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Magnetic Pc 5 Pulsations Associated with Periodical Particle Precipitation

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Abstract

A degree of the contribution of the periodically precipitating charged particles to the generation of Pc5 is investigated using the data observed at Syowa Base ($\phi_m = 69.6$) in 1968. As a result of the analysis it is supposed that the periodically precipitating particles can contribute to Pc5 as secondary effect, although the main cause of Pc5 may be the hydromagnetic wave.

Additionally the substorm is examined as a possible source of the hydromagnetic wave which is the main cause of Pc5 and the related particle precipitation.

1. Introduction

A number of papers have been published by many workers on magnetic Pc5 pulsations (abbreviated to Pc5 hereafter). Most of them have proposed the hydromagnetic wave as a possible cause of Pc5 (Dungey, 1954; Kato and Watanabe, 1956; Obayashi and Jacobs, 1958; Jacobs and Sinno, 1960; Westphal and Jacobs, 1962; Nagata et al., 1963; Saito, 1964; Jacobs and Watanabe, 1964; Kokubun et al., 1965; Troitskaya and Gul'elmi, 1967; Saito, 1969; Hirasawa, 1970).

On the other hand Sato (1962, 1964) found that Pc5 at College was sometimes concurrent with the local fluctuation of the cosmic noise absorption. Similar facts have been also reported by Saito et al. (1974). Because of the coincidence of Pc5 and the cosmic noise fluctuation the periodical particle precipitation was proposed, instead of the hydromagnetic wave, as a cause of high latitude Pc5 (Sato, 1964). Concerning a degree of the contribution of the particle precipitation to Pc5, there is no established analysis. Whether the main cause of Pc5 is the particle precipitation or not is a question.

A purpose of this paper is to investigate a relation between Pc5 and the periodical particle precipitation and to clarify a degree of the contribution of the precipitating particles to Pc5. This problem will be discussed in sections 2 and 3. Another purpose of this paper is to examine a source of the cause of Pc5 or the related precipitating particles. This problem will be discussed in section 4. A possible process concerning their generation will be proposed in section 5.

In investigation of the relation between Pc5 and the precipitating particles, it is most convenient to use the data observed at high latitude station like Syowa Base ($\phi_m = 69.6$), where both phenomena occurr most frequently. The ordinary magnetograms at Syowa Base are used for identification of Pc5. The data of the cosmic noise absorption which have been recorded by the riometer at Syowa Base are used for identification of the particle precipitation, because of its profits that the riometer have always patrolled the particle precipitation continuously and its data are easely compared with other ones, magnetograms for example. Various kinds of magnetic pulsations at Syowa Base have been also recorded on the magnetic tape by the induction magnetometer and they are analyzed by means of a new type analyzer. In addition the rapid run magnetograms at Reykjavik, which is the magnetically conjugate station of Syowa Base, and those at Memambetsu, Kanoya, Fredericksburg, Ashkabad and Onagawa, which are middle or low latitude stations, are also used. The geographic and the geomagnetic latitudes and longitudes of those stations are shown in Table 1.

Table 1. The locations of the station used in this analysis.

	Geographic		Geomagnetic	
	lat.	long.	lat.	long.
Syowa Base	S 69°02′	E 39°36′	-69.6°	77.1°
Reykjavik	N 64°11′	W 21°42′	70.3°	71.6°
Memambetsu	N 43°55′	E 144°12′	33.8°	208.4°
Onagawa	N 38°26′	E 141°28′	28.1°	206.8°
Fredericksburg	N 38°12′	E 282°30′	49.7°	349.6°
Ashkabad	N 37°57′	E 58°06′	30.4°	133.2°
Kanoya	N 31°25′	E 130°53′	20.3°	198.0°

In the present analysis magnetic local time (abbreviated to MLT) is mainly used for a time indicator, although local time (abbreviated to LT) or universal time (abbreviated to UT) are also used as occasion demands. At Syowa Base MLT is approximately equal to UT (UT = MLT) and LT proceeds three hours than MLT (LT = MLT + 3h).

A digital method is used to investigate the relation between Pc5 and the particle precipitation. Original analog data are converted to digital data at every thirty seconds both for magnetograms and records of the riometer, and high frequency components are filtered by the running average. An example of the high pass filtered digital data is shown in Fig. 2, which is obtained from the phenomena in 0556–0615 MLT of Fig. 1. Using such data as shown in Fig. 2 the relation between two phenomena is examined quantitatively. For analysis of various kinds of magnetic pulsations, high speed spectrum

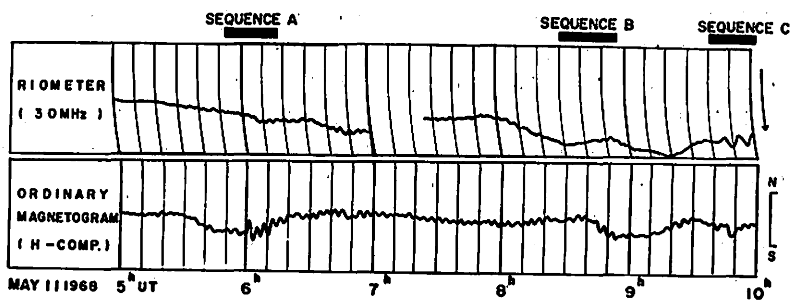


Fig. 1. An example of concurrent oscillation of Pc5 and cosmic noise absorption observed at Syowa Base on May 11 of 1968. Upper part; Record of riometer at 30 MHz, Lower part; Ordinary magnetogram.

analyzer (abbreviated to hissa hereafter) is used. Because hissa has many profits such as being able to make wide frequency band dynamic spectrum very speedily and etc. (Saito et al. 1971).

