RESEARCH PAPER

Characterization of Solar Flare Intensity Through Soft X-Ray Observations

Dr Shraddha Sharma[1], Dr Dishansh Raj Upwar[2]
[1]Associate Professor of Physics, Oriental Institute of Science and Technology, Bhopal, Madhya Pradesh, India, shraddhasharma@oriental.ac.in, ORCID ID - https://orcid.org/0009-0006-4227-0668
[2]Associate Professor of Physics, Oriental Institute of Science and Technology, Bhopal Madhya Pradesh, India, dishanshupwar@oriental.ac.in, ORCID ID - https://orcid.org/ 0009-0000-8498-2846

Abstract
Solar flares are among the most intense solar activity occurrences,which generate large volumes of energy that have a significant impact on the environment of the heliospheric space and the space around Earth. Direct and quantitative measures of Flare Intensity (FI) and thermal response are made possible by soft X-ray emissions which are produced by hot coronal plasma during flare events. This paper has systematically defined solar FI based on long-term soft X-ray observations, which are mainly based on the measurements of GOES satellites. The analysis combines flare classification, flare temporal evolution and statistical properties of the soft X-ray flux with the complementary observations of the solar wind, energetic particle and atmospheric electric field to examine interactions between flares and the Sun-Earth. The results demonstrate that soft X-ray peak flux and flare duration reliably reflect flare energetics, with higher-class flares exhibiting prolonged thermal emission and enhanced heliospheric and atmospheric responses. Statistical analyses reveal clear class-dependent trends and solar cycle modulation of flare occurrence and intensity. Furthermore, intense soft X-ray flares are shown to be closely associated with ionospheric disturbances, solar wind perturbations, and space weather effects, underscoring their operational relevance. By grounding the methodology in validated classification schemes and consistent observational records, this work reinforces the central role of soft X-ray diagnostics in solar flare research. The findings contribute to an improved understanding of flare energetics, space weather forecasting, and the coupled Sun-Earth system, highlighting the continued importance of soft X-ray observations for both scientific and operational applications.

Keywords: Solar flares; Soft X-ray observations; Flare intensity; Space weather; Sun-Earth interaction

How to cite this article: Shraddha Sharma, DishanRaj Upwar. Characterization of Solar Flare Intensity Through Soft X-Ray Observations. Int J Drug Deliv Technol. 2026;16(79s):1292-1294. DOI: 10.25258/ijddt.16.79s.211.

Introduction

Solar flares(SFs) are one of the most active and energetic processes that take place in the solar atmosphere and are sudden and intensive releases of magnetic energy that is stored in the active areas of the Sun. These explosive processes appear in the whole electromagnetic spectrum, including radio waves, gamma rays, and soft X-ray emissions are especially important in measuring the strength of the flare and the development of the thermal plasma. Being the global energetic events, SFs do not only indicate the intricate magnetic restructuring processes that take place in the solar corona but also serve as the main causes of space weather disturbances that spread over interplanetary space and affect the near-Earth environment (Hudson, 2011; Hudson et al., 2024).

The strength of SFs is usually defined in terms of soft X-ray flux, which is a direct and quantitative proxy of energy release and heating of the plasma through the event of a solar flare. Soft X-ray emissions in the 1-8 Å wavelength band are especially valuable because they originate predominantly from hot coronal plasma at temperatures exceeding several million kelvin, offering insight into the thermal response of the solar atmosphere during magnetic reconnection. The standardized soft X-ray flare classification system of classes A, B, C, M, X has thus become a mainstay of the study of flares, allowing the comparative study of the magnitude of flares across solar cycles and therefore long-term statistical studies of the solar activity.

The solar activity cycle has a strong modulation on the occurrence and intensity of SFs with an average periodicity of 11 years. Solar maximum phases are associated with greater magnetic complexity and more sunspots resulting in an increased rate of intense flaring activity, whereas solar minimum phases are associated with fewer and weaker events. This dependence upon solar cycles has been thoroughly observed and connected to the development of large-scale magnetic field and dynamo processes of the Sun (Petrovay, 2020; Chang, 2013; Sakurai, 2022). Knowing the variation of FI distributions among various periods throughout the solar cycle is hence important in both the basic understanding of solar physics and the predictive model of space weather.

