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COMPARATIVE ANALYSIS INTO THE GEOMAGNETIC INDICES (ap, AE, DST, Bz) DURING DISTURBED PERIOD AND QUIET CONDITIONS OF SOLAR MAXIMUM YEAR (2001)

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ABSTRACT: Geomagnetic indices are used to measure the intensity of geomagnetic storms. In the study of solar terrestrial relationship the use of indices of geo magnetic activity plays an important role. The aim of this work is to compare the linear relationship between geomagnetic indices at quiet and disturbed period when ap <26nTand ap > 26nT for solar maximum in the year (2001). Auroral indices obtained from the omni-web are compared for the geomagnetic disturbance of different intensities. Three hourly average values of the Dst, ap, AE and Bz indices have been studied for one year of high solar activity (2001) during quiet and disturbed period. Thus, the correlations of geomagnetic indices were determined by plotting graphs of the indices against one another. The study reveals that the annual correlation coefficient of AE×ap is 72.3% for quiet period, which is the highest correlation. Also, the coefficient of Dst ×Bz is 7.94% for quiet period, which is the least correlation. For the monthly correlation, the correlation coefficient of AE× Bz in the month of May is 84.9% for disturbed period, which is the highest correlation. Also, the correlation coefficient of ap× Dst in the month of January is 1% for disturbed period, which is the least correlation. For both annual and monthly coefficient, the correlation coefficient of AE × ap (3-hourly values) for quiet period is in general the highest of all, followed by AE × Bz for disturbed and quiet period. Thus, ap is strongly influenced by AE activity or ap is the major factor that determines the auroral activity. It is observed that when Bz has values within -10nT and lower the auroral activities (AE) increases and gives a better correlation relatively to other geomagnetic indices. Also, it is observed that there was intense (or strong) storm in the months of April and October for both disturbed and quiet period. Thus, these months (April and October) could be seen as a critical months which must be given a special attention for consideration in the further studies.

KEYWORDS: Geomagnetic storms, geomagnetic indices, magnetic field, Auroral Electrojets, Solar wind.

1 INTRODUCTION

Geo-magnetic storms generally occur due to abnormal conditions in the Interplanetary Magnetic Field (IMF) and solar wind plasma emissions caused by various solar phenomena. The study of these worldwide disturbances of Earth's magnetic field are important in understanding the dynamics of solar-terrestrial environment and furthermore because such storms can cause life threatening power outages, satellite damage, communication failure and navigational problems. As a result of their unique temporal and spatial coverage, these remarkable data series allow for instance statistical studies over long time periods (more than 125 years) of the solar wind - magnetosphere coupling. It is then possible to characterise the physical processes. Indices of geomagnetic activity (ap, AE, Dst, Bz, kp, k) were introduced over half a century ago. They reflected the prevailing pre satellite era view about generation of the external magnetic field activity. Many researchers have studied the relationship between solar terrestrial and geomagnetic activities; the main reason of this project is to suggest further investigation on the solar terrestrial relationship. Geomagnetic storm generally occurred due to abnormal conditions in the interplanetary magnetic field (IMF) and solar wind plasma caused by various solar phenomena such storm can cause satellite damage, communication failure and navigation problem [2]. When an intense and long lasting interplanetary convective electric field leads through substantial energization in the magnetosphere-ionosphere system to an intense ring current which is stronger than the threshold of the quantifying storm time Dst (disturbance storm time) index, the time interval is defined as a geomagnetic storm (GMS). GMSs are usually classified by the Dst indices as intense storms (peak Dst ≤ −100 nT), moderate storms (−100 nT < peak Dst < −50 nT) and weak storms (peak Dst > −50 nT). In the study of solar-terrestrial relationships, the use of indices of geomagnetic activity plays an important role. The five most commonly used indices are AE, Dst, Bz and the linear counterpart of the letter (National atmospheric and oceanographic Administration), ap. Available since 1932, the Kp index represents the intensity of planetary magnetic activity as seen at subauroral latitudes and is given for each 3-h interval. The individual K indices for each of the contributing mid-latitude observatories reflect the maximum range of any component of the field over the 3-h interval at each station. The Kp index is the average of the K values from all contributing observatories. A conversion scale transforms the quasi-logarithmic Kp to a linear index named ap. AE was defined to measure primarily the variations in the auroral electrojets. It is based on 1-min values of the H- component trace from auroral-zone observatories located around the world. The data of these observatories are plotted as a function of universal time. The upper and lower envelopes are defined as AU and AL indices, respectively, and are believed to represent the maximum eastward and westward electrojet currents. The sum of the absolute values of AL and AU is called AE. The ring-current index Dst. Was introduced to measures primarily the ring-current magnetic field [3]. It is based on hourly averages of the H component recorded at four low-latitude observatories, subtracting the average and the permanent field from the disturbed magnetic [4]. Although these five indices have been calculated for many years, only a few studies on their interrelationships have been published [1],[5].

