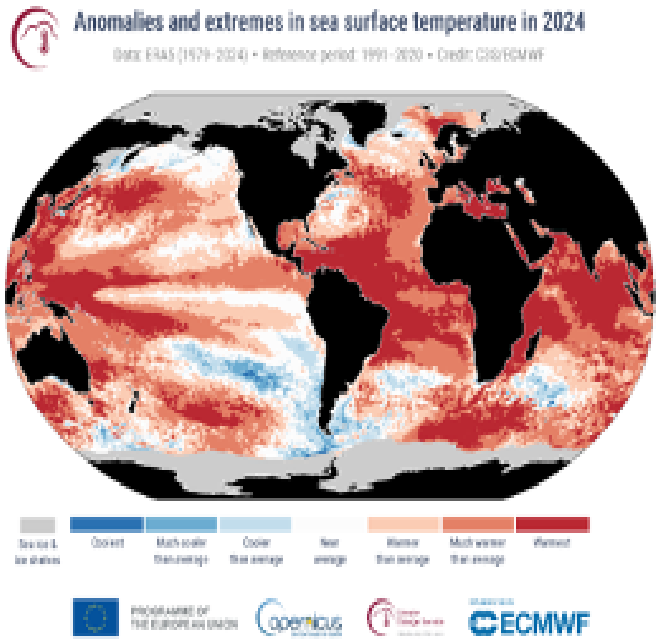
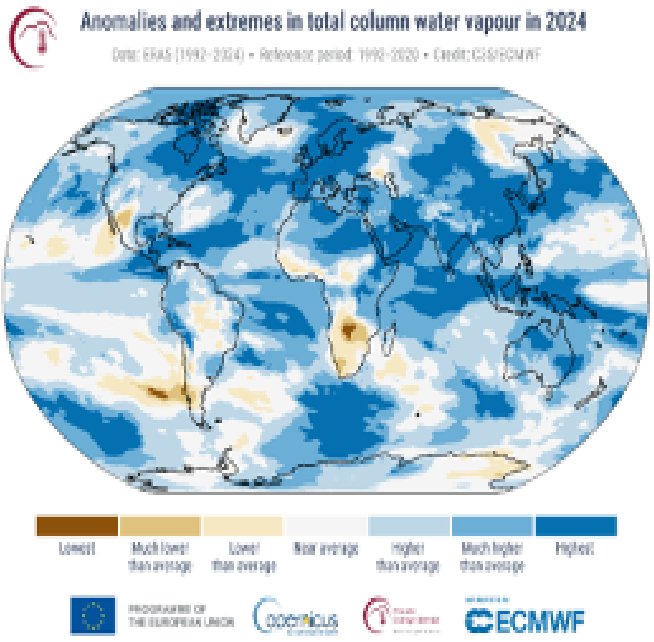
OBSERVER: Copernicus Climate Change Service tracks record atmospheric moisture and sea surface temperatures in 2024



