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CONTRIBUTION OF THE MHD WAVE MODES TO THE GLOBAL Pc5 PULSATIONS

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Abstract. The nature of so called global *Pc5* pulsations is studied. The event with global *Pc5* pulsations generated by quasi-periodic fluctuations of the solar wind dynamic pressure on 31 October 2003 is considered in detail. According to the ground magnetometer data *Pc5* pulsations are observed both in the morning and afternoon MLT sectors. The physical mechanism of global Pc5 is supposed to be different from one of the ordinary *Pc5* pulsations associated with the shear Alfven oscillations of magnetic flux tubes. We also used the EISCAT radar data from the tri-static Tromso-Kiruna-Sodankyla system allowing to calculate vectors of the F-region ionospheric plasma flow and electric field. The *Pc5* frequency band pulsations are clearly seen in the variations of the Hall and Pedersen ionosphere conductivity, ionosphere plasma density, electron and ion temperatures, and the ionospheric electric field. For the time intervals when the *Pc5* pulsations are observed on ground, hodographs of the ionospheric electric and ground magnetic fields have been compared. The angle between polarization axis of the electric and magnetic fields may show whether the pulsations are related to the Alfven mode or the magnetosonic wave. From these considerations we conclude that the morning and afternoon *Pc5* pulsations are predominantly Alfven waves. These observations do not agrees with the statistical studies by *Rostoker and Sallivan* [1987] and *Liu et al.* [2009], who have shown that the morning *Pc5* pulsations are caused mainly by the Alfven waves, whereas the afternoon Pc5 pulsations are mainly magnetosonic waves generated by the impulses of the solar wind dynamic pressure.

Introduction

During the recovery phase of strong magnetic storms the intense Pc5 pulsations which exceed the amplitude of ordinary Pc5 pulsations by the order of magnitude were observed [*Kleimenova, 2005; Belakhovsky, 2010*]. These anomalous oscillations were named as the global Pc5 pulsations [*Potapov, 2006*] because they were observed in the morning and evening sectors simultaneously in a wide latitude range. The global Pc5 pulsations can exert a great influence on the dynamics of the relativistic electrons because their frequency is close to the drift frequency of MeV electrons [*Elkington et al., 2003*]. A large intensity, huge volume of the magnetosphere occupied by these pulsations, and the presence of the significant compressional component of the magnetic field – all these factors must lead to a more strong influence on the relativistic electrons (modulation, radial diffusion, acceleration) as compared with regular Pc5 pulsations.

However, it is not finally known: do the global Pc5 pulsations have the same physical mechanism as ordinary Pc5 pulsations or they are caused by essentially different wave processes? In this study we provide some additional information on the properties of these pulsations using the simultaneous observations with ground magnetometers and EISCAT radar.

Observations facilities

The IMAGE and INTERMAGNET magnetometer data are used in this work. We also use the EISCAT radar data from the tri-static Tromso-Kiruna-Sodankyla system allowing to calculate the vectors of the F-region ionospheric plasma flow and electric field. To determine the solar wind and magnetosheath parameters ACE, WIND, GEOTAIL interplanetary spacecraft data are used in this study. The magnetic field data from GOES-10, GOES-12 geostationary spacecraft are used also.

The event of 31 October 2003

This event was well described in the previous papers [e.g., *Panasyuk et al., 2004; Pilipenko, 2010*]. Pc5 pulsations during 31 October 2003 observed by IMAGE stations were considered in detail by *Kleimenova and Kozyreva* [2005]. The global *Pc5* pulsations were observed in the morning and afternoon MLT sectors. Frequency of these pulsations was observed to be nearly the same at different latitudes, which may indicate a weak contribution of resonant effects into the spatial structure of global *Pc5* pulsations.

The variations of the proton density at ACE, GEOTAL, and WIND spacecraft and the magnetic field at Abisko (ABK) station during morning and afternoon intervals are shown in Fig.1. WIND spacecraft is located in the solar wind, but in the tailward direction. GEOTAIL spacecraft crosses the boundary between the magnetosphere and magnetosheath in the morning flank.

A detailed examination shows a close connection between the solar wind density variations and the magnetic field variations on the ground. We suppose that geomagnetic Pc5 pulsations on IMAGE profile stations (noon at ~14 UT) have been triggered by enhanced solar wind density variations.

The vectors of the plasma velocity **V** and electric field **E** in the ionosphere have been computed using data from receivers at SOD and KIR. For both intervals when *Pc5* pulsations are observed on IMAGE profile the hodographs of the ionospheric electric field **E** and the hodographs of the ground magnetic field **B** from TRO have been computed (Fig. 2,3).

