"Physics of Auroral Phenomena", Proc. XXX Annual Seminar, Apatity, pp. 30 - 33, 2007

Polar Geophysical Institute

THE ULF (1-6 mHz) WAVE SIGNATURE OF THE SUPER STRONG MAGNETIC STORM RECOVERY PHASE

N.G. Kleimenova, O.V. Kozyreva *(Institute of the Earth Physics RAS, Moscow, Russia)*

Abstract

Several super strong magnetic storms in 2000-2005 with Dst_{min}<-300 nT were selected for the analysis. The recovery phases of all storms under consideration were accompanied by morning and daytime Pc5 geomagnetic pulsations with very large amplitudes up to 500-600 nT. The afternoon pulsations were observed with a similar waveforms, intensities, and polarization in the unusually wide latitude area. Pulsations were stronger in the local afternoon than in the morning. The wave spectra changed with time and events but they did not change with latitudes. As a rule, the spectral maxima were latitude independent. The main behavior of these pulsations did not coincide with that expected from the Field Line Resonance (FLR) model which can explain the "classic" morning Pc5 waves generation. The global maps of the Pc5 amplitude distribution were computed for each storm by using multipoint observations. The unusual specific Pc5 space distribution was found. The area of enhanced Pc5 consists of the relatively narrow latitude morning band and very broad (from polar to middle/low latitudes) afternoon region, divided into two parts, separated by the wave amplitude minimum and the wave polarization reverse. It was suggested that the considered daytime Pc5 pulsations were non-resonant nature.

1. Introduction

A magnetic storm recovery phase starts with the northward IMF Bz turning and the ring current decay beginning. As a rule, a storm recovery phase is accompanied by morning Pc5 geomagnetic pulsations in the frequency range of 1-6 mHz [e.g., Troitskaya et al., 1965; Afanasieva, 1978, Posch et al., 2003], known as ULF (ultra-low frequency) waves. The Pc5 amplitude is proportional to the solar wind velocity [Engebretson et al., 1998; Baker et al., 2003]. The typical Pc5 ground-based record, wave specter and spatial geomagnetic latitude versus magnetic local time (LAT-MLT) distribution are shown in Fig.1. The strongest Pc5 pulsations with wave spectral maximum at about of 1.5-3.0 mHz are observed in the down sector (~04-10 MLT) at the relatively narrow range of the geomagnetic latitudes between 65º and 75º. Here we report the unusual spatial distribution of the afternoon Pc5 range geomagnetic pulsations exited in the late recovery phase of extremely strong magnetic storms under the very large values of the solar wind speed (≥ 1000 km/s).

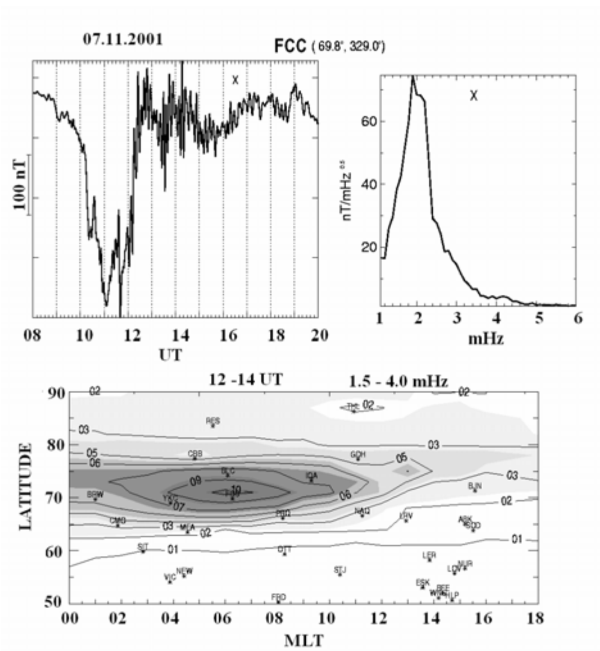

Fig. 1. Typical Pc5 geomagnetic pulsations properties: *a* – ground-based magnetogram, *b* – amplitude wave specter, *c* – LAT-MLT distribution