The purpose of this study is to understand better the possible relationships between the geomagnetic indices. This will be done for two different epochs of the same solar cycle. During the descending phase of the solar cycle, near solar minimum (1974), it is known that stable coronal holes on the sun lead to the existence of recurrent high-speed streams that are observed at earth during every solar rotation. On the other hand, at solar maximum (2001), when large-scale coronal holes retract back to higher latitudes, what produces the observed high-speed streams responsible for the storms are transient solar phenomena generally known as coronal mass ejections (involving the presence of flares or filament eruptions).

1.1 AE (Auroras Electrojets) index is defined primarily as the measurement of variation in the auroral electrojets. It is based on 1 min values of the H component trace from auroras zone observatories located around the world. It measures geomagnetic activity at high latitude. The data of these observatories are plotted as a function of universal time. The upper and lower enveloped are defined as AU and AL indices respectively and are believed to represent the maximum eastward and westward electrojets current. The sum of absolute values of AL and AU is called AE.

1.2 DST (Disturbance Storm Time) index was introduced in 1964 and is defined as the hourly average of the deviation of H (Horizontal) component of magnetic field measured by several ground status and represents the degree of equatorial magnetic field deviation specifying the magnitude of Geomagnetic storms (GMS) measured in nanotesla (nT). It measures geomagnetic activity at low latitude. It is also a measure of in the context of space weather. It gives information about the strength of ring current around earth caused by solar protons and electrons.

1.3 ap index is a measure of the general level of geomagnetic activity over the globe for a given day. It is derived from measurements made at a number of stations world-wide of the variation of the geomagnetic field due to currents flowing in the earth's ionosphere and to a lesser extent in the earth's magnetosphere. To get the ap values we convert the 3-hour Kp values to ap values. It measures geomagnetic activity at mid latitude.

1.4 Bz index. It is generally believed that the basic parameter leading to geomagnetic disturbances is the southward component of interplanetary magnetic field. The Bz value is perpendicular to the elliptic and is created by waves and other disturbances in the solar wind. The strongest connection with the most dramatic effects occurs when the Bz component is tilted heavily southward. The direction of Interplanetary Magnetic field (Bz) is the most important ingredient if we want to see the auroras.

In this paper the linear relationship between geomagnetic indices at quiet and disturbed period when ap < 26 nT and ap > 26nT for solar maximum in the year (2001) has been compared also the annual and monthly correlations between the geomagnetic indices has been investigated.

2 METHODS OF DATA ANALYSIS

In this research, ap index was used instead of Kp since it is based on linear scale and ap is a 3 hourly average index, Dst, Bz and AE were averaged for the same interval for the purpose of comparison. This implies that the result of this study is limited to 3 hourly intervals. The solar wind plasma and field measurements with 1hr time were obtained from the OMNI website [6].

In order to understand how these indices respond to interplanetary sources of activity during different periods of the solar cycle, annual and monthly averages were studied for 2001. A physical relationship between two different indices can be estimated by calculating the linear correlation coefficient 'r' which indicate whether the indices are related or not.

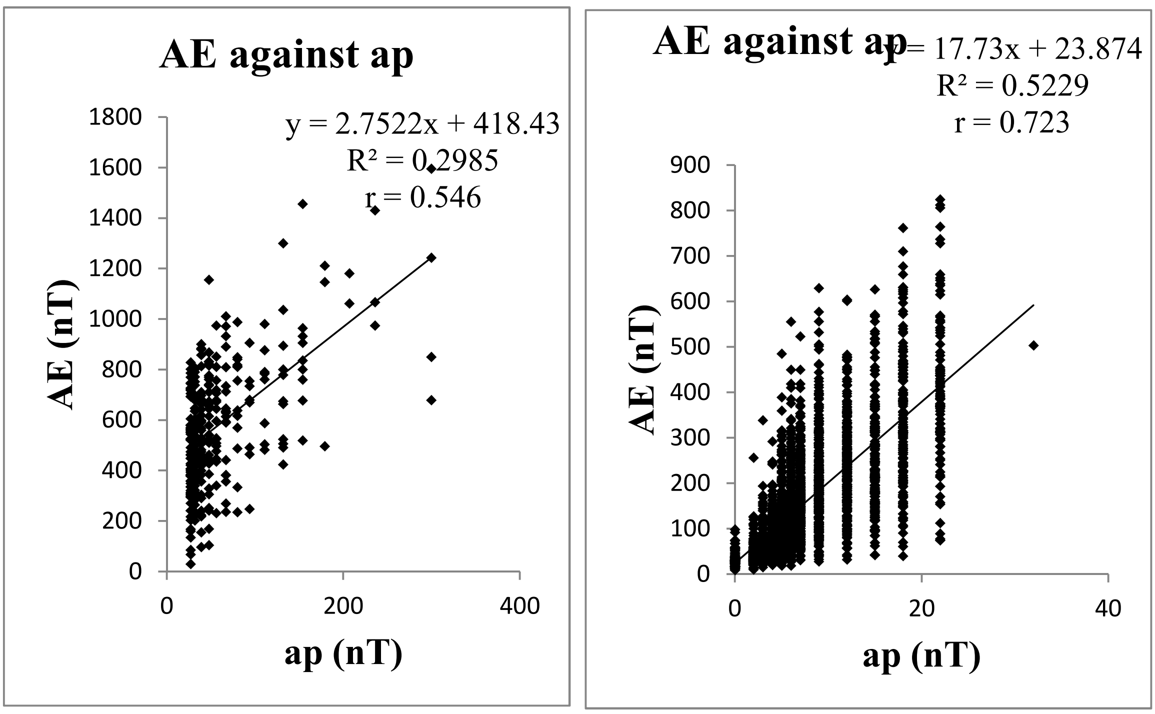
The Julian day calendar was used in getting the corresponding month from the data's of 365 days. Three hour average interval of each geomagnetic indices was calculated and graph for the annual and monthly correlation was drawn for a year of high solar activity (2001) during quiet period when ap is < 26 nT and disturbed period when ap > 26 nT in the format 'ap × AE','ap × Dst', 'ap × Bz', 'AE × Dst', 'AE ×Bz', 'Dst × Bz

