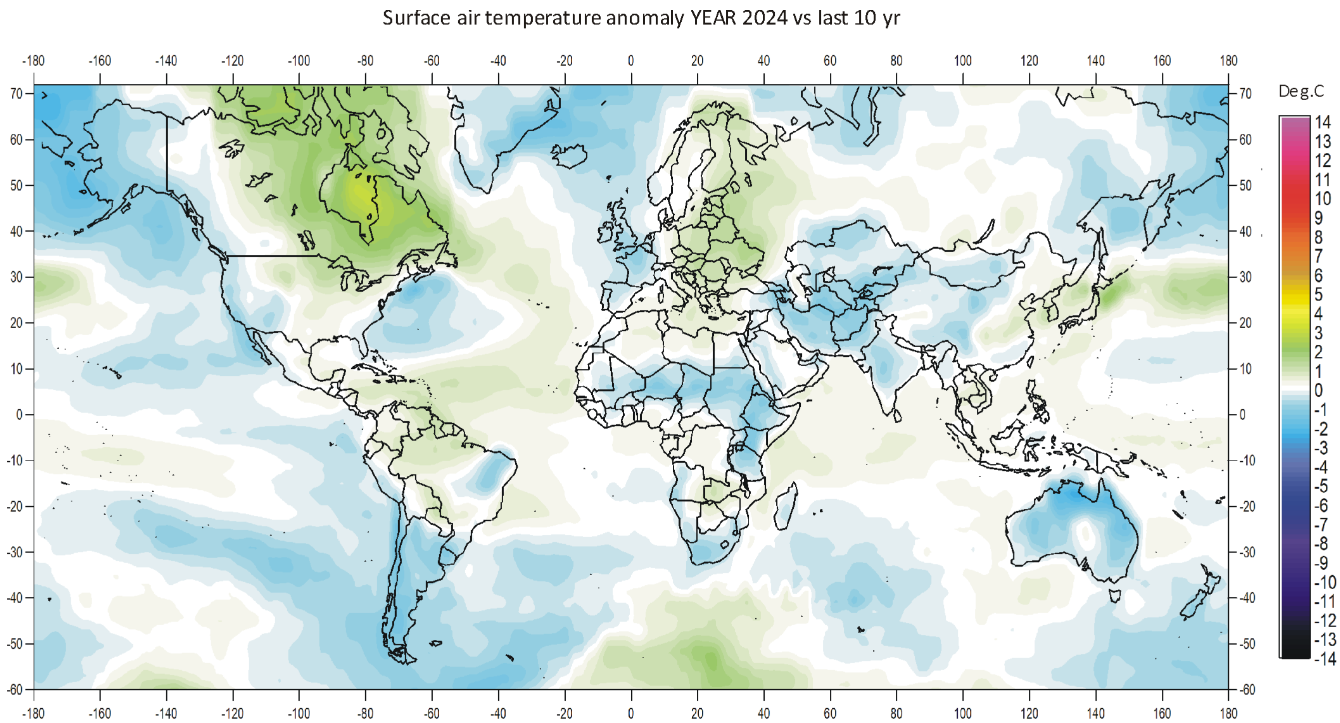
Climate4you update YEAR 2024

Contents:

All diagrams in this newsletter as well as links to the original data are available on www.climate4you.com

Year 2024 global surface air temperature overview versus average last 10 years



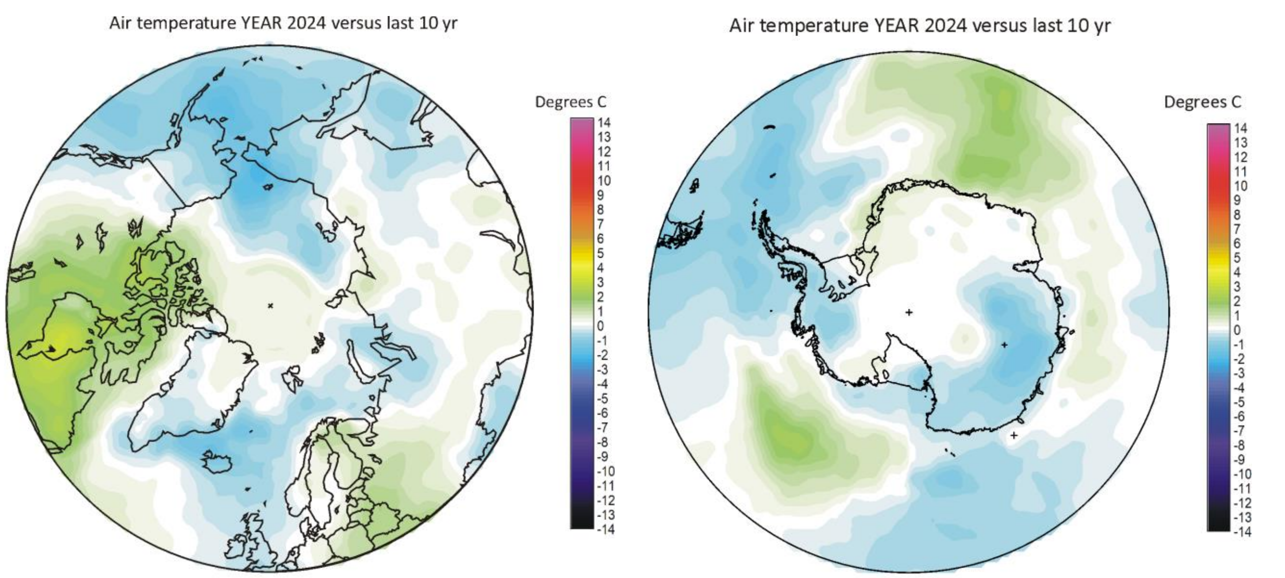


FIGURE 1. Annual 2024 average surface air temperature compared to the annual average of the last 10 years. Green-yellow-red colours indicate areas with higher temperature than the 10-year average, while blue colours indicate lower than average temperatures. Data source: Remote Sensed Surface Temperature Anomaly, AIRS/Aqua L3 Monthly Standard Physical Retrieval 1-degree x 1-degree V006 (https://airs.jpl.nasa.gov/), obtained from the GISS data portal (https://data.giss.nasa.gov/gistemp/maps/index_v4.html).

Year 2024 global surface air temperature overview versus year 2023

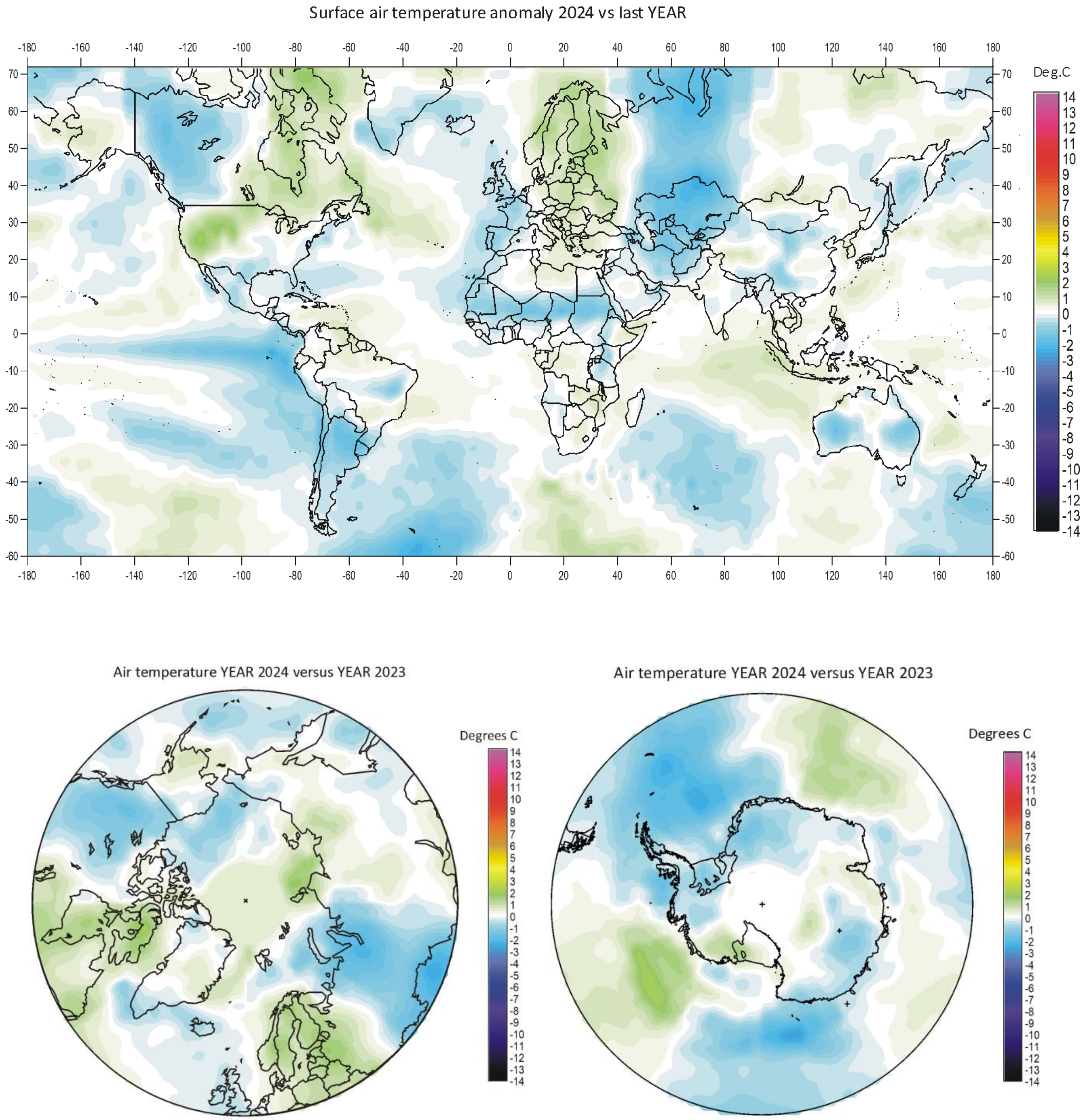


FIGURE 2. 2024 annual surface air temperature compared to year 2023. Green-yellow-red colours indicate regions where the present year was warmer than last year, while blue colours indicate regions where the present year was cooler than last year. Variations in annual temperature from one year to the next has no tangible climatic importance but may nevertheless be interesting to study. Data source: Remote Sensed Surface Temperature Anomaly, AIRS/Aqua L3 Monthly Standard Physical Retrieval 1-degree x 1-degree V006 (https://airs.jpl.nasa.gov/), obtained from the GISS data portal (https://data.giss.nasa.gov/gistemp/maps/index_v4.html).

Comments to the Year 2024 global surface air temperature overview

The present newsletter contains graphs showing a selection of key meteorological variables for the year 2024. All temperatures are given in degrees Celsius.

In the above maps showing the geographical pattern of surface air temperatures, the last previous 10 years (2014-2023) are used as reference period.

The rationale for comparing with this recent period instead of various 'normal' periods defined for parts of the past century, is that such reference periods often will be affected by past cold periods, like, e.g., 1945-1980. Most modern comparisons with such reference periods will inevitably appear as warm, and it will be difficult to decide if modern temperatures are increasing or decreasing.

Comparing instead with the last previous 10 years overcomes this problem and clearer displays the modern dynamics of ongoing change. This decadal approach also corresponds well to the usual memory horizon for many people and is now also adopted as reference period by other institutions, e.g., the Danish Meteorological Institute (DMI).

Traditionally, a 30 -year reference period is often used by various meteorological institutions for comparison purposes. However, this is a most unfortunate time interval, as observations clearly demonstrate that various global climate parameters (see, e.g., page 15) are influenced by periodic changes of 60-70 years. The often used 30-yr reference period is roughly half this period and is therefore extremely unsuited as a good reference time interval.

The average global surface air temperature for 2024

According to the AIRS remote sensed surface temperature the global average surface air temperature for year 2024 was about 0.07°C higher than the average for the previous 10 years. The first months of 2024 was affected by a strong El Niño episode, while the final months suggest the transition to a coming cold La Niña episode (Pacific Ocean, see diagram p.13).

In the Northern Hemisphere especially Canada was characterised by annual temperatures above the average for the last 10 years, while western Europe, eastern Siberia, and Alaska, had annual temperatures below the 10-yr average. Ocean wise, the northeastern North Atlantic were relatively cold, as was the northern Pacific Ocean. In the Arctic, Siberian and Barents Sea sectors were relatively cold, while the Canadian sector was relatively warm.

Near the Equator surface air temperatures were generally near the average for the previous 10 years. See also reflections on p.7.

In the Southern Hemisphere annual surface air temperatures in 2024 were near or below the average for the previous 10 years. Especially South America and most of southern Africa and Australia were cool compared to the previous 10 years, just like in 2023. Ocean wise, temperatures were near or below the 10-yr average.

The ocean around the Antarctic continent was generally characterised by both relatively high and low annual surface air temperatures in 2024. The Antarctic continent itself had annual temperatures near or below the average for the previous 10 years.

