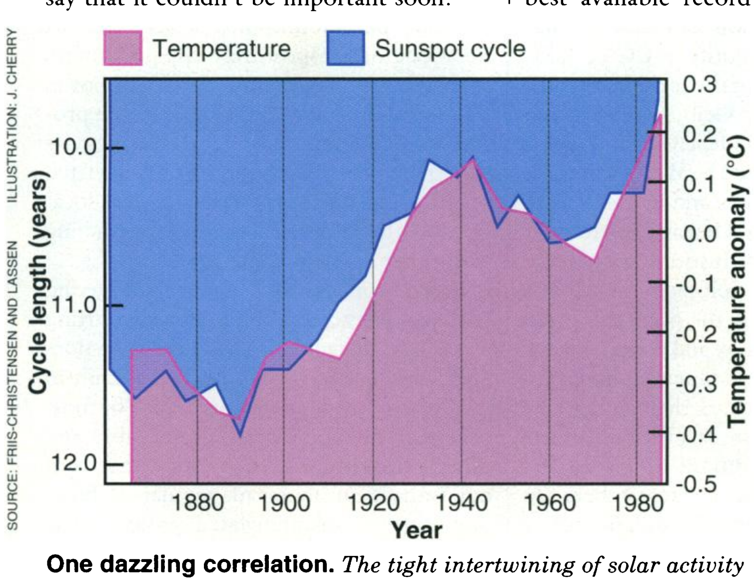
Could the Sun Be Warming the Climate?

A new correlation between solar variations and climate change hints, yet again, at a sun-climate connection

TAKE A GOOD LOOK AT THE GRAPH ON THIS page, reproduced from a report that appears on page 698. It's giving climatologists goose bumps. The curves show that when the interval between peaks in sunspot abundance began shortening at the end of the past century, the Northern Hemisphere began to warm. When the sunspot cycle stopped shortening and began lengthening around 1940, the temperature peaked and began falling. And when the solar cycle length started shortening again in the 1960s, temperature turned around too. The close association of these two curves is the most striking correlation ever found between climate and small variations in solar activity—and the strongest suggestion ever of a causal link.

"If it's correct," says atmospheric scientist Keith Shine of the University of Reading, "we have to change our view of climate fundamentally. It's an incredible correlation; it would imply that almost nothing else [beside solar variation] is important in the climate system." Even greenhouse warming would have played little role in the 0.5°C warming of the last century—which is not to say that it couldn't be important soon.



One dazzling correlation. *The tight intertwining of solar activity and terrestrial temperature has climatologists wondering.*

But Shine, like many climatologists acquainted with the new work, isn't ready to embrace all those implications. "The other extreme view you could take is that this is a statistical freak," he continues. And many researchers will assume just that, given the long, checkered history of the search for sun-climate relations.

"We have seen a number of these that haven't worked out," says John Eddy of the University Corporation for Atmospheric Research in Boulder, Colorado, who has studied possible sun-climate connections on time scales of centuries. "We've been fooled so many times that we should be careful." One memorable example he cites is a stack of 680-million-year-old sediments that to believers and even some skeptics seemed to record climate variations on a timetable uncannily similar to various sunspot cycles (*Science*, 3 September 1982, p. 917). But then the bubble burst: It turned out that the layers had recorded nothing more than the cycles of the tides (*Science*, 18 November 1988, p. 1012).

In searching for their new sun-weather link, Eigil Friis-Christensen and Knud Lassen of the Danish Meteorological Institute faced the same handicaps as their predecessors: lack of good records of either climate or the activity of the sun. The researchers used the best available record of global temperature, but it covers only the land surface of the Northern Hemisphere and goes back only to about 1870. The risk in using such a short record is the greater likelihood that, just by chance, it will seem to vary in concert with some change on the sun.

