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Variability of Relativistic Electron Flux (E>2 MeV) during Geo-Magnetically Quiet and Disturbed days: A Case Study

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Abstract

We analyzed the relativistic electron fluxes (E>2MeV) during three different geomagnetic storms: moderate, intense, and super-intense and one geo-magnetically quiet period. We have opted Continuous wavelet analysis and cross-correlation technique to extend current understanding and of the radiation-belt dynamics. We found that the fluctuation of relativistic electron fluxes dependent basically on prolonged southward interplanetary magnetic field IMF-Bz. Cross-correlation analysis depicted that SYM-H does not show a strong connection either with relativistic electron enhancement events or persistent depletion events. Our result supports the fact that geomagnetic storms are not a primary factor that pumps up the radiation belt. In fact they seem event specific; either depletion or enhancement or slight effect on the outer radiation belt might be observed depending on the event. Solar wind pressure and velocity were found to be highly and positively correlated with relativistic electron. We found that, the count of relativistic electron flux (> 2 MeV) decreases during the main phase of geomagnetic storm with the increase in -- from quiet to super intense storm -- geomagnetic storm conditions (Table 1). However, Psw was found to be weakly correlated in case of intense storms following an abrupt increase of electron flux for ~4 hrs, which is interesting and unique.

Keywords:Geomagnetic Storms, Relativistic Electron, Cross-Correlation, Continuous Wavelet Transform

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1. Introduction

The major plasma sources in the interplanetary medium responsible for geomagnetic disturbances are identified as coronal mass ejection (CMEs), which include the magnetic cloud, interplanetary shock, the co-rotating interaction region (CIR) and the high-speed solar wind streamers[Gosling et al., 1991]. The interaction between those interplanetary structures with the Earth's magnetosphere-ionosphere system can produce effects such as geomagnetic storms, sub storms and trapping of high energy charge particles in the radiation belt, known as Van Allen belt[Mauk et al., 2012]. There are various solar wind parameters that are effective enough to fluctuate the content of relativistic electron flux. Enhancement in relativistic electron fluxesmight be an important sources of energy input and chemical change to the middle atmosphere. Magnetic reconnection is the main physical phenomena transporting energy from the solar wind into the magnetosphere.

Van Allen radiation belts are composed of ions, protons and electrons with energy ranging from 100 k eV to 10 MeV. It consists of two belts: inner and outer radiation belt. Outer radiation belt usually lies at an altitude of 3 Earth radii (R_E) and extending to 10 R_E above the Earth's surface where GPS satellites, metrological satellites, broadcasting and communication satellites are operating [R. Kataoka and Y. Miyoshi, 2008]. The increasing dependency on modern infrastructure and technology and expanding human presence in space drags us more for the comprehensive study and understanding of space weather and their dynamics [Baker et al., 2000]. For the deeper understanding of the structure and dynamics of Earth's radiation belt, NASA developed the Van Allen Probes mission [Mauk et al., 2012].The aftermath of highly fluctuating electron fluxes in the Earth's outer radiation belt might be its acceleration and loss. Paulikas & Blake [1979] reported such rapid acceleration and loss of relativistic electrons. Reeves et al., [2003] and Turner et al. [2013] added relativistic electron population in the radiation belt can not only subsidize but also can be enhanced, depleted, or even not affected at all due to the acceleration and loss mechanism. Pinto et al. [2018] identified and analyzed 61 relativistic electron enhancement events and 21 depletion events during 1996 to 2006, resulting the persistent depletion events are characterized by: a low Vsw, a sudden increase in proton density, and a northward turning of IMF Bz. Also,predicted their threshold values.

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This work focuses on the loss, acceleration, and transport of relativistic electron $E > 2\ MeV$ during three different geomagnetic storms:moderate, intense, and super-intense and one geo-magnetically quiet period.

2. Dataset and Methodologies

The datasets has been extracted from OMNI (Operating Mission as Nodes on the Internet) webpage and downloaded from the official website of NASA https://omniweb.gsfc.nasa.gov/dataset to study solar wind parameters. The integrated fluxes of electrons with energies $E > 2\ MeV$ at geosynchronous orbit (L = 6.6) for our study are collected from the GOES-8 and GOES-12; *Geostationary Operational Environment Satellites* (*GOES*;http://www.ngdc.noaa.gov/stp/satellite/goes/dataaccess.html). This database provides 1 min temporal resolution data obtained from the sets of ACE, Wind, and IMP-8 satellites.The wavelet transform, particularly continuous wavelet transforms, which helps to understand the behavior of the energy at different scales and the cross-correlation techniques to find the relation between the relativistic electron and different parameters of the solar wind have been implemented. The detailed explanation of the theory associated can be found in various research papers [eg. Adhikari et al., 2015,2017(a), 2018; Usoro A. E., 2015].

2.1 Continuous Wavelet Transform

Wavelet transform is an effective mathematical tool for the analysis of transient signals. A continuous wavelet transform (CWT) maps a one-dimensional signal to a two-dimensional time-scale that produces a time- frequency decomposition of the signal which segregates individual signal components constructively unlike the short time Fourier transforms (STFT)., The square modulus of the wavelet coefficient, in analogous to the Fourier analysis, lays out the energy distribution in the time-scale plane [Adhikari et al., 2018].In our study, using CWT scaleogram, the vertical axis provides the information of periodicity at different scales as a function of time in horizontal axis. It helps to comprehend the behavior and distribution of the energy at different scales [Adhikari et al., 2017b]. The detailed analysis of CWT are shown in Figure 5.

