



Study of Solar Flares during Solar Cycle-25 Maximum using GOES Observations

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Abstract: Solar flares are rapid releases of magnetic energy in the solar atmosphere and constitute an important driver of short-term space-weather variability. This study presents a comparative observational analysis of selected C-, M-, and X-class solar flares recorded during 2025, a period associated with the maximum phase of Solar Cycle 25. One-minute-averaged soft X-ray observations from the Geostationary Operational Environmental Satellite (GOES) X-Ray Sensor (XRS), particularly the 1–8 Å channel, were used to examine the enhancement of solar X-ray flux during twelve selected events. The sample consists of four C-class flares, four M-class flares, and four X-class flares. The reported peak fluxes increase systematically from approximately $5.5\text{--}9.9 \times 10^{-6} \text{ W m}^{-2}$ for the selected C-class events, to $2.0\text{--}8.8 \times 10^{-5} \text{ W m}^{-2}$ for the selected M-class events, and $1.1\text{--}5.1 \times 10^{-4} \text{ W m}^{-2}$ for the selected X-class events. The observations illustrate the logarithmic flare classification scheme and demonstrate the substantially larger soft X-ray enhancements associated with higher-class events. The study provides a concise observational framework for examining flare intensity and its relevance to space-weather monitoring.

Index Terms - Solar flares; Solar Cycle 25; GOES; soft X-rays; space weather; solar activity

I. INTRODUCTION

Solar flares are transient eruptions in which magnetic energy stored in solar active regions is rapidly converted into thermal energy, particle acceleration, and electromagnetic radiation. Their emissions extend across a broad range of wavelengths, including radio, optical, ultraviolet, extreme ultraviolet, X-ray, and gamma-ray bands. The soft X-ray classification system developed from GOES observations is widely used to describe flare magnitude in terms of the peak irradiance measured in the 1–8 Å band [1,2, 9, 10, 11].

The classification system is logarithmic. A C-class flare has a peak flux of 10^{-6} W m^{-2} , a M-class flare has a peak flux of 10^{-5} W m^{-2} , and an X-class flare has a peak flux of 10^{-4} W m^{-2} , with the numerical multiplier specifying the intensity within each class. Consequently, an X2 event has approximately twice the peak 1–8 Å flux of an X1 event and approximately ten times the flux of an M1 event [2,3, 9, 10, 11].

Solar flares are closely associated with the evolution of sunspots and active-region magnetic fields. Magnetic reconnection is generally invoked as the fundamental process responsible for releasing stored magnetic energy. Strong flares can produce ionospheric disturbances, radio blackouts, radiation hazards, and indirect impacts on satellite and technological systems, particularly when accompanied by solar energetic particles or coronal mass ejections [4,5, 9].

Solar Cycle 25 began in December 2019 and progressed toward its maximum phase during 2024–2025 [6,7]. The present work examines a set of C-, M-, and X-class events occurring during 2025 using GOES X-ray observations, and studied the quantitative enhancement of these flares during the maximum solar activity conditions.

II. DATA AND METHODOLOGY

2.1 GOES X-ray observations

The Geostationary Operational Environmental Satellite (GOES) programme, operated through the collaboration of NASA and NOAA, provides continuous monitoring of solar X-ray irradiance. The GOES X-Ray Sensor measures soft X-ray flux in two wavelength bands: 0.5–4 Å and 1–8 Å [12]. The present study uses the 1–8 Å channel, which forms the basis of the standard A, B, C, M, and X flare classification [8].

2.2 Event selection

Twelve events were selected for comparison: four C-class, four M-class, and four X-class flares. The dates, flare magnitudes, flare time and flare peak flux are tabulated in Table-1.

