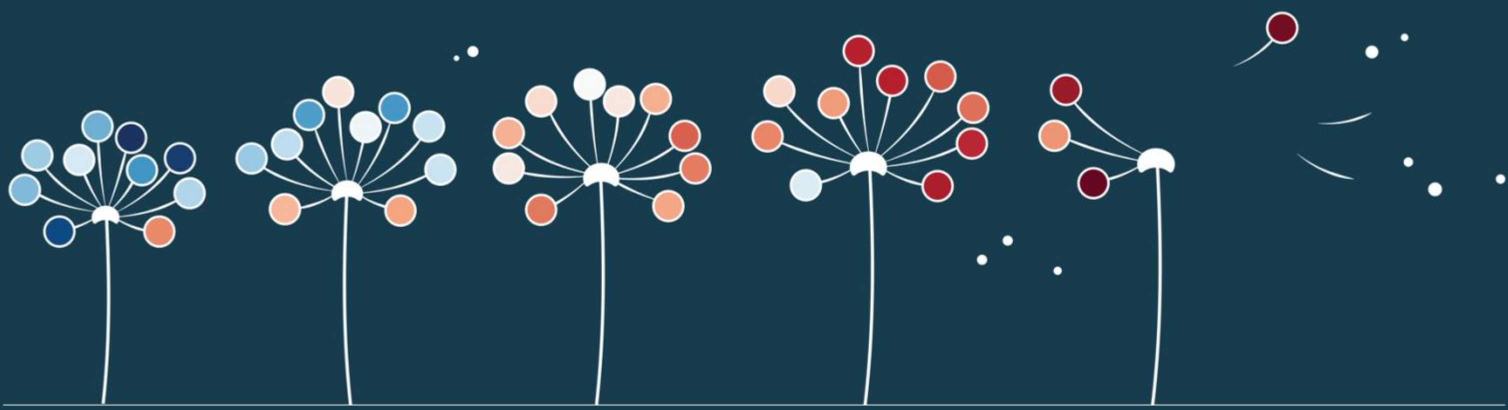
EUROPEAN STATE OF THE CLIMATE

SUMMARY 2023



Copernicus Climate Change Service
European State of the Climate | 2023

PROGRAMME OF THE EUROPEAN UNION

Copernicus
Europe's eyes on Earth

IMPLEMENTED BY ECMWF

WORLD METEOROLOGICAL ORGANIZATION

European State of the Climate 2023
Summary

The Copernicus Climate Change Service (C3S) provides climate monitoring for the globe, Europe and the Arctic; the World Meteorological Organization (WMO) is the UN authoritative organisation that collates, monitors and predicts weather, climate and water resources, and provides related services at national, regional and global scales through its 193 Members, the National Meteorological and Hydrological Services. This year, C3S and the WMO have released a joint report on the European State of the Climate (ESOTC) in 2023. This provides descriptions and analysis of climate conditions and variations from across the Earth system, key events and their impacts, and a discussion of climate policy and action with a focus on human health. The ESOTC also includes updates on the long-term evolution of key Climate Indicators.

Since the 1980s, Europe has been warming twice as fast as the global average, becoming the fastest-warming continent on Earth. This is due to several factors, including the proportion of European land in the Arctic, which is the fastest-warming region on Earth, and to changes in atmospheric circulation that favour more frequent summer heatwaves. Glaciers are melting and there are changes in the pattern of precipitation. An increase in extreme rainfall is leading to catastrophic events, such as the widespread flooding seen in Italy, Greece, Slovenia, Norway and Sweden in 2023. Meanwhile, southern Europe is seeing widespread droughts.

The frequency and severity of extreme events are increasing.

More information on the risks that Europe is facing can be found in the European Environment Agency's Climate Risk Assessment.

"The climate crisis is the biggest challenge of our generation. The cost of climate action may seem high but the cost of inaction is much higher. As this report shows, we need to leverage science to provide solutions for the good of society."
Celeste Saulo, Secretary-General, WMO

"In 2023, Europe witnessed the largest wildfire ever recorded, one of the wettest years, severe marine heatwaves and widespread devastating flooding. Temperatures continue to increase, making our data ever more vital in preparing for the impacts of climate change."
Carlo Buontempo, Director, C3S

Explore the complete ESOTC. The complete report is available online at: climate.copernicus.eu/esotc/2023

C3S is implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) with funding from the European Union.

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Europe in 2023

This section discusses the evolution of climate variables across the Earth system. Beginning with a focus on variables for which the data cover the larger WMO Regional Association VI (Europe) domain, the discussion then extends to the full range of variables across the C3S Europe domain.

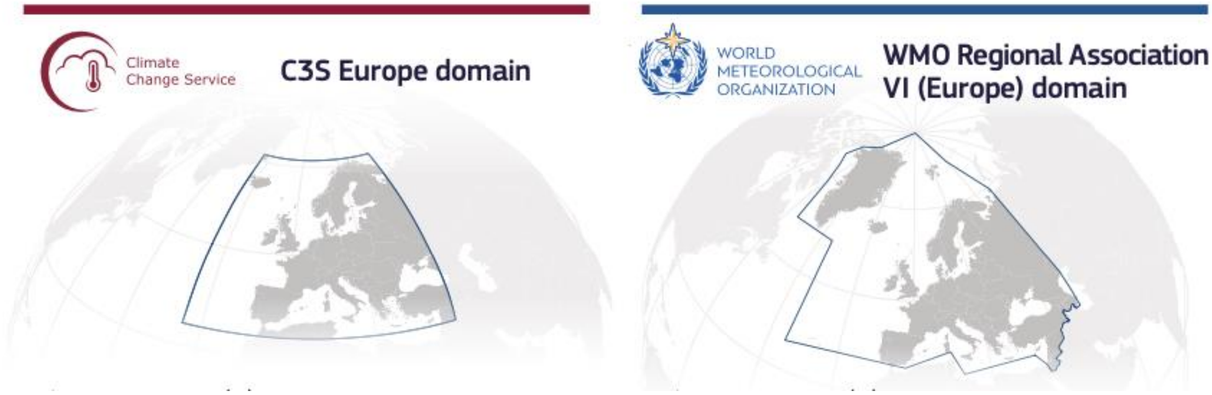
- It was a year of contrasts across Europe, with extreme heatwaves and large wildfires, alongside flooding and drought.

- The three warmest years on record for Europe have all occurred since 2020, and the ten warmest since 2007.

European records:
- Highest number of days with 'extreme heat stress'.
- Largest area of Europe affected by at least 'strong heat stress'.
- Largest wildfire.
- Warmest marine heatwave in the northeastern Atlantic.
- Highest December river flows.
- Largest proportion of renewable energy generation.

Impacts*:
- Losses estimated at 13.4 billion euros.
- 81% of economic losses attributed to flooding.
- Flooding affected around 1.6 million people.
- Storms affected around 550,000 people, and wildfires 36,000.
- At least 63 lives lost due to storms, 44 to floods and 44 to wildfires.

*According to preliminary estimates for 2023 from the International Disaster Database. Estimates of the impacts of heatwaves in 2023 are not yet available.



ESOTC 2023 is jointly produced by C3S and the WMO. C3S supports the adaptation and mitigation policies of the European Union, by providing consistent and authoritative information about climate change, while the WMO Regional Office for Europe serves its 50 Member States, covering Europe, Greenland, the South Caucasus and part of the Middle East. They therefore cover overlapping geographical domains, indicated on the maps above. The size and climatic zones of each domain differs, so variations in the statistics are expected. The ESOTC makes use of a wide range of datasets, for which geographical coverage varies. Selected key variables are discussed for both domains where it is useful to highlight differing statistics; not all variables are presented for the WMO domain. The domain used for each section is indicated by the C3S and WMO logos.

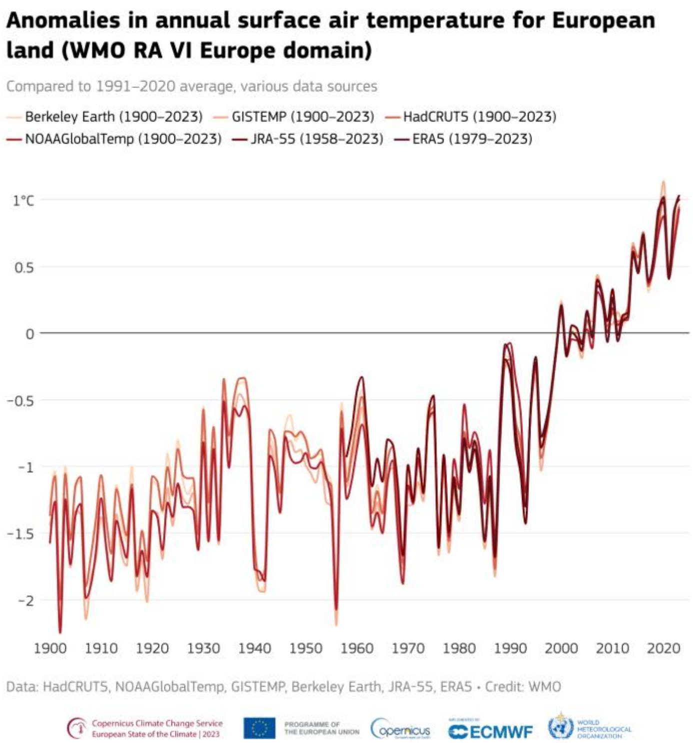
WMO Regional Association VI (Europe) domain

Temperature

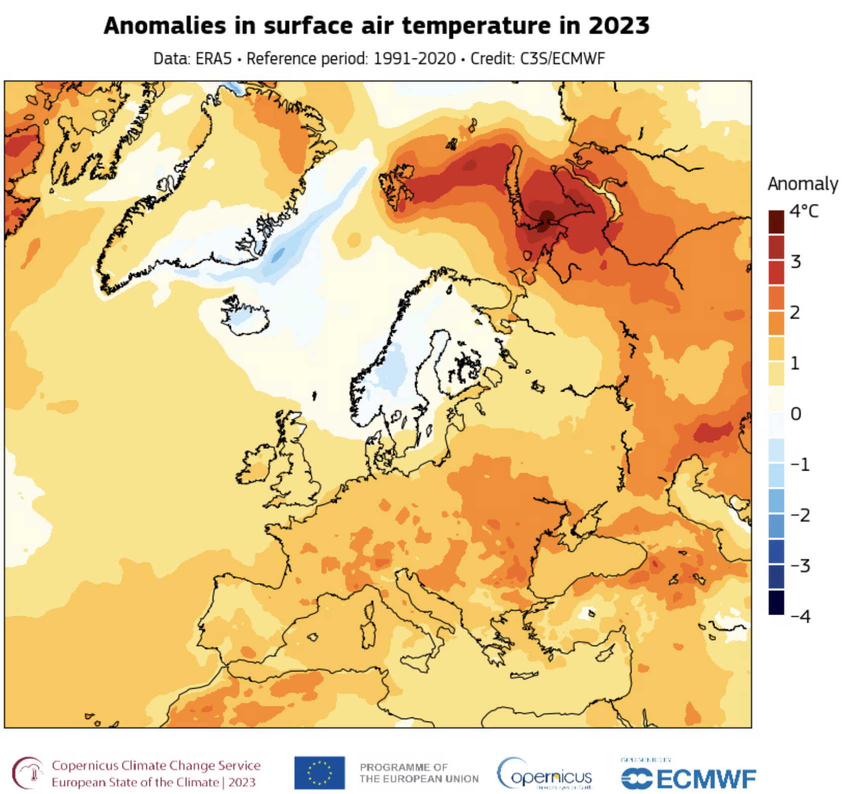
Data type: reanalysis, in situ
Reference period: 1991–2020
Domain: WMO

2023 was the joint warmest year on record, with 2020, for the WMO RA VI (Europe) domain.

At 1.0°C above average, and 2.6°C above the pre-industrial level, Europe (WMO RA VI) saw its joint-warmest year on record in 2023. Almost the entire region had above-average temperatures for the year as a whole, except for Scandinavia, Iceland and southeastern Greenland. The most-above-average temperatures were in the European Arctic. Autumn was the second-warmest on record for the region; September was exceptionally warm across much of continental Europe, while November saw temperatures up to 6°C above average in the eastern parts of the region, and in the European Arctic.



Annual surface air temperature anomalies (°C) over European land. Data source: HadCRUT5, NOAAGlobalTemp, GISTEMP, Berkeley Earth, JRA-55, ERA5. Credit: WMO.

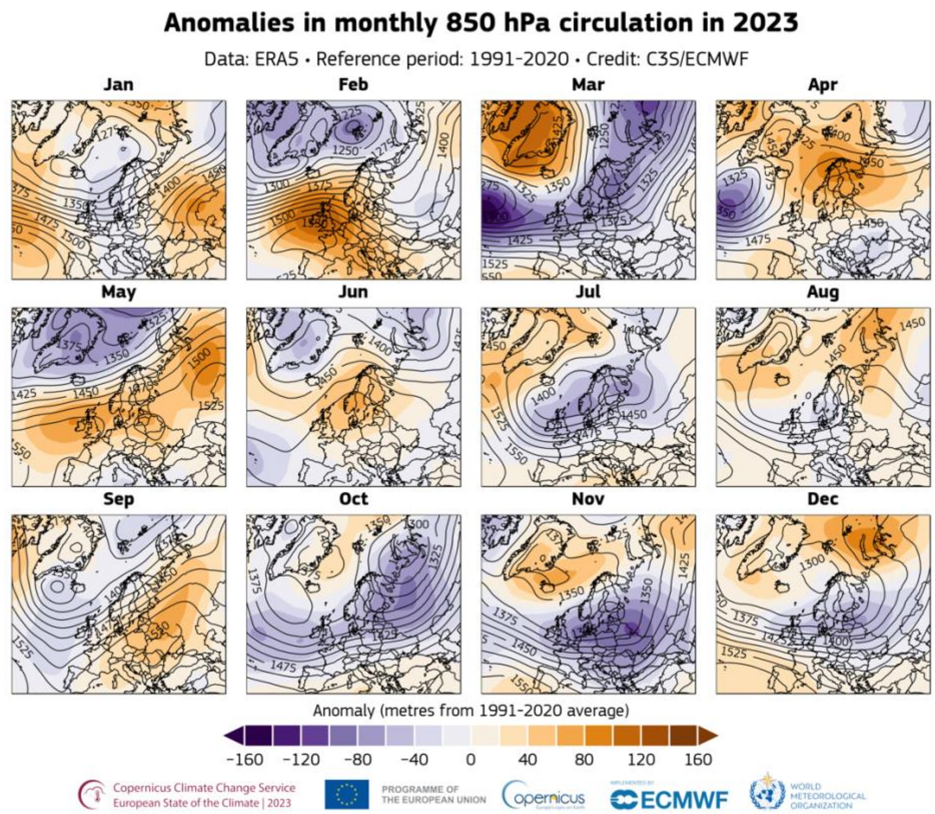


Average surface air temperature anomaly (°C) in 2023. Data source: ERA5. Credit: C3S/ECMWF.

Atmospheric circulation

Data type: reanalysis
Reference period: 1991–2020
Domain: WMO

A persistent circulation pattern brought storms and flooding



Monthly average anomalies in 850 hPa geopotential height (purple and orange shades; in metres), relative to the average for the 1991–2020 reference period, and monthly 850 hPa geopotential height (black contours; in metres) for 2023. The 850 hPa level is about 1.5 km above sea level. Data source: ERA5. Credit: C3S/ECMWF.

