STUDY OF THE VERY SLOW SPEED SOLAR WIND STREAMS WITH Kp INDEX AND SOLAR WIND PROTON DENSITY FOR SOLAR CYCLE 24 (2008-2016).

[1]Meena Pokharia, [2]Lalan Prasad

[1]Research Scholar, [2]Associate Professor

[1]Department of Physics

[1]Govt. P.G. College, Berinag, Pithoragarh, Uttarakhand, India

Abstract: The aim of this paper is to investigate the association of the VSSSWs with the planetary index Kp and solar wind proton density (n_p) for solar cycle- 24 (2008-2016). A Chree analysis by the superposed epoch method has been done in the study. The results of the present analysis shows that VSSSWs are well correlated with the planetary index Kp with a high correlation coefficient of 0.7. We have also compared the correlation values of VSSSWs with solar wind proton density (n_p) for solar cycle 24 as well as for solar cycle 23 and found that solar cycle 24 produces good correlation values as compared to solar cycle 23.

Index terms: **Very slow speed solar wind streams, Kp index, Coronal mass ejections (CMEs).**

1. Introduction

The solar wind is a stream of energized charged particles and according to the variations in their speed and density, these streams are classified into three categories high speed solar wind streams (HSSWs), slow speed solar wind streams (SSSWs) and very slow speed solar wind streams (VSSSWs). The solar wind classification procedure is described in detail by **(Cliver et al., 2000).** Generally, the HSSWs occurs when coronal mass ejections (CMEs) arrive, as CMEs brings an explosion of highly energetic charged particles which can increase the speed of wind suddenly up to 500 km/sec to even 1000 km/sec. But it doesn't mean that lower speed solar wind streams can't cause geomagnetic storms (GSs). If interplanetary magnetic field (IMF) conditions are good enough then, even slow speed streams can cause GSs. There are various indices which are used to monitor the geomagnetic activities such as aurora electrojet indices Ae, Al and Au. **Akasofu et al., 1981; Troshichev et al., 2002; Verbanac et al., 2011; Kilcik et al., 2017** found that found a negative lag between wind speed and Ap. The solar wind proton density (n_p) is also an important parameter for defining one of the space event i.e. aurora activities. The density of the solar wind determines the power of penetration of the particles, i.e. denser is the solar wind more will be the power of particles to penetrate the earth's magnetosphere and collide with the particles present near north and south poles resulting in aurora activities. **Richardson et al., 2003; John et al., 2009** found that in the inner heliosphere, the density and speed are generally anti-correlated.

In the present paper, we have studied the relationship between very slow speed solar wind streams with planetary geomagnetic index called Kp along with proton density. **Kane, 2005; Elliott et al., 2013** found that the value of Kp in between 8 to 9 leads to the severe GMs.

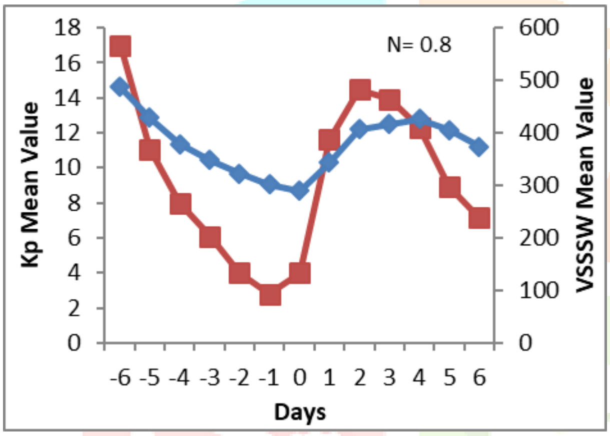
2. Data analysis and method

A Chree analysis by the superposed epoch method has been done in the present study. The occurrence day of VSSSWs (criteria $V_{sw} \leq 300$ km/sec) are considered as zero epoch days. This method is used for testing the relationship between two diverse phenomena or to search for periodicities in the data. The daily mean values of solar wind speed, Kp and solar wind proton density are taken from the Omniweb data center (http://omniweb.gsfc.nasa.gov/cgi/nx1.cgi).

