How close are we to 1.5 degC or 2 degC of global warming?

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What is meant by 1.5 degC or 2 degC of global warming?

The Paris Agreement stated that global warming should be kept to well below 2 degC and if possible limited to 1.5 degC, relative to pre-industrial times. However, the Agreement neither defined what is meant by a particular global warming level nor which period to define as pre-industrial. The research community has resorted to pragmatic approaches on these two questions. While CO_2 emissions from fossil fuel combustion started to increase rapidly in the eighteenth century with the start of the industrial revolution in Britain, accurate estimates for the global surface temperature are possible only for the period after 1850. Therefore, global warming levels are usually defined relative to the average over the period from 1850 to 1900. To acknowledge that individual years show temperatures fluctuating above and below the mean climate, by around plus or minus 0.15 degC, a global warming level is often defined as the average over twenty years. A global warming level of 1.5 degC or 2 degC therefore means that a twenty-year period has an average global surface temperature that is higher than the average over 1850 to 1900 by 1.5 degC and 2 degC, respectively.

What determines how quickly a certain global warming level is approached?

First, it is important to note how much global warming has already occurred. According to the latest IPCC report (IPCC, 2021), global warming during the first twenty years of this century (2001–2020) has reached 0.99 degC, relative to the period 1850 to 1900; the uncertainty range for this warming spans from 0.84 degC to 1.10 degC. Second, since the emissions of greenhouse gases, especially CO_2, will continue during the near future, the concentrations of greenhouse gases will continue to increase, and global surface temperature will continue to rise. The rate of the temperature rise depends on how the emissions will evolve but also on the sensitivity of the climate system to the increase in greenhouse gases. The next twenty years are expected to be warmer globally than the average over the period 2001 to 2020, by between 0.3 degC and 0.7 degC.

So when should we expect to reach or cross 1.5 degC of global warming?

Three things must come together to increase our chances of keeping global warming below 1.5 degC, two of which are outside our control: First, emissions must drop quickly and persistently – something we can control; second, climate sensitivity must be on the lower end of the estimates; and third, the historical warming must also be on the lower end of the estimates. For central values of climate sensitivity and historical warming, global warming of 1.5 degC is expected to be reached during the next twenty years, irrespective of future emissions (Figure 1). Should CO_2 emissions reach net-zero during the next thirty years and turn net-negative thereafter, and if other greenhouse gas emissions also drop, temperatures may well drop below 1.5 degC again. Under all other circumstances, however, global warming will exceed 1.5 degC.

How long will we have until 2 degC might be crossed?

The latest IPCC report concludes that if emissions remain at their currently high level or even increase, global warming of

