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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-3B-7. Cosmic Ray Effects Associated with Polar Cap Absorption Events

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§1. Data

We have studied cosmic ray effects associated with polar cap absorption during the period May 1957 to July 1959. Of the 24 intense PCA events listed by Reid and Leinbach[1], cosmic ray intensity data extending continuously from −5 to +10 days of each event are available for 21 events at Trivandrum, Huancayo and Climax. However, events on August 29, September 9 and 26 in 1957, August 21 in 1958 and July 14 and 16 in 1959 are preceded in each case by another PCA event within 10 days. These have been eliminated from the study since we are interested in the day-to-day changes of daily mean cosmic ray intensity up to 10 days following these events. Data from Trivandrum (Geographic lat. 8.48°, long. 76.95°, Geomagnetic lat. −1.13°, sea level) relate to μ meson intensity measured with vertical counter telescopes and corrected for changes of barometric pressure and upper air temperature using radio-sonde data. Data for Huancayo (Geographic lat. −12.05°, long. 284.6°, Geomagnetic lat. −0.69°, 3400 meters) and for Climax (Geographic lat. 39.37°, long. 253.8°, Geomagnetic lat. 48.17°, 3400 meters) relate to neutron monitor intensity corrected for changes of barometric pressure. We are grateful to Dr. J. A. Simpson for the use of the neutron monitor data.

We have initially examined changes of intensity at Climax for the classification of PCA events in terms of their association with changes of daily mean cosmic ray intensity. This is because, of the three stations considered, the Climax neutron monitor has the lowest mean energy of response and therefore exhibits the largest changes of intensity. We find that six PCA events are not followed within one or two days by cosmic ray decreases exceeding 2.5% in 24 hours at Climax. These are referred to as 'group A' events. The intensity changes at Climax for each of these events are shown in Fig. 1. The other nine PCA events are followed within one or two days by cosmic ray intensity decreases exceeding 3% in 24 hours at Climax. These are referred to as 'group B' events.

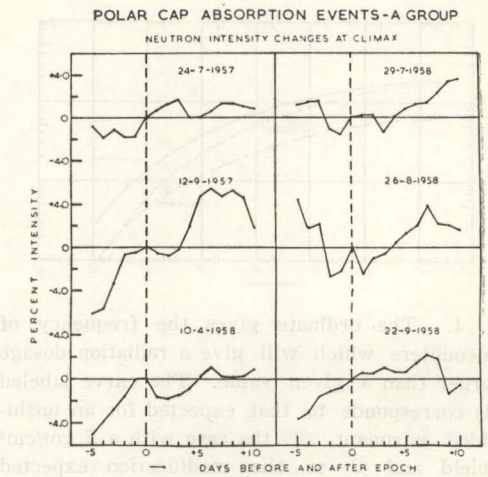

Fig. 1. Daily mean neutron intensity changes from −5 to +10 days at Climax corresponding to each polar cap absorption event of group A. All intensities are shown as derivations from the values on epoch day.

The associated solar and terrestrial relationships of the individual PCA events in each group are shown in Table I. Chree analysis has been done from −5 to +10 days for A and B groups separately for the daily means of the following:

(1) Cosmic ray intensity
  (a) Meson intensity at Trivandrum
  (b) Neutron intensity at Huancayo
  (c) Neutron intensity at Climax
(2) H, the intensity of the horizontal component of the earth's magnetic field at Kodaikanal
(3) Ionospheric absorption* at 25 Mc/s

* We are indebted to Professor K. R. Ramanathan and Dr. R. V. Bhonsle of the Physical Research Laboratory, Ahmedabad, for this data.

Table I. Table showing the particulars of different events connected with polar cap absorption events.

Date of event	PCA starts at UT	Max. absor. at 27.6 Mc/s (db)	Probable flare				Magnetic storm				Delay in events in hours.	
			Time UT	Impor-tance.	Helio. Lat.	Helio. Long.	Date	Time UT	Type	Fig. of activity	T_1	T_2
					GROUP A							
24- 7-57	2015	2.0	1816	3	S 24	W22	—	—	—	—	02	—
12- 9-57	1200	0.5	0709		N12	W15	13	0049	SC	s	05	13
10- 4-58	1130	3.0	1010	1+	N18	W78	16	0418	C	ms	01	—
29- 7-58	0405	0.7	0303	3	S 14	W43	—	—	—	—	01	—
26- 8-58	0100	10.0	0005	3	N20	W54	27	0301	SC	m	01	26
22- 9-58	1430	4.0	0741	2+	S 17	W42	25	0409	SC	ms	04	62
					GROUP B							
29- 8-57	1300	9.0	1031	3	S 24	E 22	29	1920	SC	m	02	06
21- 9-57	1930	5.0	1332	3	N13	W08	21	1006	SC	s	06	18
21-10-57	0700	5.0	1637 (20th)	3+	S 25	W45	21	2235	SC	m	14	16
10- 2-58	0700	12.0	2108 (9th)	2+	S 13	W14	11	0124	SC	s	10	13
25- 3-58	2230	12.0	0950 (23rd)	3+	S 15	E 20	—	—	—	—	61	—
7- 5-58	0130	15.0	0039	3+	N24	W02	8	0751	SC	s	01	30
16- 8-58	0600	13.0	0432	3+	S 14	W53	17	0818	SC	ms	01	24
11- 5-59	0130	15.0	2055 (10th)	3+	N23	E 47	11	2330	SC	ms	05	22
10- 7-59	0700	15.0	1937 (9th)	2+	N19	E 67	11	1628	SC	m	05	33

