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Long Period Geomagnetic Pulsations Associated with Storm Sudden Commencements (Psc5)

(I) Morphological Study

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Abstract

Damped-type long period geomagnetic pulsations having the periods of the order of a few minutes associated with storm sudden commencements, Psc5's, are studied using the rapid-run magnetograms during IGY. Important results obtained through the present analysis are:

1. That the duration and local time dependence of Psc5 show the different characteristics to those of corresponding period-range, Pc5.
2. The the events of Psc5 occur coherently over a wide area, and the coherency is more prominent along the auroral zone.
3. That the area where the event of Psc5 occur most frequently is in and near the auroral zone, and shifts depending on local time, poleward in the day-time and equatorward in the night-time.

A brief discussion is given on these results.

1. Introduction

Many workers have previously reported that various damped-type geomagnetic pulsations are often associated with drastic magnetic variations such as storm sudden commencement (Sc) (Kato and Saito, 1958, for example).

After IGY, long period geomagnetic pulsations having the periods of the order of a few minutes associated with Sc's were studied with the rapid-run magnetograms at the world-widely distributed observatories (Wilson and Sugiura, 1961; Saito and Matsushita, 1967; Saito, 1969). Sato (1962) reported concurrent pulsations of the cosmic noise absorption in relation to the geomagnetic pulsations associated with Sc's. World-wide distribution of amplitudes of long period pulsations associated with Sc (Sato, 1962) and rotational effect (Sano, 1963) were studied. Several trials to interpret those observational results theoretically were carried out (Atkinson and Watanabe, 1966; Namikawa and Matsushita, 1970). However morphological or theoretical aspects about these pulsations have been unsolved essentially.

Long period geomagnetic pulsation associated with Sc is designated as Psc5 in a similar way as geomagnetic continuous pulsations, Pc5. Saito (1967) compared diurnal variations of amplitude and period of Psc5 with those of Pc5, then reported the similarity between them. However the problem whether the generation mechanism of Psc5 and Pc5 are common or not is unsolved until the present stage. To examine this problem is necessary to ascertain their sources or exciting mechanisms.

Recently Hirasawa (1970) analyzed Pc5 morphologically and suggested that the origin of Pc5 exists in the plasma sheet.

In the present paper, a detailed examination is made on the comparison of the behaviors between Psc5 and Pc5. Moreover some investigations are made on the comparison of waveforms of Psc5 between different geomagnetic latitudes or longitudes, the latitudes profile of Psc5 amplitudes, and the statistical characteristics of the Psc5 occurrence area.

2. Data

In the present analysis the rapid-run magnetograms at world-widely distributed 15 observatories for the period of IGY from July, 1957, to December, 1958, are used for the study of Psc5.

The ordinary magnetograms at three low-latitude stations, Kakioka, Honolulu, and San Juan are mainly used to identify Sc. Sc is defined here as a magnetic positive change of H-component simultaneously observed at all the three low-latitude stations, which involve trifling one not reported by each observatory. Such a change can be regarded to represent the compression of the magnetosphere (Nishida and Jacobs, 1962).

Table 1. Locations of the stations which are referred to in this paper.

Station	Abbreviation	Corr. Geomagnetic Lat.	Corr. Geomagnetic Long.	Geomagnetic Lat.	Geomagnetic Long.	Dip angle
Point Barrow	PB	69.7°	247.0°	68.4°	240.7°	N80° 25′
Reykjavik	REY	66.6	71.2	70.3	71.6	N76 28
College	CO	64.9	260.3	64.6	256.1	N77 03
Healy	HE	63.7	260.2	63.5	256.2	N76 09
Big Delta	BD	64.5	262.5	64.2	258.9	N76 47
Sitka	SI	59.8	276.6	60.0	275.0	N74 08
Fredericksburg	FR	51.8	352.2	49.7	349.6	N70 15
Tucson	TU	39.7	311.4	40.6	312.1	N59 26
San Juan	SJ			30.1	3.2	N51 23
Kakioka	KA			25.8	205.9	N49 13
Honolulu	HO			21.0	266.4	N38 57
Guam	GU			3.7	212.8	N12 53
Koror	KO			−3.5	203.4	S00 05
Byrd Station	BY	−68.7	352.0	−70.4	336.3	S74 50
Little America	LA	−74.3	332.8	−73.9	312.5	S80 00
Wilkes	WI	−79.7	157.6	−78.0	179.1	S81 50

The location of observatories used in the present paper is listed in Table 1.

3. Comparison of the behaviors between Psc5 and Pc5

A typical example of Psc5 is shown in Figure 1 with that of Pc5. Psc5 and Pc5 show very characteristic similarities together, especially for their periods or waveforms, as shown in Figure 1. Saito reported that their diurnal variations of amplitudes and periods show a remarkable similarities together (Figure 2). The figure shows that both have the tendency to be most active in the morning hours.

