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RECOVERY PHASE OF THE SUPERSTRONG MAGNETIC STORM OF JULY 15–17, 2007 (BASTILLE DAY EVENT): ULF PULSATIONS

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Abstract. The geomagnetic data, collected from the global network of ground-based stations, have been analyzed. It was shown that the recovery phase of this superstrong magnetic storm was developed under Bz IMF >0 and accompanied by the substorm activity, which abruptly shifted to the polar latitudes. The intense Pc5 range geomagnetic pulsations were observed in the morning sector of auroral latitudes with amplitude spectra maxima at 1–2 and 3–4 mHz, coincided with the spectra of variations in the solar wind dynamic pressure. The 1-2 mHz waves were observed at Φ > 62º, but 3-4 mHz – at Φ < 62º. The Pc5 pulsations exhibited the characteristic features of the field line resonances (FLR), however they were observed at much lower latitudes than normal, suggesting a significant reduction of the local FRL. It has been established that the generation of 3–4 mHz Pc5 pulsations was spatially asymmetric about the noon. In the morning sector the intense Pc5 pulsations were observed at the auroral latitudes, but in the afternoon sector – at the subauroral and middle latitudes. The cause of this asymmetry remains unknown.

1. Introduction

The storm recovery phase usually begins when IMF Bz turns northward (i.e., when the solar wind energy terminates coming into the Earth's magnetosphere). Substorms, typical of the magnetic storm main phase, as a rule cease during the storm recovery phase. The morning sector of auroral latitudes is usually characterized by the generation of Pc5 geomagnetic pulsations [e.g., Troitskaya et al., 1965; Posch et al., 2003], with the morphological properties demonstrating their resonance nature. However, our studies of Pc5 pulsations, performed during the recovery phase of superstrong magnetic storms in 2003–2005, indicated that the characteristics of the waves observed during these storms can not be explained by the resonance theory [Kleimenova et al., 2005; Dmitriev et al., 2005; Potapov et al., 2006; Kleimenova and Kozyreva, 2007, 2008]. We assume that geomagnetic Pc5 pulsations, generated in the course of a recovery phase of large magnetic storms, can differ from "classical" Pc5.

The aim of the present work is to study peculiarities of the Pc5 geomagnetic pulsations during the recovery phase of the very strong magnetic storm of July 15–17, 2000 (Bastille Day Event, *Dst* = –301 nT).

2. Observations

In this study we used the digital 1-min data collected from the global network of ground-based stations (INTERMAGNET, IMAGE, SAMNET, CARISMA, MACCS, GREENLAND, and Meridian 210°).

The coronal mass ejection (CME), that caused the discussed magnetic storm, was observed on the Sun on July 14; therefore, the magnetic storm was called the "Bastille Day Event." At the storm main phase there were observed very large negative values of the IMF Bz (up to –60 nT) and the solar wind velocity (up to 1000 km/s). The storm recovery phase started after 02 UT July 16 with the appearance of the large positive IMF Bz values (~ 35 nT). Even in course of the late stage of recovery, the solar wind velocity remained rather high (~750 km/s), and the Dst-index values were large negative (-140 nT).

Two substorms (up to 1000 nT) at subauroral latitudes were recorded at the maximum of the storm main phase at 22–02 UT (Fig. 1). In the storm recovery phase the substorm activity at subauroral and auroral latitudes ceased. However a new intense (up to 800 nT) bay-like geomagnetic disturbance was recorded at ~04.30 UT at polar latitudes (IQA, NAQ) under positive values of IMF Bz. This disturbance was apparently caused by a pulse in IMF and in the solar wind velocity.