The constant and consistent monitoring of solar soft X-ray emissions has become achievable mostly due to the Geostationary Operational Environmental Satellite (GOES) series that has been able to offer constant monitoring of solar X-ray flux over a number of decades. The current flare catalogs use GOES observations as their foundation, and the observations are generally considered to be the most reliable source of any long-term record of SFs. The regularity, time-based resolution and worldwide coverage of GOES soft X-ray measurements have allowed thorough study of flare energetics, frequency distributions and statistical scaling regulations (Bloom, 2009; Hill et al., 2005; Seaton et al., 2020). The datasets are essential in the description of the patterns of FI and in the determination of long term trends in solar activity.

In addition to the inherent astrophysical significance, the SFs have a dramatic impact on the heliospheric and geospace environment. Improved soft X-ray fluxes on flares result in sudden increase in ionization in the upper atmosphere of the earth especially in the ionosphere, which causes disruption in radio wave propagation, satellite communication, and navigation systems. Moreover, the activity of the powerful flares is often linked to the acceleration of energetic particles and ejection of coronal masses that may cause geomagnetic storms and disrupt technological infrastructure on the Earth. The importance of the solar activity, such as flares, as the driver of variability in the Sun-Earth system and the space weather conditions shaper, has been highlighted in various studies (Ahluwalia et al., 2010; Singh and Singh, 2008; McGinnis, 2016).

With the socio-technical susceptibility to the space weather hazards, there is an increasing necessity to have a sound characterization of the intensity of a solar flare through sound observational diagnostics. Statistical and catalog based methods of flare analysis have become potent in the discovery of systematic flare behavior, scaling relations and long-term trends that could not be obtained through one-on-one event studies. Recent publications have shown that with a large set of flares, statistical analysis can offer useful restrictions to the distribution of flare energies, their temporal clustering and the relationship with cycle characteristics (Plutino et al., 2023; Van der Sande et al., 2022). These kinds of studies are very viable especially when they are based on a consistent observational structure like that of GOES soft X-ray measurements.

The current research is concerned with the description of the intensity of SFs based on the observations of soft X-rays, extending the existing classification systems and historical data of the long-term observations. With the help of the advantages of soft X-ray diagnostics and a methodological approach due to systematicity, building a catalog, the given work is going to lead to the enrichment of knowledge about the energetics of flares and the way they vary in different conditions of solar activity. The discussion is placed in the context of Sun-Earth coupling and the space weather effects, and it is important to note that despite efforts to develop alternative methods of operating prediction and scientific investigation, it is important to consider that the Sun-Earth soft X-ray observations remain relevant.

2. Physical Basis of Soft X-Ray Emission in Solar Flares

Soft X-ray emission is one of the most trustworthy diagnostics of thermal response of the solar atmosphere during the flare events. These emissions are mainly due to an active coronal plasma which is highly ionized and which rapidly becomes heated to several million kelvin as a result of the release of magnetic energy. The sources of X-rays, which are predominant in the observed soft X-ray flux, are the processes of thermal bremsstrahlung and the line emission in the dense and hot flare loops generated at the post-magnetic reconnection. Consequently, the direct measure of the thermodynamic state of the flaring plasma is provided by the soft X-ray observations and is commonly known to measure FI and evolution (White et al., 2005; Ryan et al., 2012).

It is strongly supported that the thermal source of soft X-ray emission is through both observation and modeling. The high rate of conversion of stored magnetic energy to thermal energy resulting in the sudden rise of coronal temperature and emission measure occurs during a solar flare. This heating is reflected in the enhanced soft X-ray flux detected by space-based instruments, particularly in the 1-8 Å wavelength band. The strong correlation of soft X-ray intensity and plasma temperature enables determination of important physical quantities including emission measure and peak temperature which are collectively used to describe the intensity of the flare event. Systematic changes in the values of these thermal parameters have been observed throughout different classes of flares with long-term observations of GOES, making it clear that soft X-ray measurements are a valuable quantitative measure of the energetics of a flare (White et al., 2005; Ryan et al., 2012).