However concerning their durations, there is an unmistakable difference between Psc5 and Pc5. Psc5 has the duration of the order of a few tens minutes or one hour at the most, on the other hand, the duration of Pc5 is the order of a few hours or more. This tendency is shown in Figure 3. The events of Psc5 during IGY and Pc5 during two months of IGY at College are studied respectively. Each duration is plotted in Figure 3 to its occurrence local time. Psc5's are classified into three classes according to the amplitudes of the associated Sc's. The figure suggests that Psc5 is a transient phenomenon essentially, on the contrary Pc5 is a continuous one.

It is reported by many workers that Pc5 has the characteristics local time dependence of frequent appearance in the morning and evening hours, as shown in Figure

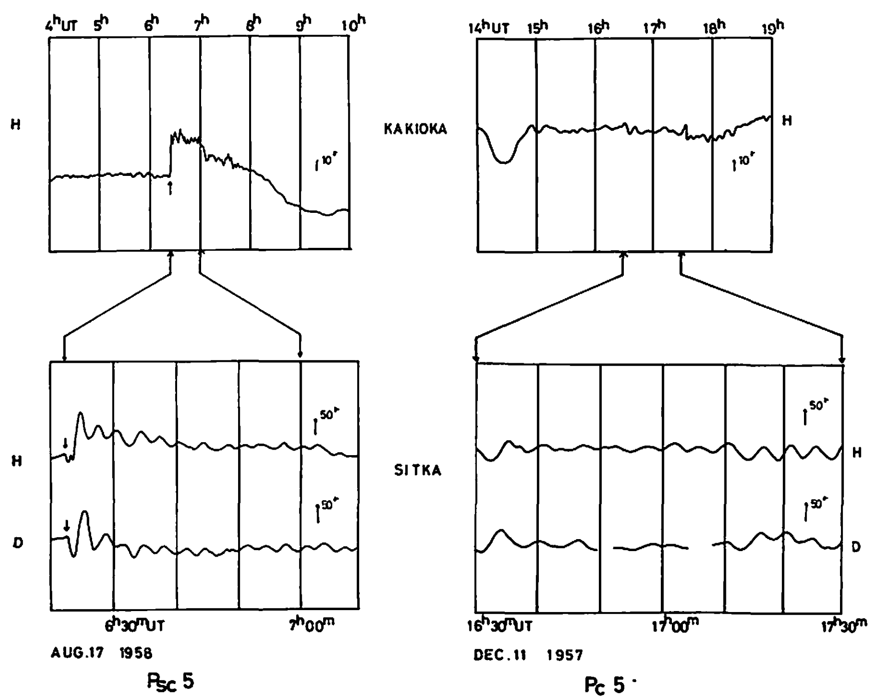

Fig. 1. Typical examples of magnetograms of Psc5 (left) and Pc5 (right).