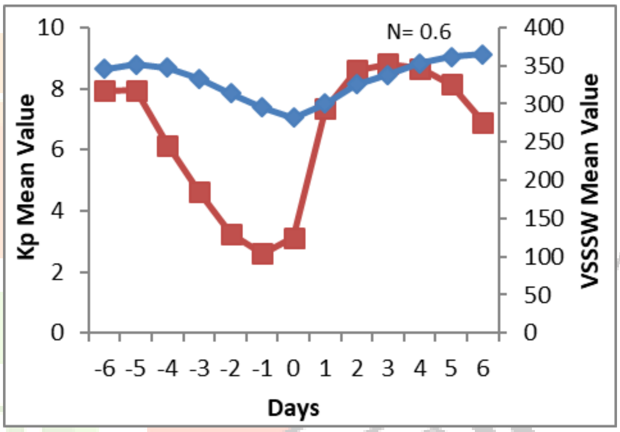
3. Results and Discussion

3.1 Kp index and VSSSWs

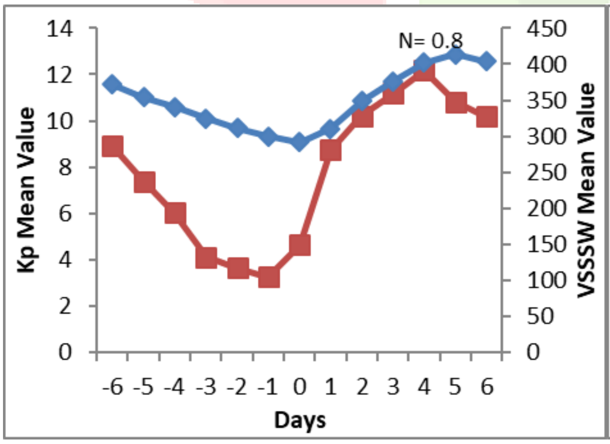
We have performed the study of the characteristic features of VSSSWs with Kp index **(Fig 1)**. With few discrepancies, Kp index shows their minimum peak on – 1 day while the VSSSW minimum peak is observed on 0 day i.e. there exists a time lag of 1 day **(Fig 1)**. This time lag can be considered as the delay response of VSSSWs in accordance with geomagnetic indices. Kp values also define the strength of geomagnetic storms (GMs) more the value of Kp (i.e Kp= 9) more will be the chances of severe GSs while lesser values of Kp indicates quiet conditions of GSs **(Kane, 2005)**. During our analysis, we have observed that Kp value exceeds “9” many times but no GSs were observed during that time period. So, from this analysis, we concluded that severe GSs are not only the result of high Kp values but, other factors such as wind speed and IMF should also be favorable. We have also found the correlation coefficients between these two parameters and found that except 2014 in every year there exist a high positive relation between VSSSWs and Kp index.



