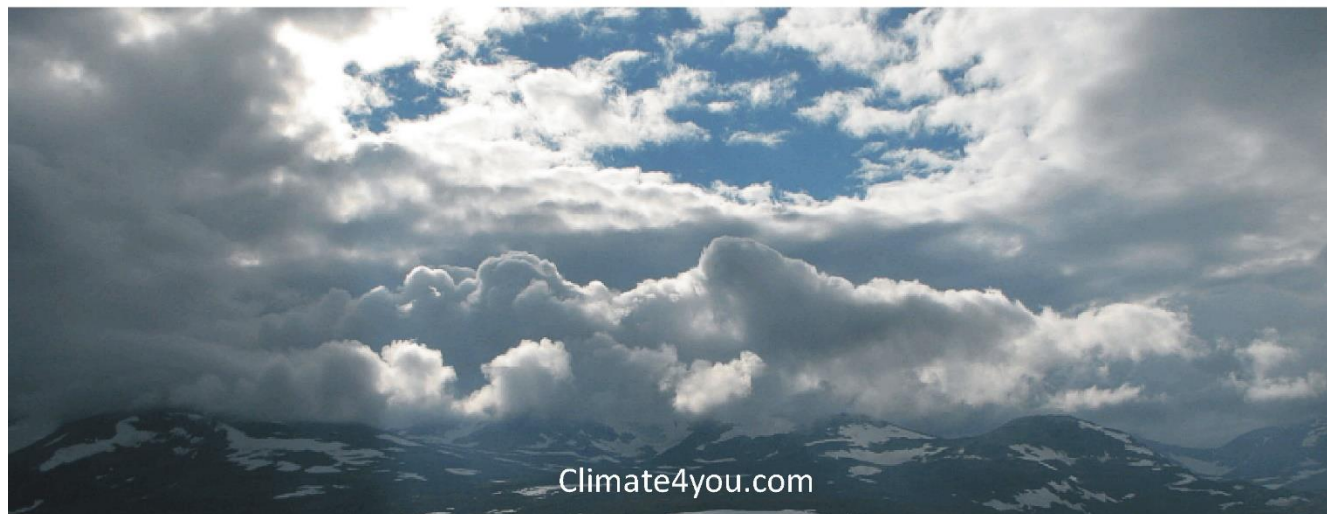


Climate4you update YEAR 2021

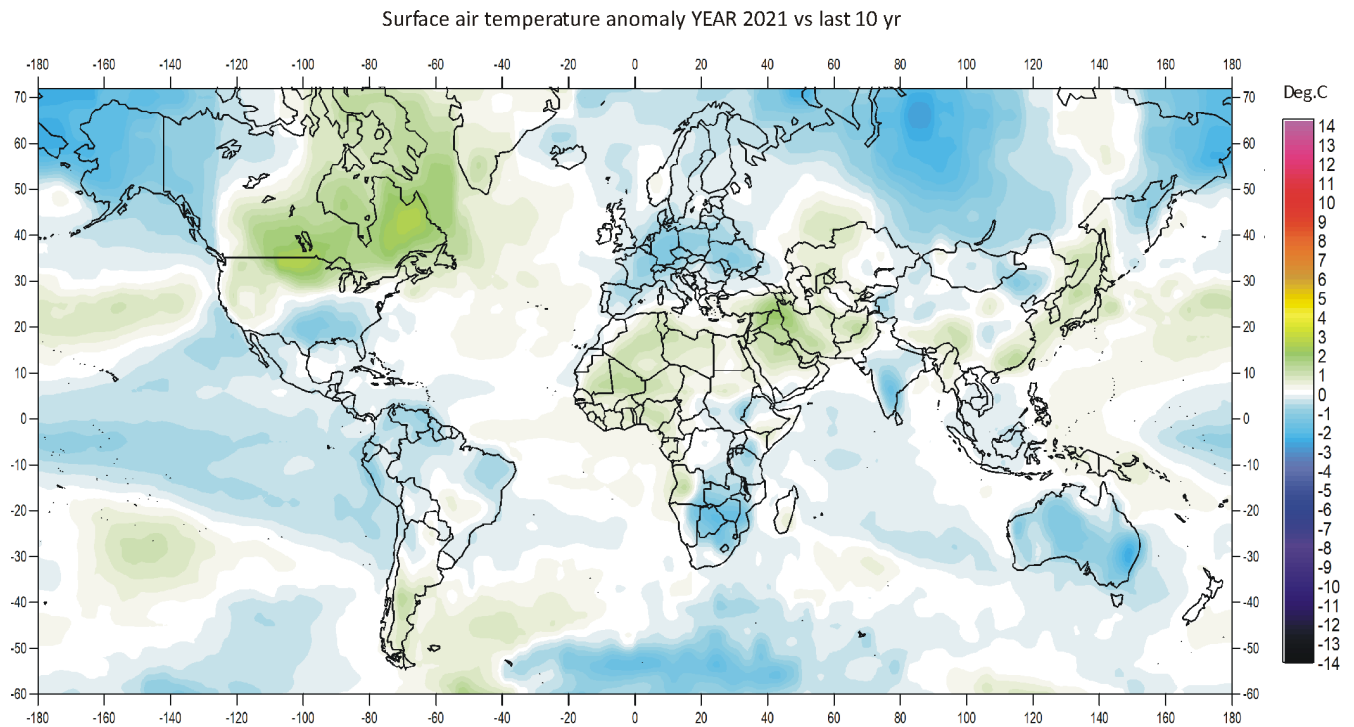


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All diagrams in this newsletter as well as links to the original data are available on www.climate4you.com

Year 2021 global surface air temperature overview versus average last 10 years



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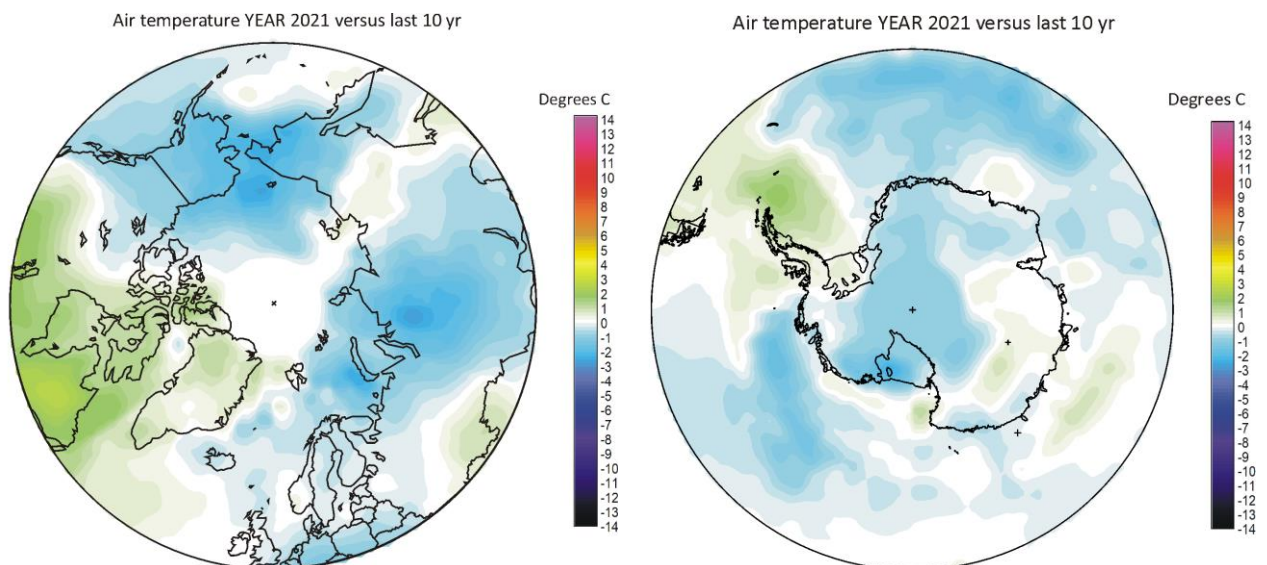
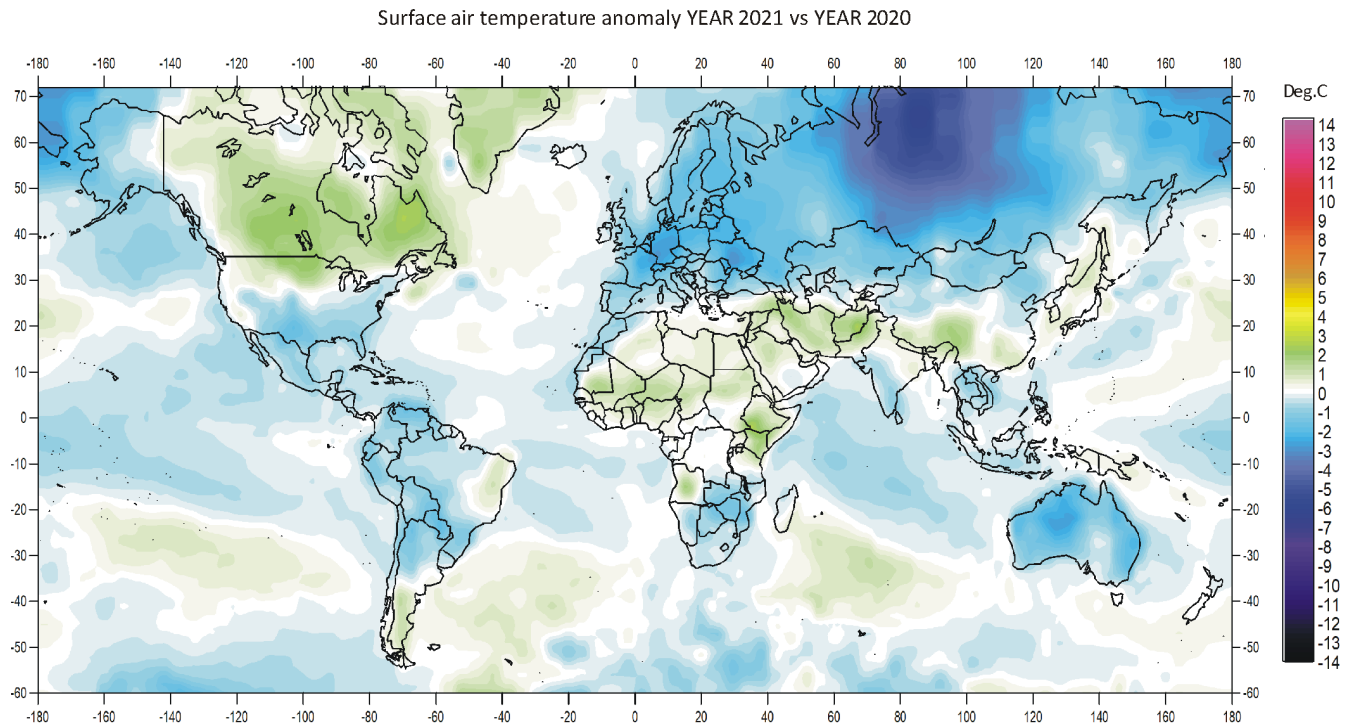


FIGURE 1. Annual 2021 average surface air temperature compared to the annual average of the last 10 years. Green-yellow-red colours indicate areas with higher temperature than the 10-year average, while blue colours indicate lower than average temperatures. Data source: Remote Sensed Surface Temperature Anomaly, AIRS/Aqua L3 Monthly Standard Physical Retrieval 1-degree x 1-degree V007 (<https://airs.jpl.nasa.gov/>), obtained from the GISS data portal (https://data.giss.nasa.gov/gistemp/maps/index_v4.html).