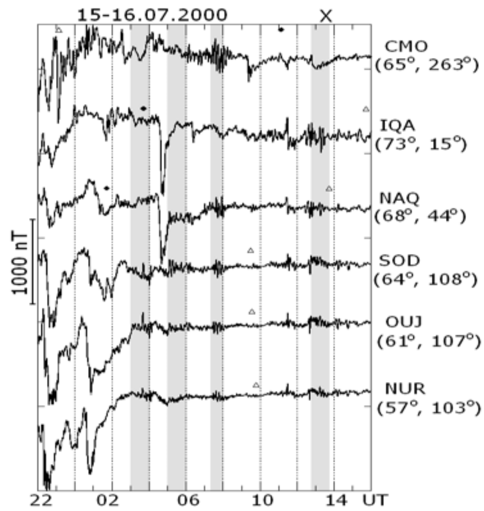

Fig. 1. Magnetograms of some stations at different longitudes; the geomagnetic coordinates and international codes are shown on the right; diamonds show the midnight, triangles - the noon.

"Physics of Auroral Phenomena", Proc. XXXII Annual Seminar, Apatity, pp. 21 - 24, 2009

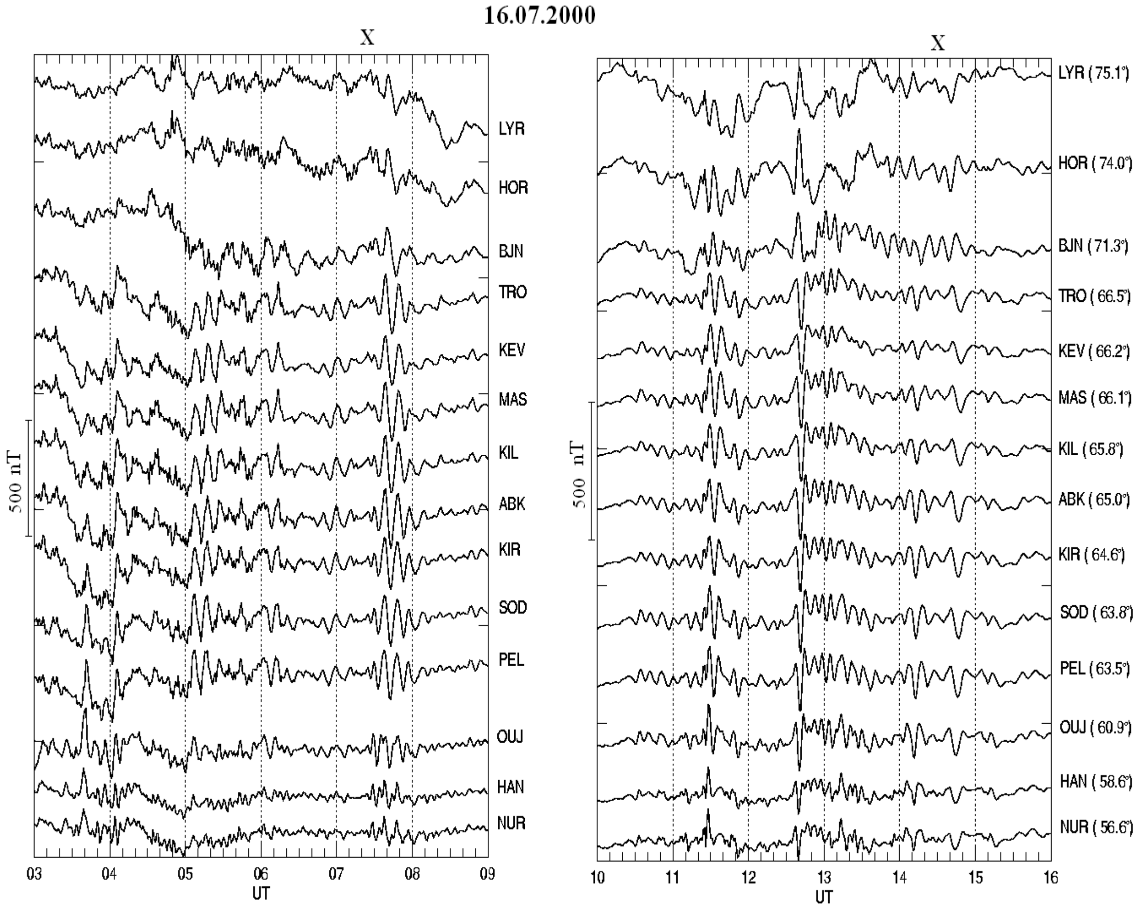

Fig. 2. Magnetograms of the IMAGE stations: at 03–09 UT (the left plot) and at 10–16 UT (the right plot).

