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A comprehensive analysis of the geomagnetic storms occurred during 18 February and 2 March 2014



Essam Ghamry^{*}, Ahmed Lethy, Tareq Arafa-Hamed, Esmat Abd Elaal

National Research Institute of Astronomy and Geophysics (NRIAG), Helwan 11421, Cairo, Egypt

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Abstract The Geomagnetic storms are considered as one of the major natural hazards. Egyptian geomagnetic observatories observed multiple geomagnetic storms during 18 February to 2 March 2014. During this period, four interplanetary shocks successively hit the Earth's magnetosphere, leading to four geomagnetic storms. The storm onsets occurred on 18, 20, 23 and 27 February. A non-substorm Pi2 pulsation was observed on 26 February. This Pi2 pulsation was detected in Egyptian observatories (Misallat and Abu Simbel), Kakioka station in Japan and Carson City station in US with nearly identical waveforms. Van Allen Probe missions observed non-compressional Pc4 pulsations on the recovery phase of the third storm. This Pc4 event is may be likely attributed to the decay of the ring current in the recovery phase.

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1. Introduction

The solar activity such as solar wind, coronal mass ejection, and solar flares propagating through the interplanetary space carries a large amount of energetic particles and electrical energy. Some of these solar activities while interacting with the Earth's magnetosphere produce several geomagnetic activities with different characteristics. One of these prominent

phenomena is the geomagnetic storm. Moos (1910a) identified a pattern in the horizontal component at Colaba, India. He found occasional sudden rise of the horizontal component followed by a rapid decrease lasting a few hours and a slow recovery lasting 1–3 days. These disturbances are defined as “magnetic storms” having the various phases of the storm as (i) storm sudden commencement (SSC), (ii) initial phase, (iii) main phase and (iv) recovery phase (Araki, 1994; Hafez and Ghamry, 2011, 2013; Hafez et al., 2012, 2013a,b; Ghamry et al., 2013).

The research on the geomagnetic effects of solar wind structures has typically distinguished between coronal mass ejections (CMEs) and corotating interaction regions (CIRs). The former are associated with strong disturbances whereas the latter usually give rise to moderate storms (Gosling et al., 1991; Richardson et al., 2001; Zhang et al., 2007; Youssef et al.,

^{*} Corresponding author.

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2012; Fathy et al., 2014). Both interplanetary (IP) shocks and CIRs result in a large solar wind dynamic pressure increase, which compresses the magnetopause and may significantly affect the magnetospheric current systems. Magnetic ejecta inside CMEs, on the other hand, primarily affect the Earth's magnetosphere through magnetic reconnection during a period of intense and prolonged southward B_z . Fast CMEs drive shocks and the shock plus ejecta may result in a two-step geomagnetic storms (Kamide et al., 1998).

Geomagnetic pulsations, Ultra Low Frequency (ULF) waves, are naturally occurring magnetohydrodynamic (MHD) waves in the Earth's magnetosphere. These ULF waves are classified as continuous (Pc) or irregular (Pi) pulsations. Each category is subdivided into period bands that roughly separate a specific type of pulsation. Pi 2 pulsation is an irregular magnetic fluctuations with period [40–150 s]. It is considered as the most common pulsations used in substorm research (Saito et al., 1976). Pi2 pulsations at low latitude are good indicators to substorm onset because they are not only observed in the nightside but also in the dayside (Yanagihara and Shimizu, 1966). Pi2 pulsation is considered as a result of hydromagnetic disturbances driven by sudden change in magnetospheric convection or reconfiguration in the magnetotail during the substorm expansive phase, so it is considered a better proxy of substorm onset than its counterpart at middle and high latitude (Yumoto 1986; Ghamry et al., 2011, 2012; Hamada et al., 2015; Ghamry and Fathy 2016). Plasmaspheric cavity resonance (PCR), plasmaspheric virtual resonance (PVR), and plasmopause surface mode are considered major source mechanisms of Pi2 pulsations (Allan et al., 1986; Zhu and Kivelson, 1989; Lee, 1996; Lee and Kim, 1999; Lee and Lysak, 1999; Takahashi et al., 2003; Lee and Takahashi, 2006; Kwon et al., 2013; Ghamry et al., 2015; Ghamry, 2015). Pc4 (7–25 mHz) ULF waves are abundant on the dayside (e.g., Chi et al., 1994, 1996; Kim and Takahashi, 1999; Takla et al., 2011) and are occasionally observed on the nightside (Takahashi et al., 2005). Takahashi and Anderson (1992) found that Pc4 poloidal waves

at dayside can mainly be categorized into plasmopause poloidal waves and second harmonic poloidal waves outside the plasmopause. Liu et al. (2009) confirmed that Pc4 poloidal waves are mostly observed near noon around $L = 5$ –6 in the inner magnetosphere.