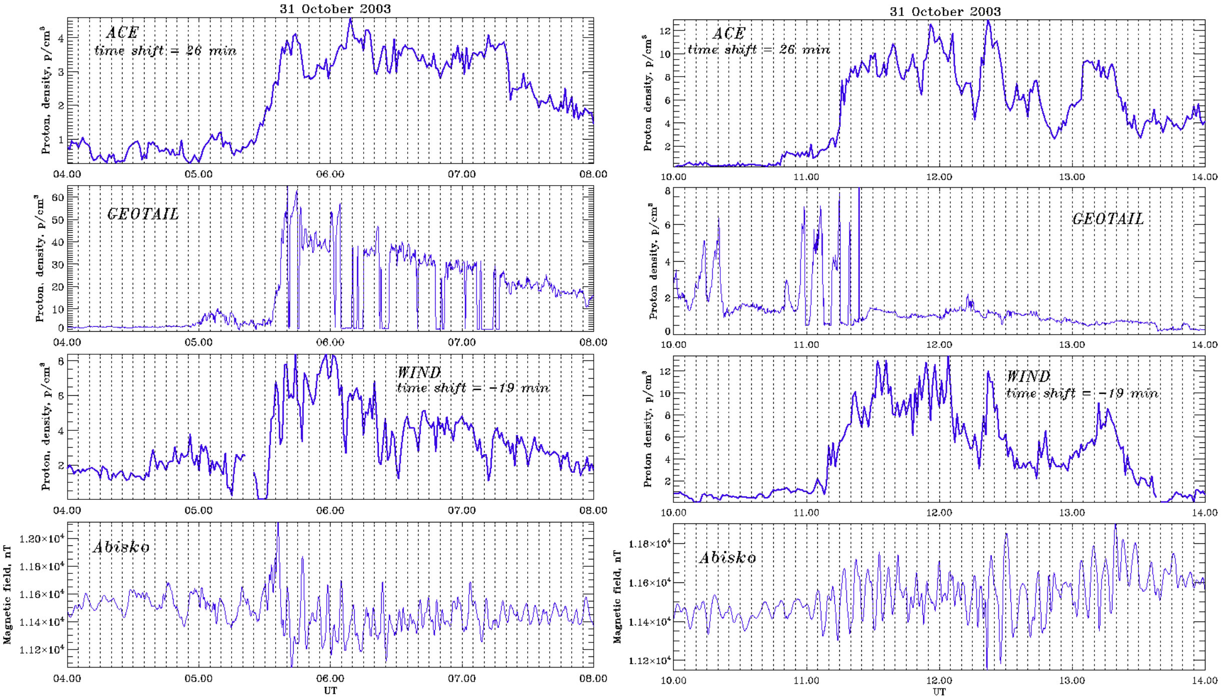

Fig. 1. Proton density at ACE, GEOTAL, WIND spacecrafts and magnetic field at ABK station for the morning (left panel) and afternoon (right panel) *Pc5* pulsations.

