

Sea Level

As the temperature of the Earth changes, so does sea level. Temperature and sea level are linked for two main reasons:

1. Changes in the volume of water and ice on land (namely glaciers and ice sheets) can increase or decrease the volume of water in the ocean.
2. As water warms, it expands slightly—an effect that is cumulative over the entire depth of the oceans.

Changing sea levels can affect human activities in coastal areas. Rising sea level inundates low-lying wetlands and dry land, erodes shorelines, contributes to coastal flooding, and increases the flow of salt water into estuaries and nearby groundwater aquifers. Higher sea level also makes coastal infrastructure more vulnerable to damage from storms.

The sea level changes that affect coastal systems involve more than just expanding oceans, however, because the Earth's continents can also rise and fall relative to the oceans. Land can rise through processes such as sediment accumulation (the process that built the Mississippi River Delta) and geological uplift (for example, as glaciers melt and the land below is no longer weighed down by heavy ice). In other areas, land can sink because of erosion, sediment compaction, natural subsidence (sinking due to geologic changes), or engineering projects that prevent rivers from naturally depositing sediments along their banks. Changes in ocean currents such as the Gulf Stream can also affect sea levels by pushing more water against some coastlines and pulling it away from others, raising or lowering sea levels accordingly.

Scientists account for these types of changes by measuring sea level change in two different ways. *Relative* sea level change is how the height of the ocean rises or falls relative to the land at a particular location. In contrast, *absolute* sea level change refers to the height of the ocean surface above the center of the earth, without regard to whether nearby land is rising or falling.

This indicator presents trends in sea level based on measurements from tide gauges and from satellites that orbit the Earth. Tide gauges measure relative sea level change at points along the coast, while satellite instruments measure absolute sea level change over nearly the entire ocean surface. Many tide gauges have collected data for more than 100 years, while satellites have collected data since the early 1990s.

Exhibit 1 shows annual absolute sea level change averaged over the entire Earth's ocean surface. The long-term trend is based on tide gauge data that have been adjusted to show absolute global trends through calibration with recent satellite data. This long-term data set has been calculated through 2013, while satellite data are now available through the end of 2015. Exhibit 2 shows how absolute change in sea level varies by location, while Exhibit 3 shows geographic differences in relative sea level change, highlighting the 1960 to 2015 change at 67 tide gauges along the Atlantic, Pacific, and Gulf coasts of the United States.

What the Data Show

After a period of approximately 2,000 years of little change (not shown here), global average sea level rose throughout the 20th century, and the rate of change has accelerated in recent years (Titus et al., 2009). When averaged over all the world's oceans, absolute sea level increased at an average

rate of 0.06 inches per year from 1880 to 2013 (Exhibit 1). Since 1993, however, average sea level has risen at a rate of 0.11 to 0.14 inches per year—roughly twice as fast as the long-term trend. All of these trends are statistically significant, and the reliability of these conclusions is reinforced by the narrow 95 percent confidence bounds shown around the long-term reconstruction in Exhibit 1.

While absolute sea level has increased steadily overall, particularly in recent decades, regional trends vary, and absolute sea level has decreased in some places (Exhibit 2). Relative sea level also has not risen uniformly because of regional and local changes in land movement and long-term changes in coastal circulation patterns. Relative sea level rose along much of the U.S. coastline between 1960 and 2015, particularly the Mid-Atlantic coast and parts of the Gulf coast, where some stations registered increases of more than 8 inches (Exhibit 3). Meanwhile, relative sea level fell at some locations in Alaska and the Pacific Northwest. At those sites, even though absolute sea level has risen, land elevation has risen more rapidly.

Limitations

- Relative sea level trends represent a combination of absolute sea level change and any local land movement. Tide gauge measurements such as those in Exhibit 3 generally cannot distinguish between these two different influences without an accurate measurement of vertical land motion nearby.
- Some changes in relative and absolute sea level can be due to multi-year cycles such as El Niño and La Niña, which affect coastal ocean temperatures, salt content, wind patterns, atmospheric pressure (and thus storm tracks), and currents. Obtaining a reliable trend can require many years of data, which is why the satellite record in Exhibit 1 has been supplemented with a longer-term reconstruction based on tide gauge measurements.

Data Sources

The absolute sea level trends in Exhibit 1 were provided by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO, 2015) and the National Oceanic and Atmospheric Administration (NOAA, 2016a). These data are based on measurements collected by satellites and tide gauges.

Exhibit 2 was produced using data provided by the University of Colorado at Boulder (2016) (<http://sealevel.colorado.edu>). These data are based on measurements from the National Aeronautics and Space Administration's (NASA's) satellite altimeters, which have been processed through April 2016.

The relative sea level trends in Exhibit 3 are based on data from NOAA (2016b). NOAA publishes an interactive online map (<http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml>) with links to detailed data for each tide gauge.