Summing up for 2024, using AIRS remote sensed surface temperatures the global average air temperatures were high when seen in the longer instrumental time scale (150 years). In fact, according to all temperature databases referred to in this newsletter, year 2024 was the warmest year on record. Both years, however, were influenced by a warm El Niño episode in the Pacific Ocean. Thus, the global surface air temperature record in 2024 continues to be substantially influenced by oceanographic phenomena.

Lower troposphere temperature from satellites, updated to year 2024

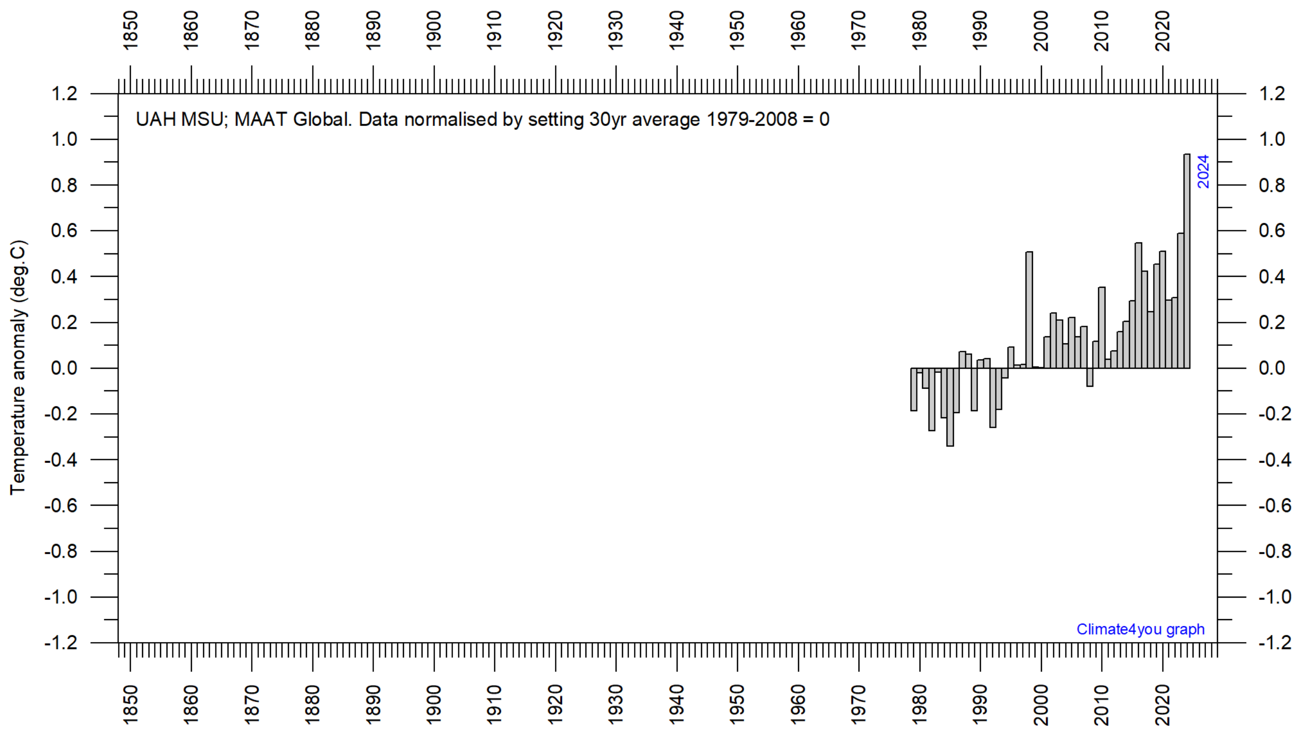


FIGURE 3. Mean annually lower troposphere temperature anomaly (thin line) since 1979 according to [University of Alabama](#) at Huntsville, USA. The average for 1979-2008 (30 years) has been set to zero, to make comparison with other temperature data series easy.

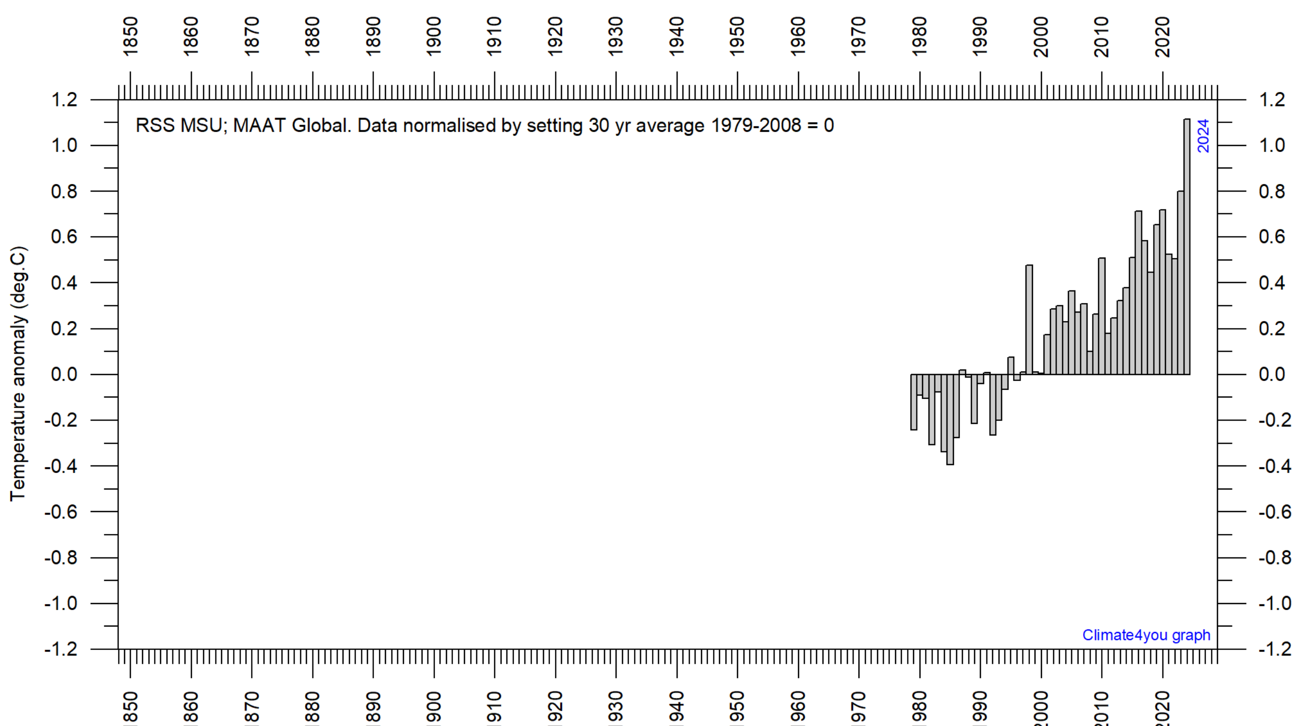


FIGURE 4. Mean annual lower troposphere temperature anomaly (thin line) since 1979 according to according to [Remote Sensing Systems](#) (RSS), USA. The average for 1979-2008 (30 years) has been set to zero, to make comparison with other temperature data series easy.

Global surface air temperature, updated to year 2024

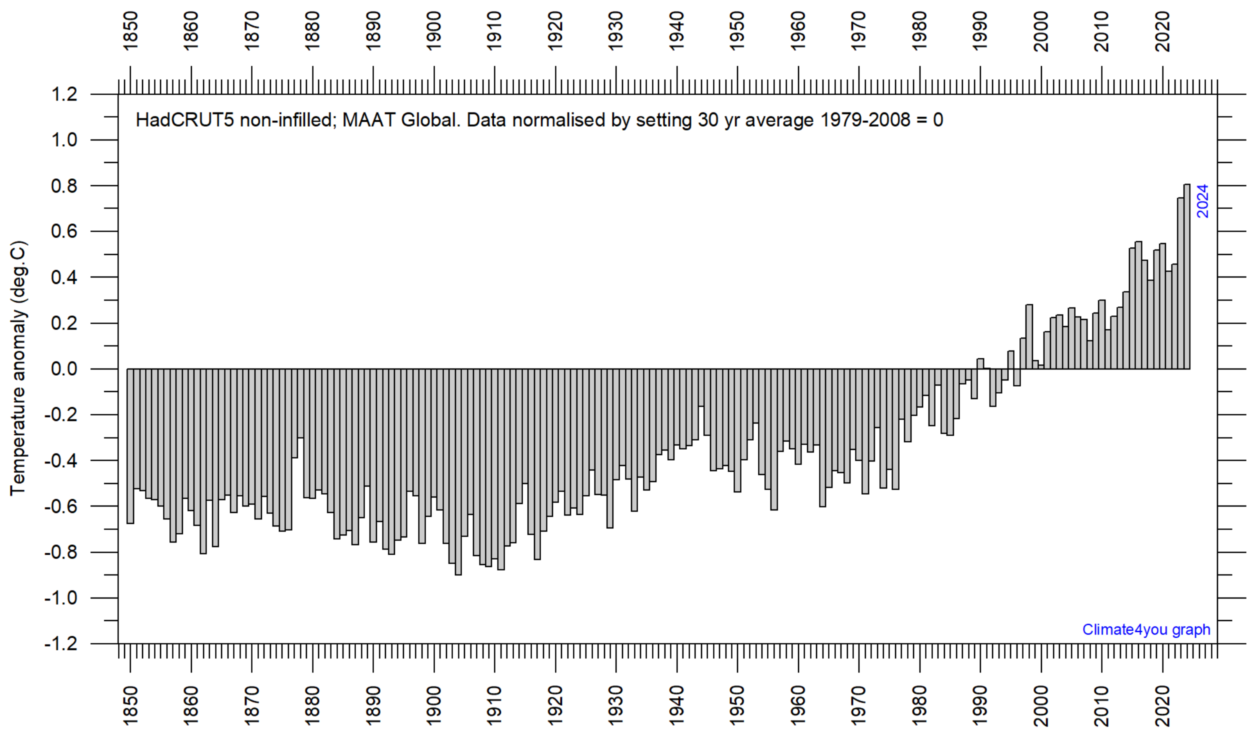


FIGURE 5. Mean annual global surface air temperature (thin line) since 1850 according to according to the Hadley Centre for Climate Prediction and Research and the University of East Anglia's [Climatic Research Unit](CRU) ([CRU]), UK. The average for 1979-2008 (30 years) has been set to zero.

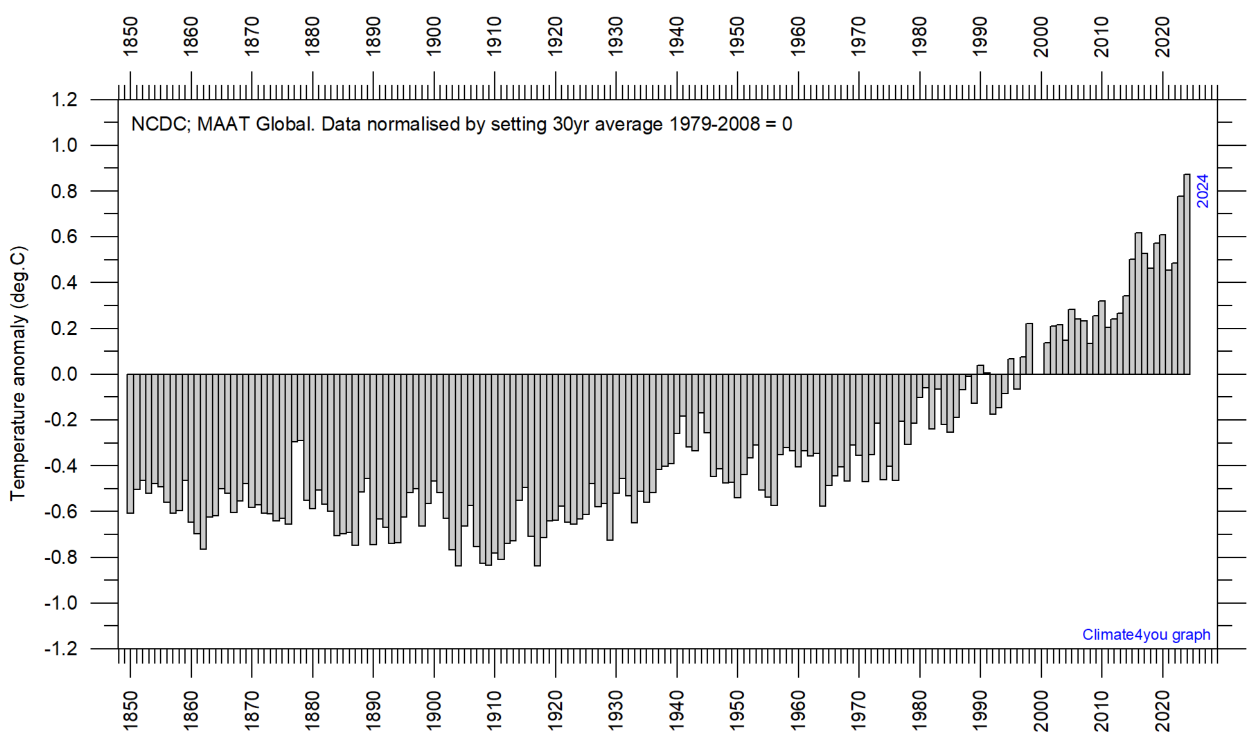


FIGURE 6. Mean annual global surface air temperature since 1880 according to according to the National Climatic Data Center (NCDC), USA. The average for 1979-2008 (30 years) has been set to zero, to make comparison with other temperature data series easy.

