

Press release Bonn, 10/01/2025

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Copernicus: 2024 is the first year to exceed 1.5°C above pre-industrial level



Global surface air temperature increases above the 1850-1900 pre-industrial reference period, based on several global temperature datasets shown as annual averages since 1967 (left) and as 5-year averages since 1850 (right). Credit: C3S / ECMWF. <u>DOWNLOAD IMAGE</u> / <u>DOWNLOAD DATA</u>

2024 is confirmed by the <u>Copernicus Climate Change Service (C3S)</u> to be the warmest year on record globally, and the first calendar year that the average global temperature exceeded 1.5°C above its pre-industrial level. C3S is implemented on













ECMWF

behalf of the European Commission by the European Centre for Medium-Range Weather Forecasts (ECMWF), whose scientists have been monitoring key climate indicators, and documenting unprecedented daily, monthly, and annual temperature records over 2024. Human-induced climate change remains the primary driver of extreme air and sea surface temperatures; while other factors, such as the El Niño Southern Oscillation (ENSO), also contributed to the unusual temperatures observed during the year.

This year the following organisations involved in global climate monitoring – ECMWF, NASA, NOAA, the UK Met Office, Berkeley Earth and the World Meteorological Organisation (WMO), have made a concerted effort to coordinate the release of their data, highlighting the exceptional conditions experienced during 2024.











Carlo Buontempo, Director of the Copernicus Climate Change Service, ECMWF comments: "All of the internationally produced global temperature datasets show that 2024 was the hottest year since records began in 1850. Humanity is in charge of its own destiny but how we respond to the climate challenge should be based on evidence. The future is in our hands - swift and decisive action can still alter the trajectory of our future climate."

Samantha Burgess, Strategic Lead for Climate, ECMWF comments: "Each year in the last decade is one of the ten warmest on record. We are now teetering on the edge of passing the 1.5°C level defined in the Paris Agreement and the average of the last two years is already above this level. These high global temperatures, coupled with record global atmospheric water vapour levels in 2024, meant unprecedented heatwaves and heavy rainfall events, causing misery for millions of people."

Global surface air temperature highlights:

- 2024 was the warmest year in global temperature records going back to 1850. According to ERA5 (1), the global average temperature of 15.10°C was 0.72°C above the 1991-2020 average, and 0.12°C above 2023, the previous warmest year on record. This is equivalent to 1.60°C above an estimate of the 1850-1900 temperature designated to be the pre-industrial level.
- 2024 is the first calendar year that has reached more than 1.5°C above the pre-industrial level.
- Each of the past 10 years (2015–2024) was one of the 10 warmest years on record.
- The monthly global average temperature exceeded 1.5°C above pre-industrial levels for 11 months of the year. Going back further, all months since July 2023, except for July 2024, have exceeded the 1.5°C level.
- A new record high for daily global average temperature was reached on 22 July 2024, at 17.16°C.
- 2024 was the warmest year for all continental regions, except Antarctica and Australasia (2), as well as for sizeable parts of the ocean, particularly the North Atlantic Ocean, the Indian Ocean, and the western Pacific Ocean.
- 2024 saw three record-warm seasons for the corresponding time of the year: boreal winter (December 2023-February 2024), boreal spring (March-May) and boreal summer (June-August) at 0.78°C, 0.68°C and 0.69°C respectively above the 1991-2020 average.
- Each month from January to June 2024 was warmer than the corresponding month in any previous year on record. Each month from July to December, except August, was each the second warmest, after 2023, for the time of year. August 2024 was tied with August 2023 as the warmest on record.

Ocean surface temperature highlights:













- In 2024, the annual average sea surface temperature (SST) over the extra-polar ocean reached a record high of 20.87°C, 0.51°C above the 1991–2020 average.
- The average extra-polar SST was at record high levels for the time of year from January to June 2024, continuing the streak of record months seen in the second half of 2023. From July to December 2024, the SST was the second warmest on record for the time of year, after 2023.
- 2024 saw the end of the El Niño event that started in 2023 and the transition towards more neutral or La Niña conditions.

European temperature highlights:

- 2024 was the warmest year on record for Europe, with an average temperature of 10.69°C, 1.47°C above the average for the 1991-2020 reference period, and 0.28°C warmer than the previous record set in 2020.
- Spring and summer were the warmest on record for Europe, with the average temperature for spring (March-May) 1.50°C higher than the 1991-2020 seasonal average and the average temperature for summer (June-August) 1.54°C above the 1991-2020 seasonal average.