3 Results and Discussion

3.1 Annual correlation

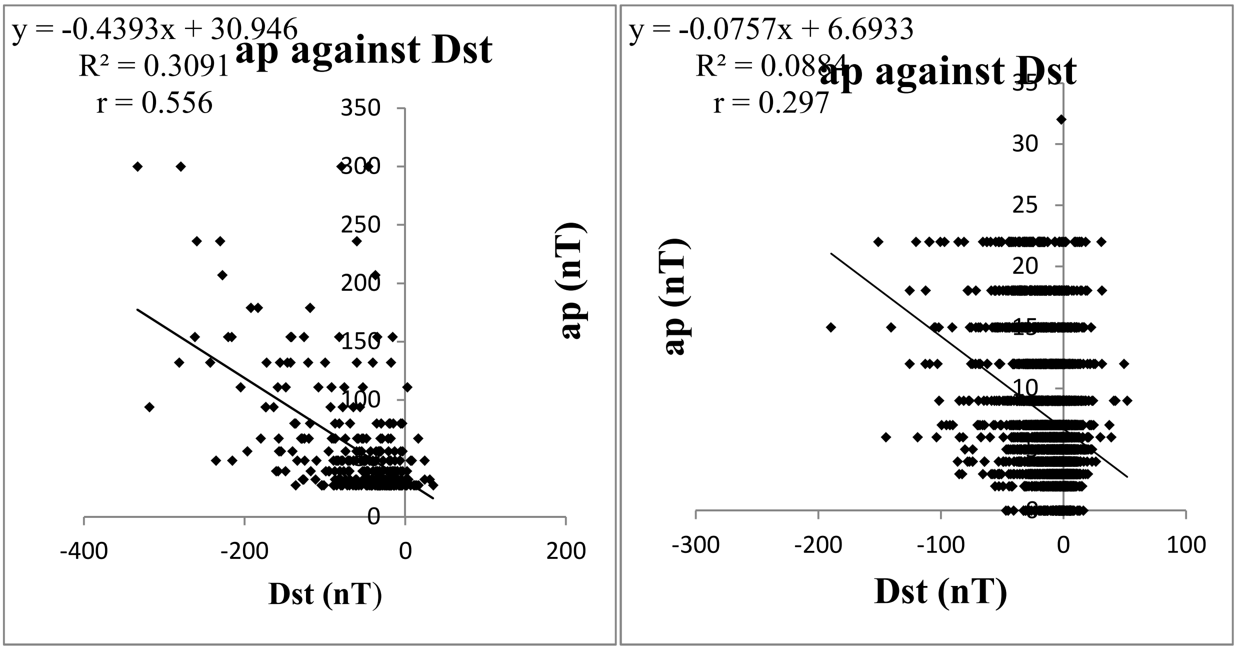
Fig 4.1- 4.6 shows the six possible annual correlation between the geomagnetic indices ap, AE, Dst, Bz during solar maximum (2001), One can see that AE **×** ap for both quiet and disturbed period, AE × Bz for both quiet period and disturbed period and ap × Dst (disturbed period) has correlation above 0.5 (50%), Thus, they can be classified under high correlation. However, AE × ap for quiet period with 72.3% correlation is the highest among all of them.

