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Some Characteristics of pc-1 Micropulsations

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Abstract

Since the IQSY we have observed pc-1 micropulsations at Memambetsu and Kanoya. In the present paper, some characteristics of pc-1 micropulsations observed in pre-IASY period (June 1967~May 1969) at Memambetsu are described and compared with those in IQSY period (April 1964~March 1966). Future plans on the research using IASY data are also described.

§1 Introduction

pc-1 micropulsations have been observed by many research workers. From those observations various interesting results are obtained about the characteristics of the micropulsations. However the period of observation are no more than about ten years and no decided interpretation is given for the origin and propagation. Therefore it may be necessary to carry out emphatically the observation of the micropulsations in the present IASY. In our research plan of pc-1 micropulsations in the IASY period the following characteristics will be mainly investigated.

i) Characteristics of occurrence in middle and low latitudes; the diurnal and annual variations of occurrence frequency.

ii) Behaviers of center frequency and spacing.

iii) Characteristics of polarization.

iv) Relation between the micropulsations and the other phenomena in solar-terrestrial physics.

v) Solar-cycle dependence of the above characteristics.

From results of the investigation it may be expected to classify the micropulsations with period of pc-1 range into some different types morphologically. After that their mechanisms of genesis and propagation of the micropulsations may be able to be discussed.

Since the IQSY the following two continuous observations have been carried out at our observatories; ULF-range (0.01 Hz~3 Hz) geomagnetic micropulsations at Memambetsu and Kanoya and ELF-range micropulsations at Kakioka. In the present IASY micropulsations in ULF-range are observed at Memambetsu, Kakioka, Kanoya and Chichijima in Ogasawara Islands. While the observation of ELF-range micropulsations is carried out at Kakioka, Chichijima or temporary sites as their suitable reference point.

The measuring devices in the IQSY are used again in the present observation. The apparatus used in measurement of ULF-range micropulsations consists of high-mu metal-cored coils, chopper-type dc amplifiers and pulse-width-modulation-type data-recorder. On the other hand the similar coils, amplifiers and amplitude-modulation-type data-recorder are applied to observation of ELF-range micropulsations. Details of these devices and some of the observational results have been reported already (Kawamura and Kashiwabara, 1965; Kawamura, 1970; Kondo, 1966 and Yanagihara, 1966 and 1968). In the present paper statistics and spectral analysis of pc-1 micropulsations observed at Memambetsu in the pre-IASY period from June 1967 to May 1969 are mainly discussed.

Particularly, diurnal and annual variations of occurrence frequency, the diurnal variation of center frequency of the micropulsations and their solar-cycle dependencies are investigated. One of the most interesting results is the clear solar-cycle dependence of center frequency. The center frequency in the IQSY period (April 1964~March 1966) is about 0.5 Hz. While in the present pre-IASY it increases remarkably to about 1.0 Hz.

§2 Characteristics of pc-1 micropulsations

1) Local-time dependence of occurrence frequency

Local-time dependence of occurrence of pc-1 micropulsations shows very similar appearance in two intervals, IQSY (1964~1966) and pre-IASY (1967~1969). In Fig. 1 the local-time dependence is illustrated. The upper and lower diagrams show the diurnal

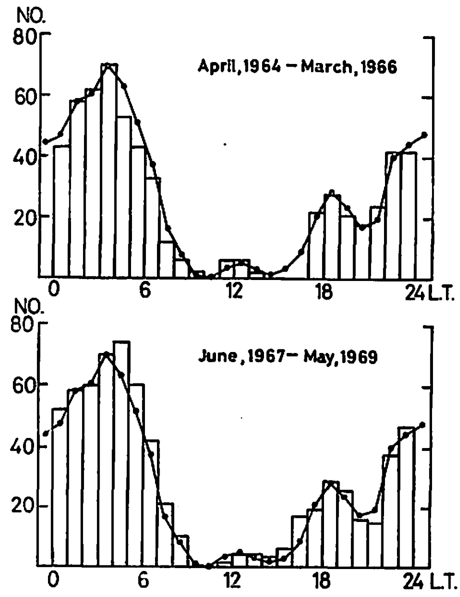


Fig. 1. Diurnal variations of occurrence frequency of pc-1 observed in IQSY (April 1964—March 1966) and pre-IASY (June 1967—May 1969) periods at Memambetsu.

variations of occurrence frequency in the IQSY (April 1964~March 1966) and in the pre-IASY (June 1967~May 1969) periods, respectively. In these diagrams, each dot is mean value of hourly occurrence frequencies in the two periods. It seems that the profile of the local-time dependence in each of two periods, IQSY and pre-IASY, is very similar. Generally pc-1 micropulsations occur in night-hours in lower latitudes. The diurnal variation of occurrence frequency shows a distinct maximum in early morning (about 4h LT) and a secondary small one after sunset (about 19h LT). The principal maximum may be explained by the ionospheric screening effect in the first approximation. However it is rather difficult to explain the secondary evening maximum observed in both periods, IQSY and pre-IASY.