The large-scale movement of air, and associated changes in air pressure, redistributes thermal energy and moisture. It drives weather patterns, which shape many climate variables, and can itself be influenced by climate change.

From February to May 2023, higher-than-average air pressure anomalies over the Iberian Peninsula led to a prolonged drought.

In June, there was below-average air pressure over Greenland and the Mediterranean and above-average air pressure across northern Europe, with the opposite pattern in July.

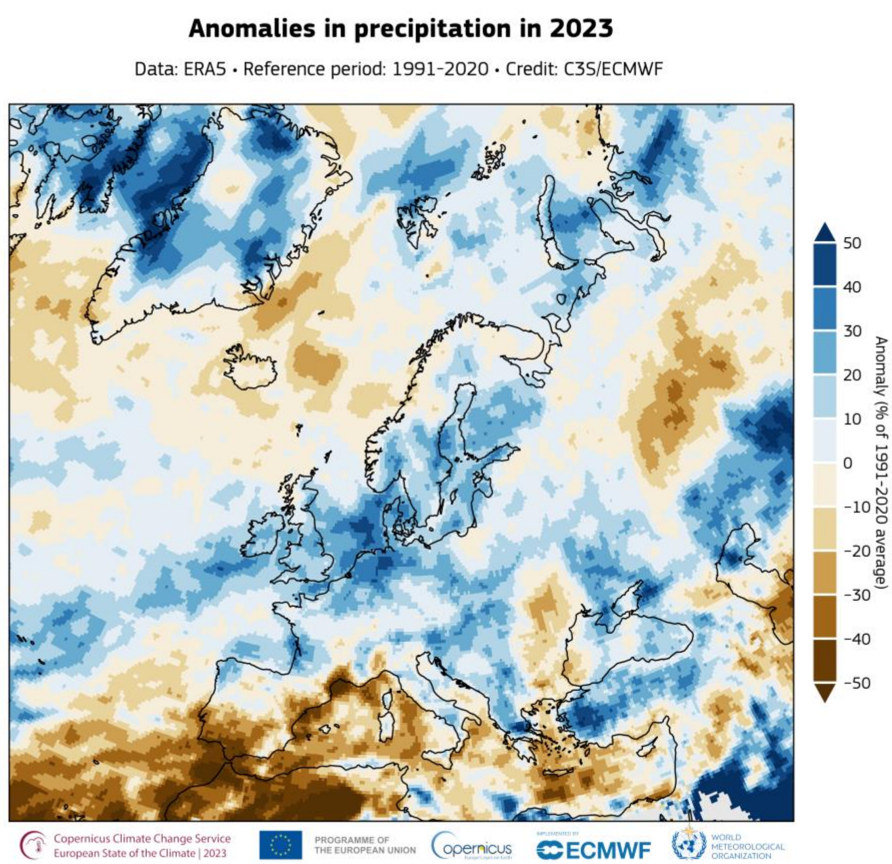
From October to December, a persistent west-to-east circulation across the North Atlantic Ocean and Europe brought storm activity, with higher-than-average precipitation and related flooding.

During the same period, there was lower-than-average air pressure over Scandinavia, associated with cooler-than-average surface air temperatures.

Precipitation

Data type: Reanalysis, in-situ
Reference period: 1991–2020
Domain: WMO

Precipitation was 7% above average for the year as a whole



Annual precipitation anomalies (%) in 2023. Data source: ERA5. Credit: C3S/ECMWF.

Precipitation is a key component of the water cycle and essential for life. It is important for sectors such as food production and transport, and can be a precursor to floods or droughts.

During 2023, Europe as a whole was around 7% wetter than average. Depending on the dataset, it was the wettest or third wettest year on record.

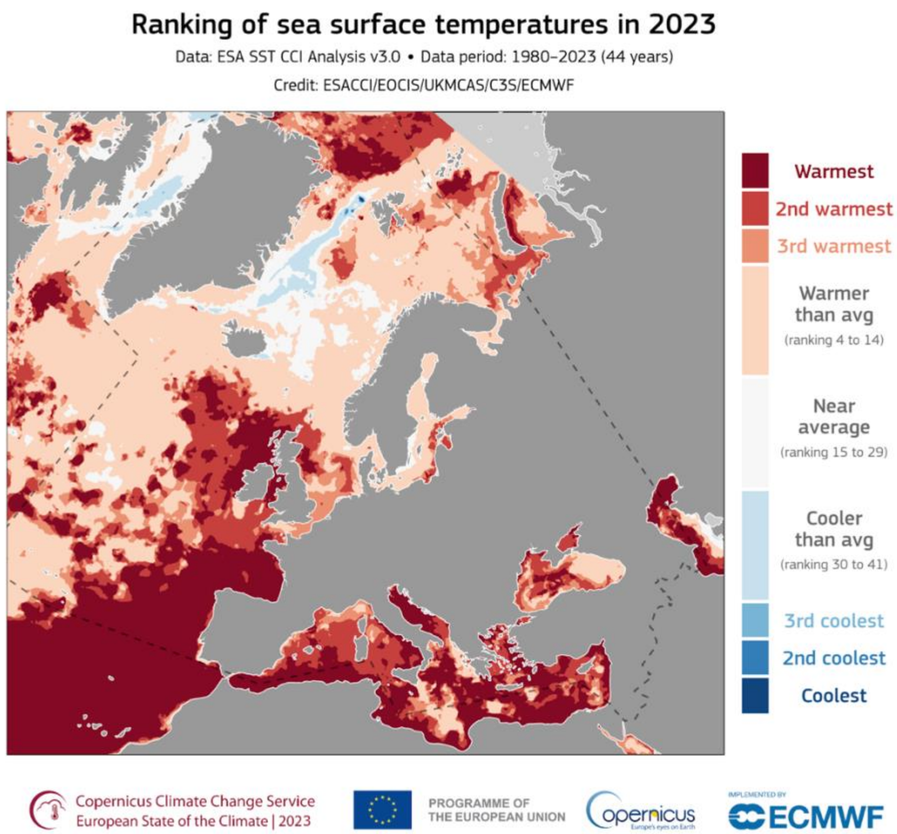
It was drier-than-average in countries to the west of the Black Sea, and across the southern Iberian Peninsula, where dry conditions occurred from February to April.

A region between western Europe and Ukraine was wetter than average from October to December, whereas most of Fennoscandia was drier than average in November and December.

Sea surface temperature

Data type: Satellite
Reference period: 1991–2020
Domain: WMO

The average sea surface temperature for the European ocean was the warmest on record



Ranking of the annual average sea surface temperatures in 2023. Data source: ESA SST CCI Analysis v3.0. Credit: ESACCI/EOCIS/UKMCAS and C3S/ECMWF.

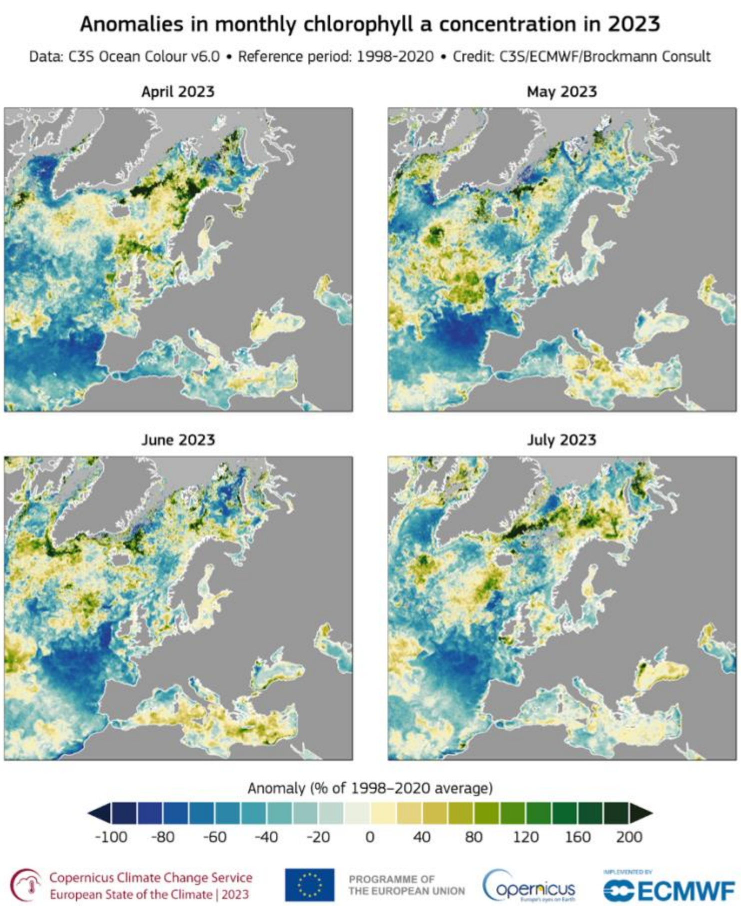
Sea surface temperatures (SSTs) can be used to understand the role of the ocean in shaping the weather and climate. Marine heatwaves can have significant impacts on ocean ecosystems and biodiversity.

For 2023, the average SST for the European ocean was the warmest on record, at 0.55°C above average. Parts of the Mediterranean Sea and the Atlantic Ocean also saw their warmest annual average SST on record. The northeastern Atlantic around Europe saw well-above-average SSTs from May to October, with exceptional conditions in June, when temperatures reached 1.76°C above average. This is the largest monthly anomaly on record. Marine heatwaves occurred throughout summer.

Ocean colour

Data type: Satellite
Reference period: 1998–2020
Domain: WMO

Ocean colour can be used to monitor ocean health and water quality



Average Chl a anomalies (%) for April to July 2023, relative to the respective monthly average for the 1998–2020 reference period. Data source: C3S Ocean Colour v6.0. Credit: C3S/ECMWF/Brockmann Consult.

Chlorophyll a (Chl a) is a photosynthetic pigment present in phytoplankton. These microscopic plant-like marine organisms at the base of the food chain are a carbon sink and an important indicator of ocean health. Levels of Chl a can be investigated through measuring ocean colour.

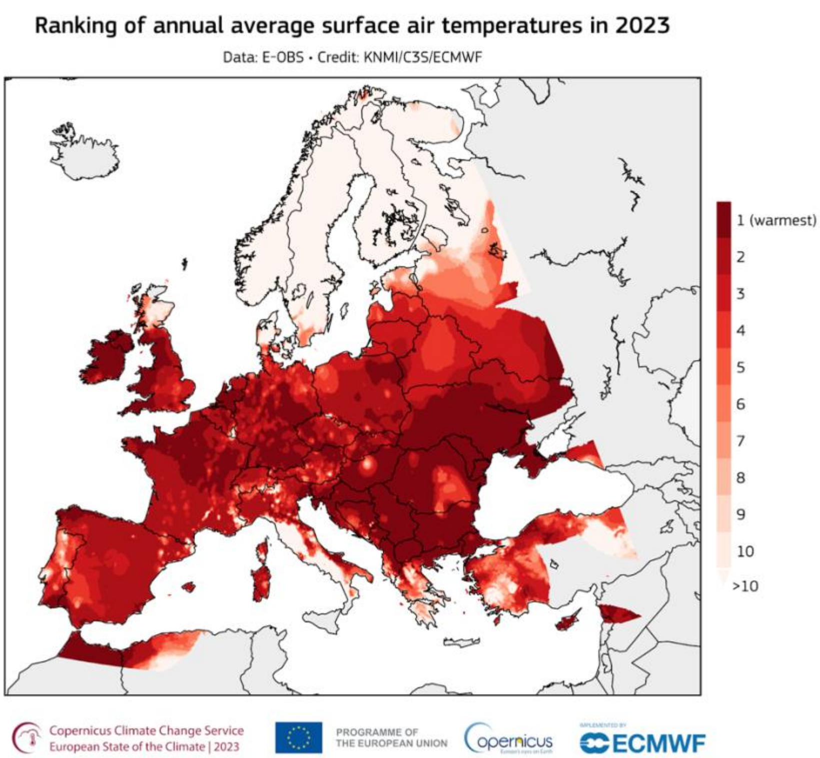
During April, Chl a was generally below average, by around 60–80%, in an area west of the Iberian Peninsula. Meanwhile, the Atlantic Ocean north of the United Kingdom, and the Norwegian Sea, saw anomalies of up to 200–500% above average. In May, higher than average Chl a concentrations were seen in central parts of the Mediterranean Sea, expanding to cover much of the basin in June, with anomalies generally 50–100% above average.

C3S domain

Temperature

Data type: Reanalysis, in situ
Reference period: 1991–2020
Domain: C3S

It was the second-warmest year on record for Europe



Ranking of the annual average surface air temperatures in 2023. Data source: E-OBS. Credit: C3S/ECMWF/KNMI.

The three warmest years on record for Europe have all occurred since 2020, and the ten warmest since 2007. At 1.02–1.12°C above average, and 2.48–2.58°C above the pre-industrial level, 2023 was the second-warmest year on record for Europe. It was 0.13–0.17°C cooler than the previous warmest year on record, in 2020.

For most of Europe, 2023 was amongst the top 10 warmest years on record. Much of southeastern Europe, and parts of western and central Europe, saw their warmest year on record.

Temperatures in Europe were above average for 11 months of the year, and September was the warmest on record.

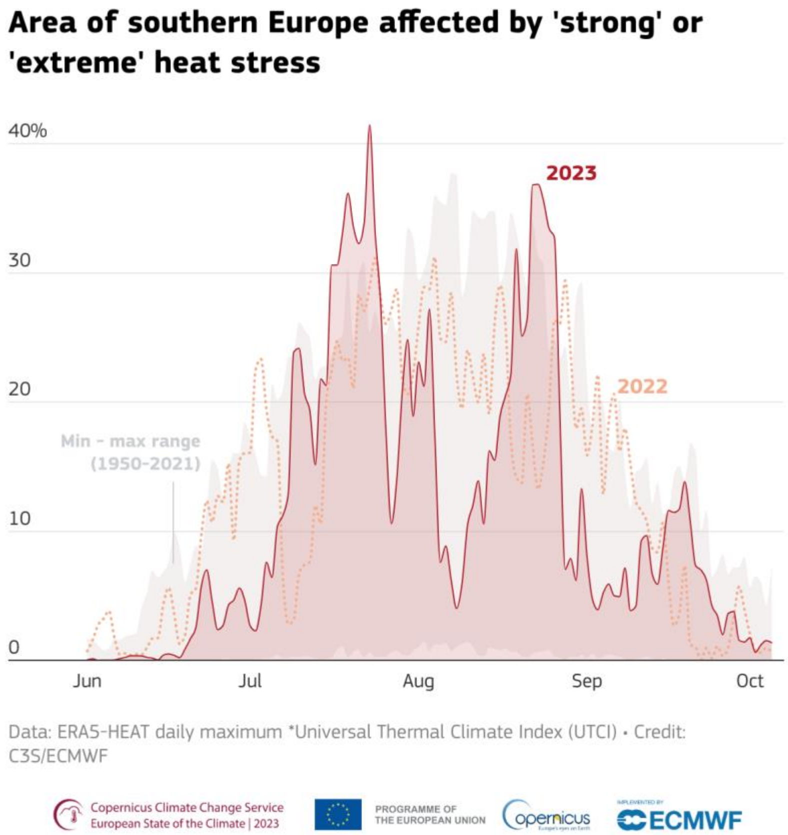
Thermal stress

Data type: Reanalysis
Domain: C3S

There were a record number of days with 'extreme heat stress'

Health is affected by extreme temperatures. This can be estimated through 'thermal comfort' or 'thermal stress' indices that represent the effect of the environment on the human body. The Universal Thermal Climate Index 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 has ten different categories of heat and cold stress, with units of ºC representing a 'feels-like' temperature.

