THE DEMISE OF SUNSPOTS—DEEP COOLING AHEAD?

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The three studies released by NSO's Solar Synoptic Network this week, predicting the virtual vanishing of sunspots for the next several decades and the possibility of a solar minimum similar to the Maunder Minimum, came as stunning news. According to Frank Hill, *"the fact that three completely different views of the Sun point in the same direction is a powerful indicator that the sunspot cycle may be going into hibernation."* The last time sunspots vanished from the sun for decades was during the Maunder Minimum from 1645 to 1700 AD was marked by drastic cooling of the climate and the maximum cold of the Little Ice Age.

What happened the last time sunspots disappeared?

Abundant physical evidence from the geologic past provides a record of former periods of global cooling. Geologic records provide clear evidence of past global cooling so we can use them to project global climate into the future—the past is the key to the future. So what can we learn from past sunspot history and climate change?

Galileo's perfection of the telescope in 1609 allowed scientists to see sunspots for the first time. From 1610 A.D. to 1645 A.D., very few sunspots were seen, despite the fact that many scientists with telescopes were looking for them, and from 1645 to 1700 AD sunspots virtually disappeared from the sun (Fig. 1). During this interval of greatly reduced sunspot activity, known as the Maunder Minimum, global climates turned bitterly cold (the Little Ice Age), demonstrating a clear correspondence between sunspots and cool climate. After 1700 A.D., the number of observed sunspots increased sharply from nearly zero to more than 50 (Fig. 1) and the global climate warmed.

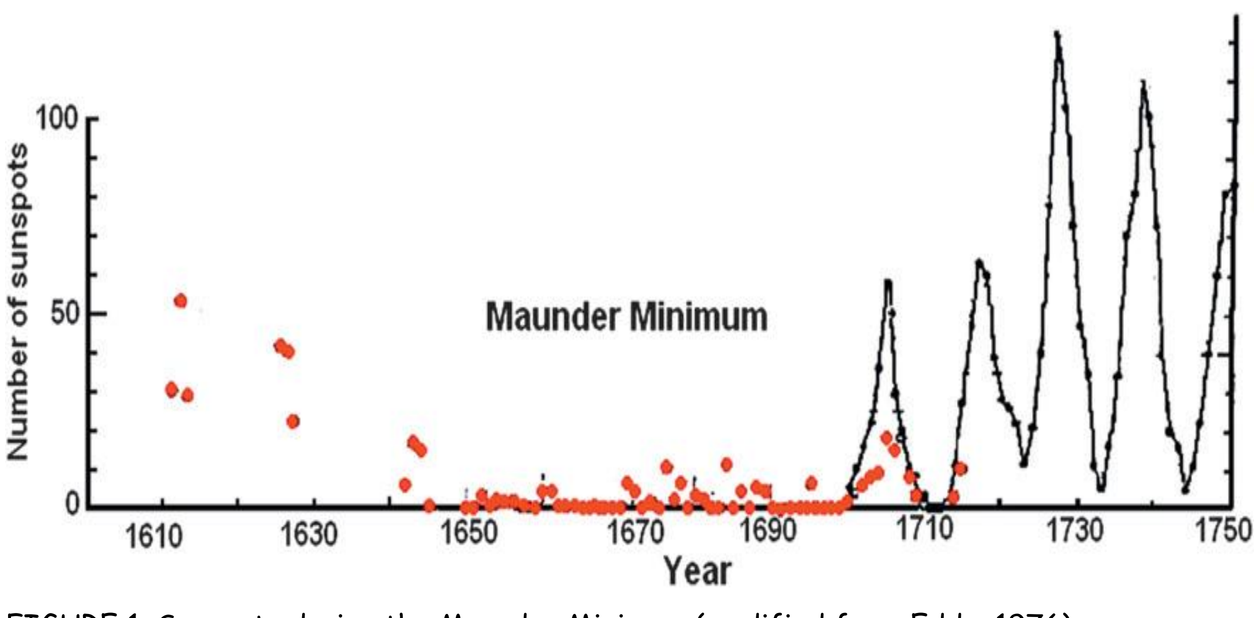

FIGURE 1. Sunspots during the Maunder Minimum (modified from Eddy, 1976).

