of land-based glaciers and the uplift response to plate tectonics.

Introduction

Just as flooding threats need to be factored into coastal community planning initiatives, so too should sea level change. Unfortunately, the "one size fits all" approach does not work.

The level of uncertainty represented in sea level projections is one challenge. Furthermore, universal projections can't be uniformly applied to all communities because of the many local variables. These variables include subsidence or uplift, and changes in estuarine and shelf hydrodynamics, regional oceanographic circulation patterns, and river flows. Local calculations are needed.

Then add in the local response, where many variables come into play as well. Even if two communities have similar projection numbers, their responses are likely to be widely different because of the external factors specific to their locations that must be considered, such as anticipated local risk, community will, and the type of planning process in which the numbers will be used.

Incorporating sea level change into planning processes involves more than selecting a number. That is why this document advocates the scenario approach.

Using the information provided here, communities can develop a process that incorporates a range of possibilities and factors. With this information various scenarios can be developed, both in terms of projections and responses, to meet the specific circumstances of a community. Moreover, working through the scenario development process provides the data and information that officials will need to make communities readily adaptable to changing circumstances.

"Incorporating Sea Level Change Scenarios at the Local Level" is a "low-tech" companion for a technical report created by the National Oceanic and Atmospheric Administration (NOAA). The original document, *Technical Considerations for Use of Geospatial Data in Sea Level Change Mapping and Assessment*, can be found on the following websites:

NOAA Coastal Services Center
www.csc.noaa.gov/publications/slc_tech.pdf

NOAA Center for Operational Oceanographic Products and Services
www.tidesandcurrents.noaa.gov/publications/tech_rpt_57.pdf

NOAA National Geodetic Survey
www.ngs.noaa.gov/PUBS_LIB/Technical_Use_of_Geospatial_Data_2010_TM_NOS_01.pdf

While the focus of both documents is on sea level *change*, most of the nation's coasts are facing rising projections, which is why a greater portion of the text focuses on sea level *rise* as opposed to reductions. Even though the word "community" is frequently used, the process is equally appropriate at local, state, and regional levels.

An example from the U.S. Army Corps of Engineers is provided in the appendix.

Step 1: Define the Context

Just as communities are very different, so are community planning processes and goals. To create appropriate community sea level change scenarios, planners should first consider how the information will be used. Answering the following questions is a good place to start.

Context question 1: What type of plan is being developed?

Sea level projections can be based on many things, from historical trends to worst-case scientific prediction models. Communities may base their plans on one projection or a range of rates.

Using a single projection is easier to use and to plan toward, but this is a riskier approach, since single rates can result in a false sense of certainty. It is impossible to precisely know the future state of the coast. Most community planning efforts should therefore include a range of possibilities, known as scenarios, particularly for visioning exercises and comprehensive, long-range plans. For planning projects that address a specific time frame, the use of specific anticipated rates of change may be more appropriate.

Considering a range of possibilities lends itself to the adaptive management style required in a changing environment. The preparation work done for scenario building should also help communities reduce the need to frequently revise rates and retool the plan.

Context question 2: What scale is meaningful?

Characteristics that may impact the expected rate of sea level change (such as geomorphic conditions—that is, tectonic rebound or variable land subsidence) can vary within a region, state, or localized area. For this reason, local projections should be used for most local and regional coastal planning and mapping applications. Local projections are typically derived from long-term tide gage records (greater than 30 years) that measure local variation of the sea surface over time relative to the local land elevation. These are often called relative rates of sea level change.

Context question 3: What is the current political environment?

Community will is an important indicator of whether sea level change data will be implemented into the planning process. Because political will can change, keeping flexibility in the plans, along with using a range of scenarios, is important. Adaptive scenarios incorporate components that are measured (highly likely) and those that are predicted (less certain). If the political climate is such that predictions will not be supported, the part of the framework devoted to measured and observed data can continue to move forward.

Step 2: Determine Which Components to Include in Local Projection Scenarios

Table 1 lists the key components often included when developing sea level change scenarios. Most scenarios are based on a combination of historical local information, global rates, and models that predict future conditions.

Communities should use a protocol that is documented and easy for citizens to obtain and review, because this transparency will build confidence in the chosen scenarios. There are various degrees of certainty for each data set, so communities should use whatever works best for their circumstances. Having a large number of community vulnerabilities (such as at-risk infrastructure or populations) might make aggressive approaches more appropriate. The table below illustrates six individual components of sea level change (in order of certainty) that when added together make up the total relative sea level change at a given location.

