Current Climate

By John Benson

May 2025

1. Introduction

This post is about the title status. I found a really good reference that will help me describe this (Reference 1 below)[1], but that is not what prompted this post instead was a very long book that I attempted to read. The book is also very strange, because of its fatalistic content and otherwise strange wording. I finally gave up on the book (too many hysterical rants), although the curiosity that led to this paper remained. The book will not be mentioned herein, and has been permanently banished to the bottom shelf of the "previous reads" bookshelf in my garage.

The data and charts in section 2 below clearly demonstrate that we (the world's economies) are nowhere close to starting to effectively mitigating climate change. If left unchecked this will bring many catastrophic effects.

Although much technological development, inventing of new replacements for current greenhouse gas (GHG) -producing processes, products and substances remain, we do already have many tools in our bag. We can start this long road to mitigating climate change by:

- Lawmakers should start to slowly raise taxes on fossil fuels, and use the proceeds from these to:
  - Fund the development and inventing described in the above paragraph.
  - Underwrite the relocation of people already suffering from the early effects of climate change such as excessive heat and humidity, sea-level rise or other dislocating effects. Lawmakers should also modify laws that that make these relocations more difficult.
  - Offset the initial cost of GHG-free replacement processes, products and substances for those that currently emit GHG.
- The public should:
  - Reduce their personal GHG emissions by displacing household processes and vehicular emissions with those that produce less or no GHG. Your author has done this by implementing PV- plus battery-energy-storage-systems to displace grid-electricity in my primary residence, and driving a very fuel-efficient car for most of my trips.
  - Change other personal choices to reduce the use of products that produce GHG, like fossil-fueled vehicles and tools.[2]
  - Reduce eating food where its production emits high GHG (such as beef).

[1] State of the Global Climate, 2024, © World Meteorological Organization (WMO), 2025, https://wmo.int/sites/default/files/2025-03/WMO-1368-2024_en.pdf

[2] All of our power-tools are electric, and we tend to keep vehicles for a very long time. Our youngest car is a 2008 model that was purchased before EVs were widely available.

2. Global Climate – Hello 1.55 °C

The annually averaged global mean near-surface temperature in 2024 was 1.55 °C ± 0.13 °C above the 1850–1900 average. This is the warmest year in the 175-year observational record, beating the previous record set only the year before. While a single year above 1.5 °C of warming does not indicate that the long-term temperature goals of the Paris Agreement are out of reach, it is a wake-up call that we are increasing the risks to our lives, economies and the planet.[1]

Over the course of 2024, our oceans continued to warm, sea levels continued to rise, and acidification increased. The frozen parts of Earth's surface, known as the cryosphere, are melting at an alarming rate: glaciers continue to retreat, and Antarctic Sea-ice reached the second-lowest extent ever recorded. Meanwhile, extreme weather continues to have devastating consequences around the world.

Authors comment: Among recent "devastating consequences" caused by the above "extreme weather" were the LA Fires.[3]

In response, WMO and the global community are intensifying efforts to strengthen early warning systems and climate services to help decision-makers and society at large be more resilient to extreme weather and climate. We are making progress but need to go further and need to go faster. Only half of all countries worldwide have adequate multi-hazard early warning systems. This must change.

Investment in National Meteorological and Hydrological Services is more important than ever to meet the challenges and build safer, more resilient communities. Authoritative scientific information and knowledge is necessary to inform decision-making in our rapidly changing world, and this report provides the latest science-based update on the state of our knowledge of key climate indicators

– Prof. Celeste Saulo, Secretary-General, World Meteorological Organization (WMO)

2.1. Key Indicators

2.1.1. Atmospheric Carbon Dioxide

The global annual average mole fraction of carbon dioxide (CO_2) in the atmosphere – the atmospheric concentration – reached a new observed high in 2023, the latest year for which consolidated global annual figures are available (Figure 1, on the next page). At 420.0 ± 0.1 parts per million (ppm), the concentration in 2023 was 2.3 ppm more than in 2022 and 151% of the pre-industrial concentration (in 1750). The concentration of 420 ppm corresponds to 3,276 Gt CO_2 in the atmosphere.[1, 4]

Concentrations of methane (CH_4) and nitrous oxide (N_2O), two other key greenhouse gases in the atmosphere, also reached record high observed levels in 2023. The concentration of CH_4 reached 1,934 ± 2 parts per billion (ppb), 265% of pre-industrial levels, and that of N_2O reached 336.9 ± 0.1 ppb, 125% of pre-industrial levels. Real-time data show that levels of CO_2, CH_4 and N_2O continued to increase in 2024

[3] https://en.wikipedia.org/wiki/January_2025_Southern_California_wildfires
[4] The abbreviation Gt stands for Gigaton, a unit of mass equivalent to one-billion metric tons.

