Sunspot-Weather Correlation Found

A stunningly strong correlation between the sunspot cycle and weather has been found; will it persist and what, if any, physical connection is responsible?

AFTER a centuries-long search "guided as much by hope as reason," as one critic put it, the first connection between variations of the sun and weather on Earth may have been found. A lone researcher may have succeeded where generations before her have failed because she found a clue about when to correlate weather with the number of sunspots and when not to. That trick transformed a complete muddle into by far the strongest sun-weather correlation ever seen.

But a correlation is not necessarily a connection, in scientists' minds. Even the strongest correlation might arise by chance, so other kinds of evidence are usually required. Not the least of the obstacles to acceptance of a sun-weather connection is the sullied reputation of the field. "There is a long history of dubious efforts to establish a connection between weather and solar activity," says Francis Bretherton of the National Center for Atmospheric Research (NCAR) in Boulder. "It's against that backdrop that you have to look at anything new. Two questions must be asked: Are the statistics reasonably convincing and is there a plausible mechanism?" There is as yet no obvious physical mechanism to explain the new correlation, but "there is a lot of internal evidence that there are changes going on, and they appear to be correlated with sunspots," says Bretherton. "I was well convinced [about the statistics] by the variety of internal checks."

The first reaction of many who have heard something of the new correlation is to assume that, as in the past, it is the result of a blind search at one site after another until by chance a decent but unfounded correlation turned up. Although a possible physical link did not guide the search, it was a bit more rational than that.

In 1982 Karin Labitzke of the Free University in Berlin noted briefly in a paper that an apparent connection between the stratospheric "weather" over the equator and in the north polar region also seemed to involve the sunspot cycle. James Holton and H.-C. Tan of the University of Washington had found, and Labitzke had confirmed, that the vortex of stratospheric winds that swirls over the North Pole during winter was stronger and colder when the wind in the lower stratosphere over the equator was blowing from the west rather than from the east. Labitzke, unlike most of her colleagues, retained an awareness of the state of the 11-year sunspot cycle, a habit she had inherited from her major professor, the late Richard Scherhag. So she pointed out that, despite this strengthening, the vortex broke down at times during west winds, but only when the number of sunspots was near its maximum. Sunspots, it seemed, were essential to breaking down the vortex when it was strengthened by conditions over the equator.

> ***"These people have the highest correlation I've seen, but . . . I would bet against it."***

There things remained until one afternoon last February when Labitzke was mulling over her data in a Washington hotel room during a break from a meeting. It suddenly occurred to her to plot on one graph the wintertime temperature at about 23 kilometers over the North Pole during west equatorial winds against sunspot number. Perhaps, she reasoned, solar activity could only make itself felt under one set of conditions. If true, observations under changing conditions would only muddle the signs of a connection, perhaps beyond recognition. And the wind in the equatorial lower stratosphere is certainly changeable. Every 2 to 3 years the wind there reverses direction in a phenomenon called the quasi-biennial oscilation or QBO.

When Labitzke plotted only pole temperatures from the QBO's west phase, a strong correlation became clear. The more sunspots, the warmer the wintertime temperature, due to vortex breakdowns and the subsequent intrusion of warmer air. Her next stop after Washington was NCAR, where she worked up a short paper that she submitted within days of her insight.

Labitzke and Harry van Loon of NCAR have now developed a bit more refined and statistically rigorous presentation of the stratospheric temperature correlation. They begin with the 32 mean temperatures for January–February from 1956 to 1986. A plot of all of these versus time, with a measure of solar activity superimposed, shows the 3½ solar cycles looping through the squiggles of wildly gyrating temperatures. The two plots have a correlation coefficient—a measure of how much they vary together—of 0.14, where 1 is a perfect correlation and 0 is no correlation at all.

If only the 17 west-phase QBO temperatures are included, the plot is transformed. Temperature and solar activity swing up and down in seemingly perfect step; the more sunspots, the warmer the temperature. The correlation coefficient becomes 0.76, meaning that the relation between the two properties accounts for 58% of the variability. That is a whopping value in any field of meteorology. The east-phase temperatures were less closely tied to the solar cycle and in the opposite sense, the correlation coefficient being −0.45.