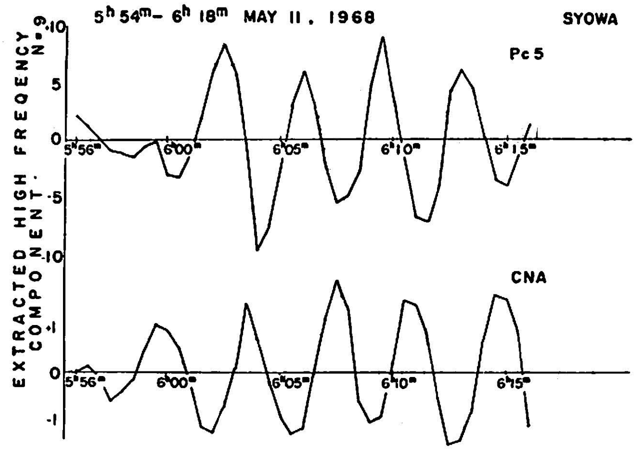


Fig. 2. Extracted high frequency components of magnetic field variation (upper part) and cosmic noise absorption (lower part).

2. Case study of the relation between magnetic Pc5 pulsations and ionospheric CNA pulsations

One example of the clear correlation between Pc5 and ionospheric CNA pulsation (abbreviated to CNA hereafter) which is a sign of the periodical particle precipitation is shown in Fig. 1. The correlation is most clear from about 06h to 08h MLT. From the fact that there are examples of the very clear correlation such as that shown in Fig. 1, the question whether the main cause of Pc5 is the periodical precipitation of charged particles or not arises. If the periodical particle precipitation plays a roll of the main cause of Pc5 as proposed by Sato (1964) (called model A), CNA has to be observed whenever Pc5 appears. On the contrary, if not the particle precipitation but any other one (hydromagnetic wave for example) is the main cause of Pc5 (called model B), Pc5 and CNA don't necessarily appear concurrently. At any rate, the examination of observational facts on the periodical particle precipitation cannot be ignored when a cause of Pc5 is discussed.

In order to estimate the contribution quantitatively the digital method is applied for several intervals of Fig. 1, sequence A (0554–0618 MLT), sequence B (0830–0858 MLT) and sequence C (1940–1005 MLT) and additionally for 1208–1216 MLT of the same day. Fig. 3 shows the computed auto-correlation functions which indicate a degree of the periodicity of the phenomena and the cross-correlation function for Pc5 and CNA. In sequence A both Pc5 and CNA show a high maximum auto-correlation value greater than 0.8, indicating their good periodicity. The cross-correlation function also shows a

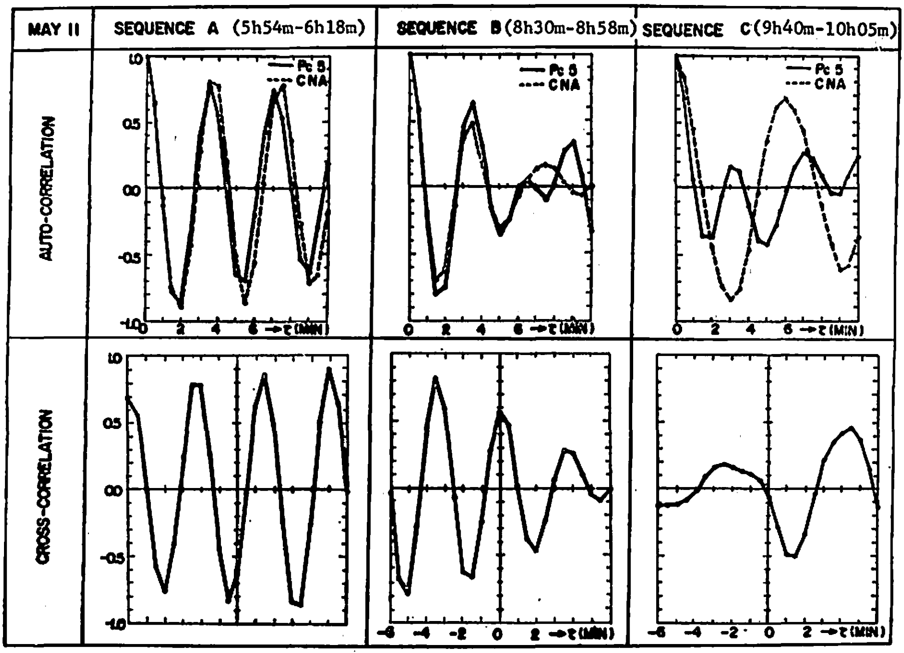


Fig. 3. Auto-correlation functions (upper part) and cross-correlation functions (lower part) for the event shown in Fig. 1.

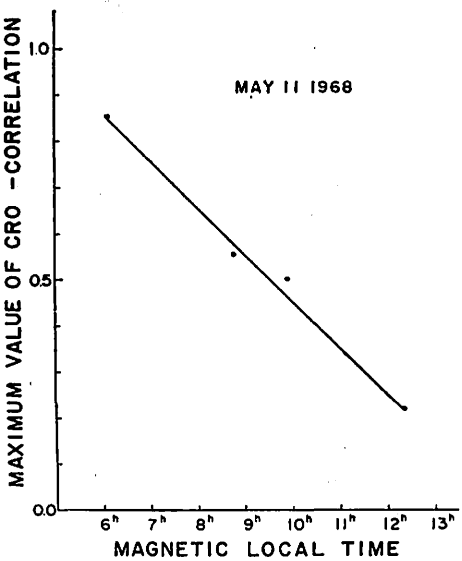


Fig. 4. Maximum value of cross-correlation function on May 11 event decreasing magnetic local time.

