

Geomagnetic disturbances and Cyclonic Activity over the North Indian Ocean during 22nd Solar Cycle

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ABSTRACT

Tropical Cyclone activities over the North Indian Ocean (comprising Bay of Bengal and Arabian Sea) constitute one of the major natural disasters of our country. To understand the Tropical Cyclonic activities, estimations of their frequencies are necessary. In this study, the number of Geomagnetic Storms (Sudden and Gradual type) during 22nd solar cycle and Cyclonic Activity includes Depression, Cyclonic Storm and Severe Cyclonic Storm over the North Indian Ocean has been analysed using Spearman Rank Correlation technique. A positive correlation is found in both cases. When compared to Sudden or Gradual type of Geomagnetic Storms, the Gradual type of Geomagnetic Storms increases the Cyclonic Activity over the North Indian Ocean during 22nd solar cycle.

INTRODUCTION

The various types of Solar Dynamic phenomena occurring on the solar surfaces are responsible for Interplanetary and Geomagnetic disturbances. A Solar phenomena known as Coronal Mass Ejection is known to be responsible for Geomagnetic storms (Jagannathan & Bhalme 1973). Jagannathan & Bhalme (1973) found smaller frequency of storms/depressions and shorter westward extent of their tracks during sunspot maximum than during sunspot minimum. Bhalme (1975b) also reported statistically significant (at 5% level) inverse relationships between the number of monsoon storms/depressions and annual sunspots, and an apparent cycle with a period of about 40 years superimposed on linear decreasing trend in monsoon storms/depressions also showing inverse resemblance with sunspot trend in recent years.

Cyclones are caused by several factors. Most important factors are Sea Surface Temperature and Coriolis force. Tropical Cyclones over Bay of Bengal are generally higher both in terms of their frequency and intensity (Krishnakumar, Gadgil Raveevan 2006). Raman & Raghavan (1961) found that the number of monsoon storms/depressions striking the Bay Coast near Calcutta respond to annual sunspots. He showed inverse relationships between them. Upper winds at 4 km and above indicated that the decline of storms/depressions striking the coast is accompanied by a southward shift of the Tibetan summer anti-cyclone in the years of maximum sunspot activity. A lot of

papers are documented in the study of cyclonic activity and magnetic storms.

Regular solar radiation changes affect the Earth's magnetic field. Irregular current systems produce magnetic field changes caused by the interaction of the solar wind with the magnetosphere, by the magnetosphere itself, by the interactions between the magnetosphere and ionosphere, and by the ionosphere itself. The variation of magnetic field, more notably its short-term components, is due to disturbances in the earth's electromagnetic environment caused by solar activity. The degree of disturbance in the magnetic field is indicated by what are called indices of geomagnetic activity. There have been several such indices devised for research and application purposes. The more prominent of these are D_{st} , A_p , k_p , C_p and AE. The official planetary K_p index is derived by calculating a weighted average of k -indices from a network of geomagnetic observatories. The k -index is a code that is related to the maximum fluctuations of horizontal components observed on a magnetometer relative to a quiet day, during a three-hour interval. D_{st} is an index of strength of the symmetric westward ring current which encircles the earth in the equatorial belt of roughly $\pm 30^\circ$ notably during storm-times. This ring current has a dipole moment which is directed opposite to the earth's natural magnetic field. A significant positive correlation between the averaged K_p index of global geomagnetic activity and hurricane intensity as measured by maximum sustained wind speed is identified for baroclinically-initiated hurricanes. A significant statistical relationship

between Geomagnetic activity as measured by the Kp index and hurricane intensity as measured by the maximum wind speed for a certain type of higher-latitude hurricanes (James Elsner & Kavlaikov 2001). Correlations between hurricane occurrence and several solar activity-related phenomena, such as the total solar irradiance, the cosmic ray flux and the Dst index of geomagnetic activity. Results indicate that the highest significant correlations are found between the Atlantic and Pacific hurricanes and the Dst index. Most importantly, both oceans present the highest hurricane–Dst correlations during the ascending part of odd solar cycles and the descending phase of even solar cycles (Mendoza & Pazos 2009).