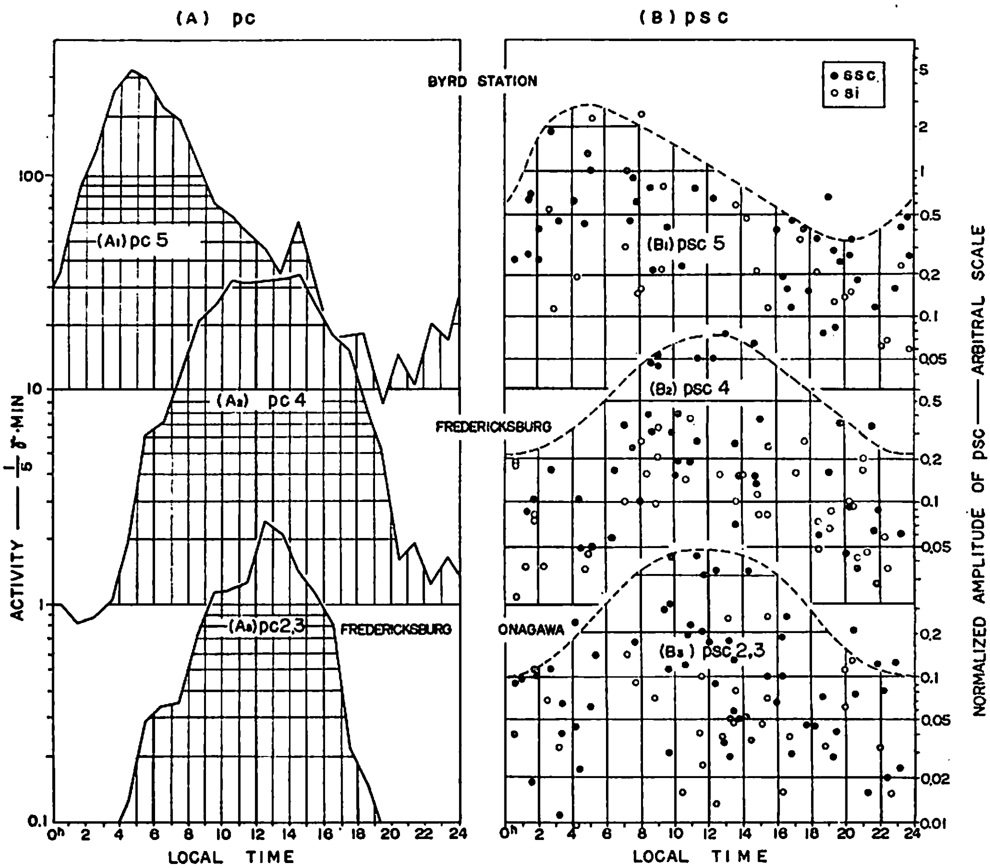

Fig. 2. Diurnal variations in the amplitudes of Pc's (left) and Psc's (right) for three period ranges (after Saito and Matsushita).

3 or Figure 4. On the other hand Psc5 shows little local time dependence in its occurrence frequency in Figure 3.

From these facts, though Psc5 shows similar behavior to that of Pc5, it should be considered that they are essentially different phenomena. Hereafter the study will be made for Psc5 only. Present author will pay attention for the events of Psc5 only which were associated with Sc's in quiet (Kp=0,1) or slightly disturbed conditions (Kp=2,3). Those Sc's are listed in Table 2.

4. Several examples of Psc5

Similar events of Psc5 with almost the same periods and waveforms are frequently observed concurrently over a wide area extending from high latitudes to the equatorial

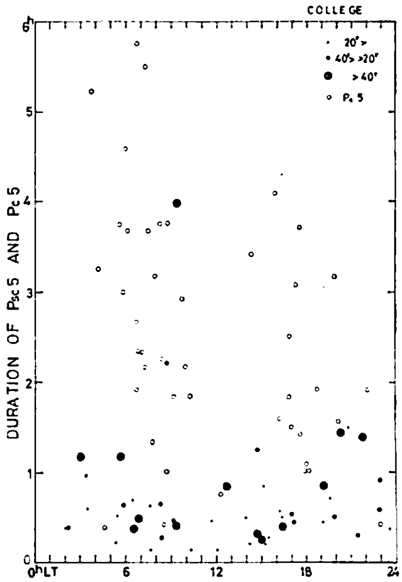

Fig. 3. Durations of Psc5 (solid circle) and Pc5 (open circle) at College. Psc5's are classified into three classes according to the amplitudes of associated Sc.

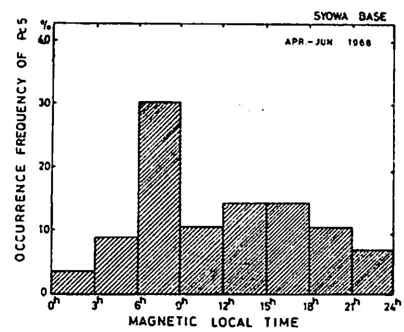

Fig. 4. Diurnal variation of occurrence frequency of Pc5 at Syowa Base during the period from April to June, 1968.

Table 2. The date and hour of the events of Sc's which are analyzed in this paper. (Hour is indicated in universal time.)

1957			1958					
		h m			h m			h m
July	2	0900	Jan.	25	1051		13	2208
Aug.	3	1557	Feb.	4	1304		22	1207
	6	0508		16	1642	Aug.	17	0622
	9	1348	Mar.	5	0537		22	0227
	17	1322		14	1212		24	0140
	29	1920		17	0750	Sept.	25	0408
	30	1628	June	8	1728		30	1005
Sept.	2	0313		14	1828	Oct.	22	0315
	4	1300		15	0509		28	0650
	13	0046		28	0713	Nov.	16	0219
	21	1005			1742	Dec.	4	0035
	29	0016	July	8	0748		15	2022
Nov.	6	1821						
	29	0225						
Dec.	19	0937						

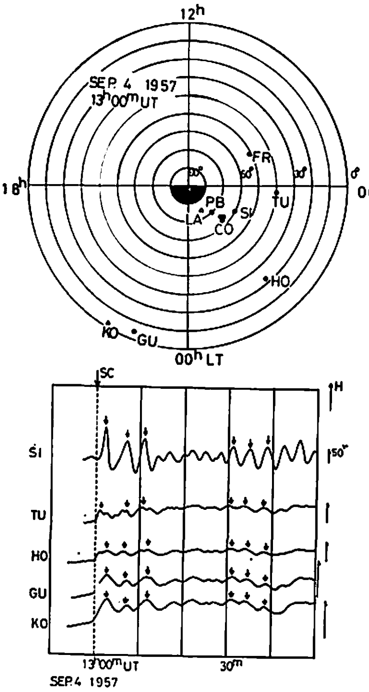

Fig. 5. Records of magnetograms (only H) at five stations for the events of Psc5 associated with the Sc which began at 1300 UT, Sep. 4, 1957.

