6. EVIDENCE FOR CYCLIC SOLAR VARIABILITY IN CLIMATE RECORDS
(11 YEARS, 22 YEARS, 80 YEARS, OR LONGER)

Summary Presented by J. A. Eddy

Continued work by Stockton, Mitchell, and Meko on recurrent patterns of
drought in the Western United States continues to support a strong case for
a Sun-climate connection of practical importance. They have continued to test
and interpret tree-ring data derived from regional areas, which gives them more
than 300 yr of record. Of particular interest at this symposium was their response
to conflicting interpretations of the same data that have been put forward by
Currie and by Bell since the time of the Ohio symposium, 4 yr ago. In two
independent studies, Currie and Bell both concluded that in the Stockton et al.
tree-ring data were a significant 18.6-yr cycle, which they ascribe to the influ-
ence of lunar motions. Stockton acknowledged the presence of an 18.6-yr signal
in some but not all of the tree-ring records. The apparent lunar signal seems
to come and go, as do so many other things in this field. When their full span
of data is considered (Currie considered only the later part), Stockton et al.
conclude that the dominant and more persistent signal is still that at 22 yr, which
is presumed to be the mark of the Hale magnetic cycle of the Sun.

It should be pointed out that we still lack a convincing theoretical explana-
tion for either a solar or a lunar influence on drought; in either case we deal
with external forcing that is weak compared to the internal energy of the tropo-
sphere. Of the two possible external perturbers, the Moon may be the stronger
force, through the acknowledged presence of lunar tides in the ocean or the
atmosphere. Such tides should be modulated in an 18.6-yr cycle. Solar mag-
netic activity indeed varies in a cycle of 22 yr, but solar physicists are hard
pressed to demonstrate whether any energetic feature of the solar output follows
this period. Does the solar constant, for example, or the solar UV flux? The
truth is that we do not know.

A careful study by Gage and Reid demonstrated a possible 11-yr forcing in
the height of the tropical tropopause. They set a good example for such work
by first testing for the larger, annual effect in tropopause height induced by
the eccentricity of the Earth’s orbit. They find the anticipated annual effect,
in the sense that the tropopause is systematically higher when the Earth is nearer
the Sun and the solar irradiance is greater. (Some have proposed using the
Milankovitch mechanism in the same way, as a test of a known modulation
of insolation since its effects on climate are thought to be understood.) Their
model to explain the annual modulation invokes increased heating of the ocean
surface at perihelion, largely in the Pacific. Gage and Reid then test for a similar
effect in phase with the 11-yr sunspot cycle, and find it, as a smaller effect:
the tropical tropopause is slightly higher at the maximum phase of the sunspot
cycle. The phase of the relationship found by Gage and Reid is at first surpris-
ing, given what we know of the short-term modulation of the solar constant
that is attributed to sunspot blocking. Sunspot blocking, when extrapolated to
time scales of years, should reduce the solar constant at sunspot maximum.
This would imply, by the Gage and Reid model, a lower, not a higher tropo-
pause. In response, Reid points out that we really know only the short-term
effects of sunspots on the solar constant. The extrapolation to 11-yr periods is, in his view, conjectural.

George Williams, a geologist, came to our symposium from Australia to explain what must be the most exciting claim in this field in the past few years. In analyzing geologic samples from central Australia he has found undeniable evidence of regular and repeated patterns of layered bands in sediments laid down in the Precambrian era, three-quarters of a billion years ago. These bands repeat in cycles of 11 and 22 layers, which he interprets as annual varves. If this is right, and if the purported 11- and 22-yr patterns are evidence of solar forcing, then the Australian sediments hold evidence of an overwhelming influence of solar activity on climate at that time. And if that is so, these records provide as well a look at the nature of solar behavior a long time ago, at a time when we know almost nothing of the Sun. It all hinges, however, on whether the bands are indeed annual, and geologists do not all agree with this interpretation. While one can argue that the bands are most likely annual layers (as opposed to monthly, tidal bands or any other temporal period) more proof is needed, perhaps by demonstrating, through geological dating methods, that N bands are separated in time by approximately N years. Williams is engaged in a study at the present time to extend the sample, and we can be sure that this program, in another field and on another continent, will be watched with great interest, both for what it says of the Sun and for what it says about Sun-weather relations. Williams has suggested that an enhanced solar modulation of Precambrian climate might be explained as the result of a reduced terrestrial magnetic field strength at the time. But again, wholly unanswered, is why the 22-yr cycle should appear so strong in Precambrian or in modern weather records, for there is no demonstrated mechanism for forcing at that frequency, given what we now know about the outputs of the Sun.