Year 2021 global surface air temperature overview versus year 2020



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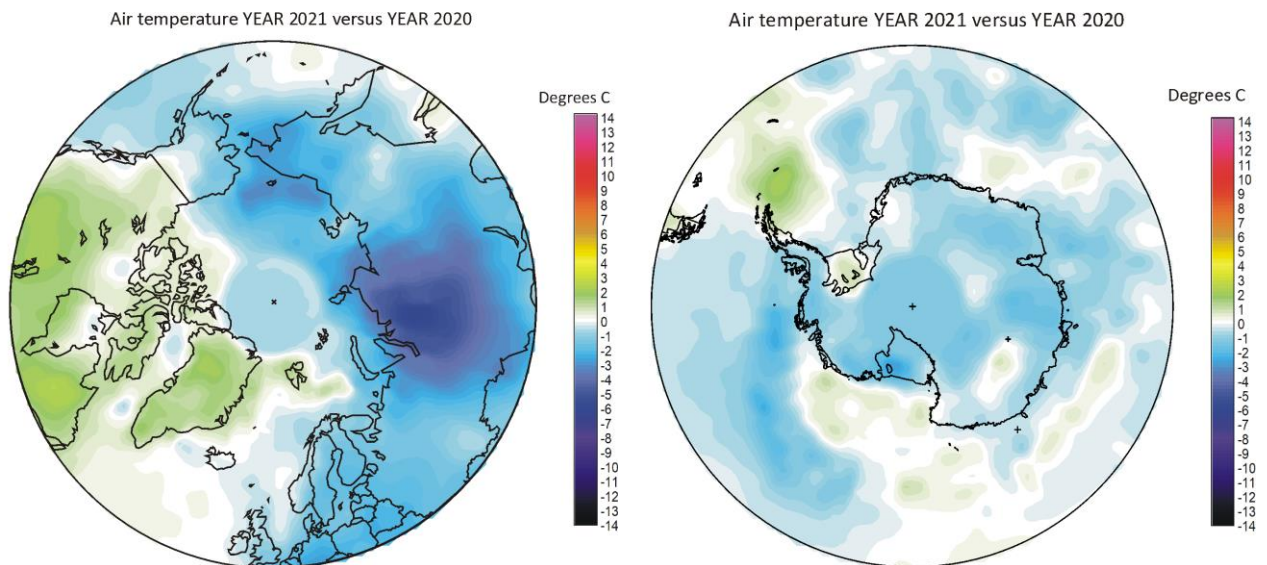


FIGURE 2. 2021 annual surface air temperature compared to year 2020. Green-yellow-red colours indicate regions where the present month was warmer than last year, while blue colours indicate regions where the present month was cooler than last year. Variations in monthly temperature from one year to the 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 V007 (<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 2021 global surface air temperature overview

The present newsletter contains graphs showing a selection of key meteorological variables for the year 2021. All temperatures are given in degrees Celsius.

In the above maps showing the geographical pattern of surface air temperatures, the last previous 10 years (2011-2020) 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 typical memory horizon for many people and is now also adopted as reference period by other institutions, e.g., the Danish Meteorological Institute (DMI).

The average global surface air temperature for 2021.

Global average surface air temperature for year 2021 was lower than the previous years. At the moment, it looks as if 2016 perhaps may indicate a global temperature peak. The coming years will show if this is correct or not. The year 2021 was affected by a cold La Niña episode (Pacific Ocean, see diagrams p. 11).

The Northern Hemisphere was characterised by regional temperature contrasts, especially north of 30°N. The most pronounced temperature events in 2021 was low average temperatures in Russia and Siberia, in strong contrast to the warm conditions in these regions in 2020. The Alaska-Russia-Siberia regions affected by the lower temperatures in 2021 (compared to last 10 years and especially 2020) encompasses some of the largest permafrost regions on planet Earth.

Near the Equator surface air temperatures were generally near or below the average for the previous 10 years. In the Pacific Ocean cooler conditions reflect the ongoing La Niña episode.

In the Southern Hemisphere surface air temperatures were near or below the average for the previous 10 years. Especially Australia was cool compared to 2020.

In the Arctic, the Europe-Russia-Siberia-Alaska sectors were relatively cold, while most of the Canada-Greenland sectors were relatively warm.

The Antarctic continent was mainly characterised by near or below 10-yr average temperatures in 2021.

Summing up for 2021, global average air temperatures were still high when seen in a long instrumental time scale (140-170 years), but clearly lower than in the previous 4-5 years. Year 2021, however, was influenced by a La Niña episode in the Pacific Ocean. Thus, the global surface air temperature record in 2021 continues to be highly influenced by such oceanographic phenomena.

Lower troposphere temperature from satellites, updated to year 2021

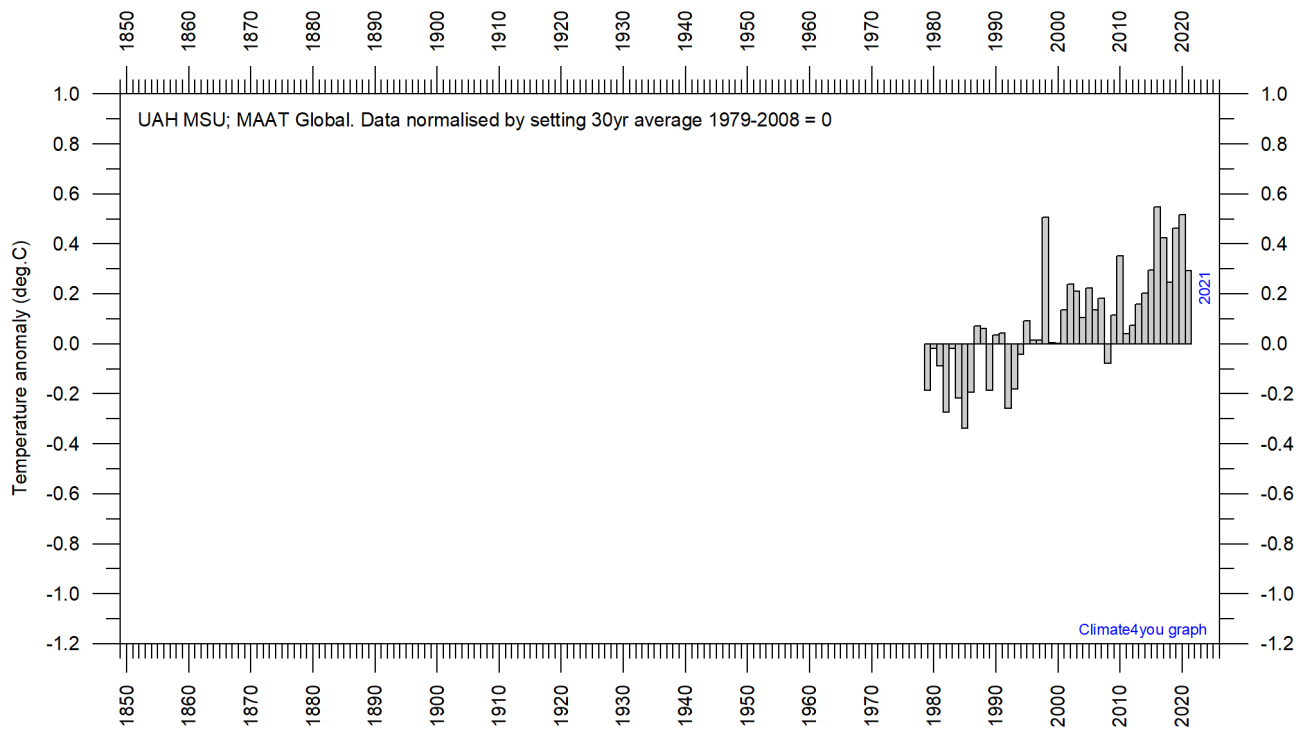


FIGURE 3. Mean annually lower troposphere temperature anomaly (thin line) since 1979 according to [University of Alabama](#) at Huntsville, USA. The average for 1979-2008 (30 years) has been set to zero, to make comparison with other temperature data series easy.

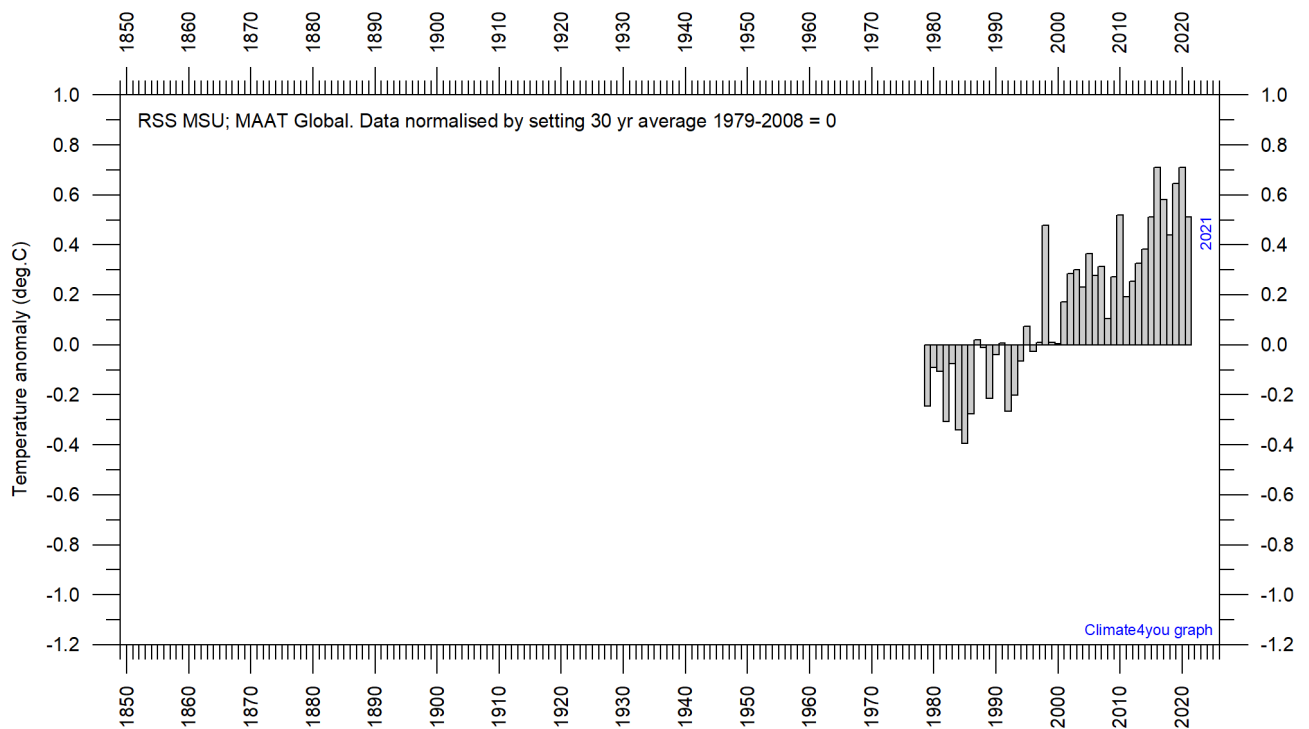


FIGURE 4. Mean annual lower troposphere temperature anomaly (thin line) since 1979 according to according to [Remote Sensing Systems](#) (RSS), USA. The average for 1979-2008 (30 years) has been set to zero, to make comparison with other temperature data series easy.

Global surface air temperature, updated to year 2021

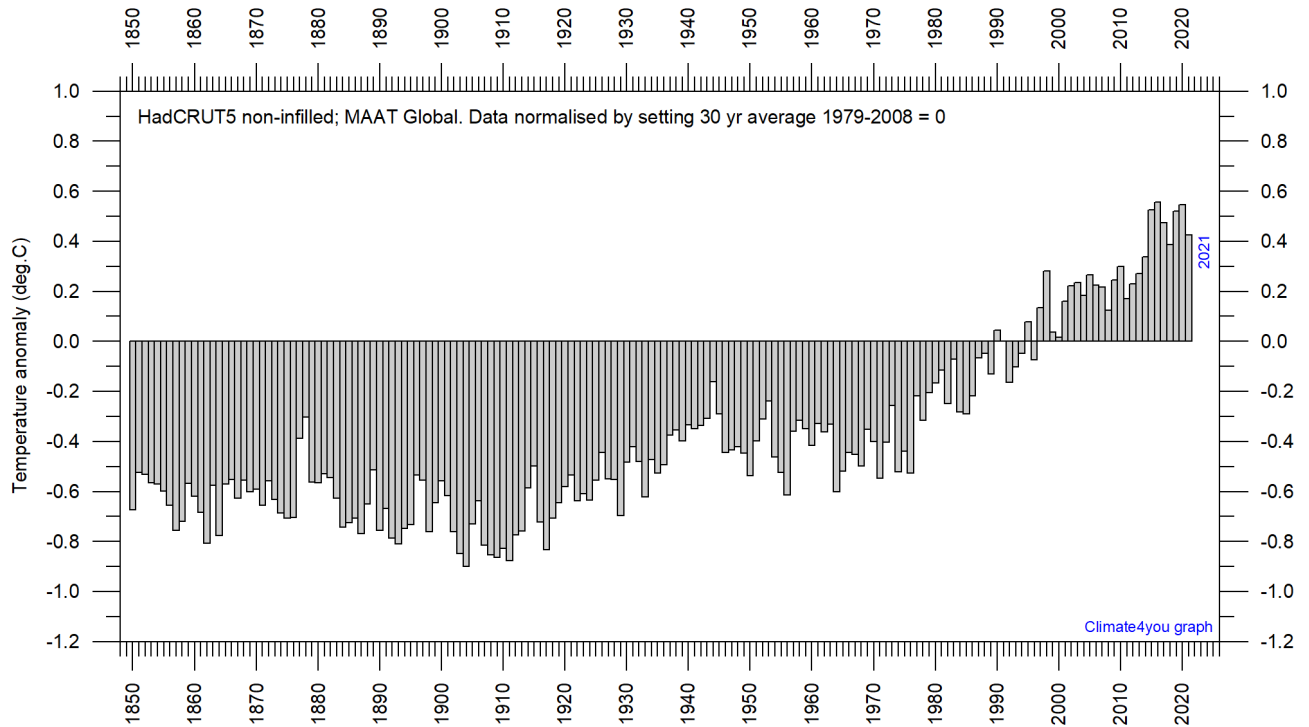


FIGURE 5. Mean annual global surface air temperature (thin line) since 1850 according to according to the Hadley Centre for Climate Prediction and Research and the University of East Anglia's [Climatic Research Unit \(CRU\)](#), UK. The average for 1979-2008 (30 years) has been set to zero.

