Effects of the Solar Flares of 7 July 1958

Observed at Kiruna Geophysical Observatory, Sweden

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Abstract

The very strong effects in the auroral zone of the solar flares of 7 July 1958 as observed at Kiruna Geophysical Observatory by means of magnetometers, an ionospheric sounder, a cosmic noise absorption receiver (riometer), oblique auroral reflection receivers, transpolar communications receivers, and cosmic ray telescopes are reported and discussed. Several remarkable features of the terrestrial disturbances were observed:

1. Extremely strong absorption became apparent a few hours after the solar flare. In spite of a linearly increasing absorption during the first seven hours after the flare no change in height or critical frequency of the F2 layer was noted during this period.
2. The SIDs reported by Pacific Observatories at the time of the flares were not observed at Kiruna although Kiruna was on the sunlit side of the earth.
3. A magnetic storm and a large decrease in the counting rate of the meson component of cosmic radiation appeared simultaneously 31 hours after the flare.
4. The maximum absorption at 27.6 Mc recorded during this period surmounted 20 decibels.

Introduction

The ionospheric black-out phenomena following the solar flares of 7 July 1958 at 0032 and 0040 U.T. had in Kiruna a longer duration (c. 73 hours) than the black-out beginning on 23 February 1956 (c. 36 hours). On Kiruna records it is surpassed with respect to duration only by the black-out period of 22 June—26 June 1957 (c. 81 hours) during the last sunspot maximum.

The geomagnetic storm, which began 31 hours after the flares were first observed, is with respect to amplitude the strongest storm of this maximum period of solar activity. Deviations from the quiet day conditions in the horizontal component amounted to as much as 2,200 gammas between positive and negative peaks.

On 7 July the sun never dipped below the horizon as seen from Kiruna. Its angle of elevation was at local midnight between 6 and 7 July only ½ degree; a refraction correction of approximately ½ degree should be added to this to obtain the apparent elevation as seen from the ground. At the time of the flares the solar altitude was 3 degrees. Thus, Kiruna was situated near the boundary of the daylight side of the earth.

During the time of the flare outburst and throughout the entire period, equipments recording six parameters correlated with solar

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conditions were being operated at the Kiruna Observatory. These are magnetometers for all three components, panoramic ionospheric recorder (ionosounder), a unit for measuring ionospheric absorption of cosmic noise at 27.6 Mc/s (riometer), a VHF receiver for recording 87.9 Mc/s oblique auroral reflections, receivers for recording transpolar transmissions from College, Alaska, on 11.805 Mc/s and 17.900 Mc/s and cosmic-ray meson telescopes.

It might be of some interest to examine in detail the effects of the solar flare on the parameters mentioned for a far northern location (geographic coord. 67.8° N, 20.4° E; geomagnetic coord. 65.3° N, 115.5° E) situated during the first hours after the flare at the boundary of the daylight side of the earth and at the same time on the geomagnetic night side.

1. Review of observations of solar flares, SIDs, and solar radio noise on 6—8 July 1958

Table I presents data concerning solar flares of importance 2 or higher that occurred on 7 July (see also Fig. 1).

It seems likely that the observations No. 2—4 concern one and the same flare.

Most of the solar-flare correlated geophysical effects observed during the 7th of July and the days immediately following might therefore be attributed to one or both of the two flares, near the center of the sun's disk, which started at 0032 and 0040 respectively.

On 6th of July the High Altitude Observatory in Boulder, Col. (USA), gives information of only three flares, all of importance 1. For 8 July there was one flare of importance 3 (outburst 0619 U.T.), one of importance 2, and 11 of importance 1 − to 1+.

In spite of the fact that the sun was almost quite undisturbed on 6 July and the important flares of 7 July have been reported to have started not earlier than 0026 U.T. two observatories, Okinawa and Hiraisho in Japan, reported very strong gradual short wave fade-out (importance 3+ and 2+ respectively) with the starting time 0000 U.T. The duration was given as > 99 min and 140 min respectively.

Hiraisho also reported the beginning of a sudden enhancement of atmospherics only a few minutes after 0000 U.T.

Two sudden short wave fade-outs of importance 2 were observed in Canberra, one starting at 0030 U.T. and with a duration of 40 minutes and the second beginning 0110 U.T. and with a duration of 55 minutes. Starting times given are less certain than two minutes.

Radio noise bursts, which might have been connected with the large solar flares, were reported at 0025 and 0027 U.T. from Hollandia (New Guinea) and Mitaka (Japan) respectively and at 0038 U.T. from Mitaka. The Mitaka observation at 0027 indicated a very strong but very short flare on 201 Mc/s. From about 0103 to approximately one hour later, very strong radio noise emission on 201, 3,000 and 9,500 Mc/s was reported from the same observatory. At Sydney intense radio emissions of spectral types II and III were observed from 0027 U.T. and some tens of minutes on. Strong receptions with starting times 0028 and 0040 U.T. were also obtained on the single frequencies 600 and 1,420 Mc/s at that observatory.

Thus, both optical flares and solar radio noise bursts were observed from the centrally located flares. The ultra violet radiation effects i.e. the short wave fade-outs were also noted.

Figures 1 A, B, and C graph the solar flares, SIDs and major radio noise outbursts for the whole period 7—12 July.