2.2 Cross-correlation

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Cross-correlation is the standard, multi-time scale, statistical tool that helps out to obtain the time-delay, determine the similarities, draw similar relative characters and can furnish with the new information [Adhikari et al., 2018]. The time scale is used to determine the lead or lags between the parameters after establishing their correlation. The horizontal plane includes the time (minutes) ranging different values and vertical plane indicates cross-correlation coefficient [Adhikari et al., 2017a]. The detailed analysis of different events are shown in Figure 6.

We have taken four different events as listed in table 1.

Events	Year/Month/day	SYM-Hvalue(nT)	Event type
Event 1	2007/01/25	0 to -50	Quiet period
Event 2	2008/09/04	-50 to ≥-100	Moderate
Event 3	2006/12/15	-100 to ≥ -250	Intense
Event 4	2001/03/31	≤-250	Super intense

Table 1: Selected storm events, their occurrence time frame in year, month, and day, SYM-H value (nT), and event types are listed out.

3. Results and Discussion

The relativistic electron population in the outer radiation belt is extremely volatile during periods of enhanced geomagnetic activity. Electron fluxes are commonly seen to be depleted during the storm main phase, fluxes can recover to pre-storm levels in the recovery phase and stay depleted or build up to exceed pre-storm levels [Reeves et al., 2003; Meredith et al., 2011]. The flux dropout can be a combination of adiabatic and non-adiabatic effects and losses through the magnetopause and atmospheric precipitation [Millan and Thorne, 2007]. In this work, we have selected four different events depicted in Table 1. The selection of storm types is based on the SYM-H value in accordance with the explanation by Perreault et al.,[1978];Gonzalez et al., [1994]; and Wanliss et al.,[2006].

3.1.1 Event 1: The Quietest day (January 25, 2007)

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Figure 1 depicts the quietest day, 25th January 2007. The value of SYM-H, on sixth panel, falls to minimum of -30 nT at ~20:00 UT and at the same time IMF-Bz~-4. In fact, the fluctuation of IMF-Bz is mostly southward for almost the entire day with small variations, may be due to the presence of Alfven waves [Adhikari et al.,2015].The first panel at the top of the Figure 1 represents the fluctuation of solar wind pressure (~2 nPa to ~2.5 nPa). The second panel shows the fluctuation of solar wind (Vsw) (~750km/s at 00:00 UT and gradually decreases to its lowest value of ~600 km/s towards the end of the day). The fluctuation of solar plasma density (Nsw) is represented by fourth panel (value lies between ~2 to ~3 n/cc). As the solar wind pressure is not so high enough to compress the magnetosphere, the high speed solar wind will bring the energetic solar wind plasma into the magnetosphere. Since, the IMF-Bz component is mostly southward through the day with little fluctuation, allowing the energetic particles to inject into the magnetosphere. Thus, the relativistic electron fluxes (E>2 MeV) seems to be populated in the radiation belt showing maximum value of ~3500 $cm^{-2}S^{-1}Sr^{-1}$, here after we call flux unit as'FU' for convenience, with slight fluctuation recording its lowest value of ~2700 FU at 22:00 UT (shown in the fifth panel of Figure 1). As high speed solar wind streams come in contact with the magnetosphere, the electrons gain their acceleration [Baker et al., 1993; Paulikas et al., 1978]. The bottom panel indicates the fluctuation of AE index, reaching maximum of ~800 nT corresponding to the minimum value of SYM-H.

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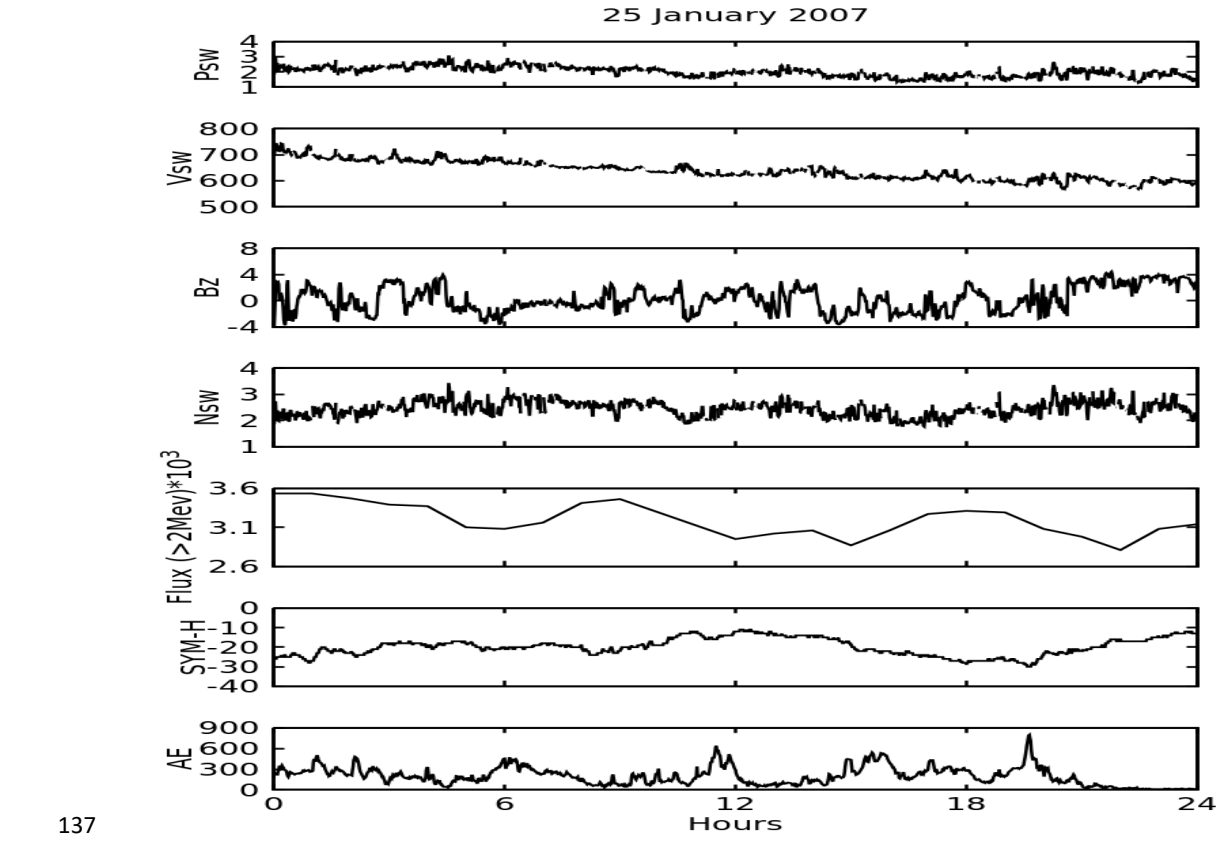

