Solar cycle dynamics of the quasi-biennial periodicities associated with the coupling of a double solar dynamo

LUIS DE CASO[1], BLANCA MENDOZA[1], VICTOR VELASCO[1]
[1] *Instituto de Geofísica UNAM, Ciudad Universitaria 04510, México D.F. México*
ldecaso@geofisica.unam.mx

Abstract: In this work we report an analysis of various indices of solar magnetic variability of closed and open field, concentrating particularly in the quasi-biennial periodicities (1.7-2.5 years). The wavelet technique is used in the time series of the solar indices to find the significant periodicities of our study, we also use other wavelet analysis already made. We consider the theory of a double solar dynamo, with its low frequency component located at the base of the convection zone, and its high frequency component in the upper part, coupled by the helicity (alpha effect). In this context, we obtain a classification of the couplings between the low and high frequency components per cycle along cycles 17 to 23, based on the strength and regularity of the quasi-biennial periodicities

Introduction

Since they may be revealing some of the basic mechanisms of solar magnetic activity and its consequences in the heliosphere, in recent years much attention has been dedicated to analyse periodic variations in solar and interplanetary phenomena. In particular, periodicities of around 1–2 yrs, were discovered in galactic cosmic ray intensity (GCR) (Valdés-Galicia et al., 1996) Cuasi-biennal periodicities were found in variations of radio flux on 10.7 cm (Belmont, Darff,& Ultad 1966), flares, and sunspot areas (Akioka et al. 1987). The high-frequency, 2 yr, component is substantially weaker than the main 22 yr cycle, and its intensity varies with time. The 2 yr component appeared more clearly in the northern hemisphere in cycle 20 and in the southern hemisphere in cycle 21; its value was smaller in cycle 22 (Benevolenskaya 1996).

The biennial cycle represents a challenge to the solar dynamo theories that usually explain only the main cycle. We believe that the origin of the quasi-biennial periodicity are the dynamics of the strong shear at the top of the convection zone creating a phenomenon known as the surface dynamo (Benevolenskaya, 1995, 2000) and the coupling of this with the 11-yr solar dynamo at the base of the convection zone.

Data and Method

We worked with the monthly data for coronal holes extracted from Green corona low-brightness (GCLBR) regions from 1940 to 2004 (cycles 17–22) as proxys of coronal hole area. This relation was established since the times of Skylab and has been confirmed later on by many authors (see, e.g., Dorotovic, 1996).

The 10.7 cm radio emission data from 1947 to 2005 were taken from the National Geophysical Data Center webpage

www.ngdc.noaa.gov/stp/SOLAR/getdata.htm.

The sunspot series is the longest set of data we have. It goes back to 1838 compiled from the Solar Influences Data Analysis Center (SIDC) at the Belgium World Data Centre for the Sunspot Index catalogues. We use the monthly sunspot number series for cycles 8–22, as a reference of a phenomenon well imbedded in the photosphere and whose evolution is certainly linked to coronal holes and radio emissions.

For magnetic fluxes we work with te extrapolation of the observed photospheric magnetic field into the corona given by Wang and Shelley (2002). They used the magnetograms of Carrington synoptic maps from Mount Wilson Observatory and the Wilson Solar Observatory for the period 1971-1999.

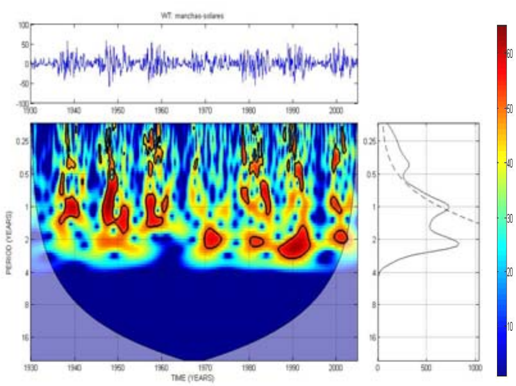

Figure 1: (a) High frequency time series of sunspot. The dashed curves are the 11 yr sunspot cycle. (b) Morlet wavelet spectrum, the significance level colour code appears at the right of the figure, in particular the 95% significance level is inside the black contours. (c) Global wavelet spectrum

For flare index, data used in this study were calculated by T.Atac and A.Ozguc from Bogazici University Kandilli Observatory, Istanbul, Turkey"

www.koeri.boun.edu.tr/astronomy/index.html

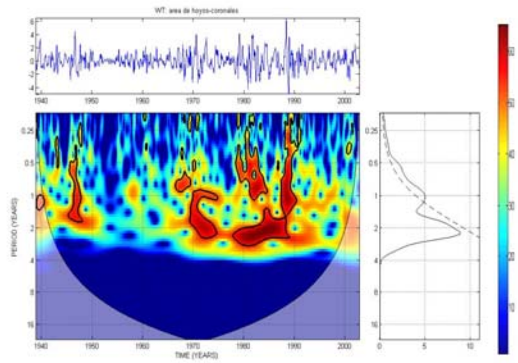

Figure 2: (a) High frequency time series of coronal hole area index b), c) And code color, same as figure 1

In order to find the time evolution of the main frequencies of the time series we apply the wavelet method using the Morlet wavelet (Torrence and Compo, 1998; Grinsted et al., 2004).