During maximum period of solar activity huge amounts of solar energy particles are released from the sun. They are responsible for geomagnetic disturbances. The solar cycle, or the solar magnetic activity cycle, is the main source of the ~10.7 year periodic solar variation (changing the level of irradiation experienced on Earth) which drives variations in space weather and to some degree weather on the ground and possibly climate change. The cycle is observed by counting the frequency and placement of sunspots visible on the Sun. In this present study, we have analysed the number of Geomagnetic storms during the 22nd solar cycle (1986-1996) and Cyclonic activity over the North Indian Ocean. A Geomagnetic activity is represented by velocity of Solar Wind Streams and Interplanetary magnetic field. Geomagnetic storm consists of sudden storm commencement and gradual storm commencement. The geomagnetic activity is represented by D_{st} index. The 22nd solar cycle contains two peaks during the year 1989 and 1991 (Dubey & Mishra 2000). The periods 1986 to 1988 and 1992 to 1996 are measured as ascending solar minimum and descending solar minimum.

DATA AND METHODOLOGY

For this study, Spearman's rank correlation technique is used to find out the statistical relationship between Geomagnetic Storms during 22nd solar cycle and frequency of Cyclonic Storm includes depression, cyclonic Storm and severe Cyclonic Storm over Indian Ocean. The "classical or parametric stat" requires three major conditions like (i) measurement of the observations are available on interval or ratio scale, (ii) the background population of the observations should be distributed normally so that the standard deviations of the observations are used predicatively, (iii) the observations be independent of each other. The non parametric statics are defined as either (i) those which

are distribution free statistics, (ii) those which are not concerned with the characteristics of population, (iii) those for which the data are not measured on interval or ratio scale.

The Spearman Rank Correlation (ρ) is a non-parametric measure of statistical dependence between two variables. It is a test for correlation using ranked data. As we use the rank order than the actual values for determining the association between the two set of values it is called a "rank correlation." The actual data are ranked, usually in ascending order i.e., a rank order 1 is allotted to the smallest values of each variable in x and y. The rank order n is given to the largest variable. If two or more values of the variable x and y are tied, they are each assigned the average of the rank positions otherwise they would have been assigned individually if ties had not occurred. For each of the n values of the variables, a set of rank difference is obtained, $d = R_x - R_y$ as the sum of the difference in rank of paired values is zero i.e., $\sum d = 0$, we use $\sum d^2$. Finally Spearman Rank Correlation (ρ) is

$$\rho = 1 - (6 \sum d^2 / n^3 - n)$$

where n is the number of data considered and d is the difference between the ranks of each observation on the two variables. The rank correlation coefficient is a relative measure which varies from -1 through 0 to +1.

Cyclonic Storm data are obtained from IMD Cyclone E- Atlas. We considered the frequency of annual cyclonic storm over the North Indian Ocean during 22nd solar cycle (1986-1996). Geomagnetic Storm activity is obtained from Solar Geophysical Data Reports (Part- I and II) of U.S. Department of Commerce, NOAA. Geomagnetic Storms are grouped year to year. Generally Geomagnetic Storms are classified into two categories as sudden type and gradual type. Table 1 & 2 illustrates No. of Geomagnetic storms (sudden and gradual) and No. of Cyclonic storms over North Indian Ocean during 22nd solar activity. Graphs are plotted separately for sudden and gradual type of the number of Geomagnetic Storms and Frequency of Cyclonic Storm over the North Indian Ocean. Figs 1 & 2 illustrates the comparison and variations of No. of Sudden and Gradual type of Geomagnetic Storms with No. of cyclonic storms during 22nd solar cycle.

The Spearman Rank correlation values of Sudden and Gradual type of Geomagnetic Storms, each with the number of Cyclonic activity over the North Indian Ocean are found to be 0.403 and 0.697 respectively. We got positive correlated values. This explains whenever geomagnetic storms forms the number of cyclone also increases to some extent over the North Indian Ocean during 22nd Solar Cycle.

Table 1. No. of Sudden type of Geomagnetic storms and No. of Cyclonic storms over North Indian Ocean during 22nd solar cycle.

Year	No. Of Geomagnetic storm (sudden type)	No. Of Cyclonic Storm
1986	4	6
1987	1	6
1988	3	9
1989	13	10
1990	5	9
1991	8	8
1992	5	12
1993	5	5
1994	5	8
1995	2	8
1996	0	8

Table 2. No. of Gradual type of Geomagnetic storms and No. of Cyclonic storms over North Indian Ocean during 22nd solar cycle.

