International Journal of Innovative Research & Growth
A Peer Reviewed Journal
ISSN: 2455-1848
Journal homepage: http://www.ijirg.com/ijirg/
Volume: 12 Issue: 4, October 2023

Impact of solar flares and geomagnetic storms on earth's IMF and solar wind velocity during the descending phase of solar cycle 24

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Article Info
Received 08 June 2023
Received in revised form 27 September 2023
Accepted for publication 02 October 2023
DOI: 10.26671/IJIRG.2023.4.12.104

Citation:
Dhurve, A., Saxena, A. K., Tiwari, C. M., Khandayat, S. K. (2023). Impact of solar flares and geomagnetic storms on earth's IMF and solar wind velocity during the descending phase of solar cycle 24. *Int J Innovat Res Growth*, 12, 144-150.

Abstract
The Earth's magnetosphere is the outermost layer of the solar system affecting cosmic rays from the Sun and solar wind. The solar wind has major impacts on the Earth's magnetosphere, but it is unclear solar flares—a sudden eruption of electromagnetic radiation on the Sun. This work thus indicates that solar flare effects extend throughout the heliosphere. Generally, heliosphere described as Earth's protective barrier against solar wind and other solar particles, as it prevents these particles from entering the planet's other protective layers. Our aim in this paper is to investigate the impact of the solar flares and geomagnetic index to the solar wind parameters, such as solar wind velocity and the interplanetary magnetic field (IMF) Bz component, associated with solar flares and Geomagnetic storms events. The output of the ground geomagnetic field (H-component) to the solar wind parameters and the IMF Bz component various-latitude stations has also been analyzed. Our findings show that the delay of the solar wind changes in the Earth's magnetosphere in response to the weak geomagnetic storm at the descending phase of solar cycle 24.
Keywords: - Magnetosphere, Heliosphere, Geomagnetic Storms, Solar wind, solar flares.

1. Introduction

The Sun is an active variable star. The most violent event on the surface of the Sun is a rapid eruption called a solar flare. Solar flare a sudden and temporary outburst of electromagnetic radiation from an extended region of the Sun's surface. A solar flare is basically a giant explosion on the surface of our Sun which occurs when magnetic field lines from sunspots tangle and erupt. A solar flare is defined as a sudden, rapid, and intense variation in brightness (a bright flash of energy over the surface of the Sun (M. Kh. Alquran, 2019). Geomagnetic storm is a disturbance of the Earth's Magnetic field (Akasofu,1963) produce due to the perturbations in the interplanetary magnetic field (IMF), these disturbances are responsible for the sudden Impulses (SI) in geomagnetic activities (C.S. Bhoj & Lalan Prasad, 2019). In 1988 Tsurutani et al., observed that perturbations in the IMF play a key role in producing geomagnetic storms (GS) and Kharayat et al., 2016 suggested that IMF is an effective parameter for production of GS.
Geomagnetic storms are caused mainly by solar wind transits from the coronal mass ejections and Solar flares (Rawat et al.,2009). Gosling,1993 showed that solar flares play no fundamental role in causing geomagnetic disturbances, but solar flares and CMEs are part of the same magnetic eruption process. (Singh et al.,2012,2013).
Impact of these disruptive solar emissions on the earth's magnetosphere leads to sudden disturbances in geomagnetic field known geomagnetic storm (Rawat et al., 2007). GSs occur when the interplanetary magnetic field turns southward and remain southward for a prolonged period of time. In other words, the geomagnetic storm is magnetic reconnection between southwardly oriented IMF (Bz). Component and anti-parallel geomagnetic field lines (Rawat et al., 2009). Orientation of IMF is transferred by the solar wind and it is also a very important factor during solar cycle 24. The north-south component (Bz) of IMF, plays a dominant role in determine the amount of solar wind energy to be transferred to the magnetosphere (Singh et al., 2017). Meena Pokharia etal. (2018) studied the period and found that the SSN does not show any relationship with Dst and Kp, while there exists an inverse relation between Dst and the solar wind speed, with some time lag. We have also found that VBz is a more relevant parameter for the production of geomagnetic storms, as compared to V and Bz

