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SUPER AND INTENSE GEOMAGNETIC STORM IN FOUR YEAR WINDOW SURROUNDING SOLAR CYCLE PEAK

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Abstract:
Sunspot cycle (SC) is an approximately-11 year period with increasing and decreasing Sun spot number(SSN).There is relationship between change in Sun spot number (SSN) and geomagnetic storm(GMS),therefore high magnitude geomagnetic storms are found in large numbers around the period of the peak point of the sun spot cycle.In this research paper statistical analyzed intense geomagnetic storm (IGMS) (Dst ranges from -300 to -200 nanoteslas) and supergeomagnetic storm (SGMS) (Dst is-300 nanoteslas or less) for period from 1964 to 2019 that cover the period of solar cycle 20-24, within the four years window starting 1-year prepeak and 3-years postpeakof SC approximately 85.4% of intense geomagnetic storms (IGMSs), approximately 87.5% of super geomagnetic storms (SGMSs), and approximately 85.9% of total geomagnetic storm (TGMS = IGMS+ SGMS) occur.We do the analysis of geomagnetic storms during the four-year window starting 1-year prepeak and 3-years postpeakof different sunspot number cycles, we find that the percentages of total geomagnetic storms (TGMS =IGMS+SGMS) for solar cycles 20, 21, 22, 23, and 24 are 72.7%, 84.6%, 93.3%, 86.9%, and 100% respectively. The above four year window greatly affects function involving magnetic field (FIMF) such as satellite launching,GPS, navigation, magnetic survey, compass use, directional drilling, power system, and radio communication etc. That's why the four year window is very important and sensitive for do the above FIMF.

Keywords-
FIMF, IGMS, SGMS

1. Introduction

When the earth's magnetic field is disturbed by solar released matter a geomagnetic storm occurs, around the peak of the solar cycle the Earth's magnetic field is greatly affected by the solar wind and shock waves emanating from the Sun, leading to high intensity and SGMS. Gonzalez W.D. et al.[2] this study provided connection between solar cycles and intense geomagnetic storm from 1965 to 1985. G. Le et al. [7] analyze solar cycle distribution of great geomagnetic storm after statistical analysis from 1957 to 2005 it was shown that 83% of great geomagnetic storm occur two year before and three year after the solar peak. Echer E. el at. [1] studied intense geomagnetic storm and analyzed their relation with interplanetary parameter for space weather forecasting. Gonzalez et al. [3] examine the distribution of super geomagnetic storm throughout solar cycle, the summary of this paper suggests that super geomagnetic storms occur in all phases of the solar cycle but are more frequent around the solar maximum and during initial descending phase. LeG. et al. [8] statistical analysis of the major geomagnetic storm from 1957 to 2006 the results obtained to show that, 82% of geomagnetic storms occur at Dst≤ - 100 nT level , about 12% are great GMS ,and about 6% are SGMS. It was also observed that 27% of geomagnetic storm occur during ascending phases of the SC and 73% of GMS occur during descending phase of the SC. Rodger C.J. et al.[9], this paper gives historical data of super geomagnetic storm of the last 50 years from 1965 to 2015. It is clear that solar cycle disrupt the geomagnetic field here we referred to the solar earth connection when high intensity and super geomagnetic storm occur the magnetic field based systems on the earth are affected. Gupta et al.[5] solar- terrestrial events and solar cycle phases were studied in this paper during 1956 to 1963, these events occur in the ascending and descending phases except at solar peak. Zang et al. [10] study the Solar terrestrial connection andGMSs are influenced by the combined impact of solar wind and IMF

parameter. Katus R. M. et al. [6] in this paper investigate effect of geomagnetic storm on space based function.

In present paper we are analyzing high intensity and super geomagnetic storms, data collection has been done from 1964 to 2019. It covers solar cycles 20 to 24. The four-year period around the solar cycle peak is very favorable for high intensity and super geomagnetic storms. In the above period, the number of high intensity and super geomagnetic storms is very high, so this period is very dangerous and sensitive for the function involving magnetic field such as satellite launching, GPS, navigation, magnetic survey, compass use, power system, and radio communication etc. Therefore, the above FIMF should not be performed in this four-year period or should be done with extra caution because there is a full possibility of affecting the results. Here is the purpose of this paper.

