October 2023

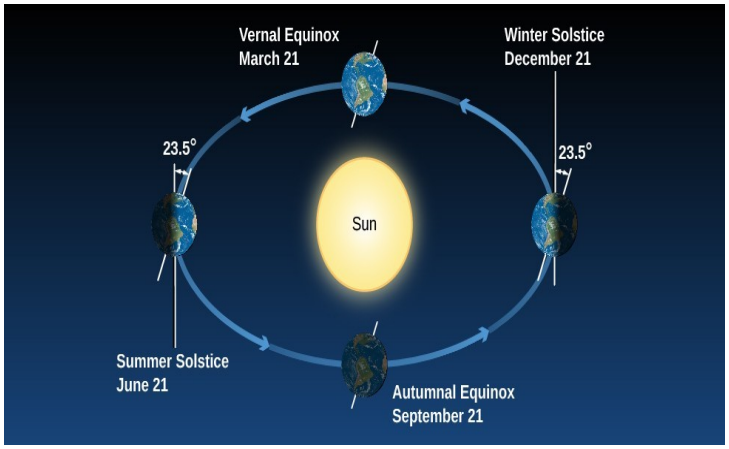
CliSciPol

Climate Science and Policy for Nonscientists

One picture is worth a thousand words.

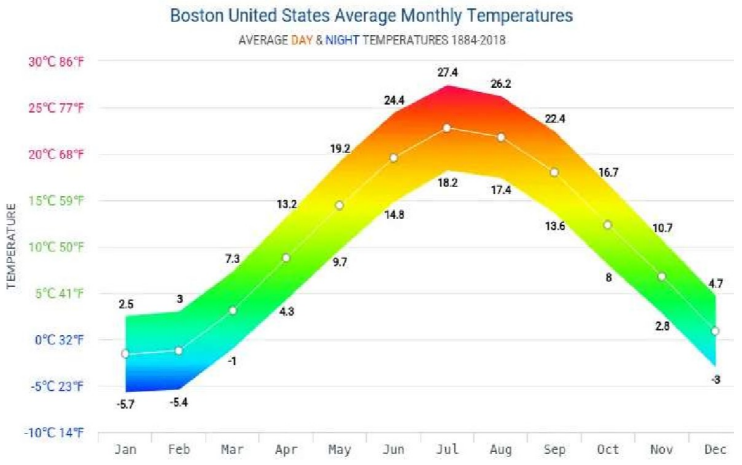
How Much of Post-Industrial Global Warming Has Been Caused by the Sun?

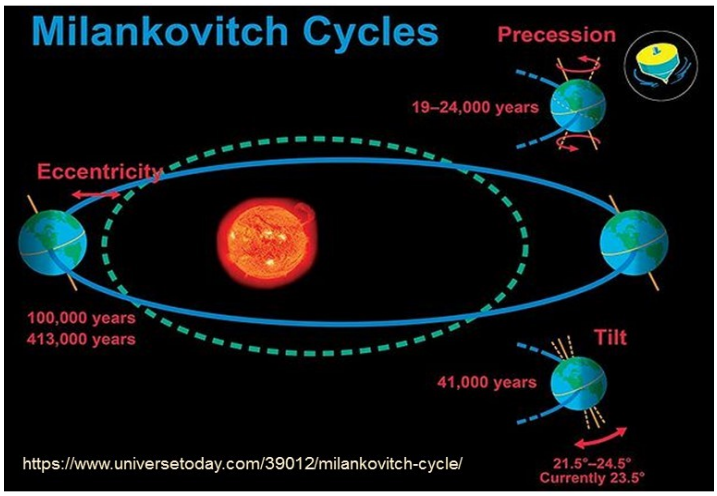
One of the most important issues on which climate scientists disagree is how much of the post-industrial global warming has been caused by the sun. The IPCC has concluded (and virtually all scientists agree) that the world has warmed roughly 1.1 C since the post-industrial period. [AR6 WGI p.5 (2021)]. The IPCC also concludes that the sun has caused virtually *none* of this warming, and that human activity (primarily CO2 emissions) has caused virtually *all* of it. [AR6 WGI p.5, 7]. But there is significant disagreement on these causation issues. What are the two sides of the argument?



Virtually 100% of the earth's heat energy comes from the sun. The world's axis is presently tilted about 23.5 degrees off the vertical in relation to its plane of rotation around the sun (called the earth's "obliquity"). As a result, during summer Boston is closer to the sun than average, and during winter it is further from the sun.

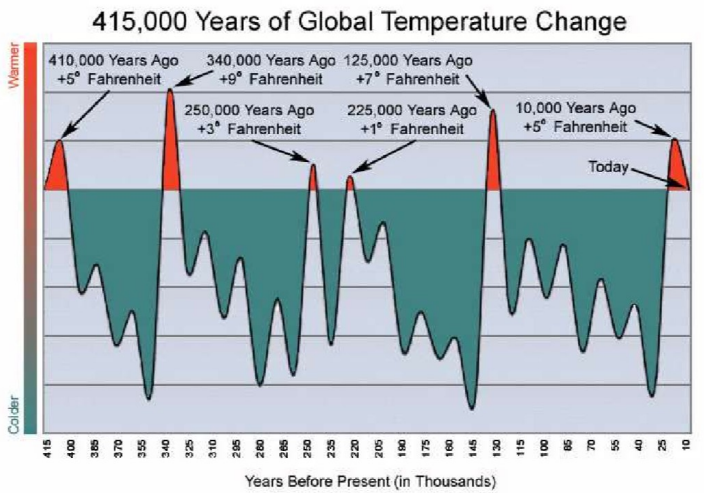
The difference in solar radiation reaching Boston over the course of the year causes the seasons. Boston's average temperature changes from around 73 F in July to around 30 F in January, a swing of 43 F or 24 C, which is caused by the changes in the amount of solar radiation reaching the Boston area.