Other highlights include:

- The total amount of water vapour in the atmosphere reached a record value in 2024, at about 5% above the 1991–2020 average, according to ERA5, more than 1% higher than in 2016 and 2023, the years with the previous highest and second highest values, respectively.
- Extreme temperatures and high humidity contribute to increased levels of heat stress. Much of the Northern Hemisphere experienced more days than average with at least 'strong heat stress' during 2024, and some areas saw more days than average with 'extreme heat stress'.
- In 2024, the area of the globe affected by at least 'strong heat stress' reached a new record annual maximum on 10 July, when around 44% of the globe was affected by 'strong' to 'extreme heat stress'. This is 5% more of the globe compared to the average annual maximum.
- Around Antarctica, after reaching record-low values for the time of year during eight months of 2023, the sea ice extent reached record or near-record low values again during a large part of 2024. From June to October, the monthly extent ranked second lowest, behind 2023, and lowest in November. At its annual minimum in February, the monthly extent ranked third lowest in the satellite record.
- In the Arctic, the sea ice extent was relatively close to its 1991–2020 average until July 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.
- The atmospheric concentrations of carbon dioxide and methane continued to increase and reached record annual levels in 2024, at 422 parts per million (ppm) and 1897 parts per billion (ppb) respectively. Carbon dioxide concentrations in 2024 were 2.9 ppm higher than in 2023, whereas methane concentrations were 3 ppb higher.













Key temperature statistics for 2024

Region	Anomaly (vs 1991–2020)	Actual temperature	Rank (out of 85 years)
Globe	+0.72°C (+1.60°C vs pre-industrial)	15.10°C	1st highest 2nd - 2023
Europe	+1.47°C	10.69°C	1st highest 2nd - 2020
Arctic	+1.34°C	-11.37ºC	4th highest 1st - 2016
Extra-polar ocean	+0.51°C	20.87°C	1st highest 2nd - 2023

The European region is defined as 25°W-40°E, 34°-72°N. The extra-polar ocean region is defined as 60°N-60°S. Statistics for *globe, Europe* and *the Arctic* refer to surface air temperatures, statistics for *extra-polar ocean* refer to the sea surface temperature. Temperatures for Europe and the Arctic are **over land only**.

Data source: ERA5 • Credit: C3S/ECMWF

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Key temperature statistics for 2024. Statistics for the globe, Europe and the Arctic refer to surface air temperatures, statistics for extra-polar ocean refer to the sea surface temperatures. Data source: ERA5. Credit: C3S / ECMWF. <u>DOWNLOAD IMAGE</u>

Florence Rabier, ECMWF Director-General, comments: "The Global Climate Highlights is a vital tool for supporting international climate adaptation efforts. We are grateful for the European Commission's continued trust towards ECMWF as an intergovernmental scientific organisation and for the dedication of our staff and collaborators, whose work makes this service possible. For 50 years, ECMWF's leadership in meteorology with real-time data assimilation, operational expertise and the world's largest meteorological historical database has been essential to ensuring global preparedness for weather-related challenges. All of this is achieved together with our Member States and their National Meteorological Services."

Mauro Facchini, Head of Earth Observation at the Directorate General for Defence Industry and Space, European Commission, comments: "The environmental and













climate targets set by the European Union are ambitious and need appropriate actions, especially considering the results presented today. With science, innovation and flagship programmes in Earth Observation such as Copernicus, we can make informed decisions to mitigate and adapt to climate change."

Unprecedented global surface air temperatures in 2024



Global surface air temperature increase (°C) above the average for the pre-industrial reference period (1850– 1900) for each month from January 1940 to December 2024, plotted as time series for each year. 2024 is shown as a thick red line and 2023 as a thick pink line, while other years are shown with thin lines and shaded according to the decade, from blue (1940s) to red (2020s). Data source: ERA5. Credit: C3S / ECMWF.

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Monthly temperature patterns provide a crucial clue to understanding some of the factors leading to 2024 becoming the hottest year on record. The first half of the year was particularly warm, with each month recording higher global temperatures than the same month in any previous year. This contributed to a 13-month streak of record-breaking monthly temperatures, which ended in June.













From July onward, global temperature anomalies remained significantly above average. August 2024 was as warm as August 2023, and the other months from July to December ranked as the second warmest on record, behind 2023. Notably, 22 July marked the hottest day ever recorded, with the global temperature reaching 17.16°C, according to ERA5.

The persistence of exceptionally high monthly global average temperatures during the first half of 2024 made it likely from late summer that it would surpass 2023 as the hottest year on record. Furthermore, 2024 became the first year to register an annual temperature anomaly exceeding the 1.5°C threshold above the pre-industrial level. The two-year average for 2023-2024 also exceeds this threshold. While this does not mean we have breached the limit set by the Paris Agreement — this refers to temperature anomalies averaged over at least 20 years — it underscores that global temperatures are rising beyond what modern humans have ever experienced.

