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Solar activity and "El Niño"

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RESUMEN

Se estudia la ocurrencia de los eventos "El Niño" y su relación con la actividad solar. Encontramos que dichos eventos se correlacionan bien con picos locales de actividad auroral, así como con períodos en los que existe un bajo número de manchas solares y gradientes pequeños y negativos de éstas. Este último resultado sugiere que la actividad solar anómala puede disparar "Niños" y en particular el evento de 1989.

PALABRAS CLAVE: "El Niño", actividad solar , relaciones Sol-Tierra.

ABSTRACT

The occurrence of "El Niño" in relation to solar activity is studied. We find that these events are correlated with local maxima of visible aurorae and with periods of small negative sunspot gradients and low sunspot numbers. The apparent correlation of "Niños" with anomalous solar activity led us to predict an event at the end of 1989, which in fact occurred.

KEY WORDS: "El Niño", solar activity, Sun-Earth relationships.

INTRODUCTION

The highly controversial problem of the influence of Sun activity on terrestrial weather and climate is far from being solved. The amount of energy involved is too small to affect the atmospheric processes significantly, and therefore the search of a mechanism that can produce such effects has led to the view of a triggering process. Although several mechanisms that indicate the existence of a link between meteorological phenomena and solar activity have been suggested (Bates, 1981; Cole, 1984; Lundstedt, 1984), there is not yet a general agreement as to what the physical processes that link the solar variability and climatic system are.

There is little doubt that the El Niño-Southern Oscillation event is produced by instabilities in the ocean/atmospheric system (Berlage, 1957, 1966; Philander, 1986; Graham *et al.*, 1987). Cane *et al.* (1986) have presented a model taking into account the ocean-atmosphere interaction, whose predictability is limited by neglect of atmospheric disturbances not attributable to air-sea coupling. The existence of a factor external to the air-sea system leads us to think of solar variability as the most obvious candidate for exerting such an influence, added to the fact that positive correlations between solar-related events and meteorological phenomena have been found (Herman and Goldberg, 1978; Heath, 1980; Mustel *et al.*, 1980; Wilcox and Scherer, 1981; Labitzke and van Loon, 1989).

As some of the most intense El Niño events have occurred during periods of anomalous solar activity (such as the great flare of 1956, the flares of August 1972 or the little maximum of 1982) we would expect to find an indication for the influence of the solar activity when looking at the past data of El Niño.

AURORAL ACTIVITY AND EL NIÑO

As aurorae are the phenomena nearest to Earth most closely related to solar activity, we studied the auroral index developed by Legrand and Simon (1987), in relation to El Niño events with the index of Quinn *et al.* (1987).

In order to examine the presence of El Niño in relation to auroral activity, we first arrange all the peaks in the auroral series around a common origin as shown in Fig. 1. In the histogram, the average period spans from -2 to 2 years, and the total range corresponds to the maximum period between visible aurorae. The occurrence of El Niño with respect to each peak is illustrated in Table 1, where only one El Niño was considered for each peak. When an El Niño event occurred during a minimum, the event was assigned to the period corresponding to the nearest peak. From the Table, we construct the corresponding frequency histogram (Fig. 2). Notice a very close similarity between the distri-

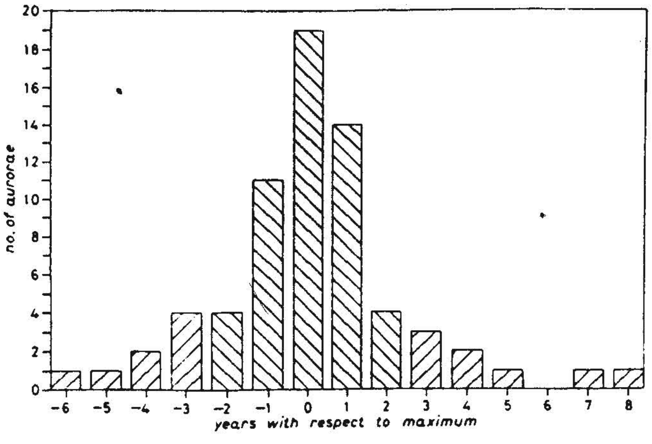

Fig. 1. Distribution of visible aurorae around their local maxima, where the maximum range between some of the peaks was considered.

