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10th January 2025

2024 - a second record-breaking year, following the exceptional 2023

2024 saw unprecedented global temperatures, following on from the remarkable warmth of 2023. It also became the first year with an average temperature clearly exceeding 1.5°C above the pre-industrial level – a threshold set by the Paris Agreement to significantly reduce the risks and impacts of climate change. Multiple global records were broken, for greenhouse gas levels, and for both air temperature and sea surface temperature, contributing to extreme events, including floods, heatwaves and wildfires. These data highlight the accelerating impacts of human-caused climate change.

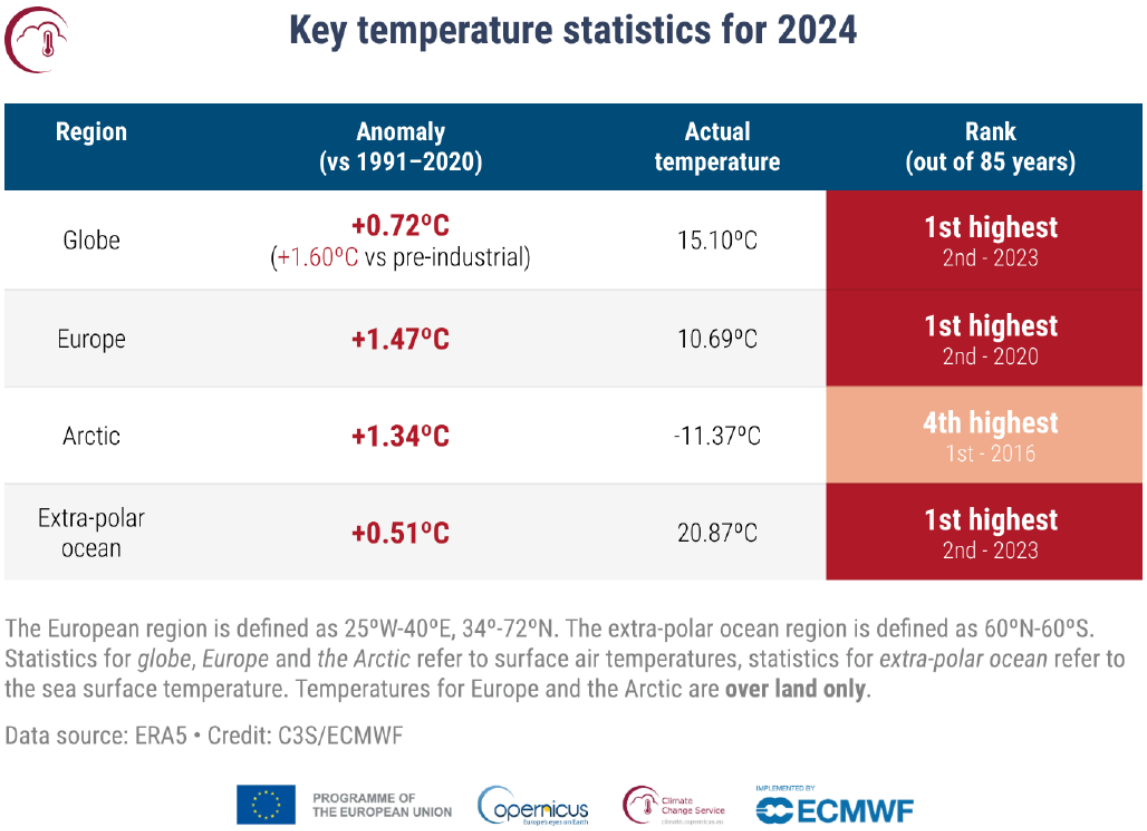

***Figure 1**. Key temperature statistics for 2024. The estimates for the globe refer to the surface air temperature over land and ocean, and for Europe and the Arctic over land only. Sea surface temperature is computed for the 60°N–60°S domain. Data source: ERA5. Credit: C3S/ECMWF.*

Global average surface air temperature

The Copernicus Climate Change Service (C3S) reports on significant global climate findings for 2024. The global temperature data below are presented relative to the pre-industrial level, which uses an average for 1850–1900, and a modern reference period, using the average for 1991–2020. All statistics, unless otherwise labelled, are sourced from the ECMWF global reanalysis dataset ERA5 used for C3S' routine monitoring.

- 2024 was the warmest year in a multi-dataset record of global temperature going back to 1850.

- 2024 had a global average temperature of 15.10°C; 0.12°C higher than the previous highest annual value in 2023.
- 2024 was 0.72°C warmer than the 1991–2020 average, and 1.60°C warmer than the pre-industrial level, making it the first calendar year to exceed 1.5 above that level[1].
- The last ten years have been the warmest ten years on record.
- Each month from January to June 2024 was warmer than the corresponding month in any previous year. August 2024 equalled the record warmth of August 2023 and the remaining months from July to December were each the second warmest for the time of year, after the corresponding months in 2023.
- There were three record seasons for the corresponding time of the year: boreal winter (December 2023–February 2024), boreal spring (March–May 2024), and boreal summer (June–August), at 0.78°C, 0.68°C and 0.69°C respectively above the 1991–2020 average.
- On 22 July 2024, the daily global average temperature reached a new record high of 17.16°C.

[1] Other global temperature data providers and the World Meteorological Organization are also releasing data for 2024 on 10 January 2024. Our statement about 2024 being the first year to exceed 1.5°C above the pre-industrial level will be updated accordingly once the statistics from the other global temperature datasets are available.

2024 was the first year with global temperature more than 1.5°C above the pre-industrial level; 11 months of the year saw the global-average surface air temperature above this threshold. The combined average temperature for 2023 and 2024 is 1.54°C above the pre-industrial level.

The UNFCCC Paris Agreement aims at “holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels”. Although the Agreement does not specify what constitutes the achievement of this goal, or indeed what precisely “well below” 2°C means, it is generally agreed that temperatures averaged over two or three decades are needed to confirm that one or other of these thresholds has been passed. The average of global temperatures between 1850–1900 is typically taken to represent the pre-industrial level.

One or two years that exceed 1.5°C above the pre-industrial level does not imply that the Paris Agreement has been breached. However, with the current rate of warming at more than 0.2°C per decade, the probability of breaching the 1.5°C target of the Paris Agreement within the 2030s is highly likely.

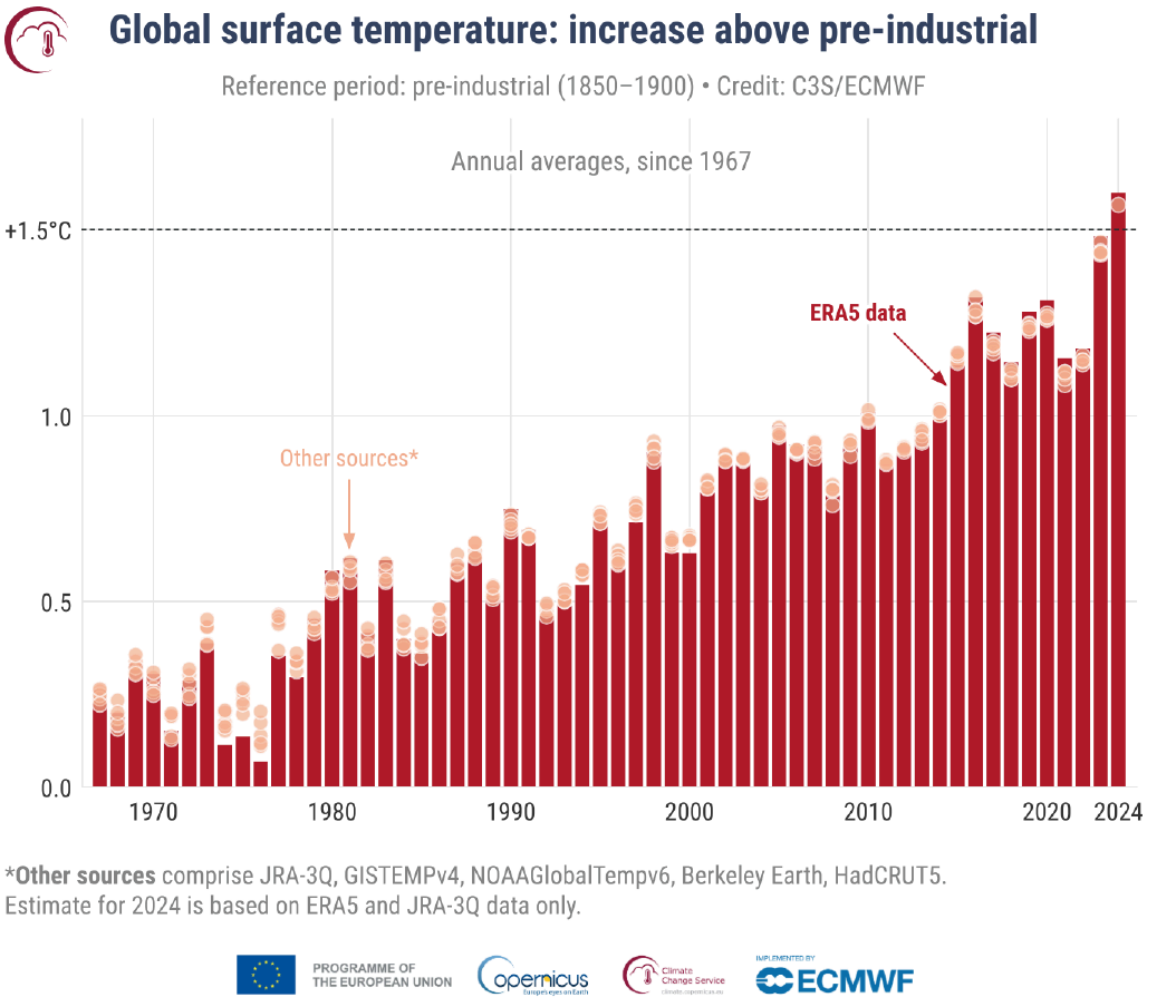

***Figure 2a**. Global surface air temperature (ºC) increase above the average for the 1850–1900 designated pre-industrial reference period, based on several global temperature datasets, shown as annual averages since 1967. Credit: C3S/ECMWF.*