Sea surface temperature (SST): High SSTs across the world's ocean















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. DOWNLOAD IMAGE / DOWNLOAD DATA

High sea surface temperatures (SSTs) have been one of the most significant drivers behind the prevalence of high global temperatures in 2023 and 2024. One of the factors behind these high SSTs was the evolution of the El Niño Southern Oscillation (ENSO). This ENSO peaked in December 2023 and continued to influence global temperatures in the first half of 2024.

Even as the El Niño event ended and the transition towards more neutral conditions in the equatorial eastern Pacific took place, many regions continued to experience unusually high SSTs, resulting in the global SST remaining higher than average. In 2024, annual average SST across the extra-polar ocean were at a record high.

Climate conditions can influence extreme weather events

In 2024, extreme weather events were observed worldwide, ranging from severe storms and floods to heatwaves, droughts and wildfires. The increasing frequency and intensity of such events pose a significant risk to the livelihoods of people across the globe. The total amount of water vapour in the atmosphere reached a record high in 2024, at about 5% above the 1991–2020 average — significantly higher than in 2023. This abundant supply of moisture amplified the potential for extreme rainfall events. In addition, combined with high sea surface temperatures, it contributed to the development of major storms, including tropical cyclones.

High temperatures can lead to situations where the body is under stress from overheating. As well as temperature, other environmental factors such as humidity can also impact heat stress. In 2024, much of the globe experienced more days than average with at least 'strong heat stress'. Some regions also saw more days than average with 'extreme heat stress', at which level it is imperative to take action to avoid heat stroke.

Prolonged dry periods in several regions created conditions conducive to wildfires. Largescale and persistent wildfires were recorded across the Americas. In terms of wildfire carbon emissions, Bolivia and Venezuela recorded their highest levels on record, while Canada saw













its second highest levels, based on data from the Copernicus Atmosphere Monitoring Service (CAMS).

Sea ice in the Arctic and the Antarctic

Sea ice extent in the Arctic and around Antarctica is an essential indicator of the stability of Earth's climate that is monitored by C3S. In 2024, sea ice extent in these regions was significantly below average.

Antarctic sea ice extent reached record or near-record low values for the second year in a row. From June to October, the monthly extent ranked second lowest behind 2023 and lowest in November, for the respective months. At its annual minimum in February, the monthly extent ranked third lowest in the satellite record. In the Arctic, sea ice extent was close to the 1991–2020 average until July 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.

Greenhouse gases



Data: C3S/Obs4MIPs (v4.5) consolidated (2003-2022), CAMS preliminary near real-time data (2023) GOSAT (CH4) and GOSAT-2 (C02) records. Spatial range: 60°S-60°N over land. Credit: C3S/CAMS/ECMWF/University of Bremen/SRON

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Monthly global atmospheric CO2 (left) and CH4 (right) column-averaged concentration derived from satellite data for 2003-2024 (dotted line) and 12-month average (solid line). Data source: C3S / Obs4MIPs (v4.5)













consolidated (2003–2022) and CAMS preliminary near real-time data (2023) GOSAT (CH₄) and GOSAT-2 (CO₂) records. Spatial range: 60°S - 60°N over land. Credit: C3S / CAMS / ECMWF / University of Bremen / SRON. DOWNLOAD IMAGE / DOWNLOAD DATA

The defining factor in the evolution of many key climate indicators in 2024 has been the increasing global temperature, which is largely associated with the increasing concentration of greenhouse gases (GHG) in the atmosphere, a consequence of human activities. Monitoring of GHGs provides information to support the implementation of mitigation policies. The rate of increase of carbon dioxide was larger than the rate observed in recent years. The rate of increase of methane was significantly lower than in the last three years.

Laurence Rouil, Director of CAMS at ECMWF concludes: "This report shows the critical value of our monitoring activities. In 2024, atmospheric GHG reached the highest annual levels ever recorded in the atmosphere, according to C3S and CAMS data. Carbon dioxide concentrations in 2024 were 2.9 ppm higher than in 2023 and methane concentrations were 3 ppb higher. This increase has brought the annual estimate of the atmospheric concentration of carbon dioxide to 422 ppm, and of methane to 1897 ppb. Our data points clearly to a steady global increase of greenhouse gas emissions and these remain the main agent of climate change."

-Ends-

Further information, a detailed description on how the data were compiled and additional media resources are available on a password protected website:

https://climate.copernicus.eu/gch-2024-pressresources?utm_source=pressrelease&utm_medium=referral&utm_campaign=gch24

Password: \$a@sk/#YFj?KsNmp8

The 2024 Global Climate highlights full report can be accessed here: (Will be visible only after the embargo is lifted)

<u>https://climate.copernicus.eu/global-climate-</u> <u>highlights?utm_source=pressrelease&utm_medium=referral&utm_campaign=gch24</u>













More information about climate variables in December and climate updates of previous months as well as high-resolution graphics and the video can be downloaded <u>here</u> (this link can be accessed when the embargo is lifted).

