

Solar Changes and the Climate

The sun plays a role in our climate in direct and indirect ways.

The sun changes in its activity on time scales that vary from 27 days to 11, 22, 80, 180 years and more. A more active sun is brighter due to the dominance of faculae over cooler sunspots with the result that the irradiance emitted by the sun and received by the earth is higher during active solar periods than during quiet solar periods. The amount of change of the solar irradiance based on satellite measurements since 1978 during the course of the 11 year cycle just 0.1% (Frohlich and Lean 1998) has caused many to conclude that the solar effect is negligible especially in recent years. Over the ultra long cycles (since the Maunder minimum), irradiance changes are estimated to be as high as 0.4% (Hoyt and Schatten (1993), Lean et al. (1995), Lean (2000), Lockwood and Stamper (1999) and Fligge and Solanki (2000)).

However this does not take into account the sun's eruptional activity (flares, solar wind bursts from coronal mass ejections and solar wind bursts from coronal holes) which may have a much greater effect. This takes on more importance since Lockwood et al., 1999) showed how the total magnetic flux leaving the sun has increased by a factor of 2.3 since 1901. This eruptional activity may enhance warming through ultraviolet induced ozone chemical reactions in the high atmosphere or ionization in higher latitudes during solar induced geomagnetic storms. In addition, the work of Svensmark (1997), Bago and Butler (2000) Tinsley and Yu (2002) have documented the possible effects of the solar cycle on cosmic rays and through them the amount of low cloudiness. It may be that through these other indirect factors, solar variance is a much more important driver for climate change than currently assumed. Because, it is more easily measured and generally we find eruptional activity tracking well with the solar irradiance, we may utilize solar irradiance measurements as a surrogate or proxy for the total solar effect.

Correlations with Total Solar Irradiance

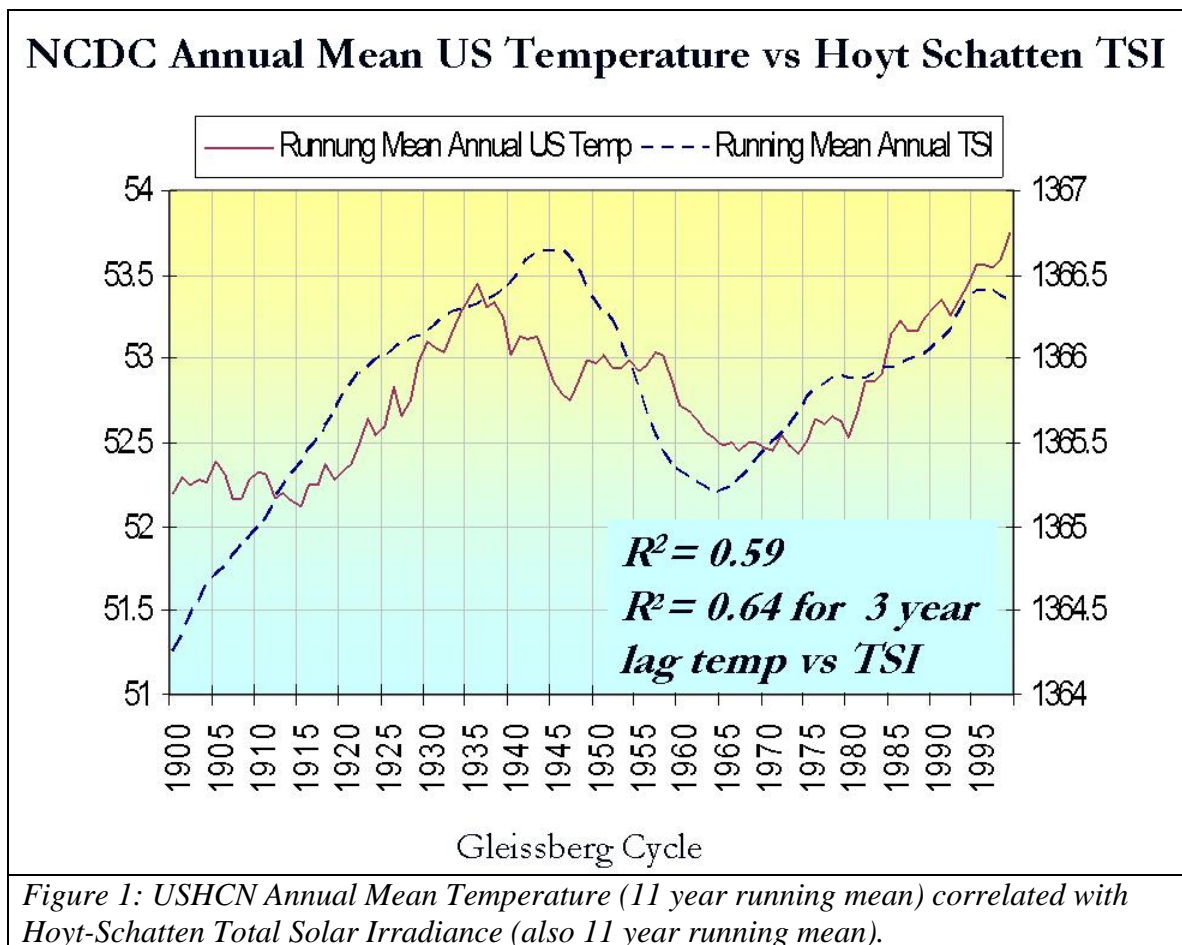
Studies vary on the importance of direct solar irradiance especially in recent decades. Lockwood and Stamper (GRL 1999), estimated that changes in solar luminosity can account for 52% of the change in temperatures from 1910 to 1960 but just 31% of the change from 1970 to 1999.