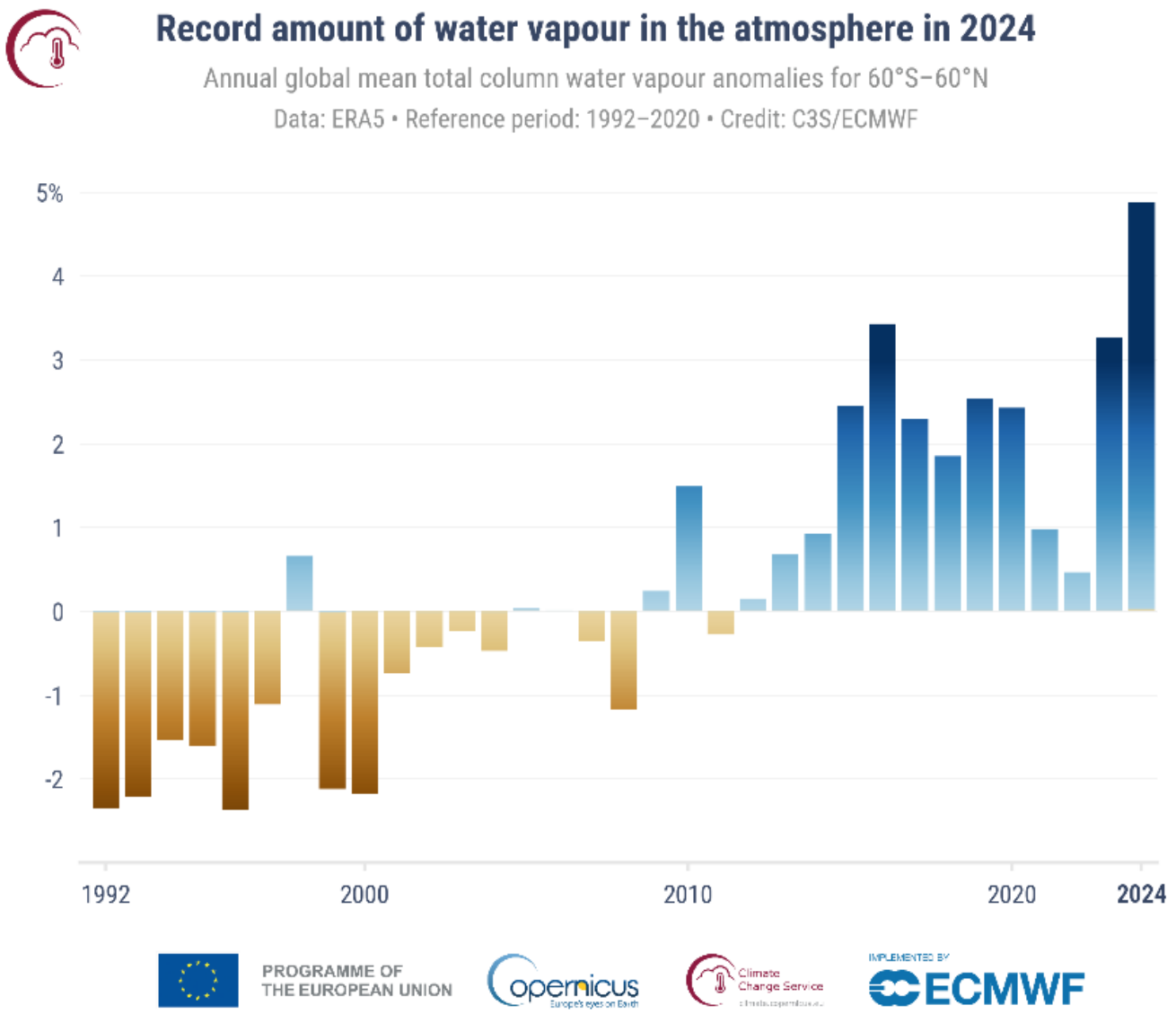


In 2024, the planet experienced extremes which were unprecedented in the instrumental record, highlighting the ongoing impact of human-induced climate change. In addition to record global temperatures which made 2024 the first year with an average temperature clearly exceeding the threshold of 1.5°C above the pre-industrial level set in the Paris Agreement, the Copernicus Climate Change Service (C3S) revealed in its *Global Climate Highlights 2024*, published on 10 January, that Earth's atmosphere and oceans reached new milestones. The report, based on C3S climate monitoring capabilities and expertise, found that atmospheric water vapour surged to unprecedented levels, while sea surface temperatures (SSTs) reached new heights, outpacing the extremes of previous El Niño years. The Global Climate Highlights set the stage for C3S's upcoming *European State of the Climate Report 2024*, a flagship joint publication with the World Meteorological Organization (WMO) due in early April. This comprehensive analysis will focus on Europe's, climate conditions in 2024, providing in-depth descriptions of climate events while updating the long-term global context with key climate indicators.

Water vapour: the invisible amplifier of global warming

In 2024 the atmosphere held more moisture than previously recorded by a large margin. Total column water vapour—the total amount of moisture in a vertical column of air extending from the surface of the Earth to the top of the atmosphere—reached 4.9% above the 1991–2020 average, far surpassing previous highs in 2016 (3.4%) and 2023 (3.3%).