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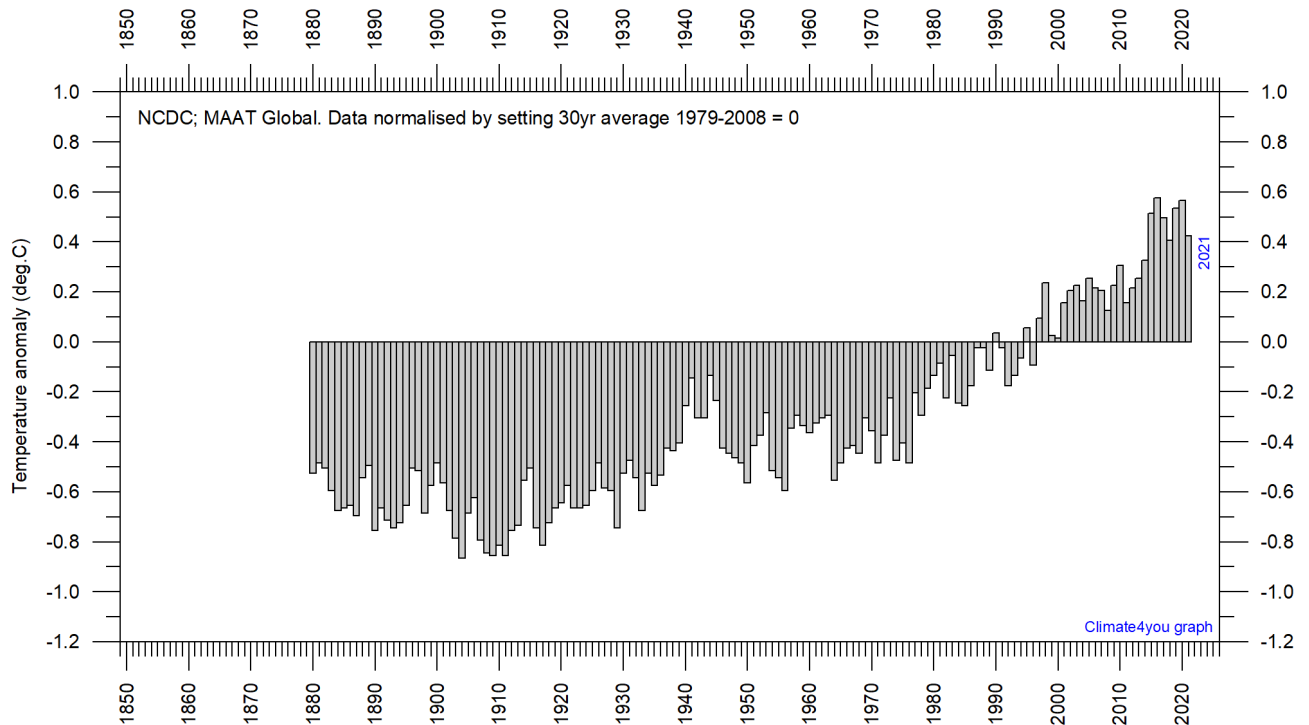


FIGURE 6. Mean annual global surface air temperature since 1880 according to according to the [National Climatic Data Center \(NCDC\)](#), USA. The average for 1979-2008 (30 years) has been set to zero, to make comparison with other temperature data series easy.

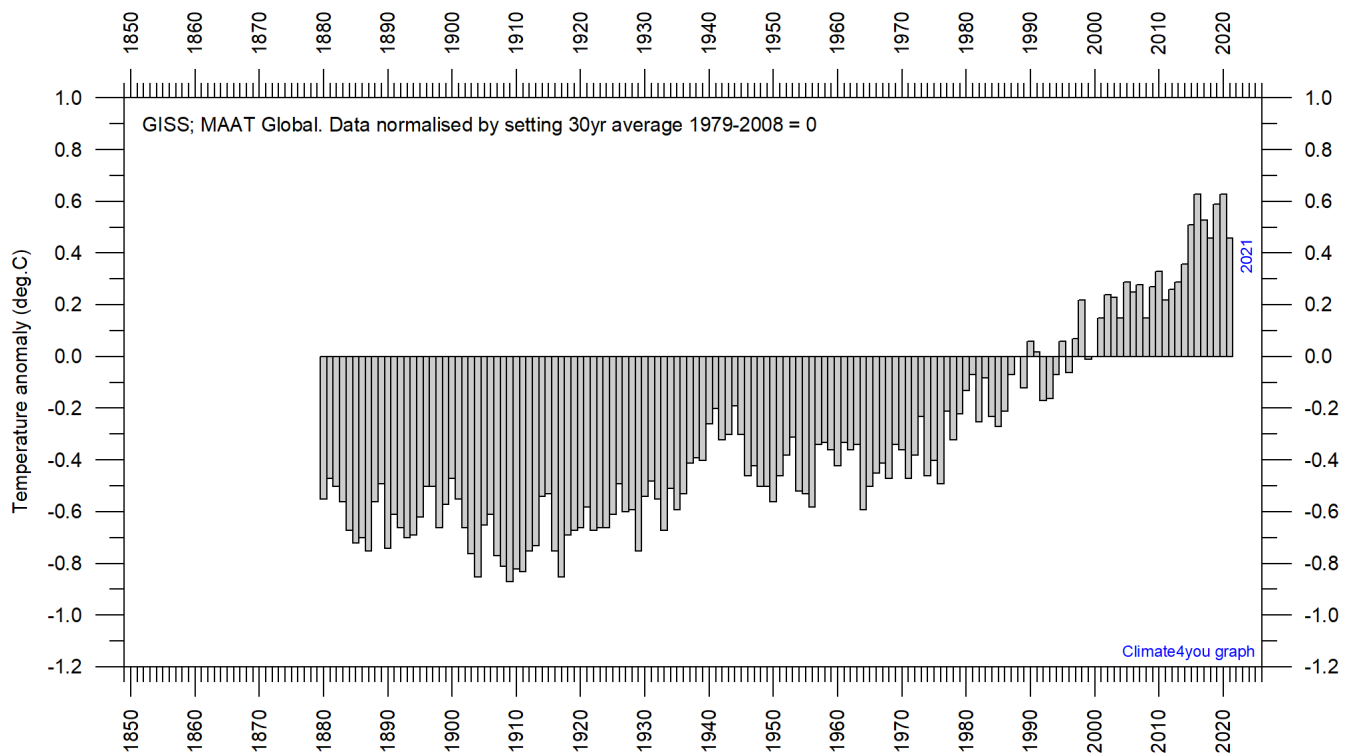


FIGURE 7. Mean annual global surface air temperature (thin line) since 1880 according to according to the [Goddard Institute for Space Studies](#) (GISS), at Columbia University, New York City, USA. The average for 1979-2008 (30 years) has been set to zero, to make comparison with other temperature data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

Reflections on the significance of the 2021 global annual surface air temperature

According to the surface stations 2021 (starting 1850 and 1880) ranks as a warm year, but suggesting a cooling trend since 2016. Also, according to the satellite records (since 1979) 2021 was a warm year.

The recent very strong El Niño terminated during 2017. Quite often -but not always- a warm El Niño episode is followed by a cool oceanographic reversal, known as La Niña, which also will influence global air temperatures, but then towards lower values. In fact, a moderate La Niña episode established itself in late 2017, lasting until early 2018 (Fig. 14). Towards the end of 2018, however a new, moderate El Niño initiated and affected global air temperatures toward their high average values in

2019 and 2020. Towards the end of 2020, a new as La Niña episode established itself, influencing global air temperatures toward lower values in 2021.

Air temperature changes do not only play out at the surface, but also at higher levels in the atmosphere (see Fig. 11). The current CO₂ hypothesis projects that the initial and largest temperature increase should affect 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 is not predominantly due to added atmospheric CO₂, but is largely caused by one or several other factors (oceans, cloud cover, etc.).

Comparing surface air temperatures with data from satellites at the end of 2021

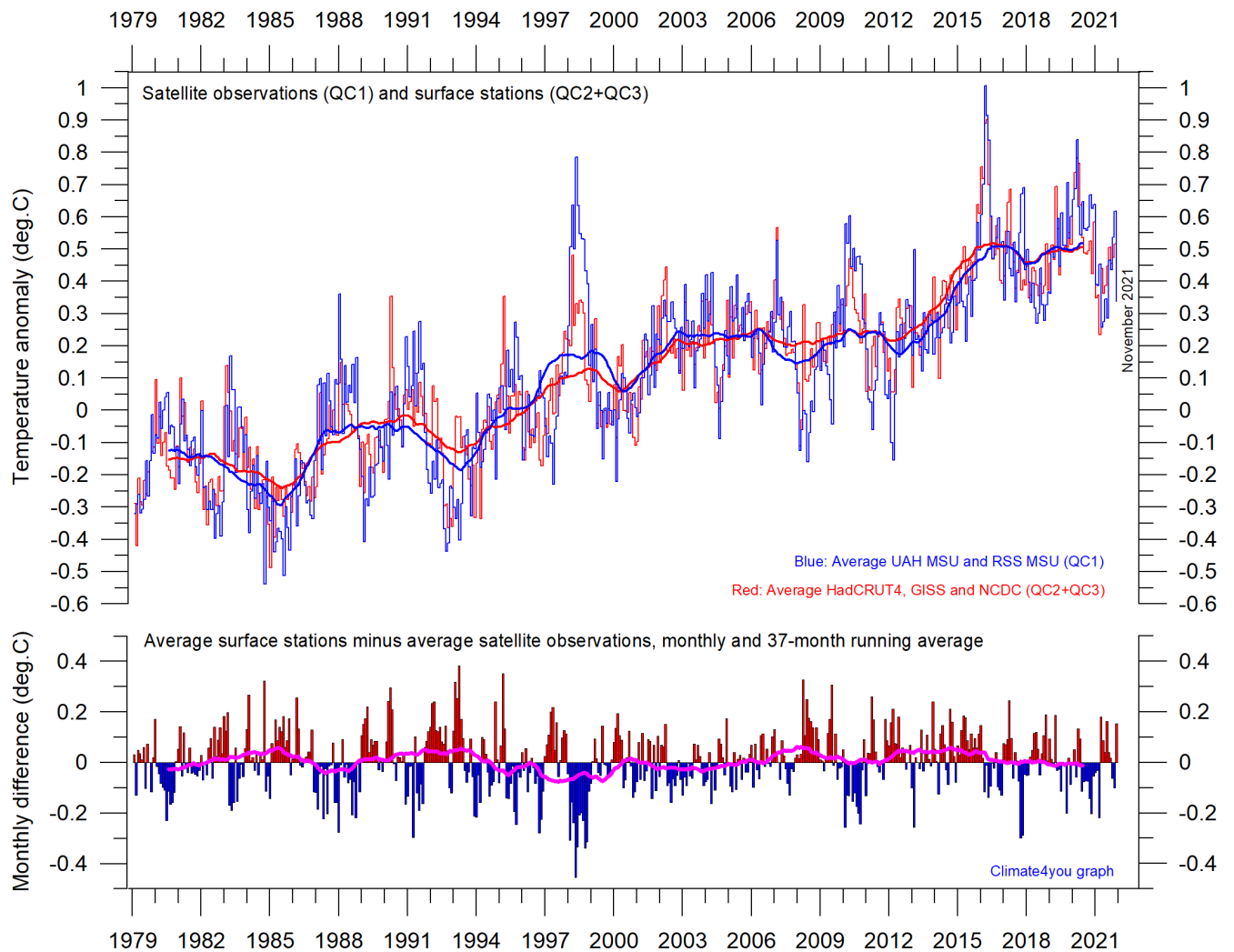


FIGURE 8. Plot showing the average of monthly global surface air temperature estimates (HadCRUT4, GISS and NCDC) and satellite-based temperature estimates (RSS MSU and UAH MSU). The thin lines indicate the monthly value, while the thick lines represent the simple running 37-month average, nearly corresponding 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. Please note: Not yet updated beyond November 2021.

