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Geomagnetic Parameters Influencing Geomagnetic Storms in Relation to Solar Terrestrial Relationship

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ABSTRACT: Major disturbances of magnetosphere occurred when the interplanetary magnetic field turns southward and remains there for a long period of time, then can produce geomagnetic storms which can last for more than a day foe severe storms. The phase is characterized by the occurrence of multiple intense substorms. In this paper, the inter correlation between the geomagnetic storms and different geomagnetic indices are critically examined in connection solar terrestrial relationship.

KEYWORDS: *Ap* and *Kp* index, Geomagnetic storms, Solar cycles, CME.

I. INTRODUCTION

Geomagnetic storms are major disturbances of the magnetosphere that occur when the interplanetary magnetic field turns southward and remains southward for an prolonged period of time. During a geomagnetic storm's main phase, which can last as long as two to two and a half days in the case of a severe storm, charged particles in the near-Earth plasma sheet are energized and injected deeper into the inner magnetosphere, producing the storm-time ring current. This phase is characterized by the occurrence of multiple intense substorms, with the attendant auroral and geomagnetic effects. (The nature of the relationship between magnetic storms and substorms is a matter of some controversy.) When the interplanetary field turns northward again, the rate of plasma energization and inward transport slows and the various loss processes that remove plasma from the ring current can begin to restore it to its pre-storm state. In the case of a great storm, the ring current can take over a month to fully return to its quiet state. The drop in the surface magnetic field strength during the main phase of a geomagnetic storm is typically preceded by a brief rise in the field strength. This increase is caused by an intensification of the magnetopause current that occurs as increased solar wind dynamic pressure drives the magnetopause inward by as much as four Earth radii. This phenomenon, which is known as the storm sudden commencement (SSC), marks the beginning of the initial phase of the storm. The variation of geomagnetic *Ap* and *Kp* index with the sunspot number are investigated and their inter-correlations with the geomagnetic storms were being analyzed for the chosen sunspot cycles. It appears that the occurrence of geomagnetic storms is more probable during solar maximum than in solar minimum.

II. TYPES OF GEOMAGNETIC STORMS: RECURRENT VS. NON-RECURRENT STORMS

Geomagnetic storms are classified as recurrent and non-recurrent. Recurrent storms occur every 27 days, corresponding to the Sun's rotation period. They are triggered by the Earth's encounters with the southward- oriented magnetic field of the high-pressure regions formed in the interplanetary medium by the interaction of low- and high-speed solar wind streams co-rotating with the Sun. Recurrent storms occur most frequently in the declining phase of the solar cycle. Non-recurrent geomagnetic storms, on the other hand, occur most frequently near solar maximum. They are caused by interplanetary disturbances driven by fast Coronal Mass Ejection (CME) and typically involve an encounter with both the interplanetary shock wave and the CME that drives it.

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III. SUBSTORMS

Substorms are short magnetospheric disturbances that occur when the interplanetary magnetic field turns southward, permitting interplanetary and terrestrial magnetic field lines to merge at the dayside magnetopause and energy to be transferred from the solar wind to the magnetosphere. The storage of some of this energy in the Earth's magnetotail constitutes the first of the three phases of the substorm(Shown in Figure 1), the "growth" phase. During the second phase, the substorm expansion phase, the energy stored in the tail is released when the field lines in the inner magnetosphere relax from their stretched, tail-like configuration and "snap" back into a more dipolar configuration. This process, known as dipolarization, results in the energization of charged particles in the plasma sheet and their injection deeper into the inner magnetosphere. It is not known what triggers substorm expansion, although several theories have been proposed. The role that this process plays in the formation of the storm-time ring current is a matter of controversy. The third phase is the recovery phase, during which the magnetosphere returns to its quiet state. The storage and release of energy in the magnetopshere during a substorm leads to characteristic changes in auroral methodology and emission intensity and to the enhancement of currents flowing in the polar ionosphere and associated disturbances in the strength of the high-latitude surface magnetic field. Substorms occur, on the average, six times a day; they occur more frequently, and are more intense, during geomagnetic storms.

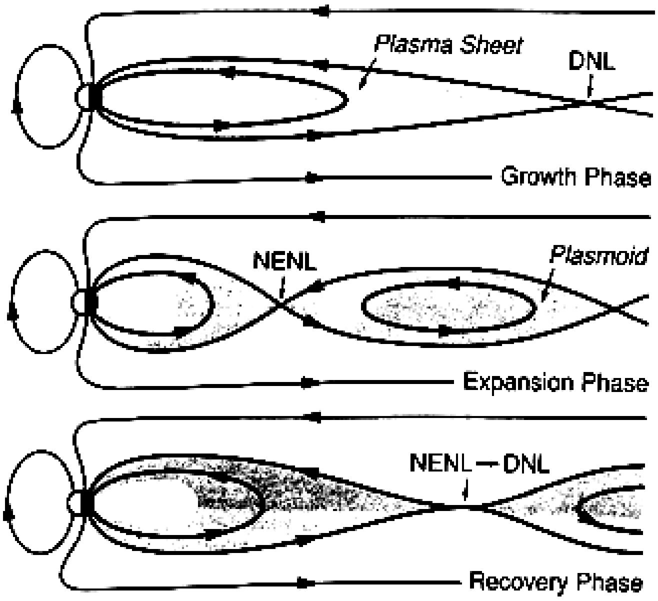

Fig.1 Illustration of different phases of substroms[1]

