January 2023

CliSciPol

Climate Science and Policy for Nonscientists

One picture is worth a thousand words.

How much will sea levels rise by 2100?

Sea level rise or fall is caused by global warming or cooling. A significant majority of the published papers find that the Medieval Warm Period was warmer than today, although this is denied by IPCC AR6. (Fn.1). Sea levels were about one foot higher than today during the Medieval Warm Period, which confirms a warmer temperature. It is generally agreed that the Little Ice Age, which bottomed out in the 1600s, was significantly colder than today. The 1600s were a miserable time to be alive in Europe. There were numerous crop failures and famines. Sea levels were about one foot lower than today during the Little Ice Age.

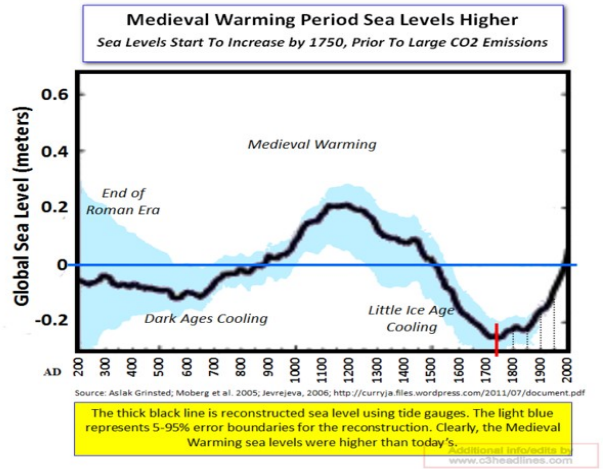
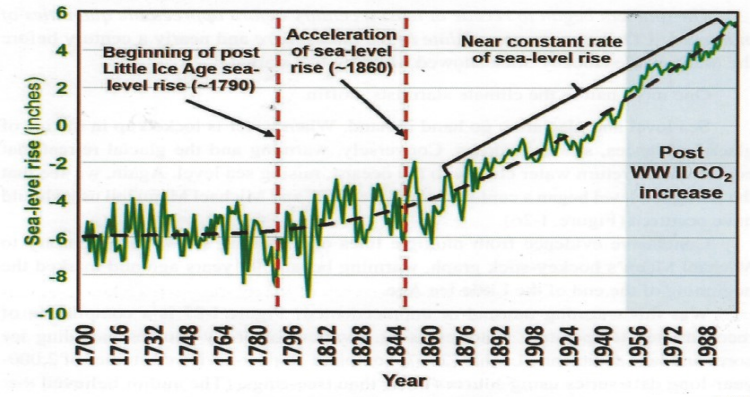


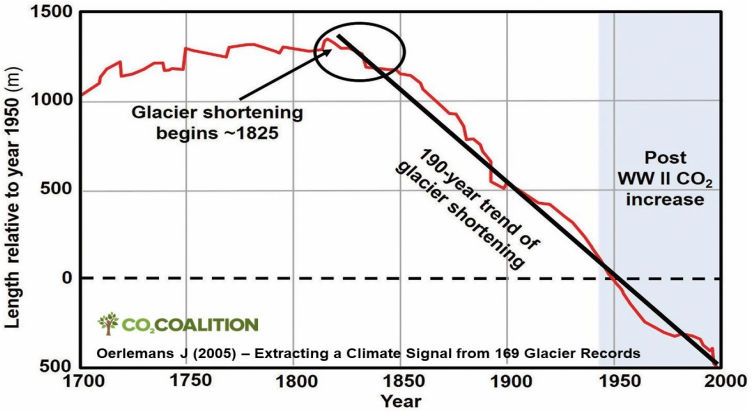
Figure I-26: Greater than 200 years of sea-level rise



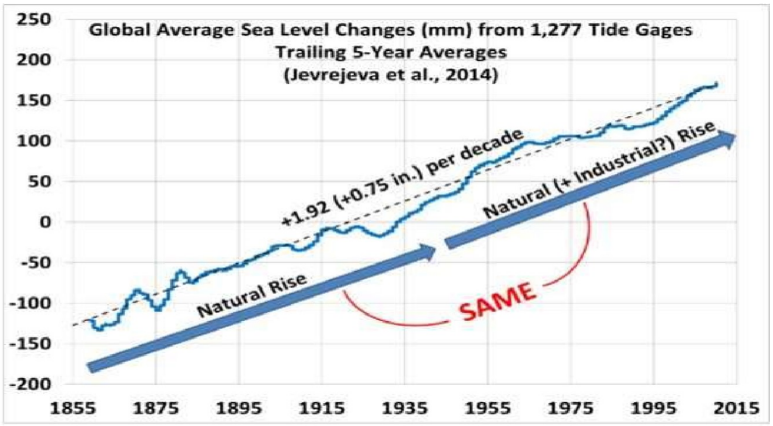
(Source data: Jevrejeva 2008, PSMSL 2008)

