AN EMPIRICAL MODEL OF THE DAILY EVOLUTION OF THE CORONAL INDEX

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Abstract. Global changes of the solar activity can be expressed by the coronal index that is based upon the total irradiance of the coronal 530.3 nm green line from observations at five stations. Daily mean values of the coronal index of solar activity and other well-correlated solar indices are analyzed for the period 1966–1998 covering over three solar cycles. The significant correlation of this index with the sunspot number and the solar flare index have led to an analytical expression which can reproduce the coronal index of solar activity as a function of these parameters. This expression explains well the existence of the two maxima during the solar cycles taking into account the evolution of the magnetic field that can be expressed by some sinusoidal terms during solar maxima and minima. The accuracy between observed and calculated values of the coronal index on a daily basis reaches the value of 71%. It is concluded that the representative character of the coronal index is preserved even when using daily data and can therefore allow us to study long-term, intermediate and short-term variations for the Sun as a star, in association with different periodical solar–terrestrial phenomena useful for space weather studies.

1. Introduction

As is known, solar activity can be expressed by many indices, such as the Wolf number, the 2800 MHz radio flux, X-ray and EUV indices, cosmic-ray flux, etc. Individual indices represent specific physical conditions on the Sun. According to many authors (e.g., Rybanský, Rušin, and Minarovjech, 2001), it is not clear yet which index is best suited to help us to understand the physics of the solar cycles and to study solar–terrestrial relations. We refer the reader to a recent review by Parker (2001) for a full and comprehensive discussion of our present knowledge about solar activity.

Gnevyshev (1967, 1977) stated that solar activity parameters show the existence of two maxima during an 11-year cycle. Coronal index data also present two maxima in each 11-year cycle contrary to the sunspot number R, which is a common tracker of solar activity, which exhibits only one distinct maximum. A theoretical relation for the green-line intensity I_{5303}, the areas index $I_a(R)$ (Xanthakis, 1969),

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the number of proton events and the evolution of the coronal magnetic field for the time interval of the 19th and 20th cycles has been given by Xanthakis, Petropoulos, and Mavromichalaki (1982) explaining satisfactorily the evolution and the secondary maximum of the green-line intensity.

Xanthakis, Petropoulos, and Mavromichalaki (1990) investigating the time interval 1964–1974 attempted to define the intensity of the coronal green line as an integrated index of solar activity which reflects photospheric activity in the solar corona.

However, Rybanský (1975) proposed a general index of solar activity named coronal index (CI), which represents the averaged daily power (irradiance) emitted by the green corona (Fe XIV, 530.3 nm line) into 1 steradian towards the Earth. The input data for the computation of the coronal index is ground based observations (around the solar limb) of the 530.3 nm line obtained at different coronal stations around the world. This index belongs to the indices characterizing the coronal activity of the Sun 'as a star'. Prediction of the exact time of solar-cycle maximum is a matter of disagreement among solar scientists and of some importance to satellite operators, space-system designers, etc. Most predictions are based on physical conditions occurring at or before the long-term minimum of activity preceding the maximum in question. However, another indicator of the timing of the maximum occurs early in the rise phase of the solar activity cycle. A study of the variation over two previous solar cycles of coronal emission features in Fe XIV from the National Solar Observatory at Sacramento Peak has shown that, prior to solar maximum, emission features appear near 55 deg latitude in both hemispheres and begin to move towards the poles at a rate of 9 to 13 deg of latitude per year (Altrock, 2002). This motion is maintained for a period of 3 or 4 years, at which time the emission features disappear near the poles. This phenomenon has been referred to as the 'Rush to the Poles'. These observations show that the maximum of solar activity, as seen in the sunspot number, occurs approximately 15 ± 1 months before the features reach the poles. In 1997, Fe XIV emission features appeared near 55 deg latitude, and began to move towards the poles. Rušin and Rybanský (2002), using the above historical data from cycles 21 and 22, have shown how the use of progressively more data from cycle 23 affects the prediction of the time of solar maximum.

A better reason to develop a new index of solar activity is that it might prove to be a better measure of solar–terrestrial effects than, say, sunspots because it is the 'home' of coronal holes and coronal mass ejections, both of which are known to be important for space weather. Also a long-term coronal index is a better indicator of the physics of the corona than the 2800 MHz radio flux and the sunspot indices that reveal more about conditions in the lower atmosphere.

Recently, Mavromichalaki, Petropoulos, and Zouganelis (2002) expressed the coronal index of solar activity using the most appropriate independent parameters of solar activity, such as sunspot number and grouped solar flares on monthly basis for the time period 1965–1997. The contribution of the solar magnetic field in connection with its polarity reversals explained discrepancies between observed and calculated values that appear during the solar cycle maxima.

In this work, an analytical relation between daily values of coronal index of solar activity and the number of sunspots and solar flare index is given in order to predict solar activity. This study has been performed in the interval 1 January 1966 –31 December 1998 covering over three solar cycles (20, 21, 22, and part of the 23), while it is applied during each solar cycle separately.