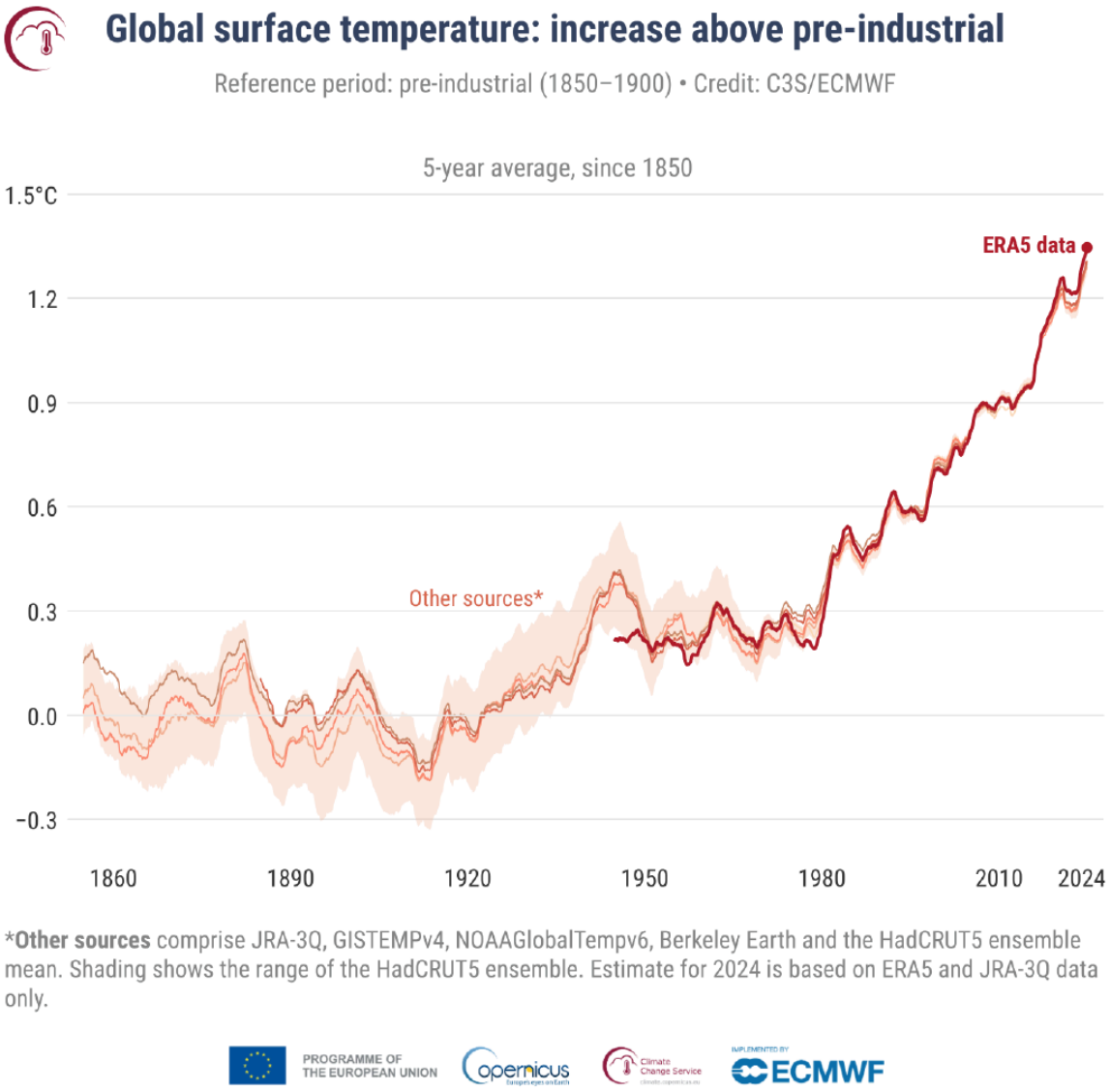

***Figure 2b**. Global surface air temperature (°C) increase above the average for the 1850–1900 designated pre-industrial reference period, based on several global temperature datasets, shown as five-year averages since 1850. Credit: C3S/ECMWF.*

2024 is the warmest year on record according to at least two widely used datasets (ERA5 and JRA-3Q). The average temperature anomaly relative to 1991–2020 for JRA-3Q is 0.03°C smaller than the anomaly indicated by ERA5. The absolute value from JRA-3Q is 0.01°C smaller than the ERA5 value. The other centres whose global temperature datasets are routinely monitored by C3S (Berkeley Earth, GISTEMPv4, HadCRUT5 and NOAAGlobalTempv6) are also expected to report that 2024 is the warmest year on record. Using data already published, it is estimated[2] that they

will place 2024 at 1.52°C to 1.56°C warmer than the 1850–1900 level, assuming the same offset of 0.88°C between 1850–1900 and 1991–2020 levels as used for ERA5 and JRA-3Q. The values actually reported by individual centres may vary more, as different offsets may be used. The values relative to 1850–1900 from ERA5 and JRA-3Q reduce to 1.57°C and 1.56°C respectively if their surface air temperatures over ice-free seas are replaced by their sea-surface temperatures, to follow more closely what is done for the other four datasets.

[2] Estimated values will be replaced by final values once all data values for December have been released.

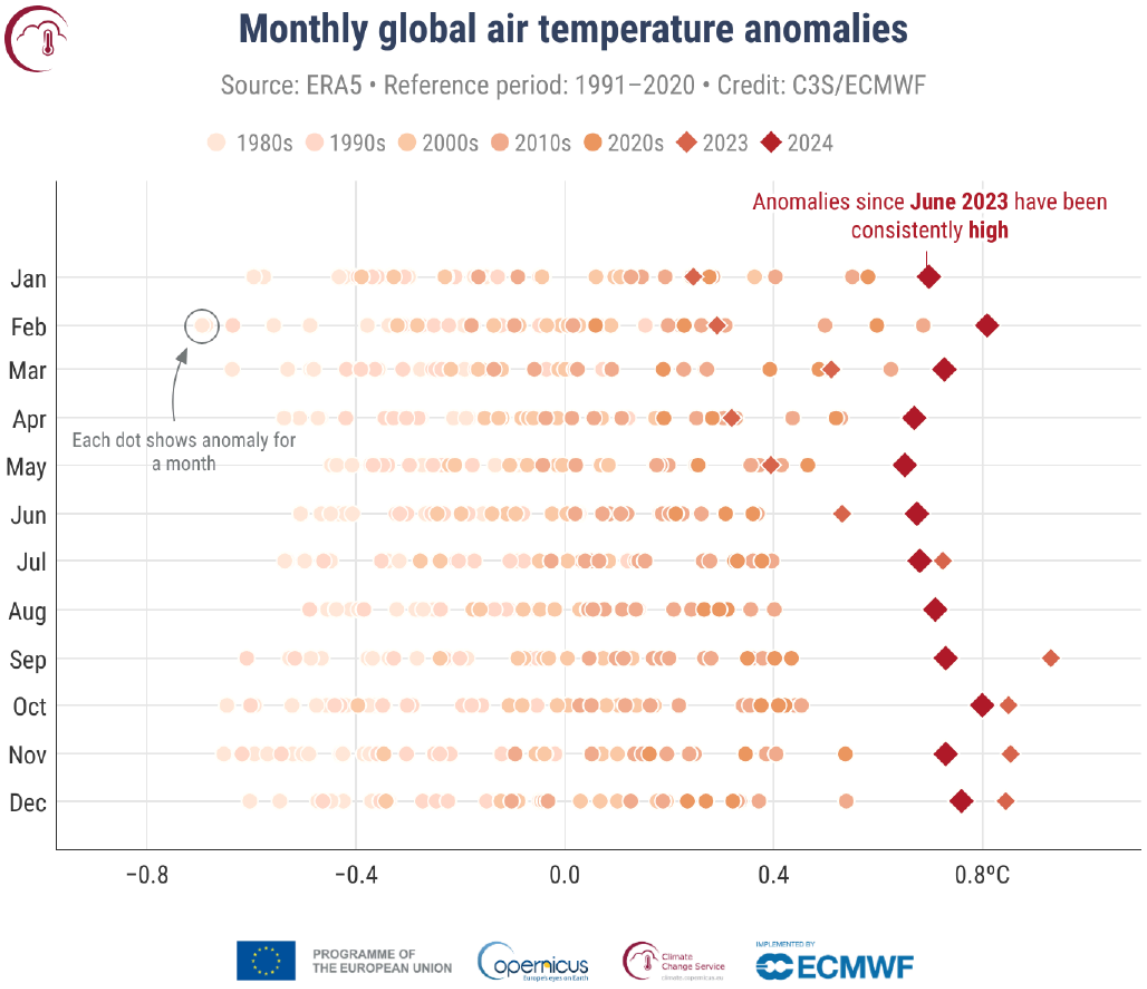

***Figure 3**. Monthly global surface air temperature anomalies (°C) relative to 1991–2020 from January 1980 to December 2024. Data source: ERA5. Credit: C3S/ECMWF.*

In 2024, 11 months and about 75% of days had global-average surface air temperatures more than 1.5°C above pre-industrial levels. January to April and October to December saw the highest monthly average anomalies, between 1.58°C and 1.78°C. The monthly values for May to September were between 1.48°C and 1.54°C. Small differences between datasets mean that the number of months that have temperatures above the 1.5°C threshold varies from dataset to dataset.

Regional temperature variations

- *In 2024, as in 2023, the tropics (20°S–20°N) and the northern mid-latitudes (20°–60°N) contributed the most to the record global temperature anomalies.*

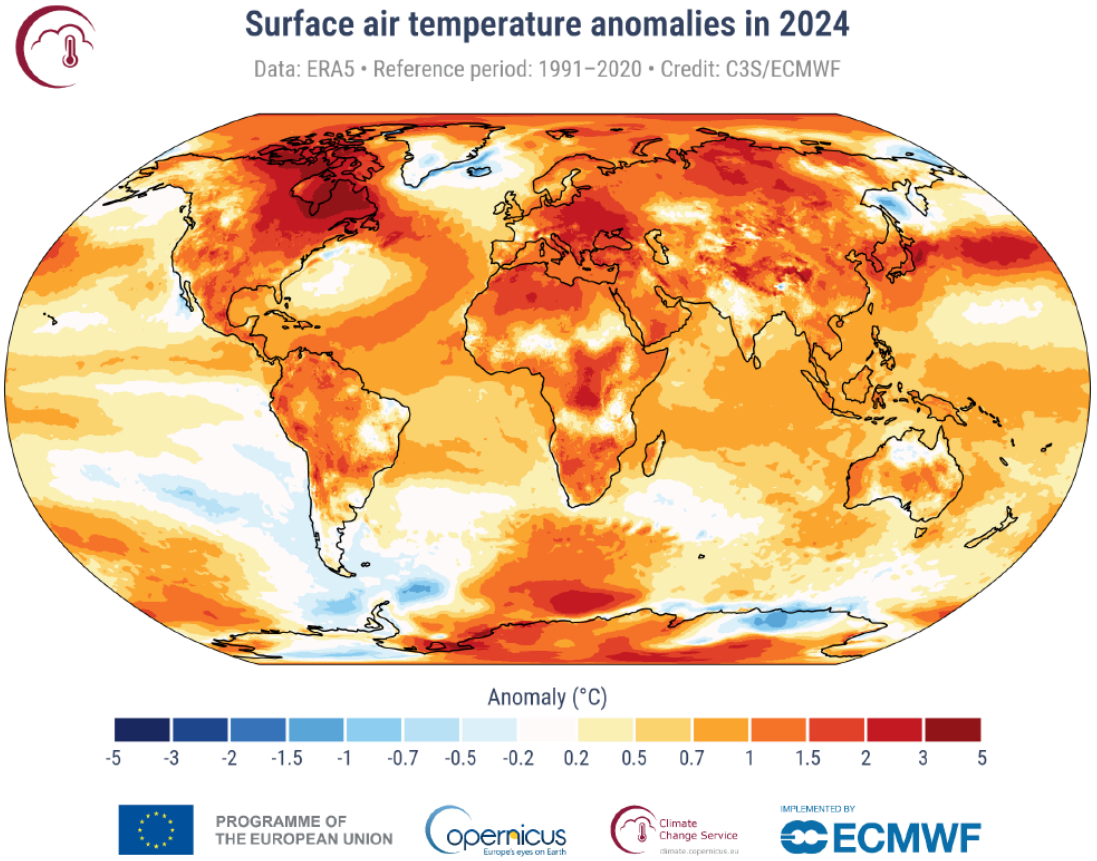

***Figure 4**. Surface air temperature anomalies in 2024, relative to the average for the 1991–2020 reference period. A non-linear colour scale is used to enhance the visibility*

of smaller anomalies and distinguish larger deviations. Data source: ERA5. Credit: C3S/ECMWF.

In 2024, annual surface air temperatures were above the 1991–2020 average across most of globe (91%). Temperatures exceeded the average by more than 1°C over more than half (52%) of land areas. Surface air temperature anomalies over the ocean largely reflected the anomalies in sea surface temperatures, which are discussed below. As in 2023, northern Canada experienced some of the largest anomalies, with values around 3°C above average.