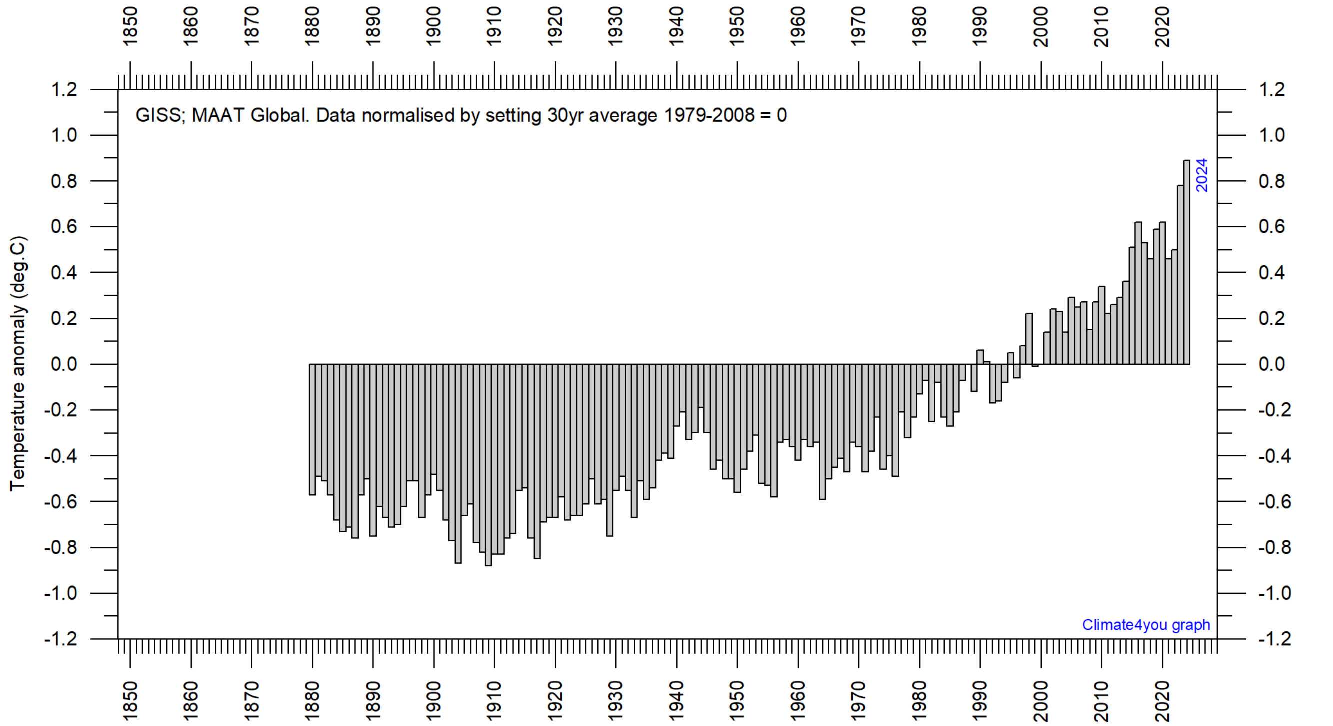


FIGURE 7. Mean annual global surface air temperature (thin line) since 1880 according to according to the [Goddard Institute for Space Studies](#) (GISS), at Columbia University, New York City, USA. The average for 1979-2008 (30 years) has been set to zero, to make comparison with other temperature data series easy.

Reflections on the significance of the 2024 global annual surface air temperature

According to the surface stations 2024 (beginning in 1850 and 1880) ranks as a record warm year. Also, according to the satellite records (since 1979) 2024 was a record warm year.

The recent strong El Niño peaked during northern hemisphere winter 2023-24 (Fig. 12 and 14) and is be the end of 2024 followed by a developing cool oceanographic reversal, known as La Niña. This recent development will probably influence global air temperatures towards lower values in 2025. The temperature effect of this oceanic phenomenon is clearly seen in figure 1 and 2.

El Niño and La Niña is playing near the Equator, which explains the large effect on the average global air temperature, including year 2024. In fact, no less than 50% of planet Earth's surface area is located within 30°N and 30°S, explaining the large effect of such phenomenon playing out near Equator.

Air temperature changes do not only play out at the planet surface, but also at higher levels in the atmosphere (see Fig. 11). The current CO_2 hypothesis projects that the initial temperature increase should initially play out in the upper Troposphere, at 6-8 km altitude. However, since 1979 the earth's surface has warmed faster than the upper Troposphere, implying that the surface heating observed (including 2024) is not predominantly due to added atmospheric CO_2, but is largely caused by variations in other factors (insolation, cloud cover, oceans, land use, etc.).

Comparing surface air temperatures with data from satellites at the end of 2024

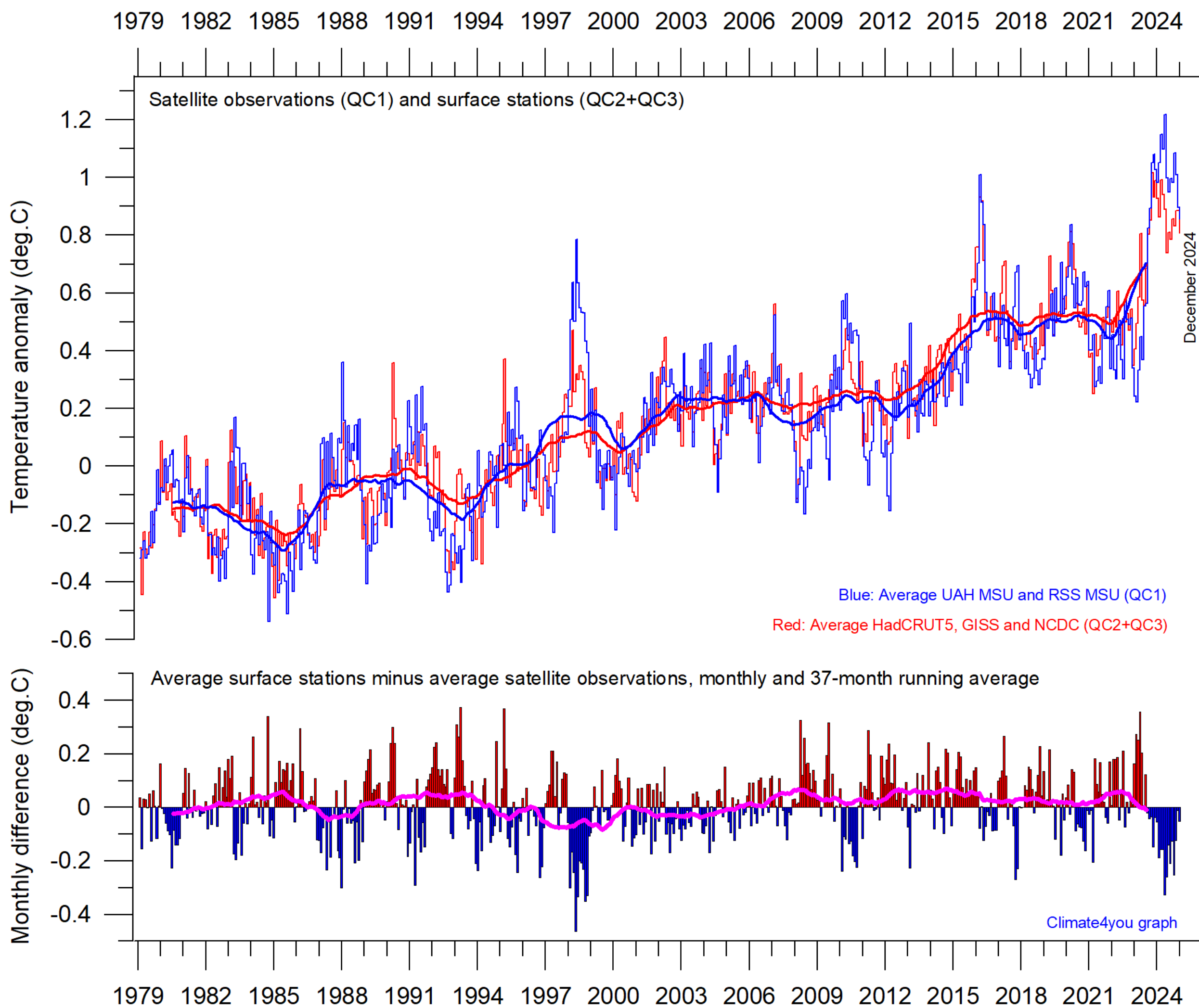


FIGURE 8. Plot showing the average of monthly global surface air temperature estimates (HadCRUT4, GISS and NCDC) and satellite-based temperature estimates (RSS MSU and UAH MSU). The thin lines indicate the monthly value, while the thick lines represent the simple running 37-month average, nearly corresponding to a running 3-yr average. The lower panel shows the monthly difference between surface air temperature and satellite temperatures. As the base period differs for the different temperature estimates, they have all been normalised by comparing to the average value of 30 years from January 1979 to December 2008.

Global satellite temperature trends calculated for different periods until end of 2024

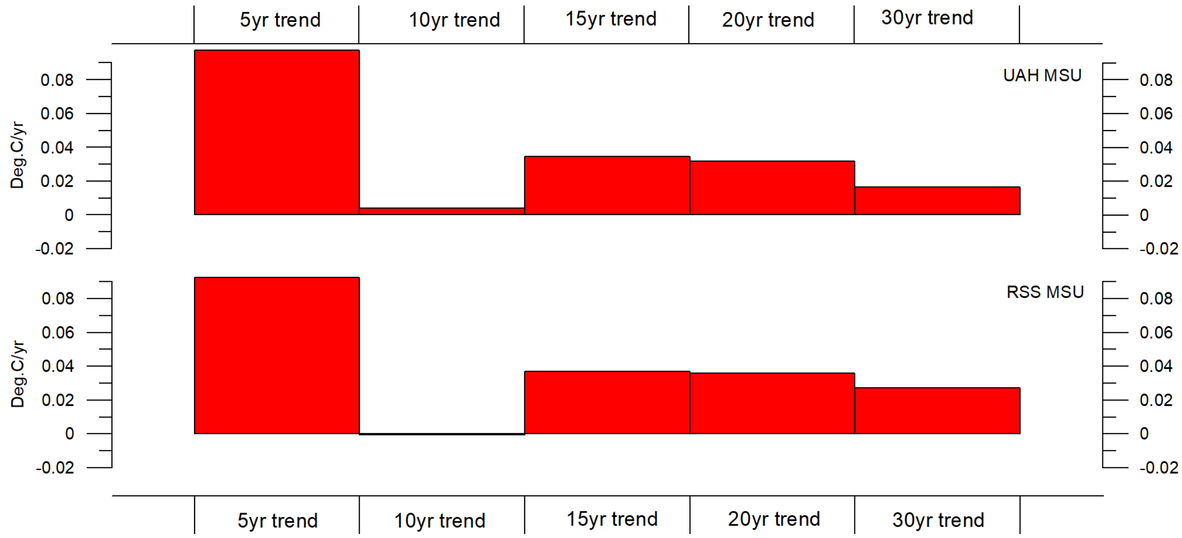


FIGURE 9. Diagram showing the latest 5, 10, 20 and 30 yr linear annual global temperature trend, calculated as the slope of the linear regression line through the data points, for two satellite-based temperature estimates (UAH MSU and RSS MSU).