Global satellite temperature trends calculated for different periods until November 2021

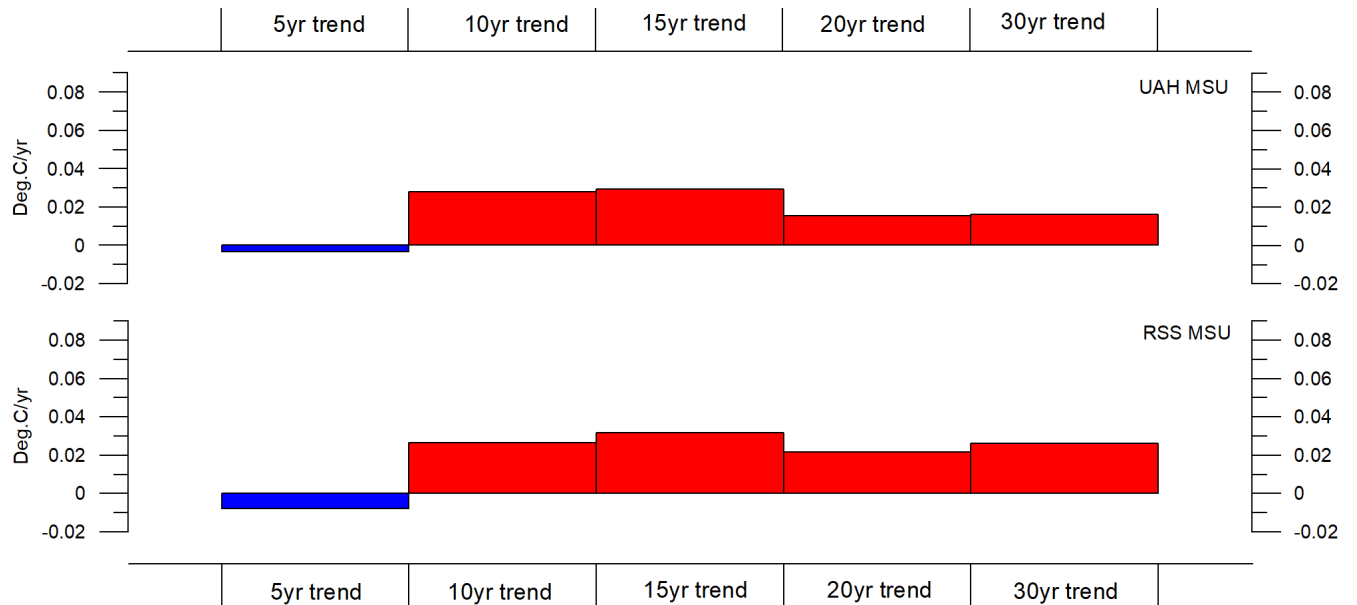


FIGURE 9. Diagram showing the latest 5, 10, 20 and 30 yr linear annual global temperature trend, calculated as the slope of the linear regression line through the data points, for two satellite-based temperature estimates (UAH MSU and RSS MSU).

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Global surface air temperature trends calculated for different periods until November 2021

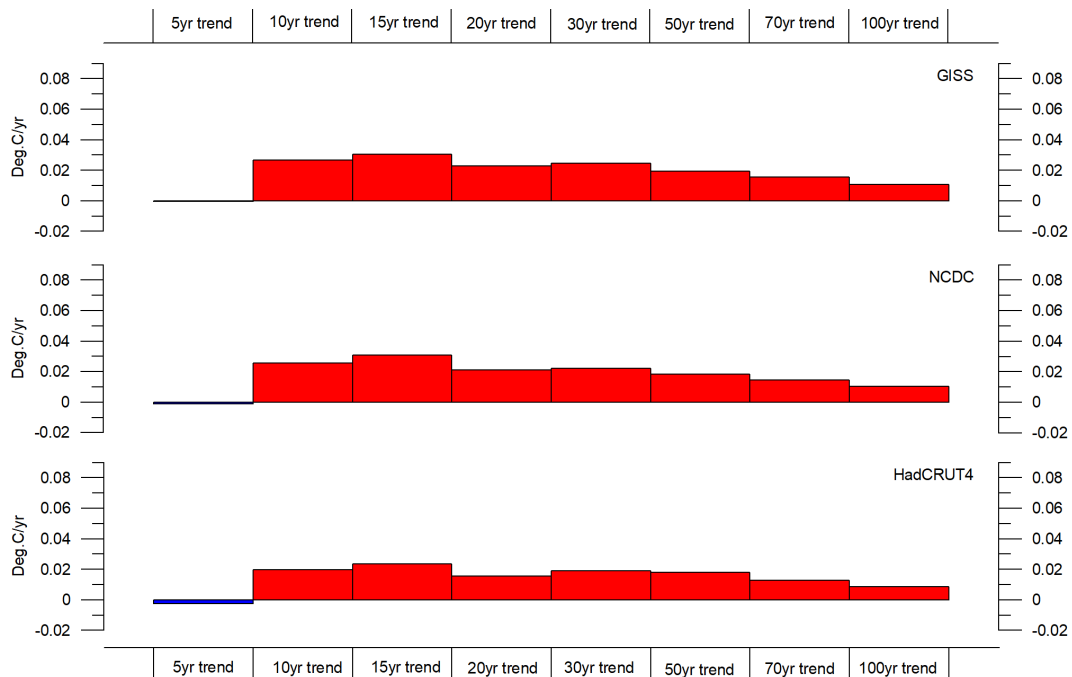


FIGURE 10. Diagram showing the latest 5, 10, 15, 20, 30, 50, 70 and 100-year linear annual global temperature trend, calculated as the slope of the linear regression line through the data points, for three surface-based temperature estimates (GISS, NCDC and HadCRUT3).

Troposphere and stratosphere temperatures from satellites at the end of 2021

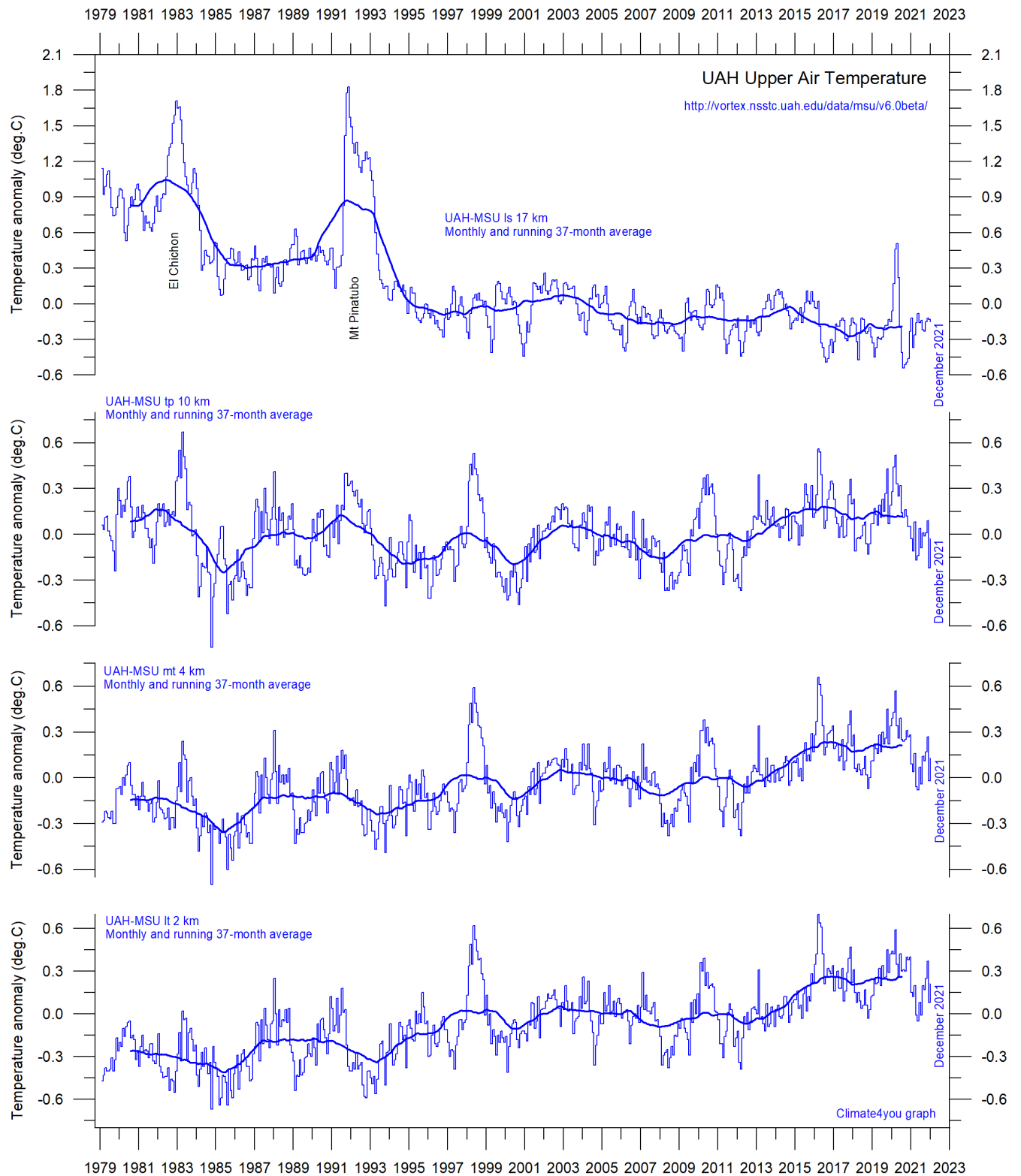
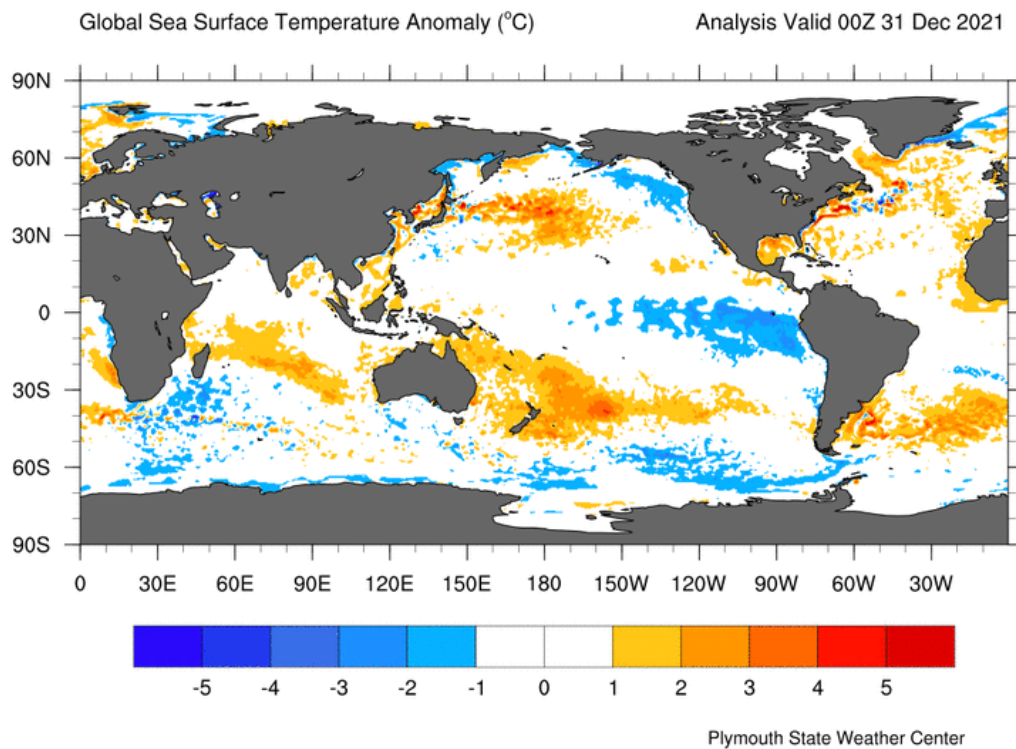


FIGURE 11. Global monthly average temperature in different according to University of Alabama at Huntsville, USA. The thin lines represent the monthly average, and the thick line the simple running 37-month average, nearly corresponding to a running 3-year average.

