Total Solar Irradiance and the Fe Xiv Corona

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Abstract Analyzing daily values of the total solar irradiance (TSI), the coronal index of solar activity (CI), and the Mg II 280-nm core-to-wing ratio (Mg II index), we have found that the temporal variations of these indices are very similar to each other during the period from 1978 to 2005. The correlation between CI and TSI, with the PSI correction lying within the interval under study, has been found to be 0.699, which is very close to the value of 0.703 of the correlation between Mg II and TSI for 27-day averages (the CI – Mg correlation is 0.824). The regression equation between CI and TSI is almost linear, except for TSI depletions when a large number of sunspots are present on the visible disk. By employing CI, an extrapolation of TSI back to 1947 is presented.

1. Introduction

Our Sun, a magnetic variable star, varies in its electromagnetic output both spectrally and in its aggregate. This finding stems from observations of different solar activity features, emissions at different wavelengths of the spectrum, and total solar irradiance (TSI). Whereas a number of indices of solar activity, such as the sunspot number, the number of faculae, the F10.7/2800 MHz radio flux, the green line (Fe Xiv, 530.3 nm) intensity, and EUV and X-ray fluxes, may change by more than 100% between solar maxima and minima, TSI, the integrated solar flux over the entire solar spectrum as inferred from space-borne observations, varies only about ±0.1% over a solar cycle (e.g., Pap, 1997; Fligge et al., 2000; Friis-Christensen, 2000; Rybanský et al., 2005; Fröhlich, 2003).

Solar activity affects the heliosphere as a whole, including the Earth and its vicinity, our climate and life, as well as sensitive electronic equipment aboard satellites. Analyzing
TSI and other variable solar features (spots, flares, CMEs, etc.) is of crucial importance for a deeper understanding of solar activity and a better prediction of solar-driven climate changes, as well as for distinguishing the effects of the latter from other climatic drivers. With this end in view, we made a comparison between TSI and the coronal index of solar activity (CI), as the latter, introduced by Rybanský (1975), represents the total energy emitted by the Sun’s outermost atmospheric layer (the emission corona) at a wavelength of 530.3 nm (Fe XIV) toward Earth, being usually expressed in 10^{16} W s r\(^{-1}\). As stated by Mavromichalaki, Petropoulos, and Zouganelis (2002) “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 with the magnetic field. All these parameters are very important for space weather studies.”

Direct measurements of TSI have only been available within the past three decades. To infer the TSI variations at earlier dates, a proxy measure is used, e.g., the sunspot number. However, the sunspot number is a “non-energetic index” of solar activity that furnishes only quantitative descriptions of solar phenomena. Moreover, there are also indices that are explicitly and directly expressed in energetic units. CI can well be ranked among these in the visible part of the electromagnetic spectrum. Our option for employing CI as a proxy for TSI was motivated by the fact that there is a close relation between the green corona intensities and photospheric magnetic-field strength (e.g., Wang et al., 1997; Zhang et al., 1999; Rušin and Rybanský, 2002; Rušin et al., 2007), even when the CI contribution to TSI is negligible. Both TSI and CI are obviously connected with magnetic fields of active regions on the solar surface. So, it is reasonable to assume that CI can be used as a reliable proxy for TSI variations. Moreover, although CI data are available for the years 1939–2005, those of TSI go back only to the end of 1978. To justify the correlation between CI and TSI, we have also compared CI with the Mg II index, given the fact that bright regions in the chromosphere and upper photosphere (which comprise Mg II variations) coincide well with photospheric magnetic fields (e.g., Cook, Brueckner, and Vanhoosier, 1980), and, as was shown by Lean, Mariska, and Acton (1997) and Krivova, Solanki, and Floyd (2006), approximately 30–60% of the actual TSI variations over the solar cycle might be produced at wavelengths below 400 nm. So, the Mg II index is a direct measure of the irradiance that provides a substantial part of the TSI variation. Using CI as a proxy makes it possible to reconstruct TSI back to 1939. To make our analysis more complete, a comparison between TSI and F10.7 radio flux has also been made.

The model reproduces observed solar-cycle variations of the irradiance at wavelengths down to 115 nm and indicates an important role of UV irradiance variability: Up to 60% of the total irradiance variations over the solar cycle might be produced at wavelengths below 400 nm.

The CI data were computed from photometric patrol observations made at all ground-based stations observing the emission corona. Patrol measurements are made with different observational methods, at different heights above the solar limb, and with different steps in positional angles. So, all the data collected have first been converted to a common intensity scale by intensity rescaling, shifting position angles of the measurements, and comparing values taken at all the sites. The Lomnický Štít coronal station was taken as the data reference station for calculations of CI; CI created this way is referred to as a “coronal homogeneous data set” (HDS) and is often employed in other fields of solar research. Missing observational data in the HDS were calculated by using a linear interpolation. (For more details about the procedure, see Rybanský et al., 2005.) CI, for a given day, is based on limb observations of the green line for that day and within intervals of six days on either side of that day. The distribution of intensity above the solar surface is obtained by using