Our Future in the Stars?

Our climate depends on the sun, which varies in ways astronomers do not understand; can the clues be found in "starspot" cycles?

LOOMING OVER ALL the efforts made so far to predict the global greenhouse warming is at least one giant uncertainty: the sun. Historical records suggest that subtle variations in the sun's energy output can have decidedly unsubtle effects on the earth's climate—effects strong enough either to delay the warming due to carbon dioxide buildup for many decades, or else accelerate it dramatically. Yet no one knows how to take those solar variations into account: astronomers can neither explain them nor predict them.

"Completely unsolved," declares Sallie L. Baliunas of the Harvard-Smithsonian Center for Astrophysics, whose efforts in this area nonetheless won her the American Astronomical Society's 1988 Newton Lacy Pierce Prize for distinguished observational work by a young astronomer.

Consider just the most famous example of solar variability, the 11-year sunspot cycle, she says. It presumably reflects turmoil in the interior of the sun, where rotation and turbulence in the incandescent plasma are constantly twisting the solar magnetic field into knots. Indeed, the sunspots themselves are essentially magnetic storms, regions where the magnetic field has become so tortured that it erupts through the surface and arcs outward into space. But why should such a messy process be periodic at all, asks Baliunas? "And why 11 years instead of 5 years or 20 years?" Nobody knows.

Or consider the Maunder minimum, a 70-year period in the 17th and early 18th centuries when the sunspots virtually disappeared. Europe became so cold at that time that the Thames froze regularly and Louis XIV had the beautiful, but chill, marble floors of Versailles covered with wood parquet to keep his feet warm. Carbon-14 data from tree rings spanning the past few thousand years suggest that such minima are actually rather common, says Baliunas. So are inverse Maunder minimums—periods of enhanced sunspot activity when the earth becomes noticably warmer than it is now. And yet, she asks, why should the sunspot cycle turn itself off and on this way? Nobody knows that, either.

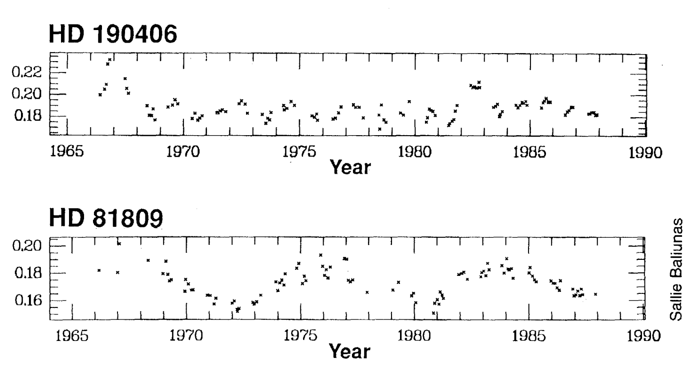
Baliunas, however, is not content with asking questions: the Pierce prize recognizes her work as principal investigator in an ambitious and dogged effort to get some answers. Instead of monitoring just the sun—concentrating on one data point, so to speak—she and her colleagues have spent the past 10 years monitoring the ups and downs of sunspot-like activity on more than 1000 nearby stars like the sun. Moreover, since cycles lasting a decade or more can be measured only by watching for decades, they hope to keep their project going for at least 50 years.

The survey is commonly known as the HK Project. And indeed, the deep violet H and K lines in the spectrum of ionized calcium are the key to the whole enterprise. They are among the strongest absorption lines in the entire solar spectrum: look at the sun through a filter attuned to either wavelength and the disk as a whole will appear quite dark. But the lines also provide a vivid marker for sunspots: the same filter will show each spot or cluster of spots surrounded by a much larger halo of bright calcium emission known as plage, the French word for "beach." Thus, the overall calcium brightness of the sun—and by extension, of any other star—is a good measure of its overall sunspot activity.