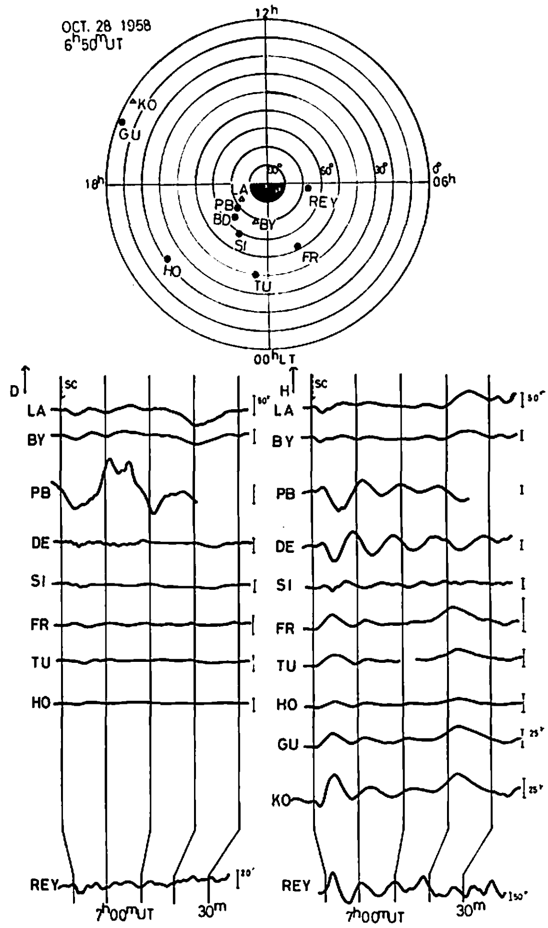

Fig. 6. Records of magnetograms at eleven stations for the events of Psc5 associated with the Sc which began at 0650 UT, Oct. 28, 1958.

region. A typical event is shown in Figure 5. Simultaneously with the Sc at 1300 UT, September 4, 1957, the events of Psc5 appeared world-widely with different amplitudes, from the auroral zone, Sitka, to low latitude, Honolulu, and the equatorial region, Koror. Amplitudes of Psc5 tend to reach maximum in the auroral zone. Examining in detail, their periods and phases show considerable coherency over a wide range of latitudes from the auroral zone to the equatorial region.

The coherency among the events of Psc5 are shown not only along the meridian from high to low latitudes but also along the auroral latitudes extending from dawn- to dusk-side. Such an evidence is presented in Figure 6. The Sc began at 0650 UT, October 28, 1958. The concurrent events of Psc5 appeared coherently over a wide

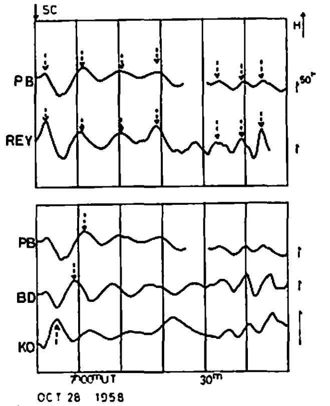

Fig. 7. The representative events of Psc5 which were shown in Fig. 6.

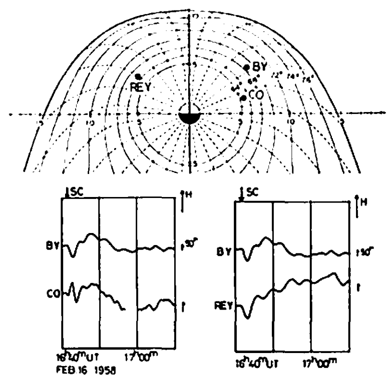

Fig. 8. Comparison the waveform of Psc5 (only H) at Byrd with that at College or at Reykjavik. The Sc began at 1542 UT, Feb. 16, 1958.

area. At this time observatories in the Alaska region were located in the dusk-side. On the other hand European station, Reykjavik, was in the dawn-side, where Psc5 was observed also. To examine the coherency of this events more in detail, horizontal components at representative station, Point Barrow and Big Delta in the dusk-side auroral zone, Reykjavik in the dawn-side auroral zone, and Koror in the equatorial region, are compared. The result is shown in Figure 7. The coherency of the events is preserved over dark-hemisphere. Moreover waves of Psc5 at Point Barrow show the peak to peak correspondence with those at Reykjavik for the period over one hour in spite of the fact that these stations are apart from dusk- to dawn-side along the auroral zone each other. On the other hand there is no such a correspondence but phase lag between the dusk-side stations, Point Barrow, Big Delta, and Koror.