N Scafetta and B. J. West of Duke University, in "*Phenomenological Solar Signature in 400 years of Reconstructed Northern Hemisphere Temperature Record*" (GRL 2006) showed how total solar irradiance accounted for up to 50% of the warming since 1900 and 25-35% since 1980. The authors noted the recent departures may result "from spurious non-climatic contamination of the surface observations such as heat-island and land-use effects [Pielke et al., 2002; Kalnay and Cai, 2003]". Their analysis was done using the global data bases which may also suffer from station dropout and improper adjustment for missing data which increased in the 1990s.

This USHCN data base though regional in nature would have been a better station data base to use for analysis of change as it is more stable, has less missing data and a better scheme for adjusting for missing data, as well as some adjustments for changes to siting and urbanization.

An independent analysis was conducted using the USHCN data and TSI data obtained from Hoyt and Schatten. The annual TSI composite record was constructed by Hoyt and Schatten [1993] (and updated in 2005) utilizing all five historical proxies of solar irradiance including sunspot cycle amplitude, sunspot cycle length, solar equatorial rotation rate, fraction of penumbral spots, and decay rate of the 11-year sunspot cycle.

The following includes a plot of this latest 11-year running mean solar irradiance versus a similar 11-year running mean of NCDC annual mean US temperatures. It confirms this strong correlation (r-squared of 0.59). The correlation increases to an r-squared value of 0.654 if you introduce a lag of 3 years for the mean USHCN data to the mean TSI. This is close to the 5 year lag suggested by Wigley and used by Scafetta and West. The highest correlation occurred with a 3 year lag.



In recent years, satellite missions designed to measure changes in solar irradiance though promising have produced their own set of problems. As Judith Lean noted the problems is that no one sensor collected data over the entire time period from 1979 “forcing a splicing of from different instruments, each with their own accuracy and reliability issues, only some of which we are able to account for”. Lean and Froelich in their 1998 GRL paper gave their assessment which suggested no increase in solar irradiance in the 1980s and 1990s.

Richard Willson, principal investigator of NASA’s ACRIM experiments though in the GRL in 2003 was able to find specific errors in the dataset used by Lean and Froelich used to bridge the gap between the ACRIM satellites and when the more accurate data set was used a trend of 0.05% per decade was seen which could account for warming since 1979 (figure 2).

