Mauna Loa carbon dioxide forecast for 2027: Unprecedented El Niño boosts forecast atmospheric CO_2 rise toward record levels

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A 'first-look' forecast of the 2026-27 increase in atmospheric CO_2 suggest a very large rise, comparable with the record increase in 2023-24, with the unprecedented El Niño magnifying the impact of emissions from fossil fuel burning and land use change. Limiting global warming to 1.5°C would have required the CO_2 rise to have now slowed to around half the rate predicted for the coming year.

We forecast the annual average CO_2 concentration at Mauna Loa, Hawaii to be 3.51 ± 0.52 parts per million (ppm) higher in 2027 than in 2026. As a result, we forecast the 2027 annual average CO_2 concentration at Mauna Loa to be 432.2 ± 0.5 ppm (Figure 1). This will continue the ongoing human-driven rising trend in CO_2 seen in the long-term record of measurements from the Mauna Loa observatory in Hawaii that date back to 1958 (also known as the Keeling Curve). The Mauna Loa record is a good guide to rise in global average CO_2 concentration, which we therefore expect to increase by a similar amount.

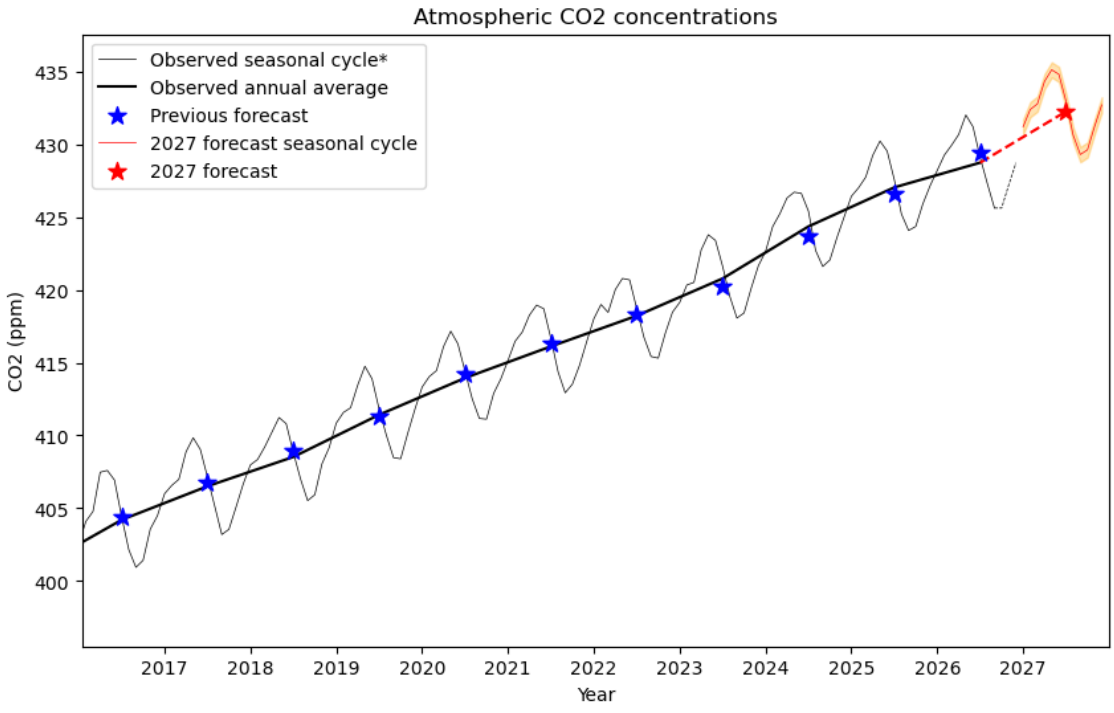


Figure 1: *Forecast CO_2 concentrations at the Mauna Loa observatory, showing monthly (red curve) and annual (red star) values. The orange band shows the forecast uncertainty ranges. The thin and thick black lines show the observed monthly and annual average concentrations respectively. Blue stars show previous forecast annual averages. Observed data is from the Scripps Institution of Oceanography, UC San Diego. *October to December 2026 is a dashed black line as the values are not yet available for observations, these values are calculated using the predicted seasonal cycle from the 2026 forecast*

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The size of the annual CO_2 rise has generally been increasing as fossil fuel emissions have grown, but with substantial variation from year-to-year due to effects of climate variability on carbon sinks (Figure 2). The forecast 2026-27 CO_2 increment (3.51 ± 0.52 ppm) is comparable with the largest ever observed rise of 3.57 ppm in 2024, due to the expected unprecedented size of the current El Niño event.

