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Studying the great solar proton events during the solar cycle 23

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Abstract. The present work concerns the study of the great solar proton events during the solar cycle 23. For this purpose, the temporal behavior of six solar indices during these great events will be studied. These indices are the radio flux (10.7cm) intensity, the sunspot no., the sunspot area, the GEOS X-ray background flux intensity, and the intensity of the X-ray flares and optical flares.

Keywords. Great proton events, Radio Flux, sunspot number, sunspot area, flare intensity

1. Introduction

It is well known that solar activity exhibits an 11-year periodicity, and the more dramatic events usually occur in the maximum of the cycle. One of the most severe events is the high solar-proton fluxes that tend to follow the well- known 11-year cycle of solar activity. These high solar proton fluxes cause very serious radiation hazards in the inner solar system and have serious effects on interplanetary spacecraft and on material exposed to these energetic protons [Reedy, 2005]. So, the predictions of the high energetic particle events are of vital importance for space navigation. [Mininni, 2000; Pontieri, 2003; and Hady and Shaltout, 2004]. Various methods of warning of these imminent proton events have been proposed in the recent years, but essentially these events are today still unpredictable [Nieminen, 2001].

The aim of present work is, to study the temporal behavior of different indices of the solar activity during the great solar proton events associated with the solar cycle 23 (1996- 2005). The analysis of six sets of solar activity characteristics data has been studied and the summary of the obtained results is represented as a conclusion.

2. Analysis of the daily solar data

Six data sets of the solar activity characteristics are used in order to study the great solar proton events. these six indices are the 10.7 cm (2800 MHz) full Sun background radio flux, the Space Environment Services Center (SESC) sunspot number, the sunspot area, the daily average background x-ray flux as measured by the GEOS satellite, the X-ray flare intensity, and the optical flare intensity.

Table (1) represents the great solar proton events during the solar cycle 23 of proton fluxes greater than 1000 pfu. The first column represents the start date of the event, The second column represents the date of the maximum peak of the event. The third column represents the proton fluxes, in particle flux units (pfu), for energies >10 MeV. The forth column represents the year of observation.

Table 1. The great solar proton events during the solar cycle 23

Start (Day/UT)	Maximum (Day/UT)	Proton Flux (pfu @ >10 MeV)	Year
Apr 20/1400	Apr 21/1205	1,700	1998
Sep 30/1520	Oct 01/0025	1,200	1998
Jul 14/1045	Jul 15/1230	24,000	2000
Nov 08/2350	Nov 09/1600	14,800	2000
Apr 02/2340	Apr 03/0745	1110	2001
Sep 24/1215	Sep 25/2235	12,900	2001
Oct 01/1145	Oct 02/0810	2360	2001
Nov 04/1705	Nov 06/0215	31,700	2001
Nov 22/2320	Nov 24/0555	18,900	2001
Apr 21/0225	Apr 21/2320	2520	2002
Oct 28/1215	Oct 29/0615	29500	2003
Nov 02/1105	Nov 03/0815	1570	2003
Jul 25/1855	Jul 26/2250	2086	2004
Jan 16/0210	Jan 17/1750	5040	2005
May 14/0525	May 15/0240	3140	2005
Sep 08/0215	Sep 11/0425	1880	2005

Table 2 represents sample of the daily solar data of the year 1998, selected to describe the solar proton event which took place in 1998, Apr., 20. The first column represents the date of the events in year, month, and day. Column number two represents the 10.7 cm (2800 MHz) full Sun background radio flux on the date indicated in units of $10^{-22}\ Wm^{-2}\ Hz^{-1}$. The third column represents the Space Environment Services Center (SESC) sunspot number for the indicated date as computed according to the Wolf Sunspot number equation. Column number 4 represents Sunspot area. The fifth column represents daily average background x-ray flux as measured by the GOES satellite. Column number six is divided into two columns. The first column represents the X-ray flare intensity and the second column represents the optical flare intensity.