2. Data Analysis

High-resolution (daily) data of the coronal index of solar activity were used in the present analysis. They were obtained from the NOAA NGDC website (*http://www.ngdc.noaa.gov/stp*). 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 530.3 nm (Fe XIV, the green corona). It is expressed in 10^{16} W sr^{-1} or 4.5×10^{-7} W m^{-2} or 1.2×10^{8} photons cm^{-2} s^{-1} at the Earth (Rybanský *et al.*, 1994a).

The values of the coronal index are derived from ground-based observations of the corona made around the solar limb with a spacing of 5 deg. Before computing the coronal index, intensities from other coronal stations were converted to the same photometric scale of Lomnický Štít Coronal Station in the Slovak Republic. Differences in the height measurement above the solar limb and shifts in positional angles were removed. Numerical values of the 530.3 nm irradiance are in W sr^{-1} units, with the basic intensity obtained at 40$''$ above the solar limb. The method of computation and final results have been published by Rybanský (1975) and Rybanský *et al.* (1996). Homogeneous coronal data sets are used for calculating the coronal index of solar activity (Rybanský *et al.*, 1994a; Altrock *et al.*, 1999). Several coronal stations such as Sacramento Peak, Arosa, Pic du Midi, Kislovodsk, etc., were used in this database with Lomnický Štít being the reference station from 1965 (Rybanský *et al.*, 1994b). The coronal index presents important advantages that make it a representative index of the solar activity (Rybanský *et al.*, 1994a; Rybanský, Rušin, and Minarovjech, 2001).

Daily values of the solar flare index for the full disk of the Sun were also used in the present work. The flare index (FI) is the total energy emitted by flares given by the quantity $Q = it$, where i represents the intensity scale of importance and t the duration (in minutes) of the flare (Ozguç and Ataç, 1994). Solar magnetic field data were obtained from the Wilcox Solar Observatory website of the Stanford University (*http://quake.stanford.edu/ wso/wso.html*).

Time distributions of daily values of the sunspot number, the flare index, the solar magnetic field and the coronal index for the cycles 20, 21, and 22 are shown in Figure 1. The highest values of the coronal index are observed in cycle 22 and continuously grew from cycle 18 as is noted by Rybanský *et al.* (1996). The

