KODAIKANAL OBSERVATORY

BULLETIN NO. CLXV

ACTIVE PROMINENCES AND ASSOCIATED TERRESTRIAL EFFECTS

Abstract

All cases of prominences with high activity were collected from I.G.Y. Solar Activity Report Series in order to find out their possible association with terrestrial effects similar to those observed in the case of solar flares. Special care was taken in selection of cases of prominences so as to avoid the overlapping effects of any solar flares. The study revealed that about 90% of cases of active prominences were followed by bursts of solar radio-radiation, about 60% by partial or complete shortwave radio fadeouts and about 7 to 20 % of other S.I.D's like S.E.A., SCNA etc. Thus it is seen that prominences of high activity are also sources of enhanced solar radio-radiation and X-rays, and are probably next in importance to that of solar flares. Some direct observational evidences and theoretical considerations are also given in support of the above conclusion.

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Introduction

Solar radio-noise bursts at different frequencies were reported by Dodson and Donselman(1), Das and Sethumadhavan(2), Davies(3) and others in the case of certain isolated eruptive prominences with high velocity ejections. An attempt is now made to collect from the I.G.Y. data all cases of prominences with high activity and determine their correlation with terrestrial effects similar to those of solar flares. Ellison (4) has also mentioned about the desirability of such an investigation. The effects due to the prominences are, however, expected to be comparatively less conspicuous.

Solar flares and prominences are two of the important manifestations of solar activity. Solar flares, which occur in the neighbourhood of active spots and confined to the sunspot zones, are short-lived chromospheric explosions characterized by sudden emission of enormous amount of energy in the form of electro-magnetic and corpuscular radiation. Prominences, on the other hand, are observed not only in the sunspot zones but also in higher latitudes right up to the poles. They exhibit a multiplicity of forms such as APR, BSL, DSD etc. However, the energy output in the case of prominences consequent to eruption is very much lower than that of solar flares.

When a flare occurs, simultaneously with its peak phase, the enhanced wave radiation is detected at the sunlit portion of the earth as brightening of the H-alpha line over the flare region, as sudden ionospheric disturbances (S.I.D's) and as outbursts of solar radio-noise. The increased corpuscular radiation gives rise to some delayed geophysical effects such as the auroral displays, sudden enhancement of cosmic rays, and sudden commencement type geomagnetic storms etc, after a lag ranging from a one or two days after the peak phase of the flare The solar phenomenon responsible for simultaneous geophysical effect due to enhanced wave radiation is however, much eas Hence a search for only the simultaneous terrestrial effects that are likely to be associated prominences has been undertaken at present The effects considered in this study are th

1 Bursts of solar radio noise at different frequencies,
2 Short wave radio-fadeouts (SWF),
3 Sudden cosmic noise absorption at 18 Mc/s (SCNA),
4 Sudden enhancement of atmospherics at 27 Kc/s (SEA), and
5 Magnetic crochets

The last four cases are some of the types of sudden ionospheric disturbances (S I D's).

Material for study

The observational material used here is confined to the period of the I G Y (December 1958) during which a specially intensified patrol on different solar and associated phenomena was undertaken on a world-wide scale and a large amount of useful data is m through different bulletins and reports, published by a number of observatories and I During this period the activity of the sun had also been found to be very great The data analysis have been collected from various reports, bulletins and records as shown in the t

TABLE I

No	Type of phenomenon	Data collected fr
1	Active prominences	A, (Nos 1, 2, 3, 5
2	Solar flares	A, (No 12), B, C
3	Bursts of solar radio-noise	B, C, T, N
4	Short wave radio fadeouts	C, N, F, I
5.	Sudden cosmic noise absorption	C, R
6	Sudden enhancement of atmospherics	C, N
7	Magnetic Crochets	G, M

Abbreviations

A I G Y Solar Activity Report Series
B I A U Quarterly Bulletin of Solar Activity
C C R P L Monthly Bulletin (Part B)
T . Bulletins of solar phenomena, Tokyo Astronomical Observatory
N Solar-geophysical data, Netherlands PTT
F : Kodaikanal records of Ionospheric Field Intensity measurements at 6·1 Mc/s
I . Bulletins of hourly ionospheric data of Slough, Ibadan, Port Stanley, Inverness, Singapore, Kodaikanal.
R : Tracings from March 1958 onwards of 18 Mc/s cosmic noise intensities from Rensselaer Poly Troy, New York
G . Quarterly reports on geomagnetic activity issued by the I A G.A
M Kodaikanal magnetograms