The two researchers also lacked any direct indicator of the sun's total energy output, the most likely driving force of any sun-related climate change. Changes in solar irradiance, after all, have been accurately monitored for only the last 10 years. So, like others in search of a sun-climate link, Friis-Christensen and Lassen had to use a stand-in. Previous workers have tried to gauge the sun's activity by such measures as the height of the peaks in the sunspot cycle, the frequency of auroras, and the variation in the amount of carbon-14 produced in the upper atmosphere and trapped in tree rings. Friis-Christensen and Lassen opted for the varying length of the sunspot cycle simply because it worked out and because it seems to track long-term variations in the solar wind—a direct, though feeble, part of the sun's energy output.

But it's far from clear that sunspot-cycle length actually changes in concert with any solar variation strong enough to drive climate change. And the fact that it is only the latest in a long line of solar-output proxies that have been tried doesn't inspire confidence. After so many rolls of the dice, some climatologists complain, a lucky number might finally have come up. "The more parameters you look at," notes climatologist David Parker of the Hadley Center for Climate Prediction and Research in Bracknell, England, "the more likely you are to find one that fits the global temperature curve [by chance]."

If such skepticism weren't enough, Friis-Christensen and Lassen have another problem to overcome in gaining acceptance for their correlation: Climate researchers can't explain how known solar variability might affect climate in the first place. The variations in solar output traced in recent years are too small to account for the temperature changes of the past century, and so far solar physicists haven't come up with any mechanism for larger swings in output. Some researchers have talked about the possibility that the upper atmosphere somehow amplifies the effects of the known changes in irradiance or other solar variations, but the search for such an atmospheric amplifier has been going on for decades without success.

After voicing all their doubts about the report, though, some researchers admit that they are mightily impressed by the close intertwining of the two curves. They have a correlation coefficient of 0.95, probably the highest ever found in this sort of work. Even Parker says he is impressed, though cautious. And Eddy goes further: "The fit is so good," he says, that "the burden of proof that something's wrong almost rests with any detractors." The usual qualifications must still apply, he says, but, "I'll still make a bet they're on to something."

Even so, it could be a long time before anyone proves it. Decades more of irradiance measurements would be required to show that the sun's output can vary enough on long time scales to have caused the half-degree warming of the past century. Until then, researchers are stuck in limbo. Meteorologist George Reid of the National Oceanic and Atmospheric Administration in Boulder, who published a similar but less striking correlation in 1987 using sunspot number as a proxy, knows the story: "You can show these correlations endlessly and people either believe them or they don't."

Politics may predispose a few people to welcome the new findings, and that possibility worries many researchers. "The discouraging thing about this," says Eddy, "is that it resurrects the ghost of the Marshall Institute report." That document, which was highly regarded in the White House, cited disputed evidence that the sun's variations over decades or centuries have affected climate. It predicted that a fading of the sun in the next century might largely counteract any greenhouse warming (*Science*, 24 November 1989, p. 992).

Scientists' response was overwhelmingly negative when the Marshall report came out, and the new sun-climate correlation isn't changing anything. For one thing, the Danish result says nothing about what the sun will do in the future; the Marshall report's premise that it will dim remains as dubious as ever, Eddy emphasizes. And no matter what the sun does, says climate modeler James Hansen of NASA's Goddard Institute for Space Studies in New York City, the doubling of greenhouse gases that seems inevitable in the next century will overwhelm any effect solar variations might have. Real or not, the sun-climate connection won't resolve the greenhouse dilemma. ■ RICHARD A. KERR

GE Achieves Dial-an-Isotope Diamonds

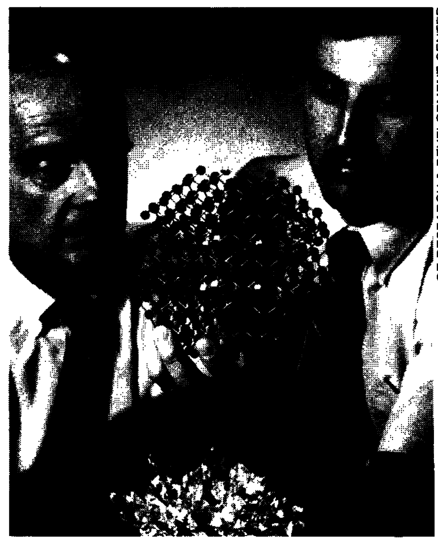
Last year, the General Electric Co. rented out the 21 Club in New York City to announce loudly that it had made synthetic diamonds that seemed better than perfect (*Science*, 6 July 1990, p. 28). The new specimens tantalized engineers with their ability to conduct heat at least 50% more efficiently and resist laser damage ten times better than any other diamond, natural or synthetic. The reason: the superdiamonds had but one carbon-13 atom for every 1000 carbon-12 atoms. The ratio in natural diamonds is about one in 100, and those extra carbon-13 atoms apparently prevent the stones from conducting heat as well as they might while making them more vulnerable to high-power lasers.