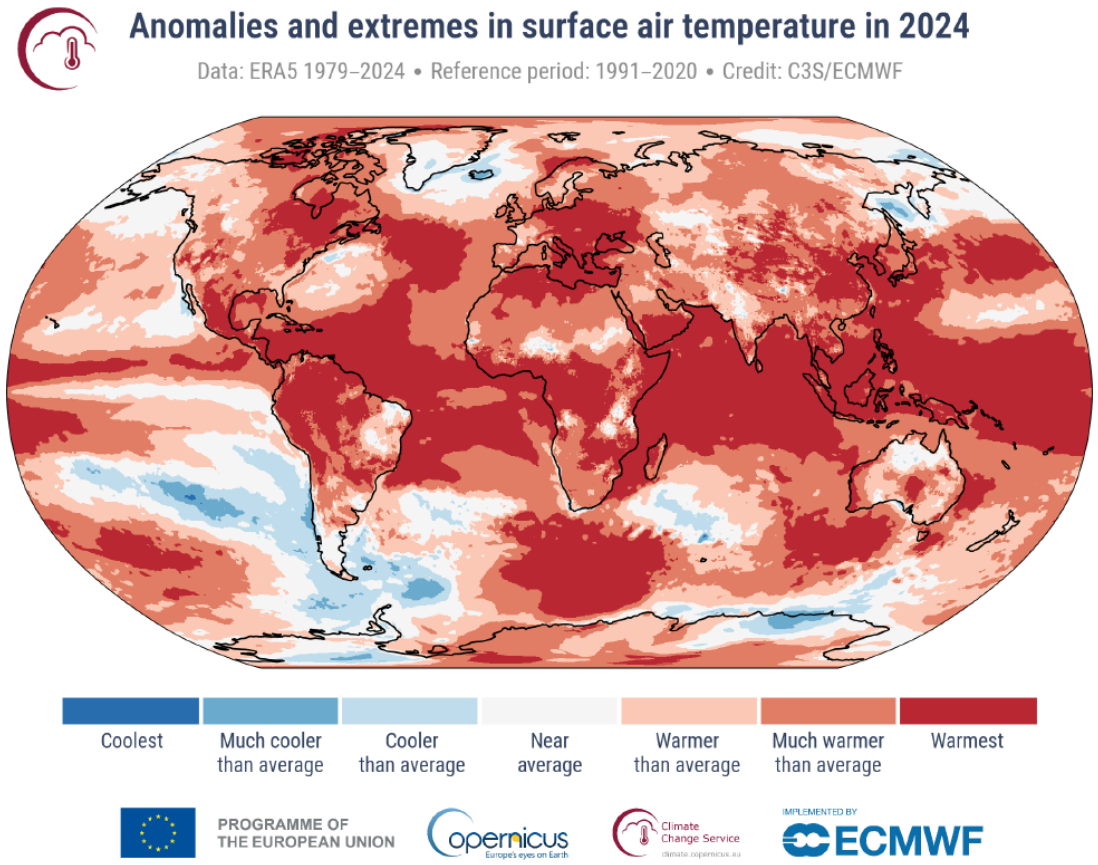

***Figure 5a**. Anomalies and extremes in surface air temperature in 2024. Colour categories refer to the percentiles of the temperature distributions for the 1991–2020 reference period. The extreme ('coolest' and 'warmest') categories are based on rankings for 1979–2024. Data source: ERA5. Credit: C3S/ECMWF.*

Ranking of annual mean temperature for 2024 for continental regions

Data source: ERA5 • Credit: C3S/ECMWF

Region*	Anomaly (vs 1991–2020)	Rank (1979–2024)
North America	+1.50°C	1st warmest
Europe	+1.24°C	1st warmest
Africa	+1.06°C	1st warmest
Asia	+1.06°C	1st warmest
Central and South America	+0.87°C	1st warmest
Australasia	+0.62°C	3rd warmest

*Based on IPCC continental regions, as defined in the AR6 WGI report

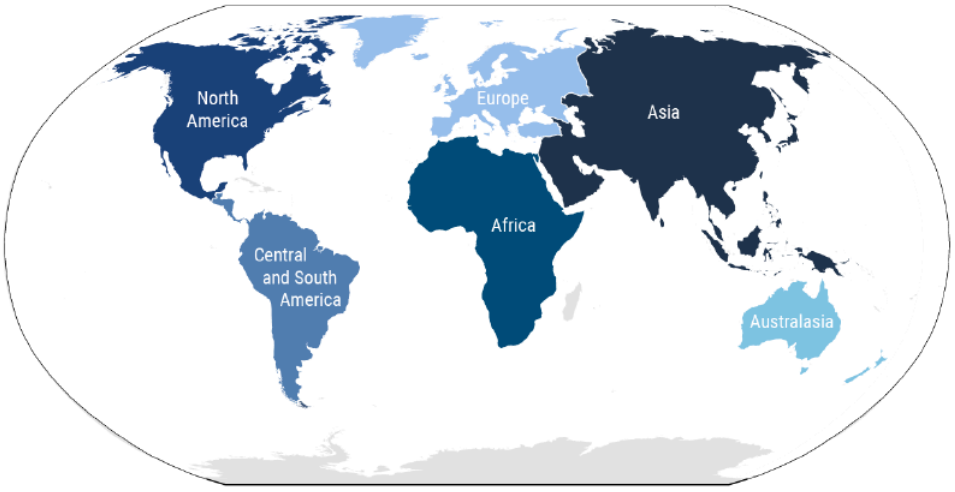

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***Figure 5b**. Ranking of annual mean surface air temperature in 2024 and corresponding anomaly, relative to the average for the 1991–2020 reference period for six continental regions (as defined in the IPCC AR6 WGI report Fig. 1.18). Data source: ERA5. Credit: C3S/ECMWF. Data source: ERA5. Credit: C3S/ECMWF.*

To assess how unusual 2024 was for different locations, annual temperatures for 1979 to 2024 were compared and ranked, revealing record highs over about one third (32%) of the planet. Furthermore, 2024

was the warmest year for all continental regions except Australasia and Antarctica.

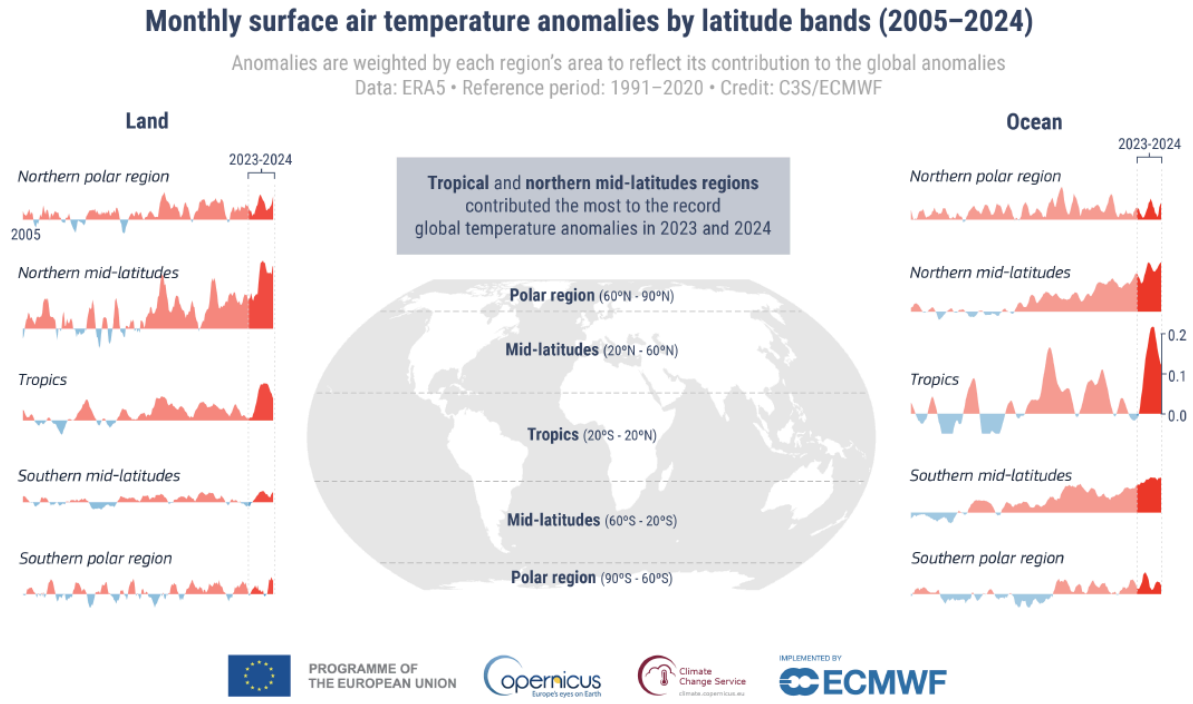

***Figure 6**. Monthly contributions to the global surface air temperature anomalies by latitude band for land (left) and ocean (right) regions for 2005–2024. Anomalies are calculated relative to the average for the 1991–2020 reference period, with each region's contribution weighted by its area on Earth's surface. For any given month, the sum of contributions from all 10 regions equals the recorded global anomaly for that month. Data source: ERA5. Credit: C3S/ECMWF.*

Analysing the contribution of different regions to global temperature anomalies provides further insight. Large contributions may result from large anomalies, extensive surface areas, or a combination of both. For 2023 and 2024, contributions were evaluated for ten land and ocean regions across five latitude bands, with the average temperature anomalies of each weighted by surface area. From mid-2023 to the end of 2024, the largest contributions came from the tropical ocean and northern mid-latitude land areas, followed by tropical land areas and the southern and northern mid-latitude ocean.

Temperature anomalies over the tropical ocean show significant variability, mainly due to the succession of El Niño and La Niña events in the tropical Pacific. In 2023 and 2024, the impact of an El Niño event on global temperatures was amplified by record-high temperatures in the tropical Atlantic and Indian Oceans. Over tropical and northern mid-latitude land areas, temperature anomalies rose sharply from mid-2023, coinciding with the onset of El Niño. In contrast, anomalies in the northern and southern mid-latitude ocean regions have shown a steadier increase over the past two decades. Compared to 2016 (the third warmest year, and influenced by a strong El Niño), a notable feature of the 2023–2024 temperature anomalies is their relatively slow decline after the El Niño peak in late 2023.

European temperatures

- 2024 was the warmest year on record for Europe, with an average temperature of 10.69°C; 0.28°C higher than the previous warmest year of 2020.
- This 2024 temperature is 1.47°C above the average for the 1991–2020 reference period, and 2.92°C above the 1850–1900 level.
- The average temperatures of the European spring (March–May) and summer (June–August) were the highest on record for the seasons, at 1.50°C and 1.54°C above the 1991–2020 average, respectively.

All four European seasons were warmer than average. Spring and summer were the warmest on record, with spring 0.36°C warmer than the previous warmest, in 2014, and summer at 0.20°C warmer than the previous warmest, in 2022. The European winter (December 2023–February 2024) was the joint second warmest on record, at 1.44°C higher than the 1991–2020 average, and 1.4°C cooler than that of 2019/20, the warmest European winter. The average temperature for European autumn (September to November) 2024 was the third highest on record, at 1.25°C above the 1991–2020 average; 0.21°C cooler than the warmest autumn in 2020.

The warmth of 2023–2024 was mainly because of record temperatures in central, eastern and southeastern Europe.