Sea surface temperature anomaly at the end of year 2021 and 2020



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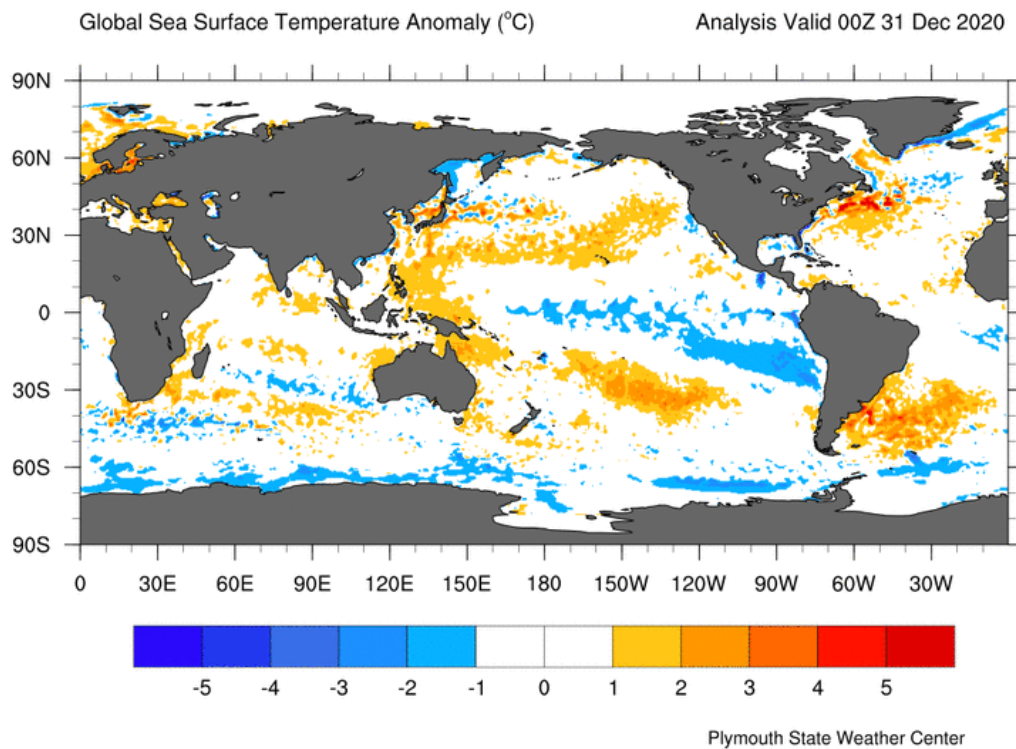


FIGURE 12. Sea surface temperature anomaly in late December 2021 and 2020, upper and lower panel, respectively. Reference period: 1977-1991. Map source: Plymouth State Weather Center. Please note the change of colour scale between the two years.

Ocean temperatures, uppermost 1900m, updated to August 2020

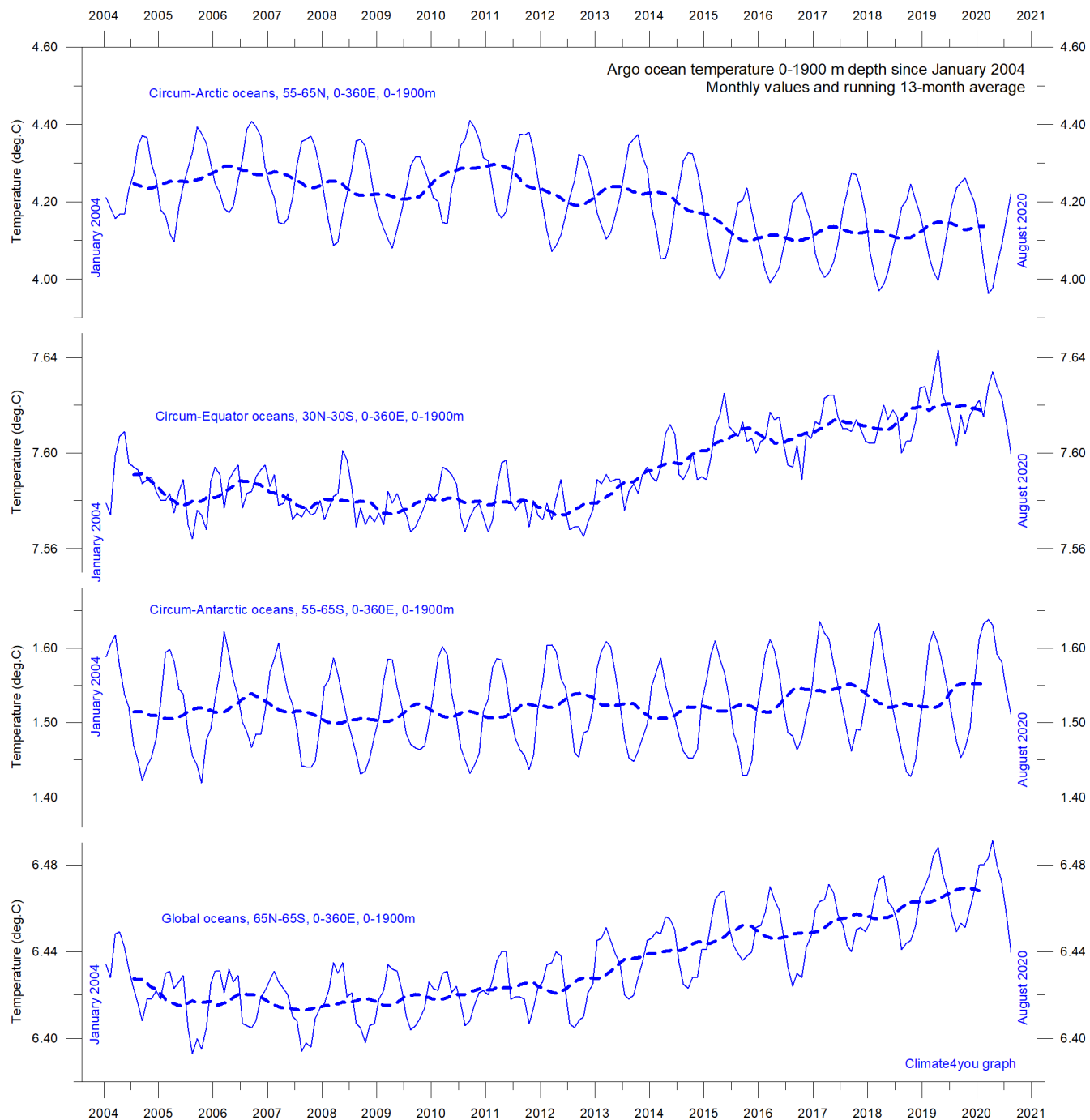


FIGURE 13. Diagram showing average 0-1900m depth ocean temperatures in selected latitudinal bands, using [Argo](#)-data. The thin line shows monthly values, and the stippled line shows the running 13-month average. Source: [Global Marine Argo Atlas](#). Please note that the Argo data series is not yet updated beyond August 2020.

La Niña and El Niño episodes, updated to October-December 2021

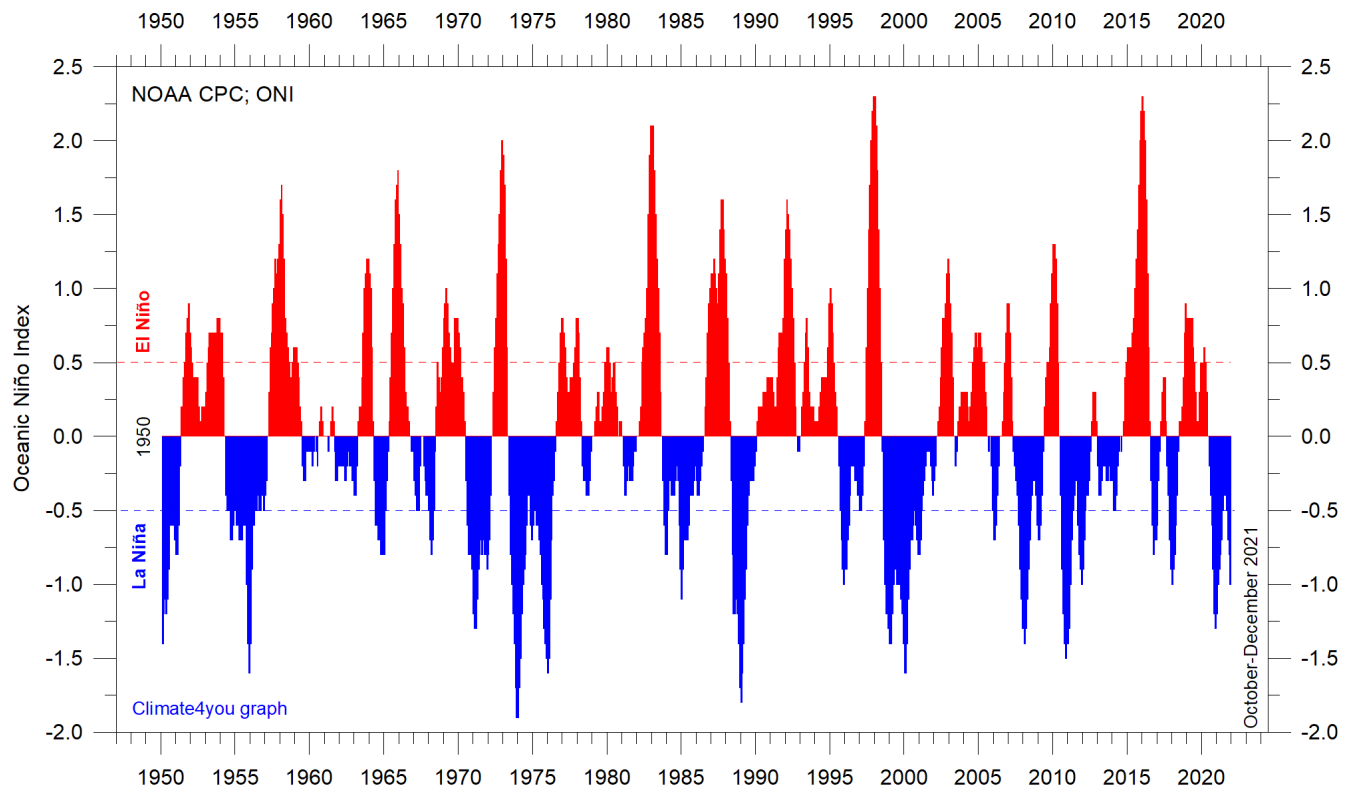


FIGURE 14. Warm ($>+0.5^{\circ}\text{C}$) and cold ($<-0.5^{\circ}\text{C}$) episodes for the Oceanic Niño Index (ONI), defined as 3 month running mean of ERSST.v3b SST anomalies in the Niño 3.4 region (5°N - 5°S , 120° - 170°W). Base period: 1971-2000. For historical purposes cold and warm episodes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

Year 2021 was characterized by a moderate La Niña episode in the Pacific Ocean. At the end of the year, the index persists at relatively low values, as shown by Figure 14 above. This diagram also shows that the recent 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 abnormal.