Table 1. Components of Sea Level Change

Component	Quantity	Source	Where to locate the Information	Certainty
Component I: Historical Local Relative Sea Level Trends	+10.0 to -15.0 millimeters (mm) per year	Measured	NOAA tide gage records	Highly Certain
Component II: Localized Vertical Land Changes (Subsidence, Isostatic Rebound)	-8.0 (subsidence) to +20.0 (uplift) mm per year	Modeled/Measured	NGS, State Advisor, USGS published subsidence/rebound rates, CO-OPS estimates from tide gage records	
Component III: 20th Century Historical Global Sea Level Change	+1.7 to 1.8 mm per year	Measured	Historical global tide gage analyses and global isostatic adjustment models	
Component IV: Global Sea Level Change since 1993	+3.1 to 3.3 mm per year	Measured	Series of satellite altimeter missions since 1993 and global tide gage records	
Component V: Future Climate Change Scenarios	Acceleration constant 2 centimeters (cm) per decade increasing by 3 cm per decade each decade	Modeled	IPCC 2007, various research papers since IPCC	
Component VI: Regional Tidal Elevation Surface	Uncertainty of modeled surfaces area-dependent: 16 cm to 45 cm 95% CI	Modeled	VDATUM	Less Certain

CI – Confidence Interval
CO-OPS – Center for Operational Oceanographic Products and Services
IPCC – Intergovernmental Panel on Climate Change
NGS – National Geodetic Survey
NOAA – National Oceanic and Atmospheric Administration
State Advisor – State National Geodetic Survey Advisor
USGS – United States Geological Survey
VDATUM – NOAA Vertical Datum Transformation Tool

Step 3: Research What Other Communities Are Doing

Understanding how other communities are addressing sea level change impacts can be enlightening. Information in figure 1 was gathered by NOAA in August 2011 to support the work of the National Climate Assessment (*www.globalchange.gov/what-we-do/assessment*). The list does not represent an exhaustive search but nevertheless provides a helpful snapshot of the various approaches currently being employed. The 2013 National Climate Assessment will provide high, intermediate, and low sea level rise projections that can be used for scenario planning.

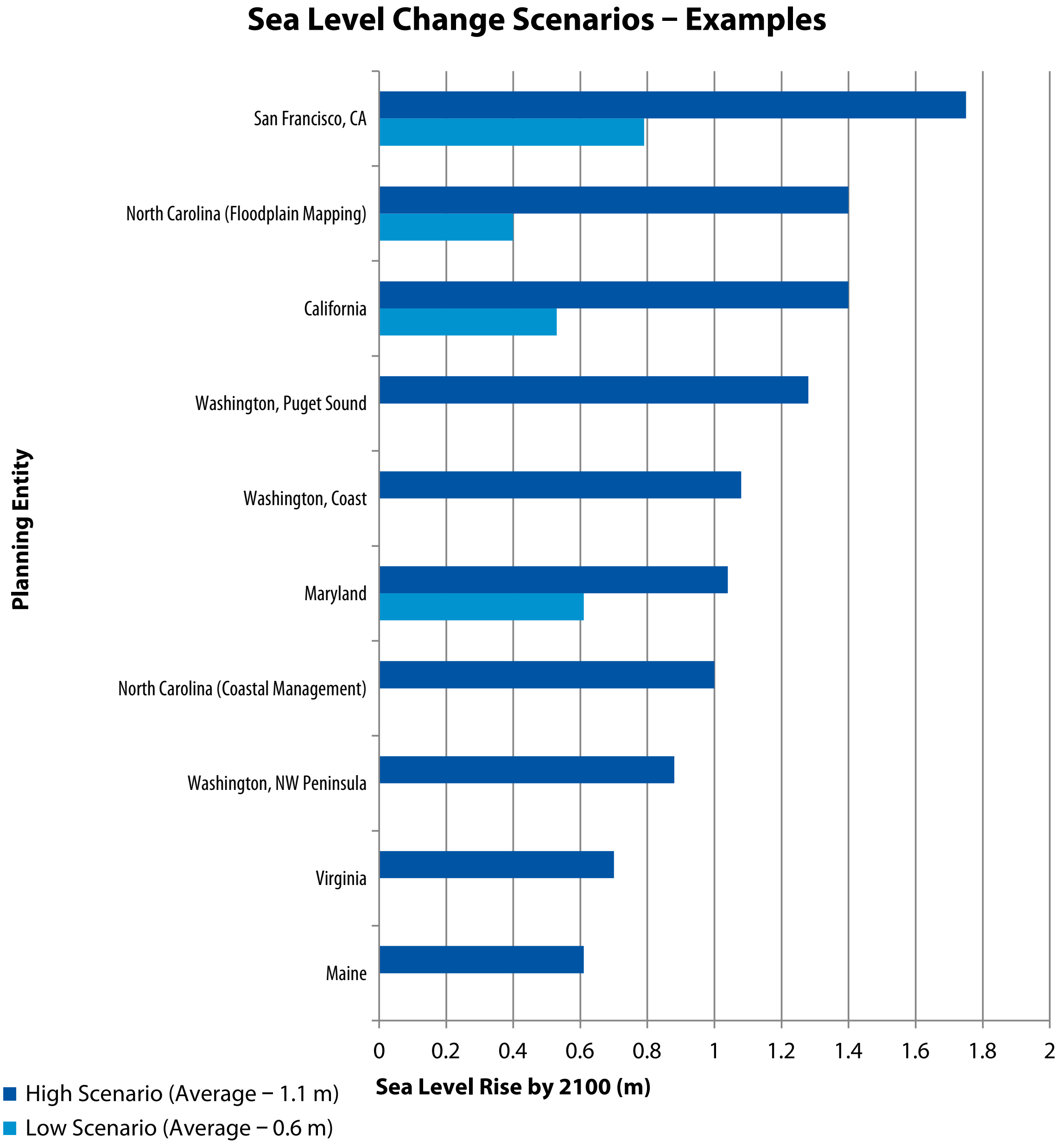


Figure 1: Sea Level Change Scenarios Used by Various State Planning Entities as of 2011.

