Solar Activity Controls El Niño and La Niña

by

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1. Forecast of ENSO events

Anomalous warming (El Niño) or cooling (La Niña) of surface water in the eastern equatorial Pacific occurs at irregular intervals between 2 and 7 years in conjunction with the Southern Oscillation, a massive seesawing of atmospheric pressure between the southeastern and the western tropical Pacific.

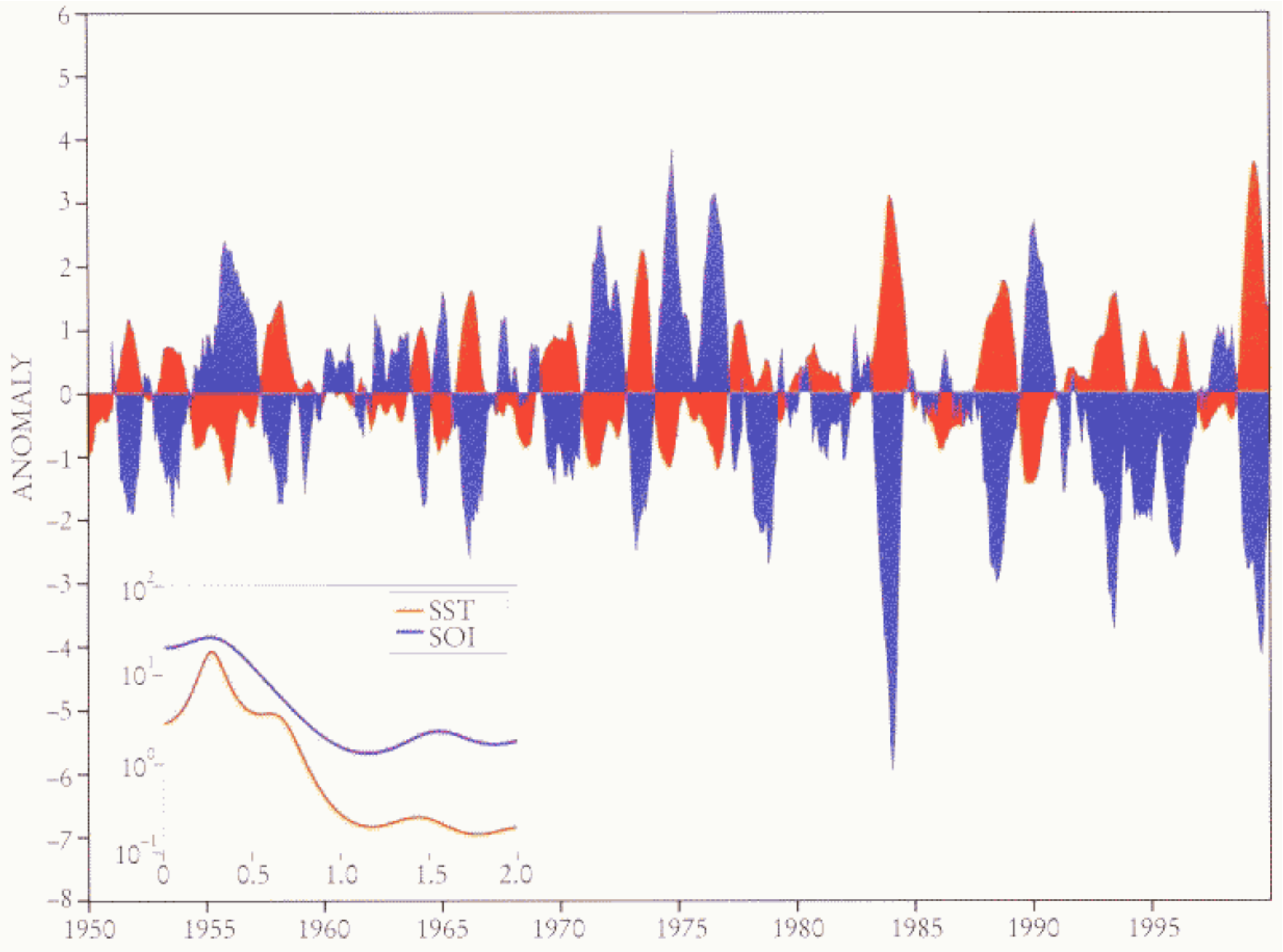


Figure 1 after J. D. Neelin and M. Latif [36] shows the anticorrelation of the covarying indices of these oscillations. Plotted in red are anomalies (deviations from the long-term mean) of sea surface temperatures (SST) averaged over the tropical east-central Pacific. Plotted in blue is the Southern Oscillation Index (SOI), the normalized pressure difference between Tahiti, in the mid-Pacific, and Darwin, Australia. The SOI measures the pressure gradient across the tropical Pacific which, in turn, is an indicator of equatorial wind variations. When the SOI index

reaches low negative values, a strong El Niño is in progress. High positive values indicate La Niña. Power spectra of the covarying time series (inset) show a distinct period at approximately 4 years. The inset axis measures cycles per year.

The coordinated El Niño/Southern Oscillation phenomenon (ENSO, for short) is the strongest source of natural variability in the global climate system [41]. During the severe ENSO event 1982/1983, when the sea surface off Peru warmed by more than 7° C, it was discovered that there are strong links to weather in other regions as, for instance, floods in California and intensified drought in Africa. The observation of this global connection implied that the oceanic and atmospheric anomalies of the equatorial Pacific might be the key to accurate seasonal weather forecasts in other regions. Since then there has been a continuous search for ENSO precursors and worldwide patterns of effect to make it possible to predict the event and its consequences for seasonal weather. This effort has a solid basis as far as the involved energy is concerned. J. L. Daly [9] has shown, that positive and negative anomalies in the global temperature of the lower troposphere, measured by satellites since 1979, are primarily driven by El Niños, La Niñas, and the Southern Oscillation. This is not easy to see as global temperature lags the SOI by 6 to 9 months. Only when severe volcanic eruptions occur, global temperature is modulated by their cooling effect.

J. P. Peixoto and A. H. Oort [40] have provided similar evidence covering the period 1958 - 1987. Their data include the whole troposphere and the lower stratosphere up to 25 km height. When they compared the time series of SST anomalies in the eastern equatorial Pacific with the time series of the atmospheric temperature averaged vertically and horizontally over the entire Northern Hemisphere, they found that the curves are highly correlated. The correlation is highest (r = 0.82) when the atmospheric temperature lags the ocean temperature by four months. They concluded: **"Since correlations with the mean Southern Hemisphere temperatures are also very high, it is clear that a large part of the observed variability in the global atmosphere must be connected with the ENSO events."** Peixoto and Oort [40] also observed that sea surface temperatures lag the SOI by 4.5 months. So they found that atmospheric temperatures lag the SOI by 8.5 months. This is just what Daly found in the satellite measurements of the lower troposphere.

When we look at Figure 1 and the rather irregular oscillations in the plotted time series, it seems impossible to predict ENSO events on a theoretical basis. Yet the NOAA tripwire open-ocean buoy array including 65 deep-ocean moorings and 135 surface drifters gives climatologists an early warning of 6 to12 months of an impending El Niño. In addition, a satellite borne microwave sensor allowed scientists in 1997/1998 to estimate the velocity and track of the large eastward-travelling Indonesian Kelvin wave and the quantity and temperature of the hot water migration from west to east. Daily observations of changes in SST, surface wind, upper ocean thermal structure, and ocean currents enable researchers to engage in modeling and predicting ENSO events. It seems to be very difficult, however, to develop models that extend the 1-year limit set by the observation of precursors. M. Cane and S. Zebiak of the Lamont-Doherty Earth Observatory of Columbia University made the first successful forecast of an El Niño in early 1986, one year ahead of the event, but their model did not indicate the strong 1997/1998 El Niño. At present, there exist no models that can skillfully predict ENSO events at lead times longer than twelve months [36].

Neelin and Latif [36] think that ENSO’s irregularity limits its predictability. They hold that weather noise, the changing background state of climate, and deterministic chaos, representing the internal variability of the climate system, set the fundamental limits to the lead time at which El Niño can be predicted. This view that ENSO events are exclusively internal phenomena of the climate system represents the accepted teaching in climatology, as expressed by Peixoto and Oort [40]:

> **"On the interannual time scale there are no large external forcings of the atmosphere-ocean system so that the variations must arise from internal interactions with many positive and negative feedbacks. The most spectacular example of an internal variation is the ENSO phenomenon that may be regarded as a free oscillation of the ocean-atmosphere system."**

I shall show that this is a preconception. Actually, El Niño and La Niña are subjected to external forcing by the sun’s varying activity to such a degree that it explains nearly all of ENSO’s irregularities and makes long-range forecasts beyond the 1-year limit possible. This is no mere theory. My forecasts of the last two El Niños [28] turned out correct and that of the last one was made more than two years ahead of the event, beyond the 1-year limit discussed in the literature. Deterministic chaos, mentioned by Neelin and Latif, does not stand in the way of external forcing. Sensitive dependence on initial conditions and ensuing limited predictability are only valid with regard to processes within the climate system. External periodic or quasiperiodic systems can positively force their rhythm on it. This is not only the case with the periodic change of day and night and the Milankovitch cycles, but also with variations in the solar energy output as far as they are periodic or quasiperiodic.