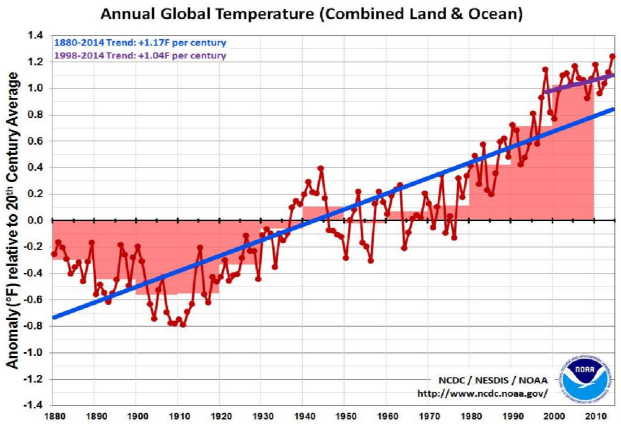
In the 1700s the world started its modern warming period, and by the late 1700s sea levels started to rise. The rate of rise increased until the mid-1800s, and, since the mid-1800s, the rate of rise, as measured by tide gauges, has remained remarkably constant, despite the significant increase in atmospheric CO2 levels after the 1950s.

Non-polar glaciers started retreating (as measured in feet per year) in the 1820s. The rate of melting has remained roughly constant since that time, again despite the significant increase in atmospheric CO2 levels after the 1950s. The run-off from melting glaciers is one of the significant contributors to sea level rise.



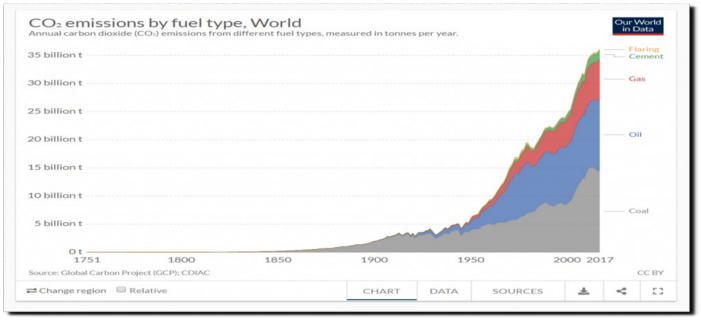
Scientists have good quantities of quality tide gauge data since the mid-1800s. Tide gauge data is available from over 2,000 ports. This study concluded that the rate of rise for the last 160-odd years has been steady at 7.5 inches/century.

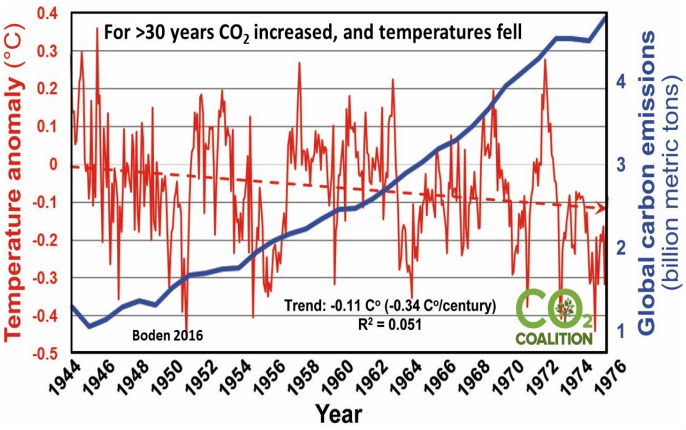




World temperatures have been rising at a relatively linear rate for the last 140 years or so. AR6 states that the temperature rise has been roughly 1.09 C since the preindustrial period (Fn.2), which means a rate of warming less than 1 C per century. The linear rate of temperature rise correlates with the linear rate of sea level rise and the linear rate of non-polar glacial melting. If temperatures continue to rise at a linear rate, it is reasonable to expect that sea levels will continue to rise at about 7.5 inches per century.

