Mem. S.A.It. Suppl. Vol. 9, 109

Memorie della
Supplementi

Latitudinal dependence of the 11-year and 22-year cycles in the green coronal brightness

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Abstract. Data of the green coronal brightness, derived from measurements of the Fe XIV 530.3 nm emission spectral line, were used to analyse the statistical significance of the 11-yr and 22-yr cycles, for different heliographic latitudes, during the period 1943 to 2001. The database consists of 36 sets of coronal intensities, one for each solar latitude with a step of 5 degrees between -90° and +90°, averaged over each Carrington Rotation. They were analysed by using both the Fast Fourier Transform and the Wavelet technique. It resulted that the 11-yr cycle is present at all latitudes, while the second significant peak of the wavelet power is centered on ~ 26 y only at high latitudes (< -50° and > +55°). We also found a North-South asymmetry in the power of the eleven year cycle. Our findings are discussed in the frame of the global magnetic field variability.

1. Introduction

Intensity of the brightest emission line (Fe XIV 530.3 nm) of the optical solar corona is a very informative index of solar activity, as it strongly depends on the temperature and density of the coronal plasma, both the parameters being modulated by solar magnetic fields. The emissivity of the so-called green line peaks at a temperature of around 2×10^6 K, making it a useful tracer of large scale structures in both the active and the quiet corona (outside of coronal holes, which were first identified for their lack of green line emission). Nowadays, quite a long set of systematic measurements of the coronal green line brightness (CGLB) is available, covering more than five solar cycles (1943-2001). The patrol coronographic measurements, regularly carried out by a small worldwide network of observatories were synthesized to create the photometrically homogeneous database of the Fe XIV 530.3 nm coronal emission line intensities (Sýkora 1994; Storini & Sýkora 1997; Badalyan et al. 2004). Data, obtained from Dr. J. Sýkora courtesy, consist of daily intensities in steps of 5° in the solar latitude, at the central meridian (CM) location. They were derived as an average of intensities measured 7 days before and 7 days later, i.e. as an average of values when the proper meridian passed the E and W limbs, correspondingly.

2. Data Analysis

We investigated the cyclic variations and evolution of the CGLB: the wavelet analysis

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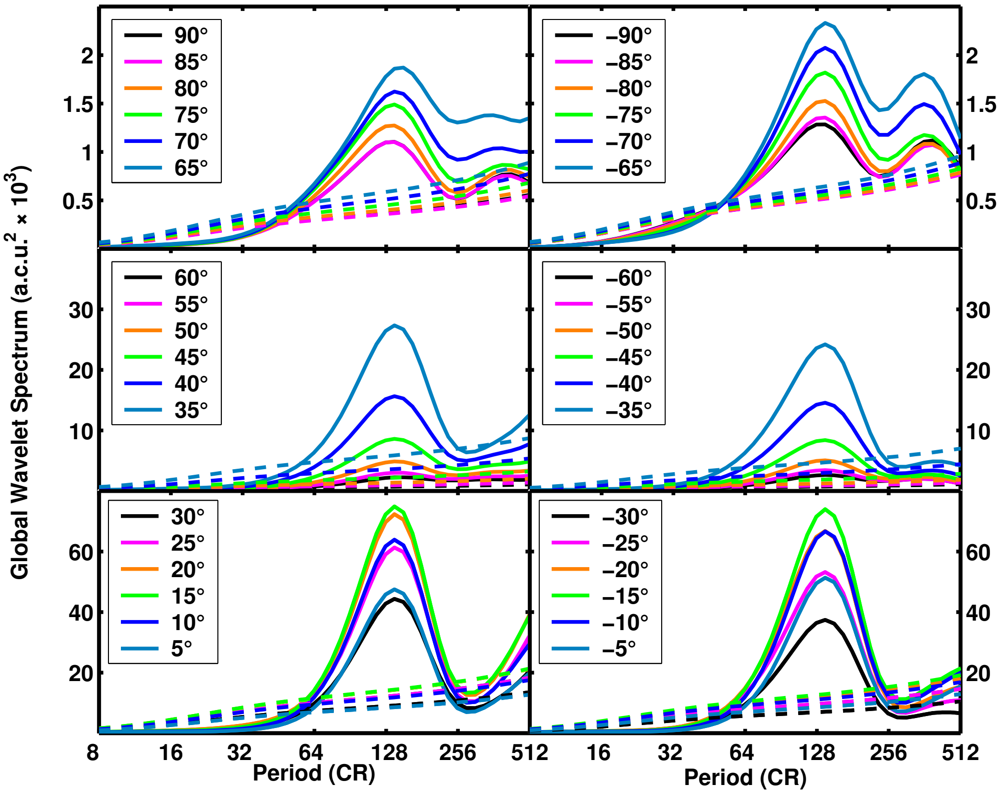

Fig. 1. Global Wavelet Spectrum for CGLB data at different heoligraphic latitudes.