References

CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2015 update to data originally published in: Church, J.A., and N.J. White. 2011. Sea-level rise from the late 19th to the early 21st century. *Surv. Geophys.* 32:585–602. www.cmar.csiro.au/sealevel/sl_data_cmar.html.

NOAA (National Oceanic and Atmospheric Administration). 2016a. Laboratory for Satellite Altimetry: Sea level rise. Accessed June 2016. http://www.star.nesdis.noaa.gov/sod/lsa/SeaLevelRise/LSA_SLR_timeseries_global.php.

NOAA. 2016b. Update to data originally published in: NOAA. 2009. Sea level variations of the United States 1854–2006. NOAA Technical Report NOS CO-OPS 053.

www.tidesandcurrents.noaa.gov/publications/Tech_rpt_53.pdf (PDF) (194 pp, 5.6MB).

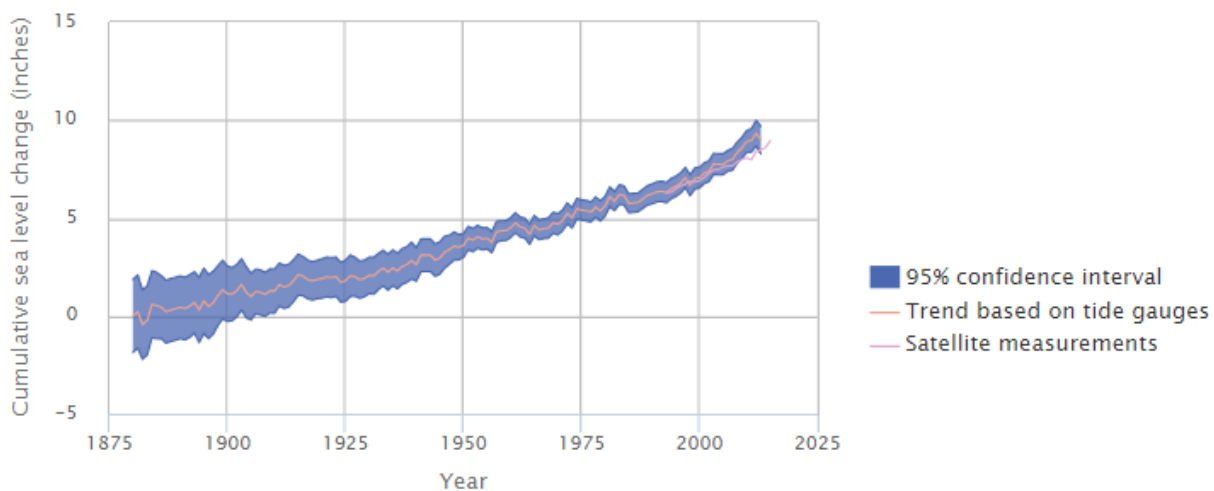
Titus, J.G., E.K. Anderson, D.R. Cahoon, S. Gill, R.E. Thieler, and J.S. Williams. 2009. Coastal sensitivity to sea-level rise: A focus on the Mid-Atlantic region. U.S. Climate Change Science Program and the Subcommittee on Global Change Research.

www.globalchange.gov/engage/process-products/sap-summary.

University of Colorado at Boulder. 2016. Sea level change: 2016 release #3. Accessed August 2016.

<http://sealevel.colorado.edu>.

Exhibit 1. Global average absolute sea level change, 1880–2015

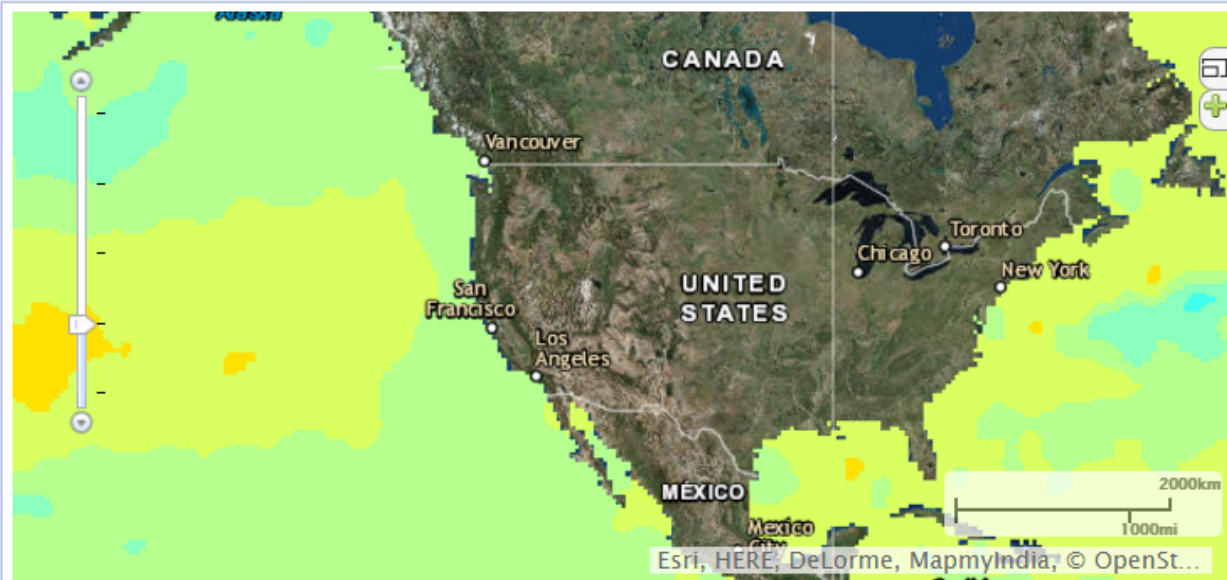


Trends are based on long-term tide gauge measurements and recent satellite measurements.