Also ap × Dst (Quiet period), ap ×Bz (Quiet and disturbed period), AE ×Dst (Quiet and disturbed period) and Dst × Bz (Quiet and disturbed) has correlation below 0.5 (50%), Thus, they can be classified under low correlation. However, Dst × Bz for quiet period with 7.94% correlation is the lowest among all of them. Further, the correlation between ap and AE is the highest of all, as they both have their geomagnetic stations fairly close. Not so well correlated are Dst and Bz, since Dst monitors mainly the ring current, whereas Bz is the basic parameter leading to geomagnetic disturbances is the southward component of interplanetary magnetic field.



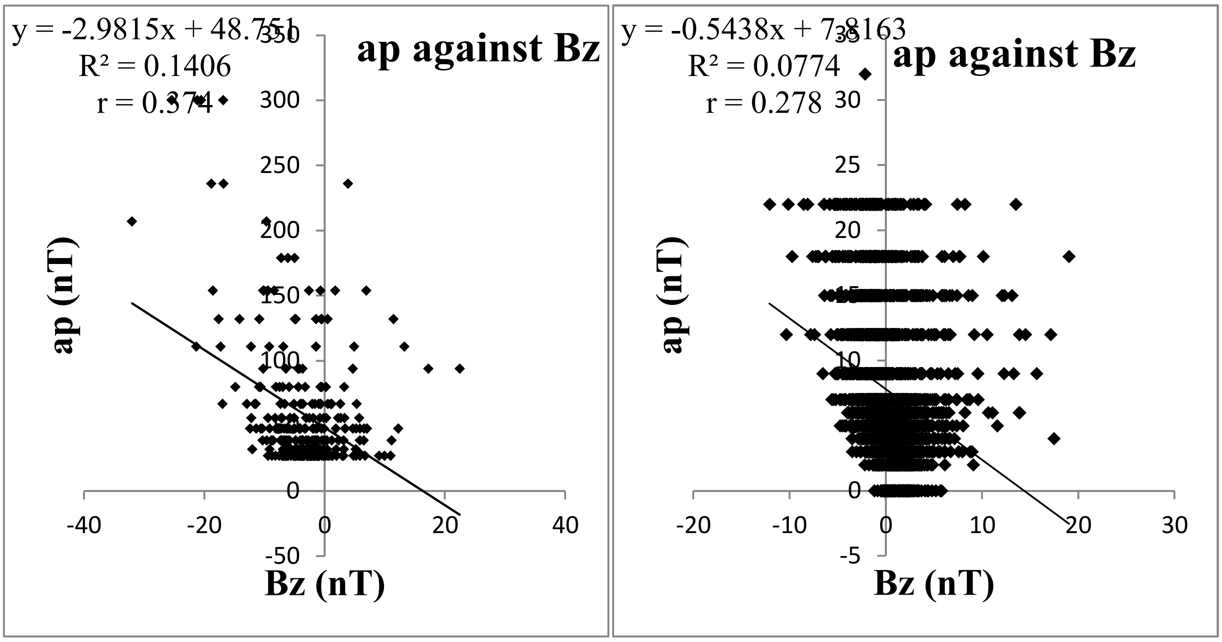
Disturbed Quiet

Fig 4.1: Annual correlation plot of AE against ap for Disturbed & Quiet period for year 2001



