IRRADIANCE OBSERVATIONS OF THE 1-8 Å SOLAR SOFT X-RAY FLUX FROM GOES*

MARKUS J. ASCHWANDEN *
University of Maryland, Astronomy Department, College Park, MD 20742

Abstract. The solar 0.5-8 Å soft X-ray flux was monitored by the NOAA Geostationary Operational Environmental Satellites (GOES) from 1974 to the present, providing a continuous record over two solar activity cycles. Attempts have been made to determine a soft X-ray (SXR) background flux by subtracting out solar flares (using the daily lowest flux level). The SXR background flux represents the quiescent SXR flux from heated plasma in active regions, and reflects similar (intermediate-term) variability and periodicities (e.g. 155-day period) as the SXR or hard X-ray (HXR) flare rate, although it is determined in non-flaring time intervals. The SXR background flux peaks late in Solar Cycle 21 (2-3 years after the sunspot maximum), similar to the flare rate measured in SXR, HXR, or gamma rays, possibly due to the increasing complexity of coronal magnetic structures in the decay phase of the solar cycle. The SXR background flux appears to be dominated by postflare emission from the dominant active regions, while the contributions from the quiet Sun are appreciable in the Solar Minimum only (Al-level). Comparisons with full-disk integrated images from YOHKOH suggest that the presence of coronal holes can decrease the quietest SXR irradiance level by an additional order of magnitude, but only in the rare case of absence of active regions.

Key words: Solar irradiance – Soft X-rays – GOES spacecraft

1. The GOES satellites

The solar 0.5-8 Å soft X-ray flux is monitored by the full-disk soft X-rays sensors (XRS) onboard the Geostationary Operational Environmental Satellites (GOES), operated by NOAA, since 1974. Earlier versions of the soft X-ray sensors (XRS) were flown on the Solar Radiation (SOLRAD) satellite (Kreplin et al. 1977), starting in 1964, and then on the NASA Synchronous Meteorological Satellite (SMS) series, in 1974. The currently operational spacecrafts are GOES-6 and GOES-7, simultaneously operating in a geostationary EAST and WEST position. Because the GOES spacecrafts are in geostationary orbits they have almost continuous coverage of the Sun. The present GOES are spinning platforms, so that the XRS flux is modulated by solar and nonsolar signals. The main source of nonsolar signals is local particle contamination, detectable on a typical level of $\approx 10^{-8}$ W m$^{-2}$. Two bands of X-rays (0.5-4 Å, 1-8 Å) are measured, in 3-second intervals, by two gas-filled ion chambers. Instrumental descriptions and details on the calibration are given in Grubb (1975), Unzicker & Donnelly (1974), Donnelly et al. (1977), and Garcia (1993). The calibration of the XRS sensors is checked by intercomparison between different GOES spacecrafts, or with SOLRAD.


No trend for a long-term drift in the sensor calibration was found (Bouwer 1983). However, below about $10^{-7}$ W m$^{-2}$ the relative error can increase to about 50% because of low-flux instrumental problems (Bouwer et al. 1982).

The effective temperature $T$ and emission measure $EM$ of an isothermal plasma can be determined from the ratio of the two SXR energy channels measured by GOES, using the analytical expressions which have been derived by Thomas, Starr & Crannell (1985), by folding the theoretical SXR spectra with the GOES detector transfer function. The evolution of the flare properties $T$ and $EM$ provide also constraints on the evaluation of the flare-unrelated background flux (Bornmann, 1990). Intercomparisons of measurements of $T$ and $EM$ between GOES, BCS/SMM, HINOTORI, and PROGNOZ agree within < 20% (Antonucci et al. 1984; Tanaka 1986; Garcia 1993).

2. Soft X-ray background flux measurements

The following reasons were brought forward to use the 1-8 Å flux to monitor solar irradiance instead of using other solar indices (Bouwer 1983): (1) the source of SXR flux is confined to the solar corona and has no chromospheric quiet Sun contribution (opposed to the 10.7 cm flux), (2) no center-to-limb darkening effects of the SXR flux and higher sensitivity at and behind the limb (compared with the 10.7 cm flux), (3) high dynamic range between solar minimum and maximum (about 3 orders of magnitude), and (4) importance of ionization in ionospheric D region during high solar activity. The long-term temporal variations of GOES X-rays is important not only to the D-region of the ionosphere, but also for modeling the temporal variations of coronal EUV emissions, which are important to the E and F regions of the ionosphere and to the thermosphere. The solar 1-8 Å flux above $\approx 10^{-6}$ W m$^{-2}$ rivals cosmic rays and Lyman $\alpha$ as a source of ionization and excitation in the D region.

The daily background flux should be an indicator of the quiescent X-ray flux from active regions, where variable emission from flares and coronal mass ejections is largely subtracted out. The Soft X-ray flux in the 1-8 Å band is of the order $10^{-6}$ W/m$^2$, which is about a factor of $10^9$ smaller than the white light solar constant of 1368 W m$^{-2}$. Methods to remove the effects of solar flares from a background flux are described in Bouwer et al. (1982) and Wagner (1988): The daily background flux is defined by the minimum hourly value, either taken in the middle 8 hours of the day, or interpolated from the other 16 hours to the middle of the day.

Wagner (1988) determined the daily background X-ray fluxes in the form of monthly averages and annually-smoothed (13-month) values of the 1-8 Å flux for 1974 to 1988 (Solar Cycle 21). He found that intermediate-term variations (on the scale of months) of the 1-8 Å flux roughly mimic those of