The HK Project grew out of an earlier survey begun in 1966 by the astronomer Olin Wilson, who used the famous 100-inch (2.5-meter) telescope on Mount Wilson to make monthly HK observations of some 100 nearby stars. Upon Wilson's retirement in 1978, the monthly observations were continued by several of his colleagues using the Mount Wilson 60-inch (1.5-meter) telescope. And in 1980, when the current HK group was formed, observations at the 60-inch telescope shifted to a nightly basis. The project is now keeping watch on some 1200 nearby stars: 1000 "dwarfs" that, like the sun, are in the prime of life, plus 200 "giants"—geriatric stars that have exhausted their hydrogen fuel and are swelling into a brief, bloated red-giant phase.

With 22 years of data now available for Olin Wilson's first 100 stars, says Baliunas, changes in activity are readily apparent. True, those changes do not always add up to a complete cycle. And even in those stars that do show complete cycles, the magnitudes and periods show little correlation with the mass, age, or rotation rate of the star—the kind of correlations that might give theorists a clue as to what is going on. But this is precisely why Baliunas and her colleagues want to keep the HK Project going for so many decades. The 11-year periodicity of our own sun is actually a long-term average, she says. Take a 20-year sample at random from the real record, which is quite irregular, and the periodicities could come out anywhere from 8 years to 15 years. Getting a more reliable number would take at least a 50-year sample.

On the other hand, she says, some of the project's interim results are already quite intriguing. For example, even though activity variations show up in most of Wilson's stars, a number of them show no changes whatsoever. These stars may be in the midst of a Maunder minimum. Indeed, says Baliunas, she and her colleagues ultimately hope to catch stars going into or coming out of such states, and perhaps discover signs that would warn us of similar behavior in



Starspot cycles. *Shown here are the HK records of two stars with about the same mass as our own sun. HD 190406 is "young"—only about a billion years old—and shows a period of about 2.6 years. HD 81809 is roughly the same age as the sun (4.6 billion years) and shows a more sedate period of about 8 years.*

our own sun. On another front, she says, the survey suggests that our own sun was once radically more active than it is now. The sun is currently some 4.6 billion years old, and its variations in luminosity during a sunspot cycle are no more than a fraction of a percent. But when it was only 1 billion years old, judging by survey stars of that age, it had ten times as much of its surface covered by sunspots, and its fluctuations in luminosity during the cycle could have been as high as several percent. No one knows how this affected the young earth, but presumably the impact on the primordial climate was large.

At the moment all these observations are being done manually, says Baliunas, which means that they take up an enormous amount of professional time. Before too much longer, however, it should be possible to ease that burden with automation. At the Smithsonian's Whipple Observatory in Arizona, for example, the three robotic telescopes of the Automatic Photoelectric Telescope Service are left unattended on the mountaintop in a building to protect them from wind and rain. Every evening at sundown, an automated weather station on the building checks the environment and, if conditions are favorable, rolls back the roof to let the telescopes measure luminosity variations in a preprogrammed list of stars. In the morning, the roof is closed again and the data sent back to headquarters.

In the future, says Baliunas, she and her colleagues on the HK Project are hoping to implement this robotic observing concept in a new, lightweight 2-meter telescope on Mount Wilson. (The existing 60-inch and its dome, which date from 1908, are considered too heavy and clumsy for entirely automated observing.) The remarkably steady atmosphere and cloudless skies of Mount Wilson continue to make it an excellent site for this kind of work, she points out, even though air pollution and sky glow from nearby Los Angeles have long since ruined it for studies of the distant galaxies and quasars. Indeed, she and her colleagues consider it crucial to keep on observing there, since moving to another site would produce a discontinuity in the survey records that would be hard to correct for.

That continuity has been in doubt since 1984, when the Carnegie Institution of Washington announced that it would withdraw as operator of the observatory. Just this past January, however, the operating responsibility was officially transferred to a new private organization, the Mount Wilson Institute. Thus, says Baliunas, it now appears that the Mount Wilson facilities will be kept open permanently.