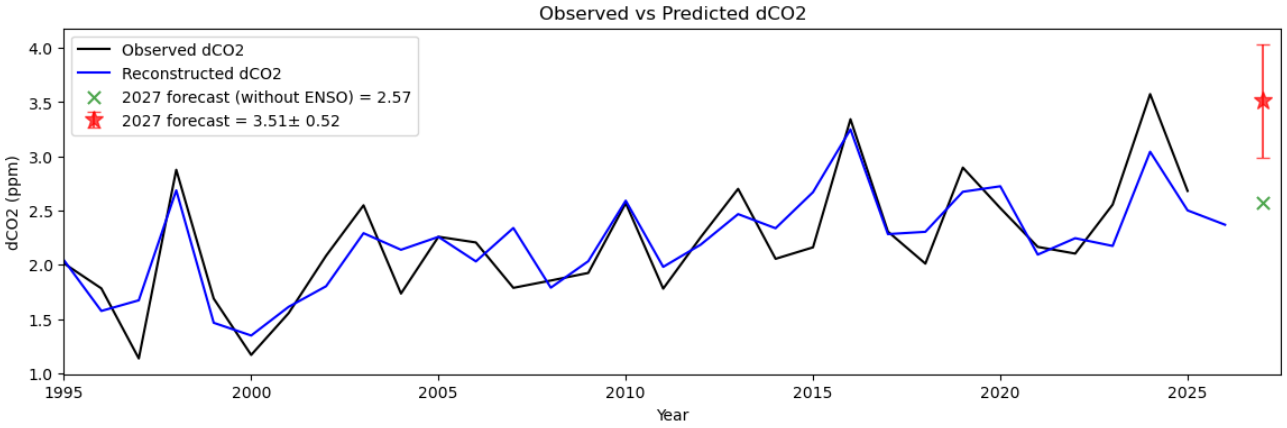


Figure 2: *Annual increments in CO_2 concentration at the Mauna Loa observatory from observations (black) and the 2027 forecast (red star). The forecast uncertainty range (red bar) is ± 2 standard deviations. The blue line shows statistical reconstructions of past annual CO_2 increments using the same method as used in the forecast. Observations are from the Scripps Institution of Oceanography, UC San Diego.*

Contributions of anthropogenic emissions and varying natural carbon sinks to the CO_2 rise:

Long-term increases in observed CO_2 are the result of human-caused emissions of carbon dioxide into the atmosphere – more than enough CO_2 has been emitted by fossil fuel burning and deforestation to account for the increase measured in the atmosphere. Although CO_2 concentrations have now increased by over 50% since the industrial revolution, this increase would have been almost twice as large if some CO_2 had not been removed from the atmosphere through natural absorption by plants and the oceans.

These natural sinks of carbon vary in strength from year to year due to short-term fluctuations in climate, principally linked to El Niño Southern Oscillation (ENSO) cycles in the tropical Pacific Ocean, but with other aspects of climate variability also having effects. This means that although emissions are increasing relatively smoothly, the rate of CO_2 increase in the atmosphere shows more year-to-year variability due to the varying strength of natural carbon sinks. El Niño conditions typically lead to a faster annual CO_2 rise, due to an overall weakening of natural carbon sinks, largely driven by hotter, drier conditions in tropical land areas. The Met Office CO_2 forecast takes account of both anthropogenic emissions and the impacts of ENSO-related climate variability on natural carbon sinks, accounting for the latter using the observed correlation between the annual CO_2 rise and sea surface temperatures (SSTs) in the equatorial Pacific Ocean (Figure 3).

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Producing this forecast in October, we use an annual mean SST anomaly in the Niño3.4 region combining observations from the previous April to August with a forecast from September to March the following year (Figure 4). With the recent development of historically strong El Niño conditions, observations and forecasts lead to an estimated April-March mean Niño3.4 SST anomaly of 2.25 ± 0.17°C. This is the highest April-March annual Niño 3.4 value obtained in 10 years of making these forecasts, and a substantial weakening of land carbon sinks has already been predicted. Consistent with this, we predict one of the largest rises in atmospheric CO_2 on record.