Heat stress

- During 2024, much of the globe experienced more days than average with at least ‘strong heat stress’.
- Several regions of the globe also saw more days than average with ‘extreme heat stress’.
- The area affected by at least ‘strong heat stress’ reached a new record maximum on 10 July, when around 44% of the globe was affected by ‘strong’ to ‘extreme heat stress’. This is 5% more than the average annual maximum.

Heat can lead to situations where the body is under stress from overheating – and beyond temperature, other environmental factors such as humidity can also impact heat stress. Thermal comfort indices can be used to represent the effect of the environment on the human body, and one such index is the Universal Thermal Climate Index (UTCI), which takes into account temperature, humidity, wind speed, sunshine and heat emitted by the surroundings, and how the human body responds to different thermal environments. It can be used to infer thermal stress in humans by classifying UTCI values into ten different heat and cold stress categories, and represents a ‘feels-like temperature’.

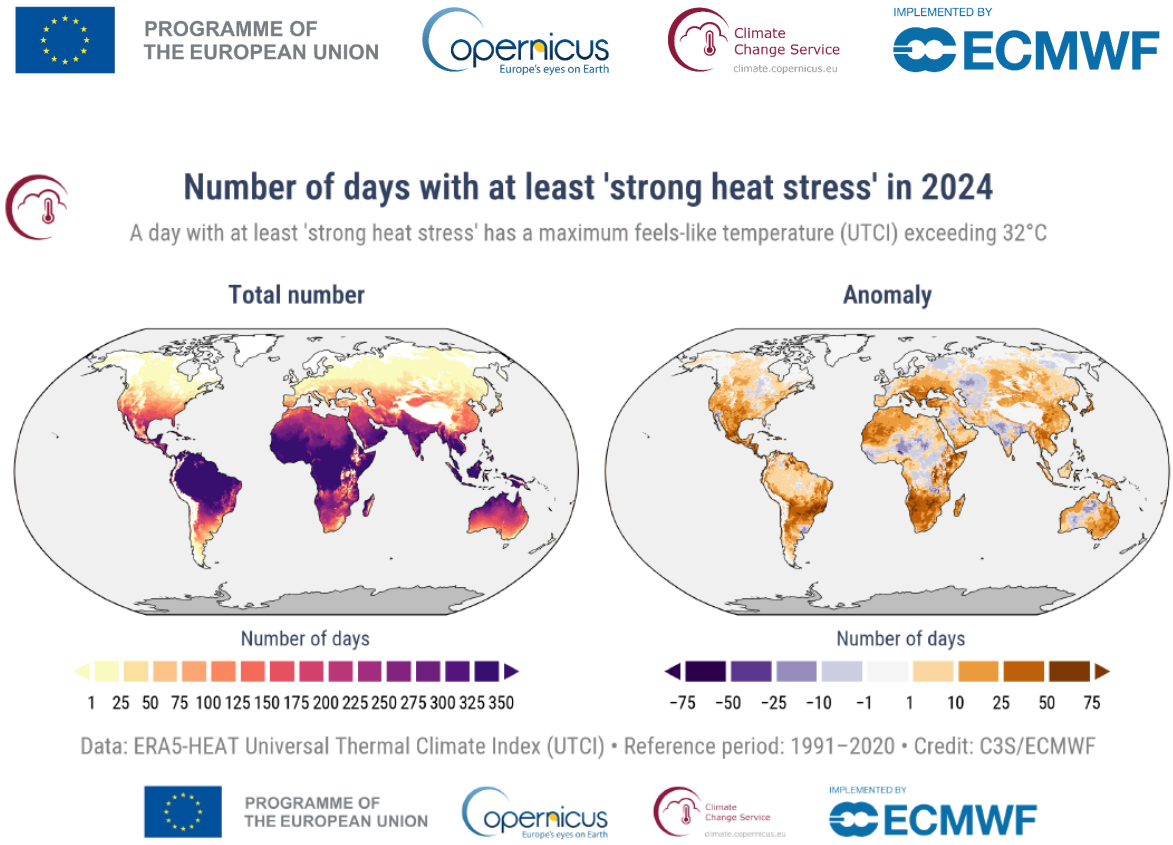

***Figure 7**. Number of days in 2024 during which at least 'strong heat stress' was experienced, based on the daily maximum feels-like temperature exceeding 32°C. Left: Total number of days. Right: Anomalies in the number of days, relative to the average for the 1991–2020 reference period. Feels-like temperature based on the Universal Thermal Climate Index (UTCI). Data source: ERA5-HEAT UTCI. Credit: C3S/ECMWF.*

The UTCI estimates presented here are based on the C3S global reanalysis dataset ERA5-HEAT. In 2024, 61% of land areas experienced more days than average with at least 'strong heat stress' (a feels-like temperature exceeding 32°C). Much of the globe, particularly beyond the subtropics, rarely experiences 'extreme heat stress', the point at which it is imperative to take actions to avoid heat stroke (a feels-like temperature exceeding 46°C). However, some of these areas, such as parts of Australia, northern Africa, the Middle East and the western USA, saw more days than average with 'extreme heat stress'. The highest feels-like temperature value recorded in 2024 was 59.1°C in Algeria in North Africa.

The area of the globe affected by heat stress in 2024 was above average for most of year. On 10 July 2024, the area of the globe affected by 'strong' to 'extreme heat stress' peaked at around 44% - the largest area of the globe to be affected by this degree of heat stress on any day on record.

There was a similar peak, of 43%, in August 2023. The average annual maximum, based on the 1991–2020 reference period, is around 39%.

Sea surface temperature

- The annual average sea surface temperature (SST) over the extra-polar ocean reached a record high of 20.87°C in 2024.
- The extra-polar SST reached record-high levels for the time of year from January to June 2024, following the streak of monthly records that started in May 2023. From July to December 2024, the SST ranked second warmest, after 2023.
- 2024 was influenced by the residual effects of the strong 2023 El Niño event and a transition towards neutral El Niño Southern Oscillation (ENSO) conditions.
- Higher than average SSTs were recorded in most ocean basins, reaching record values in the North Atlantic, Western Pacific and the Indian Ocean.

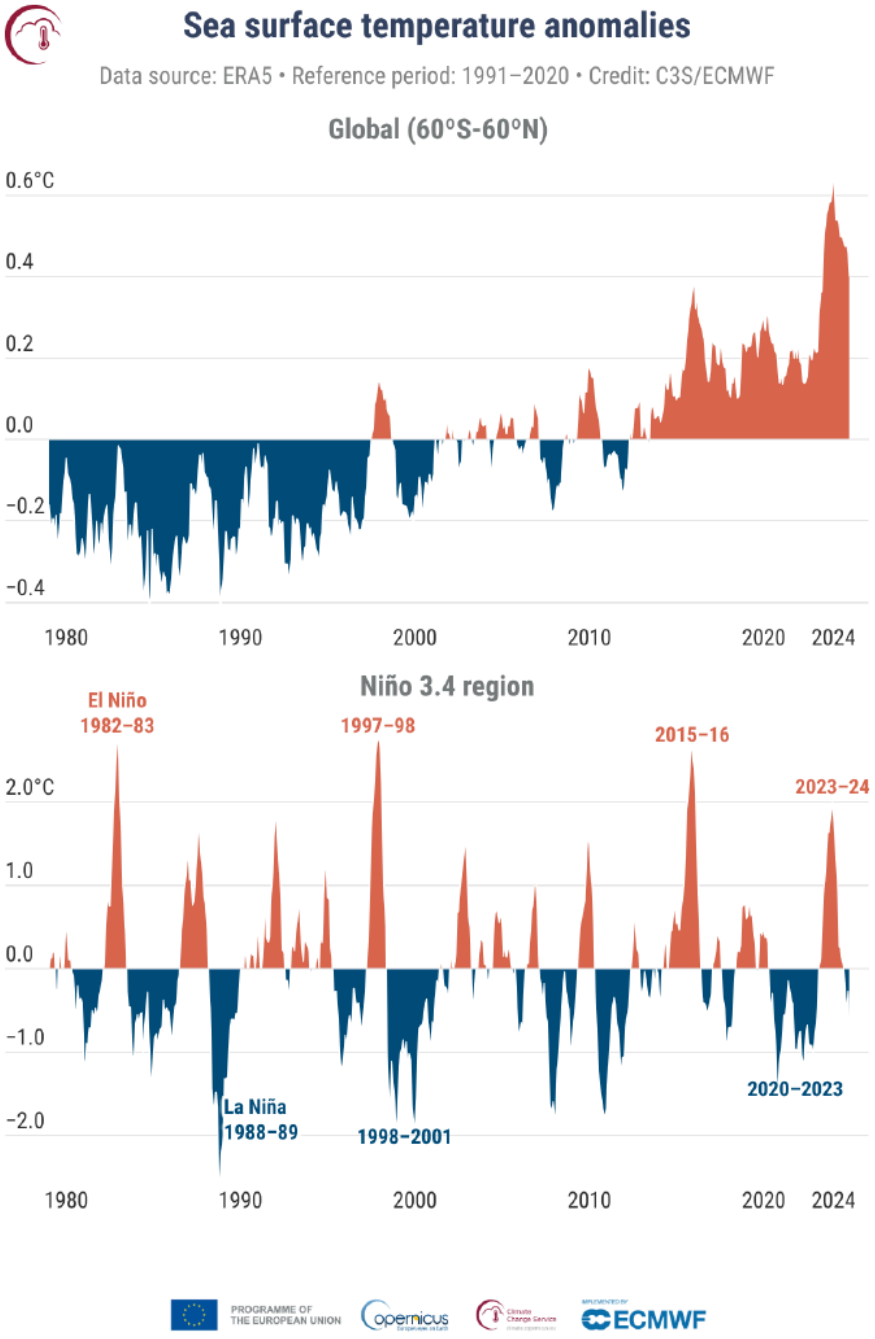

***Figure 8**. Monthly sea surface temperature (SST) anomalies averaged over the extra-polar ocean (60°S–60°N; top) and over the Niño 3.4 region (5°N–5°S, 170°–120°W; bottom). Anomalies are relative to the average for the 1991–2020 reference period for the corresponding month. Data: ERA5. Credit: C3S/ECMWF.*