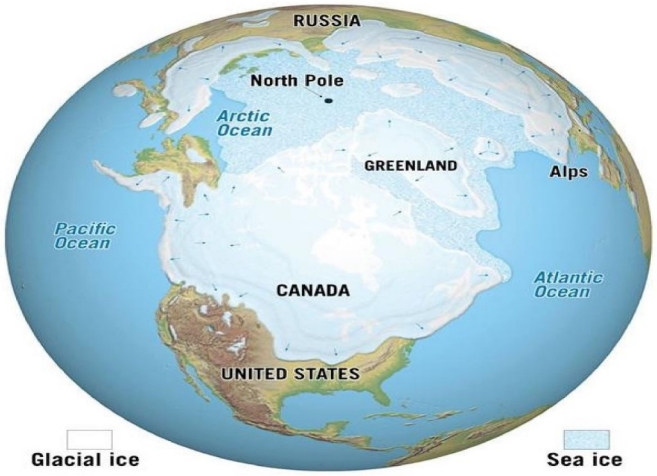




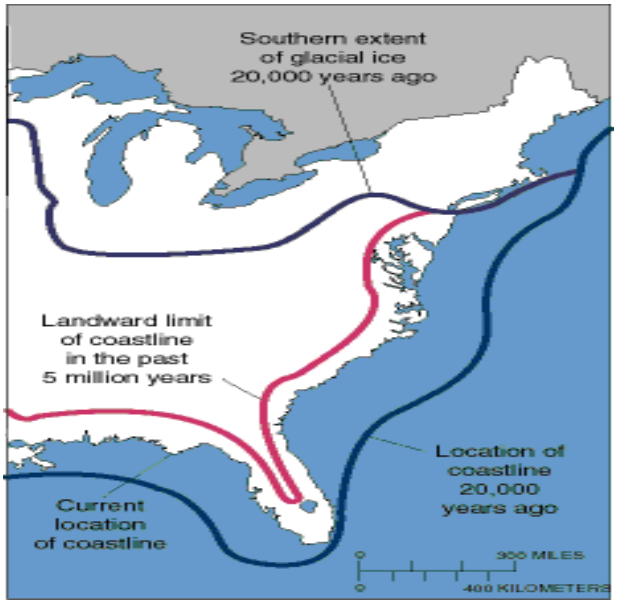
There are three slight irregularities in the earth's movement around the sun. These are called Milankovitch Cycles. The tilt or obliquity not only exists, but also the angle varies from 21.5 degrees to 24.5 degrees. These three cycles cause the amount of solar radiation reaching the earth to change significantly.

Over the last million years earth's climate has gone through massive glaciations roughly every 100,000 years. The graph shows the four most recent cycles. The temperature swings have been roughly 6-10 C or 11-18 F (with a significant margin of error). The most widely accepted theory is that these temperature swings are caused by the Milakovich Cycles. At least two of the prior temperature maximums shown have been warmer than today.

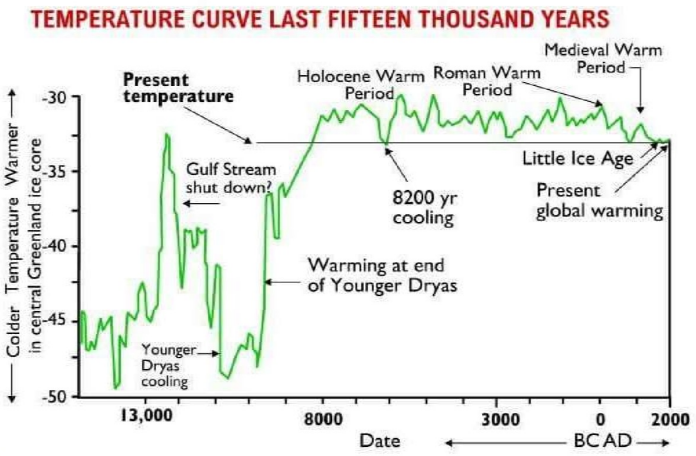




It is undisputed that at the last glacial maximum about 20,000 years ago the Laurentide Glacier covered virtually all of Canada and significant parts of what is now the Northern US. New England was buried under nearly a mile of ice up until about 12,000 years ago.

