Notes on the Geomagnetic Disturbances for the Pre-SC stage of PCA

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Abstract

On Feb. 10, 1958, magnetic disturbance occurred simultaneously with the onset of PCA (Polar Cap Absorption) in the auroral zone, before SSC at 0126 Feb. 11. Hitherto, it is well known that PCA is the ionization effect of the lower ionosphere in the polar cap, caused by the solar sub-cosmic ray bombardment and has not relation with the geomagnetic disturbance. The examination of such the events as one on Feb. 10 during the IGY, results in that the magnetic disturbances may relate more closely to AA (Auroral Absorption). An explanation of the simultaneity of the magnetic disturbance and PCA in the auroral zone is qualitatively attempted.

1. Introduction

It is now recognized that the PCA (Polar Cap Absorption) is caused by an ionizing effect of solar sub-cosmic radiations emitted from the sun. PCA events are usually initiated by a solar flare accompanied by radio outbursts of type IV, after a time delay of few hours. From 1 to 3 days after the flare, a magnetic strom begins, which is also attributable to the flare.

The PCA phenomena are observed throughout the polar regions, polewards from about 60° geomagnetic latitude, increasing slowly and lasting for several days.

On the other hand, the AA (Auroral Absorption), which is thought to be caused by aurora particles occurs in an dnear the auroral zone, but rarely is observed at Thule. And the AA records are characterized by the rapid fluctuations, often showing fast onsets and recoveries several times an hour.

A number of papers have been written on PCA and AA. The relations between PCA's and geomagnetic disturbances have been examined by many authorities. And any direct relations between them have not been found out, except the geomagnetic control on PCA after SSC, while AA corresponds very well with magnetic disturbance.

For example, C.G. Little & H. Leinbach early studied the correlation between magnetic activity and ionospheric absorption and showed that absorption activity is closely related to the simultaneous magnetic activity(1). But they used the absorption data at College and K-indices at College and Sodankylä. Roy P. Basler and Leif Owren also examined the relations between absorption at College and Kp index, though they were interested in the large time scale rather than in detailed variations of short time scale by adopting the daily average absorption values and $\sum K_p$ (daily sum of K_p)(2). In their research, absorption is one from which PCA is excluded from a point of view that PCA is caused by solar proten bombardment, occurs during the magnetically quiet period and is unrelated to magnetic activity, except the appearance of a large non-recurrent magnetic strom after about a day.

But only a few authors remarked the geomagnetic disturbances for the pre-SC stage of PCA. M. Nagai and Y. Hakura pointed out the simultaneous occurrence of polar geomagnetic disturbance with the sudden development of PCA in the auroral zone before SSC, D_p (Pre-SC), in case of the event on Feb. 11, 1958(3).

By the way, the magnetic disturbances before the sudden commencements were formerly modeled by S.F. Singer as pre-SC bay in his storm theory(4), based on the extensive studies of polar magnetic storms and geomagnetic bays by N. Fukushima(5).

From the standpoint of the background of the researches of the PCA, AA and pre-SC bay, it will be necessary that D_p (pre-SC) on Feb. 10, 1958 is examined in more detail, because it is a unique sample analysed and the associated magnetic storm is one of the greatest storms during the sun-spot maximum period. Actually it yet remains disputable whether the simultaneous occurrence of PCA and D_p (pre-SC) shows any essential relations between them.

In the present paper, we are concerned with the analysis of the geomagnetic disturbances not only in the high latitude region, but also in the low latitude region, overlooked by the authors for the pre-SC stage of PCA and the examination of their causal connection with PCA.

