When the Sun Goes Backward:

Solar Motion, Volcanic Activity, and Climate, 1990-2000

by James H. Shirley

> An unusual "solar event" will take place in the years 1990-1992. The Sun's motion relative to the solar system mass center will be retrograde, a condition that may be accompanied by unusually persistent climatic extremes.

Variations of solar activity appear to be linked with variations in the inertial motion of the Sun (Jose 1965; Landscheidt 1983; Fairbridge and Shirley 1987). And, the hypothesis of a link between solar activity and terrestrial weather has recently gained in mainstream respectability due to work by Labitzke (1987) and others.

A review of recent work in these areas reveals a steadily improving base of observational and empirical evidence. The solar motion is predictable, and has been employed as a basis for forecasts of future solar activity. These have been in turn employed in forecasting future trends of weather and climate (Landscheidt 1981).

The present study highlights an unusual "solar event" that will take place in the years 1989-1991. During this period the Sun's motion relative to the solar system mass center will be retrograde. This condition has occurred twice previously in the last millennium, in the 1630s and in the second decade of the 19th century. Both periods were characterized by climatic extremes, and by remarkable outbursts of explosive volcanic activity. A statistical evaluation suggests that the correlation in time of episodes of solar retrograde motion and major volcanic eruptions is unlikely to arise by chance.

James Shirley is an independent researcher who has contributed to the professional literature in seismology, planetary science, the atmospheric sciences, and solar physics.

There is reason to believe that the decade of the 1990's will be characterized by unusually persistent climatic extremes. Major explosive volcanic eruptions may occur. The possible consequences for society suggest the need for a greater investment in support of research to uncover the physical mechanisms and improve forecasts.

Solar Activity, Weather, and Climate

The hypothesis of a connection linking events on the Sun with terrestrial weather and climate is not a new one. Sir William Herschel suggested such a connection as early as 1801. The scientific community has been generally dubious about Sun-weather hypotheses because of the lack of a physically reasonable forcing mechanism. The differences in solar luminosity, in the solar wind, and in the interplanetary magnetic field taking place over the period of the 11-year sunspot cycle are relatively minute, and it is hard to see how tiny changes of this sort could bring on major changes in the comparatively energetic circulation of Earth's atmosphere.

Just in the last year or two, however, new results have emerged which are forcing a reconsideration of mechanisms. It is hard to overemphasize the significance of the recent papers by Labitzke (1987) and Labitzke and van Loon, for example. These authors found that a sunspot cycle signal emerges very strongly in atmospheric data when one takes the phase of the famous equatorial "quasi-biennial oscillation" into account. The results obtained by Labitzke are statistically significant at a very high level, and are free of many of the problems and ambiguities that have plagued earlier results.

Recent observations of solar output from spacecraft (Willson and others 1986) lend credence to the hypothesis of a Sun-weather effect. These show a definite drop in the solar luminosity over the 5-year period of observations, which is larger than expected (a few tenths of a percent) and which seems to follow along with the drop in sunspot numbers. Changes of the solar output of this magnitude could have significant effects on weather and climate.

New evidence likewise supports a link between solar activity and climate on longer time scales, from decades to centuries (Reid 1987; Wigley 1988). Eddy (1977) presented evidence linking solar "prolonged minima" with cold climates on Earth during the Little Ice Age (from about 1250 A.D. to 1850). His results were subsequently challenged and the connection brought into question. More recently, however, Wigley (1988) found a relationship of this sort linking times of worldwide glacier advance with times of reduced solar activity over a much longer period; that is, since the end of the last ice age.

Thus, research on the Sun-weather problem has gained considerable momentum. The linkage now seems better established by observations than at any previous time. While the actual mechanisms remain obscure, the topic has attained an unprecedented scientific respectability.

The separate question of a possible relationship of solar motion and solar activity is also gaining credibility. There is reason to believe a real relationship exists here as well. The obvious implication is that, if these connections are real, then we may be able to gain some insight into the probable course of future weather and climate events by studying the solar motion.

With this in mind, I wish to draw attention to the possible consequences of an unusual "solar event" that is, to some extent, already underway. The phenomenon in question is a feature of the motion of the Sun. Thus, our first order of business is to briefly describe this motion.

Solar Motion and Solar Activity

The Sun, for most practical purposes, represents the center of the solar system. It is about 743 times more massive than the planets taken together, and it is easy to think of the Sun as a body at rest, with the minute, distant satellites such as Earth having no great influence. However, the solar system is a system of massive bodies in motion bound by gravity, and as a necessary consequence, the Sun has a definite and predictable motion.