The visual effect of separating the data according to the rule of the QBO phase is stunning, something like snipping up a Jasper Johns abstract painting and reassembling the pieces into two Cézanne still lifes. Knowing that visual effects were not likely to suffice among their colleagues, Labitzke and van Loon tested the significance of the correlations using several different statistical techniques. The Monte Carlo technique tested how likely it was that their division of the data turned up a high correlation by chance. Only 20 to 44 times out of 10,000 could a random selection of random data do as well. In the bootstrap method, 95% of the correlation coefficients of 1000 simulations of the data fell between 0.54 and 0.91.

Reassured that their QBO rule might be a valid one, Labitzke and van Loon set out to see how far from the north polar stratosphere the apparent link to the solar cycle might extend. Horizontally at the same 23-kilometer altitude, correlations during the west phase of 0.60 and better extend over an oblong area from the Soviet Arctic to the Great Lakes. This area is surrounded at midto low latitudes by areas of significant negative correlation. In the east phase, a nearly inverse pattern held.

In the vertical, the same strong correlations extended through the lower stratosphere into the troposphere, where the weather occurs, and to the ground. During the west phase, strong positive correlations between solar activity and atmospheric pressure at sea level prevailed over much the same area centered on northern Canada as seen in the stratosphere, and areas of negative correlation appeared in the southwestern North Atlantic and southeastern North Pacific.

That pattern of effects on sea level pressure would tend to bring more cold air southward and across the central eastern United States. That is what Labitzke and van Loon found. A good part of that area tends to be up to 3.5°C colder in January and February when the west phase coincides with the peak of the solar cycle rather than with its trough. In the core of that area, cities like Nashville and Charleston have been about 7°C colder in the trough than at a peak. That is the difference between a mild winter and a severe one.

"It's remarkable to get such a strong signal," says van Loon, "considering the way things are banging around so much in the atmosphere." Eugene Rasmusson of the University of Maryland agrees. "The signal is extraordinarily strong. It's something we can't ignore."

These correlations are indeed strong, but doubts of varying degree remain. "Superficially, I can't find anything wrong with it," says Holton, "but there is absolutely no physical basis, and that bothers me. These people have the highest correlation I've seen, but if I were a betting man, I would bet against it."

Most researchers are concerned that the deception could result from the shortness of the QBO record. "This could still fall apart," says Bretherton, "because the time series is not very long." That is what happened to a lovely correlation between the water level of Lake Victoria and solar activity during two solar cycles. When the correlation was published, it promptly fell apart in the third cycle. These correlations span as much as $3\frac{1}{2}$ cycles rather than 2, but common wisdom holds that proof requires 6 well-behaved cycles, especially when there is no well-known mechanism.

The lack of a mechanism is seen as a serious obstacle, too. Most researchers are not optimistic about finding a way for the effects of the feeble solar cycle variations in solar radiation, mostly in the ultraviolet, to trickle down from the upper atmosphere to the troposphere. Meteorologists speak of the problem of the tail wagging the dog—more than 80% of the total mass of the atmosphere lies in the troposphere. How the wispy stratosphere could move the weighty troposphere below it is unclear.

Labitzke and van Loon do not know what the linkage might be, but they do see some associations between the two layers of the atmosphere that might point in a profitable direction. They point out that the tropopause, the boundary between the two layers, seems to have risen and fallen over the equator in time with the solar cycle. The height of the tropical tropopause is related to the strong convection beneath it, so they reason that if solar activity could have a direct effect on tropical convection, that effect could be transmitted poleward through the QBO.

Despite the absence of any physical understanding, the temptation to make a winter forecast might be strong. Van Loon warns against it. "Never forecast with statistics without the underlying physics." Throwing caution to the wind, against van Loon's best advice, one might guess that, being at the end of the sunspot minimum and the beginning of the west phase of the QBO, the central eastern United States will have a mild winter this year. As with the whole question of sun-weather relations, one can only wait and see. ■

