

SOLAR PHYSICS AND THE CLIMATE PROBLEM

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Abstract: When I delivered a paper on solar activity at the first SPD meeting, none of us thought it had anything to do with Earth's climate. Scientists of earlier generations had published correlations between solar variations and one or another terrestrial phenomenon, but by 1970 modern statistical analysis had driven out everyone but cranks. However, in 1976 Jack Eddy boldly nailed down the existence of a long period of low solar activity coinciding with the 'Little Ice Age' familiar to climate historians. Meanwhile solar activity was increasing to historic highs—and so was global temperature. Most experts thought the global warming was caused by emissions of greenhouse gases, but corporations that profited from emissions and others who despised government regulation exploited the hypothetical solar-climate connection to deny that we faced dangerous climate change. Debate exploded, invoking complex mechanisms whereby solar activity might affect Earth's atmosphere. These arguments collapsed when solar activity dropped yet global temperature climbed ever faster. Nevertheless, the zombie belief that global warming is a harmless 'natural cycle' persists, helping to impede urgent policy changes.

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1 INTRODUCTION

"What earthly good is there in going to some remote place with a ton of costly equipment to see an eclipse?" That question was posed by an acquaintance on my return from the expedition which produced the paper I gave at the inaugural Solar Physics Division meeting about a high-resolution temperature profile of the chromosphere (see [Figure 1](#)). I gave the usual answers about the unknown potential of curiosity-driven science, about solar activity being important for radio and satellites, and, well, maybe solar activity had an influence on the weather? Afterward I felt guilty about that last, because most of us in 1970 knew that claims of solar-terrestrial connections led into the bogs of pseudo-science and plain hogwash.

2 SOLAR VARIABILITY, WEATHER AND CLIMATE

Since the nineteenth century scientists have pursued the question of how solar variability, and in particular the 11-year sunspot cycle, might relate to short-term weather and long-term climate changes (for a more extensive history of the following and references see [Weart, 2020](#)). Despite widespread scientific skepticism, the study of cycles had been popular since the 1920s. By then there were several decades of good weather data to play with, while methods of statistical checking were primitive and idiosyncratic if attempted at all.

Inevitably people found correlations between sunspot cycles and selected weather patterns. Respected scientists and enthusiastic amateurs announced solar influences (say, on storms in a particular region) that they insisted were reliable enough to make predictions. The most persistent advocate of a solar-terrestrial connection was Charles Greeley Ab-

bot (1872–1973) of the Smithsonian Astrophysical Observatory. Self-confident and combative, Abbot defended his findings against all objections, meanwhile telling the public that solar studies would bring wonderful improvements in weather prediction. He and a few others at the Smithsonian pursued the topic single-mindedly into the 1960s, convinced that sunspot variations were a main influence on both weather and climate change.

Sooner or later, every prediction based on cycles failed. Therefore in the 1960s, according to a leading British meteorologist

For a young [climate] researcher to entertain any statement of sun-weather relationships was to brand oneself a crank. ([Lamb, 1997: 192–193](#)).

Yet alongside the cranks a few scientists pursued exasperating hints. If you applied good statistical techniques to enough tree ring records or other climate proxies, you would sometimes turn up the 11-year solar cycle in one or another region, although nothing obviously strong or consistent. For example, in the 1970s some eminent meteorologists caught public attention with claims about a 22-year cycle of droughts in the American High Plains, presumably driven by the solar magnetic cycle.

A broader claim was in press at the time our Division was founded. A team led by the Dan-

The Photosphere-Chromosphere Transition: New Eclipse Observations. SPENCER R. WEART, *Hale Observatories.* - Photoelectric observations of solar continuum radiation were made at the March 7, 1970 eclipse. Preliminary analysis of data confirms the existence of a distinct layer ≈ 1500 km thick at the base of the chromosphere. The transition from the photosphere to this layer occurs in a distance no larger than the 50 km resolution of our experiment.

Figure 1: Spencer Weart's abstract from the first SPD (after [Weart, 1971](#)).

ish glaciologist Willi Dansgaard (1922–2011), measuring layers of ancient ice in cores drilled deep into the Greenland ice cap, found cyclical variations. They supposed the Sun was responsible. For the chief cycle that they detected, about 80 years long, had already been reported by scientists who had analyzed small variations in the sunspot cycle. The oscillations were so regular that Dansgaard's group boldly extrapolated the curves into the future. They began by matching their results with a global cooling trend that, as others reported, had been underway since around 1400. The group predicted the cooling would continue through the next one or two decades, followed by a warming trend for the following three decades or so.

