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Superposed epoch analysis of MagnetosphericConvection Electric Fieldduring geomagnetic storms due to High SpeedSolar Wind during solar cycle 24

Abstract

The present study concerns the time variation of the MCEF with respect to geomagnetic phases as shown by SymH time variation by means of a superposed epoch analysis during solar cycle 24 for HSSW.For this work the magnetosphere input energy behavior is also highlighted. During IP and MP, the main effect of storm is the drop of MCEF and the decreasing particles density especially during the storm MP. During MP and RP, there is convection into a magnetosphere and the time for the total releasing of magnetosphere energy is longer that devoted to the RP. From IP to MP + RP, are pointed out the substorm onsets and the presence of substorms during the MP. From IP to MP + RP, the substorms that occur during the MP and the generated storms are not HILDCAA.

Keywords

Superposed epoch analysis, Magnetospheric convection electric fields, solar wind high speed, geomagnetic storm, geomagnetic indices

Introduction

Geomagnetic storm can be defined as a major disturbance of Earth's magnetosphere due to an efficient exchange of energy from the solar wind into the space environment surrounding Earth. The primarily causes of geomagnetic storms at Solar are Coronal Mass Ejections (CMEs) and High-Speed Solar Wind streams (HSSW). According to Gonzalez (1994) the primarilysources of geomagnetic storms at Earthare strong dawn-to-dusk electric fields associated withthe passage of southward directed Interplanetary MagneticFields (IMF), Bz, past the Earth for sufficiently long intervalsof time.

When CMEs and/or HSSW interact with Earth's magnetic field, they can provoke significantchanges in the magnetosphere with various effects on Earth (McPherron et al., 2008). During this disturbance,(MCEF plays a key role. Many studies (e.g. Akhavan-Tafti et al., 2023; Alqeeq et al., 2025; Kim et al., 2025; Bazie et al., 2025 and Desta et al., 2026)are performed to study magnetosphere variability during geomagnetic storms.Storms caused by CMEs have been particularly well-studied(e.g. Gopalswamy

N., 2002; Pulkkinen et al., 2007; 35 Gopalswamy N., 2009; Benacquista et al., 2010; Ontiveros et al., 2010; Liou et al., 2016; 36 Kabore et al., 2018; Pedersen et al., 2022 and Bazie et al. 2025)but those due to high-speed 37 solar winds are less.Several scientists (e.g. Denton et al., 2006, Borovsky et al., 38 2006),Hutchinson et al., 2011) andGrandin et al., 2019)showed that HSSW storms are 39 different from CMEs storms. It is therefore important to carry out analyses specific to these 40 storms. The present study focuses on 20 storms caused by high-speed winds and/or CIRs 41 during the declining phase of solar cycle 24. In this study, we attempt to answer the following 42 questions: How does the convective electric field vary during the different phases of storms 43 caused by high-speed solar winds? What are the solar wind parameters that determine the 44 state of the magnetosphere during each phase of a storm caused by high-speed solar winds? 45 To answer these questions, we use a statistical storm-phase approach. Several studies have 46 shown that the phase-based approach is useful for understanding the processes involved 47 during magnetic storms (Wang et al. 2024; Mishra et al. 2024; Ahmed et al. 2024). However, 48 the study of storms presents a major complexity: the events do not have the same durations, 49 and the phases of the storm do not have the same characteristics. In order to standardize them 50 and extract average trends for each phase, we use a superposed epoch analysis with time 51 normalization.It is important to note that this method has been used to study geomagnetic 52 storms by Hutchinson et al. (2011) for the intensity of the storms.; Yermolaev et al. (2010) for 53 the average behavior of the geomagnetic storms; Keesee et al. (2014) for studying the global 54 ion temperature during the ICME driven and CIR driven storms; Katsavrias et al.(2019) for 55 the acceleration and loss of relativistic electron. To improve the accurate behavior of the 56 storm Yokoyama and Kamide (1997) and Manu et al. (2023) used Double superposed epoch 57 analysis. 58 For us, the superposed epoch analysis allows on one hand, to equalize storms over the same 59 normalized time intervals, and also to deduce the mean, median, as well as the lower and 60 upper quartiles of the different parameters for each normalized time. These values allow us to 61 compare the variation of the magnetospheric convection electric field across the three phases 62