2. Event on Feb. 10, 1958

An importance 2+ flare accompanied by a type IV outburst began at 2108 UT, Feb. 9 and about 10 hours later, PCA appeared on the day side of the polar region and the region of PCA extended toward the auroral zone. The time changes of the geographical distribution of PCA region and the intensity of PCA are given on the papers by M. Nagai & Y. Hakura. Only the time change of the intensity is reproduced here. On the figures, $\Delta f_{\min}$ means the deviation of $f_{\min}$ from the monthly median values. PCA occurred at 0700 UT, Feb. 10 (indicated by the letter α) in the polar region and gradually increases till the occurrence of SSC. In the auroral zone, PCA suddenly starts at 1200 UT, Feb. 10, as shown by the sharp

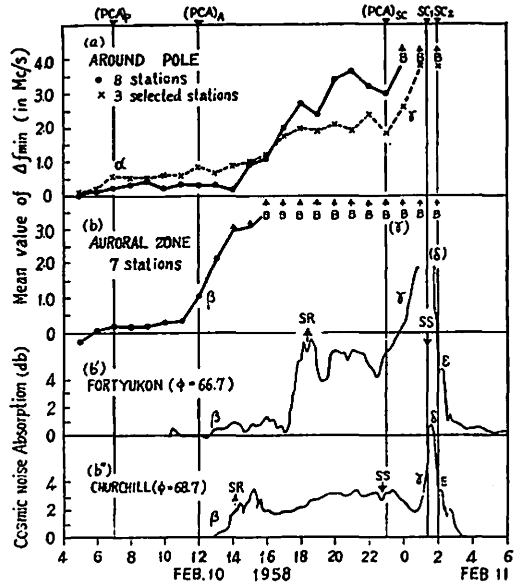


Fig. 1 Development of PCA around the pole (a) and in the auroral zone (b, b′, b″).

(a) Mean value of $\Delta f_{\min}$ at 8 polar stations: Thule, Eureka, Alert, Fletchers. Ice, Resolute Bay, Clyde River, Godhavn and Arctic II (thick line).

X: Mean value of $\Delta f_{\min}$ at 3 stations of solar side: Alert, Godhavn and Arctic II (thin line)

(b) Mean value of $\Delta f_{\min}$ at 7 stations: Tromsφ, Dixon, Arctic I, Point Barrow, Churchill, Narsarssuak and Reykjavik.

(b′), (b″) Cosmic noise absorption at Fort Yukon (27.6 Mc/s) and Churchill (30.0 Mc/s). SR: Sunrise, SS: Sunset (after M. Nagai & Y. Hakura)

increase of the mean of $\Delta f_{\min}$ at 7 stations and the riometer records (indicated by the letter β). The intensity at Fort Yukon and Churchill increase till the SSC, showing the diurnal effects and the increases immediately before SSC, as pointed out by W.I. Axford & G.C. Reid[6].

While the aspects of the geomagnetic field from 2108 UT, Feb. 9 (the occurrence time of the solar flare) to 0125 UT. Feb. 11 (the onset time of SSC) are as follows;

1) At College, the preceded minor disturbance was getting to the end at about 2100 UT, Feb. 9. The end at about 0700 UT, Feb. 10 coincides unexpectedly with the occurrence of PCA in the polar cap. For the 3.5 hours to 1035 UT, any minor irregular fluctuations were not recorded and suddenly the impulsive variation occurred at 1035 UT. The disturbance developped at about 1200 UT and began to weaken at about 2100 UT, which was the very disturbance indicated by D_p (pre-SC).

The magnetic activity in the other part of the auroral zone is nearly the same, as shown by K_p-index in Table 1. But, the impulsive variation at 1035 UT is observed only within the very confined region.

Table 1 Magnetic activity in the auroral zone around Feb. 10, 1958.

Day	9	10	11
K_p	4_0 4_0 2_0 3_- 3_- 3_+ 4_0 3_0	4_0 4_- 2_- 2_0 2_+ 5_0 5_- 4_+	9_0 8_+ 9_- 8_+ 8_0 5_+ 6_0 6_0

2) In the polar cap (Thule), only the disturbances from about 1700 to 1830 and from about 1900 to 2040 are different from the aspects on the other days.

3) In the middle latitude (Kakioka), the small bay-like disturbances are recorded at about 1200, 1730 and 1900.

4) Equatorial D_{st} after M. Sugiura[7] begins to decrease at about 12h Feb. 10 and at about 23h, reaches to the minimum value and then recovers. The maximum range of the decrease is about 60γ.

The changes of the geographical distributions of the geomagnetic disturbances, by the equivalent current system estimated from hourly values and that of PCA were compared with on the same maps by M. Nagai and Y. Hakura.