Step 4: Calculate Sea Level Change Scenarios

At some point in the planning process, sea level change scenarios must be chosen—scenarios that incorporate global projections and local change rates. Most plans use a span of 100 years or a time horizon of 2100 as the endpoint. The Intergovernmental Panel on Climate Change's international consensus report provides a range of global sea level change scenarios (IPCC 2007), and it is from this range that a community can determine which scenarios make the most sense for their needs.

In some cases sea level change scenarios are used as planning targets, such as a 1-meter (m) rise by the year 2100. The scenario chosen should be relevant to the timescale of decisions being made. Banks may prefer to use a 30-year time frame for housing projects, since that is the lifetime for the average loan. Local officials would be wise to move beyond that if possible, as housing developments and infrastructure have a much longer life span, and sea levels are expected to increase over time. This approach would require using increments of sea level change over a specified number of years, such as 0.18 m to 0.30 m by 2050, and 0.30 m to 0.58 m by 2080, which is what the state of Connecticut is currently using for planning.

Whatever the approach, the selected sea level change increments should be derived from a reputable source and the vertical distance between increments supported by the vertical accuracy of the land elevation data, particularly if maps of sea level change will be produced. Failure to do this may result in uncertainty in the maps and in the resulting impact assessment.

Sea level change increments of 0.3 m to 0.6 m are reasonable to apply in mapping projects that use most current lidar data collection specifications.

Some applications choose not to tie sea level rise increments to a specific time frame. Rather sea level rise increments are illustrated and the user can choose the time horizon. For example, a library of maps showing 0 m to 2 m of sea level rise can be linked to any sea level rise curve. The impact assessment is attached to whatever timing the user selects.

Step 5: Understand Uncertainty

Uncertainty is present in sea level change projections because of the uncertainty inherent in the forces that drive these systems (for example, rate and magnitude of sea level rise, changes in storminess, changes in daily tide range) and the future evolution of coastal landforms (examples include barrier island overwash, migration, and man-made alterations).

Marshes on the Move, a recent document from the Nature Conservancy and the NOAA Coastal Services Center (2011), discusses another way to view sea level uncertainty:

> "A non-scientist may interpret uncertainty as meaning that the answer is not known and that any projection is just a guess. Scientists think of uncertainty as a specific, quantifiable measure of how well something is known. Scientific uncertainty comes in many shades of gray, not just black ("we are absolutely certain this is correct") or white ("we have no idea what the answer is"). In the context of wetland migration [or sea level rise] modeling, for example, a model result could have a confidence level of 95%, meaning that for all practical purposes it can be considered correct, even though there is a small amount of uncertainty [5 percent] associated with it. Talking in terms of "confidence levels" instead of "uncertainty" is one way to convey the intended meaning for both scientific and non-scientific audiences."

Step 6: Consider Changes to Flood Frequency and Duration

When developing community scenarios, officials must factor in all current flood-producing events, because sea level rise will likely increase the reach, frequency, and duration of "normal" flooding. For instance, if a location has witnessed sea level change of 5 mm per year, then after 50 years, sea level would be 250 mm (0.25 m) higher, which raises the impact of future flood events accordingly.

When projecting flood frequencies (for example, the 10-year event becoming the 1-year event because of rising sea levels), a hypothetical increase in relative sea level for a particular area is chosen for a specific year.

For example, figure 2 shows that in St. Petersburg, Florida, the highest water level above mean higher high water (MHHW) exceeded 0.9 m (3 feet) in 5 out of 60 years, which is classified as a 12-year event. If a rise of 0.3 m between now and 2050 is considered, the possible highest level of the year would be estimated by adding 0.3 m to each bar, meaning there would be 15 more years exceeding 0.9 m. The expected occurrence in this case would exceed 20 years out of 60 (or a 3-year event), or four times higher than the current probability. This method assumes that the magnitude and frequency of storms—storminess—and the associated flood responses will not change over time.