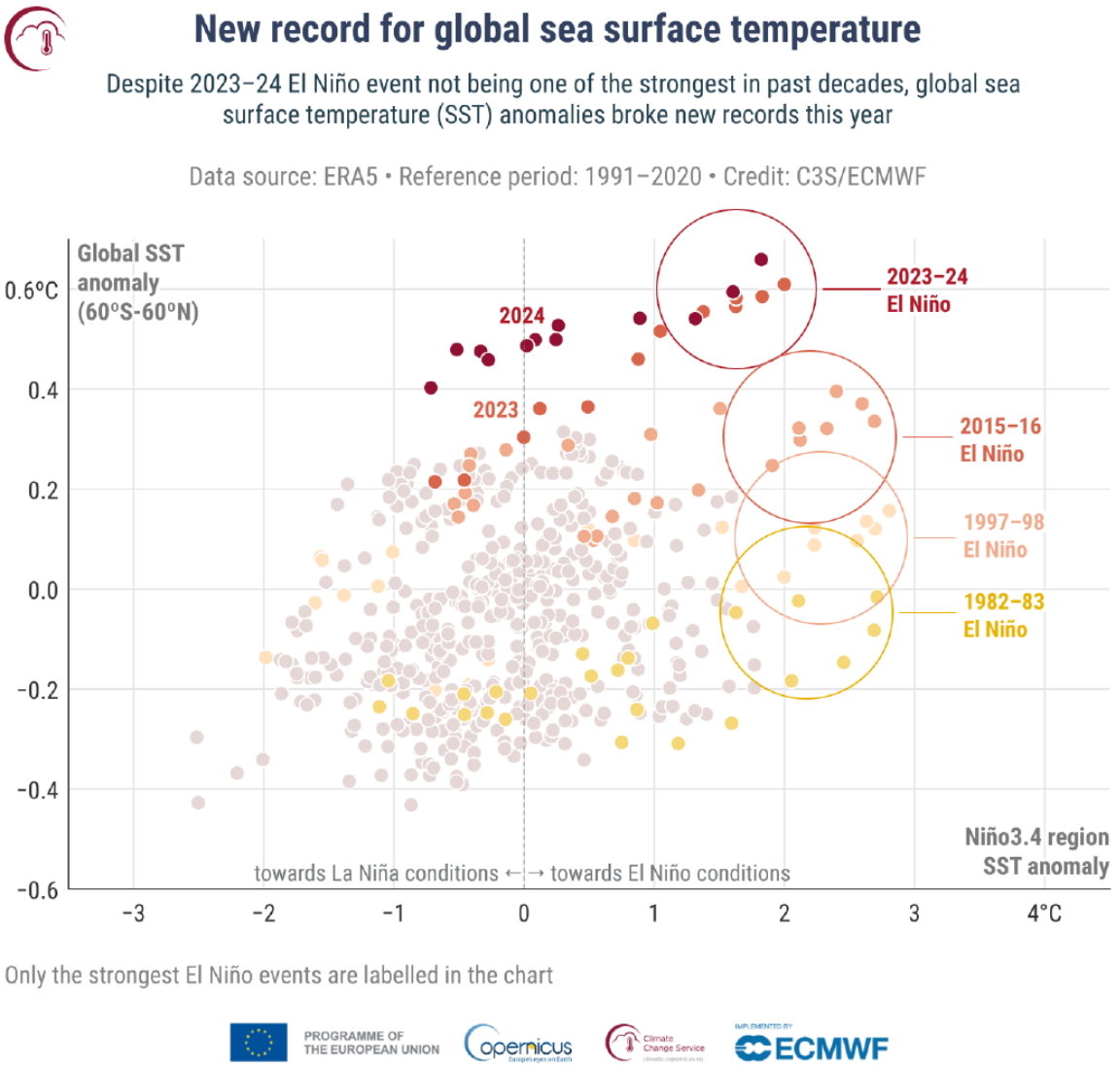

***Figure 9**. Comparison between the monthly sea surface temperature (SST) anomalies for the extra-polar ocean (60°S–60°N; vertical axis) and the monthly SST anomalies for the Niño 3.4 region (5°N–5°S, 170°–120°W; horizontal axis). Anomalies are relative to the average for the 1991–2020 reference period for the corresponding month. Data: ERA5. Credit: C3S/ECMWF.*

From January to June 2024, the average sea surface temperature (SST) over the extra-polar ocean (60°S–60°N) reached record-high values for the time of year. The monthly average SST also reached a new record in March, at 21.07°C. These high values extended a streak of records that started in May 2023 and largely coincided with the development, peak and decay of an El Niño event in the equatorial Pacific from mid-2023 to

mid-2024. The SST reached record monthly values for 15 consecutive months, from May 2023 to June 2024. The monthly SSTs in 2023 and 2024 were significantly higher when compared to other years, despite the El Niño event not being as strong as the events of 1982–1983, 1997–1998 and 2015–2016.

From July to December 2024, the SST fell below that observed in 2023, becoming the second warmest for the time of year, yet remaining well above temperatures seen in all years prior to 2023. These high SSTs reflected the persistence of well-above average, often record high, SSTs in many parts of the ocean, despite the end of the El Niño event. The average SST in December was above the value recorded in December 2015, which marked the peak of one of the strongest El Niño events on record. In contrast, December 2024 saw a transition towards La Niña conditions in the equatorial Pacific. This is a further example of the unusual warmth of the surface oceans in 2024.

For 2024, the annual average extra-polar SST was the highest on record, at 20.87°C, 0.51°C above the 1991–2020 average, surpassing the previous records of 2023 (20.80°C) and 2016 (20.61°C).

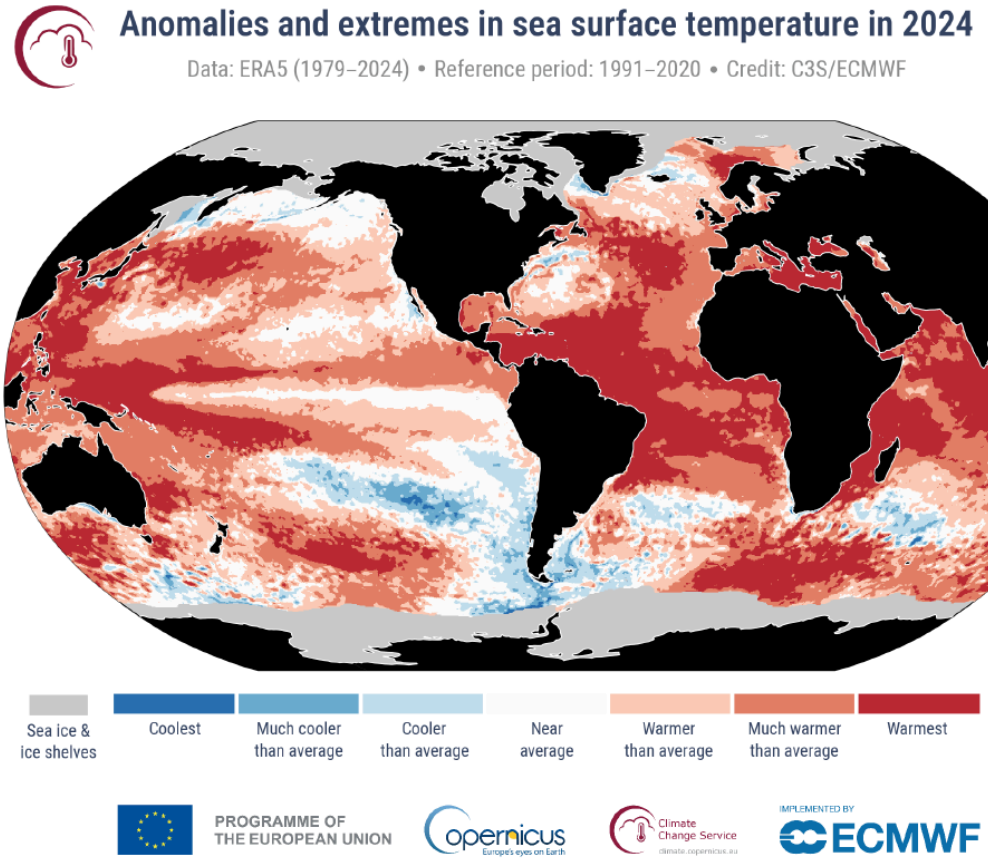

***Figure 10**. Anomalies and extremes in sea surface temperature for 2024. Colour categories refer to the percentiles of the temperature distributions for the 1991–2020 reference period. The extreme ('coolest' and 'warmest') categories are based on rankings for the period 1979–2024. Values are calculated only for the ice-free oceans. Data source: ERA5. Credit: C3S/ECMWF.*

In 2024, the annual SST reached record highs across nearly one third (27%) of the extra-polar ocean. This included vast regions of the Atlantic Ocean, particularly the tropical areas, along with most of the Indian Ocean, large parts of the Western Pacific, and portions of the Southern Ocean. In contrast, the annual average SSTs across the eastern Pacific along the equator were close to the 1991–2020 average, reflecting a transition from El Niño conditions early in the year to neutral or weak La Niña conditions in the second half of the year. In European seas, annual SSTs reached record highs in the central and eastern Mediterranean Sea, the Black Sea, and the Norwegian Sea. All areas with record annual SSTs experienced marine heatwaves of at least category II ('strong') at some point during the year.

The widespread occurrence of high SSTs led to a global coral bleaching event, declared by NOAA in April.

Atmospheric water vapour

- The total amount of water in the atmosphere reached a record value in 2024, at 4.9% above the 1991–2020 average, markedly higher than in 2016 (3.4%) and 2023 (3.3%), the years with the second and third highest values.

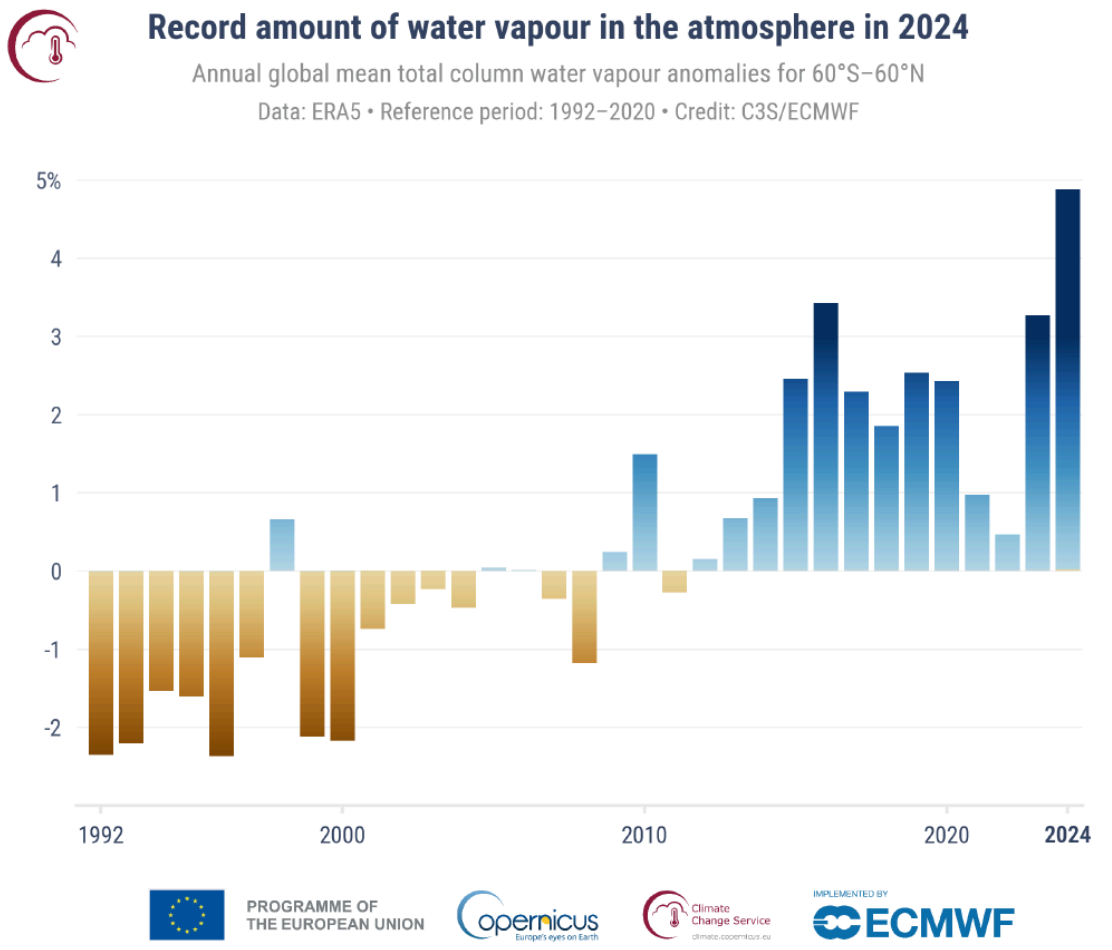

***Figure 11**. Annual anomalies in the average amount of total column water vapour over the 60°S–60°N domain relative to the average for the 1992–2020 reference period. The anomalies are expressed as a percentage of the 1992–2020 average. Data: ERA5. Credit: C3S/ECMWF.*