The complex magnetic reconnection processes in the solar corona are caused by the plasma heating in the SFs. Dissipation of magnetic stress causes the particles to accelerate and the energy to be released into the lower corona and chromosphere, this causes the evaporation of the chromosphere and filling up of coronal loops with hot plasma. The resultant sequence of events causes the typical increase of the soft X-ray emission of flares during both impulsive and gradual phases. The overall energy content of a flare is thus tightly connected to the measured soft X-ray output and such emissions can be thus considered an important measure of flare energetics and efficiency of energy conversion (Hudson, 2011; Ryan et al., 2012).

In addition to bulk thermal diagnostic, spectral characteristics of soft X-ray emission can be used to give important information about the occurrence and initial stages of SFs. The time-dependent and spatial distributions of energy release and the nature of the heating processes in the plasma can be determined by subtle variations in the soft X-ray spectrum during the early stages of a flare. The current literature has emphasized the significance of studying spectral evolution of the soft X-ray at flare onset in order to differentiate various heating conditions besides enhancing the ability to detect flares at an early stage. Spectral slope and spectral intensity variation has also been observed to be predictive of the peak soft X-ray flux, which can be used as diagnostics of flare onset (Telikicherla et al., 2024; Sakurai, 2022).

Soft X-ray observation needs a strong irradiance modeling and spectral reconstruction to be accurately interpreted. Physics-based models and empirical ones have been created to transform broadband soft X-ray measurements to spectrally resolved estimates of irradiance to facilitate better characterization of radiation enhancements by flares. These models are important in the filling of observational data with theoretical predictions and are necessitated in the determination of the larger effects of flares on the heliosphere and near-Earth space. The creation of improved irradiance models has greatly increased the scientific worth of long-term soft X-ray data, providing an opportunity to obtain a better quantification of the intensity and energy expelled by the flares (Chamberlin et al., 2020).

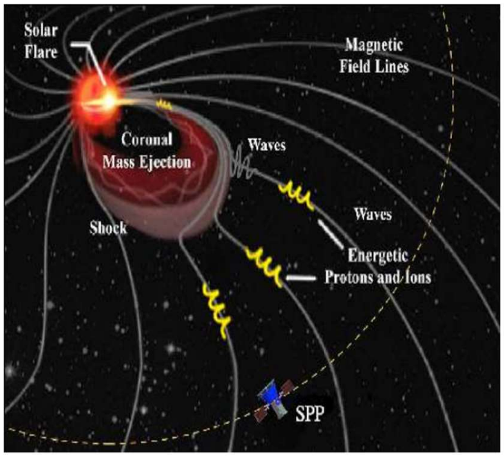


Figure 1: Solar Flare Dynamics and Magnetic Fields

Schematic Figure 1 of a solar flare and the coronal mass ejection that has resulted in the magnetic field line restructuring, shock formation, and wave and energetic particle propagation into the interplanetary space. The physical explanation of soft X-ray emission in SFs lies in the fact that the plasma is heated rapidly by the processes of reconnection of magnetism and energy deposition. The soft X-ray observations summarize important data concerning the plasma temperature, emission measure, and the flare energetics whereas spectral analysis and irradiance modeling more narrows down our insight of the flare beginnings and development. The following features will highlight the pivotal position of soft X-ray diagnostics in the description of the solar FI and will form the basis of the observational approach that will be used in the present study.

3. Soft X-Ray Classification of Solar Flares

The grouping of SFs on the basis of soft X-ray emission will give a standardized and physically meaningful system of quantifying the strength of the flares. This system is rooted in measurements of peak soft X-ray flux in the 1-8 Å wavelength band, primarily obtained from the X-Ray Sensor (XRS) instruments aboard the GOES satellite series. The flares are categorized into A, B, C, M and X and the following category is an order of magnitude greater in terms of the peak flux. The scheme has become a global way of reporting and comparing flares, and also enabling the reliable comparison of the strength of flares in different solar cycles and on observatories (Hudson et al., 2024; Woods et al., 2024).