The coherency of the events of Psc5 is studied moreover, especially concerning the behavior in the auroral zone. The situation of auroral stations is more understandable on Fairfield-map. The events of Psc5 were associated with the Sc at 1942 UT, February 16, 1958. Horizontal components of the events at Byrd, College and Reykjavik are representatively shown in Figure 8. The waveform of Psc5 at Byrd showed remarkable similarity to that at Reykjavik. On the other hand, the similarity is less between Byrd and College.

Summarizing the results in this section, the events of Psc5 appear with the considerable coherency over a wide area, and the coherency tends to be more evident along the auroral latitudes than along a meridian from high to low latitudes.

5. Latitude dependence of Psc5 amplitudes

In what area Psc5 becomes most active? To ascertain the area where maximum amplitudes are observed is one of the important subject to get the information on the source of Psc5. In this section this problem is examined with a case study. As shown in Figure 5 and 6, amplitude of Psc5 tends to be maximum in the auroral zone. Though indicated in the previous section the phases or periods of Psc5 don't necessarily show the clear coherency along the meridian, there are several cases showing the peak to peak correspondence over a wide area from high to low latitudes. An example of such a case is presented in Figure 9. Simultaneously with the Sc, which occurred at 1136 UT, May 9, 1958, the events of Psc5 occurred with the complete coherency. Concerning the first two pulses of each horizontal component at least, the peak to peak correspondence is preserved over the night-hemisphere. To examine the latitude profile of the events of Psc5, double amplitudes of the horizontal components are calculated at each observatory. The average values of the first two double amplitudes are shown

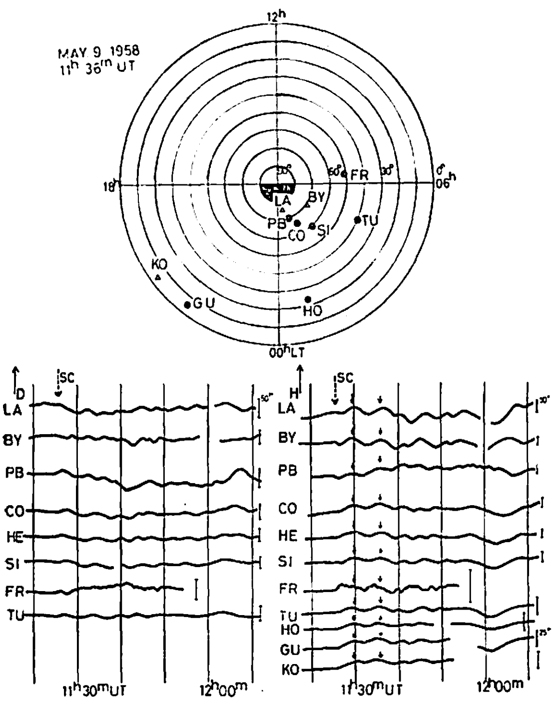

Fig. 9. Records of magnetogram at eleven stations for the events of Psc5 associated with the Sc which began at 1136 UT, May 9, 1958.

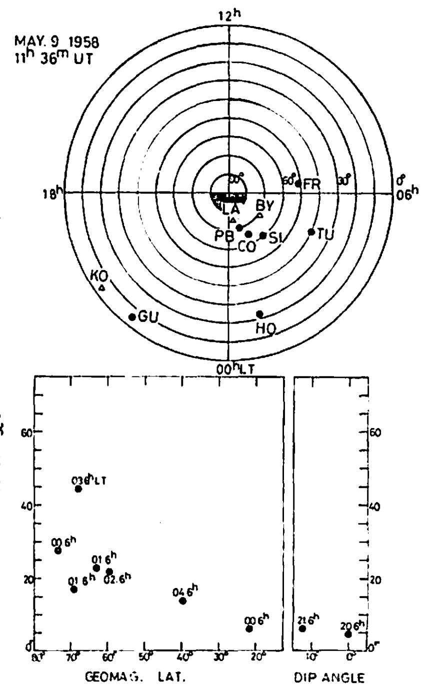

Fig. 10. Latitude dependence of the amplitudes of Psc5 in May 9 event. Local time when Sc began is indicated for every station.

in Figure 10. The figure shows the sharp maximum in the auroral zone, in other words, the events of Psc5 are the largest in the auroral zone.

Examining more carefully, the hehavior of latitude profile is complicated in higher latitudes. The average values of the first two double amplitudes at higher latitudes are divided into five classes and plotted on Fairfield-map in Figure 11. Assuming that the field lines may be approximated by Fairfield-map, the field lines rooted at Little

