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COMPREHENSIVE ANALYSIS OF THE MORNING Pc5 GEOMAGNETIC PULSATIONS GROUND-BASED OBSERVATIONS, EISCAT AND THEMIS DATA

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Abstract. The case study of Pc5 pulsations (f~1-6 mHz at Scandinavian IMAGE magnetometer network on January 18, 2008, as well as ionosphere disturbances measured by the EISCAT Svalbard Radar (ESR) and VHF EISCAT radar at Tromso, and magnetic field and particles data from THEMIS satellites have been discussed. This event was developed under the positive IMF Bz and strong solar wind velocity (~700 km/s). The Pc5 pulsations exhibited the typical resonant nature with the latitude maxima and the correspondent phase reverse. The Pc5 onset was triggered by the sharp change in IMF and a small jump in the solar wind velocity. The morning-side Pc5 pulsations suddenly "died" with the onset of the night side substorm, timing by the ground-based Pi2 pulsation burst and auroral WTS. This substorm onset was documented by magnetic field and particle observations by three THEMIS satellites (TH-A, TH-E, TH-D), and was accompanied by a sharp enhancement of the electron density (Ne) at EISCAT Svalbard and Tromso radars (that could be interpreted as a simultaneous particle precipitation in a large high-latitude area), and visible aurora intensification by NAL ASC. We suppose that the magnetic field line stretching in the substorm growth phase and following dipolarization may change the plasma and magnetic field configurations even in the inner magnetosphere and violate the ULF resonance exiting. We believe the Pc5 pulsations suddenly "died" due to the magnetic field line reconfiguration. Moreover, the enhanced ionosphere conductance near the Pc5 FLR electric field node(s) may disturb an ionosphere FLR wave reflection. The third plausible reason of the sudden Pc5 amplitude drop could be sharp increasing of the solar wind dynamic pressure. The relative value of this increasing was not big, but it could produce a significant strong nonlinear effect due to very high solar wind speed.

1. Introduction

Geomagnetic pulsations Pc5 (f = 1.6–6.6 mHz) are one of the most commonly encountered and widely discussed in the literature types of the ULF waves in the geomagnetic field. The Pc5 pulsations are typical for the morning sector of the auroral latitudes and often interpreted as an excitation of resonance oscillations of geomagnetic field lines (FLR). These pulsations are usually observed under large values of the solar wind speed, suggested the Kelvin-Helmholtz (K-H) instability as a source of the resonance energy. Many authors discussed the interplanetary medium conditions, particularly, solar wind dynamic pressure variations, which result the Pc5 pulsations generation [e.g., Motoba et al., 2003; Kessel, 2008]. However, nobody studied the magnetosphere and ionosphere state in the time of sudden drop of Pc5 activity, which often observed by ground stations.

The aim of this paper is to study the high-latitude ionosphere disturbances associated with the sudden drop of Pc5 amplitude. The suitable interval of the January 18, 2008, 0400-0600 UT, has been chosen, when the large amplitude morning Pc5 geomagnetic pulsations were observed at the IMAGE magnetometer array. In our analysis we used the simultaneous ionosphere data from EISCAT Svaldbar radar (ESR), VHF EISCAT radar at Tromso, and Svaldbar ASC data at NAL as well the THEMIS satellites and ground-based Canadian stations.

