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Temporal and spatial characteristics of Pc1 geomagnetic pulsations

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Abstract

A long-term continuous series (1957–1992) of ground-based observations of ULF emissions in the frequency range of 0.2–5.0 Hz (Pc1) was investigated. To present information uniformly and facilitate comparative analysis, a so-called index *N* has been introduced, which describes Pc1 activity. Information on cyclic variation of Pc1 activity is given. Pc1 relation to the level of solar and geomagnetic activity, interplanetary magnetic field structure and solar wind parameters (such as the plasma density and bulk velocity, magnetic field strength and direction) in front of the magnetosphere is traced. Latitude dependence of Pc1 activity and its relation to the solar wind conditions are explored.

Keywords: Geomagnetic pulsations Pc1; Solar wind parameters; Solar cycle

1. Introduction

Geomagnetic pulsations Pc1 with a pronounced structure of their dynamic spectra in the form of repetitive patterns are representative of ion cyclotron waves generated in the magnetosphere by fluxes of mid-energy particles (Guglielmi and Pokhotelov, 1996). The ion cyclotron activity in the geomagnetic field is an important property of the magnetosphere state and thus calls for its study with reference to the changing external conditions and their long-term variations. Here, we present results of multiyear Pc1 observations in the *L* range between 2.1 and 6.3. The first part of this report is devoted to the study of Pc1 connection with magnetic storms, interplanetary magnetic field (IMF) sectors and solar cycle variations using data from one mid-latitude observatory for 36 years of observations (Matveyeva, 1996). The second part contains results of simultaneous Pc1 observations during 1976–1979 at the Finnish chain of stations (Pikkarainen et al., 1982) and two Russian sites covering a wide range of geomagnetic latitude, from 47° to 66°. Both latitude peaks of Pc1 occurrence are situated in this range, so the data well reflect Pc1 latitude dependence. In this latter part the emphasis is on the response of Pc1 activity to solar wind parameters.

2. Description of data collection

Worksheets with hourly values of parameters describing Pc1 activity, along with the solar wind plasma and magnetic field hourly values and geomagnetic indices were used for analysis. In total, for 1976–1979, we have analysed 13,140 hourly values of Pc1 activity and solar wind parameters for each of 7 stations (Table 1).

Besides that, for Geophysical Observatory Borok a special daily Pc1 index *N* has been constructed. It

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describes the daily activity of Pc1 pulsations. As a measuring unit for such an index a 15-min interval is adopted where the duration of Pc1 observation exceeds 5 min. So, the *N* index is equal to the daily number of 15-min intervals containing Pc1. This index has been calculated and represented as a set of worksheets for entire period of observations at Borok from 1957 to 1992.

Solar wind and interplanetary magnetic field parameters, as well as the geomagnetic indices have been taken from the NSSDC OMNIWeb site http://nssdc.gsfc.nasa.gov/omniweb/ow.html.

3. Pc1 response to magnetic storms, IMF structure, and solar cycle

In Fig. 1, we show the dependence of Pc1 activity on time before or after magnetic storm commencement (“zeroth” day) for two types of disturbances: sporadic storms, which begin with SSC, and the recurrent ones with gradual beginning. To plot these curves we used a superposition of large numbers of storms indicated in the legend. Maximum Pc1 probability occurs 4–7 days after the storm commencement for both types of disturbances. For recurrent storms, a secondary peak can be seen in about 30 days after the first one, which is close to the Sun’s rotation period.

McPherron and Ward (1967) were the first to observe a connection between Pc1 occurrence and IMF sector boundaries. Here, we confirm their result using larger statistics. Fig. 2 shows evidence for higher Pc1 probability when the Earth crosses a sector boundary, whether it passes from the positive sector to the negative one, or vice versa.

Fig. 3 shows solar cycle variations of Pc1 activity for almost four cycles, from the 19th to the 22nd. It is clearly seen that Pc1 occurrence depends inversely on solar activity. The correlation coefficient is $r = -0.83$. The analysed time interval (1957–1992) is by far the largest in the literature (see Mursula et al., 1991).