2. Data Analysis-

We have analyzed large GMS with Dst values below -200 nanoteslas focusing on the period 1964-2019 that covers SC 20, 21, 22 ,23,and 24.Our research work used Dst values from the WDC at kyoto univ. database and SSN from the SIDC.

Table –1 The IGMS, SGMS Occurred during 1964-2019

Date of maximum decreases in Dst Value	Main phase on set date and time (DD/UT)	Dst Value (nT)
Solar cycle 20 (oct.1964-june1976) peak time- nov.1968		
25 May 1967	25 (24UT)	-312
26 May 1967	26 (05UT)	-387
31 Oct. 1968	31 (19UT)	-224
01 Nov. 1968	01 (23UT)	-216
24 Mar.1969	24 (02UT)	-218
08 Mar.1970	08 (23UT)	-284
09 Mar.1970	09 (01UT)	-258
01 Apr.1973	01 (23UT)	-211
06 Jul.1974	06 (07UT)	-204
26 Mar.1976	26 (09UT)	-226
01 Apr.1976	01 (09UT)	-218
Solar cycle 21 (jun.1976-sep.1986) peak time –dec.1979		
28 Aug.1978	28 (10UT)	-226
29 Sep.1978	29 (10UT)	-224
04 Apr.1979	04 (04UT)	-202
19 Dec.1980	19 (19UT)	-240
05 Mar.1981	05 (18UT)	-215
13 Apr.1981	13 (07UT)	-311T-1 Cont.
25 Jul.1981	25 (21UT)	-226
02 Mar.1982	02 (06UT)	-211
14 Jul.1982	14 (02UT)	-325
06 Sep.1982	06 (12UT)	-289
22 Sep.1982	22 (08UT)	-210
10 Jan.1983	10 (10UT)	-203
09 Feb.1986	09 (01UT)	-307
Solar cycle 22 (sep.1986-may.1996) peak time –jul.1989		
13 Mar. 1989	13 (24UT)	-472
14 Mar. 1989	14 (02UT)	-589
19 Sep.1989	19 (05UT)	-255
21 Oct.1989	21 (17UT)	-268

17 Nov. 1989	17 (23UT)	-266
18 Nov.1989	18 (01UT)	-235
10 Apr. 1990	10 (19UT)	-281
24 Mar. 1991	24 (24UT)	-281
25 Mar. 1991	25 (01UT)	-298
29 Oct. 1991	29 (08UT)	-254
08 Nov.1991	08 (24UT)	-280
09 Nov.1991	09 (02UT)	-354
09 Feb. 1992	09 (09UT)	-201
10 May.1992	10 (15UT)	-288
17 Apr.1994	17 (08UT)	-201
Solar cycle 23 (may 1996-dec.2008) peak time- apr.2000		
04 May 1998	04 (06UT)	-205
25 Sep. 1998	25 (10UT)	-207
22 Oct.1999	22 (07UT)	-237
06 Apr. 2000	06 (23UT)	-287
07 Apr. 2000	07 (01UT)	-288
15 Jul. 2000	15 (22UT)	-289
16 Jul. 2000	16 (01UT)	-301
12 Aug. 2000	12 (10UT)	-235
17 Sep. 2000	17 (24UT)	-201
31 Mar. 2001	31 (09UT)	-387T-1 Cont.
01 Apr. 2001	01 (01UT)	-228
11 Apr. 2001	11 (24UT)	-271
12 Apr. 2001	12 (01UT)	-236
06 Nov. 2001	06 (07UT)	-292
24 Nov. 2001	24 (17UT)	-221
29 Oct. 2003	29 (24UT)	-350
30 Oct. 2003	30 (23UT)	-383
31 Oct. 2003	31 (01UT)	-307
20 Nov. 2003	20 (21UT)	-422
21 Nov. 2003	21 (01UT)	-309
08 Nov. 2004	08 (07UT)	-374
10 Nov. 2004	10 (11UT)	-263
15 May 2005	15 (09UT)	-247
Solar cycle 24 (jan.2008-dec.2019) peak time-apr. 2014		
17 Mar. 2015	17 (23UT)	-234
18 Mar. 2015	18 (01UT)	-200

Table-2 - The IGMS,SGMS and Total TGMS for4-year window starting 1-year prepeak and 3-years postpeakof the SC