2. 11-year sunspot cycle and the Golden section

The 11-year sunspot cycle meets these conditions of external forcing. Yet climatologists who exclusively consider the change in the sun’s irradiance solely look at maxima and minima of the sunspot cycle. It is easy to see that these extrema show no consistent and sufficiently strong correlation with the El Nino phenomenon. However, recent research has shown that the solar wind, driven by solar eruptions (flares and coronal mass ejections) and plasma flux emanating from coronal holes, has a stronger impact on climate phenomena either directly or by modulating galactic cosmic rays [31]. The activity of coronal holes is not well correlated with sunspot activity, while energetic eruptions shun sunspot maxima and occur even close to minima. So it makes sense to investigate whether there are other phases than maxima and minima within the sunspot cycle which are closely correlated with El Niño events.

The 11-year sunspot cycle is not built symmetrically. The ascending part from minimum to maximum is shorter than the declining part from maximum to minimum. I have shown that the sunspot maximum divides the sunspot cycle according to the Golden section. It falls at the minor of this special irrational proportion. The Golden section divides a frame structure like a line segment, a surface, a cycle, or any other delimited feature so that the ratio of the smaller part (minor) to the larger part (major) equals the ratio of the larger part to the whole. When we set the whole equal to 1, we get 0.3819 ... : 0.618 ... = 0.618 ... : 1. To find the major of the length of a cycle, it has to be multiplied by 0.618. Multiplication by 0.382 gives the minor.

Reliable sunspot data are available since 1750. They show that the ascending part of the sunspot cycle has a mean length of 4.3 years. The mean cycle length amounts to 11.05 years. The minor of the mean length falls at 4.2 years (11.05 yrs * 0.382 = 4.22 yrs). This is close to 4.3 years, the observed mean of the interval from minimum to maximum. The descending part of the cycle has the length of the major. Magnetic cycles of solar type stars show the same structure shaped by the Golden section [28]. This is not merely a queer coincidence. The Golden section has a physical function. A. N. Kolmogorov [17], V. I. Arnol’d [1], and J. Moser [34] have proven theoretically that the stability of the solar system hinges on the Golden section. This is crucial, as we know from publications by G. J. Sussman and J. Wisdom [51] and also J. Laskar [32] that the orbits of all planets are chaotic. In my paper **"The Cosmic Function of the Golden Section"** [28] I have shown how the Golden section, which stands for stability in polar opposition to instability, has kept the solar system stable for 4.6 billion years in spite of chaos in all planetary orbits. The circumstance that the sunspot maximum falls at the minor of the sunspot cycle contributes to the stabilization of solar activity which is characterized by phenomena generated by instability. The sunspot cycle is no isolated case. It confirms the rule that minor and major of the Golden section within solar-terrestrial cycles indicate special phases with outstanding effects. I refer to numerous examples given in my paper **"Solar Activity: A Dominant Factor in Climate Dynamics"** **[31]**. Thus, an investigation of a potential correlation between the sunspot cycle and El Niños should take this point into consideration.

3. Fractal character of the sunspot cycle and energetic solar eruptions

Nature is fond of fractals. It makes use of well-tried patterns on different scales. The ascending and the declining part of the sunspot cycle could be looked at as cycles in their own right. So it should be considered whether these smaller cycles repeat the pattern of the whole sunspot cycle such that the minor of the Golden section indicates a phase of outstanding activity. To test this hypothesis I checked the distribution of energetic solar eruptions within the two subcycles. This is together the involvement of a phenomenon that drives the solar wind. I chose all X-ray eruptions equal to or greater than X6, observed by satellites from 1970 to 1998 [35]. Intense X-ray flares have a stronger impact on climate than flares categorized into classes of optical brightness [25].

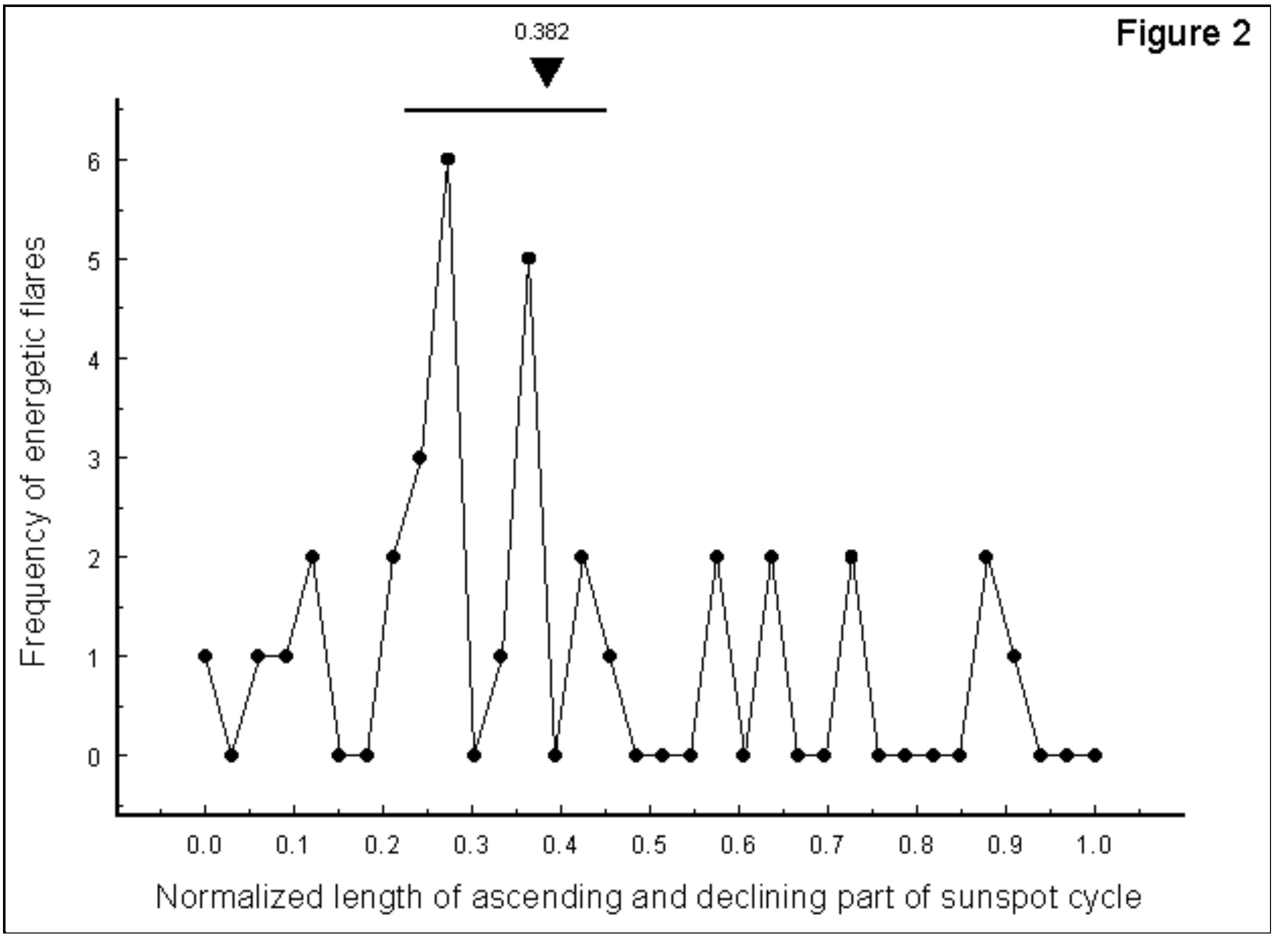
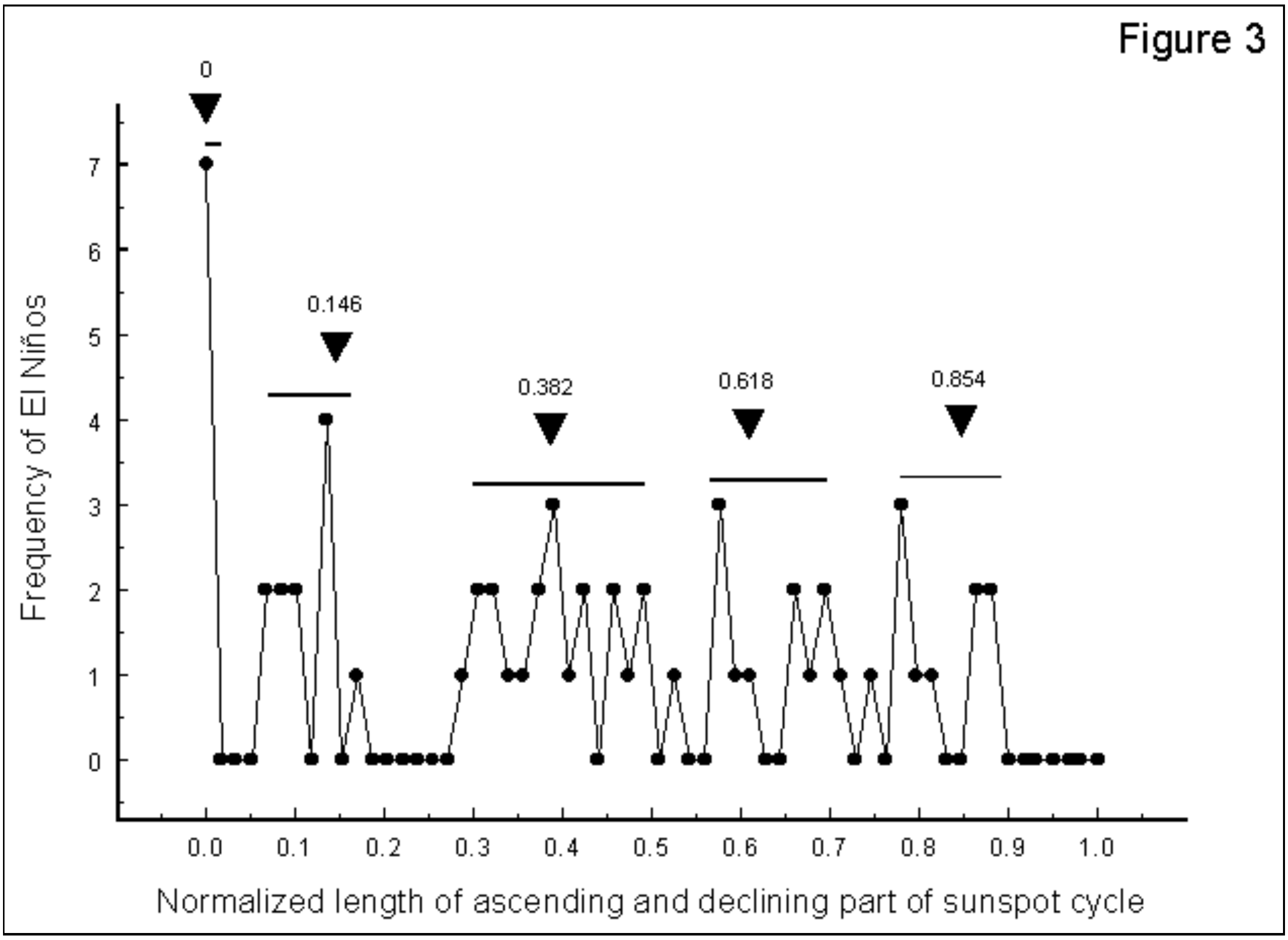