T_1—Delay between flare and PCA. T_2—Delay between PCA and magnetic storm.

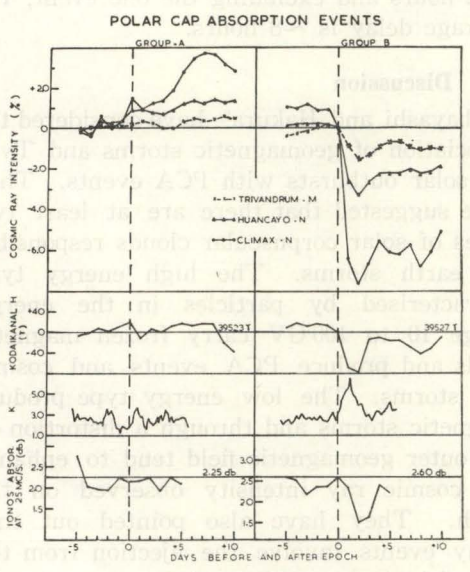

Fig. 2. Results of Chree analysis of daily mean intensity of mesons at Trivandrum, neutrons at Huancayo and Climax, ionospheric absorption at 25 Mc/s at Ahmedabad, horizontal component of earth's field at Kodaikanal and three hourly K_p indices for group A and group B PCA events.

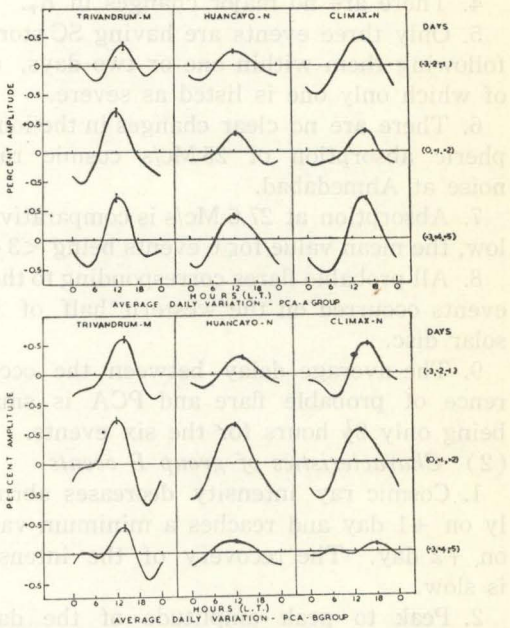

Fig. 3. Average daily variation for group A and group B PCA events for three day groups comprising (−3, −2, −1) days, (0, +1, +2) days and (+3, +4, +5) days respectively.

cosmic radio noise at Ahmedabad.

(4) Three hourly K_P indices.

We show in Fig. 2 the results of the Chree analysis of daily mean values. In Fig. 3 we indicate the average daily variation for meson intensity at Trivandrum and for neutron intensity at Huancayo, and Climax for three day groups comprising (−3, −2, −1), (0, +1, +2) and (+3, +4, +5).

§ 2. The Results

We can observe the following characteristics of associated changes for the two groups of PCA events separated in terms of their cosmic ray effects.

(1) *Characteristics of group A events*

1. Meson and neutron intensities are above normal on epoch day. They increase from +4 to +8 day. On +7 day, the intensity at Climax is 3.5% above mean.

2. Peak to peak amplitude of the daily variation of cosmic ray intensity and the diurnal and semidiurnal components are large for the group comprising +3, +4 and +5 days at equatorial and high latitude stations.

3. H, the horizontal component of the geomagnetic field at Kodaikanal is depressed by about 30 γ on +1 day but no major cosmic ray storm follows the PCA event.

4. There are no major changes in K_p.

5. Only three events are having SC storms following them within one or two days, out of which only one is listed as severe.

6. There are no clear changes in the ionospheric absorption of 25 Mc/s cosmic radio noise at Ahmedabad.

7. Absorption at 27.6 Mc/s is comparatively low, the mean value for 6 events being <3 db.

8. All probable flares corresponding to these events occurred on the western half of the solar disc.

9. The average delay between the occurrence of probable flare and PCA is small, being only $2\frac{1}{2}$ hours for the six events.