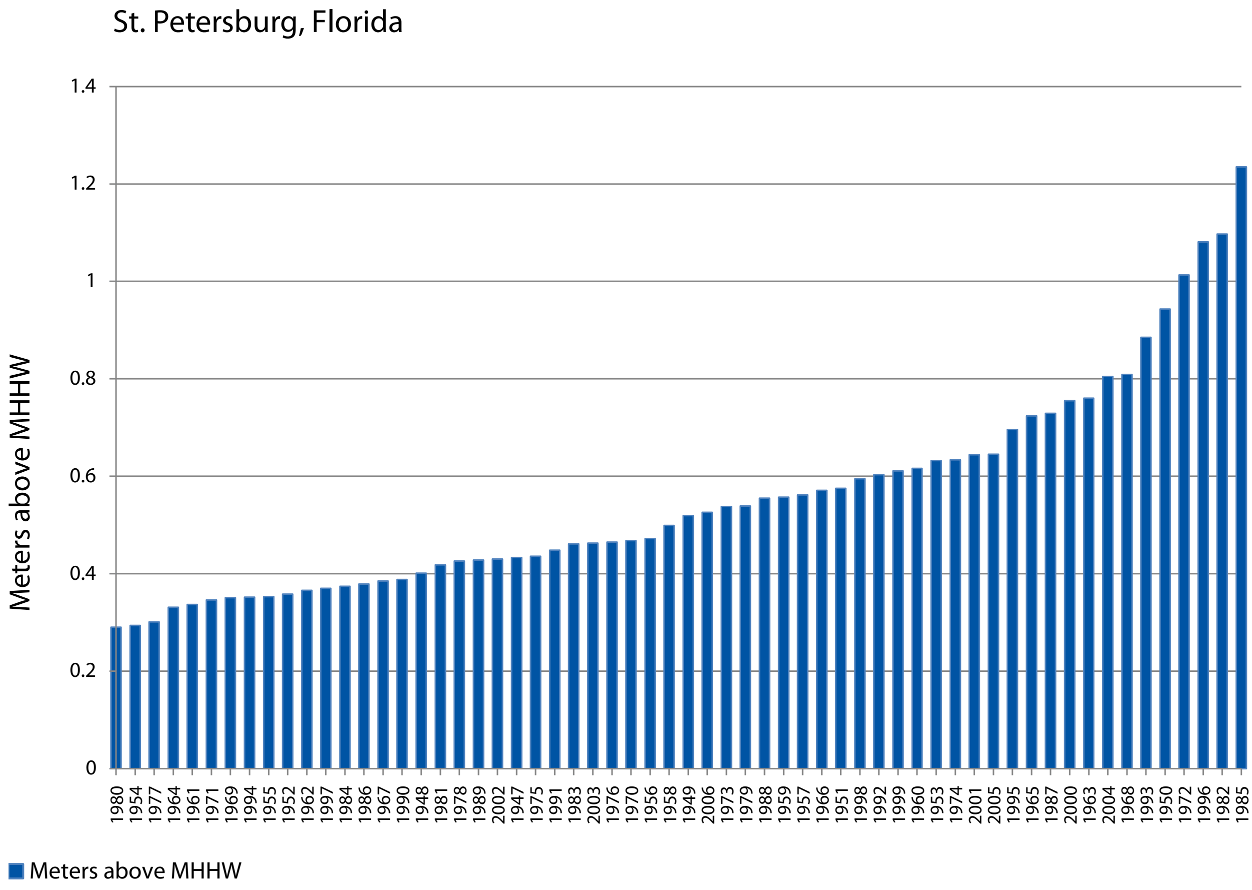


Figure 2: Annual Highest Water-Level Elevations Relative to Mean Higher High Water (MHHW) Measured at St. Petersburg, Florida, between 1947 and 2006. Return periods for high water level occurrences will increase as sea level rises.

Some of the most common extreme flood events are listed below.

Tide Heights

Tides dominate the daily change of water level along most of the coast. Because this range can vary substantially by location (figure 3), flooding should be described as it relates to the long-term average of the highest daily tide (mean higher high water, or MHHW) datum. Using these measurements creates spatial uniformity.