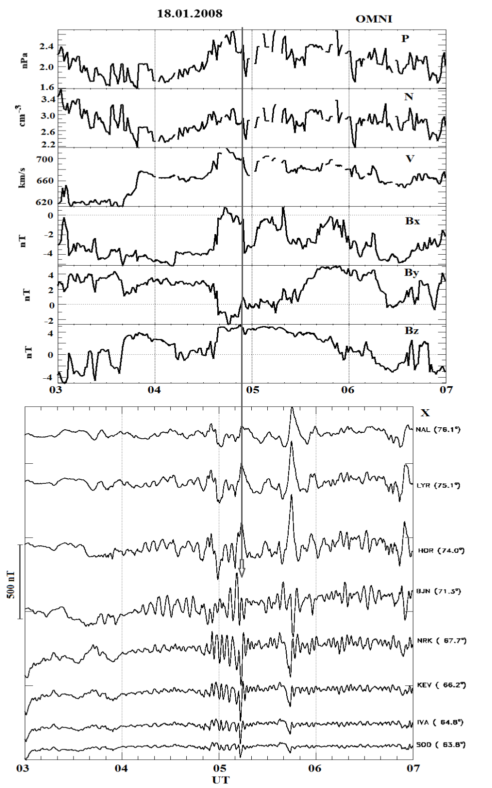

Fig. 1. The solar wind and IMF (ONMI) data and some IMAGE magnetograms shifted to 20 min.

2. Observation

Geomagnetic pulsations. The event under study was observed under high values of the solar wind speed (680-720 km/s), positive IMF Bz, and the varied dynamic pressure from 1.6 to 2.6 nPa (Fig.1, upper panel). At the IMAGE meridian, the Pc5 pulsations started at ~04.10 UT (Fig.1, bottom panel) demonstrating their resonance nature with the amplitude maximum at 3.1 mHz. (Fig. 2, left panel) located at Φ=71º. At 04.54 UT, the Pc5 pulsations intensity suddenly increased and shifted to the lower latitudes (Φ= 68º) and the spectral maximum shifted to 5.2 mHz (Fig.2, right panel). The stable Pc5 amplitude suddenly dramatically dropped at ~05.14 UT with the onset of night side substorm.

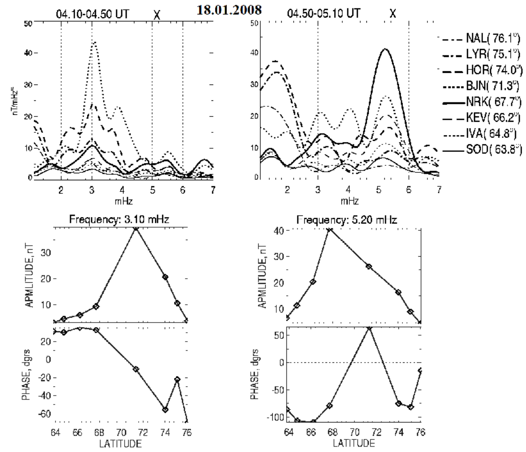

Fig. 2. The spectra of Pc5 pulsations at IMAGE stations.

To compare the IMF (OMNI) and ground data, we shifted the latest in Fig.1 for 20 min because we assume that in our case, the delay between the dayside magnetopause and the morning ground data was roughly 20 min. It is seen that the sudden change of the Pc5 frequency from 3.1 to 5.2 mHz at ~04.55 UT was coincided with the jump of the solar wind speed and dynamic pressure accompanied by the jump in increasing of IMF Bz and Bx and decreasing of IMF By. The dramatically drop of the Pc5 resonant pulsations near 05.15 UT was coincided with sharp decreasing of the solar wind dynamic pressure (from 2.6 to 1.8 nPa) and the negative deviation in the IMF Bx component.

Auroras. During this event, there were the visible auroras recorded only by the all sky camera (ASC) at NAL because in other stations the weather conditions were bad. Undulating arcs were observed in NAL starting around 03:50 UT. Several ASC frames are shown in Fig.3. The most brightening arc appeared at the equatorial ASC border at ~05.12 UT and then shifted poleward. Around of 05.14 UT, the arcs braked looking as a pseudo-breakup.

These high-latitude east-west elongated quiet arcs usually are called "morning-side Sun-aligned arcs" [Shiokawa et al., 1997], who found that they typically occur under IMF Bz > 0 around the end of substorm activity. Our event was that case (IMF Bz was positive at 04-06 UT und there were the substorm activity at IMAGE meridian at ~01.30-04.10 UT). Shiokawa et al., (1997) and Ober et al., (2000) showed that morning-side arcs are located on closed magnetic field lines and associated with accelerated electron precipitation from the low-latitude boundary layer (LLBL) or from the boundary plasma sheet (BPS). These arcs are coincided with increased upward FAC [Kletzing et al., 1996].