Table-1: List of selected solar flares				
Class	Date	Magnitude	Flare Time (UT)	Peak flux (W m^{-2})
C	10 January 2025	C9.99	22:46-22:47	9.99×10^{-6}
C	02 April 2025	C8.10	10:52-10:53	8.10×10^{-6}
C	10 May 2025	C5.56	16:20-16:21	5.56×10^{-6}
C	13 July 2025	C8.92	04:02-04:03	8.92×10^{-6}
M	03 February 2025	M8.88	03:58-03:59	8.88×10^{-5}
M	27 March 2025	M2.05	00:36-00:37	2.05×10^{-5}
M	16 June 2025	M6.40	09:38-09:39	6.40×10^{-5}
M	26 August 2025	M4.52	05:24-05:25	4.52×10^{-5}
X	23 February 2025	X2.03	19:26-19:27	2.03×10^{-4}
X	28 March 2025	X1.14	15:20-15:21	1.14×10^{-4}
X	14 May 2025	X2.70	08:24-08:25	2.70×10^{-4}
X	11 November 2025	X5.16	10:04-10:05	5.16×10^{-4}

2.3 Analysis approach

For each selected event, the reported flare class and peak flux were compared with the approximate background flux of 10^{-6} W m^{-2} . The comparison focused on the relative enhancement in the 1–8 Å band and on the consistency between the assigned flare class and the reported peak flux.

III. RESULTS AND DISCUSSION

3.1 C-class events

The four selected C-class flares occurred on 10 January, 2 April, 10 May, and 13 July 2025 are shown in Figure 1. Their reported magnitudes were C9.99, C8.1, C5.56, and C8.92, respectively. These C- class flares occurred at 22:46-22:47, 10:52-10:53, 16:20-16:21 and 04:02-04:03 UTC on 10 January 2025, 2 April 2025, 10 May 2025, and 13 July 2025, respectively. The corresponding reported peak fluxes ranged from 5.56×10^{-6} to $9.99 \times 10^{-6} \text{ W m}^{-2}$. Relative to the stated background of approximately 10^{-6} W m^{-2} , these events represent modest soft X-ray enhancements. The largest reported peak within this subset was associated with the C9.99 event on 10 January 2025.