high peak value greater than 0.8, indicating their close correlation. Later hours in sequence B (0736–0800 MLT), though Pc5 and CNA have occurred concurrently, their amplitude are smaller than those in sequence A especially for CNA, and both phenomena are a little disturbed. The disturbance of the waveform is recognizable with the auto-correlation functions in Fig. 3, where their maximum auto-correlation values in sequence B are about 0.6 for Pc5 and 0.5 for CNA respectively being smaller than those in sequence A indicating a somewhat less periodicity. Nevertheless there is still a rather good cross-correlation of about 0.6 between Pc5 and CNA. In sequence C (0940–1005 MLT), about one hour after sequence B, the cross-correlation is poor though Pc5 and CNA have occurred again concurrently. As time is progressing from the morning to the late hours, the correlation between Pc5 and CNA is getting poorer as shown in Fig. 4. In other words, the cross-correlation seems to have MLT dependence as far as May 11 event concerns.

Concerning Apr. 27 event the correlation between Pc5 and CNA is shown in Fig. 5. On the magnetogram of Fig. 5, Pc5 starts with sinusoidal waveform at about 0450 MLT but there was no CNA during the following two hours. CNA began at about 0710 MLT and simultaneously the waveform of Pc5 became a little disturbed. The maximum auto-correlation value of Pc5 in sequence A is greater than 0.65, indicating its relatively high periodicity, on the contrary the one in sequence B is about 0.3, indicating its poor periodicity (Fig. 6). In spite of less periodicity in sequence B, the correlation between Pc5 and CNA is still maintained supported by the maximum correlation value of about 0.7. The appearance of CNA disturbs the waveform of Pc5, in other words the particle precipitation modulates Pc5. The modulation of Pc5 caused by CNA may be a evidence for the idea that periodically precipitating particles are contributing to Pc5 through inducing the periodical current in the ionosphere. Pc5 in sequence A of Fig. 5 seems to be independent of CNA occurrence at the same place. But there is still a possibility that CNA may be found at other places near Syowa Base, because the occurrence area of the particle precipitation is thought to be narrower than that of Pc5 (Parks, 1967). In order to examine the possibility of CNA occurrence in sequence A of Fig. 5, the pattern of the diurnal variation of CNA intensity in the northern auroral zone (Shephered et al. 1969) is shown in Fig. 7, which is indicated by LT (at Syowa Base LT = MLT + 3h). Around 09h–10h LT which is 06h–07h MLT of sequence A, CNA has a high intensity.

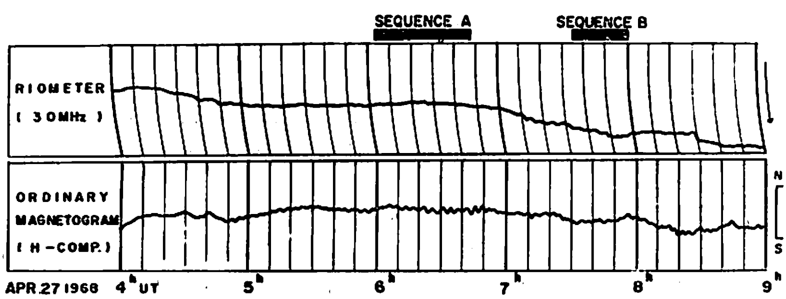


Fig. 5. Record of riometer at 30 MHz (upper part) and ordinary magnetogram (lower part) on April 27 of 1968. (Morning side).

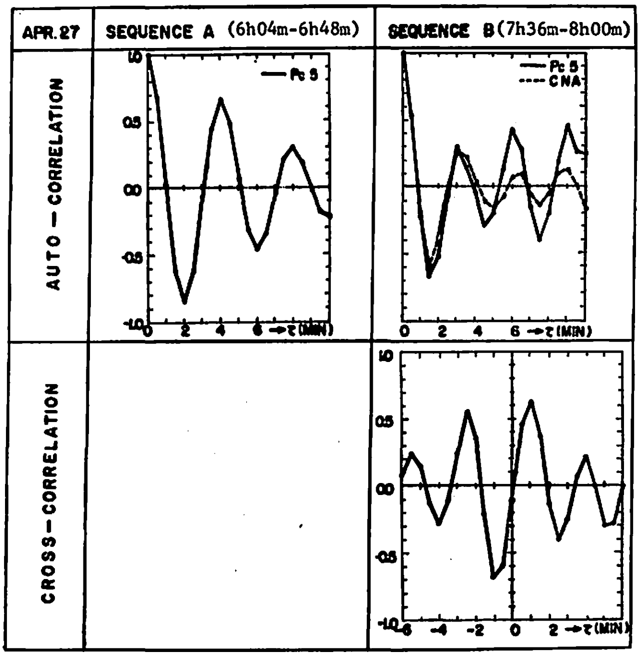


Fig. 6. Auto-correlation functions (upper part) and cross-correlation function (lower part) for the event shown in Fig. 5.

From this statistical result a high possibility of CNA occurrence is expected in the auroral zone at the time of sequence A of Fig. 5 although there is no CNA at the single place of Syowa Base. Therefore this example of sequence A doesn't necessarily show the independent occurrence and it is better to reexamine it by data in the hours when the occurrence probability of CNA is minimum, for example 17h–21h LT (14h–18h MLT). Fig. 8 shows Pc5 which has occurred in the interval of 17h–18h LT (14h–15h MLT) and is not associated with CNA. The magnetic activity at the time is the same as that of the pattern shown in Fig. 7. Judging from the statistical result of Fig. 7, the possibility of CNA occurrence during the time of Fig. 8 is very low also at other places near Syowa Base. Therefore it is supposed that the Pc5 of Fig. 8 is an example independent one of CNA.