Across Europe, there is an increasing number of days during which heat stress is experienced, and a decreasing number of days with cold stress. 2023 reached a record number of days with 'extreme heat stress', which is equivalent to a 'feels like' temperature of more than 46°C. Summer also saw the largest area of Europe affected by at least 'strong heat stress' of any day on record, with 13% of the continent, and 41% of southern Europe, experiencing 'strong', 'very strong' or 'extreme' heat stress on 23 July.



Area (% of total) of southern Europe affected by 'strong', 'very strong' or 'extreme heat stress' for each day of June to September 2023 (dark red), compared to 2022 (light orange) and alongside the minimum to maximum range for 1950 to 2021 (grey shading). Data source: ERA5-HEAT. Credit: C3S/ECMWF.

Marine heatwaves

Data type: Satellite
Reference period: 1991–2020

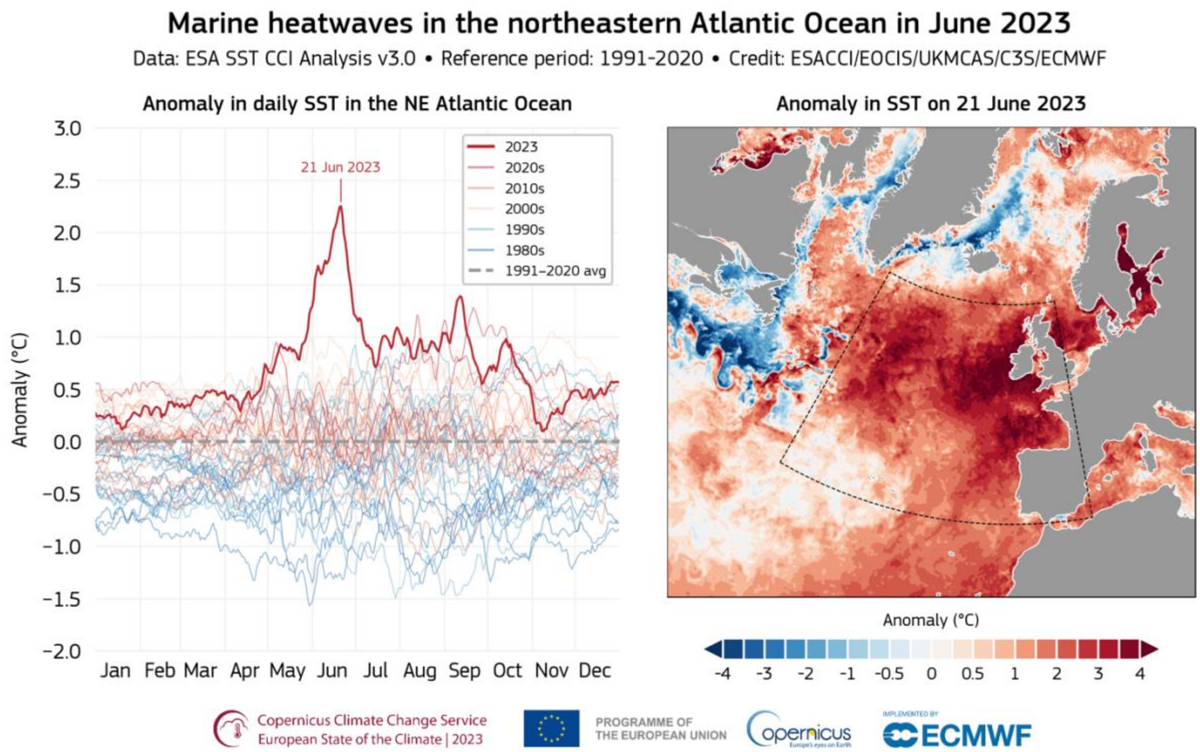
Sea surface temperatures reached 5.5°C above average

Marine heatwaves are prolonged periods of extremely high temperatures in the seas and ocean. They can have significant and sometimes devastating impacts on ocean ecosystems and biodiversity. Marine heatwaves can also have socio-economic impacts.

Warmer-than-average sea surface temperatures (SSTs) during the year were associated with marine heatwaves during the summer, in parts of Europe and across large sectors of the wider North Atlantic Ocean.

In June, the Atlantic Ocean west of Ireland and around the United Kingdom was impacted by a marine heatwave that was classified as 'extreme' and in some areas 'beyond extreme', with

SSTs as much as 5°C above average. July and August saw marine heatwaves in the Mediterranean Sea, with SSTs reaching 5.5°C above average in some areas, or up to 'extreme' conditions.



(Left) Daily sea surface temperature anomalies (°C) in the northeastern Atlantic Ocean during 2023 (thick red), and previous years since 1980 (reds and blues). The bounding box used for the time series is outlined with a dashed line in the map. (Right) Daily sea surface temperature anomalies (°C) on 21 June 2023. Data source: ESA SST CCI Analysis v3.0. Credit: ESACCI/EOCIS/UKMCAS and C3S/ECMWF.

Wildfires

Data type: Satellite, reanalysis, model-based estimates
Reference period: Wildfires: 1991–2020, Emissions: 2003–2019
Domain: C3S

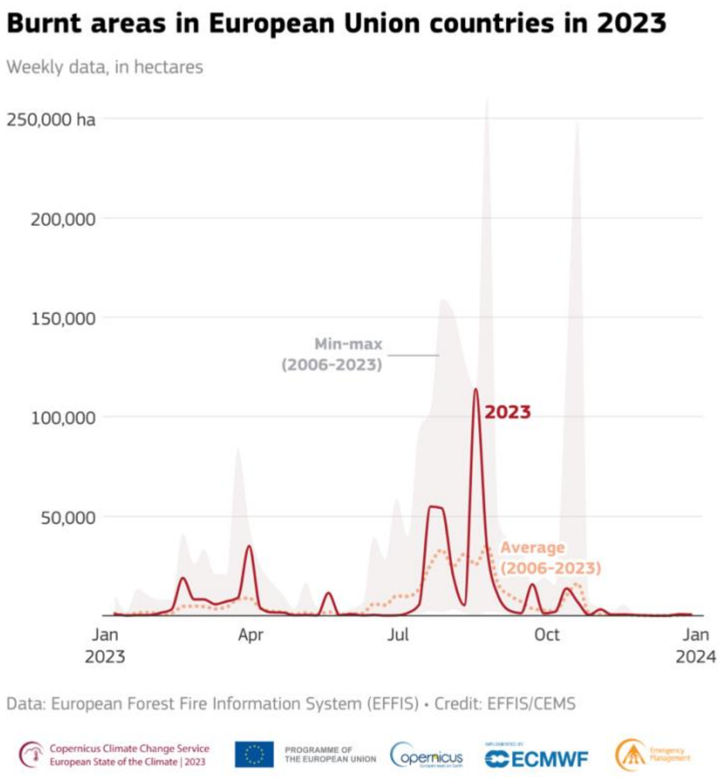
The largest wildfire ever recorded in the European Union

Wildfires are influenced by a range of factors, including vegetation type, moisture and wind. They are a natural phenomenon, but can result in habitat destruction and air quality deterioration. In recent summers, Europe has seen more and larger fires, and a longer fire season.

For most of 2023, fire danger for Europe as a whole was above average. Summer saw a contrast in fire danger between northern and southern areas, with high levels at the start of the

season in northern Europe and later in southwestern Europe. There were large fires in Portugal, Spain, Italy and especially Greece, which saw the largest wildfire ever recorded in the European Union (EU), at around 96,000 ha.
Emissions were above average in July, associated with the large fires in Greece, but at or below average for the rest of the year.

In total, the wildfire season saw the fourth largest burnt area on record in the EU with a total of around 500,000 ha.



Weekly wildfire burnt areas (hectares) in European Union countries in 2023, alongside the average (orange), and the minimum to maximum range (grey shading) for 2006–2023. Data source: EFFIS. Credit: EFFIS/CMS.

Spotlight: Europe's contrasting summer

Data type: Reanalysis, in situ
Reference period: 1991–2020

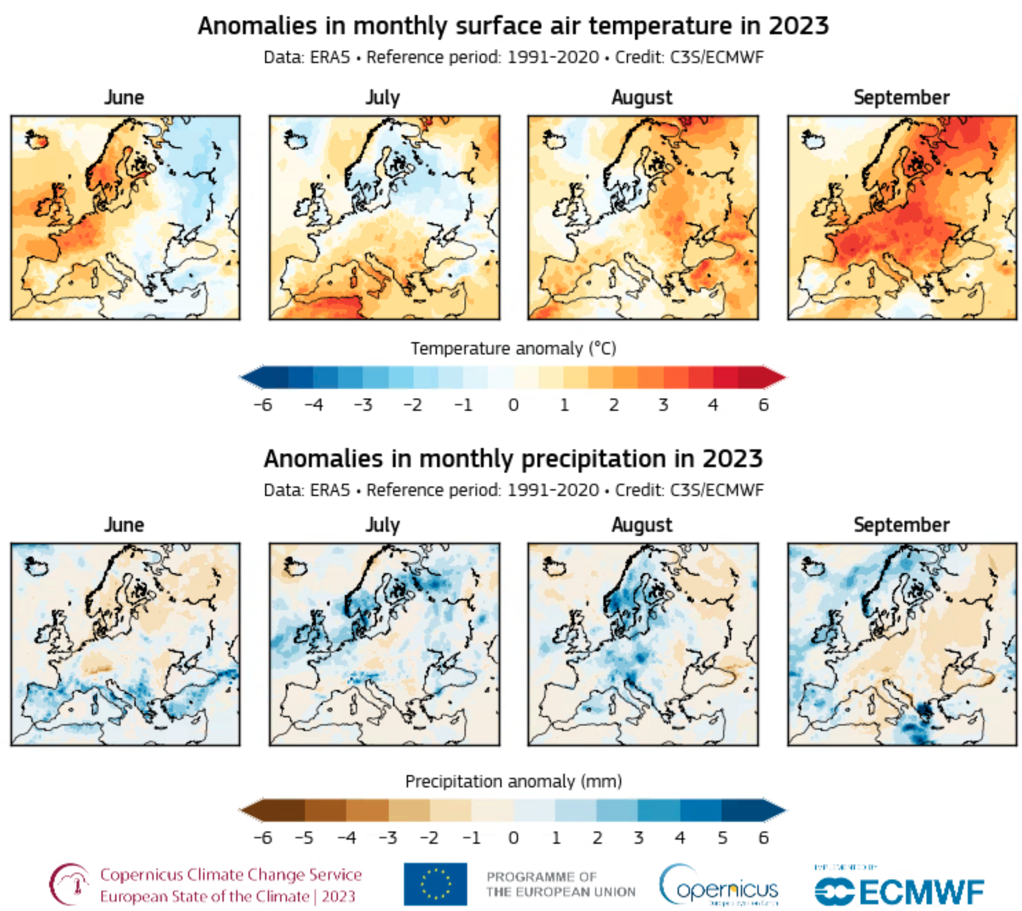
Summer 2023 was not the warmest on record, but saw conditions that were, at times, extreme. There were contrasts in temperature and precipitation, across the continent and from one month to the next. The 'extended summer' (June to September) saw heatwaves, wildfires, droughts and flooding.

Northwestern Europe saw its warmest June on record, while Mediterranean areas saw well-above-average precipitation for the month. In July, this pattern was almost reversed. In August, southern Europe saw warmer-than-average temperatures, and September was the warmest on record for Europe as a whole. Both August and September also saw severe flood events.

Much of Europe was impacted by heatwaves during the extended summer, with high temperatures during both the day and night. At the peak of a heatwave in July, 41% of southern Europe was affected by at least 'strong heat stress', with potential for health impacts.

By the end of August, large parts of southern Europe, especially the Iberian Peninsula, experienced precipitation deficits that induced drought. By late September, most of the Iberian Peninsula had recovered, but parts of eastern Europe transitioned to extreme drought conditions. Wildfires were also observed across Europe, mostly coinciding with droughts.

**High temperatures represent a hazard to human health. Heat stress indices represent how the human body responds to the impact of different thermal environments.*



(Top) Average surface air temperature anomalies (°C) and (Bottom) precipitation anomalies (mm) over Europe for June to September 2023, relative to the monthly average for the 1991–2020 reference period. Data source: ERA5. Credit: C3S/ECMWF.

Precipitation

Data type: Reanalysis, in situ
Reference period: 1991–2020
Domain: C3S

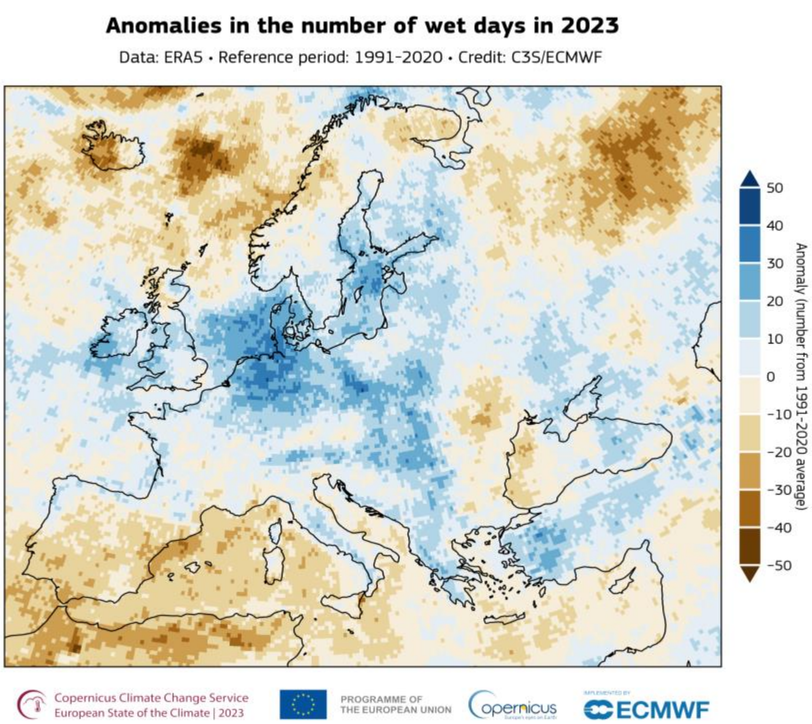
Northwestern Europe saw a higher number of wet days than average

During 2023, most of Europe was wetter than average; around 7% for the year as a whole. The year was the second to fourth wettest year on record, depending on the dataset used.

There was significant variability in precipitation throughout the year and across the continent.

The Netherlands, northwestern Germany, Denmark, Slovenia, eastern central Greece, western Türkiye, and parts of southwestern Russia and Ukraine experienced particularly wet conditions. Eastern and southern parts of the Iberian Peninsula, southern France, countries to the west of the Black Sea, and western Russia saw drier-than-average conditions.

