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Descriptive study of X-class flares released in the year 2014, during the double peak of SC-24

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Abstract. During the declining phase of the Solar cycle 24, a new peak appeared on January 7, 2014. The release of x-class flares, with the high energetic particles, were found to be more intense than that occurred during the main peak of the same cycle. Few X-class flares were released, lately, during the year 2014. We note that during the last 5 solar cycles, a new peak has appeared, releasing high energetic particles and X-class solar flares, which are called the secondary peak or the double peak of solar cycle. The aim of this descriptive study is to follow the morphological and magnetic changes of the active region before, during, and after the production of X-class flares according to data analysis. Furthermore, the causes of the release of such eruptive storms have been discussed for the period, year 2014, during the double peak of the solar cycle 24.

Keywords. Solar cycle 24, solar activity, X-class flares, solar energetic particles.

1. Introduction

The complex dynamics of magnetic fields play a key role in the solar activity (Parker, 2001). The present solar cycles 24, and the previous one, solar cycle 23, are the weakest cycles observed in the last 200 years (Hady, 2013) and (Hady, 2014). The solar cycle 23 began in May 1996 with smoothed sunspot number, and peaked in April 2001. However, a sudden increase of activities occurred during the period of so-called Halloween storms, in October-November 2003. Similar storms occurred one year later, during the period from October 3 to November 13, 2004 (Hady, 2009). The underlying physics of the solar cycles 23 and 24 is not fully understood till the present time (Kane, 2008) and (Solheim *et al.*, 2012). The aim of the present work is to study the eruptive solar events during 2014 especially that released x-class flares. Descriptive and analytical studies are given to follow the morphological and magnetic changes of the active region before, during, and after the production of X-class flares during the double peak of the solar cycle 24.

2. Data and Observations

The dataset considered in the present study is based on the eruptive solar events associated with soft X-ray flares of X class (peak flux $\sim 10^{-4}$ Wm^{-2}) during 2014. Nine events of x-class flares were observed and examined in this paper. The daily solar data of the solar events under study are represented in table 1. The first column represents the date of the events in Year, month, and day. The second column represents the 10.7cm (2800 MHz) full Sun background radio flux on the date indicated in units of 10^{-22}Wm^{-2}Hz^{-1}. The third column shows the Space Environment Services Center (SESC) sunspot number

Table 1. Daily solar data for x-class flare days occurring through the year 2014

Date	Radio Flux 10.7 cm	SSESC Sunspot Number	Sunspot Area 10^{-6}Hemis.	Sunspot Region	Flare intensity	——Flares——						
						X-Ray			Optical			
						C	M	X	S	1	2	3
2014 0107	237	196	1850	AR1944	X1.2	8	2	1	13	1	2	0
2014 02 25	174	157	910	AR1990	X4.9	4	0	1	11	1	1	0
2014 0329	143	132	470	AR2017	X1.0	14	0	1	15	1	1	0
2014 04 25	125	73	390	AR2046	X1.3	4	0	1	1	0	0	0
2014 06 10	166	149	1240	AR2087	X2.2	6	0	2	6	1	0	0
2014 06 11	168	176	1490	AR2087	X1.3	10	3	1	19	0	2	0
2014 09 10	160	161	1070	AR2158	X1.6	1	0	1	12	0	1	0
2014 10 19	173	86	1850	AR2192	X1.0	7	0	1	10	0	0	1
2014 10 22	216	123	3120	AR2192	X1.3	4	3	1	9	0	1	0
2014 10 24	218	147	2820	AR2192	X3.0	5	1	1	10	0	0	1
2014 10 25	219	115	2810	AR2192	X1.0	7	0	1	7	1	0	1
2014 10 26	217	138	3020	AR2192	X2.0	10	4	1	9	0	1	0
2014 10 27	188	120	2530	AR2192	X2.0	6	5	1	1	1	2	1
2014 11 07	146	96	510	AR2205	X1.0	6	3	1	7	0	1	1
2014 12 20	203	120	1750	AR2242	X2.0	5	0	1	12	1	0	1

for the date indicated as computed according to the Wolf Sunspot number equation. The 4^{th} column represents the sunspot area. The 5^{th} column represents the sunspot region number. The 6^{th} column shows the X- class flares intensity. The 7^{th} column is divided into two columns, representing the X-ray flare and optical flare intensity respectively. The data obtained from the Daily Solar Data were given from U.S. Dept. of Commerce, NOAA, and Space Weather Prediction Center:

http://legacy-www.swpc.noaa.gov/weekly/index.html, ftp://ftp.swpc.noaa.gov/pub/indices/old_indices/2014_DSD.txt