Figure 2 shows the superposed result for both of the subcycles which are normalized to emphasize identical phases in cycles of different length. The phase of the minor 0.382 is marked by a solid triangle. The energetic flares concentrate on the interval between 0.225 and 0.45 around the minor. As much as 19 of the 34 observed energetic flares fall at this interval and only 15 at the remaining interval covering a range of 0.775 on the unit scale. A chi-square test yields the value 21.7 for 1 degree of freedom. The probability that the observed distribution is due to chance is P = 0.000003. The sceptical null hypothesis can be considered rejected.

4. Distribution of El Niños within subcycles of the sunspot cycle since 1610

So it seems to make sense to look for a potential relationship between special phases in the ascending and declining subcycles of the 11-year sunspot cycle and El Niño events. Results based on short time series are always exposed to objections. This is why data covering nearly four centuries were chosen. Epochs of sunspot minima and maxima are available since 1610. El Niño data published by W. A. Arntz and E. Fahrbach [2], partly based on W. H. Quinn, V. T. Neal, and S. E. A. de Mayola [43], even go back beyond 1610. Only years of the event or periods of two years are given. To proceed consistently, the middle of single years, or the beginning of the second year of pairs of years was assumed to give the closest approximation to the event date. The dates of El Niños before 1875 and of sunspot extrema before 1750 cannot be considered precise, but if there is a strong correlation, it should nevertheless emerge. **Figure 3** shows the result.



There is the expected concentration of events around the minor 0.382 of the Golden section. 19 El Niños of the total of 60 fall at the interval between 0.32 and 0.5 and only 41 at the remaining interval 0.82. A chi-square test yields the chi-square value 7.6 and P = 0.006. The sceptical null hypothesis can be rejected at a high level of significance. Yet there are other deviations from the expected distribution. The accumulation around the major 0.618 complements the Golden section phases. This is also true of the concentrations around 0.146 and 0.854 though this is not easy to see. Practice shows that the larger intervals within a cycle between the initial phase and the minor and between the major and the following initial phase are often bridged by Golden sections of the second generation. The additional phase 0.146 falls at the minor of the interval between 0 and the minor 0.382, while the further phase 0.854 coincides with the major in the interval between the major 0.618 and 1. The phases 0.146, 0.382, 0.618, and 0.854 are symmetrically distributed about the phase 0.5 in the middle of the cycle. The accumulation at the phase 0, representing sunspot maxima and minima, is a surprise, as recent data show no connection of this kind. A statistical evaluation with the ranges of accumulation as indicated in Figure 3 by delimited horizontal lines yields a chi-square value 44.4 for 1 degree of freedom and $P = 3\times10^{-11}$. This clearly indicates that we are not dealing with a chance distribution, though there was no starting hypothesis covering the outstanding phases 0.146 and 0.854.

5. Distribution of SOI extrema within subcycles of the sunspot cycle since 1951

These first results should be checked by data that are not affected by inaccuracies and come as close as possible to the cause of ENSO events. Such events are characterized by a low negative Southern Oscillation Index (SOI), weaker than normal trade winds over the central Pacific, and warmer than normal sea surface temperatures (SST) in the eastern equatorial Pacific. A low SOI goes along with a reduced westward pressure gradient and changing wind stress values. According to Peixoto and Oort [40] the pressure change comes first, whereas the wind stress lags the SOI by two months. The SST lags it even by 4.5 months. So variations in the pressure gradient, expressed as change in the SOI, are closer to the cause of ENSO events than wind stress and rising sea surface temperature. This is why I investigated standardized monthly data of the SOI covering the period 1951 - 1998 [38].

The curve in **Figure 4** shows these slightly smoothed data.

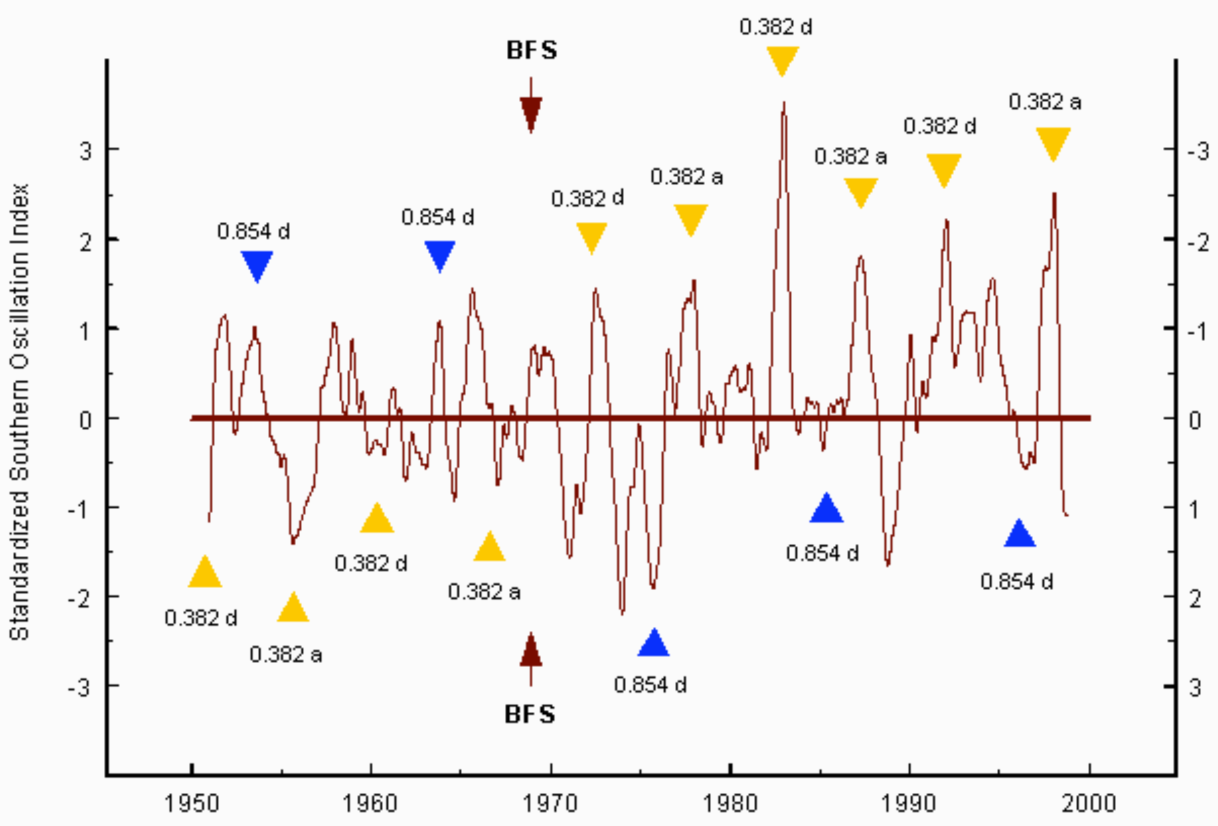


Figure 4

They have been inverted so that they run parallel with El Niños and La Niñas. The vertical scale on the right indicates the original orientation. Future verbal references to the SOI will always refer to this original orientation linked to the right scale. Obviously, extrema in the SOI are closely correlated with Golden section phases within the ascending (a) and declining (d) part of the 11-year sunspot cycle which already emerged in the El Niño investigation covering four centries. They are indicated by yellow and blue triangles. The minor 0.382 (yellow) with the strongest correlation in the earlier analysis appears as well in the ascending subcycle (0.382 a) as in the descending subcycle (0.382 d). After the year 1968, designated by arrows, the minor (0.382 a,d) marks precisely and without exception all observed strong negative extrema in the SOI, which are at the same time strong El Niños. Before 1968 the minor coincides with positive extrema in the SOI, which are at the same time La Niñas. The second generation phase 0.854 (blue) emerges only in the declining subcycle (0.854 d). Before 1968 it is consistently correlated with El Niños and after 1968 with La Niñas. The pattern is reversed in relation to the distribution of the minor 0.382. The overall impression is that of a symmetric distribution.