2. Methods of Measurements

At Kiruna Geophysical Observatory the geomagnetic field components *X*, *Y* and *Z* are

Table 1

No.	Place of observation	Time of the beg. of the flare (U.T.)	Time of first observ. (U.T.)	Importance	Heliographic coordin. of the flare	Length of duration (min.)	Quality of observation
1	Mitaka	0032	0032	2+	26° N, 10° E	≥ 45	Clouds betw. 0026 and 0032
2	Mitaka	0040	0040	3+	28° N, 07° W		
3	Honolulu ...	0040	0040	3+	25° N, 07° W	94	Excellent
4	Sidney		0045	3	25° N, 10° W	≥ 90	Very poor
5	Mitaka	0417	0417	2	31° N, 11° E	≥ 8	

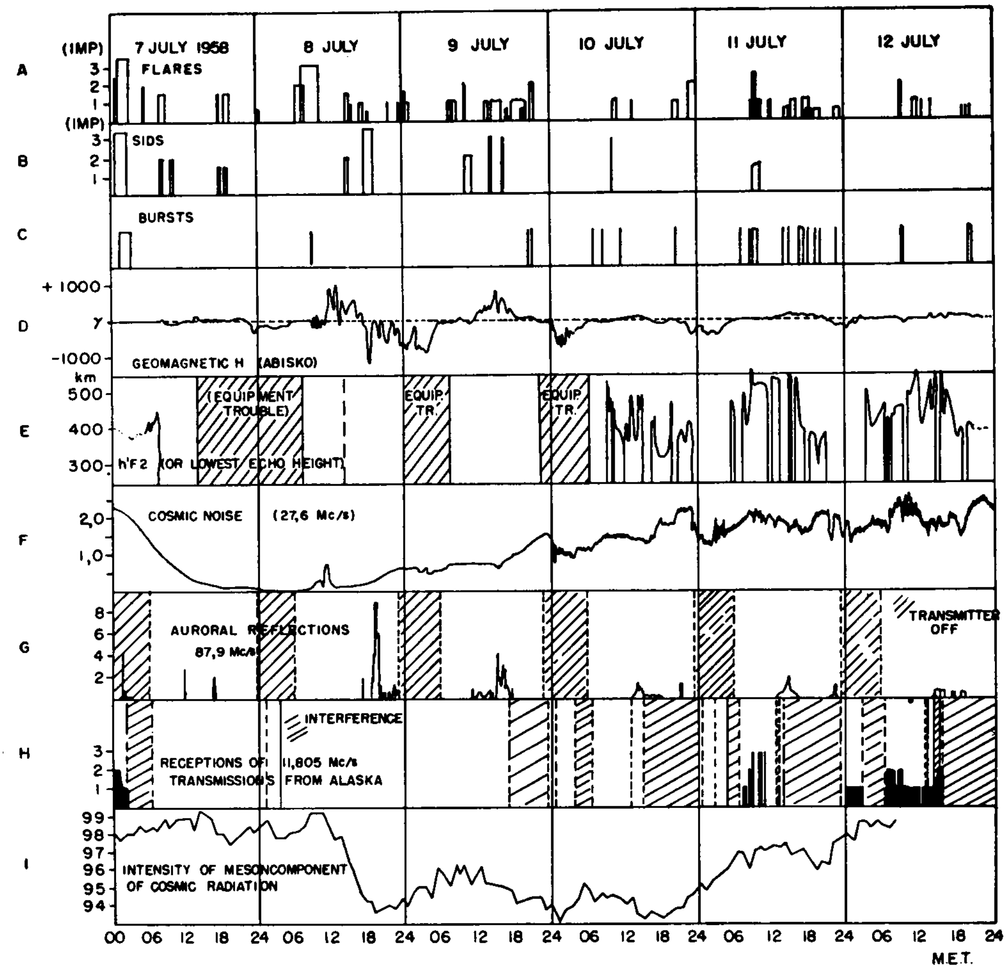


Fig. 1. Collocation of information on solar flares, SIDs, and major radio noise bursts and of records of the six parameters, geomagnetic horizontal component, the virtual height of F2, 27.6 Mc/s cosmic noise power, oblique auroral reflection on 87.9 Mc/s, reception of 11.805 Mc/s transmissions from Alaska, and the meson component of cosmic radiation.

recorded by means of three standard LA COUR variometers and a LA COUR quick-run magnetograph. At Abisko magnetic observatory,[1] situated 88 km northwest of Kiruna, the same types of instruments are used but they are arranged for measurements of D, H and *Z*.[2]

The panoramic ionosounder was constructed by LINDQUIST (1949).[3] The equipment sweeps over the frequency range 0.7—17 Mc/s in 30 seconds. The maximum pulse output power is 16 kW. On a routine basis it gives three sweeps every quarter of an hour but during special IGY world intervals it sweeps continuously (two sweeps per minute).

Since the early part of 1958 a riometer designed by C. G. LITTLE at the Geophysical Institute, College, Alaska (*vide* LITTLE and

[1] Some H-records from Abisko have been used as illustrations below, due to better quality of the records. The difference between the geomagnetic variations in Kiruna and in Abisko is very small.

[2] The magnetic recording work in Kiruna and Abisko is supervised by DR. N. AMBOLT's group at the Royal Board of Shipping and Navigation.

[3] It is operated at the Kiruna Geophysical Observatory under the supervision of DR. R. LINDQUIST by the Research Institute for National Defense.