Figure 1: From top to bottom, the panels show the variations of: solar wind pressure (Psw in nPa), solar wind speed (Vsw in km/s), interplanetary magnetic field (Bz in nT), solar wind plasma density(Nsw in n/cc), relativistic electron flux $E > 2\,MeV$(Flux in $cm^{-2}S^{-1}Sr^{-1}$), symmetric horizontal component of magnetic field (SYM-H in nT), and auroral electrojet (AE in nT) indices with time (Hours) respectively for event-1 of 25 January 2007.

3.1.2 Event 2: Moderate Storm (September 04, 2008)

Figure 2 shows the fluctuations in different interplanetary structures during a moderate storm occurred on September 04, 2008. The sequence of panel is same as that explained in previous event. The value of SYM-H drops down to ~-70 nT indicating the storm as moderate storm as defined by [Perreault et al., 1978;Wanliss et al., 2006]. The fluctuation of IMF Bz(in third panel), directed southward during storm main phase, allowing the charge particles to enter easily in the magnetosphere[Lemaire, J. F.,2012].The seventh panel shows the fluctuation of AE index

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with value ~1600 nT corresponding to lowest value of IMF-Bz, indicating the normal auroral activities. The first panel at the top of figure 2 shows the solar wind pressure around ~9nPa at the early phase of the storm at 01:00 UT and gradually goes on decreasing to attain a lowest value of~1 nPa at the end of the day. The fluctuation of solar wind velocity at the second panel shows the gradual increment of its magnitude which is about 480 km/s at 00:00 UT and reaching 600 km/s at 19:00 UT. The flux of relativistic electron is almost constant with value ~100 FU until16:00 UT and then starts to accelerate to maximum value of ~2900 FU at 24:00 UT. Rothwell and McIlwain [1960] formulated a general pattern of the relativistic electron dynamics during a geomagnetic storm. On the study of 276 geomagnetic storms, Reeves et al. [2003] found that only 53% were associated with an enhancement event at geostationary orbit, while 19% were associated with a net flux loss, and 28% showed no significant change which are in agreement with other studies [e.g., Moya et al., 2017; Turner et al., 2013; Zhao & Li, 2013], confirming that solar storms are not always associated with enhancement or depletion in relativistic electron fluxes. Moreover, WladislawLyatsky and Khazanov [2008] found that both Vsw and Nsw provide a strong effect on relativistic electrons. Furthermore, Reeves et al., [2011] have shown that relativistic electron enhancements are correlated (however, not linearly) with the presence of high-speed solar wind steams and southward IMF during the recovery phase of a geomagnetic storms. Higher the solar wind velocity, higher would be the probability of energetic electron buildup after a storm activity (the recovery phase); during which the evolution of sub storm activity may be due to the gradual enhancement of relativistic electron [Kilpua et al.,2015].Anderson et al. [2015] showed that the impact of acceleration and loss of relativistic electrons on radiation belt seems to be negligible in comparison to both small and large geomagnetic storms.

