Preliminary Analyses of Solar Flare Effects on geomagnetic H Component at Equatorial and Low Latitudes

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Research Article

Abstract: The study of solar flare effect (SFE) on geomagnetic H component at mid latitudes was carried out using data from INTERMAGNET website and the solar flare data were accessed from the National Geophysical Data Center of the National Oceanic and Atmospheric Administration, Boulder, USA. The M and X solar flares were selected from 1997 to 2005 and their effects on three stations, Addis Ababa (AAE), Bangui (BNG) and Tamanrasset (TAM) were investigated. It was found that the ratio $\Delta H_{SFE}/\Delta H_o$ is greater than zero for all the three stations used, hence SFE enhances geomagnetic field in the equatorial and low latitudes. It was equally noted that the SFE on geomagnetic field is not just a simple augmentation at the pre-flare ionospheric currents over these stations.

Keywords: Amplitude variation, geomagnetic component, latitudes, solar flare.

1. Introduction

A solar flare is a magnetic storm on the sun which appears to be a very bright spot and a gaseous surface eruption. Solar flares release huge amounts of high-energy particles and plasma into the heliosphere. This phenomenon affects the earth's atmosphere, earth's magnetic field and magnetosphere. It also has direct impact or consequences on human existence. The earth's atmosphere and magnetosphere help in absorbing harmful solar radiations and hence protect life on the earth. The study of solar flare effect (SFE) on geomagnetic fields is very important because solar flare cause power outage, tripping of circuit breakers, transformer damage, and distortion of communications, shortening of artificial satellite life and malfunctioning of human nervous system. This study seeks to investigate the effects of solar flare on geomagnetic field.

2. Materials and Method

Three stations were employed in carrying out the study of SFE on geomagnetic H component in equatorial and low latitudes. These stations are Addis Ababa, Bangui, and Tamanrasset. The minute data for the geomagnetic field of the H component were accessed from the INTERMAGNET website. These were accessed from the National Geophysical Data Centre of the National Oceanic and Atmospheric Administration (NOAA), Boulder, USA. The medium (M) and the intense (X) solar flares which showed associated SFE on the geomagnetic field were selected from 1997 to 2005 and they occurred on international quiet days.

Table 1: Stations used and their geographic positions

Station	IAGA	Country	GEO. LAT. (^{O}N)	GEO. LONG. (^{O}E)
Bangui	BNG	Central africa repulic	4.33	18.57
Addis Ababa	AAE	Ethiopia	9.03	38.77
Tamanrasset	TAM	Algeria	22.69	5.53

The solar quiet (Sq) field base line is taken as the field average of the value of the hours flanking local midnight and is calculated using the equations given below:

$$H_{00} = \frac{1}{3}(H_{23} + H_{24} + H_1) \qquad (2.1)$$

Where H_{23}, H_{24} and H_1 are the values of the H component at the twenty-third hour proceeding the day, the twenty-fourth and the first hours of the day respectively and H_{00} is their average value.

The deviation from the midnight at a particular hour (t) was calculated as:

$$H_{t0} = Ht - H_{00} \qquad (2.2)$$

Where H_t is the value of H at the time, t.

The pre-solar flare amplitude variations were thus computed using the following equations after [3, 4]:

$$\Delta H_0 = H_{bf} - H_{00} \qquad (2.3)$$

where H_{bf} is the value of field component recorded just before the start time of the flare. The enhancements due to solar flare on the component H is defined as ΔH_{sfe} and and is obtained from:

$$\Delta H_{sfe} = H_{pf} - H_{bf} \qquad (2.4)$$

where H_{pf} is the value of the geomagnetic H field at the peak (time) of the flare.

