Talk about the Weather

Insights help to explain solar effects on climate

One of the brightest gems in the New England weather is the dazzling uncertainty of it,” Mark Twain once quipped. That uncertainty is not quite so amusing to scientists attempting to understand and forecast long-term weather patterns in the U.S. and around the globe. Their task is further complicated by a surprisingly poor knowledge of how changes in the sun affect conditions on the earth. After centuries of searching, climatologists are finally finding apparently indisputable links between the 11-year cycle of solar activity and shifts observed in terrestrial weather. But why those links exist is still hotly debated.

Given that the sun provides the energy that drives all weather systems, it seems obvious that solar variations should have environmental consequences. Until recently, however, attempts to find such correlations were often viewed with the kind of skepticism that is usually reserved for ESP and flying saucers. “A lot of the meteorological community thought this wasn’t a respectable field,” laments Brian A. Tinsley of the University of Texas at Dallas. “Papers have been published that suffered from weak statistics and improbable theories. We’ve had to work hard to make it respectable.”

The turning point came during the late 1980s, when Karin Labitzke of the Free University in Berlin and Harry Van Loon of the National Center for Atmospheric Research in Boulder, Colo., presented convincing evidence that winter storms trace out a distinctive 11-year pattern of low-pressure systems over the North Atlantic Ocean. The pattern matched both the period and phase of the solar cycle, during which the level of solar activity (such as sunspots and flares) rises and falls. Unlike many previously reported sun-weather correlations, this one shows no sign of going away. “The association looks very nice and has continued through all subsequent winters,” Labitzke states.

Building on that finding, Labitzke and Van Loon reported this year a more general 10- to 12-year atmospheric oscillation that matches both the period and phase of the solar cycle, during which the total luminosity of the sun changed by only about 0.1 percent during the past cycle. How could such a tiny fluctuation in the sun’s total output significantly influence the weather? “I don’t know how the sun does it,” Labitzke confesses genially.

The search for a process that would explain the Labitzke–Van Loon findings has produced two hypotheses built around two very different ways of looking at the earth’s atmosphere. Labitzke favors the more conventional of these views: weather shifts respond to variations in the intensity of solar ultraviolet radiation, which are more pronounced than are the changes in visible light. Ultraviolet rays are absorbed by stratospheric ozone and so help to determine the temperature of that layer of the atmosphere. Ultraviolet radiation also creates additional ozone in the stratosphere, which may lead to a complex feedback process. Changes in stratospheric temperature could alter Hadley circulation or other aspects of atmospheric mixing that influence weather.

Several researchers, including David Rind of the Goddard Institute for Space Studies, are examining the plausibility of the ultraviolet hypothesis using elaborate computer models. Rind points out that during times when the sun is relatively active, the elevated intensity of ultraviolet radiation heats up the stratosphere. A hotter stratosphere, he argues, changes the manner in which giant atmospheric waves—those that are 10,000 kilometers or more in length—are generated and propagate between...
the stratosphere and the troposphere.

Such changes could affect cloud cover, winds and temperatures at the surface, perhaps by as much as five degrees Celsius locally. Moreover, Rind believes these effects could accumulate from one solar cycle to the next. Small variations in solar activity could thus bring about long-lived climate changes such as the Little Ice Age—a period of abnormally cold weather that persisted in Europe from the 15th to 18th centuries. "This sort of explanation is fairly subtle," Rind concedes. But he thinks it provides the most plausible way to amplify solar switches into shudders in the earth's climate.

Tinsley disagrees. For years he has championed the intriguing but unorthodox alternative hypothesis that charged particles, not ultraviolet light, constitute the primary mechanism by which solar variability stirs up weather. Tinsley notes that the solar wind—a stream of charged particles that continuously blows outward from the sun, past the earth—affects the electric currents that flow in the atmosphere. A slight build-up of electrical charge could promote the formation of ice crystals, effectively "seeding" clouds. The heat released by freezing, and by reduced reevaporation, would intensify vertical motions in the atmosphere and facilitate the development of winter cyclones; changes in the amount of cloud cover could alter climate over longer periods.

Tinsley freely admits that his concepts are "all still hypothetical." He observes, however, that the distribution of current in the global atmospheric electric circuit varies in step with the level of solar activity and with the intensity of cyclones and related atmospheric instabilities. More significantly, he finds that some atmospheric phenomena correlate with magnetic storms and other solar wind effects but clearly are not associated with changes in solar ultraviolet radiation. Nevertheless, he continues to face dubious reactions even from some of his close colleagues. "He says he has a mechanism, but I still don't see how it works," Labitzke remarks. Rind is a bit more equivocal. "It is not out of the question that charged particles could affect clouds," he says cautiously, "but it would have to be proved through observations."

There Tinsley finds himself in a bit of a catch-22. Because of doubts within the community, "I haven't had a peer-reviewed proposal funded in the past five years," he reports. Tinsley hopes he or other researchers will be able to carry out laboratory tests to help nail down the validity of his ideas. And studies of day-to-day effects of the ever-changing atmospheric electrical circuit "should show if the physics I've outlined works," he says doggedly.

Resolving the debate will not be easy. "We are trying to unscramble a very scrambled area," Labitzke says. Rind points out that so little is known about mechanisms linking the sun and weather that both hypotheses may be right—and that there may be others not yet

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**Global Aid Wars**

Poverty, it seems, is not foremost among the criteria by which wealthy nations choose to disburse their aid. The Human Development Report 1994, published by the United Nations Development Program, notes that two thirds of the world's poor get less than one third of the total development aid. And donor nations routinely tie assistance to military spending. In 1992 countries that spent more than 4 percent of their GDP on their military received $83 per capita in aid, whereas nations that spent less than 2 percent got $32.