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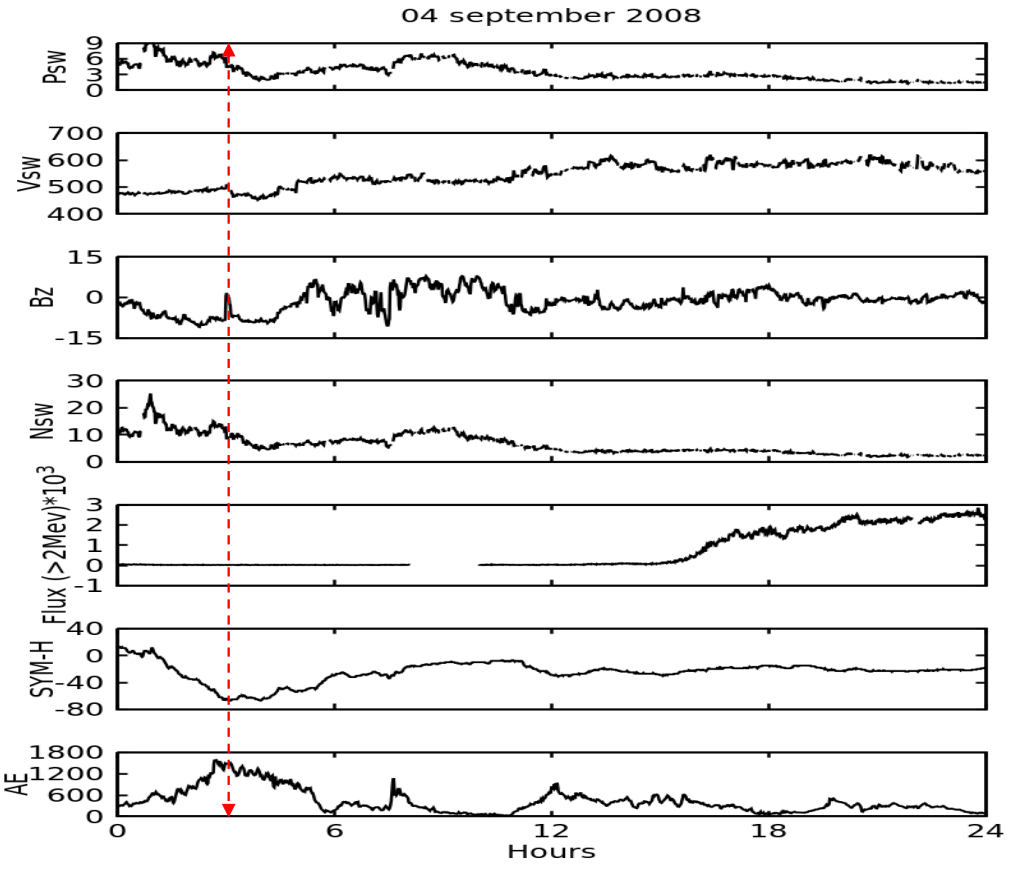

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Figure 2: From top to bottom, the panels show the variations of: solar wind pressure (Psw in nPa), solar wind speed (Vsw in km/s), interplanetary magnetic field (Bz in nT), solar wind plasma density(Nsw in n/cc), relativistic electron flux E> 2 MeV(Flux in $cm^{-2}S^{-1}Sr^{-1}$), symmetric horizontal component of magnetic field (SYM-H in nT), and auroral electrojet (AE in nT) indices with time (Hours) respectively for event-2 of 04 September,2008.

178

179 **3.1.3 Event 3: The Intense Geomagnetic storm (December 15, 2006)**

180 Figure 3 shows the fluctuation of solar wind parameters, component of interplanetary magnetic
181 field Bz, flux of relativistic electrons (E > 2 MeV)geomagnetic indices SYM-H, and AE during
182 an event on December15, 2006. The fluctuation pattern of these parameters is as same as that
183 defined in previous events. In the fifth panel of Figure 3, SYM-H shows maximum disturbance
184 of about ~-220 nT at 01:00 UT and stays under -100 nT until 12:00 UT, indicating the storm

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condition as intense geomagnetic storm as categorized by [Perreault et al., 1978; Wanliss et al., 2006].In the last (seventh) panel the fluctuation of AE index is shown which reaching its value of around ~1200 nT corresponding to which the IMF Bz (shown in third panel) shows~-18nT continuing to recover towards northern direction. In the fifth panel, we have the fluctuation of relativistic electron flux which is almost constant during the storm time attaining the value of about ~1100 FU until 12:00 UT and abruptly accelerating to maximum of ~46000 FU at 14:00 UT for almost an hour and steeping towards normal. The high solar wind speed (reaching the value of ~850 km/s at 01:00 UT, as shown in second panel) meant the injection of larger amount of relativistic electron flux inside the radiation belt. Instead, the fluxes were seen to be depleted and rather increasing its value for few hours as the velocity decreases to ~600km/s during the recovery phase. Reeves et al., [2003] analyzed the data set that compared 15 years of solar wind data of MeV electrons flux, resulting the high solar wind speeds not as the primary factor for enhancement of relativistic electrons; instead, increment in southward IMF value is the essential condition to cause acceleration of MeV electrons in the outer radiation belt. In addition, Borovsky and Denton, [2005] found that for high-speed stream-driven storms, there is considerable spatial overlap of the super-dense ion plasma sheet with plasmaspheric drainage plumes. This would lead to growth of electromagnetic ion-cyclotron waves that can cause relativistic electron precipitation loss. Since the super dense plasma sheet is associated with high Nsw, large Nsw would enhance such loss. This seems to be the case for this event as well. The first panel shows the fluctuation of solar pressure which remains under 4 nPa throughout the event.

