Summary of Key Findings

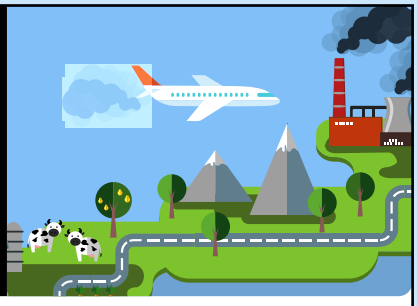
The third edition of the Indicators of Global Climate Change (IGCC) is now published in the journal *Earth System Science Data*.

Since 2023, IGCC has provided annual updates of key global climate indicators reported by the Intergovernmental Panel on Climate Change (IPCC) that can help us to understand the state of the climate system and how it is changing. The study aims to fill in the potential information gaps between IPCC reports, providing decision makers with timely and scientific information on policy-relevant global climate indicators such as levels of greenhouse gas emissions, their atmospheric concentrations, the level of human-caused warming, and the remaining global carbon budget.

The methodologies used to update the indicators are directly traceable back to the IPCC Sixth Assessment Report (AR6). This year, the authors included two additional indicators, global land precipitation and global mean sea level rise, to give a total of *ten indicators*.

Below we set out the main scientific findings from this year's publication:

Global greenhouse gas emissions are at an all-time high.

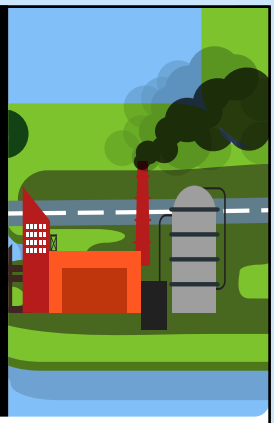


- Human activities have resulted in the equivalent of around 53 billion tonnes of carbon dioxide ($GtCO_2$) being released into the atmosphere on average each year over the last decade.
- This is primarily due to increasing greenhouse gas emissions from fossil fuels and industry. In 2024, there were also high emissions from tropical deforestation, which are partly related to climatic conditions (El Niño).
- In 2024, emissions from international aviation – the sector with the steepest drop in emissions during the pandemic – reached pre-pandemic levels.

Concentrations of three major GHGs have increased since 2019.

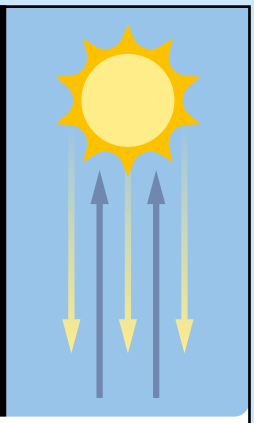
- The global surface mean concentrations of CO_2, methane (CH_4) and nitrous oxide (N_2O) in 2024 were 422.8 parts per million (ppm), 1929.7 parts per billion (ppb) and 337.9 ppb, respectively.
- Since 2019, their concentrations have increased by 3.1, 3.4 and 1.7% respectively.

Emissions of non-methane short-lived climate forcers (SLCFs) have overall decreased in 2024 relative to 2019, except for nitrogen oxide (NO_x), partly driven by increased emissions from biomass burning.



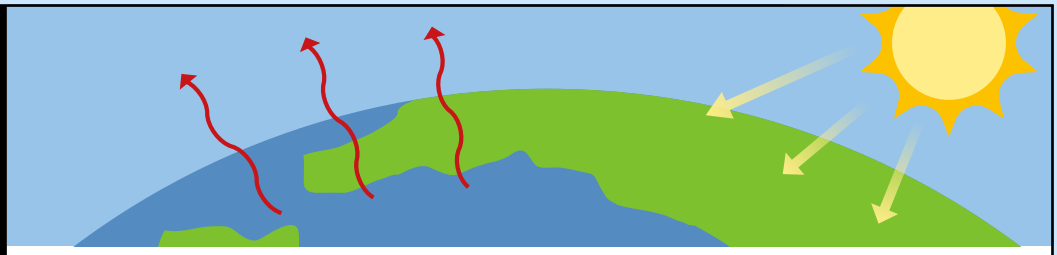
- As expected, emissions of cooling aerosols continue to decline as a result of tackling air pollution, unmasking more of the warming effect of greenhouse gases.