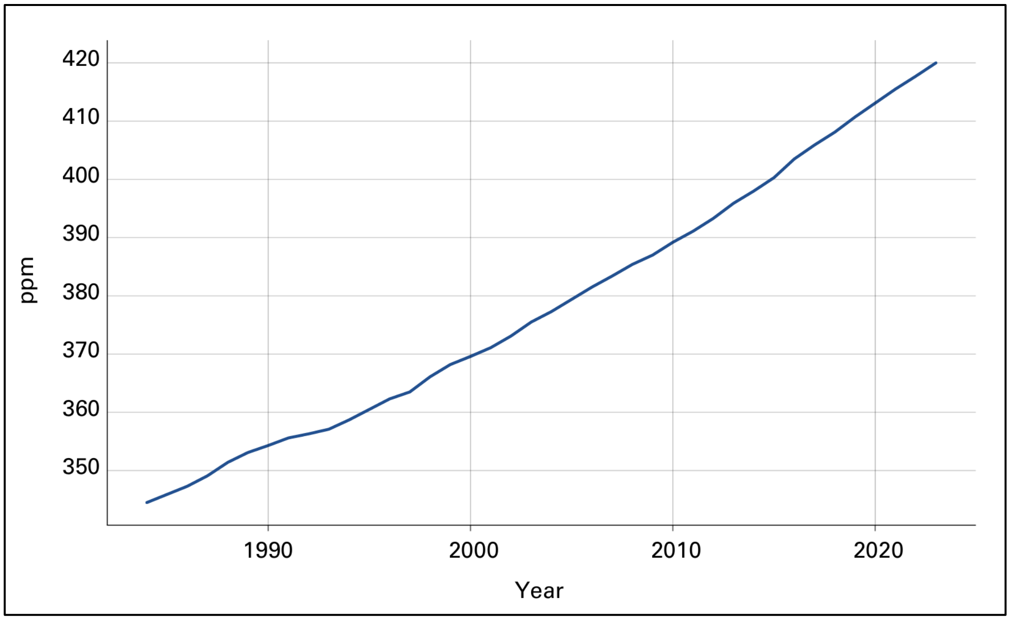


Figure 1. *Annual mean globally averaged atmospheric mole fraction of carbon dioxide from 1984 to 2023 in parts per million (ppm). Source: Data are from the World Data Centre for Greenhouse Gases (WDCGG).*

2.1.2. Mean Near-Surface Temperature

The annually averaged global mean near-surface temperature in 2024 was 1.55 °C ± 0.13 °C above the 1850–1900 average. The year 2024 was the warmest year in the 175-year observational record. The previous warmest year was 2023 with an anomaly of 1.45 °C ± 0.12 °C. Each of the past ten years, 2015–2024, were individually the ten warmest years on record. The analysis is based on a synthesis of six global temperature datasets (see Figure 2 below).

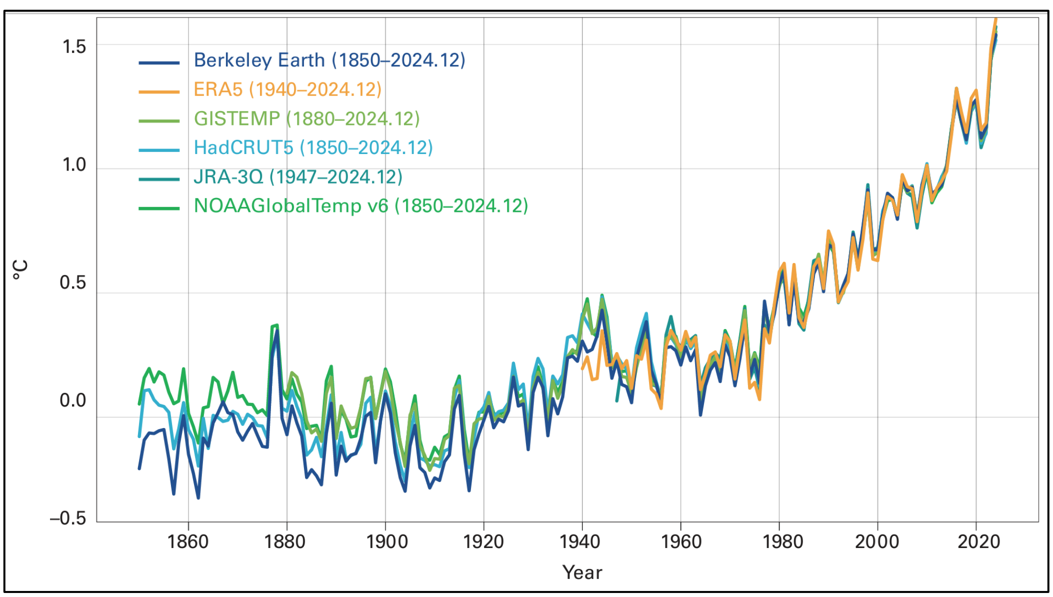


Figure 2. *Annual global mean temperature anomalies relative to a pre-industrial (1850–1900) baseline shown from 1850 to 2024. Source: Data are from the six datasets indicated in the legend.*