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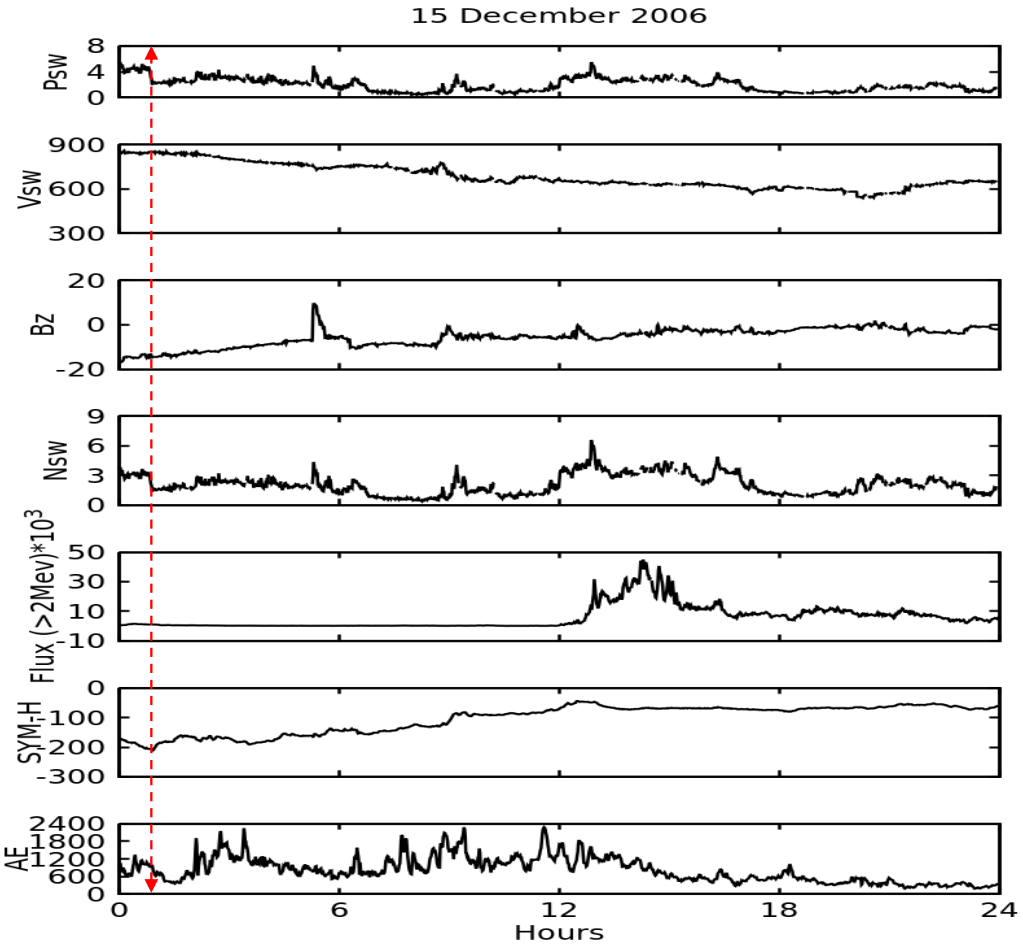

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Figure 3: From top to bottom, the panels show the variations of: solar wind pressure (Psw in nPa), solar wind speed (Vsw in km/s), interplanetary magnetic field (Bz in nT), solar wind plasma density(Nsw in n/cc), relativistic electron flux $E > 2\,MeV$(Flux in $cm^{-2}S^{-1}Sr^{-1}$), symmetric horizontal component of magnetic field (SYM-H in nT), and auroral electrojet (AE in nT) indices with time (Hours) respectively for event-3 of 15 December 2006.

207

208 **3.1.4 Event 4: The super intense storm (March 31,2001)**

209 In the figure 4, the panels from top to bottom, show solar wind pressure (Psw), solar wind
210 velocity (Vsw), Southward component of magnetic field (IMF-Bz), the solar wind density
211 (Nsw), relativistic electron flux ($E > 2\,MeV$), the geomagnetic indices SYM-H, and AE during

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march 31, 2001 respectively. In addition, in the sixth panel, the gradual decay of SYM-H value up to -410 nT at around 08:00 UT indicates the occurrence of geomagnetic storm as super-intense [Perreault et al.,1978;Wanliss et al., 2006]. The rapid fluctuation of solar wind parameters started with the compression of bow shock at around 01:00 UT. The main event occurred at around 08:00 UT and lasted for several hours. The third panel shows the variation of IMF-Bz component, having strongly negative value ~-50 nT at 06:00 UT until 08:00 UT corresponding to the SYM-H value of ~-410 nT indicating that the magnetopause was briefly pushed inward of geostationary orbit, IMF Bz turned very dynamic, fluctuating between ~-50 nT and~+50 nT, allowing the charged particles to penetrate repeatedly into the magnetosphere causing high auroral activity (AE ~2400 nT, shown in seventh panel). During the initial phase of main storm, the solar wind velocity shows abrupt increment upto ~850 km/s which then maintains to ~700 km/s during storm main phase. At the same time, the solar wind pressure (first panel of figure 4)elevates to maximum value of ~60 nPa at the initial phase of the storm and then decreases to ~20 nPa at 06:00 UT, maintaining same throughout the day. The fluctuation of Nsw with maximum peak value about ~60 n/cc at 05:00 UT, as shown in fourth panel of figure 4, followed by the decreases in its value and thereafter low fluctuation is observed. The flux of relativistic electron, shows maximum value of ~740 FU at 00:00 UT and decreases to ~160 FU after 01:00 UT. The possible mechanism for this scenario is that for high-speed stream driven storms, there is a considerable spatial overlap of super dense ion plasma sheet with plasmaspheric drainage plumes [Borovsky and Denton, 2009]. This would lead to the growth of electromagnetic ion-cyclotron waves that can cause relativistic electron precipitation loss. As the super dense plasma sheet is associated with high Nsw, large Nsw would enhance such loss [Li et al., 2011]. This implies that Nsw clearly plays a crucial role in relativistic electron loss. However, the strong effect of solar wind density on relativistic electron is relatively unexpected because the former is not a primary factor in the generation of geomagnetic disturbance [Wanliss and Showalter, 2006]. Nevertheless, the possible effects of solar wind density on relativistic electron may be due to the compression of dayside magnetosphere, by high-density solar wind, acting as shielding in the inner atmosphere thus preventing the penetration of the large-scale electric fields ultimately leading to losses of relativistic electron form the outer radiation belt. This indicates the implicit effect of Nsw on relativistic electron.