Water vapour is Earth's most abundant greenhouse gas, responsible for about half of the planet's natural greenhouse effect. Unlike other greenhouse gases such as carbon dioxide (CO?) and methane (CH4), the concentration of water vapour in the atmosphere is not directly influenced by human activities. However, water vapour concentration rises as the atmosphere warms: for every 1°C increase in atmospheric temperature, air can hold 7% more moisture. This creates a vicious cycle—warmer air absorbs more vapour, which traps more heat, further accelerating warming.



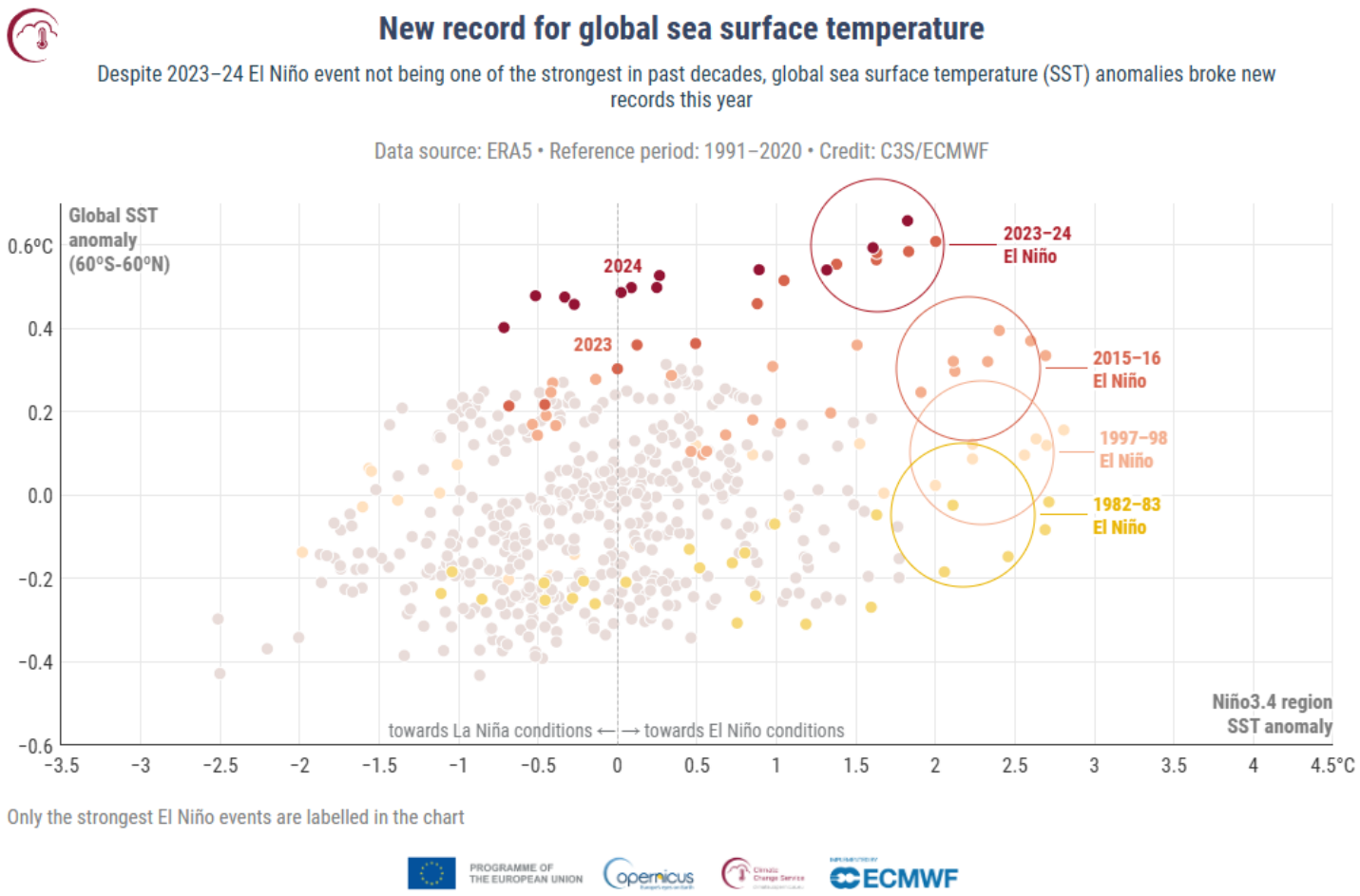
Annual anomalies in the average amount of total column water vapour over the 60°S–60°N domain relative to the average for the 1992–2020 reference period. The anomalies are expressed as a percentage of the 1992–2020 average. Data: ERA5. Credit: C3S/ECMWF.