After this magnetic bay in the morning-dayside sector, Pc5 geomagnetic pulsations with the strongest amplitudes at auroral stations (SOD–KEV) appeared at 05–14 UT (Fig. 2). At 05–06 UT pulsations with identical phases were registered at geomagnetic latitudes of ~62–70° and they were absent at latitudes higher than 70°. At 07.20–08.00 UT the region with simultaneously appeared pulsations considerably expanded toward high and low latitudes. After ~12.45 UT the well-defined wave phase change was observed between Φ~67° and Φ~70° (TRO–BJN).

Figure 3 demonstrates the Pc5 amplitude spectra at several IMAGE stations (upper plots) and the spectra of variations in the solar wind dynamic pressure and in the IMF (middle and lower plots) for four intervals marked by dark bands in Fig. 1. Two maxima (at ~1–2 and ~3–4 mHz) are seen in the pulsation spectra in all intervals. It is interesting to note that the observed maximums correspond to the discrete frequencies of resonance oscillations detected in a number of works, e.g. [Samson et al. 1992].

The global distributions of the intensity of 1–2 and 3–4 mHz geomagnetic pulsations of four UT intervals under consideration are shown on the maps (Fig. 4) constructed in the coordinates of the geomagnetic latitude – the local geomagnetic time (LAT–MLT).

3. Discussion

We consider in detail the geomagnetic pulsations in the intervals of 03–04, 05–06, 07.20–08.00, and 12.45–13.45 UT, shaded in Fig. 1.

The first interval (03–04 UT) could be related to the early stage of the storm recovery phase and includes pulsations generated after the last substorm in the storm main phase (Fig. 1). The strongest enhancement in the Pc5 spectra was observed at subauroral latitudes (OUJ) at ~ 2 mHz (Fig. 3). This maximum coincided with the maximum in the IMF Bz and By spectra. The second, twice smaller maximum in the Pc5 spectra (~3 mHz) increased with latitude and was larger at HAN (Φ=58.6°) than at OUJ (Φ=60.9°). This maximum was not observed in IMF and solar pressure spectra.

In the morning the most intense Pc5 pulsations were recorded at latitudes lower than ~65° (Fig. 4): the 1-2 mHz waves – at 02-08 MLT and 3-4 mHz waves – at 04-14 MLT. In the afternoon the pulsations were observed at the dayside polar cusp latitudes. Following to [e.g., Engebretson et al., 1998; Baker et al., 2003] we suppose that the morning Pc5 pulsations can be caused by the Kelvin–Helmholtz instability on the flanks of the magnetosphere.

"Physics of Auroral Phenomena", Proc. XXXII Annual Seminar, Apatity, pp. 21 - 24, 2009