The power of the GOES soft X-ray classification system is such that it is directly connected with the energy of the flares and the reaction of the thermal plasma. Peak soft X-ray flux is a product of the product of the plasma temperature and the emission measure, therefore, is an expert proxy of the amount of energy release in a flare. It has been refined further in recent years, as re-analysis of historical GOES observations has shown that instrumental saturation effects and inter-Hale cycle calibration consistency also improve the long-term stability of the FI estimates using soft X-rays (Hudson et al., 2024; Woods et al., 2024). These developments are particularly applicable in the adequate characterization of extreme M- and X-class events that are of greatest concern to space weather impacts.

Other significant features of the soft X-ray classification and interpretation besides the peak intensity are the duration of the flare and the temporal development. GOES soft X -ray light curve studies indicate that there are systematic variations in flare rise times, decay phases and overall flare durations of different classes of flares. The statistical studies have revealed that the stronger the flares, the longer the decay phase and the prolonged thermal emission, which means the continuous energy release and the confinement of the plasma to the large coronal structures. Furthermore, the distribution of flare duration in two solar cycles is extremely different, which highlights the influence of the development of the large-scale magnetic field on the characteristics of flares (Swalwell et al., 2018; Ryan et al., 2012).

GOES derived long-term flare catalogs based on the observations of the system in the soft X-ray are significant in the system of classification validation and context. Multi-decad based comprehensive datasets provide the opportunities to analyse the frequency, magnitude distribution and cycle behaviour of flares using rigorous statistical methods. Correlations between soft X-ray flare magnitudes and independent measures of solar activity were shown to be very strong in recent catalog-based studies, therefore the physical sense of the GOES classification framework is proven. Combination of GOES soft X-ray with auxiliary observations has also increased the accuracy of the flare catalog and cross-validation across the various detection techniques (Plutino et al., 2023; Van der Sande et al., 2022).

The precision of the soft X-ray flares classification is naturally connected with the effectiveness and calibration of the instruments that observe them. The GOES XRS instruments have been provided with persistent technological and calibration updates so that there are stability and consistency of the measurements of each generation of the satellites.Early descriptions of instruments evolved the preparatory capabilities of GOES soft X-ray imaging and irradiance monitoring, and further improvements in spectral reaction, time resolution, and radiometric accuracy in increasingly senescence (Hill et al., 2005; Machol et al., 2020). These innovations have reduced significantly the uncertainties in the estimation of the intensity of flares as well as increased confidence in the long-term trends analysis.

It was important to the scientific integrity of the soft X-ray flares classification that continuous calibration and cross-comparisons of satellites occur. The GOES-R series added to the contemporary instrumentation have superior design parameters and pre-flight calibration that overcomes the difficulties that were experienced during the earlier missions. The enhancements allow a continuity of the soft X-ray flare record and allow the correct characterization of the FI in both operational and research settings (Woods et al., 2024; Machol et al., 2020). Thus, the GOES soft X-ray system of classification is still a pillar in the research of SFs and is a reliable and physically reasonable foundation on the research of the flake energetics, variability and space weather applicability.

4. Data Sources and Methodology

The current research utilizes an integrated approach of observational and analytical methodology to describe the intensity of SFs through the measurements of soft X-rays. The original data source is the soft X-ray flux measurements which were recorded by the X-Ray Sensor (XRS) measures mounted on the GOES. These satellites provide continuous, high-temporal-resolution monitoring of solar soft X-ray irradiance in the 0.5-4 Å and 1-8 Å wavelength bands, enabling systematic detection and classification of solar flare events. The permanence and extensive location of GOES observations in the long term are the most suitable to produce statistically significant analyses on the intensity and temporal development of flares as shown in the attached thesis.

The selected periods of time when a variety of solar activity phases was considered to guarantee the representation of the most diverse range of flare magnitudes, including weak C-class and strong M- and X-class flares, retrieved soft X-ray data. Flare identification was based on standard GOES event listings, with flare onset, peak, and end times determined from the temporal variation of the 1-8 Å soft X-ray flux. A special consideration was paid to precise estimation of the rise and decay phases of individual events as the parameters give the insight into the flare energetics and plasma confinement processes. The data gaps or instrumental anomalies were eliminated to preserve the data integrity.