Table 2. Part of the daily solar data of the year 1998

Date			Radio Flux 10.7 cm	SESC sunspot no.	sunspot area 10E-6 Hemis.	GEOS 12 Bkgd Flux	Flares X-Ray			Flares Optical			
							C	M	X	1	2	3	4
1998	4	18	99	28	50	44	0	0	0	0	0	0	0
1998	4	19	96	35	90	27	0	0	0	3	0	0	0
1998	4	20	98	35	100	17	0	1	0	0	0	0	0
1998	4	21	92	47	70	29	0	0	0	1	0	0	0
1998	4	22	88	41	130	13	0	0	0	7	0	0	0
1998	4	23	90	38	90	16	0	0	1	0	0	0	0
1998	4	24	91	22	0	25	1	0	0	0	0	0	0
1998	4	25	92	50	230	17	3	0	0	2	1	0	0
1998	4	26	91	30	200	12	0	0	0	1	0	0	0
1998	4	27	91	19	200	12	1	0	1	1	0	1	0

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3. Results and Discussion

In order to analyze the solar indices mentioned above, a program, using Mathematica, has been constructed. This program is based on the ascending cumulative frequency table. It is applied for all the great solar proton events during the solar cycle (23). The results obtained are represented below for two of these proton events as examples as shown in the figures (1) and (2). Each figure represents the temporal behavior of six indices which are the radio flux (10.7cm) intensity, sunspot no., the sunspot area, the GEOS X-ray background flux intensity, and the intensity of the X-ray, optical flares.

Figure 1 represents the temporal behavior of the six solar indices for the solar proton event which started in 1998, April, 20, (the day 110), 14.00UT and reached its maximum intensity in 1998, April, 21, (the day 111), 12.05 UT with proton flux intensity 1700 pfu. The x-axis represent the day of year (DOY) 1998, while the y-axis represents the six solar indices in (a, b,...,f). It is noted from figure (1a) that the radio flux intensity (10.7cm) has no significant changes during the period of the solar proton event. Figures (1b), (1c), and (1d) represent slight changes of the temporal behavior of the sunspot number, the sunspot area and the GOES x-ray background intensity respectively. However, figure (1e) and (1f) represent sudden increases in the X-ray and optical flare intensities respectively.

Figure (2) represents the time profile of the solar indices for the solar proton event which started in 2000, November, 8, at the day 314, at 23.50 UT and reached its maximum intensity in 2000, November, 9, at the day 315, at 16.00 UT with proton flux intensity 14800 pfu. It is clear from figure (2d) that the GEOS X-ray background flux intensities shows unexpected increase at the day 314. in addition, both of the X-ray flare intensity and the optical flare intensity show considerable increases at the days 315 as shown in figures (2e) and (2f) respectively.

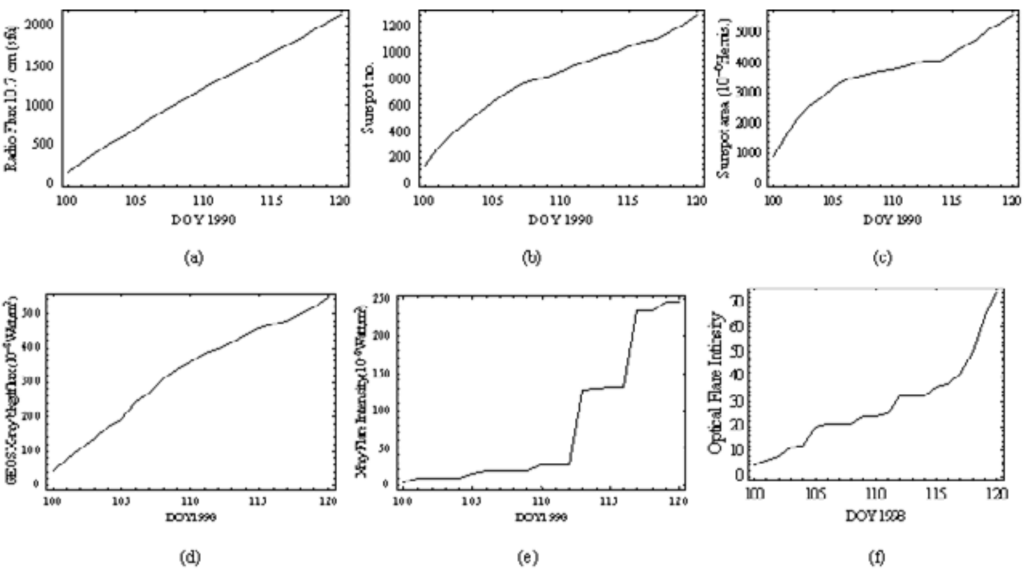

Figure 1. The temporal behavior of the six solar indices; at the interval from 1998, Apr., 18 till 1998, Apr., 27.