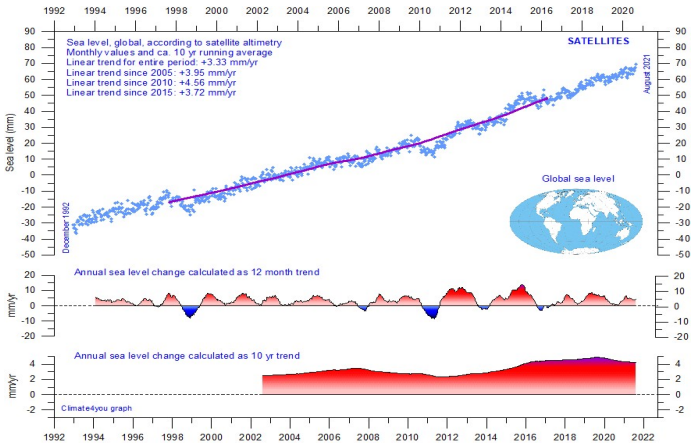
CO2 emissions spiked in the 1950s and have been rising at a rapid and steady rate ever since. But there has no corresponding increase in the rate of temperature rise or in the rate of sea level rise or the rate of non-polar glacier melt.





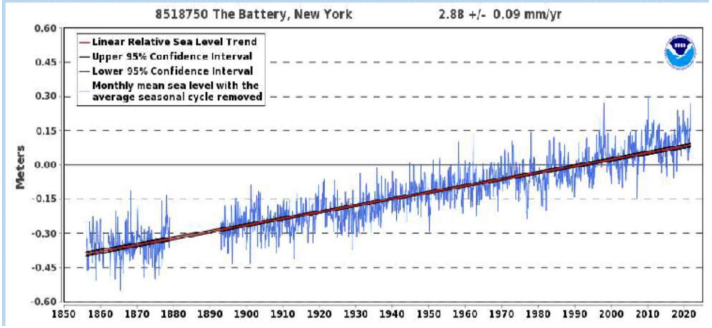
Rising sea levels are caused by long term rising world temperatures, not by rising CO2 levels. Thus from 1944-1976 sea levels continued their steady rise although world temperatures were falling and CO2 levels were rising significantly.

In December 1992 satellites started measuring sea levels. The satellite trend line for the 30 years through 2021 shows a rise at a linear rate of 3.33 mm/yr or 13.2 inches/century. If one looks at short time intervals, one finds that the rise for the period 2010-2021 was 4.56 mm/yr or 18.0 inches/century. The satellite numbers are so much larger than the tide gauge numbers (7.5 inches/century) that many scientists question the satellite data, and there is no consensus as yet about the reasons for the discrepancy.



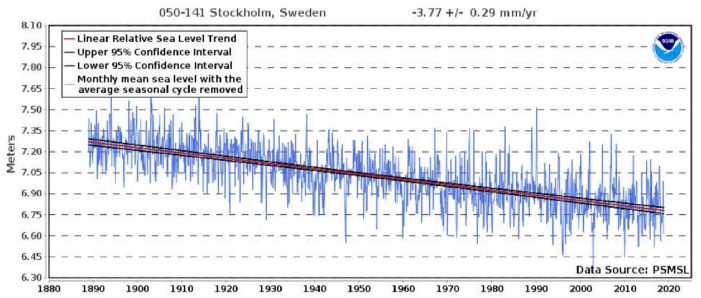
Part of the problem is that 4 different satellites have been used for measurements over different non-overlapping time periods. There are a discontinuities in the data around 2010 and 2015 when the transition from the Jason 1 to the Jason 2 satellite occurred and then the transition from Jason 2 to Jason 3 in 2016. The Jason 2 measurements are clear outliers. The trend line for the Jason 3 satellite is 3.72 mm/yr = 14.7 inches/century significantly less than the 18.0 trend for 2010-2021.

New York 2.88 mm/yr = 11.4"/cent
Sinking = 1.35 mm/yr = 5.3"/cent. Ocean rise = 11.4 – 5.3 = 6.1"/cent



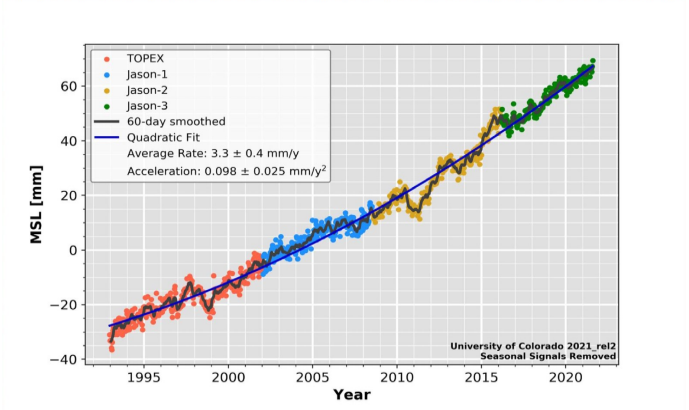
A sea level rise in the range of 6-10 inches/century is generally considered small. It is smaller than the rate of change of the land rising and/or falling. Cities with major subsidence problems (often caused by groundwater depletion) include Tokyo, Bangkok, and Jakarta. Subsidence can be a major problem for non-coastal cities like Mexico City.

