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Solar activity and climate in Central America

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RESUMEN

Se analizaron los posibles efectos de la actividad solar en la temperatura superficial del aire y precipitación en Centro América. La correlación entre las series de manchas solares y las variables climáticas mencionadas es pobre. No obstante, se observó una tendencia creciente en los datos durante el periodo considerado. Usando el análisis de Fourier se encontraron picos de frecuencia aproximadamente a los 11 años y 5 años. Esto sugiere que la actividad solar puede ser un factor que afecta las variables climáticas.

PALABRAS CLAVE: Relaciones Sol-Tierra, clima.

ABSTRACT

Possible effects of solar activity on the records of air surface temperature and rainfall in Central America are analysed. The correlation between the series of sunspot numbers, surface air temperature and precipitation, is poor. However an increasing tendency in the series is observed for the time period considered. Using Fourier analysis, frequency peaks were found close to 11 years and 5 years for both solar and climate data. This suggest that solar activity might be a factor which affects the climate's variables.

KEY WORDS: Sun-Earth relations, climate.

1. INTRODUCTION

Changes in the climatic system are due to interactions between atmosphere, oceans, land areas with their biomass, and cryosphere, and to external factors such as solar variability. There is a large literature on the topic of sun-weather relationships (e.g., Hoyt and Schatten, 1997; Roederer, 1995; Hanna, 1996a, 1996b). As pointed out by Roederer (1995), it was necessary to divide the study of sun-weather relationships according to three classes of solar variations: (1) the 11 year sunspot solar cycle and perhaps the related 22 year magnetic Hale cycle, (2) long-term secular changes of the amplitude of the sunspot cycle (the Gleissberg cycle), and (3) sporadic events of short duration, such as solar flares and sun-controlled solar wind shocks, and recurrent events related to interplanetary magnetic field (IMF) sector boundary passages.

Kyle *et al*. (1993) compared the average monthly values of total irradiance with the corresponding temporal variations of the Wolf sunspot number. The maximum total irradiance was found to correspond to the maximum sunspot number. The 11-year modulation comes from (a) enhanced emissions from bright faculae during the solar maximum, and (b) enhanced blocking produced by sunspots (Roederer, 1995).

Reid (1987, 1991) and Friis-Christensen and Lassen (1991, 1993) discussed the correlation between global air surface temperatures and sunspot numbers. Their results show that the sunspot numbers lag behind the global air surface temperature, and that the length of the sunspot cycle correlates with the global air surface temperature. Other studies have dealt with the effects of solar activity on the El Niño-Southern Oscillation occurrence (Pérez-Enríquez *et al*., 1989; Mendoza *et al*., 1990, 1991; Mendoza and Pérez-Enríquez, 1992).

Long series of air surface temperature data were obtained for San José (Costa Rica), A.C. Sandino (Nicaragua), Tegucigalpa (Honduras), La Aurora (Guatemala) and Balboa (Panama). Rainfall data for the station of San José (Costa Rica) and sunspot and solar flare data were also used in this study.

2. SUNSPOTS AS AN INDICATOR OF SOLAR ACTIVITY

Solar activity can be determined from solar flares, coronal holes, coronal mass ejections, and sunspots. It appears to be more convenient to use the number of solar flares rather than the number of sunspots; however, solar flares, coronal holes, and coronal mass ejections also occur with frequencies tied to the 11-year sunspot cycle (Roederer, 1995). This may make source identification very difficult.

Figure 1 shows the time series of solar flares and sunspot number for the period 1976-1994. It can be seen that they have very similar pattern. Since the record of sunspot number is much longer than the record of solar flares the sunspot number is used for comparison with records of air surface temperature and rainfall. However, the sunspot number may not represent all aspects of solar variability (Roederer, 1995).