“Water vapour is both a consequence and a driver of climate change,” explains C3S Director Carlo Buontempo. “In 2024, we saw this feedback loop in ‘overdrive’. Higher sea surface temperatures intensified evaporation, whilst warmer atmosphere allowed more water to be held there as vapour, adding ‘fuel’ to several extreme weather events.”

The consequences are potentially disastrous. Increased atmospheric moisture can intensify storms and increase the intensity of the most extreme rainfall. The atmosphere knows no borders, so the potential effects are global.

Rising sea surface temperatures

If 2023 was a wake-up call, 2024 sounded a louder alarm. The annual average SST for extra-polar oceans (60°S–60°N) hit 20.87°C; 0.51°C above the 1991–2020 baseline, breaking 2023's record (20.80°C). For 15 consecutive months, from April 2023 to June 2024, SSTs set new monthly highs for the time of year. Even after El Niño's influence waned, oceans remained anomalously warm, with July–December 2024 ranking as the second-hottest period on record.



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.

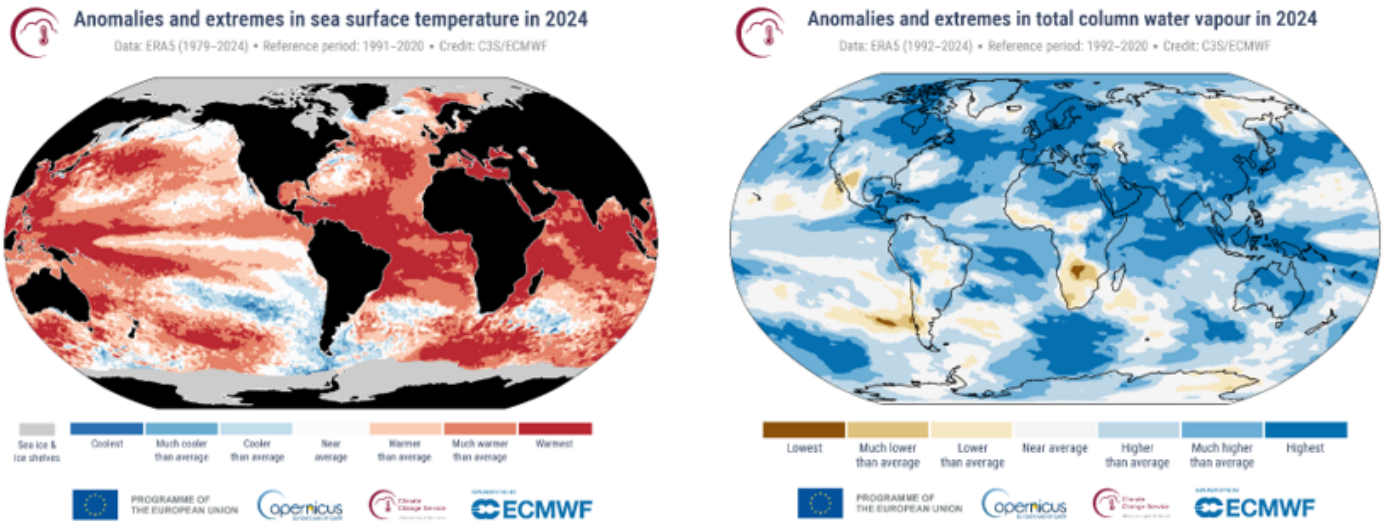
The Atlantic Ocean, and in particular the tropical areas, the Indian Ocean, and large parts of the Western Pacific bore the brunt, with SSTs reaching unprecedented levels. The global SST anomaly in December 2024 amounted to 0.61°C above the 20-year average and 2°C for the El Niño 3.4 region, which spans the central equatorial Pacific Ocean, even though 2024 ended in El Niño-Southern Oscillation (ENSO)-neutral conditions, meaning there was no dominant El Niño or La Niña influence.