Stockholm. -3.77 mm/yr = - 14.9 inches/century



The Netherlands measures steady sea level rise of 6 inches/century. Over a quarter of the Netherlands is below sea level. Amsterdam is more than six feet below sea level. Nearly half the Dutch population lives below sea level. The Dutch have successfully built dikes and other infrastructure to deal with sea level rise for over 600 years. The various studies that project millions of people displaced by sea level rise over the next century assume that no efforts were made to build dikes.

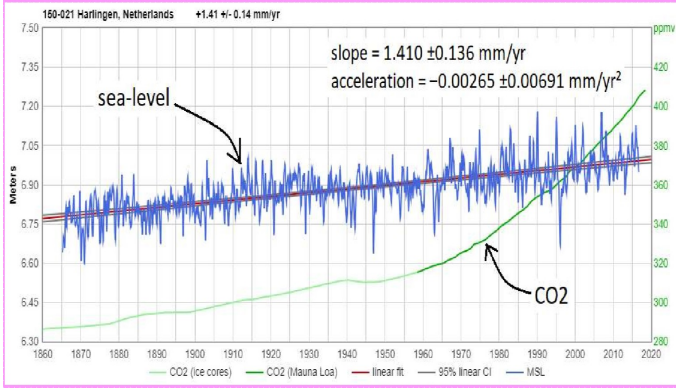
SATELLITE DATA SLR = 3.3 mm/yr = 13.0"/cent.



Despite the satellite measurements, the tide gauges continue to measure steady rates of sea level rise that are much lower than the satellite data. For example, New York City measures a steady overall rate of rise of 11.4 inches/century, but New York is subsiding (sinking) at the rate of 5.3 inches/century. So the actual measured steady rise of the sea level is 11.4 - 5.3 = 6.1 inches/century.

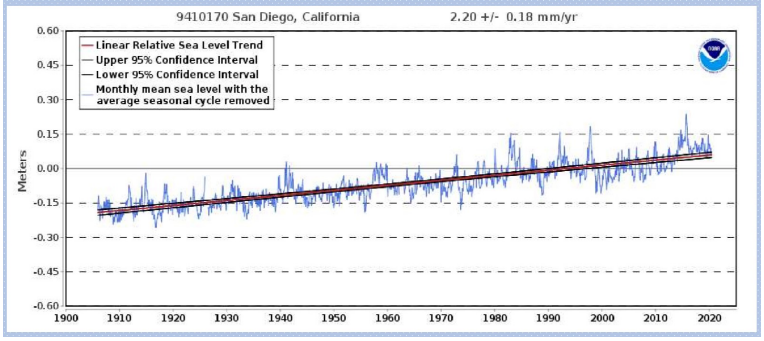
Stockholm is rising so rapidly that its tide gauge measures steady sea level decline of 14.9 inches per century. So Stockholm's problem is that its harbor is getting shallower.

NETHERLANDS 1.41 mm/yr = 6 inches/century

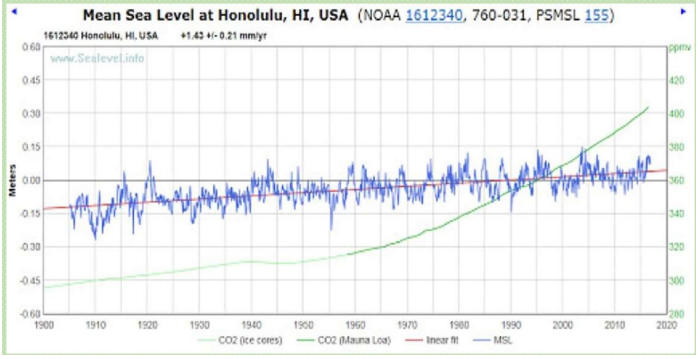


In the Pacific Ocean San Diego shows a steady rise of 8.7 inches/century.

