OBSERVATIONS OF GLOBAL Pi 2 PULSATIONS IN MID-LATITUDES DURING AURORAL SUBSTORMS

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ABSTRACT

Using geomagnetic pulsation observations obtained with induction magnetometers along the Norilsk meridian and from a network of mid-latitude observatories we investigate the excitation characteristics of Pi2 pulsations in the noon sector of the magnetosphere and in mid-latitudes.

An additional (to nighttime) stable noon maximum was revealed in the diurnal distribution of the occurrence frequency of Pi2 pulsations at the mid-latitude observatories, while the auroral stations recorded only a rare occurrence of Pi2 around noon.

The meridional intensity distribution of the daytime Pi2 has its maximum at latitudes of magnetopause projection, whereas it occurs at auroral latitudes for nighttime Pi2.

The development of the active phase of an auroral substorm is accompanied by a global excitation of Pi2 pulsations at mid-latitudes with identical dynamic spectra. At the same time the source size of Pi2 pulsations at high latitudes is limited longitudinally and appears to be determined by the zone of synchronous substorm development.

The onset time of maximum amplitude in Pi2 pulsation intensifications (inferred from dynamic spectra) varied at different stations from a few fractions of a second to several tens of seconds, and these delays did not show any definite trend.

Experimental results are discussed in terms of the existence of a global mode in the Earth's plasmasphere as a plausible source of mid-latitude Pi2 pulsations.

INTRODUCTION

The manifestations of auroral activity at high and middle latitudes in the form of the excitation of Pi2 geomagnetic pulsations is a long-explored area. A relatively thorough and comprehensive study has been made of the main excitation patterns of these pulsations in the midnight sector to the extent that competing physical mechanisms were developed [1]. As far as the appearance of such pulsations in mid-latitudes in different longitudinal sectors is concerned, however, some blanks need to be filled in. The question as to the relative position and the relationship of the source sizes of these pulsations in high and middle latitudes remains to be answered; furthermore, the particular conditions in the magnetosphere under which a global excitation of Pi2 pulsations in mid-latitudes occurs are still understood incompletely.

In this paper we investigate the excitation patterns of Pi2 pulsations in the midday sector along the meridian, with particular emphasis on the occurrence of these pulsations in different longitudinal sectors and on their dynamic spectra by taking advantage of the data from a global network of mid-latitude observatories.

This study uses the observations of geomagnetic pulsations from induction magnetometers acquired during the period of experiments "Siberia-IMS-76, 79" and "Taimyr-82" (Norilsk meridian), and results of digital recordings of geomagnetic pulsations at the network of mid-latitude observatories.

The coordinates of the stations, the data from which were used in this study, are listed in Table 1.

Table 1: List of stations

№	Station name	GM Lat	GM Long	Short station name
1	Heiss	74^0	141^0	HS
2	Sterlegov	69^0	162^0	ST
3	Tixie	66^0	195^0	TIX
4	Norilsk	64^0	160^0	NOR
5	Sodankyla	64^0	108^0	SOD
6	Athabasca	62^0	305^0	ATH
7	Turukhansk	61^0	159^0	TUR
8	Borok	54^0	113^0	BOR
9	Kaliningrad	52^0	98^0	KAL
10	Irkutsk	48^0	175^0	IRK
11	US Airforce	48^0	319^0	AFA
12	Paratunka	46^0	222^0	PTK
13	Soroa	34^0	344^0	SOR
14	Create	29^0	98^0	CRT
15	Jinghai	28^0	187^0	JIH

ANALYSES OF RESULTS

We first examined the question as to the particular kind of pulsations of the midday mid-latitude magnetosphere during the development of auroral substorms in the midnight sector. Figure 1 illustrates a typical example of a simultaneous recording of Pi2 pulsations in the midnight and midday sectors during the development of the active phase of an auroral substorm. The figure presents he H-component for an auroral station (d), and portions of geomagnetic pulsations recorded with the induction magnetometer at a pair of stations on the midnight meridian (b, c). The

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top of the figure shows a portion of a recording from the Cuban mid-latitude station located in the midday sector (a). It is easy to see that at all stations the pulsations begin almost simultaneously, their duration is identical, and the mean period and decay decrements are alike. At the midday station, the pulsations are of the form typical of Pi2. The pulsations differ in polarization: they are nearly circularly, elliptically and linearly (along the N-S direction) polarized, respectively, at the auroral station, at the mid-latitude nighttime station, and at the mid-latitude daytime station. Note that in this, and in other cases considered, the Pi2 amplitude at Irkutsk (midnight) was twice as large as that at Cuban station Soroa (midday). It should also be noted that when analog recordings of experiments from previous years were used, it was difficult to identify the Pi2 pulsations during the daytime (especially during disturbed periods) because of the masking effect of regular Pc3, as was shown in our earlier paper [2]. Nevertheless, it was possible to identify Pi2 in the presence of Pc3 through digital or hardware filtering.