Analysis of data and results

Associated geophysical effects, if any, in the case of prominences are much less conspicuous compared to those of solar flares Hence only prominences of high activity are considered in this analysis In order to find out correlation between active prominences and associated geophysical effects, special care has been taken in the selection of prominence data so as to avoid any chance of overlapping effects due to solar flares occurring at that time. In the I G Y report series, suitable remarks and classification of importance are given for every prominence For example those prominences which are categorised as B, C or D are supposed to be directly associated with solar flares of importance 1, 2 or 3 respectively It was, therefore, easy to pick out all prominences of high activity that are not directly associated with any solar flare There are 190 such cases which included 121 APR, 38 BSL, 19 AFR and DSD Further, the solar flares at any other portion of the sun's disc also will give rise to overlapping geophysical effects if the flares occur at the same time of the activity of the prominences A scrutiny of the times of activity of the 190 cases of prominences and the times of all types of flares of importance ranging from 3+ to 1 resulted in a further elimination of 55 cases in which there had been overlapping of times of occurrences of flares and of prominence activity There are thus 135 active prominences belonging to all categories which have been finally chosen for finding out the associated geophysical effects The large number of S I D's reported in the bulletins mentioned in Table I are effects mostly due to solar flares As the effects, if any, due to prominences are likely to be small, they can be detected only by closer examinaton of the original records This was done wherever possible as shown in Table I in the case of F, R and M Inspite of it, the data in respect of some types of S I D's considered here are, in fact, inadequate Nevertheless, the cases available are useful since they help to confirm some of the conclusions derived from other observations

For picking out radio-fadeout data (complete or partial fadeouts) an examination has also been made of the hourly ionospheric values of f-min reported by seven ionospheric stations including Kodaikanal A significant increase in the value of f-min above the normal recorded at stations on the sunlit portion of the earth, is taken as a fadeout The available data in respect of solar radio-noise bursts are very exhaustive and adequate for this analysis

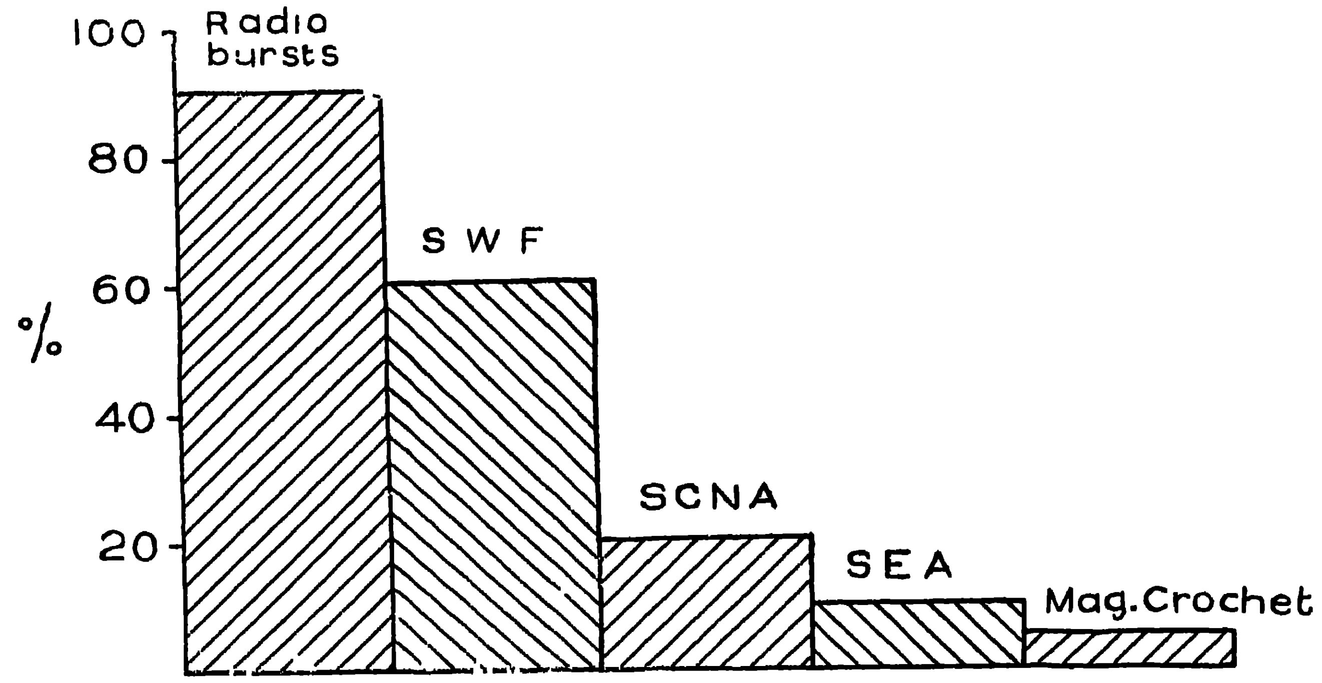

FIG. (1) *Histogram showing percentage frequency of occurrences of associated effects noticeable on the earth with active prominences*