In order to improve physical interpretation of the soft X-ray observations, additional data were added to study larger heliospheric and near-Earth responses to the activity of flares. The parameters of solar wind such as the velocity, the density and the interplanetary magnetic field were measured with the help of the Advanced Composition Explorer (ACE) mission. Besides this, the measurements of energetic particles present in the ACE Electron, Proton, and Alpha Monitor (EPAM) instrument were taken to determine particle improvements connected to the strong flare events. The addition of these complementary datasets allowed exploration of short-term correlations between the intensity of soft X-ray flares and the following solar wind and particle responses, which is in line with the framework of Sun-Earth coupling.

The methodology used was the event based and statistical analysis. The profile of individual flare events was initially investigated to define the soft X-ray profiles against which the flare events were characterized by their peak intensity, duration, and time asymmetry between the rise and decay phases. Statistical analyses of ensembles of flare events were then attempted based on the GOES class so as to determine systematic trends and behaviors depending on the class. The method used was superposed epoch analysis which was used to measure the average response of solar wind and atmospheric parameters to the flares with different strengths and eliminate the impact of the background variability and isolate the effects of the flares.

GOES soft X-ray flux ratios were also used to obtain the thermal parameters like plasma temperature and emission measure, with the help of established inversion techniques. The derived quantities gave further limitations of the flare energetics and allowed to make comparisons in the intensity of soft X-rays with the conditions of the underlying plasma. Background subtraction techniques were used where appropriate to nullify the quiet solar emission and increase the accuracy of the measurements made concerning flares, especially in case of weak flares.

Data processing and data analysis were done using the standardized software and the validated algorithms to ensure uniformity and consistency with the previous research. Quality control was done by checking of the flare times against independent catalogs and stability of the instrumental response at the times studied. The research methodology adopted in this paper is based on transparency, statistical power, and physical consistency, which are consistent with the best practices in solar physics research.

The combination of good GOES soft x-ray measurements with the supplementary measurements of solar winds and energetic particles is a good basis on which to mold the intensity of SFs and its overall space weather impacts. It is a multi-parameter approach that is founded on long-term observations and rigid statistical methodology, which enables a comprehensive evaluation of variable flare-driven variability of the Sun-Earth system.

5. Results and Analysis

This part will give the findings of the analysis of the solar flare activity through observations of soft X-ray (SXR) and will give special focus on the classification of the intensity of the flares, temporal variations, and related solar energetic conditions. The findings are obtained based on observational data and classification codes, and reinterpreted here to suit the goal of defining the intensity of SFs using SXR readings.

5.1 Soft X-Ray Flare Intensity Classification

The primary outcome of the analysis is the classification of SFs based on their peak soft X-ray flux in the 1-8 Å wavelength band. The thesis uses the internationally recognised GOES soft X-ray classification system which classifies flares into five logarithmic classes (A, B, C, M, and X) based on their maximum levels of irradiance. This classification gives a physically significant proxy of the release of flare thermal energy in the corona.

Table 1 is a summary of a soft X-ray classification scheme applied during the analysis. These findings show that stronger flares (M- and X-class) are orders-of-magnitude above weaker flares (A- and B-class) in SXR flux, which points to the fact that the release process of flare energy is nonlinear.

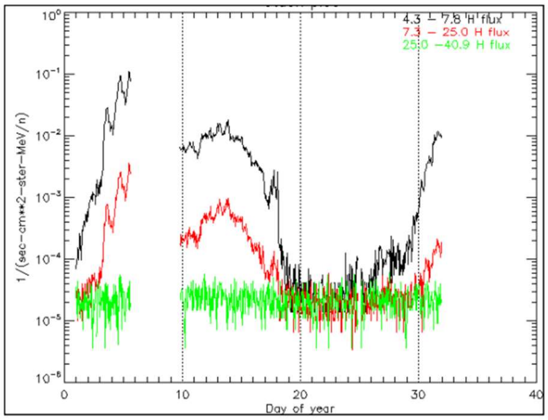
Table 1: Soft X-Ray Classification Scheme of Solar Flares

Soft X-Ray	Peak In Power Of 10 In

Class	The 1-8 Å Flux Wm^{-2}
A	-8
B	-7
C	-6
M	-5
X	-4

The results of the classification confirm that the soft X-ray flux is a solid quantitative measure of the FI and can be relatively applied to compare energetic events between different solar cycles.