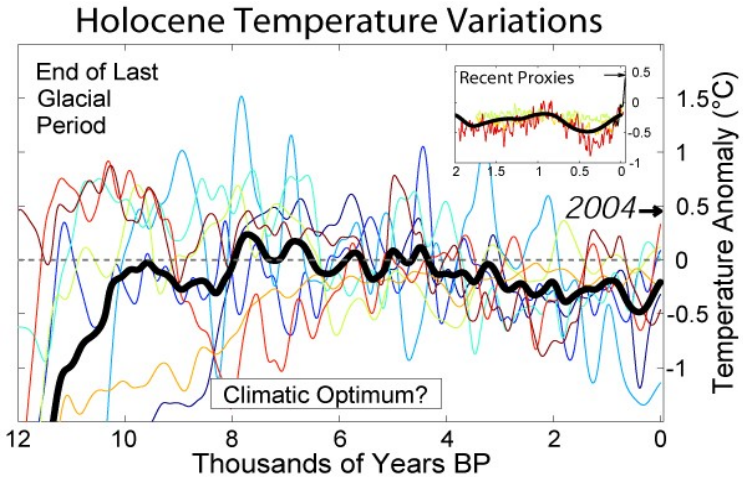


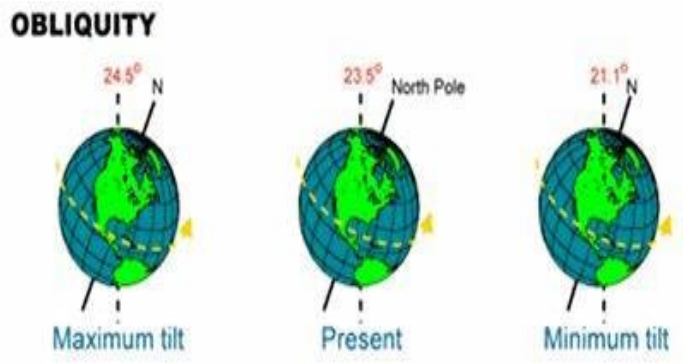
This image shows how far South of the present US-Canada boundary the glacier advanced. The sea level was nearly 400 feet lower than the present, so the US shoreline extended far into what is now the Atlantic Ocean and the Gulf of Mexico. In the last 5 million years the earth has been significantly warmer than at present, so sea levels have been significantly higher than now, as shown by the red line.



From about 17,000 years ago to 10,000 years ago world temperatures shot upwards, then downwards, and then upwards again, resulting in a massive retreat of glaciers around the world and resulting in sea levels rising nearly 400 feet to roughly the present levels. There is no general agreement as to the causes of these massive, natural swings, but the most commonly accepted theory attributes them to the Milankovich Cycles, i.e. to changes in solar radiation reaching the earth as a results of changes in the earth's position in relation to the sun.

Our present geological period is named the Holocene Interglacial. It is about 11,000 years old. Interglacials usually last 10,000-15,000 years. The Holocene temperature optimum (maximum) occurred about 8,000 years ago, and then temperatures started to decline slowly with some obvious secondary cyclical swings.





One theory is that this cooling is being caused by the earth's declining obliquity. As the angle decreases, sunlight is shifted from the poles to the tropics, causing polar regions to get colder and causing ice sheets at the poles to expand.

This graph shows a high correlation between declining temperature (the black line) and declining obliquity (the purple line) over this period of time. During this same period both CO2 (the red line) and CH4 (methane, the light blue line) were rising. IPCC computer models (e.g. the green line) can not explain the Holocene temperature decline, but reduced solar radiation as a result of reduced obliquity can. Correlation does not prove causation, but non-correlation proves non-causation.

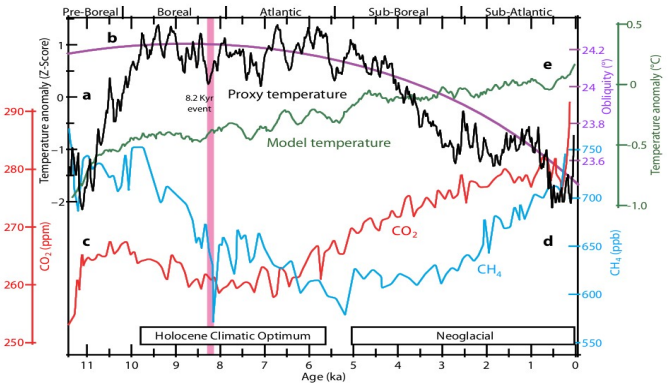
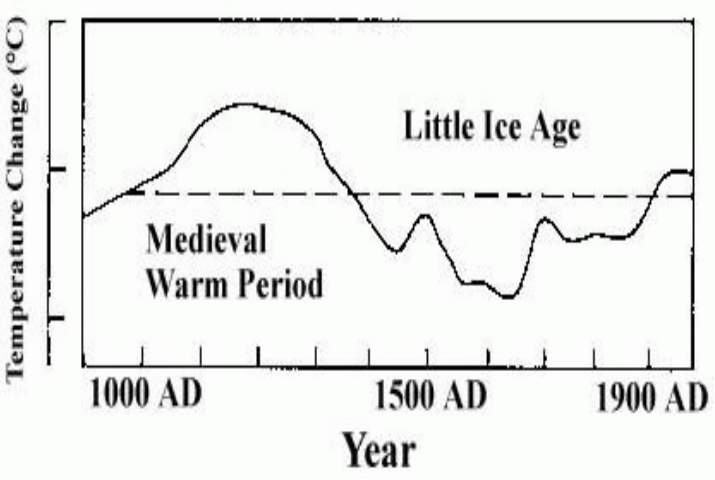
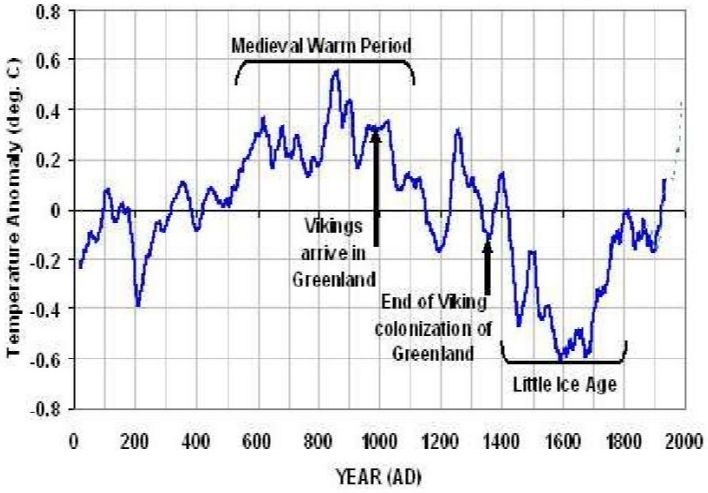