separately. In addition, we have found that in Solar Cycles 22 and 24 this combined parameter is more relevant during the descending phase as compared to the ascending phase. The solar wind speed are the primary causes of great magnetic storms, which is a measure of this current, the disturbance storm time (Dst) index, has been used historically to characterize the size of a geomagnetic storm (Shirish K. Persai et al., 2019). Rajkumar Hajra et al., (2021) is found the recently solar cycle 24 is found to be the weakest of the cycles in the space exploration era, with the lowest solar flux peak (∼146 sfu), the reduced IMF, solar wind plasma speed and solar wind-magnetosphere energy coupling compared to the previous cycles. Niyaz A. Reshi et al. (2022) studied the various solar wind parameters and geomagnetic indices have been investigated and the cross-correlation technique of Bz- component with rest of the parameters has been taken into account. We have analyzed the change in various parameters during the GMSs. P.R. Singh et al. (2021), studied the solar plasma parameter and interplanetary magnetic field associated with the Geomagnetic Disturbance storm time (Dst< -150 nT) and their effect on geomagnetic activity during solar cycles 22 and 23. Pandey et al. (2022) concluded that coronal mass ejections associated with hard X-ray solar flare are mainly responsible to cause intense geomagnetic storms. P. S. Gour & Shiva Soni (2022), perform a statistical analysis to find out the correlation between the magnitude cosmic ray intensity decreases with M and X class solar flares and obtain the correlation with correlation coefficient of 0.22, 0.77 respectively & Other B and C class flares are not correlated with Fds. Deepak Chaurasiya et al., (2023) concluded that the average and negative correlation between intense GMs with CME speed and SWpv with correlation coefficient -0.620 and -0.578. Dolly et al., (2023) has been obtained strongly suggest that IMF Bz has a strong impact on the cause of geomagnetic storms. The trend of solar interplanetary with geomagnetic indices during solar cycle 24 move upward phase of recent cycle. The sunspot number (Rz), interplanetary magnetic field and geomagnetic indices indicate a trend during solar cycle 24. In the solar cycle 24, the sunspot numbers (Rz), IMF and geomagnetic indices represent the periodic nature (Sanjay Goyal et al. 2023).
In this work, geomagnetic storms with Dst<-50nT are selected during the solar cycle 24(2008-2019), and investigated on a primarily basis at descending phase of Solar cycle 24. In this paper is to present the effect of solar flares and geomagnetic storms (Dst) on the Earth's Magnetosphere during data collection and statistical analysis for a possible relation between IMF, Bz as well as Solar wind velocity in solar cycles 24.

2. Data Set and Methodology

In this present analysis, we have selected Disturbance storm time (Dst), interplanetary magnetic field (IMF), Bz and solar plasma velocity and solar flares for the period 2008-2019.Yearly Mean values of Solar flare are taken from website: https://www.ngdc.noaa.gov/stp/solar/solarflares.html. The average annual values of the Dst, IMF, Bz and Solar wind velocity are obtained from the OMNIWEB data (http://omniweb.gsfc.nasa.gov).We have adopted linear regression methods to find the relationships between IMF, Bz and SW velocity and Solar flare index with Dst.

