Solar Tracks in the Snow

A chemical method of tracking past solar activity may yield new clues about the sun's effect on climate and weather

BY SUZANNE OLSON

Does solar activity affect our global climate? Apparently so, according to many scientists. If so, how much? More than we thought, it now appears. The results of a rather unusual method of dating solar activity — using ion concentrations in the Antarctic snow — indicate significant alterations in worldwide weather due to small-scale solar variations, suggesting a link between the earth's atmospheric circulation patterns and solar activity.

For three years, Edward J. Zeller of the University of Kansas in Lawrence and Bruce C. Parker of the Virginia Polytechnic Institute and State University in Blacksburg have made chemical analyses of ice cores taken from high altitude sites on the Antarctic plateau. Their data may well constitute the most accurate and complete index of solar activity ever obtained from the solid earth.

This index suggests that drastic changes in atmospheric circulation have coincided with a reduction in solar activity. In addition, their solar chronometer hints that such fluctuations in solar activity may be regular and cyclic and may possibly be linked to the periodicity of the ice ages.

The crux of this recently developed solar dating technique is nitrate accumulation. Produced at the poles when solar particles bombard the magnetosphere and ignite the blaze of the aurorae, nitrates fall out and are buried annually in compacted layers of snow. Recognizing that this reaction occurs, Zeller and Parker reasoned that nitrate production must be a signature of solar activity, or the extent to which the sun is flinging out solar particles. As an increased number of solar particles follow the earth's magnetic field lines toward the poles and clash with atoms in the thin upper atmosphere, auroral displays become more frequent and more spectacular and more nitrates are produced.

The by-product of each year's auroral fireworks is deposited in the annual snow layers and can be read much like the more traditional tree-rings. Using a "clean drilling" tool somewhat like a huge auger so that the ice is not contaminated with diesel fuel, Zeller and Parker have taken cores from the ice at the South Pole and more recently from Vostok Station, a Soviet research base about 1,500 kilometers from the Pole. Each annual layer is recognized by the appearance of "hoar-frost," or recrystallized snow, that is formed yearly on the snow surface. Samples are taken from each layer in the cores and analyzed by using an ultraviolet spectrophotometer. Besides nitrates, the researchers look for other substances that may indicate outside contamination or a source for the nitrates other than solar activity. Each possible source is ruled out before the nitrate concentration is attributed to solar activity, Zeller and Parker say. "We have been unable to disprove the hypothesis so far," says Parker, that the measured concentration of nitrates is attributable to solar activity alone.

The snow layers are more reliable than tree-rings, say Zeller and Parker, because temperatures at the South Pole are so cold that no snow ever melts and little sublimes. Save for occasional disruption by wind-scouring in some small local areas, the Antarctic ice blanket represents a historically consistent annual water accumulation of between 8 and 10 centimeters (approximately 20 centimeters of snow per year). It offers a record of nitrate accumulation, hence an insight into past solar activity, as long as the ice is deep. Thus, an ice core measuring 100 meters, for example, should provide year-by-year measurements dating back more than 1,000 years.

Moreover, the scientists note, nitrate analysis is far more accurate than the best currently available technique—carbon 14 dating. While carbon 14 has a resolution of 50 years, give or take 30 years, says Zeller,

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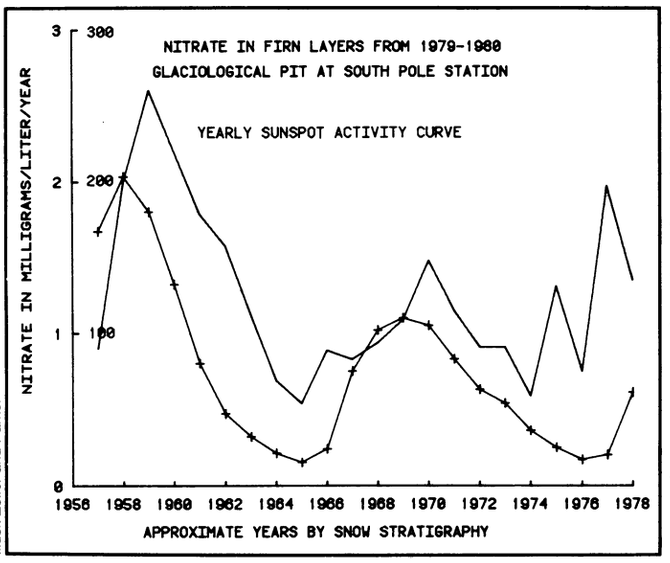
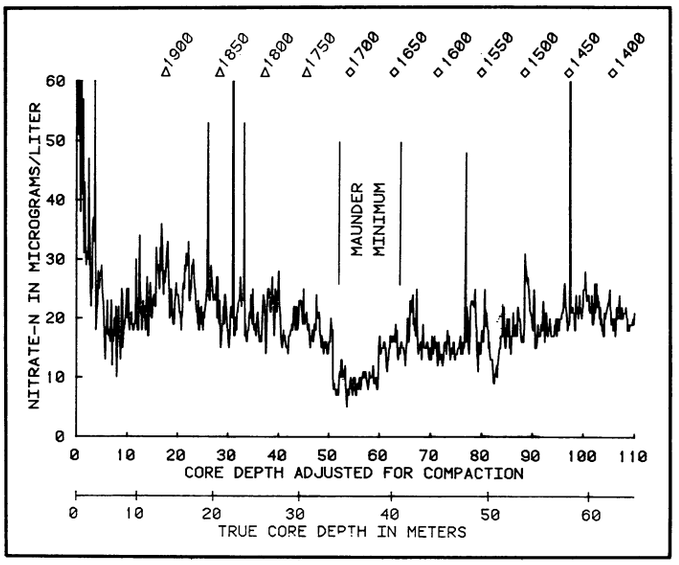
Illus.: Zeller and Parker