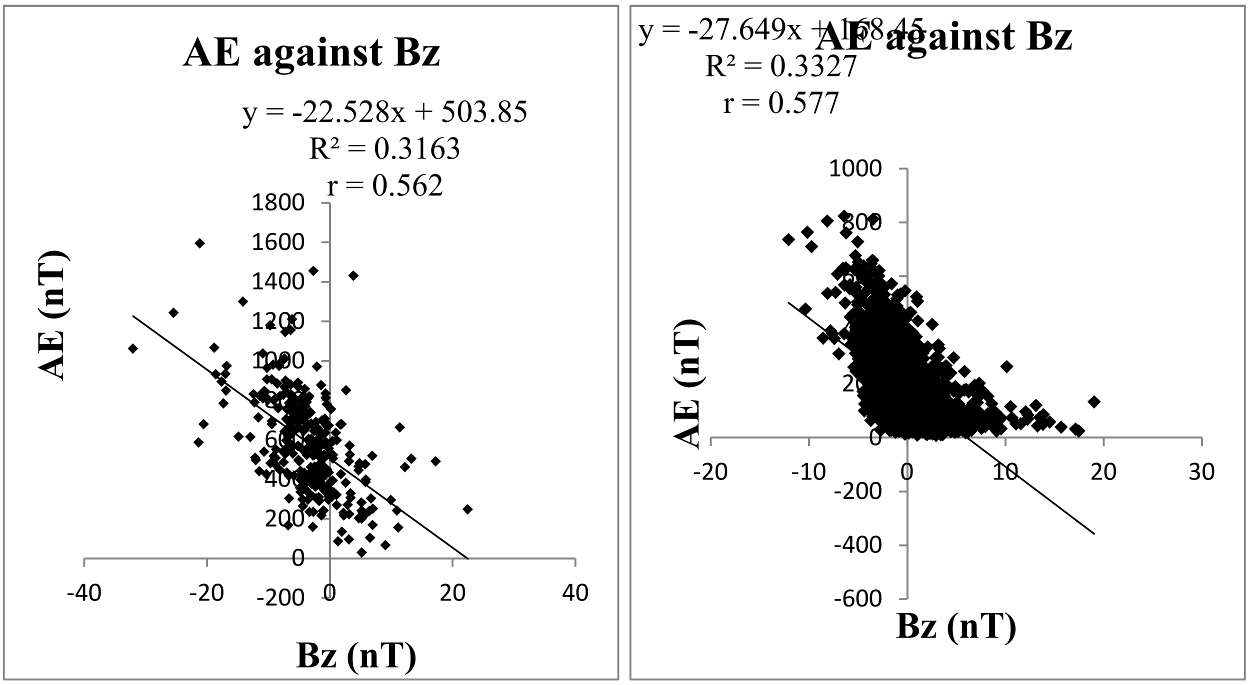
Disturbed Quiet

Fig. 4.2: Annual correlation plot of ap against Dst for Disturbed & Quiet period for year 2001



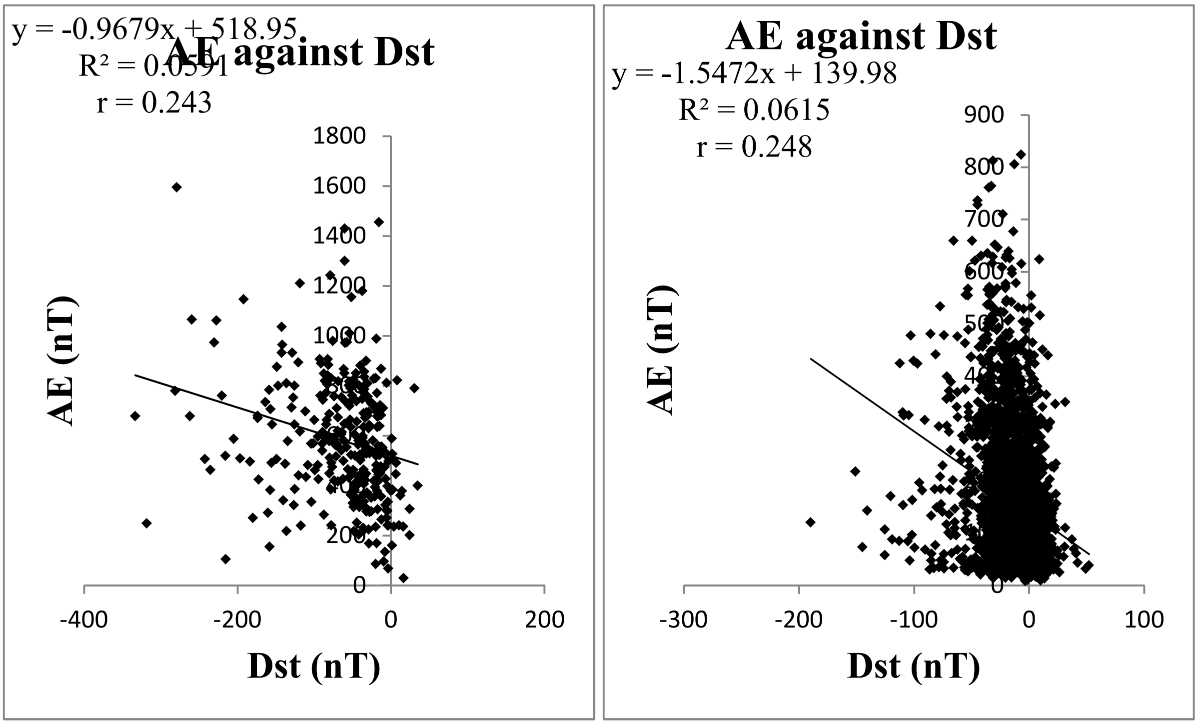
Disturbed Quiet

Fig. 4.3: Annual correlation plot of ap against Bz for Disturbed & Quiet period for year 2001



