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A CASE STUDY OF THE PROTON PRECIPITATION RELATED TO Pc2 PULSATIONS

T.A. Yahnina[1], A.G. Yahnin[1], A.I. Voronin[1], T. Bösinger[2]

[1]*Polar Geophysical Institute, Apatity, Russia*
[2]*Department of Physical Sciences, University of Oulu, Finland*

Abstract. Data from ground observations of geomagnetic pulsations along with the particle data from three low-orbiting NOAA satellites and geosynchronous spacecraft are used to determine the particle precipitation pattern related to the Pc2 geomagnetic pulsations event. The event was observed during substorm injection occurred at the recovery phase of weak geomagnetic storm. The conclusion achieved that this Pc2 event relates to the localized proton precipitation located in the day sector at geomagnetic latitude about 65°. Another type of the proton precipitation observed at the same time is the precipitation confined within 1-2 degrees equatorward of the isotropy boundary. This precipitation is found to be not related with the Pc2 pulsations.

Introduction

There exist two main sources of scattering of magnetospheric energetic protons into the loss cone: violation of the adiabatic movement of the particle due to small curvature radius of the magnetic field line (e.g., Sergeev et al., 1983) and interaction with waves (e.g., Cornwall et al., 1970). The former source produces isotropic precipitation at relatively high latitudes, while the latter one is responsible for localized isotropy regions equatorward from an isotropy boundary. An isolated energetic proton precipitation well inside the region of anisotropic fluxes has been recently found to be closely related to the electromagnetic ion-cyclotron (EMIC) waves seen on the ground as geomagnetic pulsations in the Pc1 range (Yahnina et al., 2000; Yahnina et al., 2003). Besides, the precipitation adjoining the isotropy boundary from the equatorial side (Gvozdevsky et al., 1997; Yahnina et al., 1999) is often observed. The nature of this precipitation is not understood yet. One can suggest that this precipitation is also a signature of the EMIC wave activity. Since this kind of precipitation is referred to at relatively higher latitudes as compared with the localized proton bursts, it can be associated to geomagnetic pulsations of the frequency range lower than that of Pc1. Such pulsations could be Pc2 – quasi-monochromatic geomagnetic pulsations in the frequency range 0.1-0.2 Hz.
Here we consider low-altitude observations of energetic protons during an isolated Pc2 event which occurred around 14 UT on 22 April 2005. Our aim is to distinguish which of the precipitation patterns is, in fact, related to this Pc2 event.

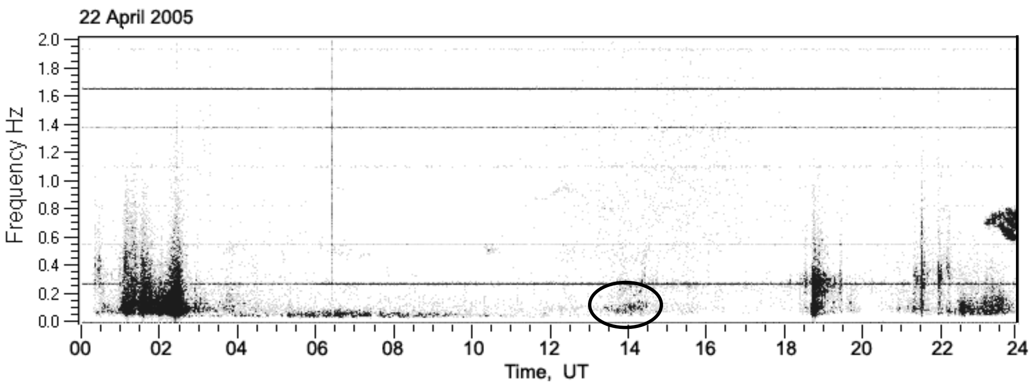

Fig. 1. Spectrogram of geomagnetic fluctuations in Lovozero for 22 April 2005. The Pc2 pulsation event under study is encircled.