Global mean temperature in 2024 was boosted by a strong El Niño which peaked at the start of the year. However, temperatures were already at record levels in 2023. In every month between June 2023 and December 2024, monthly average global temperatures exceeded all monthly records prior to 2023.

2.1.3. Ocean Heat Content

In 2024, observed global ocean heat content set a record, exceeding the previous record set in 2023 by 16 ± 8 ZJ (Figure 3). Over the past eight years, each year has set a new record for ocean heat content. Instrumental records start around 1960.[5]

The rate of ocean warming over the past two decades (2005–2024), 0.99–1.07 W m–2 or 11.2–12.1 ZJ per year, is more than twice that observed over the period 1960–2005 (0.27–0.34 W m–2 or 3.1–3.9 ZJ per year).

The latest Intergovernmental Panel on Climate Change (IPCC) report concluded that it was virtually certain that ocean heat content had increased since the 1970s and extremely likely that the main driver was human influence. Based on the datasets used here, global ocean heat content increased at a rate of 0.6 ± 0.1 W/m^2 (6.8 ZJ per year) averaged over the area of the ocean from 1971 to 2024, which is consistent with the IPCC report.

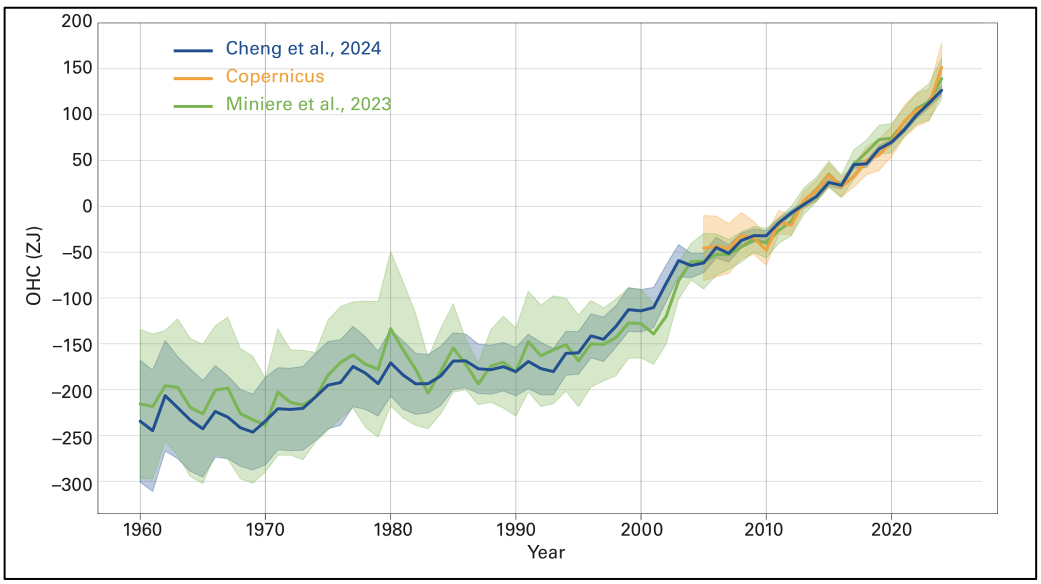


Figure 3. *Annual global ocean heat content down to 2000 m depth for the period 1960–2024, in zettajoules (1021 J). The shaded area indicates the 2-sigma uncertainty range on each estimate.*

Observed ocean warming indicates that the Earth is currently out of energy balance. The rate of warming reveals how rapidly the Earth system is trapping surplus energy in the form of heat from climate forcings. Around 5% of that surplus energy is warming the land, 1% is warming the atmosphere, and 4% is warming and melting the cryosphere. However, the majority, around 90%, goes into warming the ocean. The indicator of ocean heat content is therefore a key indicator of climate change.