The easiest way to describe the motion and its causes is by analogy. Imagine for a moment a dumbbell, with weighted ends, thrown into the air with a spin. The ends of the dumbbell will spin about one another, and the path of one end would be irregular. However, the dumbbell has a balance point, or center of mass; and if the path of this center of mass were traced over the flight, it would be found to be a regular arc (a parabola).

Similarly, the solar system has a center of mass, which traces a regular path as we orbit the center of the Milky Way galaxy. The Sun, however, like one of the weighted ends of the dumbbell, describes a rather different path. Figure 1 shows the path of the center of the Sun for the period from 1930 to 1984. The Sun moves to and fro, looping about the solar system center of mass (barycenter), with one loop taking on the order of 10-20 years. The Sun's center is at times more than a million miles from the barycenter; this distance is a little larger than the diameter of the Sun itself.

A number of scientists have wondered whether this looping motion of the Sun could be involved in generating solar activity – in the form, for instance, of the 11-year sunspot cycle. Unfortunately, in standard physics, there is no clear reason why this motion should affect the internal workings of the Sun. Nevertheless, Jose (1965) published an important paper that showed a remarkable correspondence of curves of sunspot numbers and the rate of change of the Sun's angular momentum about the barycenter. The correspondence is not perfect, but it is remarkably good.

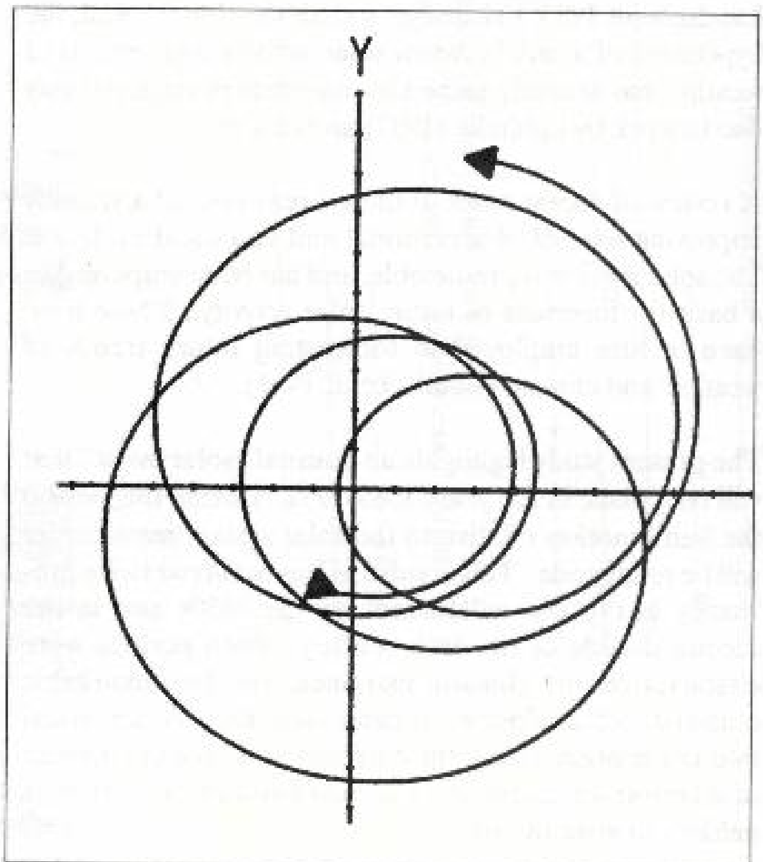

Figure 1
Motion of the Sun around the solar system barycenter in the years 1930-1984. Axis divisions are in AU x 10^{-3}.

Mörth and Schlamminger (1979), Landscheidt (1981, 1983), and many others have extended this work and provided additional evidence of a real connection linking solar motion with solar activity. The most important studies are discussed in an article published recently (Fairbridge and Shirley 1987). We were able to show that the major long-period changes in solar activity—known as prolonged minima (where the 11-year cycle is suppressed, and few spots are seen for periods of decades)—match up with periods when solar motion is particularly energetic.

Thus the question of a link between solar motion and solar activity has become more respectable in recent years. The periodicities present in the solar motion match up with the periodicities found in the sunspot data; and, there is at present no other mechanism proposed for generating solar activity that yields periodicities at all similar to those observed. Here, as in the case of a Sun-weather link, considerable supporting evidence has been advanced, but the physical mechanisms are still obscure.