Simultaneously with morning high-latitude arcs, there were auroral intensification at the night side (Fig.3. ASC at GILL station). The estimated variations of the integrated auroral bright at NAL ASC are shown in Fig. 4 (upper panel, black curve).The maximum of the integrated auroral brightening was

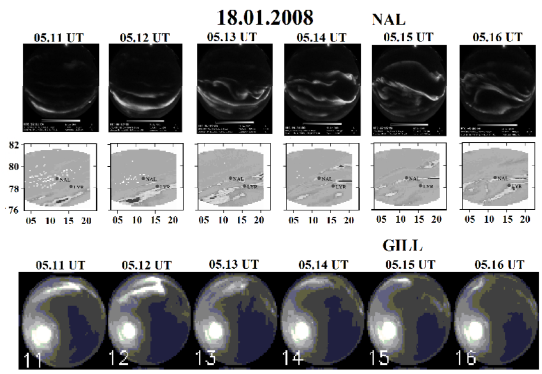

Fig. 3. The ASC data; upper panels - NAL data (morning) and its ground mapping (in geographic coordinates), bottom panel – GILL data (night side).

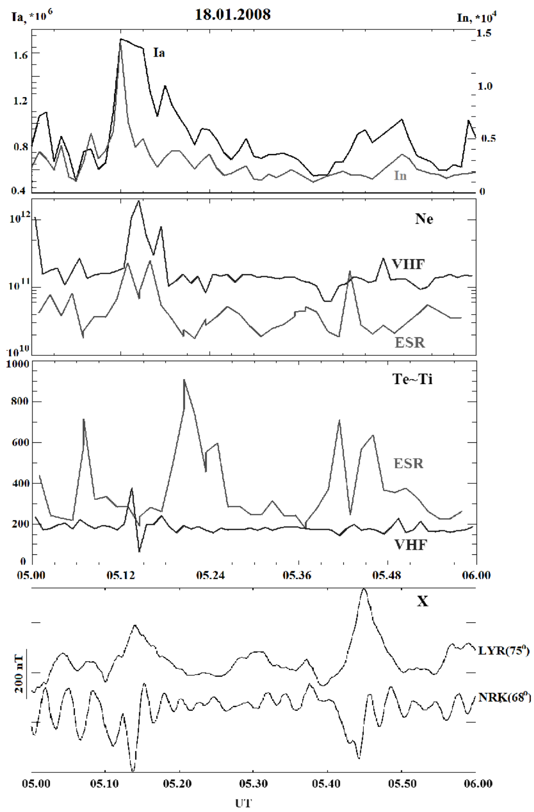

Fig. 4. The integrated aurora intensity at NAL and the EISCAT (Svalbard and Tromso) radar data.

observed at 05.12-05.16 UT and was accompanied by the strong negative magnetic impulse registered at the IMAGE stations (Fig. 1, bottom plot). Namely at the time of this impulse, the Pc5 pulsations were “switched off”.

EISCAT data. The ionosphere effects were studied based on the Svalbard EISCAT radar (ESR) and directed to Svalbard, VHF EISCAT Tromso data. The variations of electron density (Ne) and electron temperature (Te) at both radars are shown in Fig.4. The radar data were obtained at h=105-110 km, i.e., at altitudes of the ionosphere E-level. The coincided maximum in Ne at both radars is seen at 05.12-05.18 UT, demonstrating a significant enhancement of the high-latitude ionosphere conductance in a large latitude area. At this time, the maximum of aurora brightening was observed at NAL ASC data. The grey curve shows the variations of aurora intensification in the sky area correspondent to ESR beam projection. Just at this time the lower-latitude ground Pc5 pulsations suddenly died, and a night side substorm onset, accompanied by aurora WTS, was observed.