The impacts of higher SSTs are multifaceted. Prolonged spikes in sea surface temperatures are devastating coral reefs and disrupting fisheries, for example. In the Caribbean, coral bleaching has reached catastrophic levels, while in the Indian Ocean, warmer waters are displacing fish populations, threatening the livelihoods of coastal communities.

“This isn’t just about El Niño,” stresses Samantha Burgess, Strategic Lead for Climate at the European Centre for Medium-Range Weather Forecasts (ECMWF). “The oceans are absorbing around 90% of Earth’s excess heat. What we’re seeing is a relentless accumulation of energy, fundamentally altering marine ecosystems and weather patterns.”

The water vapour–SST connection: A troubling symbiosis

Coinciding with the elevated moisture levels recorded last year, 2024 saw a large number of extreme rainfall events, leading to flooding in regions from South Asia to Western Europe. Europe was impacted throughout 2024 by a range of heavy precipitation events, including 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, Ireland’s Met Éireann and Netherlands’ KNMI-storm-naming group during the 2023-2024 storm season—the highest number in a season since the UK, Ireland, and the Netherlands introduced their storm-naming system in 2015.

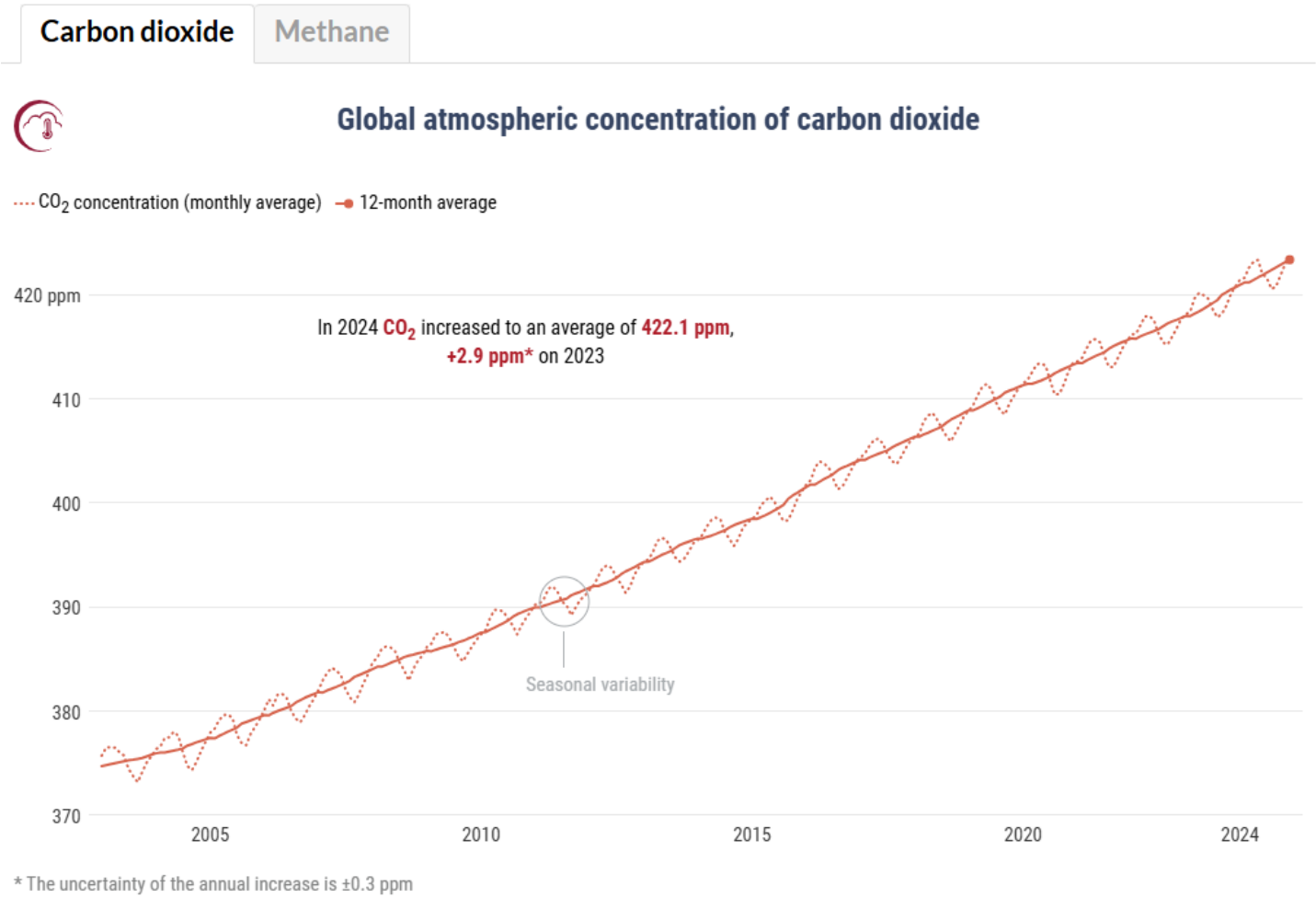


(Left) Anomalies and extremes in sea surface temperature for 2024. Colour categories refer to the percentiles of the temperature distributions for the 1991–2020 reference period. The extreme (‘coolest‘ and ‘warmest‘) categories are based on rankings for the period 1979–2024. Values are calculated only for the ice-free oceans. (Right) Anomalies and extremes in the amount of total column water vapour for 2024. Colour categories refer to the percentiles of the water vapour distribution for the 1991–2020 reference period. The extreme (‘lowest’ and ‘highest’) categories are based on rankings for 1992–2024. Credit: C3S/ECMWF, ERA5 data.

Some sources suggest that the intensity of storms will likely increase as hurricanes and typhoons draw energy from warmer waters and vapour-rich air, multiplying their destructive potential. Hurricane Helene, which struck the Gulf of Mexico in September 2024, intensified from Category 2 to Category 5 in under 24 hours—a phenomenon potentially linked to higher-than-normal sea surface temperatures.