Table 1

Occurrence of El Niño around local auroral maxima.

Year of maximum	El Niño around the local auroral maxima (y)														
	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1782															
1787					•	•									
1789									•						
1798															
1804						•	•		•	•					
1816			•		•			•							
1820						•		•							
1830	•				•										
1833						•									
1837							•								
1839												•			
1850		•					•								
1853								•							
1860				•	•		•								
1864							•								
1866							•	•	•						
1870								•			•			•	•
1883				•				•							
1887							•	•	•						
1892						•									
1896							•	•		•	•				
1906			•			•		•							
1909															
1911							•	•		•					
1917							•								
1919						•	•								
1922								•							
1926						•	•								
1930							•	•							
1932							•								
1940						•	•	•							
1943							•								
1947															
1951							•								
1954						•									
1958						•	•								
1960															
1968				•											
1971								•							
1976				•			•								
Total	1	1	2	4	4	11	19	14	4	3	2	1	0	1	1

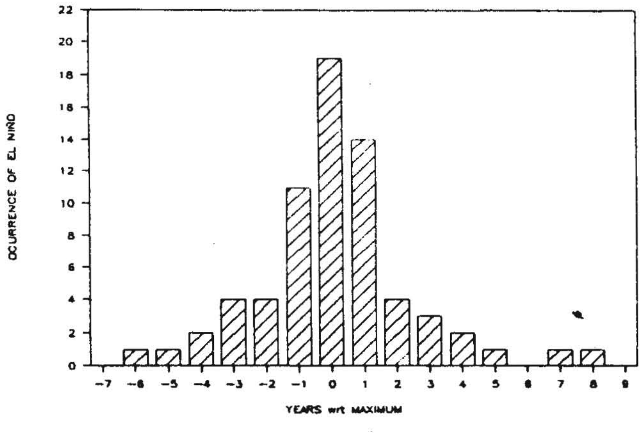

Fig. 2. Distribution of events El Niño around auroral maxima, 1780 - 1980.

butions in Fig. 1 and 2. The regression curve between the occurrence of El Niño events and the number of aurorae around their maximum indicates that a remarkably good correlation exists between these two events (coefficient of correlation 0.95, significative at 99%, see Fig. 3). Notice that such behaviour concerns local increases of the number of visible aurorae rather than a global feature.

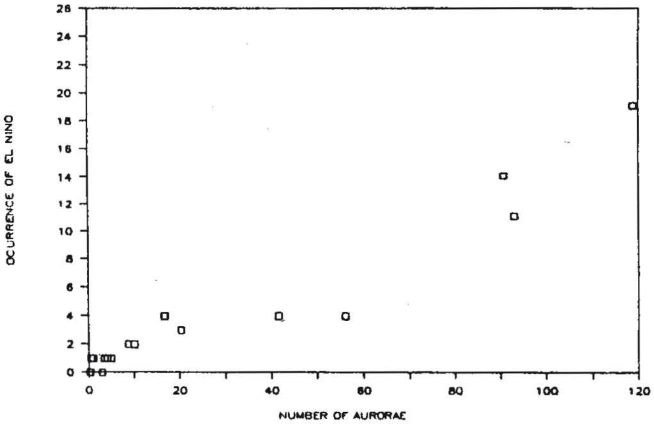

Fig. 3. Regression of visible aurorae around their local maxima on the occurrence of El Niño around the same maxima.

SOLAR ACTIVITY AND EL NIÑO

The data of the solar wind and related events (such as shocks and high-speed streams), which ultimately interact directly with the magnetosphere giving rise to aurorae, are the only available for several decades. On the other hand, sunspots are the solar phenomena recorded for the longest period. Thus we extend our analysis towards the Sun, using the sunspot number, but bearing in mind that we are aware that sunspots themselves cannot directly affect the Earth's environment and therefore may not be the most adequate parameter for finding correlations with climatic phenomena. We analyze the occurrence of El Niño events along the 11-year solar cycle in relation to solar-activity conditions such as sunspot maxima and sunspot-gradient maxima.