IV. IMPACT OF GEOMAGNETIC INDICES OVER GEOMAGNETIC STORMS

To study the condition of the earth's magnetic field, geomagnetic indices [2-5] are taken into account. The geomagnetic *Kp* index and *Ap* index are two such indices which are determining the condition of earth's magnetic field [6-8].

A. Correlation between Kp and Ap values

While the correlation between yearly *Kp* and *Ap* values for this solar cycle and the previous three were examined by using scatter plot of the yearly data, the R^2 value in the upper left corner of the plot ($R^2 = 0.962$) of Figure 2 tells us how well correlated the two values are. The black line is a best-fit linear trend line. If we take a logarithmic trend line the value of R^2 is even better ($R^2 = 0.976$), but the best (a higher value of $R^2 = 0.985$) with a second order polynomial trend line. Using the term y for the smoothed Kp values and the term x for the smoothed Ap values we have:

$y = 1.099x + 7.284$ [Linear trend line]
$y = 12.90\ lnx - 10.56$ [Logarithmic trend line]

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$y = -0.029x2 + 1.902x + 2.474$ [Second order polynomial trend line]

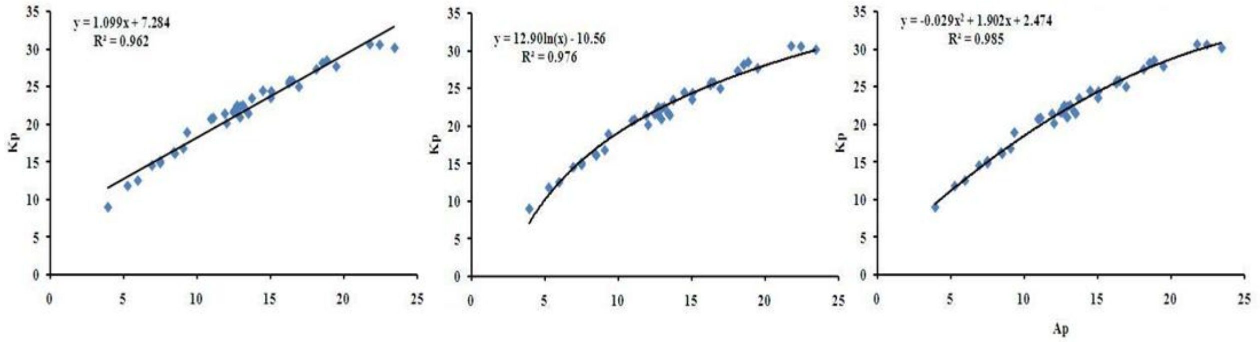

Fig.2 Correlation of geomagnetic *Kp* and *Ap* values

B. Correlation of Kp and Ap valueswith the number of geomagnetic storms

The *Ap* index ranges from 0–20 for quiet conditions and up to 400 for disturbed conditions. Table I presents the geomagnetic conditions for different values of A_P indices and the associated geomagnetic and auroral conditions.

TABLE 1
GEOMAGNETIC AND AURORAL CONDITIONS FOR DIFFERENT VALUES OF A_P INDEX [9]

A_p index	Geomagnetic conditions	Auroraal conditions
0-2	Very Quiet	None
3-5	Quiet	None
6-9	Quiet	Very low
12-19	Unsettled	Very low
22-32	Active	Low
39-56	MINOR Storm	High
67-94	MAJOR Storm	Very High
111-154	SEVERE Storm	Cery High
179-236	SEVERE STORM	Extreme
300-400	EXTREME Storm	Extreme

In Figure 3 the inter-correlation of geomagnetic *Kp* and *Ap* values with the number of storms is plotted and also from the trend line it is observer that both the $Kp(R^2)$ and $Ap(R^2)$ values are highly correlated with the number of storms.