In Figure 1 and subsequent figures, relative values are defined by

$$V_r = \frac{V_{\max} - V}{V_{\max} - V_{\min}} \tag{1}$$

where V is the variable under consideration. Subscript r refers to *relative* and subscripts *max* and *min* refer to the maximum and minimum values of the variable in the series.

3. RESULTS

Figure 2 shows the temporal variations of air surface temperature in Panama and sunspots, tendencies are also included in this figure. It can be seen that the patterns agree in some time periods (maxima or minima occur more or least at the same time) but not in others. Nevertheless, the tendencies for both series show an increase during the time period considered in Figure 2. A similar situation to the one described for the Panama data is also found for the other meteorological stations mentioned above (Figure 3).

Figure 4 shows a Fourier analysis for the sunspot number. It shows the peak in frequency at about 11 years, and a smaller peak at about 5 or 6 years (Figure 4). Figures 5 and 6 show a Fourier analysis for the air surface temperature in San José (Costa Rica) and the other meteorological stations, respectively. They show a peak in frequency at about 11 years, which might be related to the 11-year sunspot cycle.

Figure 7 shows the time series of rainfall and sunspots, and a Fourier analysis for rainfall, in San José (Costa Rica). No correlation is found among these variables. However, there is a peak in frequency at about 9 years that might be related to solar activity (see diagram on the right side of Figure 7).

4. DISCUSSION AND CONCLUSIONS

In general, the correlation between sunspot numbers and air surface temperatures is poor. When precipitation is used instead of temperature the results are even worse. Nevertheless, an increasing correlation in the series of sunspot numbers and air surface temperatures is observed for the time period considered. This tendency is also observed in records of global air surface temperature (e.g., Friis-Christensen and Lassen, 1991). In general, as pointed out by Roederer (1995), parameters such as the global air surface temperature, sunspot cycle amplitude, greenhouse gas concentrations, sunspot cycle frequency and overall solar activity show a net increasing trend since the late 1800's. This makes the determination of the climatic response to possible forcing factors a very difficult task.

The absence of a clear correlation between sunspot numbers and air surface temperatures and rainfall does not necessarily implies the non-existence of such a relationship since many other factors may intervene in a climatic system.

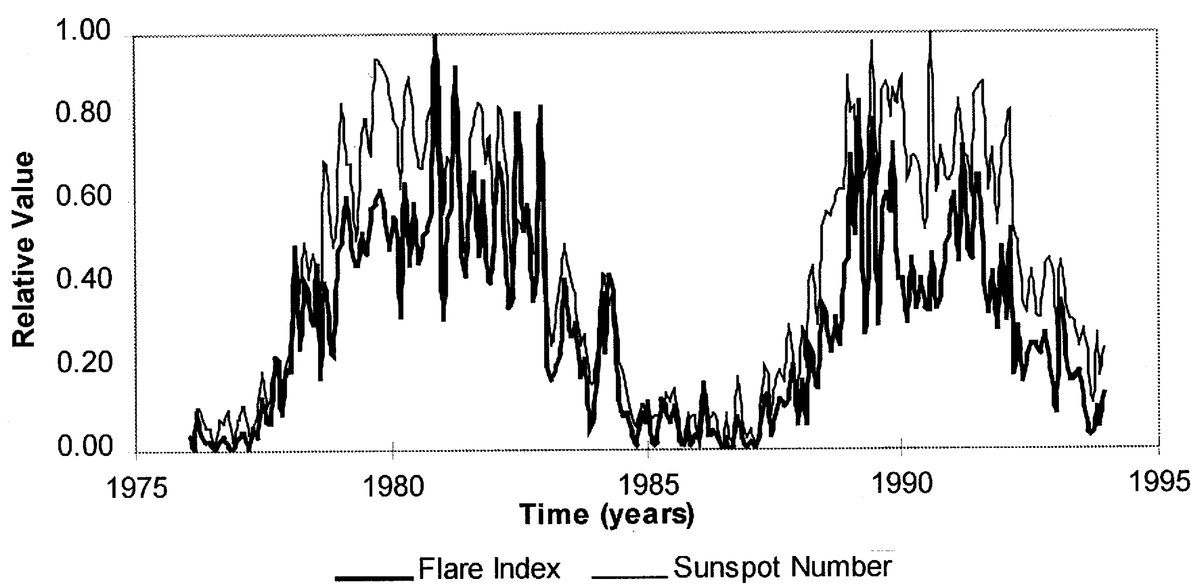

Fig. 1. Temporal variations of relative flare index and relative sunspot number.