Global surface air temperature trends calculated for different periods until end of 2024

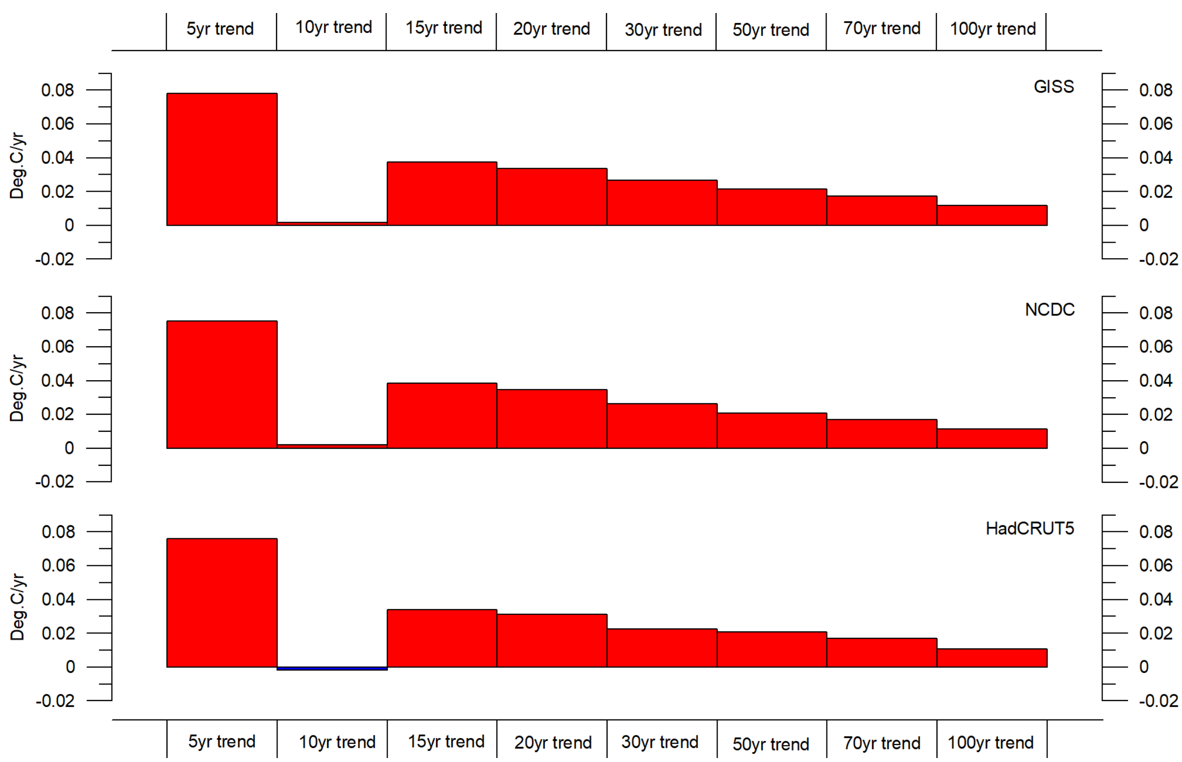


FIGURE 10. Diagram showing the latest 5, 10, 15, 20, 30, 50, 70 and 100-year linear annual global temperature trend, calculated as the slope of the linear regression line through the data points, for three surface-based temperature estimates (GISS, NCDC and HadCRUT3).

Troposphere and stratosphere temperatures from satellites at the end of 2024

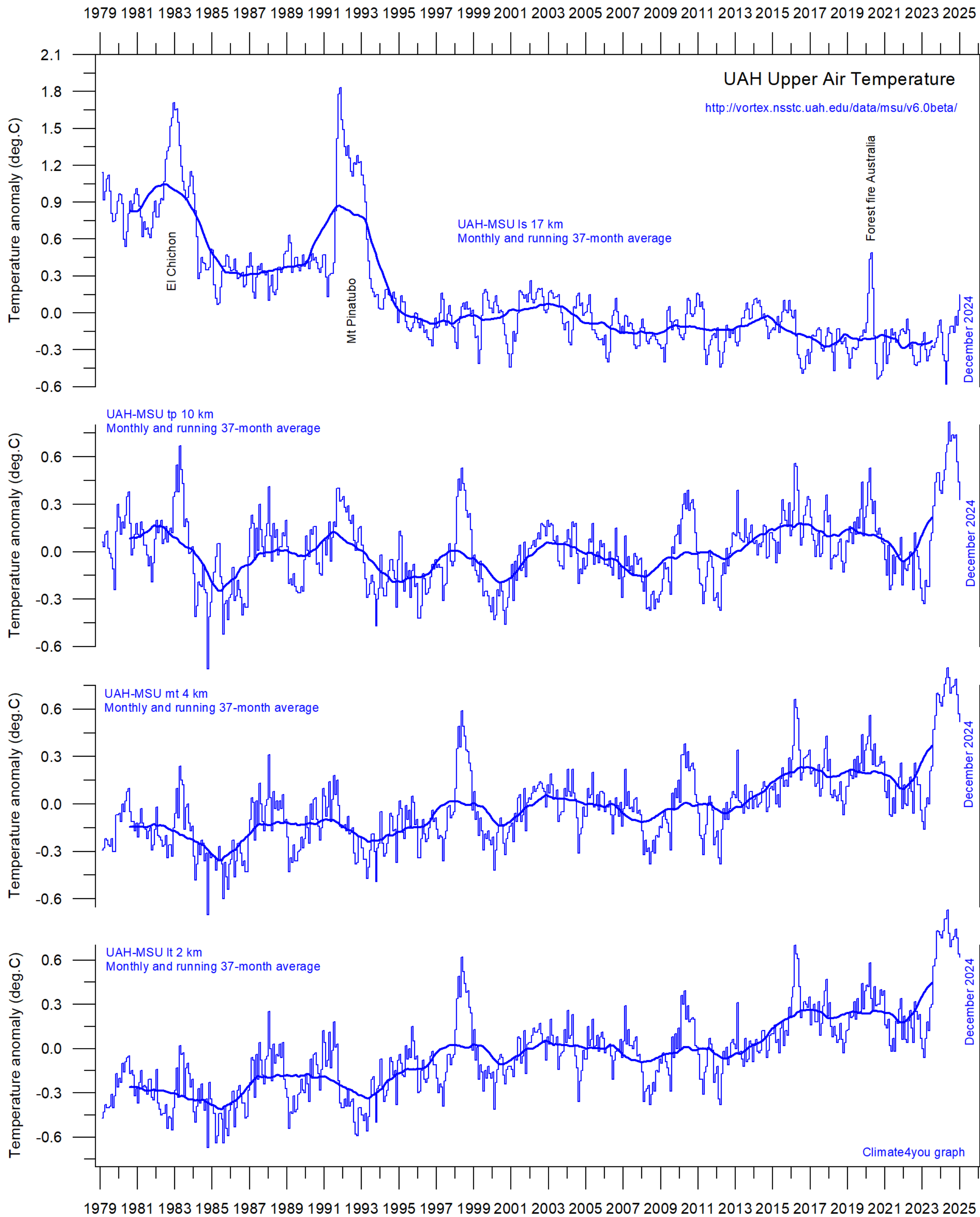


FIGURE 11. Global monthly average temperature in different according to University of Alabama at Huntsville, USA. The thin lines represent the monthly average, and the thick line the simple running 37-month average, nearly corresponding to a running 3-year average.

Sea surface temperature anomaly at the end of year 2024 and 2023

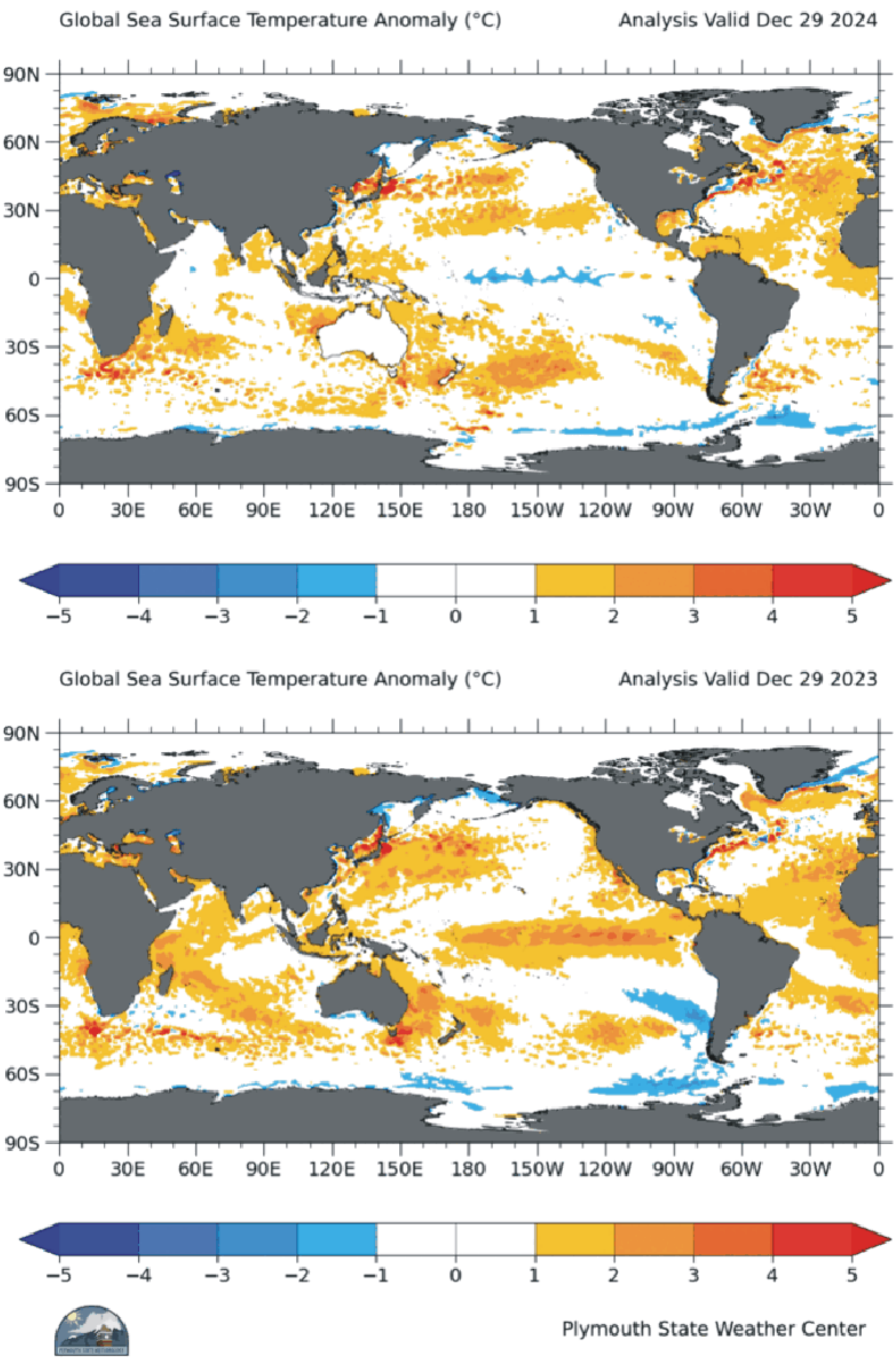


FIGURE 12. Sea surface temperature anomaly in late December 2024 and 2023, upper and lower panel, respectively. Reference period: 1977-1991. Map source: Plymouth State Weather Center.

Ocean temperatures, uppermost 1900m, updated to December 2021

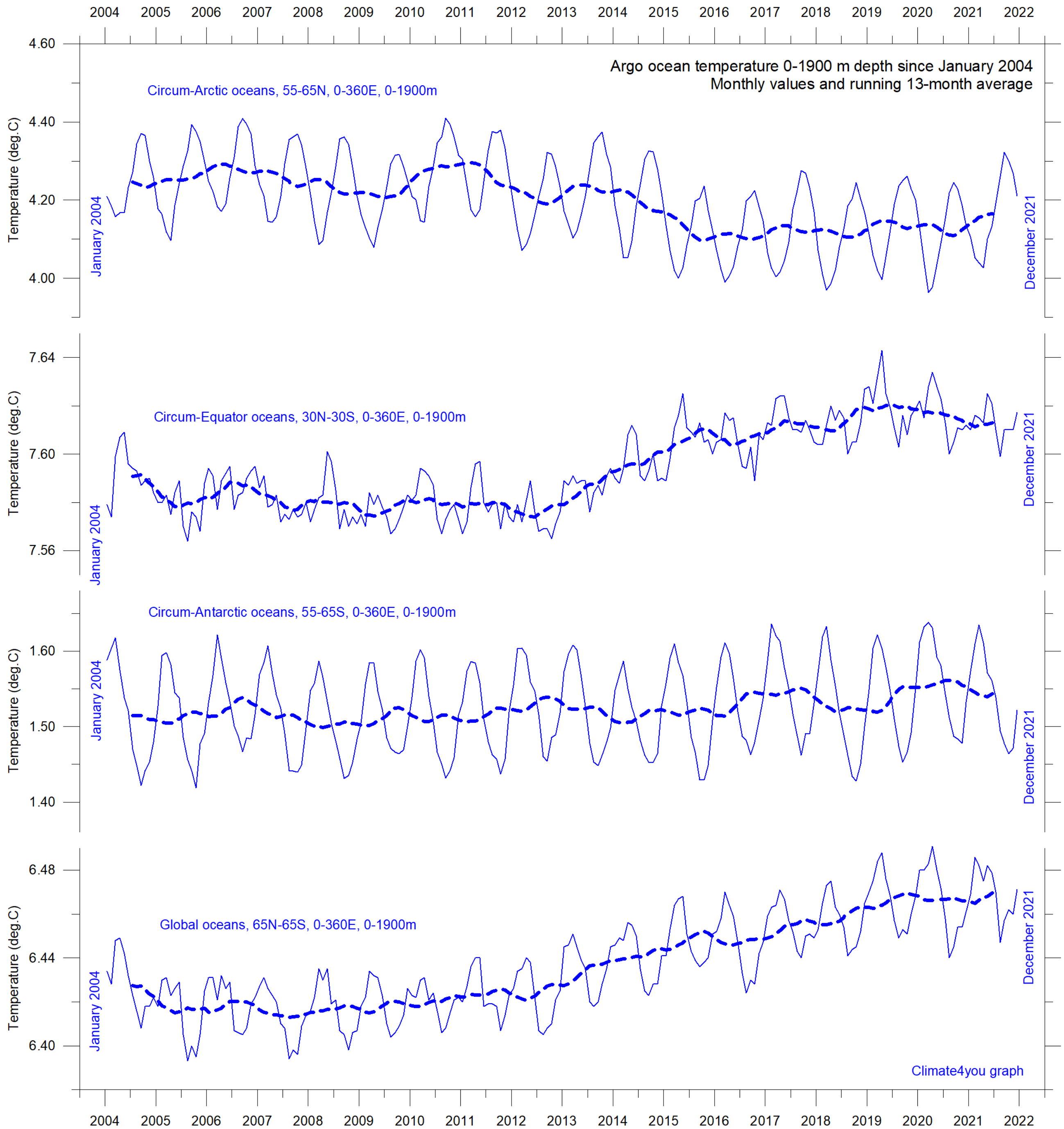


FIGURE 13. Diagram showing average 0-1900m depth ocean temperatures in selected latitudinal bands, using [Argo](#)-data. The thin line shows monthly values, and the stippled line shows the running 13-month average. Source: [Global Marine Argo Atlas](#). Please note that the Argo data series is not yet updated beyond December 2021.