Wallace Broecker (1931–2019), arguably the leading geo-chemist of his generation, was impressed. He assumed that the cycles were indeed solar and had a global reach. But there was another global influence that was beginning to catch the attention of geoscientists: Charles David Keeling (1928–2005) who took meticulous measurements showing a rise in the atmosphere's carbon dioxide. Broecker figured that in the 1980s, as Dansgaard's solar cycles bottomed out and began to rise, the CO₂ greenhouse effect warming would add additional heat. Broecker (1975) predicted an abrupt and dangerous emergence of, to coin a phrase, 'global warming'. His now famous 1975 paper in *Science* introduced the phrase and attracted some attention to the problem.

Not for the first time, Broecker's brilliant scientific intuition was better than his evidence. The 80-year cycle, if it existed at all, was later shown to be a quasi-cyclical regional shifting in the North Atlantic Ocean's surface warmth and winds. The downturn in 'global' temperature since the 1400s was actually confined to the Northern Hemisphere (Southern data had not yet been compiled); decades later its main cause was identified as an increase of industrial smog. But Broecker's conclusion was dreadfully correct: in the 1980s the greenhouse effect indeed began to outrun any other presumed influence on global temperature.

The first truly persuasive argument for a solar influence on climate came from one of us, a solar physicist. Jack Eddy (1931–2009) had lost his job because he did not focus on our traditional types of research, and he had time to pore over old books. He had decided to review historical naked-eye sunspot records with the aim of definitively confirming the long-standing belief that the sunspot cycle was stable over the centuries. Since the nineteenth century some people had noticed that during the sixteenth and seventeenth centuries sky-watchers had

reported almost no sunspot activity. But there had been few if any actual scientists back then, and absence of evidence is not evidence of absence. Hard historical work gradually persuaded Eddy that the early modern observers were reliable—the absence of sunspot evidence really was evidence of an absence. Reports of aurorae (or rather, their absence) backed it up. Eddy (1976) published over-whelming proofs of an early modern hiatus in solar activity. Understanding that it is not enough to prove a scientific point, you need people to notice it, Eddy dubbed the hiatus the 'Maunder Minimum', picking from the earlier scientists who had noticed the phenomenon a name that made a memorable phrase.

The best evidence for anything is corroboration from an entirely different line of evidence. The isolation of scientific specialties from one another is so serious that Eddy was far along in his work before someone told him about carbon-14. Back in 1965 the geochemist Hans Suess (1909–1993) had resolved a bitter controversy in radiocarbon dating by showing that the production of C¹⁴ varied over the centuries. In particular it had been unusually high during the early modern period. Suess hypothesized that the cause was low solar magnetic activity, which had permitted more cosmic rays to reach Earth. His C¹⁴ curve suggested a solar-terrestrial connection, for it matched the history that had long been popularized by climatologists: a 'Medieval Warm Period' (when Vikings settled Greenland) followed by a 'Little Ice Age' (when winter fairs were held on the frozen Thames River). Suess' claims were met with skepticism until Eddy tied it all together. Even then, scientists were wary. How could cosmic rays, depositing energy utterly negligible compared to the Sun's total output, determine whether the Thames froze over?

In 1975 the respected meteorologist Robert Dickinson had reviewed solar influence on weather for the American Astronomical Society. He endorsed the received view that there was no plausible connection—and then he suggested one. Could the electrical charges that cosmic rays generate in the atmosphere influence the formation of aerosols, which act as nuclei for water condensation, and thus affect cloudiness? It was piling speculation upon speculation, as Dickinson was first to admit, but it left the door open a crack. For a public long since accustomed to hearing that sunspots affect the weather, it now seemed a sure thing: low solar activity had caused the 'Little Ice Age'. It was only in the twenty-first century that enough historical data was analyzed to show that the pioneering climatologists, who all lived around the