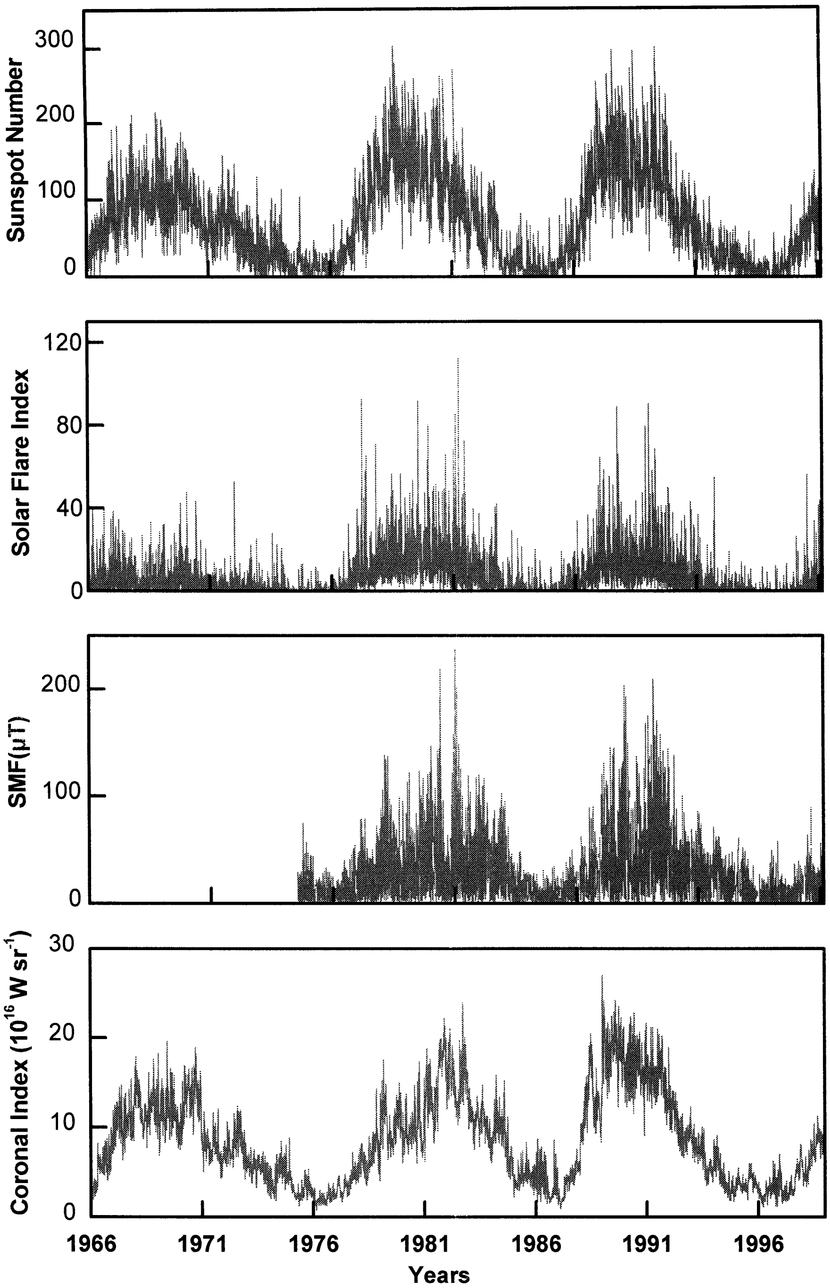

Figure 1. Daily values of sunspot number, flare index, solar magnetic field and coronal index for the time period 1966–1998.

TABLE I

Correlation coefficients of all parameters used in this work.

	20	21	22	Total
R	0.77 ± 0.02	0.62 ± 0.04	0.85 ± 0.03	0.76 ± 0.03
$\sqrt{R}$	0.77 ± 0.02	0.66 ± 0.03	0.85 ± 0.03	0.76 ± 0.03
FI	0.35 ± 0.04	0.45 ± 0.04	0.62 ± 0.05	0.51 ± 0.04
$\sqrt{FI}$	0.48 ± 0.03	0.56 ± 0.04	0.74 ± 0.04	0.62 ± 0.04
$\sqrt{RFI}$	0.58 ± 0.03	0.57 ± 0.04	0.78 ± 0.04	0.66 ± 0.04

peak value in the odd cycle (21st) is higher than that obtained in the previous one according to the well-known Gnevyshev/Ohl rule (Gnevyshev and Ohl, 1948).

Daily sunspot number values present only one distinct maximum as it is outlined from Figure 1. The first coronal index maximum is in coincidence with the sunspot number during the cycles, while the second one is observed nearly two years after the sunspot number maximum (Gnevyshev, 1977). Rušin, Rybanský, and Scheirich (1979) showed that the first maximum can be observed at the heliographic latitudes of around $\pm 25°$ and almost in coincidence with the occurrence of the Wolf number maximum. The second maximum of coronal intensities is observed at heliographic latitudes around $\pm 10°$ and appears 2–3 years after the occurrence of the first one in the corona. It is consistent with the polarity reversals of the solar magnetic field occurring 2–3 years after the sunspot maximum (Mavromichalaki, Belehaki, and Rafios, 1998). Kopecký and Kotrč (1974) investigated the contribution between the two maxima in sunspots and calculated that the first maximum is that of sunspot number and the second one is the maximum of their sizes. A theoretical explanation of the problem of the two maxima is presented by Yoshimura (1977) in connection with the development of the general magnetic field of the Sun.

In this work correlative statistical analysis between coronal index values and sunspot number as well as between coronal index and flare index has been performed. All the correlation coefficients are presented in Table I. As an example, the scatter diagrams of the coronal index with $\sqrt{R}$ and $\sqrt{RFI}$ are given in Figure 2. As in our previous work, (Mavromichalaki, Petropoulos and Zouganelis, 2002) where monthly data have been studied, the terms $\sqrt{R}$ and $\sqrt{RFI}$ are best suited for the calculation of the coronal index (Xanthakis and Poulakos, 1978; Polygiannakis, Moussas, and Sonnet, 1996). Note that the use of other terms (different powers of R and FI) and additional constants might increase the precision of the calculation of the coronal index. Nevertheless, these additional terms would not be directly associated with the theoretical explanation given in Section 4.