Total anthropogenic effective radiative forcing (ERF) has increased to 2.97 watts per square metre ($W\ m^{-2}$) in 2024 relative to 1750, compared to 2.72 $W\ m^{-2}$ for 2019 relative to 1750 in AR6.



- The rise is due to increased GHG concentrations resulting from rising emissions combined with decreases in emissions of aerosols.

Earth energy imbalance (EEI) has increased over time due to increased GHG concentrations. EEI is a crucial indicator for monitoring current and future warming.



- Surplus heat accumulating in the Earth's system at an accelerating rate is driving changes in every component of the climate system, including sea level rise, ocean warming, ice loss, continental warming and permafrost thawing.
- An increase in this imbalance over the last 20 years is a key factor in the exceptionally warm conditions.
- The rate of global heating has about doubled from the levels seen in the 1970s and 1980s to around 1 W m^{-2} (0.99 W m^{-2}) measured over 2012 to 2024.
- The ocean is storing an estimated 91% of this excess heat (this has remained stable over time).

Global surface temperatures have increased.

2024

- In 2024, the best estimate of observed global surface temperature rise was 1.52°C, of which 1.36°C can be attributed to human activity.
- Note that this does not mean there has been any breach of the Paris Agreement.
- Natural variability, such as El Niño and warmer-than-average North Atlantic waters, played a significant role in last year's observed temperatures.
- This warming is unprecedented in at least the last 2,000 years, but not surprising.
- Given the level of human-induced warming, we might currently expect to see temperatures above 1.5°C on average one year in six. However, 2024 followed an El Niño year and the North Atlantic waters were warmer than average, so the likelihood in such a scenario increases to every other year.
- This highlights the role that natural variability can play in shaping global annual temperatures. 2024 should be regarded as unexceptional.
- Note that IGCC calculated 1.52°C as the best estimate of observed global surface temperature in 2024. This number differs from the 1.55°C given by the World Meteorological Organisation (WMO) State of the Global Climate 2024 report. This is owed to slightly distinct selections from the available datasets included. The number has varied by similar amounts in past years. Future work will aim to harmonise the approaches.

Decadal

- Between 2015 and 2024, the temperature was 1.24°C higher than in pre-industrial times. Of this, 1.22°C was caused by human activities. Allowing for small uncertainties, this means that essentially all the global warming was human-induced.
- The most recent decade (2015-2024) was 0.31°C warmer than the previous decade (2005-2014). These changes, although amplified somewhat by the exceptionally warm years in 2023 and 2024, are broadly consistent with warming rates over the last few decades.
- Human-caused warming has increased at a rate of around 0.27°C/decade (2015-2024).

Over land

- The rapid warming over the last few decades has resulted in record extreme temperatures over land.
- These are now rising at a substantially faster rate than global mean surface temperature.
- Land average maximum temperature change has now reached 1.90°C (2015-2024).

The remaining carbon budget for 1.5°C is decreasing rapidly.

- At the start of 2025, the central estimate was 130 billion tonnes of carbon dioxide (30-320 gt CO_2). This would be exhausted in a little more than three years at current levels of emissions.

Global land precipitation has exhibited a large interannual variability due to El Niño.

Between 2019 and 2024, global mean sea level has also increased by around 26 mm, more than doubling the long-term rate of 1.8 mm per year seen since the turn of the twentieth century.

- Sea level rise has been accelerating over the 20th and early 21st centuries and this acceleration continues today, in line with expectations.
- Since the beginning of the 20th century, the global mean sea level has risen by around 228 mm. This is making storm surges more damaging, causing more coastal erosion and having the greatest impact on low-lying coastal areas. Around 2.2 billion people, almost a third of the world's population, live within 50 km of the coast.

Key indicators of global climate change 2024:

What's changed since AR6?

Human induced warming is increasing at the **unprecedented rate** of over 0.2°C per decade, the result of greenhouse gas emissions being at an all-time high over the last decade, as well as reductions in the strength of aerosol cooling.