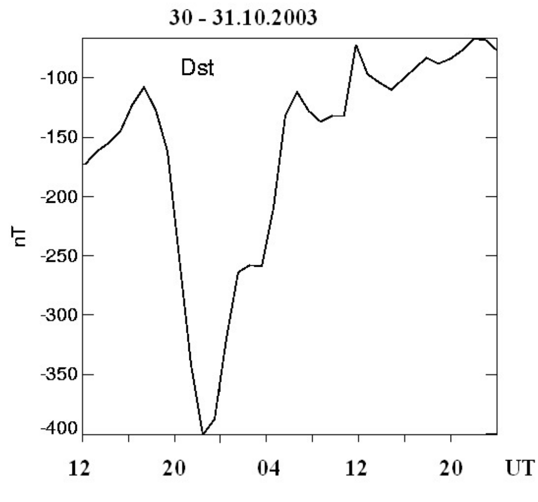

Fig. 2. Dst-variation on October 30-31, 2003

2. Observation results

Several super strong magnetic storms in 2000-2005 with Dst_{min}<-300 nT were selected for the analysis. The recovery phases of all storms under consideration were accompanied by morning and daytime ground-based Pc5 geomagnetic pulsations with very large amplitudes up to 500-600 nT. Some characteristics of Pc5 pulsations in the recovery phase of super strong magnetic storm in October and November 2003 were discussed by Kleimenova and Kozyreva (2005a, b). Our analysis showed that in the late recovery phase of the super strong storms very often the untypical spatial distribution of afternoon Pc5-range magnetic pulsations was observed. Here we present the example of such ULF waves recorded on October 31, 2003. The Dst-variation is sown in Fig.2. The global LAT-MLT plots of the wave amplitude distribution were computed for several selected UT intervals and different pulsation frequency ranges correspondent to the wave spectral maxima.

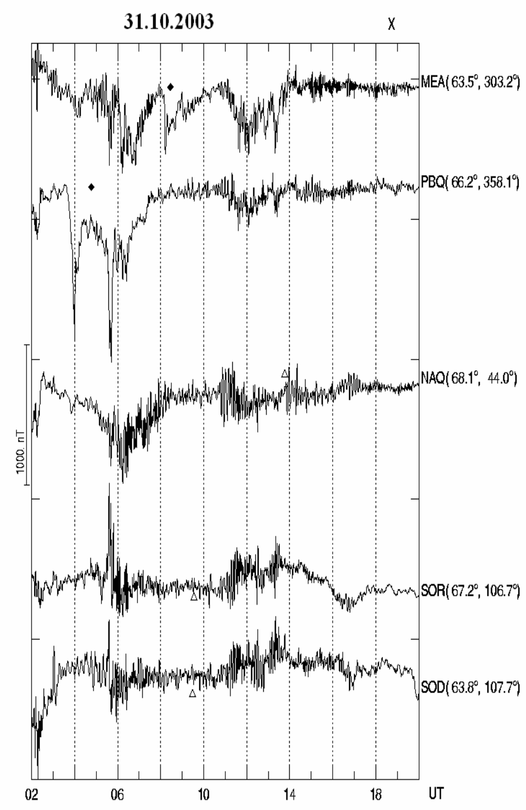

Fig. 3. Magnetograms on October 31, 2003 collected from several globally distributed auroral stations; triangle shows local magnetic noon, diamond shows local magnetic midnight

The 31 October magnetograms from globally distributed auroral stations are given in Fig.3. In the late recovery phase of this storm (09-15 UT) there were strong Pc5 range pulsations observed before noon (obs. MEA, PBQ) as well as after noon (obs. SOR, SOD). The afternoon pulsations recorded at Scandinavian IMAGE network of stations are presented in Fig.4.