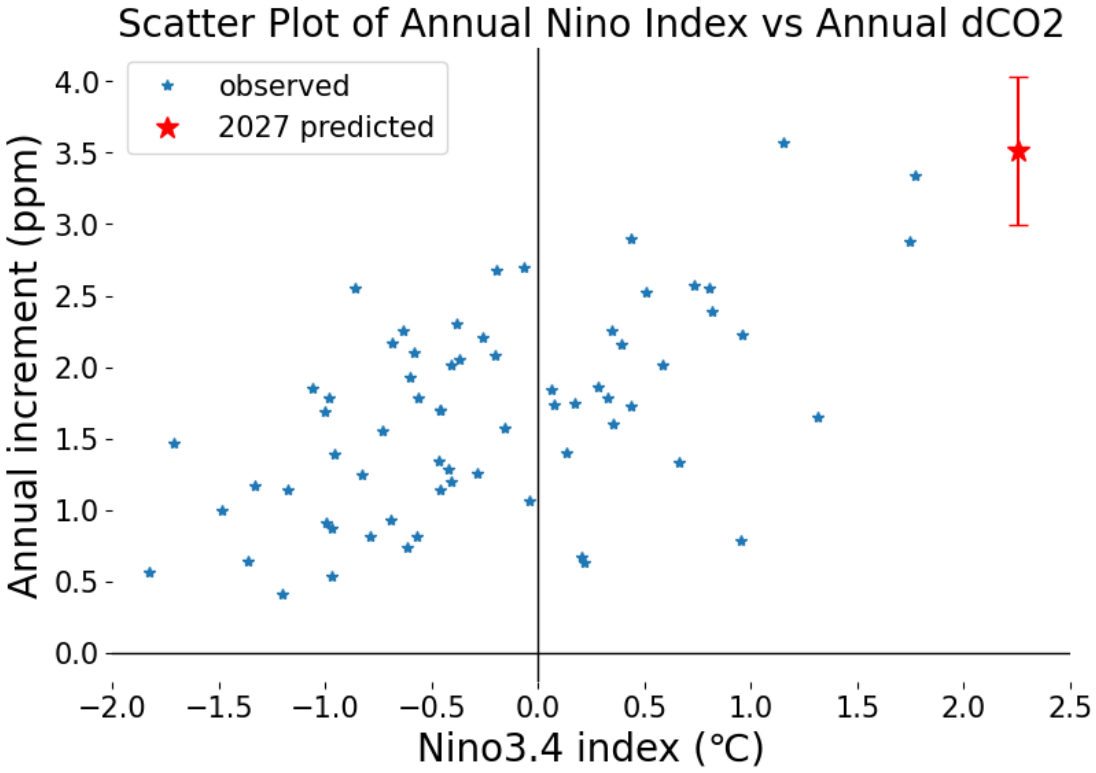


Figure 3: *Annual CO_2 increment for years 1960 to 2025 and predicted for 2027 (red star) relative to the preceding year, vs. the Niño3.4 index for April of the preceding year to March of the current year. The forecast uncertainty range (red bar) is ± 2 standard deviations. The Niño3.4 index is the sea surface temperature (SST) anomaly in region 5°N to 5°S and 170°W to 120°W in the Pacific Ocean. CO_2 increment observations are from the Scripps Institution of Oceanography, UC San Diego. Note 2026 is not included in this figure as we do not yet have a full year of observations.*

For short periods such as individual years, the observed rate of build-up of CO_2 in the atmosphere does not necessarily reflect changes in emissions – the effects of climate variability on the short-term rise can dominate. However, in the longer term, the ongoing increase in the annual rate of CO_2 rise is quite evident despite large interannual variability (Figure 5). When the effects of ENSO are removed, the calculated CO_2 rise shows an ongoing increase, but with the rate of increase slowing around 2012 due to the slowing of the rise in global emissions. There was also a temporary slowing of the ENSO-adjusted CO_2 rise in 2020 due to the reduction in global emissions following worldwide reductions in transport and energy production during the COVID-19 pandemic.

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Impact of El Niño on the forecast CO_2 rise in 2027:

The annual averaged Niño3.4 value is taken between April 2026 and March 2027. We therefore combined the observational HadSST4 data for April to August with the GloSea6 predicted data for September to March (Figure 4). This produces an annual average Niño3.4 value of 2.25±0.17. Figure 4 shows the observed and predicted development of the 2026-27 El Niño, compared to 2015-16 and 2023-24 recent significant El Niño events. This highlights the magnitude and rapid escalation seen in this year's El Niño event.

The 2026-27 El Niño is predicted to be the largest in modern history. The HadSST4 dataset showed Niño 3.4 region anomalies of 2.9°C (2.6-3.2°C) in September 2026, which are predicted to rise to a maximum of around 3.6°C in November (GloSea6). This El Niño also developed very quickly through the early part of 2026.

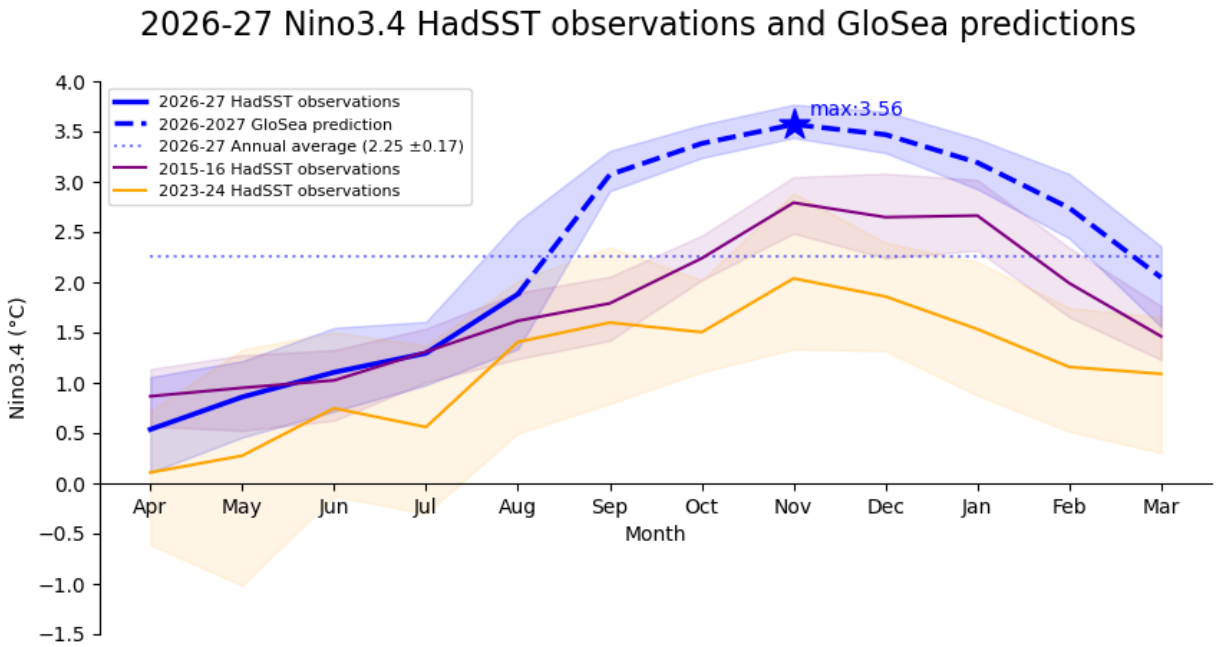


***Figure 4**: Monthly Niño3.4 index for 2027 over April-March period. Solid blue line (April26-Aug26) is for observed values from HadSST4 and the dashed blue line is the predicted values (Sept26-Mar27) from GloSea6. The dotted blue horizontal line is the 2027 annual average from these observations and predictions (2.25±0.17). The purple and yellow lines show the shape and magnitude of observed Niño3.4 index from 2015-16 and 2023-24 respectively, which are two strong El Niño years from recent history. Shaded areas show the monthly ensemble ranges for each year in their respective colours*

We can estimate the potential contribution of growing strong El Niño conditions to the CO_2 rise forecast for 2027 by repeating our forecast calculation without the sea surface temperature change, ie: with "neutral" conditions. This suggests that without the El Niño effect on tropical land ecosystems, the forecast annual mean CO_2 rise from 2026 to 2027 would be 2.57 ppm, a significantly slower rise than the 3.51 ppm forecast when accounting for El Niño (Figure 5).