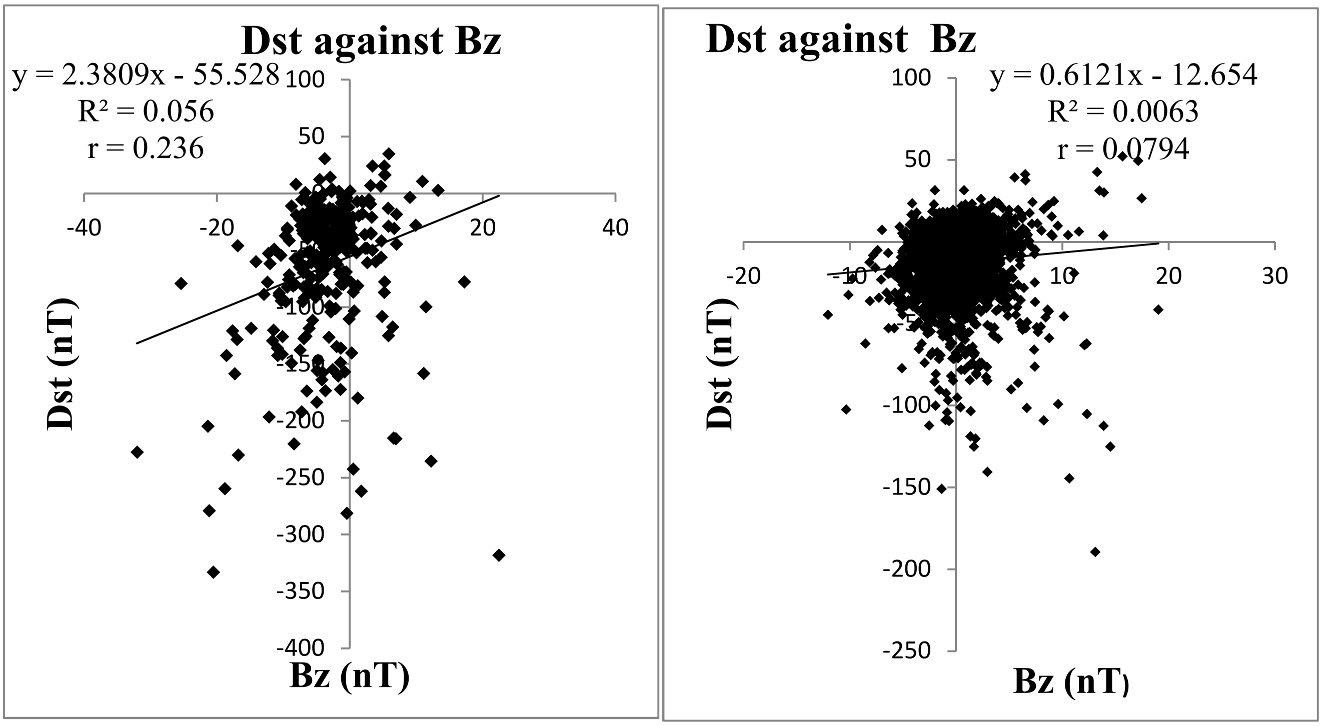
Disturbed Quiet

Fig. 4.4: Annual correlation plot of AE against Bz for Disturbed & Quiet period for year 2001



Disturbed Quiet

Fig. 4.5: Annual correlation plot of AE against Dst for Disturbed & Quiet period for year 2001



Disturbed Quiet

Fig. 4.6: Annual correlation plot of Dst against Bz for Disturbed & Quiet period for year 2001

3.2 MONTHLY CORRELATIONS

For all months of 2001 the correlations were calculated and the plot was drawn in the same format as seen in figure 4.1-4.6.

In the month of January, AE × ap (Quiet period), AE ×Dst (Disturbed period) and AE ×Bz(Quiet and disturbed period) has correlation above 0.5 (50%), Thus, they can be classified under high correlation. However, AE × ap for quiet period with 78.5% correlation is the highest among all of them.

Also AE × ap (Disturbed period), ap × Dst (Quiet and disturbed period), ap×Bz (Quiet and disturbed period), AE × Dst (Quiet period) and Dst × Bz (Quiet and disturbed period) has correlation below 0.5 (50%), Thus, they can be classified under low correlation. However, ap × Dst for disturbed period with 1% correlation is the lowest among all of them.

In the month of February AE ×ap (Quiet period), ap × Dst (Quiet period), AE × Dst (Quiet and disturbed period) and AE ×Bz (Quiet and disturbed period) has correlation above 0.5(50%), Thus, they can be classified under high correlation. However,AE × ap for quiet period with 82.5% correlation is the highest among all of them.

Also AE × ap (Disturbed period), ap × Dst (Disturbed period) ap × Bz (Quiet and disturbed period) and Dst ×Bz (Quiet and disturbed period) has correlation below 0.5(50%), Thus, they can be classified under low correlation.However,AE× ap for disturbed period with 15.6% correlation is the lowest among all of them.

In the month of March AE× ap (Quiet and disturbed period), ap × Dst (Disturbed period) and AE × Bz (Quiet and disturbed period) has correlation above 0.5(50%), Thus, they can be classified under high correlation. However,AE× ap for quiet period with 76.1% correlation is the highest among all of them.

