SHORT-TERM PERIODICITIES IN THE FLARE INDEX BETWEEN THE YEARS 1966-2001

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ABSTRACT

A brief description and the results of the temporal variability of the flare index over the epoch of almost 4 cycles (1966-2001) are presented. Using Fourier and wavelet transforms the short-term periodicities in the daily flare index data for the total surface of the Sun are presented. A significant variability was found for all periods. The wavelet transform results show that the occurrence of flare index power is highly intermittent in time.

1. INTRODUCTION

There is no doubt, at present, that solar activity dominates the entire heliosphere and may be expressed with many indices, e.g., the Wolf number (sunspot), 10.7 cm radio flux, coronal index, and various other indices covering practically the whole range of the electromagnetic spectrum. Images of the Sun show that solar flares are one of the most powerful and explosive of all forms of solar activity. The long-term evolution of solar activity, on time scales of the solar cycles and beyond, has been studied from different perspectives using a variety of short and long-term solar activity indicators. In this study the amplitude and periodicity of the solar flare index (FI) variability are examined using the data for almost 35.5 years for the total surface of the Sun. To estimate short-term periodicities the discrete Fourier transform (FT) and the wavelet transform (WT) were applied to the time series of flare index. Detailed version of this paper to be published elsewhere.

2. FLARE INDEX DATA SET

In this paper, we have considered the FI for the period data from January 1, 1966 to July 1, 2001 (total 12965 days). The quantitative flare index, $Q = i\ t$, may be roughly proportional to the total energy emitted by the flare [1]. In this relation, *i* represents the intensity scale of importance of a flare in H and *t* the duration in H (in minutes) of the flare. Table 1 lists values of *i* used for the determination of *Q*. The daily sums of the index for the total surface are divided by the total time of observation of that day. Because the time coverage of flare observations is not always complete during a day (sometimes 75% or 90%), it is corrected by dividing by the total time of observations of that day to place the daily sum of the flare index on a common 24-hour period. The daily total time of observation is calculated from Solar Geophysical Data Comprehensive Reports. Calculated values are available for general use in anonymous ftp servers of our observatory[1] and NGDC[2]. This data set constitutes almost 35.5 years and is used by several authors [2][3][4][5].

Table 1. Values of i used for the determination of Q.

Importance	i	Importance	i
SF, SN, SB	0.5	2B	2.5
1F, 1N	1.0	3F, 3N, 4F	3.0
1B	1.5	3B, 4N	3.5
2F, 2N	2.0	4B	4.0

3. METHODS

3.1. Discrete Fourier transform

We employed the discrete Fourier transform to estimate the short-term periodicities in the FI time series. This technique provides which periodicities are in operation during the studied period, which covers about 12965 days. We examined the FI time series, which are for the total surface of the Sun by computing the periodograms after tapering 5% of the data at the ends of the time intervals by applying a split bell cosine window [6].

3.2. Wavelet analysis

The wavelet transform (WT) analysis yields information in both time and frequency domains (e.g.,[7], [8]). Therefore we have also applied wavelet analysis to the time series of FI to study the temporal variation of periods. Algorithm of the continuous wavelet transform was applied within the period range 8 - 41 days[9]. The Morlet wavelet, a plane sine wave with an amplitude windowed in time by a Gaussian function, has been selected to search for variability at different frequencies over the whole length of the time series.

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[1] ftp://ftp.koeri.boun.edu.tr/pub/astronomy/flare_index
[2] ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA /SOLAR_FLARES/INDEX

Fig. 1. Normalized power spectrum for time interval of 12950 days and for period interval of 8 – 40 days. The dashed lines indicate the false-alarm probability levels [10].

The non-dimensional frequency has been set to 6 fixing the length of all wavelets according to their scale. The significance level of the calculated WT power was derived using the null hypothesis assuming existence of the global power spectrum [9]. The 95% confidence level, used in this study, implies that 5% of the wavelet power should be above this level for each period. Following this way the plots of wavelet power spectrum was prepared for the period range for data series of FI.

4. RESULTS

We tried to show the temporal variations of the flare index along the years, which we studied around the rotation period (8 - 40 days). Fig. 1 shows the normalized power spectrum of the time series for the period interval of 8 - 40 days. For this figure the power spectrum were calculated for the 289 - 1447 nHz range with 5.79 nHz intervals. There are several significant peaks in this figure whose statistical significances are enough high.