Kokubun and Oguti (1968) and Hirasawa and Nagata (1966) showed typical dynamic spectrum of geomagnetic micropulsations in auroral region with data obtained at Syowa Base in Antarctic. They classified pc-1 micropulsations into three different types: pearls, sweeper and hydromagnetic chorus. The center frequency in the present observation is somewhat different from that of sweeper (IPDP) in auroral region. However it is well known that the occurrence of the sweeper in the auroral region concentrates in evening hours. Therefore it may be deduced that sweeper-like micropulsations are partly included in our secondary maximum. The profile of the local-time dependence of occurrence frequency of pc-1 micropulsations differs with considerable contrast from that in auroral and polar region (Campbell and Stiltner, 1965). Namely the time of maximum occurrence of pc-1 in so-called auroral oval is usually in the daytime. While in lower latitudes the micropulsations are almost night-hour events. Actually the maximum is observed hours before sunrise in the present measurement. It is also fairly difficult to explain the above distinct contrast.

Pc-1 micropulsations are rather rare events in middle and low latitudes. While they occur very frequently in the auroral region. In addition the micropulsations show very distinct conjugacy in the northern and southern hemispheres. In other words it seems that only a part of pc-1 micropulsations is capable to propagate from auroral region to middle and low latitudes. If the micropulsations are observed in middle latitude, they will occur also simultaneously in longitudinally and latitudinally wide regions containing auroral oval. Their spectral structures are also very similar. In lower latitudes structure doubling is observed occasionally. It seems that it is suggested from the above facts that there are some different types in the micropulsations. They perhaps have different mechanism of genesis and propagation. In future morphological works the micropulsations should be firstly classified into the above some types. In other words more strict analysis should be based upon the classification. However in the present analysis observed micropulsations are not classified but summerized as pc-1, because available data are not so much. From comparison between observational data obtained in the two periods it may be suggested that the occurrence frequency of the micropulsations in geomagnetic active years, 1967–1969, is somewhat higher specially in several hours after morning maximum than that in quiet years, 1964–1966. It seems that the facts corresponds to the characteristics of diurnal variation of center frequency and its solar-cycle dependence as described later. The solar-cycle dependence shows also similar profile to that of pc-3 (Kawamura, 1969).

2) Diurnal variation of frequency

In respect of distinct pc-1 micropulsations observed in the pre-IASY period (June 1967~May 1969) at Memambetsu the traces of center frequency read from corresponding sonagrams are summerized in Fig. 2. There are some cases that the micropulsations

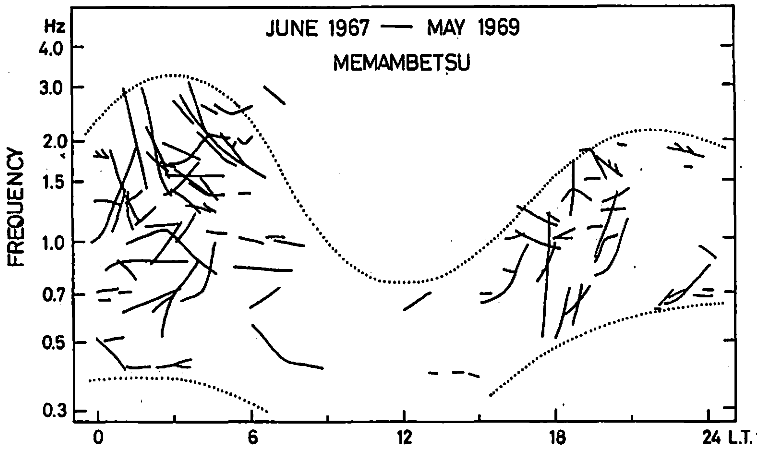


Fig. 2. Local-time dependency of center frequency of pc-1 observed in pre-IASY period at Memambetsu.

with fairly high Q-value are observed occationally. But generally the micropulsations show broad-band structure. They are sometimes observed as superposition of a few bands having descrete center frequencies. Most long-lasting pc-1 micropulsations may be also regarded as succession of sub-series whose durations are at most a few ten minutes. As it is difficult to define the representative center frequencies in these cases, roughly averaged values are used for the center frequency.