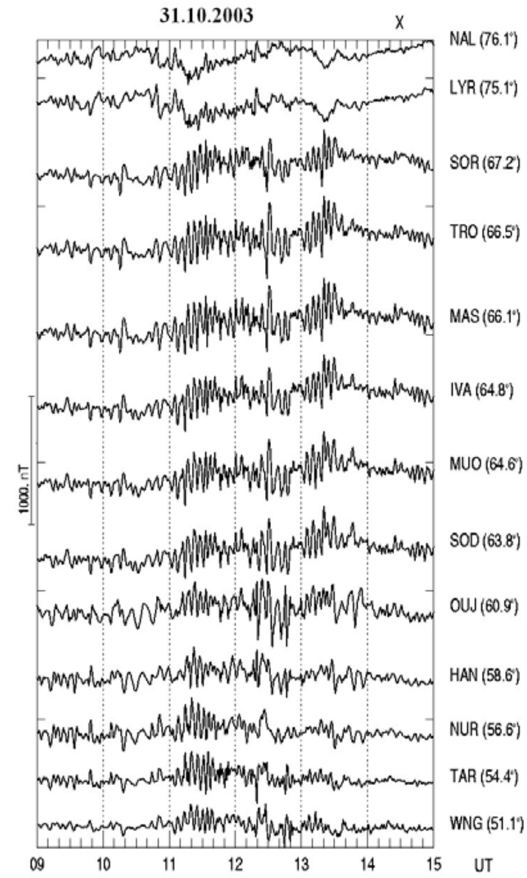

Fig. 4. Pc5 range geomagnetic pulsations at the afternoon sector (IMAGE data)

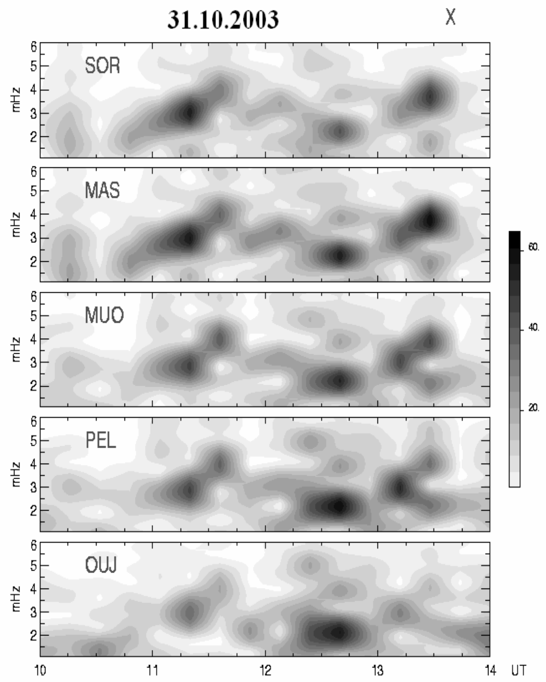

Fig. 5. The Pc5 dynamic spectra

The pulsations with similar waveform and intensity were seen at very large latitude region: from SOR (Φ=67º) to SPT (Φ=32º). Unfortunately, there were no data at latitudes between 67º and 75º.

The pulsation dynamic spectra are demonstrated in Fig.5. Three Pc5 bursts with different spectra are seen. The amplitude spectra of two first Pc5 bursts (11-12 and 12-13 UT) are demonstrated in Fig.6. At 11-12 UT two spectral maxima are seen, but according to dynamic spectra (Fig.5) they occurred not simultaneously. However, at 12-13 UT the spectral maxima in Fig.6 were corresponded to the simultaneous short-duration spots at different frequencies (Fig.5), thus, they could represent the Pc5 wave harmonics.

