Central Coast Climate Science Education
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Is the rapid rise of global temperature now occurring "unprecedented?

For whom this essay is intended

A general audience without an extensive science background

Is the rapid rise of global temperature now occurring "unprecedented"?

Many readers will, by now, have heard that 2023 set a new record for the average global temperature. This record dates back to roughly 1880 when enough thermometers were distributed around the globe that a meaningful average of the global surface temperature, including both the ocean and land surfaces, could be obtained. (The popular press sometimes mis-states this to say that "2023 was the hottest year ever" which is not true, since several tens and hundreds of millions ago there were periods when it was much hotter than today--but these were changes occurring very slowly over vast stretches of time. It is possible, however, that 2023 *was the hottest* year in the last 100,000 years.

Below is the latest plot of the earth's surface temperature, averaged over the earth's surface:

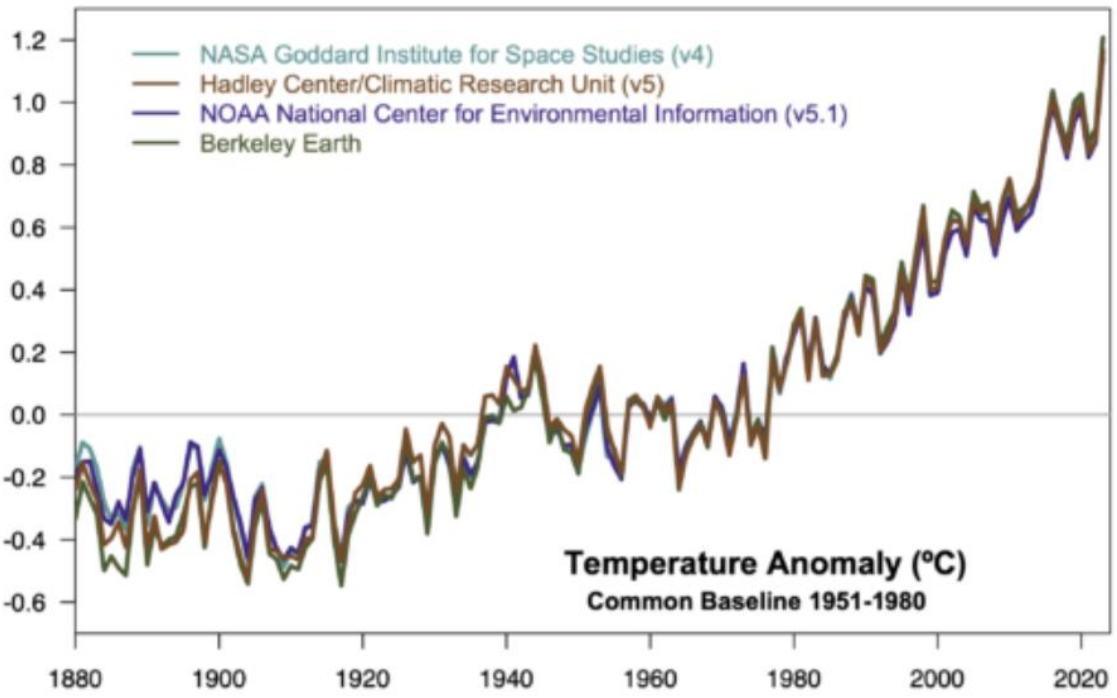

Figure 1. The plot of the global surface temperature averaged over the land and ocean surfaces[1]. Note three things: First, the temperature is on the centigrade scale. (To convert the graph to the Fahrenheit scale multiply by 1.8.) Second, the graph shows, not the actual temperature, but for each year the temperature for that year compared to the actual temperatures averaged over the years 1951 to 1980. (To convert these temperatures to the approximate actual centigrade temperature, add 15 degrees.) Third, there are actually 4 different results plotted, which are determined independently by 4 different research groups, but they are barely distinguishable.

For those of you who follow news about the climate closely, you may have also heard something like "this flood", or "this drought" or "this heat wave" or "the intensity of this tropical storm" was "unprecedented". All these climate extremes are driven by global warming.

In response to all these reports about the current temperature rise being 'unprecedented', I received an inquiry from a reader asking what the evidence actually is for the rapidity of current global warming being unprecedented.

Thus, in this essay we examine the question: Is the *rate* at which this rise has occurred unprecedented? The *rate* of increase, not just the amount of temperature increase itself, is important because this affects the ability of not only the 8 billion humans on this planet to adapt to the consequences of this warming, but also the ability of many animals and plants to adapt to such a rapid increase.

As figure 1 shows, over the last 100 years the global temperature rose by about 1.2 ºC or at a rate of 0.12 ºC per decade. Over the last half century, from about 1973 to 2023, the rate was higher still--about 0.18 ºC per decade.