(2) *Characteristics of group B events*

1. Cosmic ray intensity decreases abruptly on +1 day and reaches a minimum value on +2 day. The recovery of the intensity is slow.

2. Peak to peak amplitude of the daily variation of cosmic ray intensity is maximum for the group of days comprising epoch, +1 and +2 days. Since the daily mean intensity simultaneously undergoes a very large change, the large amplitude of daily variation can arise due to curvature effect as discussed by Kane[2]. The amplitude of variation for this period cannot therefore be directly interpreted in terms of the primary anisotropy.

3. Kodaikanal H is depressed by about 70 γ on +1 day, the depression being much larger than in group A events. Geomagnetic field recovers in a manner characteristic of the main phase of a geomagnetic storm.

4. K_p reaches maximum value on +1 day, and is significantly high on +1 and +2 days.

5. Eight out of nine events are followed by SC storms. Most of them are either moderately severe or severe.

6. Daily range and the daily mean ionospheric absorption of cosmic radio noise at Ahmedabad are low on +2 and +3 days.

7. Ionospheric absorption at 27.6 Mc/s is large, the average for nine events being >11 db.

8. The associated flare has no preference for either the eastern or the western limb on the solar disc.

9. The delay in the PCA event after the occurrence of the flare is comparatively large. On one occasion, it is ~60 hours. The average time delay for the nine events is ~12 hours and excluding the one event, the average delay is ~8 hours.

§ 3. Discussion

Obayashi and Hakura[3] have considered the association of geomagnetic storms and Type IV solar outbursts with PCA events. They have suggested that there are at least two types of solar corpuscular clouds responsible for earth storms. The high energy type characterised by particles in the energy range 10 to 100 GV carry frozen magnetic fields and produce PCA events and cosmic ray storms. The low energy type produce magnetic storms and through a distortion of the outer geomagnetic field tend to enhance the cosmic ray intensity observed on the earth. They have also pointed out that many events involve the ejection from the sun of both types of clouds.

Since we have considered only PCA events, we have according to Obayashi and Hakura, either high energy corpuscular clouds or a combination of high and low

energy clouds. We find that amongst these, many with the highest energy, *i.e.* which generally have the shortest time as in group A, produce minor geomagnetic effects and almost no cosmic ray effects. Thus Obayashi and Hakura's classification can be extended to a third category, consisting of events where relativistic protons are emitted without the arrival at the earth of either low or high energy plasma clouds. The steadily rising cosmic ray intensity in group A events from −2 to +7 days represents in many cases a recovery from earlier cosmic ray storms. This indicates that the conditions for the arrival of relativistic protons by themselves are most appropriate when the interplanetary magnetic fields have been stretched out towards the earth through earlier high or low energy plasma clouds.

Alternatively, it could also indicate the presence in interplanetary space of scattering regions of plasma clouds with magnetic fields left over from the plasma cloud resposible for the earlier Forbush decrease. The 'A' type PCA events which do no produce significant changes of daily mean cosmic ray intensity or of geomagnetic field are nevertheless associated with anisotropy of cosmic rays 3 to 5 days after the flare.

The authors are grateful to Dr. U. R. Rao for many helpful discussions and to the staff of the Computation Section of the Laboratory for assistance. It is a pleasure to acknowledge the support from the Department of Atomic Energy, Government of India.

References

1) G. C. Reid and H. Leinbach: J. Geophys. Res. **64** (1959) 1801.
2) R. P. Kane: Ind. J. of Phys. Vol. XXXV, No. 5 (1961) 213.
3) T. Obayashi and Y. Hakura: J. Geophys. Res. 65 (1960) 3131.

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-3B-8. A Synopsis of Riometer Observations on the Polar Cap Events of November 1960

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During November 1960, a number of outstanding disturbances of the earth's upper atmosphere occurred which have been attributed to the arrival of energetic, charged particles from major flares on the sun. These disturbances have been studied with the aid of a number of riometers at stations located along a north-south line across the auroral zone—from Resolute Bay to Ottawa, Canada. Ionospheric absorption data are presented for the period 12-17 November with particular emphasis being placed on the polar cap absorption events of November 12 and November 15. The ratio of absorption at 30 Mc/s to absorption at 60 Mc/s has been evaluated for certain periods. These data are discussed and interpreted in terms of height of the absorbing region.

Ionospheric absorption of high-frequency and very-high-frequency radio waves, which occurs very frequently in northern latitudes, is studied extensively at the Defence Research Telecommunications Establishment, in Ottawa. To provide data for this study, cosmic noise receivers (riometers) operating on a frequency of 30 Mc/s have been install-