COHERENCY BETWEEN SOLAR ACTIVITY AND METEOROLOGICAL PARAMETERS AT 11 YEAR PERIOD

D. Altadill, J.J. Curto, L.R. Gaya-Piqué, J.G. Solé and J.M. Torta

Observatori de l'Ebre. CSIC-URL.
Horta Alta 38, 43520, Roquetes, Spain.
Tel: +34 977-500-511 / fax: +34 977-504-660
Corresponding author e-mail: ebre.daltadill@readysoft.es

ABSTRACT

The historical records of temperature and rainfall at Ebre Observatory (40.8° N, 0.5° E) and the relative sunspot numbers have been used to study the possible influence of the 11-year solar cycle over the meteorological parameters. Spectral and cross-correlation analysis have been applied in order to find such a relationship. The yearly averaged maximum temperature displays a period near 11 years, while the yearly averaged minimum temperature and yearly rainfall values do not present any significant peak about that period. It has been obtained that the 11-year solar cycle and the 11-year oscillation found in the maximum temperature are coherent, practically in phase. Moreover, an 11-year oscillation is found to be significant in the cross-correlation between the solar activity data and maximum temperature. The results show a possible relation of the 11-year solar activity cycle on the maximum temperature data used here.

INTRODUCTION

During the last few decades, several studies have been developed to determine the relation between solar activity and climate changes (for instance Friis-Christensen and Svensmark, 1997 and references therein). Some of them have been centered on the influence of solar activity cycles, mainly the well-known 11-year period cycle, over global meteorological records or from selected places over the world.

The purpose of this work is to look for possible influence of the 11-year solar activity cycle on meteorological parameters. Although the total solar irradiance is a better indicator of solar activity when searching Sun-Climate relationships, we chose the relative sunspot numbers as indicator of solar activity because we study long term series. The results obtained are only applicable to this series, and no global conclusions can be extracted.

DATA AND METHODOLOGY

In order to carry out this study, we used the temperature and rainfall data recorded at Ebre Observatory (40.8° N, 0.5° E) from 1905 to 1999. These time series have been extended up to 1880 with the meteorological records carried out in a previous meteorological station less than 2 km far from the actual position of the observatory. From the daily temperature records, we obtained yearly averages of the daily variation and studied their extrema, hereafter Tmax and Tmin. The yearly rainfall values were obtained from the daily rainfall records. Moreover, we have studied the yearly rainfall at Valencia (39.48° N, 359.62° E) from 1864 to 1994 (Almarza et al., 1996), in order to contrast it with the data from Ebre observatory. The solar activity data that we used in this study were the yearly averages of the relative sunspot numbers (SSN) provided by the Solar-Terrestrial Physics Division of the NOAA. The temperature and solar activity data are presented in figure 1.

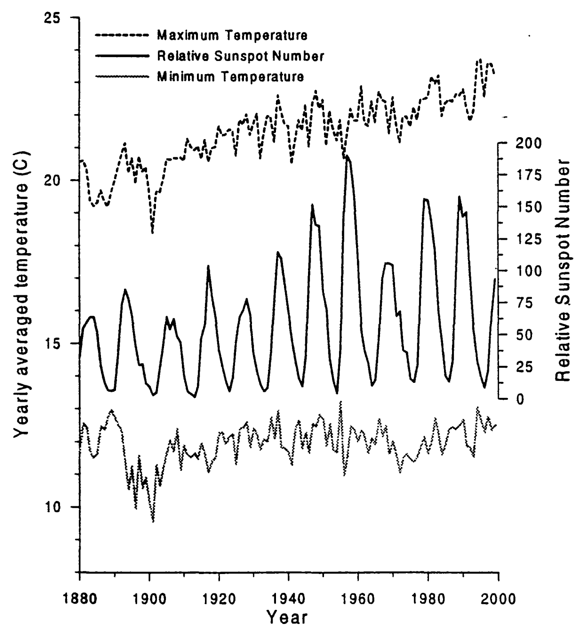

Figure 1

We used statistical methods based on high spectral resolution harmonic analysis (see Vitinsky et al., 1986 for details) in order to obtain the spectral characteristics of the temperature and rainfall variations probably related to the 11-year solar cycle. We also used cross-spectral analysis to seek for the coherency between the above-mentioned variations and from the magnitudes linked with it we used an estimation of the squared coherency and phase spectra but avoiding to filter the spectrum (Bloomfield, 1976). Moreover, cross-correlation analysis was used to evaluate the possible influence of the 11-year solar cycle on the meteorological parameters.

Proc. 1st Solar & Space Weather Euroconference, 'The Solar Cycle and Terrestrial Climate', Santa Cruz de Tenerife, Tenerife, Spain, 25-29 September 2000 (ESA SP-463, December 2000)

RESULTS

Figure 2 shows the averaged amplitude spectra corresponding to the SSN, Tmax and Tmin. The spectra have been obtained from 21 time intervals with duration of 80 years and shifted from one to each other by 2 years. The initial year of the first interval was 1880, and the ending year of the last interval was 1999. In this figure we clearly observe the 11-year solar cycle in the SSN. Such 11-year oscillation activity is also observed in Tmax data but with lower amplitude than oscillations with periods of 7.5, 14 and 17.5 years. These spectral peaks are also observed in Tmin, but no peak with period near 11-year is observed in Tmin. The 17.5-year peak could be attributed to the cycle of regression of the lunar nodes (Currie, 1981). We are not able to explain the possible origin of the other peaks.