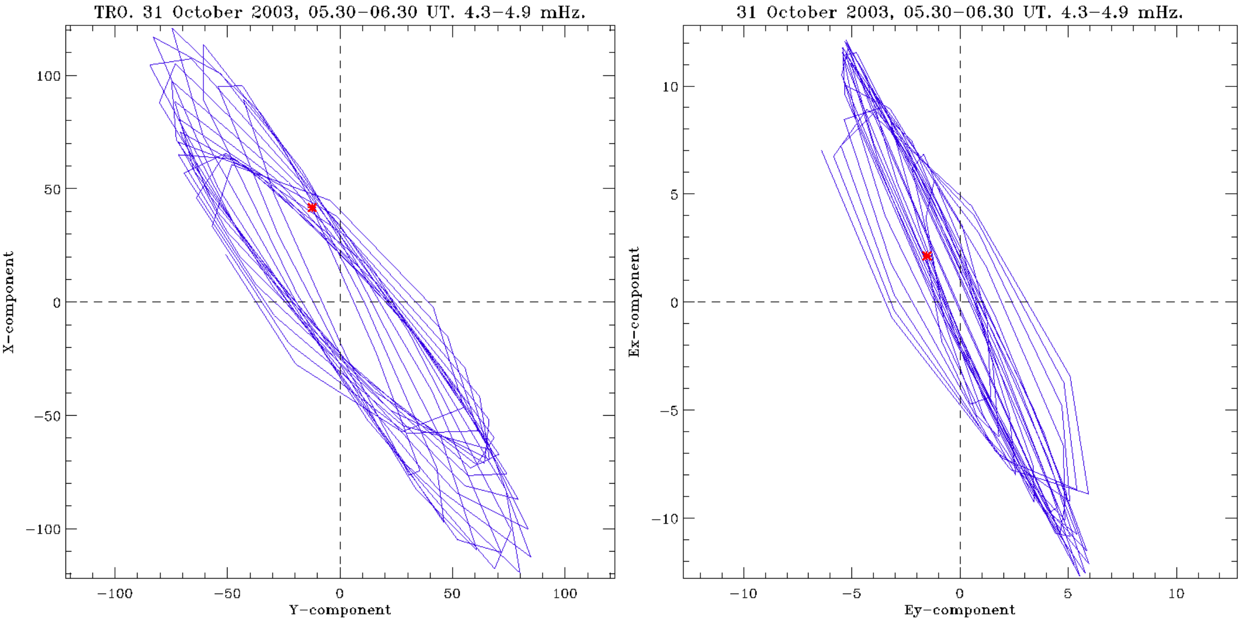

Fig. 2. Hodographs of the magnetic field at TRO station (left-hand panel) and the electric field obtained from EISCAT radar data (right-hand panel) in the interval 05.30-07.00 UT at 31 October 2003.

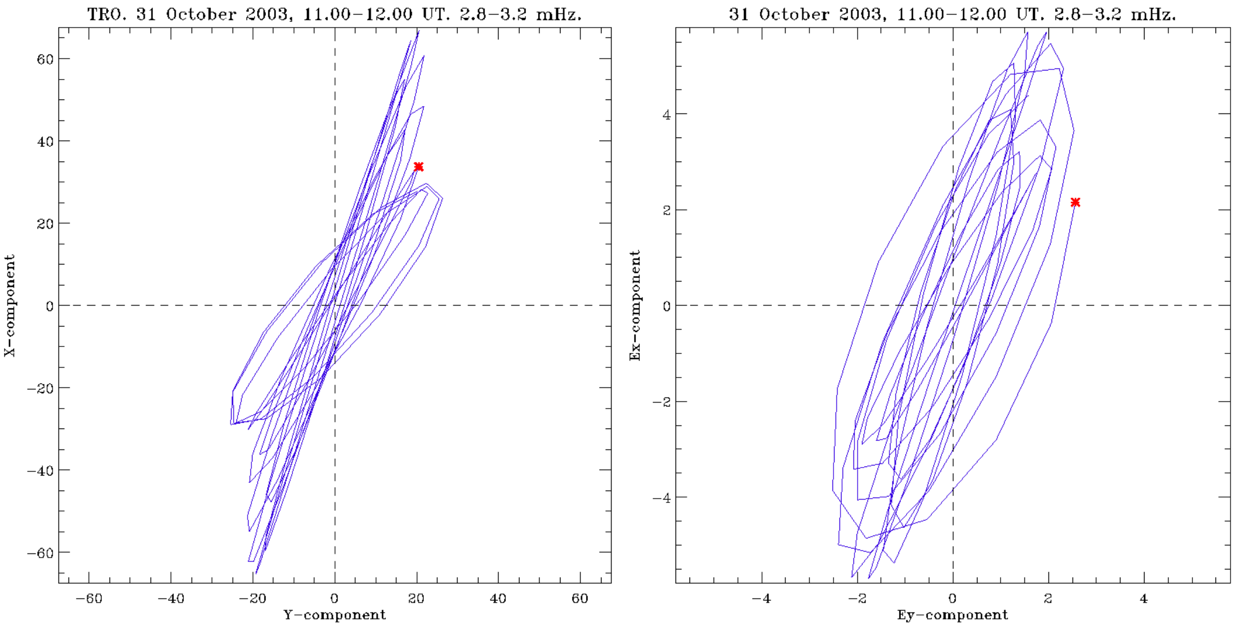

Fig. 3. Hodographs of the magnetic field at TRO station (left) and the electric field obtained from EISCAT radar data (right) in the interval 11.00-12.00 UT at 31 October 2003.

From Faraday's equation it follows that the electric and magnetic components (normal to the geomagnetic field) of an electromagnetic wave are to be in quadrature to each other. Upon the penetration through the laterally homogeneous ionosphere, the Alfven mode undergoes the additional π/2 rotation, whereas the magnetosonic mode practically is not influenced by the ionosphere. The cause of this fact is that a field-aligned current, carried by Alfven wave, does not penetrate into the atmosphere and on the ground one can see the magnetic response due to the Hall current. The magnetosonic wave does not carry a field-aligned current and propagates through the atmospheric gap freely. Therefore, for an incident Alfven mode the main axes of the polarization ellipses of ground **B** and ionospheric **E** are to be parallel to each other. An admixture of the magnetosonic mode into an incident wave will result in the deviations between the orientation of **B** and **E** ellipses. However, such deviation can be also caused by the lateral inhomogeneity of the ionospheric condactances.