May 11 event of Fig. 1 and Apr. 27 event of Figs. 5 and 8 are examples taken from the moderately disturbed stage (Kp = 2–4). An example of quiet stage is shown in Fig. 9. Pc5 lasted for a long time from 0620 to 0940 MLT on Apr. 15 without CNA but with a small amplitude, which is nearly equal to the minimum criterion value for identification of Pc5 in the present analysis. At the quiet stage (Kp = 0–1), CNA occurrence is infrequent (Shephered et al. 1969). Therefore the possibility of CNA occurrence is low near Syowa Base also and this Pc5 may be not associated with CNA. An interesting characteristics is that the amplitude of Pc5 without CNA is small as far as Apr. 15 event concerns. At about 0950 MLT CNA begins suddenly and at the same time Pc5 is also

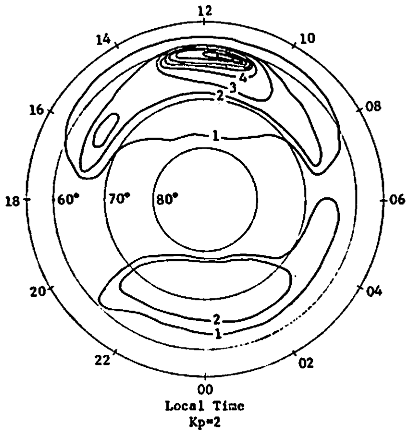


Fig. 7. The intensity of cosmic noise absorption as a function of geomagnetic latitude and local time. The outermost contour lines define the location of up to 1-db occurrences and successive inner contour lines define increasingly intense absorption occurrences in 1-db steps (after Shepherd et al. 1969).

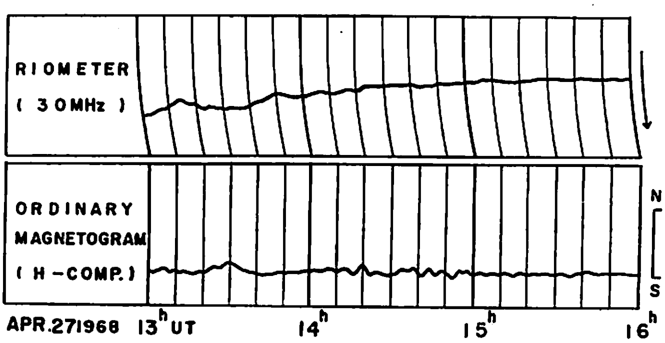


Fig. 8. Record of riometer at 30 MHz (upper part) and ordinary magnetogram (lower part) on April 27 of 1968. (Evening side).

suddenly enhanced from the small amplitude in the period of no CNA. Not only the modulation but also the enhancement of Pc5 by CNA may be a evidence for the idea that periodically precipitating particles are contributing to Pc5 through inducing the periodical current in the ionosphere.

The results from the case study are summarized as follows.

1) Sometimes the close correlation between Pc5 and CNA (the periodical particle

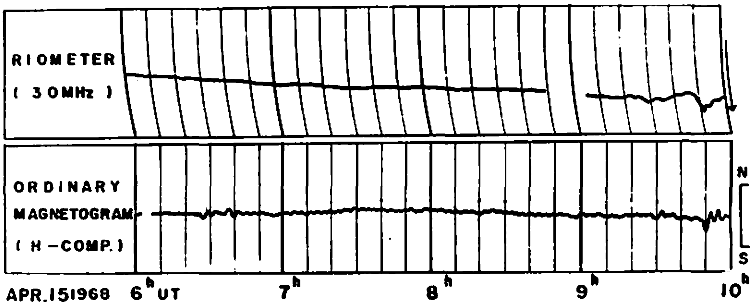


Fig. 9. Record of riometer at 30 MHz (upper part) and ordinary magnetogram (lower part) on Apr. 15 of 1968.

precipitation) exists and their maximum cross-correlations show high values, reaching greater than 0.8.

2) The precipitating particles contribute to Pc5 through the modulation as shown in sequence B of Apr. 27 event or the enhancement as shown at about 0950 MLT on Apr. 15.

3) Pc5 and CNA are most correlated in the morning hours but scarcely correlated in the afternoon hours. In other words the clear MLT dependence seems to exist on the correlation between Pc5 and CNA.

4) There exists a kind of Pc5 which is not associated with CNA, although the amplitude of such a Pc5 may be small.

The tendencies shown (1), (2), (3) and (4) will be proved by the statistical study in the next section.

3. Statistical study of the relation between magnetic Pc5 pulsations and ionospheric CNA pulsations

It has been reported that there is a distinct diurnal variation for Pc5 activity. The diurnal variation of Pc5 amplitude generally shows double maxima, one in the early morning and another in the evening. The morning maximum is much superior to the evening one at high latitude station like Syowa Base (Saito, 1964; Kokubun et al. 1965; Saito, 1969; Hirasawa, 1970).

Not only the amplitude but also the occurrence frequency of Pc5 shows the diurnal variation as shown in Fig. 10, which is obtained from data at Syowa Base. Identification of Pc5 is performed according to the criterion that the phenomenon has more than three wave trains and its peak-to-peak amplitude is greater than 10γ. Similar to the case of amplitude, the diurnal variation of Pc5 occurrence frequency shows also double maxima; the morning maximum is much superior to the evening one.