Also ap × Dst (Quiet period) ap × Bz (Quiet and disturbed period), AE × Dst (Quiet and disturbed period) and Dst × Bz (Quiet and disturbed period) has correlation below 0.5(50%), Thus they can be classified under low correlation. However,Dst × Bz for Quiet period with 13.2% correlation is the lowest among all of them.

In the month of April AE × ap (Quiet and disturbed period) and AE × Bz (Quiet and disturbed period) has correlation above 0.5(50%), Thus they can be classified under high correlation. However, AE× ap for Quiet period with 68.9% correlation is the lowest among all of them.

Also ap × Dst (Quiet and disturbed period) ap × Bz (Quiet and disturbed period), AE × Dst (Quiet and disturbed period) and Dst × Bz (Quiet and disturbed period) has correlation below 0.5(50%), Thus they can be classified under low correlation. However, AE× Dst for disturbed period with 14.6% correlation is the lowest among all of them.

In the month of May AE× ap (Quiet period), ap × Bz (Quiet period), AE × Bz(Quiet and disturbed period) and Dst ×Bz (Quiet and Disturbed period) has correlation above 0.5(50%), Thus they can be classified under high correlation. However, AE × Bz for disturbed period with 84.9% correlation is the highest among all of them.

Also AE× ap (Disturbed period), ap ×Dst (Quiet and disturbed period) ap × Bz (Disturbed period) and AE × Dst (Quiet and disturbed period) has correlation below 0.5(50%), Thus they can be classified under low correlation. However ap × Bz for disturbed period with 19% correlation is the lowest among all of them.

In the month of June AE× ap (Quiet period) and AE × Bz (Quiet and disturbed period) has correlation above 0.5(50%), Thus they can be classified under high correlation. However, Bz ×AE for disturbed period with 77.8% correlation is the highest among all of them.

Also AE × ap (Disturbed period) ap × Dst (Quiet and disturbed period) ap × Bz(Quiet and disturbed period), AE ×Dst (Quiet and disturbed period) and Dst× Bz (Quiet and disturbed period) has correlation below 0.5(50%), Thus they can be classified under low correlation. However AE× Dst for disturbed period with 16% correlation is the lowest among all of them.

In the month of July AE × ap (Quiet period) and AE × Bz (Quiet and disturbed period) has correlation above 0.5(50%), Thus they can be classified under high correlation. However, AE× ap for quiet period with 71% correlation is the highest among all of them.

Also AE × ap (Disturbed period) ap × Dst (Quiet and disturbed period) ap × Bz (Quiet and disturbed period), AE × Dst (Quiet and disturbed period) and Dst× Bz (Quiet and disturbed period) has correlation below 0.5(50%), Thus they can be classified under low correlation. However, Dst× Bz for quiet period with 20.8% correlation is the lowest among all of them.

In the month of august AE × ap (Quiet and disturbed period), ap × Dst (Disturbed period) and AE × Bz (Quiet and disturbed period) has correlation above 0.5(50%), Thus they can be classified under high correlation. However, ap × Dst for disturbed period with 69.2% correlation is the highest among all of them.

Also ap× Dst (Quiet period) ap × Bz (Quiet and disturbed period), AE × Dst (Quiet and disturbed period) and Dst × Bz (Quiet and disturbed period) has correlation below 0.5(50%), Thus they can be classified under low correlation. However, Bz × Dst for quiet period with 1.7% correlation is the lowest among all of them.

In the month of September AE× ap (Quiet and disturbed period) and AE ×Bz (Quiet and disturbed period) has correlation above 0.5(50%), Thus they can be classified under high correlation. However, AE × ap for disturbed period with 73% correlation is the highest among all of them.

Also ap× Dst (Quiet and disturbed period) ap × Bz (Quiet and disturbed period), AE × Dst (Quiet and disturbed period) and Dst× Bz (Quiet and disturbed period) has correlation below 0.5(50%), Thus they can be classified under low correlation. However, ap × Dst for disturbed period with 2.6% correlation is the lowest among all of them.

In the month of October AE × ap (Quiet period) and AE × Bz(Quiet and disturbed period) has correlation above 0.5(50%), Thus they can be classified under high correlation. However, AE × ap for quiet period with 72.6% correlation is the highest among all of them.

Also AE × ap (Disturbed period), ap × Dst (Quiet and disturbed period), ap × Bz (Quiet and disturbed period), AE × Dst (Quiet and disturbed period) and Dst × Bz (Quiet and disturbed period) has correlation below 0.5(50%), Thus they can be classified under low correlation. However, Dst × Bz for quiet period with 8.8% correlation is the lowest among all of them.