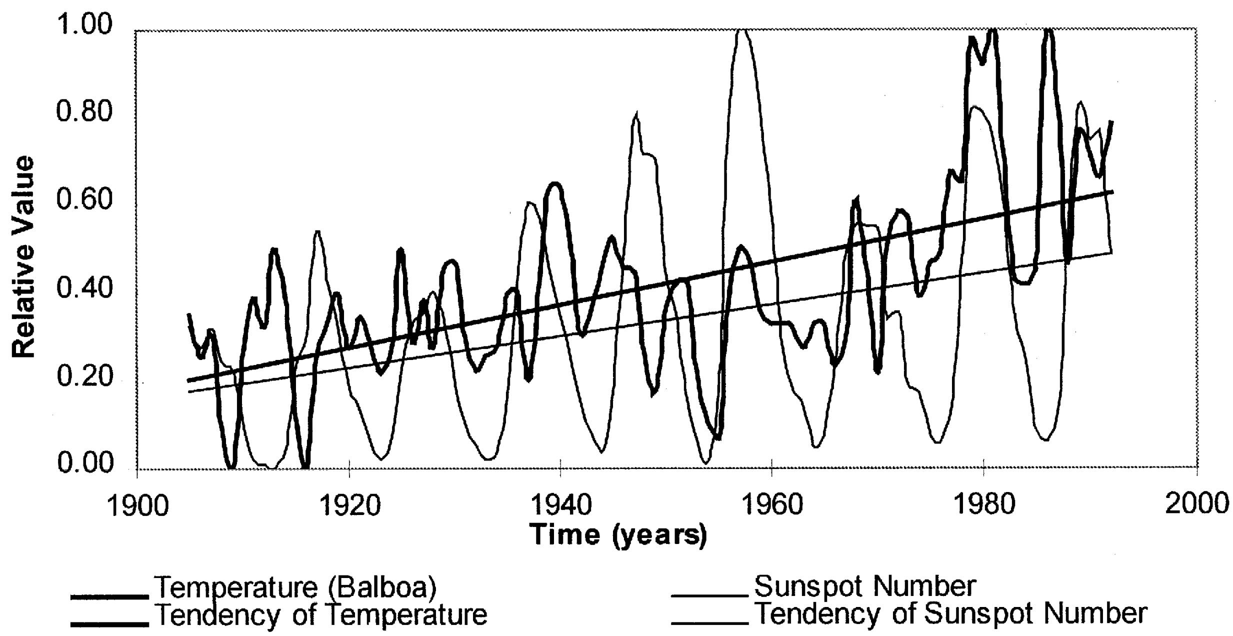

Fig. 2. Temporal variations of the relative value of sunspot number and air surface temperature in Balboa (Panama). Tendencies are also included.