According to Volland and Taubenheim [9], relative portions of the SFE current flowing in the E-layer was drawn as follows:

The S_q current i_0 is made up of i_{0E} which flows in the maximum level of the E region and the remaining portion i_{oR} flowing in other regions. This means that total S_q current is given by:

$$i_o = i_{oE} + i_{oR} \text{ (Sq current)} \tag{2.5}$$

Equally, additional current i of geomagnetic SFE is made up of i_E in the E-region maximum and a portion i_D in other regions. Therefore:

$$i = i_E + i_D \text{ (SFE current)} \tag{2.6}$$

Hence, total current flowing during the SFE is given by:

$$i_o + i = i_{oE} + i_E + i_{oR} + i_D \tag{2.7}$$

That is,

$$i_0\left(1+ {i}/{i_0}\right) = i_{0E}\left(1+ {i_E}/{i_{oE}}\right) + i_{oR} + i_D \tag{2.8}$$

But magnetic horizontal intensity is proportional to the current, we can write

$$i/i_0 = \frac{\Delta H_{SFE}}{\Delta H_0} = \frac{i_E}{i_{oE}} \tag{2.9}$$

Sq current (i_o) is calculated by adding current in E-region and the remaining part flowing in other regions, that is:

$i_o = i_{oE} + i_{oR}$ .This is the Sq current as seen (2.5)

Geomagnetic solar flare effect current (i) is calculated by summing the current in E-region maximum and a portion in other regions: $i = i_E + i_D$ (SFE current) as seen in (2.6).

Hence, total current flowing during the SFE is as seen in (2.7) and (2.8).

Then the ratio,

$i/i_0 = \frac{\Delta H_{SFE}}{\Delta H_0} = \frac{i_E}{i_{oE}}$ as seen in (2.9) was calculated and tabulated for the three stations and for all the years under study.

If the ratio in (2.9) is greater than zero, it implies that i is greater than i_o, ΔH_{SFE} is greater than ΔH_o and i_E is greater than i_{oE}. This implies that solar flare increases the geomagnetic field.

From equation (2.90, we can write,

$$\Delta H_{SFE} = \frac{\Delta H_0 i_E}{i_{oE}} \tag{2.10}$$

Equation 2.10 can be written in a more general form as:

$$\Delta H_{SFE} = K\Delta H_o + \varphi \tag{2.11}$$

Where $K \approx \frac{\Delta H_{SFE}}{\Delta H_0}$ is the slope and, φ is the intercept which is theoretically zero as could be inferred from (2.10).

Equation 2.11 therefore suggests a correlation between ΔH_{SFE} and ΔH_o for any location where SFE signature has been observed. Thus, in a linear regressed ΔH_{SFE} - ΔH_o plot, the slope (≈K) is a statistical measure of enhancement or reduction in the geomagnetic H-component. It is an enhancement if $K > 0$, in which case, a positive correlation is envisaged, otherwise $K < 0$ and a negative correlation is envisaged.