6. Phase reversals in climate cycles due to a fractal of solar cycles

Obviously, there was a phase reversal in 1968 that affected the relationship with ENSO events. What happened at that time? Fortunately, I can give a precise answer based on publications since 1976 **[20-31]**. There is an aggregation of solar-terrestrial cycles which are all related to the sun's fundamental oscillation about the center of mass of the solar system and form a fractal into which cycles of different length, but similar function are integrated. The solar dynamo theory, developed by H. Babcock, starts from the premise that the dynamics of the magnetic sunspot cycle is driven by the sun's rotation. Yet this theory only takes into account the sun's spin momentum, related to its rotation on its axis, not its orbital angular momentum linked to its very irregular motion about the center of mass. The contribution of the sun's orbital angular momentum to its total angular momentum is not negligible. It reaches 25 percent of the spin momentum. The orbital angular momentum can increase or decrease forty-fold within a few years. Thus it is conceivable that these variations are related to varying phenomena in the sun's activity. Variations of more than 7 percent in the sun's equatorial rotational velocity, going along with variations in solar activity, were observed at irregular intervals. This could be explained by transfer of angular momentum from the sun's orbit to the spin on its axis. Part of the necessary spin-orbit coupling could result from the sun's motion through its own ejected plasma. As R. H. Dicke [10] has shown, the low corona can act as a brake on the sun's surface. The four giant planets, which regulate the sun's motion, carry more than 99 percent of the angular momentum in the solar system, while the sun is confined to less than 1 percent. So there is enough angular momentum that can be transferred from the outer planets to the revolving sun and eventually to the spinning sun.

I have shown that cycles derived from the sun's motion about the center of mass make it possible to predict different facets of solar activity, including solar eruptions, and climate phenomena like temperature anomalies, droughts, and El Niños. Observation shows that the aggregate of physically and structurally connected cycles forms a hierarchy such that cycles higher up in the hierarchy do not only modulate subordinated cycles, but also induce phase reversals. Experimentation with electrical and mechanical control equipment shows that at nodal points, where the response of the system is zero, the phase can shift by pi radians [6]. If a hierarchically dominant cycle reaches a zero phase, which is a nodal point, and a subordinated cycle is close to an initial phase at the same time, a phase reversal effect occurs in most cases in the dominated cycle. This seems to solve the problem of sudden phase jumps in solar-terrestrial cycles hitherto unexplainable and unpredictable. As to a string of examples I refer to my paper **"Solar Activity: A Dominant Factor in Climate Dynamics"** [31] and other publications [27-31].

The solar cycles in question display five-fold symmetry and resemble hands and fingers when plotted. So I call them big hand cycle (178.8 years), big finger cycle (mean length 35.76 years), and small finger cycle (mean length 7.15 years). Details are given in my paper quoted above. The acronym BFS in Figure 4 refers to the starting phase of a big finger cycle. As the 11-year sunspot cycle is shorter than the big finger cycle, it ranges lower in the hierarchy of solar cycles and is exposed to the risk of a phase reversal. This all the more so, as the polar photospheric magnetic fields, linked to the sun's general magnetic field, underwent a polarity reversal just in 1968, the epoch of the big finger start in question. In addition, the initial phase of the big finger cycle coincided with the sunspot maximum 1968, the zero phase of the declining subcycle from maximum to minimum.

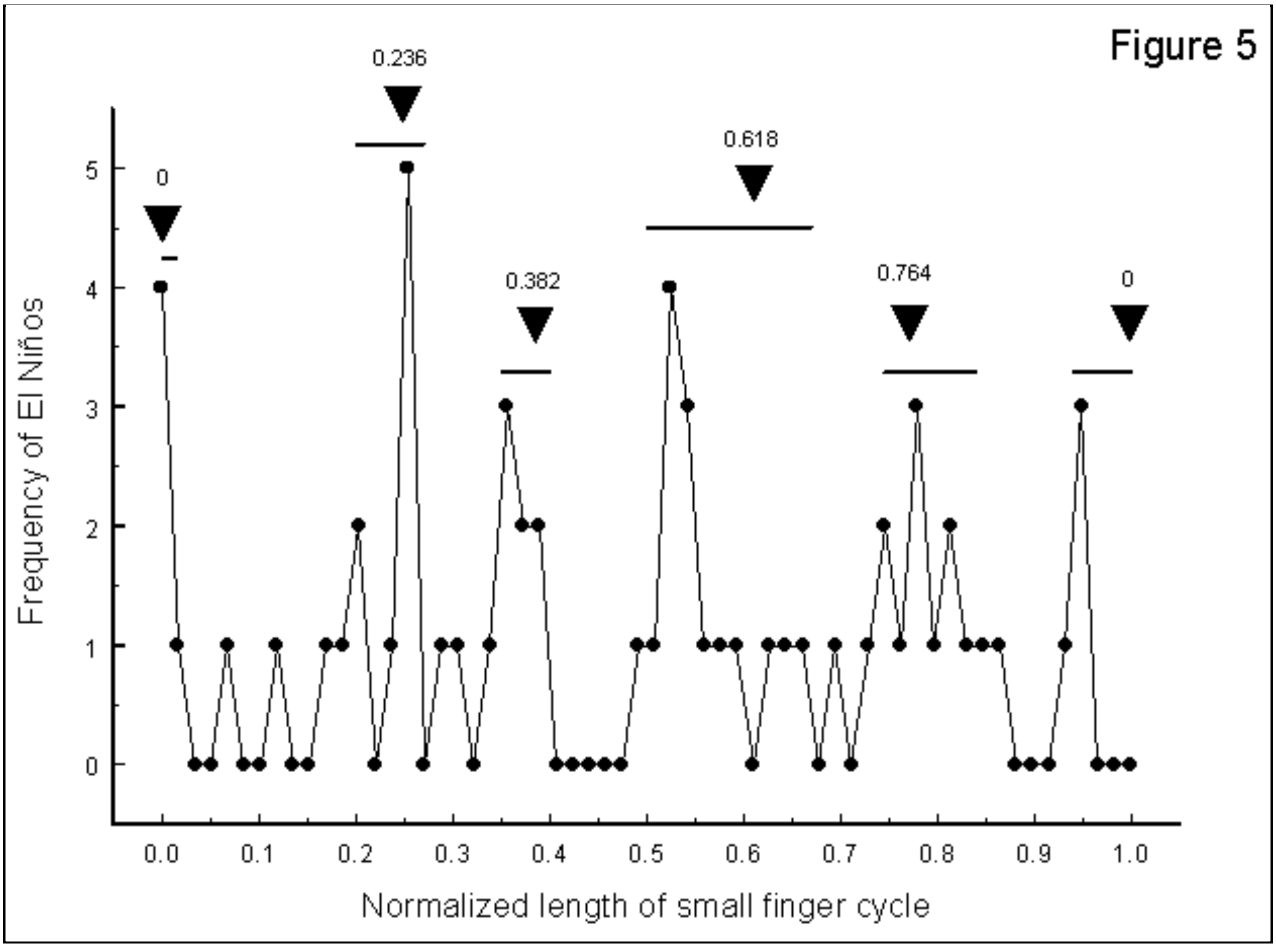
Though I was acquainted with phase reversals within the fractal of cycles created by the sun's oscillation about the center of mass, I had not expected that such events would also affect the 11-year sunspot cycle. Yet short reflection shows that it is the same sun that produces both kinds of cycles. And there is a further link. The magnetic cycle of 22.1 years, called Hale cycle, is the true cycle of sunspot activity. Groups of sunspots are usually composed of preceding and following spots with different magnetic polarity. With the commencement of a new cycle the polarity reverses so that the original polarity is only restored every second 11-year sunspot cycle. When the major of the Golden section within a big finger cycle is calculated, it turns out to be identical with the length of the Hale cycle (35.76 yrs * 0.618 = 22.1 yrs). This points to a close connection between the big finger cycle and the Hale cycle as well as the 11-year cycles that compose it.