Of the active prominences under consideration, as shown in the above histogram, about 90% cases were followed by bursts of solar radio-radiation, about 60%, by partial or complete shortwave fadeouts; about 20% by SCNA, about 7% by SEA and about 2% by magnetic crochets The coverage of observing stations in respect of solar radio-radiation is very large compared to that of stations making observations on solar geophysical effects such as SCNA, SEA etc and this fact may partly be responsible for the higher percentage correlation noticed in the case of solar noise bursts compared to SID's Statistical estimates of chance coincidences in the case of solar noise bursts and radio-fadeouts have also been made following the same procedure adopted by Elske V P Smith and McIntosh(5) for a similar analysis made by them. Instead of 90 and 60 respectively, the percentage frequency of occurrences after correction for chance coincidences in the case of solar radio-bursts and SWF work out to be 71 and 51, which are also very significant

Discussion

In this analysis the bursts of solar radio emission having time coincidences with the activity of prominences, covered frequencies ranging from 9500 Mc/s to less than 100 Mc/s including many type II and type III bursts However, in the decimetre and metre wave bands, the number of bursts noticed are comparatively larger This may be due to the following reasons

1. The number of stations operating on these frequencies may be very large
2. These bursts are more pronounced and are therefore, more easily detectable
3. The majority of prominences, because of their great heights may probably give rise to radio-radiations emanating from fairly high regions in the corona

The percentage frequency of association between solar radio-bursts and active prominences is found to be nearly the same, about 90, in each of the three types of prominences *viz* APR, BSL, and DSD

The possibility of prominences also giving rise to enhanced radio-radiation has been considered by several authors According to Pawsey and Smerd(6) the solar radio-noise bursts are supposed to be generated by plasma oscillations of coronal matter excited by corpuscular radiation originating in the inner corona Haddock (7) suggests that these bursts originate under special conditions by a high speed exciting agency like an expanding magnetic field. Kiepenheuer(8) is of the opinion that all prominences whether in the vicinity of sunspots or far away in high latitudes are related somehow to the photospheric magnetic fields and that sudden changes in those magnetic fields activate the otherwise quiescent prominences and stable filaments The activation caused by the hydromagnetic waves or shock waves is displayed either as an eruptive ascension of matter outwards into the corona, or streaming down of matter into the chromosphere From an analysis of delay times of several bursts of solar radio-emission at different frequencies, Davies(9) has found that the disturbance originates first at a level say about 15000 Km above photosphere giving rise to radio emissions at a frequency of about 3000Mc/s The material then partly moves up and partly down from that level simultaneously generating radio emissions of lower and higher frequencies respectively Portions of prominences are certainly located in this region of initial disturbance

Wild, Sheridan and Trent(10) using a swept frequency interferometer have for the first time established that type II and III bursts are generated by rapidly ascending disturbances which along their path excite electromagnetic oscillations in the successive layers of the corona A more direct observational evidence showing that active prominences also can give rise to bursts of solar radio-radiation has been provided recently by Giovanelli and Roberts(11) from their analysis of records obtained with the 40—240 Mc/s Dapto radio spectrograph They were able to identify three cases of prominences ejected from the limb and two cases of disappearing filaments which are responsible for type II bursts

It has been shown from rocket experiments by Friedman(12) etc that it is mainly the X-radiation emitted at times of chromospheric flares that causes enhanced ionization below the normal D-layer which is responsible for many types of S I D's Regarding S I D's accompanying active prominences considered in this analysis, there are a fairly large number of cases of SWF (partial or complete) and the percentage coincidence is found to be 60 The data in respect of SCNA, and SEA are somewhat incomplete and hence the time coincidences noticed are small The material regarding magnetic data, is, however, complete, but it is difficult to distinguish and separate out all probable magnetic crochets from highly agitated magnetograms obtained during the I G Y (Even in the case of solar flares, only a small percentage of them are known to be accompanied by clear cut magnetic crochets) The fewer time coincidences of SCNA, SEA and magnetic crochets by themselves may not afford complete proof of enhanced X-radiation from prominences, but they certainly help to support that conclusion arrived at by 60% association noticed between prominence activity and SWF