The number of days in 2023 where accumulated precipitation was at least 1 mm was also higher than average across most of northwestern Europe.



Anomaly in the number of wet days in 2023. Data source: ERA5. Credit: C3S/ECMWF.

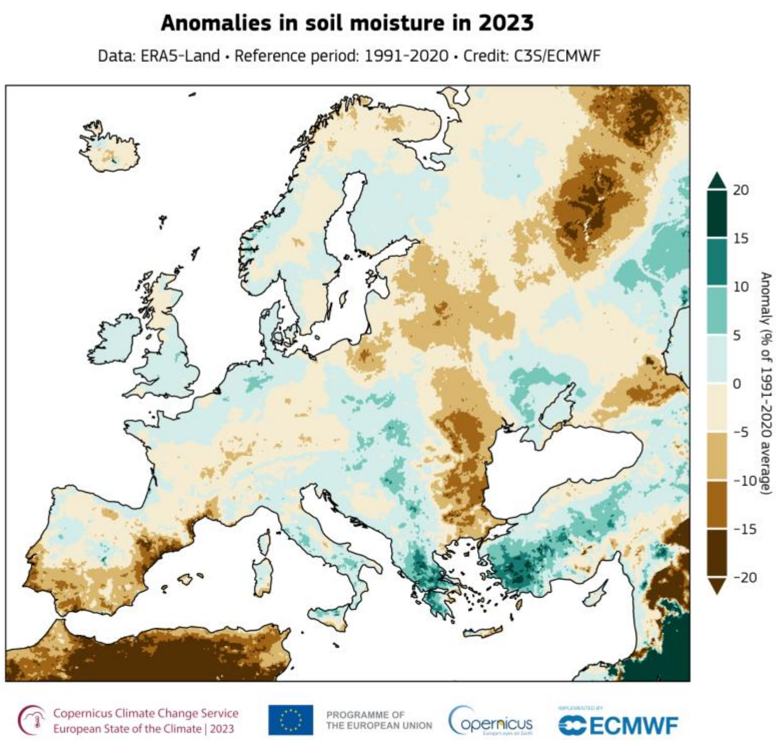
Soil moisture

Data type: Reanalysis, satellite
Reference period: 1991–2020
Domain: C3S

Periods of significant drought and extreme flooding

Soil moisture is a key environmental and hydrological variable that is involved in the exchange of water and heat between the land surface and the atmosphere. It affects vegetation growth along with the formation of precipitation and runoff, with consequences for agricultural yield, flooding and drought.

Soil moisture was drier than average across Europe for the year as a whole. From February to May, the Iberian Peninsula saw a period of drought; between March and May, most parts of the area saw their driest conditions on record. From November to December the majority of Europe had wetter-than-average soil moisture conditions, in part due to storms. This anomalous soil moisture also contributed to flooding events later in the year.



Annual surface soil moisture anomalies (%) in 2023. Data source: ERA5-Land. Credit: C3S/ECMWF.

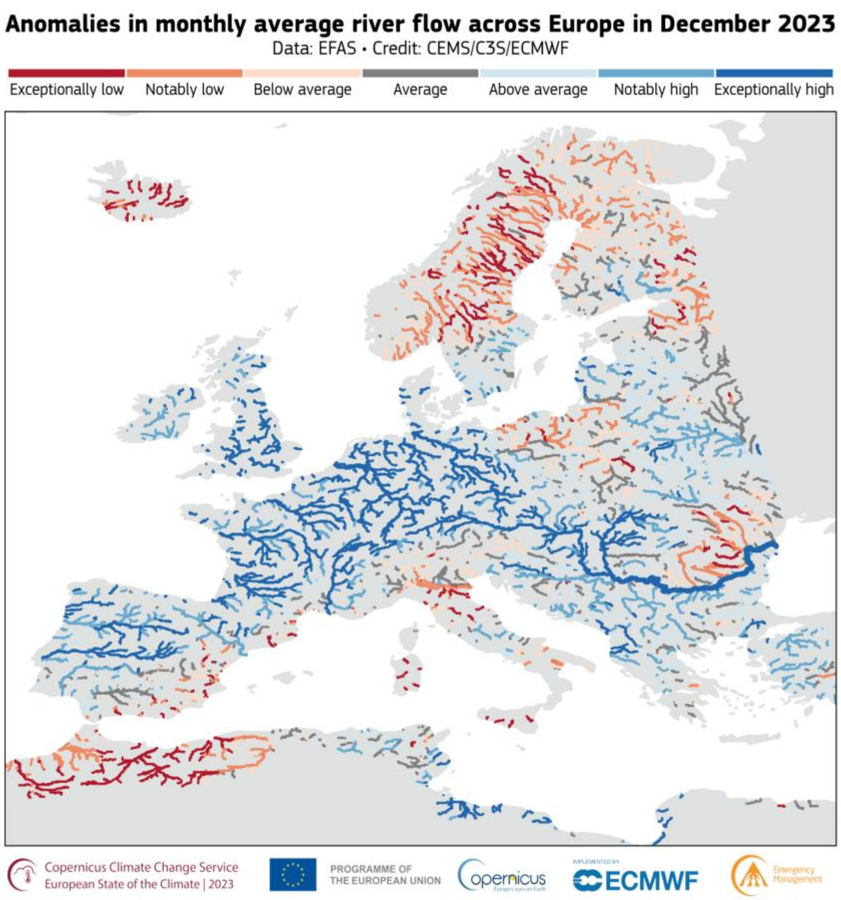
River flow

Data type: Model-based estimates
Reference period: 1991–2020
Domain: C3S

In December, river flows were the highest on record

For Europe as a whole, river flow was generally around average. It was slightly lower than average in February, June, July and October, and slightly higher than average in January, April and August. Drought conditions were seen in some rivers, such as the Ebro, which saw near-record low flows in May, and the Po, which saw below-average flows throughout the year, and near-record low flows from February to April.

In November, river flow for Europe as a whole became much higher than average and in December was the highest on record, with 'exceptionally high' flow in almost a quarter of the European river network. Record or near-record high river flows were seen in major river basins due to a series of storms between October and December.

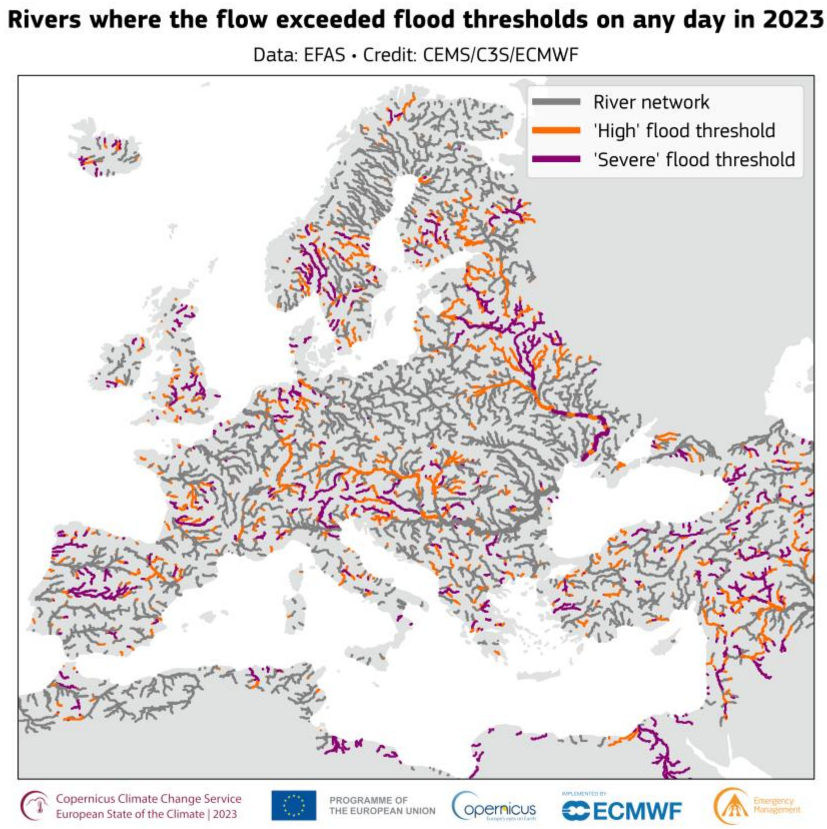


Anomalies in monthly average river flow in December 2023. Data source: EFAS. Credit: CEMS/C3S/ECMWF.

Spotlight: Flooding

Data type: Model-based, in situ
Reference period: 1991–2020

Around 1.6 million people were affected by flooding in Europe in 2023



Map showing where river flow exceeded the 'high' (5-year return period) and 'severe' (20-year return period) flood thresholds on any day in 2023. Rivers with upstream areas larger than 1000 km² are shown in grey, and are coloured orange when river flow exceeded the 'high' and purple the 'severe' flood threshold. Data source: EFAS. Credit: CEMS/C3S/ECMWF.

In May, 23 rivers in Italy burst their banks, with floods covering an area of around 540 km². Around 36,000 people were displaced, with 15 fatalities.

In August, flooding affected two thirds of Slovenia, with record-high flows at 31 stations. Around 1.5 million people were affected, with 8000 people evacuated and six fatalities. Norway and Sweden were also affected by flooding in August. In Norway, a hydroelectric power plant on the Glomma partially collapsed, leading to further flooding. More than 5000 people were displaced.

Greece, Bulgaria and Türkiye saw record-breaking rainfall and flooding in September. Greece had a flooded area of approximately 700 km². In some places, the equivalent of a year's worth of rain fell in one day. At least 17 people lost their lives in Greece, eight lives were lost in Türkiye and four in Bulgaria. The storm went on to impact Libya, where flooding and dam bursts resulted in at least 4700 fatalities. Around 8000 people were missing as of mid-December 2023.

In December, widespread flooding impacted northwestern Europe. River flow averaged across the European river network for the month was the highest on record.

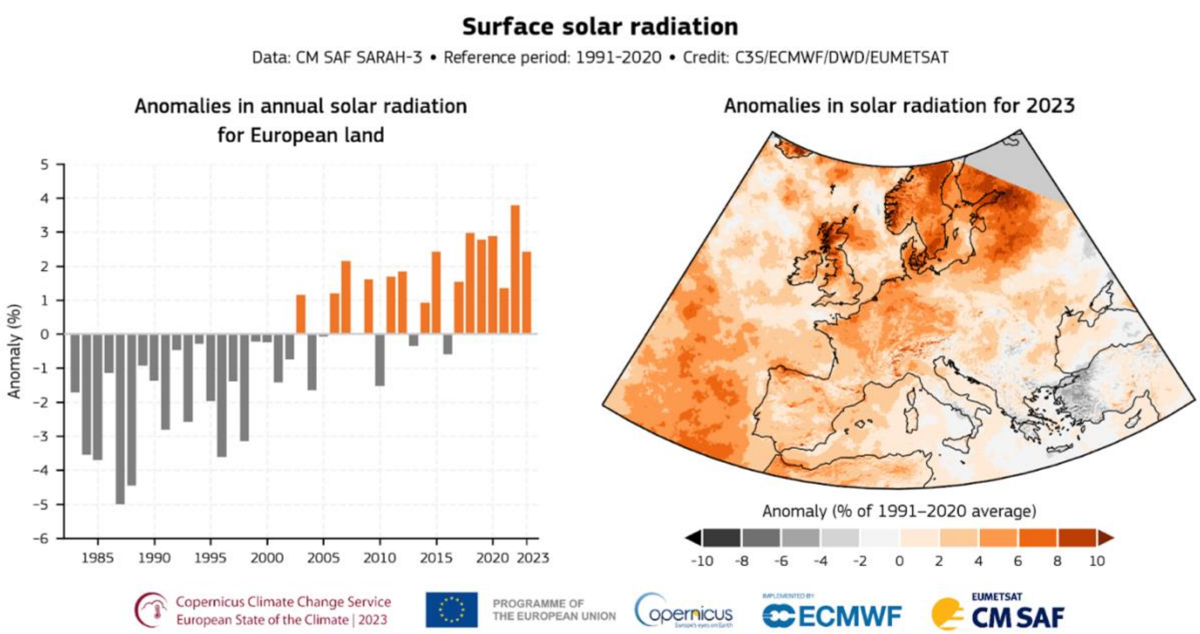
Clouds and solar radiation

Data type: Satellite
Reference period: 1991–2020
Domain: C3S

Surface solar radiation was above average

Cloud cover and sunshine duration are climate variables of relevance to many sectors, as well as to society. In 2023, surface solar radiation and sunshine duration across Europe as a whole were above average, while cloud cover was below average.

September had the most pronounced anomalies in sunshine duration, surface solar radiation and cloud cover average across Europe. The largest local anomalies, however, were in April, May and June. In April, positive surface solar radiation anomalies of around 50% occurred across the Iberian Peninsula, while a large part of eastern Europe saw negative anomalies of around 50%.



(Left) Annual surface solar radiation anomalies (%). (Right) Average annual surface solar radiation anomalies (%) in 2023. Data source: CM SAF SARAH-3 CDR and ICDR. Credit: C3S/ECMWF/DWD/EUMETSAT.

Renewable energy resources

Data type: Model-based estimates, in situ
Reference period: 1991–2020
Domain: C3S

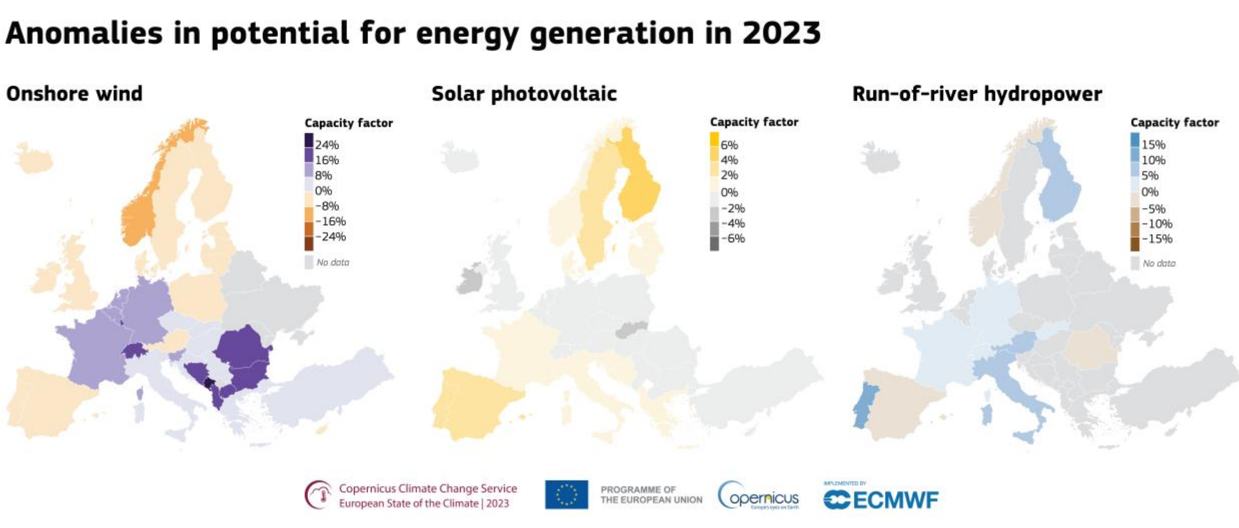
A record proportion of electricity generation by renewables

In 2023, a record proportion of actual electricity generation in Europe was from renewable sources, at 43%, compared to 36% in 2022.