and to extract the average variation during storms in order to answer the first question. To 63 answer the second question, we analyze the relationship between solar wind parameters and 64 the MCEF throughout the different phases of storms. In the following, we will describe the 65 data and the methods and we will present the results. 66 1. Data and methodology 67 1.1 Data 68 Magnetospheric activities, geomagnetic storms, substorms are due to the energy injected into 69 the magnetosphere from the solar wind (Akasofu,1981). This energy injected is responsible 70 for the dynamics of the magnetosphere-ionosphere system (Newell et al., 2007).To determine 71 the energy input, several energy coupling functionsare used (Perreault and Akasofu, 1978; 72 Kan and Lee, 1979; Murayama, 1982;Vasyliunas et al. 1982; Wygant et al. 1983; Bargatze et 73 al., 1986; Xu and Shi, 1986; Mac-Mahon and Gonzalez,1997; Stamper et al., 1999; Koskinen 74 and Tanskanen, 2002; Vichare et al., 2005; Finch and Lockwood, 2007; Wang et al., 2014). In 75 this work the coupling function of Wang et al. (2014) is used. 76 The energy input can be predicted by means ofBz component of the IMF, the solar wind 77 velocity (V) and the dynamic pressure (p) (Dungey, 1961; Kan and Lee, 1979; Wygant et al., 78 1983; Scurry and Russell, 1991; Temerin and Li, 2006; Newell et al., 2007). It can be also 79 noted that the magnetospheric state variables can be determined by using Bz. 80 Therefore, in the present study, the following data are used: solar wind velocity (V); the Z 81 component of Interplanetary magnetic Field (IM (Bz) and the Y component of Interplanetary 82 Electric Field (IEF) (Ey), solar wind particles density (n). 83 To determine storm time phases, we utilized the geomagnetic index SymH (according to 84 Iyemori (1990), SymH measures the activity of ring current with 1 minute as time resolution 85 and is same as Dst with 1 hour as time resolution. To estimate the overall intensity of auroral 86 currents the Auroral Electrojet (AE) is used in this work. 87 This study focuses on the variation of the magnetospheric convection electric field (MCEF) 88 under the influence of High-Speed Solar Wind (HSSW). It is important to note that this 89 influence can be interpreted in terms of, on the one hand, energy injected into the magnetosphere as a function of the characteristics ofsolar wind parameters and, on the other hand, geomagnetic storms intensity and time variation. Therefore,we will use the geomagnetic activity indices SymH and AE and solar wind parameters that are available on the

OMNIWEB websitehttps://omniweb.gsfc.nasa.gov/form/omni_min.htmland recorded in Table 1. Table1: Geomagnetic index and solar wind parameters Parameters (Unit) Resolution Description Utilisation V (Km/s) 5 min Solar wind speed For analyzing changes in solar wind speed Bz (nT) 5 min Component along the z-axis of the interplanetary magnetic field For analyzing conditions favorable to reconnection Ey (mV/m) 5 min Component of the electric field along the y-axis of the interplanetary magnetic field For calculating the MCEF AE (nT) 5 min AE index for monitoring auroral activity For evaluating auroral activity SymH (nT) 5 min Index quantifying variations in the ring current For dividing storms into different phases n, particles density (particles/cm3) 5 min Densité des particules du vent solaire 1.2 Methodology 1.2.1Study of geomagnetic storms a) Determination of geomagnetic storms In this study that covers the period from 2008 to 2018, we focus on geomagnetic storms. The start of a storm is identified by the conditionSymH < −60 nT and the end by the conditionSymH > −20 nT. There were 125 storms during the period in question, regardless of their origin or source. Several classifications of storms exist: a) Classification according to Hutchinson et al. (2011) and Walach et al. (2019). Low-intensity storms: − 150 nT < SymH$_{min}$ ≤ −80 nT Moderate storms: − 300 nT < SymH$_{min}$ ≤ −150 nT

Intense or strong storms: SymH$_{min}$ ≤ −300 nT where SymHmin is the minimum value of SymH b) Classification according to Li et al. (2010; 2012) Moderatestorms:

100

The storm time is divided into three phases with respect to SymH time variation (figure 1): (a) the Initial Phase (IP) with time interval (t0-t1); the Main Phase (MP) characterized by a time interval (t1-t2)and the Recovery Phase (RP) with time interval(t2-t3) (table 2)