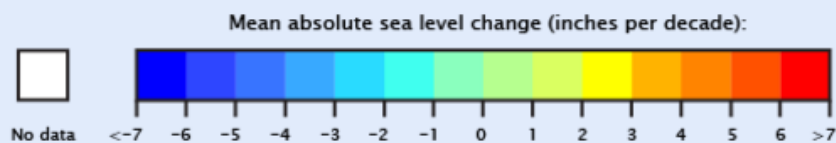
Analysis shows that these trends are statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: CSIRO, 2015; NOAA, 2016a

Exhibit 2. Changes in absolute sea level along U.S. coasts, 1993–2016



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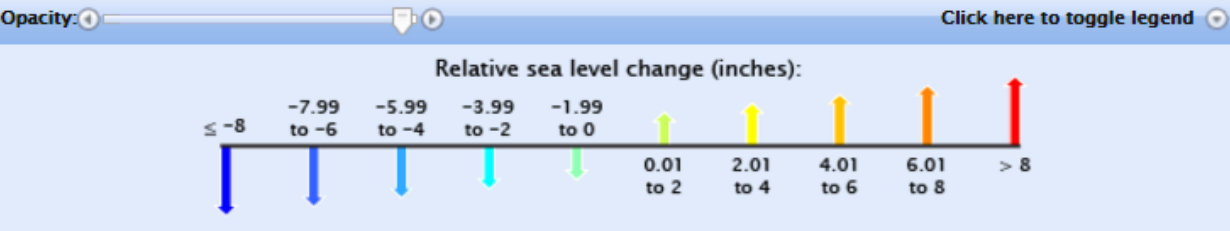
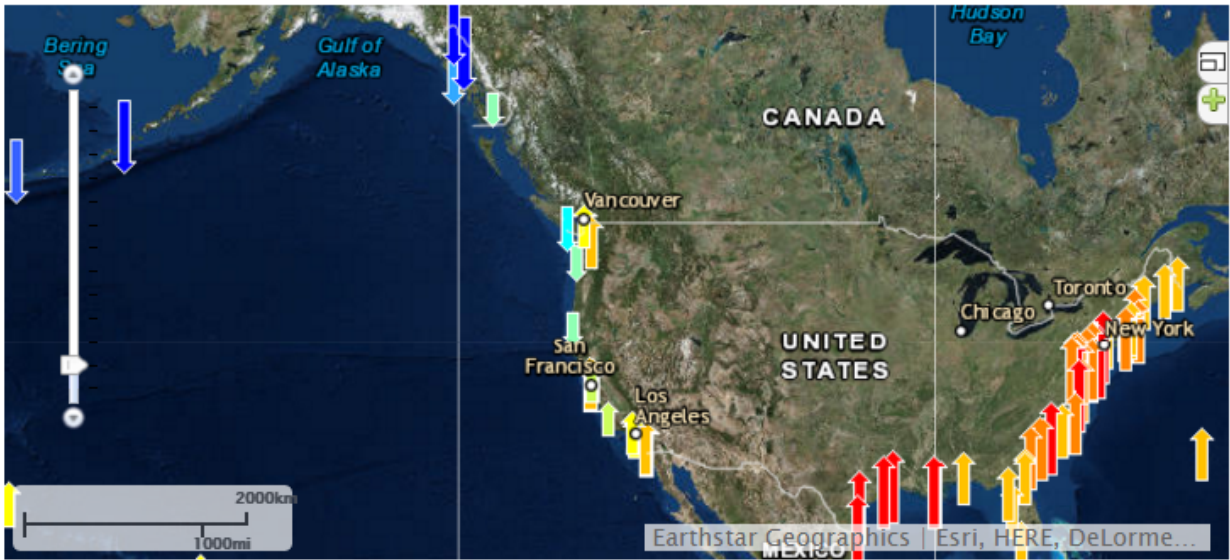


Trends are based on satellite measurements. Data were adjusted by applying an inverted barometer (air pressure) correction.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: University of Colorado at Boulder, 2016

Exhibit 3. Relative sea level change along U.S. coasts, 1960–2015



Trends are based on tide gauge measurements. Each arrow represents a tide gauge station that operated during the period 1960–2015.

Analysis shows that most of these trends are statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: NOAA, 2016b