Climate-driven electricity demand was above average in southern Europe, due to cooling required during exceptional summer temperatures, and in Scandinavia, where cooler-than-average temperatures in several months led to increased demand for heating.

For the year as a whole, potential for solar photovoltaic power generation was below average in northwestern and central Europe, and above average in southwestern and southern Europe, and Fennoscandia. Potential for run-of-river hydropower generation was above average across much of Europe, linked to above-average precipitation and river flow.

Increased storm activity from October to December resulted in above-average potential for wind power production.

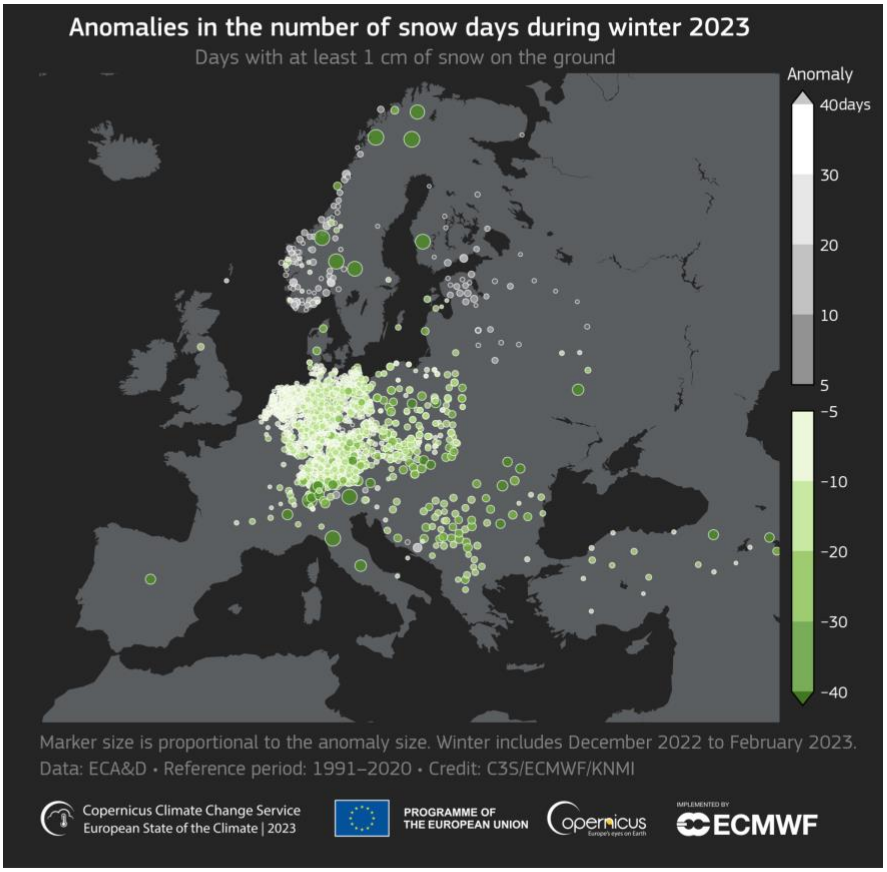


Anomalies (%) in potential electricity generation (capacity factor) in 2023 from: onshore wind (left), solar PV (centre), run-of-river hydropower (right). Data source: C3S Climate and Energy Indicators for Europe. Credit: C3S/ECMWF.

Snow

Data type: In situ
Reference period: 1991–2020
Domain: C3S

Fewer days with snow than average across much of Europe



Anomalies in the number of snow days during winter (December 2022 to February 2023), relative to the average for the 1991–2020 reference period. Locations with a close-to-average (within +/- five days) number of snow days are not shown. Data source: ECA&D[1]. Credit: C3S/ECMWF/KNMI.

Snow plays an important role in the climate, and changes in snow cover can impact other aspects of the Earth system, such as glaciers, river flow, flooding and droughts.

In 2023, much of Europe experienced fewer days with snow than average. Many locations in Fennoscandia, however, saw a near-average or higher-than-average number of days with snow.

With some exceptions, Europe generally saw a well-below-average number of days with snow during winter, and a near-average or below-average number during spring. In the Alps in winter, just three locations saw more days with snow than average, while most saw far fewer than average.

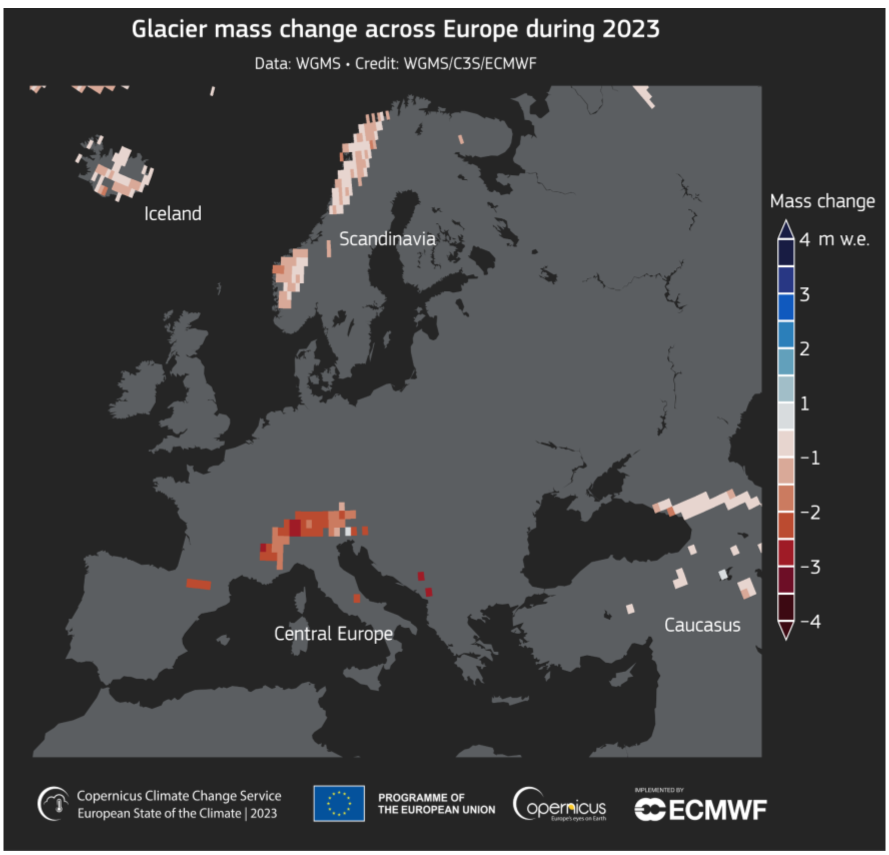
Glaciers

Data type: In situ, satellite
Domain: C3S

Glaciers in the Alps have lost 10% of their volume in two years

Changes in glacier mass are directly linked to climate change and therefore are important for climate monitoring. Since the mid-19th century, glaciers around the globe have been experiencing mass loss, and the European Alps is one of the regions where glaciers are shrinking the most.

In 2023, glaciers in all parts of Europe saw a net loss of ice. Following record ice loss in 2022, it was another exceptional year of loss in the Alps, due to below-average winter accumulation and strong summer melt. Over these two years, glaciers in the Alps lost around 10% of their volume.



Mass change of glaciers across Europe in 2023. Annual mass change values are given in the unit 'metre water equivalent (m w.e.)'. Data source: WGMS. Credit: WGMS.

Arctic in 2023

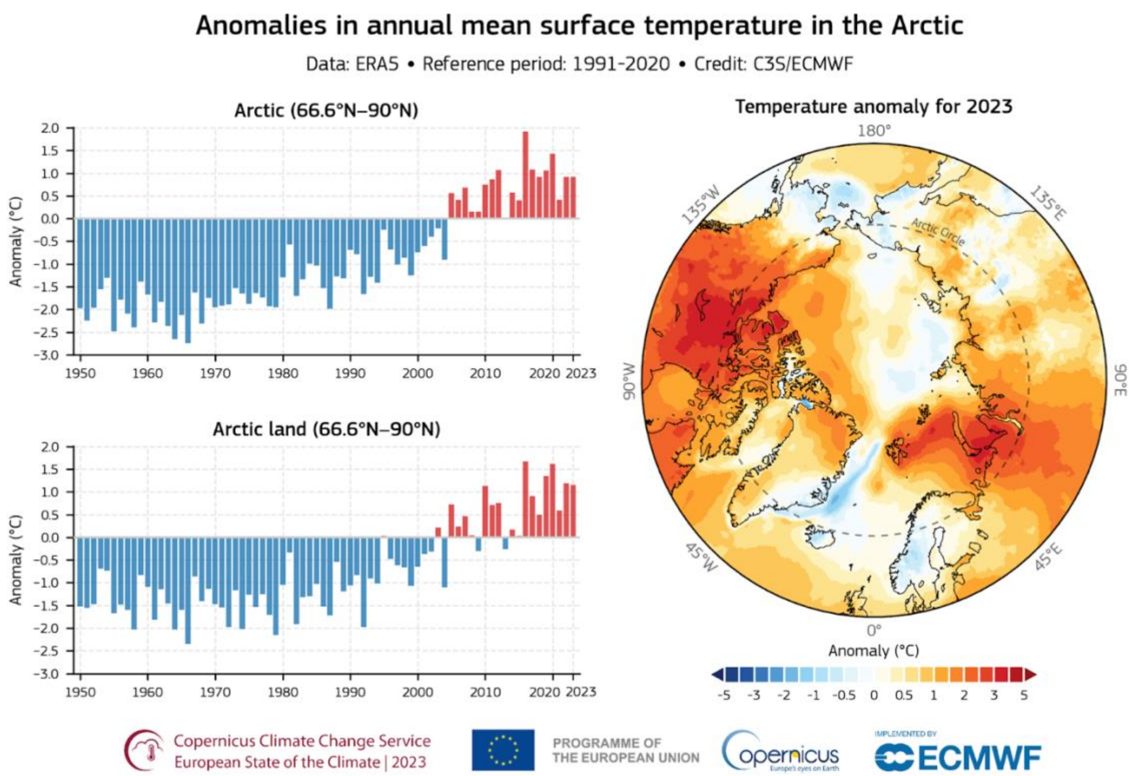
The Arctic section provides an overview of key climate events in high northern latitudes.

- In recent decades, the Arctic has been warming around three times faster than the planet as a whole.
- The region encompassing the Barents Sea and Svalbard has been one of the fastest-warming places on Earth.

Arctic temperature

Data type: Reanalysis, satellite, in situ
Reference period: 1991–2020
Domain: Arctic

Warmest summer on record for Svalbard



(Left) Time series of annual average surface air temperature anomalies from 1950 to 2023 (top) for the Arctic as a whole (66.6°–90°N) and (bottom) over all Arctic land areas. (Right) Map of the annual average surface air temperature anomalies for 2023 over the north polar region. All anomalies are relative to the average for the 1991–2020 reference period. Data source: ERA5. Credit: C3S/ECMWF.

Since the 1990s, the Arctic has been warming at a rate well above that of the global average. For Arctic land, 2023 was the fifth warmest year on record. The five warmest years on record for Arctic land have all occurred since 2016.

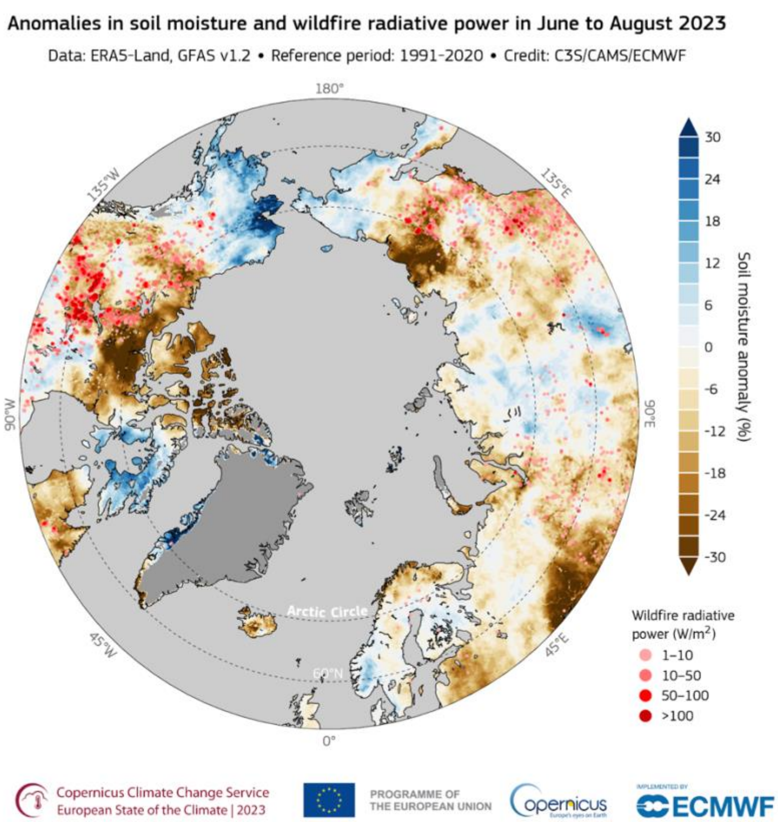
Svalbard is one of the fastest-warming places on Earth. In 2023, the average summer temperature was the highest on record, linked in part to below-average sea ice and above-average sea surface temperatures.

In Greenland, below-average temperatures in May and June led to delayed onset of the ice sheet melt season. In July and August, however, heatwaves led to substantial summer melt and greater-than-average annual ice loss, despite the late start to the melt season.

Arctic wildfires

Data type: Satellite, reanalysis, model-derived estimates
Reference period: 1991–2020
Domain: Arctic

Carbon emissions from sub-Arctic and Arctic regions were the second highest on record



Map showing soil moisture anomalies and locations of wildfires in June–August 2023. The Arctic Circle is indicated with a dashed line. The red-shaded dots represent the total wildfire radiative power (W/m^2). The soil moisture anomalies are relative to the average for the 1991–2020 reference period and expressed as a percentage of this average. Data sources: ERA5-Land soil moisture and CAMS GFAS v1.2 wildfire data. Credit: C3S/ECMWF/CAMS.

As Earth's climate continues to warm, and with the Arctic warming more rapidly than the global average, conditions at high northern latitudes are becoming more conducive to wildfires.

In 2023, the Arctic and sub-Arctic saw high levels of wildfire activity, and the second-highest carbon emissions on record. The majority of high-latitude wildfires occurred in Canada between May and September, contributing to the highest total annual emissions for the western Arctic on record. In July, the prevailing weather conditions transported smoke from Canadian wildfires to Greenland, possibly contributing to a significant melt event by darkening the ice surface.

