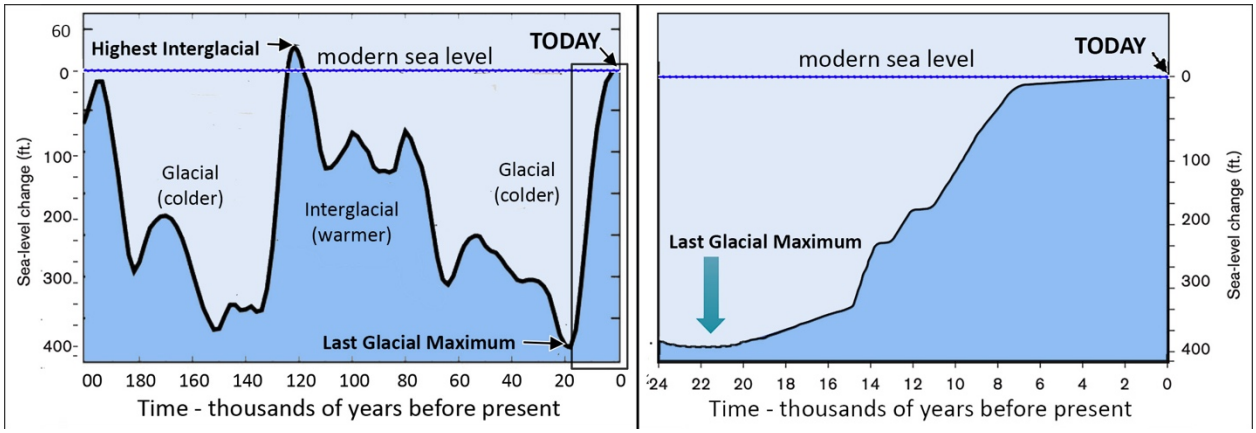
Times Standard

Not My Fault: Sea level is changing in a complex way

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These graphs show sea level relative to the modern global average. The graph on the left shows the past 200,000 years, based on ice volume estimated from ocean chemistry (modified from Martinson et al.,1987). Ocean levels plunged close to 400 feet below the modern level during glacial maximums and was about 20 feet higher at the peak of the last interglacial period. The area in the box is expanded on the right to show how sea level has risen since the last glacial maximum about 20,000 years ago. It is based on actual sea level measurements from 10 sites around the globe and shows the steady rise up until 8,000 years ago and the relatively stable sea level since then (modified from Global Warming Art Project by Robert A. Rohde.)

There's a good chance that Humboldt County and other locations on the California coast will set new all-time high-water records during this week's king tides. Astronomical tide forecasts for the North Spit gauge located near the Coast Guard Station at the south end of the Samoa Peninsula will exceed 8 feet Monday through Friday and reach a maximum of 8.6 feet on Wednesday. These high tides will be riding atop a base sea level already elevated by about 1.5 feet from this year's El Niño. Storm dynamics could easily add another foot. If we don't set a record this month, the king tide cycles near Christmas and in January will provide more opportunities.

Human settlement has always been drawn to the coast by its gentler topography, fertile coastal planes, access to marine resources, and ocean-moderated climate. Even today with our abilities to live almost anywhere, about 40% of the global population live within 60 miles of the coast. We've built massive coastal infrastructure based on our "fixed" coastline and, until the latter part of the 20th century, most thought of mean sea level as a constant.

The current El Niño sea level bulge has piqued my interest in how sea level is changing so here's an overview of my modest dive into the data. Sea level is not a constant and changes enormously in space and time. Despite a warming planet, there are a number of places where

the level of the ocean relative to land is dropping. Forget your bathtub analogy where adding water causes a uniform rise. Sea level change is far more complicated.

We know about the present sea level with a high degree of accuracy. Satellites sample ocean surfaces to yield 10-day averages with centimeter precision. Averaging about 2 mm/yr in the 1990s, the current global average rate has more than doubled to 4.5 mm/yr. Global tide gauges give a more detailed spatial story and show the variability of sea level change at specific coastal locations. In some places the sea is rising (or falling) about ten times faster than the average.

Human activities and geologic processes can cause the land to sink or rise, adding to or subtracting from that global average. The sea is rising in Jakarta, Indonesia at an astounding 45 mm/yr. Areas in Bangladesh and Vietnam show rises of about 20 mm/yr, much higher than the global average. These areas are all located on river deltas with soft sediments that compact with urbanization. Ground water pumping exacerbates the rate of land subsidence. These same factors make Grand Isle, Louisiana, located on the Mississippi delta, the U.S. sea level rise champion at a rate of 10 mm/yr.