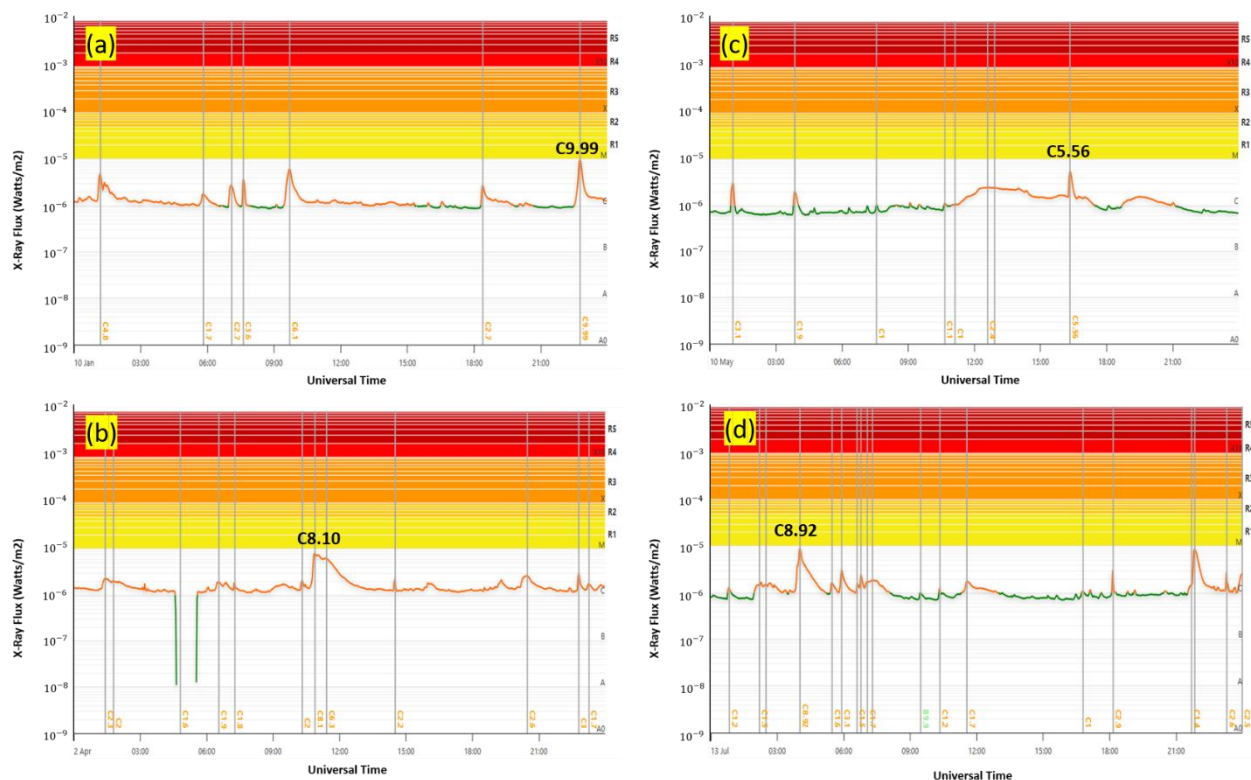


Figure 1: Variation of GOES X-ray flux with universal time on: (a) 10 January 2025, C9.99 flare occurred at 22:46-22:47 UTC; (b) 2 April 2025, C8.10 flare occurred at 10:52-10:53 UTC; (c) 10 May 2025, C5.56 flare occurred at 16:20-16:21 UTC; and (d) 13 July 2025, C8.92 flare occurred at 04:02-04:03 UTC.

3.2 M-class events

The selected M-class flares occurred on 3 February, 27 March, 16 June, and 26 August 2025, with magnitudes M8.88, M2.05, M6.40, and M4.52 are shown in Figure 2, respectively. These M- class flares occurred at 03:58-03:59, 00:36-00:37, 09:38-09:39 and 05:24-05:25 UTC on 27 March, 16 June, and 26 August 2025, respectively. Their reported peak fluxes ranged from 2.05×10^{-5}

to $8.88 \times 10^{-5} \text{ W m}^{-2}$. As expected from the classification system, the M-class events produced peak fluxes approximately an order of magnitude or more above the nominal C1 threshold. The highest reported peak among the selected M-class events was $8.88 \times 10^{-5} \text{ W m}^{-2}$ for the M8.88 event on 3 February 2025.