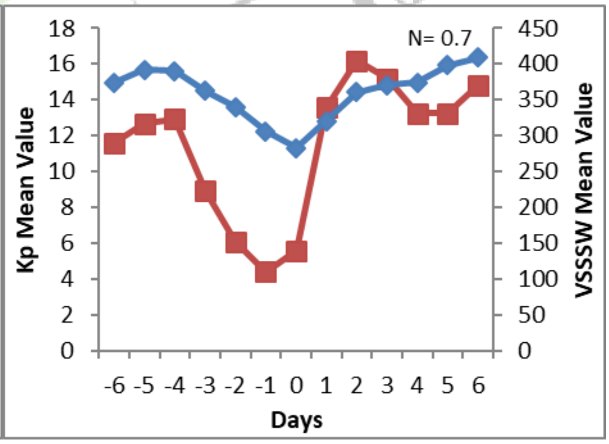
2008



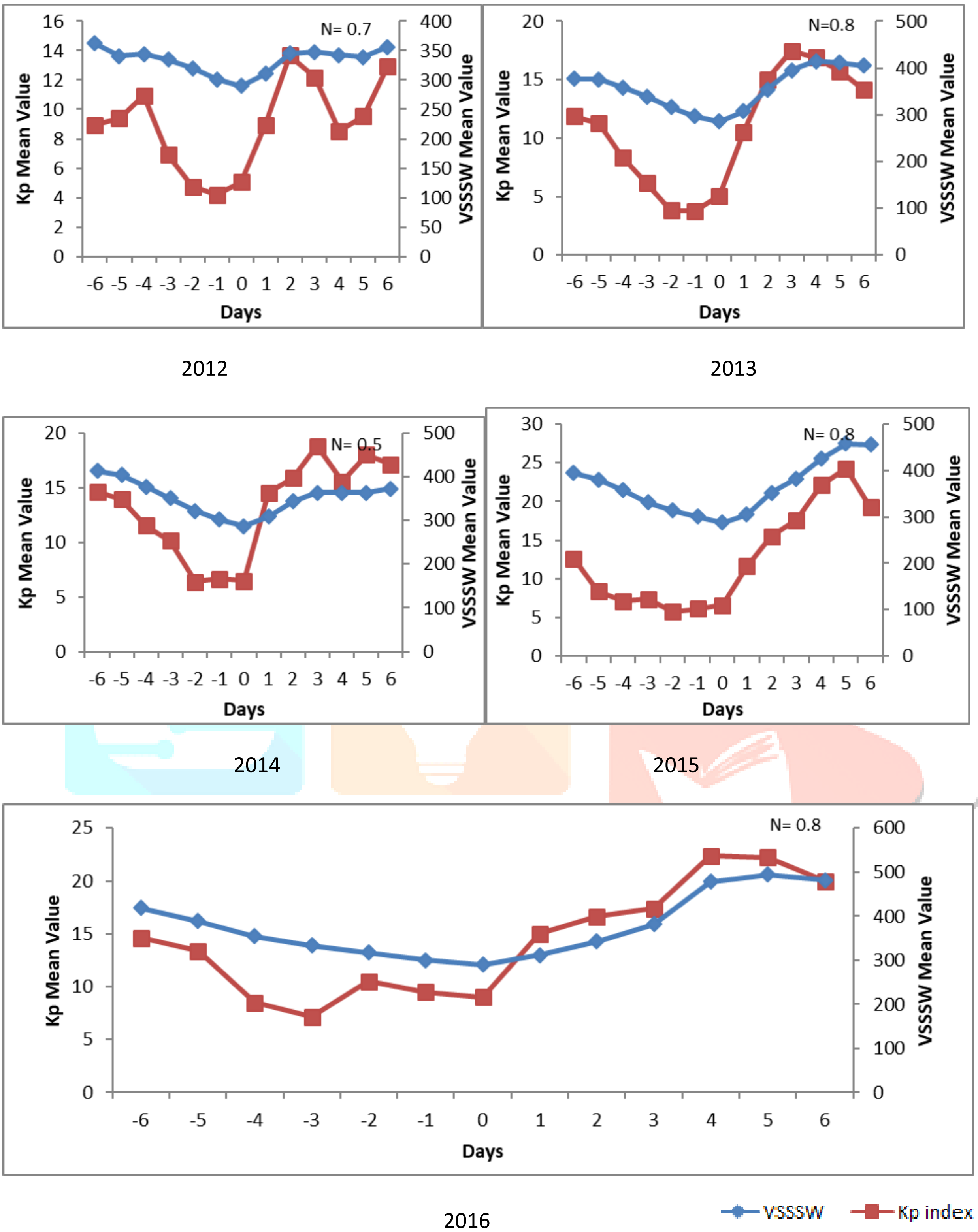
2009



2010



2011



2012

2013

2014

2015

2016

Figure 1. The result of Chree analysis from -6 day to +6 days with respect to zero epoch day. The variation of mean values of VSSSWs and Kp index is plotted. Zero day corresponds to the starting day of occurrence of VSSSWs.

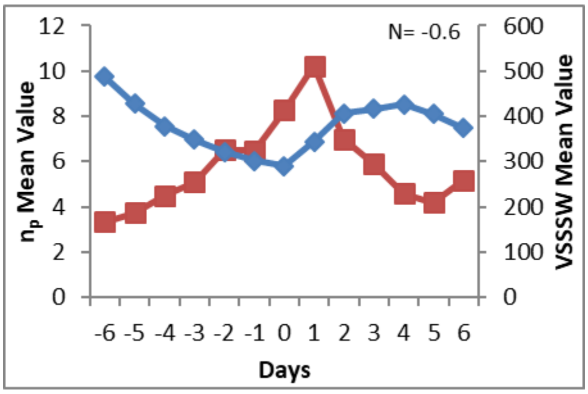
3.2 Solar wind proton density (n_p) and VSSSWs

We have performed the correlative study for solar cycle 23 as well as 24 to establish a relationship between VSSSWs and solar wind proton density (n_p).