Observations and analysis

The isolated Pc2 event was registered around 14 UT on 22 April 2005 by a search-coil magnetometer in Lovozero, L=5.4 (Fig. 1) and by the Finnish meridional magnetometer network (L=3.4-6.1). The Pc2 event occurred during the

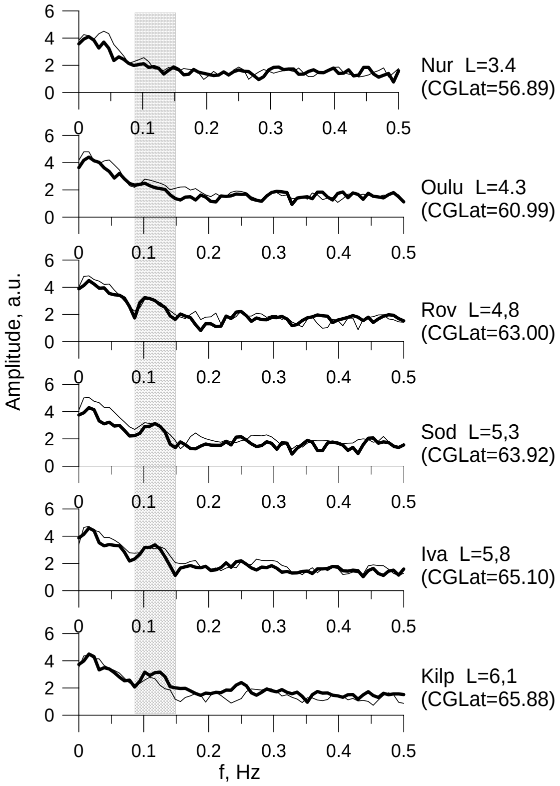

Fig. 2. Spectra of fluctuations of the magnetic field for the 1350-1410 UT interval at stations of the Finnish network. Thin line – spectra of H component; thick line – D component.

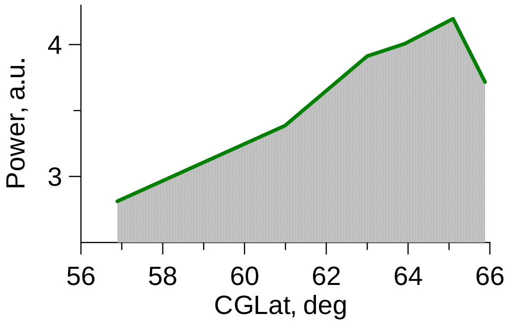

Fig. 3. Meridional distribution of the total power of Pc2 pulsations for the event of 22 April 2005.

recovery phase of a weak geomagnetic storm (minimal Dst=-40 nT), and after an isolated substorm (AE~500 nT). In Fig. 2 spectra of magnetic fluctuations in H and D components for the time interval 1350-1410 UT are shown for every station of the Finnish meridional network. An enhancement of the amplitude of the fluctuations in the frequency range 0.08-015 Hz representing the Pc2 pulsations is clearly seen. From these spectra a total power of the horizontal component of the pulsations (H^2+D^2) at every station of the network was calculated, and the result is presented in Fig. 3 in the form of the meridional distribution of the total power. The maximal power is found at the station Ivalo, at CGLat=65.1.

The data of the MEPED instruments (Evans and Greer, 2000) mounted on board the NOAA POES satellites were used for an analysis of energetic proton fluxes at the altitude of ~800 km. The MEPED instrument consists of two groups of detectors measuring particles in two directions. At high latitudes the directions are approximately along and perpendicular to the magnetic field line, so precipitating and locally mirroring particles are measured. Energetic protons are measured in several energy channels; here the 30-80 keV protons are considered.

