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Solar Variability:

Does variation in the Sun’s output affect climate?

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Solar Variability:

Does variation in the Sun's output affect climate?

How does the Sun's output vary?

The Sun provides the energy that drives Earth's climate and this varies through the seasons and also over thousands of years due to changes in Earth's orbit. Although it is not possible to detect with the naked eye, the radiation leaving the sun also varies and it follows a fairly regular cycle of 11 years. Called the Schwabe cycle (after its discoverer), it is clearly seen in changes in the number of sunspots. The fluctuations of total solar radiation integrated over the whole electromagnetic spectrum amount to just 0.1%. However, much larger percentage changes occur in the flux of energetic particles and in short wavelength radiation that has effects high in the atmosphere. For example, changes of up to 10% occur in the amount of ultraviolet light leaving the Sun. The Sun's output also changes over centuries and almost no sunspots were observed during the 'Maunder Minimum' between 1645 and 1715. The mechanisms for the generation of these variations in the Sun are not very well understood, even for the 11 year cycle, but they involve both fluid dynamics (like the Earth's atmosphere) and magnetic forces due to the ionised nature of the Sun's atmosphere. Computer simulations of sun-like stars are improving, and some simulations are now beginning to reproduce low frequency variations that resemble observed changes in solar output.

How do we measure the Sun's variability?

The best known indicator of solar variability is the record of sunspot numbers which spans several hundred years. Other measures come from century long records of geomagnetic indices and also radio wave fluxes which extend back to the middle of the 20th century. Cosmogenic isotopes from ice-cores and other sources can also be calibrated to give estimates of solar variability on millennial timescales. More recently, several decades of satellite data have been provided by instruments positioned outside the ozone layer, allowing direct measurement of solar radiation across different wavelengths, including the large variations in UV. These latest data give a good idea of the total output of solar energy, but they still have difficulty measuring variations at different wavelengths over long periods.

How does solar variability affect global climate?

We now have global climate observations spanning more than 10 solar cycles and so it is possible to estimate the impacts of the 11 year solar cycle on global surface temperature using observations alone. These estimates suggest that averaged over the globe, the Earth's surface warms by as much as 0.1K following the 11 year cycle from solar minimum to solar maximum. The effects seem to lag the peaks and troughs of the solar cycle, as expected as variations are integrated in the world's oceans. Computer climate simulations suggest similar effects but the model results are generally at the lower end of the observational estimates.

How does solar variability affect regional climate?

There is a long history of suggestions that aspects of the weather could be related to the 11 year solar cycle, but some of these proposed links appear to be temporary correlations without cause. Nevertheless, links between European and UK climate and solar activity appear to be standing the test of time. Perhaps the best-known example is a suggested link between the Maunder Minimum and the Little Ice Age. This latter period was punctuated by many severe winters and it contained the coldest UK winter in our observational records (1684). Similarly, analyses of more recent climate data suggest that northern Europe appears to cool when the Sun's activity is low. However, there is continuing debate about these observed correlations and whether other factors were involved.

In recent years, additional theoretical evidence suggests that solar variability causes a change in regional climate. Using improved computer climate models to simulate the effects of the 11 year solar cycle, it is now possible to reproduce some of the observed changes in the stratosphere, the jet stream and in sea level pressure. These changes amount to a fraction of the total year-to-year variation in the atmosphere but they alter the risk of cold winters across Northern Europe. They also imprint a pattern of heat in the North Atlantic Ocean where the response builds up for a few years and peaks after solar maximum or solar minimum. There are ongoing questions and scientific debate about the magnitude and significance of these effects but the emerging agreement between models and observations adds weight to the scientific evidence for solar variability effects on regional climate.

Some scientists propose that a so-called 'Grand Minimum' in solar variability may be on the way for the next few decades, akin to the Maunder Minimum, but climate model experiments suggest that even if that does occur, cooling effects are highly likely to be outweighed by global warming in the long term.

Notes, further reading and references:

Observational monitoring of the state of the sunspot cycle:
http://www.sidc.be/silso/dayssnplot

Estimates of solar variability:
https://www.geosci-model-dev.net/10/2247/2017/

UK and international research on the solar cycle:
https://www.metoffice.gov.uk/research/news/2011/solar-variability
http://solarisheppa.geomar.de/
http://www.varsiti.org/