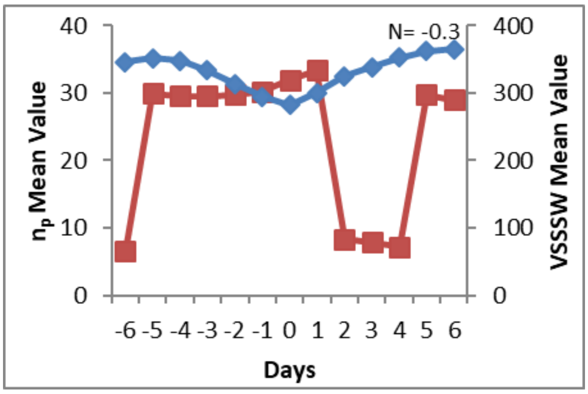
Fig 2 shows that VSSSWs and solar wind proton density (n_p) are inversely related to each other for solar cycle 24. To identify a possible correlation between these parameters, we have also calculated the correlation coefficient between these data strings for solar cycles 23 & 24. Except in the year 2009 and

2013, all the years shows a good anti-correlation between VSSSW and n_p **Fig 2**. While in case of solar cycle 23 we have observed that the even years shows the poor correlation as compared to odd years.

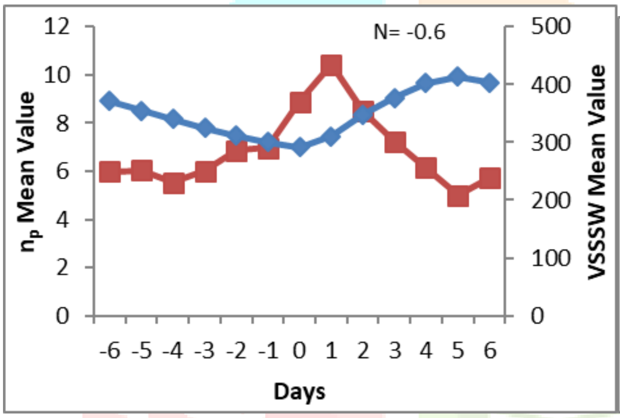
We have also compared the correlation coefficients of various parameters with respect to VSSSWs for the solar cycle- 23 as well as for solar cycle- 24 and found that the correlation values for solar cycle- 24 are good as compared to the solar cycle- 23 **(Table 1)**.