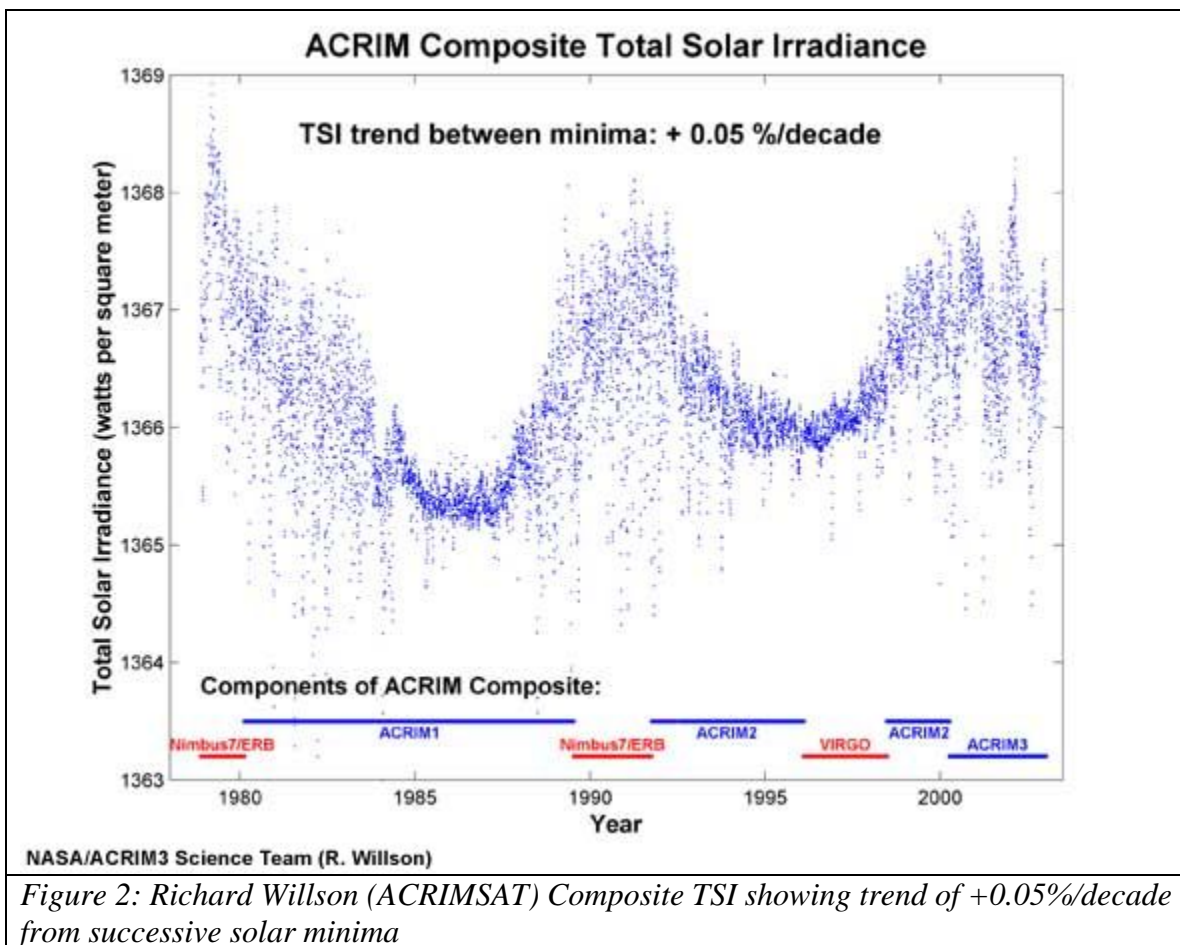


Figure 2: Richard Willson (ACRIMSAT) Composite TSI showing trend of +0.05%/decade from successive solar minima

Two other recent studies that have drawn clear connections between solar changes and the Earth’s climate are Soon (2005) and Kärner (2004). Soon (2005 GRL) showed how the arctic temperatures correlated with solar irradiance far better than with the greenhouse gases over the last century (see Figure 3). For the 10 year running mean of total solar irradiance (TSI) vs Arctic-wide air temperature anomalies (Polyokov), he found a strong

correlation of (r-squared of 0.79) compared to a correlation vs greenhouse gases of just 0.22.