THEMIS data. The THEMIS mission includes five identical satellites and measures the plasma sheet particles and fields. On 18 January 2008 (05-06 UT), three inner THEMIS satellites (TH-A, X=8.9 Re, Y=-1.1 Re; TH-E, X=9.7 Re, Y=-0.8 Re, and TH-D, X=10.2 Re, Y=-1.9 Re) were monitoring the region from ~9 to ~11 Re in the magnetotail (Fig. 5), while two other satellites TH-B (X~-28 Re, Z~-10 Re) and TH-C (X~-8 Re, Z~-3 Re) were located at the morning side (Y~-8 Re). At 05-06 UT, all three THEMIS probes were lined up along the plasma sheet, however, TH-D was located a little outside of the central line of the neutral sheet in the azimuth direction and was below it (Z ~-4 Re).

The substorm onset had a clearly signature of growth phase, i.e. increasing of the Bx before the depolarization (positive excursion in Bz). That was observed by all three THEMIS satellites (Fig. 5). The strongest effect was observed by TH-D, located in the early morning sector. The Bx behavior could be interpreted as the tailward stretching of the magnetic field lines prior a substorm development. The strong electron (Ne) and ion (Ni) burst were observed by THEMIS in the substorm onset. The Ne burst was recorded at 05.12 UT at first by the TH-D (X=-10.2 Re,) and 3 min later by TH-A (X=-8. 9 Re).

Ground-based substorms. The ground stations at the night side (FCC and GIL, the closest located to the TH-A, E, D satellites projections), demonstrated the sudstorm development after 05 UT, timed by Pi2 geomagnetic pulsations (Fig. 6). The GILL ASC records (Fig. 3, bottom panet) demonstrated a typical substorm signature, i.e. the WTS at 05.11-05.16 UT. The amplitude of the morning Pc5 dropped with the night side substorm onset.

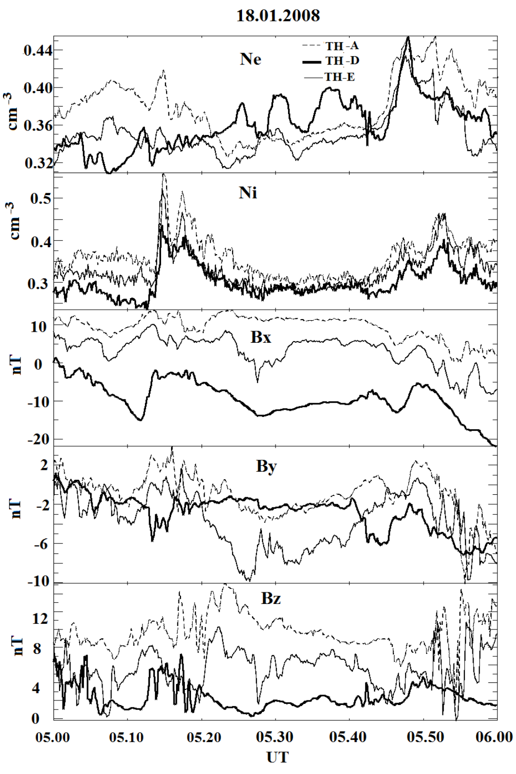

Fig. 5. The THEMIS satellites data.

The ceasing of Pc5 pulsation with night side substorm onset is seems to contradict the basic results published in the previous time. Many authors [e.g., Samson and Rostoker et al., 1981; Glassmeier et al., 1984; Rostoker et al., 1984; Kleimenova et al., 2005] examined the response of Pc5 activity at the morning sector to substorm onsets near midnight and found that the morning Pc5 intensification coincides with substorm onset at the night side.