Wavelet analysis can be used for analyzing localized variations of power within a time series at many different frequencies. To determine significance levels of the wavelet power spectrum, it is necessary to choose an appropriate background spectrum. Then different realizations of the process are assumed to be randomly distributed about this mean or expected background, and the actual spectrum may be compared against this random distribution.

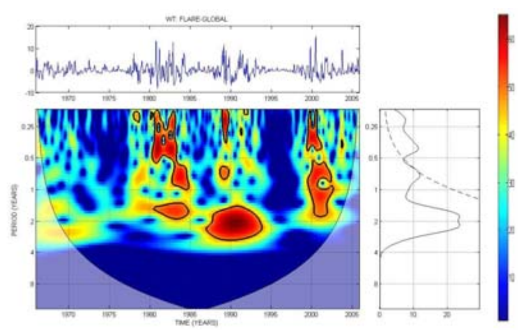

Figure 3: (a) High frequency time series of global flare index. b), c) And code color, same as figure 1

For many phenomena, an appropriate background spectrum is either white noise (with a flat Fourier spectrum) or red noise (increasing power with decreasing frequency). A simple model for red noise is the autoregressive linear Markov process (Gilman et al., 1963). Here we use red noise for our significance calculations.

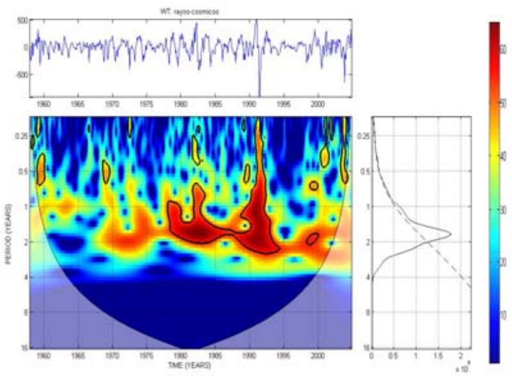

Figure 4: (a) High frequency time series of cosmic rays. b,), c) And code color, same as figure 1

Results

1 The quasi-biennial periodicities appear alone or with the cuasi-anual periodicities.

2 The quasi-biennial periodicities are stronger in the Souhern hemisphere except in solar cycle 20 where the northern hemisphere periodicity was stronger.

3 The quasi-biennial periodicities were absent in many indices of solar cycle 19.

4 The quasi-biennial periodicities has a strong tendency to appear in the descending phase of the 11 year solar Cycle

5 Using the wavelet interpretation the table 1 we can make a sequence of coupling of each solar cycle from 17 to 23 in agreement with the theory of Benevolenskaya, (1998) as follows

19>17>18>20>23>22>21

where the couplings comes from stronger to lighter.

Strength of Cuasi-Biennal Periodicities: Closed Field Indices

Solar Cycle Number	17	18	19	20	21	22	23	Global
Sunspots	1	2	A	4	3	4	3	2
Radio Flux 10.7 cm	ND	3	A	2	2	3	4	2
Total Magnetic Flux	ND	ND	ND	2	4	2	ND	3
Closed Magnetic Flux	ND	ND	ND	3	4	1	1	3
Flare Index (Global)	ND	ND	ND	1	4	4	3	2
Flare Index (Southern Hemisphere)	ND	ND	ND	1	4	4	3	2
Flare Index (Northern Hemisphere)	ND	ND	ND	2	2	3	2	1

Table 1: Regularity and strength of quasi-biennial periodicities in closed field indices. ND: no data. A: absent. 1: Very low power. 2: Low power. 3: Medium power with over 95% of confidence. 4: Very powerful with over 95% of confidence. For global wavelets: 1: Very under the red noise limit. 2: Under the red noise limit. 3: at the border of the red noise limit. 4: clearly above of the red noise limit.

Strength of Cuasi-Biennal Periodicities: Open Field Indices

Solar Cycle Number	17	18	19	20	21	22	23	Global
Coronal Hole Index	ND	4	A	4	4	3	ND	3
Cosmic Rays	ND	ND	A	2	4	4	3	4
Open Magnetic Flux	ND	ND	ND	2	4	3	ND	2
High Latitude Open Magnetic Flux	ND	ND	ND	2	4	2	ND	3
Low Latitude Open Magnetic Flux	ND	ND	ND	2	3	4	ND	3

Table 2: Regularity and strength of quasi-biennial periodicities in open field indices. Table code same as in Table 1.

References

[1] Benevolenskaya, E.E. Solar Phys. 161, 1, 1995

[2] Benevolenskaya, E.E. Solar Phys. 191, 247–255, 2000
[3] Dorotovic, I. Solar Phys. 167, 419, 1996
[4] Grinsted, A., Moore, J., Jevrejera, S. Nonlinear Process. Geophy. 11, 561, 2004.

[5] Mendoza, B., Velasco, V.M., Valde´s-Galicia, J.F. Solar Phys. 233, 319, 2006.
[6] Torrence, Ch., Compo, G.P. Bull. Am. Met. Soc. 79, 61, 1998
[7] Valdés-Galicia, J.F., Otaola, J., Pérez-Enríquez, R. Solar Phys. 169, 409, 1996
[8] J.F. Valdés-Galicia, V.M. Velasco Adv.in Sp. Res. (2007) in press.

.