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THE DETERMINATION OF THE LATITUDE DISTRIBUTION OF THE RESONANCE FREQUENCY OF *PC5* PULSATIONS FROM THE RADAR DATA

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Abstract. The event of 29 April 2001 was considered when geomagnetic *Pc5* pulsations were observed in the morning sector at the latitudinal profile of the *IMAGE* magnetometers network. The following signatures of resonance properties were observed in the pulsations: the decrease of frequency of *Pc5* pulsations with increase of the geomagnetic latitude and change of the phase and ellipticity during passage thought the resonance region. The beam of the *VHF EISCAT* radar in Tromso was inclining at 30° to the horizon and was directed northward toward Spitsbergen, so the increase of height along the radar beam was accompanied by the increase of the geomagnetic latitude. Clear *Pc5* pulsations were observed in the line-of-sight velocity of the ionospheric plasma measured by the radar at 68 - 72 degrees of geomagnetic latitude that corresponded to the height of 100-410 km. There were no clear signatures of *Pc5* pulsations observed in the density of ionosphere plasma and the ion and electron temperatures. The spectral analysis shows decrease of the frequency of *Pc5* pulsations in ionosphere plasma velocity with increase of geomagnetic latitude, which is a manifestation of the resonance properties in the ionospheric plasma velocity. Thus, we show the possibility to determine the latitude distribution of resonance frequency of Pc5 pulsations from the radar data.

1. Introduction

Geomagnetic *Pc5* pulsations are the most powerful wave processes in the near-Erath space, which may distinctly modulate the magnetosphere and ionosphere plasma. The interaction of geomagnetic *Pc5* pulsations with the ionosphere may be examined by the EISCAT radar. The radar allows studying the ionosphere with better spatial resolution than the ground-based magnetometer. The magnetometers register ionospheric disturbances of the scales larger than 100 km.
Walker et al., [1979] were the first who measured the electric fields associated with geomagnetic Pc5 pulsations using the *STARE* radar. Later radars were utilized for studying so-called "*storm-time*" (poloidal) *Pc5* pulsations with large (20-100) azimuthal wave number *m* [*Allan et al., 1982*]. The poloidal pulsations excited by proton clouds have different physical nature than the toroidal *Pc5* pulsations. These *Pc5* pulsations were weekly observed by ground magnetometers due to the shielding effect of the ionosphere.

Most of the studies of Pc5 pulsations in ionosphere were done by using the coherent radars, like, e.g., *SuperDARN* radars. However, the coherent scatter radars usually do not provide continuous data (i.e., there are big data gaps in space and time). Another way is using the incoherent scatter radars *EISCAT*. The incoherent scatter radars may provide continuous measurements and allow determining not only the velocity of the ionosphere plasma but also ionospheric plasma density and temperatures of ions and electrons. Indeed, signatures of *Pc5* pulsations were seen in the ion temperature [*Lathuillere et al., 1986*].]. In paper [*Buchert et al., 1999*] the authors seen the *Pc5* pulsations in ionosphere plasma density and ionosphere conductivity. The pulsations in the ionospheric plasma density and conductivity were associated with poloidal geomagnetic pulsations.

The resonance properties of *Pc5* pulsations in the ionosphere were studied by [*Walker, 1979, 1992*]. *Walker et al.,* [*1979*] have shown the presence of the phase shift of *Pc5* pulsations in the ionosphere plasma velocity at latitude of resonance peak. *Walker et al.,* **[***1992*] used the *SuperDARN* radar in Goose Bay for studying ionospheric signatures of the ULF oscillations in mHz range excited by the field line resonance (FLR). They picked out the discrete frequencies 1.3, 1.9, 2.6, 3.3 MHz and supposed that the cavity mode may be responsible for the generation of these "magic" discrete frequencies. They investigate ULF pulsations at the night sector (01.00-04.00 MLT).

However, on the dayside the manifestation of resonance properties of *Pc5* pulsations in the ionospheric parameters is still an open question. In the present study we investigate the ionospheric manifestation of the large-scale (toroidal) *Pc5* pulsations observed in the morning sector using the *VHF ESICAT* radar in Tromso.

2. Data

The data from *VHF EISCAT* radar is used in this study complemented by the data from *IMAGE* magnetometer network. The data from *IRIS* imaging riometer is used for monitoring precipitation of energetic electrons. The data from the *LANL*-01 geostationary spacecraft is used for monitoring trapped particles. The parameters of the solar wind are taken from the *OMNI* database.

3. Observations

The event 29 April 2001 was considered when the geomagnetic *Pc5* pulsations were observed at the latitudinal profile of magnetic observatories of the *IMAGE* network. During the event the solar wind velocity was 650 km/s, the solar wind density was 6 m^{-3}, and *Bz*-component of IMF was about -5 nT. The *SYM-H* index value was about -40 nT. The magnetic activity was not large during this day.