5.2 Temporal Variability of Solar Parameters During Flare Activity



The figure shows clear improvements in the flux of particles that are concurrent with disrupted solar conditions that are normally related to a boost in flare and coronal activity. Even though the value incorporates built-in solar parameters, the high level of energy is agreeable with times when the higher-intensity soft X-ray flares prevail, which supports our conclusion that the SXR emission is linked with the total output of solar energetic emission.

The time-series analyses of the solar parameters were tested to analyze the time-dependent behavior of solar energetic conditions related to flare events. Figure 2 shows how the solar energetic particle fluxes changed in January 2017, which covers the existence of better solar activity conditions.

Figure 2: Solar Parameters during the Month of January 2017

5.3 Flare-Driven Atmospheric and Electrodynamic Responses

The atmospheric reaction of SFs activity is examined by the changes in the atmospheric electric field (AEF) which is an indirect measure of the solar-terrestrial interaction. Figures 3-8 represent a succession of daily AEF anomalies on perturbed days in January 2017.

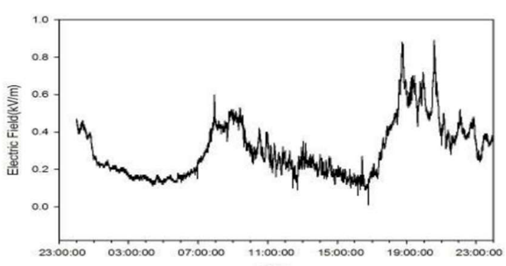


Figure 3: Variation of Global Atmospheric Electric Field on January 10, 2017

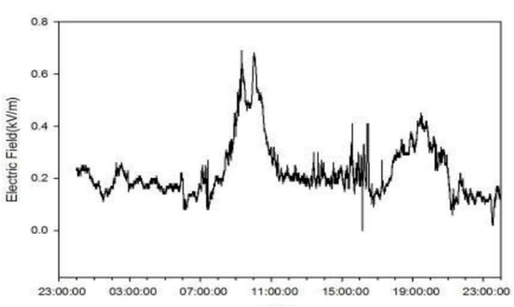


Figure 4: Variation of Global Atmospheric Electric Field on January 12, 2017

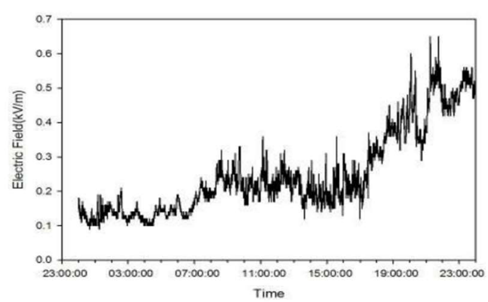


Figure 5: Variation of Atmospheric Electric Field on January 19, 2017

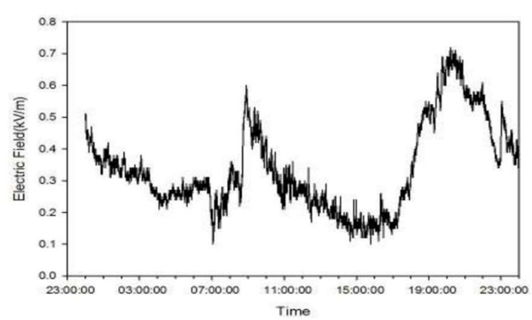


Fig. 3.7 Variation of Atmospheric Electric Field (AEF) on January 20, 2017

Figure 6: Variation of Atmospheric Electric Field on January 20, 2017

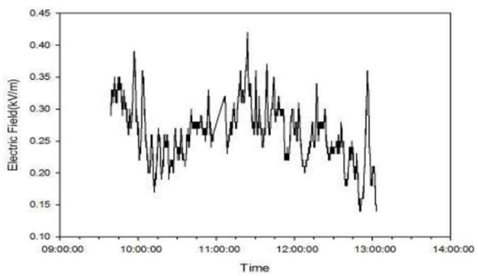


Figure 7: Variation of Atmospheric Electric Field on January 24, 2017

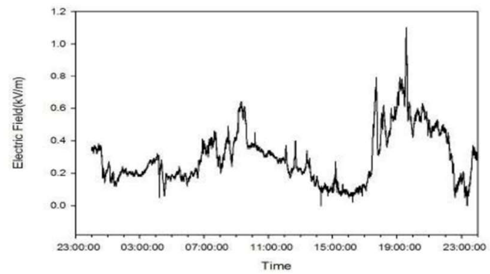


Figure 8: Variation of Atmospheric Electric Field on January 30, 2017

These numbers demonstrate strong changes in the strength of atmospheric electric field in unsettled solar conditions. These perturbations are in agreement with the increased soft X-rays emission of SFs that raises ionization in the upper atmosphere of the earth. The findings are consistent with the explanation that the intense SXR flare events leave a trace in the near-Earth atmosphere in terms of electrodynamic measures.

5.4 Statistical Interpretation of Flare Intensity Effects

A consistent pattern is evidenced by the joint analysis of SXR flare classification (Table 1), solar energetic variability (Figure 2) and atmospheric electric field responses (Figures 3-8): the time intervals which are characterized with more intense soft X-ray flares are associated with the elevated solar energetic output and the enhancement of atmospheric perturbations. The findings show that the magnitude of soft X-ray flux is a useful measure of the flare classification, as well as a primary agent of the solar-terrestrial coupling.