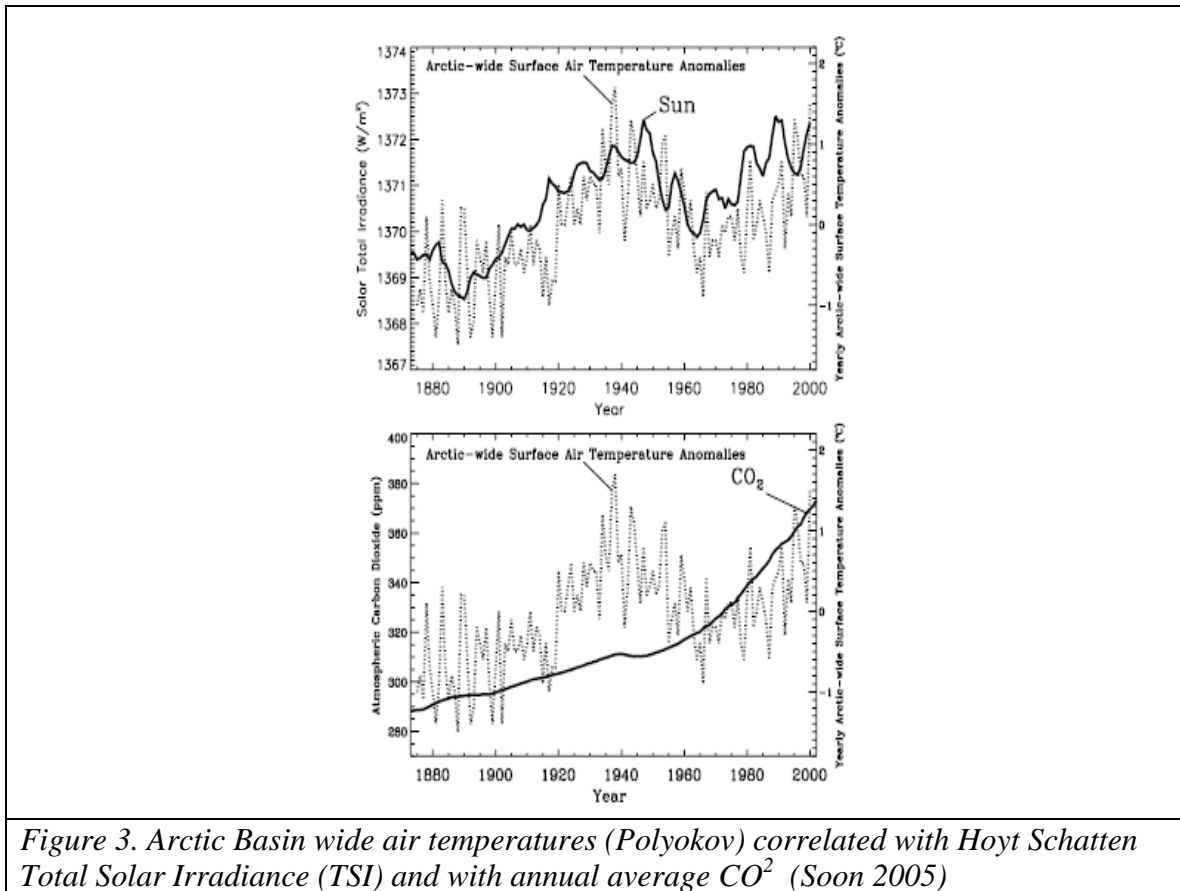
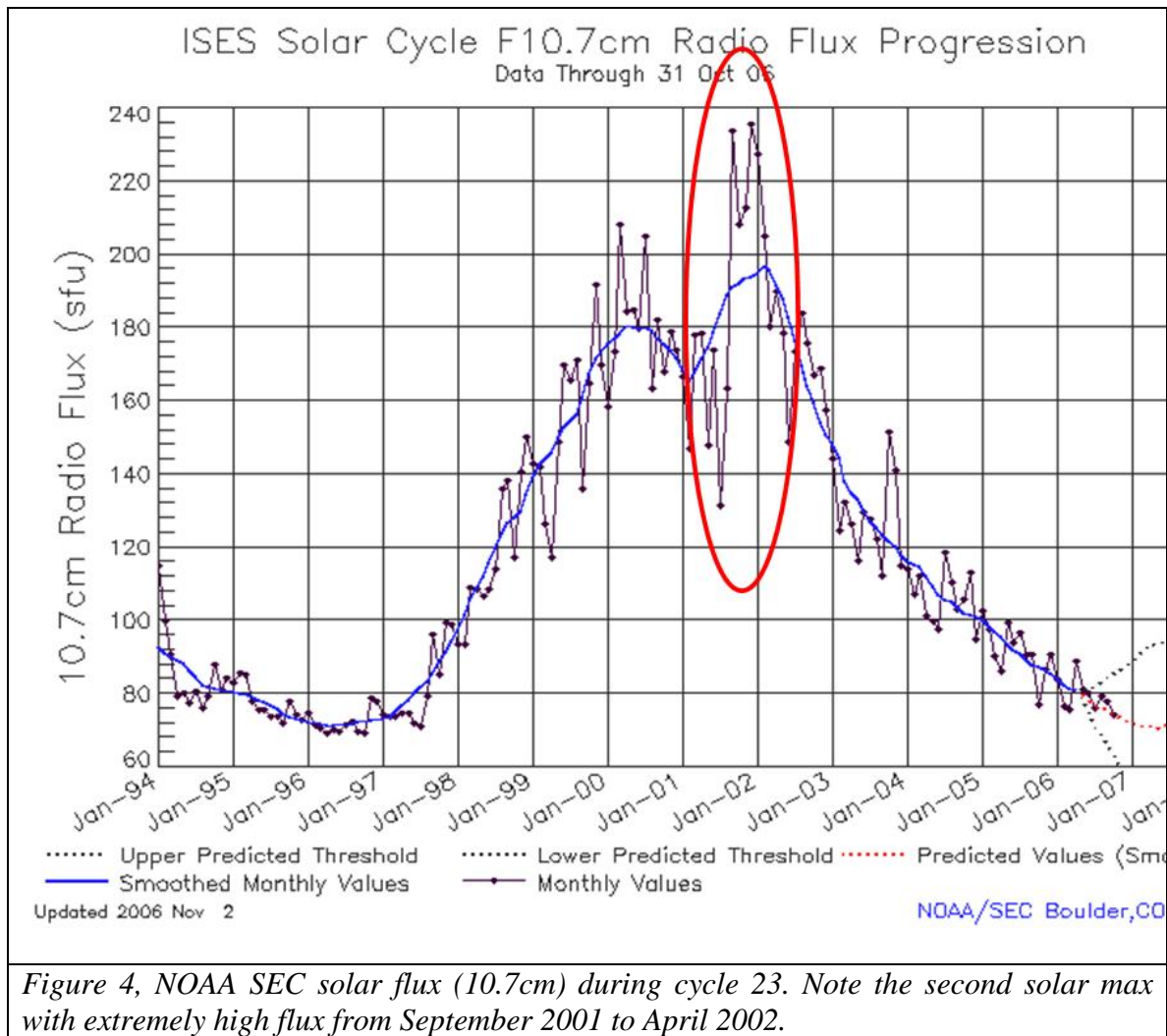