As the authors stated, the discrepancy between the most active Δf_{min} region in the afternoon side aruond Tromsø and the geomagnetic active region in the midnight auroral zone around College at 13h should be in mind, though the occurrence time of PCA in the auroral zone coincides with the development of the geomagnetic polar disturbance.

Also they made the comparison among the storm time variations of the cosmic noise absorption, ΔX_m at Churchill and $D_{st}^{32.5}$ (according to their notations). The comparison between the storm time variations of absorption and ΔX_m shows that the parallelism between them at Churchill is not very good. The peak of ΔX_m around 13h corresponds the development of PCA, but the whole processes of the time variations considerably differ from each other. These points, shown by an analysis of hourly values, may give the conclusion that the D_p (pre-SC) is not the direct manifestation of the ionization enhancement, caused by the PCA-producing particles. Because the variation in electron number in the E region is proportinal to the variation of the horizontal component H in bay-like disturbances in the high latitude[8]. It should be, however, remarked in the comparison of D_{st}, ΔX_m and PCA, that the maximum of PCA occurs simultaneously with the minimum of

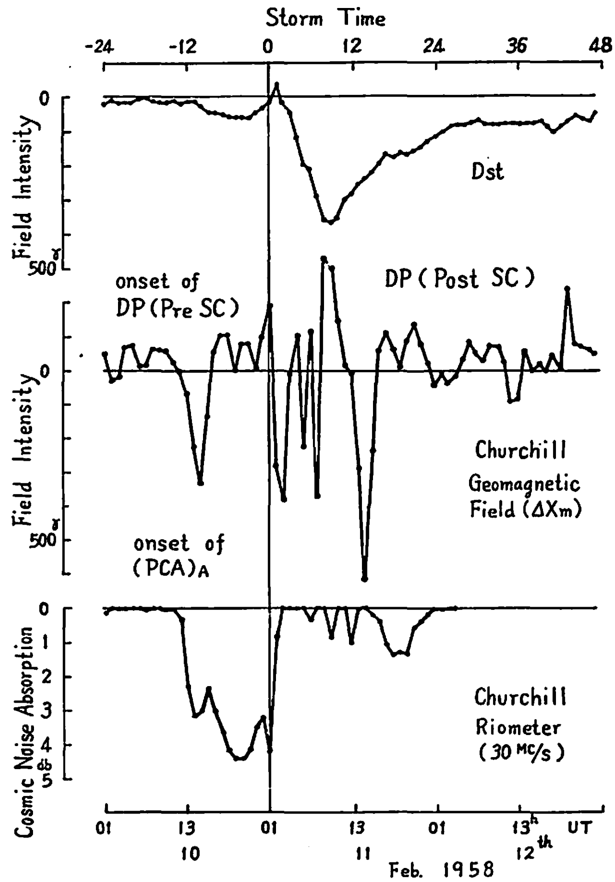


Fig. 2 Storm time variations of D_{st} (32.5°), ΔX_m and cosmic noise at Churchill. (after M. Nagai & Y. Hakura)

D_{st}. Also the occurrence of the peak of ΔX_m at the developping stage of D_{st} is noticeable. These points seem to be overlooked by the original authors. In addition, this author examined the magnetogram at Thule. The storm time variation of PCA in the polar cap (shown in Fig. 1), which is considered approximately to be in proportion to the flux of PCA-producing particles, is not coincident with the geomagnetic disturbances around 1700 and 1900 UT, at Thule (shown in Fig. 3). Glancing over the magnetogram at Thule, the westward excursion of declination seems to begin simultaneously with the increase of PCA. But the excursion includes moderately the diurnal component and the time-coincidence may be in appearance.

Furthermore, the inspection of the original riometer record and the magnetogram at College shows that not only the magnetic disturbance around 1200, but also the impulsive variation at 1035 coincide surprisingly with the small peaks of the riometer record, as indicated by arrows in Fig. 4. The fact indicates that the magnetic disturbances around 1200 are closely related to Auroral Absorption. That is, D_p (pre-SC) may be a usual polar magnetic disturbance, associated with AA.

