

The Varying Sun & Climate Change

by Willie Soon &
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He had been Eight Years upon a Project for extracting Sun Beams out of Cucumbers, which were to be put into Vials hermetically sealed, and let out to warm the Air in the raw inclement Summers.

—“A Visit to the Grand Academy of Lagado,” Jonathan Swift, 1726

Early in the nineteenth century, William Herschel (1738-1822), discoverer of Uranus and one of the greatest minds in astronomy, wondered if the sun could vary in ways that would affect the climate of earth. He did so while uncovering the first proof for “invisible light,” or infrared radiation, through an ingenious study of the solar spectrum.

Starting around late 1610, Galileo Galilei in Italy, Johann Goldsmid (or Johann Fabricius) and his father in Holland, Thomas Harriot in England, and Christoph Scheiner in Germany, had begun recording the dark sunspots on the disk of the sun through early telescopes. The *maculae* could emerge, evolve in shape, migrate across the disk of the sun as they were carried by rotation, and disappear. The nature of sun-

spots would remain mysterious until the twentieth century.

By Herschel’s time, 200 years later, it had been seen that the quantity of sunspots on the solar disk varied. Herschel examined available historical records and noted periods of sustained high numbers of sunspots, and also periods of low numbers of spots. Herschel speculated in 1801 that when the sun was highly spotted, it “may lead us to expect copious emission of heat and therefore mild seasons,” while few spots suggested “sparse emission of heat” accompanied by “severe seasons” (Herschel, 1801). In order to test his speculation that the observed changes on the sun might affect climate, Herschel turned to records of the price of wheat in England as a proxy for climate, because meteorological measurements were lacking. Herschel imagined that costly wheat would result from “severe seasons,” while the “mild seasons” would moderate the price of wheat. Herschel found in records of wheat prices support for his speculation—five lengthy periods of few sunspots were tied to costly wheat. When Herschel, a first-class, imaginative scientist, presented his carefully-worded report to the Royal Society, Lord Brougham (1778-1868; of the brougham carriage fame) scoffed, and called them a “grand absurdity” for “[s]ince the publication of Gulliver’s

voyage to Laputa, nothing so ridiculous has ever been offered to the world” (*Edinburgh Review*, 1803).

Since Herschel’s report, the nature of the sun and its spots has been refined. High numbers of sunspots appear approximately every 11 years, with few sunspots seen at times between the 11-year peaks. In 1908 at Mount Wilson Observatory, George Ellery Hale (1868-1938) discovered that sunspots were relatively tiny regions of densely packed magnetic fields on the sun’s surface, shaped in large loops, similar to that of one end of a bar magnet’s field lines. In the last two decades, NASA satellites have monitored changes in the sun’s energy output that vary in step with changes in the number of sunspots. The sun’s total energy output is higher at sunspot or magnetic maximum in the 11-year cycle, while the energy output is lower at sunspot minimum. As a result, the amount of energy that the earth receives varies, with slightly more energy received at sunspot maximum than sunspot minimum. According to two decades of satellite measurements, the difference in energy delivered to the earth between sunspot maximum and minimum is a scant one-tenth of one percent.

That variable one-tenth of one percent of the sun’s total energy output, and the long duration of the period of change, are thought to be too small and too

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short in duration to modify the globally-averaged temperature at the earth's surface. At first glance, one might expect that the earth's surface temperature is secure from a variable sun.

However, the measurements of the sun's energy output only extend back two decades. The sun varies more dramatically over centuries. And, as with Herschel's lack of temperature records, researchers lack direct measurements of the sun's energy output over centuries. As Herschel did, modern researchers turn to proxies of the sun's energy output.

As noted above, the sun's total energy output varies in step with changes in its magnetism, as contained in the sunspot record that goes back nearly 400 years since the times of Galileo and those early solar astronomers.

The centuries-long view of the sun differs significantly from that seen in the short, two-decade window afforded by satellites. About 100 years ago, E. Walter Maunder (1851-1928) reawakened the early idea, based on early sunspot sightings, that the sun had displayed unusually low magnetism during most of the seventeenth century. This period of low magnetism, along with the almost total disappearance of sunspots for the extended interval from about 1620 to 1720, is now called the Maunder Minimum.

Information on the sun's magnetism stretching back 10,000 years or so can be derived from measurements of radiocarbon, or carbon 14, in tree rings of old and dead trees. (Another, independent estimate of the sun's magnetic history comes from trace amount of Beryllium 10 (^{10}Be) in ice cores.¹) During the Maunder Minimum, the sun's weak magnetic field allows more energetic charged particles from the galaxy, called cosmic rays, to hit the earth's atmosphere, and create more radiocarbon

and ^{10}Be . The amount of radioactive isotopes in tree rings or ice cores is an inverse indicator of the sun's magnetic field strength. Because satellite measurements suggest that the sun's energy output varies in step with the changes in the magnetic field over decades to centuries, the tree ring and ice core measurements imply that the sun's energy output also changes over decades to centuries. In the last several hundred years, the sun's magnetism has been low in the nineteenth, seventeenth, fifteenth, and fourteenth centuries.