Instances of active prominences being accompanied by S I D's have been noticed by some workers recently Kleczek and Krivsky (13) have studied in detail a system of loop prominences which quickly developed between about 1000 U T and 1130 U T on May 4, 1960 and found that the optical event was followed by significant SEA at 27 Kc/s, radio fadeout, bursts of solar radio-radiation and also an increase of cosmic ray nucleonic component Later it was known that a solar flare of importance 3 (N12, W90°) was observed between 1015 and 1105 U T. along with sub flare at 1155 U T on the same day It is possible that the flares might be responsible to a large extent for the terrestrial effects noticed by the authors But some more investigations made by the same authors showed that a number of active prominences were accompanied by SEA at 27 Kc/s, and they therefore believe that at least some limb surges and loop prominences are likely sources of X-radiation

A more direct observational evidence in favour of emission of X-radiation from active prominence was provided by Chubb, Friedman and Kreplin(14) from their rocket firings during July-September, 1959 Employing suitable detectors for recording the flux at different spectral regions in the short wavelength range, they have flown successfully seven rockets One of them went up coincident in time with the occurrence of an active prominence BSL of class 3 (09° N and 90° E) The X-ray flux measured in this case was relatively much higher compared to the values obtained in the cases of firings made when there was no flare or prominence activity on the sun This experiment showed that active prominences also emit enhanced X-radiation similar to solar flares but on a smaller scale De Jager(15) has recently suggested that type III radio-bursts and X-rays from flares are caused by accelerated electron jets and the acceleration mechanism in principle is independent of the existence of flares and also, that the required acceleration of the electron jets is possible in the case of even the quiescent prominences with knots According to him the prominences often appear between two oppositely polarised tracks of an activity centre where they are supposed to be held by local magnetic lines of force which are slightly concave If two such fields approach each other, the changing magnetic field induces electric fields which provide necessary acceleration of the particles to yield X-ray energies of the order of 10^5ev.

In this analysis the probable effect of secondary radiation from the highly energetic particles of the newly discovered Van Allen Belts on the geophysical phenomena Minnaert (16), and the possibility of associated terrestrial effects of some large flares conjectured to be occurring behind the sun's limb even up to 30° as mentioned by Hansen(17) were not taken into account We may still justifiably conclude that the prominences of high activity are also likely sources of enhanced solar radio-radiation and X-rays and are probably, next in importance to that of flares

Acknowledgement

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J. V. NARAYANA.

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ERRATA FOR KODAIKANAL OBSERVATORY BULLETIN NO.CLXVI

Part I.

Page	Title	Date	Column	Read	For
3	Table I	February	3	80.5	81.0
		February	4	169	168
		June	3	58.2	53.3
		1st Quarter	3	323.0	323.5
		1st Quarter	4	639	638
		2nd Quarter	3	311.6	311.7
		1st half-year	3	634.6	635.2
		1st half-year	4	1192	1191
3	Distribution of Prominences		2	289.8	2898
			3	344.8	3448
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Part II.

Magnetic Data.

Top page	Table No.	Line/Date	Hour/Column	Read	For
278	19	-	-	This should come under page 316	
280	1	9	Date	9 ††	9 †
280	1	16	09	36.0	36.6
231	1	25	Mean	37.8	37.4
281	1	Mean †	18	38.3	39.3
283	2	Mean	22	38.2	38.0
287	3	23	Min/Mag.	36.7	36.5
287	3	26	Range	~~3.7~~	3.9
288	4	22	03	38.4	88.4
291	5	23	21	39.3	38.3
294	7	27	04	566	556
293	7	30	Max./Time	05 11	15 11
293	7	Mean ††	17	476	576
294	8	2	08	590	690
295	8	18	Date	18††	18
295	8	20	Date	20††	20†
297	9	27	Range	259	249
303	12	28	Date	28†	28††
304	13	Mean ††	11	247	245
307	14	25	Date	25†	25
308	15	Mean‡	03	269	259
310	16	8	08	231	243
312	17	25	Date	25††	25
312	17	25	09	252	242
313	17	Mean†	20	256	250
314	18	24	10	233	333

Part III.

Ionospheric Data.

Top page	Table No.	Line/Date	Hour/Column	Read	For
116	26 contd.	31	1130	8.8	9.8
122	28	25	0600	2.1	.21
160	37 contd.	count	0630	6	0
176	41 contd.	18	1030	200	220
189	44 contd.	1730	1730	2.55	2.40

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