Data analysis and results

Taking the sunspot maxima as the reference year and using the series of El Niño events of Quinn *et al.*, we construct the distribution of events along the sunspot cycle (Fig. 4). There is no clear tendency for El Niño events to be distributed around a particular time along the solar cycle. However, there are more events after the maximum than before the maximum. For the period under consideration (1927-1983) the relative percentages are 63% and 37%, respectively.

To study the problem further, the distribution of El Niño events is tested with respect to the sunspot gradients for the period 1700-1985 (Fig. 5). The events cluster around negative and relatively small sunspot gradients. This behaviour is also present when we consider smaller time intervals (see Fig. 6).

In order to see if the occurrence of El Niño is related to solar activity conditions (sunspot numbers and gradients

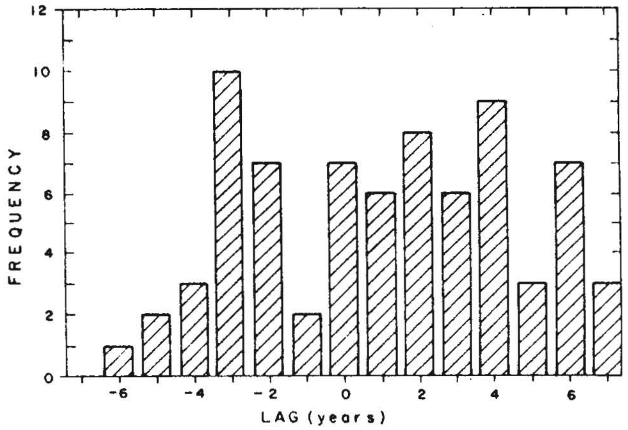

Fig. 4. Frequency histogram of El Niño events around local sunspot peaks for the period 1927 - 1983 (Pérez-Enríquez *et al.*, 1989).

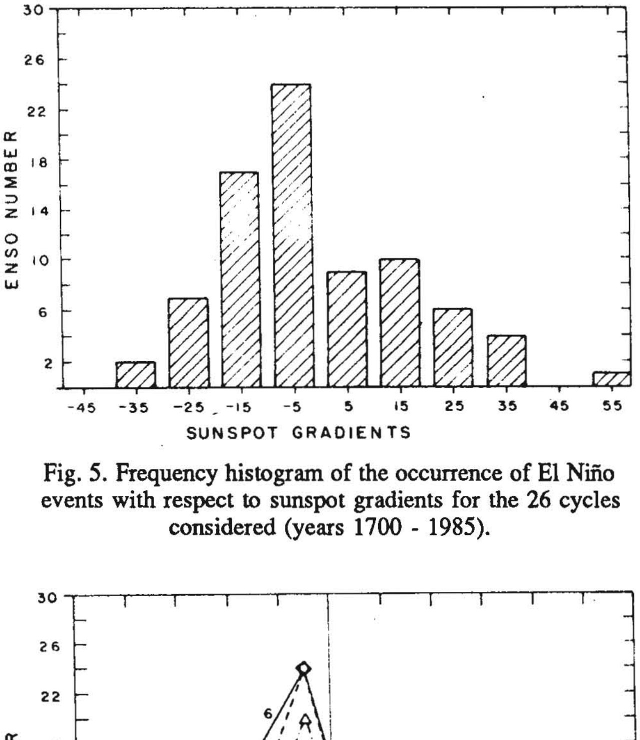

Fig. 5. Frequency histogram of the occurrence of El Niño events with respect to sunspot gradients for the 26 cycles considered (years 1700 - 1985).

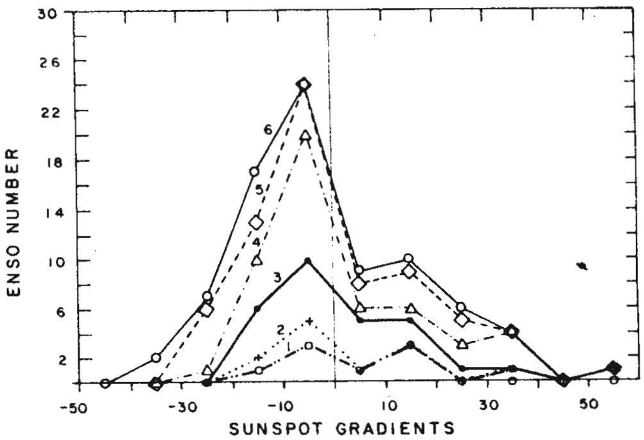

Fig. 6. Distribution of El Niño events with respect to sunspot gradients for different time intervals in the period. Curve 1 from 1700 to 1750; curve 2 from 1700 to 1800; curve 3 from 1700 to 1850; curve 4 from 1700 to 1900; curve 5 from 1700 to 1950, and curve 6 from 1700 to 1985.

