23 February 1956 with Particular Reference to Auroral Zone Absorption, J. Geophys. Res., **62** No. 3, (Sept. 1957) 431-463.
R. R., Brown: Balloon Observations of Auroral-Zone X Rays, J. Geophys. Res., **66** No. 5, (May 1961) 1379-1388.
J. W. Cox, and K. Davies: Statistical Studies of of Polar Radio Blackouts, Can. Jour. Phys., **32** (1954) 743-756.
T. Gold: Origin of the Radiation Near the Earth Discovered by Means of Satellites, Nature, Lond., **183**, (Feb. 7, 1959) 355-358.
E. L. Hagg, D. Muldrew and E. Warren: Spiral Occurrence of Sporadic-E, J. Atomos. Terr. Phys., **14** Nos. 3/4, (1959) 345-347.
Y. Hakura, Y. Takenoshita and T. Otsuki: Polar Blackouts Associated with Severe Geomagnetic Storms on Sept. 13th 1957 and Feb. 11th, 1958, Rep. Ionos. Res. Japan, **12** (1958) 459-468.
I. Kasuya: Statistical Study in the Occurrence of Polar Blackouts, J. Radio Res. Labs. (Japan), **7** No. 33, (Sept. 1960) 451-465).
J. H. Meek: Ionospheric Disturbances in Canada, J. Geophys. Res., **57** No. 2, (1952) 177-190.
A. P. Nikolski: On the High-Latitude Geographic Distribution of Anomalous Absorption of Radio Waves in the Ionosphere, Dok. Akad. Nauk. USSR, **112**, 4, (1957) 628-631; (Translated by E. R. Hope, DRB, Canada, translation number T244R).
E. N., Parker: Interaction of the Solar Wind with the Geomagnetic Field, Phys. Fluids, **1** No. 3, (May-June, 1958) 171-187.
G. C. Reid and H. Leinbach: Low-Energy Cosmic-Ray Events Associated with Solar Flares, J. Geophys. Res., **64** No. 11, (Nov. 1959) 1801-1805.
G. C. Reid and M. H. Rees: The Systematic Behavior of Hydrogen Emission in the Auroral II, Planet. Space Sci., **5** No. 2, (June 1961) 99-104.
L. Thomas: The Temporal Distribution of Storm-type Sporadic E in the Northern Hemisphere, Some Ionospheric Results Obtained during the International Geophysical Year (Elsevier Pub. Co.) pp. (1960) 172-179.
L. Thomas and W. R. Piggott: Some Aspects of the Incidence of Polar Blackout during the IGY, Some Ionospheric Results Obtained during the the International Geophysical Year, (Elesevier Pub. Co.) pp. (1960) 62-71.
J. A. Van Allen and L. A. Frank: Radiation Around the Earth to a Radial Distance of 107,400 km., Nature, Lond., **183** (Feb. 14, 1959) 430-434.

Discussion

Hill, G. E.: The occurrence of more blackout in the morning hours compared to the evening may be mainly due to the diurnal variation of the $F2$ layer critical frequency.

Agy, V.: Perhaps, but it is doubtful that this effect is strong in the auroral zone where the maximum frequency of occurrence is well after sunrise.

JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-I, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part I

I-2-3. Polar Cap and Auroral Zone Absorption Events During the First Six Months of the I.G.Y.

G. E. HILL
AVCO Research and Advanced Development Division, Wilmington, Mass., U.S.A.

Our investigation consisted of synoptic analysis of ionosonde data for the first six months of the IGY. The purpose was to study thoroughly the development of high latitude absorption events. To do this Northern Hemisphere synoptic charts of f_{min} (the lowest frequency observed on ionograms) were analyzed for the six-month period at intervals of three hours. From these charts, a comprehensive list of polar cap and auroral zone absorption events has been compiled. To illustrate quickly the technique of analysis a typical SID is shown as it appears on a synoptic chart. Important features of this SID are seen at a glance: absorption on only the sunlit side of the earth and increased absorption going toward the equator.