La Niña and El Niño episodes, updated to October-December 2024

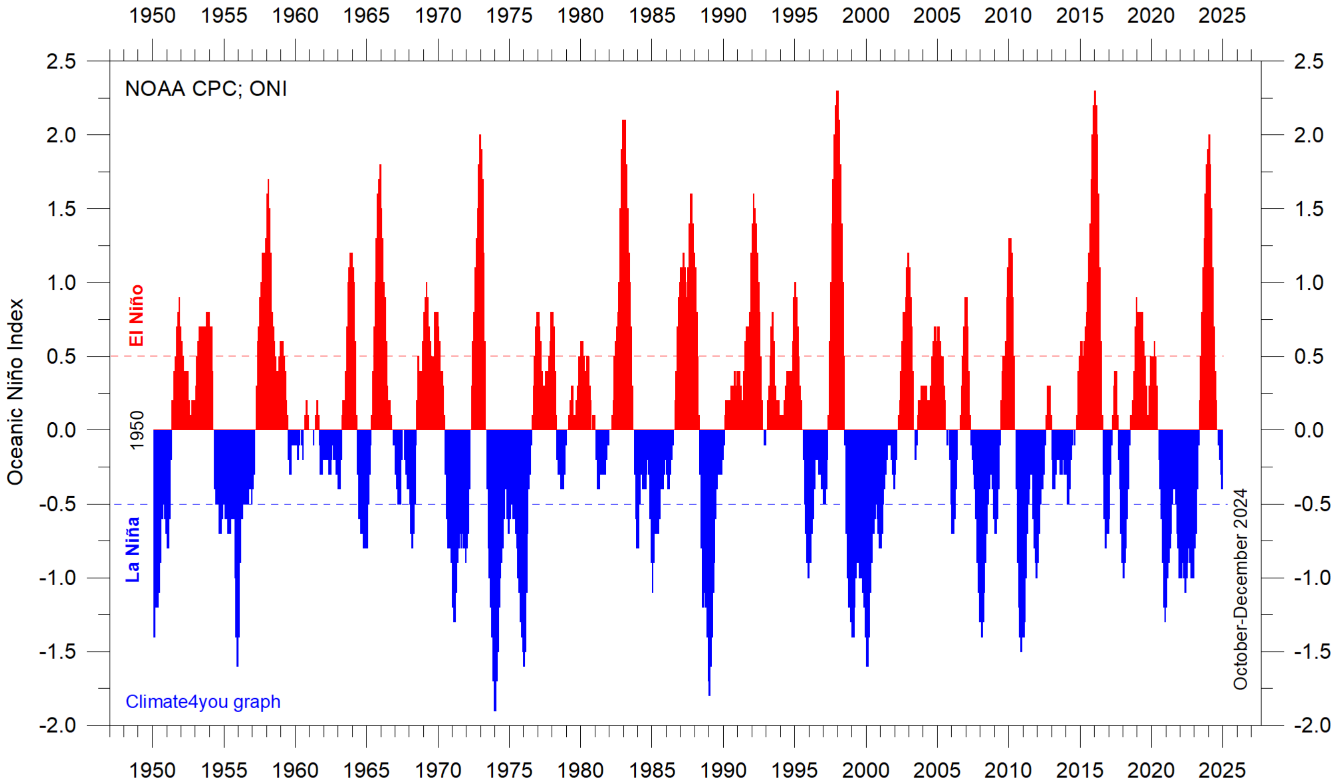
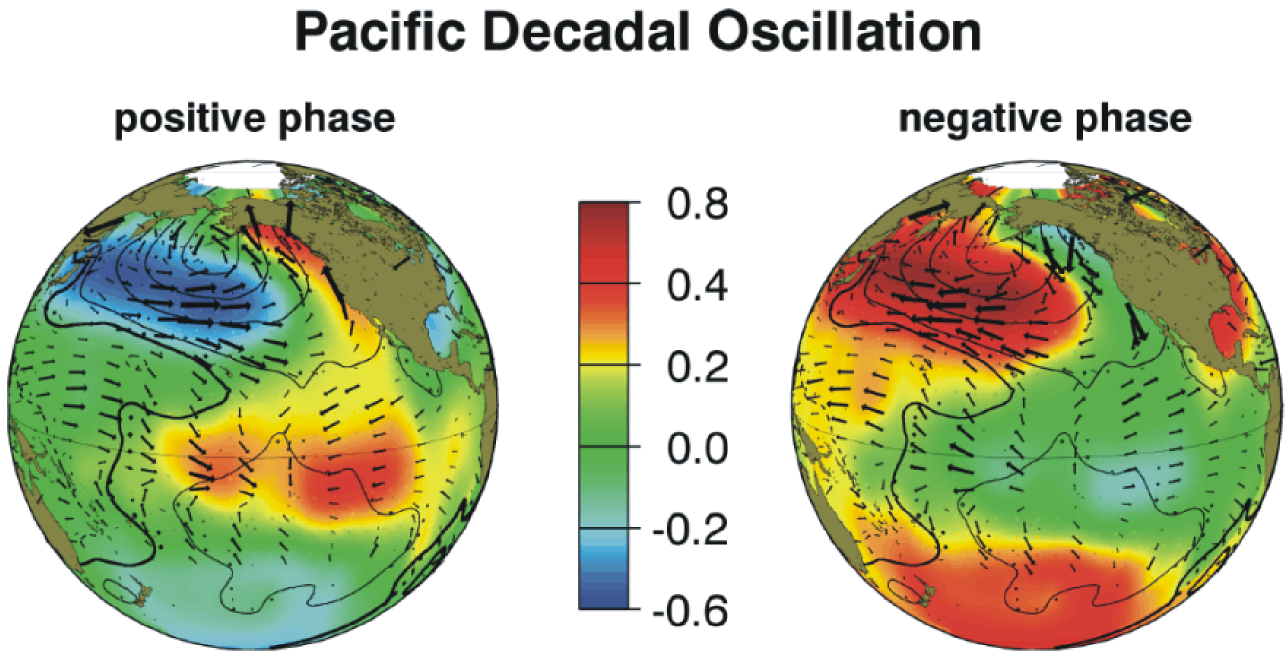


FIGURE 14. Warm (>+0.5°C) and cold (<0.5°C) episodes for the Oceanic Niño Index (ONI), defined as 3 month running mean of ERSST.v3b SST anomalies in the Niño 3.4 region (5°N-5°S, 120°-170°W)]. Base period: 1971-2000. For historical purposes cold and warm episodes are defined when the threshold is met for a minimum of 5 consecutive over-lapping seasons.

Years 2023-2024 was characterized by a strong El Niño episode developing in the Pacific Ocean. At the end of the year, the index is now declining (Fig.14), presumably indicating the coming development of a La Niña episode. This diagram also shows that the previous 2015-16 El Niño is among the strongest El Niño episodes since the beginning of the record in 1950. Considering the entire record, however, recent variations between El Niño and La Niña episodes are not unusual.

PDO - Pacific Decadal Oscillation, updated to 2024



Typical wintertime Sea Surface Temperature (colors), Sea Level Pressure (black lines) and surface wind stress (arrows) anomaly patterns during warm and cool phases of PDO.

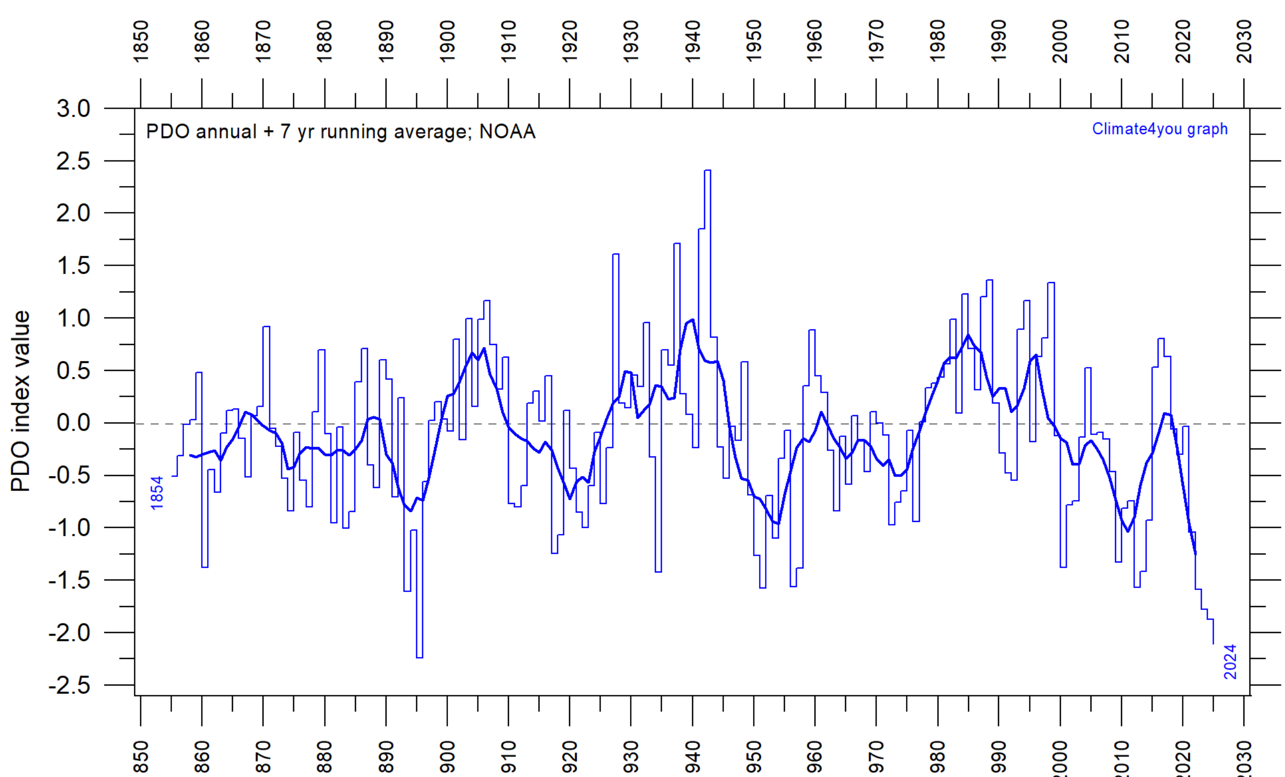


FIGURE 15. Annual values of the Pacific Decadal Oscillation (PDO) according to the Joint Institute for the Study of the Atmosphere and Ocean (JISAO), a Cooperative Institute between the National Oceanic and Atmospheric Administration and the University of Washington. The PDO is a long-lived El Niño-like pattern of Pacific climate variability, and the data series goes back to January 1900. The thin line indicates annual PDO values, and the thick line is the simple running 7-year average.