San Diego 2.20 mm/yr = 8.7 inches/century

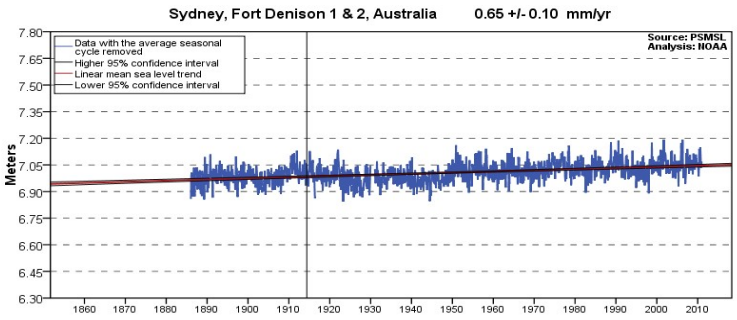


HONOLULU 1.43 mm/yr = 6 inches/century



Honolulu shows a steady rise of 6 inches/century, perhaps even decreasing a little.

Sydney, Australia, shows a steady rise of less than one inch/century.



University of Aukland (2018)

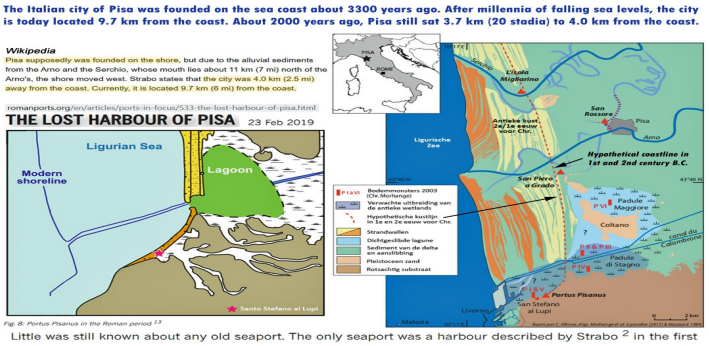
Studied the shorelines of Tuvalu's 101 islands over 40 years.

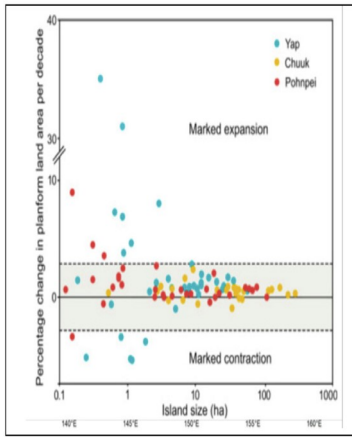
All islands have changed in size, and the dominant mode has been expansion.

The total land area of the country has increased by 2.9%.

So what about those low-lying island nations supposedly at risk of inundation? Tuvalu is the nation most commonly cited. But the land area of Tuvalu is expanding, not shrinking, as a result of progradation, or accretion.

Pisa in Italy used to be a major sea port. But it is now about six miles inland as the Italian coast line has expanded into the sea. Ephesus was one of the greatest seaports of the ancient world. It now, like Pisa, is about six miles inland.





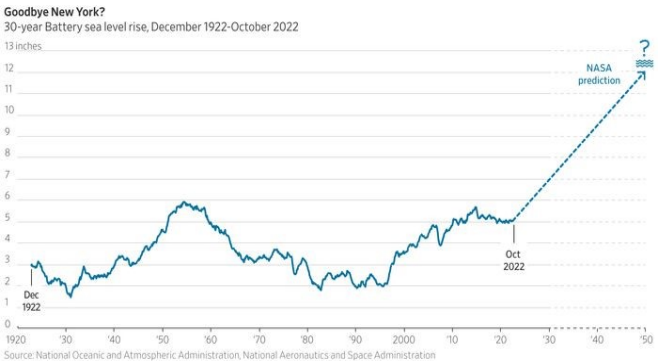
A 2019 global-scale analysis of 709 islands in the Pacific and Indian Oceans revealed 89% were either stable or growing in size, and that no island larger than 10 ha (and only 1.2% of islands larger than 5 ha) had decreased in size since the 1980s (Duvat, 2019).

A new analysis of post-2000 trends also indicates global-scale stable to expanding shorelines for hundreds of Pacific and Indian Ocean islands, with over half of the net growth (39 km² of 62 km²) occurring from 2013 to 2017.