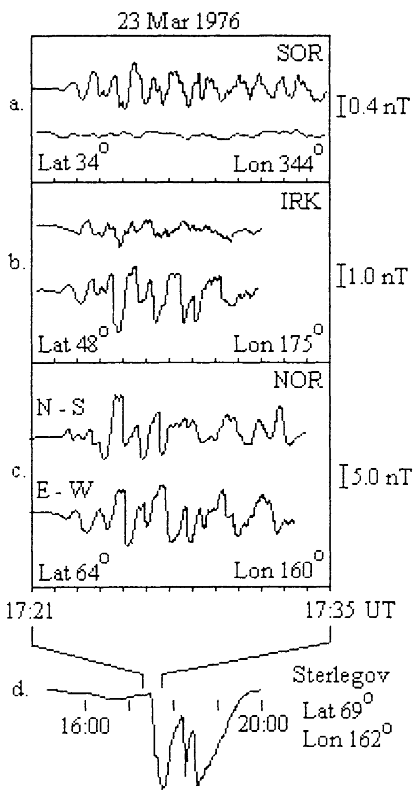

Figure 1: The time history of the active phase of the May 23, 1976 substorm in the magnetic field and geomagnetic pulsations:
a, b, c - portions of the geomagnetic pulsations recorded (N_{N-S} and N_{E-W}-components);
d - H-component from the auroral station.

If, however, we analyze the cases the reverse of that considered here (when the stations of the meridional chain are in the midday sector), the following regularity may be revealed: depending on magnetic activity, Pi2 pulsations during the daytime were reliably recorded at stations limited by the latitudes $61^0 - 63^0$ (L = 4.3-5.3). Figure 2 presents the instant of Pi2 observation during the daytime at the stations on the Norilsk meridian (c, d, e, f).

One can clearly see a difference of the pulsat9ion regimes at stations Norilsk and Turukhansk - no Pi2 are recorded at Norilsk and at more northward stations.

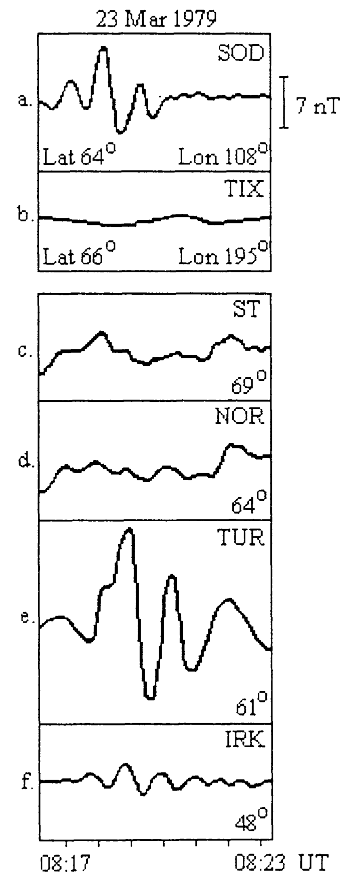

Figure 2: Time history of the intensification of Pi2 pulsations during the March 23, 1979 substorm as deduced using the data from a network of stations (H_{N-S} -component): a - st. Sodankyla; b - st. Tixie; c, d, e, f - stations along the Norilsk meridian.

An analysis of some other similar cases confirms the steadiness of the tendency observed. For all cases of Pi2 recordings during the daytime hours, the amplitude at st. Turukhansk was maximal or comparable with Pi2 amplitudes at the northern stations. Considering that st. Turukhansk (Φ=61.1; L=4.3) is located in the region of statistical plasmapause projection onto the ground (L_{pl}=6-0.6 Kp) [3], one is led to an obvious conclusion that the meridional maximum of the daytime Pi2 occurs at these latitudes.

As far as Figures 2a and 2b is concerned, however, it will be discussed somewhat later in the text.