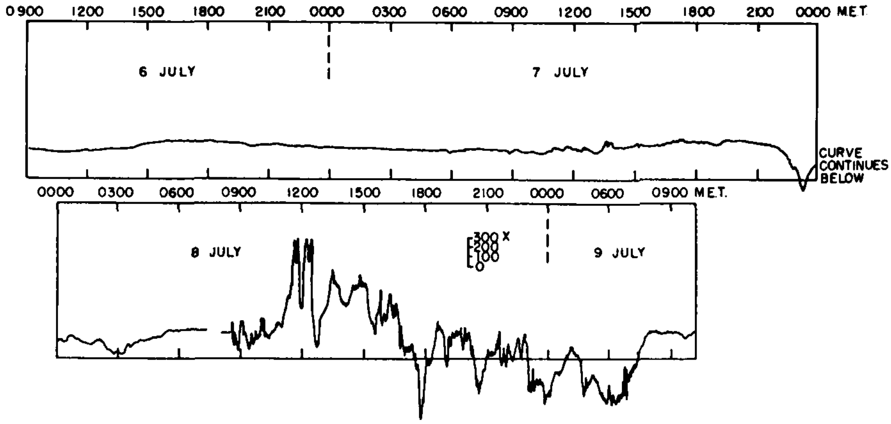


Fig. 2. Standard record of geomagnetic horizontal component at Abisko 6—9 July 1958.

LEINBACH, 1958), is being operated at Kiruna on a cooperative basis between Geophysical Institute, College, and Kiruna Geophysical Observatory. The riometer is a self-balancing cosmic-noise recorder giving information about the vertical total ionospheric absorption for the operating frequency (27.6 Mc/s). Its Yagi antenna is pointed at the zenith.

Since February 1958, aurorally propagated VHF signals from the Swedish F.M-broadcast transmitter in Östersund (87.9 Mc/s) situated 600 km SSW of Kiruna, and the Finnish F. M.-station in Kemi (92.8 Mc/s), 300 km towards SE have been recorded by means of a 90 Mc/s rhombic antenna pointing towards magnetic north, VHF receivers and pen recorders.

Two IGY backscatter-sounder transmitters with frequencies 11.805 Mc/s and 17.900 Mc/s operated by the Geophysical Institute in College, Alaska, have been monitored in Kiruna since the early spring of 1958 for investigations of transpolar communication with special reference to the effects of aurora. The transmitters are pulsed with a peak pulse output power of 4 kW. The output of the receivers modulate the intensity of oscilloscopes, the sweeps of which are synchronized with the pulse repetition frequency of the transmitters and the intensity of the light spots are recorded on continuously moving film.

The meson component of the cosmic radiation is measured on a routine basis by means of two international cubic G.M.-tube telescopes of the type recommended by CSAGI and by another big meson telescope, built by DR. A. E. SANDSTRÖM's group at the University of Uppsala.[1]

3. Observations in Kiruna during the first hour after the start of the flares

Fig. 1 shows what happened with the previously mentioned six interconnected parameters measured at Kiruna during the days 7th to 12th of July. The geomagnetic record was very quiet on 6 July (Fig. 2) and the first hours of 7 July. The equipment sensitivity was such that a crochet in the H-record of 5 γ amplitude was observable. No crochet could be observed which is in accordance with a statement of MCNISH (1937), that solar flare crochets are never observed further from the subsolar point than 70°. In this case the angle was 87°.

According to RAWER (1953), MITRA (1952) and other standard works a SID is observed over the entire sunlit side of the earth. No significant absorption that might be associated with the solar flare was, however, observed in Kiruna (sun's elevation 3.4°; cf. Figs. 1 F, 3 and 4). The SIDs observed in Japan and Australia were very strong, so the result seems to indicate that SIDs do not usually reach within 4—5 degrees from the boundary between the day- and night-sides of the earth. During the first hour following the flares the sun reached about 6—7° above horizon, so the change in the elevation was small. Such observational condi-

[1] The cosmic radiation registration at the Kiruna Observatory is supervised by Dr. A. E. SANDSTRÖM.