The histogram which expresses MLT dependence of the correlation between Pc5 and CNA is shown in Fig. 11. Pc5's which satisfy the said criterion are picked up from three months period of April, May and June and then those Pc5's are compared with the concurrent CNA events, where those not associated with any CNA have been excluded. The correlated in Fig. 11 means the case that Pc5 and CNA vary with nearly same periods together. The non-correlated means the case that Pc5 and CNA vary independently with different periods. The ratio of correlated case to non-correlated one is highest in the morning hours (06h–09h MLT), and very low from the afternoon to the evening. Especially in the interval 12h–15h MLT, the non-correlated case occurr very frequently, though concurrent occurrences are doubtlessly numerous. This statistical tendency supports the results 3) and 4) in the case study.

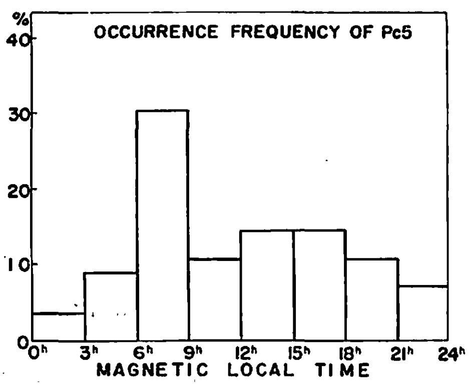


Fig. 10. Histogram of the occurrence frequency of Pc5 at Syowa Base on April of 1968.

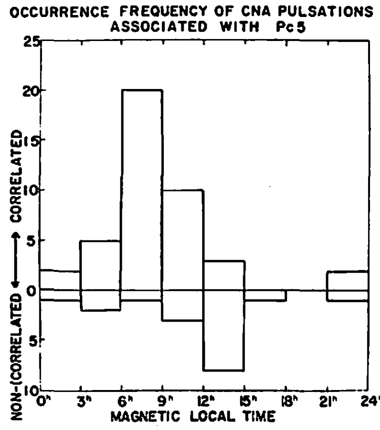


Fig. 11. Histogram of the correlated (upper part) and the non-correlated (lower part) between Pc5 and CNA at Syowa Base from April to June in 1968.

The correlation between the amplitude of Pc5 and that of the corresponding CNA is investigated and illustrated in Fig. 12 for those in the hours of the most frequent occurrence 06h–09h MLT in April, May and June. In this case all Pc5's have been selected, regardless of the concurrent occurrence of CNA. When CNA varies with a period different from that of Pc5, or when there is no CNA, zero is given for its amplitude. Considering the fact that the occurrence area of the particle precipitation is narrower than that of Pc5 (Parks, 1967), so two phenomena are not necessarily observed simultaneously at the same place even if they have occurred concurrently, the tendency found in Fig. 12 indicates a comparatively possitive correlation. It is supposed that the higher the activity of Pc5 becomes, the larger the amplitude of the associated CNA grows. On the contrary the amplitude of Pc5 associated with the small amplitude CNA or not associated with CNA is small, and this tendency supports the result 4) in the case study. The fact that there exists a kind of Pc5 which is not associated with CNA contradicts model (A) and is favourable for model (B), in which the main cause of Pc5 is supposed to be hydromagnetic wave. The hydromagnetic wave may cause the periodical particle precipitation as well as Pc5. The periodically precipitating particles will induce the periodical current in the ionosphere and this current may modulate or enhance Pc5. As

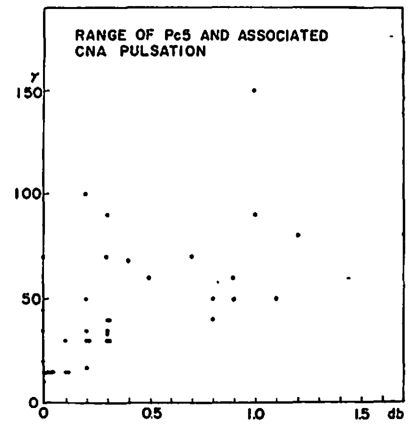


Fig. 12. The correlation between the range of Pc5 and that of correlated CNA at Syowa Base from April to June in 1968.

a secondary effect the precipitating particles may contribute to Pc5. Statistical results of the correlation support this idea.

In addition it becomes clear that the morning hours (06h–09h MLT) is the most important and the most convenient period in investigating a source of Pc5 and the associated periodically precipitating particles.

4. The morning side Pc5 and other magnetic phenomena

In order to search the origin of Pc5, it may be useful to investigate simultaneous magnetic phenomena. When Pc5 is strong and associated with CNA in the morning hours (06h–09h MLT), many kinds of magnetic pulsations occur in the hours and before.

Diurnal occurrence pattern of magnetic pulsations including Pc5 is summarized in Fig. 13, in which the results of Pi2, Pi(c) and Pc3 are referred to McPherron et al. (1968) and that of Pid is referred to Morioka et al. (1971) respectively. LT is used in the figure instead of MLT (LT = MLT + 3h at Syowa Base). According to the statistical pattern, occurrences of the morning side Pc5 are situated in the boundary hours between Pi(c) and Pid. Though the occurrence hours of Pi2 are separated from those of the morning side Pc5, occurrences of the two phenomena seem to be not independent as several Pi2's have usually occurred before the onset of Pc5. Fig. 14 shows time lags between the Pi2's and the Pc5 for thirteen damped type Pc5's whose commencement is clear enough to find the onset time. Those Pc5's are well correlated with CNA. Pi2 occurs essentially at the same time of the beginning of the substorm and these two phenomena are in one-to-one relation together (Saito, 1969). Pi(c) is thought to be caused by the precipitations of energetic particles which have been produced during the progress of a substorm. The activity of Pi(c) on the dynamic spectrum is in proportion to the intensity of the substorm, so the change of Pi(c) shows the rising or falling of the substorm activity (Heacock, 1967). In other word Pi2 and Pi(c) are considered to be phenomena representing the behaviour of the substorm. Pid is also called as magnetic impulses because of its sudden appearance and noisy waveform. Pid, which is the day side phenomena occurring mainly at 05–13h MLT (08–16h MLT), seems to have its source in a substorm which occurs in the night side. High energetic electrons generated during the progress of the substorm drift eastward along L shell from the night side to the day side, via the morning side. From the day side magnetosphere those electrons precipitate into the ionosphere intermitently to cause Pid (Morioka et al. 1971). Pid is also the phenomena closely associated with the substorm.