Figure 1 presents the *Pc5* pulsations observed at the meridian profile *SOD-IVA-BJN-HOP* The maximum amplitude of geomagnetic Pc5 pulsations was observed at *HOP* station. The spectral analyze shows the decrease of the frequency of geomagnetic *Pc5* with increase of the geomagnetic latitude. At the lower-latitude stations *SOD* and *IVA* the spectral maximum was observed approximately at the frequency of 2.9 mHz, whereas at the higher-latitude stations *BJN* and *HOP* the spectral maximum was observed at the frequency of 1.5 mHz. The latitudinal distance between the lower- and higher- latitude stations (*IVA* and *BJN*) is about 4° of geomagnetic latitude. So that, there is an abrupt change of the resonant frequency observed between these stations. The decrease of frequency of geomagnetic *Pc5* pulsations is indeed seen from the visual inspection of the magnetograms.

There was observed one more manifestation of the resonance properties of the pulsations in this event, namely the change of the phase and ellipticity during passage thought the resonance region (not shown).

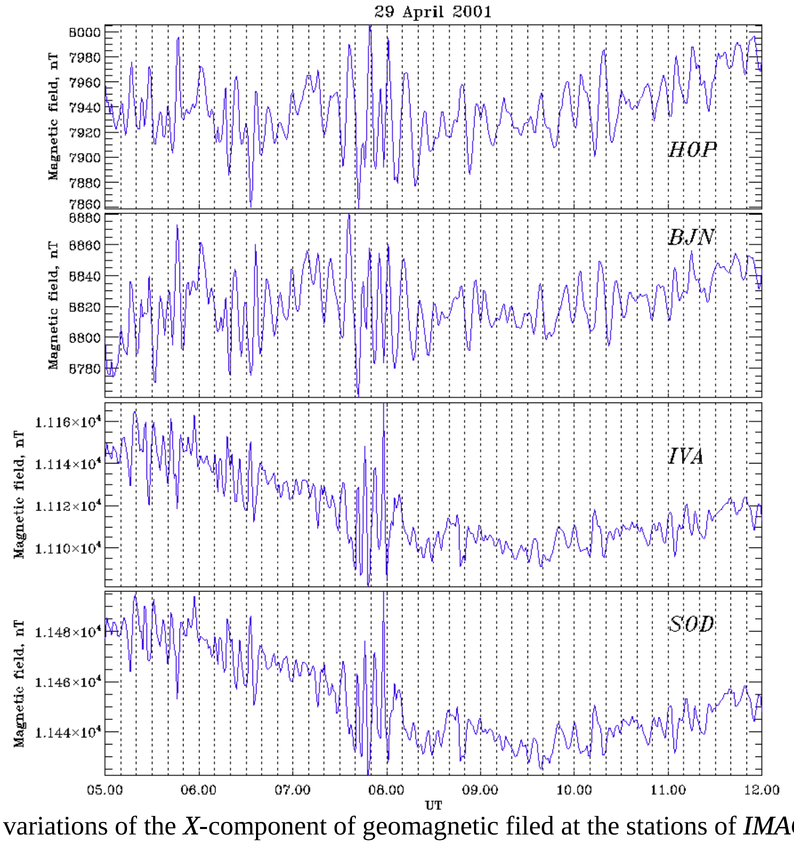

Fig. 1. The variations of the *X*-component of geomagnetic filed at the stations of *IMAGE* profile.

We determined the azimuthal wave number ***m*** for the geomagnetic *Pc5* pulsations using the azimuthal pare of stations *ABK-IVA*. The cross-correlation method was used to determine the ***m***. The ***m*** was determined by the formula $m=f\cdot\Delta t\cdot360°/\Delta\lambda$, were *f* is the frequency of pulsations determined from the spectral analyze, Δt is the time shift corresponding to the maximum of correlation coefficient, and $\Delta\lambda$ – the longitudinal distance in deg between *ABK* and *IVA* ($\Delta\lambda$=6.75°).

The frequency of *Pc5* pulsations in 06.00-08.30 UT at the *ABK-IVA* stations was *f*=3.2 mHz, the time shift between *ABK* and *IVA* stations during this time interval was Δt=20 sec (*r* = 0.98). The phase shift was $\Delta\varphi$=23.04°

and, hence, the azimuthal wave number was *m*=3.41. The phase shift indicates an anti-sunward propagation of these *Pc5* pulsations. Their azimuthal wave number corresponds to the toroidal geomagnetic *Pc5* pulsations.

The beam of the *VHF EISCAT* radar in Tromso was inclining at 30° to the horizon and was directed northward toward Spitsbergen. So the increase of height along the radar beam was accompanied by the increase of the geomagnetic latitude. The clear *Pc5* pulsations were observed in the line-of-sight velocity of the ionospheric plasma at 68 - 72 degrees of geomagnetic latitude that correspond to the height of 100-410 km (**Fig. 2**.). The spectral analysis shows the decrease of frequency of *Pc5* pulsations in ionosphere plasma velocity with increase of the geomagnetic latitude (**Fig. 3**.). Starting from the height of 160 km the frequency changes from the 2.8 to 2.2 mHz. This indicates resonance properties in the oscillations of ionosphere plasma velocity. We also examined how the phase of the *Pc5* pulsations in plasma velocity changed with geomagnetic latitude. However, we could not see a phase shift during the propagation trough the resonance region. Obviously the resonance region was located outside the field of view of the radar.