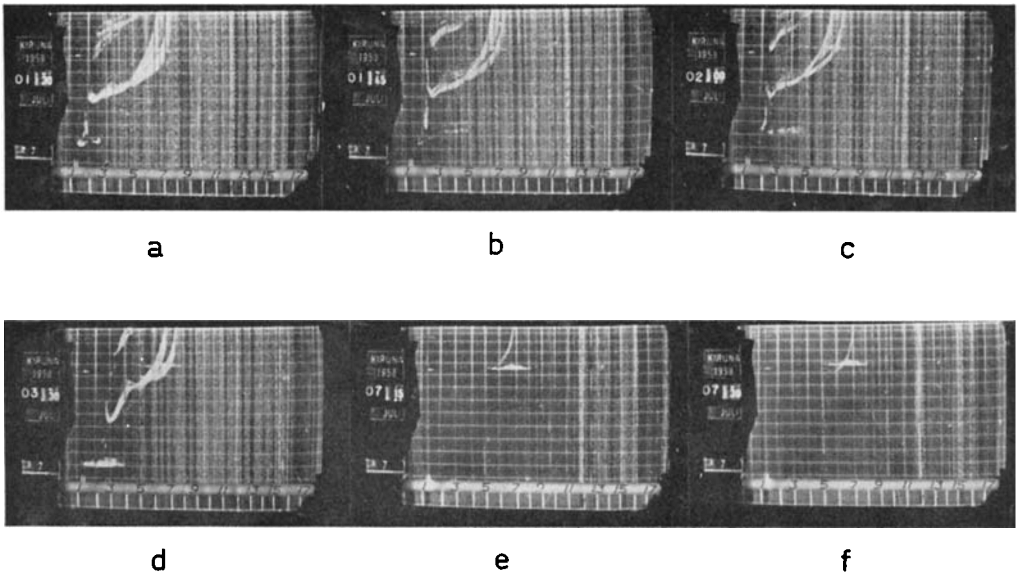


Fig. 3 a—f. Ionograms a—c show the situation before, 5 minutes after and 20 minutes after the 3 + flare outbreak at 0140 MET (no significant absorption visible on b and c); d was obtained almost two hours after the flare (Es, but no other important change); e and f show the last two returns that were found before the long blackout period began.

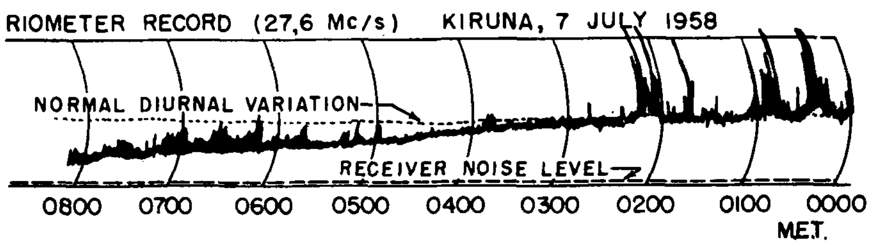


Fig. 4. Cosmic noise power measured by means of the Riometer during the hours before and after the 3 + flare outburst at 0140 MET on 7 July.

tions are relatively unusual and can of course be obtained in the northern hemisphere only at points to the north of the polar circle during the weeks around the summer solstice within a few hours from local midnight.

The propagation path of the transmissions from College, Alaska, to Kiruna was entirely over the sunlit side of the earth at the time of the flare outburst. It is therefore interesting that unusually good reception was obtained from 0035 to 0300 MET on 17.900 Mc/s (Fig. 5) and good reception was obtained also

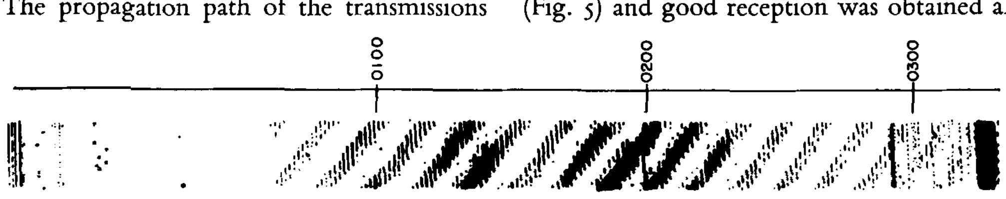


Fig. 5. Record showing reception in Kiruna of transmission on 17.900 Mc/s from College, Alaska. The received signal modulates the intensity of the beam of an oscilloscope, the sweep of which is approximately synchronized with the pulse repetition frequency of the transmitter. The periodicity of the record is due to the rotation of the transmitter antenna.

on 11.805 Mc/s. This indicates that the observed SID had little effect even for angular distances from the sub-solar point below 60 degrees (at the solar flare outbreak the sun's elevation was about 40 degrees at College).

Two equipments with which strong solar radio noise bursts can be recorded were being operated at the time of the flares; namely, the riometer and the recording receiver for reception of VHF aurorally propagated signals. The direction to the sun was almost perpendicular to the plane of the vertical riometer three element Yagi antenna. The angle between the sun and the lobe direction of the 90 Mc/s rhombic (pointing towards magnetic north) used for reception of auroral reflections was about 55° at 0130 MET. Thus, the sun was far out of the beam for both antennas. In spite of this, high intensity signals, not obtained during four months of operation, were received on both equipments.[1]

On the riometer record of Fig. 4 can be seen a strong intensity increase on 27.6 Mc/s starting at 0204 MET and lasting for about 12 minutes. It coincided with an intensive burst of long duration observed at the Mitaka Observatory on the frequencies 201, 3,000 and 9,500 Mc/s. The signal was quite different in fading character than interference, indicating that the band width of the increasing radiation was at least of the order of the sweep range of the Riometer (100 kc/s).[1]

The broadcast transmitter at 89.7 Mc/s used for recording VHF-auroral reflections halted operations after local midnight. The transmitter off times are indicated in Fig. 1 G. A strong signal of short duration was recorded during the off period of 7 July (starting at 0128 MET). Since the transmitter was off, the signal is assumed to have been of solar origin, which is supported by the coincidence with the strong burst on 201 Mc/s observed in Mitaka starting at 0219 MET.

The counting rate of the meson telescope did not show any marked variation for the hours immediately following the flare outbursts.

Thus the first hour after the start of the flares was characterized by the absence of a SID, the absence of a magnetic crochet, and a lack of change in the meson counting rate. However, the data show solar noise bursts on 27.6 Mc/s and 87.9 Mc/s receivers and enhanced reception of signal propagation across the pole from Alaska to Kiruna.