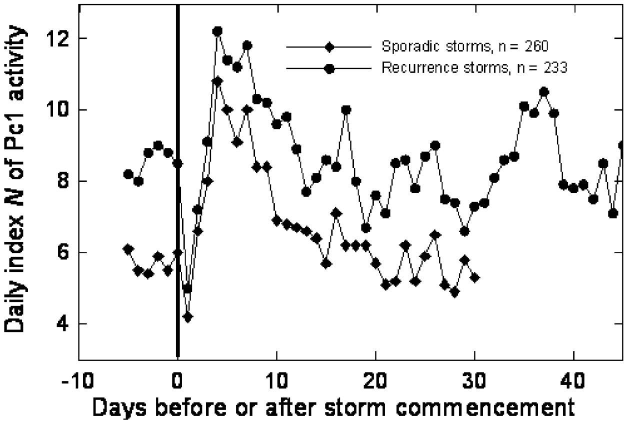

Fig. 1. Pc1 daily occurrence rate at Borok observatory versus time since magnetic storm commencement (“zeroth” day) for sporadic (diamonds) and recurrent (circles) storms.

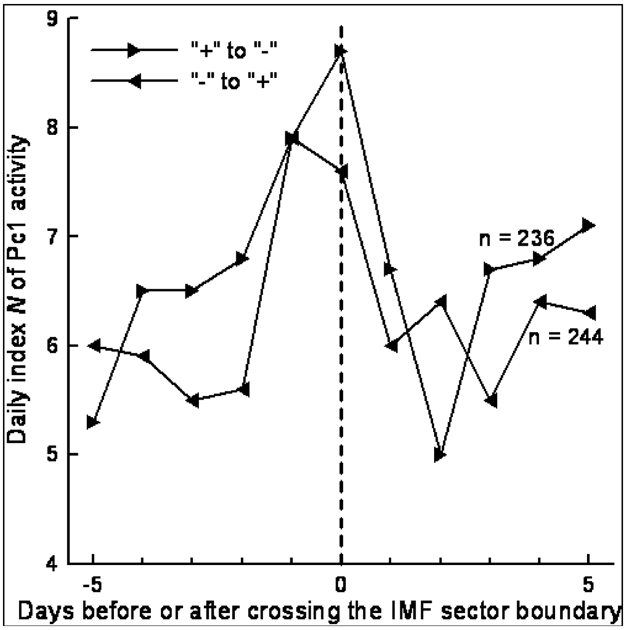

Fig. 2. Pc1 daily occurrence rate at Borok observatory versus time before or after the day of the Earth’s crossing the IMF sector boundary.

Table 1
Magnetic observatories, their coordinates and observation periods used for the current study

Station	Geographic coordinates		Corrected geomagnetic coordinates		*L*-value	Years processed
	ϕ	λ	Φ	Λ		
Kevo	69.8	27.0	66.4	109.5	6.3	1976–1979
Sodankylä	67.4	26.6	63.8	108.0	5.1	1976–1979
Oulu	65.1	25.5	61.5	105.6	4.4	1976–1979
Jyväskylä	62.4	25.7	58.8	104.0	3.8	1976–1979
Nurmijärvi	60.5	24.6	56.8	102.7	3.3	1976–1979
Borok	58.0	39.0	53.9	114.3	2.9	1957–1992
Mondy	51.6	100.8	46.7	173.6	2.1	1976–1992