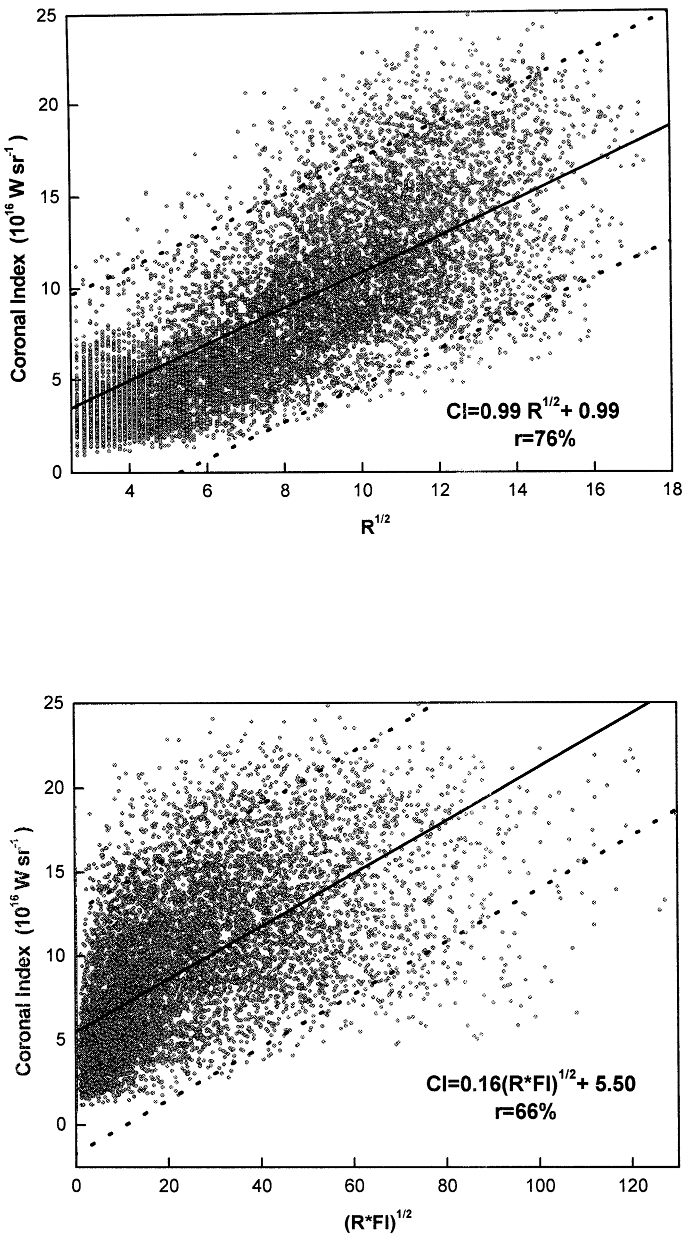

Figure 2. Scatter diagrams of the coronal index with $\sqrt{R}$ and $\sqrt{RFI}$ are given. In each panel, 95% of the points are included between the *dashed lines.*

3. Empirical Formulation

In a previous work Xanthakis, Petropoulos, and Mavromichalaki (1982) found a relation for the green-line intensity for the cycles 19 and 20 with respect to the number of proton events and the index $I_a(R)$ introduced by Xanthakis and Poulakos (1978) using data from the Pic-du-Midi Observatory on a semi-annual basis. The use of the number of proton events has given an explanation of the secondary maximum of these cycles. The addition of a sinusoidal term $P(t)$ related to the solar magnetic field has improved the accuracy of this computation.

In a recent work, Mavromichalaki, Petropoulos, and Zouganelis (2002) tried to give a more representative expression for the calculation of the green line intensity over the three last solar cycles, using monthly data of the coronal index. In the present work, using high-resolution data (daily values) and taking into account the correlation expressions we found the following empirical relation for the daily values of the coronal index:

$$CI = 3.06 + 0.53\left(1 + 0.14\sqrt{FI}\right)\sqrt{R}. \tag{1}$$

Calculating the coronal index by this expression we have an accuracy of (62.0 ± 0.3)% between observed (CI_{obs}) and calculated (CI_{cal}) values, for the time interval 1966–1998. Moreover the accuracy that is calculated after applying this relation in each cycle separately is relatively better in the case of the even cycles 20 and 22 than in cycle 21 (Table II). It is well known that cycle 21 is characterized by a large number of strong flares. The differences between observed and calculated by Equation (1) values of the coronal index are given in the upper panel of Figure 3. This time series seems to be correlated well with the magnetic field (Figure 1). Some sinusoidal terms are apparent during the different phases of the solar cycles. Inserting some $P(t)$ terms during the maxima and $M(t)$ terms during the minima of the solar cycles, a corrected equation for the coronal index is given:

$$CI = 3.06 + 0.53\left(1 + 0.14\sqrt{FI}\right)\sqrt{R} + \Pi(t), \tag{2}$$

where $\Pi(t)$ is the sum of some sinusoidal terms $P(t)$ and $M(t)$:

$$P(t) = \begin{cases} +1\ \sin\left(\dfrac{\pi}{72}\right)t, & t = 0, 1, \ldots, 72 \quad (1968\text{–}1974), \\ -4\ \sin\left(\dfrac{\pi}{36}\right)t, & t = 0, 1, \ldots, 36 \quad (1978\text{–}1981), \\ +4\ \sin\left(\dfrac{\pi}{36}\right)t, & t = 0, 1, \ldots, 36 \quad (1981\text{–}1984), \\ +4.5\ \sin\left(\dfrac{\pi}{60}\right)t, & t = 0, 1, \ldots, 60 \quad (1988\text{–}1993); \end{cases} \tag{3.1}$$