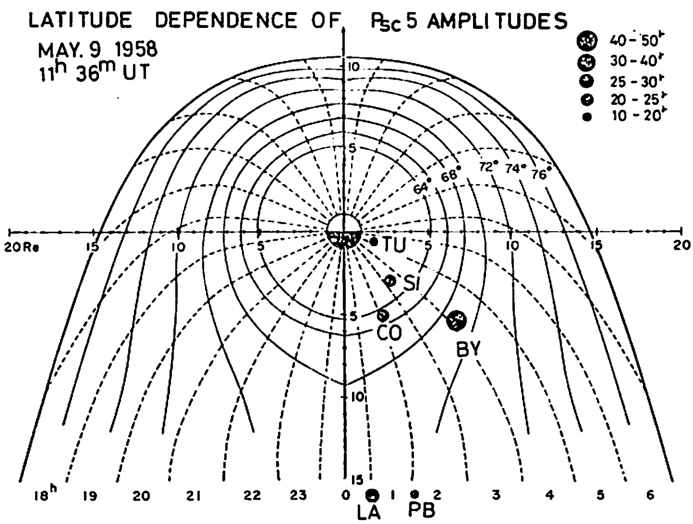

Fig. 11. The behavior of the amplitudes of Psc5 in high latitudes. The double amplitudes are divided into five classes.

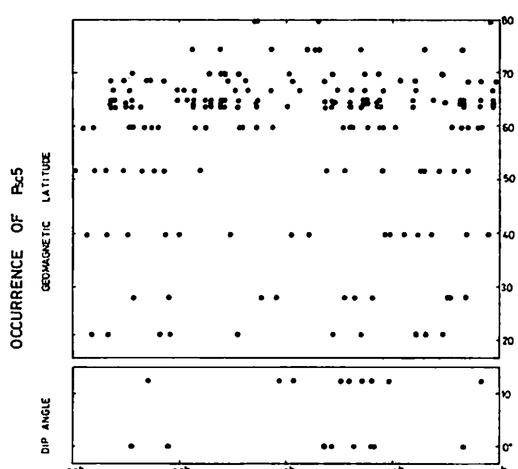

Fig. 12. The events of Psc5 which occurred at the quiet condition ($Kp=3$) during the period from July, 1957 to December, 1958.

America or Point Barrow must sweep away and form the geomagnetic tail. While the ones at Byrd, College and Sitka must be closed and form the closed shell. Within 6 observatories in the figure, the maximum amplitude was observed at Byrd, which was located at the outermost part of the closed shell.

The May 9 event supports the hypothesis that amplitudes of Psc5 reach a maximum on the outer boundary of the closed shell.

6. General characters about the occurrence area of Psc5

In this section the distribution of the events of Psc5 will be statistically studied. All the events associated with Sc's which listed in Tables 2 are shown in Figure

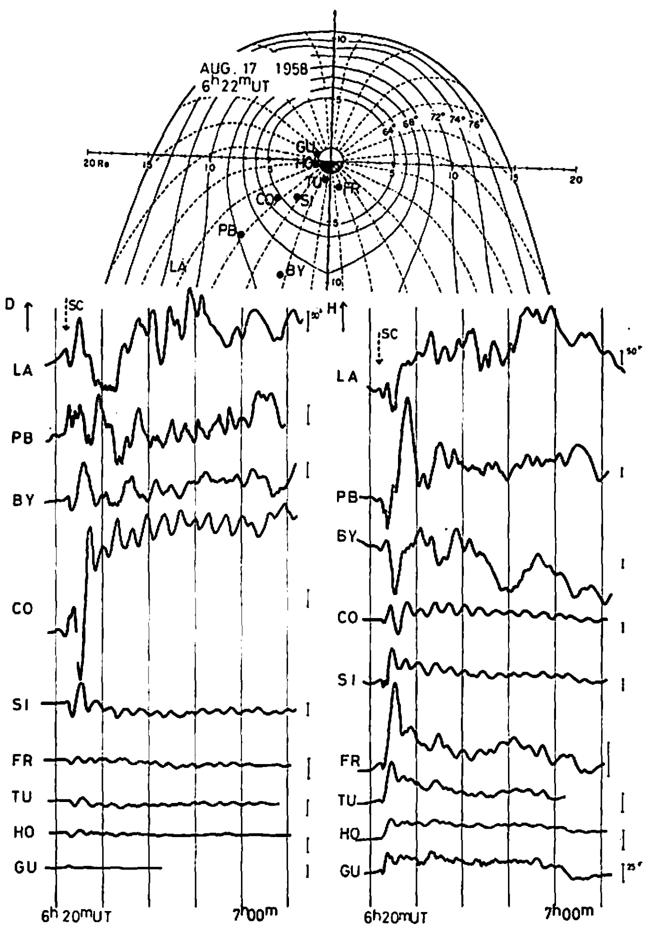

Fig. 13. The events of Psc5 associated with the Sc which began at 0622 UT, Aug. 17, 1958, when the stations in Alaska region were in the dark-hemisphere.

12, taking the local time of occurrence as the abscissa and the geomagnetic latitude as the ordinate. The events of Psc5 picked up here satisfy the following criteria.