Climatic Extremes, and Forecasts Based on the Solar Motion

A "climatic extreme" is an anomalous condition of the weather and the atmospheric circulation that persists for time periods of a season or longer. A prolonged drought is one example. Record temperatures, on the other hand, or an isolated disastrous storm, do not qualify; these are "weather," rather than "climate."

How climatic extremes most often come to occur can be seen with the aid of a diagram. Figure 2 shows two polar views of the Earth, with arbitrary high and low pressure systems and jet streams sketched in. View A is a relatively regular pattern of jet stream flow, without large north and south excursions. When the atmospheric circulation is in this state, middle-latitude low pressure systems move regularly eastward, giving rise to an alternation of wet and dry episodes, with neither predominating. This is known as a zonal pattern.

View B is a more complex pattern, with large north and south shifts of the jet streams; this is known as a meridional pattern. Here the pressure systems may be more or less anchored in place. Dry weather persists beneath high pressures, while heavy precipitation and flooding may occur in areas near low pressure centers. The condition on the right is the state of the atmospheric circulation that gives rise to climatic extremes when it persists for long periods. (A period with "normal weather" will have episodes where the circulation pattern looks like Figure 2B, but these will not last for long periods).

Patterns like that of Figure 2B tend to predominate in historic periods of extreme climates, like the little ice age (1250-1850 A.D.). This period was generally characterized by (1) low values of long-term mean temperatures during all seasons of the year, (2) enhanced variability of temperatures from spell to spell and year to year, and (3) an enlarged "polar cap" of frigid air over the northern hemisphere, accompanied by jet streams that were significantly weaker and were displaced farther south than is typical for today (Lamb 1982). The return of conditions similar to those of the little ice age would have significant impacts on agriculture and society today. But most atmospheric scientists are more worried about a global warming due to increased carbon dioxide. Nevertheless, climate history emphatically demonstrates that this possibility is very real.

Fairbridge and Shirley (1987) suggested that we may be on the brink of a new prolonged minimum of solar activity. Characteristics of the solar motion that were linked with

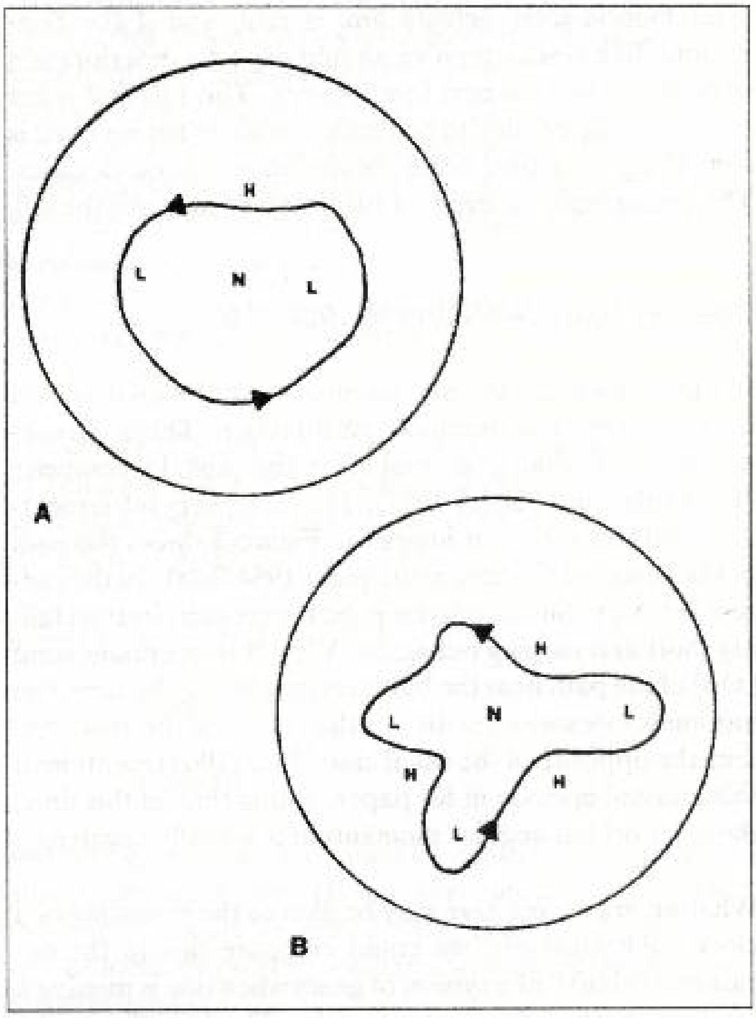

Figure 2
Cartoon showing typical zonal (A) and meridional (B) patterns of jet stream flow over the northern hemisphere. High and low pressure centers are indicated by (H, L).

the occurrence of earlier prolonged minima now are attaining similar values. Our prediction is for inception of a new prolonged minimum sometime in the two decades following 1990 (so it will be some time before we learn if our forecast is accurate!). The prediction does agree with that of Landscheidt (1981), who also employed solar motion as a means to forecast solar activity and climatic change.