As mentioned before, the occurrence of D_p (pre-SC) at the developing stage of D_{st} seems to show that the concerned disturbance is similar to those around the developing stage of the main phase in usual SSC storms. Also the decrease of D_{st} of the order of 60γ is as large as one in low latitude of the average D_{st} of usual moderate SSC storms, though it is much less than that of SSC storm on Feb. 11(9). These give us an impetus to presume that such the geomagnetic effects on PCA as appear usually after the associated SSC may be effective even before SSC. It is well known that the geomagnetic effects on PCA are (1)—the southward expansion of the polar cap region during the main phase of magnetic storm, (2)—the midday recovery of absorption near the southern boundary of the polar cap region and (3)—the short lived recovery observed at the southern boundary of the polar cap region during the initial phase of the magnetic storm. These phenomena can

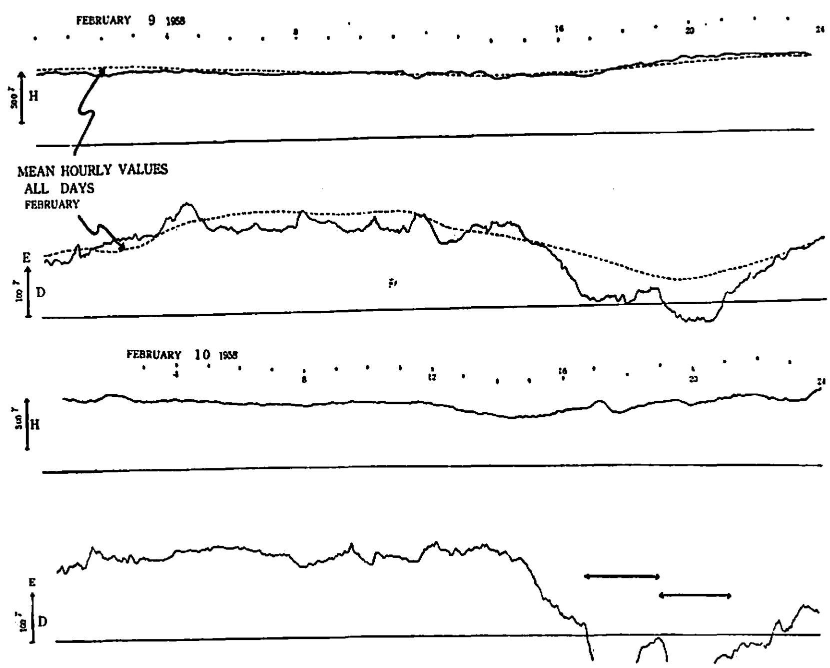


Fig. 3 The magnetograms on Feb. 9 and 10, 1958 at Thule. (geog. lat.: N 77°29′, geog. lon. W 069°19′; geom. lat.: 88°9 geom. lon.: 357°8)