Table2: Start and End phases of the retained geomagnetic storms

Number of storm	Start of IP	Start of MP or End of IP	Start of RP or End of MP	End of RP	SymHmin
1	03/09/2008 14:50	03/09/2008 23:15	04/09/2008 03:05	04/09/2008 11:00	-67
2	10/10/2008 03:05	11/10/2008 07:20	11/10/2008 11:30	14/10/2008 22:55	-64
3	21/07/2009 03:20	21/07/2009 22:25	22/07/2009 05:55	25/07/2009 11:35	-93
4	01/05/2010 12:30	02/05/2010 08:15	02/05/2010 20:30	05/05/2010 05:35	-75
5	04/02/2011 07:05	04/02/2011 16:55	04/02/2011 21:20	07/02/2011 02:15	-67
6	01/03/2011 07:40	01/03/2011 09:20	01/03/2011 14:25	03/03/2011 11:50	-71
7	31/05/2013 13:55	01/06/2013 01:35	01/06/2013 07:45	03/06/2013 01:10	-134
8	07/12/2013 15:20	07/12/2013 22:40	08/12/2013 08:30	09/12/2013 05:50	-72
9	03/07/2015 23:10	04/07/2015 15:55	05/07/2015 04:55	07/07/2015 20:05	-86
10	05/03/2016 13:05	06/03/2016 15:00	06/03/2016 21:20	09/03/2016 03:05	-120
11	23/10/2016 02:40	23/10/2016 05:50	25/10/2016 22:55	28/10/2016 17:45	-80
12	26/03/2017 19:55	27/03/2017 01:00	27/03/2017 16:10	29/03/2017 20:45	-86
13	26/09/2017 19:55	27/09/2017 05:30	28/09/2017 05:50	29/09/2017 07:35	-74
14	06/11/2017 12:25	07/11/2017 04:35	08/11/2017 04:05	10/11/2017 01:00	-89
15	20/11/2017 07:40	20/11/2017 17:20	21/11/2017 06:50	24/11/2017 12:25	-60
16	05/05/2018 04:05	05/05/2018 14:20	06/05/2018 02:30	08/05/2018 01:35	-66

Figure 1: SymH time variation with storm time phases

1.2.2 Superposed Epoch Analysis method

Studying storms presents difficulties due to their different characteristics. Indeed, they have different durations and intensities. This makes it difficult to calculate averages per phase for a set of storms and to perform a general analysis of trends for each phase. An alternative is to use the method called “superposed epoch analysis with time normalization”. For more details about this method see Walton and Murphy (2022). Their method execution code can be foundat the following link https://github.com/samwalton7645/SEA_Code. To analyze storm parameters (Bz, AE, Em, Wrecon, Wothers, n, SymH) , each storm SymH is divided into three phases (see figure 1). For analyzing each storm phase effect on the parameters, we define four cases that can be named events. To apply the Superposed Epoch Analysis (SEA) method, firstly, the event time must be divided into two parts named in the method phases. The first one, from the beginning of the event (t_{begin}) to the event development called by Walton and Murphy (2022) epoch (t_{epoch}) and the second one from the epoch (t_{epoch}) to the end of the event (t_{end}); secondly, each part time interval is normalized in order to transform it to a standard interval O 1 ; thirdly, the standard interval is binned into a set of equally spaced bins; fourthly, for each part interval, a set of statistics (mean, median, etc.) is then determined for thedata residing in each bin. a) Time normalization The SEA code is run four times with respect to the two parts or code phases per event. We have:

- Run 1: Obtention of parameters time variation for IP and MP $Code\_Phase\ 1 = IP$ and $code\_Phase\ 2 = MP$ This is done for having on one hand the effects of IP and the effects of MP, on the other hand. The time intervals are ($t0$-$t1$) and ($t1$-$t2$)
- Run 2: Obtention of parameters time variation for MP and RP $Code\_Phase\ 1 = MP$ and $Code\_Phase\ 2 = RP$ The SEA code program is run for having on one hand, the effects of MP and the effects of RP, on the other hand. The time intervals are ($t1$-$t2$) and ($t2$-$t3$)
- Run 3: Obtention of parameters time variation for IP + MP and RP $Code\_Phase$ 1=IP + MPand $Code\_Phase\ 2 = RP$

The SEA code script is executed for having on one the hand, the global effects of IP and MP together and on the other hand, the effects of RP.The time intervals are ($t0$-$t2$) and ($t2$-$t3$)

- Run 4: Obtention of storm parameters time variation for IP and MP + RP $Code\_Phase$ 1=IP and $Code\_Phase\ 2 = MP + RP$ This is done for having on one hand, the effects of IP and on the other hand, the global effects of MP and RP together. The time intervals are ($t0$-$t1$) and ($t1$-$t3$).