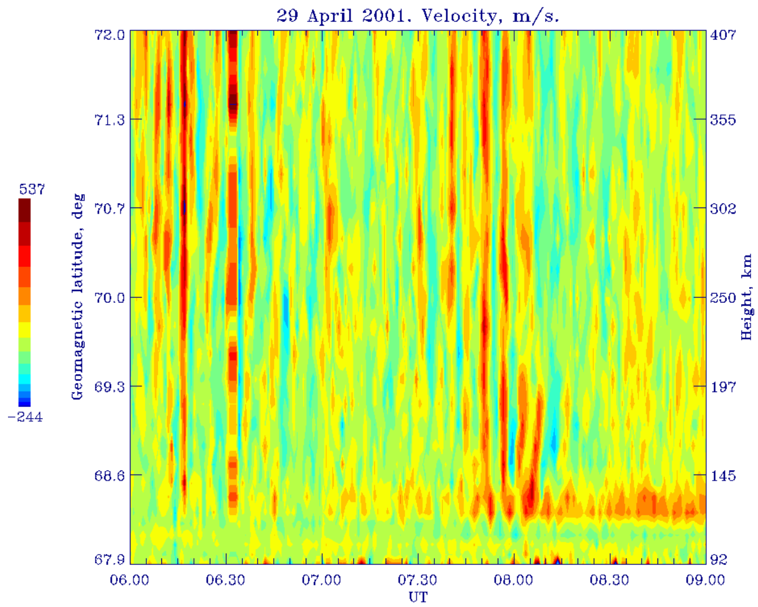

Fig. 2. Variations of the line-of-sight ionospheric plasma velocity measured by the EISCAT VHF radar

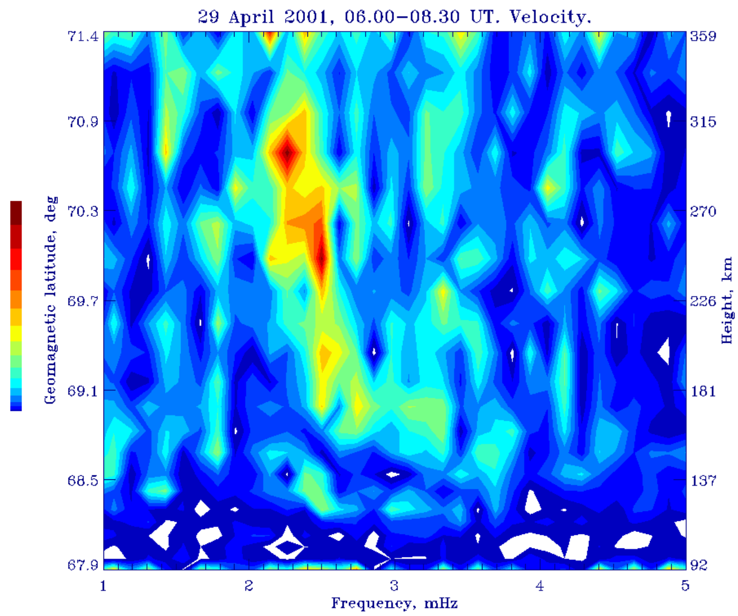

Fig. 3. Power spectrum of the ionospheric plasma velocity measured by the EISCAT VHF radar.

We could not identify clear signatures of *Pc5* pulsations in the radar data of plasma density, ion and electron temperature along the latitude profile. However, *Pc5* pulsations were observed in the cosmic noise absorption (*CNA*) at *IRIS* riometer in Kilpisjarvi and also pulsations of the same frequency were seen in the flux of electrons with energy 50-75 keV at *LANL*-01 geostationary spacecraft.

4. Discussion and conclusions

In the present study we considered the morning toroidal geomagnetic *Pc5* pulsations and associated pulsations in ionosphere plasma velocity. It was observed that the frequency of *Pc5* pulsations of ionospheric plasma velocity associated with toroidal geomagnetic *Pc5* pulsations decreased with geomagnetic latitude. Earlier *Walker et al.* [*1992*] observed such a decrease of the frequency of ULF pulsations with latitude, but they investigated the *ULF* oscillations of ionosphere plasma velocity in the night sector (01.00-04.00 MLT). These ULF oscillations should be classified as the *Pi3* pulsations associated with the substorm. These authors did not use data of geomagnetic filed. Indeed, it is not clear whether these oscillations were indicating geomagnetic *Pc5* pulsations or just ionosphere noise.

Thus, we demonstrate the possibility to determine the latitude distribution of the resonance frequency of *Pc5* pulsations using data from the single EISCAT radar.

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