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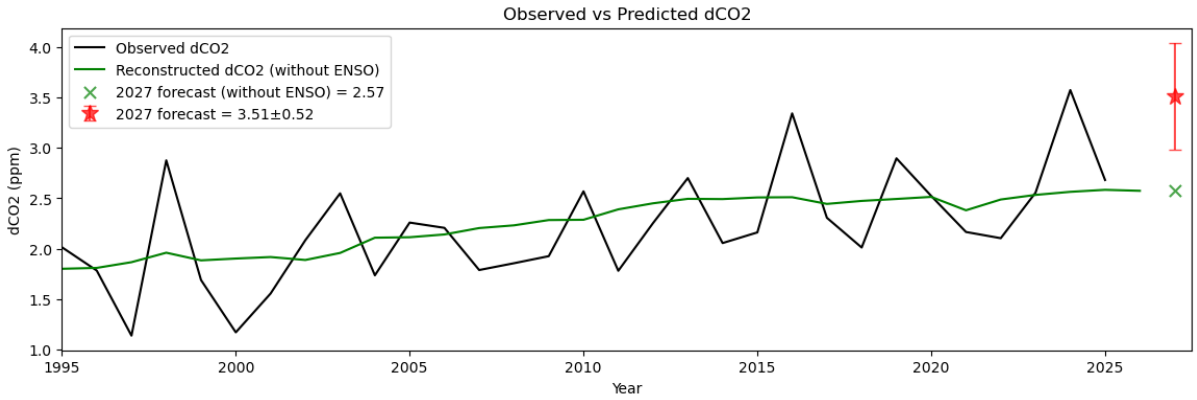


***Figure 5**: Annual increments in CO_2 concentration at the Mauna Loa observatory from observations (black) and the 2027 forecast (red star), and the estimated increments without the influence of ENSO (green line and green cross). The forecast uncertainty range (red bar) is ± 2 standard deviations. Observations are from the [Scripps Institution of Oceanography, UC San Diego](#).*

Comparison with previous annual CO_2 increments

The average annual CO_2 rise has increased over the 6 decades of the Mauna Loa record (Table 1), due to ongoing rise in human-caused emissions, mainly due to fossil fuel burning. With emissions remaining at very high levels and a unprecedented El Niño event, the forecast rise of 3.51±0.52 ppm for 2026-27 would rank among the highest annual increments recorded, similar to the record rise seen in 2024, with an uncertainty range of between the 1st and 3rd largest (Figure 6).

Despite the 2027 forecast increment (3.51 ± 0.52 ppm) being comparable to the observed 2024 value (3.57), the 2024 Niño3.4 index was only 1.15°C (0.60-1.68°C), compared to the predicted 2.25°C in 2027, so the high forecast 2024 CO_2 increment was not driven only by El Niño, see Figure 3. 2024 was an abnormally warm year due to other factors in addition to the El Nino some of which also impacted the CO_2 rise (see [2025 forecast](#)).

Table 1. Decadal average annual CO_2 rises in the Mauna Loa record

Decade	Average CO_2 rise (ppm per year)
1960s	0.86
1970s	1.22
1980s	1.58
1990s	1.55
2000s	1.91
2010s	2.41

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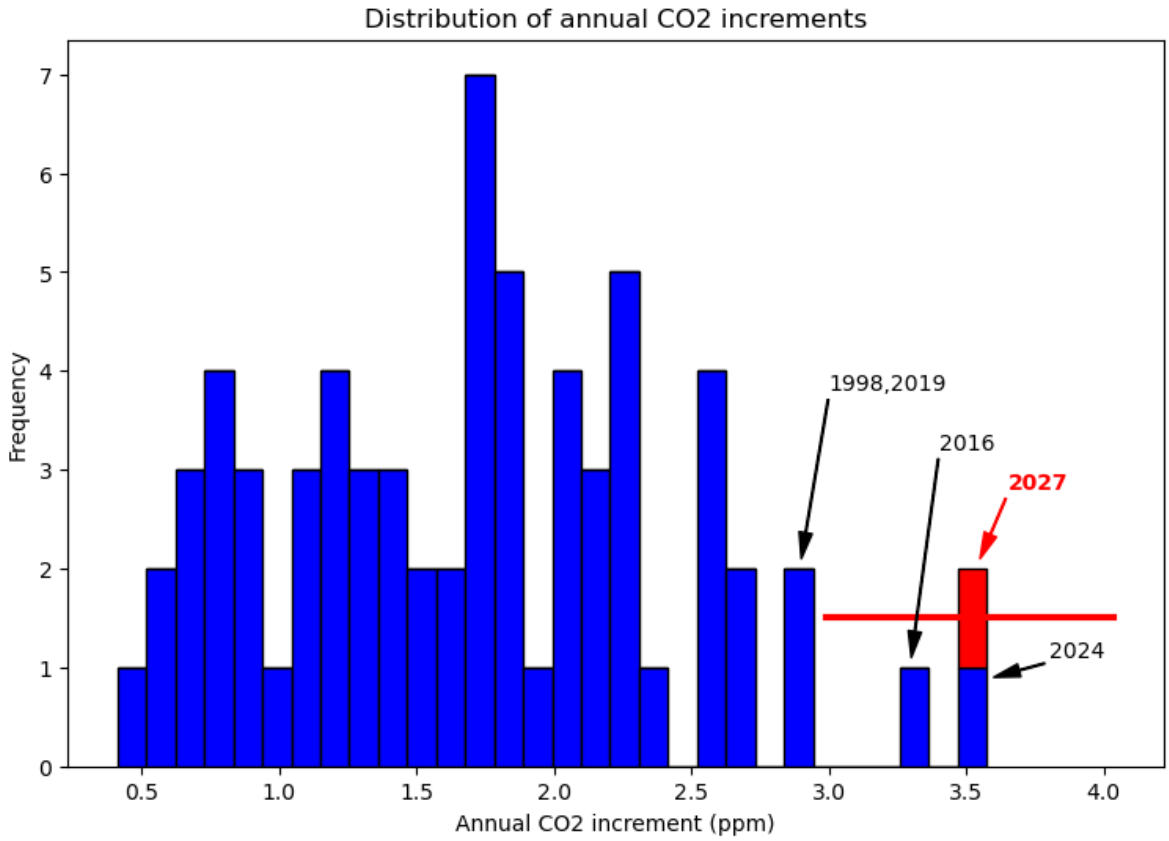