The Maunder Minimum was not the beginning of The Little Ice Age—it actually began about 1300 AD—but it marked perhaps the bitterest part of the cooling. Temperatures dropped ~4° C (~7 ° F) in ~20 years in mid-to high latitudes. The colder climate that ensued for several centuries was devastating. The population of Europe had become dependent on cereal grains as their main food supply during the Medieval Warm Period and when the colder climate, early snows, violent storms, and recurrent flooding swept Europe, massive crop failures occurred. Winters in Europe were bitterly cold, and summers were rainy and too cool for growing cereal crops, resulting in widespread famine and disease. About a third of the population of Europe perished.

Glaciers all over the world advanced and pack ice extended southward in the North Atlantic. Glaciers in the Alps advanced and overran farms and buried entire villages. The Thames River and canals and rivers of the Netherlands frequently froze over during the winter. New York Harbor froze in the winter of 1780 and people could walk from Manhattan to Staten Island. Sea ice surrounding Iceland extended for miles in every direction, closing many harbors. The population of Iceland decreased by half and the Viking colonies in Greenland died out in the 1400s because they could no longer grow enough food there. In parts of China, warm weather crops that had been grown for centuries were abandoned. In North America, early European settlers experienced exceptionally severe winters.

So what can we learn from the Maunder? Perhaps most important is that the Earth's climate is related to sunspots. The cause of this relationship is not understood, but it definitely exists. The second thing is that cooling of the climate during sunspot minima imposes great suffering on humans—global cooling is much more damaging than global warming.

Global cooling during other sunspot minima

The global cooling that occurred during the Maunder Minimum was neither the first nor the only such event. The Maunder was preceded by the Sporer Minimum (~1410–1540 A.D.) and the Wolf Minimum (~1290–1320 A.D.) and succeeded by the Daltong Minimum (1790–1830), the unnamed 1880–1915 minima, and the unnamed 1945–1977 Minima (Fig. 2). Each of these periods is characterized by low numbers of sunspots, cooler global climates, and changes in the rate of production of ^{14}C and ^{10}Be in the upper atmosphere. As shown in Fig. 2, each minimum was a time of global cooling, recorded in the advance of alpine glaciers.