AMO (Atlantic Multidecadal Oscillation) Index, updated to 2022

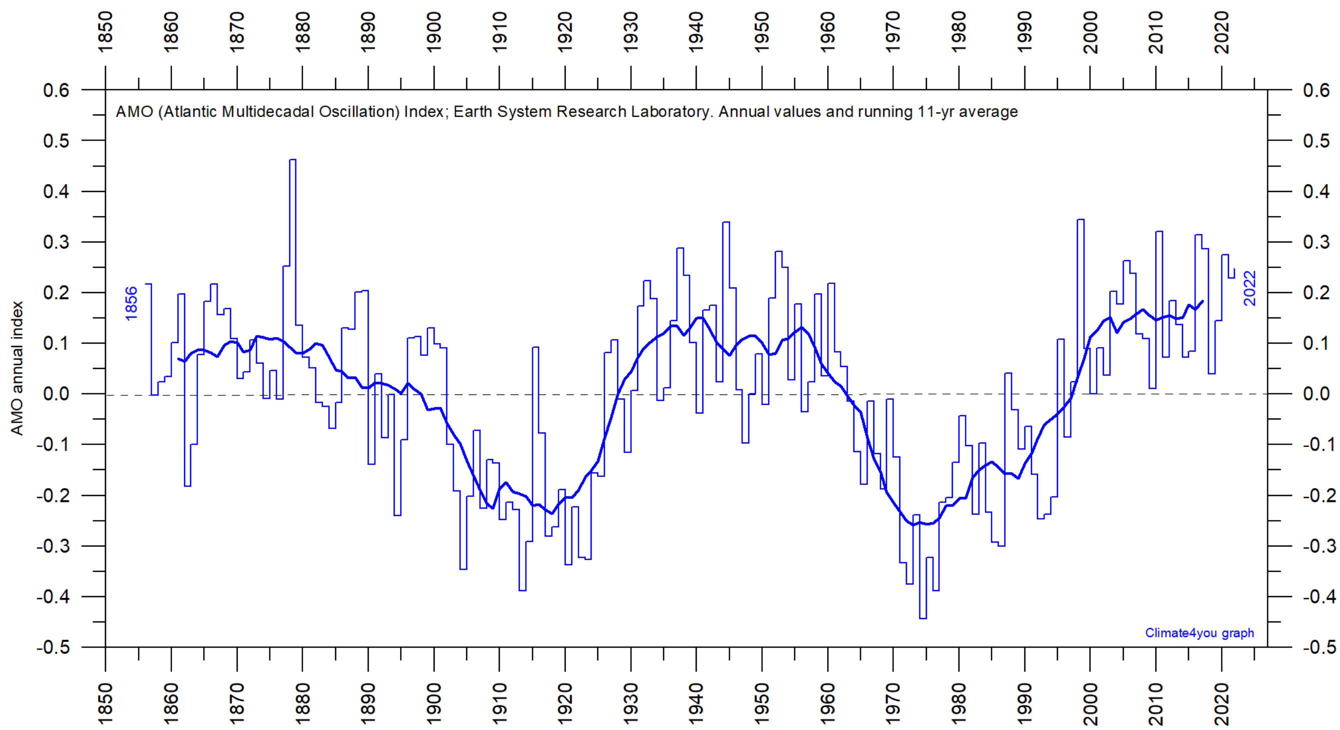


FIGURE 16. Annual Atlantic Multidecadal Oscillation (AMO) detrended index values since 1856. The thin line indicates the annual values, and the thick line is the simple running 11-year average. Data source: Earth System Research Laboratory at NOAA.

The Atlantic Multidecadal Oscillation (AMO; Fig. 40) is a mode of variability occurring in the North Atlantic Ocean sea surface temperature field. The AMO is basically an index of North Atlantic Sea surface temperatures (SST).

The AMO index appears to be correlated to air temperatures and rainfall over much of the Northern Hemisphere. The association appears to be high for northeastern Brazil, African Sahel rainfall and North American and European summer climate. The AMO index also appears to be associated with changes in the frequency of North American droughts and is reflected in the frequency of severe Atlantic hurricanes.

As one example, the AMO index may be related to the past occurrence of major droughts in the US Midwest and the Southwest. When the AMO is high, these droughts tend to be more frequent or prolonged, and vice-versa for low values of AMO. Two of the most severe droughts of the 20th century in US occurred during the peak AMO values between 1925 and 1965: The Dust Bowl of the 1930s and the 1950s droughts. On the other hand, Florida and the Pacific Northwest tend to be the opposite; high AMO is here associated with relatively high precipitation.

A Fourier-analysis (not shown here) show the AMO record to be controlled by an about 67-year long cycle, and to a lesser degree by a 3.5-year cycle.

Tropical storm and hurricane accumulated cyclone energy (ACE), updated to 2020

Accumulated cyclone energy (ACE) is a measure used by the National Oceanic and Atmospheric Administration (NOAA) to express the activity of individual tropical cyclones and entire tropical cyclone seasons. ACE is calculated as the square of the wind speed every 6 hours and is then scaled by a factor of 10,000 for usability, using a unit of 10^4 knots^2. The ACE of a season is the sum of the ACE for each storm and considers the number, strength, and duration of all the tropical storms in the season.

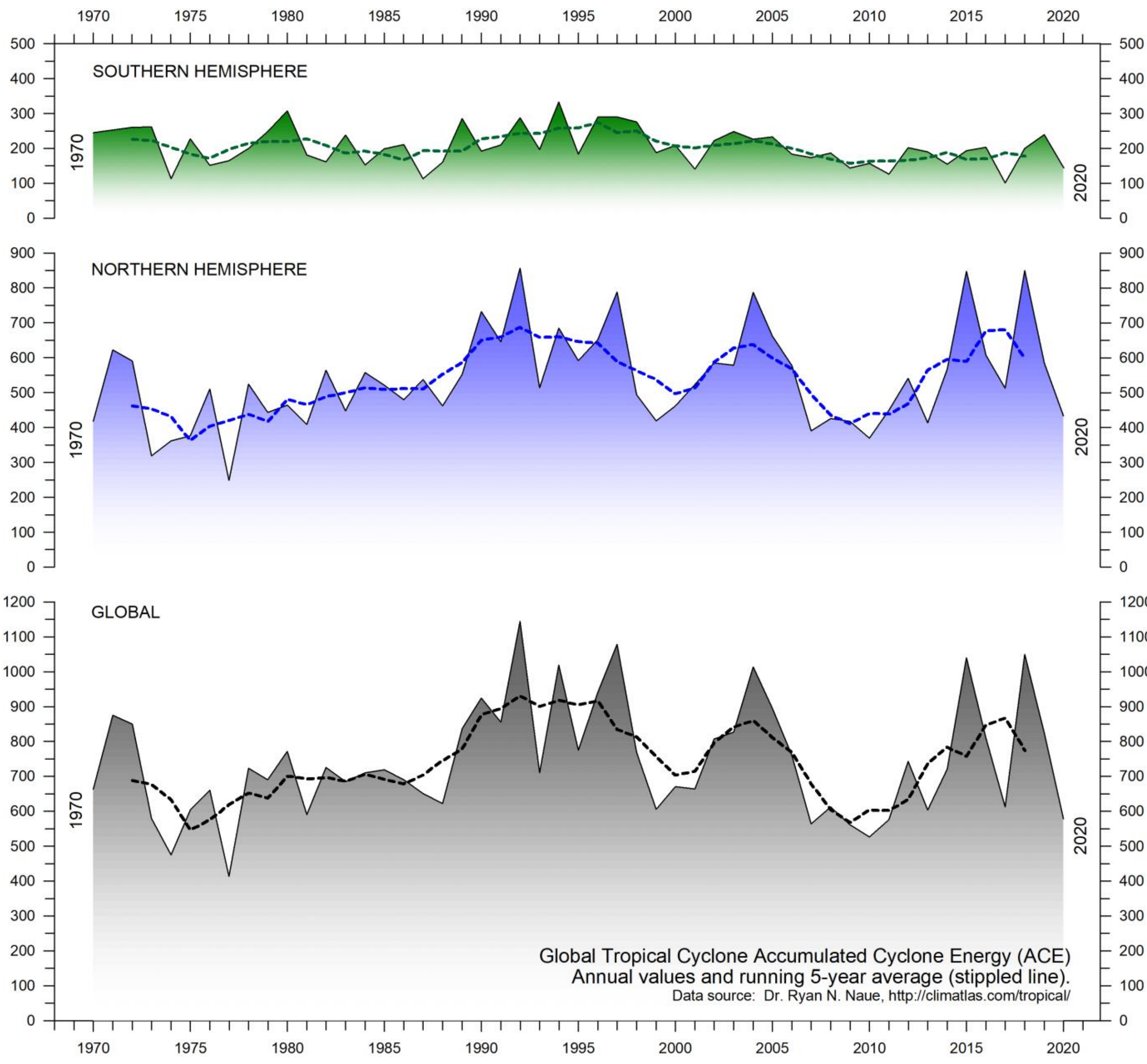


FIGURE 17: The diagram above shows the annual global tropical storm and hurricane accumulated cyclone energy (ACE) 10^4 Knots^2, since 1970. Data source: Maue ACE data.

The damage potential of a hurricane is proportional to the square or cube of the maximum wind speed, and thus ACE is therefore not only a measure of tropical cyclone activity, but also a measure of the damage potential of an individual cyclone or a season. Existing records (Fig. 17) do not suggest any abnormal cyclone activity in recent years.

The global ACE data since 1970 display a variable pattern over time (Fig. 17), but without any clear trend, as are the diagrams for the Northern- and Southern Hemisphere (panels in Fig. 17). A Fourier analysis (not shown here) shows a significant period of about 3.6 year in the ACE data, and furthermore suggests the existence of a 11.5-year period, but the data series is still too short to conclude anything decisively on this.

The period 1989-1998 was characterised by high values, other peaks were seen 2004, 2015 and 2018, while the periods 1973-1988, 1999-2003 and 2006-2014 were characterised by low values. The peaks in 1997/98 and 2016 coincide with strong El Niño events in the Pacific Ocean (Fig. 14). The ACE data and ongoing cyclone dynamics are detailed in Maue (2011). The Northern Hemisphere ACE values (central panel in figure 17) dominates the global signal (lower panel in figure 17) and therefore show similar peaks and lows as displayed by the global data, without any clear trend for the entire observational period. The Northern Hemisphere main cyclone season is June-November. The Southern Hemisphere ACE values (upper panel in Fig. 17) are generally lower than for the Northern Hemisphere, and the main cyclone season is December-April.

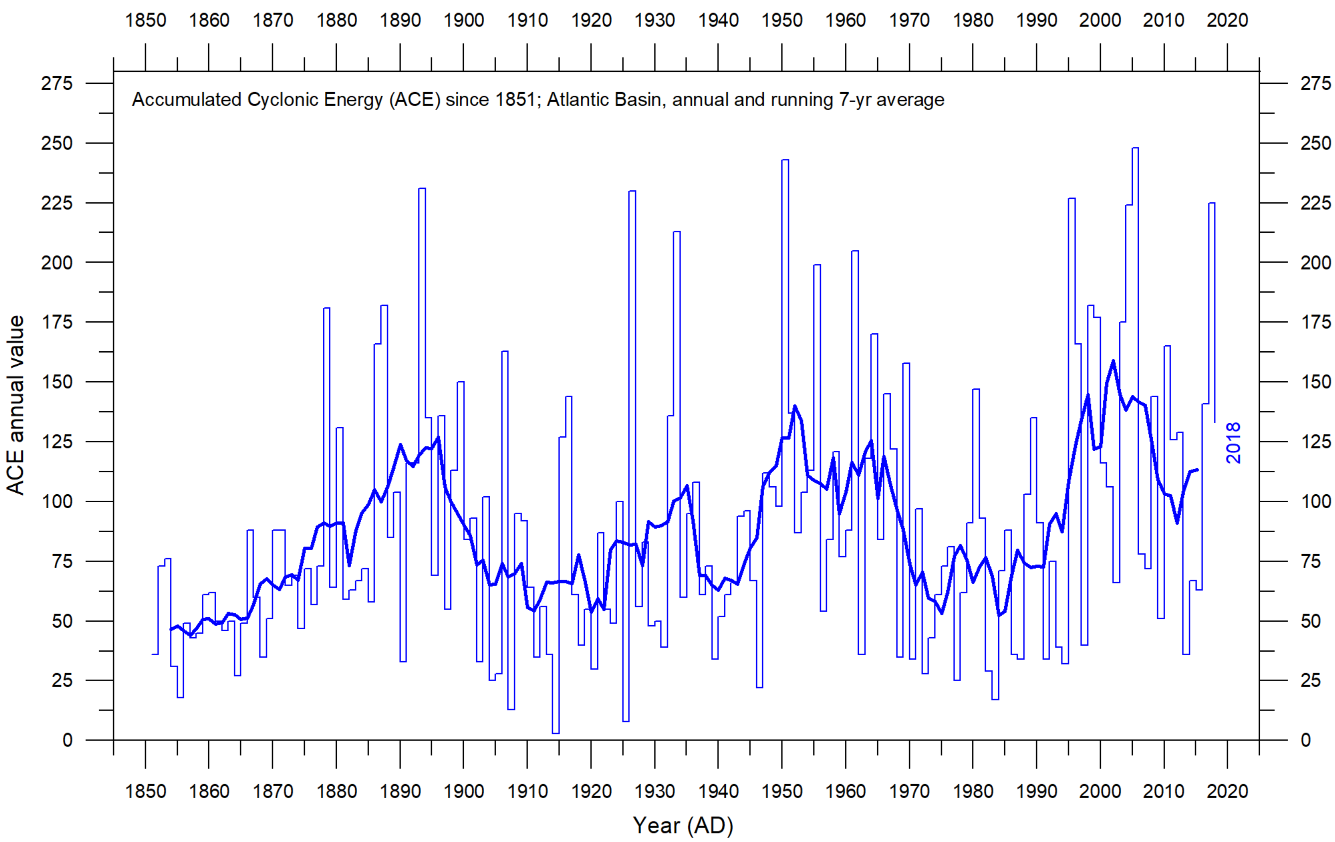


FIGURE 18: Accumulated cyclonic energy (ACE; Atlantic basin) per year since 1850 AD. Thin lines show annual ACE values, and the thick line shows the running 7-year average. Data source: Atlantic Oceanographic and Meteorological Laboratory (AOML), Hurricane research Division. Please note that these data are not yet updated beyond 2018.