In finding the PCA and AZA events, all available f_{min} data was analyzed north of 20°N (seventy stations). Poleward of 50°N there are forty-two stations which are distributed in such a way that the polar cap and the auroral zone regions are well sampled. In the construction of the charts some smoothing was done to allow for short-term fluctuations of f_{min} and for differences in f_{min} due to equipment. The existence of a PCA was defined according to the following criteria:

a. the f_{min} as analyzed on the charts was either 3 Mc/s or more in the darkened portion of the polar cap or 4 Mc/s or more in the illuminated portion.
b. the above criterion was satisfied on at least two consecutive charts.
c. the area covered on at least one chart was a third or more of the polar cap region.

All PCA events determined by these criteria are listed in Table I.

Having established the existence of a PCA event, the onset time is defined according to the first criterion alone. In general, a PCA event may have begun up to three hours prior to the onset time listed because these times are based on the three hourly charts. The intensity of each PCA event is measured by the maximum f_{min}, which is defined by the highest analyzed value of f_{min} during the event. When blackout occurs the maximum value is indicated by the letter B. The duration of each PCA event is classified into three categories; less than 12 hours, 12 to 24 hours, and greater than 24 hours; and the end of the PCA event is defined as the time when the f_{min} value drops below the value established for the onset.

Of the 22 PCA events listed in Table I only 10 have been previously reported. To identify the unreported ones, the onset times have been underlined. At least three of the unreported events are major ones; *i.e.*, events with a duration of more than 24 hours and an intensity great enough to cause blackout conditions. These events occurred on July 1, August 10, and September 19–20, 1957.

There are several reasons why some PCA events have remained hitherto undetected. One reason is that in the past the data used in measuring absorption has been taken from only a few locations. For instance, if f_{min} data from College, Alaska alone were used, only about half of the listed event could have been detected. Furthermore, unless a minimum absorption required for the existence of a PCA event was set high enough so that only the severe cases were found, many events would have to be listed which were not actually PCA events. A similar difficulty exists with limited riometer data.

Another reason is that in measuring absorption by riometer, and forward scatter techniques, higher frequencies are used than with the ionosondes. The riometers and forward scatter circuits will be less sensitive to ionization in the upper *D* region than ionosondes. Since it is particles in 1–10 Mev range that ionize the upper *D* region, PCA events caused by protons with energies in this range may not be detected by riometer or VHF forward scatter techniques.

It should be emphasized that in establishing the PCA events in Table I, absorption in the auroral zone was not considered the same as polar cap absorption. The distinction between a PCA event and an auroral zone absorption (AZA) event has been described already in the literature. Occasionally it is difficult to separate the PCA and AZA events. During the summer months an AZA event is easily masked by a PCA since most of the polar cap is sunlit. During the winter months, the reverse is true; and AZA may mask a PCA because only a small portion of the polar cap near the auroral zone is illuminated. This latter difficulty was apparent in the PCA events of October 5 and November 26, 1957 when it was difficult to distinguish between the two types of absorption.

Although PCAs and AZAs usually occur fairly close together in time, and sometimes even overlap, there are cases where one or the other occurs alone. This happens because the basic causes of the two types of events differ. In recent studies of solar-terrestrial disturbances, it has been found that following the occurrence of a solar flare and prior to a sudden commencement of geomagnetic activity, energetic particles enter the polar regions of the earth's atmosphere and cause enhanced ionization in the *D*-region and in

Table I. List of PCA Events During the First Six Months of IGY.