along the cycle), we plot such conditions for the time of the onset of each event (Fig. 7). There seems to be a tendency for the events to gather around small gradients, some corresponding to the maximum and some to the minimum. As there has not been a solar cycle with a maximum sunspot number less than approximately Rz = 40 since the Maunder minimum, we choose this value to construct Table 2, which shows how the events are distributed with the sunspot gradients for Rz less and greater than 40. A greater percentage of El Niño events occurs for sunspot numbers <40. This result, together with Fig. 5, indicates that El Niño events tend to occur for small negative gradients and low sunspot numbers, conditions that correspond mainly to the descending phase of the solar cycle and around the minimum.

Furthermore, we explore the descending phase by superimposing the El Niño events along the descending solar phase epochs for the whole period, taking as origin the years of maximum negative gradient, i.e. those of the maximum rate of disappearance of sunspots (see Fig. 8). We observe a peak within the year following this maximum with a dispersion of 2.46. The quasiperiod of the El Niño events is between 3 to 4 years (Cane, 1986), giving a random probability of yearly occurrence of about

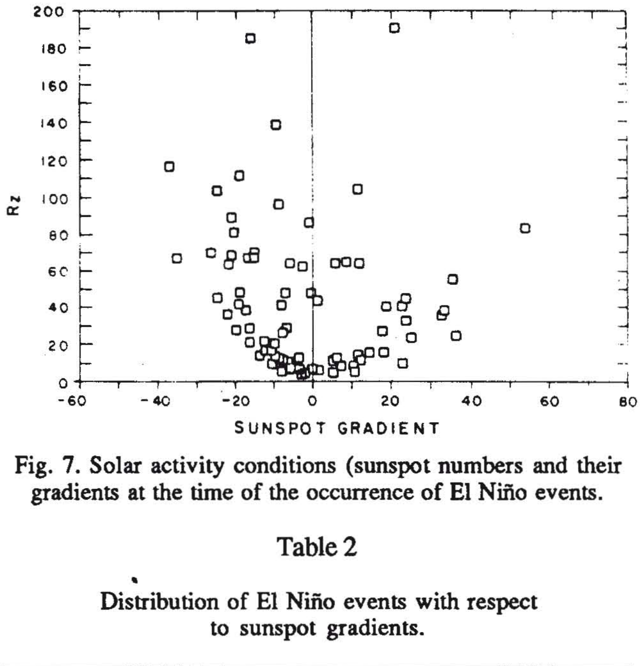

Fig. 7. Solar activity conditions (sunspot numbers and their gradients at the time of the occurrence of El Niño events.

Table 2

Distribution of El Niño events with respect to sunspot gradients.

Sunspot gradients	Total number of Niños	Number of Niños with R = < 40	%	Number of Niños with R = > 40	%
- 10 10	35	22	67	11	33
- 20 20	58	38	65	20	35
- 30 30	73	43	59	30	41
- 40 40	79	46	58	33	42
- 50 50	79	46	58	33	42
- 50 60	80	46	58	34	42

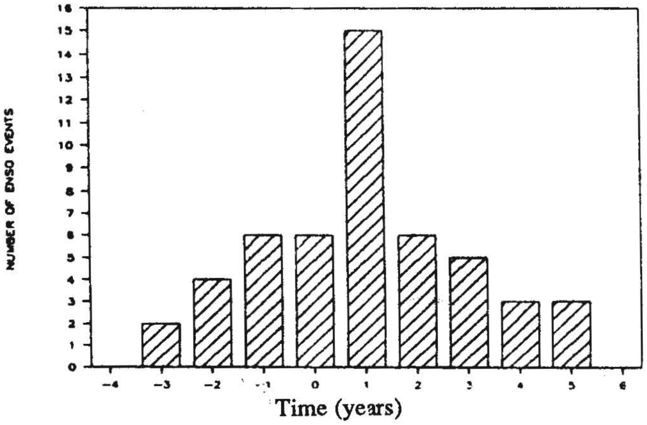

Fig. 8. A histogram of El Niño events around the maximum rate of sunspot disappearance, during the descending solar-cycle phase.