[5] ZJ stands for zettajoule, which is a multiple of the metric unit joule (J) for energy (in this case the energy in the ocean's heat). One zettajoule is equal to 10^{21} joules

The integration of ocean temperatures from the surface to the deep ocean – typically down to 2000 m – provides a measure of ocean heat content. Ocean temperatures have been measured by research ships for over a century, but observations are too sparse to form a global average before 1960. Additional measurements have been made using expendable devices launched from ships since the 1970s. Since around 2005, near-global coverage down to 2000 m has been provided by autonomous Argo buoys.[6]

The time series of ocean heat content at a global scale shows that the global ocean is clearly warming. Changes in global ocean temperature are irreversible on centennial to millennial time scales, and climate projections show that ocean warming will continue over the rest of the twenty-first century and beyond, even for low emission scenarios.

Ocean warming has wide-reaching consequences, such as degradation of marine ecosystems, biodiversity loss and reduction of the ocean carbon sink. It fuels tropical and subtropical storms and exacerbates ongoing sea-ice loss in the polar regions. Ocean warming together with ice loss on land is causing sea levels to rise.

2.1.4. Sea Level Rise

The long-term rate of sea-level rise (Figure 4) has more than doubled since the start of the satellite record, increasing from 2.1 mm per year between 1993 and 2002 to 4.7 mm per year between 2015 and 2024. In 2024, global mean sea level reached a record high in the satellite record (from 1993 to present).

The year-to-year variability of global mean sea level around the long-term trend is correlated with the El Niño–Southern Oscillation (ENSO). The rise and fall of global mean sea level due to El Niño and La Niña arise because of the characteristic shifts in rainfall patterns that exchange water between the ocean and land as well as local changes in ocean heat content.

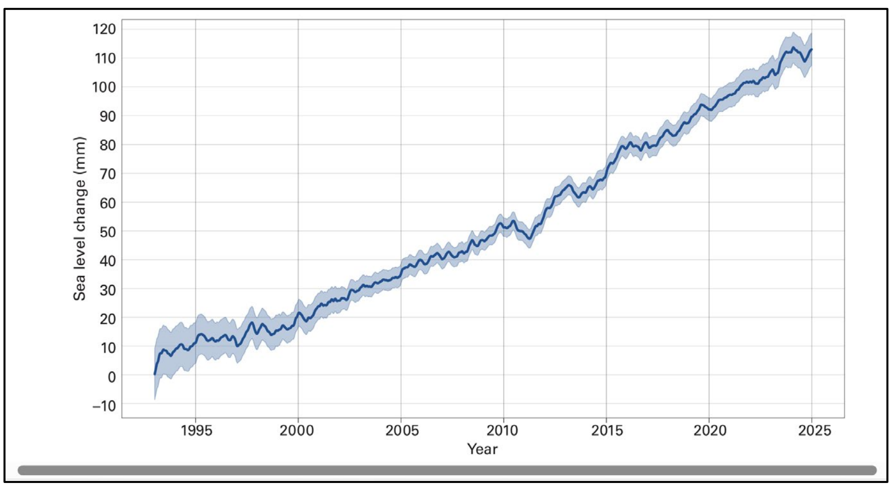


Figure 4. Seasonal global mean sea level change from 1993 shown for 1993–2024. The seasonal cycle has been removed from the data. The shaded area indicates the uncertainty.

The strong 2023/2024 El Niño temporarily raised global mean sea level by several millimeters, reaching its peak in the northern hemisphere winter 2023/2024. The temporary drop in global mean sea level in the early part of 2024 was mostly due to the end of the El Niño and a return to neutral conditions.

[6] https://en.wikipedia.org/wiki/Argo_(oceanography)

Global mean sea level is measured by satellites using radar altimeters that record the time taken for a radar signal to reach the sea surface and return to the satellite. Longer records of global mean sea level exist based on tide gauge measurements made along coastlines around the world since the late nineteenth century.

The warming of the ocean causes the water to expand and global mean sea level to rise. The melting of ice on the land also contributes to sea-level rise. Because warming of the oceans will continue for centuries even if emissions of greenhouse gases cease, sea level will continue to rise on the same time scale.

Changes in sea level have wide-ranging effects on coastal areas and communities. Sea-level rise will bring cascading and compounding impacts resulting in losses of coastal ecosystems and ecosystem services, groundwater salinization, flooding and damage to coastal infrastructure. These impacts cascade into risks to livelihoods, settlements, health, well-being, food and water security in the near- to long-term.

2.1.5. Ocean pH

Globally, ocean surface pH has changed at a rate of –0.017 ± 0.001 pH units per decade over the period 1985–2023 (Figure 5). The year 2023 is the latest year for which we have consolidated global figures. The decline in pH is referred to as ocean acidification. The rate of change in pH is consistent with the estimate of the latest IPCC report.

