The Sunny Side of Weather

How can minute changes in solar rays influence conditions on the ground?

By RICHARD MONASTERSKY

Karin Labitzke knew she was asking for trouble when she starting talking about sunspots and weather in the same sentence.

Various scientists had explored this topic for at least 200 years before she began in 1987, but such pursuits had earned a dubious reputation. No one had ever found convincing evidence that solar activity influences weather, and it didn't help that sunspots had been connected at various times to such oddities as outbreaks of plague in India, skirt fashions among women, and even the number of Republicans in the U.S. Senate.

Despite its shady pedigree, Labitzke's work looked promising.

A meteorologist from Free University in Berlin, she noticed that when stratospheric winds above the tropics are taken into account, temperatures above the North Pole follow the sun's 11-year cycle quite closely. Later, Labitzke and colleague Harry van Loon of the National Center for Atmospheric Research in Boulder, Colo., extended the sun-weather correlation to other parts of the world. The patterns appeared consistent over 40 years of data, generating intense interest among other scientists.

Labitzke and van Loon recognized the limits of their work, however. What they had discovered were correlations, similarities of pattern — and strange ones at that: Weather appeared to keep pace with minute variations in the energy emanating from the sun. But no one had a solid idea of how such small solar changes could produce such profound effects on Earth's lower atmosphere, or troposphere, the region that makes the weather we feel. Lacking any physical explanation, many scientists were prepared to write the correlations off as coincidence, not cause and effect.

Now, 7 years later, several atmospheric researchers are stepping forward with theories that could fill in the missing pieces of the puzzle. Their studies offer physical mechanisms to explain how the solar cycle might influence weather and possibly even long-term climate shifts.

The term "solar cycle" refers to the natural waxing and waning of the sun's output that runs from high to low and back again roughly every 11 years. Satellite measurements made in the last 16 years show that between the solar maximum in 1979 and the solar minimum in 1986, total energy varied by only about 0.1 percent. But while total light output flickered only slightly, some types of radiation exhibited much larger swings during the cycle. The strength of ultraviolet light, for example, grew by a few percent during the solar maximum.

Could these relatively large ultraviolet changes account for the solar cycle–weather link? Joanna D. Haigh of the Imperial College of Science, Technology, and Medicine in London explored this question with a computer model that simulates chemical properties of the atmosphere and how radiation passes through it.

Haigh's work points to ozone as a potential link between the upper atmosphere and Earth's surface. Because ultraviolet radiation creates ozone in the stratosphere — the atmospheric layer above the troposphere — ozone concentrations vary by about 1.5 percent between the solar maximum and minimum.

According to her model, ozone increases have an unexpected effect. Because the sun's output grows during a solar maximum, most scientists had assumed that Earth's surface receives slightly more visible light at this time. But Haigh found that for parts of the globe far from the sun, the thickened ozone layer actually blocks the extra light during a solar maximum. So while the sun shines more brightly on the tropics at this time, the polar region on the winter side of Earth gets less light, Haigh reports in the Aug. 18 NATURE.

The end result is heating at the tropics and cooling at one of Earth's poles. "That's rather different from what's been thought previously," she says.

Since the sun's energy provides the driving force for Earth's weather, such uneven heating and cooling could alter the way storms sweep around the globe, Haigh surmises. She can't say, however, how great an effect it will have. Her model is too simple to gauge how the troposphere will respond to lopsided radiation. For that, Haigh must consult the complex general circulation models (GCM) used in forecasting weather, which she plans to do next.

Ozone may be only part of the story. When David Rind and Nambath K. Balachandran of Columbia University ran a GCM experiment, they discovered a different potential link between the solar cycle and weather.

The two researchers found that shifts in the strength of ultraviolet light combine with wind currents in the stratosphere to alter the large-scale pressure systems of the troposphere. When that happens, says Rind, "a lot of other things start coming into play — for example, rainfall patterns, cloud cover patterns, and in particular in the upper troposphere, the [extent] and locations of cirrus clouds."

In fact, the weather changes simulated by the model have a familiar look. "In our model results, we can produce to some degree the type of things that are seen by Labitzke and van Loon, but it's through a very roundabout way," says Rind.

Other scientists remain skeptical of the Rind and Balachandran study because their first experiment used unnaturally large swings in ultraviolet light — roughly 5 to 20 times what occurs during an actual solar cycle. But the two researchers have since worked with more realistic ultraviolet variations and have found an even closer correspondence to Labitzke and van Loon's observations.

Rind and Balachandran's results extend beyond day-to-day weather to the issue of climate change. In the past, scientists have presumed that the 11-year solar cycle did not significantly alter climate because the extra radiation during a solar maximum would balance out the weakened light of the solar minimum. If the sun played any significant role in climate change, it would have to do so through a much longer cycle of energy adjustments — something that scientists have hypothesized but lack the long-term satellite measurements to document.