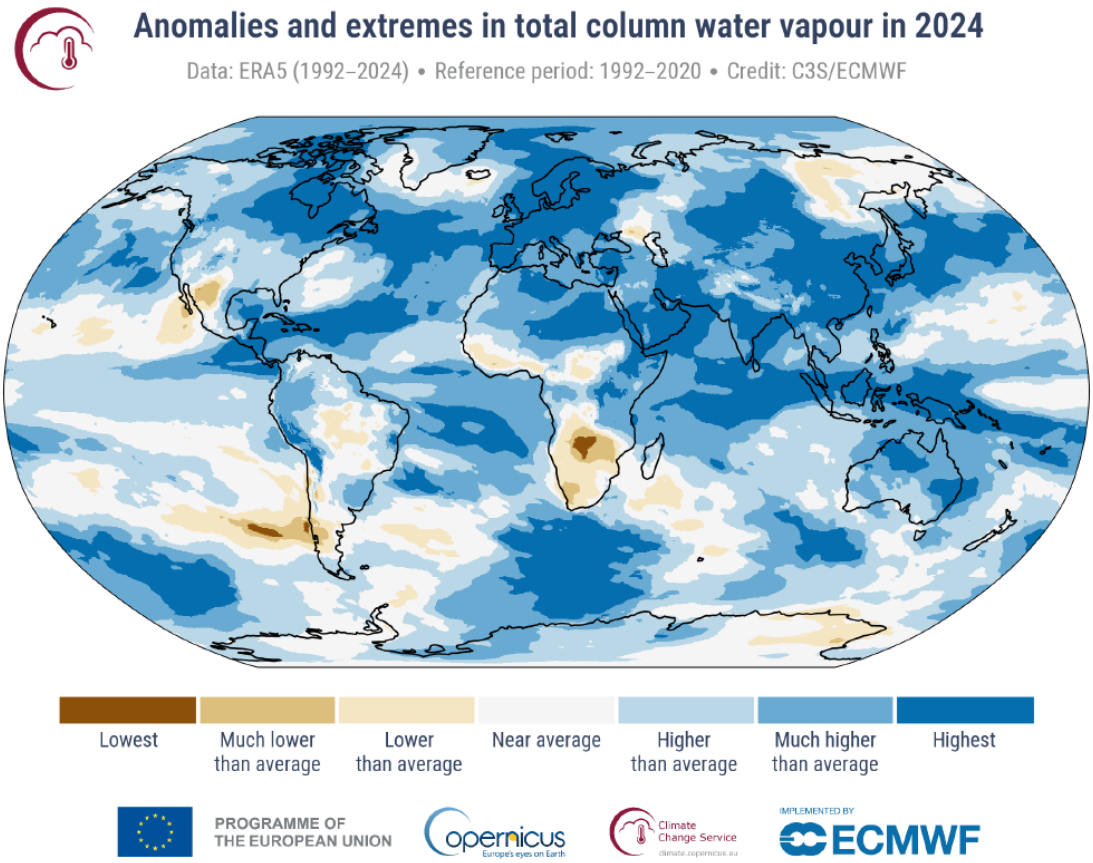

***Figure 12**. Anomalies and extremes in the amount of total column water vapour for 2024. Colour categories refer to the percentiles of the temperature distributions for the 1992–2020 reference period. The extreme ('lowest' and 'highest') categories are based on rankings for 1992–2024. Data source: ERA5. Credit: C3S/ECMWF.*

Water vapour plays a crucial role in the climate system, as it significantly contributes to Earth's natural greenhouse effect. Unlike other greenhouse gases, such as carbon dioxide and methane, the concentration of water vapour is not directly influenced by human activities. However, as the atmosphere warms, it can hold more water vapour (about 7% more for each additional degree Celsius). In turn, the greater water vapour content further amplifies warming, a process known as 'temperature-water vapour feedback'. Increased moisture in the atmosphere also heightens the potential for extreme rainfall events and provides energy for more intense tropical storms.

'Total column water vapour', referred to as 'water vapour' here, is a measure of the amount of moisture in a vertical column of air extending from Earth's surface to the top of the atmosphere. In 2024, the annual average water vapour over the 60°S–60°N domain reached its highest value in at least 33 years, at 4.9% above the 1991–2020 average. This is well above the second highest value (3.4%) recorded in 2016 and third highest value (3.3%) recorded in 2023. The record high water vapour value for 2024 was influenced by a combination of increased surface evaporation from the ocean due to higher sea surface temperatures and by the ability of a warmer atmosphere to hold more moisture.

How unusual was the global warmth of 2023 and 2024?

Since the late 1970s, the global warming trend has averaged an increase of around 0.2°C per decade. Alongside this trend there are natural fluctuations in annual global temperatures from one year to the next of up to around 0.3°C. Several relatively strong El Niño events, with Oceanic Niño Indices peaking at or above 1.5°C, occurred during this period, resulting in pairs of consecutive years that were, at the time, the warmest two years on record. The most recent such years are 2023 and 2024.

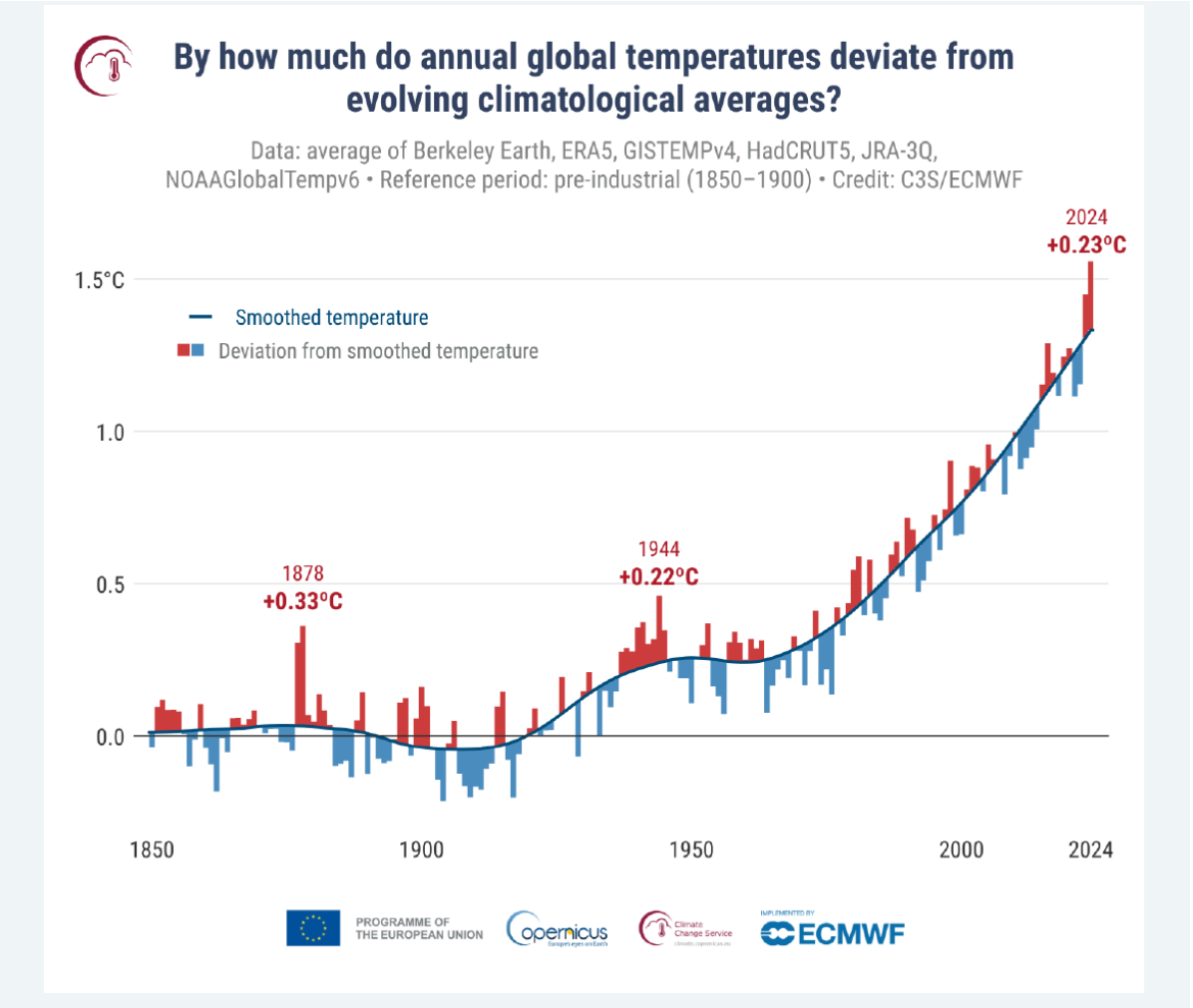

***Figure 13**. Difference in global-average temperature (°C) from the 1850–1900 level, based on the averages of monthly values from up to six datasets: Berkeley Earth, HadCRUT5 and NOAAGlobalTemp (from 1850), GISTEMP (from 1880), ERA5 (from 1940) and JRA-3Q (from September 1947). Datasets are normalised to have the same averages for 1991–2020 and an average dataset offset of 0.88°C is used to relate 1991–2020 and 1850–1900 averages. The black curve shows an estimate of the long-term climatological variation of temperature (see About the Data and Methods). The red and blue bars show the deviations of annual-average temperatures from this estimate. Credit: C3S/ECMWF.*

How unusual were 2023 and 2024?

To investigate infrequent climate events, a statistical approach with a moving average is used – rather than the traditionally-used fixed 30-year

average. In this way, annual anomalies are more easily identified against an evolving background.

Using this approach for global-mean temperature, averaged over multiple datasets, confirms that 2023 and 2024 are two of the warmest years on record relative to the evolving background. The only warmer years compared to the climatological state at the time are 1877 and 1878 for the example shown in Figure 13. These were during the 'Great Drought' of 1875 to 1878, when it is estimated that around 50 million people died in India, China and parts of Africa and South America. This period was characterised by a strong El Niño in the tropical eastern Pacific, and unusually warm SSTs elsewhere, although gaps in data coverage prevent full comparison with 2023 and 2024. 1944[3] was another relatively warm year, with a deviation from the evolving background that is almost as large as that of 2024.

Figure 13 also shows that the warming rate of the background climatological state increases from the late 1970s to the present day. It changes from 0.19°C per decade at the mid-point of the thirty-year period 1979–2008 to 0.24°C per decade at the end of 2024.

What factors were behind the warmth of 2023 and 2024?

The 2023–2024 El Niño was a strong but not exceptional event, having a peak Oceanic Niño Index of 2.0°C; smaller than the peaks of the 2015–2016, 1997–1998 and 1982–1983[4] events. In addition to the El Niño, a significant fraction of the atmospheric warming and moistening in 2023 and 2024 appears to originate from SSTs across other ocean basins. 2024 was also slow to move from El Niño towards neutral ENSO conditions.

2024 and 2023 appear to be exceptionally warm because of accelerating human-induced climate warming and an unusually warm phase of oceanic variability, with unprecedented SST anomalies in multiple regions. Other factors which may also have had an influence on one or both years include:

- the Hunga Tonga–Hunga Ha'apai volcanic eruption in January 2022 - warming due to increased stratospheric water vapour, but cooling due to aerosols

- lower sulphur dioxide emissions by shipping - warming due to reduced aerosols
- reduced amounts of low-level cloud - warming of the climate system from increased absorption of solar radiation
- solar cycle maximum - warming from increased solar energy reaching Earth
- temperature/water-vapour feedback mechanism - warming from the enhanced greenhouse effect of additional water vapour in the atmosphere

What are the expectations for 2025 and beyond?