A recently-published massive survey paper summarized other papers that had studied in total 709 low-lying islands. The survey concluded that 73% of the islands were stable in area, 15.5% increased in area, and only 11.4% decreased in area. This study was cited by the IPCC in AR6 (Fn.3), and AR6 concluded that "over the past three to five decades, shoreline changes were dominated by stability on reef islands." (Fn.4)

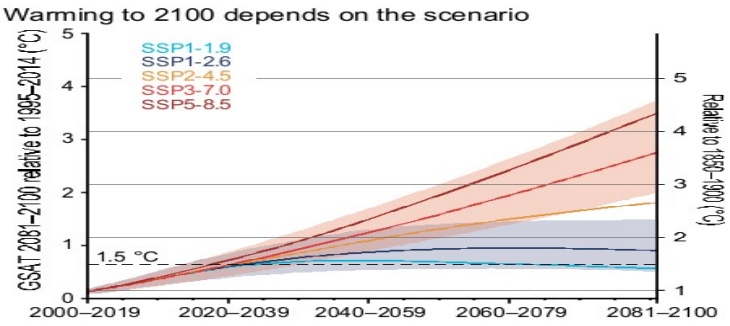
Mao (2021) concluded from satellite data that coastlines around the world have been generally expanding from 1984-2019 at a rate of net 10.2 inches/year, because accretion has been greater than erosion. Luijendijk (2018) concluded that 48% of world beach have been stable while 28% have been growing and only 24% have been shrinking. These two images of the same section of Miami Beach taken 95 years apart show a stable, if not slighting growing, beach.

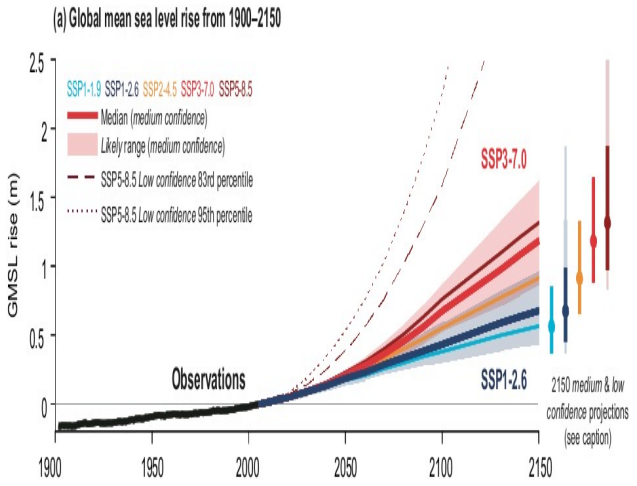
AR6 concludes that sea level (1) from 1901-1971 rose at 5.1 inches/century, (2) from 1971-2006 the rise was 7.5 inches/century, and (3) from 2006-2018 the rate of rise was 14.6 inches/century. (Fn.5). AR6 compares the tide gauge data up to 2006 with the satellite data from 2006 forward in order to support its conclusion that sea level rise is accelerating. (Fn.6). But AR6 provides no discussion or explanation of why it considers the satellite data more accurate than the tide gauge data for 2006 to date, or of how it justifies mixing the satellite data with the tide gauge data to support the conclusion of acceleration when the tide gauge data for 2006-2018 does not show acceleration.



The tide gauge data can be reconstructed to show cyclical variation, but, for example, the New York increase from 1995-2015 is slightly smaller than the increase from 1930-1955, which could not have been human caused, and, since 2015, the rate of increase has been slowing. AR5 (2013) admitted that the trend since 1990-2013 was not significantly larger than the estimate of 18-years trends in previous decades (e.g. 1920-1950). (Fn.7).

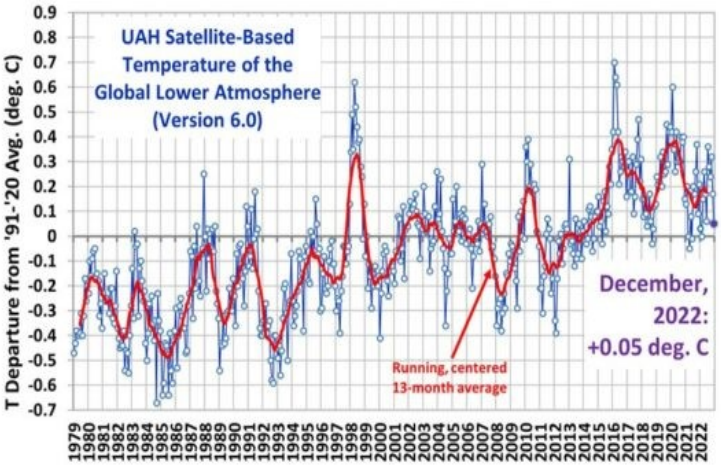
AR6 projections of future temperatures are based on different sets of assumptions called "scenarios." (Fn.8).