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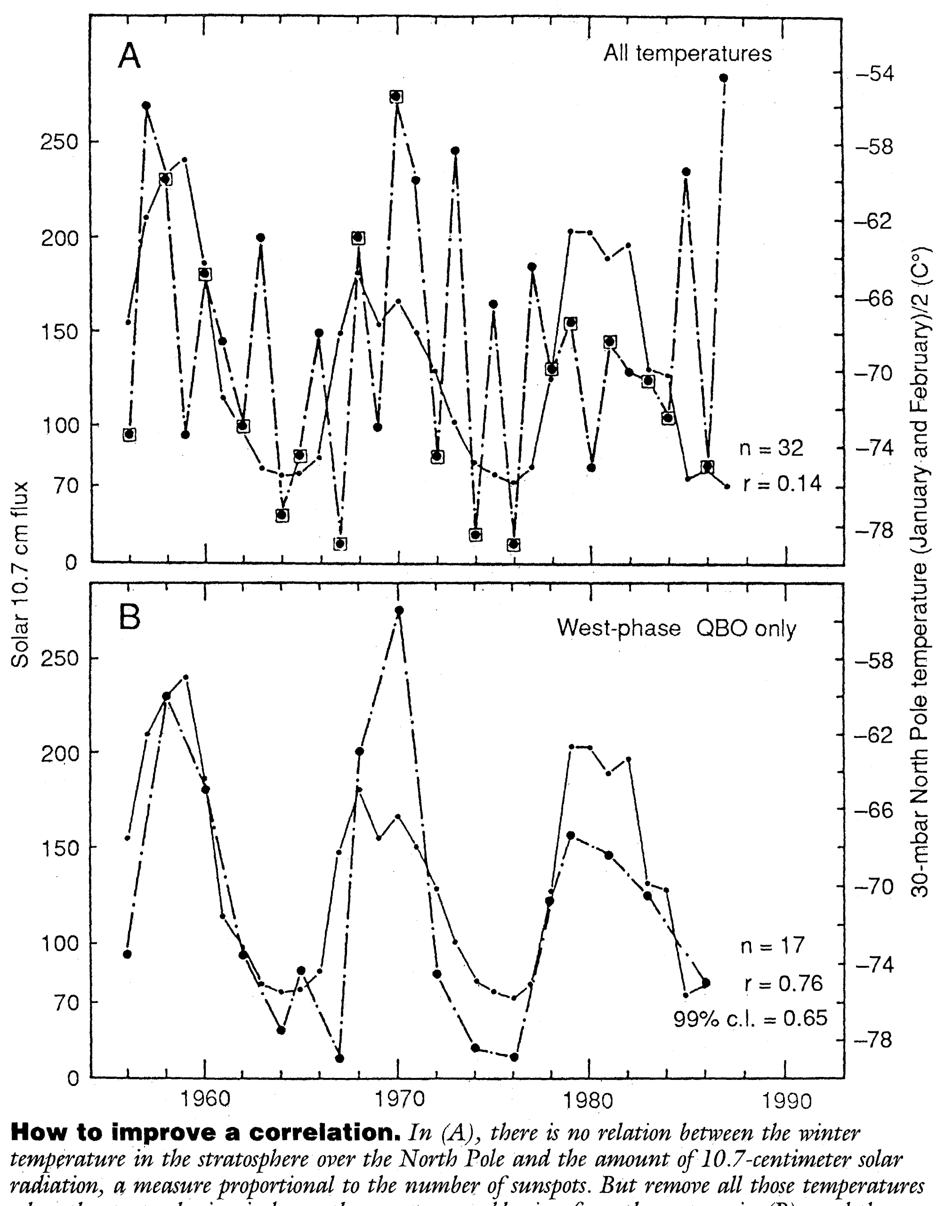

How to improve a correlation. *In (A), there is no relation between the winter temperature in the stratosphere over the North Pole and the amount of 10.7-centimeter solar radiation, a measure proportional to the number of sunspots. But remove all those temperatures when the stratospheric wind over the equator was blowing from the east, as in (B), and the correlation becomes obvious. [Modified from Labitzke and van Loon]*

ADDITIONAL READING

K. Labitzke, "Sunspots, the QBO, and the stratospheric temperature in the north polar region," *Geophys. Res. Letts.* **14**, 535 (1987).

——— and H. van Loon, "Associations between the 11-year solar cycle, the QBO, and the atmosphere," *J. Atmos. Terr. Phys.*, in press.