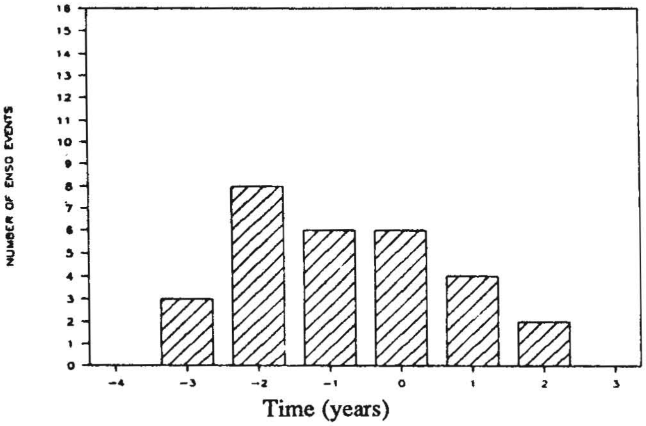

Fig. 9. A histogram of El Niño events around the maximum rate of sunspot appearance, during the ascending phase of the solar cycle.

0.28. The probability of occurrence in the year of the peak in Fig. 8 is 0.58, almost twice the random probability, while the average probability in the other years is 0.23, very close to the random value of 0.28. The analysis for the ascending phase of the solar cycle is shown in Fig. 9. No peak can be seen. And the average probability of El Niño occurrence is 0.18, again close to the random value. A possible explanation is that the peak displayed in Fig. 8 may have occurred by chance. However, we performed 2 000 experiments in which El Niño events were assumed to occur randomly along the same epochs and we calculated the dispersion of the peak for each experiment with respect to the average. Fig. 10 indicates that only in 7 cases the dispersion exceeds 2.4, yielding a probability less than 0.35% for the peak in Fig. 8 to have occurred by chance.

Figure 11 shows the distribution of the years of maximum rate of sunspot disappearance with respect to the years before the solar minimum. The maximum rate of sunspot disappearance occurs about 4 years before the solar minimum. This result, together with the findings of the maximum negative gradient, implies that El Niño events are likely to occur 3 years before a minimum of solar activity.

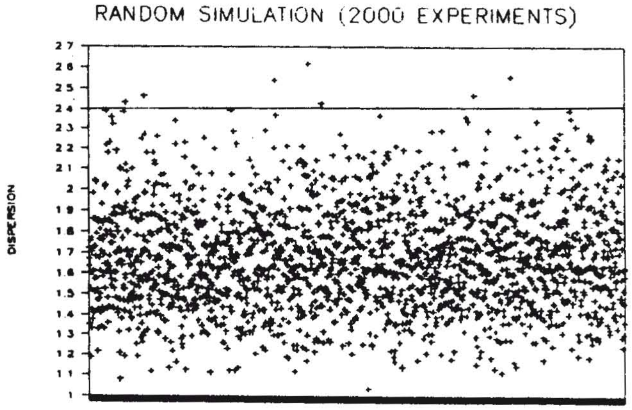

Fig. 10. Two thousand experiments considering El Niño events occurring randomly along the descending phase of the solar cycle. The crosses correspond to the dispersion values of the experiments. The horizontal line indicates a dispersion of 2.4.