In this paper, we analyze the multiple geomagnetic storms that occurred during 18 February to 2 March 2014. The organization of this paper is as follows. In Section 2 we describe the observations. In Section 3, we show the signature of the storms on the Egyptian observatories. In Section 4 we investigate Pi2 pulsations occurred on 26 February on the ground. In Section 5 we show Pc4 pulsations occurred on 27 February in space. In Section 6 we give the summary and conclusions.

2. Observations

During 18 February to 2 March 2014, four strong interplanetary shocks successively hit the Earth's magnetosphere, leading to four geomagnetic storms. Fig. 1 shows the solar wind speed, density, dynamic pressure, the interplanetary magnetic field B and B_z , and the disturbance storm time Dst index, respectively. The first storm started at 14:00 UT on 18 February. The Dst index dropped rapidly down to -112 nT at 09:00 UT on 19 February, corresponding to a positive pulse $P = \sim 15$ nPa and a negative (or southern) $B_z = \sim -15$ nT. The second storm began at 04:00 UT on 20 February when there were a sharp pulse $P = \sim 10$ nPa and a negative $B_z = \sim -10$ nT. The storm main phase had two-step development. On 20 February, the Dst index at first dropped from -40 nT down to -86 nT at 13:00 UT and recovered rapidly up to -40 nT at 19:00 UT, dropped rapidly again down to -66 nT at 02:00 UT on 22 February, and then gradually increases to 4 nT until the onset of the third storm at 08:00 UT on 23 February when $P = \sim 14$ nPa and $B_z = \sim -5$ nT. In the meanwhile, the Dst index dropped from -4 nT down to -56 nT at 00:00 UT on 24 February. The fourth storm began at 16:00 UT on 27 February when $P = \sim 16$ nPa and $B_z = \sim -18$ nT, with a minimum $Dst = \sim -99$ nT at 00:00 UT on 28 February.

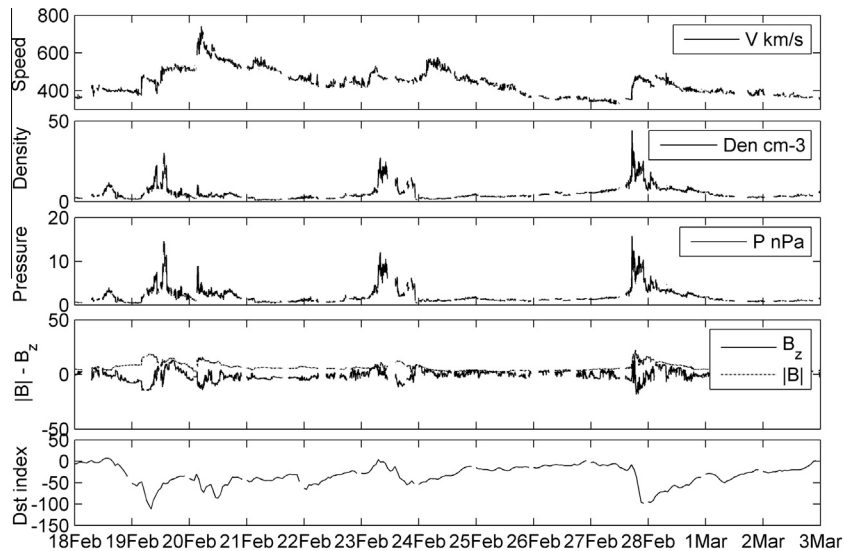


Figure 1 Shows the solar wind speed, density, dynamic pressure, the interplanetary magnetic field B and B_z , and the disturbance storm time Dst index through 18 February to 2 March 2014.