PCA							Flare			Solar Radio Noise (Mc/s) $(10^{-22}\ wm^{-2}(c/s)^{-1})$			
Month	Day	Onset	Intensity	Duration <12	Duration 12-24	Duration >24	Start	Imp.	Position	10000 to 3000	3000 to 1000	1000 to 450	450 to 80
July	1	<*00*	B*			X	Pre IGY						
	3	09	B			X	3/0712	3_+	N14 W40	M 600	M 585	L >282	M (700)
							3/0830	3_+	N10 W42	L *2380*	M *8200*	L 5200	S 3400
	25	00	5		X		24/1712	3	S 24 W27	M *336*	S 352	—	—
							24/1801	3	S 24 W27	—	L 1275	L 1700	M 1000
	28	15	5		X		—						
Aug.	10	*00*	B			X	Prominence (9/1530)	3_+	S 29 W90				
	28	21	B			X	28/0913	3	S 31 E 33	—	—	( )	( )
							28/0913	3	S 31 E 33	L *693*	M 1192	M >99	M 106
	31	15	B			X	31/1257	3	N25 W02	L >*900*	L 3900	L >*8500*	M >*1400*
							31/1338	2_+	N12 W02	L >*900*	L <3900	L >14000	L >1400
Sept.	2	19	B		X		2/1313	2_+	S 34 W36	—	—	L 360	—
							2/1313	2_+	S 34 W36	—	L *304*	—	L 3000
	3	*15*	B			X							
	10	*06*	4	X			—						
	12	09	B		X		11/0236	3	N13 W02	L 584	L 604	M >30000	M 520
	19	*03*	4			X	18/1722	3_+	N23 E 08	—	—	—	—
							18/1818	3_+	N20 E 03	—	M L *275, 92*	L 980	L 2000
	20	*03*	6		X								
	21	15	B			X	21/1330	3	N10 W06	L *1095*	M *785*	M 600	S 4000
							21/1440	2	N08 W22	L —	M *200*	L 160	—
	22	*12*	B			X							
	26	21	6			X	26/1907	3	N22 E 15	—	L *67*	L 450	L >4000
Oct.	5	*03*	5	X			—						
	21	00	7			X	20/1637	3_+	S 26 W45	—	—	—	—
							20/1644	3_+	S 26 W35	—	M(L) *4000*	M >14000	L >3700
Nov.	5	*03*	7		X		—						
	26	*12*	4	X			24/0848	3	S 14 E 37	L *543*	M >998	L 210	L >50000
			B S.H.				24/1100	3	S 12 E 35	M *313*	S *179*	S 240	—
Dec.	17	*03*	4			X	—						
	29	*00*	— 5 S.H.	X			—						

* B=Blackout; L=Duration greater than 60 minutes; M=Duration between 10 and 60 minutes; S=Duration less than 10 minutes.

the stratosphere. It is generally accepted that the energy of these particles is of the order of 100 Mev. It has been shown that such particles are low energy solar cosmic rays associated with flare activity. Analysis of f_{min} data reveals that the bombardment of the ionosphere by these low energy cosmic rays occurs in the region poleward of the auroral zone.

The development of two storms will be shown to point out their characteristic features. One storm occurred on July 24–25, 1957 and the other on September 18–22, 1957. Both the July and September storms are characterized by the development of a PCA within a few hours after the occurrence of the solar flare responsible. The July PCA lasted about a day and the September PCA about two days.

In both events, the PCA was more intense in the sunlit portion of the polar cap than in the darkened portion by several Mc/s. This difference in absorption between the sunlit and darkened regions is more noticeable in the September storm than the July storm because in September about half of the polar region is in sunlight and half is in darkness.

The main difference between the two absorption events described is that in the July storm no auroral zone f_{min} disturbance developed, whereas in the September storm one did develop following the sudden commencement of geomagnetic activity.

The behavior of both the geomagnetic field and the $F2$-layer critical frequency also showed a basic difference in the period following the July and September PCA events. The planetary index of geomagnetic activity, K_p, reached no higher than four during the whole week following the occurrence of the

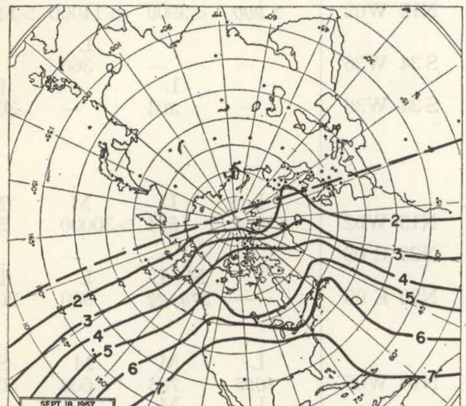

Fig. 1.