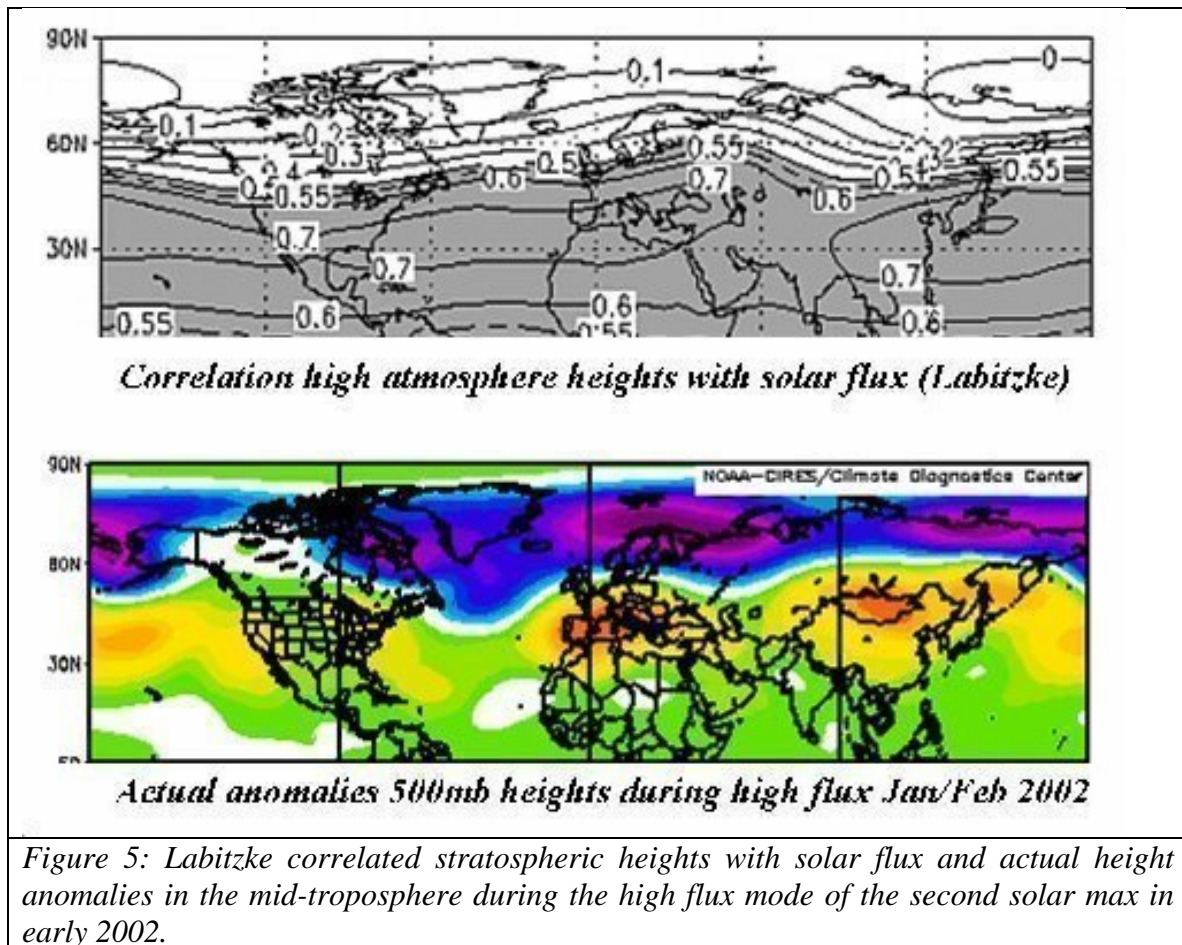
Figure 3. Arctic Basin wide air temperatures (Polyokov) correlated with Hoyt Schatten Total Solar Irradiance (TSI) and with annual average CO₂ (Soon 2005)

Warming Due To Ultraviolet Effects Through Ozone Chemistry

Though solar irradiance varies slightly over the 11 year cycle, radiation at longer UV wavelengths are known to increase by several percent with still larger changes (factor of two or more) at extremely short UV and X-ray wavelengths (Baldwin and Dunkerton, JAS 2004).

Energetic flares increase the UV radiation by 16%. Ozone in the stratosphere absorbs this excess energy and this heat has been shown to propagate downward and affect the general circulation in the troposphere. Shindell (1999) used a climate model that included ozone chemistry to reproduce this warming during high flux (high UV) years. Labitzke and Van Loon (1988) and later Labitzke in numerous papers has shown that high flux (which correlates very well with UV) produces a warming in low and middle latitudes in winter in the stratosphere with subsequent dynamical and radiative coupling to the troposphere. The winter of 2001/02, when cycle 23 had a very strong high flux second maxima provided a perfect verification of Shindell and Labitzke and Van Loon's work.