A paper by Schuurmans concentrated on detailed meteorological data to demonstrate a modulation of surface temperature that shows a similar 22-yr cycle. The effect he finds has apparently opposite phases in summer and in winter, which may support a finding reported in the same session by Kirby Hanson. Schuurmans feels that the modulation is caused by an unspecified solar influence on large-scale circulation, which he conjectures is tied to a planetary-wave coupling mechanism. At the Boulder symposium planetary waves appeared to be a popular candidate for a workable mechanism for Sun-weather connections.

A paper given by Wigley for Kelly and Jones, all of the Climatic Research Unit, Norwich, looked for possible solar forcing in a set of Northern Hemisphere temperature and pressure data which they had recently compiled in grid form. They find a possible 11-yr signal in some grid areas, but conclude that the number of areas in which the signal is found is close to that which could arise by chance. Their findings are similar for a 22-yr cycle. Kelly and Jones feel that their study supports Pittcock's attitude of skepticism, particularly since the regions where an apparent solar signal is found were distributed, spatially, more or less at random, again as one would expect from chance. On the other hand they throw away a lot of information in their analysis, since they keep only those areas where the apparent signal is above the 95% confidence level. Often voiced at this symposium were warnings against throwing out the baby of solar influence with the statistical bath water. Such doubts will probably always be raised in studies that are based on statistical searches.
Hanson's paper, based also on historical station data, reminded us that we may have to look deeper into the circulation of the atmosphere and more thoroughly at meteorological data to find or to understand subtle solar-weather effects. Certainly an important facet of Sun-weather studies is the problem of understanding the complex circulation of the lower atmosphere. It is unfortunately true that considerations of tropospheric meteorology are often omitted in both individual studies and in committee recommendations in the field.

Hanson examined station data that were averaged by states (of the United States) and by months for the last 100 yr. He found that when one looked in this detail, one could identify a marked 11-yr variability in surface temperature that is pronounced in the Great Lakes states and in June. The sense of the relationship—higher summer temperatures at times of lower sunspot numbers—is consistent with what we now expect from sunspot-blocking of the solar constant. The variation that Hanson finds is, however, much larger than what one would anticipate from canonical estimates of the sensitivity of surface temperature to solar constant changes. Hanson finds a modulation that is several degrees in amplitude. This could demonstrate the inaccuracy in present estimates of the sensitivity parameter, now taken as about 1 C per 1% change in S. More to Hanson's point, it underlines the need to include realistic circulation in the application of such estimates, since the canonical estimates of sensitivity ignore detailed processes that could amplify or suppress the response of the atmosphere to solar constant forcing.

A tantalizing paper on patterns found in fossilized wood was presented by the Ammons family, showing evidence of apparent cycles of various lengths in ring-widths in trees of fossil age. The samples that they have studied are not dated. In them they find evidence of periods of 5, 7, 10, 13, 15, and 20 yr that suggest possible meteorological cycles of this length. By comparison, the examination of a much larger body of data from modern trees several years ago by LaMarche and Fritts at the Laboratory of Tree-Ring Research failed to find any clear cycles in this range. Why should climatic or other cycles be clearer in fossil wood? The same question haunts Williams's findings of apparent 11- and 22-yr sediment patterns in Precambrian rocks. Can it be that the processes of nature were much simpler in the past? Could it be a trick of chance selection, since the ancient samples are of necessity sparse? Or is it only our tendency, given fewer constraints, to paint the past with simpler strokes and a broader brush?

Sonnett's paper closed the session with an analysis of the power spectrum of sunspot numbers and ways of mathematically modeling and interpreting them. The well-worn series of annual sunspot numbers, stretching as it does several hundred years into the past, is surely among the most intensively studied strings of numbers in physics or mathematics. There are probably things we can learn from them still, although their quality is far from uniform in time, as Sonnett and others before him have pointed out. Studies such as his remind us that there is much we do not know with certainty about solar behavior, including the most basic questions of why and how activity varies as it does.