A large part of this imbalance is brought about by bilateral donors, who offer not just military but economic aid to strategic allies. For instance, Israel and Egypt will receive more than $2 billion of the $7.4 billion of bilateral assistance the U.S. plans to give in 1994. (The two nations receive an additional $3.1 billion in military assistance from the U.S. every year.) The U.S., Russia, China, France and the U.K.—the five permanent members of the U.N. Security Council—continue to supply the most weapons to developing countries.

Although multilateral institutions are more evenhanded—the World Bank gives about half its aid to two thirds of the world's poor—they do not redress the imbalance. As a result, a Brazilian woman living below the poverty line receives $3 in support a year, whereas her Egyptian counterpart receives $280.

These days far more foreign capital flows to developing countries in the form of private investment instead of aid. In 1992 more than $100 billion was invested—as opposed to the $60 billion donated. Unfortunately for the poorest of the poor, this form of cash flow misses them, too. In the late 1980s sub-Saharan Africa received only 6 percent of foreign direct investment.

Trade, another means by which developing countries earn foreign capital, also benefits the more developed—and illustrates the ambivalence of wealthy states toward the world's poor. Although poverty wins a measure of sympathy, the cheap workforce of poor nations makes them an economic threat. By one estimate, if developed countries lifted all trade barriers to Third World goods, the latter would gain in exports twice what they now receive in aid.

Another constraint on the development of the Third World—foreign debt—keeps growing. In 1970 total debt was $100 billion; in 1992 it stood at $1.5 trillion, including service charges. During the decade preceding 1992, net financial transfers related to loans amounted to $125 billion—from the developing to the developed world. — Madhusree Mukerjee
dramatic. But the mere existence of clear-cut connections between tiny variations in the sun and measurable changes on the Earth demonstrates that amazingly delicate balances are at work in the atmosphere. “The climate system has extreme points of sensitivity that were not previously appreciated,” Rind observes—a sensitivity that could turn out to be relevant to changes wrought by humans in addition to those doled out by the sun. —Corey S. Powell

**Sex, Death and Sugar**

*Researchers try to “grow” societies on a computer*

In the trendy field of artificial life, researchers seek the rules underlying nature by mimicking it on a computer. Although most artificial lifers focus on colonies of bacteria or flocks of birds, Joshua M. Epstein and Robert L. Axtell are more ambitious. These two social scientists are trying to simulate and thereby understand the most complex of all biological phenomena: human societies.

The simulation shown here may look like red and blue dots moving around on a yellow background, but it actually shows the evolution of two human societies, complete with birth, sex, death, tribal conflict and other constants of nature. The blue and red dots are people, or “agents,” to use the term favored by economists. The yellow regions represent food. Epstein and Axtell refer to this sustenance as sugar and to their artificial world as the Sugarscape.

Epstein and Axtell, who hold joint appointments at the Brookings Institution in Washington, D.C., and the Santa Fe Institute in New Mexico (the latter is a hotbed of artificial life), consider the Sugarscape to be a laboratory in which they can test ideas about social evolution. Whereas most economists and social scientists build large-scale demographic trends into their models, Epstein and Axtell take a more bottom-up approach. They want to show how such trends may emerge, or “grow,” from the interactions of individual agents. Conventional models, if they employ such agents at all, usually bless them with attributes rarely seen in the real world, such as immortality and a perfect knowledge of their economic environment.

Epstein and Axtell have sought to make their agents more, well, human. For example, not all agents are born equal in the Sugarscape. Some can spot sugar at greater distances than can others, and some have metabolisms that allow them to survive on a given amount of food for longer periods. Natural selection thus comes into play. Agents are either male or female, and each one belongs to one of two tribes: red or blue. When a red agent moves next to a blue agent (or vice versa), the red agent has a better than random chance of converting the stranger to his or her tribe. If a male and female of either tribe meet, they may have children if both are of childbearing age and have enough food stored up. The children inherit the vision, metabolism and tribal affiliation of their parents according to a simple Mendelian scheme. If the agents do not starve, they eventually die of old age.

In the first picture of the sequence, agents are scattered at random across the Sugarscape. They soon migrate toward the two sugar-rich mountains, where they begin to reproduce more rapidly than they die; the population of each mountain also becomes ethnically homogeneous. As the populations soar, the tribes consume the sugar faster than it can be replenished, and some agents venture away from their mountains in search of new sources of food. In the final picture, a blue “forager” enters red territory, where he or she can try to convert blues to red or be converted.

In more complicated simulations, Epstein and Axtell have investigated the effects of combat (one agent can kill another and steal his or her sugar), trade (agents can exchange sugar for another resource, “spice”), infectious diseases, pollution and the inheritance of wealth. The researchers claim that their agent-based simulations generate many of the same results—such as the tendency of inheritance rules to suppress natural selection and make populations more susceptible to disease—that scientists have observed in the real world.

Epstein concedes that the simulations are still merely “cartoons” compared with the intricacies of modern societies, but he thinks they may offer insights into the evolution of relatively simple cultures. He and Axtell are now collaborating with archaeologists affiliated with the Santa Fe Institute. The group is trying to understand the rise and sudden fall of the Anasazi, a civilization that thrived in the southwest U.S. from A.D. 1000 to 1300. One archaeologist, George J. Gumerman of Southern Illinois University, hopes the Sugarscape may illuminate links between maize production and population fluctuations.