(Torrence & Compo 1998) was performed for all the available solar latitudes, after averaging the data over each Carrington Rotation (CR). The mother wavelet used is the DOG (m=2) one, because it has a much smaller cone of influence and hence it is more suitable to detect an eventual 22-y periodicity in our data set. We chose a red noise background spectrum and a confidence level of 95 % for the wavelet peaks. Figure 1 shows the global wavelet power spectrum (solid lines) and its background level (dashed lines) for each latitude considered. A first peak is clearly distinguished above the noise at the period of $\sim$ 11 y for all latitudes, although the power at middle and low latitudes is greater than that at high latitudes of about an order of magnitude. We also performed a Fast Fourier transform to have a better estimation of the periodicity related to the solar cycle. It resulted to be 10.93 y. A second peak is found at $\sim$ 26 y, but its overall importance is different at different latitudes: it is significant over the whole period only at latitudes $> +55°$ and $<$ -50°, being more pronounced in the Southern hemisphere. We also determined the localized variation in time of the solar cycle periodicity. Figure 2 shows the ratio of the wavelet power spectrum to the noise for the 11-y period vs. latitude and time. As the DOG wavelet captures both positive and negative oscillations of a time series as separates peaks in the wavelet power, we can see strong power both in solar cycle maximum and mimimum phases. We found that the periodicity is always present at middle latitudes, although it is strongest in cycle 21, i.e. the solar cycle is always well manifested. A N-S asymmetry exists in the period 1943-1970: the 11-y is always not relevant between +50° and +90°. Instead, in the Southern hemisphere it is absent at high latitudes only

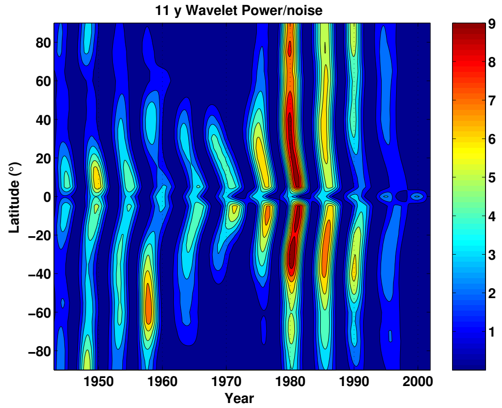

Fig. 2. Wavelet power to noise of the CGLB 11 y periodicity vs. solar latitude and time.

during solar cycle 20. Moreover, the 11-y cycle is more or less simultaneous at all the latitudes where it is effective. We also compared the wavelet power at -30° and +30° to the ones computed for sunspot area in the Southern and Northern hemisphere, respectively. They have a general good phase coherence in the Northern hemisphere, except for solar cycle 20 and 21, as noted by Sýkora and Rybák (private communication, 2004). As the observed high latitude enhancements in CGLB (Rybanský et al. 2003) are attributed to the poleward concentration of the large scale photospheric field (Wang et al. 1997), we performed the same wavelet analysis to the photospheric magnetic field (PMF) data recorded by NSO/Kitt Peak since 1976. We obtained a significant 22-y periodicity. In particular at low and middle latitudes it peaks in the maximum phases of solar cycles 21 and 22. At high latitudes it has strong peaks in the decreasing phases of the cycles 21 and 22 when the CGLB is not modulated. This can be related to the fact that solar polar regions are mostly occupied by polar coronal holes, the density and temperature of which are not enough favourable for the generation of the CGLB.

3. Conclusions

We found a persistence of the 11-y cycle of CGLB at low and middle latitudes over the whole period considered, related to the active regions variability and a phase coherence with the sunspot area 11-y periodicity particularly in the northern hemisphere. Instead, the 11-y cyclicity at high latitudes is intermittent and non symmetric for the two hemispheres. The ~ 22-y periodicity is very significant in the PMF data at all latitudes, while for CGLB at high latitudes much of the wavelet power is shifted to a ~ 26-y periodicity with a clear North - South asymmetry. Our results confirms that the low and middle latitude CGLB is well connected with photospheric active regions and their 11-y variation, while the CGLB behavior at high latitudes is less clear because of the interplay of local, large-scale and global fields.

Acknowledgements. NSO/Kitt Peak data used here are produced cooperatively by NSF/NOAO, NASA/GSFC, and NOAA/SEL. Sunspot area data are from http://science.nasa.gov/ssl/pad/solar/greenwch.htm. Thanks are due to the C. Torrence & G. Compo for the wavelet software (http://paos.colorado.edu/reseach/wavelets/).
M. L. thanks a Ph. D. fellowship from La Sapienza University.

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