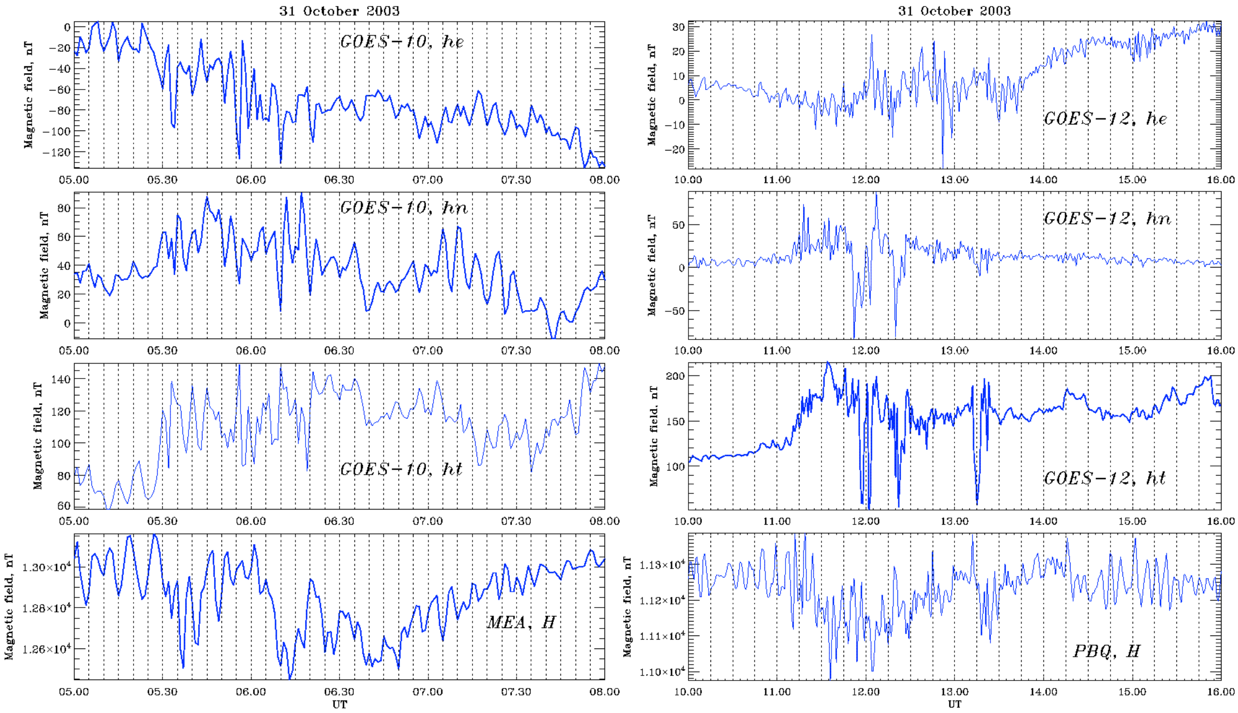

Fig. 4. Geomagnetic field variations at GOES-10 geostationary spacecraft and conjugate station MEA (left-hand panel), and at GOES-12 geostationary spacecraft and conjugate station PBQ (right-hand panel).

As we can see from the Fig. 2. for the early morning Pc5 pulsations and for the afternoon Pc5 pulsations the main polarization axes of the ionospheric electric field and ground magnetic field are nearly parallel. Thus, we conclude that the early morning *Pc5* pulsations and the afternoon Pc5 pulsations are produced by incident Alfven waves.

The variations of the geomagnetic field at GOES-10 geostationary spacecraft and its conjugate station MEA during the time interval 05.00-08.00 UT, when the morning Pc5 pulsations are observed at IMAGE stations, are shown in Fig. 4 (left-hand panel). Though GOES spacecraft are located in other MLT sector than the IMAGE profile, the global Pc5 pulsations can be seen at GOES-10 and GOES-12. The similar observations of the afternoon Pc5 pulsations at GOES-12 geostationary spacecraft and its conjugate station PBQ in the interval 10.00-16.00 UT are presented in Fig. 4 (right-hand panel). The spectral analysis shows the presence of the strong toroidal hn-component during the both intervals. So we suppose that these Pc5 pulsations are mainly Alfven waves. These conclusions made from the GOES spacecraft observations were well correlate with observations made from EISCAT radar.

From the statistical studies it is known that morning *Pc5* pulsations are mainly Alfven waves, whereas afternoon Pc5 pulsations are mainly magnetosonic waves generated by impulses of the solar wind dynamic pressure [*Rostoker and Sallivan,* 1987; *Liu et al.,* 2009]. Global Pc5 pulsations on 31 October 2003 are Alfven waves as on the morning as on the afternoon sides. So we conclude that the global *Pc5* pulsations on its nature differ from the ordinary *Pc5* pulsations and generated during extreme events.

Conclusion

So it is shown that the global Pc5 pulsations at 31 October 2003 distinct on physical nature from the ordinary Pc5 pulsations. On the morning and afternoon sides the global Pc5 pulsations are Alfven waves while the ordinary Pc5 pulsations on the morning side are Alfven waves and on the afternoon side are magnetosonic waves.

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