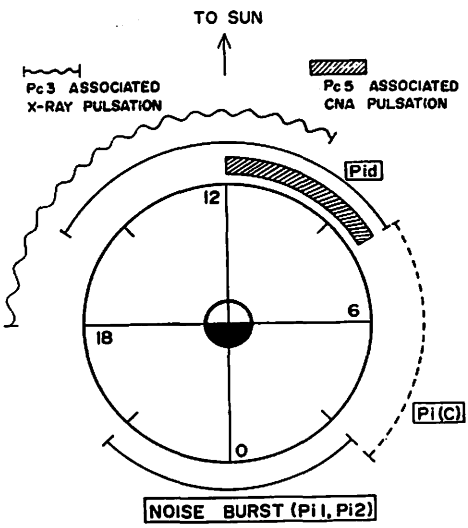


Fig. 13. Summary of diurnal occurrence pattern for magnetic pulsations. Pi2, Pi(c) and Pc3 are referred to McPherron et al. (1968) and Pid to Morioka et al. (1971).

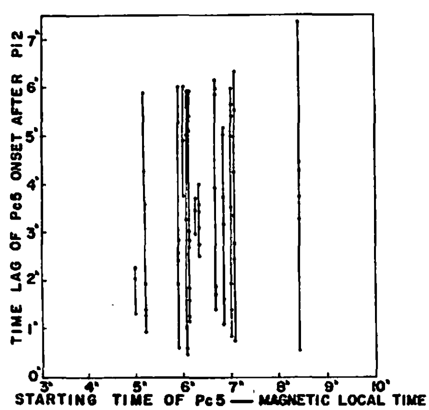


Fig. 14. Time lag of Pc5 from Pi2's arranged according to the starting time of Pc5. Thirteen Pc5's are of clear damped type taken from three months from April to June in 1968 at Syowa Base. Preceding Pi2's are identified on the rapid-run magnetogram in the low or middle latitude stations.

The relation of occurrence between the morning side Pc5 and Pi2, Pi(c) or Pid are found more directely on a dynamic spectrum. Hissa is used for this purpose because it can display all kinds of magnetic pulsation, from Pc1 to Pc5, simultaneously and rapidly (Saito et al. 1971). The block diagram of hissa is shown in Fig. 15. The dynamic spectrum made by hissa is called hissagram.

The hissagram of Apr. 13 event is shown in Fig. 16 together with the magnetogram and the record of riometer. In the event Pi2 occurs at about 0120 MLT and 0300 MLT and the latter was followed by Pi(c) which continues till about 05h MLT. A negative

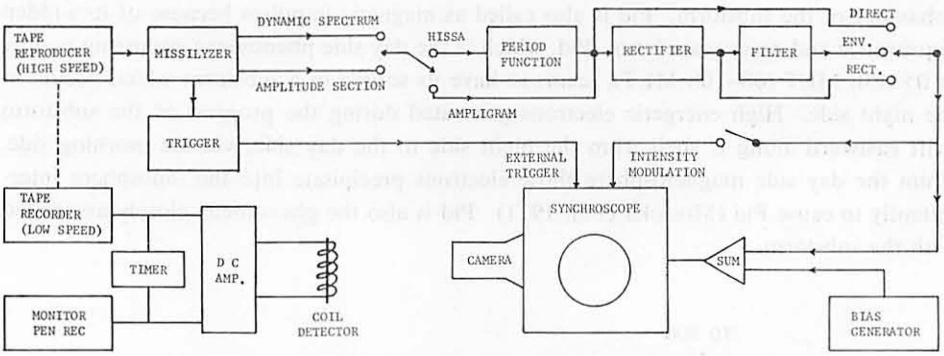


Fig. 15. The block diagram of hissa (high speed spectrum analyzer).

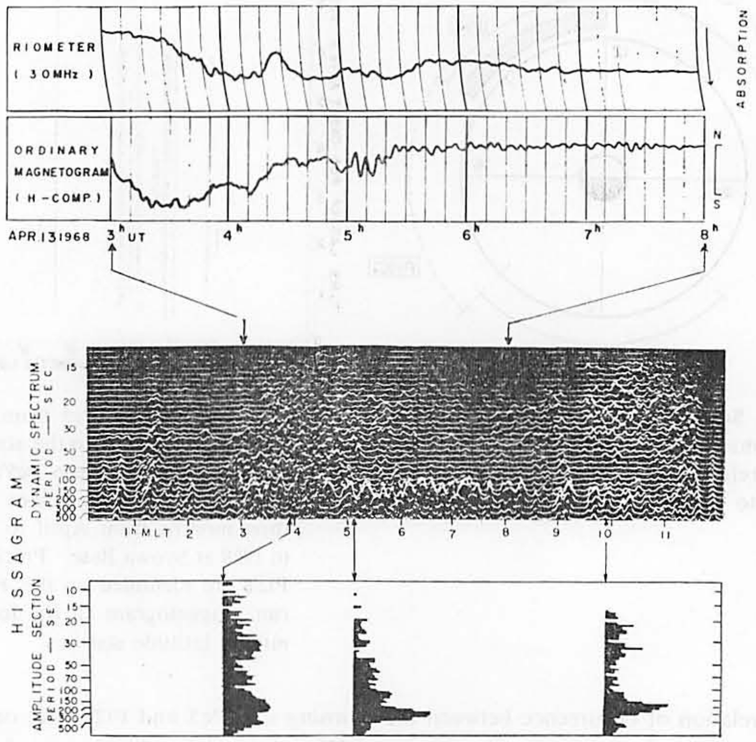


Fig. 16. Record of riometer at 30 MHz and ordinary magnetogram (upper) and hissagram (lower) on Apr. 13 of 1968.