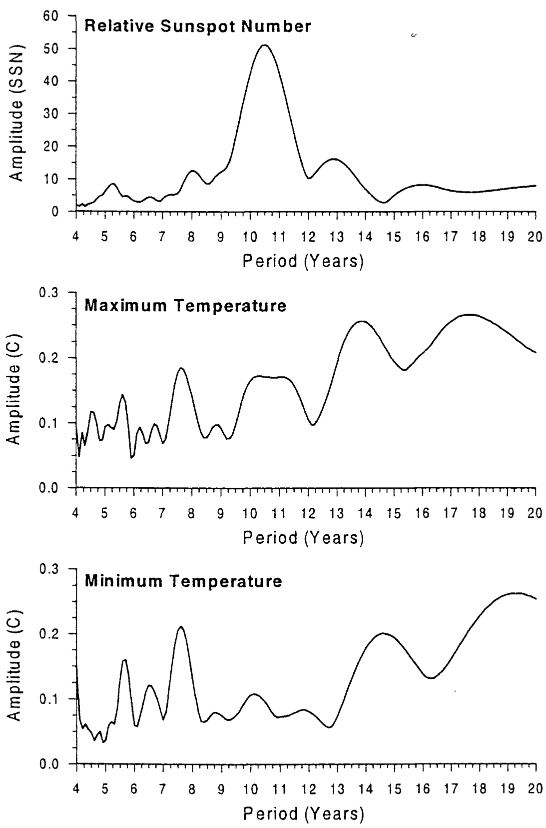

Figure 2

Figure 3 shows the squared coherency and phase spectra between the SSN and Tmax (left) and Tmin (right). To obtain this figure we have used the same spectral windows as in figure 2. It is noticeable the large coherency between the SSN and Tmax at near 11-year period. Moreover, the phase spectrum shows phase stability for the harmonics near such oscillation activity. This figure shows also large coherency between SSN and Tmin. However, the phase stability is not as clear as in the previous results.

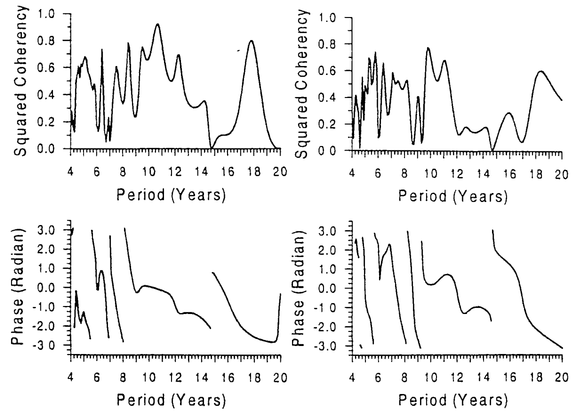

Figure 3

Figure 4 shows the dynamic amplitude spectra corresponding to SSN (top), Tmax (middle) and Tmin (bottom). The plots were obtained using spectral windows of 63-year time length shifted by 1 year from one to each other. Only those harmonics having a probability of existence larger than 90% were taken into account, the others were set to have zero amplitude. It is interesting the slowly change of the dominant period of the 11-year solar cycle as observed from SSN, decreasing from 11.1-year in the early 10's to 10.5 in the 40's and increasing to 10.8 in the late 60's. This result probably reflects the well-known Gleissberg period. The 11-year cycle shows an intermittent presence in Tmax, being most persistent from the late 40's to the late 60's, when the 11-year solar cycle has the largest amplitude in the SSN. No significant presence of the 11-year cycle is observed in the Tmin data.

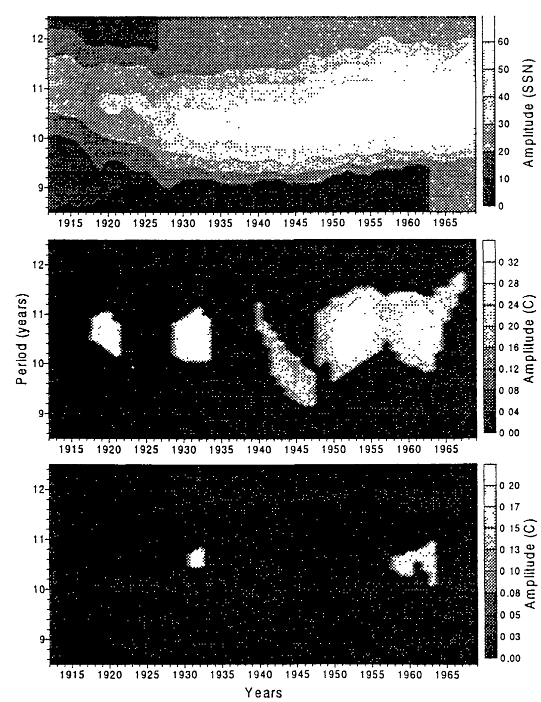

Figure 4

Figure 5 shows the results of cross-correlation functions between SSN and temperatures. The 0.99 and 0.95 confidence levels of correlation are plotted to confirm the statistical significance of the 11-year solar cycle on the meteorological parameters. We clearly observe the oscillations in the cross-correlation functions with a period near 11 years in analysis, SSN vs. Tmax and SSN vs. Tmin. However, only the former displays consecutive maxima above the 0.99 confidence level, particularly 4 recurrences.