Regionally, ocean acidification has not proceeded uniformly. The most intense decreases in regional surface pH are observed in the Indian Ocean, the Southern Ocean, the eastern equatorial Pacific Ocean, the northern tropical Pacific and some regions in the Atlantic Ocean. In these areas, which amount to 47% of the sampled global ocean, the surface of the ocean is getting more acidic at a faster rate than the global average.

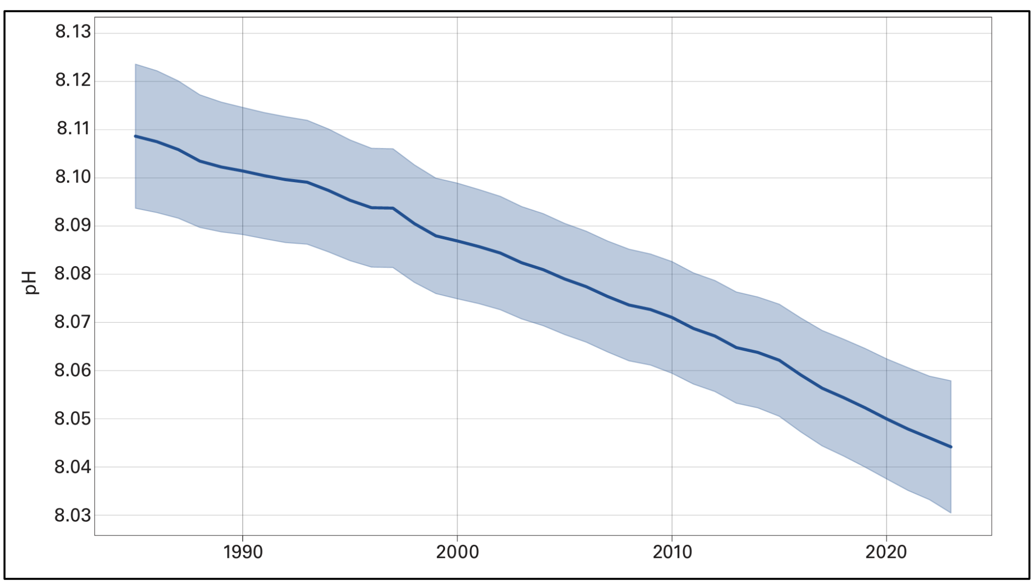


Figure 5. *Annual global mean surface ocean pH 1985 to 2023. The dark line is the central estimate and the shaded area is the uncertainty range. Source: Data from Copernicus Marine Environment Monitoring Service (CMEMS).*

Climate projections show that ocean acidification will continue to increase in the twenty-first century, at rates dependent on future emissions. Changes in deep-ocean pH are irreversible on centennial to millennial time scales.

It is well established that ocean acidification is affecting marine life. The responses of marine organisms to the compound effects of acidification, ocean warming and deoxygenation occur at different metabolic levels for different groups, and include respiratory stress and reduction of thermal tolerance.

The effects of ocean acidification on habitat area, biodiversity, ecosystem function and ecosystem services have already been clearly observed, and food production from shellfish aquaculture and fisheries has been adversely affected.

Warm-water coral reefs and rocky shores dominated by immobile, calcifying organisms that produce shells and skeletons, such as corals, barnacles and mussels, are also affected by extreme temperatures and changes in pH. The monitoring of surface ocean pH has become a focus of many international scientific initiatives and constitutes one target for Sustainable Development Goal (SDG)

2.1.6. Glacier Mass-Balance

Data on glacier mass balance – the amount of mass gained or lost by glaciers – for the 2023/2024 hydrological year (September–August) are not yet fully available, but preliminary observations from about 90% of the glacier data that are reported annually to the World Glacier Monitoring Service indicate that 2023/2024 was another year of extremely negative mass balance worldwide (Figure 6).