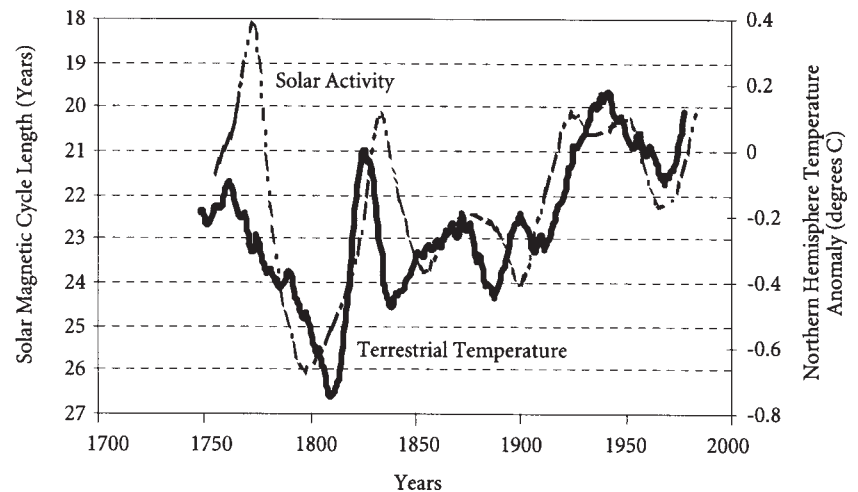
The coldest century of the last millennium, with worldwide evidence for significant advances of glaciers, coincides with the Maunder Minimum of the seventeenth century. Thus, periods of low solar magnetism and cold spells are linked. Gradual changes in the sun's magnetism over decades or longer may correspond with changes in the sun's total energy output, and contribute to

some of the observed climate change in the last millennium.

Figure 1 shows a connection of this type. The sun's increasing and decreasing magnetism over the decades is correlated with terrestrial temperature change. In figure 1, estimates of the northern hemisphere land temperature are shown because global temperature estimates do not go back beyond the mid-nineteenth century; however, the two records agree well when they overlap. Changes in the sun's magnetism, if accompanied by modest brightness changes of a few tenths of a percent, could explain the reconstructed temperature change of the past 200 to 250 years.²

The chart stops around 1980 because the sun's changes are presumed to operate over two decades or longer. Yet the period beyond 1980 is interesting because it corresponds to the period

Figure 1: A Sun-Climate Link?



Changes in the sun's magnetism and in the reconstructed northern hemisphere's land temperature are highly correlated over the last 240 years. The sun's magnetic changes are associated with changes in its total energy output, and may explain the close connection to terrestrial temperatures on time scales of decades to centuries. The changes in the sun's magnetism are represented by changes in the length of the "Hale polarity" or 22-year cycle, which is closely linked to the 11-year sunspot cycle. (Source: Baliunas and Soon, 1995, p. 896.)



when the air's carbon dioxide content rose, and also shows a major surface warming trend. Some say this indicates that carbon dioxide is responsible for the warming of the last 20 years. But for this to be true, the raised carbon dioxide concentration in the air must, according to computer simulations of climate, also produce a warming trend in the low layer of air, from about 2 to 8 km in height. NASA/NOAA satellite- and balloon-borne instruments, however, show little evidence for the human-made warming trend forecast by computer simulations.

Instead, the surface warming, as displayed in figure 1, may be largely natural and result from the varying total energy output of the sun. In this scenario, a persistent and systematic impact of the changing solar light energy may modify the sea surface temperature and evaporate more or less water vapor to the air, and thus, in turn, warm or cool the near-surface temperature through the greenhouse effect (for a short, but accurate, explanation of the greenhouse effect, see our article "Can Climate Models Predict Future Weather?" in the January 2002 *Fraser*

Forum). Other fluctuations of the sun (for example, its speedy wind of charged particles, its magnetic field, and ultraviolet light) may also affect terrestrial climate. For instance, fast-moving particles from the sun may alter the properties of terrestrial clouds or stratospheric ozone, or both, and so affect the pattern of air circulation in the troposphere below, and hence air temperature near the earth's surface.

The cold periods of the last 1,000 years, often seen in conjunction with periods of low magnetism on the sun, may be a clue to one of several factors influencing climate. Those natural factors must be accurately known in order to understand the backdrop against which human-caused climate change would be seen. As new discoveries of natural climate factors are determined, in part from advanced space technology, researchers hope to improve climate forecasts so that they can understand the human-made global climate factor. In the case of the sun and climate change, Herschel may have made an interestingly correct guess, backed with scanty but intriguing evidence.

Note

¹Beryllium 10, or ¹⁰Be, is a cosmogenic isotope (it has a half life of 1.5 million years, instead of the some 5,730 years of carbon 14) of ⁹Be, which is the dominant beryllium element on Earth.

²Brightness refers to the total wavelength-integrated amount of solar light energy. Measurements of the total wavelength-integrated amount of solar light energy or solar brightness changes are done with very precise, satellite-borne radiometers. The difficulties with these measurements are related to the small amount of change and the requirement that the measurements be sustained for at least 10 to 20 years.

References

- Baliunas, Sallie and Willie Soon (1995). *Astrophysical Journal*, 450.
- Brougham, Lord (1803). Critique. *Edinburgh Review* (January).
- Herschel, W. (1801). "Observations Tending to Investigate the Nature of the Sun, in Order to Find the Causes and Symptoms of its Variable Emission of Light and Heat ..." *Philosophical Transactions of the Royal Society of London*. Vol. 91, pp. 261-331.

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