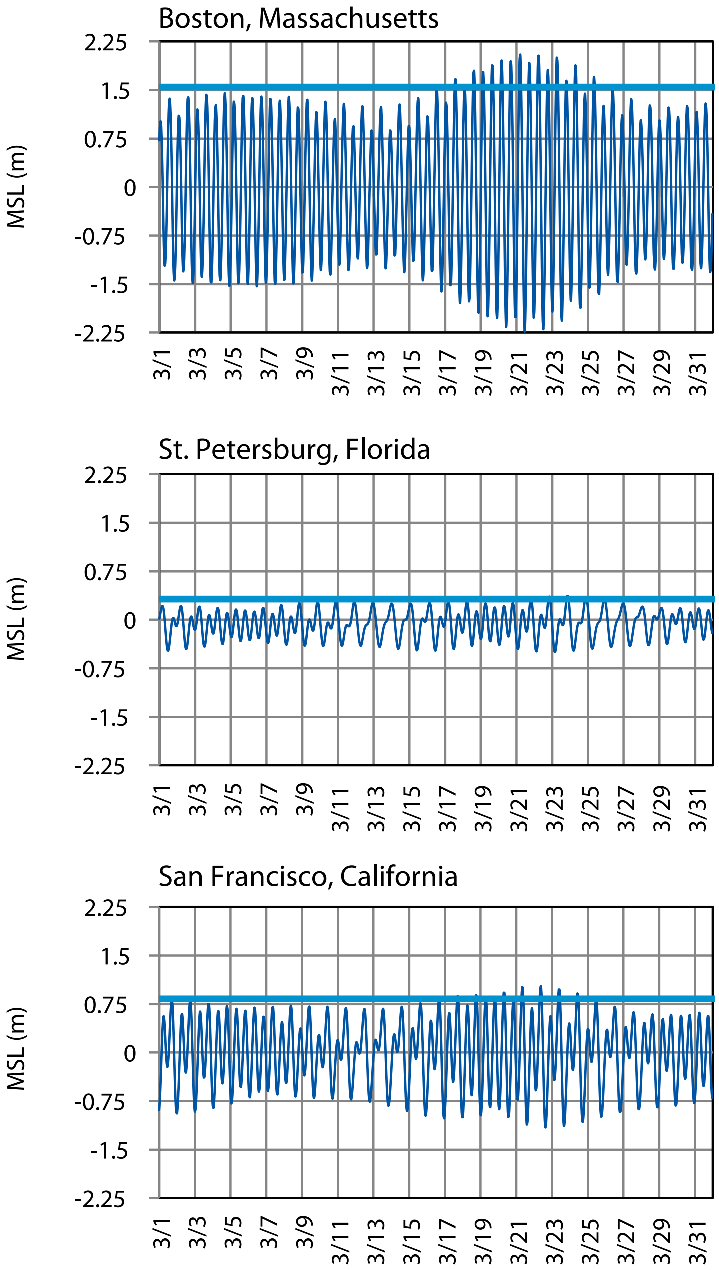


Figure 3: Predicted Tides for March 2011 along the Atlantic, Gulf, and Pacific Coasts Relative to Mean Sea Level (MSL). The tides exceed the mean higher high water (MHHW) datum during periods of large spring tides (March 19-25), which show even higher elevations as sea level seasonally changes.

Throughout the year a slow seasonal change of sea level also occurs and affects the flood height during the daily, spring, and neap tide cycles (figure 4). This cycle occurs in response to the normal seasonal changes of regional atmospheric pressure, wind patterns, coastal currents, river flows, and the heating and cooling of the ocean. Within the United States, the seasonal range of sea level typically varies by 0.1 to 0.3 m.

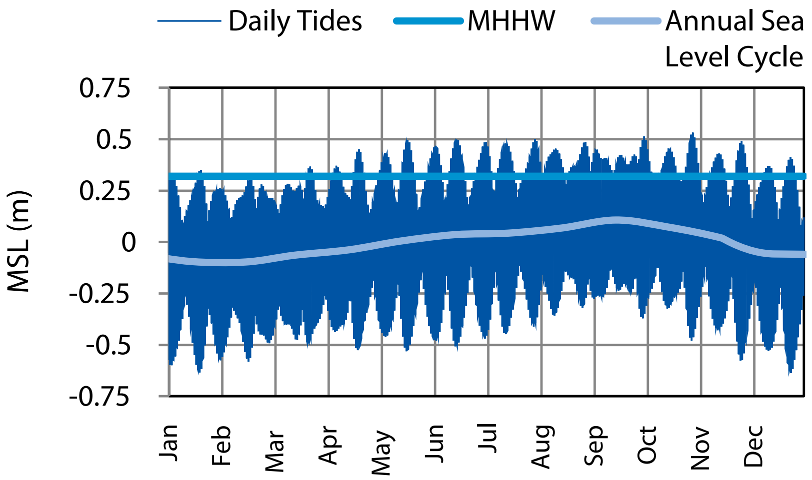


Figure 4: The Annual Cycle of Mean Sea Level (MSL) for St. Petersburg, Florida. The annual cycle changes the elevation or area impacted by the daily tidal range.

Storm Surge

Winds and low pressures associated with an atmospheric front can produce a storm surge. Storm surge, a non-tidal addition to the predicted tide level, is of concern when the surge is large in magnitude and persists over a complete tide cycle. The precise timing of a storm surge is random in nature, but it is often seasonal. For instance, the New England coastline is normally impacted during late fall to early spring, as shown in figure 5 below.

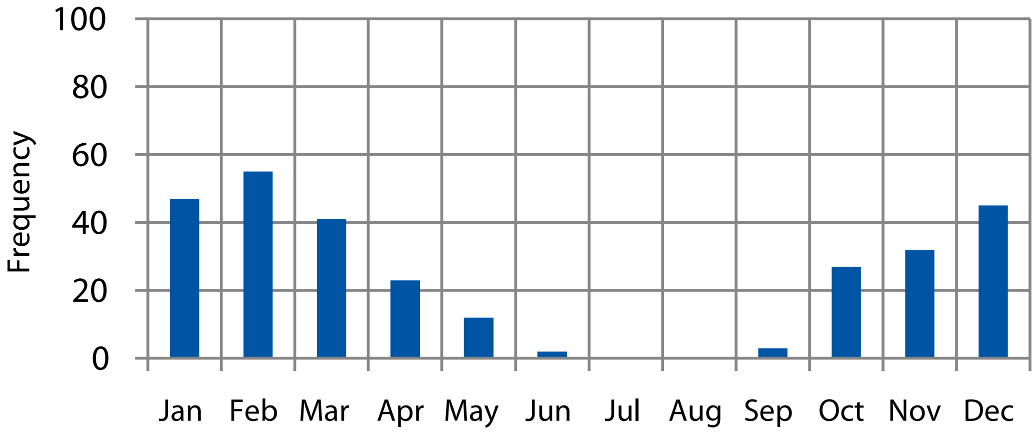


Figure 5: Number of Significant Storm Surges per Month in Boston, Massachusetts, 1960-2010. There is a higher frequency of nor'easter wind storms from October to April.

Extreme Water Levels

Equally important to consider are the episodic events such as flooding associated with a hurricane. Coastal storms and extreme floods are rare events that can result from a single cause (an extremely large storm surge) or a combination of causes (large surge at peak high tide). Water levels termed "extreme" vary widely in height along the U.S. coast, often because of the differences in the width of the continental shelf and the power of the storm event.