Figure 6: *The central estimate of the forecast annual CO_2 increment for 2026-2027 in the context of the frequency distribution of observed annual increment for each year in the Mauna Loa record. The horizontal red bar shows the forecast uncertainty range of ± 2 standard deviations. Observations are from the Scripps Institution of Oceanography, UC San Diego. Note 2026 is not included in this figure as we do not yet have a full year of observations.*

Comparison with CO_2 trajectory consistent with limiting global warming to 1.5°C

The Paris Agreement commits nations to pursuing efforts to limit the rise in global temperatures to 1.5°C above pre-industrial levels. In modelled scenarios that achieve this, the rise in atmospheric CO_2 slows rapidly and ceases completely within the next two decades. The IPCC 6th Assessment Report included 3 scenarios which have at least a 50% likelihood of limiting global warming to 1.5°C with little or no overshoot (Table 2). The C1-IMP-LD scenario features efficient resource use and changing consumption patterns leading to low demand for resources; C1-IMP-REN focusses on renewables; and C1-IMP-SP illustrates shifting global pathways towards sustainable development. Other scenarios could also be followed, but all would require the rise in CO_2 to be slowing to zero urgently for global warming to be limited to 1.5°C, unless interventions such as solar radiation modification were assumed.

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The IPCC scenarios can provide a benchmark against which the observed and forecast atmospheric CO_2 rise can be compared as part of assessing progress towards the Paris Agreement goal. All three scenarios require the decadal average rate of rise in the 2020s to be 1.33 to 1.79 ppm/year, slower than the average rate of 2.41 ppm/year seen in the 2010s, but for the first 5 years of the 2020s the average rate of rise observed at Mauno Loa was faster at 2.61 ppm / year.

Figure 7 makes a more detailed comparison with the C1-IMP-SP scenario, which is the least ambitious of the three scenarios in the near term, allowing for the fastest CO_2 rise in the 2020s. The central estimate of the forecast rise for 2026-2027 (red star) remains above the rate required to track the 1.5°C-compatible scenario. This is also the first year where the lowest point of our forecast uncertainty (vertical red bar) exceeds the 1.5ºC scenario and even without the effects of climate variability (green star) the 2027 rise would still be above the 1.5°C scenario.