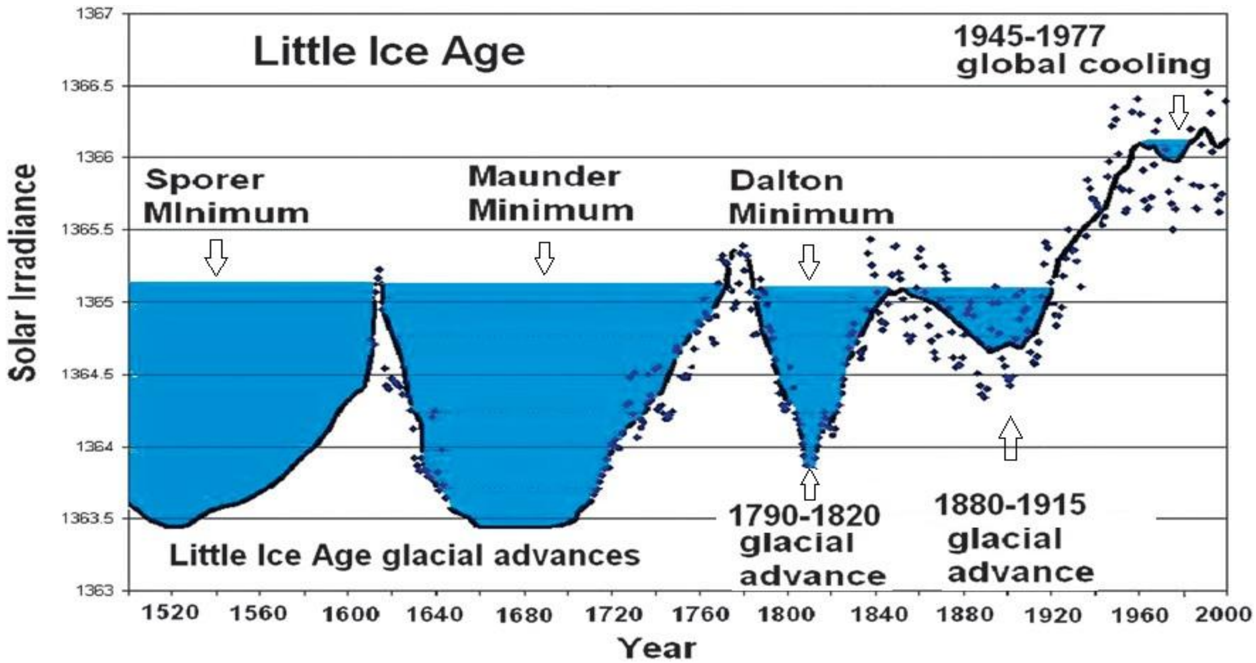

Figure 2. Correspondence of cold periods and solar minima from 1500 to 2000 AD. Each of the five solar minima was a time of sharply reduced global temperatures (blue areas).

The same relationship between sunspots and temperature is also seen between sunspot numbers and temperatures in Greenland and Antarctica (Fig. 3). Each of the four minima in sunspot numbers seen in Fig. 3 also occurs in Fig. 2. All of them correspond to advances of alpine glaciers during each of the cool periods.

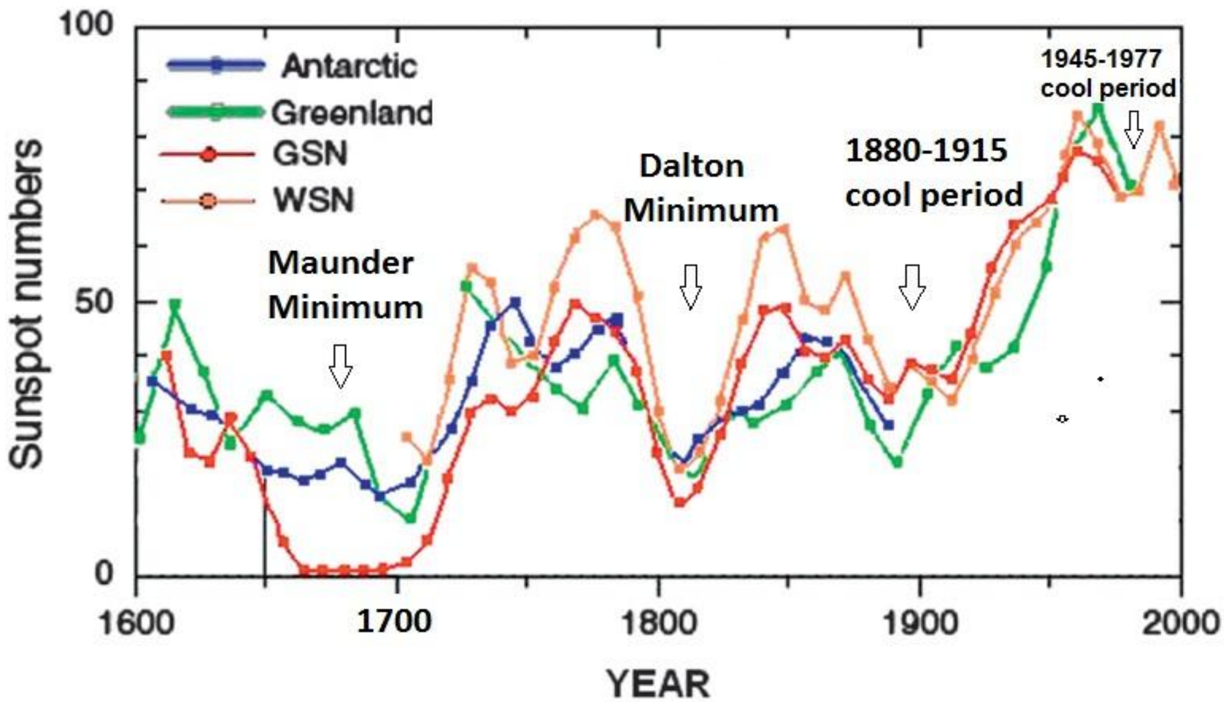

Figure 3. Correlation of sunspot numbers and temperatures in Greenland and Antarctica (modified from Usoskin et al., 2004).