To apply SEA method, we convert each storm phase intervals into a standard one 0 1 . The process is:having $\forall t \epsilon\ ti$; $t\ j$ with$i$ = 0,1,2and$j$ = 1,2,3we define the normalized time as 190 follows: $tnorm$ = $t{-}ti\ tj\ {-}ti$. This leads to a normalized interval so that for a given time$tnorm$ we 191 have$tnorm\ \epsilon$ 0; 1 192 For each phase and for each instant t, we calculate the time elapsed between the start of the 193 phase and instant t. That is, the time elapsed between t0and $t$for any instant t of phase 1 or 194 between t1 and t for any instant t in phase 2 or for any instant t between t2 and t for any 195 instant t in phase 3. Each elapsed time value is converted to a value between 0 and 1 by 196 dividing it by the total duration of the phase. Thus, 0 corresponds to the beginning of the 197 phase and 1 to the end of the phase. This means that regardless of the duration of the storms, 198 they can be aligned on an evolution scale. 199 200 b) binning into a set of equally spaced bins 201 Firstly, each codephase standard interval is binned. The number of bins is given in table 3. 202 Secondly, the binned normalized time is obtained by starting to count bins at the epoch time. 203 Thus, bin numbers before epoch time are negatives and that after epoch time are positive. 204 205 Table 3: Number of bins per code phase forgiven Run 206 207 Run number Number of bins forCode_Phase1 Number of bins forCode_Phase2 1 40 120 2 80 100 3 40 100

4 40 40 208 1.2.3Determination of Magnetospheric Convection Electric Field (MCEF) 209 To determine the values of the magnetospheric convection electric field (MCEF), we will use 210 the relationship proposed by Wu et al. (1981) and validated by Revah and Bauer (1983), 211 which links the Ey component of the Interplanetary Electric Field (IEF) to $B\ z$ component of 212 the Interplanetary Magnetic Field (IMF):EM = 0.13 Ey + 0.09 withEy = $-VB\ z$ where V is 213 the solar wind speed. 214 215 1.2.4Determination of the input energy components 216 To determine the energy transferred during the coupling between the solar wind and the 217 magnetosphere, we will use the relationship described by Wang et al. (2014): 218 $W\ in$ = 3.78 107n0.24V1.47BT 0.86[sin2.70 θ/2 + 0.25]where: 219 $\theta$is the shock incidence angle of the interplanetary magnetic field. It is defined as follows: 220 θ = tan−1 $By\ Bz\ ifB\ z$ > 0 θ = π − tan−1 $By\ Bz\ ifB\ z$ < 0 221 $V$the solar wind speed,

B_T the IMF magnitude expressed as: $B_T = B_y^2 + B_z^2$, n_{sw} the solar wind particles density. The equation that gives the input energy can be rewritten as: $W_{in} = 3.78\,10^7 n^{0.24} V^{1.47} B_T^{0.86} \sin^{2.70}\frac{\theta}{2} + 3.78\,10^7 n^{0.24} V^{1.47} B_T^{0.86} 0.25$. It can be seen that we have the sum of two expressions which can be expressed as: $W_{recon} = 3.78\,10^7 n^{0.24} V^{1.47} B_T^{0.86} \sin^{2.70}\frac{\theta}{2}$ and $W_{others} = 3.78\,10^7 n^{0.24} V^{1.47} B_T^{0.86} 0.25$. therefore $W_{in} = W_{recon} + W_{others}$ The first term (W_{recon}) represents the injected electromagnetic energy, mainly due to magnetic reconnection on the day side, which varies with $\sin(\frac{\theta}{2})$. This term reaches its

maximum when the IMF is oriented towards the south ($\theta = 180°$ and $\sin\frac{\theta}{2} = 1$) and cancels out when the IMF is oriented towards the north ($\theta = 0°$). The second term (W_{others}) represents an energy contribution independent of the clock angle, attributed to other processes such as reconnection at high latitudes (in the lobes), viscous interactions, or mechanical energy transfer (e.g., via Kelvin–Helmholtz instabilities). This component becomes relatively more important when the IMF is oriented northward.