1. The period is from 100 to 600 seconds.
2. There are more than two sinusoidal waves.
3. Two time intervals between successive peaks are the same within the difference of 20%.
4. The maximum amplitudes of H or D-component is larger than 5 gammas.
5. The events are associated with Sc's which occurred under quiet or slightly disturbed condition (Kp=3).

208 events of Psc5 are picked up during the IGY from July, 1957 to December, 1958.

In Figure 12, it is recognized that Psc5's appear over a wide area, and the area where Psc5 occurred most frequently is in and near the auroral zone ($\phi_m=60°–70°$). Moreover the area tends to expand poleward near the noon and to the sub-auroral zone from the evening to the midnight.

The representative case in the night-time is shown in Figure 13. The Sc began at 0622 UT, August 17, 1958, when the high latitudes stations shown in Figure 13 were located in the dark-hemisphere. Simultaneously the events of Psc5 appeared in the form of damped-type oscillations at College, Sitka, Fredericksburg and Tucson, where

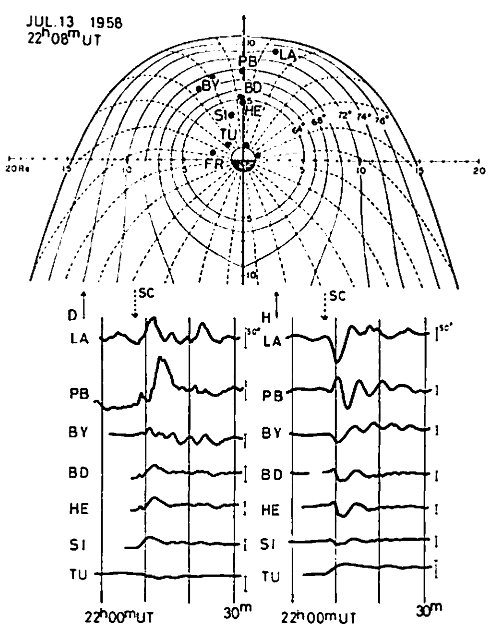

Fig. 14. The events of Psc5 associated with the Sc which began at 2208 UT, Jul. 13, 1958, when the stations in Alaska region were in the sunlit-side.

the field lines must be closed. On the contrary at higher latitudes stations, Little America, Point Barrow and Byrd, no oscillation regarded as Psc5 existed but irregular fluctuations. During this event the field lines rooted at these three observatories must sweep away.

The behavior of Psc5 in the day-time is shown in Figure 14. The Sc began at 2208 UT, July 13, 1958. At this time the field lines rooted at Little America, Point Barrow and Byrd, must be closed as the ones rooted at lower latitudes. Simultaneously with the Sc the events of Psc5 appeared at these three stations. Moreover the events at these stations in high latitude seem to be more distinct than that in the auroral stations, Big Delta and Healy, or in the sub-auroral station, Fredericksburg (not presented in Figure 14). Such a relation about the occurrence area of Psc5 is examined by the statistical study.

The polar map is divided into five zones, the poleward region (ϕ_m 70°–80°), the auroral zone (60°–70°), the sub-auroral zone (40°–60°), middle and low latitudes (20°–40°) and the equatorial region (0°–20°) in Figure 15. Each area is divided into four parts, the morning-side (03–09 LT), the day-side (09–15 LT), the evening-side (15–21

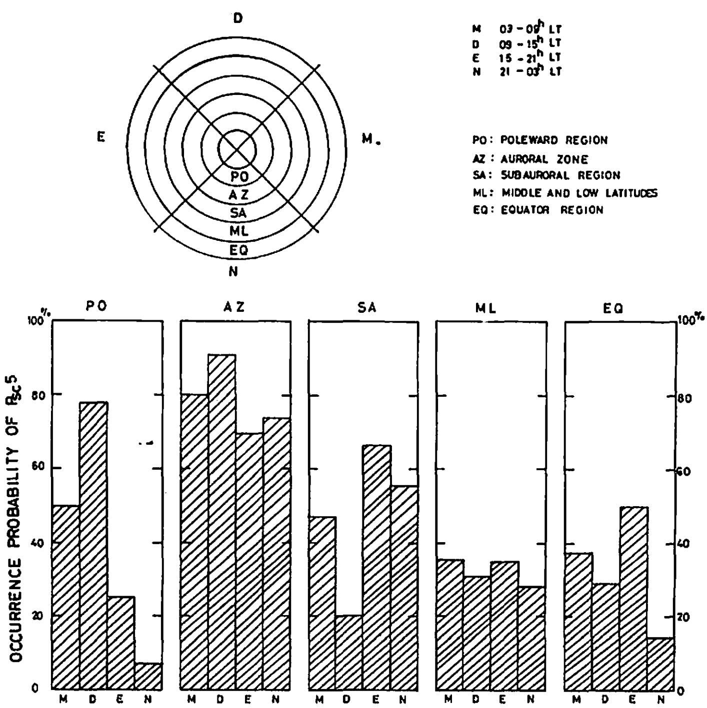

Fig. 15. The occurrence probability of Psc5 for each zone. Each zone is divided into four parts, morning-side (03h-09hLT), day-side (09h-15h LT), evening-side (15–21h LT), and night-side (21h–03h LT).