A comparison of the nitrate record in Antarctic snow with the cycle of sunspot numbers shows that nitrates accurately trace solar activity with the expected 2-year lag behind the sunspot curve. Sunspots themselves do not affect weather or climate but are a convenient marker of the solar activity that may be responsible for such effects.



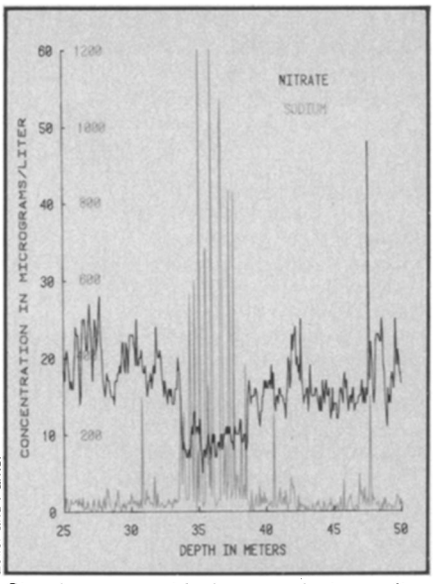
Nitrate concentration plotted against snow depth gives a record of year-by-year changes in nitrates — and therefore solar activity. Note the drastic drop in nitrate concentration that corresponds to the Maunder Minimum, when solar activity is believed to have decreased dramatically and global weather became very cold and dry.

. . . Solar weather

nitrate analysis has, at worst, a resolution of two years — that is, the timing of an event can be pinpointed to within two years. "And there is no indication that we lose this resolution in older ice," says Zeller. "We may be able to go back 30,000 to 40,000 years."

Satisfied that their nitrate measurements correlate well with recent variations in solar activity as determined from sunspot activity, the researchers began to look for other implications. Several recent findings support the possibility of a link between solar variability and climate. One of the most convincing is that when a graph indicating nitrate concentration found in Antarctic snow (plotted as a function of depth) is aligned with a timetable, significant benchmark variations are apparent at a section of the ice cores correlating to a period of history called the Maunder Minimum or the Little Ice Age (1645 to 1715). A time when little to no sunspot activity was reported by astronomers and extremely cold, dry conditions prevailed throughout the world, the Maunder Minimum is also marked by a dramatic drop in nitrate accumulation. From an annual average of about 23 parts per billion, nitrate concentrations fall during this period to about 10 and sometimes 6 parts per billion.

Simultaneously, and quite curiously, on the graph there appears a series of pulses of high sodium concentration in the cores. Under normal conditions, little sodium is found in the bulk of Antarctic snow, despite the proximity to the Southern Ocean, a major source of the element. This is because the global atmospheric circulation forms a vortex at the poles, which tends to inhibit the incursion of large oceanic air masses over the continent. In addition, the South Pole rises more than 9,000 feet above sea level and lies about 800 miles from the ocean. Thus, the sharp spikes of sodium concentration, sometimes registering more than 50 times the usual amount, captured the curiosity of solar chronologers Zeller and Parker.



Simultaneous with decreased nitrate (i.e., decreased solar activity) in the Maunder Minimum, sodium concentration rose. This indicates that global circulation may have changed and allowed winds to sweep sodium from the ocean to the continent.

"Conditions must have been drastically altered for a period of about 50 years," Zeller explains. "There seems to have been a change in the circulation patterns of the planet, a breakdown of the vortex, and the incursion of giant salt storms sweeping over the interior of the South Pole."

The nitrate calendar reveals other possible clues in the solar-weather connection. Based on preliminary results, the researchers believe that the nitrate record may indicate cyclic swings in solar activity. Depending on the timing of the cycle, this sort of regular swing in solar activity may be linked to the apparent regularity of ice ages, says Zeller. With only 3,500 years' worth of ice cores analyzed so far, the researchers expect further studies of cores that extend back 12,000 years to provide a better view of the long-term cycle of solar activity. To that end, they plan to establish a permanent nitrate analysis laboratory and to double their current core record during the scientific research season in Antarctica this year.

As to what extent these alterations in circulation patterns were driven by changes in the sun's activities, "We're just not sure yet," Zeller says, "but the propinquity of the drop in nitrates to the pulses of sodium increase certainly intimates a link between the sun's activities and the world's atmospheric circulation patterns."

Although their results certainly have important bearing on paleoclimatic research, "The object of our work is not climatic studies," Zeller says. "What we are attempting to do is to provide a more finite mechanism, a higher resolution mechanism, that can give us year-by-year information about solar and climatic variations of yesterday. This in turn may give us insight into what to expect for tomorrow." □

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