The bigger picture: Greenhouse gases and global temperatures

Water vapour was not the only greenhouse gas to see an increase in 2024. Preliminary analysis of satellite data, averaged over the entire atmospheric column, shows that carbon dioxide and methane concentrations continued their upward trajectory, reaching record levels. These rising greenhouse gas levels underscore the urgent need to curb emissions and accelerate climate action to mitigate the impacts of global warming.



Monthly global mean atmospheric CO2 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.

The rate of increase of carbon dioxide was higher than that observed in recent years. As a result of this relentless growth, atmospheric carbon dioxide concentrations were higher in 2024 than at any time in at least 2,000,000 years, while methane levels were higher than at any time in at least 800,000 years.

A planet at a crossroads

For the first time, C3S synchronised its annual Global Climate Highlights release with other leading agencies, including the US National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the UK Met Office. This collaboration marks a watershed moment in climate communication, ensuring policymakers receive a consistent, evidence-based narrative. While datasets and methodologies may differ between different institutions the consensus is clear: 2024 was unequivocally Earth's hottest year, as confirmed by all five global temperature datasets. "When every major dataset, every agency, and every scientist is saying the same thing, it's time to listen," Burgess said.

April's European State of the Climate Report (ESOTC) 2024 will focus on key variables in Europe, providing regional analyses of 2024's extremes including flooding, heatwaves and drought. This year's report will also provide deeper insights into rising temperatures, glacier loss, the warming of European seas and oceans, sunshine duration, renewable energy and much more.

The C3S Global Climate Highlights 2024 paint a picture of a planet pushed to its limits. As multiple climate variables grow to unprecedented levels, the message is clear: incremental action is insufficient. With the ESOTC report on the horizon, the data-driven case for rapid emissions cuts has never been stronger. "We're writing the playbook for future generations," Buontempo concludes. "What's at stake isn't just a climate statistic—it's the liveability of our planet."