The warming that took place with the high flux from September 2001 to April 2002 caused the northern winter polar vortex to shrink and the southern summer vortex to break into two centers for the first time ever observed. This disrupted the flow patterns and may have contributed to the brief summer breakup of the Larsen ice sheet.

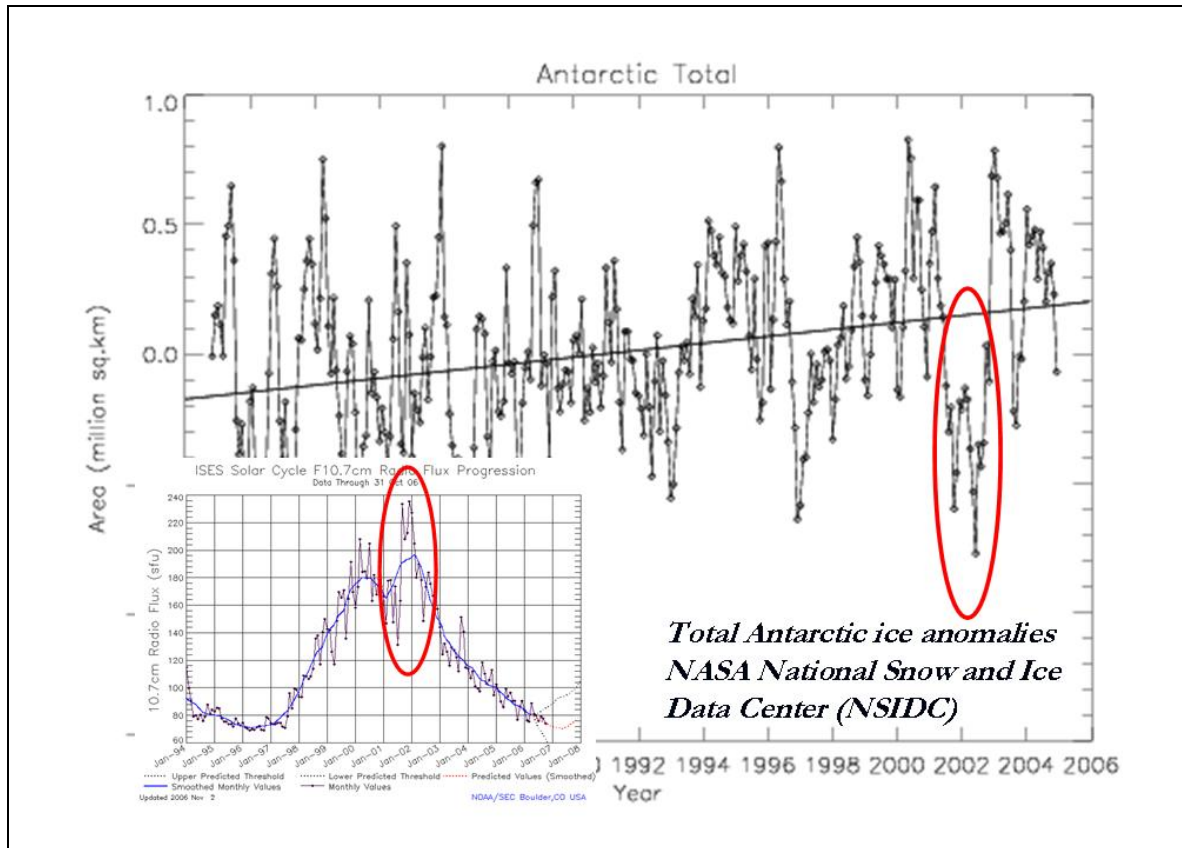


Figure 6: NASA NSIDC satellite derived Total Antarctic ice extent anomalies from 1979 to 2005. Note the dropoff with the Larsen ice sheet break-up in the summer of 2002 corresponding to major atmospheric changes during the high flux second solar max.

Cycle Length/Strength and Global Temperatures

When Gleissberg (1958) first investigated solar cycle lengths, he found short cycles had high sunspot numbers and strong eruptive activity while long cycles were characterized by low maxima and fewer solar eruptions. This may explain why Friis-Christensen and Lassen (1991) found a correlation of solar cycle length with temperatures.