4. The behaviour of the observed parameters during the next few days after the flare

a. The Geomagnetic Field

As mentioned above the geomagnetic field was unusually quiet on 6 July and the exceptionally quiet condition continued during the first 8—10 hours of 7 July. From the forenoon of 7 July to 0845 MET of 8 July the H-curve was of the most common type obtained at Kiruna, being only somewhat disturbed with the fine structure of the curve having somewhat higher amplitudes than on a slightly disturbed day. The deflections did not surpass 100 gammas except during the normal night time bay (cf. Fig. 2).

At 0845 MET on 8 July the magnetogram for the H-component showed a sudden commencement followed by a rapidly varying trace with peak amplitudes of the order of only 100 gammas. At 1115 MET H began to increase very rapidly. A positive peak deflection of 1,200 gammas above normal level occurred at 1250 MET. The smoothed curve crossed the Zero-variation line again between 1700 and 1800 MET and decreased to 1,000 gammas below zero at 1810 MET. Except for some sporadic small positive deflections H stayed negative then until noon of 9 July. During the following days similar curves with steadily decreasing amplitudes appeared (Fig. 1 D).

The large scale appearance with positive deflections during the days and negative deflections during the nights is the normal one at Kiruna. The common interpretation of this data with a rotating earth in a declining auroral zone current system with the current direction from west to east on the dayside and in the opposite direction on the night side is well adaptable.

b. The Ionospheric Absorption

The ionosounder records showed a slow continuous increase in absorption during the morning hours of 7 July giving a decreasing intensity of the echoes and an increasing f_{min}

[1] Similar records have been obtained later in the summer of 1958 in connection with strong solar radio noise outbursts.

(compare Fig. 3a—d with 3 e and 3 f). After 0600 MET no extraordinary ray echo appeared until 10 July. Fig. 3f shows the last record containing any return before the very long blackout (73 hours) started. The next echo appeared first at 0910 MET on 10 July.[1] Several days followed with ionospheric reflections appearing and disappearing producing an oscillating blackout condition. A weak sporadic E layer was present before the flares started and could be found up to 0415 MET with only about half an hour of interruption. At the disappearance of Es the $f_{min}F$ was approximately 3 Mc/s.

The last receptions from College, Alaska, were obtained at 0230 MET on 7 July on 11.805 Mc/s, and did not reappear again until 11 July at 0730 MET (Fig. 1 H). BBC London interfered usually very strongly on that frequency during the whole day and night except for the forenoon hours. The interference could be seen up to 0630 MET on 7 July and returned on 9 July at 1700 MET, which was 38.5 hours before the Alaska transmissions returned. On 17.900 Mc/s the last reception from College was recorded at 0330 MET on 7 July. It appears that normal propagation conditions returned quite a good deal earlier where the midpath was south of the auroral zone than across the pole.

On the riometer record an increasing absorption began within two hours after the start of the flares (Figs. 4 and 6). The decrease in signal strength of incoming cosmic noise (measured in db) was nearly linear through the morning hours and had at 0700 MET on 7 July reached − 2.7 db below the average value for that hour for the previous week. The absorption increased all through the day and reached a maximum a few hours after midnight between the 7th and 8th of July (Fig. 6). For about 10 hours the cosmic noise intensity level differed from the zero line (obtained when calibrating with the noise diode shorted) by only a very small amount. During those 10 hours the cosmic noise level never was higher than − 17 db. Due to the uncertainty in the readings of the record it can only be said with

[1] As can be seen from Fig. 1 there were some equipment troubles during the nights, but there are reason to believe that no echoes occurred during those periods (there was total blackout in Tromsö; TÖNSBERG, 1958, personal communication).

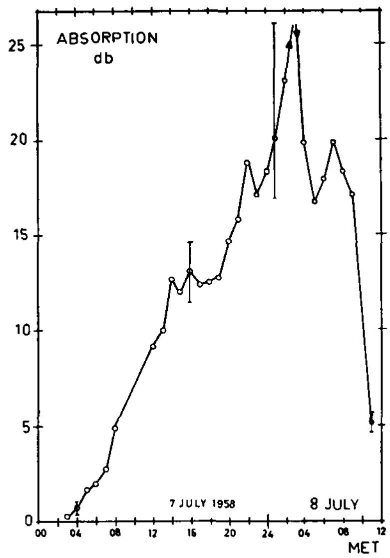


Fig. 6. Absorption in db as function of time, obtained from the Riometer record.

any certainty that the lower limit of signal strength was lower than − 20 db.

As far as we are aware absorption as great as this level has not been reported earlier in the literature.[1] During the solar flare of 23 February 1956, a maximal absorption of 1.8 db during night time and 8 db during the day was reported from College, Alaska (LITTLE and LEINBACH, 1958), which was on the night side of the earth at the time of the flare outburst.

The sudden commencement of the magnetic storm occurred at 0845 MET on 8 July but not until 1150 MET did the first high positive peak value in H appear (Fig. 2). During that transition period a large increase in cosmic noise signal strength from about − 17 db to a peak value of − 5.2 db was observed (Figs. 6 and 7). After that period the absorption never reached its maximum value again. A very slow recovery began in the afternoon of 8 July

[1] An absorption of 27 db was measured by the group at Sodankylä, Finland, after the flare of 7 July by means of a radio astronomy interferometer. (Personal communication to one of the authors by Prof. DIEMINGER.)