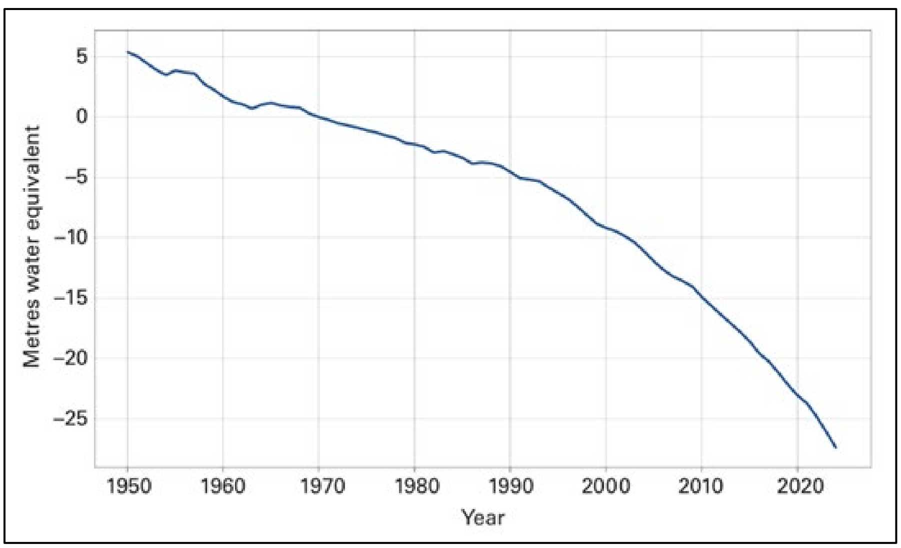


Figure 6. *Cumulative annual mass balance of reference glaciers with more than 30 years of ongoing glaciological measurements. Annual mass change values are expressed in meters water equivalent, which corresponds to tonnes per square meter (1 000 kg/m^2). The 2024 value is preliminary.*

Exceptionally negative mass balances were experienced in Norway, Sweden, Svalbard and the tropical Andes. Only 2 out of the 141 glaciers reporting to date (out of a possible total of around 160) had a positive mass balance, and the composite value from the subset of 58 out of around 60 global reference glaciers indicates an average mass loss consistent with the exceptionally negative mass balance years 2021/2022 and 2022/2023, projected to be close to –1.1 meters water equivalent.

This continues a trend of accelerated glacier mass loss in the 2020s. The last three years (2021/2022–2023/2024) represent the largest negative three-year mass balance on record, and 7 of the 10 largest negative mass balance years since 1950 have occurred since 2016.

Glaciers are formed from snow that has compacted to form ice, which then deforms and flows downhill. Glaciers comprise two zones: an accumulation zone where accumulation of mass from snowfall exceeds ice loss, and an ablation zone where ice loss (ablation) from melting and other mechanisms exceeds accumulation. Where glaciers end in a lake or the ocean, ice loss can occur through melting where the ice meets the water, and via calving when chunks of the glacier break off.

Glacier mass balance – the amount of mass gained or lost by the glacier – is commonly expressed as the annual thickness change averaged over the glacier area, expressed in meters water equivalent. One meter water equivalent is approximately the same as one tonne per square meter. Ice loss from glaciers contributed around 21% of the total sea-level rise over the period 1993–2018, around half the contribution from expansion due to ocean warming (42%) but larger than contributions from melting of the ice sheets in Greenland (15%) and Antarctica (8%).

The mass balances of individual glaciers are affected by changes in temperature, precipitation, humidity and cloudiness. The IPCC Sixth Assessment Report (AR6) concluded that human influence is very likely the main driver of the global retreat of glaciers since the 1990s, stating that "the global nature of glacier retreat since the 1950s, with almost all of the world's glaciers retreating synchronously, is unprecedented in at least the last 2 000 years (medium confidence)".

Melt rates are also strongly affected by the glacier albedo, the fraction of sunlight that is reflected by the glacier surface. Exposed glacier ice is darker and therefore has a lower albedo than the seasonal snowpack; it is also sensitive to darkening from mineral dust, black carbon, algal activity and fallout from forest fires. Reduced snow cover, long melt seasons and wildfire activity all concentrate darker material on the glacier surface, decreasing its albedo and thereby increasing the rate of melting.

2.1.7. Sea-Ice Extent

The extents of sea-ice in the Antarctic and Arctic regions in 2024 were both below their respective 1991–2020 averages throughout the annual cycle (Figure 7).