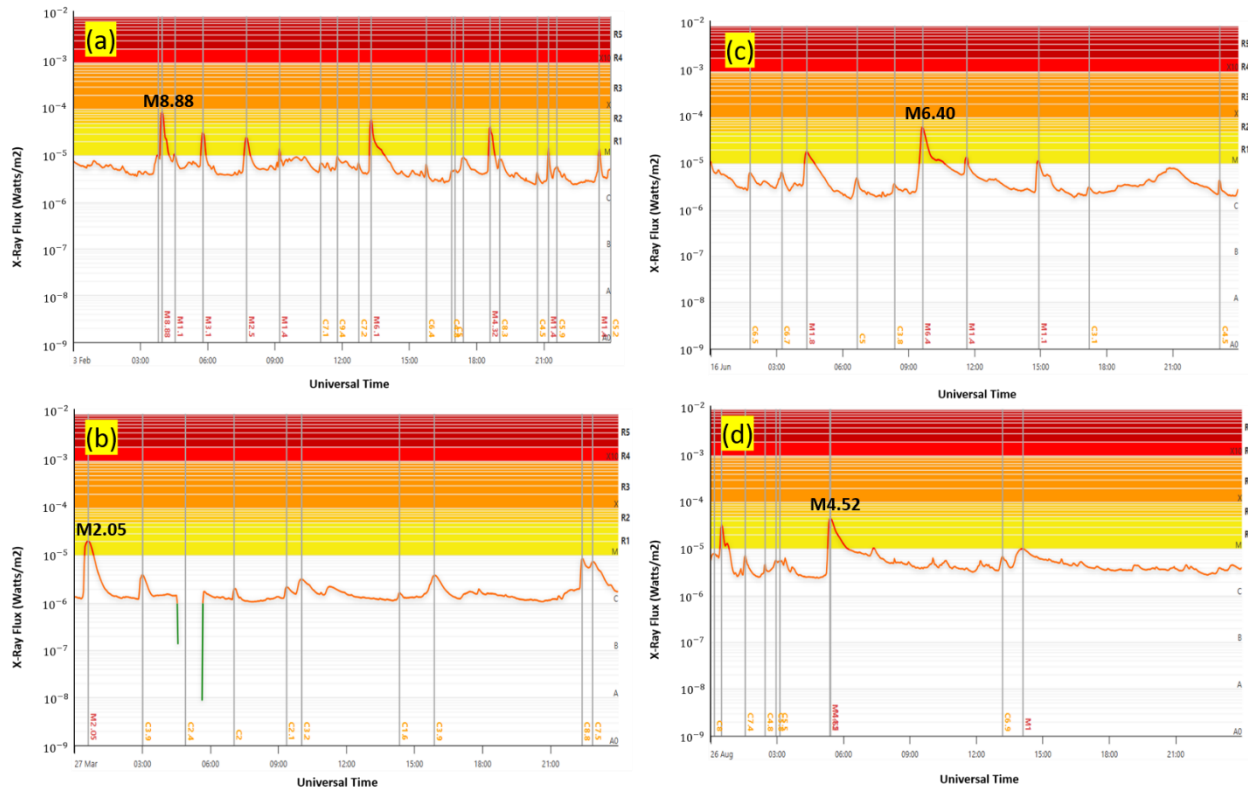


Figure 2: Variation of GOES X-ray flux with universal time on: (a) 3 February 2025, M8.88 flare occurred at 03:58-03:59 UTC; (b) 27 March 2025, M2.05 flare occurred at 00:36-00:37 UTC; (c) 16 June 2025, M6.40 flare occurred at 09:38-09:39 UTC; and (d) 26 August 2025, M4.52 flare occurred at 05:24-05:25 UTC.

3.3 X-class events

The four selected X-class flares occurred on 23 February, 28 March, 14 May, and 11 November 2025 are shown in Figure 3. These X-class flares occurred at 19:26-19:27, 15:20-15:21, 08:24-08:25 and 10:04-10:05 UTC on 23 February, 28 March, 14 May, and 11 November 2025, respectively. Their reported magnitudes were X2.03, X1.14, X2.7, and X5.16, with reported peak fluxes of 2.03×10^{-4} , 1.14×10^{-4} , 2.7×10^{-4} , and $5.16 \times 10^{-4} \text{ W m}^{-2}$, respectively. The X5.16 event on 11 November 2025 produced the highest reported peak flux in the selected sample. The X-class events therefore exhibited the strongest soft X-ray enhancements among the three groups. These X-Class flares can cause ionospheric disturbances, radio blackouts, radiation hazards, and indirect impacts on satellite and technological systems. Hence, understanding these flares are important.