PDO - Pacific Decadal Oscillation, updated to 2021

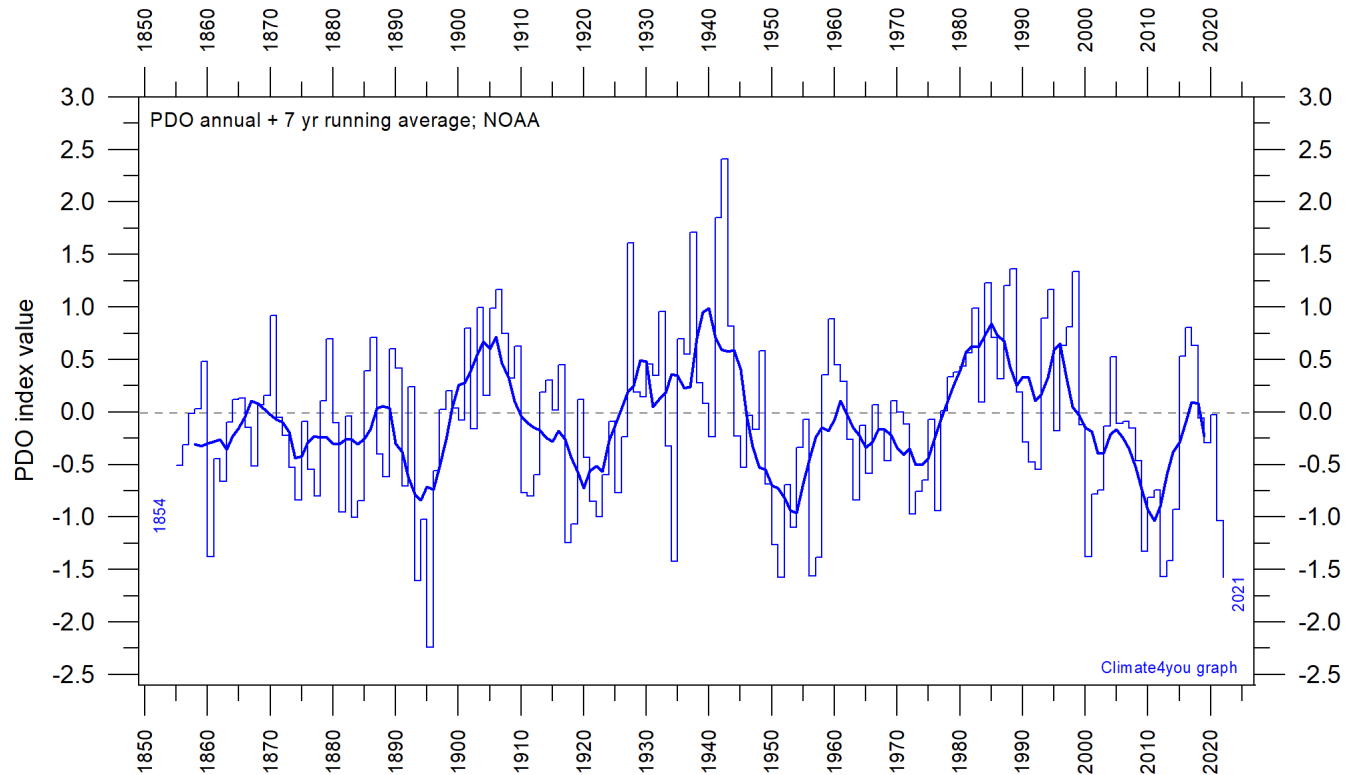


FIGURE 15. Annual values of the Pacific Decadal Oscillation (PDO) according to the Joint Institute for the Study of the Atmosphere and Ocean (JISAO), a Cooperative Institute between the National Oceanic and Atmospheric Administration and the University of Washington. The PDO is a long-lived El Niño-like 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 2021

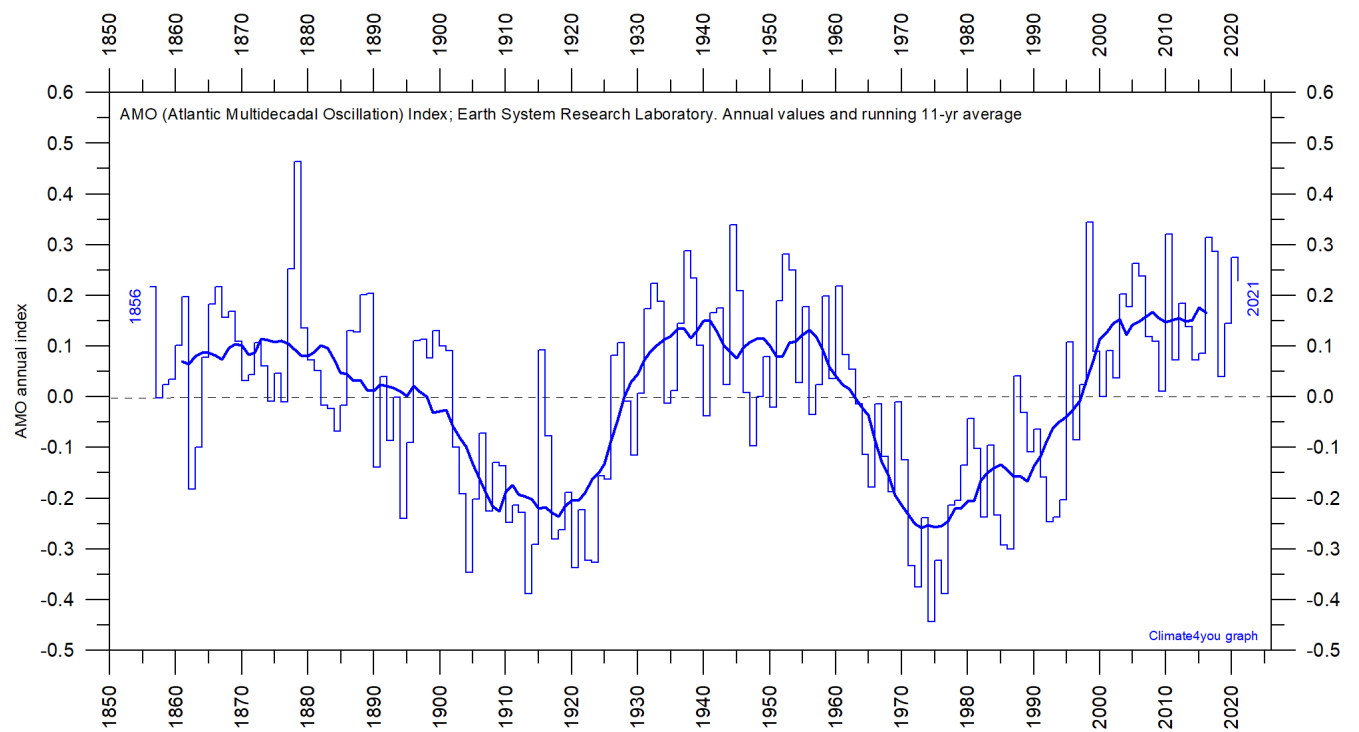


FIGURE 16. Annual Atlantic Multidecadal Oscillation (AMO) detrended index values since 1856. The thin line indicates the annual values, and the thick line is the simple running 11-year average. Data source: Earth System Research Laboratory at NOAA.

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.

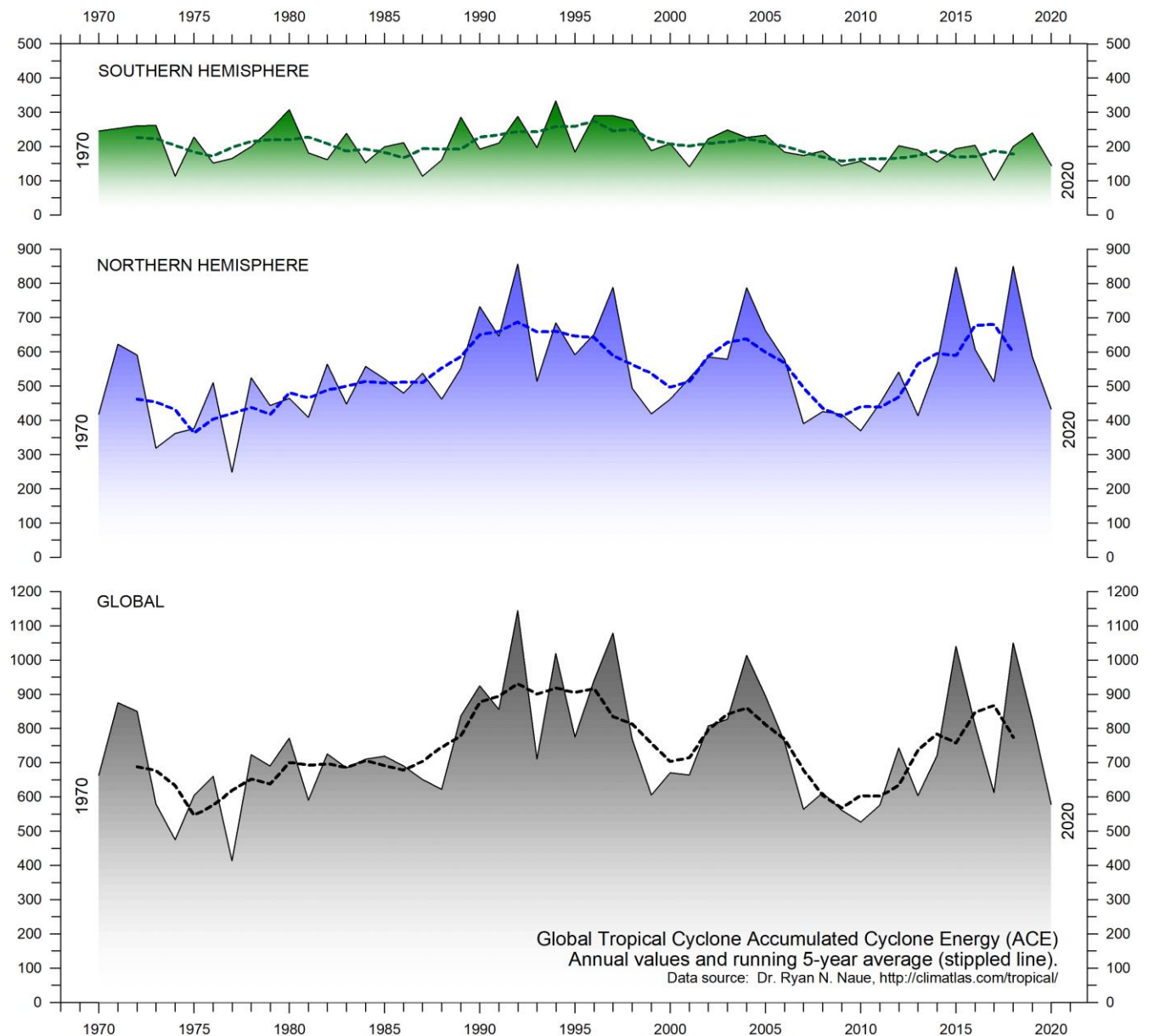


FIGURE 17: The diagram above shows the annual global tropical storm and hurricane accumulated cyclone energy (ACE) 10^4 knots^2 , since 1970. Data source: Maue ACE data.

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.

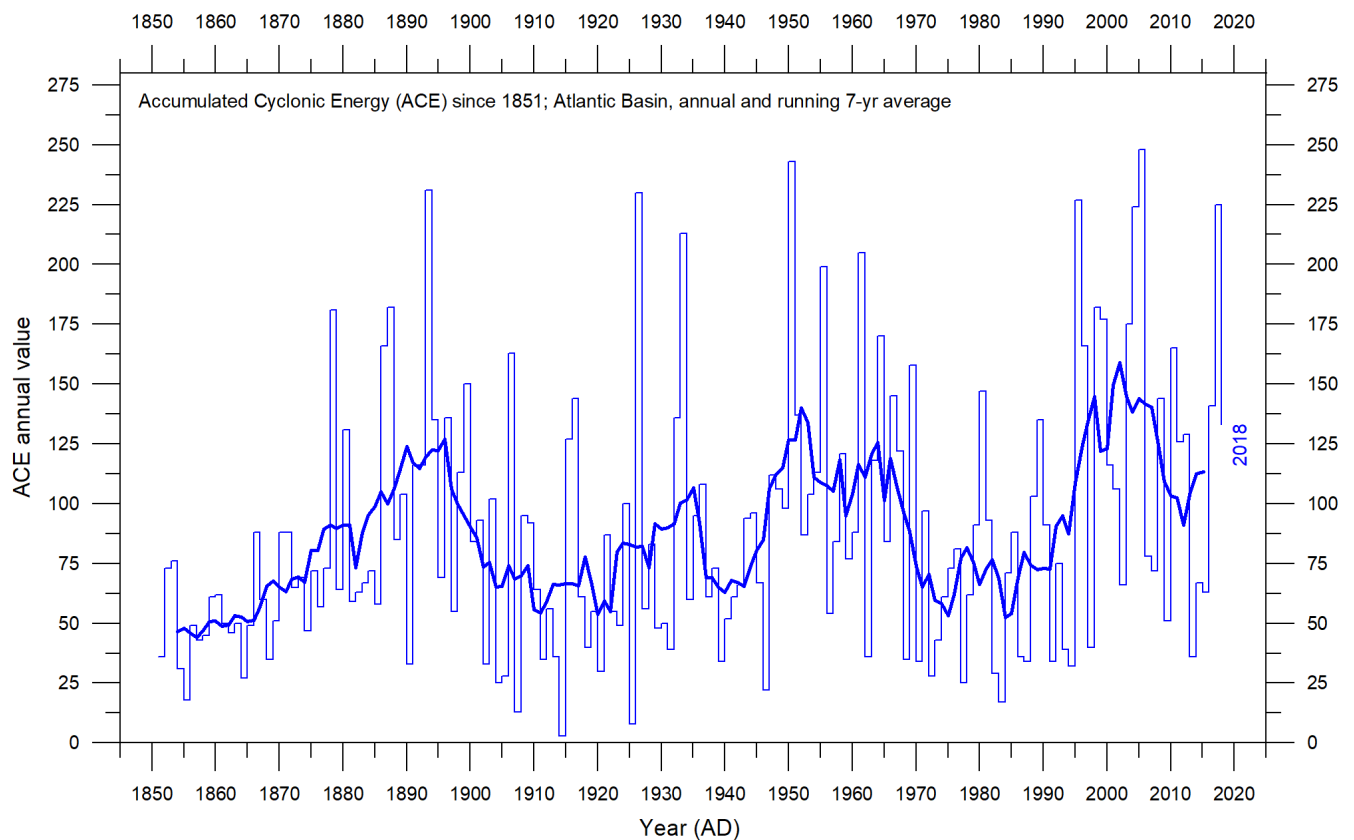


FIGURE 18: Accumulated cyclonic energy (ACE; Atlantic basin) per year since 1850 AD. Thin lines show annual ACE values, and the thick line shows the running 7-year average. Data source: Atlantic Oceanographic and Meteorological Laboratory (AOML), Hurricane research Division. Please note that these data 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 2021