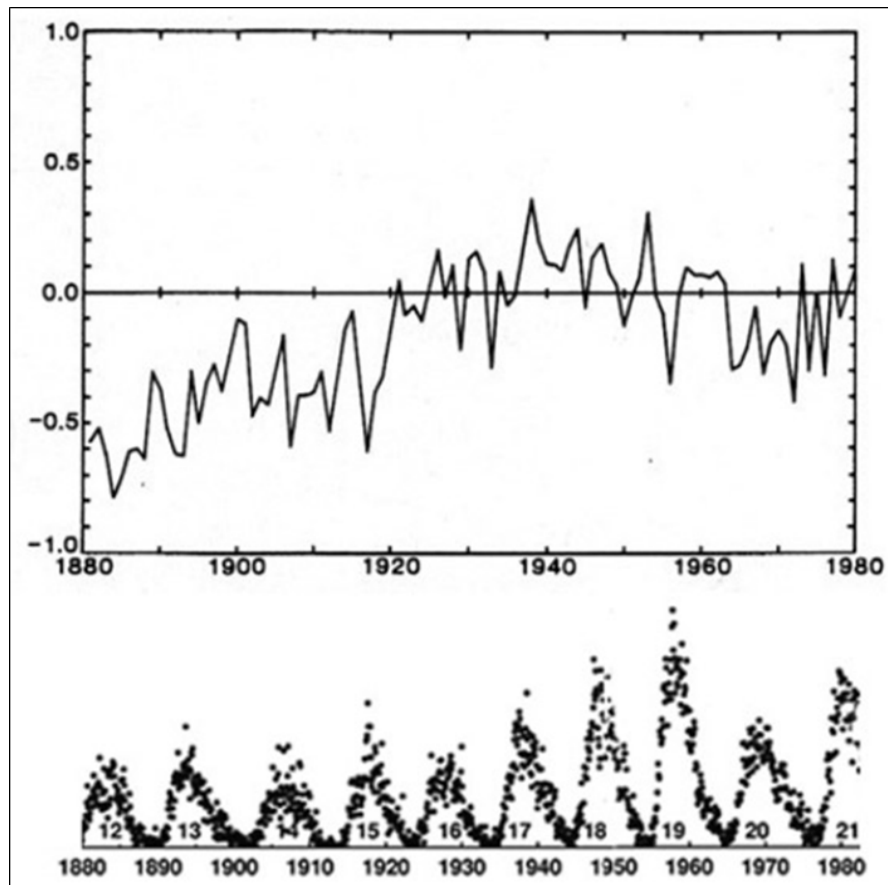


Figure 2: A synthesis of Northern Hemisphere temperatures in comparison with sunspot numbers, 1880–1982. Temperature graph adapted from Jones, Wigley and Kelly (1982: 67).

North Atlantic, had lavished too much attention on their home region. The Medieval Warm Period was scarcely seen elsewhere, and the Little Ice Age was global only as a set of cold spells in different regions at different times.

Interest naturally centered on graphs of global temperature—Northern Hemisphere temperature really, but few thought that mattered. From the earliest good records in the 1880s you saw a clear rise to about 1940, then a slow decline, followed by a turn back up around 1980. And behold, this roughly matched the intensity of sunspot activity (Figure 2)! Scientists remained dubious so long as there was no demonstrated mechanism to connect the solar and terrestrial trends. Not until the twenty-first century did it become possible to compare massive weather model computations with gigabytes of weather data alongside experimental tests on proposed cosmic ray effects. Various proposals for complex mechanisms left open a possibility that solar activity could have a small influence, not on global climate but on particular types of weather in particular regions; research continues. In the 1980s, despite doubts about a mechanism, it looked like *something* might be going on.

Arguments that solar activity swayed global temperature were a godsend to the fossil fuel industries. Warnings by Broecker and others that the rise of atmospheric CO₂ would bring a dangerous global warming had begun to threaten the entire modern system of resource extraction for short-term private profit. Coal, oil, and related industries, collaborating with extremely wealthy individuals who despised government regulations, lavished attention and money on anyone who would deny that greenhouse gas emissions posed a problem.

Of the many deniers, arguably the most important was Fred Singer (1924–2020). Once a respected meteorologist, in retirement Singer became a main opponent of action to restrain global warming, giving talks and mailing newsletters that claimed the actual temperature trend was flat or cooling. Given a dataset, Singer would pluck out and publicize the portions that supported his assertions. His greatest coup was persuading his old friend Fred Seitz (1911–2008) a solid-state physicist and former president of the National Academy of Sciences, to sign off on statements that had a superficially scientific appearance. One significant example was a ‘report’ issued by the right-wing George

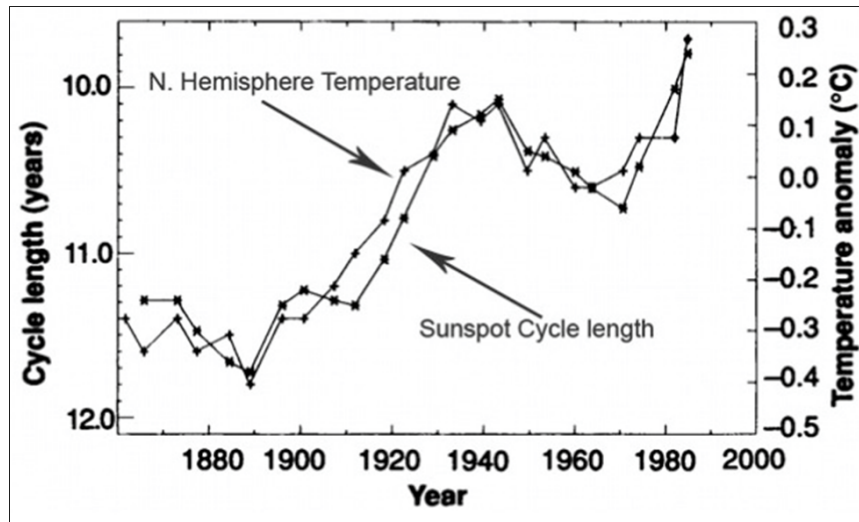


Figure 3: A comparison of Northern Hemisphere temperatures with the length of sunspot cycles (later shown to be calculated erroneously) (adapted from Friis-Christensen and Lassen, 1991).