3. Results and Discussion

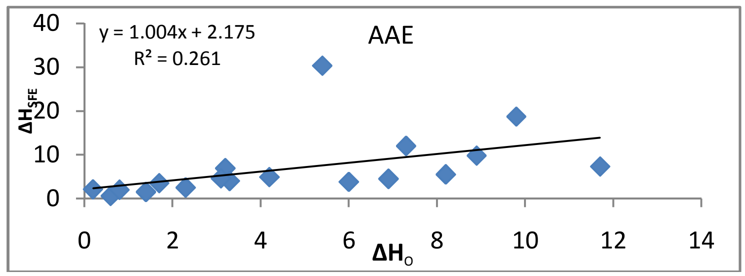

Figure a

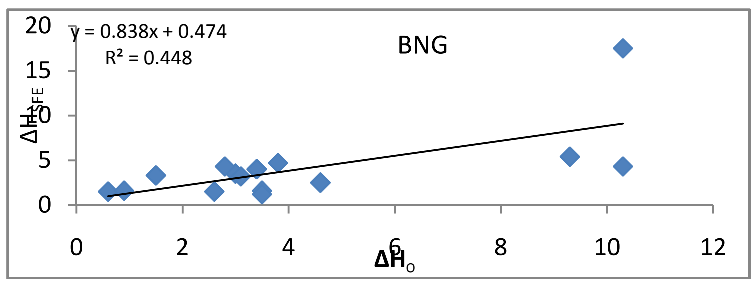

Figure b

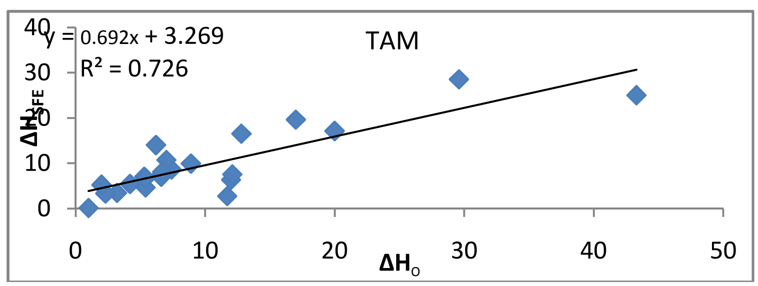

Figure c

Figure 1 (a-c): Ratio of ΔH_{sfe} to ΔH_0 for AAE, BNG and TAM stations

Table 2: Results of Regression Analysis

Station	Slope, k	Intercept, φ	Correlation coefficient, r
AAE	1.004	2.175	0.48
BNG	0.838	0.474	0.67
TAM	0.632	3.269	0.85

At Addis Ababa station, 19 solar flare events recorded 14 flares whose ratios of $\Delta H_{SFE}/\Delta H_o$ ranged between 1.07 and 52.50, while 4 recorded ratios between 0.62 and 0.67 and only 1 flare recorded ratio equal to 1. At Bangui station, 15 solar flare events recorded 9 flares whose ratios of $\Delta H_{SFE}/\Delta H_o$ ranged between 1.03 and 2.50 and 6 flares recorded ratios between 0.34 and 0.58. At Tamanrasset station, 23 solar flare events depict 15 flares of which had $\Delta H_{SFE}/\Delta H_o$ ratios ranging between 1.06 and 2.60, while 8 had ratios ranging between 0.10 and 0.96. These results revealed that SFE consists mostly of positive impulse in H. These could be attributed to the simultaneous existence of zonal and meridional currents that are responsible for Sq currents. The ratio of SFE current to Sq current is greater than zero for the three stations used in the study. Solar flare has effects on geomagnetic field at equatorial and low latitudes. SFE on geomagnetic field is not a simple augmentation at the pre-flare ionospheric currents over these stations. Solar flare enhances geomagnetic field. This result is in agreement with Rastogi [6]. Table 1 show the stations used in the work and their latitudes. Figure1 (a-c) shows the plots of the ratio of ΔHSFE to ΔHo for the three stations. Table 2 summarizes the result of the regression analyses as seen from Fig.1 (a-c).It could be observed from Table 2 that for each of the stations, there is a clear correlation between ΔHSFE and ΔHo with a positive slope. All the results are statistically significant at 95% confidence. Furthermore, it could be observed from the distribution of slope for the three stations that the degree of enhancement of the H-component of the geomagnetic field by SFE is high at the equatorial and low latitude stations. However, it is apparent from Table 2 that the intercepts deviate significantly from the theoretical prediction of zero. Perhaps, this could arise due to the coarse approximations of the local times and minor effects of longitudinal variations [4]. The results therefore suggest strongly that SFE enhances the H-component of geomagnetic field, which is consistent with the results by [1, 2, 5, 6, 7, 8].

5. Conclusion

The arrival of X-rays and Ultraviolet radiations from the sun following a solar flare results in an immediate increase of the ionization production rate, electron densities and electric current in the ionosphere followed simultaneously by disturbances of the magnetic element at the ground level (SFE). The study of SFE on geomagnetic field becomes imperative for now; because the SFE signals and the other ionospheric disturbances in all have a far-reaching influence on life on earth. The study has yielded some interesting results. The results revealed that pre-solar flare and solar flare amplitude variations of H are high in equatorial and low latitude stations. Correlation existed between the solar flare amplitude variations of H and the pre-solar amplitude variations. The ratios of $\Delta H_{SFE}/\Delta H_o$ were greater than zero for the three stations used in the study. Hence, solar flare effects enhance the geomagnetic field in the equatorial and low latitudes.

Acknowledgments

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