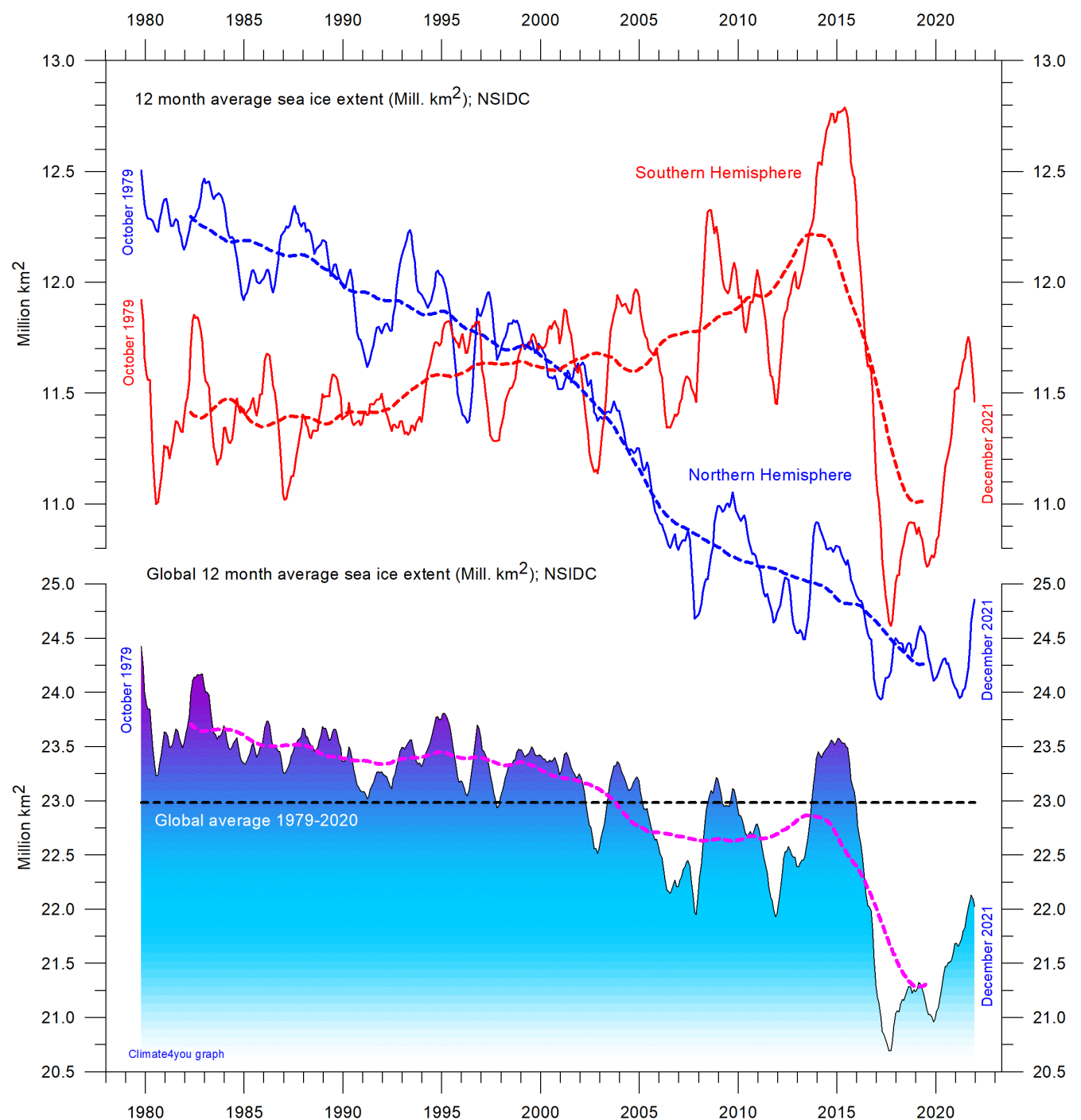


FIGURE 19. Global and hemispheric 12 month running average sea ice extension since 1979, the satellite-era. The October 1979 value represents the monthly average of November 1978 - October 1979, the November 1979 value represents the average of December 1978 - November 1979, etc. The stippled lines represent 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](https://nsidc.org/) (NSIDC).

Northern Hemisphere snow cover, updated to December 2021

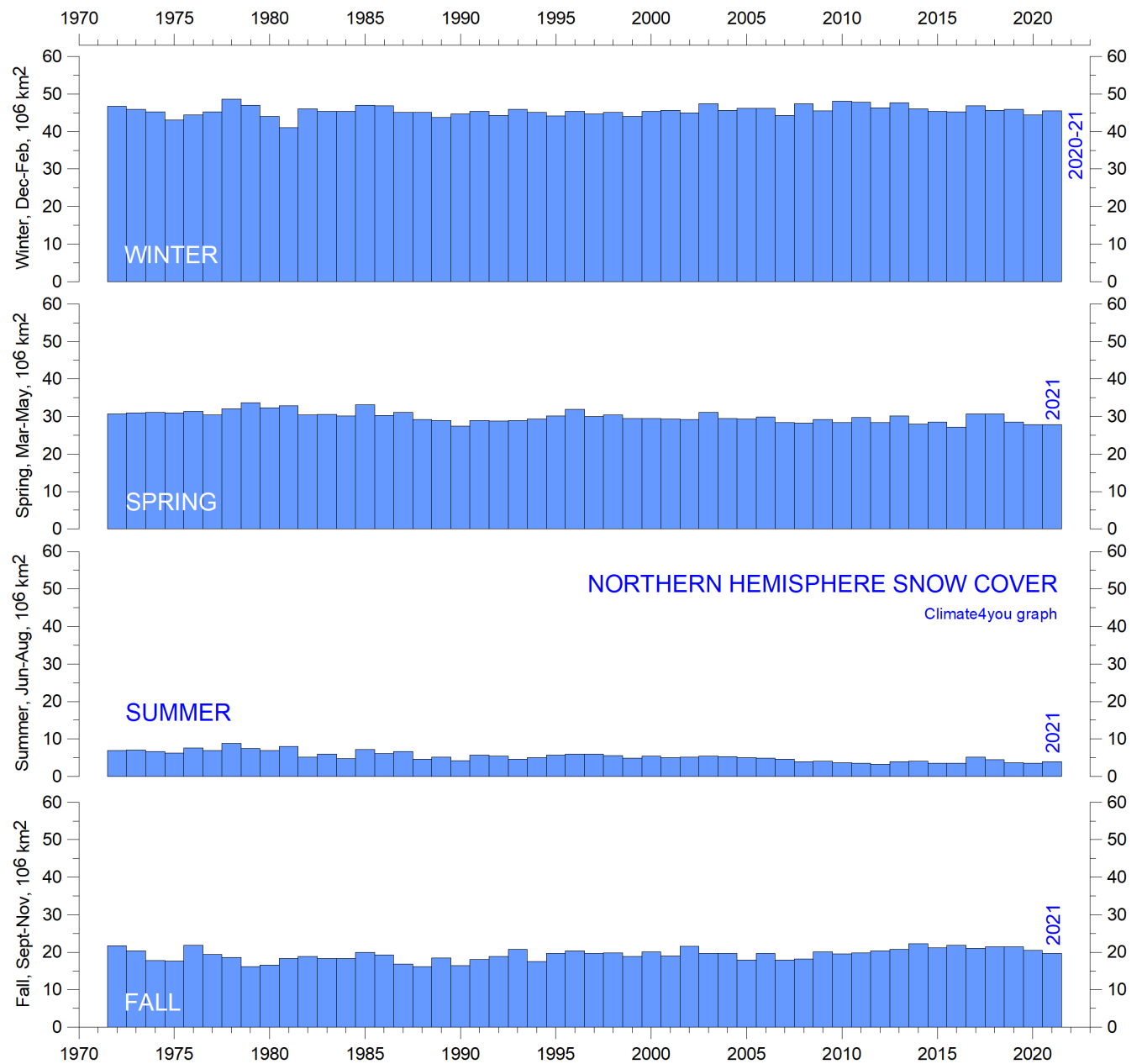


FIGURE 20. Northern Hemisphere seasonal snow cover since 1972 according to [Rutgers University Global Snow Laboratory](#).

Atmospheric specific humidity, updated to December 2021

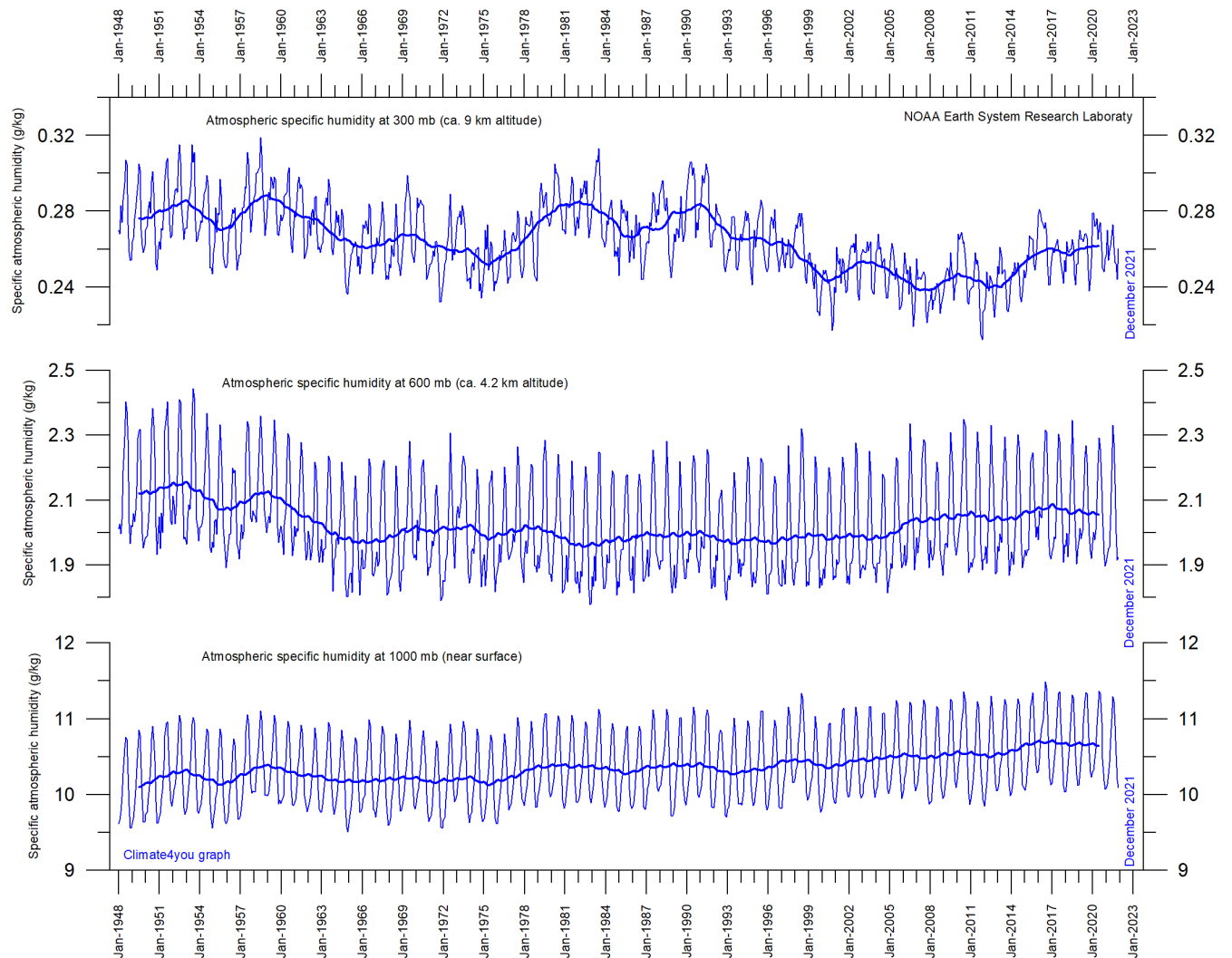


FIGURE 21. Specific atmospheric humidity (g/kg) at three different altitudes in the lower part of the atmosphere (the Troposphere) since January 1948 (Kalnay et al. 1996). The thin blue lines show monthly values, while the thick blue lines show the running 37-month average (about 3 years). Data source: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

Water vapour is the most important greenhouse gas in Earth's atmosphere, considerably more important than CO₂.