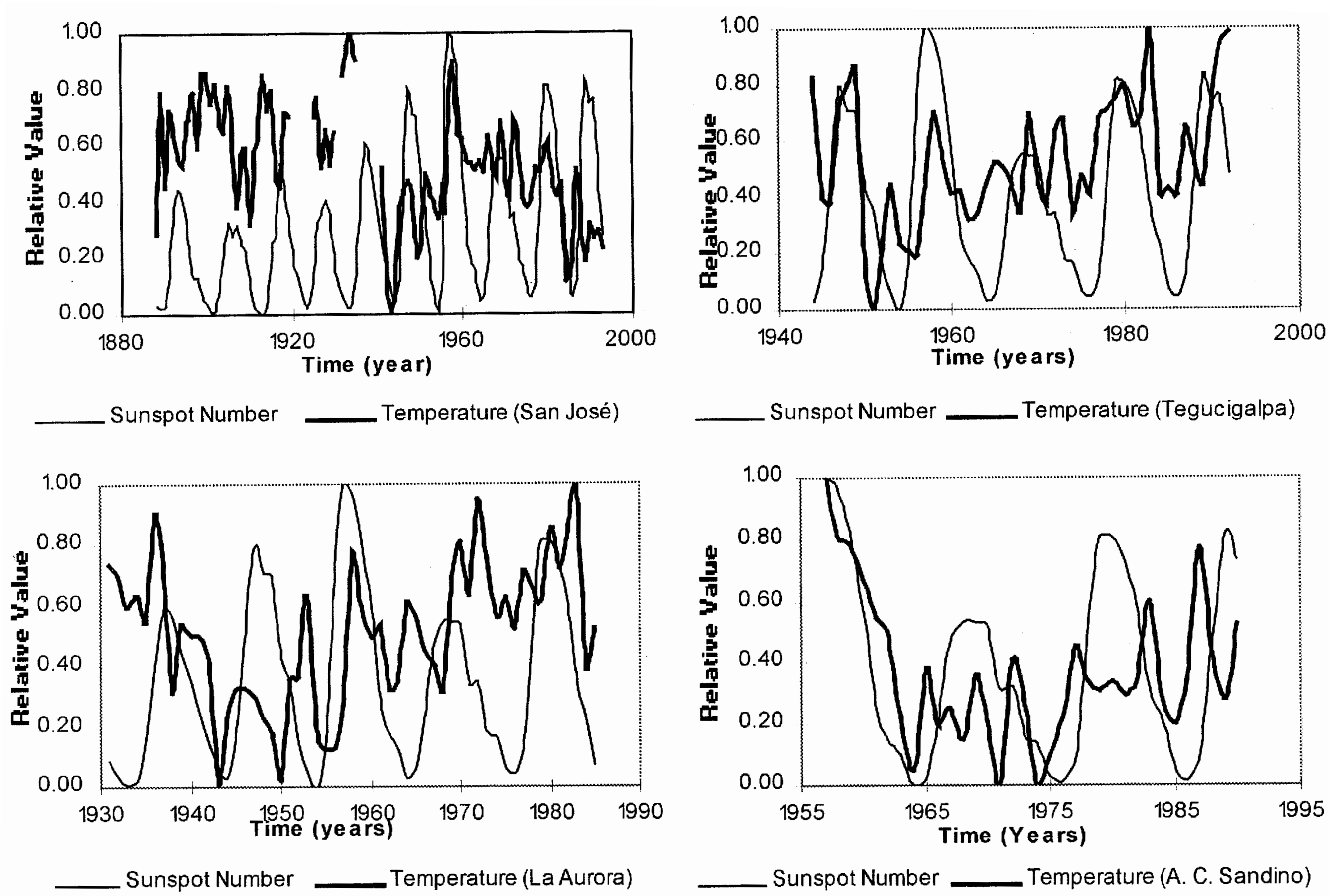

Fig. 3. Temporal variations of the relative value of sunspot number and air surface temperature in: San José (Costa Rica), Tegucigalpa (Honduras), La Aurora (Guatemala), and A.C. Sandino (Nicaragua).