- *Winter storms* cover large areas and can build up extreme storm surges (greater than 2 m) over the course of several days. A long-lasting storm surge can cause multiple floods as it interacts with several tidal cycles. Winter storms and their surges drive extreme events along the New England coast and to a lesser extent, the mid-Atlantic and southeastern coasts.
- A *hurricane* is the primary driver of extreme events along the southeastern, Gulf, and U.S. tropical island coasts. The passage of an unusually strong hurricane over the shallow continental shelf can cause extremely high water levels. Hurricanes are usually smaller in area and move faster than winter storms, so they affect more limited areas and their storm surges interact with only one or two tidal cycles.
- *El Niño-Southern Oscillation* (ENSO) is most often associated with extreme events along the contiguous U.S. Pacific coast, though storm surges are relatively small due to the narrow continental shelves. During the El Niño phase, higher than average water levels appear along the coast, and a large spring tide or a wind storm in conjunction can cause an extreme event.

Likelihoods of extreme-flood events can be based on analyses of historical observations if the record adequately represents the possible combinations of the above-mentioned factors such as storm surge, tide level, and seasonal sea level. Computation of extreme-event likelihood is usually based on historical yearly water level events ranked from highest to lowest (for example, the 10-year event occurring on average once every 10 years would be nearly equal to the value ranked 10th out of 100 years).

Step 7: Consider Potential Impacts

Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region (CCSP 2009) provides a detailed description of some of the likely impacts of sea level change in the Mid-Atlantic region. Some of these are summarized here.

Along the coast, environmental health is closely linked to sea level. Many environments, including beaches, barrier islands, wetlands, and estuarine systems, adjust to increasing water level by growing vertically, migrating inland, or expanding laterally. If the rate of sea level change accelerates significantly, coastal environments may not be able to respond accordingly and will decrease in size or be submerged. These changes can fundamentally change the state of the coast.

Rapid sea level rise can force rapid landward migration that could submerge some barrier islands or destroy wetlands. The lower portion of Louisiana and the Mississippi Delta is a good example of this happening today. Other impacts are portrayed below.

Infrastructure and Land Loss

Rising seas are submerging low-lying lands, eroding beaches, converting wetlands to open water, exacerbating coastal flooding, and increasing the salinity of estuaries and freshwater aquifers. Additional contributors include coastal storms, development, and natural processes.

In undeveloped or less developed coastal areas, ecosystems and geological systems can sometimes shift upward and landward with the rising water levels. Coastal development often presents a barrier to this natural migration. This eventually results in the ecosystem converting to open water, rendering coastal development more vulnerable to storm and flooding impacts.

In coastal cities, critical infrastructure and facilities are already susceptible to flooding. Overlaying future sea level change scenario maps on critical facilities and infrastructure data maps helps people visualize potential impacts. Much of the preliminary work for this task has been done for most coastal communities with NOAA's Coastal County Snapshots tool. Visit *www.csc.noaa.gov/snapshots* to see coastal county data and the corresponding graphics.

Marsh Migration

As local sea levels increase, some marshes may migrate into neighboring low-lying areas, while other sections of marsh will be lost to open water or convert to an intertidal mudflat. The result is the loss of critical habitat for larval fish, natural sinks for sediments and pollutants, natural storage for floodwaters, and a cherished aesthetic quality of coastal regions.

Flooding Impacts

The expression "today's flood is tomorrow's high tide" has been used to convey future flooding impacts, since the floods of today will become more frequent and last longer. Low-lying coastal cities that occasionally experience coastal flooding problems will eventually be inaccessible during much of the year as relative sea level changes. Increased flooding can cause salt water to back up through storm drains and can cause hazardous road conditions. In some communities roads and businesses must close, and damage to buildings from repeated saltwater intrusion is a near certainty.

Social and Economic Impacts

A large portion of the nation's people and businesses are in coastal areas already vulnerable to flooding, and coastal flood losses make up the largest amount of total flood losses to the National Flood Insurance Program each year. Rising sea level will make this situation worse.

By overlaying social and economic data on a map that depicts potential sea level change, citizens can see the potential impact that sea level change can have on vulnerable people and businesses. The Social Vulnerability Index (*http://webra.cas.sc.edu/hvri/products/sovi.aspx*) can be used for this purpose.

Saltwater Intrusion

Storm surge can cause problematic saltwater intrusion into freshwater systems. In Florida, for example, the freshwater Everglades currently recharges Florida's Biscayne aquifer, the primary water supply to the Florida Keys. As rising water levels submerge low-lying portions of the Everglades, portions of the aquifer will become saline. Aquifers in New Jersey east of Philadelphia, which are recharged by freshwater portions of the Delaware River, are facing the same threat.

Bank and Bluff Failure

Much of the Great Lakes region of the United States may have to contend with bluff failure as climate change impacts are realized. As lake levels fall, so does the groundwater table, which decreases the hydrostatic pressure that keeps cliffs and bluffs stable. The result is a collapse of the bluff system, leading to coastal erosion. Another side effect is the increased spread of invasive plant species on the newly exposed land, choking native vegetation and thus negatively affecting the entire ecosystem.