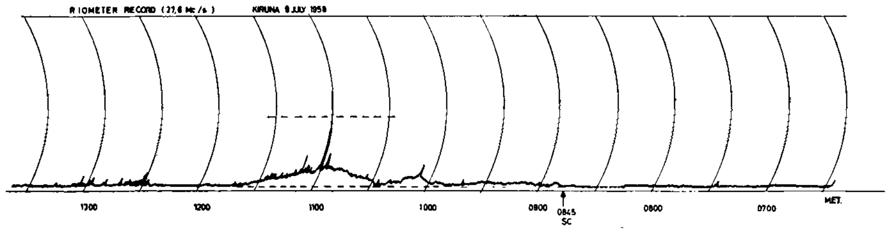


Fig. 7. Riometer record showing the strong decrease of absorption during the first few hours following the sudden commencement at 0845 MET.

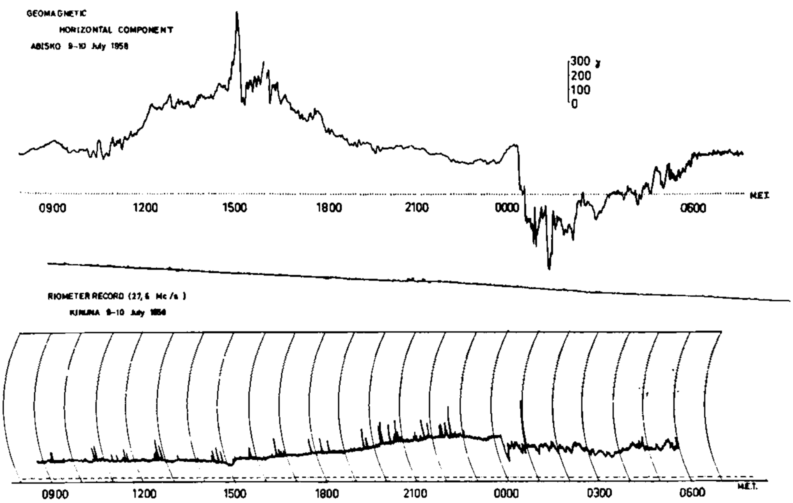


Fig. 8. Examples of correlation between changes of the geomagnetic H-component and of the ionospheric absorption.

bringing the signal strength back to its normal value in about 3 days.

The smoothness of the absorption record during the whole period 7—9 July is remarkable, and indicates a homogeneous absorption over a very large area. The contrast to absorption caused by auroral forms is evident.

During the recovery period two strong magnetic disturbances occurred, one positive and the second negative. On both occasions disturbances could also be seen on the riometer record (cf. Fig. 8). The positive magnetic disturbance, however, only caused a small smooth increase of absorption, while the disturbance crossing from a positive to a negative value of the horizontal magnetic component gave a sudden strong increase of absorption. This might indicate that different mechanisms are operating for production of positive and negative magnetic disturbances. The matter will be studied further with emphasis on the study of periods when the magnetic field variations change from positive to negative or vice versa.

During the period of short term appearance and disappearance of blackouts on 10—12 July a fairly good correlation existed between blackouts on the ionograms and the absorption record on the riometer (see Fig. 1 and Fig. 8). The riometer records were characterized by sudden absorption dips while the ionospheric records showed no returns at all for periods ranging from several minutes to several hours.

For the hours following the flare outbreaks and up to the blackout no deviations from the normal behaviour could be seen on the f_0F_2 curve. A comparison with the average curves for June and July of 1956 and 1957 showed a small increase from year to year of the critical frequency of the F_2 layer. The variations of the curve of midnight to 0500 MET, 7 July 1958, were similar to those of the same hours for June and July of 1956 and 1957.

The above can be said for the $h'F_2$ curve too, up to 0500, at which time the F_1 layer disappeared completely. From 0500 on only the lowest height from which echoes were received could be obtained from the records. That height is of course also a function of the absorption of lower layers.

Thus it should be emphasized that while the absorption effects were obvious during this period of 0230 to 0500 from the decreased cosmic noise background signal, from the decreased intensity of the returns on the ionosond and from the increase of lowest usable frequency, both the height of the F_2 layer and the critical frequency of the same layer were unaffected.

Up to 0908 MET on 10 July there was total blackout. During the following days blackouts of long and short duration were appearing and disappearing. The ionospheric returns would be present and then completely absorbed. If all—even very short blackouts were taken into account—no clear relation could be seen between f_0F_2 before or after a blackout. However, in investigating only blackouts with a duration longer than two hours (five occurred between 10 July and 14 July) it was found that in all cases f_0F_2 was lower after the blackout than before. The average change was about 0.5 Mc/s. Again looking at only these longer duration blackouts there is a clear tendency after the end of the blackouts for a slow increase of f_0F_2 at least during the first hour following the blackout.

Concerning $h'F_2$, it is more difficult to give any statement on the basis of the actual data, because it could fairly seldom be read from the records. The lowest height from which echoes were obtained, however, showed a very clear tendency to be a good deal higher after a long duration blackout than before (average change 91 km for the five blackout periods mentioned above). When short blackouts were included in the statistics the tendency was found to be not quite as definite. Fig. 1 E, which gives the value of $h'F_2$ or, when not observable, the lowest echo height, illustrates this. It can also be seen that the echo height almost always decreased during the first hour after the end of a blackout.