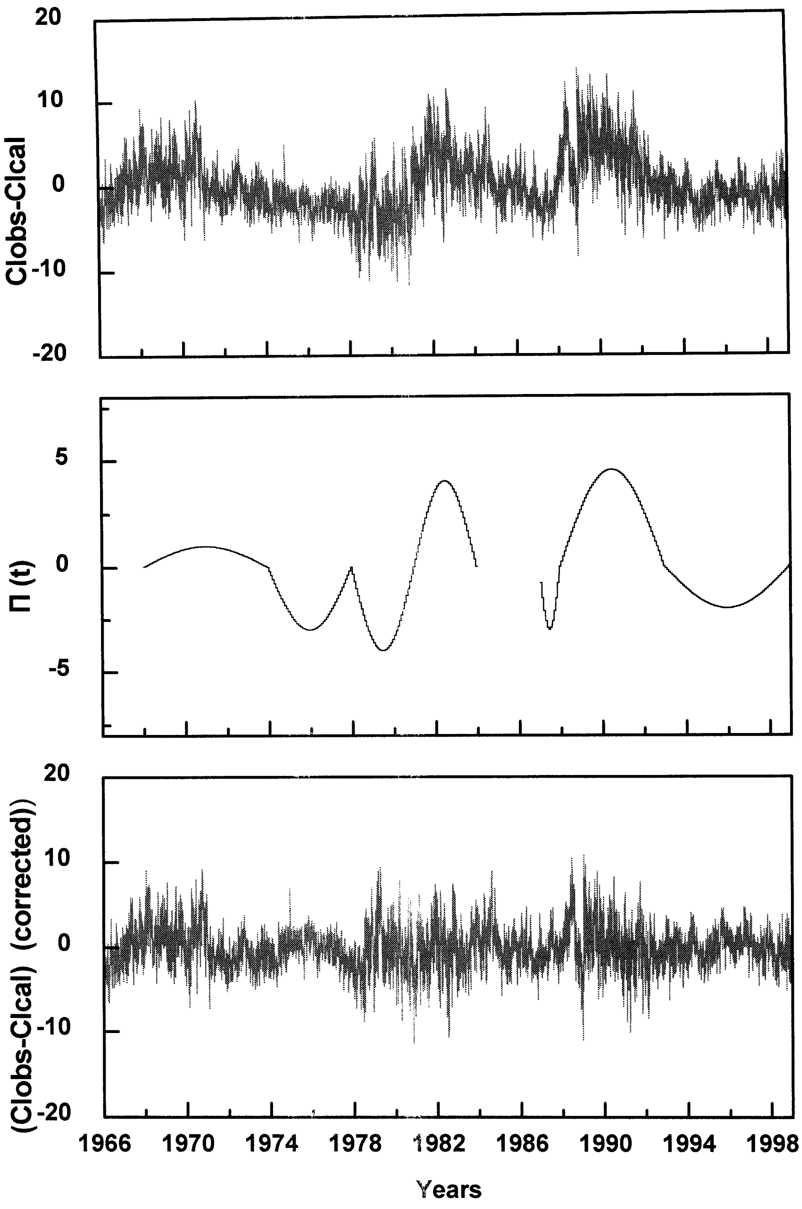

Figure 3. The residuals between observed CI_{obs} and calculated CI_{cal} by the Equation (1) values (*upper panel*) and by Equation (2) ones (*lower panel*) are presented. The $\Pi(t)$ terms are given in the *middle panel* as well.

TABLE II

Standard deviation (σ) and accuracy (A) obtained from our calculations for each cycle separately and for the total time span as well.

Cycles	20	21	22	Total
Without $\Pi(t)$				
σ	0.003	0.003	0.003	0.003
A	68%	61%	65%	62%
Corrected with $\Pi(t)$				
σ	0.002	0.003	0.002	0.002
A	71%	69%	75%	71%

$$M(t) = \begin{cases} -3\ \sin\left(\frac{\pi}{48}\right)t, & t = 0, 1, \ldots, 48 \quad (1974\text{–}1978) \\ -3\ \sin\left(\frac{\pi}{12}\right)t, & t = 0, 1, \ldots, 12 \quad (1987\text{–}1988), \\ -2\ \sin\left(\frac{\pi}{72}\right)t, & t = 0, 1, \ldots, 72 \quad (1993\text{–}1999). \end{cases} \tag{3.2}$$

The $\Pi(t)$ terms are presented graphically in the middle panel of Figure 3. The residuals between observed and calculated values by Equation (2), i.e., after correction with the $\Pi(t)$ terms, are presented in the lower panel of Figure 3.

The observed values of the coronal index (CI_{obs}) and the calculated by Equation (2) ones (CI_{cal}) for all time interval 1 January 1966–31 December 1998 are given in Figure 4. It is obvious that there is a good agreement between observed and calculated values of the coronal index of the solar activity. The standard deviation and the corresponding accuracy of our calculations for each solar cycle separately and for the total time interval examined in this work are given in Table II. The mean accuracy of our calculations for all the examined period on a daily basis is 71%.

It is interesting to examine the behavior of these parameters considering alone the ascending and descending phases of cycles 21 and 22 in order to explain the $P(t)$ form. The mean annual behavior of the coronal index, the sunspot number and the flare index for cycles 21 and 22 is given in Figure 5. The derivatives in ascending and descending phases represent the mean speed at which a parameter attains its maximum or minimum value, respectively. Note that we use annual data in order to extract the fundamental behavior of these parameters and this plot is therefore shown for illustration purpose only.