Arctic ocean

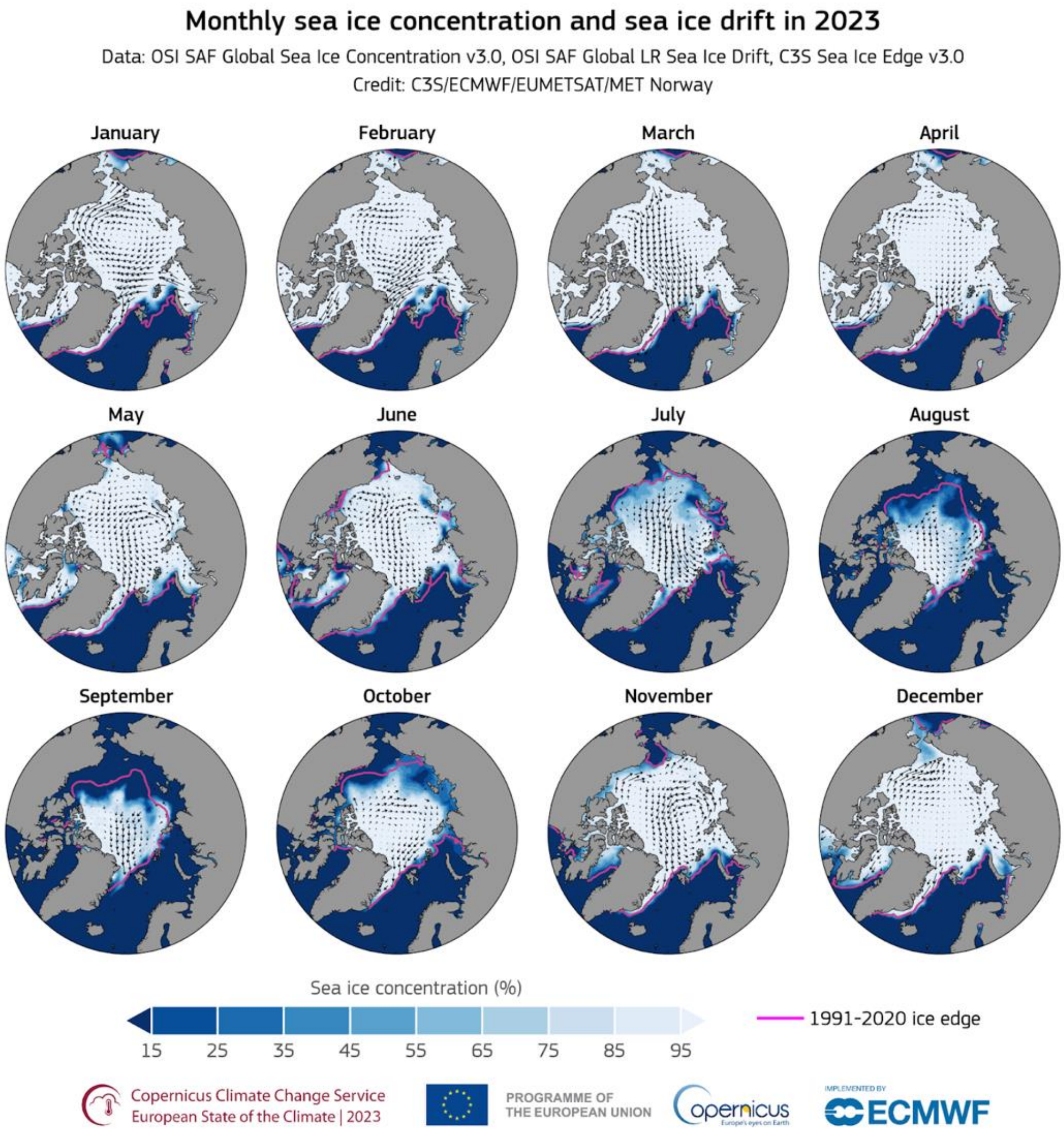
Data type: Satellite
Reference period: 1991–2020
Domain: Arctic

Sea ice extent in the Arctic remained lower than average for most of the year

Sea ice covers between around 25% (September) and 75% (March) of the area north of the Arctic Circle. Arctic sea ice extent remained lower than average during most of 2023, particularly from January to March and from August to October.

At its annual maximum in March, sea ice extent was 4% below average, ranking fifth lowest on record. At its minimum in September, it ranked sixth lowest, at 18% below average.

Sea ice concentrations were most below average in the Barents Sea in January and February, and on the Pacific side of the Arctic Ocean from August to October. In the Greenland Sea, however, concentrations of 10 to 20% above average were observed from March to June and September to December.

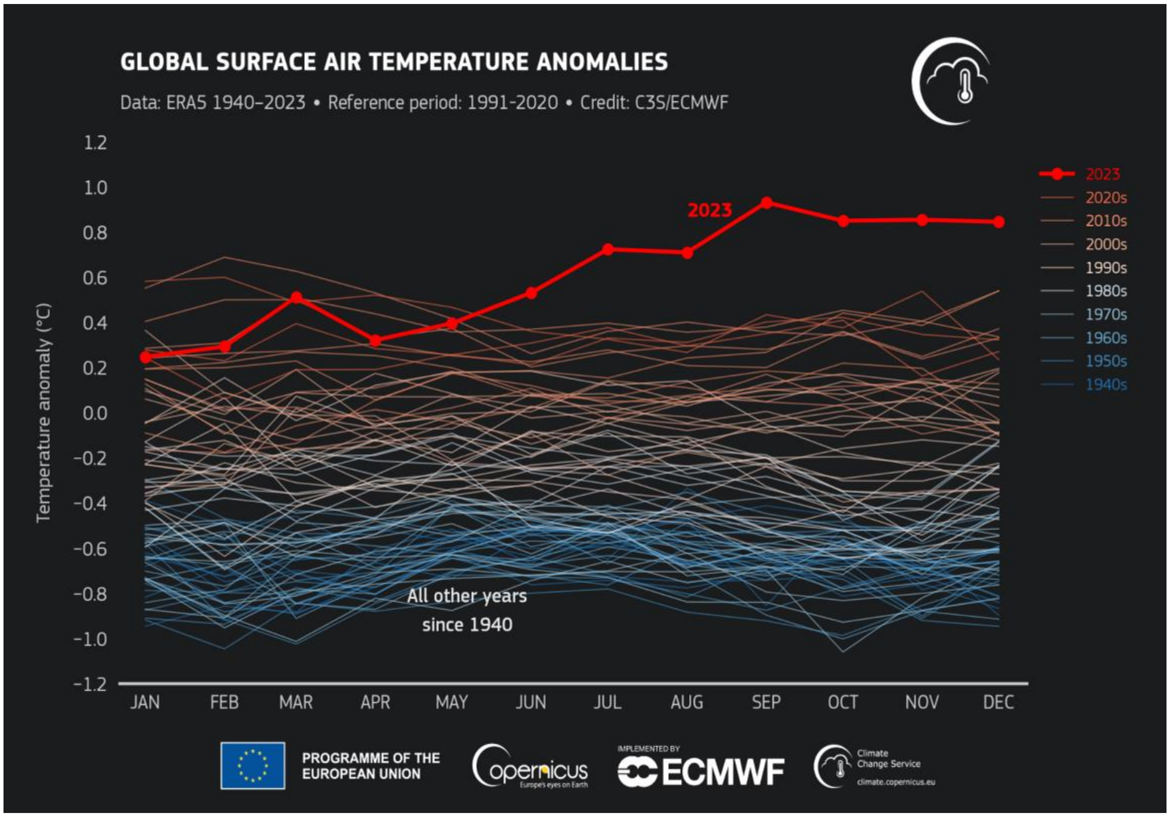


Monthly average sea ice concentration (%) and sea ice drift (arrows) in 2023. The pink line represents the median sea ice edge for the 1991–2020 reference period. Data source: OSI SAF Global Sea Ice Concentration v3.0; OSI SAF Global Low-Resolution Sea Ice Drift; C3S Sea Ice Edge v3.0. Credit: C3S/ECMWF/EUMETSAT.

Globe in 2023

The global context is provided by C3S Climate Indicators.

Additional information about the global climate during 2023 can be found in the WMO State of the Global Climate in 2023, and the C3S 2023 Global Climate Highlights.



Monthly global surface air temperature anomalies (°C) relative to 1991–2020 from January 1940 to December 2023, plotted as time series for each year. 2023 is shown with a thick red line while other years are shown with thin lines and shaded according to the decade, from blue (1940s) to brick red (2020s). Data source: ERA5. Credit: C3S/ECMWF.

Temperature

Globally, it was the warmest year on record. Each month from June to December was warmer than the corresponding month in any previous year, and September saw the largest monthly temperature anomaly on record, at 0.93°C above average. It was the first year in which every day exceeded 1°C above the pre-industrial level. Nearly half the days were more than 1.5°C above the pre-industrial level, and two days were, for the first time, more than 2°C warmer.

Sea surface temperature

Sea surface temperatures (SSTs) were persistently high, reaching record levels for each month from April to December, and breaking daily records. A transition from La Niña* to El Niño** conditions, and high temperatures in most ocean basins, in particular the North Atlantic, played an important role in the record-breaking SSTs. Marine heatwaves were seen around the globe.

Ocean heat content

The global ocean heat content was the highest on record. The transition from La Niña to El Niño, and conditions in the Indian Ocean, contributed to an increase in global upper ocean heat content from 2022 to 2023.

Sea level

Data available for the first six months of the year show a continuing rise in global mean sea level, reaching a new record high. The rate of rise is accelerating.

Greenhouse gases

Atmospheric concentrations of the greenhouse gases carbon dioxide and methane continued to increase, reaching record levels, and were their highest in at least hundreds of thousands of years. The annual increase in methane was significantly higher than the average annual increase during the 2010s, while the annual increase in carbon dioxide was similar to previous years.

Glaciers

Glaciers around the globe saw a new record annual loss of ice, at around 600 Gigatonnes of water. This is 100 Gigatonnes more than any other year on record, and equivalent to almost five times the amount of ice contained in all the glaciers in central Europe. Estimates indicate that this ice loss has contributed 1.7 mm to sea level rise; the largest annual contribution on record.

Sea ice

Antarctic sea ice extent reached record low values for the time of year in eight months and an all-time minimum in February. Arctic sea ice extent at its annual peak in March ranked fifth lowest on record, and at its minimum in September was sixth lowest.

*La Niña - Cooler than average conditions in central and eastern areas of the tropical Pacific.

**El Niño - Warmer than average conditions in central and eastern areas of the tropical Pacific.

1 gigatonne (Gt) = 1,000,000,000 tonnes
1 gigatonne (Gt) = 1 km^3 of water, or 1.1 km^3 of ice

Climate policy and action

This section focuses on climate policy and action in the health sector. The impact of extreme weather and climate events on human health, and the importance of climate services for the health sector, are highlighted.

- The number of adverse health impacts related to extreme weather and climate events is rising.
- In July 2023, for the first time in history, the climate crisis and related extreme weather events were declared a public health emergency by the World Health Organization Europe regional office.

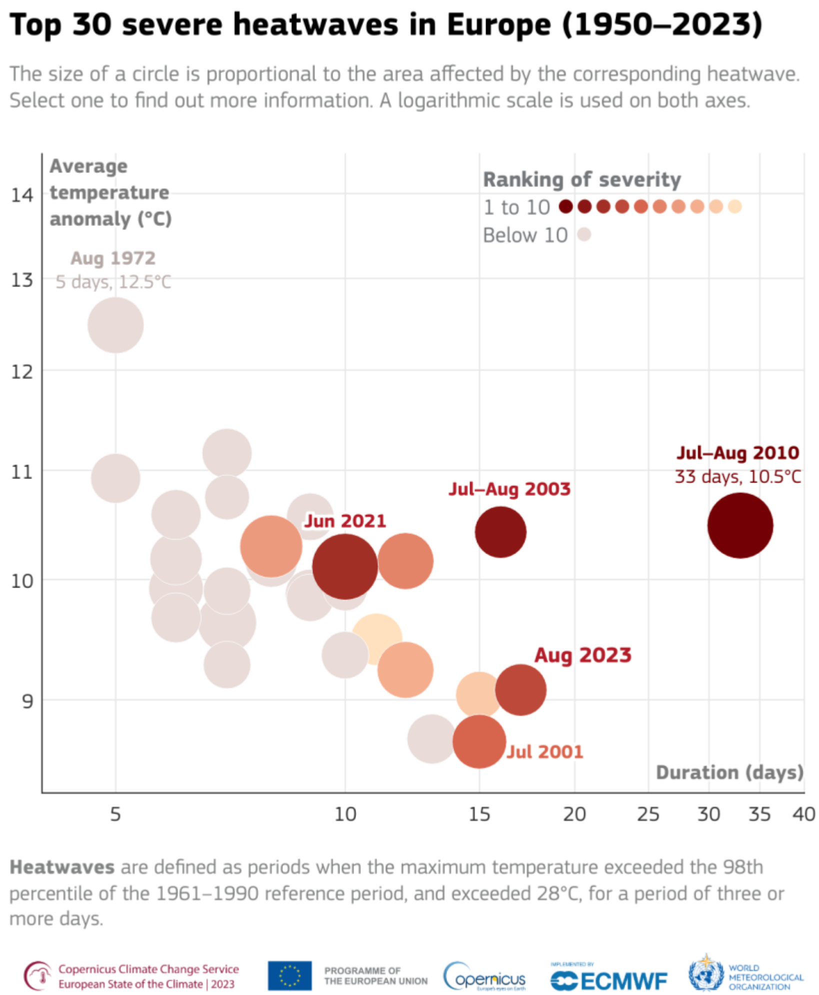
The impact of extreme weather and climate events on human health

Climate change impacts health in various ways. It can exacerbate existing problems like disease and death from heatwaves, wildfires, storms and floods. It also increases the prevalence of non-communicable diseases, such as mental health disorders, while indirect effects include changes in air quality, and food and water security.

Heat-related deaths have increased in 94% of European regions

Since 1970, extreme heat has been the leading cause of weather- and climate-related deaths in Europe. 23 of the 30 most severe heatwaves have occurred since 2000, and five in the last three years. Between 55,000 and 72,000 deaths due to heatwaves were estimated in each summer of 2003, 2010 and 2022. An estimate for 2023 is not yet available. In the World Health Organization's European Region, heat-related mortality has increased by around 30% in the past 20 years. Between 2000 and 2020, heat-related deaths are estimated to have increased in 94% of the European regions monitored. The effect of heat on human health is more pronounced in cities.

The frequency, intensity and duration of heatwaves will continue to increase, with serious consequences for public health. The combined effects of climate change, urbanisation and population ageing is likely to significantly exacerbate heat-related impacts. Current heatwave interventions will soon be insufficient to deal with the expected heat-related health burden.