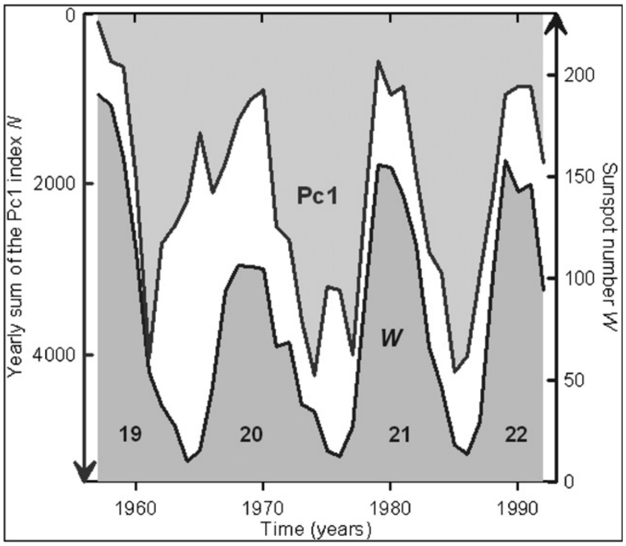

Fig. 3. Solar cycle variations of Pc1 activity for about four cycles.

4. Response of activity and latitude distribution of Pc1 to the IMF components and solar wind flow regime

The latitude distribution of Pc1 occurrence probability in relation to the IMF intensity is shown in the bottom panel of Fig. 4. The upper panel shows logarithmic fits of B-profiles of Pc1 occurrence for two stations SOD and NUR corresponding to the ridges in the bottom panel and for the lowermost station MON.

L-profiles of Pc1 probability versus the solar wind bulk velocity (Fig. 5) demonstrate invariance of the profile shape for all values of V_{sw}. At all latitudes the most favourable conditions for Pc1 occurrence correspond to the lowest values of the solar wind velocity.

Solar wind plasma density has a pronounced effect on the Pc1 pulsation occurrence at all latitudes (see Fig. 6). For instance, the probability of Pc1 observation at

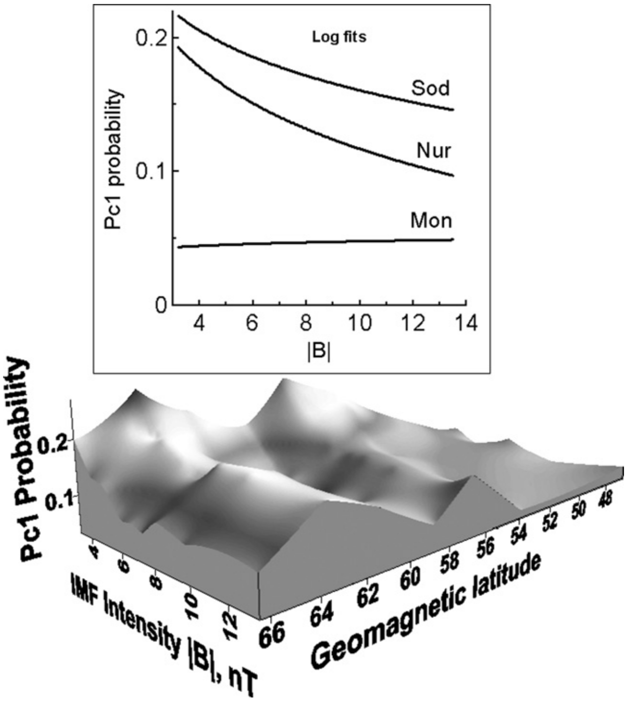

Fig. 4. Dependence of Pc1 occurrence probability on the IMF intensity at various latitudes. The bottom panel shows this dependence as a 3D surface, and the upper panel shows logarithmic fits of B-profiles of Pc1 occurrence for three selected stations.