The circumstance that the Golden section phases 0.618 and 0.146, which also stand out in Figure 3, do not emerge in the detailed investigation covering the SOI 1951 - 1998, does not mean that they are generally not valid. It could be that they are prominent in other intervals of the span of nearly four hundred years. In 1933, for instance, the big hand cycle reached a zero phase that could have affected the effects of the big finger cycle and eventually the subcycles of the sunspot cycle. It is imaginable that in such cases a switch occurs which exchanges the pair 0.382/0.854 for 0.146/0.618. Detailed analyses covering earlier periods are necessary to answer these questions

7. Distribution of El Niños within the small finger cycle since 1610

My correct forecast of the last two El Niños was based on an analysis of tropical seasurface temperatures in relation to the small finger cycle (SFC) covering the period 1960 to 1990. The analysis indicated that the initial phase of the SFC and the major 0.618 within this cycle are associated with El Niño events. When the cycle was longer than 7.5 years, also the minor

0.382 proved effective. A further investigation making use of the El Niño data going back to 1610 should confirm this result, if it is real. The evaluation of the small finger phases is no problem. They can be calculated back or ahead for thousands of years. **Figure 5** shows the resultant distribution.



The initial phase of the SFC, the minor 0.382, and the major 0.618 stand out. A chi-square test yields the value 15.2 for 1 degree of freedom. The null hypothesis of no correlation between the studied variables can be rejected at a high level of significance: P = 0.0001. As with the sunspot cycle, additional Golden section phases of the second generation emerge in Figure 5. The phase 0.236 falls at the major of the interval between 0 and 0.382, and the phase 0.764 is identical with the minor of the interval between 0.618 and 1. Again, the overall distribution of the four Golden section phases is symmetrical about the middle 0.5 of the unit cycle. A chi-square test of all outstanding phases with ranges of accumulation as indicated in Figure 5 by horizontal bars yields the chi-square value 34.7 for 1 degree of freedom. The probability of a chance distribution is $P = 4\times10^{-9}$. The hypothesis formulated at the outset does not cover the two additional phases that emerged unexpectedly, but the result deviates so far from the expected distribution that it points to a real connection.

8. Distribution of El Niños within the small finger cycle since 1951

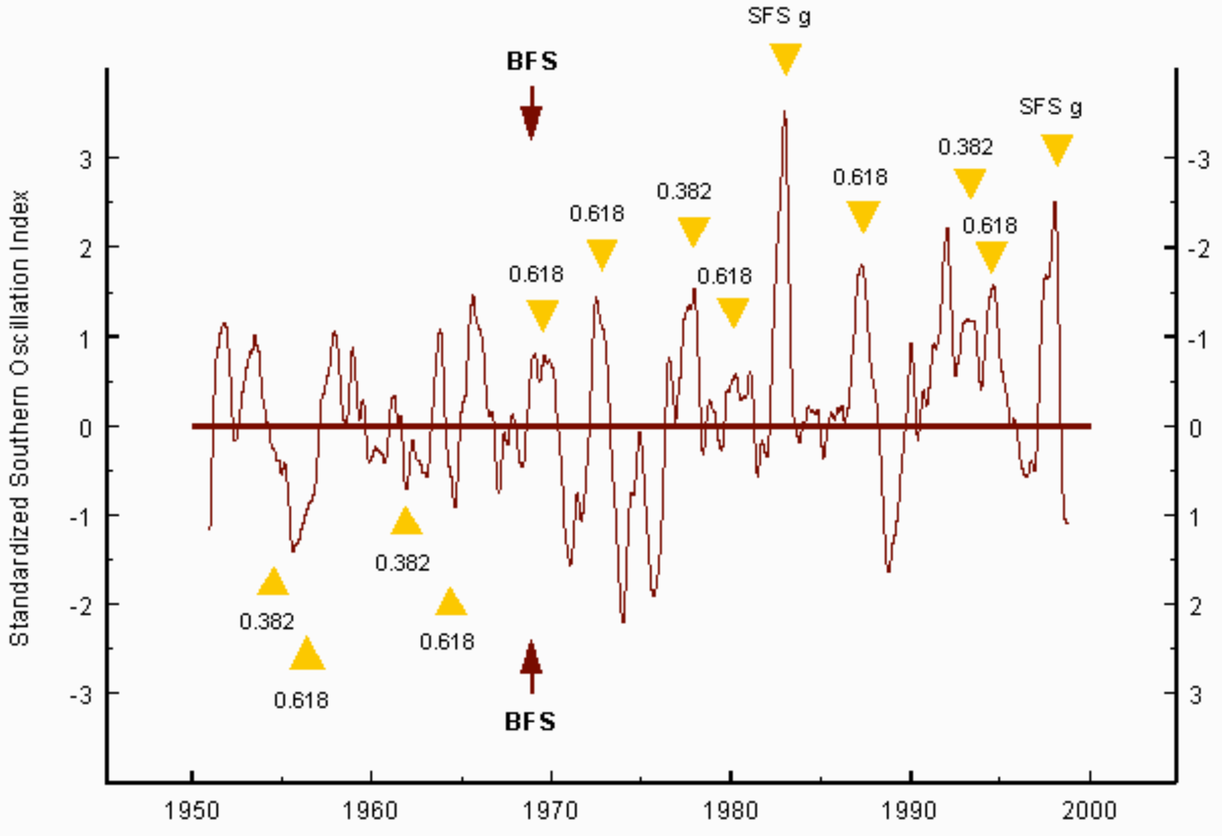


Figure 6

Figure 6 shows how the SFC phases 0.382 and 0.618, prominent in Figure 5, are in detail associated with SOI extrema in the interval 1951 - 1998. After BFS 1968 they are closely correlated with negative extrema (El Niños) and before 1968 with positive extrema (La Niñas). Initial phases of special small finger cycles (SFS g) are also indicated, but only tentatively and only after 1968. Before 1968 they do not show the usual reversed pattern, or better, there is no consistent pattern at all. This speaks against the dependability of this factor, at least in the period 1951 - 1998. This all the more so as the two cases where there is a coincidence with El Niños can as well be explained by 0.382 a,d within subcycles of the sunspot cycle.

Figure 7 displays the detailed relationship between the two other SFC phases 0.764 (yellow) and 0.236 (blue), outstanding in Figure 5, and the SOI 1951 - 1998.

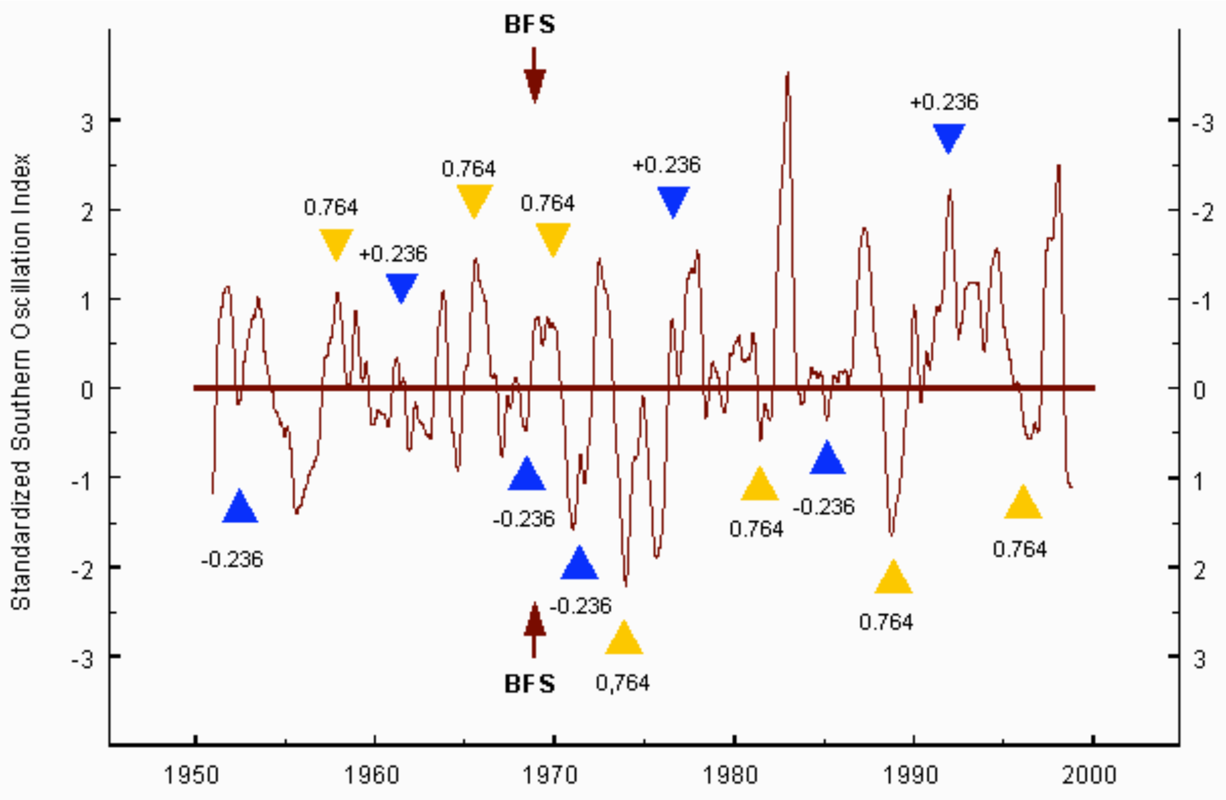


Figure 7

Before BFS 1968, the 0.764 phases are closely correlated with negative extrema (El Niños) and after 1968 with positive extrema (La Niñas). The distribution of the SFC phase 0.236 is again a surprise. It displays an alternating pattern, first an association with El Niño (+ 0.236), then with La Niña (- 0.236), again with El Niño and so on. BFS 1968 induced a phase reversal such that another association with La Niña occurred instead of the expected alternating association with El Niño. I observed such alternating patterns already in other relationships between cycles derived from the sun's oscillations about the center of mass and climate phenomena [31]. Such unexpected patterns show as well as the observed phase reversals that Nature seems to be much more inclined to vary, jump and permute than we expect. Our result teaches us that crude statistical investigations like my examination of four centuries of data can give some hints, but cannot replace a thorough, unprejudiced analysis that elaborates the implications of a significant correlation. Rigid dogmatism will surely prevent us from adjusting our world view to Nature's flexibility.