Coastal Erosion

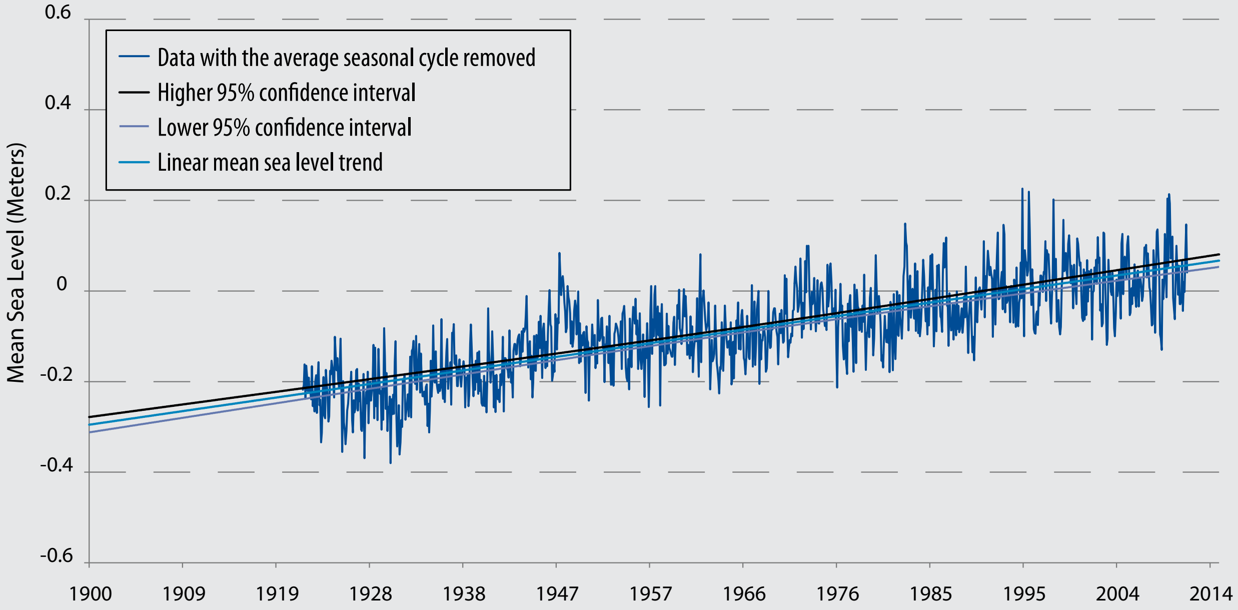
Coastal erosion is expected to increase. The exact manner and rates at which these changes are likely to occur will depend on the character of coastal landforms and physical processes. Particularly in sandy shore environments, which make up the entire mid-Atlantic ocean coast, coastal headlands, spits, and barrier islands will erode at a faster pace. Shore erosion increases vulnerability to storms by removing the beaches and dunes that would otherwise protect coastal property from storm waves. As the rate of sea level rise accelerates, it is likely that some barrier islands in this region will cross a threshold where rapid barrier island migration or segmentation will occur.

Flooding Magnified

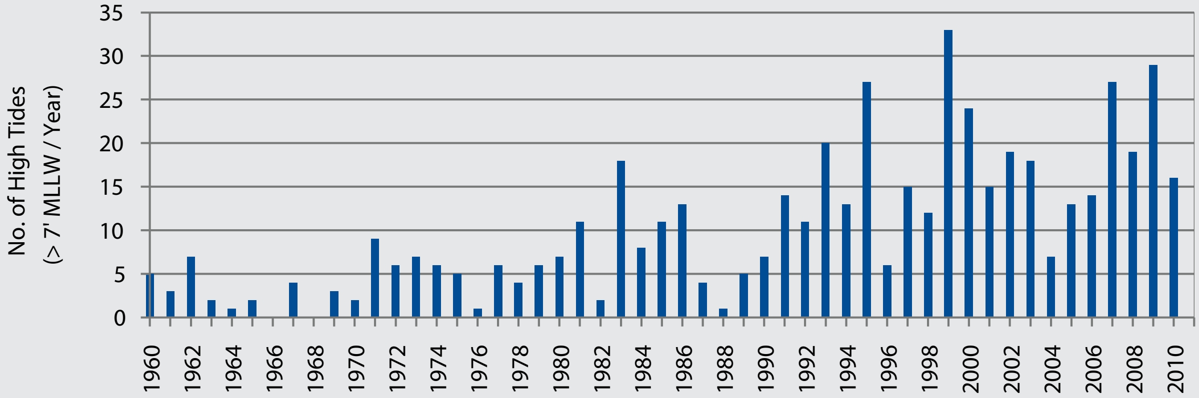
Water level data measured since the early 1920s in Charleston, South Carolina, indicate a slow increase in sea level (see graphs below). Five flood-producing tides (defined as seven feet or more above mean lower low water, or MLLW) were predicted for 2010. However, these types of predictions are based strictly on astronomical tides and don't take into account the increased extent of the flooding made likely when other factors such as rainfall and winds are added. Observed hourly records indicate that water levels reached 7 feet MLLW or higher 16 times in 2010, and the number of instances has been steadily rising in tandem with sea level. Eventually, today's occasional coastal floods will become regular events.