Figure 4 shows the same pattern between solar variation and temperature. Temperatures were cooler during each solar minima.

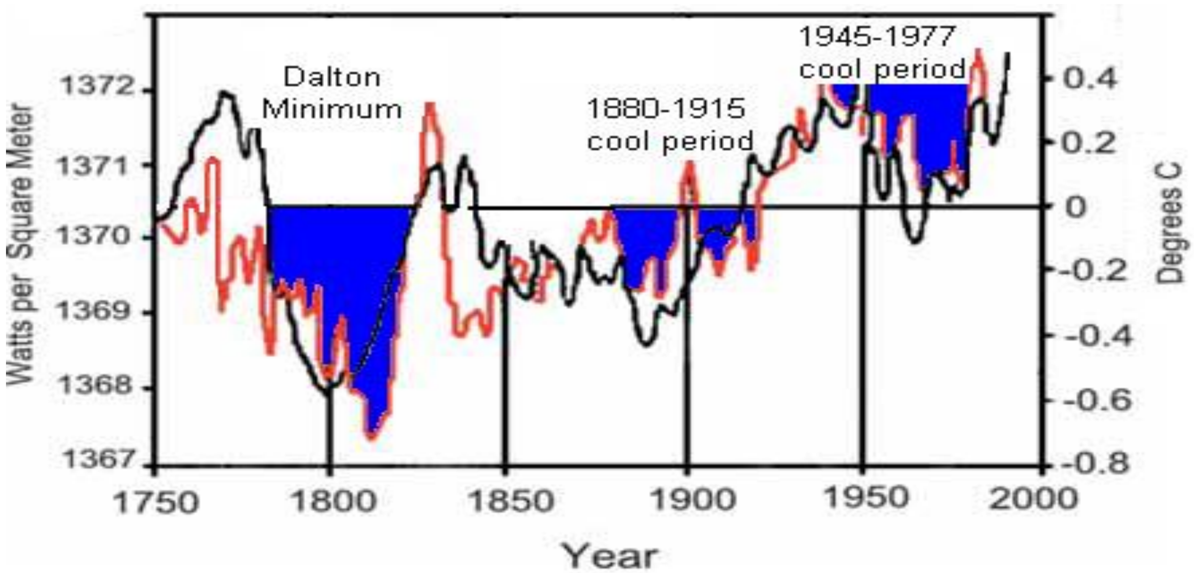

Figure 4. Solar irradiance and temperature from 1750 to 1990 AD. During this 250-year period, the two curves follow remarkably similar patterns (modified from Hoyt and Schatten, 1997). Each solar minima corresponds to climatic cooling.

What can we learn from this historic data? Clearly, a strong correlation exists between solar variation and temperature. Although this correlation is too robust to be merely coincidental, exactly how solar variation are translated into climatic changes on Earth is not clear. For many years, solar scientists considered variation in solar irradiance to be too small to cause significant climate changes. However, Svensmark (Svensmark and Calder, 2007; Svensmark and Friis-Christensen, 1997; Svensmark et al., 2007) has proposed a new concept of how the sun may impact Earth's climate. Svensmark recognized the importance of cloud generation as a result of ionization in the atmosphere caused by cosmic rays. Clouds reflect incoming sunlight and tend to cool the Earth. The amount of cosmic radiation is greatly affected by the sun's magnetic field, so during times of weak solar magnetic field, more cosmic radiation reaches the Earth. Thus, perhaps variation in the intensity of the solar magnetic field may play an important role in climate change.

Are we headed for another Little Ice Age?

In 1999, the year after the high temperatures of the 1998 El Nino, I became convinced that geologic data of recurring climatic cycles (ice core isotopes, glacial advances and retreats, and sun spot minima) showed conclusively that we were headed for several decades of global cooling and presented a paper to that effect (Fig. 5). The evidence for this conclusion was presented in a series of papers from 2000 to 2011 (The data are available in several GSA papers, my website, a

2010 paper, and in a paper scheduled to be published in Sept 2011). The evidence consisted of temperature data from isotope analyses in the Greenland ice cores, the past history of the PDO, alpine glacial fluctuations, and the abrupt Pacific SST flips from cool to warm in 1977 and from warm to cool in 1999. Projection of the PDO to 2040 forms an important part of this cooling prediction.