Year	No. Of Geomagnetic storm (gradual type)	No.Of Cyclonic Storm
1986	1	6
1987	4	6
1988	7	9
1989	7	10
1990	9	9
1991	8	8
1992	8	12
1993	1	5
1994	2	8
1995	1	8
1996	1	8

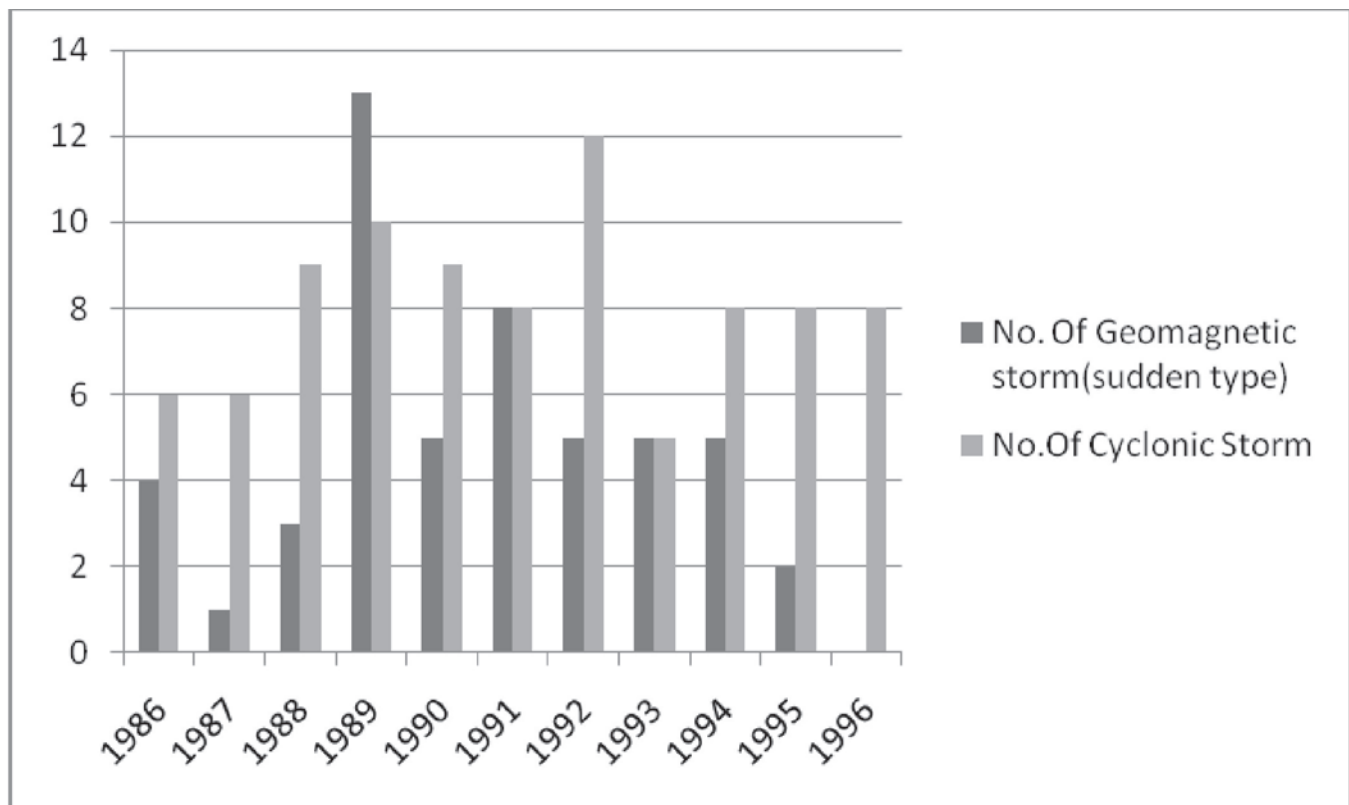


Figure 1. Variations of No. of Sudden type of Geomagnetic Storms and No. of cyclonic storms during 22nd solar cycle.