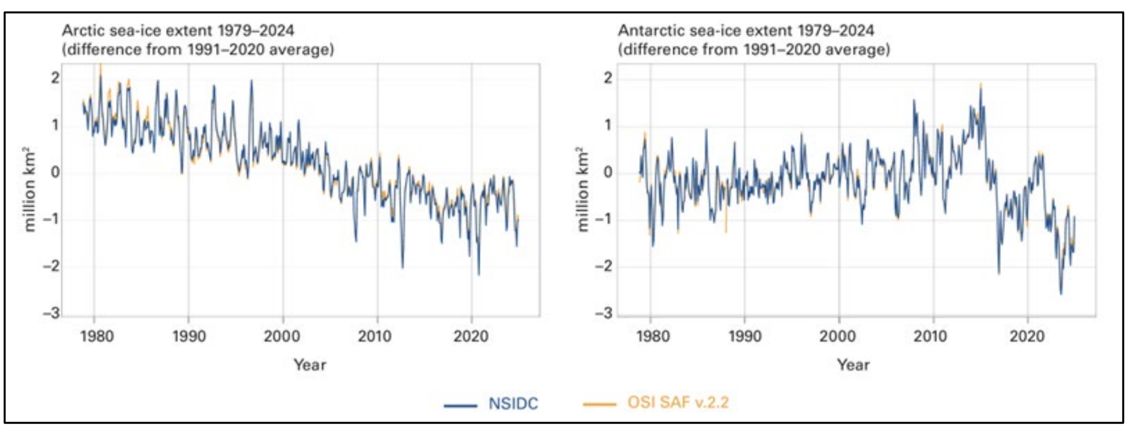


Figure 7. *Monthly Arctic (left) and Antarctic (right) sea-ice extent anomalies (difference from the 1991–2020 average) in millions of square km from 1979 to 2024 Data from NSIDC and OSI SAF.*

The minimum daily extent of sea-ice in the Arctic in 2024 was 4.28 million km^2 on 11 September, which is the seventh lowest extent in the 46-year satellite record. This is 1.17 million km^2 below the average minimum daily extent from 1991–2020. The 18 lowest minima in the satellite record all occurred in the past 18 years.

The minimum daily extent of sea-ice in the Antarctic region in 2024 was 1.99 million km^2 on 20 February, which tied for the second lowest minimum in the satellite era and marked the third consecutive year that minimum Antarctic sea-ice extent dropped below 2 million km^2. These are the three lowest Antarctic ice minima in the satellite record.

Antarctic ice extent remained below the 1991–2020 average throughout the year and reached its annual maximum daily extent of 17.16 million km^2 around 19 September. Six days of missing data near the maximum mean there is some uncertainty in the exact extent and date. The observed maximum was 1.55 million km^2 below the average Antarctic maximum daily ice extent from 1991–2020 and is the second lowest maximum ice extent on record; only in 2023 was it lower. The year ended with extents slightly below the 1991–2020 average.

Sea ice is frozen sea water that floats on the surface of the ocean. Sea-ice cover expands in Earth's polar regions each autumn and winter, as ocean water freezes in response to cooling of the atmosphere and ocean. Summer warming melts much of this seasonal ice, with annual sea ice minima in each hemisphere typically recorded in late summer or early autumn (September in the northern hemisphere, February in the southern hemisphere). Changes in sea-ice cover can affect ocean circulation, atmospheric dynamics and surface heating.

Sea-ice extent is defined as the area of the ocean with at least 15% ice cover. This is a dynamic quantity, which changes in response to both thermodynamic growth (freezing) and decay (melting) as well as when the ice pack moves with winds and ocean currents. Sea-ice extent and sea-ice cover are mapped using microwave satellite imagery.

Long-term changes in Arctic sea-ice extent have been seen throughout the seasonal cycle. The downward trend in the minimum Arctic sea-ice extent from 1979 to 2024 is around 14% of the 1991–2020 average per decade, equivalent to a sea-ice loss of 77,000 km^2 per year.

Until 2015, Antarctic maximum sea-ice extent had a small but positive long-term trend. However, after recent low extents, that is no longer the case. While the last three years have had anomalously low Antarctic ice cover, it remains to be seen if there has been a regime shift in Antarctic Sea-ice.

Author's comment: I covered enough of reference 1 for readers to get a strong understanding of the fluctuations to our ecosystem caused by climate change, but not all of it. The uncovered additional information is certainly informative, and you would like to read it go through the link in this reference.

3. Trump Tries to Dodge Science

President Donald Trump's administration will try to reverse a key 2009 finding by the U.S. Environmental Protection Agency that greenhouse gas emissions endanger public health and welfare, EPA Administrator Lee Zeldin said last week in unveiling more than two dozen initiatives to ease environmental regulations. The so-called endangerment finding, which relied heavily on scientific studies, provides the legal foundation for a wide range of U.S. regulations aimed at reducing emissions from power plants, vehicles, and other sources. Overturning it could be difficult given the depth of scientific evidence on which it is based, legal specialists say.[7]

3.1. Climate Change will Impact Everyone

As I was 10-days away from posting this paper and interesting article from April's Scientific American, brought home this subsection's title message. Yes, it will affect everyone, you and me, and everyone we know. Just because it's off our radar-screens now doesn't mean it will be there in a few years.

The general public perception is: "yes, it would be good if we could remedy this, but if not, no big deal." Yes, it **is** a big deal because:

- It will take major changes in our economy to fix, and
- It is an accumulating detriment – that is, the long-term impact of climate change gets worse every year, irrespective of whether we notice it or not.