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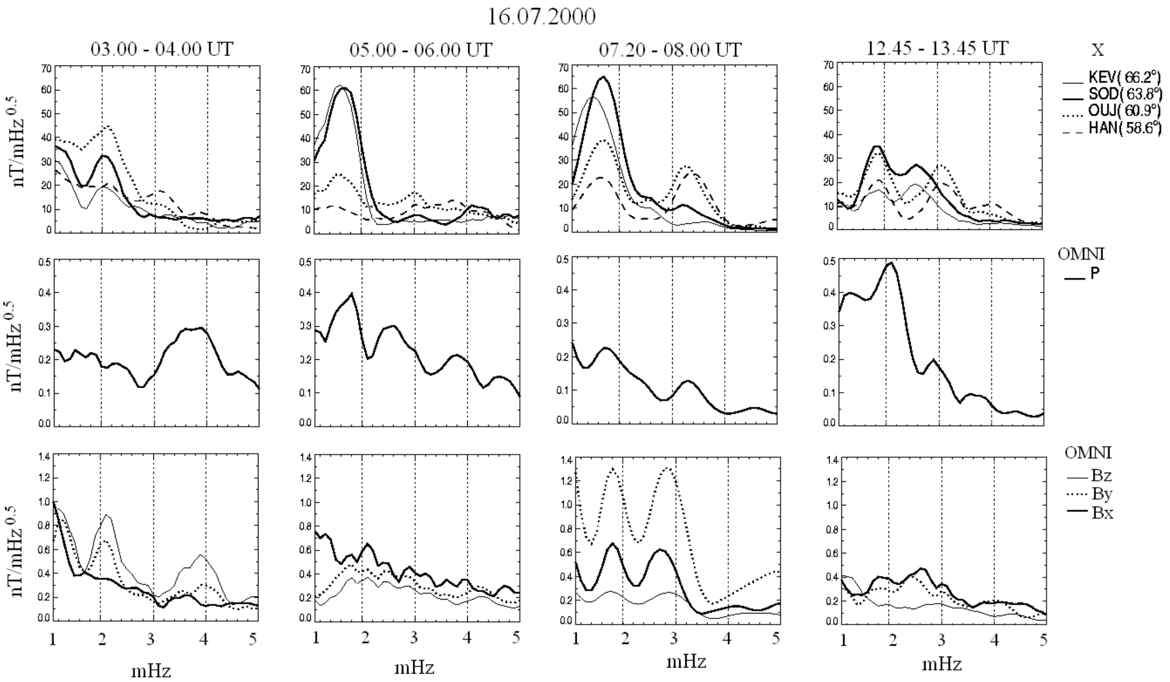

Fig. 3. The amplitude spectra of geomagnetic pulsations (the upper plots) and spectra of variations in the solar wind density (the middle plots), and IMF (the lower plots).

The second interval (05.00–06.00 UT) corresponds to the morning Pc5 pulsations observed at auroral latitudes after the polar substorm (Fig. 1) with the maximum at 1–2 mHz (Fig. 3) which shifted poleward – to Φ ~ 64°-66° (SOD–KEV). This spectral maximum was seen in the solar wind pressure fluctuations. According to some works, e.g. [Kepko, 2002; Kessel, 2008; Takahashi and Ukhorskiy, 2008] the observed Pc5 pulsations cold be a result of a direct penetration of compression wave from the solar wind.

A new burst of 3-4 mHz waves appeared in the afternoon sector gradually shifting from ~ 70° (12-16 MLT) to ~ 63° (19-23 MLT). The similar pulsations were recorded in Bx component on the geostationary GOES-10 satellite located at the 20–21 MLT sector. The nature of these pulsations is still unclear.

The third interval (07.20–08.00 UT) is characterized by one spectral maximum (1-2 mHz) at SOD and KEV (Fig. 3) and two maxima (1-2 mHz and 3-4 mHz) at lower latitudes (OUJ, HAN). The similar spectral latitude distribution at SOD and OUJ was observed in the recovery phase of the very strong magnetic storm of November 21, 2003 [Kleimenova et al., 2005; Fig.4]. The amplitude of 1-2 mHz waves was the largest at SOD and decreased toward higher (KEV) and lower (OUJ) latitudes; however, the wave phase did not change in this case. The 1-2 mHz peak is seen in the spectra in solar wind pressure and IMF variations.

A very intense 1-2 mHz Pc5 burst was observed not only in the late morning (IMAGE stations) but in the evening sector (CMO) as well (Fig. 1). Contrary to typical FLR waves the 1-2 mHz pulsations propagated from the evening/night to the morning/day sector. The wave phase at CMO (evening) led the phase at LRV (morning), which in turn led the wave phase at SOD (daytime). A similar, spatially localized, evening burst of ULF waves was observed simultaneously with the morning Pc5 pulsations and propagated to the dayside, was also reported by [Pilipenko et al., 2001, 2002] in course of the large magnetic storm of May 15, 2007. According to these authors, the generation of the storm-time evening Pc5 range geomagnetic pulsation could be associated with an injection of the ring current protons.