A recent Met Office forecast indicates that it is likely that 2025 will become the third, or even second, warmest year on record globally. 2024 has already fulfilled the expectation of the WMO Global Annual to Decadal Climate Update for 2024-2028 released in June 2024 that at least one year between 2024 and 2028 would be more than 1.5°C above the 1850–1900 level and become the warmest year on record. The report indicates that a single year in the period could reach as high as 1.9°C above the 1850–1900 level, and that there is a 47% chance that the five-year average will exceed the 1.5°C threshold.

[3] There is evidence that the sea surface temperature analyses for the early 1940s used here are biased warm, but surface air temperatures averaged only over land for 1938 and 1944 are higher than for any other year prior to 1973.

[4] Warming of the global atmosphere in this case was offset by cooling due to the volcanic eruption of El Chichón.

Extreme events around the world

- A large number of extreme events were recorded across the globe, including heatwaves, floods, droughts and wildfires.

Extreme events in 2024 had significant impacts on human health, ecosystems and infrastructure. Among the most exceptional events were flooding, extreme heat, drought and wildfires.

Flash floods were caused by intense, in some cases record, precipitation (for example in California in January, Persian Gulf countries in April, eastern Spain in October). There was also larger scale flooding due to the passage of atmospheric rivers (such as in California in February), monsoon rainfall (in Australia and South Asia during the respective wet seasons), large low-pressure systems and tropical cyclones.

Provisional data from NOAA IBTrACS indicate that 2024 saw 86 tropical storms, of which 43 became tropical cyclone strength and 22 major tropical cyclones. Many resulted in impacts on populations and infrastructure around the world. Among others, tropical cyclones that resulted in flooding around the world in 2024 included: Cyclone Alvaro, Madagascar (January); Storm Akarà, Brazil, Cyclone Lincoln, Australia (February); Cyclone Megan, Australia, Cyclone Gamane, Madagascar (March); Typhoon Ewiniar, the Philippines, Cyclone Ialy, south-eastern Africa (May); Storm Alberto and Storm Chris, North America (June); Hurricane Beryl (June-July); Typhoon Gaemi, eastern Asia, Hurricane Debby, eastern North America, Cyclone Asna, the Indian subcontinent, Typhoon Shanshan, Japan (August); Hurricane Helene, eastern United States, Typhoon Krathon, Taiwan and the Philippines, Hurricane Milton the southeastern USA, Storm Kong-rey, Taiwan and China (October); Typhoons Yinxing, Toraji and Usagi, the Philippines (November); Storm Chido, southeast Africa (December).

Europe was impacted throughout the year by a range of precipitation events, from convective storms to named storms, such as Storm Boris in September, which brought record-breaking rainfall and severe flooding to central and eastern regions. In northwestern Europe, 12 storms were named by the UK Met Office, Met Éireann and KNMI (Netherlands) storm-naming group during the 2023-2024 storm season. This is the highest number of named storms in a season since storm-naming was introduced in 2015. Across Europe, estimates suggest close to 50 named storms[5] occurred during 2024.

During 2024, there were numerous heatwaves, often breaking national or local temperature records. Significant heatwaves occurred in southeastern Europe, North Africa, the Sahel, the Middle East and parts of the Americas, central and south and east Asia, southern Africa and Australia.

Several regions saw a prolonged lack of precipitation, often coincident with high temperature extremes, in particular in Central and South America (Amazon basin, Pantanal wetlands, among others), southern Africa, regions of the Mediterranean and eastern Europe.

Dry conditions were conducive to wildfires in several regions. The Americas were the most affected continents according to the Copernicus Atmosphere Monitoring Service (CAMS) GFAS wildfire emission data. Persistent and large-scale vegetation fires were observed across Canada (July and August), and south Brazil and Bolivia (August to October). Fire carbon emissions were the highest on record for Bolivia and Venezuela, and Canada ranked second after 2023.

[5] 2024–25 European windstorm season, 2023–24 European windstorm season, last accessed 07/01/2025

Sea ice

- During a large part of 2024, sea ice extent reached historically low values around Antarctica. At its annual minimum in February, the monthly extent ranked third lowest on record. From June onward, the monthly extent ranked either second lowest behind 2023, or lowest (in November).
- In the Arctic, the sea ice extent was relatively close to its 1991–2020 average until June but fell well below average in the following months. At its annual minimum in September, the monthly extent ranked fifth lowest in the satellite record.

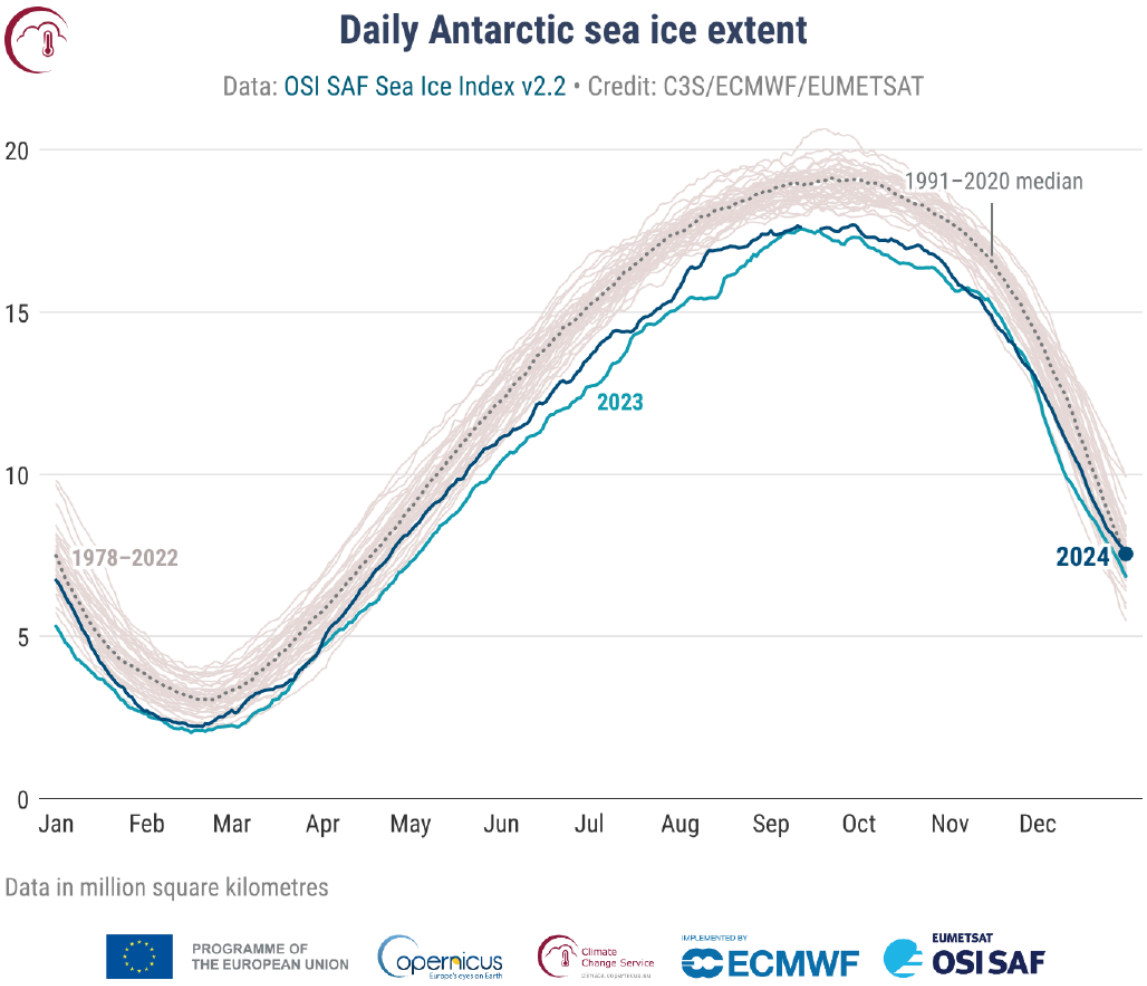

***Figure 14a**. Daily Antarctic sea ice extent from 1979 to 31 December 2024. 2024 is shown with a dark blue line and 2023 with a teal line. Data source: EUMETSAT OSI SAF Sea Ice Index v2.2. Credit: C3S/ECMWF/EUMETSAT.*

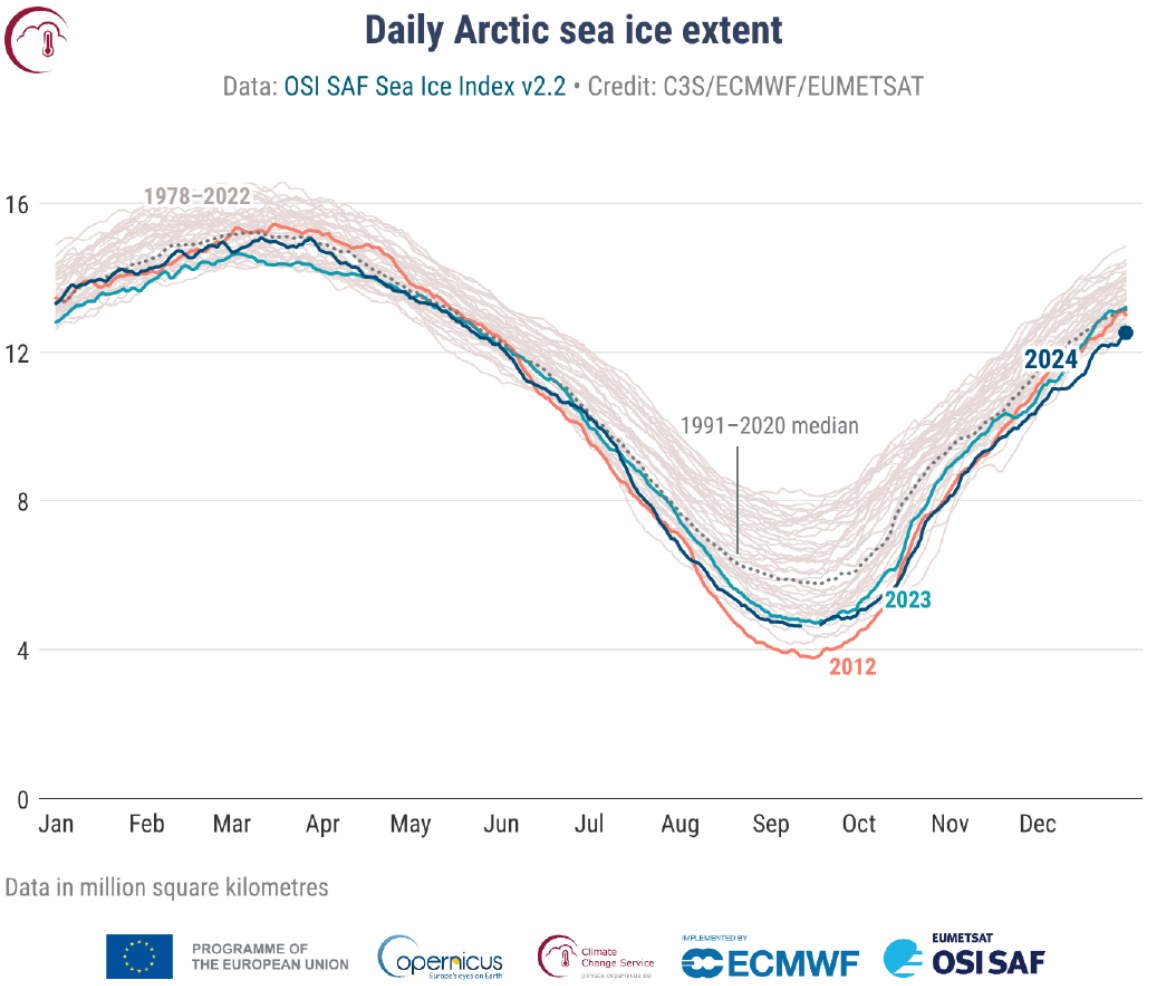

***Figure 14b**. Daily Arctic sea ice extent from 1979 to 31 December 2024. 2024 is shown with a dark blue line, 2023 with a teal line, and 2012 (year of the lowest daily sea ice extent) with an orange line. Data source: EUMETSAT OSI SAF Sea Ice Index v2.2. Credit: C3S/ECMWF/EUMETSAT.*

In the Antarctic, after reaching record lows for the time of year through most of 2023, the sea ice extent was again well below average during several months of 2024. The annual minimum extent in February was the third lowest in the satellite record. From June to October, the monthly extents were the second lowest for those months, behind 2023, while November set a new record low for the month. Antarctic sea ice concentration anomalies varied by ocean sector and by month but notably there was much-reduced ice cover in the Atlantic sector. Open water is often warmer than the air above, particularly during winter months, so the reduced sea ice cover contributed to unusually high surface air

temperatures around Antarctica. These elevated regional temperatures were a factor, albeit not a primary one, in the record or near-record global temperatures of 2024. In contrast to the pronounced decline in Arctic sea ice since the 1980s, persistent large negative anomalies in Antarctic sea ice extent have only been observed since 2016. Warmer ocean temperatures and atmospheric circulation patterns are likely contributing factors, but research is ongoing.