The most prominent period is the 27.0-day peak in the

power spectrum of the total surface of the Sun which corresponds to the rotational period. The second ones are the 29.1-day and 25.3-day peaks whose significance levels are around 10 % of the false-alarm probability level [10].

The FI power of WT is highly intermittent in time for the data set. Additionally different pulses of the enhanced power appear for the quite different values of the period around the common rotation period of the Sun. No special localization of the pulses has been found according to the solar cycle except their absence during solar minima.

In conclusion, comparing the FT and WT results on the FI short-term periodicities one can see that the quite different periods obtained by the FT for the FI data set are caused by just one or only few pulses of power of that particular period over the whole time interval under study. Therefore the FT results on the short-term periodicities of the FI should be reconsidered in the series of the case studies of the evolution and peculiarities of different active regions (active longitudes or nests of the active regions) as these

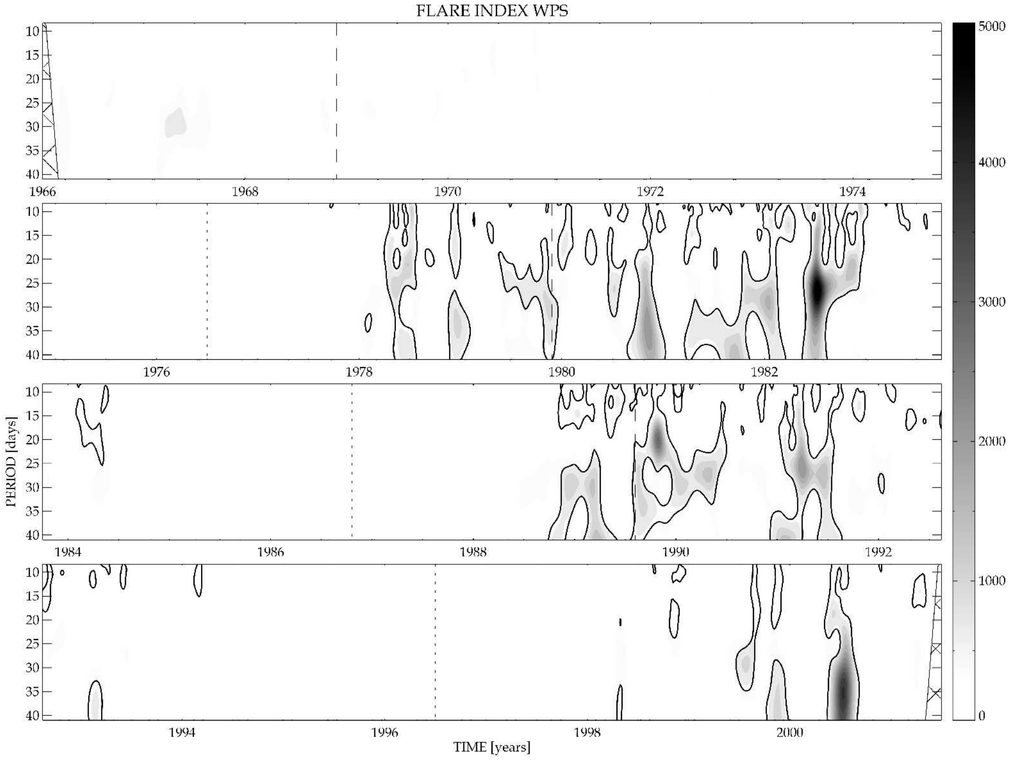

Fig. 2. The wavelet power spectra of the FI time series for the period range 8 - 41 days. Grey-scale coding of power from white to black represents the square root of power in a linear scale given on the right side bar. The solid curve shows the 95 % confidence levels of the local power above the noise level assuming noise independence on periods. The cone of incidence is marked by the cross-hatched regions. Dashed and dotted vertical lines mark the solar activity cycle maxima and minima according to the Wolf's sunspot index respectively.

periodicities seems to be quite localized in time and not valid for the FI over the whole solar cycle length.

ACKNOWLEDGMENTS

The wavelet transform algorithm of C. Torrence and G. P. Compo, available at http://paos.colorado.edu research/wavelets/ has been used in this work. One of the authors (A. Ö) is very thankful to the organizers of the International Solar Cycle Studies 2003 Symposium for providing financial support. This work was supported by Boğaziçi University Research Fund by the project of 00T101 and by the Slovak grant agency VEGA (2/3015/23). J.R. is member of the European Solar Magnetism Network (ESMN) supported by the EC through the RTN programme.

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