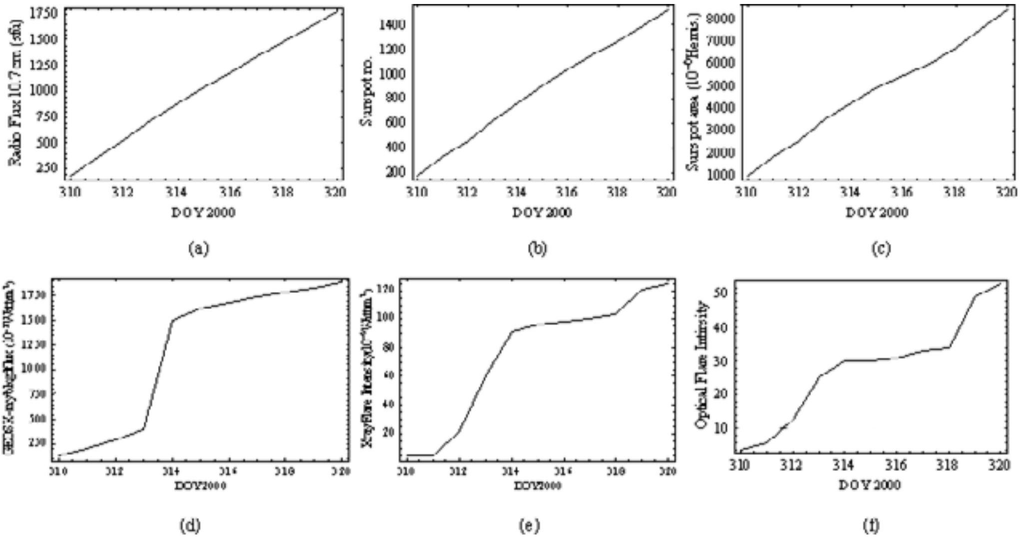

Figure 2. The temporal behavior of the six solar indices at the interval from 2000, Nov., 4 till 2000, Nov., 13

4. Conclusions

In this work, the great solar proton events during the solar cycle 23 are studied. These events are taken for proton fluxes greater than 1000 pfu. In order to perform this study, the temporal behavior of six solar indices during these great events is represented. It is found that the behavior of the X-ray flare intensity shows significant changes during all the great solar proton events under study. The GEOS X-ray background flux intensity and the optical flare intensity show considerable changes during most of the events while the temporal behavior of the sunspot area shows considerable changes during some of the events under study while shows trivial changes during others. On the other hand, the radio flux (10.7 cm) intensity is more or less stable during all the events. Likewise, the time profile of the sunspot number shows only trivial changes during most of the events. In addition to that, this work shows that, during the declining phase of the solar cycle (23), the significant changes of the temporal behavior of some indices start day or two days before the beginning of the proton event which may be an indicator of a coming great solar proton event.

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References

Reedy, R.C. 2005, *Lunar and Planetary Science XXXVI.*

Mininni, P. D., Gomez, D. O. and Mindline, G. B. 2000, *Solar physics Rev Lett.* 85, 5476.

Pontieri, A., Lepreti, F., Sorriso-Volvo, L., Vecchio, A. and Carbone, V. 2003, *Solar Physics* ,213, 198-201.

Hady, A., A., and Shaltout, M. A. 2004, *Proceedings IAU Symposium No. 223.*

Nieminen, P. 2001 *Proceedings of the conference" The calibration legacy of the ISO mission", VILSPA, Spain.*

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