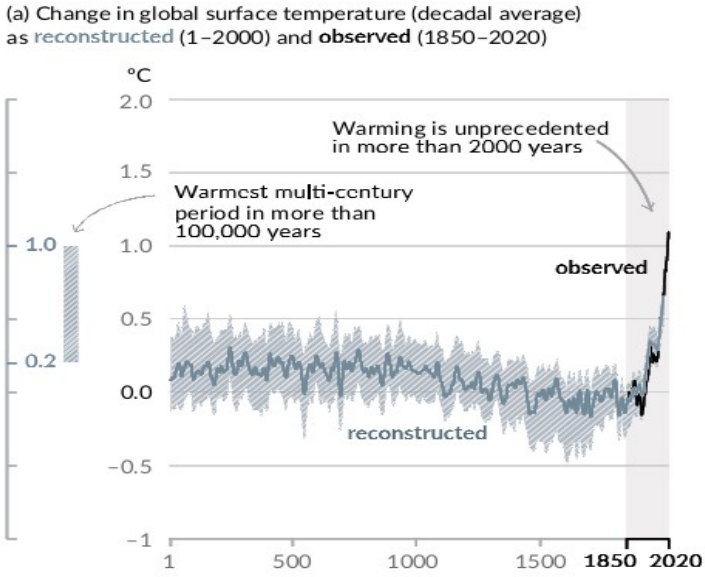
Fig. 4.5 Temperature and greenhouse gases during the Holocene
a) Black curve, global temperature reconstruction as in Fig. 4.4b. **b)** Purple curve, Earth's axis obliquity cycle. **c)** Red curve, CO_2 levels as measured in Epica Dome C (Antarctica) ice core, reported in Monnin et al. (2004). **d)** Blue curve, methane levels as measured in GRIP, GISP2, and NEEM (Greenland) ice cores as reported by Kobashi et al. (2007). Notice the great effect of the 8.2 kyr event on methane concentrations. **e)** Green curve, simulated global temperature from an ensemble of three models (CCSM3, FAMOUS, and LOVECLIM) from Liu et al. (2014), show the inability of general climate models to replicate the Holocene general temperature downward trend. Vertical bar, 8.2 kyr BP ACE. Major Holocene climatic periods are indicated.



In its First Assessment Report (1990) the IPCC acknowledged as temperature anomalies both the Medieval Warm Period (variously dated about 900-1100) and the Little Ice Age (variously dated about 1500-1800), as shown in this image.

This graph is a more modern rendering of this temperature history, showing the Medieval Warm Period significantly warmer than today and the Little Ice Age significantly colder. Traditionally scientists attributed these temperature swings to solar variability. All temperatures before about 1850 are based on proxy data, not direct measurements, and so subject to some significant level of uncertainty.

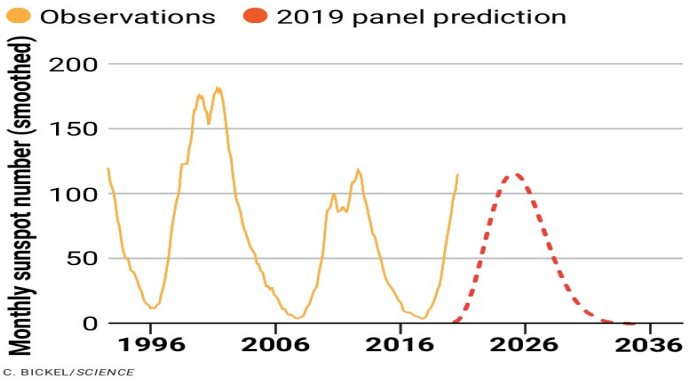




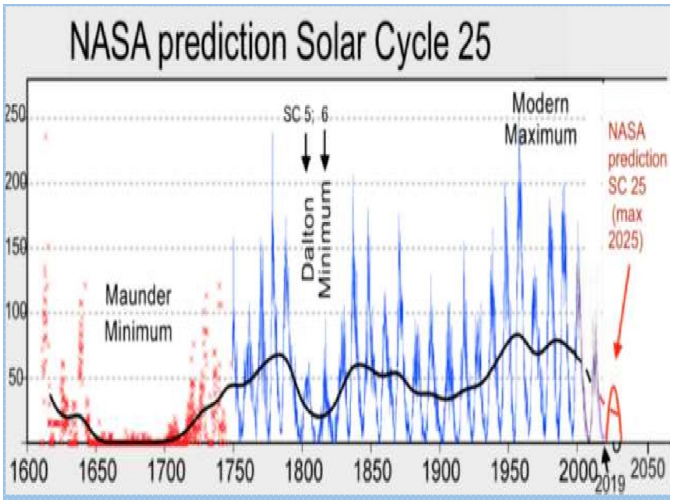
But, as shown in this graph from AR6 [WGI p.6 (2021)], the IPCC now rejects this traditional understanding of earth's temperature history over the last 2,000 years. The IPCC now denies the existence of the Medieval Warm Period and minimizes the cooling of the Little Ice Age. As a result, for the IPCC, neither of these temperature anomalies require an explanation. If these anomalies existed, CO2 fluctuations could not explain them.

