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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-3B-12. Observations at College, Alaska, of the November, 1960 Cosmic Ray Increases*

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The cosmic ray intensity and its variations, in the time interval between November 9 and 23rd, 1960 is presented and discussed. The time-sequence of the fluctuations and the connections with other geophysical parameters such as aurorae, magnetic indices, and forward-scatter ionosphere observations is described. It is suggested that the high energy particles and the low energy plasma clouds are not necessarily always emitted in the same directions from the sun.

Introduction

The New York University Cosmic Ray Research Project operates a standard Simpson type cosmic ray neutron monitor at the Geophysical Institute, College, Alaska. The geographical and geomagnetic latitudes are each about 65 degrees north. This monitor observed increases in the cosmic ray intensity, in November, on the 12th, 15th and 20th. In this report we shall (a) describe the cosmic ray effects phenomenologically, (b) show the time-correlation with other geophysical variations, and (c) briefly discuss the possible interpretation of the effects.

The Cosmic Ray Increases

Fig. 1 shows the cosmic ray intensity and other variables, for the November event. In this event there were three separate increases. The first of these is a complex event, observed in Alaska to start at 1322 UT, rising to a broad maximum with fluctuations in it, then again rising to a higher maximum. We have called the first rise the "lead-in event" and the second and higher maximum the "main event". The amplitude of the "lead-in event" in College was about 100 percent above normal counting levels. The abrupt start upward to the main event took place at about 1930, and the maximum of the main event was some 110 percent above normal levels. The level after the event was depressed below that before, due to a large Forbush decrease which the meson monitors at Lincoln, Nebraska[1] show

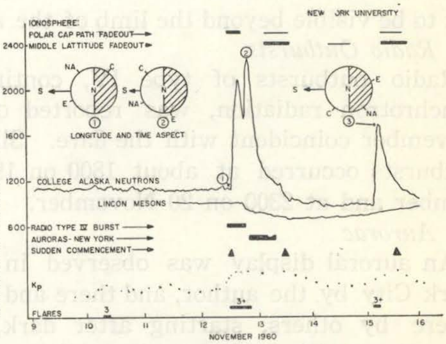

Fig. 1. Cosmic ray neutron intensity and other variables, November 9 to 16, 1960. Top line, polar cap ionosphere fadeouts; second line, middle latitude ionosphere fadeouts. Neutrons at College, Alaska, and mesons at Lincoln, Nebraska are shown. Below, Radio bursts, Auroras in New York, Magnetic SC and K_p indices, and flares. Circles, longitude aspect of earth at times indicated by numbers in small circle; S is direction to sun, E is Europe, NA is North America, C is College, Alaska, looking down on North Pole. Note that College was in the night hemisphere when the first event started, and Europe when the 15 Nov. event started.

occurred, starting at about 1930 UT.

A second large increase occurred on November 15th, and a very small increase of some 8% at about 2300 UT on November 20th. The November 15th event started in College at 0233 UT and reached a maximum of about 90 percent above normal.

Variations in the Associated Geophysical Phenomena

1. *Solar flares*

In November, 1960, the CRPL report[2]

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shows a class 3 plus flare on 12 November from 1323 to 1830, unusually long in duration, about centrally located, solar longitude W 01. On 15 November another 3 plus flare took place from 0207 to 0427, UT. at solar longitude W 33. The spot group with which this was associated was the same as the flare of 12 November. On 20 November this spot group had turned around the limb of the sun and was no longer visible. The only flares on that day were much smaller ones, of size 1, and one or two of size two on that and the day before. However, this large spot group was still active and a large flare was seen to blow material far enough out to be visible beyond the limb of the sun[3].

2. *Radio Outbursts*

Radio outbursts of type IV, continuum synchrotron radiation, was reported on 12 November coincident with the flare. Similar outbursts occurred at about 1800 on 19 November and at 2300 on 20 November.