There are several spots on the planet where the relative sea level is lowering nearly as fast as the rise in the delta locations. The ocean is dropping in the Amundsen Sea Embayment of West Antarctica at an astounding rate of 35 – 45 mm/yr. Greenland coastlines show lowering rates between 10 – 30 mm/yr. Scandinavia, Hudson Bay, and Alaska all feature areas where sea level is dropping. I was fascinated by the coastal changes in Iceland where we visited in 2023 where sea level is dropping at rates of 10 – 38 mm/yr along some areas of the southeastern coast. In contrast, the northern part of the island has shown almost no change in sea level.

Isostasy is to blame for most of these areas where the ocean height appears to be dropping. During the last glacial maximum about 20,000 years ago, these land masses were covered in thick ice sheets. The earth's mantle is not rigid and slowly deforms when weight is added or removed from the crust above it. Nearly 6% of earth's water was locked up on land during the peak of the ice age and these weighty sheets caused the land to sink. As the planet warmed and the ice melted or thinned, the weight was removed and, just like a bathtub duck pushed below the water, land rose when the force was removed. Iceland's lopsided sea level changes are the result of ice retreating at different times over the island.

Sea level changes on the U.S. west coast illustrate another factor that complicates relative land-to-ocean heights. NOAA operates 43 tide gauges that continuously measure water levels between the Baja border and British Columbia and can be used to determine precise sea levels during their time of operation. Only the northernmost part of this area was glaciated yet four tide gauges show a lowering sea level and the others have rates of rise that vary by a factor of about 6. The reason for the variability is tectonics. Compression and stretching deforms coastal rocks causing some areas to uplift and others to subside.

The Neah Bay tide gauge on Washington's Olympic Peninsula shows the sea level dropping at a rate of nearly 1.8 mm/yr. To overcome the global average sea level rise, this means the Neah Bay area must be uplifting at a rate of over 6 mm/yr. The compressional forces associated with the convergence of the Juan De Fuca and North American plates along the Cascadia subduction zone is currently causing this area to uplift much faster than the ocean is rising. The nearby Astoria gauge in Oregon also shows a relative ocean drop but at a much lower rate. Further

south along the Oregon coast, tide gauges all show rising sea levels, but at rates below the global average, suggesting tectonic compression is still causing the land to uplift but not by enough to outpace the ocean.

The most interesting place to look at sea level variability is in our own backyard. The North Spit tide gauge shows sea level rising at a rate of nearly 6 mm/yr, the highest of any site on the U.S. west coast. The Crescent City gauge located about 70 miles to the north shows the ocean dropping at a rate of over 0.7 mm/yr. Compressional forces are causing the downward fold that Humboldt Bay sits in to deepen and upward folding near Crescent City to grow higher. I wish we had more tide gauges between these two instruments. I expect we would see much more variability in rates of sea level change reflecting the complexity of our coastal tectonics.

The present-day sea-level changes are miniscule compared to the more distant past. During the last glacial maximum about 20,000 years ago when the ice caps were weighting down Iceland, Scandinavia and much of the northernmost part of our hemisphere, sea levels dropped nearly 400 feet relative to current coastlines. In Humboldt County, all of Humboldt Bay was dry and the coast was roughly 10 miles further west. Similar low levels occurred roughly 150,000 years ago during the previous glacial maximum. In between the two was a warmer interglacial period when all of the Greenland ice melted and the Antarctic cap was greatly reduced. Ocean levels may have been 30 feet higher than today's sea level about 125,000 years ago.

Human civilization developed in this environment of rapidly changing sea level and climate. An article by Toby Lester in this month's Atlantic (https://www.theatlantic.com/magazine/2026/12/aquaterra-ancient-human-migration/689029/) addresses how our perception of human history has been warped by the rising sea. Aquaterra, a term coined by anthropologist Nicholas Fleming, includes all the land between about 300 feet depth offshore to the modern coastline that has been submerged as the ocean rose. It's an enormous amount of real estate, roughly equivalent to the size of South America and would have been the home to most of our human ancestors during the stone age when human societies were first developing. A new branch of anthropology has emerged focusing on submerged prehistory and is revealing a multitude of communities and artifacts around the globe.

Early peoples were adept at adapting to their changing environment. Modern civilization may find it more of a challenge. A look at sea levels since the last glacial maximum shows rapid water rise between 18,000 and 8,000 years ago. Since then, the sea has been remarkably stable, enabling rapid coastal development and a sense of permanence. In the next few decades, we will be tested and how we respond to a changing sea level will provide the outcome.

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