The solar radiation reaching the earth varies not only due to changes in the earth's orbit, but it also varies due to a number of cycles internal to the sun. Solar scientists are only at the very beginning stages of sorting out and understanding the different solar cycles that appear to exist and understanding how these cycles affect the earth's climate.

CYCLE NAME	CYCLE LENGTH
Schwabe Cycle	11 years
Unnamed Cycle	60 years
Gleissberg Cycle	88 years
Eddy Cycle	1,000 years
Bond Cycle	1,470 +/- 500 years
Bray Cycle	2,400 (2,100-2,500) years
Sanchez-Sesma Cycle	9,600 years

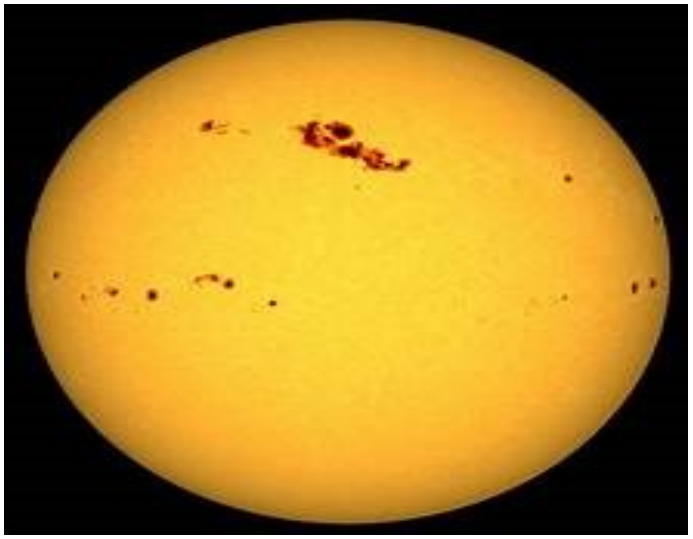


For many centuries scientists have counted the numbers of spots on the surface of the sun. These spots are solar storms. In 1801 William Herschel proposed that low numbers of sun spots indicated low solar radiation emission, which would then mean lower temperatures on earth, lower wheat production, and higher wheat prices. Herschel assembled data showing that periods of high sunspot activity correlated with low wheat prices and that periods of low sunspot activity correlated with high wheat prices. Ever since scientists have been finding strong correlations between solar variations and various climate variables, such as temperature, precipitation, droughts, floods, stream flow, and monsoons.



Variations in solar activity can explain the Roman Warm Period, the Medieval Warm Period, and the Little Ice Age. The black line represents solar activity and the blue line world temperatures. The pink line is a 1,000-year sine curve, so the graph suggests a roughly 1,000 year solar cycle (the Eddy Cycle?). The IPCC's CO2 theory of causation can not explain any of these temperature swings.

The 11 year Schwabe Cycle is the best established of these cycles, but there is substantial disagreement about the existence and period of a number of the other cycles. Even as to the Schwabe Cycle, solar scientists can not accurately predict the commencement or the strength of individual cycles even a few years in advance. Solar physics is a relatively young field. One solar scientist has commented, "We're about 60 years behind the weather forecasters."



Perhaps the most dramatic correlation found to date has been the correlation of the Maunder Grand Solar Minimum with the depth of the Little Ice Age in the 1600s. This century was a miserable time to be alive in Europe. Crops failed repeatedly producing famines. Glaciers advanced in the Alps crushing whole villages. In 1651 Thomas Hobbes penned his famous line, "The life of man [is] solitary, poor, nasty, brutish, and short."

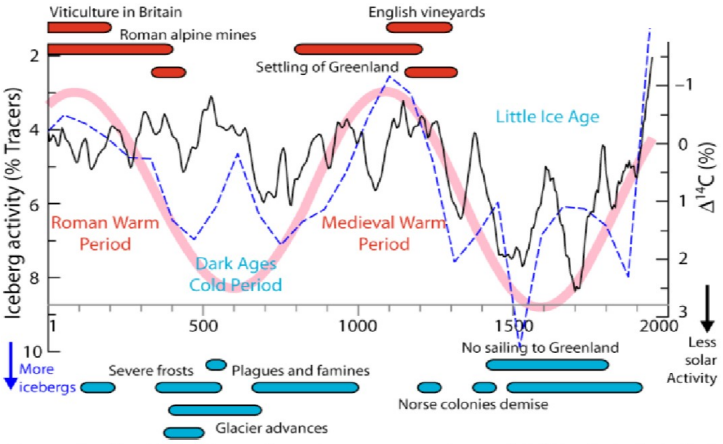


Figure 5. The millennial solar-climate cycle over the past 2000 years. The anomaly in ^{14}C production levels (black curve), a proxy for solar activity, is compared to iceberg activity in the North Atlantic (dashed blue curve), a climate proxy. The pink sine curve shows the millennial frequency. It defines two warm and two cold periods, supported by a large amount of evidence, some of which are represented by red and blue bars (see main text).