The spatial distribution of the 3–4 mHz geomagnetic pulsations in this interval changed even stronger (Fig. 4). The morning (02-07 MLT) maximum shifted to higher geomagnetic latitudes (~66-70°) a new daytime (08-15 MLT) region of strong pulsations appeared at the latitudes (~56-62°) This cannot be a result of the asymmetric position of the plasmapause since it is well known that the plasmapause is usually located in the morning at lower latitudes than near the noon. The high latitude (~70°) maximum of 3–4 mHz pulsations also remained in the evening sector (16-21 MLT).

The fourth interval corresponds to the burst of Pc5 pulsations, caused by a sudden impulse Si (Fig. 1, 2), and can be attributed to the late recovery phase of magnetic storm. Two maxima (~2 and ~3 mHz) of comparable intensities were detected in the spectra of the pulsations at the IMAGE profile (Fig. 3), located in the afternoon. The amplitudes of the first maximum rapidly decreased toward lower (HAN) and higher (KEV) latitudes with a constant phase. The phases of pulsations and Si changed only between ~67° (TRO) and~70° (BJN) as it is seen in Fig. 2. That, probably, corresponds to the magnetosphere boundary.

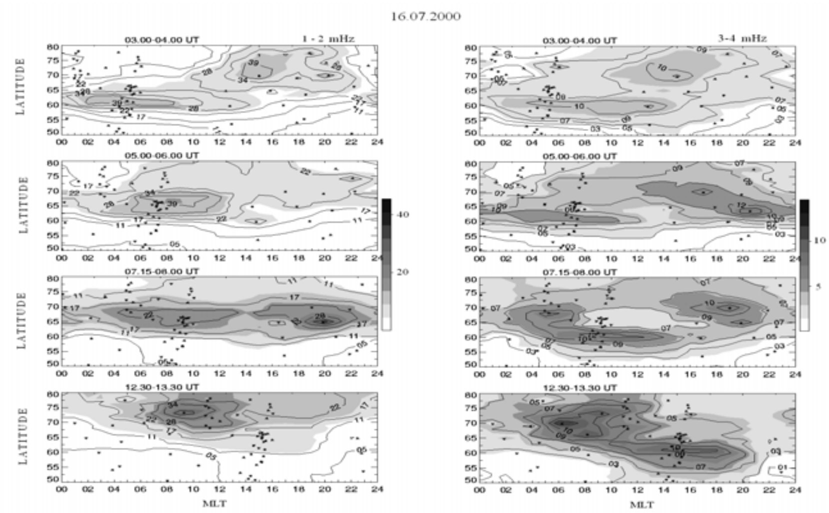

Fig. 4. Maps of the global distribution of the geomagnetic pulsation intensity in the frequency bands of 1–2 mHz (the left plot) and 3–4 mHz (the right plot) for different UT intervals in the geomagnetic latitude–magnetic local time (LAT–MLT) coordinates; asterisks show the positions of the stations.

The spatial location of the region of 1–2 mHz wave activity shifted to the dayside polar cusp (Fig. 4). The evening 3-4 mHz pulsations disappeared. The spatial distribution of 3-4 mHz pulsations remained generally the same as in the previous interval, demonstrating the spatial asymmetry as it was found early by Kleimenova and Kozyreva (2008) in the late recovery phase of other superstrong magnetic storms. Thus, it was confirmed the asymmetry in Pc5 pulsation generation in the recovery phase of large magnetic storms: the intense Pc5 pulsations are observed at auroral latitudes in the morning and but – at subauroral and middle latitudes in the afternoon.

4. Conclusions

(1) An analysis of the data from ground-based worldwide networks of stations during the recovery phase of the large magnetic storm of July 15–17, 2000 (the Bastille Day Event) showed that, even under the positive IMF Bz, the substorm activity did not cease, but shifted from subauroral to polar latitudes.

(2) The Pc5 geomagnetic pulsations, generated in the storm recovery phase, demonstrated two spectral maxima: at 1-2 mHz and 3-4 mHz. The first one usually was observed at latitudes higher than ~62° and the second at lower ones. We assume that these pulsations could be attributed to field line resonance waves (FLR) behind and within the plasmasphere

(3) We established spatial-temporal asymmetry of the intense Pc5 pulsations about the noon: in the morning the wave were generated at auroral latitudes, but in the afternoon – at subauroral and middle latitudes.