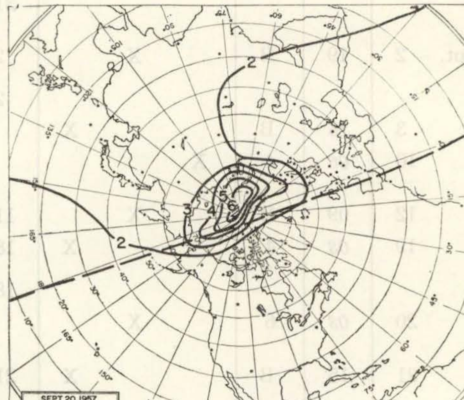

Fig. 3.

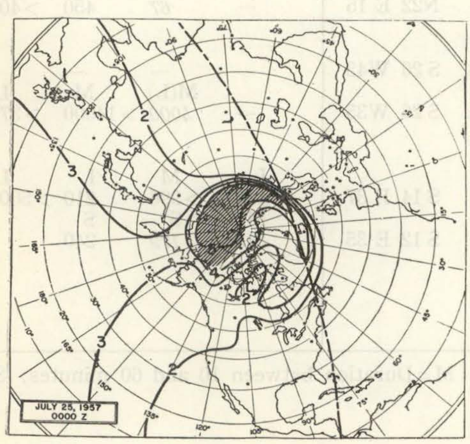

Fig. 2.

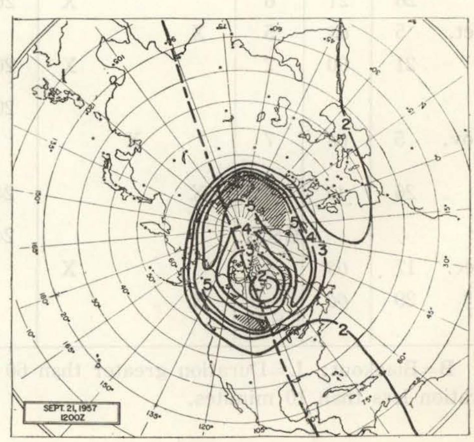

Fig. 4.

flare on July 24, while K_p reached 7_+ a few hours after the sudden commencement on September 21. The increase in K_p to 8_+ on the 22nd appears to be associated with another geomagnetic storm which began at 1344Z on the 22nd. In summary, both PCA events began within about six hours after the solar flare responsible and remained mostly in the sunlit portion of the polar cap. Following the PCA of the September storm, strong auroral zone absorption occurred, a geomagnetic storm developed, and the *F2*-layer critical frequency decreased markedly, whereas following the July PCA none of these additional disturbances were found.

The PCA event of August 10–11, 1957 has several very interesting features. Although it has been previously unreported and no associated flare was observed, this PCA is typical of a moderate to severe event. It was characterized by rapid initial growth, which took place between 2100Z on the 9th and 0000Z on the 10th. The duration of this PCA was about 48 hours, one of the longest observed. Its cause was probably an unreported flare near the limb (29S, 90W). There is strong evidence that a flare did, in fact, occur in the area of 29°S, 90°W around 1600Z on the 9th. A 250 Mc/s radio noise storm was observed on the 9th at 1.2 solar radii from the center of the solar disk. Furthermore, a 3_+ prominence region was observed between 1530Z and 2357Z. Between 1636Z and 1722Z down-flowing streamers were reported. It is known that flare activity usually precedes such streamers. Assuming that a flare did occur near the limb, the particles causing the PCA must have escaped from the ensuing solar cloud rather than from the immediate region of the flare.

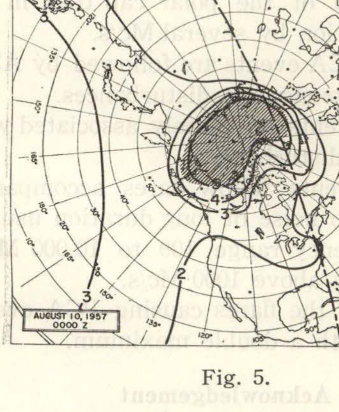

Fig. 5.