3. Results and Discussion

The sun and its outputs in the form of various interplanetary features such as interplanetary magnetic field (IMF), Bz, Solar wind velocity and solar flare index (SFI), Disturbances storm time (Dst) are related to the disturbances in earth magnetic field. Figure [1] it shows the linear fit scatter plot between yearly values of Disturbances storm time (Dst) with interplanetary magnetic field (IMF) respectively. From the analysis it is clear that cosmic ray intensity (CRI) and interplanetary magnetic field (IMF) are correlated. It is clear from Figure [1] Disturbances storm time (Dst) shows high correlation with interplanetary magnetic fields (IMF) and correlation coefficient is found = -0.88 for the solar cycles 24. Similarly, from Figure [2] & [3], it is clear that Disturbances storm time (Dst)shows weak correlation with Bz and Solar wind velocity and correlation coefficient between these two parameters is found = -0.055 and -0.44 for the solar cycles 24. Figure [4] shows linear plot between solar flare index (SFI) with interplanetary magnetic field (IMF). From Figures (4) it is clear that solar flare index (SFI) also shows strong positive -correlation with interplanetary magnetic field (IMF) and correlation coefficient is found = 0.70 for the solar cycles 24. Figure [5] & [6] shows yearly linear plot between solar flare index (SFI) and Bz during the period of 2008-2019. Figure [7] shows yearly linear plot between solar flare index (SFI) and disturbances storm time (Dst) during the period of solar cycle 24 and found the correlation coefficient is strong negative r= -0.55.

I. Linear fit profile for Value Dst with IMF, Bz and Solar Wind velocity:

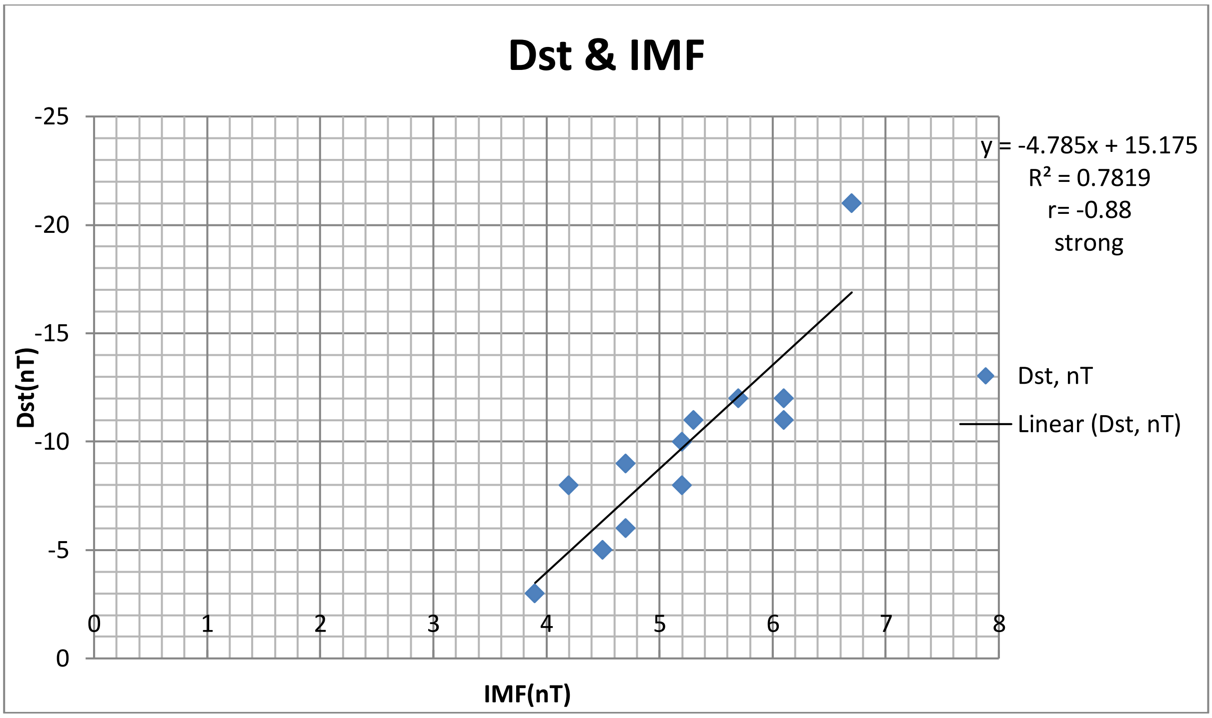

Figure-1 Shows scatter plot between the Dst and IMF events showing strong negative correlation with correlation coefficient -0.88.