C. Marshall Institute. It featured a chart showing a tight correlation between global temperature and the *length* of the sunspot cycle (Figure 3). There was not even an attempt at proposing a mechanism, and the correlation naturally fell apart at the very next cycle—but damage was done. The pamphlet circulated in the administration of George H.W. Bush, who as a presidential candidate had conceded that global warming should be addressed. The Marshall Institute's hokum gave scientific cover to the administration's retreat into full support of the fossil fuel industries.

Meanwhile, a slightly different question attracted attention: was the 'solar constant' as we used to call it, now styled Total Solar Irradiance, really constant? Abbott claimed he had found variations of at least 1%, and in our founding year 1970, Leningrad meteorologist Kirill Ya. Kondratyev (1920–2006) reported stratosphere balloon observations that the Sun's output varied with the number of sunspots by as much as 2%. Most scientists were skeptical. The question was settled definitively in the 1980s when two groups separately mounted incredibly precise instruments on NASA satellites. The energy the Earth gets from the Sun does vary along with sunspots, but by scarcely one part in a thousand. A change as great as the Maunder Minimum would have less effect on climate than ten or twenty years of greenhouse gas emissions.

The long solar-terrestrial story came to a neat conclusion in the 1990s. Any honest observer could see that global temperature was climbing at an unprecedented pace while solar activity was sinking to unprecedented lows; as usual the correlation had eventually failed. We

are fortunate that solar activity did not continue to rise, for it would have perpetuated reasonable doubts about the true cause of the warming. The undeniable temperature rise did not embarrass Singer and Avery (2007) who published a book titled *Unstoppable Global Warming: Every 1,500 Years*, purporting to prove that global warming was caused by a long-term solar cycle—so, again, no need for governments to regulate anything. The book was briefly a *New York Times* best-seller and got hundreds of favorable reviews on amazon.com (of course, these could have been due to an infusion of cash from somewhere rather than actual readership).

This and a great deal of similar pseudoscience perpetuated the old tales that connected solar cycles with weather. A 2020 poll found that nearly a third of American citizens believed that global warming, if it was even happening, was due to natural causes rather than human activities. Asked what might be causing global warming, the majority of citizens answered correctly that it was greenhouse gases emitted by human activities. But among the large minority who ascribed warming to natural causes, the Sun took pride of place (Leiserowitz et al., 2010; 2020).

The false belief in a solar influence on climate was a factor in the failure of most of the world's governments to take serious action to restrict greenhouse gas emissions. The delay has meant that it is now nearly too late to prevent grave damage. If leading nations do not make fundamental changes during this decade, global temperature could rise to 3° or possibly 4° C above pre-industrial temperatures by the time our young children reach retirement age

(IPCC, 2018). At 3° C it is doubtful that we will be able to maintain a broadly prosperous and tolerant civilization; at 4° C it is doubtful that we will be able to sustain any advanced civilization at all. There is also a significant risk of setting off irreversible feedbacks that would raise global temperature in the following century to a

level where the survival of most species, including our own, comes into question (Lynas, 2020). It behooves solar physicists, even more than specialists in many other fields, to make strenuous efforts to inform the public about the real causes of global warming.

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Dr Spencer Weart was trained in physics and astrophysics (BA Cornell University, PhD University of Colorado, Boulder, 1968) and worked as a Fellow of the Mt. Wilson and Palomar Observatories, publishing papers in leading scientific journals. In 1971 he went to the University of California, Berkeley to study history of science.

From 1974 until his retirement in 2009 he served as Director of the Center for History of Physics at the American Institute of Physics; the Center and its Niels Bohr Library are dedicated to preserving and making known the history of physics and related disciplines through preservation of archives, oral history interviews, promotion of scholarship, and public education. Meanwhile he taught courses at leading universities.

His numerous publications include books on the history of nuclear energy in France, the history of solid-state physics, *Nuclear Fear: A History of Images* (1988), *Never at War: Why Democracies Will Not Fight One Another* (1998), *The Discovery of Global Warming* (2003, rev. ed. 2008, with translations in six languages and an annually updated website (<https://history.aip.org/climate/index.htm>) and *The Rise of Nuclear Fear* (2012).