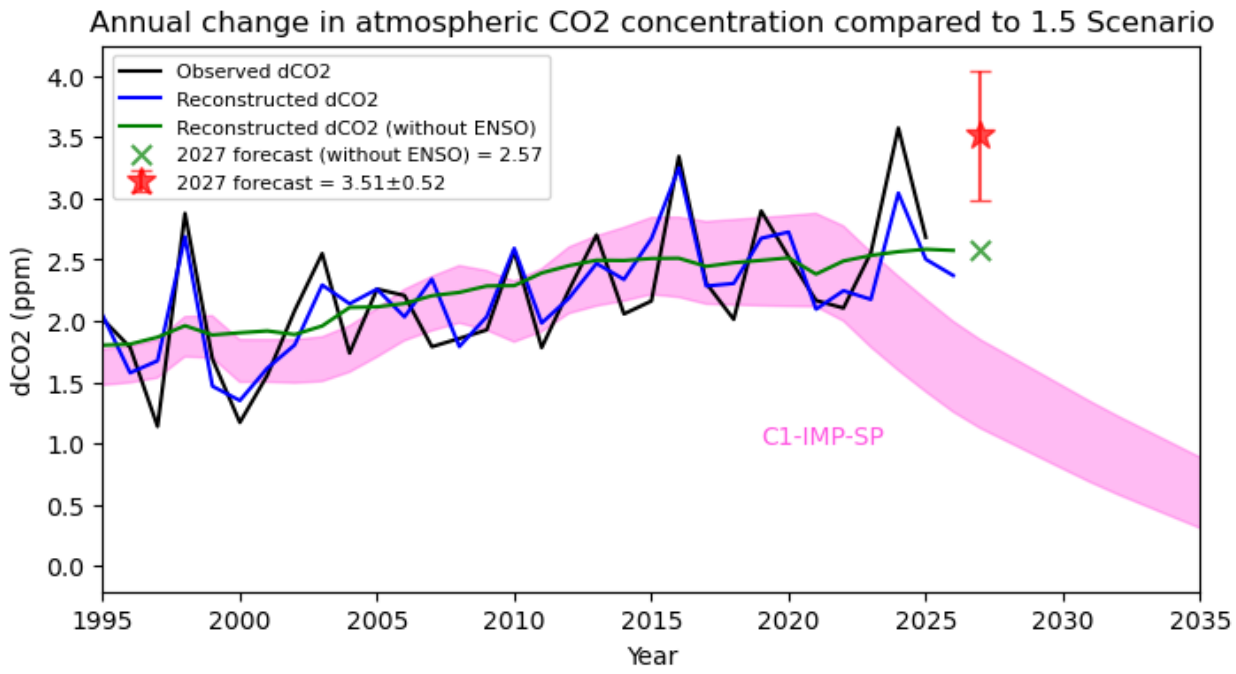


Figure 7: *Comparison of recent and forecast annual CO_2 increments with an illustrative scenario limiting global warming to 1.5°C. Black line: Annual increments in CO_2 concentration at the Mauna Loa observatory from observations. Blue line: Annual increments in CO_2 concentration at the Mauna Loa observatory reconstructed using a statistical relationship between concentrations, emissions and ENSO. Red star with vertical error bars: the 2027 forecast increment. Green line and green cross: Estimated increments without the influence of ENSO. Purple plume: simulated CO_2 concentrations in the C1-IMP-SP scenario limiting global warming to 1.5°C with >50% likelihood. Observations are from the Scripps Institution of Oceanography, UC San Diego.*

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Table 2. Decadal average CO_2 rises in three illustrative scenarios limiting global warming to 1.5° with little or no overshoot (IPCC 2022), compared with observed average in the first half of the 2020s.

Decade	Average CO_2 rise (ppm per year)			
	C1-IMP-LD	C1-IMP-REN	C1-IMP-SP	Observed
2020s	1.33	1.75	1.79	2.61 (2020-2025)
2030s	-0.14	0.13	0.57	
2040s	-0.53	-0.46	-0.07	
2050s	-0.65	-0.61	-0.41	

The extent to which the CO_2 rise would need to slow for global warming to be limited to 1.5°C can be further put into context by extending the Keeling Curve with projected concentrations from one of the illustrative 1.5°C-compatible scenarios (Figure 8). The observed rises from 2024 to 2025, and 2025 to 2026 were already tracking above the 1.5°C scenario, and the gap is predicted to increase in 2027.

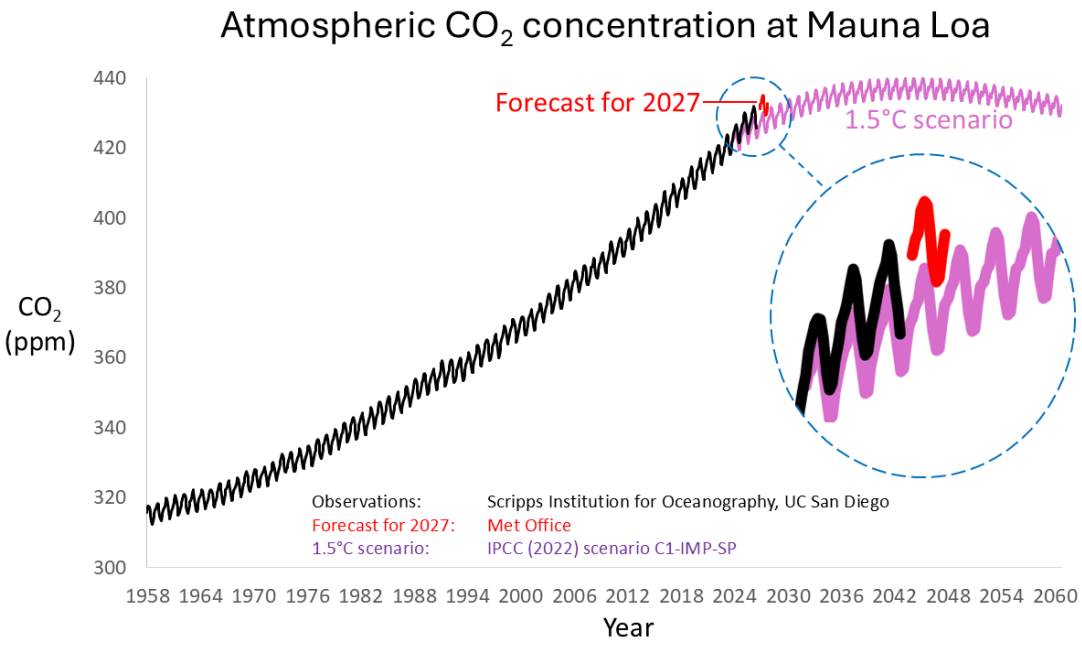


Figure 8: *Monthly CO_2 concentrations from observations up to September 2027 (black) and a scenario consistent with limiting global warming to 1.5°C (purple). Also shown is the Met Office forecast for 2027 (red). Observations are the Keeling Curve record at Mauna Loa, from the Scripps Institution for Oceanography, UC San Diego, which began in March 1958. From 2024 onwards, monthly values are calculated from the annual mean concentrations in the C1-IMP-SP scenario, with an illustrative seasonal cycle imposed which continues the amplitude seen in recent years.*