9. Synopsis of the correlation between solar cycles and ENSO events

Figure 8 shows the synopsis of the relationship between Golden section phases within the investigated cycles and SOI extrema phase-locked with El Niños and La Niñas.

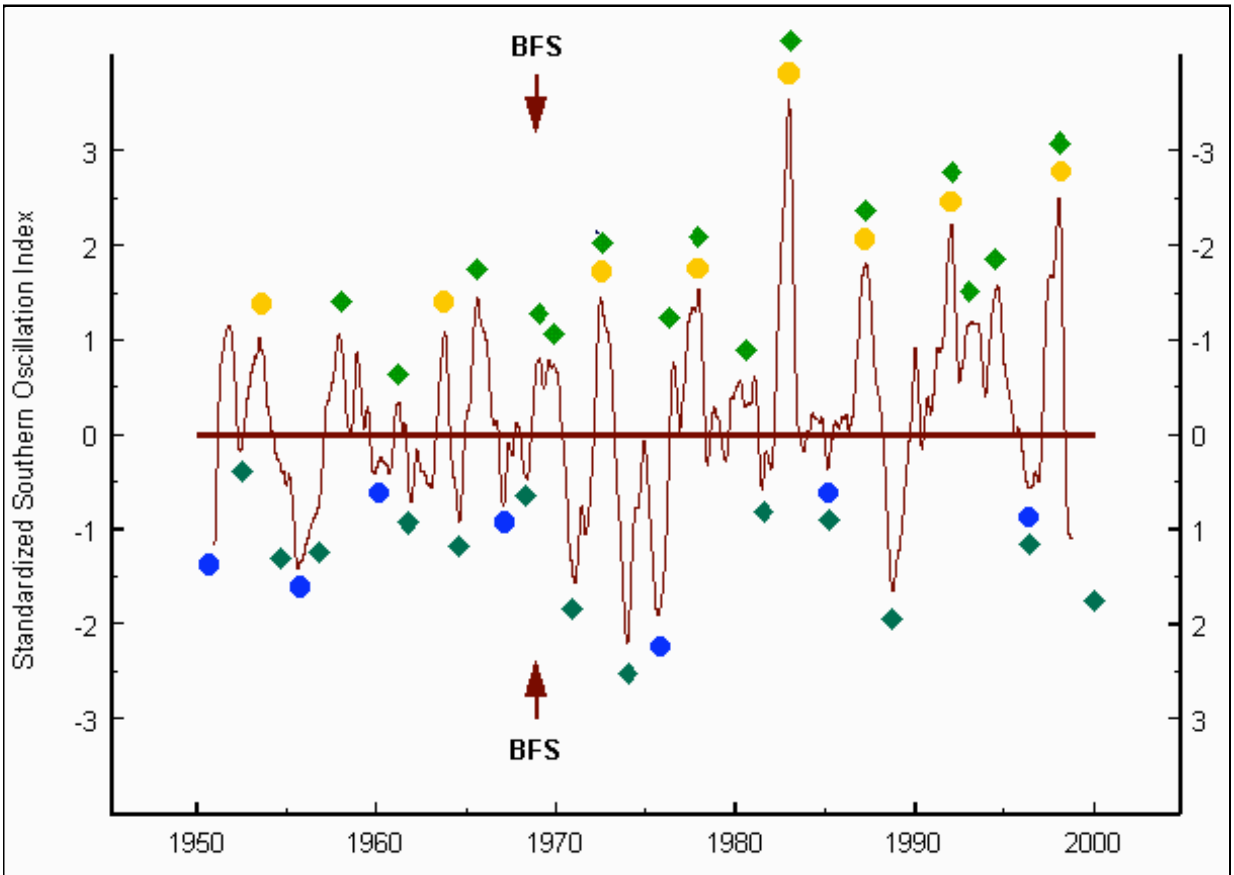


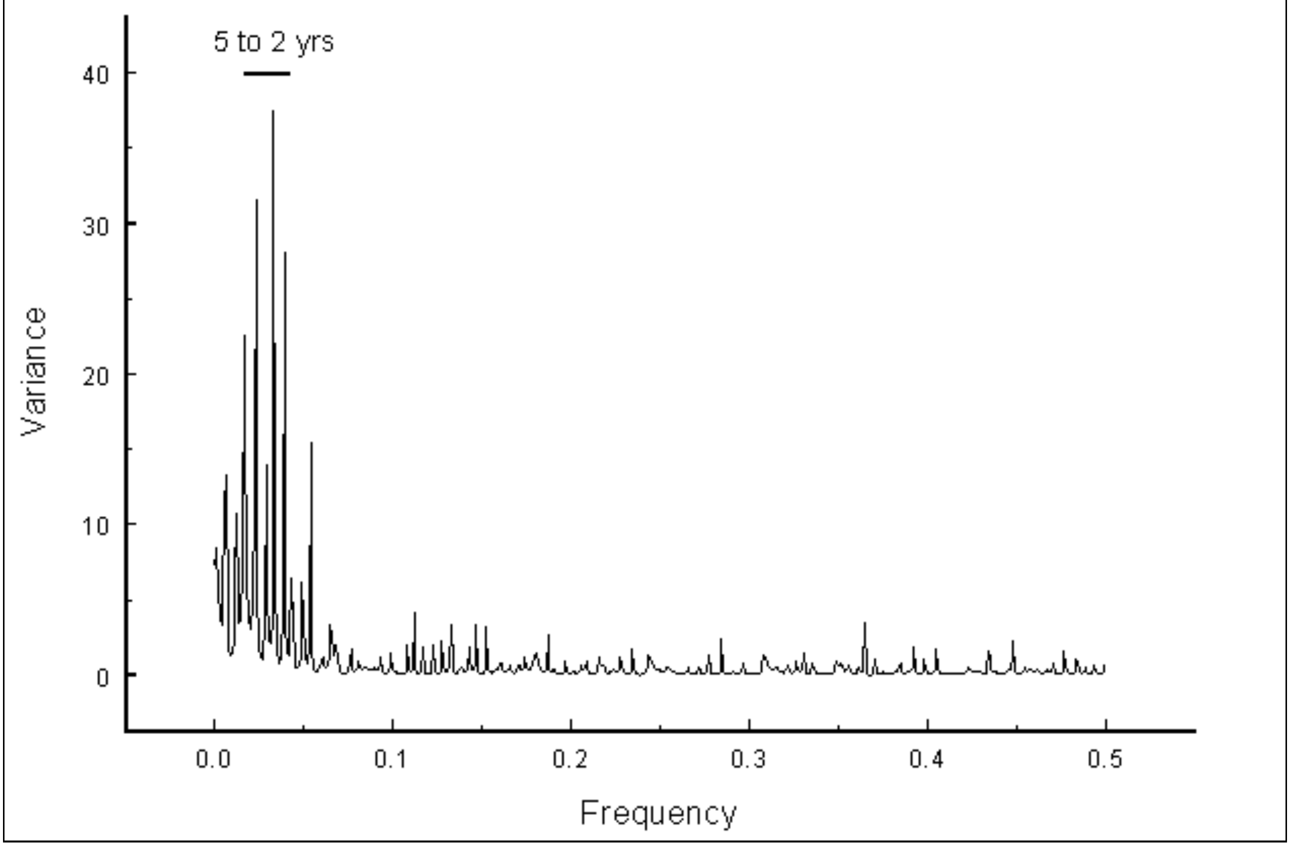
Figure 8

Yellow circles mark correlations of phases within the subcycles of the 11-year sunspot cycle with El Niños and blue circles with La Niñas. Bright green diamonds point to connections of SFC phases with El Niños and dark green diamonds with La Niñas. It is easy to see that all notable deviations from the zero line are explained with the exception of a single El Niño at the beginning of the curve. It should be noted that all of the respective Golden section phases that fall into the period 1951 - 1998 appear in the synopsis. There is not a single one that does not coincide with SOI extrema. Because of the phase reversal induced by BFS 1968 the same phases can be linked to El Niños as well as to La Niñas and can be used to predict both of these events depending on the phase of the dominating big finger cycle. There are no exceptions to this consistent pattern. Climatologists have been wondering why there were three consecutive El Niños without any interruption by La Niñas between 1991 and 1995. Figure 8 gives the answer. During the five years in question there were not any Golden section phases that indicate La Niñas, but four of them that point to El Niños.