The Atlantic Oceanographic and Meteorological Laboratory ACE data series goes back to 1850. A Fourier analysis for the Atlantic Basin (Fig. 18) show the ACE series to be strongly influenced by a periodic variation of about 60 years' duration. At present, since 2002, the Atlantic ACE series is displaying an overall declining trend, but with large interannual variations. The North Atlantic hurricane season often shows above average activity when La Nina conditions are present in Pacific during late summer (August-October), as was the case in 2017 (Johnstone and Curry, 2017).

Golany (2021) presents many additional observations and reflections on recent storm and hurricane activity.

Golany, I.M. 2021: *Impacts of Climate Change Perception and Reality*. The Global Warming Policy Foundation, report 46, 44pp. https://www.thegwpf.org/content/uploads/2021/02/Goklany-EmpiricalTrends.pdf

Arctic and Antarctic sea ice extension, updated to December 2024

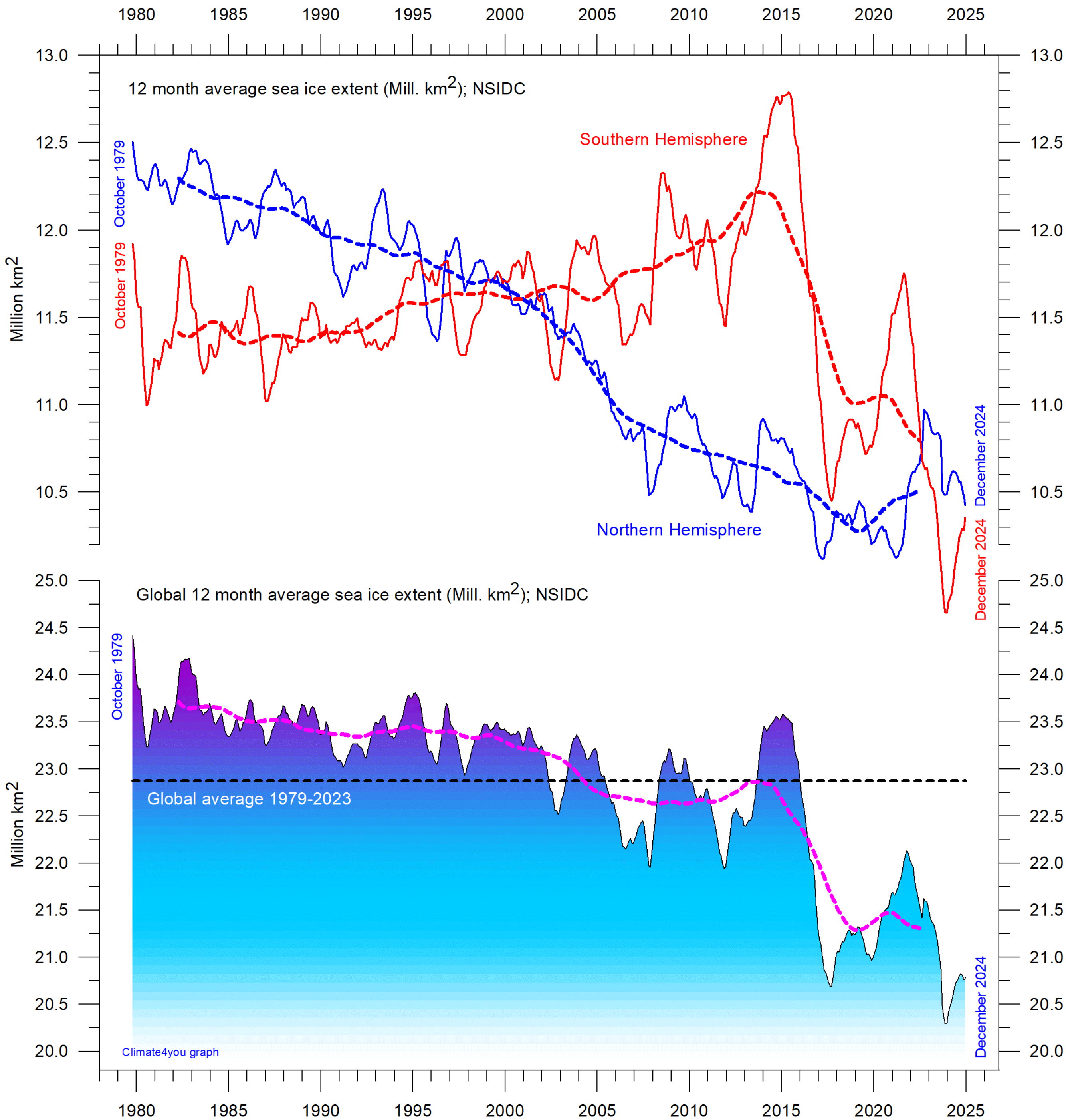


FIGURE 19. Global and hemispheric 12 month running average sea ice extension since 1979, the satellite-era. The October 1979 value represents the monthly average of November 1978 - October 1979, the November 1979 value represents the average of December 1978 - November 1979, etc. The stippled lines represent a 61-month (ca.5 years) average. Last month included in the 12-month calculations is shown to the right in the diagram. Data source: National Snow and Ice Data Center (NSIDC).

Northern Hemisphere snow cover, updated to December 2024

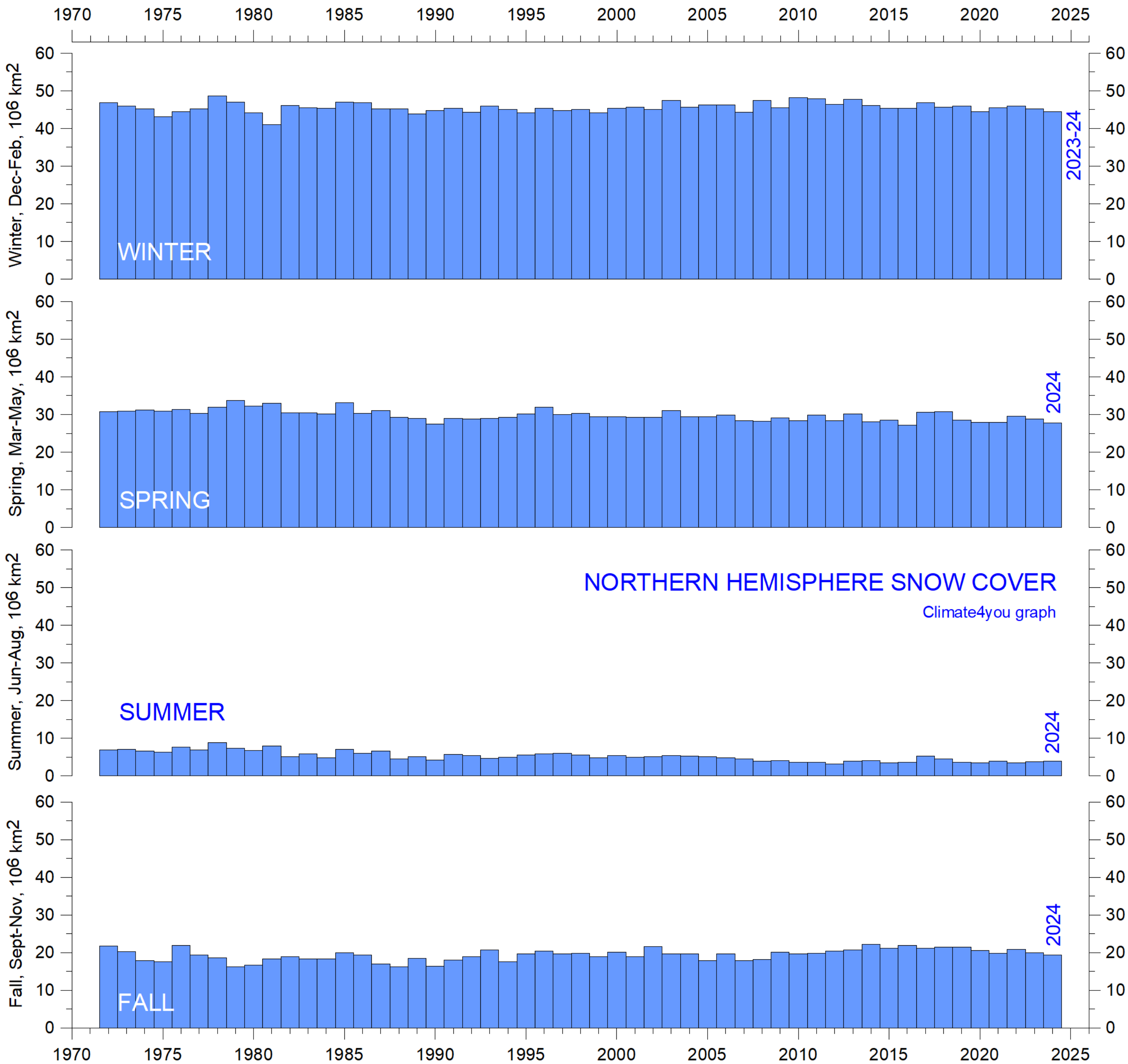


FIGURE 20. Northern Hemisphere seasonal snow cover since 1972 according to Rutgers University Global Snow Laboratory.

Atmospheric specific humidity, updated to December 2024

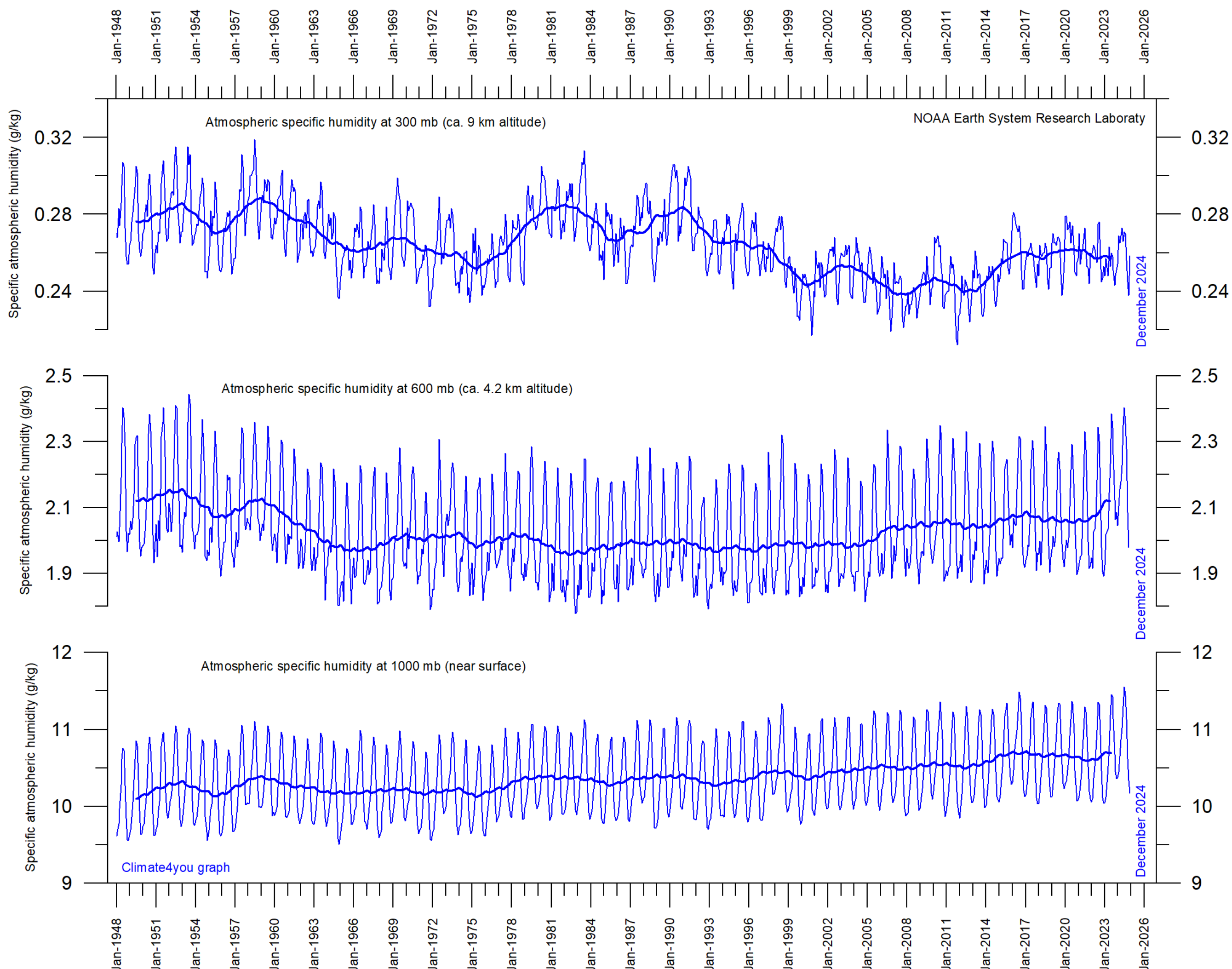


FIGURE 21. Specific atmospheric humidity (g/kg) at three different altitudes in the lower part of the atmosphere (the Troposphere) since January 1948 (Kalnay et al. 1996). The thin blue lines show monthly values, while the thick blue lines show the running 37-month average (about 3 years). Data source: Earth System Research Laboratory (NOAA).