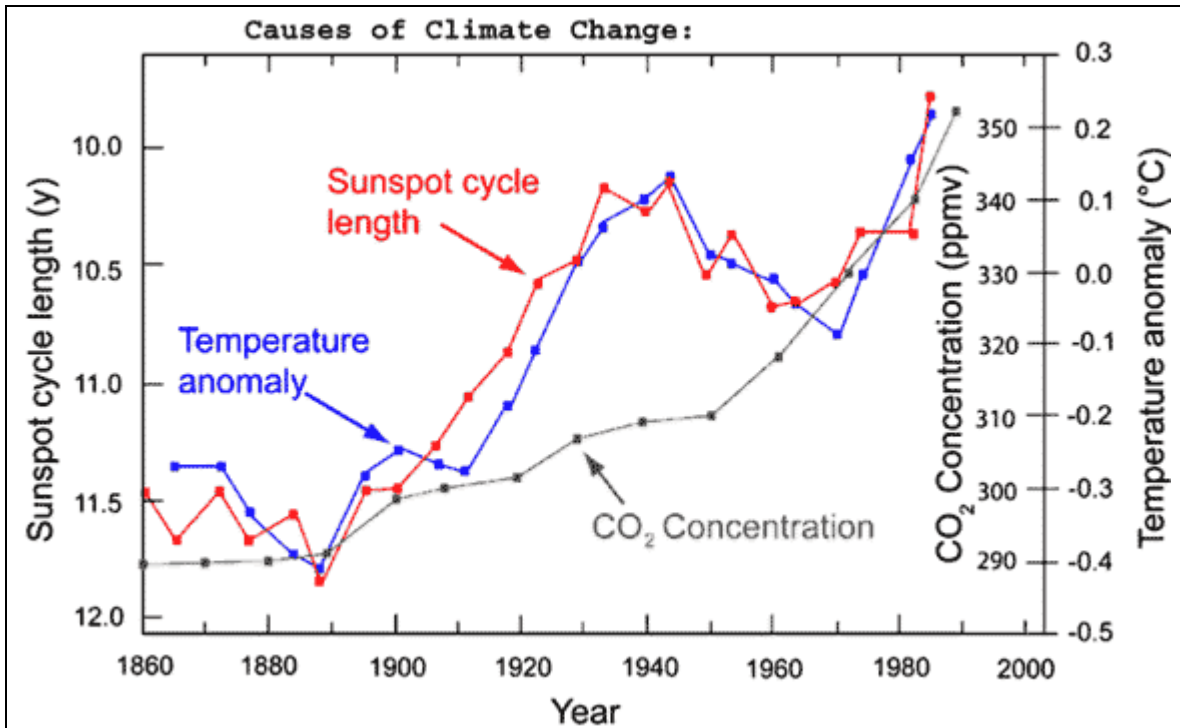


Figure 7: Sunspot cycle length versus smoothed global mean temperatures from 1850 to 1970 and compared with CO₂ concentration

Solar Winds, Cosmic Rays and Clouds

A key aspect of the sun's effect on climate is the indirect effect on the flux of Galactic Cosmic Rays (GCR) into the atmosphere. GCR is an ionizing radiation that supports low cloud formation. As the sun's output increases the solar wind shields the atmosphere from GCR flux. Consequently the increased solar irradiance is accompanied by reduced low cloud cover, amplifying the climatic effect. Likewise when solar output declines, increased GCR flux enters the atmosphere, increasing low cloudiness and adding to the cooling effect associated with the diminished solar energy.

The conjectured mechanism connecting GCR flux to cloud formation received experimental confirmation in the recent laboratory experiments of Svensmark (Proceedings of the Royal Society, Series A, October 2006), in which he demonstrated exactly how cosmic rays could make water droplet clouds.

Palle Bago and Butler showed in 2002 (Intl J Climat.) how the low clouds in all global regions changed with the 11 year cycle in inverse relation to the solar activity. Changes of 1 to 2% in low cloudiness could have a significant effect on temperatures through changes in albedo.