In the Arctic, sea ice extent was close to its 1991–2020 average until June. This behaviour was in line with that often observed since 2021. However, from July 2024 onward, the sea ice extent was significantly below average. At its annual minimum in September, the monthly extent ranked fifth lowest in the satellite record. The year ended with the lowest December extent on record.

Greenhouse gas concentrations

- The atmospheric concentrations of carbon dioxide and methane reached record levels in 2024, at 422.1 ppm and 1897 ppb respectively.

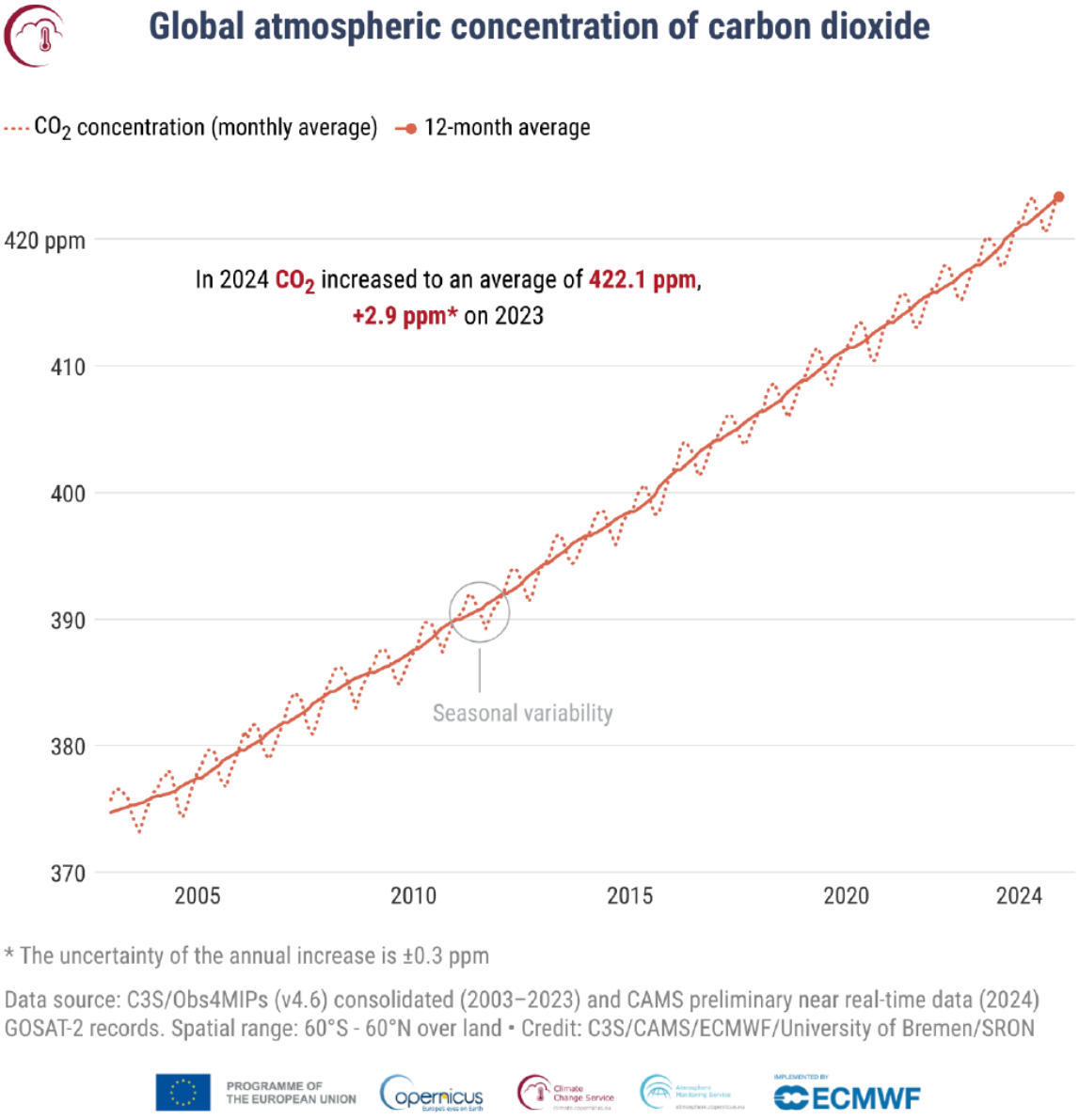

***Figure 15a**. Monthly global mean atmospheric CO_2 column-averaged concentration from satellites for 2003–2024 and the 12-month average. Data source: C3S/Obs4MIPs (v4.6) consolidated (2003–2023) and CAMS preliminary near real-time data (2024) GOSAT-2 records. Spatial range: 60°S-60°N over land. Credit: C3S/CAMS/ECMWF/University of Bremen/SRON.*

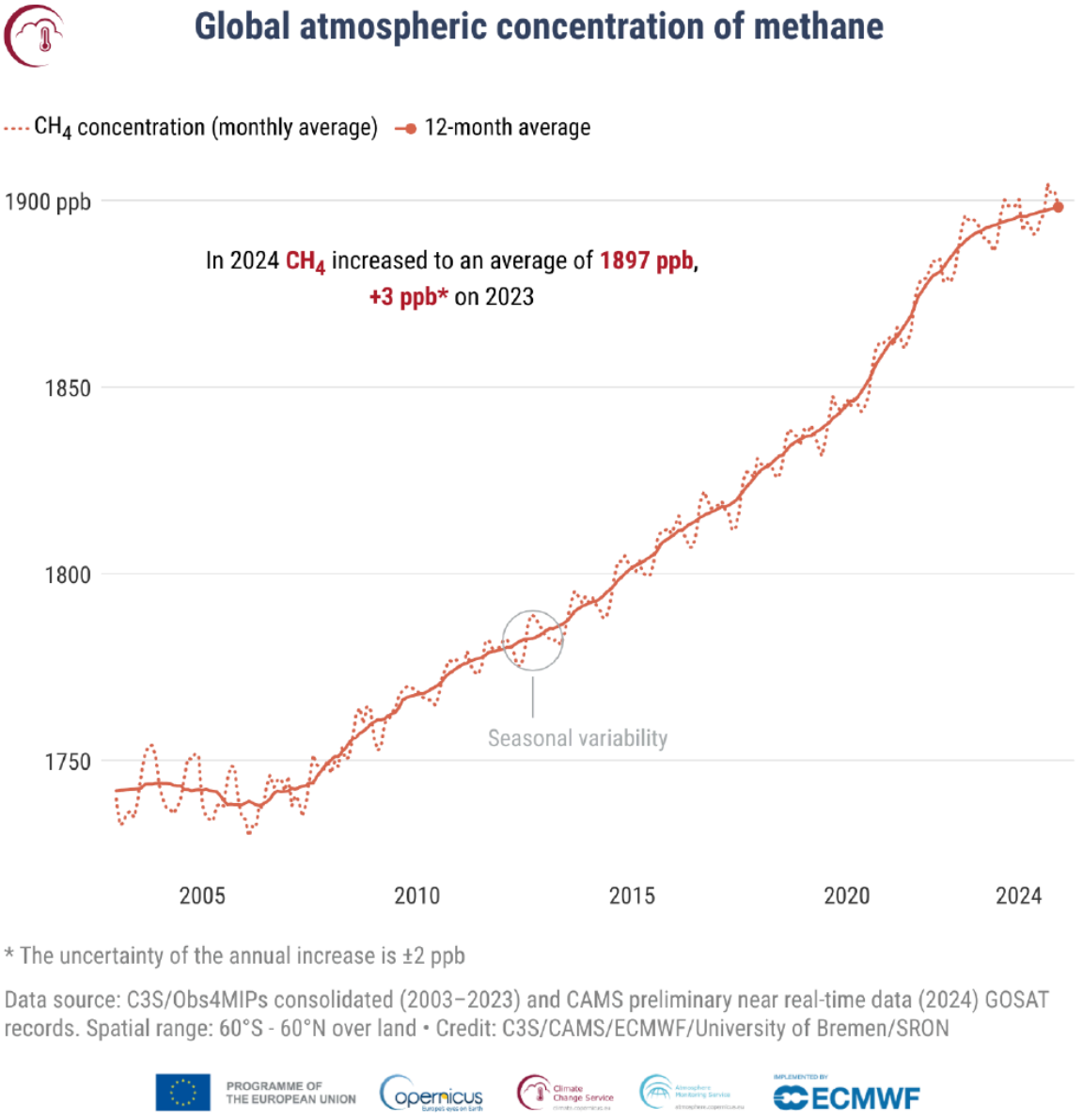

***Figure 15b**. Monthly global mean atmospheric CH_4 column-averaged concentration from satellites for 2003–2024 (blue curve) and 12-month average (black curve). Data source: C3S/Obs4MIPs (v4.6) consolidated (2003–2023) and CAMS preliminary near real-time data (2024) GOSAT records. Spatial range: 60°S-60°N over land. Credit: C3S/CAMS/ECMWF/University of Bremen/SRON.*

The atmospheric concentration of the greenhouse gases carbon dioxide and methane continued to increase during 2024. Preliminary analysis of satellite data, averaged over the whole atmospheric column, shows that carbon dioxide concentrations are approximately 2.9 ppm (+/- 0.3 ppm) higher in 2024 compared to the previous record year of 2023, while

methane rose by around 3 ppb (+/- 2 ppb). This resulted in an annual average for 2024 of approximately 422.1 ppm for carbon dioxide and 1897 ppb for methane. The rate of increase of carbon dioxide was larger than the rate observed in recent years (the increase from 2022 to 2023 was 2.5 ppm).

The rate of increase of methane was lower than in previous years. For example, the increase from 2022 to 2023 was twice as large. Atmospheric concentrations of methane had substantially grown throughout the 20th century, before plateauing from 2000 to 2006.

Atmospheric carbon dioxide concentrations were higher in 2024 than at any time in at least 2,000,000 years. Atmospheric concentrations of methane in 2024 were higher than at any time in at least 800,000 years.

Useful links

- Online version of the report
- Graphics Gallery
- About the data and methods
- Press release