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STATISTICAL FEATURES OF Pc3-4 PULSATIONS AT VERY HIGH LATITUDES

O.M. Chugunova[1], V.A. Pilipenko[1], and M.J. Engebretson[2]

[1] *Institute of the Physics of the Earth, Moscow*
[2] *Augsburg College, Minneapolis, MN*

Abstract. Using the data of search-coil magnetometers from two Antarctic stations - sub-auroral P3 at -72° CGM and P5 which is deep in the polar cap (-87° CGM), we have analyzed the statistics of Pc3-4 activity and its correlative relationships with the solar wind and IMF parameters. A new approach based on the determination of the wave packet parameters from the signal's dynamic spectra has been applied. Diurnal variations of the wave power are different at the auroral zone latitudes and in the polar cap. At 72° latitude, two maxima have been revealed: one at near-noon hours and midnight hours, corresponding to the cusp and substorm wave activities. At latitude 87° only one early morning maximum has been detected. The *f-B* diagram reveals the occurrence of two sub-classes of wave packets – with linear *f-B* dependence and B-independent signals. The wave power nearly linearly grows with increasing the solar wind velocity at both stations. The statistical features found fit the earlier suggested idea about a possibility of two channels of the penetration of primary upstream turbulence, i.e. via the cusp and via the lobe flanks.

1. Introduction

The prevailing viewpoint is that the primary source of the Pc3-4 pulsations (10-100 mHz) is the turbulence upstream the magnetospheric bow shock. This turbulence is assumed to drift with the solar wind plasma flow in the magnetosheath. Then, the broad-band waves from the turbulent magnetosheath penetrate in the equatorial magnetosphere and resonantly convert into the Alfven field line oscillations. This resonant conversion mechanism, which is confirmed by observations, acts as a natural band-pass filter producing narrow-band signals at low and middle latitudes. An additional source of the broad-band Pc3-4 activity is related to the dayside cusp/cleft projection. Thus, according to the existing concepts, the narrow-band Pc3 pulsations cannot form in the regions with open magnetic field lines, e.g. in the polar cap, where no field line Alfven resonances are possible.

Nevertheless, in our recent case study of the ULF pulsations at very high latitudes [*Chugunova et al.*, 2002] the events were found that revealed the narrow-band Pc3-4 waves at geomagnetic latitudes up to 80°, that is deep in the polar cap. We have searched for Pc3 activity using the data from the trans-Antarctic meridional array of the US automated geophysical observatories (AGO) extending from the auroral zone deep into the polar cap along the longitude of ~40°. The narrow-band Pc3 pulsation activity was found to be high not only in the dayside region adjacent to the magnetopause, but in the regions of the magnetotail lobe as well. It was suggested that different channels of propagation of the upstream turbulence to the ground are possible: via the equatorial magnetosphere, the cusp (LLBL), and the lobe flanks. The mechanism of narrow-band filtering/amplification of Pc3 waves on the open field lines has not been identified yet.

In the present work, based on the statistical analysis, we verify the conclusions on the two sources of Pc3-4 pulsations at very high latitudes suggested by the case study that we performed earlier.

2. Observational facilities and data analysis technique.

Statistical features of Pc3-4 pulsations are examined with the data from two stations: P3 which is located near the nominal latitude of the dayside cusp/cleft (-72°, MLT=UT-02 h), and P5 that is sited deep in the polar cap (-87°, MLT=UT-02 h). Both stations are equipped with search-coil magnetometers with 2 Hz sampling rate and linear frequency response. For station P5 the data from 02.01.1997 to 04.03.1997 and for P3 the data from 01.01.1997 to 31.03.1997 have been available. Station P3 is likely to be mapped to the closed field line region adjacent to the magnetopause in the dayside sector, whereas P5 is on the open field lines all the time.

In contrast with the previous statistical studies, where the wave and IMF/solar wind parameters averaged over a fixed interval (commonly, 1 hour) had been used, here the following technique of more detailed event selection is applied. Data have been de-spiked and band-pass filtered in the range 0.008-0.1 Hz. First, FFT dynamic spectrograms in the frequency band 10-60 mHz for each station in three time intervals (00-05, 05–17, and 17-24 UT) are calculated. Then, averaged spectral power and standard deviations for every frequency band are estimated for these time intervals. In the dynamic spectrograms the values less than the threshold - mean power plus 3 standard deviations, are omitted. Two or more adjacent values above the threshold in a dynamic spectrogram are considered to be a wave packet. For each wave packet the onset and end times, total energy, peak amplitude of the H and D components and its frequency are calculated. Finally, the time-shifted and averaged over the wave event duration, values of the IMF components, and solar wind velocity, as measured by Wind spacecraft, have been calculated.