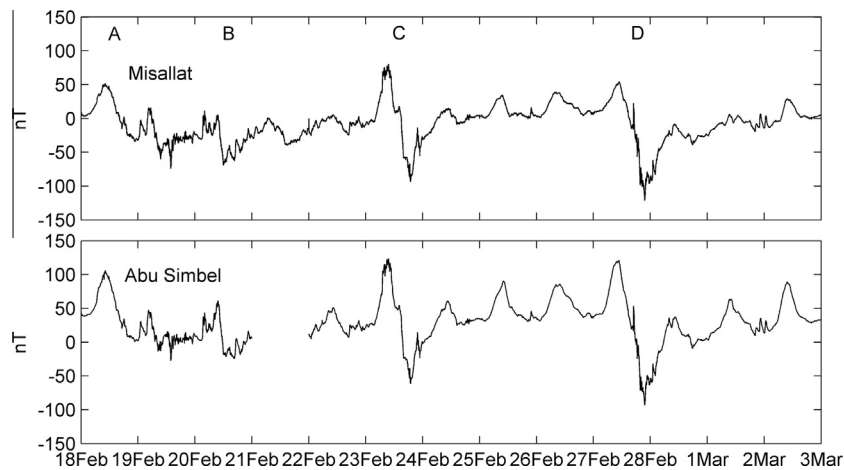


Figure 2 Shows the signature of 2014 multiple storms on the Egyptian observatories at Misallat and Abu Simbel.

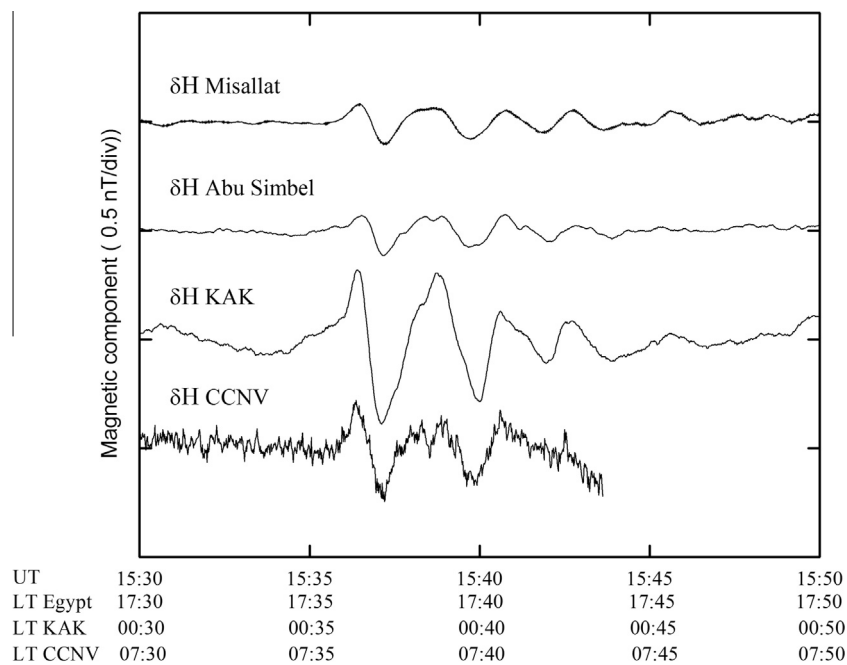


Figure 3 Illustrates Pi2 pulsation occurred at H components of Misallat, Abu Simbel, KAK and CCNV stations on 26 February 2014.

3. Signature of 2014 multiple storms at Egyptian observatories

Fig. 2 shows the signature of 2014 multiple storms on the Egyptian observatories at Misallat (upper panel) and Abu Simbel (lower panel). The letters A–D show the onset time of four magnetic storms at the two observatories. Note that there are no data on 21 February at Abu Simbel station. As we see, the X component of Misallat and Abu Simbel was affected by the first storm (A), at around 14:00 UT on 18 February, and the second storm (B), at around 04:00 UT on 20 February, without significant change resulting in small bay structures. On the other hand, a significant change was found during both the third storm (C), at around 08:00 UT on 23 February, and the fourth storm (D), at around 16:00 UT on 27 February, resulting in decrease of X components reached to minimum value of ~ -92 nT, ~ -120 nT and ~ -62 nT, ~ -94 nT, at Misallat and Abu Simbel, respectively.