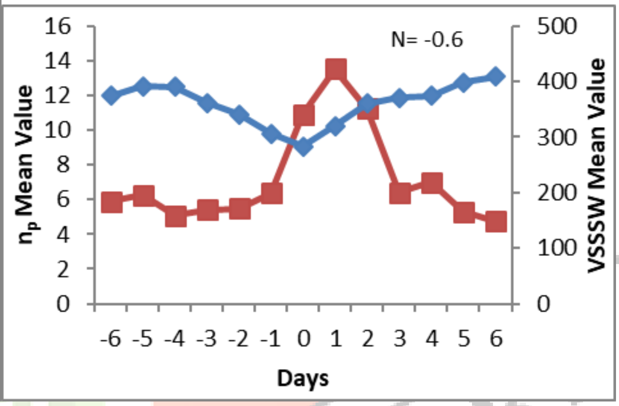
2008



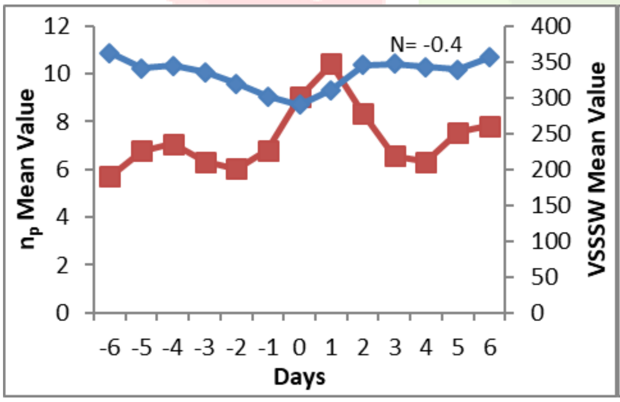
2009



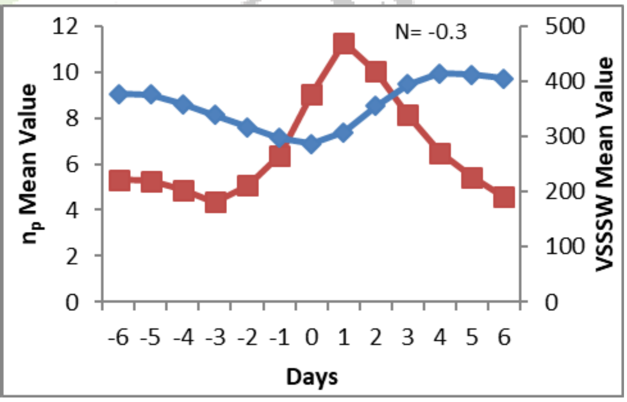
2010



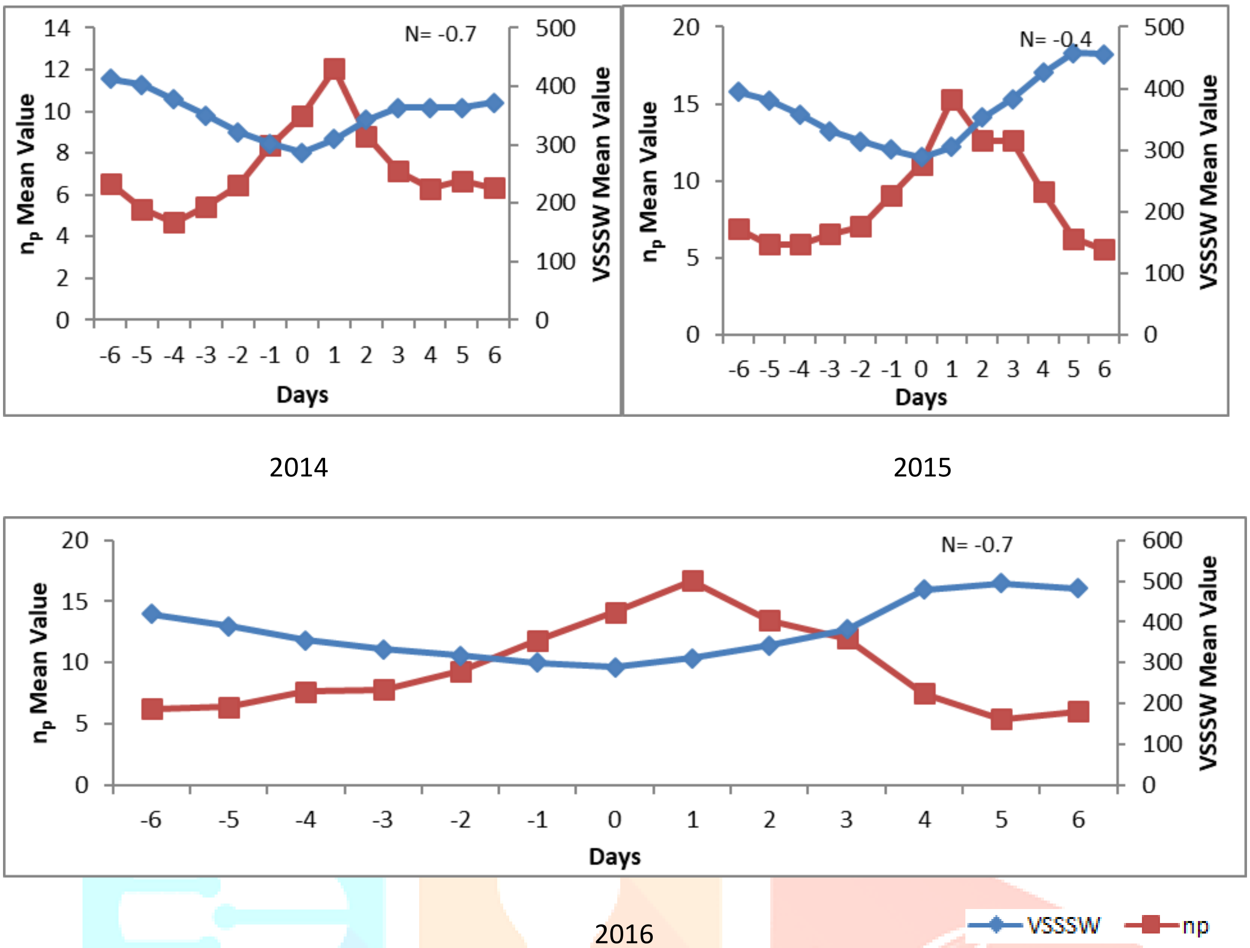
2011



2012



2013



2014

2015

2016

Figure 2. The result of Chree analysis from -6 day to +6 days with respect to zero epoch day. The variation of mean values of VSSSWs and n_p is plotted. Zero day corresponds to the starting day of occurrence of VSSSWs.

Table 1. The correlation coefficients of various parameters

Parameters	Solar Cycle - 23	Solar Cycle- 24
Kp index and VSSSWs	0.70	0.72
n_p and VSSSWs	-0.46	-0.51

Conclusions

The following conclusions are drawn on the basis of analysis :

1. As Kp= 9 leads to severe GSs condition, but during our studied period Kp values exceeded 9 so many times corresponding to VSSSW but no GSs were observed. This indicates that for GSs not only Kp values are responsible, but the IMF and wind speed should also be favorable.
2. When we have compared the correlation coefficients of Kp and n_p with respect to VSSSWs for both solar cycles 23 and 24. We have found that solar cycle 24 showed good correlations with their respective parameters as compared to solar cycle 23.
3. Except in the year 2009 and 2013, all the years shows a good anti-correlation between VSSSW and n_p for SC-24.
4. In case of solar cycle 23, we have observed that the even years shows poor correlation between VSSSW and n_p as compared to odd years.

Acknowledgement