3. *Aurorae*

An auroral display was observed in New York City by the author, and there and elsewhere by others, starting after dark, *i.e.*, after about 2200 on 12 November. The aurora reports indicate that aurorae were seen as far south as 35° N geographic latitude that night. They lasted until lost in the dawn. Aurorae were again seen on the 15th.

4. *Magnetic disturbances*

The Göttingen K_p index reports show high K_p indices[4] starting to be high about midday on 12 November, and remaining high until late on 13 November. A Sudden Storm Commencement (SC) was reported at about 1100 on 12 November and at about 1200 on 13 November, at about 1300 on 15 November and at about 0800 on 21 November. The K_p indices again were high during the middle of the day of 15 November, but were not especially high on 19, 20 or 21 November.

5. *Longitude effects*

The position of the various cosmic ray stations on the earth with respect to the earth-sun line at the various times is shown in the diagrams, figs. 1 and 2. The longitude of the College station is indicated by *C*, stations in Europe by *E*. It will be noted that College was still on the night side of the earth at the time when the event of 12 November started, although Europe was on the sunlit side. On 15 November, at the onset of the event, College, Europe and North America were on the dark side of the earth. On 20 November, College was approaching sunset while Europe had already passed into darkness. The flare longitudes on the sun have already been cited.

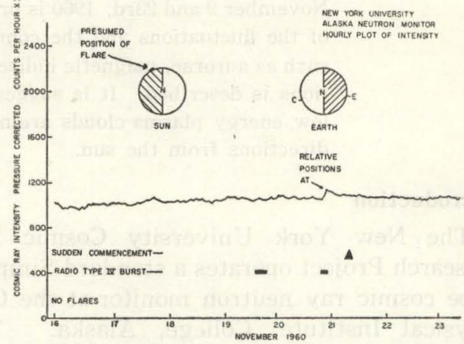

Fig. 2. Cosmic ray neutron intensity at College Alaska 16-23 Nov., showing arrival of solar rays on 20 Nov. Relative aspects of sun and earth, looking down from north pole.

6. *Ionosphere effects*

Polar fadeouts of the forward-scatter ionosphere transmissions, corresponding to appreciable ionization below the normal base of the *E* layer, were reported by Bailey[5] to have occurred on 12 November starting at about 1100, persisting for the balance of the day, and returning rather weakly the following day. Weak polar cap absorption was also reported on 15 November. Effects south of the auroral zone, at more nearly middle latitudes were not observed on 12 November, but were very strong on 13 November, weak on 14 November, strong again on 15 November.

Discussion

Consider first the event of 12 November. Here we have an occurrence in which by chance an SC due to a previous flare arrived at the earth just about simultaneously with the high speed particles and photons from the flare on 12 November. The result is that the fast particles had to penetrate the magnetic field associated with the cloud of low energy particles, thus giving the unusual shape of the "lead-in event". One may suppose that six hours later the earth was inside the cloud, so that the "main event" could assume a normal appearance of a rapid rise and an exponential decay. By 2200 the Störmer cutoffs must have been well reduced, for aurorae were observed far to the south of their usual latitude band. The onset of the Forbush decrease at 1930 is presumably associated with the passage of a cloud of particles past the earth.

The event of 15 November has a more normal sequence of associated phenomena. Here the flare occurs, and the particles arrive, about simultaneously. The SC follows, with, in this case, a very short interval, about 6 hours. The K_p indices are high. We note here that the biggest ionospheric effect occurs in the middle-latitude instead of in the the polar cap stations, thus suggesting that the Störmer cutoffs may have been somewhat modified. Again the station at College and those in Europe receive radiation which has been deflected through a considerable angle as they are on the dark side of the earth.

The small increase on 20 November is of interest. There was no important solar flare within several days, to which this could be attributed. On the other hand, the very active sunspot group which had given rise to the previous increases had just passed around the limb of the sun. Further, there was a type IV radio outburst, such as is produced by flares which give rise to cosmic ray increases. Therefore we may surmise that the flare which produced this effect took place on the far side of the sun.

