Coronal index modulation by solar magnetic field

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Abstract

Monthly mean values of the coronal index of solar activity and other solar indices are analyzed for the period 1965-1997 covering over three solar cycles. The coronal index is based upon the total irradiance of the coronal 530.3nm green line from observations at five stations. The significant correlation of this index with the sunspot number and the number of the grouped solar flares has led to an analytical expression. This expression is well explaining the existence of the secondary maximum during the solar cycles taking into account the evolution of the coronal magnetic field that can be expressed by a sinusoidal term with a 6-year period. The accuracy between observed and calculated values of the coronal index is high enough and reaches the value of 92%. We can conclude that the solar magnetic field modulates the coronal intensity and the coronal index can be used as a representative index of solar activity in order to be correlated with different periodical solar or terrestrial phenomena useful for Space Weather studies.

1 Introduction

As the origin of solar activity is one of the basic problems of solar physics, it is not clear which index is best suited to help us to understand the physics of the solar cycle and to study solar-terrestrial relations, as each of them has its own advantages and disadvantages. Rybansky (1975) proposed a coronal index (CI) as a general index of solar activity. This is a full disk index and represents the averaged daily power (irradiance) emitted by the green corona (530.3nm) into one steradian towards the Earth. The input data for the coronal index computation are ground-based data obtained at different observatories with coronal measurements around the world (Rybansky et al., 1996; Altrock et al., 1999). The existence of two maxima in the solar activity parameters during an 11-year cycle was first shown by Gnevyshev (1977). Coronal index data presents two maxima in each 11-year cycle in contrary to the sunspot number, where it seems to exist only one distinct maximum.

In this work we try to find out an empirical relation for the green line intensity expressed by the coronal index of solar activity using the most appropriate independent parameters of solar activity, such as sunspot number R and grouped solar flares NF, on monthly basis. The residuals between the observed and calculated values of the coronal index, which appear in the solar cycle maxima, can be explained, in our model, by the contribution of the solar magnetic field in connection with its polarity reversals.

2 Data analysis

The coronal index of solar activity (CI) presents the total energy emitted by the Sun's outermost atmosphere (the E-corona) at the wavelength of 530.3nm (Fe XIV, the green corona). It is expressed in 10^{16} W sr^{-1} or $4.5x10^{-7}$ W m^{-2} or $1.2x10^{8}$

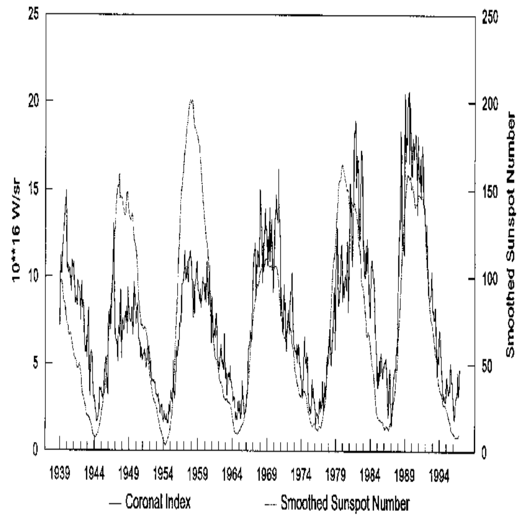

Figure 1: Monthly values of the coronal index of solar activity and smoothed sunspot number for the cycles 20, 21, 22.

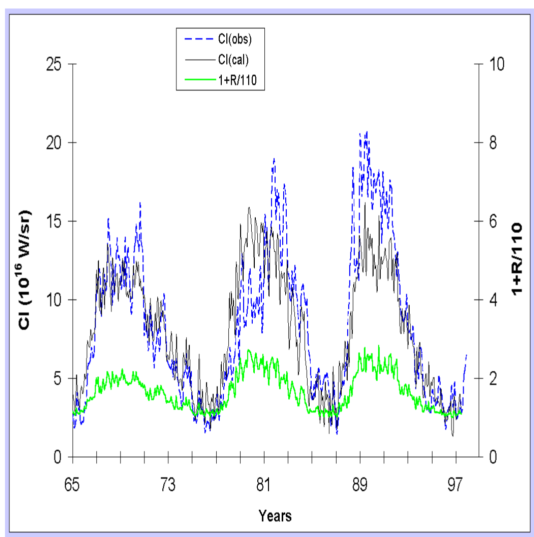

Figure 2: Observed (Clobs) and calculated (Clcal) by the equation (2) values of the coronal index of solar activity are presented. The term 1+R/110 is also illustrated.

photons $cm^{-2}s^{-1}$ at the Earth (Rybansky et al., 1996). Monthly values of the coronal index of solar activity used in the present analysis have been obtained from the NOAA NGDC website (http://www.ngdc.noaa.gov/stp). Time distribution of monthly mean values of the coronal index and smoothed sunspot number for the period 1939-1997 is appeared in Fig.1. Correlative analysis between coronal index values and sunspot number as well as between coronal index and grouped solar flares show that the coronal index is better correlated with $\sqrt{R}$ and $\sqrt{R \cdot N_f}$. This is an evidence to use the term $\sqrt{R}$ and not R for the calculation of the coronal index. This is also obtained theoretically from the definition of the area index Ia(R) by Xanthakis and Poulakos (1978) and Polygiannakis et al. 1996.