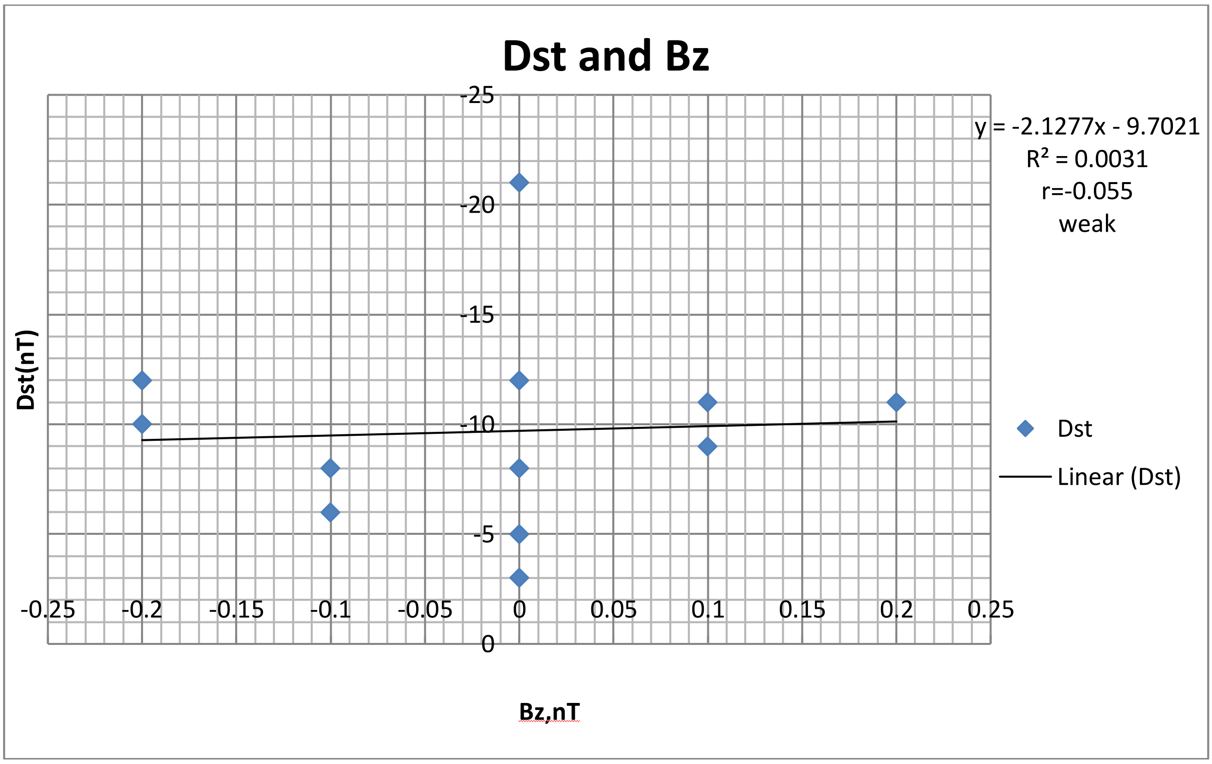

Figure-2 Shows scatter plot between the Dst and Bz events showing weak negative correlation with correlation coefficient -0.055.