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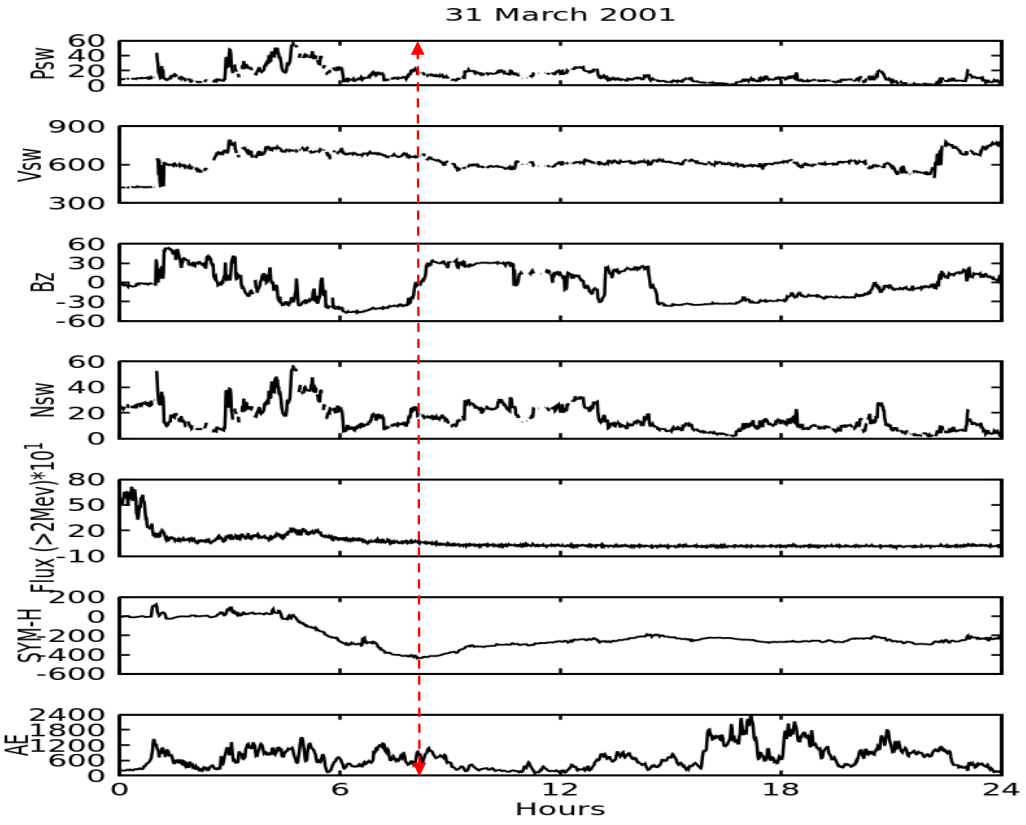

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Figure 4: From top to bottom, the panels show the variations of: solar wind pressure(Psw in nPa), solar wind speed (Vsw in km/s), interplanetary magnetic field (Bz in nT), solar wind plasma density(Nsw in n/cc), relativistic electron flux $E > 2\,MeV$(Flux in $cm^{-2}S^{-1}Sr^{-1}$), symmetric horizontal component of magnetic field (SYM-H in nT), and auroral electrojet (AE in nT) indices with time (Hours) respectively for event-4 of 31 March 2001.

243

244 **3.2 Continuous Wavelet Transform**

245 Figure 5 depicts the scalograms for the relativistic electrons (E>2 MeV).In Figure 5,magenta
246 indicates the highest power areas while red represents low power areas value as shown on the
247 vertical color bar of each plot on the right. Furthermore,Time (in minutes) are placed on the
248 horizontal axis whereas period (in minutes) in the vertical axis.

249 Figure 5 (a) represents the scalogram for the main event of intense storm, stronger wavelet power
250 areas of flux intensities between 0.4-0.7 FU are accumulated around 65-85 minutes at the time

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scales (period) range of 14-16 minutes. This shows the flow of energy lasted for few minutes, the low flux intensities (less intense power area) dominated the event. Figure 5 (b) and (c) represents the scalogram plot for the main event of super-intense and moderate storm respectively. Moreover, the wavelet powers areas of higher flux intensities ranging from 1.2 to 2 FU are found to be distributed at lower to higher time scales range of 2-15 minutes throughout the event time. In Figure 5(b), the highest power areas is around 60-100 minutes at time scales approximately 1-3minutes and again at time scales approximately 10-15 minutes. The other power areas covered by blue color are seen scattered at different times throughout the time scales between 10-170 minutes. Figure 5(c) shows the scalograms for moderate storm where the highest power area is around 65-85 minutes at time scales approximately 14-16 minutes. The other power areas covered by blue color are seen around 60-90 minutes at timescales between 12-16 minutes. Furthermore, such variation of flux intensities on both figures resemble the highly perturbed state during the happening of main event as compared to the quiet event shown in Figure 5 (d), where low intensities dominated the wavelet powers areas at different times and scales. The power areas covered by green color are seen distributed discontinuously over the cone of influence. The non-uniform distribution of energy at different time scales inconsistent with time strongly suggests the true dynamic nature of relativistic electron flux. This observation insists that the geomagnetic storm is not the primary cause of accumulation or loss of charge particles over the radiation belt. In fact, it shows event-specific behavior.