In the month of November AE × ap (Quiet and disturbed period) and Dst × Bz (Quiet period) has correlation above 0.5(50%), Thus they can be classified under high correlation. However, AE ×ap Disturbed period with 83.2% correlation is the highest among all of them.

Also ap × Dst (Quiet and disturbed period), ap × Bz (Quiet and disturbed period), AE ×Dst (Quiet and disturbed period), AE ×Bz (Quiet and disturbed period) and Dst ×Bz (Disturbed period) has correlation below 0.5(50%), Thus they can be classified under low correlation. However, AE× Dst for quiet period with 15.1% correlation is the lowest among all of them.

In the month of December AE × ap (Quiet period) and AE × Dst(Disturbed period) has correlation above 0.5(50%), Thus they can be classified under high correlation. However, AE × Dst for disturbed period and AE × Bz for disturbed period with 78.5% correlation is the highest among all of them.

Also AE× ap (Disturbed period),ap × Dst (Quiet and disturbed period), ap × Bz (Quiet and disturbed period), AE × Dst (Quiet period), AE ×Bz (Quiet and disturbed period) and Dst × Bz (Quiet and disturbed period) has correlation below 0.5(50%), Thus they can be classified under low correlation. However, ap× Dst for disturbed period with 15.3% correlation is the lowest among all of them.

Table 3.3: Categorization of results using the Dst index for disturbed period

Classification	Months
Normal/Minor	Nil
Moderate	January, February, May, June, July, August, September
Intense/ Strong storm	April, October, December
Super storm	March, November

During the disturbed period, it is observed that there is intense (strong) storm in the month of April, October and December and super storm in the months of March and November. All other months fall under moderate storm.

Table 3.4: Categorization of results using the Dst index for quiet period

Classification	Months
Normal/Minor	March
Moderate	January, February, May, June, July, August, September, December
Intense/ Strong storm	April, October, November
Super storm	Nil

During the quiet period, it is observed that there is no month with super storm. However, there is intense (strong) storm in the months of April, October and November. There is normal (minor) storm in the month of March while there is moderate storm in the other months. A glance at the categorisation, it will be observed that there is intense (or strong) storm in the months of April and October for both disturbed and quiet period. Thus, these months (April and October) could be seen as a critical months which must be given a special attention for consideration in the further studies.

4 CONCLUSIONS

During geomagnetic disturbance the auroral indices AE, ap, Bz, Dst have been compared. Effort has been made to achieve a better understanding of the indices and comparing them at disturbed and quiet period during high solar activity by calculating their 3-hourly averages and correlations. Dst index was used to measure the intensity of the geomagnetic storm for each day of year (2001) which shows occurrence of super storm for two month (March and November) which makes (2001) a year of high solar activities. The main conclusions are as follows:

For the annual correlation, the coefficient of AE ×ap (r =72.3%) for quiet period has the highest correlation. This implies that during quiet storm, measure of the level of geomagnetic activity determines the intensity of auroral activity. Also, the coefficient of Dst ×Bz (r =7.94%) for quiet period has the lowest correlation. This implies that for larger positive values of Bz during quiet storm, the direction of the interplanetary magnetic field does not determine the intensity/strength of geomagnetic storm.

For the monthly correlation, the coefficient of AE× ap (quiet period) has high correlation for all the 12 months, AE× ap (disturbed period) has high correlation for 5 months and low correlation for 7 months, ap × Dst (disturbed period) has high correlation for 2 months and low correlation for 10 months, ap× Dst (quiet period), has high correlation for 1 month and low correlation for 11 months, ap × Bz (disturbed and quiet period) has low correlation for all the 12 months, AE× Dst (disturbed period) has high correlation for 4 months and low correlation for 8 months, AE× Dst (quiet period) has high correlation for 2 months and low correlation for 10 months, Bz ×AE (quiet and disturbed period) has high correlation for 11 months and low correlation for 1 month, Dst × Bz(disturbed period) has low correlation for all the 12 months and Dst × Bz (quiet period) has high correlation for 1month and low correlation for 11 months. For the monthly correlation, the correlation coefficient of AE× Bz in the month of May is 84.9% for disturbed period, which is the highest correlation. Also, the correlation coefficient of ap× Dst in the month of January is 1% for disturbed period, which is the least correlation For both annual and monthly coefficient, the correlation coefficient of AE ×ap (3-hourly values) for quiet period is in general the highest of all, being followed by AE × Bz for disturbed and quiet period. Thus, during quiet storm, ap is strongly influenced by AE activity or ap determines the auroral activity. It is observed that when Bz has values within -10nT and lower the auroral activities (AE) increases and gives a better correlation relatively to other geomagnetic indices.

Also from Table 3.3- 3.4, it is observed that there was intense (or strong) storm in the months of April and October for both disturbed and quiet period. Thus, these months (April and October) could be seen as a critical months which must be given a special attention for consideration in the further studies.

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