Sun luminosity over time

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Over the following approximately 4 billion years, the Sun"s energy output increased and the composition of the Earth atmosphere changed. The Great Oxygenation Event around 2.4 billion years ago was the most notable alteration of the atmosphere. Over the next five billion years, the Sun"s ultimate death as it becomes a very bright red giant and then a very faint white dwarf will have dramatic effects on climate, with the red giant phase likely already ending any life on Earth.

In the modern era, the Sun has operated within a sufficiently narrow band that climate has been little affected. Models indicate that the combination of solar variations and volcanic activity can explain periods of relative warmth and cold between A.D. 1000 and 1900.

Numerous paleoenvironmental reconstructions have looked for relationships between solar variability and climate. Arctic paleoclimate, in particular, has linked total solar irradiance variations and climate variability. A 2001 paper identified a ~1500 year solar cycle that was a significant influence on North Atlantic climate throughout the Holocene.[17]

One historical long-term correlation between solar activity and climate change is the 1645-1715 Maunder minimum, a period of little or no sunspot activity which partially overlapped the "Little Ice Age" during which cold weather prevailed in Europe. The Little Ice Age encompassed roughly the 16th to the 19th centuries.[18][19][20] Whether the low solar activity or other factors caused the cooling is debated.

A 2012 paper instead linked the Little Ice Age to volcanism, through an "unusual 50-year-long episode with four large sulfur-rich explosive eruptions," and claimed "large changes in solar irradiance are not required" to explain the phenomenon.[22]

A 2010 paper suggested that a new 90-year period of low solar activity would reduce global average temperatures by about 0.3 ?C, which would be far from enough to offset the increased forcing from greenhouse gases.[23]

Climate models have been unable to reproduce the rapid warming observed in recent decades when they only consider variations in total solar irradiance and volcanic activity. Hegerl et al. (2007) concluded that greenhouse gas forcing had "very likely" caused most of the observed global warming since the mid-20th century. In making this conclusion, they allowed for the possibility that climate models had been underestimating the effect of solar forcing.[29]

Early research attempted to find a correlation between weather and sunspot activity, mostly without notable success.[33][34] Later research has concentrated more on correlating solar activity with

global temperature.

The 2001 Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) concluded that the measured impact of recent solar variation is much smaller than the amplification effect due to greenhouse gases, but acknowledged that scientific understanding is poor with respect to solar variation.[38][39]

Estimates of long-term solar irradiance changes have decreased since the TAR. However, empirical results of detectable tropospheric changes have strengthened the evidence for solar forcing of climate change. The most likely mechanism is considered to be some combination of direct forcing by TSI changes and indirect effects of ultraviolet (UV) radiation on the stratosphere. Least certain are indirect effects induced by galactic cosmic rays.[40]

Neither direct measurements nor proxies of solar variation correlate well with Earth global temperature,[57] particularly in recent decades when both quantities are best known.[51][58]