4. Irregular pulsation on the ground

A Pi2 pulsation has been observed at 15:36 UT on 26 February at both Misallat and Abu Simbel observatories. To confirm these observations, we examine Kakioka station (KAK) in Japan and Carson City station (CCNV) in US. CCNV is located nearly in the opposite side of the globe with respect to KAK. We found that the Pi2 pulsation occurred simultaneously at all stations with nearly identical waveform. Note that Pi2 pulsation at both Egyptian stations and KAK events occurred during nightside but CCNV event occurred during morning side as shown in Fig. 3.

In order to examine the geomagnetic activity during this Pi2 event, we plotted the AE and AL indices shown in Fig. 4. At 15:36 (Pi2 onset), the magnitude of $|AL|$ is very small (< -30 nT). This magnitude is significantly less than that for typical substorm. From these observations we suggest that

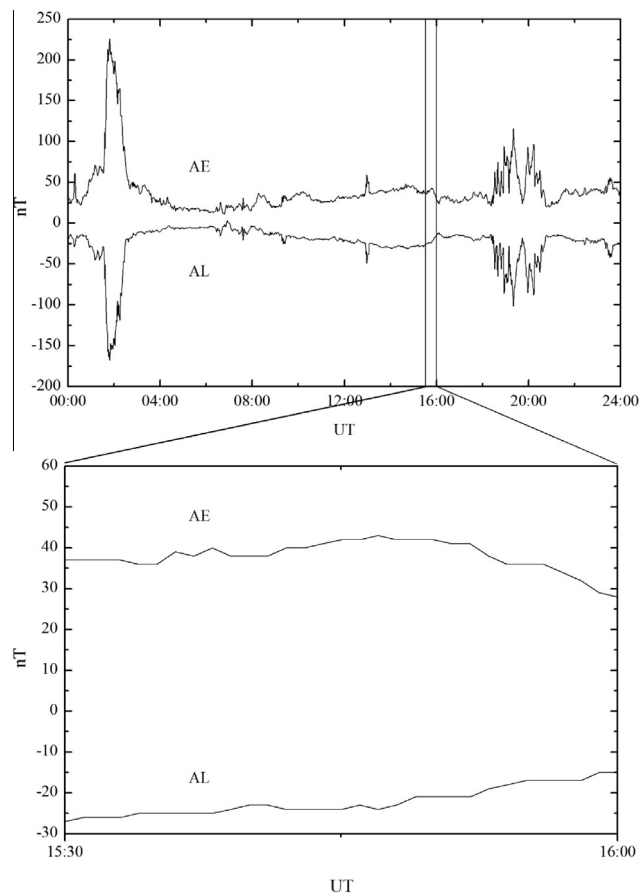


Figure 4 Shows the auroral electrojet AE and AL index on 26 February 2014.

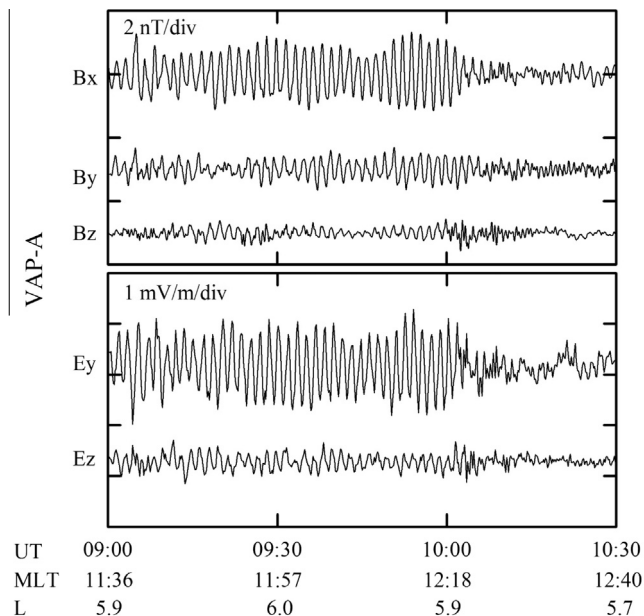


Figure 5 Displays the time series plot of magnetic and electric field perturbations (Bx, By, Bz, Ey and Ez) at VAP-A.