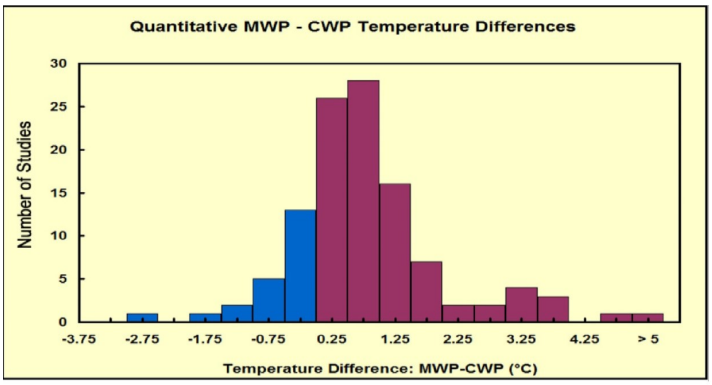
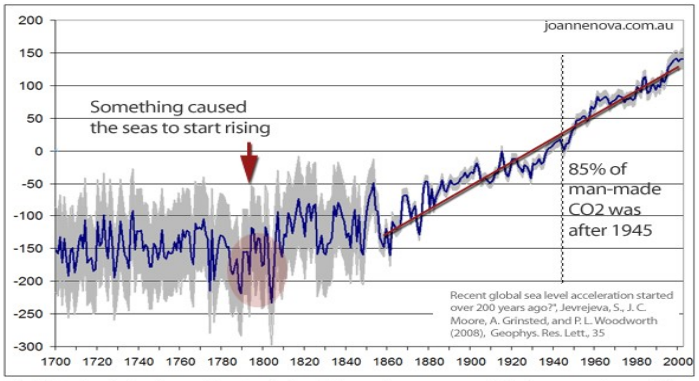


Figure 4.2.2.2. The distribution, in 0.5°C increments, of studies that allow the identification of the degree by which peak Medieval Warm Period temperatures either exceeded (positive values, red) or fell short of (negative values, blue) peak Current Warm Period temperatures.

In denying the existence of the Medieval Warm Period, the IPCC ignores a massive amount of research. This graph summarizes the findings of over 100 papers addressing whether the Medieval Warm Period was warmer than today. There is obviously disagreement, but about 3/4ths of the papers have concluded that the Medieval Warm Period was, in fact, significantly warmer than the present, and the average finding is that the Medieval Warm Period was about 0.5-1.0 C warmer.

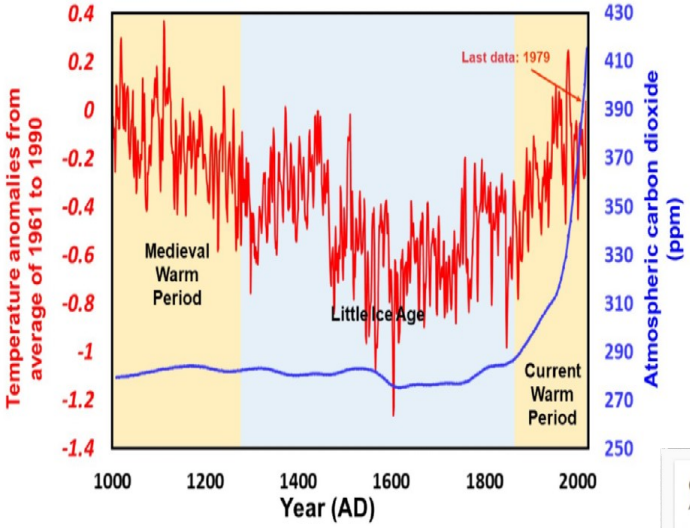
Rising temperatures cause sea level rise. After the lows in the 1600s, temperatures recovered enough in the mid-to-late 1700s that the modern sea level rise commenced in the 1790s.

Sea Levels have been rising for 200 years



Global Sea-Levels have been rising since before1800, yet there were no coal fired power stations until the late 1800's.The rate seas have been rising has been surprisingly constant for the last 150 years. Significantly most human emissions of CO2 did not even occur until after 1945.

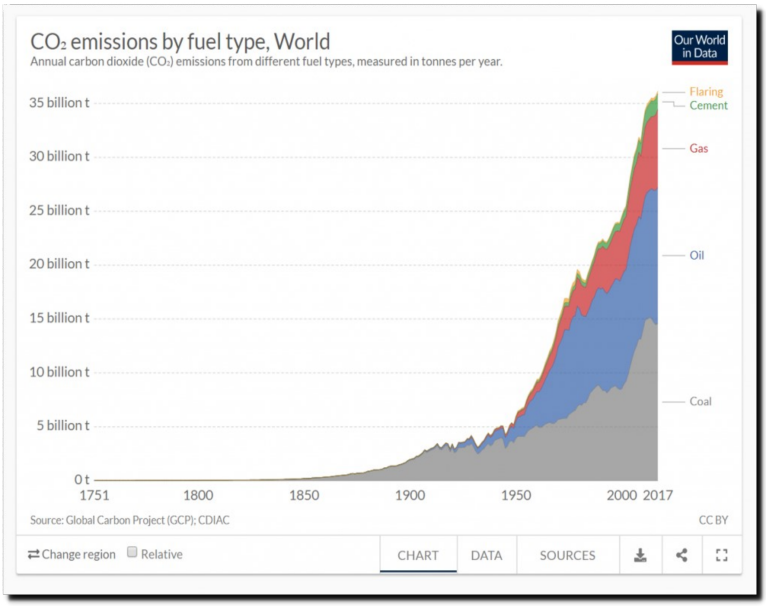
Figure 6: 1,000 Years of Temperature and CO_2 Show No Linkage Between the Two