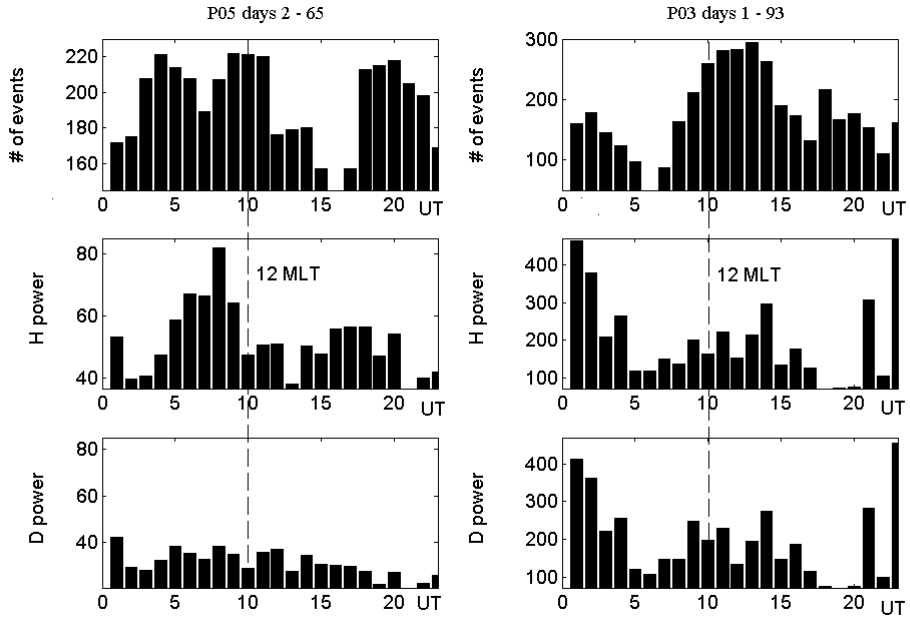

Fig.1 Diurnal variations of number of wave events, power of H and D components for the polar cap station (P5) and cusp stations (P3). For visual guidance a vertical line denoting the MLT noon at both stations is indicated.

Thus, this new statistical approach operates not just with the time-averaged characteristics of wave activity, but with isolated wave packets and relevant IMF/solar wind parameters.

3. Diurnal variations of wave events characteristics

Diurnal variations of basic ULF wave parameters for the polar cap and cusp stations, P5 (left) and P3 (right), correspondingly, are shown in Figure 1. The number (top panel), total power of H (middle panel) and D components (bottom panel) of wave packets are given.

At the equatorward auroral boundary (station P3) diurnal variations of the number of events and their power have two maxima. The nightside peak between 22 and 04 UT evidently corresponds to the influence of the substorm activity. Another broad maximum at the near-noon hours, 10-15 UT, may be associated with the dayside cusp/cleft region. The power of H component is comparable to that of D component.

In the polar cap (station P5) the nighttime peak in the diurnal variations of the Pc3-4 power related to the substorm activity, is absent. Also, the near-noon maximum of the ULF power is much weaker at P5 than that at P3. At the same time, there is a spectacular broad maximum of the number of events and their power at early morning hours, 06-10 UT. Polarization of this peak at P5 is different compared to the near-noon peak at P3: the power of H component is bigger than power of D component. Along with the early morning maximum, there is another, though weaker, maximum of H component power in the evening hours, 18-20 UT.

4. IMF and solar wind control of the Pc3-4 activity in the cusp and polar cap

For the search of correlative relationships from P3 station only the dayside events (09-17 UT) corresponding to the daytime maximum in Fig. 1, have been selected. In a similar way, from P5 station only the group of early morning events (05-12 UT) have been selected.

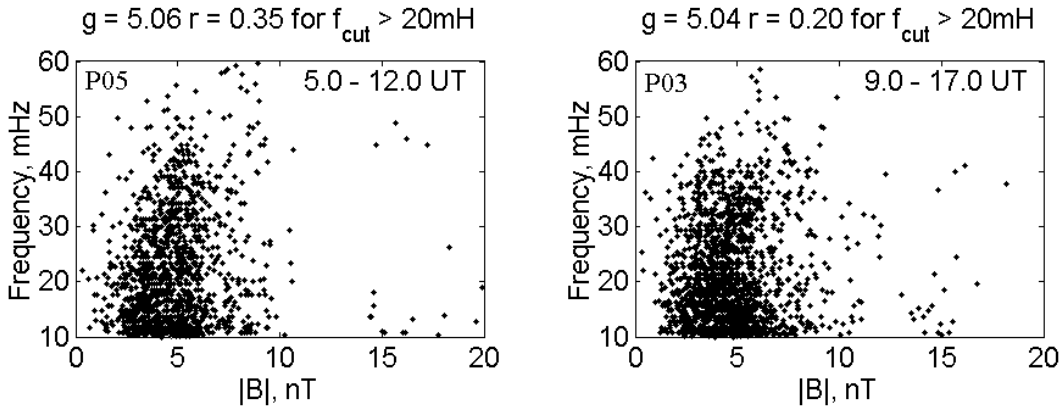

Fig.2 The dependence of the wave frequency on the IMF magnitude |B| for the tail-related and cusp-related waves.