bay (or a substorm) begins at 03h MLT on the magnetogram and then recovers at about 05h MLT coinciding with the decrease of Pi(c). At this time of the decrease of Pi(c), that is the stage of the substorm recovery, an intensified Pc5 occurs abruptly. CNA also occurs simultaneously suggesting the wave-particle interaction. Afterwards Pid begins at about 0930 MLT. Three amplitude sections of Fig. 16 show Pi(c) at about 0355 MLT, Pc5 at about 0510 MLT and Pid at about 0950 MLT respectively.

Another example is shown in Fig. 17, where the active Pc5 with the period around 200 sec is found from about 05h to 10h MLT on the dynamic spectrum of the hissagram.

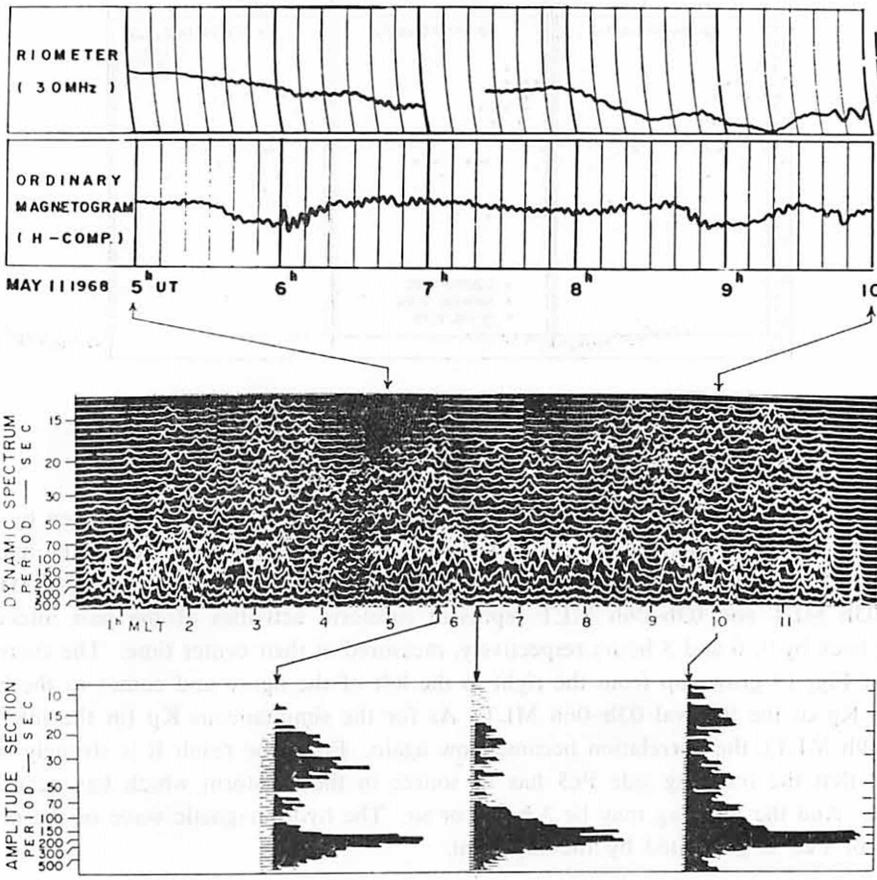


Fig. 17. Record of riometer at 30 MHz and ordinary magnetogram (upper) and hissagram (lower) on May 11 of 1968.

Preceding the Pc5, Pi2 has occurred at 0107 MLT and then Pi(c) has followed until about 04h MLT. The occurrence of the active Pc5 coincides with the recovery phase of the substorm judging from the decayed Pi(c). Pid occurs after 08h MLT, when Pc5 still continued. Three amplitude sections show Pc5 + decreasing Pi(c) at about 0545 MLT, the intensified Pc5 at about 0620 MLT and Pc5 + Pid at about 10h MLT respectively.

Occurrences of the morning side Pc5 seem to be related with Pi2, Pi(c) and Pid, at least in the shown hissagrams. If the relation is true in physical meaning, the source of Pc5 is supposed to be in the substorm because all of Pi2, Pi(c) and Pid are closely related with the substorm as said above. In this case a possitive correlation should be found between the activity of Pc5 and that of the substorm. To study the correlation it may be necessary to consider the time lag between Pi2 and Pc5 shown in Fig. 14 or the fact that the substorm may have been developed before. Fig. 18 shows the correlation