The detected regularity can also be confirmed through a comparison of the diagrams of the diurnal variation in the occurrence frequency of the pulsations observed in middle and high latitudes (Figure 3). The figure shows the sum of Pi2 occurrences in each hour of local time for December 1994 according to the data from st. Irkutsk (solid line) and st. Norilsk (dashes). It is evident that the data from Irkutsk have the form of an asymmetric distribution with a clear midnight maximum, with an abrupt drop toward the morning hours, and a gradual drop to the evening hours. Furthermore, the diagram for st. Irkutsk reveals an additional midday maximum. Noteworthy also the valleys are in the distribution during the morning and evening hours, with a deeper valley in the morning than in the evening. The low probability for recording the pulsations at the time when the observing station traverses the terminators seems to indicate an important role of ionospheric plasma density gradients in the Pi2 propagation mechanism. We have already called the reader's attention to this fact in [4].

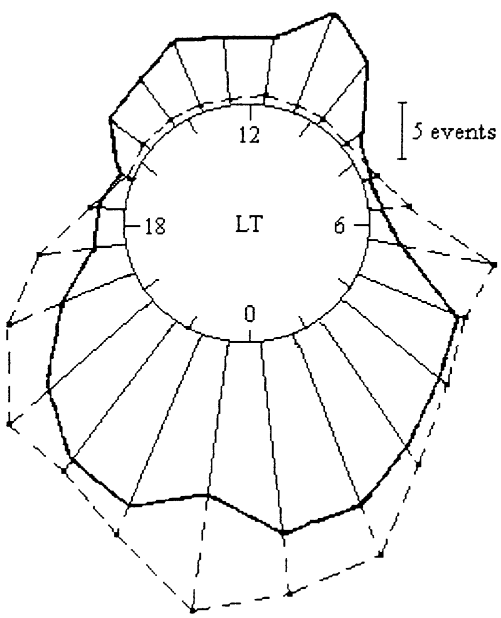

Figure 3: Number of Pi2 pulsation observations in each hour of local time for December 1994.
—— st. Irkutsk; - - st. Norilsk.

Unlike the mid-latitudes, the diurnal variation in the probability of Pi2 observations at auroral station Norilsk has one midnight maximum only.

Next, we consider the way in which Pi2 pulsations are excited in mid-latitudes in different longitudinal sectors during the development of auroral substorms. We have carried out such an analysis using dynamic spectra that were inferred using the data from a number of mid-latitude observatories (Table 1).

Figure 4 gives an example of such an analysis. One can see that the commencement of the negative bay at 17.19 UT at st. Norilsk is accompanied by an intensification of Pi2 pulsations (Fig. 4f).

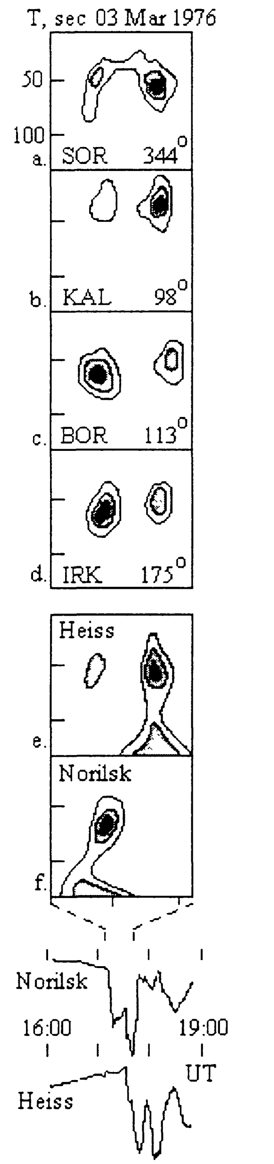

Figure 4: Dynamic spectra of Pi2 pulsations as deduced using the data from high-latitude stations (e, f) and mid-latitude observatories (a, b, c, d).

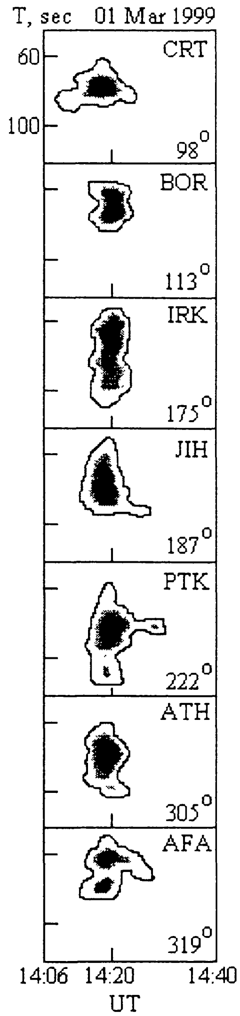

Figure 5: Dynamic spectra of Pi2 pulsations as deduced using the data from a global network of mid-latitude observatories.