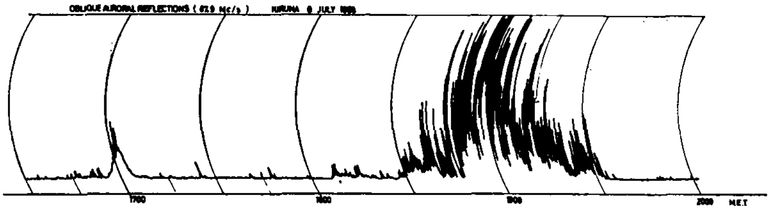
Thus, in analyzing the data from the longer lived but still relatively short duration blackouts, we find that the critical frequency of the F_2 layer immediately after the blackout was lower than before the blackout. The height of the F_2 layer was higher after the blackout than before indicating a possible expansion of the layer during the blackout period. During the next hour or so following the blackout the f_0F_2 would gradually increase and $h'F_2$ would gradually decrease.

c. 87.9 Mc/s Oblique Auroral Reflections

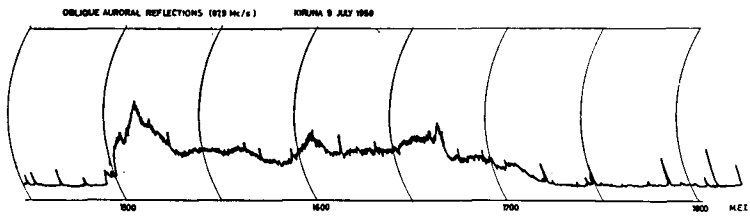
On Fig. 1G a few small amplitude bursts recorded with the auroral reflection receiver can be seen during the latter part of the 7th of July. These short duration signals are fairly common. Unlike the bursts mentioned previously at 0128 MET on 7 July, which occurred while the transmitter was off, these signals were received when the Östersund, Sweden, transmitter was on the air. The absorption had reached a very high value by this time but it was still many hours before the magnetic storm-causing beam arrived at the earth. These bursts received during the broadcasting period of 7 July were in general of much shorter duration than the normal oblique auroral reflections received before 7 July.

Not until the afternoon of the 8th of July (at 1700 MET) did new echoes of the ordinary fading type appear. Some hours later (beginning at 1827) an echo type was recorded that had never been observed earlier in Kiruna during four months observation. The fading spectrum of the signal had an appreciable portion within the frequency range of the recorder and the fading amplitude was very large. The recorder was overloaded during the peaks of incoming signal (see Fig. 9a).

At the time of the auroral reflection the absorption curve showed a smooth, slowly rising curve (Fig. 1F) with no indication of any rapid changes taking place in that part of the ionosphere which was in the beam of the vertical Riometer antenna.



a.



b.

Fig. 9. Records of oblique auroral reflections on 87.9 Mc/s. Transmissions from the Swedish FM-station Östersund were recorded in Kiruna by means of a rhombic antenna pointing to magnetic north.

The magnetic *X*-component had just reached the quiet day level again after a very large negative deflection. The *Z*-component had returned to a quiet level after negative deflections of great amplitude. The horizontal current parallel to the auroral zone was localized to the south of Kiruna, if we interpret the magnetic deflections as caused by a horizontal auroral zone current system.

During the largest magnetic deviations no auroral reflections could be seen, not even during the first few hours when the deflection in *Z* indicated that the current was flowing north of Kiruna, which is remarkable. As very strong reflections occurred a few hours later, when the absorption still was extremely strong, it is doubtful that the lack of reflections during the earlier period was due to absorption of the scattered radiation. It seems more likely that the aurora in spite of the magnetogram indications was to the south of Kiruna, which is supported by the information in the High Altitude Observatory's weekly report that the aurora was observed down to 39 degrees latitude.

Several suggestions might be put forward concerning the interpretation of the strong fading reception. As no effect could be seen on the cosmic noise incoming signal strength the aurora must have been very local and outside the beam of the vertical Riometer antenna. The corpuscular beam giving rise to the scattering aurora might be strongly modulated. However, the rapid rise and decay of signal strength are too fast to be caused by attachment, plus the fact that the decay time of the turbulence is supposed to be longer than a few seconds. A possible explanation of the strong fading amplitude might be that the number of scatterers giving rise to the signal was small. As the incoming signal strength was very high the turbulence and the electron density must have been very high.

What seems to be the most probable is, however, that the signal was not due to auroral propagation but came in via other modes of propagation from the south, the signal strength being so high that it could be recorded by means of the back lobe of the rhombic antenna. The latter assumption is supported by the following facts: F.M. transmitters in central Europe could be listened to at Sodankylä, Finland, during 8 July (KATAJA, 1958, personal communication), and the fading of the record was fairly like that of records obtained when receiving the transmissions from the Finnish F.M.-Station in Kemi with the Yagi antenna pointing towards the transmitter. If this explanation were correct the condition of the lower ionosphere was very

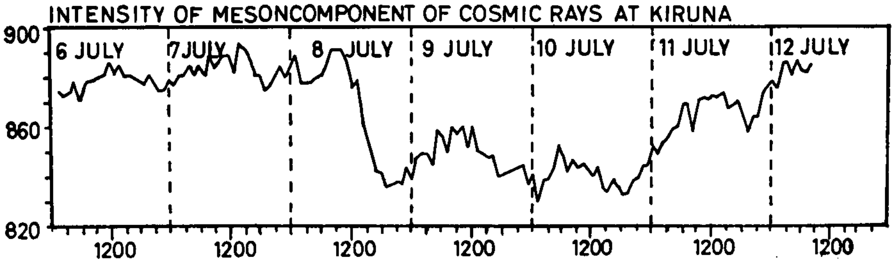


Fig. 10. Intensity of the meson component of cosmic radiation, recorded by means of the vertical channels of a G.M.-tube telescope.

unusual to the south of Kiruna rather than to north of it. This is in accord with the fact that blackout was first observed after the flare in Uppsala, Sweden (geomagnetic latitude 58.4° N) between 1600 and 2300 MET, on 8 July but not before that time interval. A final possibility is that signals came from both south and north.