We can expect to encounter increased frequency and duration of meridional circulation patterns, with associated climatic extremes of drought, flood, and other severe and unusual weather.

The forecast has significant implications, because the last three prolonged minima of solar activity correspond in time to the coldest periods of the little ice age. Thus, if the solar motion-solar activity link is real, and if the Sun-weather link is real, then we should expect a deterioration of climates over the next few decades. This forecast is not really specific enough to be really useful. What we need is something on a time scale shorter than several decades. The upcoming solar event of 1989-1991 seems to fit the bill.

Solar Retrograde Motion in 1989-1991

In Figure 1 we saw the Sun looping about the solar system barycenter in a counterclockwise direction. This is the normal state of affairs, at least over the past 13 centuries (Fairbridge and Shirley 1987). However, very infrequently, something different happens. Figure 3 shows the path of the center of the Sun in the years 1984-2000. In the current orbit, the Sun fails to loop the barycenter, instead falling short and looping out again. View B is an enlargement (x10) of the path near the barycenter. During this time, the motion is clockwise relative to the center of the solar system, the opposite of the usual case. Jose (1965) mentioned this unusual episode in his paper, noting that, at this time, the solar orbital angular momentum is actually negative.

What we are seeing here may be akin to the re-setting of a clock. Alternatively, we could compare this to the occasional "clunk" of a system of gears when one is missing a tooth, causing slippage at intervals. The hypothesis of a relationship linking the solar motion with the generation of solar activity implies that this event is likely to perturb magnetic fields and/or the flows of materials within the Sun, perhaps in important ways.

I do not propose to discuss the physics of such processes here, as these are not known even in outline. What I would like to do is review the events which accompanied previous episodes of solar retrograde motion. There have been two similar cases in the past 13 centuries; the first of these occurred in the years 1632-33, and the second more recently, in 1810-1812. These dates have some significance in connection with the record of solar activity. The first episode took place about a decade before the famous Maunder Minimum of solar activity, while the second took place near the middle of another period of strongly suppressed activity, where sunspot numbers at solar maximum were under 50, lower than at any time since.

Weather and Climate Records for 1633-1643 and 1812-1822

The climate of the 1630s and 1640s was comparable to that of the subsequent Maunder Minimum period, if not somewhat colder (Robock 1979). It was not uncommon for the