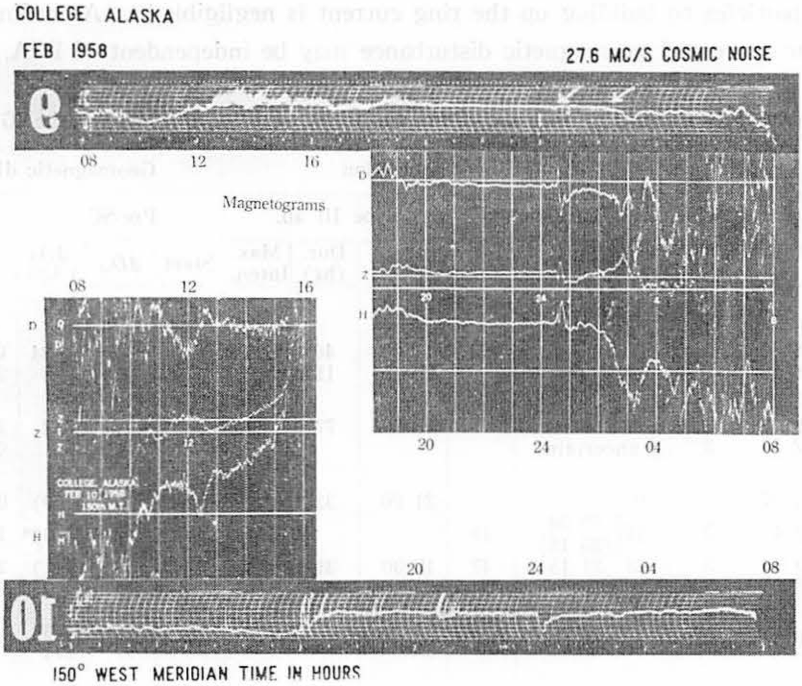


Fig. 4 The comparison of the riometer records with magnetograms on Feb. 9 and 10, 1958 at College. (geog. lat.: N 64°52′, geog. lon.: 147°50′; geom. lat.: 64.6°, geom. lon.: 256.5°). For the sake of convenience, riometer records are reproduced inside out.

be discussed in terms of the effective cutoff energy for the solar particles as a function of time and location[10].

Although the observed absorption will be complicated, owing to the superposition of the diurnal effect etc, it may be possible that in favorable case, the geomagnetic disturbance (especially, the intensification of the ring current) affects the cutoff rigidity of the solar particle and then makes PCA observable in the southern boundary of the polar cap region. Apart from the view that the special polar magnetic disturbance, D_p (pre-SC), was caused by invasion of the PCA-producing particles, it may be able to consider that a usual polar magnetic disturbance, which occurred accidentally around an onset of PCA in the polar cap, excited PCA in the auroral zone (southward shift of the boundary). Thus the simultaneity of occurrence of PCA in the auroral zone and the polar geomagnetic disturbance may be observed.

Also, S.I. Akasofu studied the close relation between the development of D_{st} and polar geomagnetic storm, and discussed that the contribution of the PCA-producing particles to building up the ring current is negligible[11]. According to the view, the concerned geomagnetic disturbance may be independent of PCA, even in

Table 2 Geomagnetic disturbances for the pre-SC stage of PCA during the IGY.

Solar flare		Polar cap ionization					Geomagnetic dist.			
		Black out		Type III ab.			Pre-SC			SC
Start	Imp.	Start	Dur. (hr)	Start	Dur. (hr)	Max. Inten.	Start	ΔD_{st}	ΔA_p (Ap)	Start
1957										
July h m		d h m		h m		db	h	γ		d h m
03 08 30	2+	03 08 45	52	11 00	46	6	13	−20	+24	05 00 42
24 18 16	3	24		20 15	11	2		?	−3	27 19 59
Aug.										
28 09 13	3+	29 05 00	41	13 00	77	9		?	−2	29 19 20
31 12 57	3−	uncertain				5		?		02 03 14
Sep.										
02 12 57	1+	02		21 00	32	9		?E	(179)	04 13 00
11 02 43	3	12 { 09 30 (23 15)	19			0.5		?	(179)*	13 00 46
21 13 40	3	21 21 15	47	19 30	31	5		?E	(111)	22 13 45
26 19 07	3	26		23 15	29	2		?	−2	29 00 16
Oct.										
20 16 37	3+	21 11 30	32	07 00	13	5	08	−13	−6* (27)	21 22 41
1958										
Feb.										
09 21 08	2	10 { 12 00 24 00	34			>12	12	59	+39	11 01 25
Mar.										
23 09 50	3+	25 03 00	96	22 30	96	12		?E	(48)	25 15 40
June										
05 16 58	2+	06 13 45	11							07 00 46
July										
07 00 39	3+	07 05 15	88	01 30	78	>15		?E	(32)	08 07 48
29 03 03	3	29		04 05	30	1.5		?E	(9)	31 15 32
Aug.										
16 04 32	3+	16 11 00	53	06 00	56	>15	16	−16	+10	17 06 22
22 14 17	3	22 15 30	76	17 00	80	>10	{ 16, d h 23 03	−12, − 9	+ 3, +13	24 01 40
26 00 05	3	26 02 15	49	01 00	71	>13	01	−33	+21	27 03 03
Sep.										
—	—	22 17 30	55	14 30	68	4				25 04 08

Notes 1. The maximum intensity is quoted from "Solar Activity and polar cap absorption events" by Anne B. Kahle.
Anne B. Kahle (1962): Solar activity and polar cap absorption events. Scientific Report No. 2 UAG-R129, University of Alaska.
2. ΔD_{st}: variation of Equatorial D_{st} by M. Sugiura
? denotes the case of small quantity within an error.
? E. denotes the case obscured by other disturbances.
3. Ap: numerals signed by + or − denote the increase or decrease of Ap from the immediately before values. Also numerals in round brackets denote the maximum Ap for the pre-SC stage of PCA.

its origin.

