State of the Science FACT SHEET

Sea Level Rise and Coastal Flooding

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

This summary provides the current state of the science related to sea level rise, its causes, future projections, and its impacts on coastal communities as developed by NOAA.

What is sea level and how do we measure it?

Sea level—the average height of the ocean relative to a specific point on land— is measured using a combination of tide stations along the coast and satellites. Tide stations around the globe tell us what is happening at a local level--how the ocean level is changing relative to the land. Satellite altimeters tell us how the height of the entire ocean is changing. Together, these tools tell us where sea level is today and how sea levels have been changing over time.

Is sea level rising?

Just as the surface of the Earth is not flat, the surface of the ocean is also not flat and it is not rising at the same rate either. 'Relative' sea level rise at specific locations may be more or less than the global average[1] due to factors like changes in regional ocean currents or the land height itself.

Global sea level has been rising since the last ice age, but the rate in the last century has been the fastest in the last 3000 years.[1] Global sea level rise and the rate of change along the US coast specifically are both accelerating. Global sea level has risen about 6-8 inches in the last 100 years (1920-2020), whereas relative sea level along the U.S coast has risen about 10-12 inches on average. Regional variation exists. Over the last 30 years, relative sea levels have risen about 5 inches nationally on average, with higher amounts along the Atlantic and eastern Gulf Coasts (6 in) and even higher (9 in) along the western Gulf Coast, but less (3-4 in) along the Hawaiian and Caribbean Coasts and (2-3 in) along the West Coast.[2]

Contributors to Global Sea Level Rise

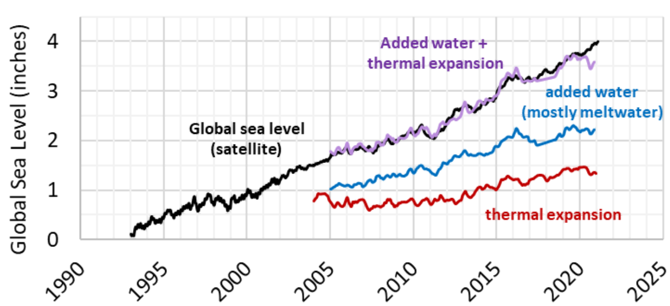

Figure 1: Observed sea level since the start of the satellite measurements (black line), with estimates of thermal expansion (red) and added water from ice sheet and glacier melt (blue). Added together (purple), these separate estimates match the observed sea level. Adapted from Figure 3.15a in State of the Climate in 2020.[3]

What is causing sea levels to rise?

The two major causes of global sea level rise (Fig.1) are melting of alpine glaciers and the ice sheets in Greenland and Antarctica and thermal expansion caused by warming of the ocean. More than 90 percent of the heating associated with human activity is being absorbed by the ocean,[1] causing it to further expand and melting the ice shelves that hold back inland ice sheets. Another incremental factor, although small, results primarily from groundwater pumping and dam building.

The Effects of Vertical Land Motion (VLM)

Even if sea levels were to remain constant, we would still perceive an apparent change due to the fact that land levels themselves are changing over time. Land subsidence (sinking) increases relative sea level change while uplift (rising) decreases the apparent change in sea level. Both subsidence and uplift are driven by the process of our earth's crust continuing to adjust to the large-scale glacial retreat that marked the end of the last ice age. On local and regional scales, subsidence can result from sediment compaction or by groundwater and fossil fuel extraction. VLM can significantly impact near-term inundation and long-term sea level rise models.

There are big differences in relative sea level trends due to differences in VLM alone, in addition to changes in mean sea level. For example, relative sea level in Grand Isle, LA has risen over 3 feet due in large part to subsidence, while relative sea level has decreased by more than 4 feet in Juneau, AK due in large part to uplift.[1]

The projections of US sea level rise referenced in this fact sheet account for both changes in global mean sea level and changes due to VLM.[2]

What impacts are rising sea levels having on coastal communities and ecosystems?

Higher sea levels mean that destructive storm surges will push farther inland and it also means more frequent high tide flooding, even in the absence of storms or heavy rainfall. Disruptive and expensive, high tide flooding is happening today at double the rate it was happening 20 years ago along the U.S. coastline as a whole, with 14 locations setting high tide flooding records with 2020 high tide flooding frequencies increasing between 400% to 1100% from 2000 frequencies.[4]

In urban settings, rising seas threaten private and commercial property and public systems like roads, storm and wastewater systems, buried cables, landfills—virtually all coastal infrastructure—are at risk from sea level rise. Rising seas stress coastal ecosystems that provide recreation, protection from storms, and habitat for fish and wildlife, including commercially valuable fisheries. As seas rise, saltwater is also contaminating freshwater aquifers, many of which sustain municipal and agricultural water supplies and natural ecosystems.