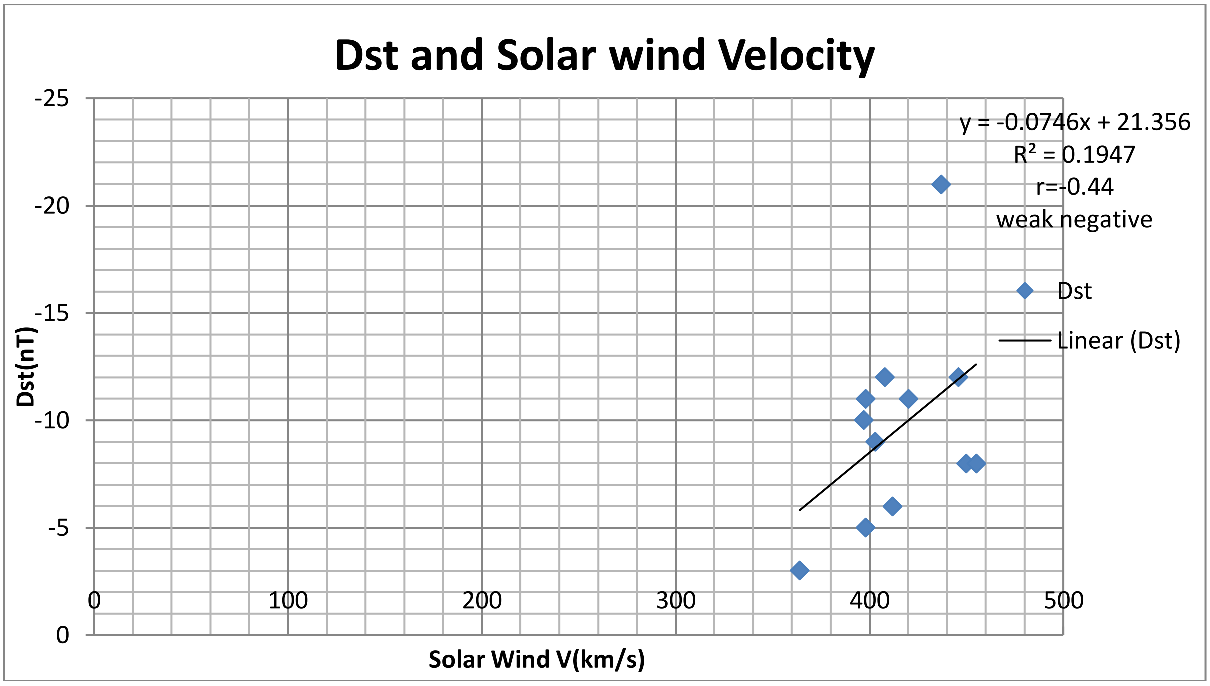

Figure-3 Shows scatter plot between the Dst and solar wind velocity events showing weak negative correlation with correlation coefficient -0.44.