During the Pc2 event three NOAA satellites provided the particle observation in different MLTs (Fig. 4). Both the proton precipitation adjoining the isotropy boundary from the equatorial side and the localized energetic proton precipitation well inside the region of anisotropic fluxes were observed. As follows from Fig. 4 (the fourth and fifth panels from the top), the intense localized energetic proton precipitation were

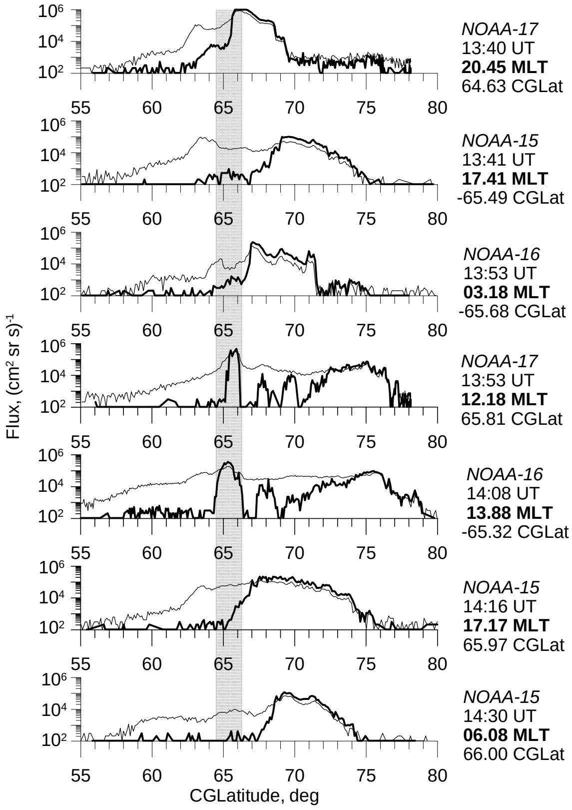

Fig. 4. Energetic proton observations from three NOAA satellites at around 14 UT of 22 April 2005. Thick line – precipitating flux, thin line – locally mirroring flux.

observed on the dayside. The latitude of the precipitation burst is just the same as the latitude of the Pc2 maximum. Note, that the localized precipitation structures appeared only at the time of the Pc2 event, and were not observed before and after it (data not shown). As to precipitation adjoining the isotropy boundary, they were observed at different MLTs, but the intensity of these precipitating proton fluxes was small in comparison with the intensity of the dayside localized precipitation. The strongest intensity of the fluxes (however, two orders less than the intensity of the localized precipitation on the day side) was registered in the late evening (Fig. 4, upper panel).

A schematic representation of the ground and low-altitude observations is shown in Fig.5. Three NOAA satellites were in orbit at that time (NOAA-15, -16, and -17). Traces of the satellite passes occurred during the considered event are shown by lines with arrows (the arrows indicate the direction of the satellite movement). Diamonds mark the location of the isotropy boundary of energetic protons determined from the data of the MEPED instrument. A thick line is an interpolation of the isotropy boundary for all MLTs. A strip just equatorward of this line indicates the location of the precipitation adjoining the isotropy boundary. The latitudinal width of the strip is 1-2 degrees according to the typical width of this precipitation pattern (Gvozdevsky et al., 1997; Yahnina et al., 1999). Triangles indicate the localized precipitation bursts. The location of the Finnish magnetometer network at 14 UT is shown by a thick bar at around 16 MLT.