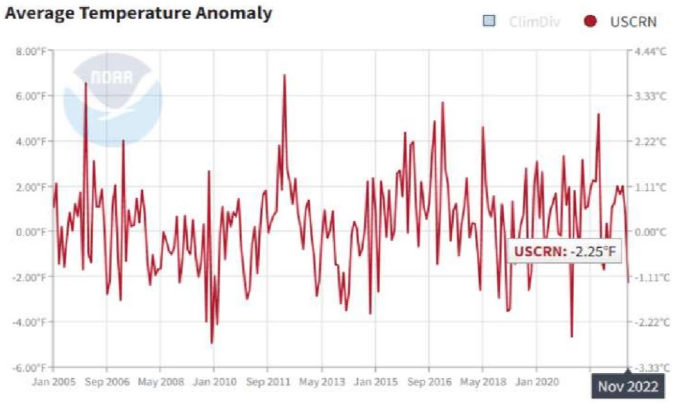




The models projecting sea level rise use these same scenarios. (Fn.9). There is a growing consensus that scenarios SSP3-7.0 and SSP5-8.5 are highly unlikely, and that the earth's actual path of development is following, or falling below, scenario SSP2-4.5. For this scenario the models calculate sea level rise by 2100 of 17-30 inches (Fn.10), which is a rate of linear rise of 21-38 inches per century, and which is 3-5 times higher that the rate of sea level rise actually measured by the tide gauges. The AR6 models projecting sea level rise have never been verified.

The rate of world temperature rise is arguably decreasing. The world temperature for December 2022 was lower than the temperature 20 years prior. A decreasing rate of temperature rise means a decreasing rate of sea level rise. The existence of such a decrease is disputed.





The most accurate US government data set for the continental US shows that the temperature has been flat for the entire 17 years covered by the data set.

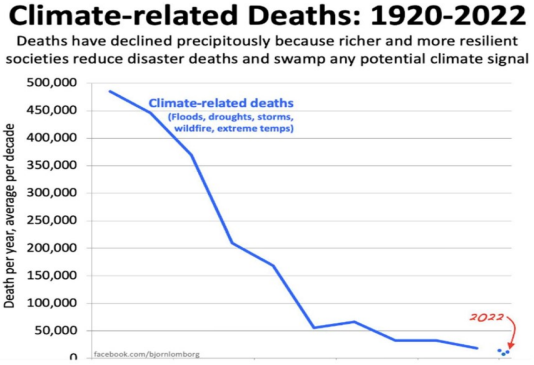
Conclusion

Sea levels may reasonably be expected to continue their slow, steady, non-threatening rise somewhere in the range of 5-10 inches/century. Low-lying islands are mostly safe, and, in general, coastlines are expanding into the sea, not being flooded by sea level rise.

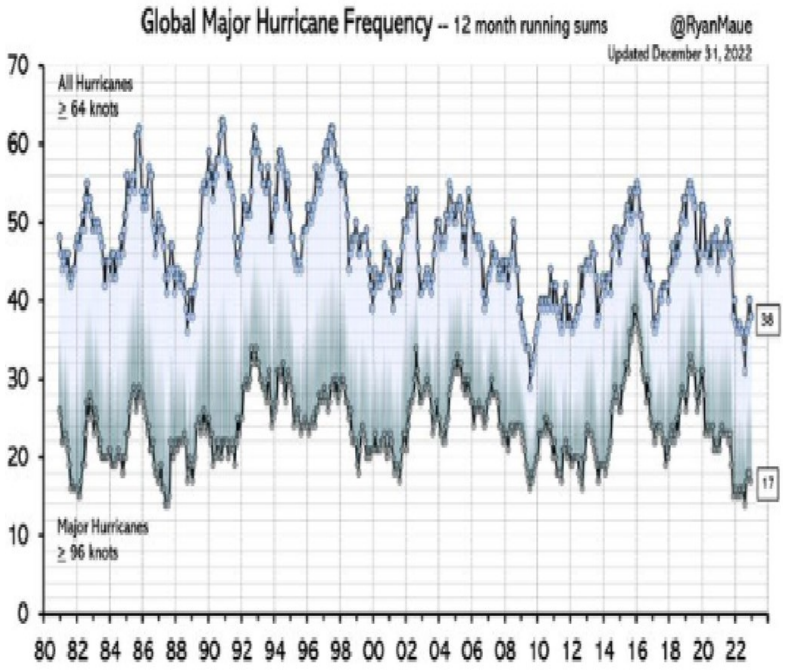
AR6 describes Bangladesh as one of the most vulnerable countries in the world to climate risks and natural hazards. (Fn.11). AR4 (2007) predicted that under the most conservative scenario sea level will be about 16 inches higher by 2100, and the annual number of people flooded in Bangladesh coastal populations will increase from 13 million to 94 million, which is over half the total population of the country. (Fn.12). So Bangladesh provides a good example of relative future risks.