II. Linear fit profile for Value Solar flare with IMF, Bz and Solar Wind velocity:

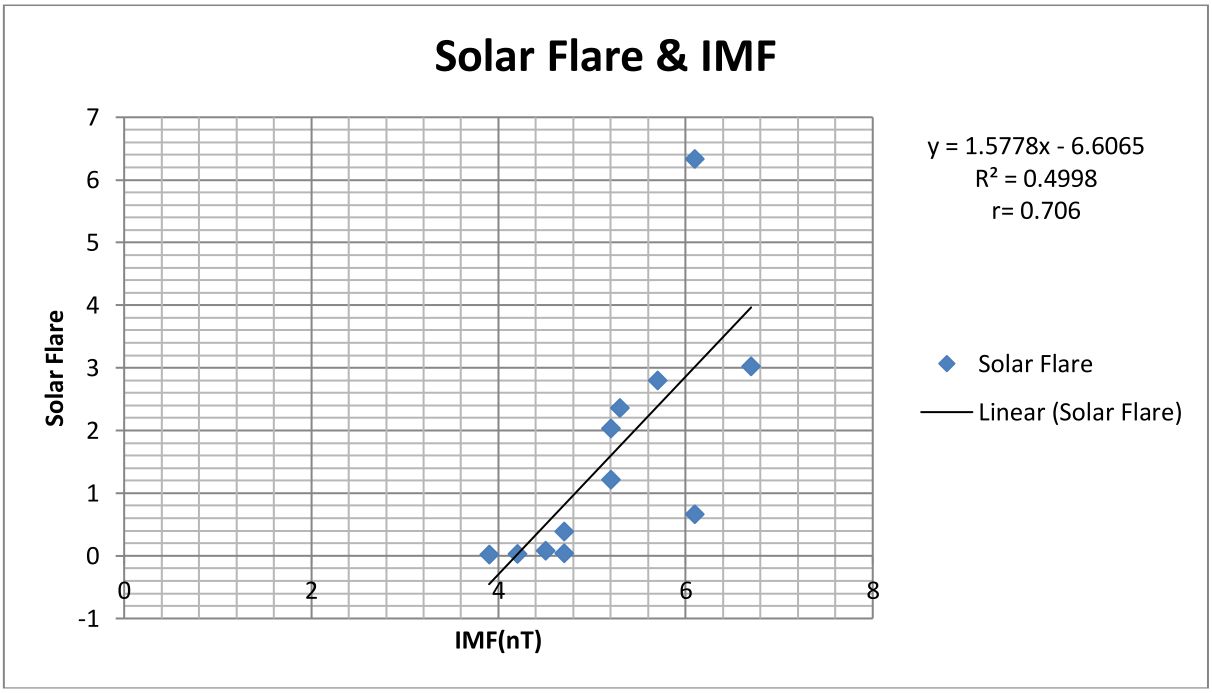

Figure-4 Shows scatter plot between the Solar flare and IMF events showing Strong positive correlation with correlation coefficient 0.70.