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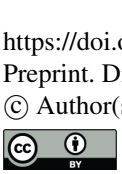

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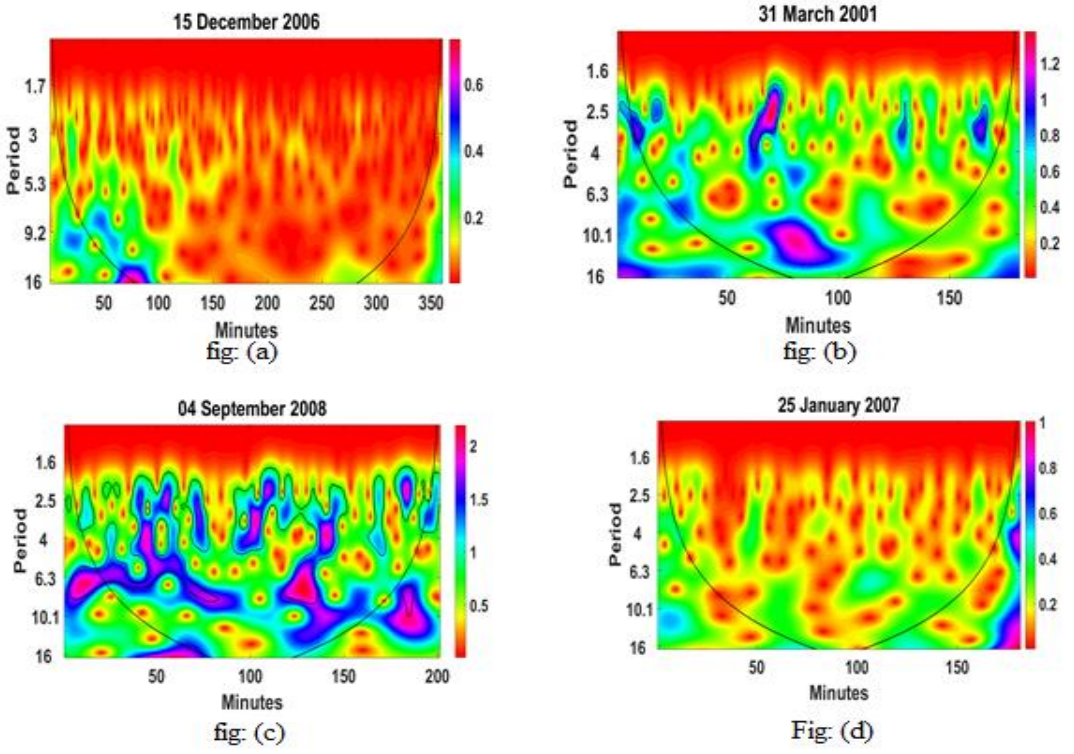

Figure 5: Scalograms for the relativistic electron flux (Rel.) E > 2 MeV for (a)Intense storm, 15 December,2006 (b) Super intense storm,31 March,2001 (c)Moderate storm,04 September, 2008, and (d) Quiet Period, 25 January,2007.

3.3 Cross Correlation

Figure 6 shows the cross-correlation between the relativistic electron flux E > 2 MeV (Refer to as Rel. in legend) with different solar parameters. It is clearly evident that the magenta curve (Rel.-Nsw), green curve (Rel.-Vsw)and red curve (Rel.-Psw) almost overlap to each other and attains a good positive correlation with cross-correlation coefficient of 0.9 at lags of 0 minute (when no lags is applied). In addition, no large variation is observed in the value of cross-correlation coefficient for relativistic electron flux and solar wind velocity during main phase of three geomagnetic storm events (our work) and a geoeffectively quiet event. This suggest that high solar wind velocity is an important condition for enhancing the high radiation belt electron fluxes but not a determining condition. However, on intense storm, fig (d), the red curve shows weak correlation with cross-correlation coefficient of 0.3. Indeed, this result is expected as Vsw,