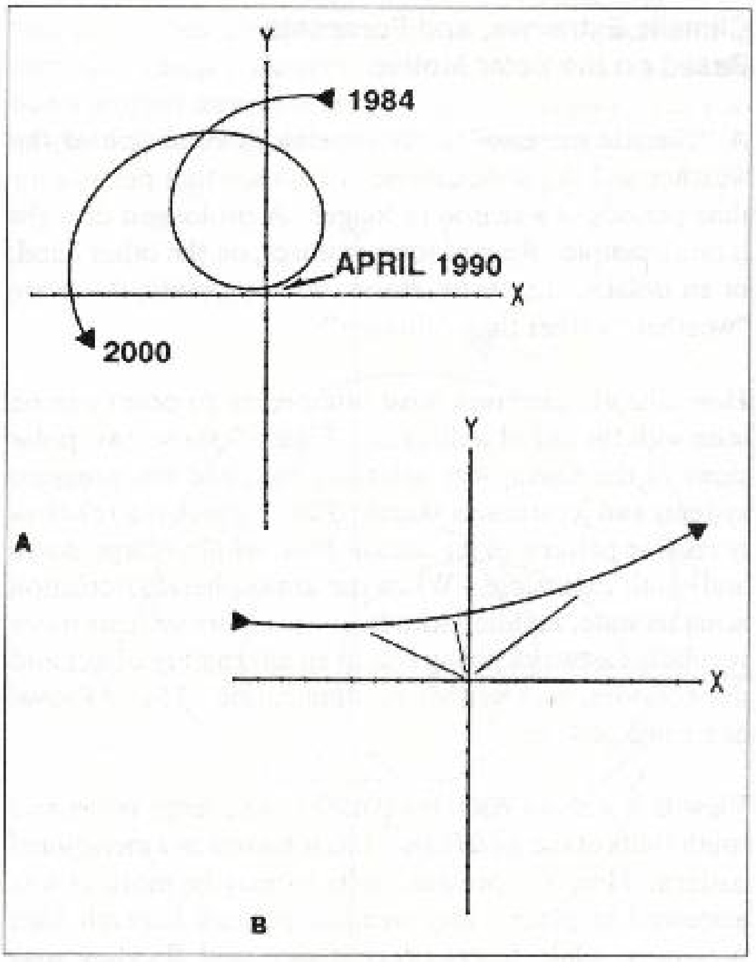

Figure 3
(A) Path of the center of the Sun, relative to the solar system center of mass, for the years 1984-2000.
(B) An enlarged version of (A), showing that the sense of the motion is clockwise here (left to right, relative to the origin) during 1990.

river Thames to freeze solid in this latter period, permitting the populace to hold "frost fairs" on the ice. This has not occurred during the present century. Lamb (1972, 1977) comments on the short growing seasons and growth of glaciers in the 1630s and 1640s. And, Ludlum (1968) describes the "landmark" winter of 1641 as one of the three worst of the entire century in the American colonies. Our records are not particularly complete for these times; nevertheless, it appears that this period included one of the most intensive bursts of explosive volcanic eruptions of the past 500 years. Important eruptions included those of Hekla (1636), Roung (1638), Komagatake (1640), Awu (1641), and Gunung Adiksa (1641) (Lamb 1970).

Weather and climate conditions in the period subsequent to 1810 were more extreme than anything ever experienced by anyone living today. This was the period of the "year without a summer" (1816) in the northeastern U.S. and western Europe, when it reportedly froze during every month of the year. The cold winter that stopped Napoleon's advance in Russia took place during this period. The period was remarkable not only for single extreme years, but for a succession of these; cold summers and short growing seasons triggered major famines in places like Switzerland and the Ukraine. Post (1973) provides a succinct summary: "The years 1812-1817 introduced three decades of economic pause punctuated by recurring crises, distress, social upheaval, international migration, political rebellion and pandemic disease."

The cold interval was worldwide; it can be identified in ice cores from southern hemisphere glaciers (Thompson and others 1986). And, as with the earlier period, major volcanic eruptions took place. The 1815 eruption of Tambora is probably the largest eruption since the end of the last ice age (Stothers 1984), and a number of others (Sabrina in 1811, Soufriere in 1812, Awu in 1812, Mayon in 1814, and Roung in 1817) that occurred around this time injected large amounts of material into the stratosphere.

Climatic conditions during these two periods were arguably more extreme than anything experienced in this century. If the decade of the 1990s is similar, modern societies may be subjected to severe environmental stresses. Caution is needed here, however; other times during the past 500 years had conditions comparable to these episodes, and the correspondence in time of severe climates and episodes of solar retrograde motion might be a coincidence. Volcanic activity occurred in both periods, for instance; it has been shown that some eruptions cause climatic cooling, and this might independently account for the climate conditions (Porter 1981; Kelly and Sear 1984).

Solar Motion and Explosive Volcanic Activity

The correspondence in time of solar retrograde motion and explosive volcanic activity in these two episodes poses a question that is somewhat easier to evaluate. Could there be some relationship? We now have catalogs of major eruptions that are reasonably complete for the period since 1500 (Lamb 1970; Newhall and Self 1982).

We can also expect to encounter major explosive volcanic eruptions, principally between 1993 and 1999. Some may be of immediate climatological significance.

Binomial distribution can be used to assess the probability that episodes of solar retrograde motion and episodes of large explosive eruptions would occur at the same times, if these types of events were completely unrelated. To apply this test we need to identify four quantities. We can say that the simple probability (p) of a large eruption falling in one of our two 10-year episodes is the number of years in the episodes (20) divided by the number of years in the catalog (1500-1980, 480 years), or .0416 percent. The corresponding probability that one will not (q) is 1.00 minus .0416, or .9584.

The number of years having major eruptions in Newhall and Self's catalog is 103 (= n), and the number of hits (years with eruptions, during the decades 1633-43 and 1812-22) is 7 (= x).