10. Maximum entropy spectral analysis of SOI data 1951 - 1998

These results are confirmed by a different approach. J. P. Burg [5] has developed a new form of spectral variance analysis, the maximum entropy spectral method which shows much higher resolution than earlier frequency analyses, especially at lower frequencies. **Figure 9** shows the maximum entropy spectrum of the SOI data 1951 - 1998.

Figure 9



The frequency is measured in cycles per month. The analysis is based on 575 data points and makes use of a filter length of 230, which is in accordance with the suggestion of most authors not to go beyond 40 percent of the length of the time series to avoid spectral shifts. The spectrum shows prominent peaks only in the frequency range 0 to 0.06. The four outstanding peaks lie in the period range between 2 and 5 years. The resolution is much finer than in the inset in Figure 1.

Figure 10 sets off the frequency range of interest between 0 and 0.1 and shows an even better resolution.

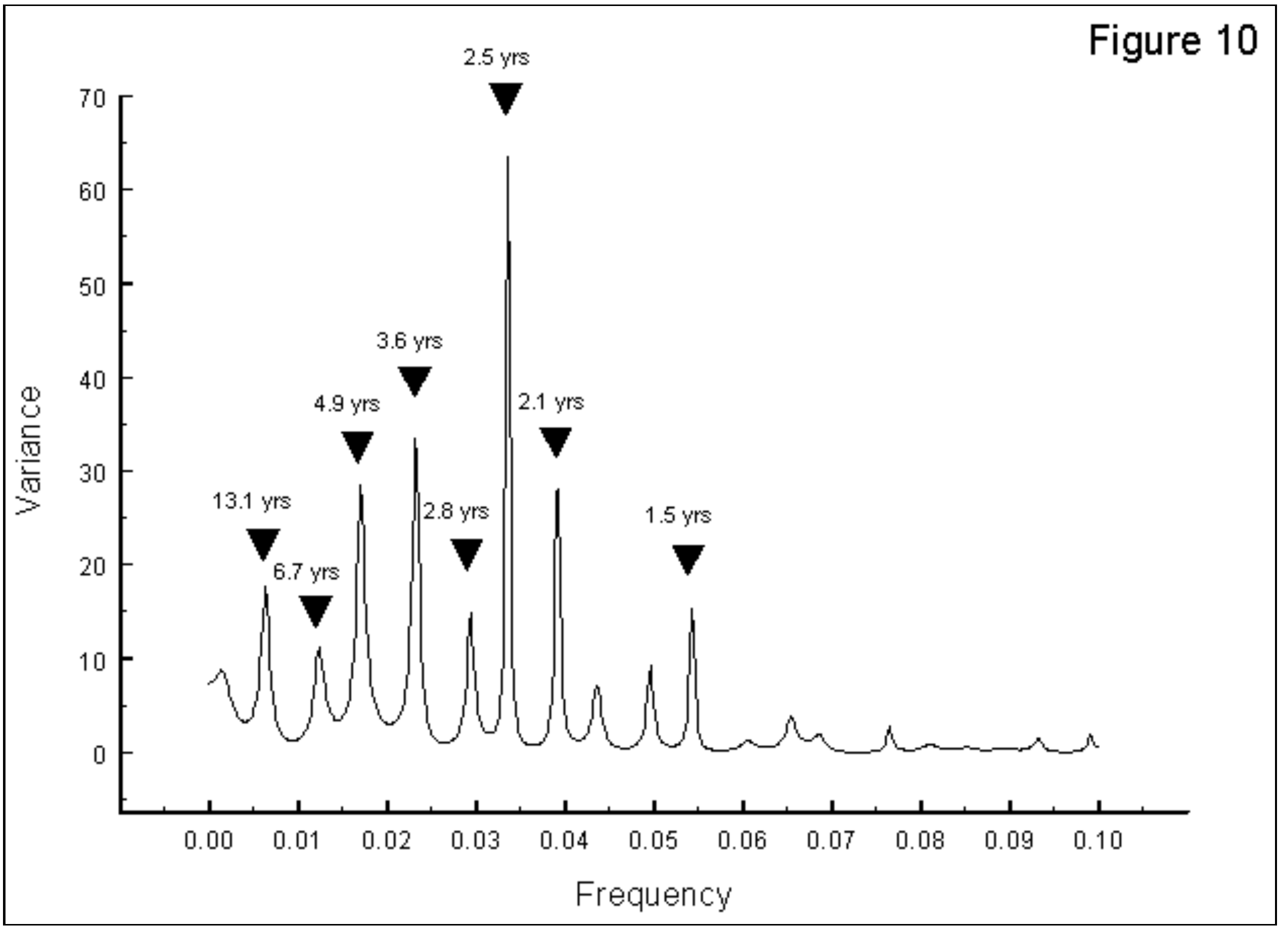


Figure 10

The periods of the prominent peaks are indicated. They can be compared with the distance of the crucial Golden section phases from the zero phases of the investigated three cycles. In the course of the years 1951 - 1998 these cycles had the following mean lengths: the ascending subcycle (a) of the sunspot cycle (SC) 3.4 years, the declining subcycle (b) 7.1 years, and the small finger cycle (SFC) 6.8 years. In the following, the distances of the Golden section phases from the beginning of the respective cycle are given first and then in parantheses the periods of the maximum entropy spectrum (MES) that come closest:

SC 0.382 a: 1.3 years (MES: 1.5 years)
SFC 0.236: 1.6 years (MES: 1.5 years)
SFC 0.382: 2.6 years (MES: 2.5 and 2.1 years)
SC 0.382 d: 2.7 years (MES: 2.8 and 2.5 years)
SFC 0.618: 4.2 years (MES: 3.6 years)
SFC 0.764: 5.2 years (MES: 4.9 years)
SC 0.854 d: 6.1 years (MES: 6.7 years)

Considering the uncertainties inherent in spectrum analysis, especially at low frequencies, this is a rather exact match. It is corroborated by comparing the means of the two data sets. The mean of the distances of the seven Golden section phases from the beginning of the respective cycles is 3.4 years. The mean of the outstanding SOI periods, marked in Figure 10, is also just 3.4 years when we exclude the long period of 13.1 years that is far beyond the range which is of interest in this respect. It should be noted, however, that 13.1 is close to the second subharmonic of the MES period 6.7 years. The long period could be of import with respect to the strength of ENSO events. The interval between the two very strong El Niños 1982/1983 and 1987/1988 is relatively close to that period. As to modulations of the strength of El Niños it is of interest, too, that the SC and SFC periods 1.3 years and 1.6 years as well as 2.6 years and 2.7 years are so close to each other that resonance is possible.

Finally, it should be noted that the highest spectral peak at 2.5 years falls at the phase 0.382 of the descending sunspot cycle that stands out in every respect and is together the phase of the outstanding accumulation of energetic solar eruptions in Figure 2. The prominent periods of the maximum entropy spectrum are significant. An acknowledged reliability test of maximum entropy peaks does not exist, but according to a simple and useful rule of thumb, given by W. F. Stuart, V. Sherwood, and S. M. MacIntosh [50], a spectral peak is regarded to be significant if it contains at least three computed points which deviate from the noise and has a maximum two or three times greater than the surrounding noise level. On the basis of this standard the peaks marked in Figure 10 deviate significantly from the noise.

A further confirmation is provided by a Blackman-Tukey power spectrum [3] of the SOI data 1951 - 1998. The four outstanding peaks of this spectrum at 2.1, 2.6, 3.8, and 4.8 years nearly coincide with the respective maximum entropy peaks, and the mean of these four periods equals 3.3 years, rather close to the maximum entropy mean of 3.4 years. H. A. Panofsky and G. W. Brier [39] have developed a special reliability test of peaks in a Blackman-Tukey spectrum. Checked against a white noise background, the peaks in Figure 10 go far beyond the 99 percent confidence level. The significance of the deviation from the Markov red noise level, taking into account potential autocorrelation, reaches at least the 95 percent level.

11. Forecasts of future ENSO events

Precise forecasts that prove correct are the sharpest criterion of effective science. So I will try my third long-range El Niño forecast. It goes nearly three years beyond the lead time of 12 months, discussed in the beginning. **The next negative extremum in the SOI going along with an El Niño should occur around 2002.9 (± 6 months).** The last zero phase of a small finger cycle fell at 1998.3. The following one will occur in 2005.8. The length of the SFC cycle reaches just 7.5 years. So the probability is low, though not zero, that the phase 0.382 within the SFC will release an El Niño around 2001.2. The following 0.618 phase falls at 2002.9. It should be effective. This all the more so as around this time the descending part of the sunspot cycle is expected to reach the phase 0.382. The next negative 0.236 phase within the small finger cycle will fall at 2000.1. The present positive SOI and the accompanying La Niña seem to be related to it. So **La Niña conditions should prevail till 2000.1 and beyond.**

12. Objections to a strong link between solar activity and climate

Taken together, the lines of evidence presented here leave little doubt that the relationship between Golden section phases within solar cycles and ENSO events is real. Nonetheless, it is to be expected that sceptics will point at the lack of detailed cause and effect arguments and properly quantified physical mechanisms. Seen in a historical light, such objections are not valid. The lack of elaborate theory does not impair the heuristic importance of the results.You cannot achieve everything at the same time. Epistemologically, the stage of gathering data, establishing morphological relations, and setting up working hypotheses necessarily precedes the stage of elaborated theories. How can we solidly connect solar activity with climatic change as long as neither of these fields rests on a solid theoretical foundation? An accepted full theory of solar activity does not yet exist. What we have is only the hope of a future theory. According to P. V. Foukal [11] the mechanism that causes the solar magnetic cycle remains poorly understood, although it has been the focus of intense research during the past half century. There is a lot of literature about aw-dynamos, but they are coping with incompatibilities of observation with theory, and they do not offer any explanation of longer solar cycles like the Gleissberg cycle that modulates the amplitudes of the 11-year cycle.