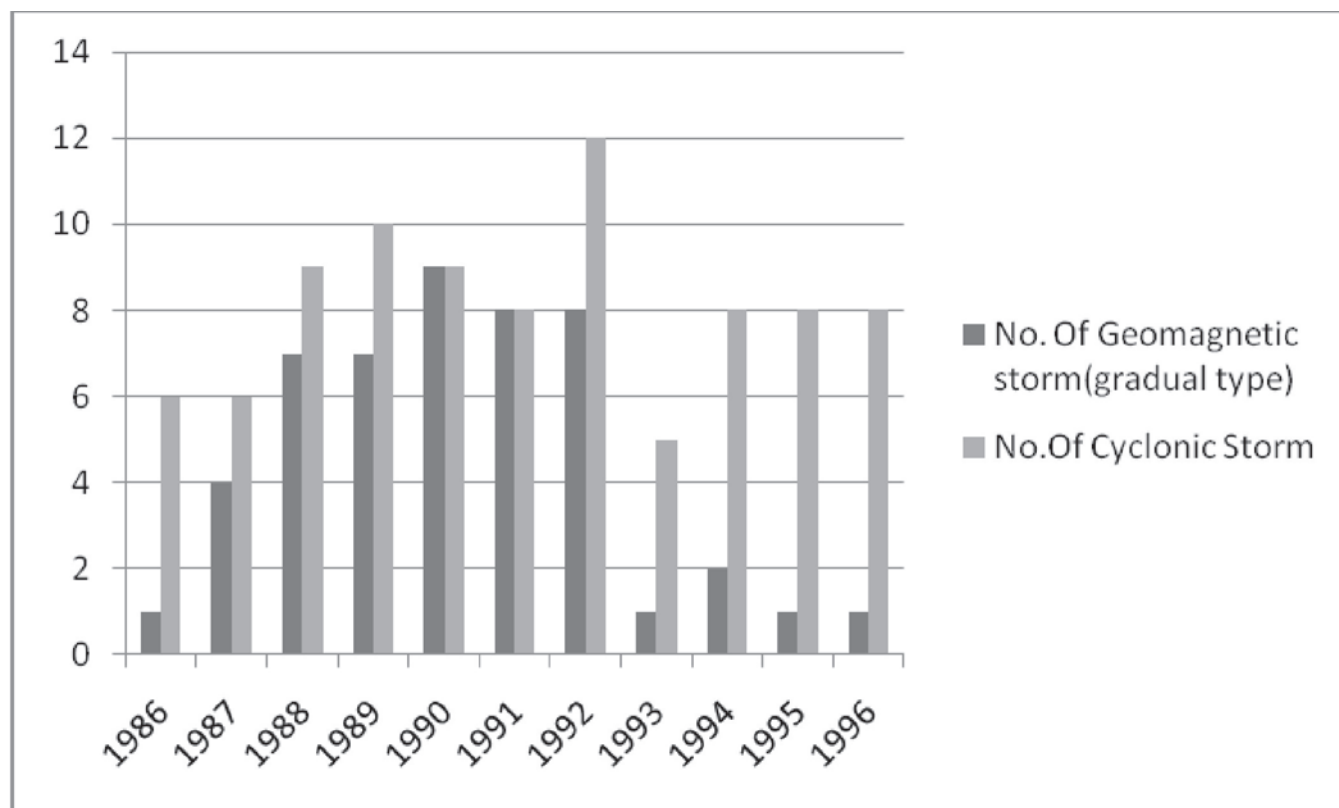


Figure 2. Variations of No. of Gradual type of Geomagnetic Storms and No. of cyclonic storms during 22nd solar cycle.

SUMMARY AND CONCLUSIONS

From this paper we infer that geomagnetic activity, both sudden and gradual type influences the cyclonic activity over the North Indian Ocean. The Spearman's Rank Correlation Coefficient has been calculated for 22nd solar cycle and it takes the value of 0.297 for sudden type and 0.771 for gradual type of geomagnetic storms. This explains whenever geomagnetic storms forms; the number of cyclone also increases to some extent over the North Indian Ocean during 22nd Solar Cycle. As the Spearman Rank Correlation Value of Gradual type of Geomagnetic Storms with the Cyclonic activity is more positive when compared to that of the sudden type of Geomagnetic Storms, the influence of the former is high on the Cyclonic activity than the latter. The Gradual type of Geomagnetic storms increases the Cyclonic Activity over the North Indian Ocean during 22nd solar cycle. This result is in agreement with the other research papers related to the cyclonic activity.

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(Revised accepted 2011 March 1, Received 2010 July 19)



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