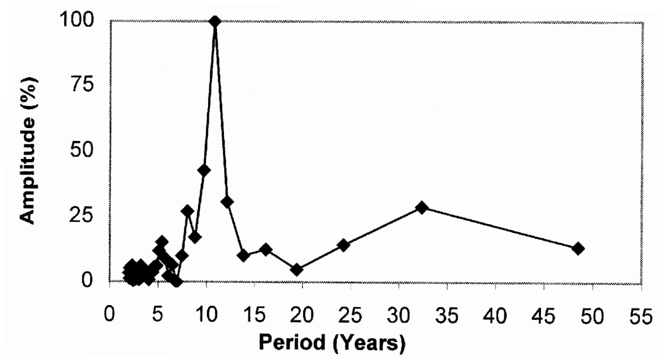

Fig. 4. Frequency analysis for sunspot number. The period considered is 1900-1996.

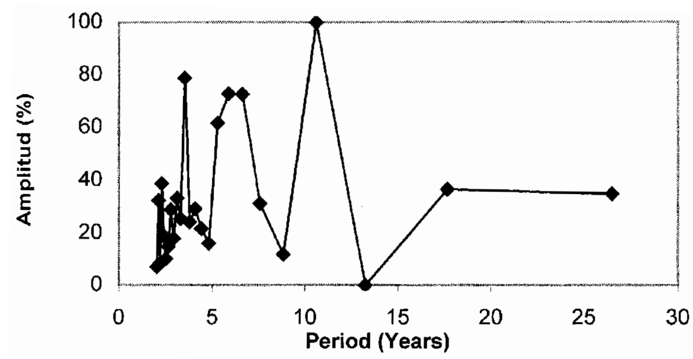

Fig. 5. Frequency analysis for air surface temperature in San José (Costa Rica). The period considered is 1941-1993.