Simply posing the question as to whether this rate is 'unprecedented' is meaningless unless some limiting past time is specified. This is because, before the start of the record based on actual thermometers, one must rely on "proxies" or stand-ins, for thermometers: Proxies are natural records like tree rings, which are sensitive to temperature and can be dated reasonably accurately. Unsurprisingly, the further back in time one goes, the more uncertain the dating of these proxies becomes, as well as their sensitivity to the temperature.

The proxy temperature records for two different times in the past

The temperature record of the last 2000 years.

As suggested above, these records become less definitive as one attempts to go back farther into the past. Thus, we first look the temperature record going back over just the past 2000 years, as shown in this plot:

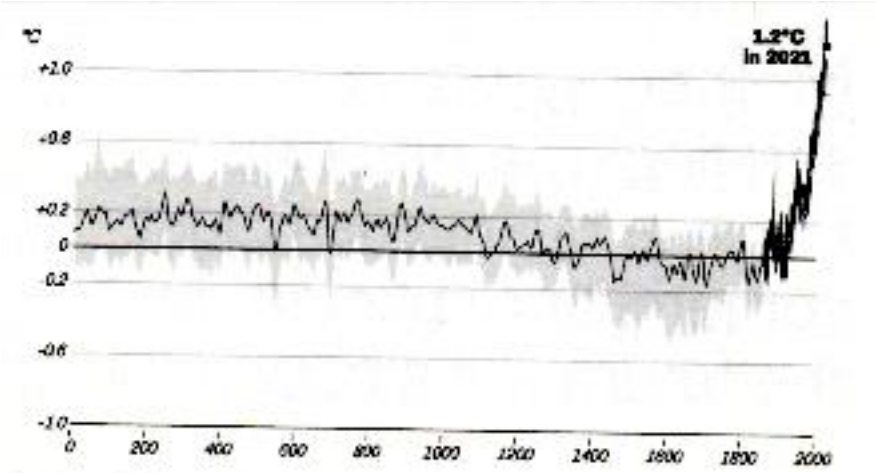

Figure 2. A land temperature determination over the past 2000 years based on temperature "proxies", mainly tree rings and ice cores.[2] As in figure 1, the temperature being plotted is relative to a base line and is once again in centigrade degrees. Note also that these temperature estimates are determined annually, though this graph is too compressed to clearly see each individual year.

The graph in figure 2 is based on tree rings and ice cores. Tree rings are deposited in the trees annually. The width of each ring can be affected by both the temperatur ,and the amount of precipitation, at the time each ring was formed. Careful choice of the tree species as well as the location where the trees grew enables separation of the temperature from the precipitation. For a brief description of recovering climate data from tree ring data, see the reference in this end note[3]. In polar regions, glaciologists drill through the ice and bring up cores of the ice. Similar to the annual tree rings, each year a fresh layer

of ice is deposited and each layer can thus be dated. The detailed composition of the air bubbles trapped in the ice is a proxy for the temperature for that year.

In order to establish the relation between the tree ring data and the actual temperatures, *i.e.* to "calibrate" the data, tree ring specialists compare tree ring data with the actual temperature record shown in figure 1 during some recent time interval which overlaps with the thermometer records, and similarly for the ice cores. To bring the plot up to the present day , the actual temperature record of figure 1 has been attached to the tree ring and ice core data. This is shown by the heavy dark line of figure 2. There is of course uncertainty in the temperature record based on tree ring and ice core data and the estimate of this uncertainty is shown by the light gray shading in figure 2.

It is apparent from figure 2 *that at no other time in these past 2000 years* has there been anything remotely like a temperature rise of the *rapidity and magnitude* shown in figure 1 and the tail end of figure 2. A temperature rise of about 1 ^{o}C over a period of just 50 years would have surely been easily detected.

<u>The temperature record of the last 24000 years.</u>

A recent analysis reconstructed the global temperature going back from about 24,000 years ago to the present.[4] This analysis thus begins near the "Last Glacial Maximum", the last time during the sequence of ice ages when a lot of land, especially in the northern hemisphere, was covered with thick ice. The authors track how the surface temperature changed as the glaciers retreated and was then followed by a long period of quite stable temperatures --up until the very rapid rise in global temperatures shown in figure 1.

The result of this analysis is shown below in my Figure 3 (but labeled as Figure 2 in the publication in which it appeared.)