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290 Psw,and Nsw are taken as the plausible factors for the fluctuation of relativistic electron in outer
291 radiation belt [WladislawLyatsky and Khazanov, 2008]. Li et al. [2005] studied the cross-
292 correlation of electron flux at 50 Kev to 2 MeV energies with Vsw; the strong correlation with
293 zero lag for low energies and longer lags for higher energies was observed. Paulikas and Blake
294 [1979, 2010] found a good correlation between the solar wind velocity and the MeV electron
295 flux at geostationary orbit.However, they found out the unprecedented complex relationship
296 between solar wind velocity and radiation belt electron fluxes. It has also been established that
297 high-speed solar wind and geomagnetic activity are strongly associated with the appearances of
298 relativistic electrons [Baker et al., 1993]. For the identification of relativistic electrons, the rapid
299 increment of the sustained solar wind velocity greater than 450 km/s acts as a strong external
300 indicator [Reeves et al., 2001]. In each of the events, SYM-H seems to be negatively
301 correlated (in fact it is about 85-90% in average) and so does the IMF Bz. Hence it is not a
302 reliable predictor as decrease in SYM-H value in not necessarily for relativistic event to occur.
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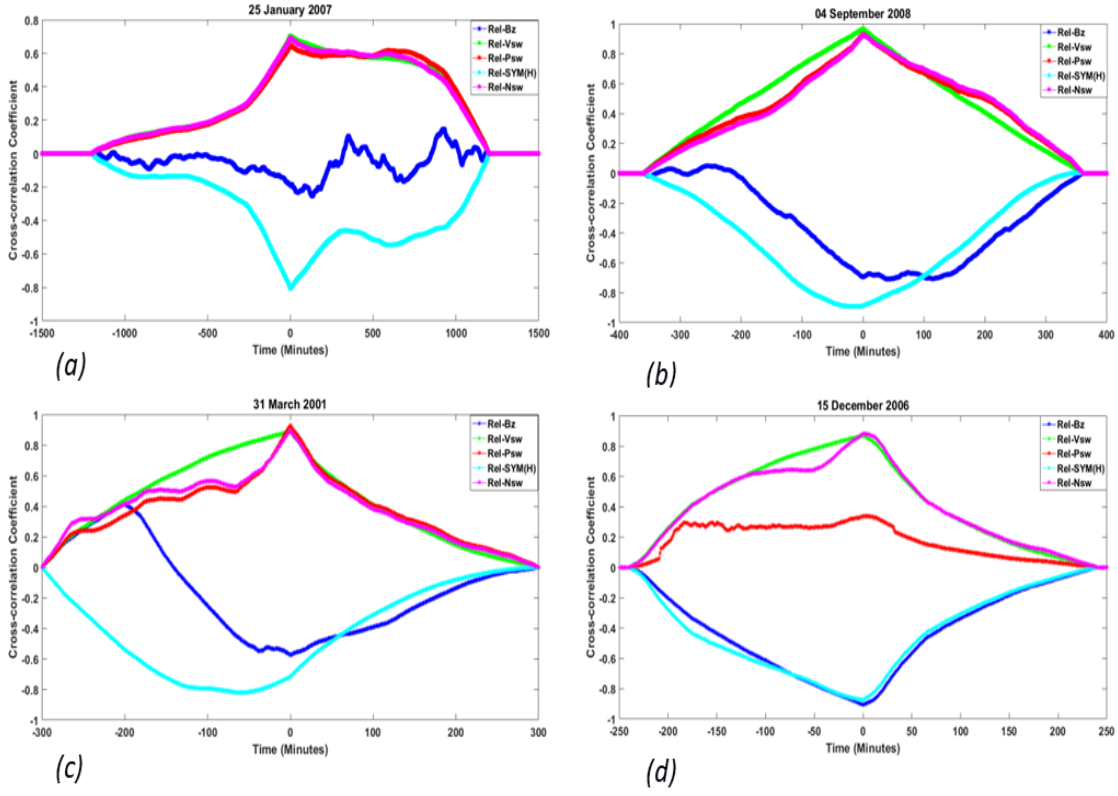

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Figure 6: Cross correlation between Relativistic electron flux (E>2MeV) with Bz (blue), Vsw (green), Psw (red), SYM-H (sky blue) and Nsw (pink) during (a) Quiet Period, 25 January,2007 (b) Moderate storm,04 September, 2008 (c) Super intense storm,31 March,2001 and (d) Intense storm,15 December,2006 .

305

306 **4. Conclusion**

307 In this paper, we have analyzed various solar wind parameters and geomagnetic indices with
308 relativistic electron flux ($E > 2\ MeV$) datasets for the four geomagnetic events selected. To
309 enhance the analysis of relativistic electron flux, the cross-correlation and CWT analysis was
310 adopted [Adhikari 2015; Adhikari et al. 2017a, b; Adhikari et al., 2018]. The work presented
311 here shows good correlation, having positive cross-correlation coefficient (> 0.8), for
312 relativistic electron flux with the solar wind velocity, pressure, and solar density. Thus, the
313 choosing of these parameters are well justified as they are highly geoeffective. In each of the
314 event, except super-intense, whenever the solar wind exceeds 600 km/s, there seems to increase
315 in relativistic electron flux. This is consistent with previous results which shows a large average
316 solar wind speed (Vsw> 500 km/s) is characteristic of enhancement events [Paulikas& Blake
317 1978, 2010; Reeves et al., 2011].
318 As depicted in the event-4 (Figure 4), with the increase in solar wind dynamic pressure, the
319 electron flux shows a decrement factor of 3. The solar wind dynamic pressure and IMF Bz play
320 indispensable role in causing the relativistic flux dropouts as the magnetopause is compressed
321 closer to earth or located very far (>10 Earth Radii) [Gao et al., 2015]. The impingement of high
322 speed solar wind, suppressing the dayside magnetosphere enhancing the drift shell splitting of
323 charged particles, has impacts onthe possible loss mechanisms of the magnetospheric relativistic
324 electron, as in the case of super intense storms (super sub-storms). Our result substantiates the
325 geomagnetic storms are not a primary factor that pumps up the radiation belt. In fact, the
326 geomagnetic storms can deplete, enhance or cause little effect on the outer radiation belt. To be
327 precise, it shows event-specific behavior.
328 In addition, all the geomagnetic storm events, except intense storm, Psw is found to be highly
329 and positively correlated with relativistic electron flux. The higher Psw leads to the depletion of
330 the electron flux presumably through compressing the inner magnetosphere and intensifying the

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ring current [Gao et al., 2015].However, for intense storm, Psw is found to be weakly correlated followed by an abrupt increase of electron flux value for ~4 hrs, which is interesting and unique.

In sum, the count of relativistic electron flux (> 2 MeV) decreases during the main phase of geomagnetic storm with the increase in -- from quiet to super intense storm -- geomagnetic storm conditions (Table 1). Furthermore, in case of intense geomagnetic storm: during the post-storm condition, sharp increase in flux count (even larger than in normal quiet condition) is observed, inkling of unperturbed ionosphere which might be the precursor for any sort of space weather effects in near future. Thus, there is a need of careful and extensive study of large events over extended period through more advanced tools and techniques for better understanding of the inherent physical mechanism.

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