Number →	For 4-year window starting 1-year pre peak and 3-years post peak	For the whole period 1964-2019	Ratio
Storm Intensity ↓			
Dst≤-300nT (SGMS)	14	16	87.5%
-300nT<Dst≤-200nT (IGMS)	41	48	85.4%

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	55	64	85.9%

Table-3(TGMS=IGMS+SGMS) for different SC 20-24

Solar Cycle	Sunspot Number	(TGMS=IGMS+SGMS)for 4-year window starting 1-year pre peak and 3-years post peak	(TGMS=IGMS+SGMS) For the whole period	Ratio
20	110.6	08	11	72.7%
21	164.5	11	13	84.6%
22	158.5	14	15	93.3%
23	120.4	20	23	86.9%
24	81.8	02	02	100%

Table [1] shows IGMSs and SGMSs for the period 1964 - 2019, in which 48 IGMS and 16 SGMS occurred, thus a total of 64 TGMS (IGMS + SGMS) occurred. Table [2] shows IGMS and SGMS for the period one year before and three years after the peak of the solar cycle. 41 IGMS, 14 SGMS and 55 total TGMS (IGMS + SGMS)occurred in 4-year windowstarting 1-year pre peak and 3-years post peak. Table [3]displaysTGMS (IGMS + SGMS) individually for SC from 20 to 24. In this, for the whole period of SC from 20 to 24 the TGMS(IGMS+ SGMS) are 11, 13, 15, 23, and 02 respectively, and for 4-year windowstarting 1-year pre peak and 3-years post peak, TGMS (IGMS+GMS) are 08, 11, 14, 20, and 02 respectively.

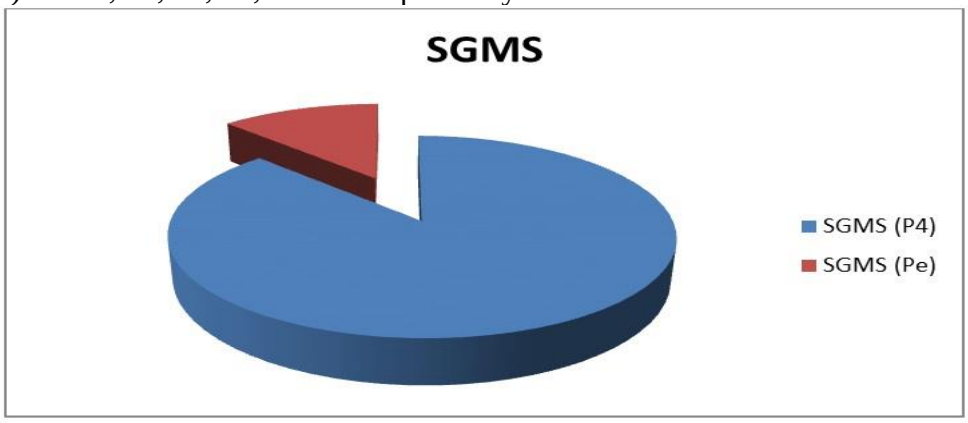

Figure [1] –Relative share of SGMS in 4-year window starting 1-year pre peak and 3-years post peak (P4) and for remaining period (Pe) excluding this.

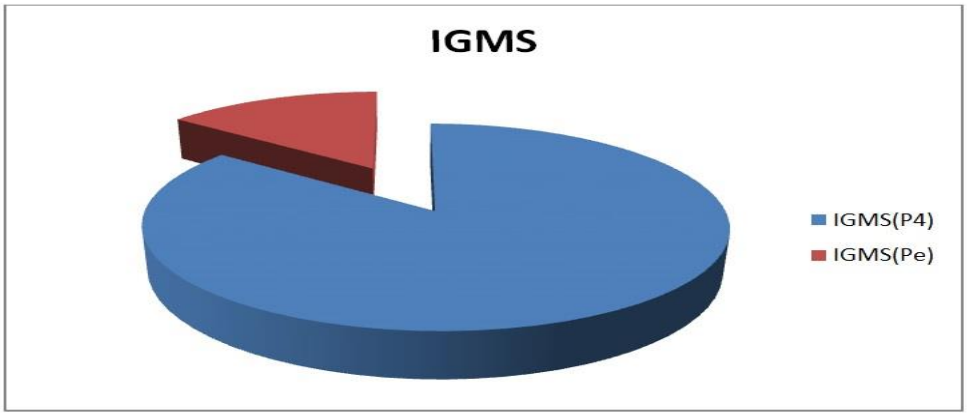

Figure [2] –Relative share of IGMS in 4-year windowstarting 1-year pre peak and 3-years post peak (P4) and for remaining period (Pe) excluding this.