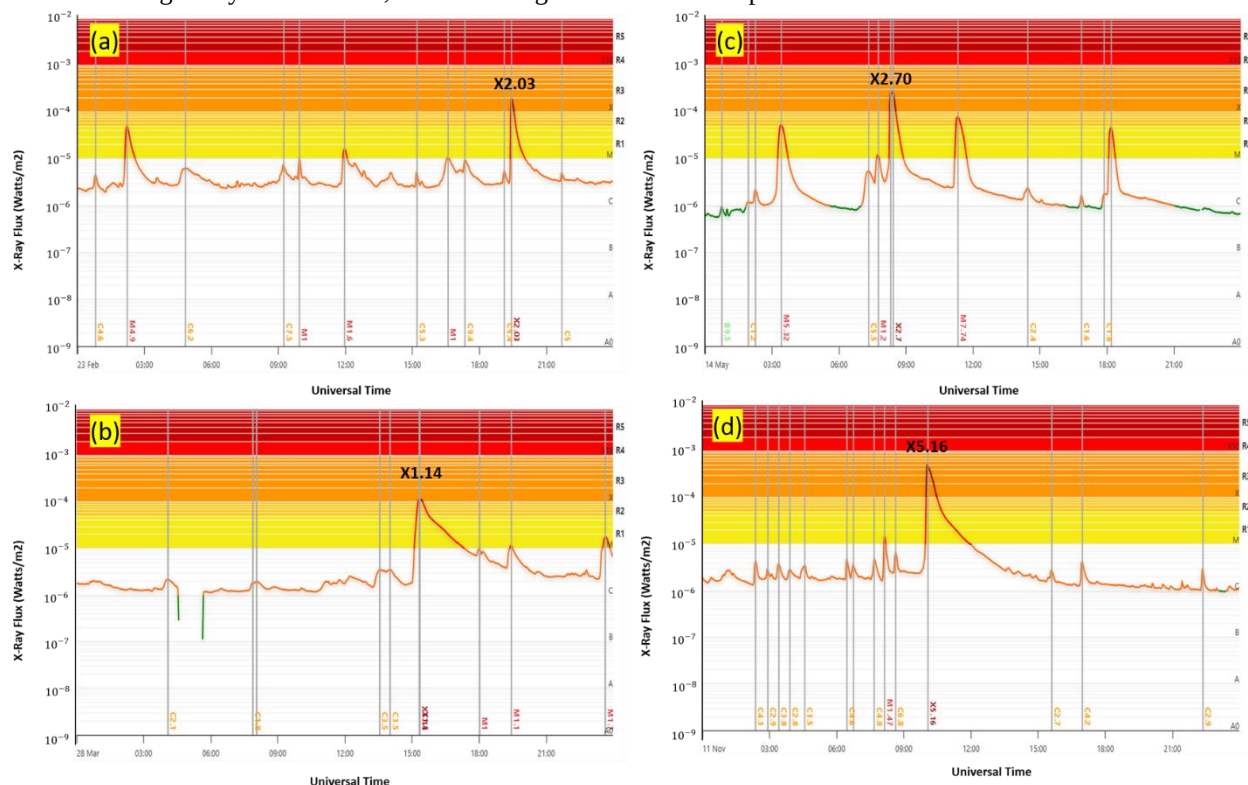


Figure 3: Variation of GOES X-ray flux with universal time on: (a) 23 February 2025, X2.03 flare occurred at 19:26-19:27 UTC; (b) 28 March 2025, X1.14 flare occurred at 15:20-15:21 UTC; (c) 14 May 2025, X2.70 flare occurred at 08:24-08:25 UTC; and (d) 11 November 2025, X5.16 flare occurred at 10:04-10:05 UTC.

The selected observations display the expected ordering of soft X-ray intensity: C-class events have the lowest peak fluxes, M-class events occupy an intermediate range, and X-class events have the highest peak fluxes. This pattern follows directly from the logarithmic GOES classification scheme and is evident in the reported values.

The comparison also illustrates why flare class alone should not be treated as a complete measure of space-weather impact. The geoeffectiveness of a solar eruption depends on additional properties, including its location on the solar disk, associated coronal mass ejection, particle acceleration, magnetic-field orientation in interplanetary space, and the response of the terrestrial magnetosphere and ionosphere. A high soft X-ray class indicates strong electromagnetic emission, but it does not by itself establish the occurrence or severity of a geomagnetic storm [1,4,5].

3.4 Comparative summary

Flare class	Number of events	Magnitude range	Peak-flux range (W m^{-2})
C	4	C5.56–C9.99	$5.5\text{--}9.9 \times 10^{-6}$
M	4	M2.05–M8.88	$2.0\text{--}8.8 \times 10^{-5}$
X	4	X1.14–X5.16	$1.1\text{--}5.1 \times 10^{-4}$

IV. CONCLUSIONS

This paper presented a comparative analysis of twelve selected solar flares observed during 2025, representing C-, M-, and X-class events during the maximum phase of Solar Cycle 25. The reported peak soft X-ray flux increased systematically from the selected C-class events to the M-class and X-class events. The selected C-class events exhibited peak fluxes of approximately $5.5\text{--}9.9 \times 10^{-6} \text{ W m}^{-2}$, while the selected M-class and X-class events reached approximately $2.0\text{--}8.8 \times 10^{-5} \text{ W m}^{-2}$ and $1.1\text{--}5.1 \times 10^{-4} \text{ W m}^{-2}$, respectively. The largest reported event in the selected sample was the X5.16 flare on 11 November 2025, with a reported peak flux of approximately $5.1 \times 10^{-4} \text{ W m}^{-2}$.

V. ACKNOWLEDGEMENT

The GOES Solar X-ray sensor data used in this work is obtained from NASA NOAA Database and Space weather live website. The links are given below:

- <https://www.ngdc.noaa.gov/stp/satellite/goes/dataaccess.html>
- <https://www.spaceweatherlive.com/en/archive/2000/11/07/xray.html>

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