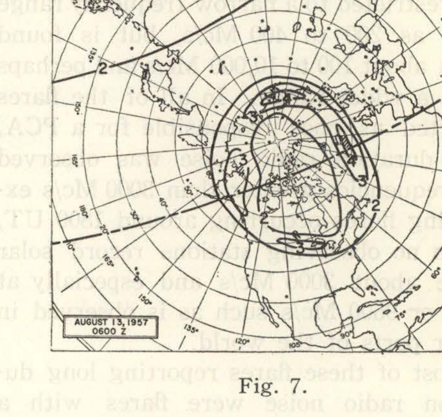

Fig. 7.

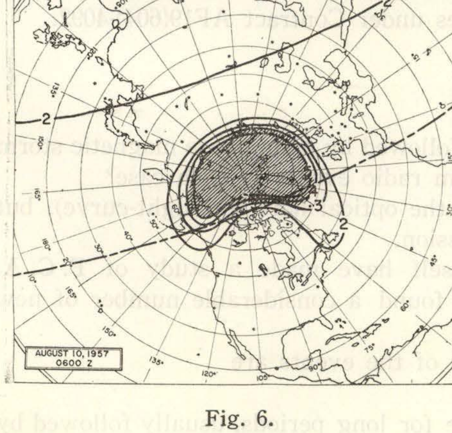

Fig. 6.

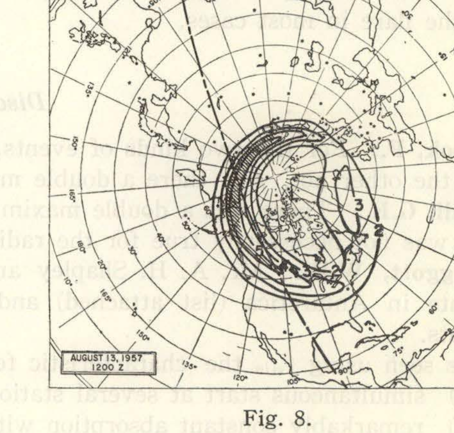

Fig. 8.

Early on the 13th, an auroral zone ring of absorption developed and lasted about fifteen hours. Whether or not this disturbance is connected with the PCA is not known. However, this is a typical example of an AZA. At the time of maximum absorption the K_p index reached 6.

Although it is generally conceded that all PCAs are preceded by a large solar flare, the converse is not true. That is, not all large solar flares are followed by PCAs. Therefore, we have sought to establish whether or not flares followed by PCAs have some common identifiable characteristics. A list was made of all classes 2, or greater, flares occurring during the six month period and of any solar radio noise accompanying these flares. This list was compared with our PCA list and the results indicate the following:

i. A PCA is caused by a flare accompanied by solar radio noise of long duration; i.e., the order of an hour.

ii. The long duration solar radio noise is not restricted to a narrow frequency range such as 200 to 400 Mc/s, but is found from about 100 to 10,000 Mc/s and perhaps even a wider range. In all of the flares selected as ones responsible for a PCA, long duration radio noise was observed at frequencies greater than 3000 Mc/s excepting flares occurring around 1800 UT, when no observing stations record solar noise about 3000 Mc/s and especially at 9400 or 9500 Mc/s such as is observed in other parts of the world.

iii. Most of these flares reporting long duration radio noise were flares with a double maximum. The long duration radio noise began during the second part of the flare in most cases.

Following the sudden commencement of geomagnetic storms, auroral zone disturbances develop. In terms of absorption, this development constitutes the second phase of the storm.

It is suggested that f_{min} auroral zone ring disturbances and geomagnetic main phase storms occur together. In those of the ionospheric storms, July 24–25, August 10–11, and October 21–22, no f_{min} ring or geomagnetic main phase storm occurred. In all the other storms, an enhancement of auroral zone absorption and a geomagnetic storm was found.

Conclusions:

1. Besides the SID type absorption, there are two other types—polar cap and auroral zone.

2. The analysis of f_{min} data on a hemispheric scale shows the occurrence of many PCA events which have not been found by other techniques.