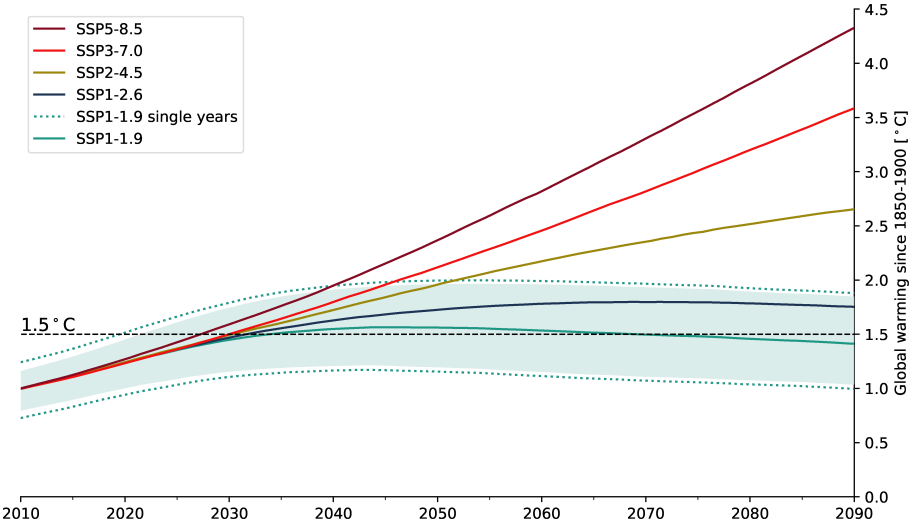

Figure 1. Future global warming depends on how emissions evolve and thus on humans' decisions. Each colour corresponds to one particular scenario of future emissions, ranging from very low CO_2 emissions (implying rapid, strong, and sustained emissions reductions; green) to very high CO_2 emissions (dark red). Shown are global warming levels as a function of time, for each scenario; note that since global warming is defined as an average over twenty years, the years on the x-axis indicate the midpoint of a twenty-year period. The curves show the most likely temperature for a given time and a given scenario; the green shading indicates the uncertainty range for the very low scenario, arising from uncertainty in climate sensitivity and historical warming. For the other scenarios, the uncertainty ranges are roughly similar but somewhat larger. The dotted line represents the additional uncertainty if year-to-year fluctuations are considered. Single-year exceedance of 1.5 degC could occur before the 1.5 degC global warming level would be reached.

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2 degC will be crossed by mid-century. On the other hand, if CO_2 emissions begin to decrease quickly and reach net-zero by around 2070, with substantial declines in other greenhouse gases, too, global warming of 2 degC can reasonably confidently be avoided.

What does it mean if some regions or a single year warm by more than 1.5 degC?

The air over land has warmed more than the air over the ocean, so some regions (such as Germany) have already experienced more than 1.5 degC long-term warming, although globally the level of 1.5 degC has not been exceeded. Likewise, if global temperature rise lies above 1.5 degC in just a single year, this does not mean that the long-term warming level of 1.5 degC has been exceeded. For that, the exceedance would have to occur persistently. However, the closer the world comes to a global warming level of 1.5 degC, the more likely it is that individual years exceed a temperature rise of 1.5 degC. The current chance of a single year reaching 1.5 degC is only around 10% (Smith *et al.*, 2018; WMO Lead Centre for Annual-to-Decadal Climate Prediction, 2020), but by 2030 the chance will be roughly fifty-fifty that an individual year shows a global temperature rise above 1.5 degC.

What are the consequences of exceeding global warming of 1.5 degC or 2 degC?

The latest IPCC report stated that every half-degree in global warming would lead to a discernible increase in the risk from climate change. Every increment leads to additional changes in temperature and rainfall, with extreme heat or drought being substantially more intense and frequent at 2 degC than at 1.5 degC. Hartley and Turnock (2021) describe how rapid and strong mitigation can avoid impacts to human and natural systems around the world.

That said, it is important to remember that there is no sharp distinction between safe and dangerous climate conditions. Even in an unchanging climate, weather extremes such as heat waves, flash floods, storm surges, and destructive storms happen. However, on a global scale, such events will happen more frequently the higher the global warming level. Nevertheless, at any level of global warming that might have been reached, cutting our emissions and preventing even more warming will avoid additional risks from climate change.

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Obituary

Ronald Saunders

Ron Saunders, a frequent contributor of photographs to *Weather* and active promoter of the Royal Meteorological Society (RMetS) over the last 40 years, died of natural causes on 2 November 2020 at the age of 87. His daughter was by his bedside.

Ron was born in Stockton-on-Tees in 1933. His early passions included steam engines and cycling. Through his adult life, he pursued a career as a structural engineer and developed a great love for photographing the natural world: the weather, wildflowers, butterflies and fungi featured heavily. He pursued this hobby actively, both in this country, and when travelling with his wife Liz, most often in recent years during trips to the USA.

His interest in weather was perhaps given a fillip by his son's hobby and later profession – the latter started working for the Met Office in 1986. In the 1980s, Ron became a regular contributor of weather photographs to various publications; his pictures adorned the cover of many issues of *Weather* and RMetS calendars, as well as the pages of various weather books. One photograph of his of a rainbow was displayed in The Science Museum in London for several years. In 1988, two of his submissions to *Weather* were 'particularly commended' and later he was awarded the RMetS's *James Paton Memorial Prize* in both 1997 and 2003. In 2002, he was also awarded the *Gordon Manley Weather Prize* for his 'outstanding contribution' to *Weather*, relating to the long-running and regular series of published photographs: since 1983, well over 50 of his photographs were published in *Weather*.

Ron is survived by his son, Frank, and daughter, Ruth, who will continue to miss him and his unstinting enthusiasm in so many directions.

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