As shown in this figure the profile of center frequency of each individual event is very complicated and distribution is also dispersive but as a whole the envelopes of the distribution show clear diurnal variation as given by dotted curves. However many events showing sharp increase or decrease of center frequency are observed in the present investigation. Particularly the events with the above tendency are observed usually at about 20h and about 2~3h LT. So that they may include the events similar to so-called sweeper observed generally in auroral region. Moreover there are some micropulsations which show the spectral microstructure of clear dispersive type besides the above sharp change of frequency. Examples of various types are shown by sonagrams in appendix.

As a whole pc-1 micropulsations show clear diurnal variation of center frequency as represented by dotted curves in Fig. 2. The variation corresponds closely to diurnal variations of occurrence frequency and amplitude. In order to illustrate the above fact

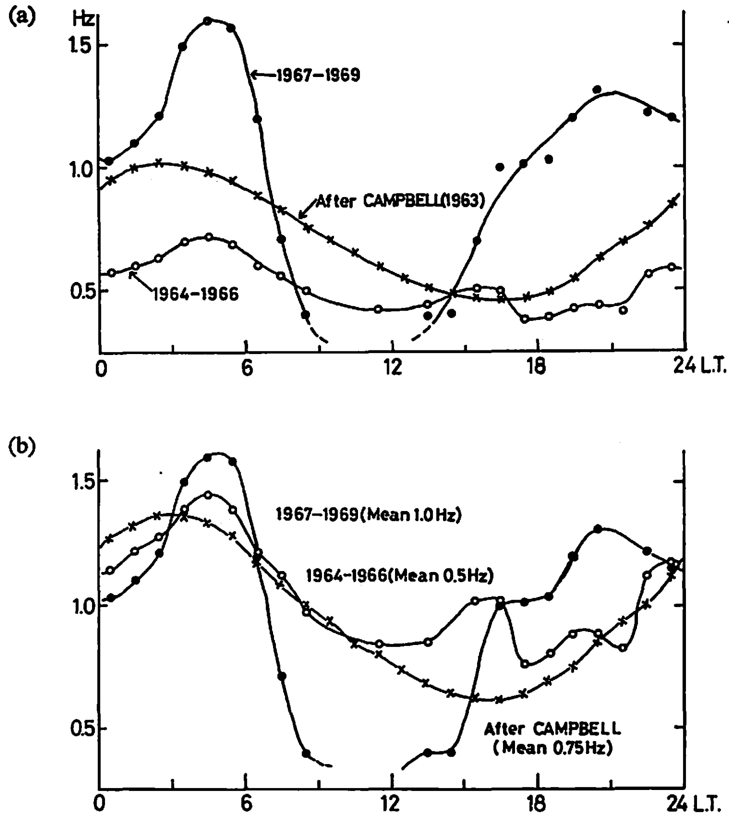


Fig. 3 (a) Diurnal variation and (b) variation ratio of hourly mean center frequencies in IQSY and pre IASY periods at Memambetsu and Campbell's result in higher latitudes.

hourly mean values of center frequency obtained from the distribution in Fig. 2 are given by black dots in Fig. 3 (a) and (b). Hollow circles are the same values in the IQSY period (April 1964~March 1966). And cross marks show the same hourly mean frequencies obtained by Campbell (1967) from his observations in higher latitudes. Fig. 3 (a) and (b) show diurnal variations of original mean center frequency and of normalized one by daily mean value, respectively. Daily mean values of center frequency increased from about 0.5 Hz in 1964~1966 to about 1.0 Hz in 1967~1969. While it was about 0.75 Hz in Campbell's results. Three curves in Fig. 3 are roughly similar. But in afternoon hours there is considerable discrepancy among these curves. At present the cause of the discrepancy may not be explained, because our available data are too incomplete to point out whether the discrepancy is essential or not.

It should be noticed that the diurnal variations of center frequency are almost similar in both auroral region and lower latitudes but the variations of occurrence frequency are quite different between the above two regions. Moreover it is one of important results that the center frequency fairly increases together with solar activity. The author (Kawamura, 1969) investigated solar-cycle- and Kp-dependencies of period of pc-2, 3 observed at Memambetsu for about 10 years from July, 1957 to December, 1966. He described that the period showed some distinct solar-cycle- and Kp-dependencies. Annual mean period changed considerably from about 18 sec for the earlier five active years (1957~1961) to about 27 sec for the latter five quiet year (1962~1966). While mean period for each Kp-value also decreased gradually from about 30 sec at Kp = 0 to about 15 sec at Kp = 8. It is very interesting that the period of pc-1 shows similar tendency to that of pc-2, 3 about the above dependencies. While amplitude of pc-1 micropulsations is not so minutely investigated. However diurnal and annual variations of amplitude of the pulsations perhaps show similar characteristics to those of their occurrence frequency.