3. Analysis of the other events during the IGY

Untill now, more than 40 PCA's have been observed since 1957 by means of f_{min} ionospheric data and the riometer. Preliminarily, PCA's during the IGY are here examined, when 18 PCA's were observed (after T. Obayashi)[12]. The geomagnetic disturbances, observed at any rate for the pre-SC stage of PCA are described by Equatorial D_{st} and A_p in Table 2. In some cases of PCA events (6 among 18 events), we can clearly find out the geomagnetic disturbances before the

Table 3 Scheme of PCA on Aug. 26, 1958.

Class	SC-max
Riometer Data Available	Thule, Barrow, College, Farewell
Associated Flare	
importance	3
onset time	0005 Aug. 26
position	N 20 W 54
Onset of PCA	0100 Aug. 26
Initial Rate of Increase of Absorption	1 db/hr (01 h–15 h Aug. 26; Thule)
Maximum Absorption	16 db (18 h Aug. 26–03 h Aug. 27)
Time of Associated Magnetic Storm	SC 0243 Aug. 27 SC 0303 Aug. 27
Beginning of Recovery Phase of PCA	in progress by 04 h Aug. 27

(after H. Leinbach, 1962)

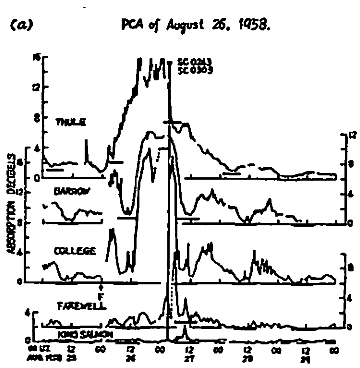


Fig. 5 (a) PCA on Aug. 26, 1958 detected by riometer sin the north America region. (after H. Leinbach)

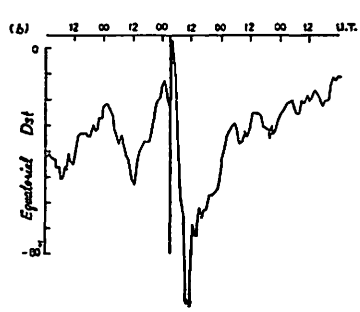


Fig. 5 (b) Equatorial D_{st} during the same period. (after M. Sugiura) occurrence of SSC. All of them, however, shows the close relation to AA, as stated about the event on Feb. 10, 1958. For example, the event on Aug. 26, 1958 will be described. The event is noticeable in the simultaneity and the intensity of both phenomena. Table 3 gives the scheme of PCA and Fig. 5 shows PCA detected by riometers in the North America region and Equatorial D_{st}. About a