The excerpt below is from the April issue of Scientific American. It convinced me of the above subsection-title. It is about astronomers that have suffered a major impact from climate change. I believe most readers, especially those with an understanding of the universe, will react with confusion. Well, read on.

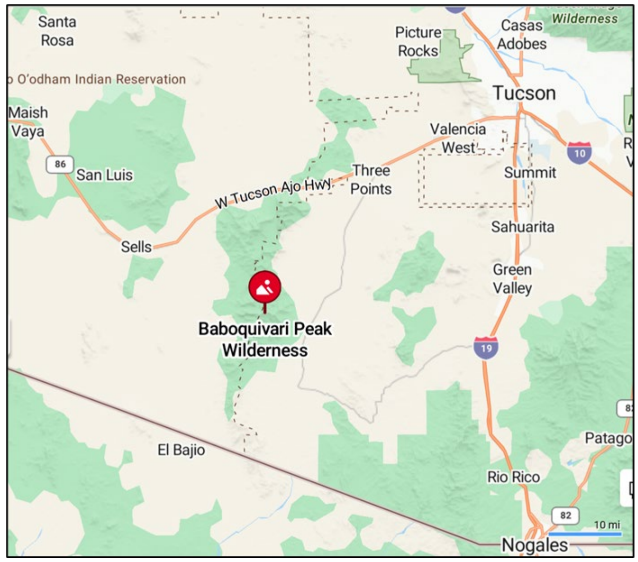
Last summer I and many others around the world watched in horror.as wildfires reduced nearly a third of the town of Jasper, Alberta, to ashes and incinerated some 150.square miles of the surrounding Jasper National Park. Although I now live and work in Tucson, Ariz., the devastation still felt personal: Jasper is part of a dark sky preserve I helped to create in the Canadian Rockies and is where my wife and I spent nine years building a stargazing tour company and planetarium.[8]

The disastrous convergence of two forest fires in late July saw 300-foot-high flames launch charred pine cones and embers out ahead of the blaze. The fire generated lightning strikes and downdrafts as it moved, accelerating the hellish inferno. Roughly 25,000 people fled before the fire hit, and a firefighter died battling it. Unlike some, our business endured, but it was not unscathed: smoke had marred our telescopes and other equipment. Insurance claim estimates for wildfire-related damages in the park may eventually top $1 billion Canadian.

[7] Edited by Jeffrey Brainard, March 21, 2025 Issue of "Science," American Association for the Advancement of Science, News at a Glance.
[8] Peter McMahon, Scientific American, April 2025 Issue, "Wildfires Threaten Astonomy."

Yet as damaging as this event was, it foretells possibly greater harm and disruption. As wildfires have grown in number and intensity in recent years, they have increasingly threatened our ability to see and study the heavens. If we don't find solutions soon, such blazes could top light pollution as the most pervasive threat to astronomical observation. Many cherished views of the cosmos could figuratively go up in flames.

On a mountain summit in Arizona's Sonoran Desert, a dead oak tree blackened by fire stands about three feet from a dormitory at Kitt Peak National Observatory, where I currently serve as the visitor center operations manager. The charred tree is a reminder of how close an earlier disaster came. A lightning strike in June 2022 sparked a wildfire that swept across the Baboquivari Mountains (see image to the right), destroying four buildings and approaching within dozens of feet of some of Kitt Peak's 22 major research telescopes…



Final author's comment: Further to the above, there have been a cluster of weather-related disasters in the last few weeks. Go back to section 2.1.2, and look at the "Mean Near-Surface Temperature" graph. Note that since 1960, this temperature has been rising rapidly, and this seems to be accelerating.

When the atmosphere warms, it supports: (1) more water (humidity) content, and thus more floods when humid cells encounter cold-fronts, and (2) more violent weather of all types because the warmer atmosphere has more energy.

In different areas of the US, the above effects are currently felt more and less strongly. In the Southeastern and Midwest Continental US, warm, humid air comes up from the Gulf of Mexico, and during Spring (now) and Fall, these frequently encounter cold-fronts coming down out of Canada. Since weather conditions generally move from west to east, these "combat zones" often end up on the east coast. Think about this when you see the headlines about the ongoing weather disasters.[9]

On the other hand, even though we have seen atypical weather on the West Coast lately (partially causing the LA Fires), the cool California Current minimizes high-humidity cells coming ashore. The Cascade, Sierra-Nevada and Rocky Mountains block cold weather cells coming out of Central-Canada. However, it wouldn't surprise me to see these patterns change more significantly in the next few decades.

[9] https://www.usnews.com/news/us/articles/2025-04-06/at-least-16-dead-in-flooding-and-tornadoes-as-storms-slash-us-south-and-midwest