LT), and the night-side (21–03 LT). The occurrence probability of Psc5 in time of Sc is calculated for each part of each zone. The result is shown in Figure 15. The tendency that Psc5's occur in the auroral zone with high probability for every local time is apparant. In other words, whenever Sc occurs, simultaneosly Psc5 appears in the auroral latitudes. In the poleward region Psc5's occur with high occurrence probability in the day-time but scarcely in the night-time. On the other hand, in the sub-auroral zone the occurrence probability of Psc5 takes minimum in the day-time. In that region the events of Psc5 have higher occurrence probability in the evening or in the night-time. In lower latitudes the occurrence probability of Psc5 is low and no apparant local time dependence exists except a small maximum at the equatorial evening-side.

The representation in Figure 15 is rearranged and shown in Figure 16. It is confirmed that the area related to the source of Psc5 is located in the auroral zone for every local time. The area expands poleward in the day-time and equatorward in the evening and the night-time.

7. Discussion and conclusion

In this paper Psc5's have been analyzed from the point of ascertaining their characters morphologically. The results are summarized as follows.

1. It should be considered that Psc5 has a different excitation mechanism from that of Pc5.

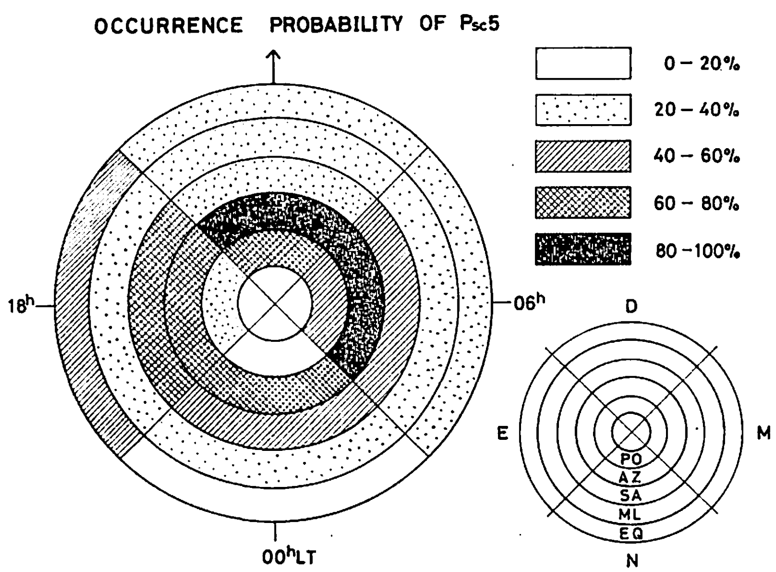

Fig. 16. Rearrangement of Fig. 15.

2. Simultaneously with Sc, the events of Psc5 are observed with the considerable coherency over a wide area extending from high latitudes to the equatorial region.
3. The coherency tends to be more prominent along the auroral latitudes than along a meridian from high to low latitudes.
4. The amplitudes of Psc5 reach maximum on the outer boundary of the closed shell.
5. The area where the events of Psc5 are most frequently observed is in and near the auroral zone.
6. That area tends to expand poleward in the day-time or equatorward in the evening and the night-time.

These results suggest that the source of Psc5 should be closely related to auroral latitudes. From the results (3), (4), (5) and (6), it may be suggested that the events of Psc5 are most active along the auroral oval.

To ascertain more complete features of Psc5 including the generation mechanism, the author will study several associated phenomena with Sc, the particle precipitation for example, in relation to Psc5. And to ascertain whether the excitation of Psc5 occurs on the magnetopause or on the trapping boundary, the simultaneous observation among the stations which located closely together in the auroral zone and the sub-auroral zone along a common meridian should be operated in the furture.

Acknowledgment

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SC に伴う長周期地磁気脈動 (Psc5) について (I)

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概 要

SC に伴って発生する周期が数分の長周期地磁気脈動 (Psc 5) について，IGY の期間の地磁気早回し記録を用いて解析を行った。その結果次のことが明らかになった。

1. Psc 5 の存続時間あるいは Psc 5 の発生頻度の地方時依存性は，Psc 5 と同じ周期帯にある Pc5 のそれと異る傾向を示す。
2. Psc 5 は汎世界的に，同時にしかも一様性をもって出現する。一様性は特に極光帯に沿って顕著である。
3. Psc 5 が最も発生しやすい領域は極光帯近傍にある。その領域は昼側では極光帯よりも高緯度側に，また午後側から夜側にかけては低緯度側に拡っていく。

これらの結果について簡単な議論を加える。