In the present study, 6 daily solar parameters were analyzed, namely, 10.7cm radio flux, sunspot number, sunspot area, daily average background x-ray flux, X-ray flare intensity and optical flare intensity. A MATHEMATICA program was constructed to analyze the six solar indices mentioned above. The program is based on the ascending cumulative frequency table. It is found that the effect of the eruptive X-class flares was clearly appeared, for the majority of the events understudy, only on three parameters; X-ray Background Flux, X-ray Flares intensity and Optical Flares intensity. The changes started, at least, one day before the release of X-class flares. This means that we can have a one day forecast before the X-class flare release using this simplified technique. This result is consistent with the finding of (Samwel *et al.*, 2006) that the x-ray flares showed significant changes during the great solar proton events of the solar cycle 23. The highly variation of sunspot number and area during the x-class flare release took place early before the occurrence the events. These variations disappeared in our accumulation curve analysis. As an example, the time profiles of the three solar indices; X-ray Background Flux, X-ray Flares intensity and Optical Flares intensity, for the event which took place on the 7^{th} of January 2014 are represented in Fig. 1(a, b, and c) respectively during and after the release of the eruptive flares.

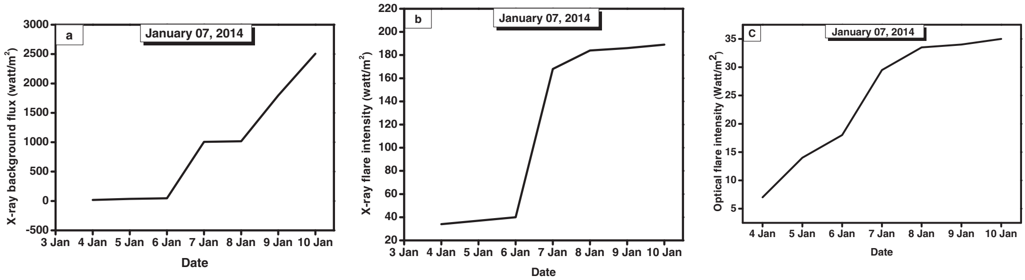

Figure 1. The time profiles of: a) x-ray background flux, b) x-ray flare intensity, and c) optical flare intensity of the event occurred on 7^{th} of January 2014

3. Conclusions

The six solar parameters were analyzed. Sunspot active region AR1990 (formerly AR1967) returned to the earth side of the sun on Feb. 25^{th}, 2014, and promptly erupted, producing an X4. 9-class solar flare. This is the strongest flare of the year, but the giant Sunspot AR2192 is the biggest sunspot in nearly 25 years. It covers 2750 millionths of the solar disk. The changes of the temporal behavior of the sunspot number and area during the x-class flare release happened earlier before the occurrence of the events. This means that these two parameters can be used for a short time forecast, one day earlier before the occurrence of the x-class Flares. The optical flares intensity parameter shows no change in all events under study except in the event which took place in April 25, 2014. At this event, a considerable change was noted, two days after the occurrence of the flare event, attributed to the wavelength of the Optical Flares intensity. The effects of the eruptive X-class flares clearly appeared on three parameters: X-ray Background Flux, X-ray Flares intensity and Optical Flares intensity. The cause of this phenomenon is related to the changes of the area of the active regions which releases these events. The temporal behavior of the 6 parameters shows changes due to some degree, to the flare releasing, However, the time profile of the Radio Flux, Sunspot Numbers and Sunspot Area shows trivial changes compared to the x-ray background flux, X-ray Flare intensity and optical flare intensity.

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