One is able to see directly that the configuration is radically different between the two cycles. In the first case (the odd cycle 21), the flare index and the sunspot

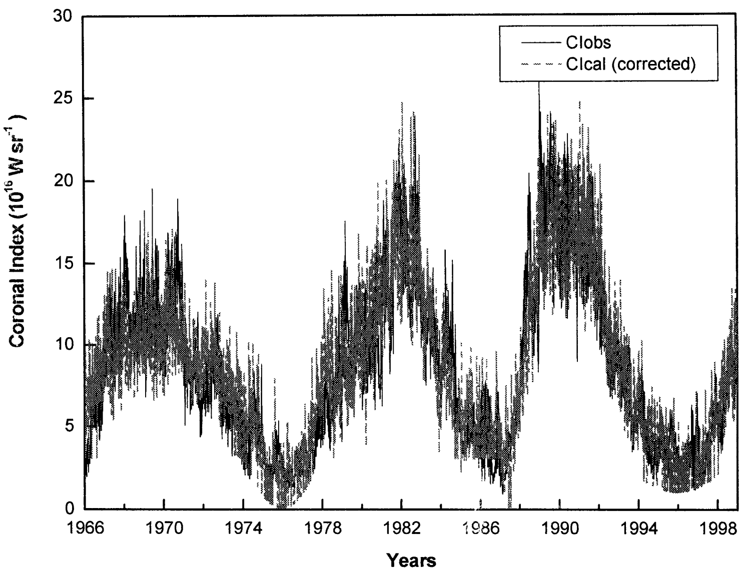

Figure 4. Daily observed (CI_{obs}) and calculated by Equation (2) values of the coronal index for the time interval 1966–1998 are presented.

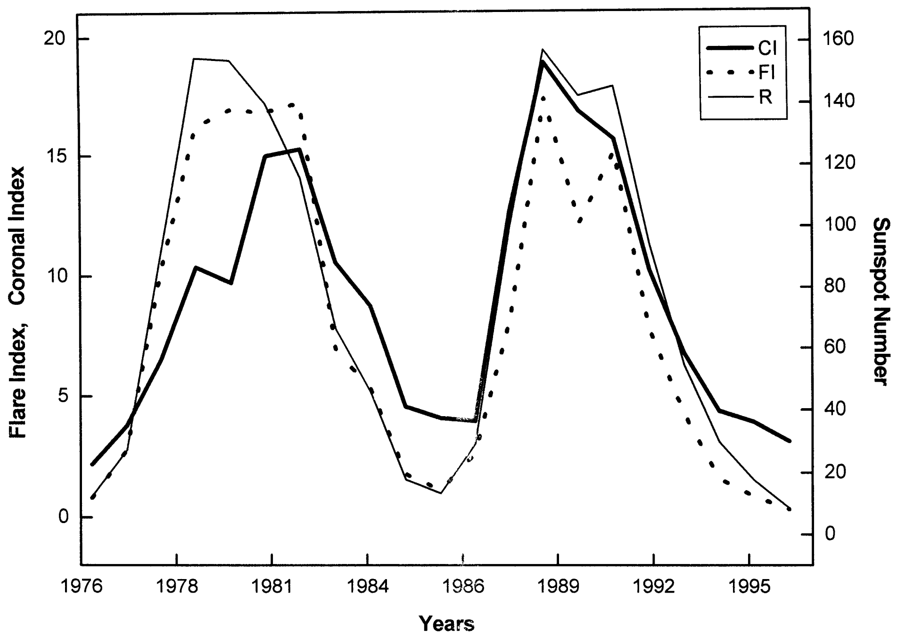

Figure 5. Annual values of the sunspot number, the flare index, and the coronal index for solar cycles 21 and 22.

number are growing more rapidly than the coronal index, reaching their maxima sooner. Therefore, in order to well reproduce the values of the coronal index using the two other parameters, a negative $P(t)$ term has to be taken into account, which will attenuate their relative preponderance. The opposite is happening in the ascending phase of the even cycle 22, where the coronal index growth rate is large enough (larger than the flare index growth rate), and therefore requiring an additional (positive) strengthening of the other two slower parameters. If we now examine the descending phases, the relative order of decreasing rate is the same in two cycles, with the coronal index being the slower parameter. A positive $P(t)$ term is needed in order to decelerate the coronal index calculated by the two faster parameters and that is common in two cycles. We can therefore see that the form of $P(t)$ terms is directly associated with the relative evolution rates of the used parameters during solar activity. These terms cannot be the same in two different cycles because of the inherent diversity of the ascending phase. This is a more general characteristic consistent with the existence of two maxima in coronal intensities and the polarity reversals of the magnetic field. We will return to this point in the next section.