3) Other characteristics

Annual variation of occurrence frequency. Annual variation of occurrence frequency of pc-1 is fairly different in each year. In Fig. 4 the annual variations in both IQSY and pre-IASY periods are shown. The occurrence of pc-1 concentrates rather in several special intervals. Wentworth (1964) and the auther (Kawamura, 1970) pointed out previously that pc-1 micropulsations occur successively in continuous calm nights after large geomagnetic activity such as storm. As a whole it is also clear from data obtained in and after the IQSY that the maxima occur generally in equinoxial months.

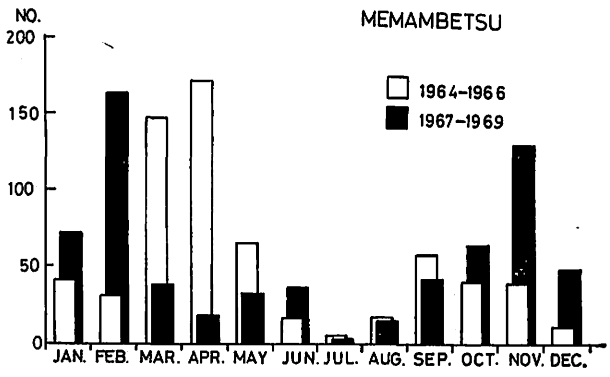


Fig. 4. Monthly occurrence frequency of pc-1 in IQSY and pre-IASY periods of Memambetsu.

Occurrence of pc-1 and geomagnetic activity. As well-known there is some correlation between occurrence of pc-2, 3 and geomagnetic activity. While in respect of pc-1 micropulsations it is not so clear. Actually no decided difference of total occurrence between our two periods, IQSY and pre-IASY, is confirmed.

In the present paper no detailed analysis about these characteristics will be carried out. However it may be concluded that its annual variation in each year is also related to the corresponding variation of geomagnetic activity.

Therefore it may be deduced that the occurrence in magnetosphere is related closely to geomagnetic activity but its propagation to the earth's surface in lower latitudes is fairly controled by the ionospheric condition. As the condition of ionospheric duct in F-region may be very disturbed in storm time the micropulsations perhaps become hard to propagate to lower latitudes.

§3 Conclusions

The following interesting conclusions may be derived from the present investigation of pc-1 micropulsations observed at Memambetsu in both IQSY and pre-IASY periods:

1) The center frequency of pc-1 fairly increases together with solar activity.
2) The diurnal variations of center frequency in different latitudes or in different solar activities are similar in general trend.
3) The diurnal variations of occurrence frequency in both periods, IQSY and pre-IASY are very similar.
4) Pc-1 micropulsations should be classified morphologically into some different types.

§4 Future investigations

In future works of geomagnetic micropulsations, specially ULF in pc-1 frequency range and sub-Schumann ELF, the following investigations should be carried out.

1) Diurnal and annual variations of occurrence frequency, center frequency and others as well as their relations to geomagnetic activity,
2) spectral microstructure on sonagram and its latitudinal and local-time dependencies,
3) worldwide comparison of occurrence characteristics,
4) conjugacy in northern and southern hemispheres, for instance structure-doubling and 180° phase shift and
5) correlation between ULF and ELF events

should be investigated first statistically. According to the above investigations.

6) these ULF and ELF micropulsations

should be classified morphologically. Under the classification.

7) magnetospheric origin and its responsible instability,
8) mechanism of resonance,
9) path of propagation and its ionospheric control for each micropulsation

should be considered theoretically.

Therefore in the present IASY we will observe simultaneously these ULF and

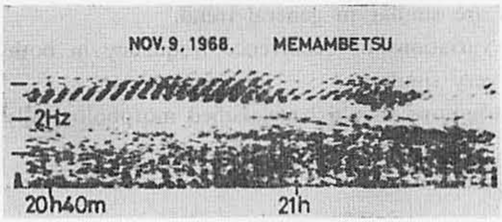
ELF micropulsations at fairly widely-distributed our stations, Memambetsu, Kakioka, Kanoya, Chichijima and others, in some selected intervals.

