

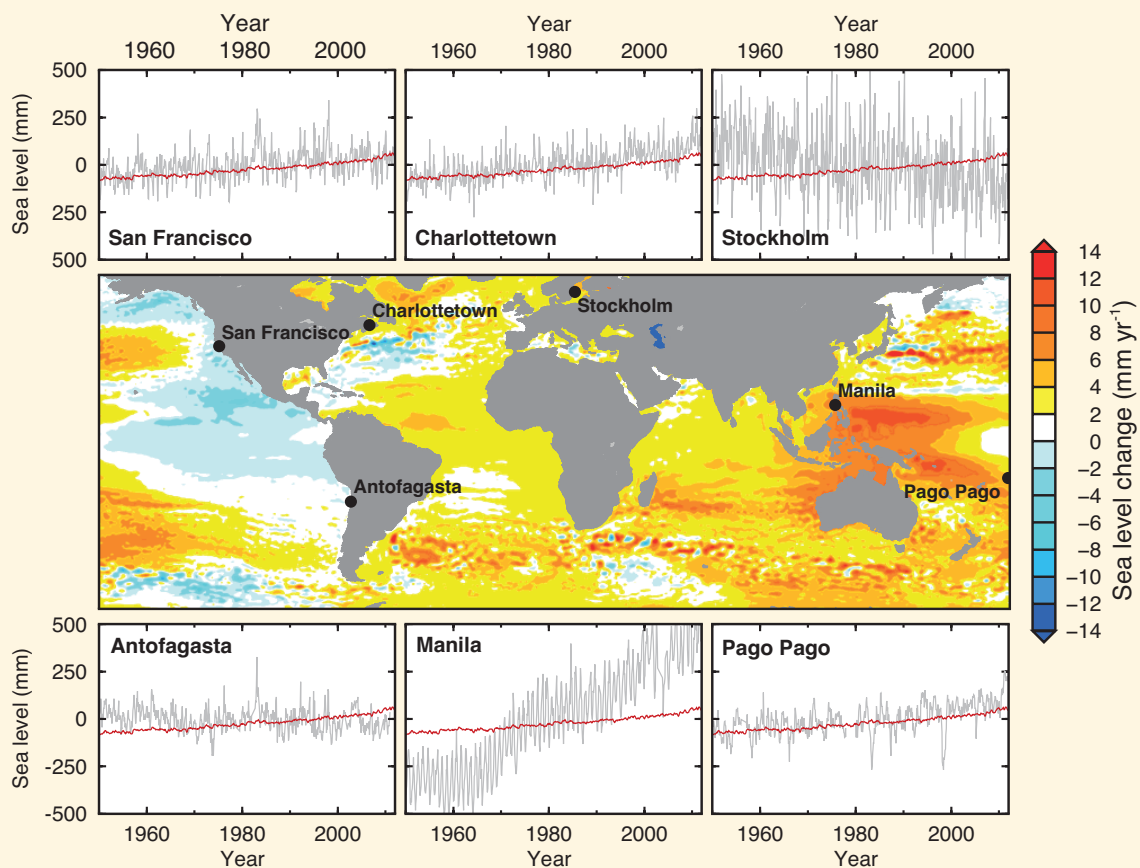
Frequently Asked Questions

FAQ 13.1 | Why Does Local Sea Level Change Differ from the Global Average?

Shifting surface winds, the expansion of warming ocean water, and the addition of melting ice can alter ocean currents which, in turn, lead to changes in sea level that vary from place to place. Past and present variations in the distribution of land ice affect the shape and gravitational field of the Earth, which also cause regional fluctuations in sea level. Additional variations in sea level are caused by the influence of more localized processes such as sediment compaction and tectonics.

Along any coast, vertical motion of either the sea or land surface can cause changes in sea level relative to the land (known as relative sea level). For example, a local change can be caused by an increase in sea surface height, or by a decrease in land height. Over relatively short time spans (hours to years), the influence of tides, storms and climatic variability—such as El Niño—dominates sea level variations. Earthquakes and landslides can also have an effect by causing changes in land height and, sometimes, tsunamis. Over longer time spans (decades to centuries), the influence of climate change—with consequent changes in volume of ocean water and land ice—is the main contributor to sea level change in most regions. Over these longer time scales, various processes may also cause vertical motion of the land surface, which can also result in substantial changes in relative sea level.

Since the late 20th century, satellite measurements of the height of the ocean surface relative to the center of the Earth (known as geocentric sea level) show differing rates of geocentric sea level change around the world (see FAQ 13.1, Figure 1). For example, in the western Pacific Ocean, rates were about three times greater than the global mean value of about 3 mm per year from 1993 to 2012. In contrast, those in the eastern Pacific Ocean are lower than the global mean value, with much of the west coast of the Americas experiencing a fall in sea surface height over the same period. *(continued on next page)*



FAQ13.1, Figure 1 | Map of rates of change in sea surface height (geocentric sea level) for the period 1993–2012 from satellite altimetry. Also shown are relative sea level changes (grey lines) from selected tide gauge stations for the period 1950–2012. For comparison, an estimate of global mean sea level change is also shown (red lines) with each tide gauge time series. The relatively large, short-term oscillations in local sea level (grey lines) are due to the natural climate variability described in the main text. For example, the large, regular deviations at Pago Pago are associated with the El Niño-Southern Oscillation.