The atmospheric reactions Rind and Balachandran studied do not necessarily cancel each other out as the solar cycle progresses, they found. So over the course of a cycle, shifting pressure patterns can theoretically cause a general warming or cooling in climate that would last far longer than a decade. Rind believes modelers should include such effects when studying how Earth's climate will react to greenhouse gas pollution and other influences.

Indeed, many researchers are starting to believe that long-term variations in the sun's output have made their mark on climate in the past. Strong circumstantial evidence, for example, implicates the sun in causing the coldest part of the Little Ice Age — an extended period of below-average temperatures that lasted from the 16th to the mid-19th century (SN: 10/24/92, p.282). But this growing acceptance of solar links with climate does not answer the question of whether the sun affects daily and monthly weather.

Brian A. Tinsley approaches the weather question from a different direction. Instead of examining the flickering amounts of visible light or ultraviolet radiation, this physicist from the University of Texas at Dallas focuses on the solar wind — the stream of charged particles speeding away from the sun. As it envelops Earth, the solar wind forms a shield that blocks many of the galactic cosmic rays streaming toward the planet.

While the visible and ultraviolet rays change by only 1 or 2 percent at most throughout the solar cycle, the strength of the solar wind varies considerably. That, in turn, causes large changes in the number of cosmic rays penetrating the atmosphere of Earth's high latitudes, the part of the planet most vulnerable to this radiation. During the weakest phase of the solar cycle, when the solar wind provides diminished protection, up to 10 times more cosmic rays reach Earth's middle atmosphere as during the strongest phase.

According to Tinsley's model, the heavier bombardment by cosmic rays causes the atmosphere to conduct electricity better in the middle to high latitudes. This, in turn, helps particles clump together to form precipitation drops — a process that releases energy into the air and pumps up the power of storms, says Tinsley, who presented this theory in the Aug. 9 Eos. If true, the idea could help explain a previous observation that storms follow more northerly paths during a solar minimum.

As yet, many aspects of the theory remain untested. "It's very speculative, and I'd say that most meteorologists are probably pretty skeptical of it," says atmospheric physicist George C. Reid of the National Oceanic and Atmospheric Administration in Boulder, Colo. But Reid also notes that meteorologists might be inclined to dismiss such a complex theory because it strays far from the domain of most atmospheric scientists.

According to Tinsley, aircraft measurements could strengthen some of the links in his theory. He holds out little hope of any missions, though, because research on solar influences has received scant funding in recent years, he says.

Can variations in the solar wind stoke storm strength?

Fans of solar cycle–weather research try to counter skepticism among meteorologists by noting that the U.S. weather service explored the Labitzke and van Loon correlation and found that it aided forecasting. A National Research Council committee makes this point in the recent report "Solar Influences on Climate Change." The document states that while the Labitzke and van Loon correlation remains unproved, "the relationship is considered sufficiently useful to be incorporated in techniques for seasonal forecasting of U.S. weather."

Actually, the weather service abandoned this practice several years ago, says Anthony G. Barnston of the National Meteorological Center in Camp Springs, Md. Barnston says that, initially, he was intrigued by the Labitzke and van Loon observations about the solar cycle and temperatures near the ground. But when he and colleagues tried incorporating this correlation into forecasts for the winters of 1989 and 1990, the weather went completely against the solar cycle predictions, leaving the meteorologists feeling burned. "We don't really believe in this [at the weather service]," says Barnston.

Van Loon himself thinks it is quite possible that the sun's influence may not extend to the lower atmosphere. The turbulence and chaos of this region could easily wipe out any subtle solar signal, he says.

It's a different story higher up, in the top of the troposphere and in the stratosphere, where correlations with the sun are strongest. "I still believe the correlations are too strong to ignore," says van Loon.

Reid and others agree that Labitzke and van Loon have uncovered something in the meteorological records. "They've certainly discovered a very real oscillation in the atmosphere — there's no doubt about that. There is a decadal scale — a 10- to 12-year oscillation, they call it — that hasn't been picked out before," says Reid.

He's just not convinced that the sun drives such a cycle. Several researchers have argued that the ocean and atmosphere may have a natural rhythm that has — by chance — coincided with the solar cycle during the past few decades. If that's the case, the correlation between sun and weather will eventually fall apart.

"Whether it is coincidence or not, we can't tell with only four cycles of data," says van Loon.

But the increased attention in recent years has buoyed his hopes that scientists may eventually flesh out a mechanism to explain such correlations. "A few years ago, it was at the bottom of topics to be tackled in terms of funding. But I think it is moving up slowly." □