3. A PCA event is more intense in the sunlit portion of the polar cap than in the darkened portion by several Mc/s.

4. Most PCA events are followed by AZA, $foF2$, and geomagnetic disturbances.

5. AZA events are closely associated with geomagnetic disturbances.

6. PCA events follow flares accompanied by solar radio noise of long duration usually in the frequency range 100 to 10,000 Mc/s, and especially above 1000 Mc/s.

7. Most of the flares causing PCA events were ones with a double maximum.

Acknowledgement

The research in this document was supported by AF Cambridge Research Laboratories under Contract AF19(604)-4092.

Discussion

Cook, F.: For the two kinds of events, one followed by main phase magnetic storm and the other not, was there a double maximum radio events in each case?

Hill, G.E.: There was a double maximum in the optical flare (i.e. light-curve), but this was not necessarily true for the radio emission.

Piggott, W.R.: Mr. A. H. Shapley and myself have made a study of P. C. A. events in Antarctica (list attached) and also found a considerable number of new events.

As seen using f_{min} the characteristic features of the events are

(a) simultaneous start at several stations;

(b) remarkably constant absorption with time for long periods, usually followed by a tail;

(c) increased absorption when the sun is above about 97°.

In contrast auroral events are usually local, very variable in time and shows different incidence at widely spaced stations.

JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-I, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part I

I-2-4. Sudden Cosmic Noise Absorption at the Moment of Geomagnetic Storm Sudden Commencements*

J. ORTNER,** T. R. HARTZ,*** O. HOLT,**** B. HULTQVIST,**
R. R. BROWN,***** H. LEINBACH****** and C. G. LITTLE*******

As has been reported by Brown (1961) bursts of X-rays have been observed at balloon altitude at the moment of SC of magnetic storms and sudden ionospheric absorption has been measured simultaneously with the X-rays by means of riometers in North America and Scandinavia. The original riometer records for the event of 27 June, 1960, are shown in Fig. 1. At the moment of the SC both the College and Kiruna records showed SCNA simultaneously, while the absorption during the rest of the interval represented in the figure does not show any marked correlation at the two observatories. This indicates that the electron bombardment of the upper atmosphere giving rise to the X-rays occures on a large scale.

Brown et al. (1961) raised the question if the short influx of electrons at the specific moment of the sudden commencement of a geomagnetic storm could be interpreted either

(1) by a "dumping" of electrons from the outer radiation belt brought about by the rapid geomagnetic field change at the time of the sudden commencement or

(2) by the escape of electrons from the plasma cloud encountering the geomagnetic field.

Since Brown's observations were made riometer information has been collected and studied for all SCs listed by Bartels in his three-hour-indices plottings for the period July 1958 to Dec. 1960. In this study all riometers situated in the northern hemisphere will be included. These are about 25 in number distributed between 56.4° and 88.0° geomagnetic north. At the present time data from the 5 Alaskan riometers are missing but it will be available in the near future. The report is therefore preliminary. The first results of this study are summarized in Table I.

For 31 of the 75 investigated sudden commencements a definite SCNA effect at all stations was observed. In 10 cases the effect was only visible on the European side of the earth, and in 3 cases only on the American part. The remaining 31 SCs were not associated with any effect at all. In order to eliminate the possibility that the described SCNA effect might be auroral absorption coinciding with the sudden commencement, all cases were eliminated for which the riometer recorded absorption already before the sudden commencement. Even then, however, there remain 20 cases, for which the effect can be definitely observed on both the day and night side of the earth within the same minute.

The data show also clearly a pronounced latitude effect with regard to the strength

* This paper was read by B. Hultqvist.

** Kiruna Geophysical Observatory, Kiruna C. Sweden.

*** Radiophysics Laboratory Defence Research Telecommunications Establishment, Ottawa, Canada.

**** Norwagian Defence Research Establishment, Kjeller, Norway.

***** Department of Physics, University of California, Berkeley, California, U.S.A.

****** Geophysical Institute, Univ. of Alaska, College, Alaska, U.S.A.

******* C.R.P.L., National Bureau of Standards Boulder, Colorado, U.S.A.