An inverse relationship

Cosmic Rays and the Solar Cycle

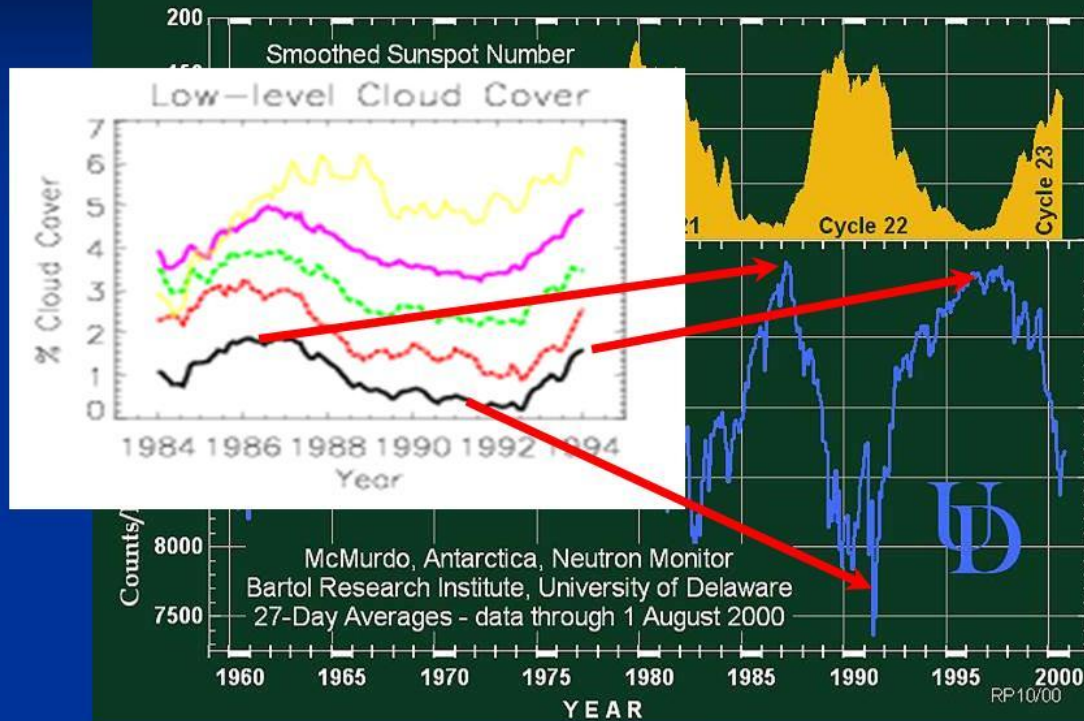


Figure 8: Cosmic ray neutrons are inversely proportional to solar activity and directly proportional to low cloudiness (cloud data from *Palle-Bago and Butler 2002*)

Shaviv (JGR 2005) estimated from the combination of increased radiative forcing through cosmic ray reduction and the estimated changes in total solar luminosity (irradiance) over the last century that the sun could be responsible for up to 77% of the temperature changes over the 20th century with 23% for the anthropogenic. He also found the correlation extended back in the ice core data 500 million years.

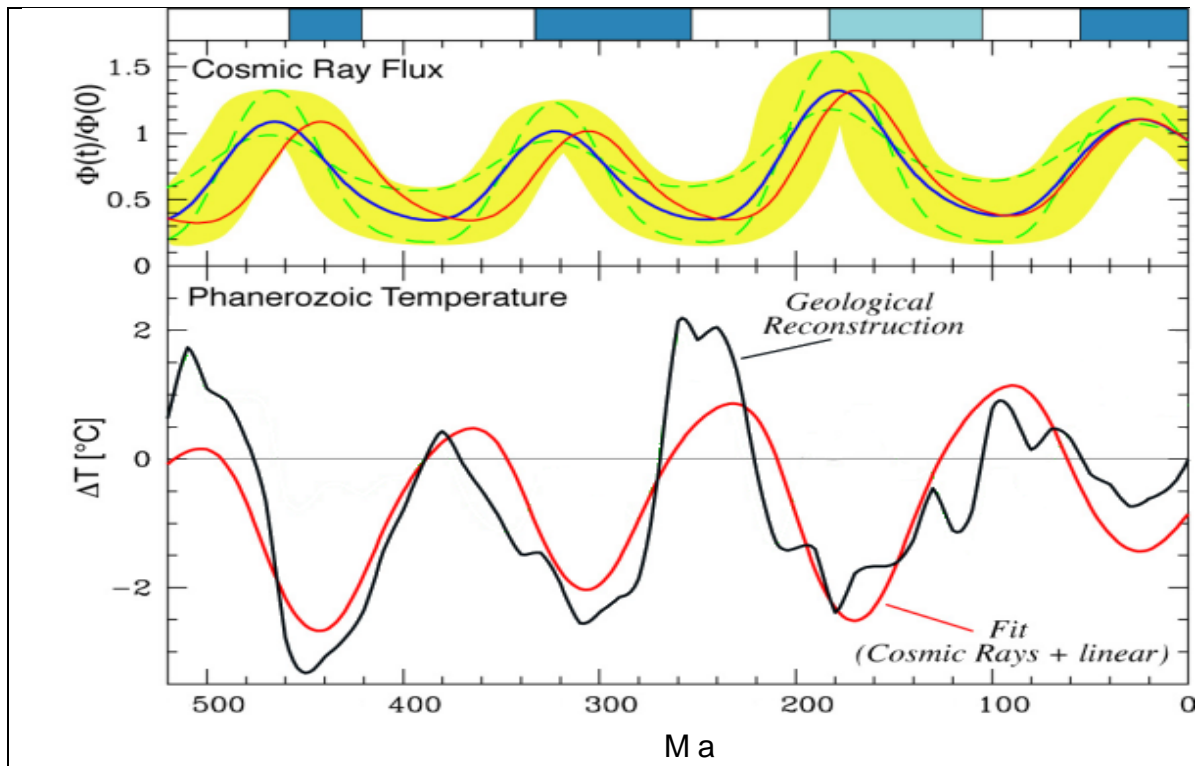


Figure 9: Shaviv Cosmic ray flux plus irradiance versus geological reconstruction of temperatures

Summary:

Though the sun's brightness or irradiance changes only slightly with the solar cycles, the indirect effects of enhanced solar activity including warming of the atmosphere in low and mid latitudes by ozone reactions due to increased ultraviolet radiation, in higher latitudes by geomagnetic activity and generally by increased radiative forcing due to less clouds caused by cosmic ray reduction may greatly magnify the total solar effect on temperatures.

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