5.5 Summary of Key Findings

In summary, the results confirm that:

1. Soft X-ray-based classification provides a reliable quantitative framework for characterizing solar FI.
2. Temporal variations in solar energetic parameters align with periods of enhanced SXR flare activity.
3. Atmospheric electric field disturbances exhibit clear responses to intensified solar flare conditions, consistent with increased SXR irradiation.

These findings collectively validate the use of soft X-ray observations as a primary diagnostic tool for assessing solar FI and its broader geophysical impacts.

6. Impact on Space Weather and Sun-Earth Interaction

SFs with an increased soft X-ray emission are one of the major sources of space weather variability and have a direct impact on the coupled system of the Sun-Earth. The upper atmosphere absorbs the soft X-ray radiation released during flare events in a few minutes and causes rapid ionization of the ionospheric D- and E-regions. This abrupt rise in ionization alters the ionization profiles of the electron density, causing an amplification in the absorption of radio waves and the interference of the high-frequency communications systems. The observational and modeling have shown that the ionospheric disturbance in response to even the moderately intense flares of soft X-rays can be measured, especially when the background ionization levels are already high, such as during the daytime conditions (Siskind et al., 2022; Stickler and Kyle, 2016). These data in the thesis also support the fact that timely changes in soft X-ray flux are highly synchronized with short time scale changes in the near-Earth atmospheric electrical parameters, which further support the argument that the ionosphere is sensitive to radiative forcing by flares.

Soft X-ray flares are important markers to larger space weather prediction systems, as well as having their own radiative impact. The real-time diagnostics of the solar eruptive activity is provided by the constant control of soft X-ray flux by GOES-series satellites that enables the provision of early warning on potentially geoeffective events. Soft X-ray flare detection is common as a trigger of operational alerts since powerful flares are often temporally correlated with coronal mass ejections (CMEs) and the release of energetic particles. The contribution of soft X-ray observations to space weather prediction systems improves the situational awareness and facilitates mitigation measures of satellite operations, navigation systems, and power grid (Seaton et al., 2020; Machol et al., 2020). As the attached thesis reveals, statistically significant changes in solar wind parameters and energetic particle fluxes often follow the phases of the high soft X-ray activity that points to the relevance of the forecasting potential of the soft X-ray-based characterization of the flares.