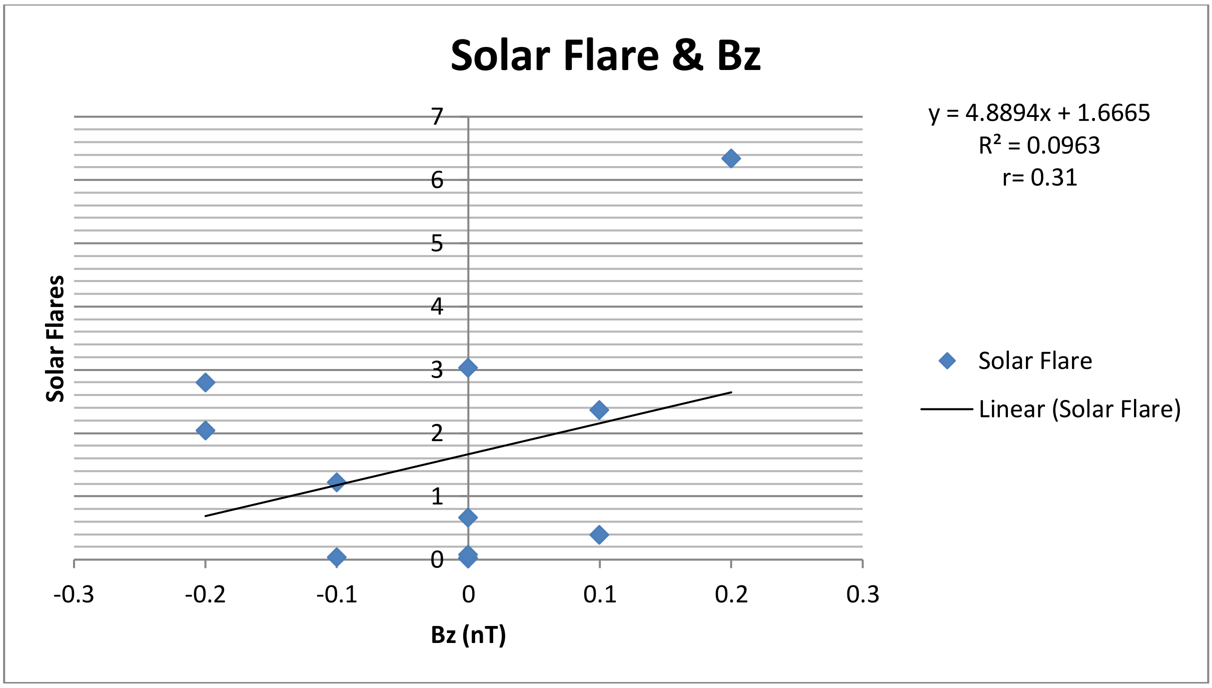

Figure-5 Shows scatter plot between the solar flare and Bz events showing weak positive correlation with correlation coefficient 0.31.

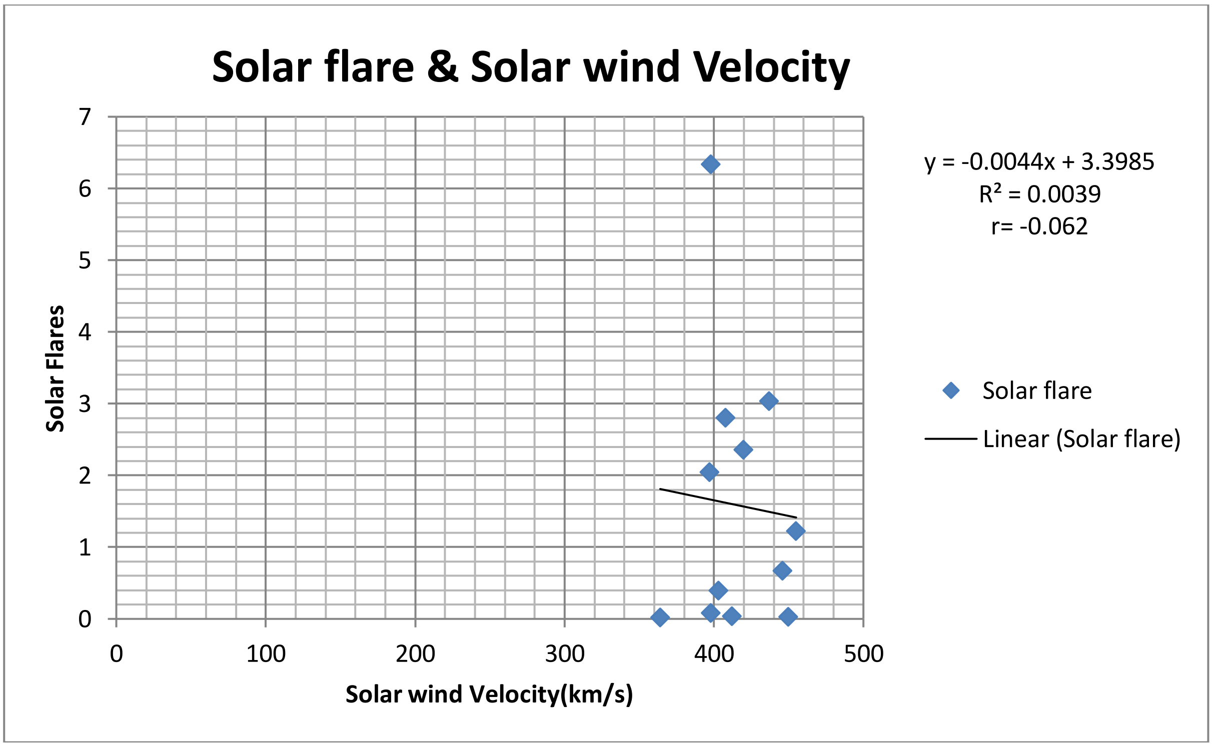

Figure-6 Shows scatter plot between the solar flare and solar wind velocity events showing weak negative correlation with correlation coefficient -0.062.