2. ResultsandDiscussions

Figures 2-6 show the bin normalized time (BNT) for some solar wind parameters (particles density, Z component of IMF), the geomagnetic indices AE and SymH and the calculated injected energy from solar wind into the magnetosphere components (reconnexion energy and other sources of energy). In figures 2-5, panel a concerns AE index, panel b is devoted to Bz, panel c shows the BNT evolution of SymH, panel d concerns particles density, panel e, presents the BNT variation of MCEF and panels f and g are devoted to Wrecons and Wothers, respectively.

2.1. Case of Run 1

In figure 2 BNT varies from -40 to 39 BNT with IP (from - 40 to 0 BNT) and MP (from 0 to 39 BNT). It can be seen that during IP all parameters exhibit constant value close to zero, exceptparticles density and the injected energy due to other sources. This observation let us say before storm (1) there is no convection electric, (2) magnetosphere is submitted to input energy independently to the coupling solar wind magnetosphere interactions; (3) the particles density is remained at 12.5 particles /cm3.When Bz decreases and tends toward zero there is a slight increase of other sources input energy and particles density. When Bz passes from northward to southward we enter into MP and we observe a sudden increase of all parameters. During the remain southward Bz, the particles density decreases and tends toward a value before the begining of the storm. For the other parameters, they slightly increase. At the end of MP, the reconnected input energy drops from 0 W to 3 W while that of the other sources passes from 0.25 W to 1.25 W and the MCEF value goes from 0 mV/m to 0.4 mV/m.

The main effect of storm is the drop of all parameters since Bz passes southward and the smooth increase of all parameters except the particles density which highlights a maximum when Bz passes southward and after decreases. This shows the loss of particles during storm MP.

Figure 2: Solar wind parameters and geomagnetic indices BNT variation during IP and MP. From top to bottom: a) AE index; b)Bz; c)SymH; d) particles density; e) MCEF; f) input energy due to reconnection and g) input energy due to the other sources

2.2. Case of Run 2

Figure 3 shows BNT evolution of solar wind parameters and geomagnetic indices (SymH and AE) and input energy components for MP and RP. BNT varies from -40 to 0 for MP and from 0 to 100 for RP. It can be seen, when Bz remains southward, the decreasing of SymH and particles density and the increasing of the other parameters. At the minimum value of SymH (- 75 nT), the end of MP and the beginning of RP, Bz reaches 0 nT, AE its maximum value (850 nT). Particles density, MCEF, and input energy curves present a maximum (15 particles/cm-3, 0.5 mV/m, 3 W and 1.3 W, respectively) before the end of MP at -5 BNT. During RP, all parameters decrease and tend smoothly toward 08 mV/m for MCEF, 0.5 W for the reconnecting energy and 0.25 W for that due to other sources. The MCEF not reaches 0 mV/m that exhibits the remain of convection into the magnetosphere, even though there is a decreasing of the input energy, it is not totally dissipated after the end of storm. Thispointed out that there is remaining energy at the end of the storm. Consequently, the input energy is not completely dissipated. The consequence is that the time for total releasing of magnetosphere energy is longer that devoted to the RP.

Figure 3: Same as Figure 2 but during MP and RP

2.3. Case of Run 3

Figure 3 presents two parts of storm time variation: the whole IP and MP (from -80 BNT to 0 BNT) as the first part and the RP (from 0 BNT to 99 BNT) as the second part. During the whole IP and MP, the parameters (AE, n, Em, Wrecon, Wothers) simultaneously increase and during RP they decrease at the same time and tend toward their minimum value. At -40 BNT Bz becomes northward and parameters decrease. AE, MCEF and reconnection input Energy are more sensitive to this change in Bz direction. When Bz passes from northward to southward, AE increases until the end of MP and decreases after. Its minimum value is superior to that before storm. This proves that the magnetosphere does not return to its initial state after the storm has passed. The particles density decreases when Bzturns southward and stabilizes at 2 particles/cm3close very lower than its value (8 particles/cm3) before the storm. Everything happens as the storm depletes the magnetosphere from a particle perspective. The MCEF increases when Bz passes southward and starts decreasing before the end of MP. The decrease continues during the recovery phase, tending towards zero and very close to the state before the storm. We can conclude that the magnetospheric convection electric field created by the storm fades away at the end of the storm. The variability of input energy is the same as that of MCEF but with a pronounced slope at the beginning of the decreasing. The final value