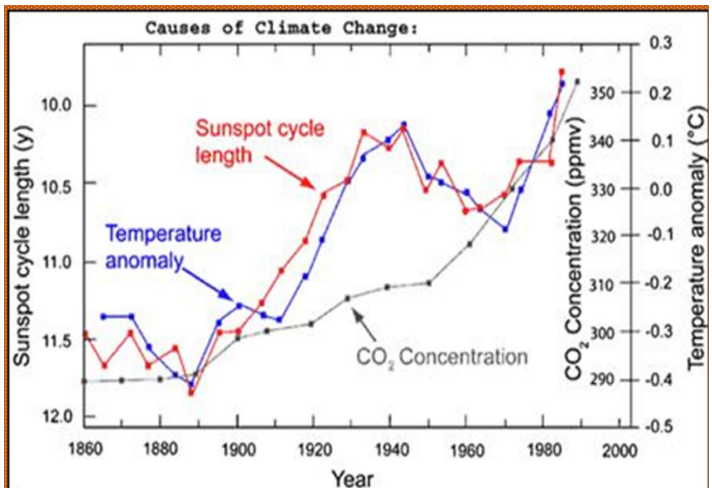


(Source data: Temperature: Moberg 2005; CO_2: EEA 2022, Law Dome C)

The blue line shows CO2 levels over the last 1,000 years. The temperature warming and sea level rising in the 1700s and 1800s can be explained by solar cycles but can not be explained by the CO2 Causation Theory.

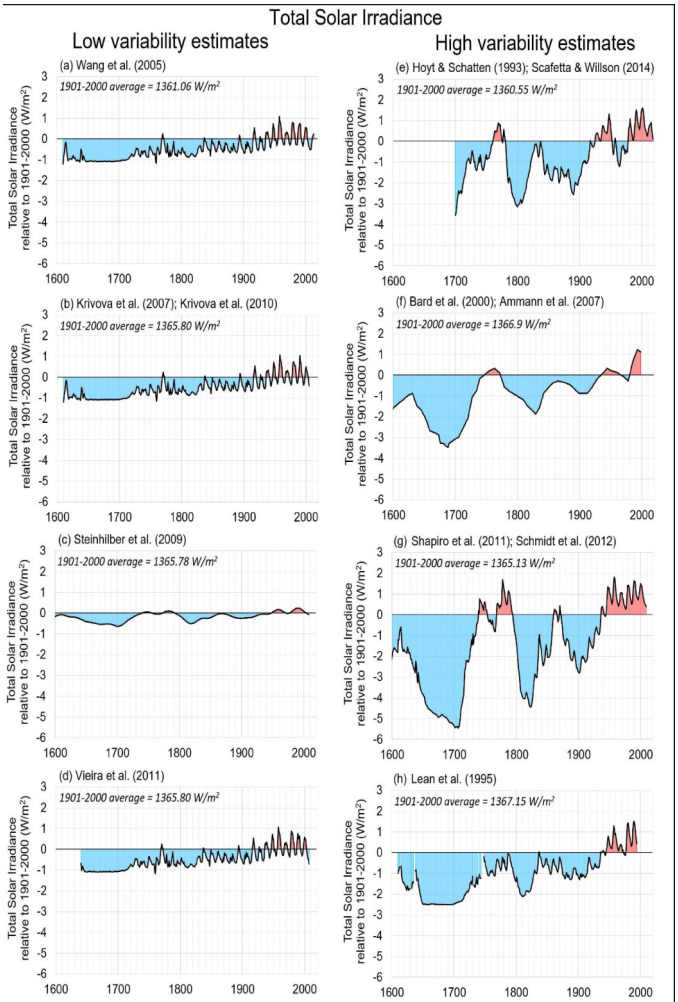
One of the major problems with the CO2 Causation Theory is that CO2 emissions (human or otherwise) did not become significant until the 1950s. Therefore it is difficult to explain the changes in world temperatures that occurred prior to the 1950s by the CO2 theory. If solar variation caused temperature changes before the 1950s, it can also cause changes after the 1950s.





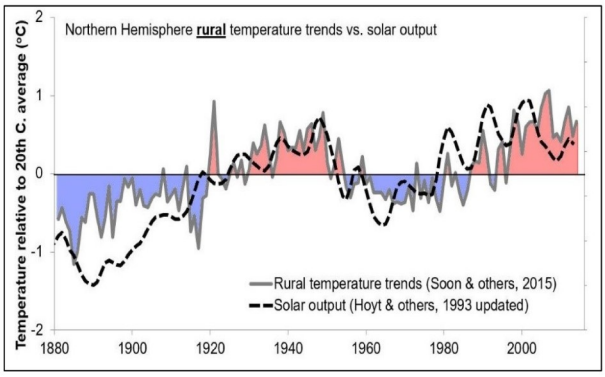
In the post-industrial world there have been three periods of significant temperature change: (1) a period of significant rise in temperatures from 1890-1940, then (2) a period of decline in temperatures 1940-1970, and finally (3) another period of significant rise since 1970. CO2 can explain the 3rd temperature movement, but not the prior two. Solar activity can explain all three movements.

Here is another more recent presentation of the correlation between post-industrial temperatures and solar activity.