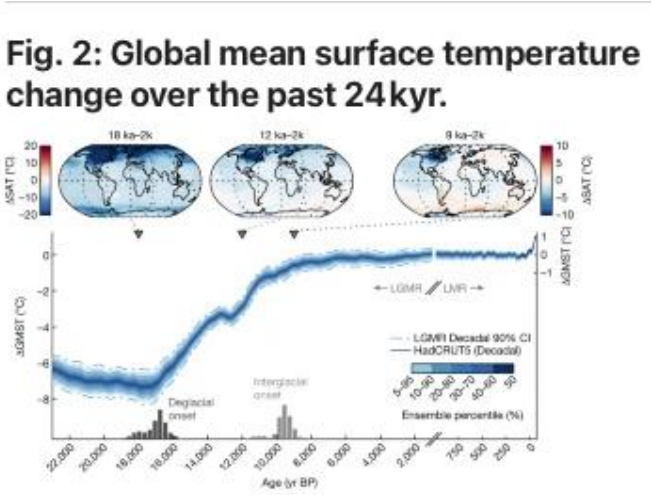

Figure 3. This is "figure 2" of the paper reconstructing the global temperature (shown here over the last 23,000 years, not 24,000 years) to the present. The X axis is the time before the present and the Y axis is the estimated global temperature relative to the sharp current rise. See the text for further discussion of this figure.

This is a rather "busy" graph and has a lot of interesting information on it. But we only need to be concerned with the thick dark blue curve. That curve is the estimate of the global temperature record reconstructed, as before, from "proxies" such as ice cores. The retreat of glaciers began in earnest around 17,000 years ago as the global temperature slowly transitioned to a warming trend.

(For readers interested in more information about the ice ages, see my simplified discussion of the "ice age cycles" here: http://www.centralcoastclimatescience.org/uploads/5/3/8/1/53812733/tutorial-lesson-07-looking-forward-backward-12-16-12.pdf. See here[5] for a more recent discussion.)

This warming was briefly interrupted about 12,000 ago. This was probably due primarily to episodes of sudden releases of fresh, cold water into the Atlantic when "ice dams" broke, releasing cold, "fresh" (salt-free) water into the Atlantic. This slowed, or perhaps even stopped, the ocean currents carrying warm water from more southerly portions of the Atlantic. This resulted in a brief period of significant cooling in portions of the northern hemisphere. Though this cooling can be seen in the global average temperature record, the actual cooling was in higher northern latitudes of North America and Asia rather than globally. *(*There is some evidence that these currents are again slowing because of fresh water from glacier melting associated with the current warming.)

The warming resumed until about 8000 years ago when the Earth entered an "interglacial" period. Since then, the global temperature was remarkably stable. This stability was one factor which enabled the birth of modern civilization and agriculture. Then came the industrial revolution, which saw a large increase in the use of coal, and subsequently oil and natural gas.

Use of these fossil fuels led to the abrupt increase in the amount of carbon dioxide in the atmosphere and with it a rapid increase in the global temperature. This is shown in the right-most part of the blue curve after the small gap in the blue curve between the 2000 year and 750 year tick marks. **Note:** At this point *there is a change of scale in the graph for the time axis of the graph. Prior* to the gap, the time tick marks are every *2000* years, whereas *after* that time the tick marks are every *250* years.

Since the blue curve before change in the time scale covers about 20,000 years, changes in temperature of a degree or so over periods as short as a half century would not be apparent on this graph . This is because it had to be compressed to cover such a long interval of time. We therefore quote the conclusion the authors of this paper draw from their work regarding the question of whether the present rate of warming is unprecedented. Their closing sentence is rather unequivocal: "[Our work] *underscores the dramatic nature of anthropogenic* [i.e. human-caused] *warming, whose magnitude and rate appears unprecedented in the context of the last 24,000 years."*

I have reviewed the evidence that the current rate of warming *is indeed unprecedented*, at least as far back as about 24,000 years. But *even if it were not*, our focus should really be on the *cause of the **current** warming*. There are two reasons for this. First, the present

situation has no counterpart to any time in the past. For one thing, there are now 8 billion people on the planet and we have exerted a marked impact on it. Second, and equally important, the current rapid temperature rise has associated with it changes in the climate, which are increasingly damaging to ourselves and much of the rest of the life on our planet. If we wish to deal with this, we obviously need to know the cause.

In an essay to shortly follow I will therefore review the evidence for the cause of the present unprecedented rate of warming. It will include a powerful line of evidence that is not often discussed. Namely, the fact that while the earth's surface and lower levels of the atmosphere (the troposphere) are warming; the upper levels (the stratosphere) are cooling.

Stay tuned.

LINKS TO REFERENCES:

[1] https://www.realclimate.org/index.php/archives/2024/01/not-just-another-dot-on-the-graph/
[2] This is figure 2, p. 373 in contribution 5.12 by M. Mann in essays assembled by G. Thunberg in The Climate Book, Penguin Press, New York, 2023
[3] https://www.climate.gov/news-features/blogs/beyond-data/how-tree-rings-tell-time-and-climate-history
[4] Osman et al. Nature 599, p.239 2021)
[5] https://en.wikipedia.org/wiki/Ice_age - :~:text=The geological record appears to,the absorption of solar radiation. Scroll down to the heading "CAUSES" and in particular to the subheading "Variations in Earth's orbit."