4. Theoretical Interpretation

According to Leroy, Poulain, and Fort (1973) the following equation can be applied for the coronal index (CI):

$$CI = \int_{-\infty}^{+\infty} A(T_e) N_e^{1+\alpha} \, \mathrm{d}x, \tag{4}$$

where $A(T_e)$ is a contribution function of the electron temperature estimated theoretically as

$$A(T_e) = K_i T_e^{-1/2} e^{-W/kT_e} \frac{N_z}{N_0}, \tag{5}$$

where N_e is the local electron density, T_e the electron temperature, N_0 the total number of the atoms of the element, N_z the population of the upper level, W the transition energy, k the Boltzmann constant, and K_i, α constants with $0 \leq \alpha \leq 1$.

Taking into account $\alpha = 0.5$ (Dollfus, 1971) we express the function $A(T_e)$ as

$$A(T_e) = \sqrt{R} F(T_e), \tag{6}$$

where $F(T_e)$ is a function of the electron temperature obtained from Equation (5) (Mavromichalaki, Petropoulos, and Zouganelis, 2002).

Moreover, the electron density variation can be given by the relation $\Delta N_e = \overline{N}_e \sqrt{FI}$ (7) where $\overline{N}_e$ is the electron density in the corona of the quiet Sun.

The theoretical relation (4) of the coronal index was developed into a Taylor series and taking into account only the first three terms, it can be reproduced by the relation

$$CI = CI_0 + \sqrt{R} \int_{-\infty}^{+\infty} \Delta F(T_e) N_e^{3/2}\, \mathrm{d}x + 1.5\sqrt{R}\sqrt{N_F} \int_{-\infty}^{+\infty} F(T_e)\overline{N}_e \sqrt{N_e}\, \mathrm{d}x, \quad (8)$$

where $\Delta CI = CI - CI_0$ and CI_0 is the coronal index corresponding to the quiet solar corona.

In a recent work (Mavromichalaki, Petropoulos, and Zouganelis, 2002) this relation was verified very well for the monthly values of the coronal index of solar activity. Admitting this relation for the daily values of the coronal index of solar activity and identifying it with the empirical relation (1), we find that

$$CI_0 = 3.06, \quad (9)$$

$$\int_{-\infty}^{+\infty} \Delta F(T_e) N_e^{3/2}\, \mathrm{d}x = 0.53, \quad (10)$$

and

$$\int_{-\infty}^{+\infty} \overline{N}_e \sqrt{N_e} F(T_e)\, \mathrm{d}x = 0.05. \quad (11)$$

If we take into account all the Taylor series (Mavromichalaki, Petropoulos, and Zouganelis, 2002), we can introduce a periodic term $P(t)$ simulating the underlying magnetic field intensity B theoretically given by

$$P(t) = \left[\Delta B_{\theta,\phi} + \sum_{i=1}^{n} \Delta(A_i + S_i) \right] \sqrt{R} \int_{-\infty}^{+\infty} \frac{\mathrm{d}F(T_e)}{dB} N_e^{3/2}\, \mathrm{d}x, \quad (12)$$

where $B_{\theta,\varphi}$ is the toroidal component of the field, A_i are the axisymmetric with respect to the equator antisymmetric parts of the field (E–W asymmetry) and S_i are also axisymmetric but symmetric with respect to the equator (N–S asymmetry), and Δ designates the variation of each component in relation to its value in the period of low solar activity. From the above equation, it can be clearly seen that $P(t)$ is negligible for the periods around the solar minimum, which justifies the addition of $P(t)$ terms only in the maximum of the solar cycles. In the present work where daily values are taken into account, it is obvious from the data analysis that an additional term $M(t)$ is needed around the solar minima in order to achieve a better precision when reproducing the CI values. This additional term may not be explained by the presence of the magnetic field.

However, a general characteristic of the $P(t)$ terms is present in this work as is also reported by Mavromichalaki, Petropoulos, and Zouganelis (2002). These terms are different in odd and even cycles. In the odd cycle 21 a complete sinusoidal term has been considered, instead of a semi-periodical one in the even cycles 20 and 22. This is in agreement with the polarity reversals of the solar magnetic field occurring around the maxima. The difference between the odd and the even cycles can be explained by the transition from parallel to antiparallel states of the magnetic field with respect to the angular velocity of the rotation of the Sun (Page, 1995; Mavromichalaki, Belehaki, and Rafios, 1998). Storini and Sýkora (1995) have also noticed differences of the corona brightness in even and odd cycles.

5. Discussion and Conclusions

It is known that 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. The coronal index can be used to study, among other things, the rotation of the Sun as a star, and long-, intermediate-, and short-term periodicities. The coronal index is inferred from a homogeneous coronal data set that can be used to study such topics as the 2D distribution of the green corona, and the relationship between the green corona and cosmic rays (Rybanský, Rušin, and Minarovjech, 2001).