(0.38 W) at the end of the storm is higher 319 than that before storm (~0 W) for the input energy due to reconnection while the input energy 320 coming from the other sources last value (~039 W) is the same as before the storm. We can 321 conclude that the magnetosphere gains energy after the storm in terms of energy due to 322 reconnection despite tail reconnection and substorm activity allow the system to return to a 323 more normal configuration with respect to the size of the storm (Hutchinson et al., 2011; 324 Gonzalez et al., 1994; Daglis et al., 1999; Liemohn et al., 1999 and Reeves et al., 2003) 325 326

327 Figure 4: Same as Figure 2 but during IP +MP and RP 328 329 330

331 2.4. Case of Run 4 332 333 Figure 4 shows the evolution through all storm phases in accordance with the temporal 334 evolution of SymH of the parameters AE index, IMF component Bz, the density of particles in 335 the magnetosphere n, the MCEF Em, and the components of energy injected into the 336 magnetosphere, namely the reconnection component Wrecon and the component due to other 337 sources Wothers. In this figure, the IP starts from -42 bin normalized time (BNT). and ends at 0 338 BNT. The whole main and recovery phases (MP and RP) start from 0 to 120 BNT. At 0 BNT, 339 the IMFBz turns from northward to southward and reaches its minimum at 7.5 BNT. At the 340 same time (0 BNT) all parameters increase and reach their maximum at 7.5 BNT. 341 We have 610 nT, for AE; - 10 nT for Bz;40.6 mV/m for Em, 3.75 W for Wrecon and 1 W for 342 Wothers. The particles density n reaches its maximum at 0 BNT with 30 cm-3. During the RP, 343 the MCEF decreases and fluctuates around a level slightly higher than the level before the 344 storm 345 The particles density decreases and reaches a level lower than that before the storm. The 346 injected energies (Wrecon and Wothers) and AE index decrease and stabilize at levels slightly 347 higher than those before the storm. 348 The prompt increases of AE at 0 BNT when Bz turns from northward to southward lets us 349 assert that at this time there is an increase of the overall intensity of auroral current 350

(Nakamura et al., 2015) and characterizes not only a substorm onsets (Wang et al., 2014) but 351 also the presence of substorms because these are observed to occur during the MP of magnetic 352 storms (Gonzalez, 1994). As the sudden increases of AE index appears during the MP instead 353 of RP and AE values are less than 1000 nT it emerges that the present storm events are not 354 those qualified by Tsurutani and Gonzalez (1987) and Hajra et al. (2014) High-Intensity, 355 Long-Duration, Continuous AE Activity (HILDCAA) events. 356 The maximum AE reached during the main phase and its subsequent exponential decrease 357 confirms the assumption made by Kamide and Fukushima (1971) that the rate of energy 358 injection into the annular current depends on the AE index. 359 Figure 4 exhibits that solar wind velocity increases when the particles density decreases. This 360 expresses the behavior of storms provoked by CIRs as asserted by Hutchinson et al. (2011). 361 362 363 364

365 366 367 Figure 2: Solar wind parameters and geomagnetic indices BNT variation during IP and 368 MP +RP. From top to bottom: a) Solar wind velocity; b)AE index; c); Bz; d) SymH; e) 369

particles density; f) MCEF; g) input energy due to reconnection and h) input energy due 370 to the other sources 371 Conclusion 372 The MCEF time variation was studied by means of superposed epoch analysis during 373 geomagnetic storms caused by HSSW for solar cycle 24. The analysis of MCEF through the 374 three phases of storm time with respect to SymH variation shows that: From IP to MP, the 375 main effect of storm is the drop of MCEF since Bz passes southward and its smooth 376 increasing during the storm MP. From the MP to RP, the convection remains into the 377 magnetosphere even though there is a decreasing of the input energy. This energy does not 378 completely dissipate. From IP + MP to RP the MCEF created by the storm fades away at the 379 end of the storm. The magnetosphere gains energy after the storm in terms of energy due to 380 reconnection despite tail reconnection and substorm activity allow the system to return to a more normal configuration.From IP to MP + RP, we have the substorm onsets during the storm MP and the behavior of storms due to CIRs. The concerning storms are different to those of HILDCAA events.

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