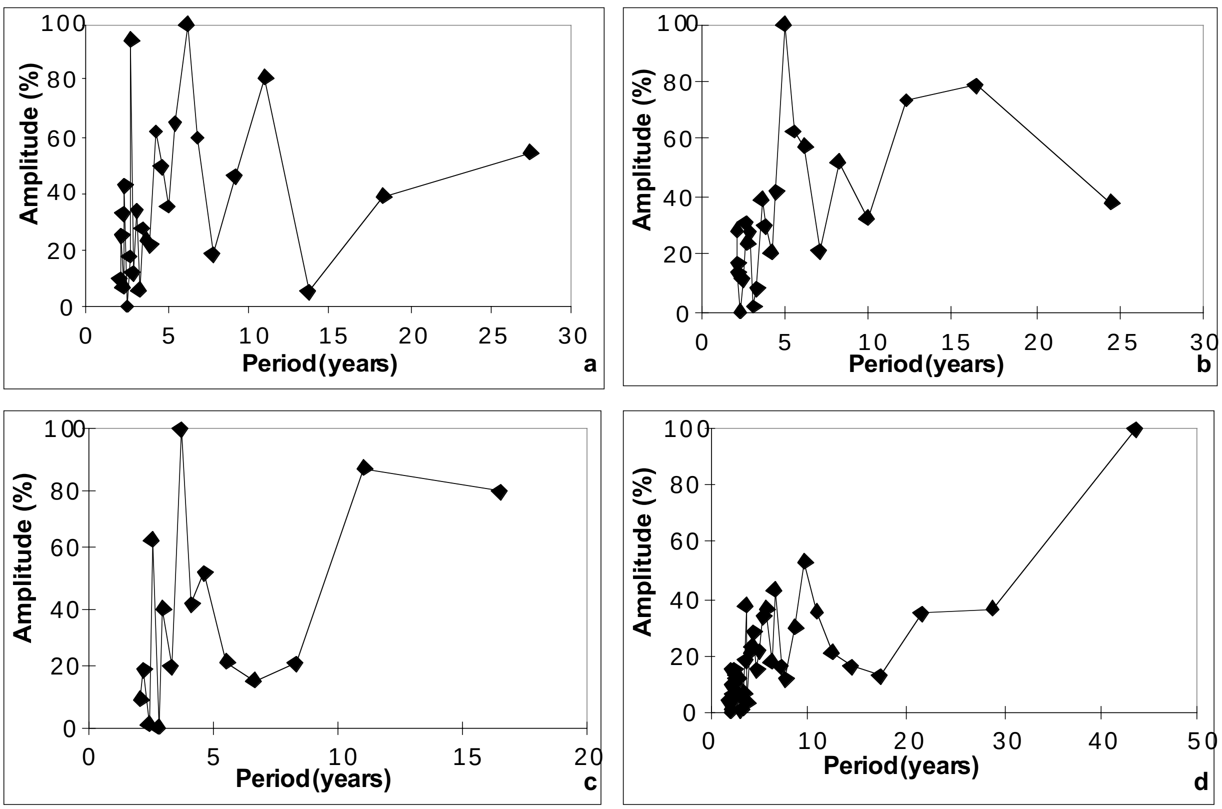

Fig. 6. Frequency analysis for air surface temperature in: (a) La Aurora, Guatemala (1935-1985); (b) Tegucigalpa, Honduras (1944-1992); (c) A.C. Sandino, Nicaragua (1957-1989); and (d) Balboa, Panama (1905-1992).

Using Fourier analysis a peak in frequency close to 11 years was found for sunspot numbers (as expected) and air surface temperatures. This suggests that solar activity might affect air surface temperature. The series of sunspot number shows a relatively small peak at about 5 years. A peak in frequency between 4 and 6 years was also found in some series of air surface temperatures.

It may be objected that the time periods for which data are available for correlation studies are very short. As pointed out by Roederer (1995), the bandwidth of uncertainty in the period using data from a limited timeinterval of, say, three solar cycles is ± 2 years. Thus an intrinsic atmospheric periodicity between 9 and 13 years could be expected to show an acceptable correlation with the solar cycle (e.g., Salby and Shea, 1991). However, no plausible decadal cyclic variation of the atmosphere unrelated to the Sun has been identified or proposed.

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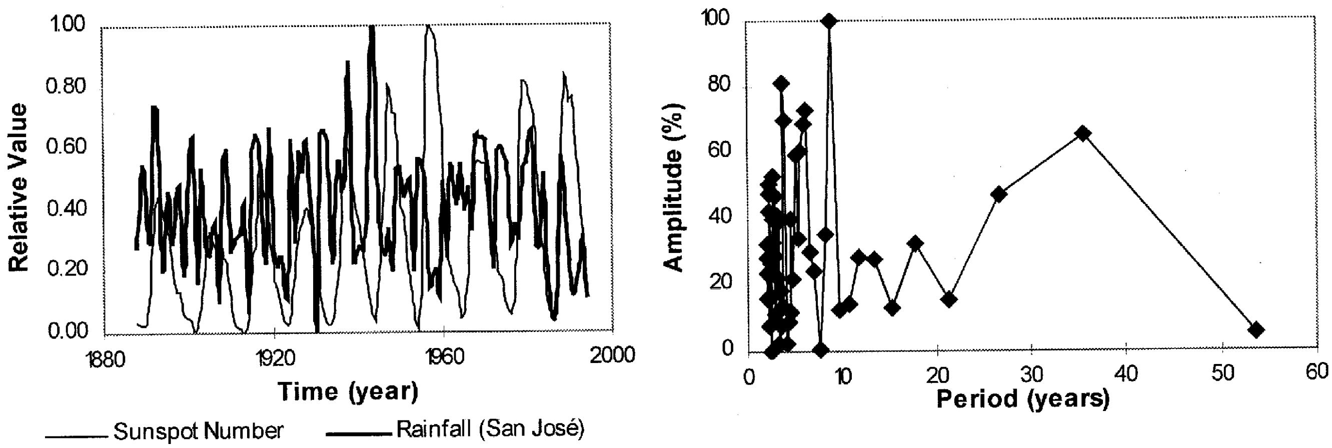

Fig. 7. Temporal variations of rainfall and sunspots (left) and frequency analysis for rainfall (right) in San José, Costa Rica.

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