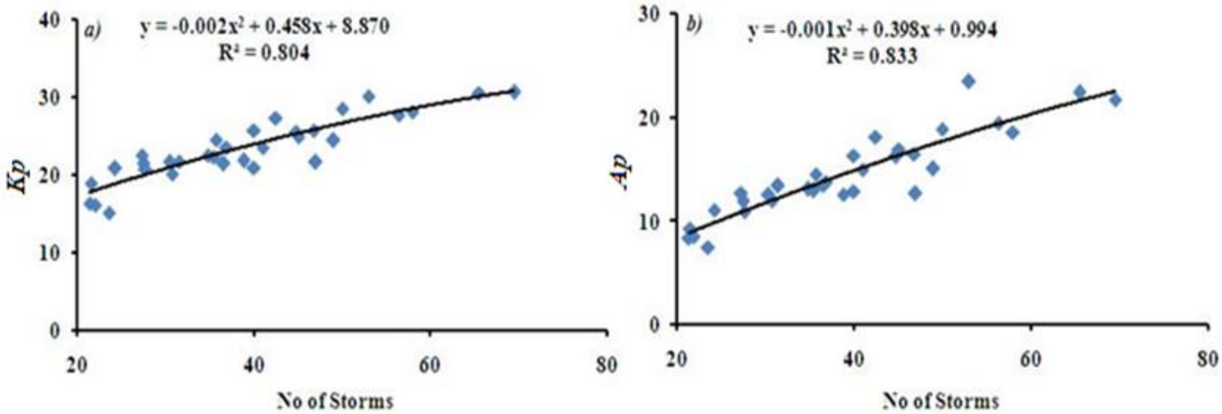

Fig.3 Inter-correlation of geomagnetic *Kp* and *Ap* values with the number of storms

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V. ACTIVITY OF GEOMAGNETIC STORMS

In Table II, the details of the solar cycles 21-24 is presented showing their start, end, duration and monthly smoothed maximum sunspot number.

TABLE II
DETAILS OF SOLAR CYCLES 21-24

Cycle	Start	End	Duration	Monthly smoothed Maximum Sunspot number
21	June 1976	September 1986	10.3	164.5
22	September 1986	May 1996	9.7	158.5
23	May 1996	January 2008	12.6	120.8
24	January 2008	-	-	-

Figure 4 illustrates the variations of A_p during solar cycles 21-24. From the Figure it is obviously observed that severe geomagnetic storms with extreme auroral activity occurred mostly in solar maximum years and there is negligible occurrence of geomagnetic storms in solar minimum years. Thus occurrence of geomagnetic storms is more probable during solar maximum than in solar minimum.

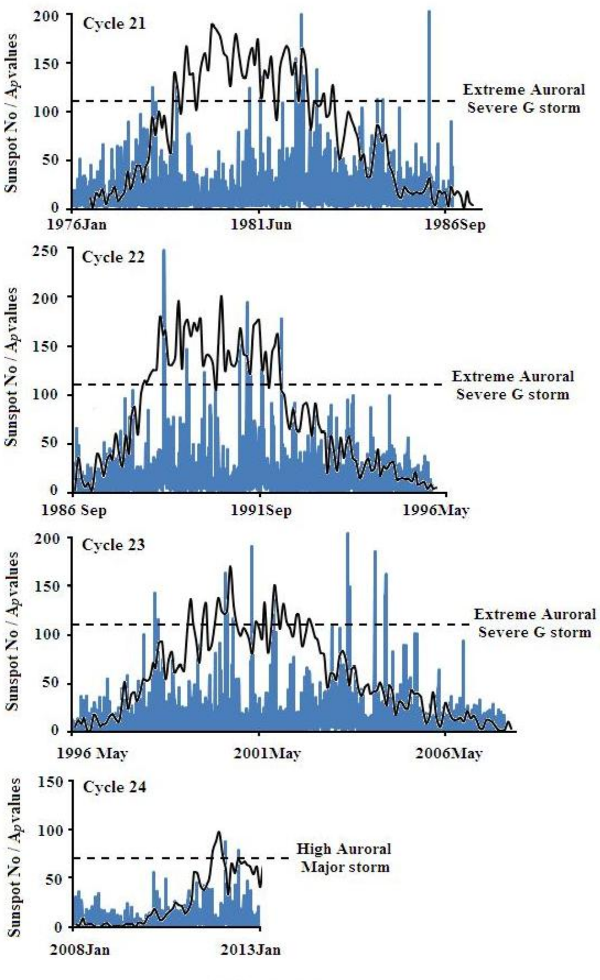

Fig.4 Variations of A_p during solar cycles 21-24 and the association of severe geomagnetic storms

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VI.CONCLUSION

High energetic charged particles, in the form of solar wind are continuously released from the corona of the Sun, when increases may cause solar flares. The Sun is the strongest source of radio waves in our solar system which affects the earth's atmosphere including its geomagnetic field. For investigating solar terrestrial relations the variations of geomagnetic parameters, as we have done in the present study, may grant precious information. During solar maximum greater number of sunspot is observed and greater number of flares occur than that during solar minimum. On comparing the variations of $\boldsymbol{A_p}$ during solar cycles 21-24 we observed that severe geomagnetic storms with extreme auroral activity occurred mostly in solar maximum years and there is negligible occurrence of geomagnetic storms in solar minimum years. Thus occurrence of geomagnetic storms is more probable during solar maximum than in solar minimum [10]. The variations of the northern and southern hemisphere temperature when studied it is observed that there is a rising trend for both of them although the total solar irradiance trend is decreasing and this in turn may cause global warming to affect the human civilization a lot.

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