At the same time, as can be seen from the dynamic spectra presented (Fig. 4a, 4b, 4c, 4d), Pi2 are observed at stations Irkutsk, Borok and Kaliningrad, i.e. at all mid-latitude stations on the midnight magnetosphere. Midday station Soroa (Cuba) also observed pulsations in this same range of periods, which can be classed as midday Pi2. It should be noted that the central period of the first intensification at all mid-latitude stations (including st. Soroa) is about 60 s.

The development of a substorm in the northwestward direction initiated a new intensification at 17.23 UT on the st. Heiss meridian where the commencement of a negative bay was observed with an intensification of Pi2. As in the former case, all mid-latitude stations observed Pi2 pulsations whose spectra are identical and are in the same range of periods. Results derived from analyzing such cases suggest the conclusion that each appearance of high-latitude Pi2 pulsations is stimulatory to the excitation of Pi2 pulsations at mid-latitudes. Using recordings from a global network of state-of-the-art digital induction magnetometers we considered analogous cases of the development of Pi2 pulsations in mid-latitudes. We used the data from high-latitude observatories to determine the beginning of the substorm active phase, and then to calculate dynamic spectra of the mid-latitude Pi2. Figure 5 exemplifies the development of Pi2 pulsations as deduced using the data from a global network of digital induction magnetometers. An analysis of the dynamic spectra shows that all stations observed pulsations with identical dynamic spectra in the range of 60-100 s periods. Thus the experimental results presented here bear witness to a global excitation of Pi2 pulsations in mid-latitudes.

Subsequently, we made an attempt to determine the simultaneity of the Pi2 onset at mid-latitude stations. To do this, we determined from dynamic spectra the onset time of maximum amplitude. The onset time was different for different stations, and varied from a few fractions of a second to several tens of seconds. Furthermore, we did not detect any clear tendency for the delay times.

We now revert to Figure 2 in order to compare the source sizes of the auroral and mid-latitude Pi2 pulsations. The figure (top) shows portions of the pulsations recorded at high-latitude stations Tixie and Sodankyla that are separated from the Norilsk meridian by 35^0 and 50^0, respectively, to the east and west. The amplitude's meridional maximum is observed at st. Turukhansk. Unfortunately, data from the global network of mid-latitude observatories for this period are unavailable to us in order to estimate the source size of the Pi2 pulsations. However, our research results induce us to suggest (as in the other, similar cases considered above) that the excitation of Pi2 has a global character in this case as well.

We now wish to emphasize that high-latitude st. Tixie at that period did not record any marked intensification in the band of geomagnetic pulsations, whereas clear - cut Pi2 were observed at st. Sodankyla. This might indicate that the source size of the high-latitude Pi2 pulsations are limited longitudinally, and are determined by the longitudinal size of the zone of synchronous development of a substorm.

Thus we can suggest that during the development of the substorm active phase in mid-latitudes Pi2 pulsations are observed on a global scale, whereas in high latitudes the Pi2 source size is limited in longitude.

CONCLUSIONS

Our investigations permitted us to reveal new, formerly unknown, regularities in the excitation of geomagnetic pulsations Pi2 during a substorm:

- a steady midday maximum in the diurnal variation of the Pi2 occurrence frequency is observed;
- the meridional distribution of the daytime Pi2 amplitude has its maximum at the latitude of plasmapause projection onto the ground;
- the excitation of Pi2 pulsations at mid-latitudes has a global character in the same band of periods; at the same time, in the auroral latitudes the longitudinal source size of these pulsations is significantly smaller, and the spectrum has a noisy character;
- the onset time of a maximum amplitude in Pi2 pulsations at mid-latitude stations varied from a few fractions of a second to several tens of seconds, and these delays did not show any definite tendency.

Results of our investigations suggest the conclusion that the plasmapause and the plasmasphere have an important role for the formation of the Pi2 pulsation source in mid-latitudes.

One cannot rule out the assumption that a secondary source of waves, the so-called global mode, is formed at the plasmapause or in the plasmasphere under the action of impulsive substorm disturbances [5].

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