SOLAR VARIATION AND GLOBAL CLIMATE CHANGE

SOLAR IRRADIANCE AND GLOBAL CLIMATE CHANGE

The global climate changes described above have coincided with changes in sunspot activity, solar irradiance, and rates of production of ^{14}C and ^{10}Be in the atmosphere by radiation, suggesting that the climate changes are caused by fluctuations in solar activity. A good example of the relationship between solar activity and climate occurred

When Galileo perfected the telescope in 1609, scientists could see sunspots for the first time. They were of such interest that records were kept of the number of sunspots observed, and although perhaps not entirely accurate due to cloudy days, lost records, etc., the records show a remarkable pattern for nearly a century (Fig. 16). From 1600 to 1700 AD, very few sunspots were seen, despite the fact that many scientists with telescopes were looking for them, and reports of aurora borealis were minimal. This interval is known as the Maunder Minimum (E.W. Maunder, 1894; E.E. Maundeer, 1922). After 1700 AD, the number of observed sunspots increased sharply from nearly zero to 50–100 (Fig. 16). The Maunder Minimum was preceded by the Sporer Minimum (~1410–1540 AD) and the Wolf Minimum (~1290–1320 AD). Each of these periods is characterized by low numbers of sunspots, significant changes in the rate of production of ^{14}C in the atmosphere, and cooler global climates.

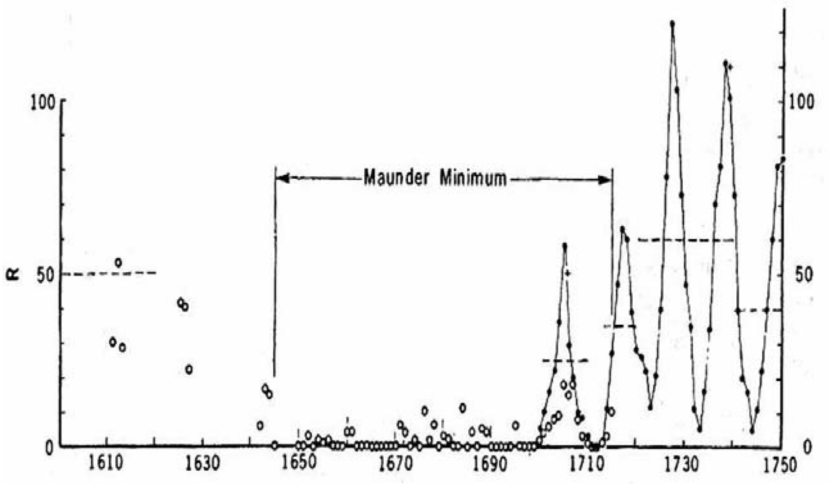

Figure 16. Sunspots during the Little Ice Age. (Modified from Eddy, 1976)

Global temperature change, sunspots, solar irradiance, ^{10}Be and ^{14}C production

Good correlations can now be made between global temperature change, sunspots (Eddy, 1976; Stuiver and Quay, 1980), solar irradiance (Lean, 1989, 1991, 2000, 2001, Lean and Rind, 1998; Lean et al., 1995, 2002), and ^{10}Be (Beer et al., 1994, 1996, 2000) and ^{14}C production (Stuiver, 1961, 1994; Stuiver and Brasiunas, 1991, 1992; Stuiver et al., 1991, 1995) in the atmosphere. ^{10}Be is produced in the upper atmosphere by radiation bombardment of oxygen. Increased radiation results in increased ^{10}Be production. Plots of ^{10}Be production and sunspots indicate a good correlation between the two. Thus, ^{10}Be measurements can serve as a proxy for solar activity.

The close correspondence of solar activity to global climate change from 1860 to 1990 is shown in Figure 9. This is in sharp contrast to the lack of correlation of atmospheric CO_2 changes to global warming and cooling prior to 1980.

Not only did atmospheric global temperature change with solar activity, but so did sea surface temperatures. Figure 11 shows the close correspondence between sunspot number and sea surface temperature.

A similar relationship between solar irradiance and climate change for the past 400 years is shown in Figure 12. The very low sunspot activity that began about 1600 AD is also marked by a decrease in solar irradiance that heralded the beginning of the Little Ice Age. Solar irradiance also dropped during the Dalton Minimum in the early 1800s. Since then, solar irradiance has risen with an oscillatory pattern (Fig. 12)

Solar irradiance and global temperature (Fig. 13) show the same relationship as solar activity (sunspots) and global temperature (Fig. 10). Solar irradiance from 1750 to 1990 shows almost exactly the same pattern as global warming and cooling over the past 250 years.