Acknowledgement

The authors wish to thank Dr. K. Yanagihara, Director of the Kakioka Magnetic Observatory, for his helpful advice.

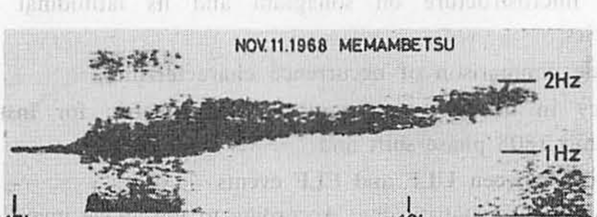
Appendix

Several interesting sonagrams of pc-1 events are shown in the following photographs. They are selected from those which show various characteristic traces of center frequency, as illustrated in Fig. 2.



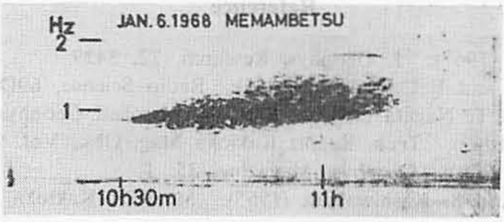
Photograph 1.

This is a part of sonagram of long lasting pc-1 event recorded on Nov. 9, 1968 at Memambetsu. This event shows the typical feature of clear funshaped microstructure with wide frequency band, of pc-1. The center frequency is about 2.7 Hz. This value is considerably higher than that of of usual pc-1.



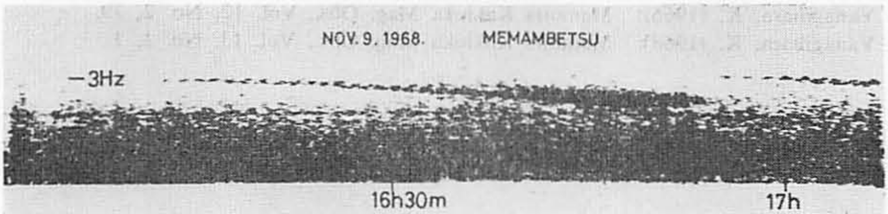
Photograph 2.

In this sonagram very intense sweeper-like micropulsation observed on Nov. 11. 1968 at Memambetsu is shown. The event shows outstanding burst-type onset together with abrupt increase of back-ground geomagnetic activity at about 15:11. It may be also noticed that the event is preceded by week well-structured micropulsation, pearls. In this event center frequency increases from 1 Hz at the onset to about 2 Hz after an hour but microstructure is not so clear.



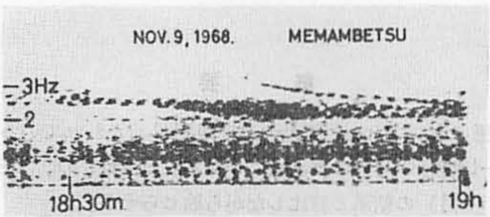
Photograph 3.

This sonagram is an example of isolated pc-1 event with very short duration observed on Jan. 8. 1968 at Memambetsu. This event also shows fairly sharp increase of center frequency and broad-band structure.



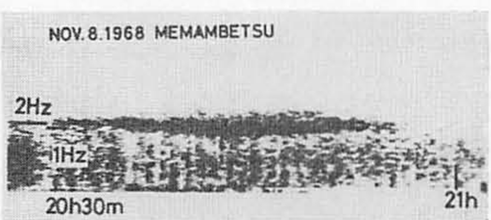
Photograph 4.

This is the sonagram of long-lasting pc-1 event recorded on Nov. 9. 1968 at Memambetsu. This event shows a linear decending of the frequency as well as very narrow frequency band. But rather clear microstructure may be seen.



Photograph 5.

This is another part of the same pc-1 event as shown in photograph 1. In this sonagram rather exponentially decending feature with very narrow frequency band can be seen. The spectral microstructure is fairly clear. In other wards it seems that the event shows a falling-tone dispersion similar too VLF whisther.



Photograph 6.

This sonagram is of the isolated pc-1 event recorded on Nov. 8. 1968 at Memambetsu. This event shows abrupt change of lower cut-off frequency.

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pc-1 脈動の特性について

河村　譜・佐野幸三

概　要

IQSY 以来女満別，鹿屋において pc-1 脈動の連続観測が行なわれている。この論文では，pre-IASY 期間（1967年 6 月―1969年 5 月）に女満別で観測された pc-1 の二，三の特性について IQSY 期間（1964年 4 月―1966年 3 月）の結果と対比しながら論じらそる。

最後に IASY における観測及び研究のねらいについて述べる。