Pi2 pulsation presented in Fig. 3 occurred during the absence of substorm. We examined the space measurement via Van Allen Probe satellites, but we found no events. The source of

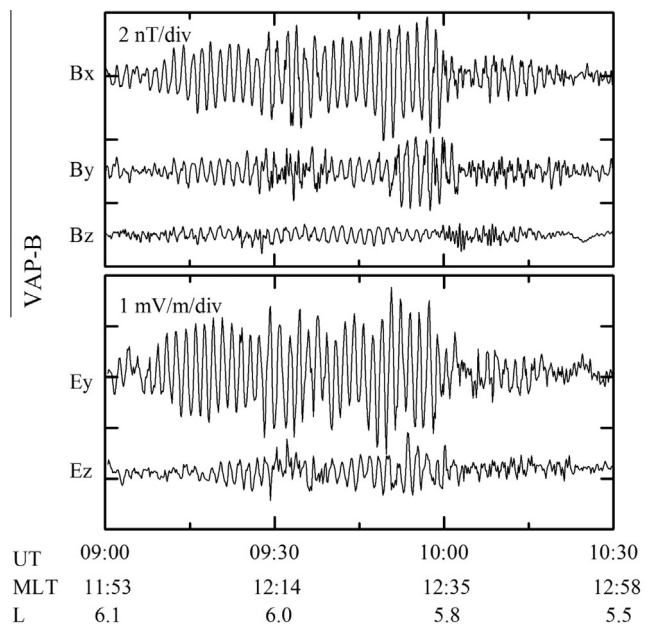


Figure 6 Displays the time series plot of magnetic and electric field perturbations (Bx, By, Bz, Ey and Ez) at VAP-B.

these Pi2 pulsations could come from the ionospheric current systems rather than by the cavity resonance mode.

5. Pc4 pulsation in space

On 27 February, Van Allen Probe Missions (VAP-A and VAP-B) detected Pc4 pulsations. The Van Allen Probes (Mauk et al., 2012), launched on 30 August 2012, provides comprehensive measurements of particles, electric fields, and magnetic fields in the inner magnetosphere. We use the magnetic field measurement from Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) (Kletzing et al., 2013) to identify micropulsation events. We use the 1 s resolution fluxgate magnetometer data. The magnetic field data acquired by VAP-A and VAP-B are expressed in a mean field-aligned coordinate system. The components in this system are denoted Bx (outward, perpendicular to the averaged magnetic field), By (eastward, perpendicular to the averaged magnetic field), and Bz (northward, along the averaged magnetic field).

Figs. 5 and 6 show Pc4 pulsations observed at VAP-A and VAP-B respectively. We can see that the radial component (Bx) has a significant wave but there is no significant wave at the compressional component (Bz). This event called non-compressional Pc4 wave. These non-compressional Pc4 wave in Figs. 5 and 6 was observed on 27 February before the arrival of an IP shock at ~ 17 UT.

It had been previously noted by Southwood (1976) that the ring current ions considered one important free energy source for the instability, which drives the low frequency oscillations. Southwood and Kivelson (1981, 1982) have developed the theory of particle flux pulsations induced by ULF transverse waves. In their theory, the particles experience the wave-carried electric field during their drift-bounce motions (Zong et al., 2007, 2009; Korotova et al., 2015). In the recovery phase of the third storm, the occurrence of non-compressional Pc4

waves associated with a gradual increase of Dst index (toward zero), Fig. 1, suggests that ring current ions (during decay period) provide free energy source for the non-compressional waves. So, we suggested that this non-compressional Pc4 may be generated by drift/drift-bounce resonance interactions with ring current ions.

6. Summary and conclusion

We present a comprehensive analyses of the multiple geomagnetic storms which occurred during 18 February to 2 March 2014. We investigate the signature of these multiple storms on the ground, at the Egyptian observatories and some other geomagnetic stations in Japan and US, and in space at Van Allen Probe missions. During this period, four interplanetary shocks successively hit the Earth's magnetosphere, leading to four geomagnetic storms. The storm onsets occurred on 18, 20, 23 and 27 February. A non-substorm Pi2 pulsation has been observed on 26 February. This Pi2 pulsation has been detected in Misallat and Abu Simbel in Egypt, Kakioka station in Japan and Carson City station in US with nearly identical waveforms. We examined the space measurements via Van Allen Probe satellites, but no events were detected. The source of these Pi2 pulsations may be come from the ionospheric current systems rather than by the cavity resonance mode. Van Allen Probe missions observed non-compressional Pc4 pulsations on the recovery phase of the third storm. This Pc4 event is may be likely attributed to the decay of the ring current in the recovery phase.

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