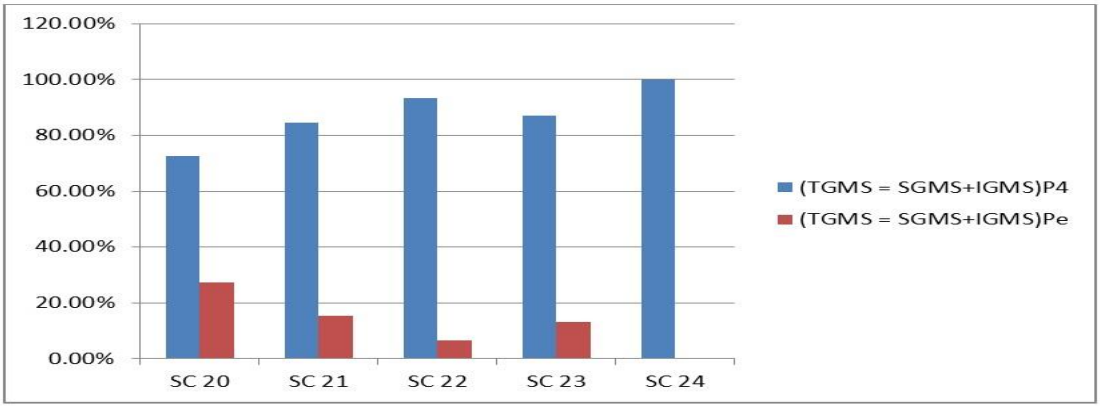

Figure [3] –Relative share of TGMS (SGMS+ IGMS)for solar cycle 20,21,22,23,and 24 in 4 year windowstarting 1- year pre peak and 3-years post peak of the sun spot cycle (P4) and excluding this period (Pe).

3. Result and Discussion :

[1]We find during the period of 1964 to 2019 total intense geomagnetic storm ($D_{st}\leq$-200nT) are 48 storm and total super magnetic storm(-300nT<$D_{st}\leq$-200nT) are 14 Storm.

[2] 85.4% of the total intense geomagnetic storms ($D_{st}\leq$-200nT), i.e. 41 out of 48 storms, occurred in thefour-year windowstarting 1-year pre peak and 3-years post peak of the sun spot cycle.

[3]87.5% of the total super geomagnetic storms (-300nT<$D_{st}\leq$-200nT), i.e. 14 out of 16 storms, occurred inthe four-year windowstarting 1-year pre peak and 3-years post peak of the sun spot cycle.

[4]In SC from 20 to 24 TGM(IGMS+SGMS)relative shareare 72%, 84.6%, 93.3%, 86.9% and 100% respectively in thefour-year window around the solar cycle peak. It is clear from this that the frequency of above storm is high in solar cycles 21, 22, 23 and 24 but the frequency of above storm is low in solar cycle 20.

[5]Three geomagnetic storms with Dst < -400 nT have been observed from Solar Cycles 20 to 24 ,two of these storms were observed in Solar Cycle 22 and one storm in Solar Cycle 23. The geomagnetic storm on 14 March 1989 is the strongest in which the value of Dst was -589 nT.

4. Conclusion

In present paper,after above statistical analysis,it has been found thatapproximately85.4% intense geomagnetic storms (IGMSs), approximately87.5% super geomagnetic storms (SGMSs), and approximately 85.9% TGMS (IGMS+ SGMS) are obtained inthe four year window starting 1- year pre peak and 3-years post peak of the sun spot cycle.In SC from 20 to 24 TGM (IGMS+SGMS) relative share are 72%, 84.6%, 93.3%, 86.9% and 100% respectivelyinthe four year window around the solar peak.It is clear that inthe four year window around the solar peak, FIMF such as satellite launching, GPS, navigation, magnetic survey, compass use, power system, and radio communication will be affected, hence extra caution should be taken for FIMF in the above period.

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