The binomial formula is:

$$P = \frac{n!}{x!\,(n-x)!}\, p^x\, q^{n-x}$$

Substituting the numerical values here gives P = .07, which is marginally significant. (If the eruptions and retrograde motion episodes are unrelated, there is only a 7% chance that 7 or more major eruption years will fall within the two 10-year intervals).

From the standpoint of climatic impacts, it is better to use an eruption catalog keyed to the dust veil index (DVI) developed by H.H. Lamb, which takes account of a number of variables to describe the climatic significance of the eruptions. LaMarche and Hirschboeck (1984) give a curve of yearly values of DVI since 1500. Their figure shows 8 peaks with DVI 300; of these, two are the episodes we are considering here. Using this sample, n = 8, x = 2, and P = .039. The chance of 2 of 8 major outbursts coinciding with the 1633-43 and 1812-1822 periods is only 4%, if the two sorts of phenomena are in reality unrelated.

The probability of the observed correspondence occurring by chance is small, and thus it seems reasonable to conclude that there is some real relationship linking episodes of solar retrograde motion with episodes of major explosive volcanic activity.

Discussion and Conclusions

Observational results provide strong support for the reality of a Sun-weather effect, and for a real relationship of solar motion and solar activity; these hypotheses today enjoy unprecedented scientific credibility. Information relevant to the question of future terrestrial climatic variation may be derived from the study of solar motion, if both of these models are not substantially in error.

This study has highlighted an unusual solar event, an episode of retrograde motion relative to the solar system center of mass. I have described the known solar, volcanic, and climatological events of two previous similar episodes to illustrate the possible effects of the upcoming episode.

This study also has uncovered an apparent relationship linking episodes of solar retrograde motion and episodes of major explosive volcanic activity. This previously unsuspected relationship tends to corroborate the reality of a solar motion-solar activity-terrestrial systems linkage (see also Jakubcova and Pick 1987; Landscheidt 1988).

I have presented a simple forecast model based on these mechanisms. The simplest statement that can be made is, if conditions in the 1990s are similar to those of the two previous episodes of solar retrograde motion, then societies will experience climatological extremes of a magnitude and persistence unprecedented thus far in this century. The scenario can be developed in a little more detail. We can expect to encounter:

- Increased frequency and duration of meridional circulation patterns, with associated climatic extremes of drought, flood, and other severe and unusual weather; along with, possibly,
- Major explosive volcanic eruptions. Based on analog periods, these should occur principally between 1993-99. Some may be of immediate climatological significance, cooling the northern hemisphere after the manner of Tambora (Stothers 1984; Kelly et al 1984).

The mid- to late 1990s also represents the next expected episode of severe drought in the western U.S., based on the results of Mitchell and others (1979). Severe cooling of the northern hemisphere (similar to that of the analog periods) cannot be predicted with confidence, however, in light of the uncertainties surrounding the expected warming due to carbon dioxide.

It would be irresponsible to present such a forecast without noting the various limitations of this study and the model presented. For one thing, the number of events employed in the statistical treatment is small, and the results cannot be considered to be conclusive. The systems under consideration are complex and definitely not fully understood. The association of previous episodes of solar retrograde motion and extreme conditions is largely circumstantial; one could argue, for instance, that conditions were already bad before 1811, and that the occurrence of the retrograde motion is not in consequence a valid forecasting indicator.

How, then, can we assign a level of probability for this scenario? There appears to be no simple and dependable way to do this. This survey has covered only a tiny part of the evidence for the connections, and my own feeling based on the published evidence is that this scenario has a high probability of being substantially accurate. It may be more appropriate to ask, what level of probability is negligible?

The socio-economic and political consequences of a decade-long climatic change to conditions similar to those of the analog periods would be massive, though presumably not unmanageable if the situation were appreciated. We must invest in additional research to gain a better understanding of these systems and their interactions.

References Cited

Eddy, J.A., 1977. The Case of the Missing Sunspots. *Scientific American* 230:80-92.

Fairbridge, R.W., and J.H. Shirley, 1987. Prolonged Minima and the 179-Yr Cycle of the Solar Inertial Motion. *Solar Physics* 110:191-210.

Jakubcova, I., and M. Pick, 1987. Correlation Between Solar Motion, Earthquakes, and Other Geophysical Phenomena. *Annales Geophysicae* 5B:135-142.

Jose, P.D., 1965. Sun's Motion and Sunspots. *Astronomical Journal* 70:193-200.

Kelly, P.M., and C.B. Sear, 1984. Climatic Impact of Explosive Volcanic Eruptions. *Nature* 311:740-743.