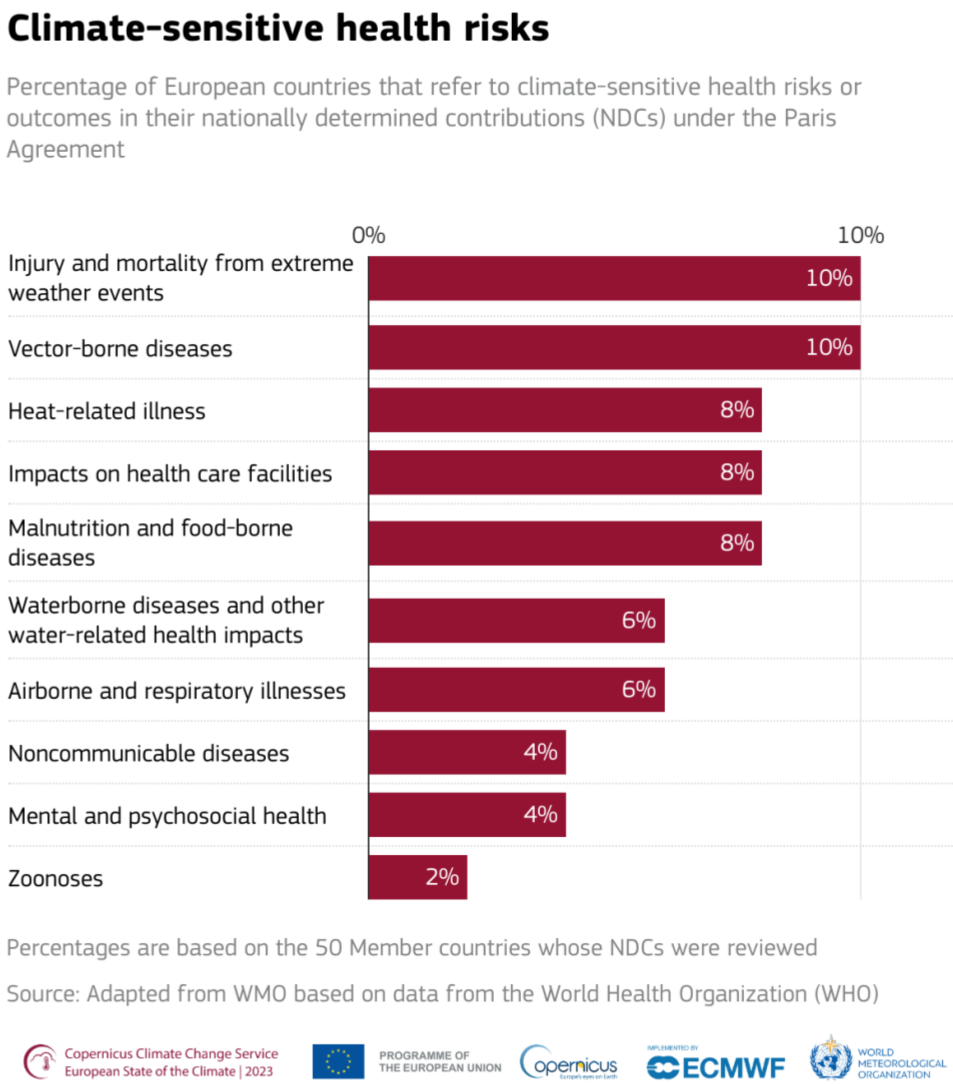


The 30 most severe heatwaves in Europe, 1950–2023. The size of a circle is proportional to the area affected. Source: DWD. Credit: DWD/C3S/ECMWF.

Fewer than a quarter of European Parties to the Paris Agreement have integrated health into their adaptation strategies

Parties to the Paris Agreement, which aims to limit the global average temperature increase to well below 2°C above pre-industrial levels and pursue efforts to limit the increase to 1.5°C, make commitments of policies and measures in the form of nationally determined contributions (NDCs).

The NDCs submitted by European countries have prominently emphasised mitigation efforts, but few have included adaptation. Only 12 of the 50 European Parties analysed have integrated health into their adaptation strategies and 11 made reference to climate-sensitive health risks. Only five highlighted injury and mortality from extreme weather events and vector-borne diseases as their climate health risk areas of concern, and just four Parties highlighted heat-related illnesses.



Percentage of European Member countries that refer to climate-sensitive health risks or outcomes in their NDCs. Percentages in the chart are based on the 50 Member countries whose NDCs were reviewed. Source: Adapted from WMO based on data from the WHO Review of Health in Nationally Determined Contributions and Long-term Strategies: Health at the Heart of the Paris Agreement, 2023.

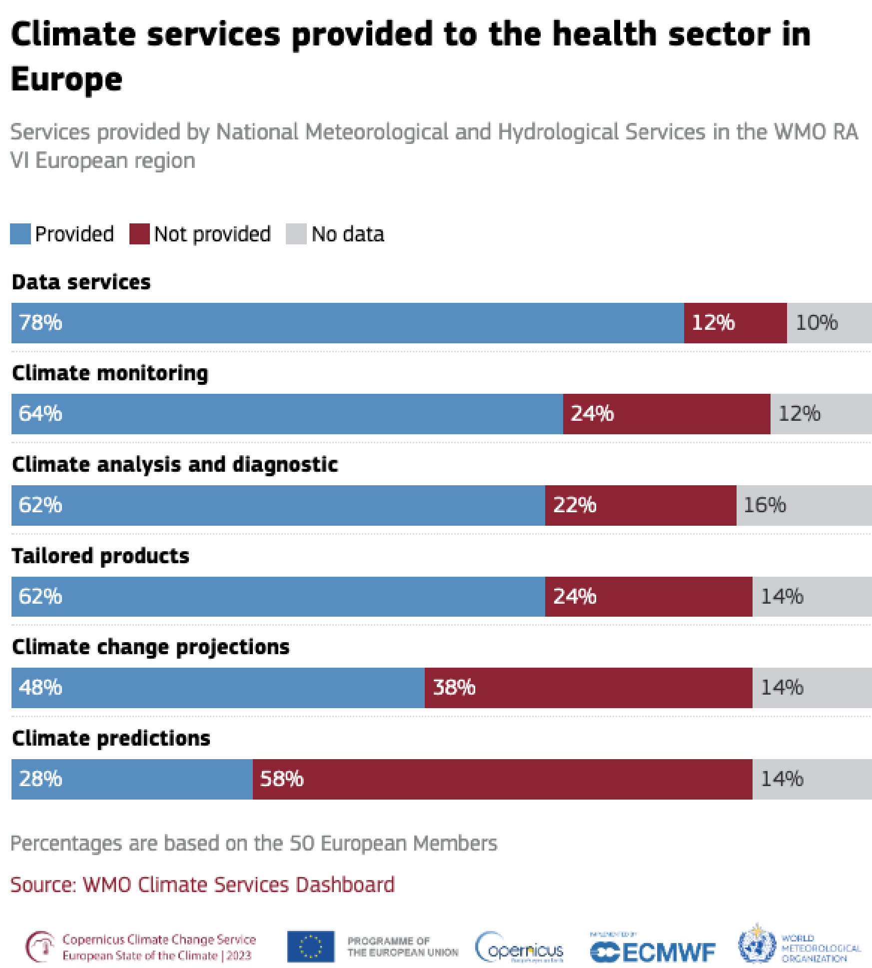
Enhancing climate resilience in the health sector

Tailored climate services for the health sector are effective in increasing resilience, but not widely provided

Climate services are vital for safeguarding lives. Of the WMO's 50 European Member Countries, 78% provide data services for the health sector, but only 28% provide climate prediction services to the sector. Despite 62% indicating that they provide tailored products for the health sector, the majority are not yet customised to capture the sector's needs.

The level of service provision to the health sector by National Meteorological and Hydrological Services has been assessed on a scale of one to six. On this scale, where one corresponds to 'initial engagement' and six to 'full engagement', the WMO's RA VI region (Europe) achieved an average score of 3.3.

Data from the WHO for 20 European countries reveal that 10 of them have implemented a health surveillance system, integrating meteorological information tailored for monitoring heat-related illnesses.



Breakdown of the climate services provided by National Meteorological and Hydrological Services to the health sector in the WMO RA VI region (Europe). Source: WMO Climate Services Dashboard.

Health adaptation can build on established health system infrastructures, but progress has been limited

Opportunities to implement health adaptation options are increasing. Health adaptation can build on, and integrate into, established health system infrastructures. These infrastructures differ significantly between countries, as do existing capacities to deal with climate-related events. Progress has been limited, particularly due to low societal pressure, confidence in existing health systems, and lack of awareness of links between health and climate change.

Increasing the role of governments in facilitating knowledge sharing, allocating financial resources, and creating knowledge and policy programmes on climate and health could all bring benefits. Increasing overall investment in public healthcare systems improves their capacity to respond to climate-related extreme events and will ensure wider societal benefits.

Heat Health Action Plans (HHAPs) include early warning and response systems, and are effective adaptation options for extreme heat. Out of 27 WHO European Member Countries surveyed, 17 have a fully-operational heat-health warning system as part of their HHAPs.

Trends in Climate Indicators

Climate indicators show the long-term evolution of several key variables that are used to assess the global and regional trends of our changing climate.

Increasing temperatures over land and ocean

The Paris Agreement aims to hold the increase in global average temperature to well below 2°C above pre-industrial levels, and preferably below 1.5°C. The five-yearly Global Stocktake assesses the collective progress in the implementation of the Paris Agreement. The first was completed at the end of 2023.

Monitoring surface air and sea surface temperatures globally and regionally contributes to the Stocktake. Global average values for these variables have increased significantly since the pre-industrial era, by around 1.3°C* and 0.9°C, respectively.

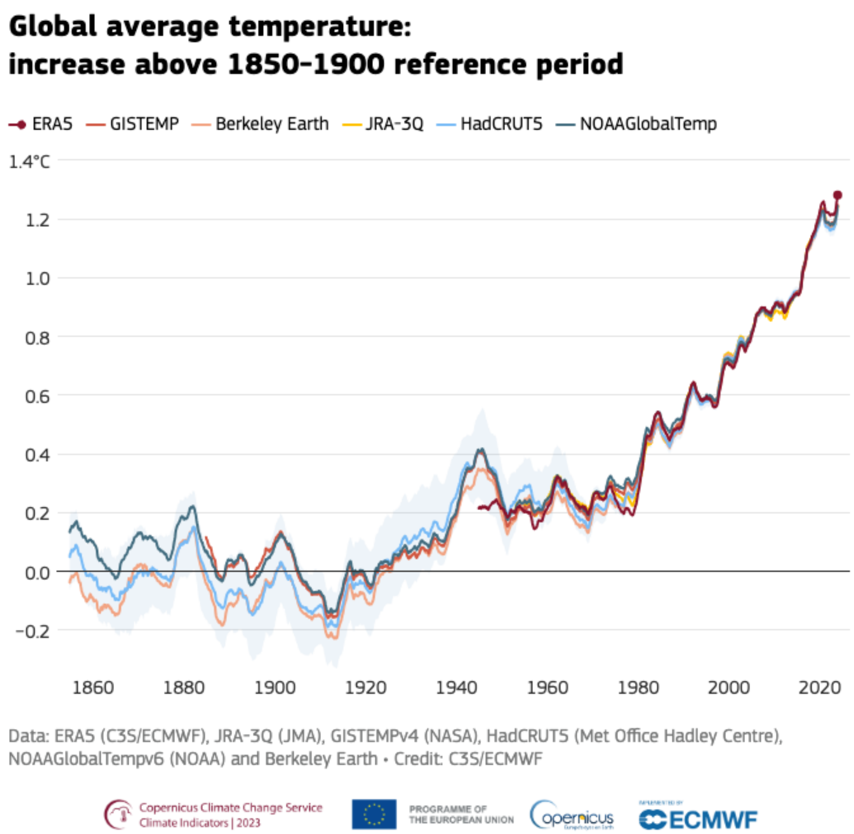
Temperature

Since 1850—1900, an increase in surface air temperature of around

Globe: 1.3°C
WMO RA VI: 2.5°C
Europe: 2.3°C
Arctic: 3.3°C
**(Latest five-year averages)*

Data type: Reanalysis, in situ
Data note: Based on ERA5. Values for Europe, WMO RA VI and the Arctic are over land only.

In recent decades, temperatures over land have risen around twice as fast as those over the ocean. Europe is the fastest warming of all the WMO regions, at around twice as fast as the global average. Temperatures over the Arctic have risen more rapidly than those over most of the rest of the globe, with an estimated warming of around 3°C since the 1970s.



Global average near-surface temperature for centred running 60-month periods, as an increase above the 1850–1900 reference period, according to six datasets. Data source: Six temperature datasets covering all or part of 1850-2023. Credit: C3S/ECMWF.

Sea surface temperature

Since 1980, an increase in SST of around

Extrapolar: +0.6°C
60°S–60°N
WMO RA VI: +1.1°C

Data type: Satellite
Data note: Five SST datasets covering 1980-2023.

Global average sea surface temperature (SST) has increased by around 0.9°C since the late 1800s. A key modulator of global SSTs on interannual timescales is the El Niño Southern Oscillation, which sees periods of warmer (El Niño) or cooler (La Niña) than average conditions in the central and eastern tropical Pacific. These changes in SST influence circulation patterns and surface air temperatures around the globe. 2023 marked a shift to El Niño following three years of La Niña.

The ocean is impacted by and regulating our climate

The ocean plays a crucial role in regulating Earth's climate; it absorbs and stores up to 90% of the excess heat that is associated with human-induced greenhouse gas emissions.

Large-scale circulation within the ocean redistributes this heat from low to mid and high latitudes, and from the surface to deeper layers. The balance between heat absorption and release results in variations in ocean heat content.

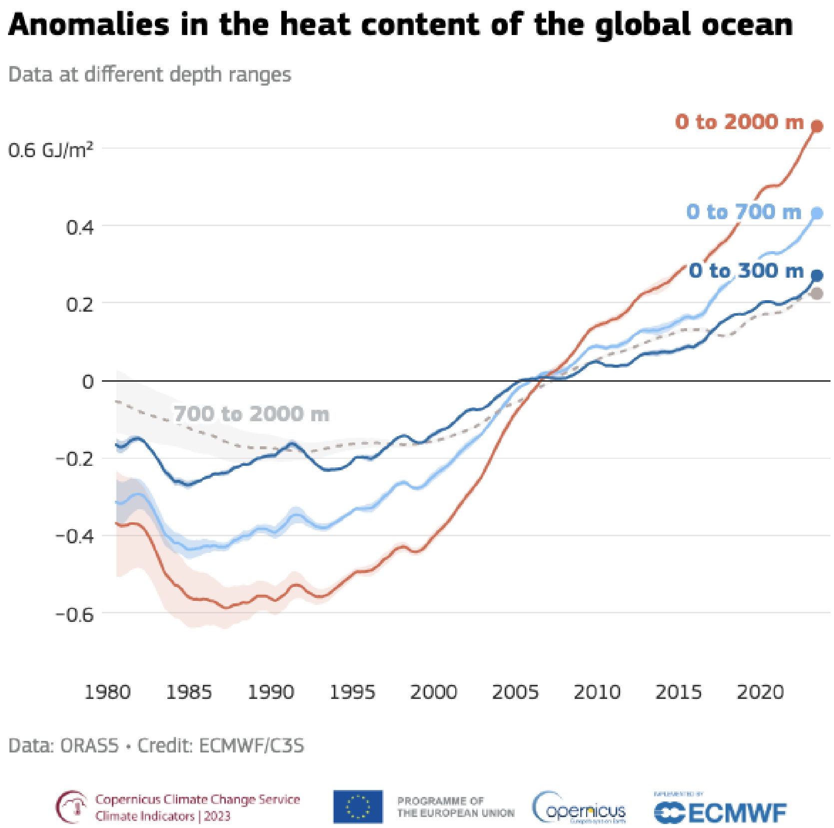
Change in mean sea level is an essential indicator of our evolving climate. It reflects both the thermal expansion of the ocean in response to its warming and the increase in ocean mass due to the melting of ice sheets and glaciers.