Atmospheric CO₂, updated to December 2021

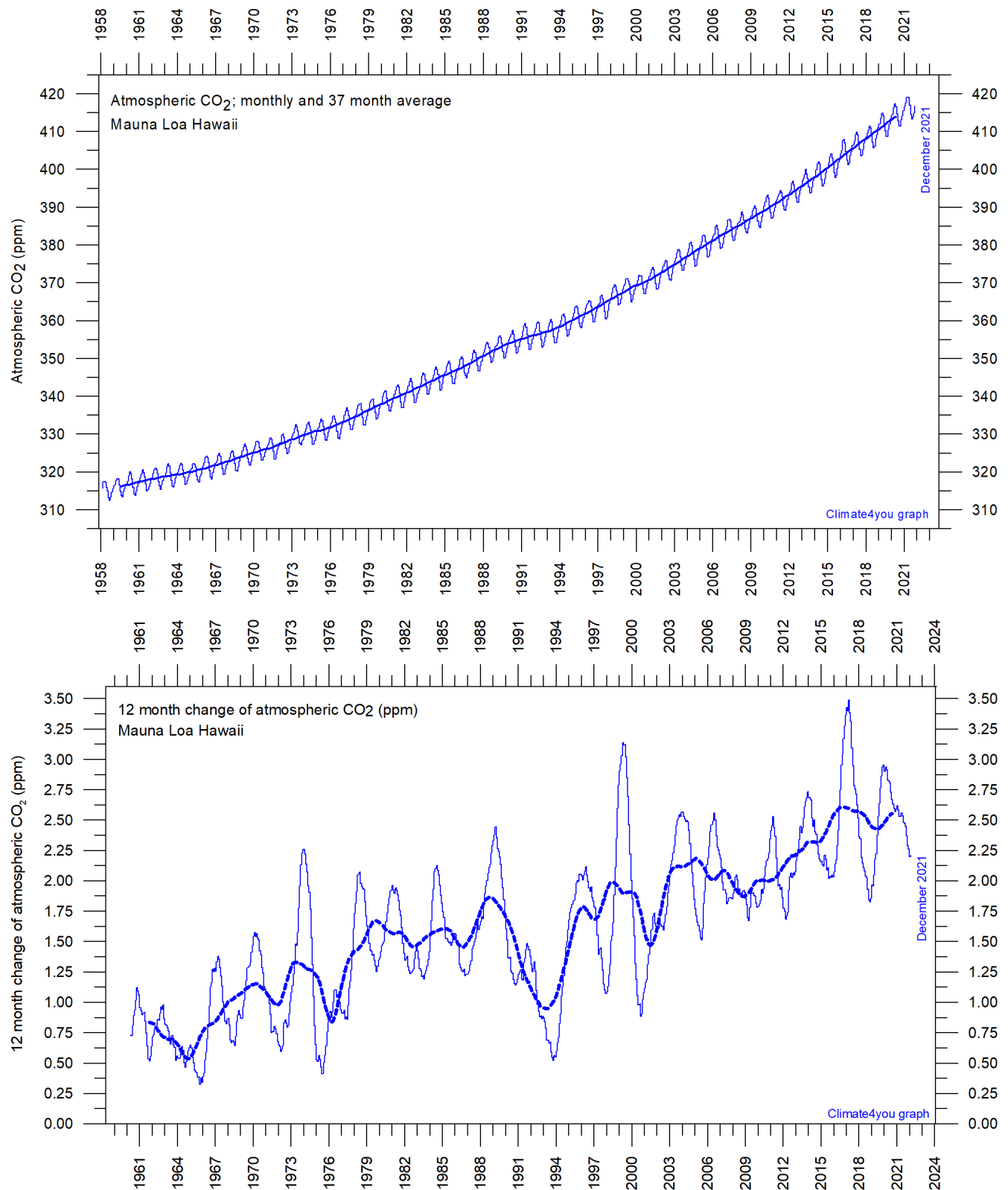


FIGURE 22. Monthly amount of atmospheric CO₂ (upper diagram) and annual growth rate (lower diagram); average last 12 months minus average preceding 12 months, thin line) of atmospheric CO₂ since 1959, according to data provided by the [Mauna Loa Observatory](#), Hawaii, USA. The thick, stippled line is the simple running 37-month average, nearly corresponding to a running 3-year average.

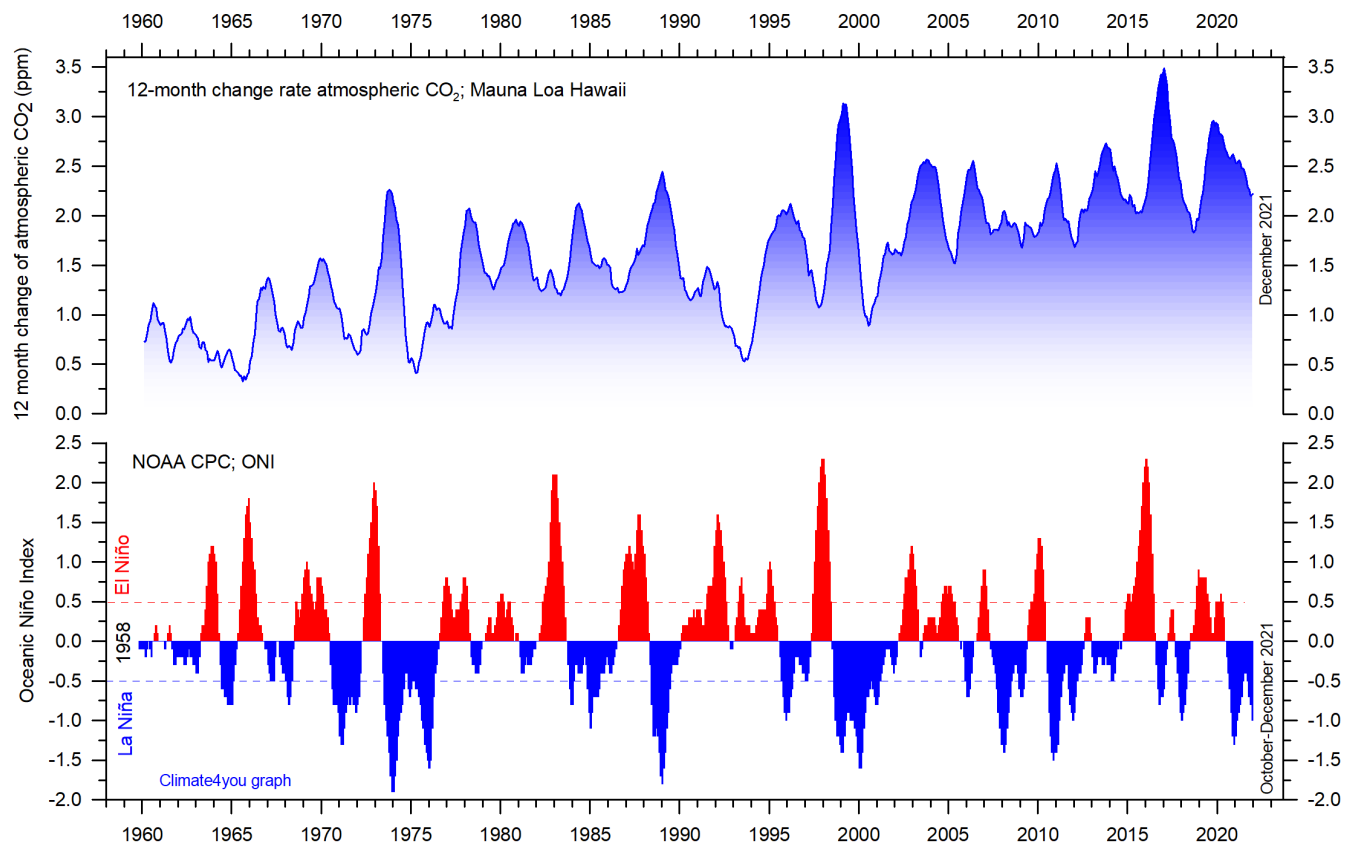


FIGURE 23. Visual association between annual growth rate of atmospheric CO₂ (upper panel) and Oceanic Niño Index (lower panel). See also Figure 14 and 21, respectively.

Number of daily sunspots since 1900, updated to December 31, 2021

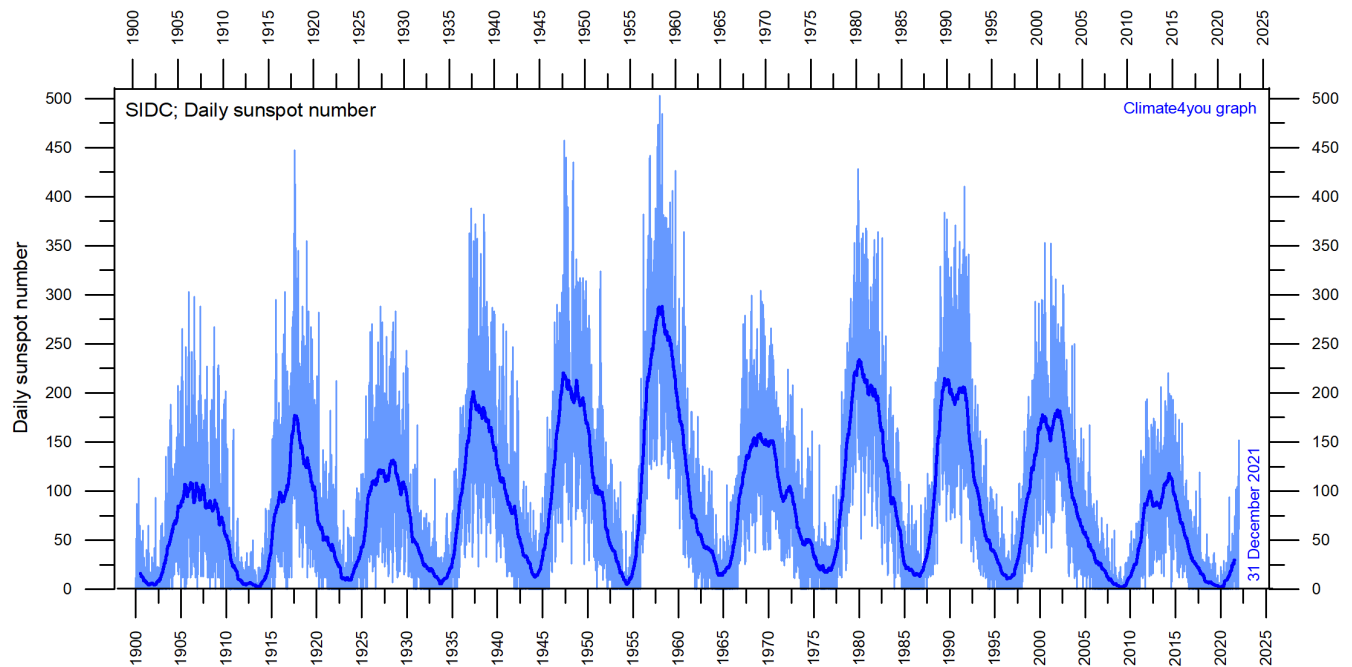


FIGURE 24. Daily observations of the number of sunspots since 1 January 1900 according to Solar Influences Data Analysis Center (SIDC). The thin blue line indicates the daily sunspot number, while the dark blue line indicates the running annual average.

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,

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Arctic Historical Evaluation and Research Organisation, Longyearbyen, Svalbard

20 January 2022.