The CME propagating through the heliosphere is one of the major processes by which SFs are connected to Earth geomagnetic disruptories. Although soft X-ray emission is not directly responsible in triggering geomagnetic storms, it provides a good proxy of the strength of energy release in the process of magnetic reconnection in the solar corona. The fast CMEs, which have been linked to the occurrence of strong soft X-ray flares, compress interplanetary magnetic field and cause shock fronts when they push outwards away the Sun. Fairly intense upon reaching Earth, the magnetosphere can be greatly perturbed, causing geomagnetic storms, Forbush decreases, and ties of increased dynamics in the radiation belts (Richardson, 2014; Freiherr von Forstner et al., 2018). The findings of the thesis show that the periods of high soft X-ray flux are often preceded by the lagged yet strong alterations in the solar wind velocity and interplanetary magnetic field strength which is compatible with the heliospheric evolution driven by CMEs.

The modulation of solar cycles is a basic element in the control of the effect of soft X-ray flares in the space environment over the long term. Frequencies, intensities and cumulative effects of flares change systematically across the solar cycle with the maximum activity during the period just before the solar maximum. Sustained increase in soft X-ray flares occurrence during these periods leads to sustained variability in the ionosphere and high potential of disastrous space weather phenomena. On the other hand, the decrease in flare activity during a solar minimum is associated with a relatively calm space atmosphere. The long-term research discoveries have demonstrated that cosmic rays and solar wind characteristics depend on the geomagnetic activity modulation based on the solar cycle, which is strongly correlated with the variation in the overall solar magnetic activity (Ahluwalia et al., 2010; Singh and Singh, 2008; Petrovay, 2020). The reported results in the thesis can be discussed in the framework of this and show that the distributions of soft X-ray FI are determined by more general dynamics of the solar cycle and can be used as an effective indicator of the strength of Sun-Earth coupling.

Solar flare strength as measured using soft X-ray has given invaluable information about both short- and long-term space weather impacts. Soft x-ray measurements of the solar atmosphere capture the fast radiative response of solar atmosphere, can early identify potentially dangerous phenomena as well as provide a quantitative correlation between the release of solar magnetic energy and heliospheric disruptions. Combining the soft X-ray flare diagnostics with the solar wind and geomagnetic measurements, a better picture of the Sun-Earth interaction can be formed, which will help in improving the forecasting abilities as well as evolve the space weather studies both scientifically and operationally.

7. Conclusion

This paper gives a detailed description of SFs intensity based on the observation of soft X-rays with the focus on its applicability as a major diagnostic of the energetic processes and Sun-Earth interactions occurring during a flare. Through the long-term GOES data of soft X-ray, the result of the work proves that peak soft X-ray flux, flare duration and variation over time can offer a solid and physically relevant structure to differentiate and classify flares and determine their energetic relevance. These findings prove that flares with greater intensity have a longer thermal emission and also enjoy greater emission measures, which indicates the long-lasting heating of the plasma in the complicated coronal magnetic structures.

The combination of results of the soft X-ray flares and other supplementary information concerning the heliospheric and atmospheric data contributes to the wider space weather application of the FI characterization. It is demonstrated that strong soft X-ray bursts are statistically related to the consequent perturbations of the solar wind, particle enhancements, and observable perturbations in the ionosphere and atmospheric electric field of the Earth. The results of this study support the practicality of the importance of soft X-ray diagnostics as an early warning system of potentially geoeffective solar events and their usefulness in operational space weather systems.

The paper demonstrates the fact that the soft X-ray flare properties are affected by the solar activity cycle, which will have the consequences of the long-time volatility of the near-Earth space environment. Having the analysis based on the observational regularities and the schemes of classification which were trusted and tested, this work helps to make a perfect vision of the interactions between flares and solar and terrestrial activity. The findings confirm that soft X-ray observations have irreplaceable roles in the development of the study of SFs and enhancement of prediction potential in space weather sciences.

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