The statistical *f-B* diagram (Fig. 2), that is the dependence of the wave frequency on the corresponding IMF magnitude *B*, has been constructed from ~1300 events for P5 (polar cap) and ~1800 events for P3 (cusp). This continuum can be delineated into two sub-classes of Pc3-4 pulsations - the first with $f \geq 20$mHz that obeys the relationship *f~B*, and the second one with $f < 20$mHz, that does not obey this relationship. The coefficients of the linear relationship *f*(mHz) ~ *g*B (nT) (for 95% confidence interval) and the correlation coefficients above the cut-off frequency (20mHz) are as follows:

for P5: $g = 5.06 \pm 0.17$, and $r = 0.35$;

for P3: $g = 5.04 \pm 0.17$, and $r = 0.2$.

These values of *g* are somewhat smaller than the typical estimates $g = 5.8 \pm 0.3$ for the middle latitude Pc3 waves [*Gugliel'mi*, 1988].

It seems that only the first sub-class is related to the turbulence upstream of the magnetospheric bow shock. Our results confirm the comparison of hourly daytime Pc3 spectra in both hemispheres with IMF parameters performed by *Wolfe et al.* [1990] at ~ 74° latitude. The authors have established that there are two groups of ULF pulsations - a group of Pc3 with frequencies higher 27 mHz, which follow the *f~B* dependence, and another one, below 27 mHz, without *f~B* dependence. The source of the low-frequency part of the Pc3-4 activity is probably related to the intrinsic magnetosheath turbulence, though this problem needs further examination.

The dependence of the peak spectral power of the wave packets on the corresponding solar wind velocity, or *A-V* diagram, is shown in Fig. 3. For both polar cap morning waves and dayside cusp waves the power nearly linearly grows upon increase of the solar wind velocity with the correlation coefficient $r = 0.6$.

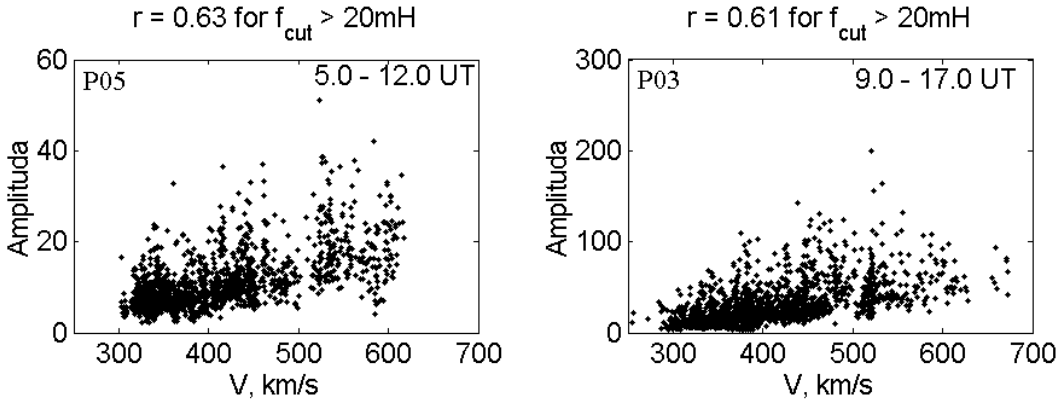

Fig.3 . The dependence of the peak wave packets power on the solar wind velocity for the polar cap morning waves (left panel) and dayside cusp waves (right panel).

The dependence obtained is similar to the *A-V* dependence of the Pc3-4 pulsations at middle latitudes [*Gugliel'mi and Potapov*, 1994]

5. Summary

Unexpectedly, the narrow-band Pc3 activity was found to be high not only in the regions corresponding to the dayside closed field lines adjacent to the cusp/LLBL, but even to the magnetotail lobe. The statistical dependences of the wave powers and frequency at both high-latitude stations P3 and P5 on *V* and *B* are similar to the relationships commonly found for ULF waves related to the upstream turbulence. Thus, the common primary source of both dayside cusp waves and morning cap waves with $f > 20$ mHz is, probably, the upstream ULF turbulence.

Diurnal variations of wave power are different at cusp latitudes and in the polar cap:

- at 70^0-80^0 CGM there are near-noon and mid-night maxima, related to the cusp and substorm activities;
- at $> 85^0$ there is the morning maximum and weaker evening maximum, possibly, conjugate to the lobe flanks. Influence of the nightside substorm activity is hardly noticeable at these latitudes.

Comparison of the diurnal variations at the cusp latitudes and in the polar cap confirms the occurrence of two sources of Pc3 wave activity at very high latitudes, proposed on the basis of the case study [*Chugunova et al.,* 2002]. The occurence of the cusp-associated intensification of Pc3 activity at near-noon hours was known from prevous studies [*Bolshakova and Troitskaya*, 1984; *Engebretson et al.,* 1990]. Both case study of *Chugunova et al*. [2002] and the present statistical analysis indicate the occurrence of an additional source of the Pc3-4 wave activity in the polar cap, probably related to the penetration and conversion of the waves at the lobe flanks. However, the particular wave conversion mechanism from the magnetosheath ULF turbulence into the band-limited Pc3-4 waves on the ground in the region with open field lines has yet to be identified.

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