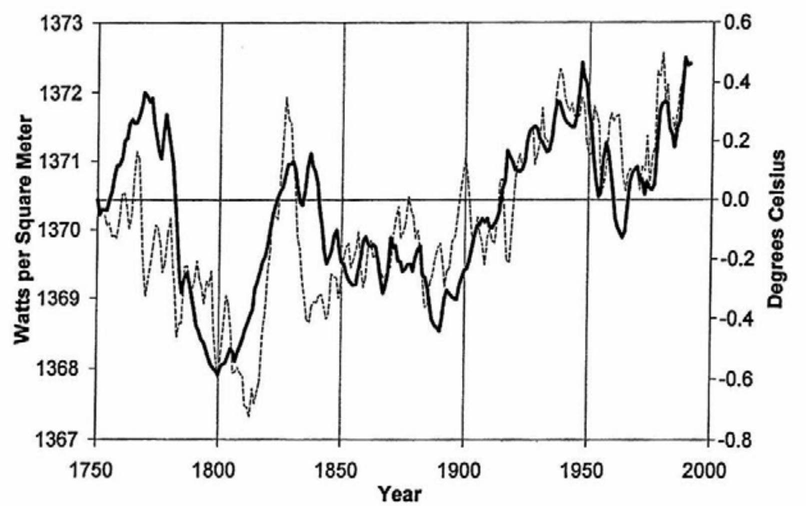

Figure 18. Solar irradiance and global warming and cooling from 1750 to 1990. During this 250 year period, the two curves follow a remarkably similar pattern. (Modified from Hoyt and Schatten, 1997)

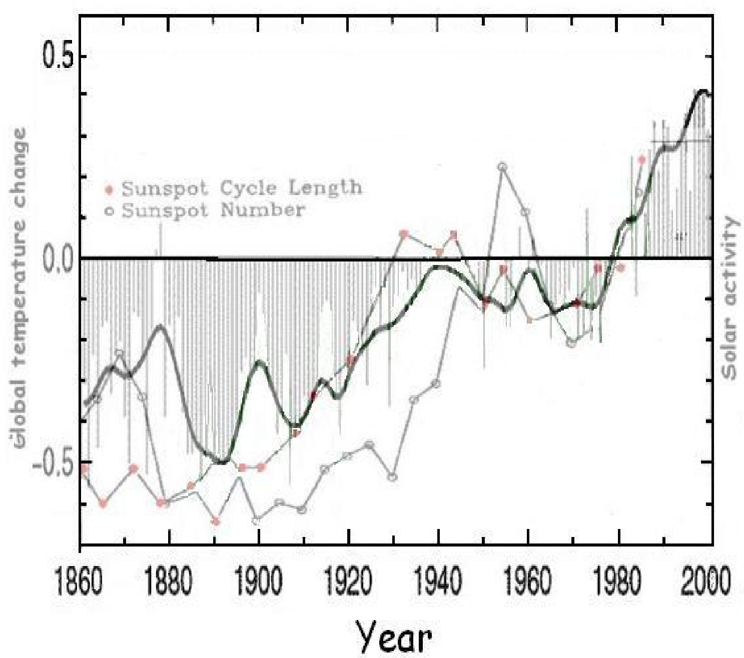

Figure 17. Variation in global warming and cooling with solar activity from 1860 to 1990. Note how closely the trends of the curves follow one another almost exactly. Contrast this with the lack of correlation of CO_2 variation and global temperature shown in Figure 3 and in pre–1980 global temperature changes.

Most atmospheric oxygen consists of ^{16}O but a small amount consists of ^{18}O, an isotope of oxygen that is somewhat heavier. When water vapor (H_2O) condenses from the atmosphere as snow, it contains a ratio of $^{16}O/^{18}O$ ($\Delta^{18}O$) that reflects the temperature at the time. When the snow falls on a glacier and is converted to ice, it retains an isotopic 'fingerprint' of the temperature conditions at the time of condensation. Measurement of the $^{16}O/^{18}O$ ratios in glacial ice hundreds or thousands of years old allows reconstruction of past temperature conditions. Figure 14 shows the variation of temperature change with variation of solar irradiance from 1840 to 1960.