Find out more about C3S climate monitoring products in the <u>Climate Intelligence</u> <u>Hub</u> with monthly climate bulletins, annual reports and ongoing monitoring of key climate variables.

Footnotes:

- ERA5 is the fifth generation European Centre for Medium-Range Weather Forecasts (ECMWF) atmospheric reanalysis of the global climate covering the period from January 1940 to present. All quoted temperature statistics covered in the global climate highlights are derived from ERA5.
- These temperature rankings for continents are based on IPCC continental regions as defined in the AR6 WGI report (Fig. 1.18) and include North America, Central and South America, Europe, Africa, Asia, Australasia, and Antarctica.
- 3) When we use the term 'temperature' here, we mean the temperature close to Earth's surface, hence the term 'surface air temperatures.' For land areas, this usually refers to the air temperature at a 2 m height above the land surface. For the ocean, this can either refer to the same 2 m air temperature, or to the temperature of the ocean or sea surface layer. This is dependent on the dataset used.
- 4) The findings about global sea surface temperatures (SSTs) presented here are based on SST data from ERA5 averaged over the 60°S-60°N domain. Note that ERA5 SSTs are estimates of the ocean temperature at about 10 m depth (known as foundation temperature). The results may differ from other SST products providing temperature estimates at different depths.

Data and methods

A full description of the data and methods used can be found in the About the data and methods, available as part of the full Global Climate Highlights 2024 report. A subset of this information is provided here:

Surface air temperature data, sea surface temperature and total column water vapour data are from the ECMWF Copernicus Climate Change Service's global ERA5 <u>reanalysis dataset</u>, which combines in-situ and satellite-based observations with state-of-the-art numerical weather prediction modelling.













Sea ice data are from a combination of information from ERA5 and the EUMETSAT OSI SAF Sea Ice Index v2.2.

Heat stress data are based on the Universal Thermal Climate Index (UTCI) from the ERA5-HEAT dataset.

Regional area averages quoted here, where not otherwise indicated, are calculated based on the following longitude/latitude bounds:

Globe, 180°W-180°E, 90°S-90°N, over land and ocean surfaces.

Europe, 25°W-40°E, 34°N-72°N, over land surfaces only.

C3S ERA5 1950–2024: <u>Data</u> | <u>Documentation</u> C3S ERA5 –HEAT: <u>Data</u> <u>[Documentation</u> EUMETSAT OSI SAF Sea Ice Index v2.2 <u>Data and Documentation</u> C3S climate data record XCO₂ (2003-2023) <u>Data</u> | <u>Documentation</u> C3S climate data record XCH₄ (2003-2023) <u>Data</u> | <u>Documentation</u> CAMS near real-time data record XCO₂ V3.1 <u>Data and Documentation</u> CAMS near real-time data record XCH₄ available at FTP: anonymous@ftp.sron.nl,

directory: /pub/pub/RemoTeC/PROXY_NRT_L1X/. CAMS GFAS V1.2 wildfire emissions Data | Documentation

Explore the data of the December climate bulletin:

https://cds.climate.copernicus.eu/cdsapp#!/software/app-c3s-monthly-climate-bulletinexplorer?tab=app

About Copernicus

Copernicus is a component of the European Union's space programme, with funding by the EU, and is its flagship Earth observation programme, which operates through six thematic services: Atmosphere, Climate Change, Emergency, Land, Marine, and Security. It delivers freely accessible operational data and services providing users with reliable and up-to-date information related to our planet and its environment. The programme is coordinated and managed by the European Commission and implemented in partnership with Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Ocean, amongst others.

ECMWF operates two services from the EU's Copernicus Earth observation programme: the Copernicus Atmosphere Monitoring Service (CAMS) and the Copernicus Climate Change













Service (C3S). ECMWF also contributes to the Copernicus Emergency Management Service (CEMS), which is implemented by the EU Joint Research Centre (JRC).

About ECMWF

The European Centre for Medium-Range Weather Forecasts (ECMWF) is an independent intergovernmental organisation supported by 35 states. It is both a research institute and a 24/7 operational service, producing and disseminating numerical weather predictions to its Member States. This data is fully available to the national meteorological services in the Member States. The supercomputer facility (and associated data archive) at ECMWF is one of the largest of its type in Europe and Member States can use 25% of its capacity for their own purposes.

ECMWF has expanded its location across its Member States for some activities. In addition to an HQ in the UK and Computing Centre in Italy, offices with a focus on activities conducted in partnership with the EU, such as Copernicus, are in Bonn, Germany.

The Copernicus Atmosphere Monitoring Service: <u>http://atmosphere.copernicus.eu/</u> The Copernicus Climate Change Service: <u>https://climate.copernicus.eu/</u> More information on Copernicus: <u>www.copernicus.eu</u> ECMWF: <u>https://www.ecmwf.int/</u>

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