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How does the sun effect our climate?

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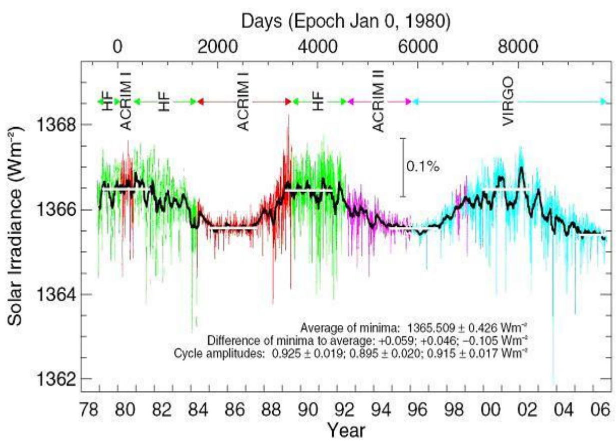
The sun is the source of most of the energy that drives the biological and physical processes in the world around us—in oceans and on land it fuels plant growth that forms the base of the food chain, and in the atmosphere it warms air which drives our weather. The rate of energy coming from the sun changes slightly day to day. Over many millennia in the Earth-Sun orbital relationship can change the geographical distribution of the sun's energy over the Earth's surface. It has been suggested that changes in solar output might affect our climate—both directly, by changing the rate of solar heating of the Earth and atmosphere, and indirectly, by changing cloud forming processes.

Over the time-scale of millions of years the change in solar intensity is a critical factor influencing climate (e.g., ice ages). However, changes in solar heating rate over the last century cannot account for the magnitude and distribution of the rise in global mean temperature during that time period and there is no convincing evidence for significant indirect influences on our climate due to twentieth century changes in solar output.

Figure 1. Record of Minimal Variation in Sun's Energy



(Click image to enlarge) Figure 1. Two and a half solar cycles of Total Solar Irradiance (TSI), also called 'solar constant'. This composite, compiled by the VIRGO team at the Physikalisch-Meteorologisches Observatorium / World Radiation Center Davos, Switzerland, shows TSI as daily values plotted in different colors for the different originating experiments. The difference between the minima values is also indicated, together with amplitudes of the three cycles. Image courtesy of SOHO consortium a project of international cooperation between ESA and NASA.

The Sun-Climate Connection

The rate at which energy from the sun reaches the top of Earth's atmosphere is denoted by the term "total solar irradiance" (or TSI). TSI fluctuates slightly from day to day and week to week. Superimposed on these rapid short-term fluctuations is a cycle related to sunspots in the outer layers of the Sun that lasts approximately every 11 years.

The current TSI varies with season, time of day, and latitude. Yet it is thought that small changes in this relatively small amount of absorbed solar energy can make a difference to our climate. Might changes in the rate of solar absorption, called radiative forcing (RF), be influencing our climate today?

(1) Direct changes in climate due to solar output
The average increase in solar radiative forcing since 1750 is much smaller (~ 0.12 W m-2) than the increase in RF due to heat-trapping gases (~2.6 W m-2) over that same time period. [3] The slight increase in solar absorption is, moreover, more than offset by natural cooling. The twentieth century witnessed the eruption of major volcanoes— the most recent, Pinatubo, in 1991—that spewed tiny reflective particles into the atmosphere. Incoming energy from the sun that encountered these particles was reflected back into space. In other words, natural processes alone would have brought about slight late twentieth century cooling—not the warming we have experienced.

(2) Indirect changes in climate due to solar output

The variations of the rate of emission of solar radiation on the 11 year time scale, as well as the small long-term increase in TSI over the past few centuries, appear in some studies to be correlated with variations in cloud patterns. These changes in absorbed solar energy appear to be far too small to explain the major changes in our climate.

Two different hypotheses have been proposed to test whether solar radiation can explain climate change. The first relies on the fact that in both the 11 year cycle and, in the longer term, the changes in solar energy are highest at ultraviolet (short) wavelengths. The short wavelength radiation is particularly effective in modifying ozone concentrations in the level of the atmosphere above where typical weather occurs. According to this hypothesis, modifications in the ozone layer could in turn filter down to that level of the atmosphere where our weather is formed, potentially modifying clouds and temperatures there.

The second hypothesis relies on the fact that changes in solar activity also change the flow of small, charged, highly energetic particles (known as galactic cosmic rays) that travel through the atmosphere toward Earth [1, 2]. These particles in turn create more ions (charged atoms or molecules) from air molecules in the atmosphere, and it has been suggested [3] that these ions might modify cloud formation, causing large changes in weather and temperatures below.

So far, there is no convincing evidence that either of these ideas adequately demonstrate a causal links between small changes in solar irradiance and the relatively large, measurable changes in Earth's surface temperature over the past century

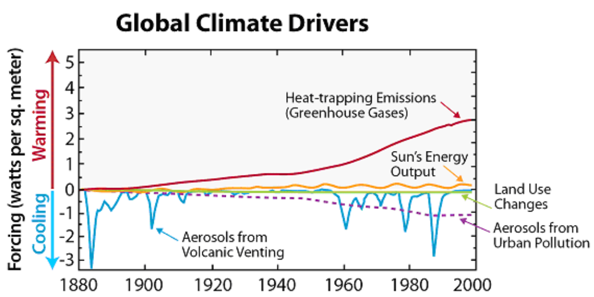
Twentieth century climate and solar variations

The rate at which solar energy reaches the Earth's surface in any location depends on the season, time of day, cloudiness and the concentration of small aerosol particles in the atmosphere. (see aerosols FAQ). During the late twentieth century, the average amount of solar energy reaching the surface decreased slightly due to atmospheric particles (aerosols), particularly in urban locations, that reflect the sun's energy back into space. This pollution did not cause net global cooling because it was more than counteracted by the increasing concentrations of heat- trapping gases in the atmosphere.

In its Fourth Assessment Report [3], IPCC scientists evaluated simulations of twentieth century climate variables using a number of numerical models. They first assumed no increase in heat-trapping gases over this period, so that the temperatures calculated were those that would have been achieved if only solar variability, volcanic eruptions, and other natural climate drivers were included. The temperature results were similar to observed temperatures only for the first half of the century, but the models did not accurately show the general warming trend that has been recorded during the second half of the twentieth century. However, when the human-induced heat-trapping gases were included in the computer model, it accurately reproduced the observed warming during the twentieth century.

Thus, although fluctuations in the amount of solar energy reaching our atmosphere do influence our climate, the global warming trend of the past six decades cannot be attributed to changes in the sun (see Figure 2).

Figure 2. Twentieth Century History of Climate Drivers



(Click image to enlarge) Heat-trapping emissions (greenhouse gases) far outweigh the effects of other drivers acting on Earth's climate. Source: Hansen et al. 2005, Figure adapted by Union of Concerned Scientists. [5]

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