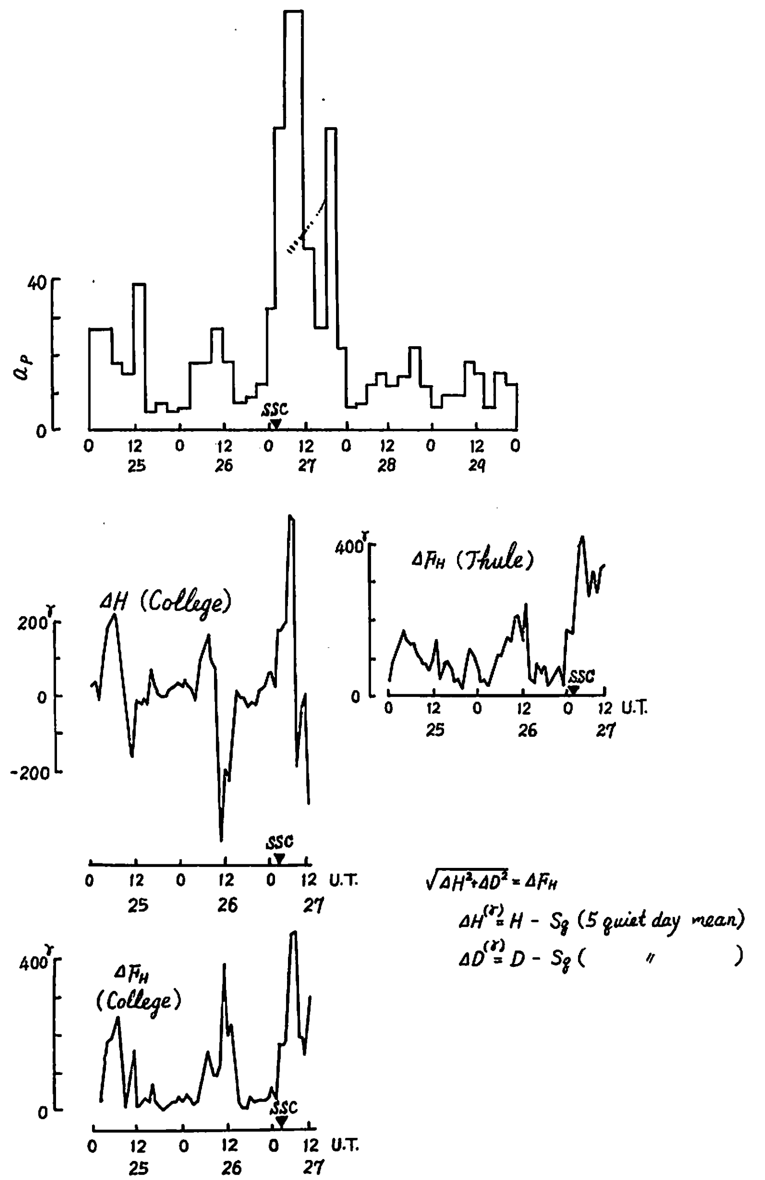
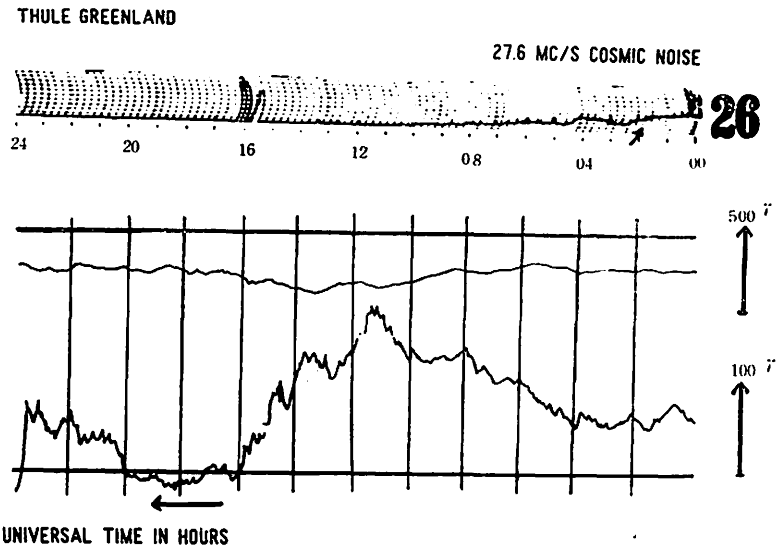
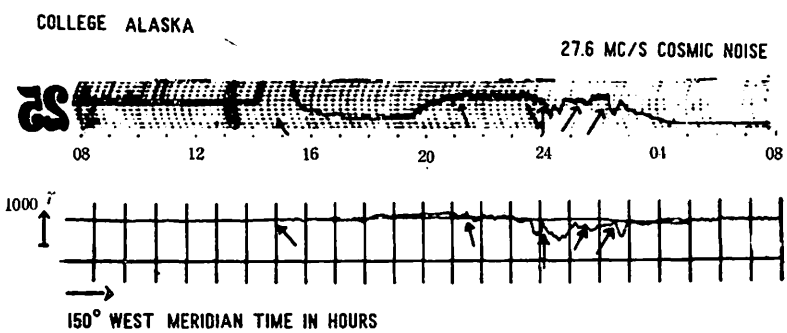