FAQ 13.1 (continued)

Much of the spatial variation shown in FAQ 13.1, Figure 1 is a result of natural climate variability—such as El Niño and the Pacific Decadal Oscillation—over time scales from about a year to several decades. These climate variations alter surface winds, ocean currents, temperature and salinity, and hence affect sea level. The influence of these processes will continue during the 21st century, and will be superimposed on the spatial pattern of sea level change associated with longer term climate change, which also arises through changes in surface winds, ocean currents, temperature and salinity, as well as ocean volume. However, in contrast to the natural variability, the longer term trends accumulate over time and so are expected to dominate over the 21st century. The resulting rates of geocentric sea level change over this longer period may therefore exhibit a very different pattern from that shown in FAQ 13.1, Figure 1.

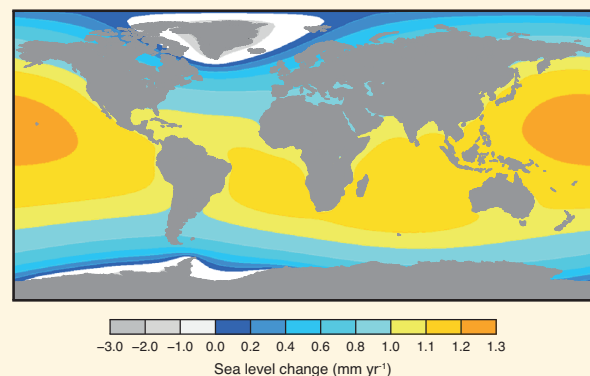
Tide gauges measure relative sea level, and so they include changes resulting from vertical motion of both the land and the sea surface. Over many coastal regions, vertical land motion is small, and so the long-term rate of sea level change recorded by coastal and island tide gauges is similar to the global mean value (see records at San Francisco and Pago Pago in FAQ 13.1, Figure 1). In some regions, vertical land motion has had an important influence. For example, the steady fall in sea level recorded at Stockholm (FAQ 13.1, Figure 1) is caused by uplift of this region after the melting of a large (>1 km thick) continental ice sheet at the end of the last Ice Age, between ~20,000 and ~9000 years ago. Such ongoing land deformation as a response to the melting of ancient ice sheets is a significant contributor to regional sea level changes in North America and northwest Eurasia, which were covered by large continental ice sheets during the peak of the last Ice Age.

In other regions, this process can also lead to land subsidence, which elevates relative sea levels, as it has at Charlottetown, where a relatively large increase has been observed, compared to the global mean rate (FAQ 13.1, Figure 1). Vertical land motion due to movement of the Earth's tectonic plates can also cause departures from the global mean sea level trend in some areas—most significantly, those located near active subduction zones, where one tectonic plate slips beneath another. For the case of Antofagasta (FAQ 13.1, Figure 1) this appears to result in steady land uplift and therefore relative sea level fall.

In addition to regional influences of vertical land motion on relative sea level change, some processes lead to land motion that is rapid but highly localized. For example, the greater rate of rise relative to the global mean at Manila (FAQ 13.1, Figure 1) is dominated by land subsidence caused by intensive groundwater pumping. Land subsidence due to natural and anthropogenic processes, such as the extraction of groundwater or hydrocarbons, is common in many coastal regions, particularly in large river deltas.

It is commonly assumed that melting ice from glaciers or the Greenland and Antarctic ice sheets would cause globally uniform sea level rise, much like filling a bath tub with water. In fact, such melting results in regional variations in sea level due to a variety of processes, including changes in ocean currents, winds, the Earth's gravity field and land height. For example, computer models that simulate these latter two processes predict a regional fall in relative sea level around the melting ice sheets, because the gravitational attraction between ice and ocean water is reduced, and the land tends to rise as the ice melts (FAQ 13.1, Figure 2). However, further away from the ice sheet melting, sea level rise is enhanced, compared to the global average value.

In summary, a variety of processes drive height changes of the ocean surface and ocean floor, resulting in distinct spatial patterns of sea level change at local to regional scales. The combination of these processes produces a complex pattern of total sea level change, which varies through time as the relative contribution of each process changes. The global average change is a useful single value that reflects the contribution of climatic processes (e.g., land-ice melting and ocean warming), and represents a good estimate of sea level change at many coastal locations. At the same time, however, where the various regional processes result in a strong signal, there can be large departures from the global average value.



FAQ 13.1, Figure 2 | Model output showing relative sea level change due to melting of the Greenland ice sheet and the West Antarctic ice sheet at rates of 0.5 mm yr^{-1} each (giving a global mean value for sea level rise of 1 mm yr^{-1}). The modelled sea level changes are less than the global mean value in areas near the melting ice but enhanced further afield. (Adapted from Milne et al., 2009)