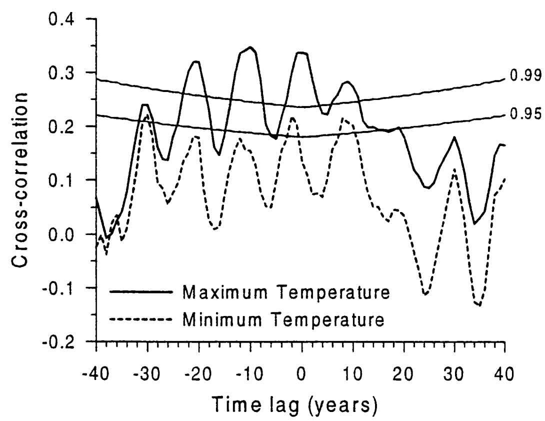

Figure 5

We made the same analysis for the rainfall data and we found that the 11-year solar cycle is not sensitive in such data. Figure 6 was obtained in the same way as figure 4. We observe that practically there is no significant 11-year oscillation in the rainfall records at Ebre Observatory, and the dominant period observed from data at Valencia is outside of the periodic range of the 11-year solar cycle. Moreover, the results of cross-correlation analysis show no consecutive peaks rising the confidence levels (Figure 7).

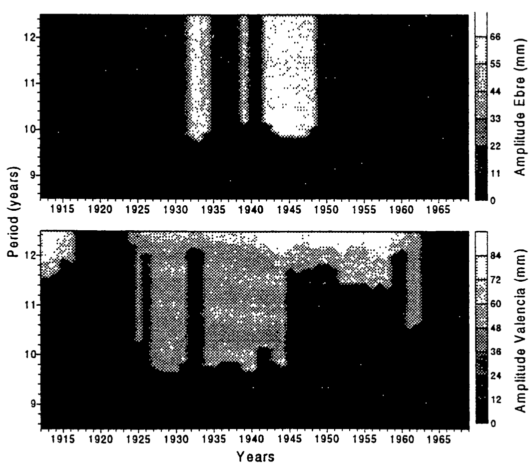

Figure 6

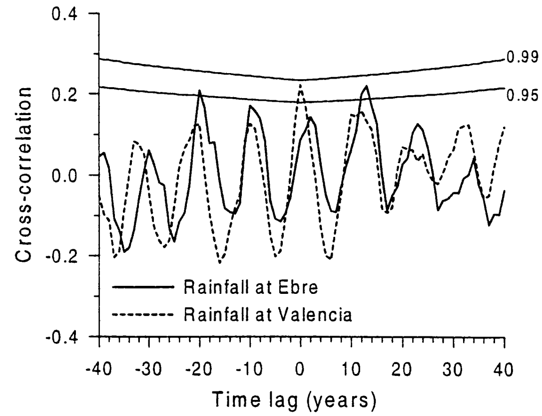

Figure 7

We performed the same type of analyses by using monthly mean values in the aforementioned time series, and the results we found are qualitatively indistinguishable from those obtained with yearly values.

CONCLUDING REMARKS

All the results presented here lead to the conclusion that the maximum temperature data recorded in the vicinity of the Ebre Observatory is sensitive to the 11-year solar cycle, being more stable in the second half of the time series when the solar cycle is most energetic. Another interesting fact is that the 11-year oscillation is practically in phase between SSN and Tmax (figures 3 and 5). However, the cross-correlation maximum at a time lag of –9 years is larger than that at 1 year. This fact may be related with the 22-year solar cycle, essentially due to the fact that, although the well-known Gnevyshev-Ohl rule is applicable in the SSN considered here, the solar cycle 18 (1945 – 1954) is most active than cycle 17 (1934 – 1944).

REFERENCES

Almarza C., López J.A. and Flores C. (1996): Homogeneidad y variabilidad de los registros históricos de precipitación de España. *Publicación A-143 del Instituto Nacional de Meteorología*, Ministerio de Medio Ambiente, Madrid.

Bloomfield P. (1976): Fourier analysis of time series: an introduction. John Wiley, NY.

Currie, R.G. (1981): Evidence for 18.6 year M_N signal in temperature and drought conditions in North America since AD 1800. *Journal of Geophysical Research*, Vol. 86, pp. 11055-11064.

Friis-Christensen E. and Svensmark H. (1997): What do we really know about the Sun-Climate connection? *Advances in Space Research*, Vol. 20, No. 4/5, pp. 913-921.

Vitinsky Y. I., Kopecky M. and Kuklin G. (1986): *Statistics of sunspot-creating activity* (in Russian). Nauka, Moscow.