Further studies will be devoted to this type of propagation with special emphasis on finding out whether such signals are arriving from the south, or if the auroral propagation mechanism in special cases can differ fundamentally from the common type.

On 9 July a long duration auroral reflection of common fading type was observed (Fig. 9b). During the days 10—12 July a slow decrease to ordinary reflection activity took place (Fig. 1G).

d. The meson component of cosmic radiation

The sudden commencement of the geomagnetic storm occurred at 0845 MET, 8 July, and a decline could be seen in the counting rates of the meson telescopes within the first hour thereafter. Fig. 10 diagrams this period, with the points representing the countrate integrated over one hour before the time in question. The decrease continued for about ten hours, reaching at 1900 MET a value some 5 % lower than during the morning hours. After that a slow regression began, lasting for several days (Fig. 1I and 10). The start of this FORBUSH type decrease, coincident with the start of the magnetic storm, seems to have been the normal behaviour at the time in question (SANDSTRÖM, 1958; personal communication).

Discussion

The most interesting feature of the disturbances mentioned above is without doubt the strong ionization in the lower ionosphere on 7 July, showing up in the very strong absorption of HF radio waves, and the fact that no magnetic effects could be observed. Such an effect was observed the first time in connection with the large solar flare of 23 February 1956 (according to SHAPLEY and ROBERTS, 1957) and several reports were published on it (BAILEY, 1957; LIED, 1957; SHAPLEY and ROBERTS, 1957, and others).

At least two mechanisms have been proposed for ionization of the lowest layers of the ionosphere. Based on observations by VAN ALLEN and his co-workers (cf. MEREDITH et al., 1955) CHAPMAN and LITTLE (1957) have postulated that bremsstrahlung is responsible for the ionization. That mechanism may be operating during auroral displays and geomagnetic storms of ordinary type but for flares of the kind discussed in this report it seems improbable that the necessary large electron flux should not cause any currents at all in the ionosphere.

BAILEY (1957) has assumed that heavy ions (chiefly calcium ions) were causing the strong absorption effect of 23 Februari 1956. The main difficulty with his hypothesis seems to be that effects should be observable far below 60 degrees geomagnetic latitude if calcium ions are the ionizing agent.

Arguments can be given for the hypothesis that the absorption is caused chiefly by solar ions of mass numbers below that of calcium (cf. HULTQVIST 1959a) and it seems even to be possible to explain hitherto observed effects with only protons as ionizors. The flux necessary for the observed absorption is extremely small, so the ions can move in STÖRMER orbits. Such a hypothesis also makes understandable the geographic distribution and the almost linear increase of absorption during the first 8—10 hours (HULTQVIST, 1959b).

It seems probable that the corpuscular radiation producing the effects discussed in this report is identical with that one deduced from radio observations of the sun by WILD, ROBERTS and MURRAY (1954).

The rapid decrease of absorption at the start of the magnetic storm may possibly be due to heating and expansion of the ionosphere, bringing the electrons towards higher levels where the absorption effect is smaller. From the fading characteristics of the record and the time displacement, the possible influence on the cosmic noise signal strength of the major radio noise burst at 0840—0850 MET on 8 July can be ruled out.

The proposed interpretation is in accordance with the well established fact that the F_2-layer in polar regions very often is destroyed at the beginning of a magnetic storm (RAWER, 1953), and also with the dynamo theoretical explanation of sudden commencement. ECKERSLEY'S (1942) theory for the destruction of the F_2-layer, mentioned, seems not to be adaptable (cf. HULTQVIST, 1959a).

Summary

There are many interesting facets to the details of this particular polar blackout. The solar flares occurring around local midnight at Kiruna produced SIDs in Pacific areas but not at sunlit Kiruna. Within two hours after the commencement of the solar flares, the ionization of the lower atmosphere had started. However, during these first few hours of increasing absorption, both the height and the critical frequency of the F_2-layer remained unaffected. The absorption kept increasing reaching a maximum about 24 hours after the flare.

The effect of the absorption was to produce a blackout of vertical incidence ionospheric returns and oblique trans-polar reflections for approximately three days. The first ionospherically reflected signals to return were transmissions (BBC-London) where the propagation midpoint area was situated to the south of Kiruna. 16 hours later vertical returns and still 22 hours later transpolar signals were received.

During flare observations the magnetic records were undisturbed. 31 hours after the flare a sudden commencement magnetic storm started. Simultaneously the cosmic ray equipment registered a clear decline in meson counting rates. During the magnetic storm oblique signals from distant transmitters at 87.9 Mc/s showed signs of very fast and very deep fading, similar to sputter on scatter circuits.

The ionospheric and magnetic storm period which followed the long blackout period showed many of the well-known effects; i.e., appearance and disappearance of ionospheric reflections, sudden short dips in the cosmic noise intensity, and large intensity variations of the horizontal component of the earth's magnetic field.

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