Ocean heat content

Since 1993, an increase of
Global ocean: 0.22°C
Northeastern Atlantic: 0.04°C

Data type: Reanalysis

Long-term trends in ocean heat content indicate that most of the heat gain is happening in the upper 700 m of the ocean. This heat is slowly being transferred to the 700–2000 m layer. Even small changes in temperature correspond to large changes in energy, due to the immense volume of the ocean.



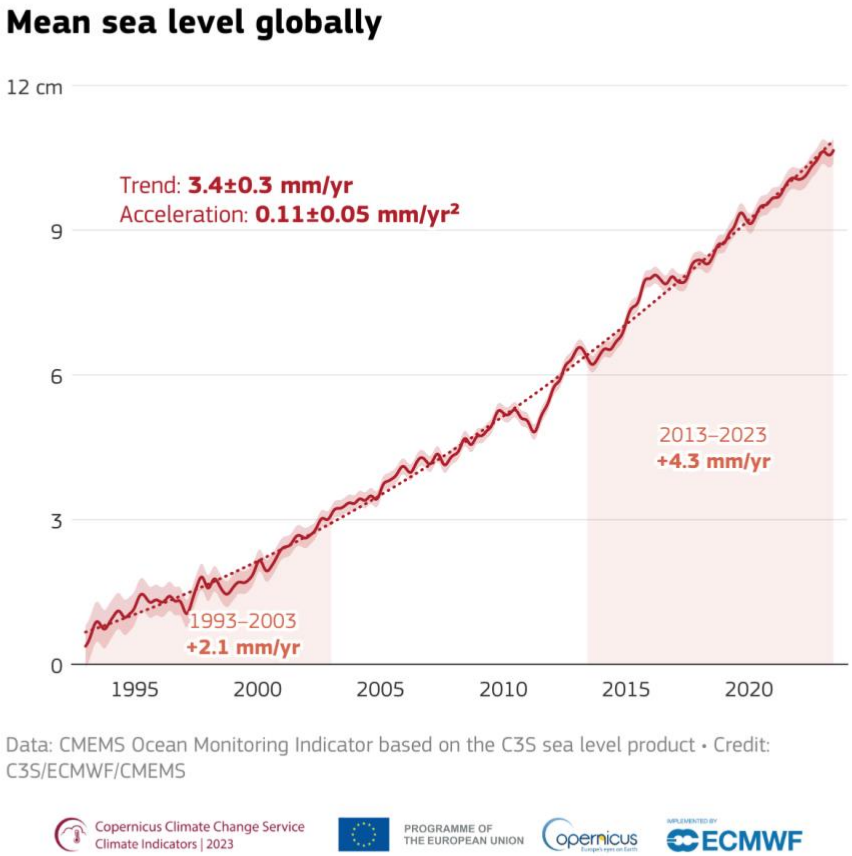
Anomalies (GJ/m²) in the heat content of the global ocean from 1980 to 2023 at different depth ranges, relative to the average for the 1993–2022 reference period. Source: ORAS5. Credit: ECMWF/C3S.

Sea level

Since 1993, an average sea level increase of around
Global: 3.4 mm
Europe: 2–4 mm
(per year)

Data type: Satellite
Data note: January 1993 to June 2023.

Since 1993, there has been a rise in global mean sea level of around 10.3 cm. Sea level is also rising more quickly, with the past 10 years seeing an increase of 4.3 mm per year compared to 2.1 mm per year between 1993 and 2003. Regionally, there can be variation. For example, across Europe, sea level changes differ between the open ocean and coastal areas due to various oceanic and geophysical processes.



Daily change in global mean sea level from January 1993 to June 2023 (red solid line), and the associated uncertainty (red shading) and trend over 1993–2023 (dashed line). Data source: CMEMS Ocean Monitoring Indicator based on the C3S sea level product. Credit: C3S/ECMWF/CMEMS.

Greenhouse gases driving climate change

Greenhouse gases (GHGs) in the atmosphere trap heat close to Earth's surface. As concentrations increase, the near-surface temperature is also rising, with significant impacts. Human activities lead to the emission of GHGs in various ways, including the combustion of fossil fuels for energy, deforestation, the use of fertilisers in agriculture, livestock farming, and the decomposition of organic material in landfills. Of all the long-lived GHGs that are emitted by human activities, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have the largest impact on the climate.

ppm: parts per million
ppb: parts per billion
1 teragram (Tg) = 1,000,000,000,000 (10^{12}) grams

Greenhouse gas concentrations

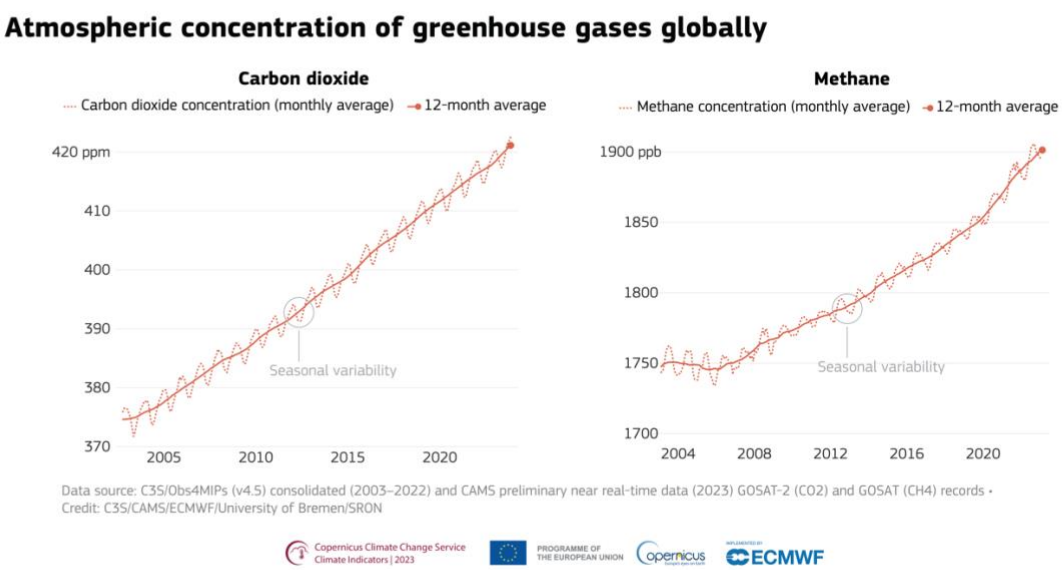
The amount of a gas contained in a certain volume of air.

In 2023, the annual average concentrations of greenhouse gases were:

CO_2: 419 ppm
CH_4: 1902 ppb

Data type: Satellite
Data note: Concentrations (column-averaged mixing ratios) for CO_2 and CH_4 covering 2003–2023.

Atmospheric concentrations of the two most important anthropogenic greenhouse gases, carbon dioxide (CO_2) and methane (CH_4), continued to increase in 2023, reaching record levels.



Global atmospheric concentrations of carbon dioxide (CO_2) and methane (CH_4). Data are derived from satellite measurements and averaged over the whole atmospheric column and for 60°S–60°N. Data source: C3S/Obs4MIPs (v4.5) consolidated (2003–2022) and CAMS preliminary near real-time data (2023) GOSAT-2 (CO_2) and GOSAT (CH_4) records. Credit: C3S/CAMS/ECMWF/University of Bremen/SRON.

Greenhouse gas fluxes

The net difference between the amount of a gas added to the atmosphere by emissions from various ‘sources’ and the amount taken up by various ‘sinks’.

Over the last decade, net fluxes of greenhouse gases at Earth’s surface of around

CO_2: 5000 TgC
CH_4: 420 TgC
N_2O: 16 TgN
(per year)

Data type: Satellite, model-derived
Data note: CO_2: 1979–2022 CH_4: 1979–2022 N_2O: 1996–2021

Estimated net surface fluxes of CO_2, CH_4 and N_2O have been increasing during recent decades. Only around half of anthropogenic emissions of CO_2 have been absorbed by land vegetation and oceans.

The cryosphere in a changing climate

The cryosphere encompasses all parts of the Earth system where water is in solid form, including ice sheets, glaciers, snow cover, permafrost and sea ice. The cryosphere and the climate exert a strong influence on each other. Due to its high reflectivity, changes in the cryosphere impact the amount of solar energy taken up by the planet's surface, and consequently temperatures. As temperatures rise, vast amounts of water stored on land, in glaciers and ice sheets, melt, which contributes to global sea level rise. The changing cryosphere therefore has many further environmental and societal implications.

Glaciers

Since 1976, a loss of glacier ice of around

Global: 8200 km^3
Europe: 850 km^3

Data type: Satellite, in situ
Data note: Glacier mass-change estimates from in situ and remotely sensed observations. Ice loss for Europe does not include peripheral glaciers in Greenland.

Globally, around 220,000 glaciers cover an area of approximately 700,000 km^2. Both globally and across Europe, glaciers have seen a substantial and prolonged loss of ice mass since the mid 19th century. Globally, an average of about 14 m reduction in ice thickness has been observed since satellite records began in 1976, and glaciers have contributed about 1 mm per year to global mean sea level rise during the last decade. In 2023, this reached a high of 1.7 mm due to record global glacier mass loss.

Sea ice

Since the 1980s, a loss of sea ice of around

Arctic: 2.6 million km^2
Antarctic: no long-term trend

Data type: Satellite

Arctic sea ice extent has declined markedly since records began. The decline is largest around the annual minimum in September, with widespread retreat across the region. In addition to the decline in Arctic sea ice extent, the proportion of multiyear ice has decreased while the proportion of first-year ice has increased. In the Antarctic, sea ice extent shows no clear long-term trend, despite reaching successive all-time minima in February 2022 and 2023.

Ice sheets

Since the 1970s, a loss of ice sheet of around

Greenland: 5467 ± 535 Gt
1972–2022
Antarctica: 4790 ± 987 Gt
1979–2022

Data type: Satellite

Earth's polar ice sheets cover most of Greenland and Antarctica, and store about 68% of the planet's freshwater resources. If the ice sheets were to melt entirely, they would raise global mean sea level by 7.4 ± 0.05 m for the Greenland Ice Sheet and 57.9 ± 0.9 m for the Antarctic Ice Sheet. Since the 1970s, melting of these ice sheets has caused sea level to rise by almost 3 cm. It is estimated that for every centimetre of sea level rise, around six million people around the planet are exposed to coastal flooding. The rate of ice loss has increased by around three times (Antarctica) to five times (Greenland) since the 1980s.

About the report

Contributors

The ESOTC's findings are based on expertise from across the C3S and WMO communities, as well as other Copernicus services and external partners. The sections are authored by C3S, the WMO and data providers from institutions across Europe, and edited by the C3S team. This report is reviewed by colleagues across the Copernicus network, the WMO, WMO ET-CMA and representatives from national meteorological and hydrological services.

The EU Copernicus Services:

C3S, CAMS, CEMS, CMEMS, CLMS.

International organisations and initiatives: ECMWF, EC JRC, EEA, ESA, EUMETSAT SAF Network, GCOS, WHO Regional Office for Europe, WMO and WMO the WMO RA VI RCC network.

European national and regional meteorological and hydrological services: DMI (Denmark), DWD (Germany), National Observatory of Athens (Greece), ASTA (Luxembourg), KNMI (the Netherlands), MET Norway, Météo-France, and the Met Office (United Kingdom), alongside expert review and indirect contributions from many others.

Universities and research organisations: ENVEO, EODC, TU Wien (Austria), GEUS (Denmark), CEA/LSCE, CLS, CNES, LEGOS and RTE (France), AWI, Brockmann Consult and University of Bremen (Germany), Inside Climate Service (Italy), SRON, Rabobank, TNO VanderSat and VU Amsterdam (the Netherlands), NILU (Norway), Barcelona Supercomputing Centre (Spain), Umeå University (Sweden), University of Zurich and WGMS (Switzerland), University of Northumbria, University of Reading and WEMC (United Kingdom).

The data behind the ESOTC 2023 and the Climate Indicators

The ESOTC 2023 relies extensively on datasets provided operationally and in near real-time by the Copernicus Services, to give an overview of 2023 in the long-term context. The operational data are freely accessible via data catalogues such as the C3S Climate Data Store (CDS). These operational data services build on extensive research and development undertaken by institutions across Europe and the rest of the world. Explore the full ESOTC online to download the data shown in this summary.

Climate Indicators provide the long-term context for the globe, Europe and the Arctic, and build on datasets and estimates which are brought together to provide a comprehensive multi-source reference, based on data from Copernicus and from other monitoring activities. Where data do not yet fully cover the reporting period, the most up to date information is included.

Reference periods

By comparing 2023 against the average for a reference period, we can see how the year fits within a longer-term context. Generally, the reference period used is 1991–2020, but where less extensive data records are available, other periods may be used, as indicated by this symbol. Some variables are compared to the pre-industrial level, for which the reference period used is 1850–1900.

Averages

Throughout the report, use of the word 'average' refers to the mean, unless stated otherwise.

In situ

Measurements from an instrument located at the point of interest, such as a land station, at sea or in an aeroplane.

Model-based estimates

Using the laws of physics and statistics to build large-scale models of environmental indicators.

Satellites

Providing information about Earth’s surface and its atmosphere from spaceborne orbit.

Reanalysis

Using a combination of observations and computer models to recreate historical climate conditions.

About us

Copernicus services implemented by ECMWF

Vital environmental information for a changing world

The European Centre for Medium-Range Weather Forecasts (ECMWF) has been entrusted by the European Commission to implement two of the six services of the Copernicus programme: the Copernicus Climate Change Service (C3S) and the Copernicus Atmosphere Monitoring Service (CAMS). In addition, ECMWF provides support to the Copernicus Emergency Management Service (CEMS).

To meet the challenge of global climate change, accurate, reliable and timely data are key. The Copernicus Services at ECMWF routinely monitor data on a global scale, including a wide range of climate variables and indicators from across the Earth system.

The Copernicus Climate Change Service (C3S)

The C3S mission is to support adaptation and mitigation policies of the European Union by providing consistent and authoritative information about climate change. C3S adds value to environmental measurements by providing free access to quality-assured, traceable data and applications, all day, every day. We offer consistent information on the climate anywhere in the world, and support policymakers, businesses and citizens in preparing for future climate change impacts.

World Meteorological Organization (WMO)

The WMO is the United Nations system's authoritative voice on the state and behaviour of Earth's atmosphere, its interaction with the land and oceans, the weather and climate it produces and the resulting distribution of water resources.

As weather, climate and the water cycle know no national boundaries, international cooperation at a global scale is essential for the development of meteorology and operational hydrology as well as to reap the benefits from their application. The WMO provides the framework for such international cooperation for its 193 Member States and Territories, and plays a leading role in international efforts to monitor and protect the climate and the environment.

WMO regional office for Europe and RCC network

The Regional Office for Europe is responsible for achieving the WMO's long-term goals and strategic objectives for the 50 WMO Regional Association VI (Europe) Member States.

Regional Climate Centres are operational entities of the Global Framework for Climate Services' Climate Services Information System. They serve the members of the WMO through their respective National Meteorological and Hydrological Services (NMHSs), supporting NMHSs in meeting their national climate-related duties.

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