It is of interest to keep in mind the travel times from the sun. Particles of 2 Bev or more will arrive very shortly after photons. A travel time of 6, 12, 24 and 36 hours corresponds to protons of energies of about 120 Kev, 30 Kev, 7 and 3 Kev. This computation is made on the assumption of straight trajectories. However, it must be recognized that because of magnetic fields the trajectories are not straight so the particle energies cited are minimum energies and in fact must exceed the values cited by appreciable amounts. A 100 Kev proton can only penetrate down to about the 100 km level in the atmosphere, and those of lower energy can only reach still higher altitudes. Hence they can be associated with aurorae but not with cosmic ray effects.

The wide variations in the travel time of the plasma following the outbursts on the sun is noteworthy. Sometimes these clouds require as much as 36 hours or even more, and at other times they appear to need only 6 or 8 hours. It is evident then that there must be a considerable variation in the average energy produced in the various solar events.

The other feature of interest is that the direction of emission of the plasma and the direction of the high energy component seems to be different. On the July 1959 event[6], there were three flares, each followed by an FD, and the usual magnetic and ionospheric effects. No increase was seen in our meters, except for the small "spike" in the recovery phase of the last of the three FD's, which Carmichael and Steljes[7] has attributed to a feature of the radiation in space. On the May event, there was an increase, which was observed by ourselves[8] and others, but this was not followed by the arrival of a low energy cloud. Indeed the FD which did follow on 8 May is presumably due to the flare late on 6 May.

Turning next to the November events discussed in the present work, we call attention to the fact that the event on 12 November is complex, with a cloud from a previous flare arriving at about the same time as the fast particles from the flare on 12 November. The flare on 15 November produced only a very small magnetic effect, and that on the 20th likewise. Now all these seven quite different phenomena seem to have the following common characteristics. If one supposes that the high energy particles, responsible for the increases, are not necessarily or always emitted in the same direction from the sun as the low energy plasma, then the events all become explainable by one mechanism. If the earth is in such a position as to intercept the high energy particles it will not necessarily be in the right position to receive the main impact of the plasma cloud also. On May 4, 1960, the earth intercepted the high energy stream but not the plasma. In November, on the 12th, the earth received the plasma from an earlier flare, and then the high energy particles from the flare of 12 November, followed by some of the low energy particles. On 15 November the earth received the high energy part, and later some but not a very large number of slower particles. On 20 November, the earth received a few high energy particles but very few low energy ones. All these phenomena are consistent with a view that the low energy cloud is of considerable angular extent, and goes out more or less radially from the sun while the high energy particles are sometimes emitted at larger angles to the solar radius.

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-3B-13. Increase of the Cosmic-Ray Nucleonic Intensity in November, 1960*

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Introduction

Two large increases and at least two rapid Forbush decreases in the cosmic radiation at the earth were observed between November 12 and 16, 1960. A third, smaller increase was observed on November 20. The increases in the cosmic-ray intensity occurred shortly after class 3^+ solar flares in region 5925. The Forbush decreases followed large geomagnetic disturbances and indicate the immersion of the earth in solar gas clouds or beams.

This unusual sequence of events is important to the study of the electromagnetic state of the earth-sun region, because we have the injection of relativistic particles from the sun into a region where solar-controlled modulating mechanisms were operative to suppress the galactic cosmic radiation.

We would like to report here briefly on (1) the intensities of the nucleonic component of cosmic radiation at Mount Washington and Durham, New Hampshire; (2) the rigidity spectra of the relativistic solar-produced particles; (3) preferred regions of impact at the earth for solar particles; and (4) evidence for dispersion effects during the first flare event.

* This paper was read by K. G. McCracken.

Observations

Fig. 1: Hourly average nucleonic intensities at Mount Washington (elevation 1910 m.) and Durham (sea level) for November 11–16. The differences in shape and magnitude of the two events are evident and appear to be characteristic of all nucleonic detectors regarding the increase.

Fig. 2: 10-minute average counting rates at Mount Washington for the first flare event, normalized to the preceding twelve-hour period. The maximum at 1614–1624 was fol-