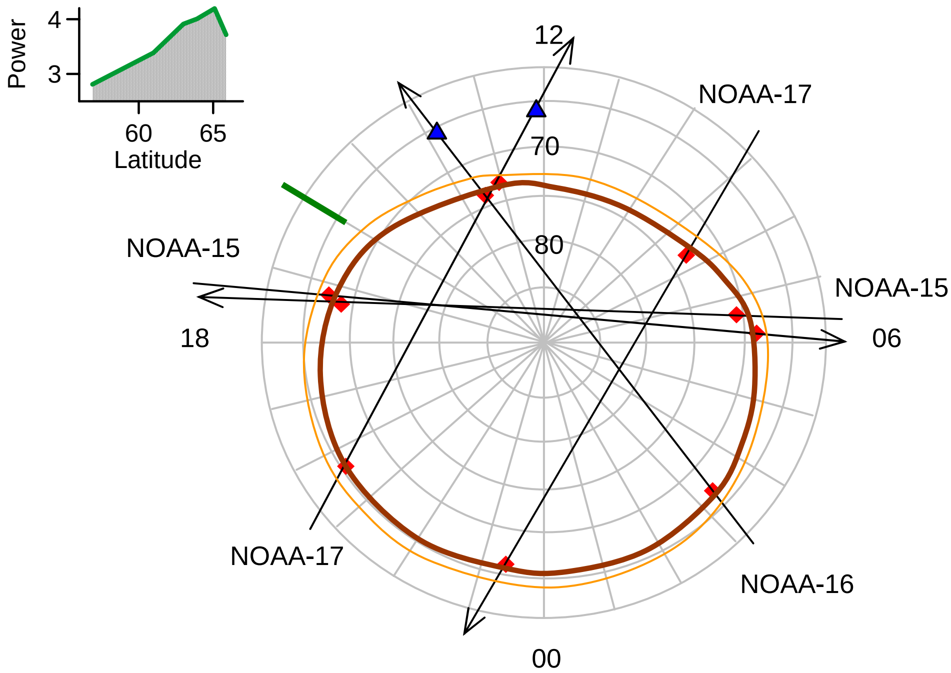

Fig. 5. Schematic presentation of the low-altitude particle observations and ground observations of geomagnetic pulsations. In the left-upper corner the Pc2 power distribution from Fig. 4 is reproduced. See other details in the text.

It is reasonable to suggest that the maximum of the latitudinal distribution of the ground pulsation power represents the latitudinal location of the magnetospheric source of the pulsations (e.g. Baransky et al., 1981). If so, Figs. 4 and 5 relate the source of the considered Pc2 with the localized proton precipitation observed on the dayside.

At the same time, it is doubtful that the precipitation adjoining the isotropy boundary relates to this Pc2 event. As follows from Fig. 4, the intensity of this type of precipitation is low. The precipitation is observed at different latitudes in different MLT; at the meridian of the ground observations this precipitation is located well poleward of the Pc2 maximum. During the event the precipitation may change its location (at least in the evening sector, see, Fig. 4, second and sixth panels), so, in the case of relationship between this precipitation and pulsations, one can expect the change of the pulsation frequency. In fact, it is not the case. At last, this kind of precipitation exists well before and after the Pc2 observation.

In addition to the low-altitude observations, the MPA and SOPA instruments on board three LANL spacecraft provided information on, respectively, the cold (<10 eV) plasma and hot (>50 keV) particle flux variations along the geosynchronous orbit (data not shown). At around 14 UT the SOPA instrument on board two LANL spacecraft (97A и 02A) showed the injection of energetic protons at 23 MLT and 18 MLT. The injection registration in the evening sector is delayed relative to that in the night sector. This fact evidences the westward drift of the proton cloud. At the same time, the geosynchronous spacecraft LANL 095 situated on the dayside registered several cold plasma density enhancements up to 40-80 cm^{-3}. Thus, one can expect that on the dayside the drifting energetic protons pass through the cold plasma region. This is favorable conditions for the ion-cyclotron interaction and associated ion precipitation (e.g., Bespalov et al., 1994). The localized proton precipitation on the dayside is, most probably, due just to such interaction. Similar conditions were revealed by Yahnina et al. (2003) for the localized proton precipitation related to the EMIC waves in the evening sector (their "precipitation of Type 2").

Conclusion

The data set available for the considered Pc2 event enables us to locate the pulsation source on the field lines related with the localized proton precipitation on the dayside rather than the proton precipitation just equatorward from the isotropy boundary. These localized precipitation bursts on the dayside occurred, most probably, as a result of the ion-cyclotron interaction in the region where the westward drifting energetic protons contacted with the cold plasmaspheric plasma.

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