Water vapor is the most important greenhouse gas in the Troposphere. The highest concentration is found within a latitudinal range from 50°N to 60°S. The two polar regions of the Troposphere are comparatively dry.

Climate models assume that the atmosphere during a CO_2 induced warming should display rising specific humidity but maintain a constant relative humidity.

The diagram above shows the specific atmospheric humidity to be stable or slightly increasing up to about 4-5 km altitude. At higher levels in the Troposphere (about 9 km), the specific humidity has been decreasing for the duration of the record (since 1948), although with shorter variations superimposed on the falling trend.

The persistent decrease in specific humidity at about 9 km altitude is particularly noteworthy, as this altitude roughly corresponds to the level where the theoretical temperature effect of increased atmospheric CO_2 is expected initially to play out. In contrast, climate models assume specific humidity to increase at this height.

A Fourier frequency analysis (not shown here) suggests these changes are influenced, not only by the significant annual variation, but feasibly also by a longer variation of about 35-years' duration. Much is still to be learnt on controls on atmospheric water vapor, and its climatic significance.

Atmospheric CO2, updated to December 2024

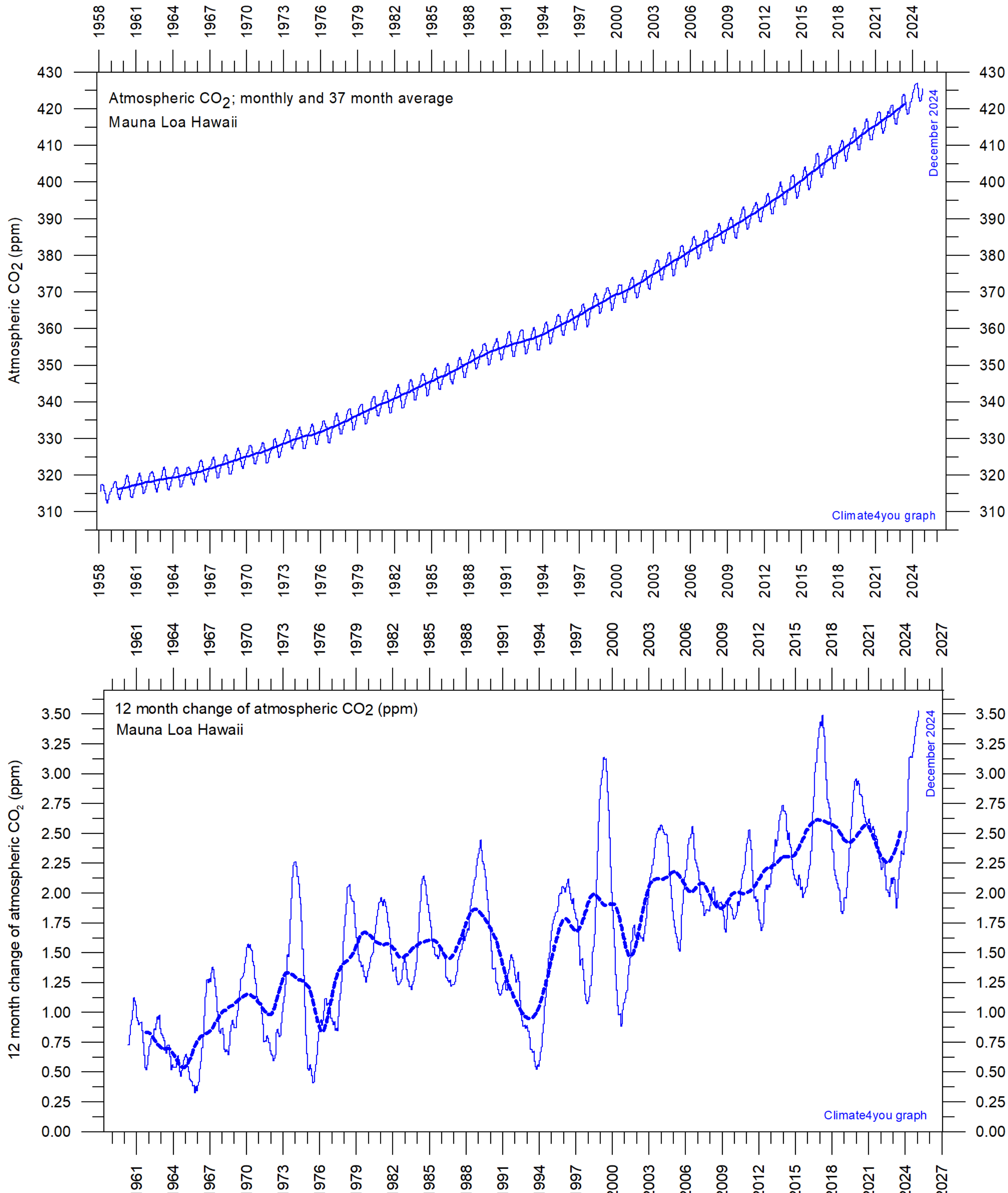


FIGURE 22. Monthly amount of atmospheric CO_2 (upper diagram) and annual growth rate (lower diagram); average last 12 months minus average preceding 12 months, thin line) of atmospheric CO_2 since 1959, according to data provided by the [Mauna Loa Observatory](), Hawaii, USA. The thick, stippled line is the simple running 37-month average, nearly corresponding to a running 3-year average.

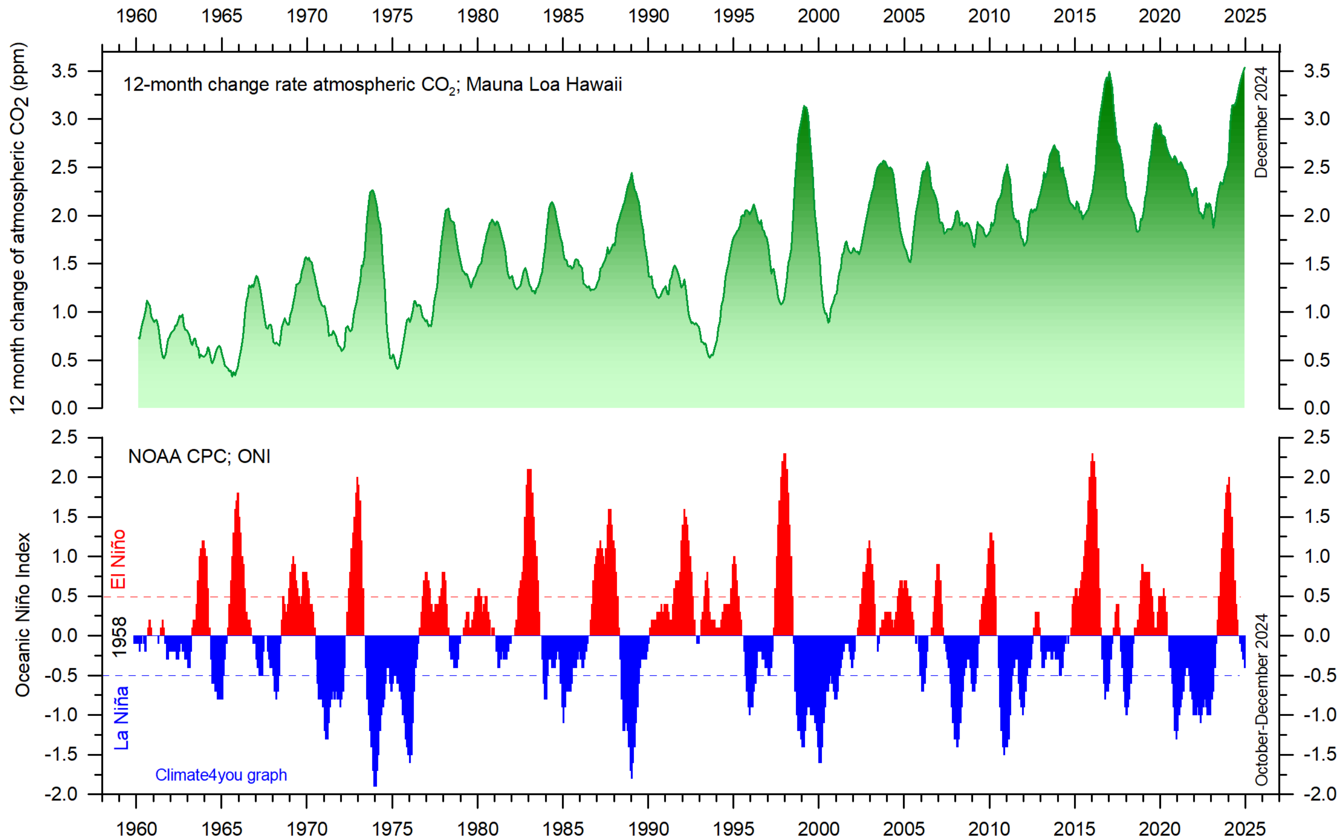


FIGURE 23. Visual association between annual growth rate of atmospheric CO_2 (upper panel) and Oceanic Niño Index (lower panel). See also Figure 14 and 21, respectively.

Number of daily sunspots since 1900, updated to December 31, 2024

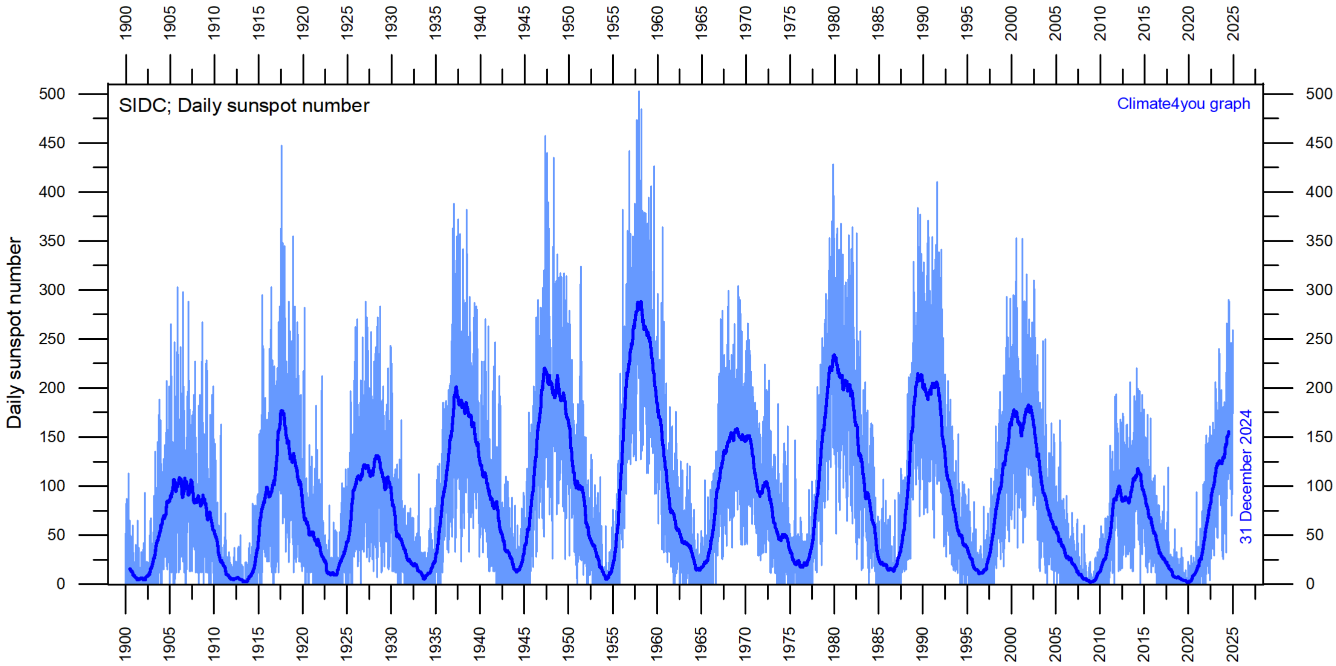


FIGURE 24. Daily observations of the number of sunspots since 1 January 1900 according to Solar Influences Data Analysis Center (SIDC). The thin blue line indicates the daily sunspot number, while the dark blue line indicates the running annual average.

****

All above diagrams with supplementary information (including links to data sources and previous issues of this newsletter) are available on www.climate4you.com

Yours sincerely,

Ole Humlum

(Ole.Humlum@gmail.com)

Arctic Historical Evaluation and Research Organisation, Longyearbyen, Svalbard

27 January 2025.