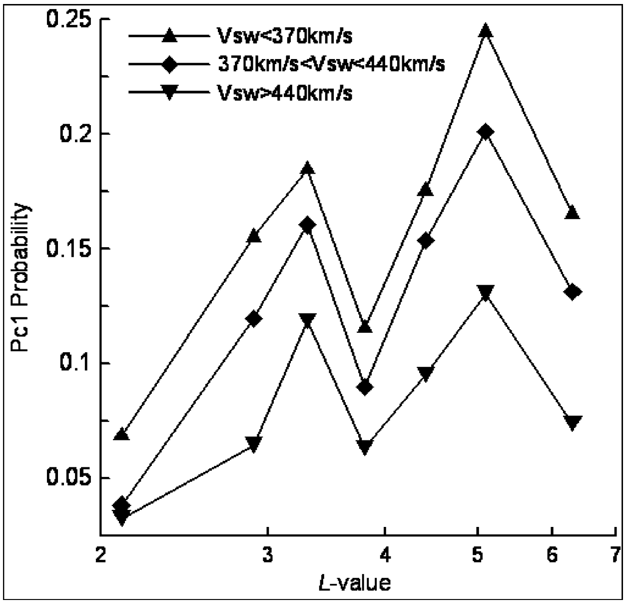

Fig. 5. *L*-profiles of Pc1 probability versus the solar wind bulk velocity.

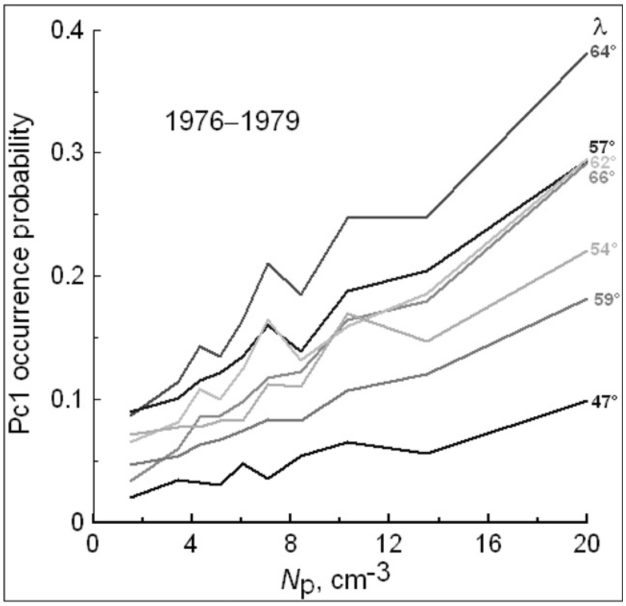

Fig. 6. Pc1 occurrence rate versus the solar wind plasma density at various geomagnetic latitudes.

Sodankylä increases four times when plasma density rises from 2 to 20 cm^{-3}.

5. Discussion

Using ground based observations of the structured Pc1 to study ion cyclotron activity and its dependence on the external conditions provides clear merits. A meridional chain of magnetometers allows us to detect waves coming from various parts of the magnetosphere thus giving information about the spatial distribution of the ion cyclotron wave field.

Stable generation of ICW in the magnetosphere requires at least two conditions: (1) the absence of significant magnetic disturbances, and (2) retention of a sufficient amount of mid-energy ions capable of producing ion cyclotron instability. That is why we observe many Pc1 events after magnetic storm, when on the one hand, magnetic disturbance decays and on the other hand many energetic particles have been captured in the geomagnetic field. However, these reasons are not applicable to the observed inverse correlation between Pc1 activity and the solar cycle sunspot variations. It is common accepted that the long-term Pc1 variation is due to corresponding variations of ionospheric and magnetospheric parameters in the course of the solar cycle. Specifically, the 11-year variation of O^{+} ions in the magnetosphere (Young et al., 1982) causes the modulation of energy leakage from the magnetosphere-borne open resonator in which the ion cyclotron wave packets are generated in the Pc1 frequency band (Guglielmi et al., 2001).

The impact of the solar wind status on the magnetospheric ion cyclotron activity can be explained by its influence on geomagnetic disturbances. But it is only true for such parameters as the bulk velocity and IMF components: low velocity and IMF intensity, positive B_z create quiet conditions in the magnetosphere. As regards the density of solar wind plasma, another explanation is required to understand why dense plasma impinging on the magnetosphere leads to generation of ion cyclotron waves. To our mind, in order to explain this phenomenon we must invoke ponderomotive forces acting on the magnetopause and providing penetration of solar wind plasma into the magnetosphere. Study of physical processes involved there is in progress now.

Acknowledgements

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