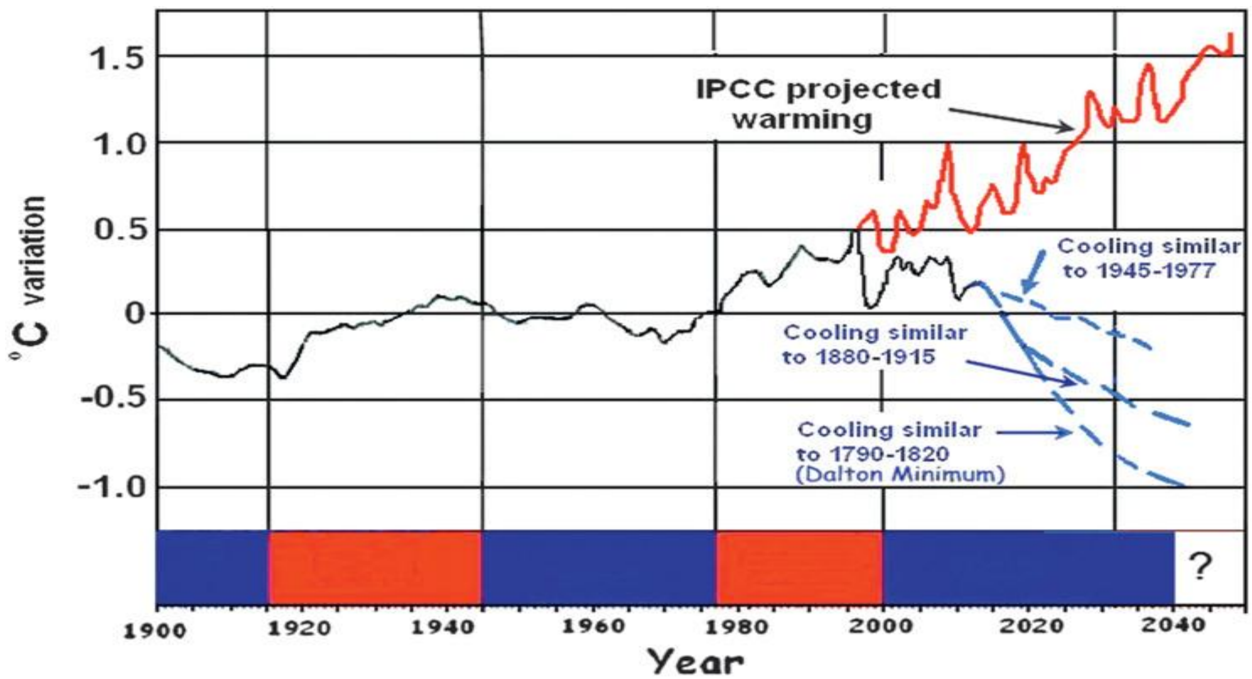

Figure 5. Projected temperature changes to 2040 AD. Three possible scenarios are shown: (1) cooling similar to the 1945-1977 cooling, cooling similar to the 1880-1915 cooling, and cooling similar to the Dalton Minimum (1790-1820). Cooling similar to the Maunder Minimum would be an extension of the Dalton curve off the graph.

So far, my cooling prediction seems to be coming to pass, with no global warming above the 1998 temperatures and a gradually deepening cooling since then. However, until now, I have suggested that it was too early to tell which of these possible cooling scenarios were most likely. If we are indeed headed toward a disappearance of sunspots similar to the Maunder Minimum during the Little Ice Age then perhaps my most dire prediction may come to pass. As I have said many times over the past 10 years, time will tell whether my prediction is correct or not. The announcement that sun spots may disappear totally for several decades is very disturbing because it could mean that we are headed for another Little Ice Age during a time when world population is predicted to increase by 50% with sharply increasing demands for energy, food production, and other human needs. Hardest hit will be poor countries that already have low food production, but everyone would feel the effect of such cooling. The clock is ticking. Time will tell!

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