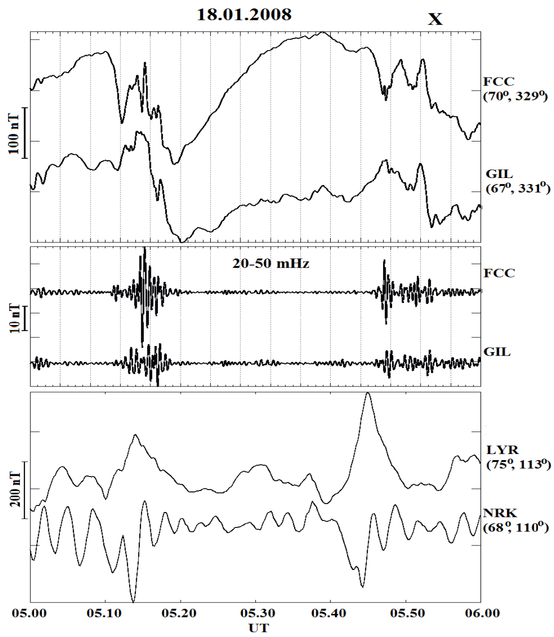

Fig. 6. Magnetic disturbances in the night-time (magnetic substorm and Pi2 pulsations at FCC and GILL) and Pc5 pulsation in the morning.

All stations under study were located at the closed magnetosphere. The morning arcs, observed by NAL ASC, supported its location inside of the closed field lines. The estimated auroral oval location based on the OVATION data is shown in Fig. 7. The long bar indicates the beam direction of the Tromso radar.

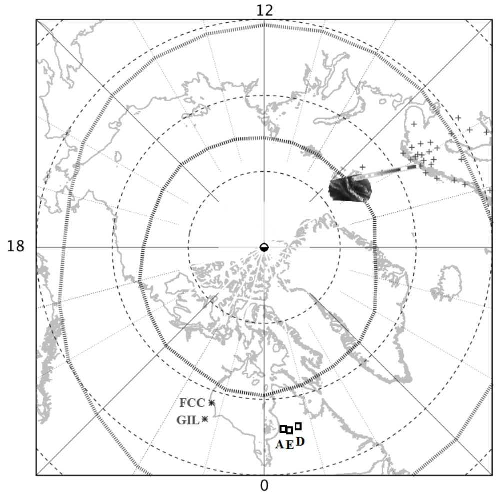

Fig. 7. The auroral oval location with the FCC and GILL location and the projection of the THEMIS satellites foot print.

3. Discussion and conclusion

We presented a detailed case study of morning Pc5 pulsations observed at IMAGE stations on January 18, 2008 in 04-06 UT (~07-09 MLT). The considered event was observed under high values of the solar wind speed (680-720 km/s), positive IMF Bz, and the slightly varied dynamic pressure from 1.6 to 2.6 nPa. The pulsations exhibited the typical for field line resonance (FLR) latitudinal structure. The high values of the solar speed provide conditions for coupling of a surface wave produced by the Kelvin-Helmholtz (K-H) instability to shear Alfven wave. We suppose that the trigger of FLR generation was the sharp increasing of IMF Bz and Bx accompanied by a small jump of the solar wind velocity.

The discussed resonant Pc5 geomagnetic pulsation "died" with the onset of the night side substorm, timing by the ground-based Pi2 pulsation burst and auroral WTS. This substorm onset was documented by magnetic field and particle observations by three THEMIS probes (TH-A, TH-E, TH-D), and was accompanied by a sharp enhancement of the electron density (Ne) at EISCAT Svalbard and Tromso radars, while the IMF Bz was positive.

The constant length of a resonant magnetic field line and the magnetic field strength along this line as well as cold plasma density at the equatorial plane of the magnetosphere should be a necessary condition for stable FLR processes (at least, several oscillations with similar amplitudes). The conditions of the wave reflection from both ionospheres also should be stable. We suppose that magnetic field stretching in the substorm growth phase and following dipolarization change the plasma and magnetic field configurations even in the inner magnetosphere. This change breaks the FLR processes.

The standing wave nature of the FLR provides the electric field nodes in the northern and southern ionosphere. The increasing of the high-latitude ionosphere conductance (due to particle precipitation) results an additional factor of the ionosphere loss which could lead to the destruction of the resonant wave reflection.

One more plausible reason of the sudden Pc5 amplitude drop could be sharp increasing of the solar wind dynamic pressure. The relative value of this increasing was not big, but it could produce a significant strong nonlinear effect due to very high solar wind speed.

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