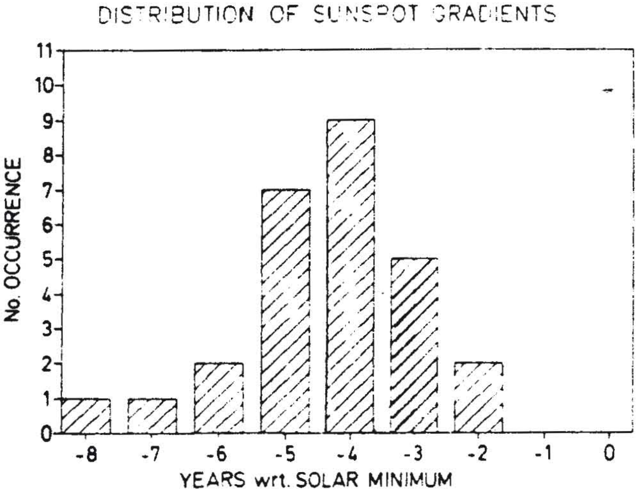

Fig. 11. Distribution of the year of the maximum of sunspot disappearance with respect to the years before the minimum of solar activity.

DISCUSSION

Our results indicate a good correlation between El Niño events and individual peaks of auroral activity. We would not expect the correlation to hold for average auroral activity, as it correlates well with the sunspot cycle, which yields insignificant results. But if we consider individual peaks, we see that some coincide closely with the maximum sunspot number while others (whose peaks are sometimes higher than at the maximum) often occur several years later.

On the other hand, the probability of occurrence of El Niño events is highest during the year after the maximum negative gradient of sunspot, during the descending part of the solar cycle. In fact, some of the strongest El Niño events have occurred during the descending solar cycle phase and in times of highly anomalous solar activity, such as the events of 1972 or 1982. In March 1989 highly anomalous activity was observed. There were many flares including an X15 and a 4B on 6 and 10 March, respectively (Solar Geophysical Data, 1989) and a low latitude coronal hole passed through the central meridian on the 9th. There were two strong shocks at 1 AU, the latter giving rise to an aurora on the 13th which extended to low latitudes. Furthermore, intense low coronal hole activity has been observed since the end of 1988. Studying the southern oscillation we observe that the pressure anomaly was in a descending phase in March 1989. Therefore, we expected that the extreme solar activity mentioned could precipitate the anomaly towards negative values and give rise to an El Niño event by the end of 1989, which in fact occurred. Furthermore, at the times of this anomalous solar activity, negative sunspot gradients were present. It remains for a further study to verify if during times of anomalous solar activity we consistently have negative sunspot gradients.

We may speculate on the features on the Sun that might trigger El Niño events. High-speed streams have been associated with magnetic disturbances (Crooker and Siscoe, 1986). Bucha (1988) studied the effects of geomagnetic activity on the atmosphere at the auroral ovals. He found that enhanced geomagnetic activity results in an increase of temperature and pressure even at the tropospheric level, changing the flow from meridional to zonal. This in turn generates a pronounced increase of temperature at all latitudes. Such a situation may trigger phenomena like El Niño, if the ocean-atmospheric system is in the appropriate state. As is well known, coronal holes are the sources of high-speed streams (Zirker, 1977). During the dipole phase of the solar cycle the polar holes are large, stable structures with lifetimes of 10 or more rotations. During the multipolar phase, their size is reduced, and near the maximum the polar holes disappear, reappearing again at the end of the dipolar phase (Legrand and Simon, 1989; Simon and Legrand, 1989). Polar holes might ultimately be the phenomena to consider when studying possible triggering mechanisms of El Niño events, external to the ocean-atmospheric system.

CONCLUSIONS

The remarkable correlation between the distribution of El Niño events and the presence of visible aurorae around the local maximum of aurorae enables us to conclude that a relation between the two phenomena may exist.

We have analyzed the distribution of El Niño events with respect to solar sunspot maxima and found no evidence of any particular distribution of the events around this time. Yet 63% of El Niño events occur during the descending phase of the solar cycle, while only 37% take place during the ascending phase.

Considering the solar activity conditions (sunspot numbers and their gradients) during which the events occurred, our findings suggest that the events tend to gather around small negative sunspot gradients and small sunspot numbers, conditions mainly present in the descending phase of the solar cycle and close to the minimum.

Finally, the detailed behaviour of the distribution of El Niño events along the ascending and descending phases of the solar cycle suggests that in the ascending phase the average probability of occurrence is close to the random value, while during the descending phase there is a peak within one year following the maximum negative sunspot gradient, with a probability twice the random value. As the maximum of sunspot disappearance occurs 4 years before the minimum, El Niño is likely to occur 3 years before the solar activity minimum.

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