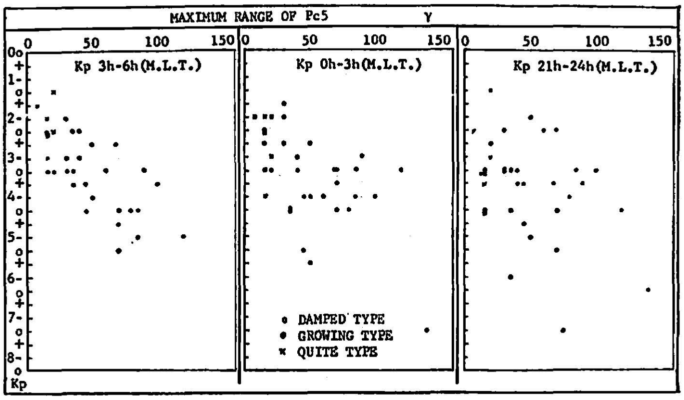


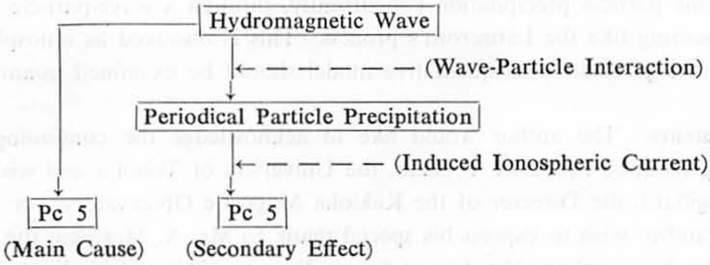
Fig. 18. The correlation between the maximum range (peak to pake amplitude) of Pc5 in 06h-09h MLT and Kp (the activity of the substorm) of the indicated intervals.

based on the shifted hours for the substorm activity. The activity of Pc5 is given by the peak to peak amplitude and that of the substorm is expressed by Kp-index in the figure. As the Pc5 is taken from the morning hours (06h–09h MLT), the Kp's of 21h–24h MLT, 00h–03h MLT and 03h–06h MLT represent substorm activities of the past intervals going back by 9, 6 and 3 hours respectively, measured at their center time. The correlation of Fig. 18 grows up from the right to the left of the figure and comes to the best at the Kp of the interval 03h–06h MLT. As for the simultaneous Kp (in the interval 06h–09h MLT), the correlation becomes low again. From the result it is strongly suggested that the morning side Pc5 has its source in the substorm which has occurred before. And the time lag may be 3 hours or so. The hydromagnetic wave of the main cause of Pc5 is generated by the substorm.

5. Discussion and conclusion

Typical examples of the relation between Pc5 and CNA have been given in section 2 and the general tendencies assumed from the examples have been supported by the statistical study in section 3. From the results it becomes clear that the main cause of Pc5 should be ascribed to hydromagnetic wave (model (B)) as many researchers have supposed, though CNA also contributes to the observed Pc5 as a secondary effect through modulation or enhancement. This situation may be shown briefly by the next illustration.

The hydromagnetic wave, which is generated by a substorm as it is discussed in the last half of this section, is the direct cause of Pc5 observed on the ground. On the other hand, the wave causes periodical particle precipitation through wave-particle



interaction. The precipitation generates currents in the ionosphere, resulting in the secondary Pc5 which observed as a modulation or an enhancement of the main Pc5. Observational facts of section 4 supports the idea that the substorm is the source of the morning side Pc5 which is the most typical Pc5 in the diurnal course and is associated with CNA.

In the magnetosphere, close correlation between the magnetic field oscillations and the energetic particles have been also observed by the direct measurements using satellites. For example Sonnerup et al. (1969) found the very clear anticorrelation between the oscillations of the magnetic field intensity, B, and that of the particle flux (proton and electron), n. Several workers have tried to explain the fact theoretically. Lanzerotti et al. (1969) proposed the drift mirror instability theory in which the instability generated under the existence of the gradient of B (∇ B) and the gradient of n (∇ n) produces the drift wave, resulting in the concurrent oscillations of B and n. His drift wave frequency is 0.015 to 0.04 Hz, which is in good agreement with the observed frequency. As the frequency is also very similar to that of Pc5, the mechanism of wave generation may be supposed for Pc5 too. Necessary gradient of particle density will be given by a substorm. Fig. 19 is a schematic show of energetic electron distribution during a substorm. The

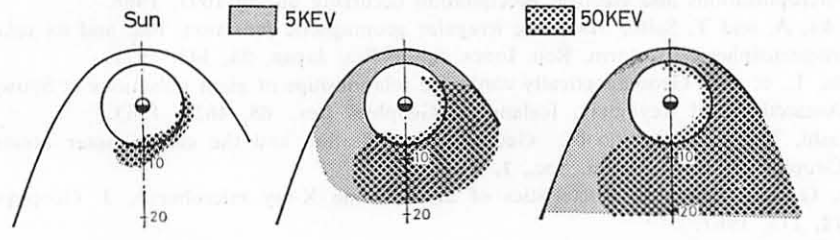


Fig. 19. Development of the electron distribution in the magnetosphere during the substorm (taken from Fig. 158 of Akasofu, 1968, Original figures are rearranged).

figure is taken from Akasofu (1968). The energetic electrons which have been heated during the progress of the substorm are going to drift eastward along L shell in the magnetosphere (1) $\longrightarrow$ (2). In consequence, they construct the density gap (∇ n) around L = 5–6 on the dawn side (3). Based on this density gap, the drastic plasma instability (the drift mirror instability) should occur and the hydromagnetic wave having the drift wave frequency is produced. This is observed as Pc5 on the ground. In addition this wave causes the particle precipitation concurrently, through a wave-particle interaction which is something like the Lanzerotti's process. This is observed as ionospheric CNA pulsation on the ground. This qualitative model should be examined quantitatively in the furture.

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周期的粒子降下を伴う磁気脈動 Pc 5

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概 要

周期的な粒子降下が磁気脈動 Pc 5 の発生に及ぼす効果の度合を，1968 年の昭和基地（磁気緯度 69.6°）の資料を使って調べた。その結果，Pc 5 の主原因は磁気流体波であっても，周期的な粒子降下は 2 次的効果として Pc 5 の発生に寄与しうることが明らかになった。

さらに，Pc 5 及び周期的粒子降下の主原因である磁気流体波の発生の起源として，サブストームを吟味する。