How high will future sea levels rise?

Sea levels will likely rise for many centuries at rates higher than those experienced today. How much it will rise (i.e., "sea level rise scenarios") depends mostly on the rate of future greenhouse gas emissions and how our atmosphere warms as a result of those emissions. How fast sea level will rise depends mostly on the melt rates or abrupt changes in the Greenland and Antarctic ice sheets. With almost 40 percent of the U.S. population living in densely populated coastal areas, coastal flooding and erosion hazard risks are certain to grow, increasing the urgency to plan for and adapt to these changes.

Both observations and the most recent sea level models[1] project that relative sea level along the U.S. coast will rise an additional 10-12 inches or so in the next 30 years (2020-2050; Fig. 2) which is equal to the amount of rise measured over the past 100 years.[2] Regionally, rise by 2050 is projected to be greater than average for the Atlantic (10-14 in) and Gulf (14-18 in) Coasts , less than average for the West Coast (4-8 in), the Caribbean (8-10 in) and Hawaiian (6-8 in) Islands and Alaska, and varied for the Pacific Islands.

By 2100, a rise of 2 feet (0.6 m) above 2020 levels is increasingly likely (Int. Low Projection in Fig. 2) based on current global warming and greenhouse gas trends. This translates to even a higher rise along the East and Gulf coasts because of land subsidence (e.g., a 3-foot rise along the Western Gulf). If emissions are not curbed, there is a possibility for rapid ice sheet loss in Greenland and in Antarctica that could lead to a rise of 3.5-7 feet along the U.S. coast by 2100, and even higher amounts by 2150.[2]

Additional Resources

- 2022 Sea Level Rise Technical Report
- NOAA Tides and Currents: The State of High Tide Flooding and Annual Outlook, 2021 Report
- Climate.gov, Climate Change and Sea Level Rise Webpage
- NOAA Tides and Currents Sea Level Trends
- NOAA Sea Level Rise Viewer
- Digital Coast: Stories from the Field

Contiguous U.S. Sea Levels Rise Scenarios

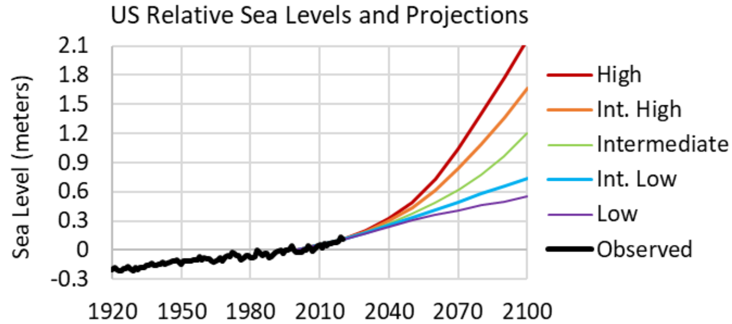

Figure 2: Observed (median) relative sea level from U.S. contiguous tide gauges (black) with projections through 2100 for five future scenarios (colored lines). The scenarios differ based on potential global warming amounts and Greenland and Antarctic ice sheet responses.[2] Note: 0.3 m = 1 foot.

What does this mean for communities?

Impacts due to rising seas are happening now and are expected to grow more severe.[4] By 2050, US coastal communities will have experienced a shift in coastal flood regimes. Major (destructive) and moderate (damaging) high tide floods will occur as often as moderate and minor (disruptive) floods occur today.[2] For example, moderate flooding today occurs less than once per year on average within East and Gulf Coast communities. By 2050, such flood events are projected to occur about 3-10 times per year, often lasting 1-2 days and several tide cycles.

Our coasts will be different in the decades to come, in some cases dramatically so. While sobering, we understand that these challenges present us with an important opportunity to define and shape the future of our coasts by taking informed action. Coastal communities should be undertaking adaptation planning efforts today which might include consideration of where to protect, accommodate, or retreat from anticipated impacts.

Citations

1 USGCRP. (2017).*Climate Science Special Report: Fourth National Climate Assessment*, Volume I: U.S. Global Climate Research Program. Washington, DC.
2 Sweet, W.V., B. Hamlington, R. Kopp, C. Weaver, P. Barnard, et al. (2022). *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD.
3 Johnson, G. C. and R. L. Lumpkin, Eds. (2021). Global Oceans [in "*State of the Climate in 2020*"]. Bull. Amer. Meteor. Soc., 102 (8): S143–S198.
4 Sweet, W.V., Simon, S., Dusek, G., Marcy, D., Brooks, W., Pendleton, M., Marra, J. (2021). *2021 State of High Tide Flooding and Annual Outlook.* National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD.
5 IPCC. (2021) *Climate Change 2021: The Physical Science Basis.* Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, et al. Eds. Cambridge University Press. In Press.