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Seasonal cycle of CO_2 concentrations

We also predict the maximum and minimum monthly values in the seasonal cycle of CO_2 concentrations at Mauna Loa (Figure 1, Table 3). Each year, the CO_2 value at Mauna Loa increases in the first 5 months, peaks in or around May, then declines for the next 4 months due to the uptake of CO_2 by land ecosystems in the northern hemisphere growing season. Following a minimum, which is usually in September, atmospheric CO_2 then increases again as autumn and winter leaf-fall and decay cause a release of CO_2 back to the atmosphere. In 2027, we predict this seasonal cycle to peak at a monthly mean value of 435.1 ± 0.5 ppm in May (Figure 9, Table 3). From comparison with reconstructions of past CO_2 levels from isotopes of carbon and boron in marine sediments, this will be the highest atmospheric CO_2 concentration for over 2 million years. CO_2 will then return to a minimum monthly value of 429.3 ± 0.5 ppm in September before rising again.

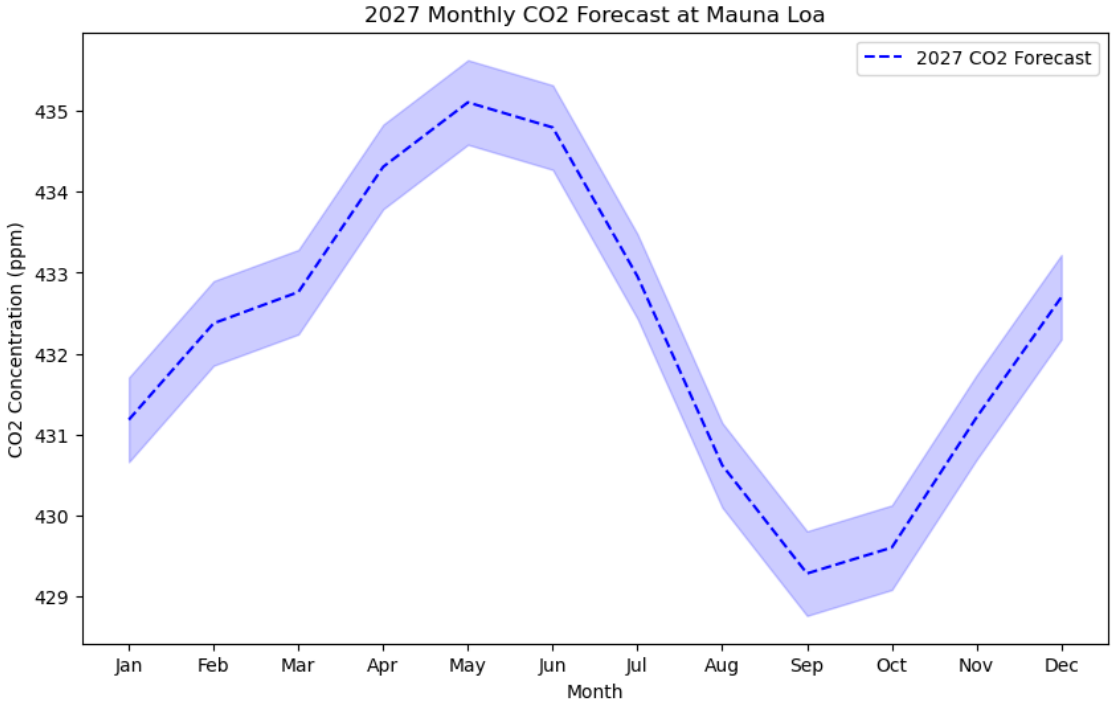


***Figure 9**: Forecast monthly CO_2 concentrations (seasonal cycle) in 2027 at Mauna Loa (dashed blue line). The shaded blue area shows the forecast uncertainty range (2 standard deviations).*

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Table 3. Forecast monthly average CO_2 concentrations at Mauna Loa in 2027. The 2 standard deviations uncertainty is ± 0.5 ppm

Month	Forecast CO_2 concentration (ppm)
January	431.2
February	432.4
March	432.8
April	434.3
May	435.1
June	434.8
July	433.0
August	430.6
September	429.3
October	429.6
November	431.2
December	432.7

Methods and Uncertainties

The technique* used to make this forecast was also used to make forecasts ahead of time for 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023 and 2024, 2025 and 2026. In 2020 we also issued an updated forecast once it became clear that the response to the Covid-19 pandemic would cause global CO_2 emissions to be much smaller than expected that year.

***Note for 2026**: This year's forecast is being released earlier than in previous years. We are therefore using three additional months predicted values for Niño3.4 index (between Sep26-Mar27) to input into the 2027 forecast, whereas normally we would have observed values up to and including November. We also do not have the full year of CO_2 observations for 2026 yet so cannot currently perform the full verification of previous forecast. Also, the primary quantity we are predicting is the annual increment between 2026 and 2027. The predictions of absolute CO_2 concentrations for 2027 require a baseline annual mean concentration for 2026, which we have estimated by assuming the monthly concentrations in the remainder of the year follow the 5-year average seasonal cycle. The observed values may differ and hence this introduces an additional uncertainty in the prediction of the absolute CO_2 concentrations, which we have not attempted to quantify.

Our usual methodology uses a statistical relationship between the annual CO_2 rise, human-caused emissions and changes in sea surface temperature (SST) in the equatorial Pacific Ocean as a measure of the strength of the dominant pattern of natural climate variability that is known to affect the strength of carbon sinks. We use an average of SSTs from ocean observations in recent months and seasonal forecasts for the coming months. Previous work found that the CO_2 increment between 2 consecutive calendar years correlates most strongly with the SSTs in the 12 months from April to March within those 2 years.