3 Empirical formulation

In order to estimate the green line emission measured at the Pic- du-Midi Observatory for the time period 1946-1972, Leroy and Trellis (1974)gave the following

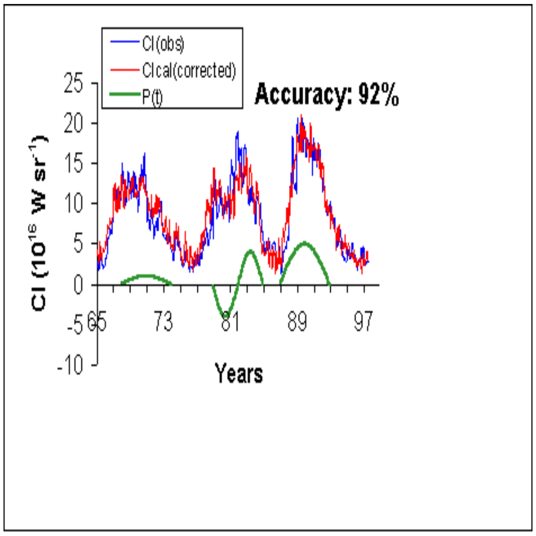

Figure 3: Observed (Clobs) and calculated (Clcal) values of the coronal index taking into account the solar magnetic field. P(t) terms are also indicated.

empirical relation with respect to the sunspot number:

$$I_{5303} = (1 + \frac{R}{110})28 \cdot 10^{-8} I_0 \quad (1)$$

where I_0 is the solar constant and R the sunspot number In this work using monthly data of the coronal index, we try to give a more representative expression for the calculation of the green line intensity over the three last solar cycles. Taking into account the correlation expressions, we can find the following empirical relation for the coronal index

$$CI_{cal} = 0.78 + 0.63(1 + 0.24\sqrt{N_f})\sqrt{R} \quad (2)$$

Calculating the coronal index by this expression we have an accuracy of $(85.0 \pm 2.0)\%$ between observed (CI_{0bs}) and calculated (CI_{cal}) values, as we can see in Figure 2. In the same figure the values obtained from the expression (1) are also indicated. During the solar maxima the residuals CI between observed (CI_{obs}) and calculated (CI_{cal}) values of the coronal index of solar activity seem to follow the behahiour of the solar magnetic field. The introduction of a new sinusoidal term P(t) in our relation is necessary. So, if we take into consideration the magnetic field, a corrected formula for the calculation of the coronal index can be given.

$$P(t) = +1sin(\frac{\pi}{72})t, t = 0, 1, ..., 72 \;\; (1968 - 1974) \quad (3)$$

$$P(t) = -4sin(\frac{\pi}{36})t, t = 0, 1, ..., 36 \;\; (1978 - 1981) \quad (4)$$

$$P(t) = +4sin(\frac{\pi}{36})t, t = 0, 1, ..., 36 \;\; (1981 - 1984) \quad (5)$$

$$P(t) = +5sin(\frac{\pi}{72})t, t = 0, 1, ..., 72 \;\; (1987 - 1993) \quad (6)$$

The above empirical relation has been theoretically interpreted as in a previous work by Mavromichalaki et al. (2001).

4 Conclusions

The coronal index belongs to the class of ground-based indices used to study solar activity and its influence on the heliosphere. Comparative studies have shown relatively good agreement with similar solar indices (Rybansky et al., 2001). The coronal index is inferred from a homogeneous coronal data set using several coronal stations. Gnevyshev (1977) proved that the two maxima in the 11-year cycle of solar activity are very different events and not two simple fluctuations. As the physical conditions during the two maxima are very different, the theory and forecasting of solar activity, investigations of solar-terrestrial relations and investigations of individual solar events must be taken into account, in order to determine the features of the 11-year cycle. In this work a relation between the coronal index, the sunspot number and the grouped solar flares has been found. This relation gives a physical meaning of the coronal index of solar activity and can be used in order to verify the reliability of the coronal index measurements. It can be also used in order to reproduce the coronal index values with a very good approximation and to predict the maxima of next cycles, if the modulation of the solar magnetic field is known. The secondary maximum of the coronal index has been explained very well by the use of the number of solar flares, while the magnetic field intensity has given a better precision around the maxima of solar activity (Xanthakis et al., 1982)

Summarizing we can say that the coronal index of solar activity may give a better measure of solar-terrestrial effects than sunspots, because it can be modulated by both solar flares and sunspots, as well as by the magnetic field. All these parameters are very important for Space Weather studies. The results of these studies may be improved using this index, instead of the green line intensity, as it is derived from more than one station. Further investigation for the next solar cycles could improve our understanding about this modulation and its related physical processes.

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