Eight different estimates of how TSI has changed since the 17th century relative to the 20th century average (1901-2000). All estimates are calibrated to match with one of the satellite based TSI composites over the satellite era and then each uses different "solar proxies" to describe the trends before the satellite era. (Adapted from Soon, Connolly, and Connolly, 2015)

Northern Hemisphere rural temperature trends vs. solar output

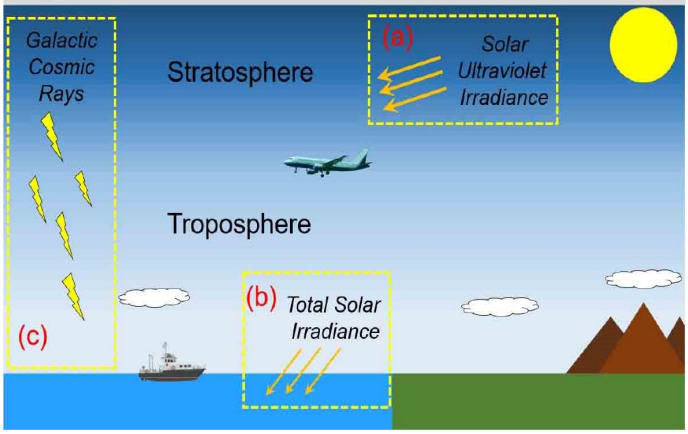


Red and blue represent positive and negative temperature anomalies from twentieth-century average for a Northern Hemisphere temperature reconstruction using primarily rural surface stations (to control for urban heat island effect). Dashed line is solar output according to Hoyt and Schatten (1993) as updated by Scafetta and Willson (2014). *Source:* Adapted from Soon *et al.*, 2015, Figure 27, p. 442.

A fundamental problem for climate scientists is that there is no agreement on measurements for the energy coming from the sun. The formal name for this variable is Total Solar Irradience (TSI). There are a number of what have been called "plausible reconstructions" of TSI over recent centuries, and they differ greatly, as shown in the image. The IPCC without discussion relies on the reconstructions that show very little TSI variance [AR6 WGI, p.297-298], which is consistent with the IPCC's conclusion that TSI has caused virtually none of the post-industrial global warming, and which then allows the IPCC to conclude that CO2 has caused most of the warming. By contrast, the reconstructions that show significant TSI variance lead to the conclusion that solar activity has caused much, if not most, of the post-industrial warming.

This quote reflects the dissatisfaction that exists among some solar scientists with the IPCC's treatment of their specialty. Unfortunately solar scientists have not been able to agree among themselves on the two fundamental issues: (1) how does the activity of the sun vary? And (2) how does this variability of the sun affect the earth's climate?

Schematic illustrating three distinct sets of current hypotheses for an indirect Sun/climate relationship

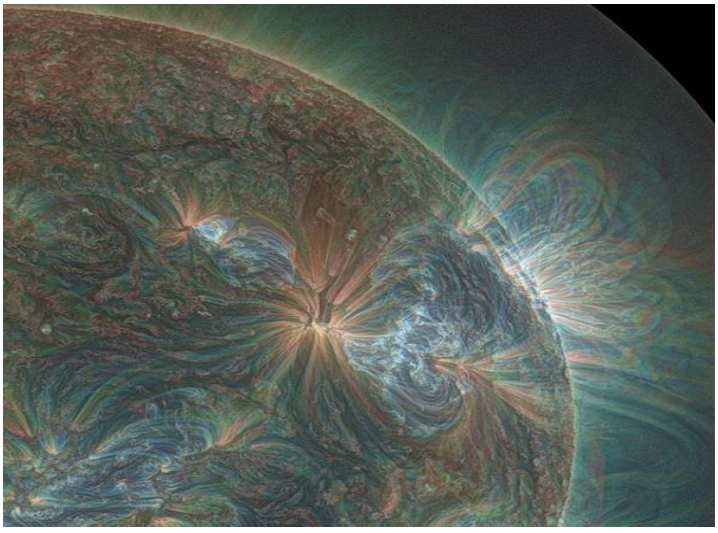


This is an image of solar UV activity. UV emissions from the sun can vary as much as 10% over a number of years. Solar scientists are just beginning to grapple with the issues of indirect solar influence on the climate. They have not yet been able to quantify these influences or to even demonstrate conclusively that these influences are significant, but there is ample reason for the investigation of these possible influences to continue.

Carter (2017)

- The IPCC represents the large corpus of research into Sun-Earth climate relations poorly and has not made any significant attempt to include solar effects in the IPCC's modeling.

Even more unsettled than the TSI issue is the issue of whether the sun can cause climate change in ways other than by direct solar irradiance (TSI), such as by the solar wind that effects incoming galactic cosmic rays, or by UV irradiance. Other mechanisms have also been proposed.



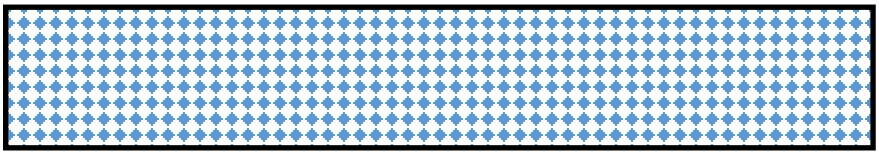
CONCLUSION

There is much circumstantial evidence suggesting that solar variability has caused at least a substantial amount of the post-industrial global warming. But there is not yet enough evidence to prove this proposition to the satisfaction of a majority of the world's climate scientists.

The evidence that CO2 caused the warming from the pre-industrial period to 1950 is weak, because CO2 emissions were growing so slowly during this period. There is evidence that this warming was caused by the sun.

Dr. Willie Soon, a highly-respected solar scientist, sums up the situation as follows -

> "It is still unclear which (if any) of the many TSI time series in the literature are accurate estimates of past TSI. ... [T]he scientific community is not yet in a position to confidently establish whether the warming since 1850 is mostly human-caused, mostly natural, or some combination."



Work Cited

The United Nations Intergovernmental Panel on Climate Change, Assessment Report 6, Working Group I, The Physical Science Basis (2021) (WGI)