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For most our forecast calculations used the annual emissions from the previous year as published in the Global Carbon Budget (GCB), as normally the ongoing trend in emissions is not large enough to affect the forecast substantially. The GCB estimate of emissions for 2026 is not yet available, so we have used the 2025 emissions here.

In our forecast we assign the same uncertainty to monthly and annual values, but this ignores the role of within-year impacts such as periods of fire activity in areas not typically affected by ENSO, or anomalous wind directions at the measurement site at Mauna Loa. Quantification of these additional sources of uncertainty at monthly levels are a topic of ongoing research and our stated uncertainty on the monthly averages will therefore be an underestimate.

The seasonal cycle is calculated by averaging the seasonal cycle shape of the last 5 years and impose this on our forecast annual average. There are clear oversimplifications here, but is normally a good indication of seasonal cycle shape. However, it is likely that strong El Niño year like that predicted for 2027 will not present with a 'regular' seasonal cycle shape.

As the 2027 forecast is driven significantly by the strong El Nino, and one to this magnitude has not been experienced in recent history, there is a level of uncertainty as to how the earth system will respond to such extreme and hence how well this simple but historically accurate CO_2 forecast will fair.

Verification of 2026 CO_2 forecast

The observed monthly 2026 CO_2 concentrations were lower than or equal to the central estimate of the forecast for every month in current observations (Jan-Sept) (*from the Scripps Institution for Oceanography, UC San Diego*) (Figure 10, Table 4) and multiple of these observations sit outside of even the 2-sigma uncertainty range (±0.6ppm) of our forecast. Therefore, we expect that our 2026 annual forecast of 2.37 to be an underprediction. Once the final months of 2026 observational data are available, a more detailed verification of the 2026 forecast can be performed.

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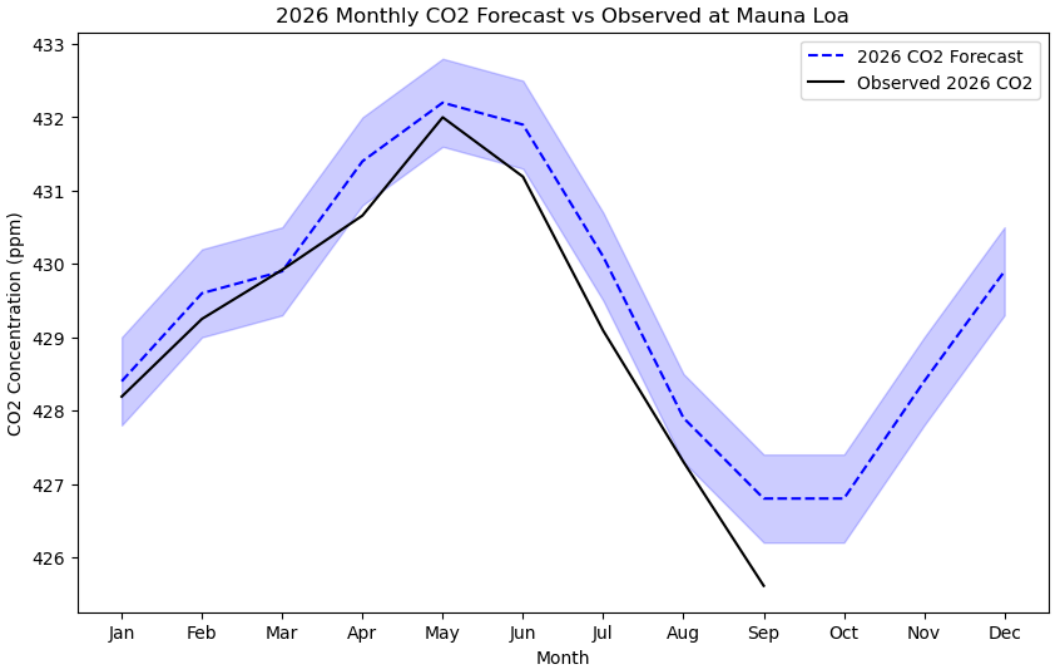


Figure 10: *Comparison of Met Office forecasts of monthly CO_2 concentrations in 2026 at Mauna Loa (dashed blue line) with measurements for 2026 (solid black line) from the Scripps Institution for Oceanography UC San Diego. The shaded blue area shows the forecast uncertainty range (2 standard deviations). Note that at the time of publishing observational values for Oct-Dec were not yet available.*

Table 4. Forecast and observed monthly average CO_2 concentrations at Mauna Loa over 2026. The uncertainty in the forecast values was ±0.6 ppm. Observed monthly averages for January to Septemeber are those published by the Scripps Institution for Oceanography at UC San Diego.

Month	Forecast (ppm)	Observations (ppm)
January	428.4	428.2
February	429.6	429.3
March	429.9	429.9
April	431.4	430.7
May	432.2	432.0
June	431.9	431.2
July	430.1	429.1
August	427.9	427.3
September	426.8	425.6
October	426.8	
November	428.4	
December	429.9	

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Note: definitions of annual CO_2 rise, increment and growth rate

We define the annual CO_2 rise or annual increment for a particular year as the difference in annual average concentration for that calendar year and that of the previous calendar year. This is different to the definition of annual 'growth rate' as published by NOAA which is the average change across an individual calendar year.

Acknowledgements

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