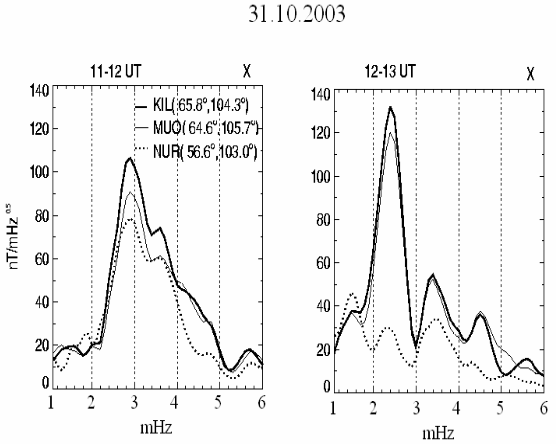

Fig. 6. The Pc5 amplitude spectra

The Pc5 global LAT-MLT plots for these two time intervals were calculated separately for each spectral maximum. The results are shown in Fig.7 and Fig. 8. The all four maps demonstrate the similar spatial distribution. In the morning sector the pulsation were observed at the relatively narrow range of the geomagnetic latitudes (~62-66º). That looks like the "classic" Pc5 spatial distribution (Fig. 1). However, in the afternoon there were the unusual spatial picture were observed as two latitude Pc5 enhancement regions, separated by the amplitude minimum and wave phase reversal, recorded between Φ=57º and Φ=58º (Fig.4). The very deep wave penetration into the low latitudes is seen in the afternoon sector.

The similar two latitude areas of the afternoon Pc5 enhancement were observed in the late recovery phase of the strong magnetic storms on October 29, 2003 and May 15, 2005. It should be pointed out that the discussed afternoon Pc5`s were observed under positive IMF Bz and a very strong solar wind velocity (~ 1000 km/s).

3. Discussion and conclusion

The considered afternoon Pc5 range pulsations could not be associated with to the "classic" Field Line Resonance (FLR) model, as it is generally accepted for the typical morning Pc5 ULF waves. The following properties of the discussed Pc5 pulsations do not fit the FLR model and are inconsistent with a large number of typical Pc5 observations, e.g. [Gupta, 1975; Afanasieva, 1978; Ziesolleck and McDiarmid, 1995; Baker et al., 2003]:

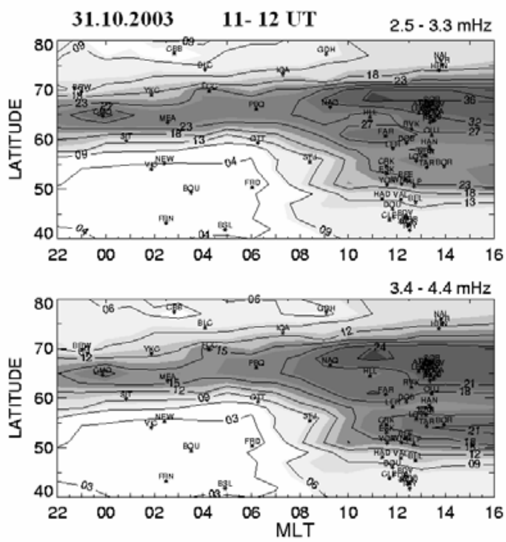

Fig. 7. Pc5 global LAT-MLT plots (11-12 UT)

(1) The Pc5 pulsations were stronger in the local afternoon than in the morning. According to the CRRES magnetic field data [Hudson et al., 2004] it is typical for the standing compressional wave (global mode) inside the magnetosphere. But such waves cannot directly reach the ground. Unfortunately, we could not compare the ground and magnetosphere data because at the analysed time all geostationary satellites were located at the night side sector of the magnetosphere.

(2) The Pc5 waveforms were coherent with the similar amplitudes at a very large latitude range. The spectral maxima of the wave were latitude independent; contrary to that, the spectral maxima of FLR waves increase with the latitude decreasing.

(3) The amplitude spatial distributions of the different wave frequencies were similar. It is not fit the FLR model of wave generation.

(4) There no phase reversal across the latitude of the Pc5 amplitude maximum as it is provided by the FLR theory.

(5) The Pc5 global distribution maps demonstrated the unusual deep afternoon wave penetration in the magnetosphere up to latitudes of Φ~40-50º with two areas of the enhanced Pc5`s, separated by the wave phase reversal (probably at the plasmapause?).

Thus, the Pc5 pulsations under consideration were not "classical" resonant nature. However, the observed ULF waveforms represented the long-lasing quasi-monochromatic oscillations. That can suggest their resonant nature. Probably, the FRL theory has to be modified.