(a)

Source: NOAA



(b)



In Charleston, South Carolina, (a) relative sea level has increased (on the order of 1 foot, or 0.3 meters, in 100 years) and so too has (b) the number of high tides that have reached a flood-potential level (7 feet or more above MLLW).

Step 8: Communicate the Impacts

Sea level changes represent a serious problem for coastal communities. Unfortunately, the concept can be difficult to understand and the conversation can be politically charged.

The steps provided in this document are meant to help officials lead their communities to incorporate sea level change scenarios in local, state, and regional planning. Encouraging citizens to become knowledgeable and involved in the process is important but also challenging. To aid in communicating sea level rise scenarios, many communities are turning to visualizations.

The CanVis tool (*www.csc.noaa.gov/canvis*) is a helpful program that is easy to use. Users insert a picture of their community to serve as a backdrop, and various levels of sea level rise can be depicted on the image. This format has proven helpful in public meetings and for informational websites.

Another helpful tool is the Sea Level Rise and Coastal Flooding Impacts Viewer, which is found at *www.csc.noaa.gov/SLR* and is shown in figure 6.

A slider bar and a map are used to show how various levels of sea level change will impact a coastal community. Many of the nation's coastal communities are represented here, with new locations being added regularly.

The viewer is a screening-level tool that uses nationally consistent data sets and analyses. The viewer also provides simulations of sea level change at local landmarks, models potential marsh migration, provides information about social and economic impacts, and examines how tidal flooding will become more frequent with sea level change.

The data and maps in this tool illustrate the scale of potential flooding, not the exact location, and do not account for erosion, subsidence, or future construction.

Figure 6: Sea Level Rise and Coastal Flooding Impacts Viewer for Galveston, Texas. Use the tool by going to *www.csc.noaa.gov/SLR*.

Conclusion

When it comes to planning for sea level change impacts, the "one-size-fits-all" approach is not realistic. There are simply too many scientific variables, risk perceptions, and political implications unique to each location to consider. For this reason a scenario approach is preferred. Considering a range of possibilities lets community members and officials incorporate appropriate variables for their community when deciding how to best prepare for the future.

This publication, a companion document for a NOAA technical publication, outlines eight steps a community can take to develop site-appropriate scenarios. Due diligence is required for this process, but the result will be a reasonable and realistic approach to coastal community planning.

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Appendix

Sample Decision Tree for Planning for Sea Level Change Developed by the U.S. Army Corps of Engineers

Global mean sea level has risen over the past century, and the rate of rise will continue and may accelerate in the future. Future development and land use practices need to be planned, designed, constructed, and operated with the understanding that the rate of rise of global mean sea level may accelerate and affect areas next to the nation's coastal zone.

In other locations, the relative sea level is dropping, and therefore planners must account for the decrease in water levels and must balance this with the potential for increasing global mean sea level (MSL). In short, these factors need to be considered in relation to a planning horizon.

1. Determine if the study area (area of concern, or AOC) is in the coastal/tidal/estuarine zone, or if it borders those zones such that it may now or in the future be subject to influence by continued or accelerated rate of sea level rise. Determine the area's current georeferenced tidal datums.
2. Locate existing long-term tide stations in closest proximity to AOC that have similar physical conditions (coastal/estuarine location, bathymetry, topography, shoreline geometry, and hydrodynamic conditions). Consult with a tidal hydrodynamics expert if necessary.
3. Calculate local historic trends for MSL at long-term gauge. Use CO-OPS values, if available. If not available, use CO-OPS method for sea-level trend analysis (see NOAA Technical Report NOS 2010-01). This historic trend is now the low estimate or the baseline trend rate for AOC.
4. Evaluate whether there is a regional mean sea-level trend that is different from the global (eustatic) mean sea-level trend of 1.7 mm/year over the 20th century (+/- 0.5 mm/year, IPCC 2007) and determine if this "difference" will be consistent through planning horizon.
5. Estimate local rate of vertical land movement by sampling velocities of GPS-based continuously operating reference station (CORS) in and around the AOC. If a CORS rate is not available, then alternative methods can be applied. Other options include using values from glacial isostatic adjustment (GIA) models or relating (usually a simple subtraction between) the global MSL trend and the local MSL trend after a regional interannual-to-decadal signal has been removed from the local signal. Consult NOAA NGS and CO-OPS for assistance.
6. Calculate future MSL values for sea-level change for various scenarios including values that capture the lower and higher estimates of sea-level change based on state policy, or rates published in the latest peer-reviewed literature. Include different planning horizons (e.g., 25, 50, 75, 100 years).
7. Determine important flood-impact heights (e.g., 10-year or 100-year event) above MHHW now and compare to the resultant changes that will take place in the future after applying each of these rates (in step 6). Future flood-impact heights should be considered as low-end heights for planning (e.g., does not account for changes in future "storminess"). Map the inundation extent and depth for the various scenarios using a geographic information system.
8. Overlay inundation extents and depths for each sea-level change scenario on relevant planning layers to determine impacts for each scenario.
9. Assess risk and planning alternatives. Consider at a minimum: planning for adaptive management, designing to facilitate future modifications, and designing for a more aggressive future sea-level change scenario.
10. Select a planning scenario that best accommodates the range of sea-level change scenarios and perform cost-benefit analysis for planning alternatives to see if thresholds justify alternative.

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