Most predictions of the exact time of solar-cycle maximum, being very important to the satellite operators and technological systems, are based on physical conditions occurring at or before the long-term minimum of activity preceding the maximum in question. The predictions of maximum sunspot number for solar cycle 23 were reviewed by Kane (2001) to see which ones proved to be reasonably accurate. A study of the variation over two previous solar cycles of coronal emission features in Fe XIV from the National Solar Observatory at Sacramento Peak has shown that, prior to solar maximum, emission features demonstrate the 'Rush to the Poles' phenomenon (Altrock, 2002). This motion is maintained for a period of 3 or 4 years, at which time the emission features disappear near the poles. In 1997, Fe XIV emission features appeared near 55 deg latitude, and began to move towards the poles. Rušin and Rybanský (2002) using the above historical data from cycles 21 and 22, saw how the use of progressively more data from cycle 23 affects the prediction of the time of solar maximum. Recently, the coronal index of solar activity for the years 1996 and 1997 has been used for determination of solar minimum period between cycles 22 and 23 (Altrock *et al.*, 1999). According to this the length of cycle 22 is only 9.7 years, which means that it is shorter than in earlier cycles. We note that the length of the solar cycle may be a very important parameter for the average temperature on Earth, as was shown by Friis-Christensen and Lassen (1991).

Moreover, the coronal index is a strongly non-stationary data series describing the green-line emission of the 'Sun as a star' showing variability of power for all found periods according to Rybák and Dorotovič (2002). Its power in the period ranges of 150 days, 1 year as well as 28 days varies significantly. A double peak power behaviour in the 150 day period range was found in the solar cycles, where power is located in the intervals of the enhanced local magnetic activity but only before and after the actual solar maxima, while there is no enhanced power at intervals of the highest Wolf's number.

On the other hand, it is assumed that local and global as well, magnetic fields of the Sun, govern the dynamics of the solar corona and properties of the solar wind. This is one reason why knowledge of the distribution of magnetic fields on the solar surface during an activity cycle has great importance. However, the time series of satisfactory magnetic field measurements has a short period. For example, data from the Wilcox Solar Observatory cover the period since 1976 only. According to some preliminary conclusions there seems to be, even if contradictory, a connection between the magnetic field of the Sun and the 530.3 nm coronal intensity, and/or between prominence positions. For example, Stenflo (1972) showed that the green-line intensity should not be related so much to the polarity pattern of the field but more directly to the field strength. On the other hand, Bumba and Sýkora (1974) concluded that higher green-line intensities had been observed above the southern polarity over the studied periods in January 1969–December 1969 and August 1960–September 1961. Rybanský and Tyagun (1980) did not confirm the result of Bumba and Sýkora; however, they found that higher green-line intensities had been observed above the leading sunspot. Rušin (1980) proposed that the coronal intensities of the emission line 530.3 nm are in general higher above this hemisphere of the Sun, where stronger magnetic fields are observed. The existence of a homogeneous coronal data set over the period 1939–2000, (e.g., Rybanský, Sýkora, and Minarovjech, 2001) and solar surface magnetic field measurements since 1976 provides a good opportunity to compare these data, in general, and to try to find the relation between them from a quantitative point of view.

Gnevyshev (1967) has shown that each 11-year cycle consists of two different maxima that are seen in photosphere, chromosphere and corona with optical and radio observations. 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. Results of periodicity analyses of sunspot areas and numbers of recent cycles generally agree that the periodicity near 154 days operated during cycles 19–21 (Lean and Brueckner, 1989; Krivova and Solanki, 2002), but Verma and Joshi (1987) did not detect the 154-day periodicity from sunspot numbers of cycle 21. Bai (2003), analyzing solar flare occurrence for cycles 19–23, found mid-range periodicities of 153 days and 51 days with some differences from cycle to cycle, which are very close to integral multiples of 25.5 days. These flare periodicities can provide information on properties of the Sun. Bai and Cliver (1990) noted that only statistically significant detections seem to come from flares associated with solar energetic protons. Daily values of the coronal index used in this work allow us to study long-term, intermediate and short-term variations for the Sun as a star as well as its rotational rate. Obtained results, e.g., Rušin and Zverko (1990), Rybak *et al.* (1994) have shown similar results as were obtained for other features of solar activity by different authors.

In this work a relation between the coronal index, the sunspot number and the solar flare index on a daily basis 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 flare index, while the magnetic field intensity has given a better precision around the maxima of solar activity. The study between the coronal index and magnetic fields may be useful either to find the relation between them or extend the behavior of magnetic field back to 1939, where data are not available.

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 expressed by the flare index and sunspots, as well as with the magnetic field. The large-scale magnetic fields play an important role in the global organization of solar activity and formation of the heliosphere (Ivanov, Obridko, and Ananyev, 2001). Especially, the green-line intensity is shown to be closely related to the underlying photospheric magnetic field strength (Wang *et al.*, 1997). Badalyan, Obridko, and Sýkora (1999) have recently shown that the coronal magnetic fields influence the formation of the green-line polarization. These close relations of the coronal index with the magnetic field are very important for space weather studies. The results of these studies may be improved by the use of this index, instead of the green-line intensity, as it is derived using data 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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