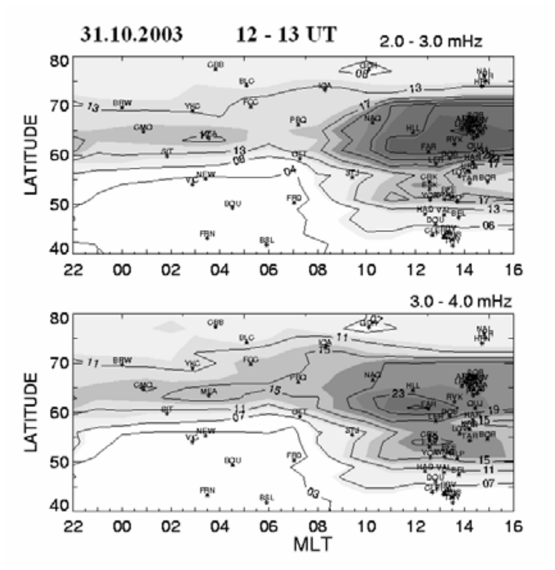

Fig. 8. Pc5 global LAT-MLT plots (12-13 UT)

The obtained results arise many questions: Why the Pc5 range pulsations were coherent in so large latitude region. Why there were two latitude areas of the afternoon ULF enhancement, separated by the wave phase reversal? Why it was observed only in the afternoon sector? Why such wave spatial distribution was observed only under huge values of the solar wind velocity? That is the real nature of these pulsations?

Acknowledgments. The authors thank the INTERMAGNET, IMAGE, SAMNET, CARISMA and MACCS teams for magnetometer data**.** This study was supported by RFBR grant 05-05-64495 and partly by RAS Program No.16.

References

-*Afanasyeva L.T.* Space-time distribution of geomagnetic pulsations and its dependence on the geomagnetic activity // Acta Geod. Geophys. Mont. Acad Sci. Hungary. Vol. 13(1-2), pp. 239-271, 1978.

-*Baker G.E., Donovan E.F., Jackel B.J.* A comprehensive survey of auroral latitude Pc5 pulsations characteristics // J. Geophys. Res. Vol. 108 (A10). 1385, doi: 10.1029/2002JA009801, 2003.

-*Engebretson M.J., Glassmeir K.-H., Stellmacher M.* The dependence of high-latitude Pc5 power on solar wind velocity and phase of high-speed solar wind streams // J. Geophys. Res. V. 103. pp. 26271-26283. 1998.

-*Gupta J.C.* Some characteristics of large amplitude Pc5 pulsations // Austral. J. Phys., Vol. 29, pp. 67-87, 1975.

-*Hudson M.K., Denton R.E., Lessard M.R., Miftakhova E.G., Anderson R.R.* A study of Pc-5 ULF oscillations// Ann. Geophys. 22, pp. 289-302, 2004.

-*Kleimenova N.G., Kozyreva O.V.* Spatial-temporal dynamics g Pi3 and Pc5 geomagnetic pulsations during superstorms of October 2003// Geomagnetism and Aeronomy, vol.45, No. 1, pp. 75-83, 2005a.

-*Kleimenova N.G., Kozyreva O.V.* Intense Pc5 geomagnetic pulsations in the recovery phase of the October and November 2003 superstorms // Geomagnetism and Aeronomy, vol.45, No. 5, pp. 597-612, 2005b.

-*Posch J.L., Engebretson M.J., Pilipenko V.A., Hughes W.J., Russel C.T., Lanzerotti L.J.* Characterizing the long-period ULF response to magnetic storms // J. Geophys. Res. Vol. 108 (A1). 1029, doi: 10.1029/2002JA009386, 2003.

-*Troitskaya V.A., Melnikova M.V., Bolshakova O.V., Rokityanskaya D.A., Bulatova G.A.* Magnetic storms fine structure // Ann. USSR Acad. Sci., Earth physics, No6, pp. 82-86, 1965.

-*Ziesolleck C.W.S., McDiarmid D.R.*: Statistical survey of auroral latitude Pc5 spectral and polarization characteristics // J. Geophys. Res., Vol. 100, A10, pp. 19299-19312, 1995.