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References

Baker G.E., E.F. Donovan, B.J. Jacke (2003), “A Comprehensive Survey of Auroral Latitude Pc5 Pulsations Characteristics”, J. Geophys. Res. 108 (A10), doi:10.1029/2002JA009801.

Dmitriev A., J.-K. Chao, M. Thomsen., A. Suvorova (2005), “Geosynchronous Magnetopause Crossings on 29-31 October 2003”, J. Geophys. Res. 110. A08209, doi:10.1029/2004JA010582.

Engebretson M.J., K.-H. Glassmeier, M. Stellmacher. et al. (1998), “The Dependence of High-latitude Pc5 Power on Solar Wind Velocity and Phase of High-speed Solar Wind Streams”, J. Geophys. Res. 103, 26271-26283.

Kepko L., H.E. Spenc, and H.J. Singer (2002), “ULF Waves in the Solar Wind as Direct Drivers of Magnetosphere Pulsations,” Geophys. Res. Lett. 29 (8), doi: 10.1029/2001GL014405.

Kessel R.L. (2008), “Solar Wind Exitation of Pc5 Fluctuations in the Magnetosphere and on the Ground,” J. Geophys. Res. 113, A04202, doi:10.1029/2007JA012255.

Kleimenova N.G., O.V. Kozyreva, J. Manninen, and A. Ranta (2005), “Unusual Strong Quasi_Monochromatic Ground Geomagnetic Pc5 Pulsations in the Recovery Phase of November 2003 Superstorm,” Ann. Geophys. 23, 2621–2634.

Kleimenova N.G. and O.V. Kozyreva (2007), “Daytime Quasi-periodic Geomagnetic Pulsations during the Recovery Phase of the Strong Magnetic Storm of May 15, 2005,” Geomagn. Aeron. 47 (5), 616–623 07)

Kleimenova N.G. and O.V. Kozyreva (2008), “Deep Latitude Penetration of the Pc5 Geomagnetic Pulsations in theRecovery Phase of Super Strong Magnetic Storms,” *Solar–Terrestrial Physics*, 1, Issue 12,174–178.

Pilipenko V.A., N.G. Kleimenova, O.V. Kozyreva, et al. (2001), “Long Period Magnetic Activity during the May,15 1997 Storm,” J. Atmos. Sol. Terr. Phys. 63, 489-501.

Pilipenko V.A., O. V. Kozyreva, M. J. Engebretson, et al. (2002), “Dynamics of Long_Period Magnetic Activity and Energetic Particle Precipitation during the May, 15 1997 Storm,” J. Atmos. Sol.Terr. Phys. 64, 831–843.

Posch J.L., M.J. Engebretson, V.A. Pilipenko, et al. (2003), “Characterizing the Long_Period ULF Response to Magnetic Storms,” J. Geophys. Res. 108, doi: 10.1029/2002JA009386.

Potapov A., A. Guglielmi, B. Tsegmed, and J. Kultima (2006), “Global Pc5 Event during 29–31 October 2003 Magnetic Storm,” Adv. Space Res. 38 (8), 1582–1586.

Samson J.C., B.G. Harrold, J.M. Ruohoniemi, et al. (1992),“Field Line Resonances Associated with MHDWaveguides in the Magnetosphere,” Geophys. Res.Lett. 19, 19 441–19 444.

Takahashi K.and A. Y. Ukhorskiy (2008), “Timing Analysis ofthe Relationship between Solar Wind Parameters and Geosynchronous Pc5 Amplitude,” J. Geophys. Res. 113, A12204 doi:10.1029/2008JA013327.

Troitskaya V.A., M. V. Mel’nikova, O. V. Bolshakova et al. (1965), “Fine Structure of Magnetic Storms,” Izv. Akad. Nauk SSSR, Fiz. Zemli, No. 6, 82–86.