Authors are thankful to IUCAA, Pune for content page service and also thankful to ARIES, Nainital for providing library and computing facilities. Thankfully, acknowledge the UGC, New Delhi for financial assistance under the MRP No. F42-825.

References

Akasofu, S. I. 1981, *JGR*, **86** (A6), 4820-4822.

Cliver, E. W., Cane, H. V., Richardson, I. G. 2000, *J. Geophys. Res.*, **105**, 18, 203.

Cane, H. V., Wibberenz, G., Richardson, I. G. and Von Rosenvinge, T. T 1999, *Geophys. Res. Lett*. **26**, 565.

Elliott, H. A., Jahn, J-M., McComas, D. J. 2013, *AGU: Space Weather*, **11**(6): 339-349.

John, S., Kurian, P. J. 2009, *Research in Astron. Astrophys.*, **9** (4), 485–493.

Kharayat, H., Prasad, L., Mathpal, R. 2016, *AJSIR*, **1** (1), 79-83.

Kilcik, A., Yiğit, E., Yurchyshyn, V., Ozguc, A., Rozelot, J. P. 2017, *Sun and Geosphere*,**12**(1), 31-39.

Kane, R. P. 2005, *Journal of Geophysical Research: Space Physics*, **110**(A2).

Lockwood J. A., Webber W. R. 1992, *J. Geophys. Res*., **97**, 8221-8230.

Pokharia, M., Prasad, L., Mathpal, C., Bhoj, C., Kharayat, H. and Mathpal, R. 2017, *J. Astrophys. Astr.* ,**38.**

Richardson, J. D., Wang, C. 2003, *GEOPHYSICAL RESEARCH LETTERS*, **30** (23), 2207.

Singh, S. P., Saxena, A. K., Singh, R. P., Singh, Y. K. 2013, *International Journal of Science, Environment and Technology*, **2** (1), 56-59.

Troshichev, O.A., Lukianova, R. Yu. 2002, *Journal of Atmospheric and Solar-Terrestrial Physics*, **64**, 585-591

Verbanac, G., Vrsnak, B., Zivkovi, S., Hojsak, T., Veronig, A. M., and Temmer, M. 2011, *A&A*, **533** **(**A49**).**