The understanding of climate change, too, is in a rudimentary stage. Especially complex coupling processes that could link the upper with the lower atmosphere are far from being well understood, and even the most advanced general circulation models yield contradictory results. Revealing is a recent statement by J. E. Hansen [13], a protagonist of global warming:

> **"The forcings that drive long-term climate change are not known with an accuracy sufficient to define future climate change ... The natural forcing due to solar irradiance changes may play a larger role in long-term climate change than inferred from comparisons with general circulation models alone."**

Hansen does not even mention the effect of solar eruptions and the solar wind on climate.

The usual additional objection that the solar effect is much too weak to affect climate, too, is not tenable. J. G. Roederer [47] has aptly remarked:

> **"The energy argument is not valid for highly nonlinear complex systems such as the coupled atmosphere-ocean-cryosphere-biosphere. It is well known that complex systems can behave chaotically, i.e., follow very different paths after the smallest change in initial or boundary conditions, or in response to the smallest perturbation. In a highly nonlinear system with large reservoirs of latent energy such as the atmosphere-ocean-biosphere, global redistributions of energy can be triggered by very small inputs, a process that depends far more on their spatial and temporal pattern than on their magnitude."**

H. Svensmark and E. Friis-Christensen [53] have demonstrated that this is in accordance with reality. Clouds have a hundred times stronger effect on weather and climate than carbon dioxide in the atmosphere. Even if the atmosphere's carbon dioxide content doubled, its effect would be cancelled out if the cloud cover expanded by 1 percent, as shown by H. E. Landsberg [19]. So it is of great importance that Svensmark and Friis-Christensen have shown that global cloud cover, observed by satellites, is linked to the strength of cosmic rays modulated by the solar wind. When the solar wind is strong and cosmic rays are weak, the global cloud cover shrinks. It extends when cosmic rays are strong because the solar wind is weak. This effect, attributed to cloud seeding by ionized secondary particles, causes a change in cloud cover by more than 3 percent within 3 ½ years. The corresponding change in solar irradiance reaches about 1.5 W/m^2. This is a considerable amount, since the total radiative forcing by carbon dioxide accumulated in the atmosphere since 1750 does not go beyond 1.5 W/m^2. One would assume that such a tremendous effect should be caused by a huge amount of energy, but cosmic rays inject a total energy into the atmosphere that is very small. Astonishingly, it is equal to the intensity of starlight in the night skies [16]. This is practical proof that Roederer's argument is not only of theoretical import.

13. Potential connections between solar eruptions and ENSO events

Though there are no strict physical arguments that could explain in detail how solar activity causes ENSO events, it is quite possible to develop working hypotheses that suggest potential connections. Figure 2 shows that energetic solar eruptions coincide with the Golden section phase 0.382 in the subcycles of the sunspot cycle which are closely correlated with ENSO events, as shown in Figure 4. Strong solar eruptions cause the highest velocities in the solar wind and create shockwaves that compress and intensify magnetic fields in the sun's plasma moving outward to the boundary of the solar system. The solar wind strenghtened by solar eruptions weakens cosmic rays. The ensuing Svensmark-effect is regionally strongest where cloudiness is highest. It is very high around Indonesia [40] where el Niños seem to develop. So one would think that shrinking cloud cover, stronger irradiance, intensified Hadley circulation and changing trade winds, caused by the modulating effect of solar eruptions on cosmic rays, improve the conditions for the birth of El Niños. This all the more so as M. Pudvokin and S. Veretenenko [42] as well as Svensmark and Friis-Christensen [53] have shown that Forbush decreases - dips in cosmic rays by several percent within 2 days after a strong solar eruption - are associated with immediate decreases in cloudiness by 2 - 3 percent that last a week or longer. Such short-term effects, especially when they trigger tropical cyclones [44], may release and sustain El Niños.

The enhancement of the Svensmark-effect by the very high cloudiness around Indonesia is countered by the circumstance that Indonesia is situated on the equator where the field lines of the Earth's magnetic field run parallel with the surface. As less energetic cosmic-ray particles follow the magnetic field lines on screw shaped trajectories, it is more difficult for them to penetrate into the atmosphere above the equator than near the poles where the field lines run vertically. This magnetic obstacle is especially effective when particles try to penetrate to the Earth's surface. They reach the ground only when their energy is at the 15 GeV level. Yet it is much easier to reach targets higher up in the atmosphere. One of the stations that observe cosmic rays, the Huancayo Neutron Monitor, is located close to the equator (12° S 75° W), but at an altitude of 3400 m where the cutoff rigidity is not as high. The Huancayo reports reflect the change in cosmic rays as well as data by other stations at higher latitudes. Especially, it has to be taken into consideration that high clouds like cirrus, cirrocumulus, and cirrostratus reach altitudes of 18 km at the equator where the height of the tropopause goes far beyond that at the poles (8 km). Cumulonimbus reaching an altitude of 10 - 14 km at temperate latitudes climb to 16 - 22 km in the tropics, where they form huge cloud clusters covering ranges of more than 100 km [33]. The generation of secondary cosmic rays by primary cosmic rays and the related degree of ionization reach a maximum (300 pairs of ions/cm3 sec) just at 20 km altitude [16], close to the altitude of tropical cumulonimbus as well as of cirrus, cirrocumulus, and cirrostratus.

Furthermore, the geomagnetic equator, not the geographical equator is relevant as to the cutoff conditions of cosmic ray particles. At present the observed geomagnetic pole in the Northern Hemisphere is at 73° N 100 W. Calculation shows that a location on the equator in Indonesia (longitude 105° E) has a geomagnetic latitude of -15° where particles can easier penetrate to those high altitudes where clouds are to be found in the tropics. All arguments taken together, it is not unimaginable that the Svensmark-effect works in the region close to the equator where El-Niños are thought to come into existence. Conditions should be favourable for La Niña when cosmic rays are very strong because the sun’s eruptional activity is exceptionally weak.

Further working hypotheses may be based on the fact that solar X-rays and UV radiation increase sharply at the time of energetic solar eruptions. It would go beyond the frame of this paper to describe these working hypotheses in detail. They can only be presented in a nutshell. Flares increase the sun’s UV radiation level by at least16 percent [15]. Ozone in the stratosphere absorbs this excess energy that causes local warming. The 70-mb polar vortex is displaced. This disturbance is propagated downward to the troposphere where it affects the intensity of the Hadley circulation. D. E. Hartley, J. T. Villarin, R. X. Black , and C. A. Davis [14] have shown that there is a dynamical link between stratospheric polar vortex distortions and meteorological events in the troposphere. Observations by other authors confirm this result [12, 18, 37, 45, 46]. As El Niños are linked to trade winds and tradewinds to the Hadley cells that may be affected by circulation change in the stratosphere, it seems plausible that energetic solar eruptions could be the cause of this chain of links. This all the more so as observations show distinct change in diverse weather phenomena within days after energetic solar eruptions [4, 8, 48, 49, 55].

Solar X-rays around 10 Å intensify by a factor of 100 or more during moderate-sized flares, and strong flares can amplify the X-ray level by a factor of 1000. I refer to my paper "Solar Rotation, Impulses of the Torque in the Sun’s Motion, and Climatic Variation" [25] which describes how strong X-rays produced by energetic solar eruptions may enhance thunderstorm activity. Severe thunderstorms are linked to tropical cyclones [54] which may trigger and sustain El Niños [44]. A marked lull in the sun’s UV radiation and X-rays should be favourable for La Niñas.

These theoretical arguments were only presented to show that it is not out of the question that there are physical links between energetic solar eruptions and El Niños. Whether these lines of reasoning turn out correct or spurious is of no import regarding the practical results of this investigation. They leave little doubt that solar activity and ENSO events are closely connected to such a degree that long-range forecasts beyond the 12-month lead time are now possible. The consequences of these results for the hypothesis of anthropogenic climate change are far-reaching. As stated in the beginning, ENSO events are the strongest source of variability in the global climate system and explain most of the global temperature anomalies. Our result that solar activity regulates these powerful climate phenomena shows clearly that the impact of the sun’s variability has been underestimated in a way that reverses the proportions. Recent research published by H. Svensmark [52] and N. Calder [7] corroborate this statement. Actually, solar activity turns out to be the dominant factor in climate change. IPCC scientists can no longer uphold their contention that **"solar variability over the next 50 years will not induce a prolonged forcing significant in comparison with the effect of increasing carbon dioxide concentrations."**

Acknowledgements

I owe special thanks to Nigel Calder for his suggestion to investigate associations between El Niños and special phases in the 11-year sunspot cycle. I am a convert in this respect. Before Nigel Calder's stimulating intervention I thought that only cycles based on the sun's motion about the center of mass of the solar system could affect ENSO events.

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