Still flushed with their success in making C-12 enriched diamonds, the same researchers have now turned the isotopic cards around, bumping up the carbon-13-to-12 ratio. Out come materials with more atoms per given volume than any other in the world.

The secret behind all these crystalline successes is isotopic control. The GE group now can make every kind of gem-quality diamond from the nearly pure C-12 variety to the nearly pure C-13. And the payoff is more than intriguing new properties, they say. "We now have a way to use diamond as a vehicle to study fundamental physics" in materials as their isotopic composition varies systematically, says William F. Banholzer, who led the effort with Thomas R. Anthony.

Take the distances between diamond's carbon atoms, which theorists had argued—based on quantum mechanical calculations and previous observations in other crystals—should decrease slightly with increasing carbon-13 abundance. In the 1 October *Physical Review B*, Banholzer and his GE colleagues, together with collaborators at the Ford Motor Company, report the first experimental confirmation of this isotope effect for diamond. As a diamond's composition changes from nearly all C-12 to all C-13, its atoms get about .015% closer together, according to x-ray measurements done at Ford. As a consequence, the C-13 diamonds contain slightly more atoms in a given volume than any known solid, Banholzer says. The researchers raise the possibility that the world-record atomic density of C-13 diamond will translate into increased hardness or some other physical improvement, though that remains to be seen.

The key to making these isotopically adjustable diamonds is to mix separate sources of carbon in the form of methane gas that has been enriched in either C-12 or C-13 by a supplier. The researchers then apply chemical vapor deposition (CVD) methods to deposit the chosen mixture of isotopes as thin mosaics of tiny diamond grains. These serve as feed stock for a hellish synthetic gem-making process, developed during the late 1960s by other GE scientists, that involves a 1000-ton press, 1500°C of heat, and as long as a week. In this slow and expensive heat-and-press treatment, the diamond "nutrient" dissolves into an underlying slug of molten metal, and then diffuses downward toward a tiny diamond seed at the bottom of the liquid metal, where the temperature is slightly lower than at the top. Since carbon is less soluble in cooler metal, it readily deposits onto the solid diamond seed, yielding gem-quality diamonds.



GE RESEARCH & DEVELOPMENT CENTER

Designer diamonds. *Anthony* (left) *and Banholzer make diamonds with isotopic ratios not found in nature.*

With its cost and slowness, the method isn't likely to become a practical way of making the super-premium diamonds, even if—like the C-12 diamonds—the high C-13 gems turn out to have technological advantages. But John Angus, a leader in CVD diamond research at Case Western Reserve University, thinks an alternative route for growing the gem-sized diamonds might develop from the vapor deposition methods now used for growing diamond films.

Even if he's wrong and no one comes up with a practical alternative for producing these aristocrats of stones, the GE group's achievement is bound to get more attention than Herb Strong's C-13-rich diamond, which glittered unnoticed 20 years ago. Strong is a retired member of the GE quartet that first made small synthetic diamonds in 1954. Back in 1971, he and his co-workers fed their high-pressure apparatus with an exotic starting material. "I got carbon-13 graphite from the Oak Ridge National Laboratory," Strong told *Science*. Out popped the world's first C-13 enriched diamond. Though Strong says he recorded the feat in his notebook, the team never published the result or studied their creation—they did it just for fun. That unique diamond ended up embellishing an award presented to Robert Wentorf—another member of the original GE quartet—for achievements as a glider pilot. ■ IVAN AMATO