Fig. 6 Geomagnetic disturbance on Aug. 25, 26 and 27 in the high latitude region.

day before SSC, PCA and D_{st} begin to change. Compared with Fig. 5, Fig. 6 shows the discrepancy of time variations of the geomagnetic disturbance and PCA, together with their simultaneity. The geomagnetic disturbance develops remarkably around midnight at College, while PCA at College shows the typical midnight recovery. Also the comparison of the original riometer records to magnetograms in Fig. 7 shows that at College, even the small peaks of riometer records coincide



(a) Thule



(b) College

For the convenience, magnetogram at Thule and riometer record at College are reproduced inside out.

Fig. 7 Comparison of the riometer records and magnetograms on Aug. 26, 1958.

very well with the magnetic disturbances and at Thule, the small peaks are not observed as well the parallelism between the geomagnetic variation and PCA.

Thus the concerned geomagnetic disturbance seems to relate closely to AA.

On the other hand, the geomagnetic effects on PCA looks ambiguous in PCA, which are detected by riometers in the North America region in Fig. 5, too. But the maximum depression of D_{st} occurs midnight in this region. Therefore, the effects will be perhaps masked by the well developped midnight recovery. The

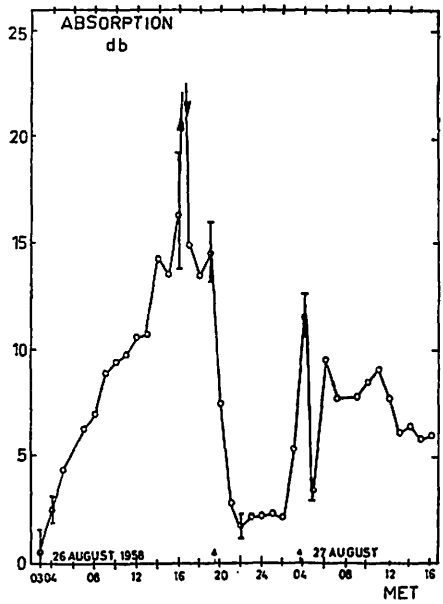


Fig. 8 PCA of Aug. 26, 1958, observed at Kiruna (geog. lat.: N 67°50′, geog. lon. E 020°25′; geom. lat.: 65.3°, geom. lon. 115.6°). (after B. Hultqvist & J. Ortner, 1962)

PCA observed at Kiruna where is in the dayside, in Fig. 8 seems to support the view. At the station, PCA suddenly develops corresponding to the maximum decrease of D_{st}, in spite of gradual increase at Thule, denoting the gradual increase of solar sub-cosmic ray. The subsequent midnight recovery is distinct.

In other events, the circumstances are nearly the same, though the small magnetic disturbances have no control over PCA.

4. Conclusion

On Feb. 11, 1958, magnetic disturbance occurred simultaneously with the onset of PCA in the auroral zone and it seems possible to suggest any relation between PCA and such magnetic disturbance. The examination of the events during the

IGY, with more detailed research of one on Feb. 11, 1958 results in that the magnetic disturbances relate more closely to Auroral Absorption than to PCA itself, and the simultaneity seems to be caused by the geomagnetic effects on PCA, apart from that the disturbances are those caused by invasion of the PCA-producing particles. But it may be necessary to examine more events, in order to establish the above mentioned view.

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PCA の Pre-SC 過程における地磁気変化

山 口 又 新

概　　要

PCA は Solar sub-cosmic ray が，極域下層電離層を異常電離することによって起こり，同時の磁気擾乱とは対応しないといわれている。たまたま 1958 年2月 11 日の磁気嵐に先行して起ったた PCA の場合には，極光帯で PCA が発生するのと，ほとんど同時に磁気擾乱が起こり，両者の間の何等かの関係が想像された。IGY 中に起った PCA について，この種の磁気擾乱を調査した。数例が見出された。しかしながら，これらの磁気擾乱は，AA と密接に関係し，PCA との直接的関係は認め難い。