Bangladesh is about 80% flood plain with 75% of its land area less than 10 meters above sea level. Ahmed (2018) studied the erosion and accretion along the country's coast. He concluded that from 1985-2015 there was a slight net gain in land area. As is the trend worldwide, Bangladesh is growing into the sea, which means that no significant percentage of its population will be displaced by sea level rise.

Tropical storms are a far, far greater risk than sea level rise for Bangladesh. In 1970 Cyclone Bhola killed roughly 500,000 people. In 1991 a storm of similar strength killed 140,000. In 2007 for Cyclone Sidr (cat 4) only 3,400 died. But in 2020 when supercyclone Amphan hit (one of the fiercest to hit West Bengal in the last 100 years and stronger than Bhola), only around 100-200 died due to all the adaptive measures in place. (Fn.13). The world is making remarkable progress in reducing the number of climate-related deaths per year.



Here in the US hurricanes are also a far, far greater problem than sea level rise. The US has handled the sea level rise of the last century without any particular hardship. But Hurricanes regularly cause massive damage to life and property. The number of hurricanes per year is not increasing, and the number of major hurricanes is not increasing. (Fn.16). But hurricanes are a fact of life. Without any climate change the world can expect about 38 hurricanes in 2023 and about 17 major hurricanes. Many US coastal cities have not made adequate preparation for the existing level of hurricane activity. A classic example was New Orleans. Katrina caused so much damage, because the city's levees failed due to inadequate design and poor maintenance.



For Bangladesh flooding is a far, far greater risk than sea level rise. Bangladesh is criss-crossed by a network of more than 200 rivers. Heavy monsoon rains commonly cause widespread flooding as in Pakistan. In an average year 18% of the Bangladesh landmass is inundated, but this is highly variable from year to year without any trend (influenced by the El Nino/La Nina cycle). It was 75% in 1988 and 70% in 1998. But average country-wide inundation depth decreased during 2002-2010 due to improved flood management. (Fn. 14)

Bangladesh in 2018 adopted the Bangladesh Delta Plan 2100 to achieve a safe, climate-resilient, and prosperous delta through robust, adaptive and integrated strategies. (Fn.15). Dutch engineers are advising Bangladesh on various water management projects.

Overall, sea level rise is a concern, particularly in certain cities that are subsiding, but it is slow and predictable. In most cases, it can be readily handled by the construction of dikes, sea walls, or levees, as the Dutch have been doing for centuries.

Works Cited

Intergovernmental Panel on Climate Change Assessment Report 4, Working Group II, Impacts, Adaptation and Vulnerability (2007) (AR4 WGII)

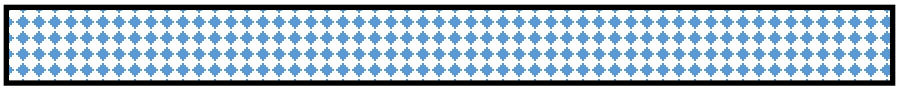
Intergovernmental Panel on Climate Change Assessment Report 5, Working Group I, The Physical Science Basis (2013) (AR 5 WGI)

Intergovernmental Panel on Climate Change Assessment Report 6, Working Group I, The Physical Science Basis (2021) (AR6 WGI)

Intergovernmental Panel on Climate Change Assessment Report 6, Working Group II, Impacts, Adaptation and Vulnerability (2022) (AR6 WGII)

Footnotes

1. AR6 WGI p.6.
2. AR6 WGI p.5
3. AR6 WGII p.2055
4. AR6 WGII p. 2055
5. AR6 WGI p. 5
6. AR6 WGI p.77
7. AR5 WGI p. 290
8. Ar6 WGII p. 61
9. AR6 WGI p.89
10. AR6 WGI p. 21
11. AR6 WGII p.1467
12. AR4 WGII p.484
13. AR6 WGII p.588
14. AR6 WGI p.1800
15. AR6 WGII p.1513
16. AR6 WGI p.9



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