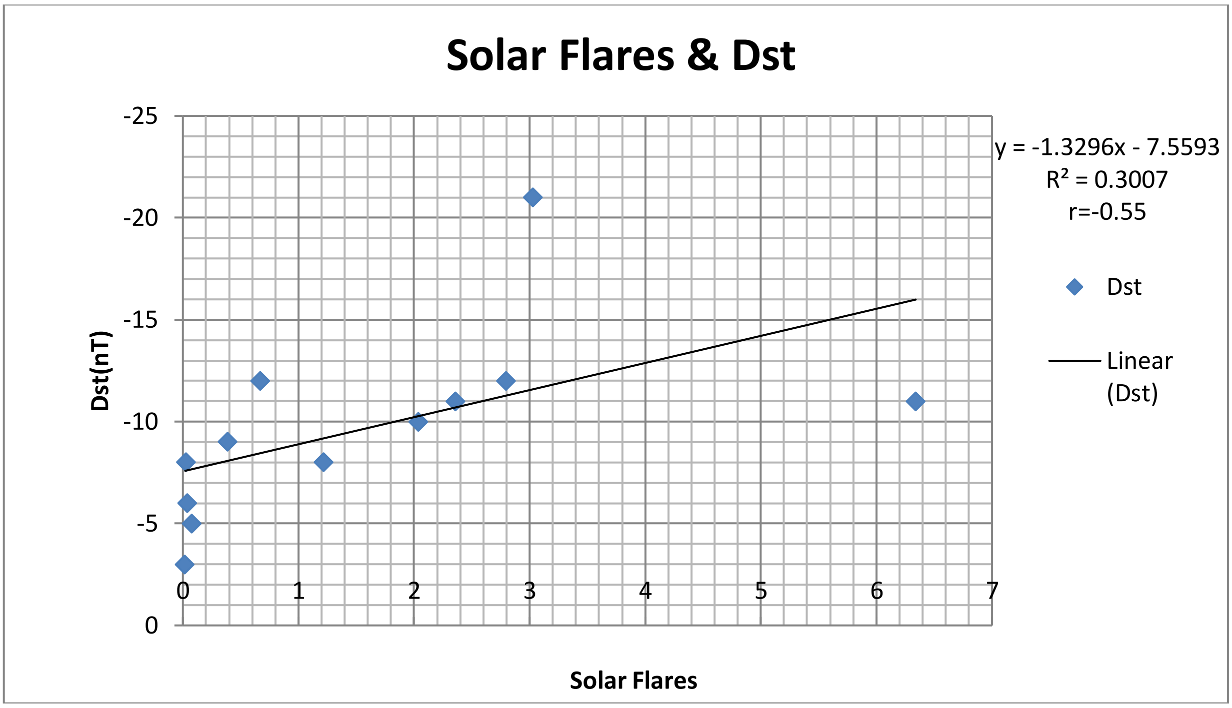

Figure-7 Shows scatter plot between the Dst and Solar flare events showing Strong negative correlation with correlation coefficient -0.55.

4. Conclusion

On the basis of observations and analysis we found the results. We have concluded that in following manners:

- IMF B is better indicator of GS with respect to Bz and Flow.
- We can say that GS is correlated well with the IMF better than Bz component of the IMF and solar wind velocity. r= -0.88.
- Solar flare and Dst are correlated with coefficient r=-0.55.
- Solar flare and IMF are correlated with correlation coefficient 0.70.
- It is observed that the velocity effect to produce GS's.

Finally, the sun is the source of energy that produce disturbance in interplanetary medium and control the geomagnetic activity.

Acknowledgement

The authors are grateful to the OMNIWeb data site is generated and maintained the data. The authors are also grateful to NGDC and NOAA to provide Observations data for free available the data of Dst, IMF, Bz and solar plasma velocity. We are also thankful to 2nd Global conference ETRD-2023 organizing team to given an opportunity to present this paper.

Conflict of Interest

The authors have declared that there is no conflict of interest in the manuscript.

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