■ M. MITCHELL WALDROP

1988 Ties for Warmest Year

The man who last summer said the greenhouse warming is here, James Hansen of the Goddard Institute for Space Studies, also said that, barring an improbable event, 1988 would be the warmest year on record. Well, he was right about 1988, but only barely. A consortium of British climatologists announced at the end of January that the globe's average temperature for 1988 was 0.34°C above that of the 1950–79 reference period. The past year thus noses out 1987, at 0.33°C above the reference, for the honor of warmest year in the 100-year record of instrumentally recorded global temperatures. But it is only a titular honor. "It's above the previous year," says Philip Jones of the University of East Anglia, but considering the inherent errors "it's not any different than the previous year." The year 1988 will have to settle for a tie.

Nineteen-eighty-eight does continue the run of warm years in the 1980s, according to the British group, which is composed of Jones and David Parker of the Meteorological Office in Bracknell and their colleagues. This decade lays claim to the six warmest years in the instrumental record, as analyzed for land by the East Anglia group and for sea surface temperatures by the Met Office group.

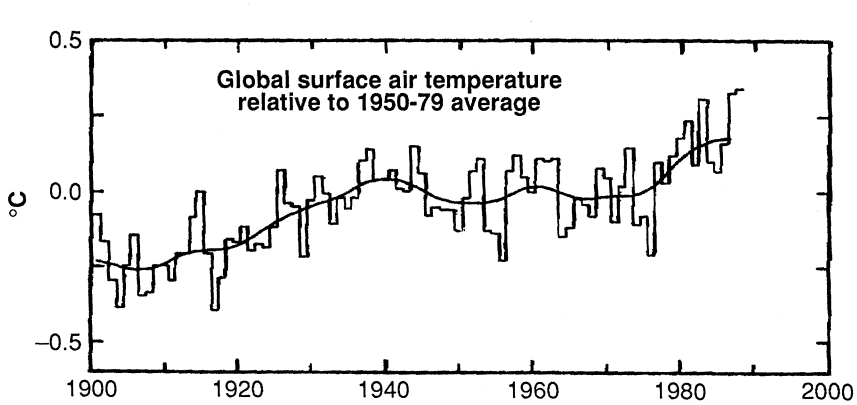
That the year managed even a tie might be taken as a sign of the robustness of the current surge of warming. Hansen's "improbable event" materialized last spring in the form of a sudden cooling of the tropical Pacific Ocean at the end of the 1986–87 El Niño (*Science*, 26 August 1988, p. 1037). It was a strong cooling, or La Niña, and the first major cooling since 1975 even though such coolings had recurred about every 4 years on average during the past century. Nineteen-seventy-five was also, perhaps only incidentally, the beginning of the current surge of global warming. There is an approximate 6-month lag between the beginning of a La Niña and its effect on global temperatures, but 1988 still "shouldn't have been as warm as 1987," says Jones, all else being equal.

The thought that it may be the greenhouse effect that is making all else less than equal is on everyone's mind. The British are still cautious. "It's the multiyear and decadal trends, not the individual years, that are important," says Jones. "While this [trend] is consistent with the theory, it can't be taken as unambiguous proof. We still need more warm years before we can say we've detected an effect."

This year should offer an interesting test. The global temperature was dropping toward the end of last year, especially at low latitudes, as La Niña took effect. And 1989 will likely be a La Niña year from beginning to end. On the assumption that only La Niña will be cooling the globe, Jones "would expect 1989 to be about 0.2°C colder than 1988," or still about 0.15°C above the reference period.

Another warm year in the 80s, in the face of La Niña cooling, would certainly impress climatologists, but it would not convince them. The cautious attitude pervading the climate community can even at times temper Hansen's confidence in his claimed detection of a greenhouse warming in 1988. Writing in the *Journal of Geophysical Research* last August, with seven coauthors, he concluded that "The greenhouse warming should be clearly identifiable in the 1990s." Perhaps in several years, when the next La Niña again tests the robustness of the warming trend, the consensus could shift.

■ RICHARD A. KERR



University of East Anglia/UK Meteorological Office

The warming trend continues. *The century-long global warming of about 0.5°C has had its ups and downs, the latest upturn coming in the mid-1970s.*